IEEE-ISIE 2014

The 23rd IEEE International Symposium on Industrial Electronics
1-4 June 2014, Istanbul, TURKEY

PROGRAM AND ABSTRACTS

Grand Cevahir Hotel and Convention Center, Istanbul, TURKEY
1-4 June 2014
http://www.isie.boun.edu.tr/
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2014 International Symposium on Industrial Electronics

IEEE ISIE 2014

Organized by:
IEEE Industrial Electronics Society (http://ieee-ies.org/)

Overview:
IEEE-ISIE is the largest summer conference of the IEEE Industrial Electronics Society, which is an international conference for sharing breakthroughs in research, emerging technologies, and success stories in industrial electronics and its applications. IEEE ISIE 2014 is the 23rd IEEE International Symposium on Industrial Electronics which will be held in Istanbul, Turkey during June 1-4, 2014. Researchers and engineers from industry, research, and academia are cordially invited to participate in an array of presentations, tutorials, and social activities for the advancement of science, technology, engineering education, and fellowship.
Message from the General Chair

It is my great pleasure and honor to welcome you to the 23rd IEEE International Symposium on Industrial Electronics, which is the largest summer conference of the IEEE Industrial Electronics Society as an international event for sharing breakthroughs in research, emerging technologies, and success stories in industrial electronics and its applications. We believe that with its wide participation from many parts of the world, ISIE 2014 will be a unique opportunity for researchers and engineers from academia and industries to exchange their research results and new findings.

The history of ISIE goes back to 1992, when an event held in Xian, China, chaired by one of the leading volunteers (a past President) of IEEE Industrial Electronics Society, Prof. James Hung, was so successful that it was decided to organize similar events annually in different parts of the world. The second ISIE was held in Budapest, Hungary and I had the honor of being its General Chair! The subsequent events were held in many different parts of the world, the last one; ISIE 2013, was held in Taipei, Taiwan. ISIE 2015 will be held in Búzios, Rio de Janeiro, Brazil.

The technical program of ISIE 2014 is very rich, the topics of interest of cover a wide range, from classical to emerging ones. We have a number of special session organized, dedicated to various advanced areas. The richness of the program will certainly broaden our perspective of control and deepen our knowledge in the particular areas that we are interested in.

Istanbul is a unique city in the world. It was the capital of three great empires; Roman, Byzantine and Ottoman, and two religions; Christian and Islamic for more than 2000 years. It is therefore full of historic and cultural monumental buildings and masterpieces of Roman, Byzantine and Christian art. It is our hope that you will be able to spare some time to experience its cultural and historical riches.

A conference of this size cannot be brought together without the dedicated efforts of many people. I would like to take this opportunity to thank everybody involved in many committees. My special thanks go to the Technical Program Chair; Prof. Huijun Gao and his co-chairs; Profs. Carlo Cecati, Onder Efe, Yen-Shin Lai, and Shen Yin. The graduate students in my laboratory, Yeşim Öniz and Çisel Aras deserve my very special thanks because without their involvement, I would not have been able to face the challenges of my responsibilities.

Finally I would like to wish you all a very pleasant stay in Turkey and a safe return home. I hope that the international atmosphere at ISIE 2014 will inspire new friendships among engineers and scientists of the world and we will see each other in Búzios, Rio de Janeiro, Brazil for the next edition of ISIE.

Okyay Kaynak
General Chair
Message from the Technical Program Chair

It is my great pleasure and honor to welcome you to the 23rd IEEE International Symposium on Industrial Electronics (ISIE 2014) in Istanbul, which is a unique city on two continents in the world and also was the capital of three great empires, Roman, Byzantine and Ottoman, and two religions, Christian and Islamic, for more than 2,000 years.

ISIE 2014 has received overwhelming responses from researchers around the globe with 707 submissions for regular submissions, from which 442 papers were accepted. This corresponds to an acceptance rate of 62.52%. The exciting technical program is designed to create a platform for researchers and engineers to showcase their latest research findings, exchange ideas and network with fellow researchers. The technical program is composed of 57 Lecture Sessions and 2 Poster Sessions covering emerging and interdisciplinary topics ranging from several representative fields of industrial electronics. Furthermore, the program consists of keynote speeches by some of renowned experts worldwide. Tianyou Chai from Northeastern University, China will discuss on recent advances of intelligent feedback control for operation of complex industrial processes. Metin Sitti from Carnegie Mellon University, USA will share his vision on miniature mobile robots down to micron scale. Emil Levi from Liverpool John Moores University, UK will look into the future of power electronic supply control and EV charging options. We hope the rich technical content provides wonderful opportunities for all participants from academia and industries to network with colleagues and to exchange latest findings in industrial electronics.

We are very grateful to the Technical Program Committee members for organizing the reviews and paper selections in the final program. We wish to express our sincere appreciation to the reviewers for their devoted efforts, and of course to all the authors for their efforts in preparing their papers. The smooth review process is not possible without the strongest support of Carlo Cecati, Onder Efe, Yen-Shin Lai and Shen Yin, the Co-Chairs of Technical Program.

Finally, we would like to specially express our gratitude to the Special Session Chairs, Kim Man, Tian-Hua Liu, Juan Jose Rodri-guez Andina and Lixian Zhang, who put considerable effort into coordinating all special session papers, and also the Tutorials/Workshop Chairs, Levent Guvenc and Yousef Ibrahim, for putting together a wonderful set of tutorial and tutorials with exciting topics and speakers.

We hope each and every one of you enjoys the technical program and Istanbul. We also hope you find time to feel the spirit of “Turkey Culture” besides the technical program and appreciate the Cappadocia and Ephesus, and many other historical sites during your stay in Istanbul.

Huijun Gao
Technical Program Chair
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Intelligent Feedback Control for Operation of Complex Industrial Processes

Tianyou Chai

Northeastern University, China

Abstract: Process control should aim at not only ensuring controlled variables to best follow their set points, but also requiring the optimal control for the operation of the whole plant to make the operational indices (e.g. quality, efficiency and consumptions during the production phase) into their targeted ranges. It also requires that operational indices for quality and efficiency should be enhanced as high as possible, whilst the indices related to consumptions are kept at their lowest possible level. Based upon a survey on the existing operational optimization and control methodologies, this talk presents a data-driven hybrid intelligent feedback control for operation of complex industrial processes and a hybrid simulation system. Simulations and industrial applications to a roasting process for the hematite ore mineral processing industry are used to demonstrate the effectiveness of the proposed method. Issues for future research on the optimal operational control for complex industrial processes are outlined in the final section.

Biography: Prof. Tianyou Chai is Member of Chinese Academy of Engineering, IFAC Fellow and IEEE Fellow. He received his Ph. D. degree in Control Theory and Engineering from Northeastern University in 1985 and became a Professor in 1988 in the same university. He is the founder and Director of the Automation Research Center, which became a National Engineering and Technology Research Center and a State Key Laboratory. He has served as a member of IFAC Technical Board and Chairman of IFAC Coordinating Committee on Manufacturing and Instrumentation during 1996-1999. He serves as director of Department of Information Sciences of National Natural Science Foundation of China (NSFC) since 2010. He is a distinguished visiting fellow of The Royal Academy of Engineering (UK) and an invitation fellow of Japan Society for the Promotion of Science (JSPS).

Prof. Chai’s research interests include modeling, control, optimization and integrated automation of complex industrial processes. He has published two monographs and 148 peer reviewed international journal papers and around 255 international conference papers. He has also been invited to deliver more than 30 plenary speeches in international conferences of IFAC and IEEE.
He has made a number of important contributions in control technologies and applications. These include multivariable adaptive decoupling control theory and applications, innovative intelligent decoupling control technology, the development of a hybrid intelligent optimal control technique for automation systems, which has been successfully applied to process industries such as iron and steal, minerals processing, nonferrous metals, and electric power, resulting in enormous economic benefits.

For his contributions, he has won numerous awards including three National Science and Technology Progress Awards, one National Technological Innovation Award, the Technological Science Progress Award from Ho Leung Ho Lee Foundation in 2002, the Science and Technology Honor Prize of Liaoning Province in 2003, and honor of “National Advanced Worker” in 2005, respectively. He received the 2007 Industry Award for Excellence in Transitional Control Research from IEEE Multiple-conference on Systems and Control. In addition, he won 2010 Yang Jia-Chi Science and Technology Award from Chinese Association of Automation.
Miniature Mobile Robots Down to Micron Scale

Metin Sitti
Carnegie Mellon University, USA

Abstract: Miniature mobile robots have the unique capability of accessing to small spaces and scales directly. Due to their small size and small-scale physics and dynamics, they could be agile and portable, and could be inexpensive and in large numbers if they are mass-produced. Miniature robots would have high impact applications in health-care, bioengineering, mobile sensor networks, desktop micro manufacturing, and inspection. In this talk, dynamics and control of different size scale miniature robots with various locomotion capabilities are presented. First, as milli/centimeter scale mobile robots, mechanics, design, and control of climbing, flying, and water-walking robots inspired by insects and lizards are presented. Pill-size untethered soft capsule robots are proposed to enable minimally invasive medical diagnosis and therapeutic operations inside stomach. Next, going down to submillimeter size mobile robots, the grand challenge is the limitations on scaling down on-board actuators and power sources. Two alternative approaches are proposed to solve this challenge. First, biological cells, e.g. bacteria, attached to the surface of a micro-robot are used as on-board micro-actuators using the chemical energy. Current status of this approach is reported briefly while focusing on a second approach: external actuation of untethered magnetic micro-robots using remote magnetic fields in enclosed spaces. New magnetic micro-robot locomotion principles based on rotational stick-slip, spinning, and rolling dynamics are proposed. Vision-based control schemes are used to control teams of micro-robots using novel addressing methods where each robot in the team could be individually actuated while the global magnetic fields exerted on each robot is the same. Such untethered micro-robot teams are demonstrated to control microfluidic flow locally, trap live cells and transport them, and manipulate micro-gels with embedded cells with or without contact inside microfluidic channels for tissue engineering applications.

Biography: Metin Sitti received the BSc and MSc degrees in electrical and electronics engineering from Bogazici University, Istanbul, Turkey, in 1992 and 1994, respectively, and the PhD degree in electrical engineering from the University of Tokyo, Tokyo, Japan, in 1999. He was a research scientist at UC Berkeley during 1999-2002. He is currently a professor in Department of Mechanical Engineering at Carnegie Mellon University. He is the director of Nano Robotics Lab and Center for Bio-Robotics. His research interests include mobile micro-robots, bio-inspired micro/nanomaterials, bio-inspired robot locomotion, and micro/nano- manipulation. He is an IEEE Fellow. He received the SPIE Nano engineering Pioneer Award in 2011 and NSF CAREER Award in 2005. He received best paper and best video awards in major robotics conferences. He was elected as the Distinguished Lecturer of the IEEE Robotics and Automation Society during 2006-2008 and the Vice President of the Technical Activities in the IEEE Nanotechnology Council during 2008-2010. He is the editor-in-chief of Journal of Micro-Bio Robotics.
Multiphase Drives: Power Electronic Supply Control and EV Charging Options

Emil Levi
Liverpool John Moores University, UK

Abstract: Multiphase (more than three phases) machines are characterised with a number of favourable features that make them an excellent candidate for a range of applications, such as electric vehicles, locomotive traction, electric ship propulsion, ‘more-electric’ aircraft, and various high-power industrial processes. At the heart of any variable-speed multiphase drive or generation system is a multiphase power electronic converter. The first part of the presentation will therefore concentrate on recent advances in the area of multilevel multiphase inverter PWM control. Two topologies will be addressed, a three-level supply in single-sided supply mode and dual two-level inverter supply with open-end stator winding configuration. Some of the recently developed carrier-based and space vector based PWM techniques will be surveyed and the achievable performance illustrated using experimental laboratory prototypes. Multiphase machines are characterised with existence of additional degrees of freedom, since only two independently controllable currents are required for flux and torque control. In very recent times it has been shown that one of the potential uses of these additional degrees of freedom is for realisation of integrated on-board battery chargers for electric vehicles. For this purpose the machine is brought into an open-end stator winding configuration, so that this established the link with the first topic of the presentation. The second part of the talk will therefore address topologies and control of multiphase converter/propulsion motor powertrains, in relation to charging and vehicle-to-grid (V2G) operation. The emphasis will be placed on the nine-phase topology, which appears as the best candidate for future EVs, since exactly the same system suffices for both propulsion and charging/V2G modes of operation. Experimental results will again be included to validate the theoretical concepts.

Biography: Emil Levi received the BEng (Honours) degree from the University of Novi Sad in 1982 and M.Sc. and Ph.D. degrees from the University of Belgrade, Belgrade, Yugoslavia, in 1986 and 1990, respectively. From 1982 to 1992, he was with the Department of Electrical Engineering, University of Novi Sad. In May 1992, he joined Liverpool John Moores University, Liverpool, U.K., where since September 2000, he has been a Professor of electric machines and drives. Prof. Levi is an IEEE Fellow and he has served as the Co-Editor-in-Chief of the IEEE Trans. on Industrial Electronics from 2009 until 2013. He currently serves as an Editor of the IEEE Trans. on Energy Conversion and as the Editor-in-Chief of the IET Electric Power Applications. He is a recipient of the Cyril Veinott award of the IEEE Power and Energy Society for 2009 and the recipient of the Best Paper Award of the IEEE Trans. on Industrial Electronics for 2008.
Tutorial 1:

June 1 2014, Sunday, 14:00-17:00 at Room 1

Service-oriented Architecture and Cloud Computing Technologies - Innovation Backbone to Implement Industrial Cyber-Physical Systems

Presenter:

- Prof. Armando Walter Colombo (Schneider Electric / University of Applied Sciences Emden/Leer Germany)
  Email: armando.colombo@schneider-electric.com;
  awcolombo@technik-emden.de
- Stamatis Karnouskos (SAP, Germany)
  Email: stamatis.karnouskos@sap.com

Brief Description

We are witnessing today several concepts and technology trends when designing and implementing solutions on Industry Cyber-Physical Infrastructures e.g., the Smart Grid, the Factory of the Future, the Industry 4.0, etc. Especially when key issues on cross-layer collaboration, (near) real-time interaction, complexity and emergency behavior management, support of system of systems evolvability, heterogeneity, interoperability, scalability etc. are coming into play, we have to radically rethink approaches under the requirements and constraints of the Industrial Systems. Structural Integration and Behavioral Collaboration are major goals especially for a domain relative new to IT technologies and their rapid evolution pace. Service-oriented Architectures (SoA), Web and Cloud Computing Technologies have been proven to be a real and feasible innovation backbone at Internet scale, and are finding their way in the future Industrial Systems. Based on Lessons learned from latest prototype industrial applications, we need to further evaluate and assess their capability and applicability and ask key questions e.g., how deep can we go with web technologies in real-time monitoring and control; how can we realize the next generation large-scale distributed monitoring systems; how to support the lifecycle of industrial solutions viewed under the system of systems engineering viewpoint; how to architect the next generation SCADA/DCS systems; what is the tradeoff for security, trust and privacy; how can we migrate towards web-technology based systems; how to design today the best legacy system of tomorrow; etc.

The tutorial will serve as an introductory session to the developments made in several European industry-driven projects such as SOCRADES (www.socrates.eu), IMC-AESOP (www.imc-aesop.eu), SmartKYE (www.smartkye.eu) who have focused on cross-layer Cyber-Physical System interactions and SOA-based industrial system integration. The tutorial aims at providing an insight to aspects such as: web services on devices, integration with enterprise systems, collaborative automation, and future cloud-based SCADA/DCS, directions for large scale systems, migration of legacy infrastructures, technologies and challenges for the future. We aim to strike the balance in providing lessons learned, hands-on experiences as well as future directions, aspects of interest and challenges.

This Tutorial is the consecutive action to the series of Tutorials and Keynotes presented by the authors during the latest IEEE IECON, IEEE ISIE, IEEE INDIN Conferences. It summarizes a set of scientific and technical results of application of the Cyber-Physical Systems Paradigm in different industrial domains,
mainly in manufacturing and process industry. The presenters are experts on the tutorial subject matter proposed, and content presented can be also found in numerous IEEE papers and book chapters published by the presenters. As IECON 2013 has a very strong focus on Industrial Manufacturing, Applications and infrastructures as well as emerging domains such as the SmartGrid, we think this tutorial is an excellent fit as it covers from multiple angles the IECON 2013 focus.

**Presenter Biographies:**

Prof. Armando Walter Colombo joined the Department of Electrotechnic and Industrial Informatics at the University of Applied Sciences Emden-Leer, Germany, and became Full Professor in August 2010. He is also Edison Level 2 Group Senior Expert and Research Program Manager at Schneider Electric. He received the MSc. on Control System Engineering from the National University of San Juan, Argentina, in 1994, and the Doctor degree in Engineering from the University of Erlangen-Nuremberg, Germany, in 1998. He is a Senior Member of the IEEE, member of the IEEE IES Administrative Committee (AdCom) and of the Gesellschaft fuer Informatik e.V. The last 12 years Prof. Colombo coordinated efforts in several European Commission and industry funded projects related to emerging technologies in key areas such as service-oriented architectures, cyber-physical systems, collaborative agent-based industrial automation, etc. He has served/serves as Associated Editor of the IEEE Transactions on Industrial Informatics, IEEE Transactions on Automation Systems Engineering (IEEE T-ASE) and Associated Editor of the IFAC Associated Journal ATP-International. Prof. Colombo is the co-leader of the ARTEMIS (European Embedded Systems Platform) Strategic Research Agenda - Sub-Program ASP4. He has more than 200 per-review publications and 23 industrial patent applications (see http://scholar.google.com/citations?user=csLRR18AAAAJ). Prof. Colombo is listed in Who’s Who in the World /Engineering 99-00/01 and in Outstanding People of the XX Century (Bibliographic Centre Cambridge, UK).

Stamatis Karnouskos is with SAP as a Research Expert on M2M / Internet of Things. He investigates the added-value of integrating networked embedded devices in enterprise systems. For more than 15 years Stamatis leads efforts in several European Commission and industry funded projects related to industrial automation, smart grids, Internet-based services and architectures, software agents, mobile commerce, security and mobility. Stamatis is actively involved in several consultations at European Commission and German level dealing with Cyber-Physical systems, System of Systems, Internet of Things, energy efficiency and SmartGrids. He has co-authored and edited several books, technical papers, acted as guest editor in IEEE/Elsevier journals, and participates as a program member committee and reviewer in several international journals, conferences and workshops. Stamatis serves in the technical advisory board of Internet Protocol for Smart Objects Alliance (IPSO), the Permanent Stakeholder Group of the European Network and Information Security Agency (ENISA).
Tutorial 2:
June 1 2014, Sunday, 14:00-17:00 at Room 2

Current state of Industrial Ethernet

Presenter:
• Dietmar Bruckner, Bernecker + Rainer Industrie-Elektronik Ges.m.b.H., Eggelsberg, Austria
  Email: dietmar.bruckner@br-automation.com

Brief Description

Since about ten years, Ethernet-based solutions have become popular in industrial communications. Like with the traditional fieldbus systems, there is a wide variety of mutually incompatible concepts addressing various application domains. Looking at the status of international standardization, there are even more standardized approaches than in the fieldbus era, which makes selection of the best solution for a given task even more difficult.

The tutorial intends to present an overview of industrial Ethernet solutions especially for real-time automation applications as considered by the IEC in the standards IEC 61158 and IEC 61784. The focus will be on the basic operation principles of the various approaches to give the audience an understanding of how Ethernet, which is essentially not designed for real-time operation, can cope with requirements typical for automation systems. The status of standardization will be briefly reviewed as well.

The second part of the tutorial will be devoted to practical aspects of using industrial Ethernet from an industry perspective. Key performance indicators will be introduced that attempt to make network solutions comparable, and different networks will be compared by means of concrete practical examples.

Brief biography:

Dietmar Bruckner works as the Technical Manager for Open Automation Technologies and as a system architect for hard real-time industrial Ethernet-based control systems for Bernecker + Rainer Industrial Electronics since 2013. Before that, he worked, first as a research assistant, then as a University Assistant (i.e. Assistant Professor) and project manager at the Institute of Computer Technology of the Vienna University of Technology.

He started the study of Electrical Engineering in fall 1999, where he obtained an MSc in January 2004 and a PhD in January 2007. He finished his master study one semester earlier than minimum duration and passed both degrees with distinction. During study he received four merit awards from the faculty of Electrical Engineering and Information Technology and one from the state Lower Austria.

Bruckner is a Senior Member of IEEE, and an IES AdCom member and Section Austria Chapter Coordinator. He published ~70 reviewed scientific publications, and ~100 scientific publications in total. He is actively involved in organizing international conferences in various positions and editing high ranked international journals.
Tutorial 3:
June 1 2014, Sunday, 14:00-17:00 at Room 3

Small-Scale Mobile Robotics

Presenter:
- Metin Sitti, NanoRobotics Lab, Carnegie Mellon University, Pittsburgh, USA
  Email: msitti@andrew.cmu.edu

Brief Description

This tutorial aims to analyze, design and build small-scale mobile robots for researchers interested in robotics, micro/nanotechnology, design, controls, mechanics, medicine, and bioengineering. It would cover the underlying micro/nano-mechanical principles, scaling laws, and actuation, sensing and powering principles of such tiny robots down to micron scale overall sizes. Besides the basic background knowledge, it includes the current trends in the literature, detailed case studies from research projects at NanoRobotics Lab at Carnegie Mellon, and discussions.

Presenter Biography:

Prof. Metin Sitti received the B.Sc. and M.Sc. degrees in electrical and electronics engineering from Bogazici University, Istanbul, Turkey, in 1992 and 1994, respectively, and the PhD degree in electrical engineering from University of Tokyo, Japan, in 1999. At University of California at Berkeley, he was a research scientist during 1999-2002 and a lecturer in 2002. He is currently a professor in Department of Mechanical Engineering and Robotics Institute at Carnegie Mellon University. He is the director of NanoRobotics Lab and Center for BioRobotics. His research interests include magnetically- and cel-actuated mobile micro-robots, bio-inspired micro/nano-materials, bio-inspired miniature robot locomotion, medical miniature robots, and micro/nano-manipulation. He received the SPIE Nanoengineering Pioneer Award in 2011, National Science Foundation CAREER Award in 2005, and IBM Smarter Planet Award in 2012. He was invited to the World Science Festival in 2013 as a keynote speaker on Cellular Surgeons. He was appointed as the Adamson Career Faculty Fellow during 2007-2010. He was the Vice President of the Technical Activities in the IEEE Nanotechnology Council during 2008-2010. He was elected as the Distinguished Lecturer of the IEEE Robotics and Automation Society during 2006-2008. He received the Best Paper Award in the IEEE/RSJ International Conference on Intelligent Robots and Systems in 2009 and 1998, the first prize in the World RoboCup Micro-Robotics Competition in 2012 and 2013, the Best Biomimetics Paper Award in the IEEE Robotics and Biomimetics Conference in 2004, and the Best Video Award in the IEEE Robotics and Automation Conference in 2002. He founded nano Griptech Inc. in 2009 to commercialize gecko inspired adhesives. He was the guest editor-in-chief of IEEE/ASME Trans. on Mechatronics during 2011-2012 and the Associate Editor for IEEE Trans. on Robotics during 2007-2011 and for ACS Applied Materials and Interfaces during 2010-2012. He is the editor-in-chief of Journal of Micro-BioRobotics currently.
Conference Venue

All Tutorials and sessions of ISIE 2014 are held at Grand Cevahir Hotel and Convention Center.

Location

Grand Cevahir Hotel and Convention Center is located at Darulaceze Cad. No: 9 Okmeydani /Sisli Istanbul Turkiye.

Language

The native language in Turkey is Turkish, but the language of this conference will be English. Simultaneous translation will not be provided.

Currency

The Turkish monetary unit is “Turkish Lira”. The exchange rates can be learned at the information desk of the hotel or at exchange offices nearby.

Electricity

Turkey operates on 220 volts, 50 Hz, with round-prong European-style plugs that fit into recessed wall sockets/points.
Modeling and Control of a STATCOM-Supercapacitors Energy Storage System Associated with a Wind Generator

Bensmaine, Faycal\textsuperscript{1,2}; Bachelier, Olivier\textsuperscript{1}; Tnani, Slim\textsuperscript{1}; Champenois, Gerard\textsuperscript{1}; Mouni, Emile\textsuperscript{2}
\textsuperscript{1}University of Poitiers, France; \textsuperscript{2}Motors Leroy Somer, France

The influence of constant speed wind turbine in an electrical network during torque impact can lead various problems. The disturbances affect active power quality, reactive power and r.m.s. phase to phase voltage. In this paper, we propose an original system and control to solve firstly, the problems due to the brutal impact of active power and secondly the control of reactive power. The principle of the proposed wind energy system with STATCOM-supercapacitors energy storage is to limit the rapid variation of active power and give the required reactive power compensation to the induction machine during the torque change. The supercapacitor is directly coupled to the common dc-link of the whole bidirectional DC-AC converter. The control strategy of the STATCOM uses a Linear Matrix Inequalities (LMIs) technic to regulate the currents injected or absorbed by the inverter. The same strategy is used to control the variable DC supercapacitor voltage. The simulation results of the STATCOM using a state-feedback with integral controller for id, iq currents converter and a simple proportional (Kp) controller cascaded to d axis current loop for DC voltage source are presented and discussed.

Adaptive fuzzy tracking control of nonlinear systems with input time delay

Yousef, Hassan; AL-Abri, Said
Sultan Qaboos University, Oman

This paper proposes an adaptive fuzzy logic tracking control for unknown nonlinear systems having input time delay. In the controller design, a filtered tracking error to facilitate handling of the time delay and fuzzy approximation of nonlinear function are introduced. Lyapunov stability analysis shows that the designed tracking control yields bounded signals of the closedloop system. Two simulation examples are provided to prove the effectiveness of the proposed controller in achieving tracking with bounded control signals.

Automatic Landing Control of Unmanned Aerial Vehicles on Moving Platforms

Hervas, Jaime Rubio\textsuperscript{1}; Reyhanoglu, Mahmut\textsuperscript{2}; Tang, Hui\textsuperscript{1}
\textsuperscript{1}Nanyang Technological University, Singapore; \textsuperscript{2}Embry-Riddle Aeronautical University, USA

This paper studies the landing control problem for Unmanned Aerial Vehicles (UAVs) on an oscillating platform such as a ship deck in a rough sea. A full nonlinear mathematical model is first introduced for the UAV in an inertial frame. A Fourier transform based method is then
employed for a realistic characterization of the sea motion and the ship dynamics. Finally, a landing control algorithm is developed based on the dynamics of the UAV relative to the ship. The effectiveness of the control algorithm is illustrated through a simulation example.

**A Frequency-Specific Enhanced Approach to Transfer Function Approximation**

Li, Xianwei¹; Gao, Huijun¹,²

¹Harbin Institute of Technology, China; ²Bohai University, China

This paper investigates the problem of frequency-specific (FS) model approximation of transfer functions. The objective is to find an approximation transfer function for a higher-order one such that the approximation error over a specific frequency range is minimized. The importance of this problem lies that, in practice, a better approximation performance within a certain frequency range is often required than that outside the frequency range. First, a linear matrix inequality condition characterizing the FS gain performance of a transfer function is derived by the generalized Kalman-Yakubovich-Popov lemma, and then a simple iterative approach based on an upper-bounding technique is proposed to optimize the approximation model. Numerical experiment shows that the proposed approach is more effective in enhancing the approximation performance over a specific frequency range than some existing approaches.

**Nonlinear Feedback Control of Thermoacoustic Oscillations in a Rijke Tube**

Hervas, Jaime Rubio¹; Zhao, Dan¹; Reyhanoglu, Mahmut²

¹Nanyang Technological University, Singapore; ²Embry-Riddle Aeronautical University, USA

Flow disturbances could undergo transient growth to trigger thermoacoustic instability in a combustion system with non-orthogonal eigenmodes. In this work, nonlinear feedback control of thermoacoustic oscillations in a Rijke-type combustion system is considered. A generalized thermoacoustic model with distributed monopole-like actuators is proposed. To stabilize the thermoacoustic system, a Lyapunov-based nonlinear controller is developed. It is shown that the nonlinear feedback controller achieves both exponential decay of the flow disturbance energy and unity maximum transient growth.

**Enhancing Motor Torque Control by implementing H-infinity Controller and compensating Electronics Nonlinearities**

Abroug, Neil; Moriniere, Boris

Clinatec Biomedical Research Center, France

Motor torque control is a key feature in force centered robotic applications such as haptics, force amplification and telemanipulation with force feedback. Most of the actually applied control schemes for this type of applications are based on 3 levels cascade control: high level force/torque loop, inner velocity loop, inner current loop. The two inner loops are respectively of P and PI type. The main goal of the two inner loops is to limit the effect of the counter-electromotive force and linearize the torque transfer by squeezing mechatronics nonlinearities. This paper presents another approach that explicitly deals with the nonlinearities and avoids the use of a velocity loop. This approach consists in adding a lag compensator to the PI current loop to enhance the torque control bandwidth, respectively the controllability of the system from the higher level controller viewpoint. The PI-Lag
compensator parametrization based on fixed structure H-infinity synthesis is illustrated. In addition, the performances of the implemented control law are discussed in comparison with other approaches.

Design, Implementation and Experimental Validation of Explicit MPC in Programmable Logic Controller

Velagic, Jasmin; Sabic, Belmin
University of Sarajevo, Bosnia and Herzegovina

This paper describes the model predictive control (MPC) in terms of an explicit controller without on-line optimization problem solving and its implementation in the programmable logic controller (PLC). For this purpose the multi-parametric quadratic programming (MPQP) approach with binary search tree (BST) is used. The optimal values are computed off-line for all possible system states and then stored in the form of appropriate table, while the computation of current system states and the search for proper control output are performed on-line. The task is to control the temperature in an incubator unit with the PLC, which executes an explicit MPC algorithm. Setting the reference value and monitoring of the processes are carried out by the human machine interface (HMI) which communicates with the PLC via Ethernet network. So, the objective is to show that the MPC control can adequately be adapted in PLC, which is commonly used for the control of industrial processes. The effectiveness and robustness of this approach are verified through experiments.

Performance Evaluation of GPC Algorithms based on Different Network-induced Delay Modeling Methods

Caruntu, Constantin-Florin
Technical University of Iasi, Romania

The networked control systems (NCSs) are now widely used in different industries with applications ranging from factory and home automation, to automotive and avionic control systems and to military and spatial applications. These NCSs have many attractive advantages (low cost, simple installation and maintenance, increased system agility, higher reliability and greater flexibility), but there is also a main disadvantage, the network-induced time-varying delay, that can deteriorate the closed-loop performances and even lead to instability. In this paper, firstly, the generalized predictive control (GPC) strategy is briefly presented and then the modeling methods for the network-induced time-varying delays are introduced. These methods assume that the delays induced by the communication network are time-varying, but bounded. Finally, the performances obtained by the networked predictive control strategy which is based on the different network-induced delay modeling methods are evaluated in
order to illustrate its efficiency in controlling the clutch displacement of an electro-hydraulic actuated wet clutch.

**Distributed Formation Control of Autonomous Underwater Vehicles with Impulsive Information Exchanges and Disturbances under Fixed and Switching Topologies**

Hu, Zhongliang\(^1\); Ma, Chao\(^2\); Zhang, Lixian\(^2\); Halme, Aarne\(^1\)

\(^1\)Aalto University, Finland; \(^2\)Harbin Institute of Technology, China

In this paper, the distributed formation problem of multiple autonomous underwater vehicles (AUVs) with impulsive information exchanges and disturbances is investigated. In the studied case, all the information exchanges among the AUVs are completed according to the admissible impulse time sequence, which is more practical in the weak underwater communication environment. By model transformation, sufficient conditions are derived to ensure that the desired formation of multiple AUVs can be achieved under both fixed and switching communication topologies. Finally, a numerical example is presented to verify the effectiveness of the theoretical results.

**Automatic Loop Shaping in MIMO QFT using Interval Consistency based Optimization Technique**

Jeyasenthil, R; Purohit, Harsh; Nataraj, P.S.V

*Indian Institute of Technology Bombay, India*

Robust Control of Multi Input Multi Output (MIMO) systems are important class of problems and their design is challenging one. This paper proposes an efficient algorithm for automatic synthesis of Quantitative Feedback Theory (QFT) based robust controllers. The proposed method uses Interval Analysis, hybrid optimization and consistency techniques. Hull consistency is used to prune the initial input domain by removing the inconsistent values which are not part of the solution. Hybrid optimization part combines interval global optimization and nonlinear local optimization methods. The proposed overall algorithm is demonstrated to design a robust MIMO QFT controller for uncertain Magnetic levitation System (ECP 750).

**A New Efficient Reconfiguration Approach Based on Genetic Algorithm in PV Systems**

Karakose, Mehmet; Murat, Kagan; Akin, Erhan; Parlak, Koray Sener

*Firat University, Turkey*

The purpose of reconfiguration process in PV systems is to find the connection structure of the highest amount of power obtained by the system under partial shading conditions. In this paper, a new genetic-algorithm based approach was presented for the reconfiguration. The system tries to maximize the obtained power in the same sub-module combining the ones that have the most approximate radiation value to each other between the panels exposing to partial shading. The proposed method only needs to short-circuit currents pertaining to an adaptive and fixed panel as the input parameter. So, it has a flexible structure that can work independently from the hardware features of PV panels. It creates the initial population generating random values by benefiting from short-circuit current information it receives. Based on these values, optimum connection diagram can be obtained in a short time. The most important advantage of the proposed algorithm is its applicability in PV systems including a great number of panels and the efficient results it generated in terms of the operating speed.
For the test of the proposed method, test data were obtained by the help of simulation prepared in MATLAB-SIMULINK environment. Then, these received data were used in genetic algorithm based reconfiguration algorithm, and the required result was obtained. The obtained results revealed that the proposed approach yielded more efficient results in PV systems.

Real-time predictive control of 3D tower crane

Iles, Sandor; Matusko, Jadranko; Kolonic, Fetah

University of Zagreb, Croatia

In this paper a real-time Model Predictive Control (MPC) for a 3D tower crane, based on subsequent solving of three quadratic programs, is proposed. Three motions of the tower crane are considered as separate subsystems with couplings among them treated as a change in system parameters. Such linear parameter varying (LPV) system can be sampled and transformed into the corresponding polytopic model, by using a Tensor Product (TP) Model Transformation. Polytopic TP model of the tower crane is used to calculate the terminal set and the terminal cost via solving Linear Matrix Inequalities (LMI). In order to guarantee recursive feasibility, system states are kept in ellipsoidal approximation of worst case initial feasible set, while the asymptotic stability is ensured by using a dual-mode MPC strategy. The proposed approach is verified through simulation and experimental test on laboratory model of a 3D tower crane.

Loss Analysis of Non-Isolated Bidirectional DC/DC Converters for Hybrid Energy Storage System in EVs

Dusmez, Serkan¹; Hasanzadeh, Amin²; Khaligh, Alireza²

¹University of Texas, USA; ²University of Maryland, USA

The selection of a bidirectional non-isolated dc-dc converter interfacing the battery and ultracapacitor (UC) in electric vehicles (EVs) is of critical importance for the overall system efficiency. Generally, efficiency comparison of converters is conducted based on given fixed input and output parameters. Such a comparison may not provide fair results for EV applications since energy source voltages and traction power vary dynamically depending on the driving conditions. This paper provides a comprehensive efficiency comparison of three level, two-level and interleaved bidirectional buck/boost converters through developed loss models considering the dynamic variables in a drive cycle. The results of the analyses show that three-level converter exhibits higher overall efficiency. A 1kW prototype has been designed and developed to serve as a proof of concept.
A Novel Control Algorithm for Magnetically Controlled Reactor
Wang, Yifan; Sun, Cong; Chen, Guozhu
Zhejiang University, China
In order to reduce the response time and solve the problem of reactive power overcompensation of the magnetically controlled reactor (MCR), a novel compensation algorithm is proposed in this paper. The algorithm is based on the principles and algorithms of unbalanced load compensation and via modifying the compensation conditions of the Steinmetz principle. The general formula of the compensatory algorithm is derived from instantaneous reactive power theory. The algorithm can be used as the control strategy to balance the three-phase active power, but also can compensate loads to specified power factor and effectively prevent reactive power feeding inversely that caused by overcompensation. The results of simulations are coincided with the theory analyses, which demonstrate that the algorithm proposed by this paper has high precision and good dynamic characteristics.

Comprehensive Steady State Analysis of Bidirectional Dual Active Bridge DC/DC Converter Using Triple Phase Shift Control
Harrye, Yasen A.1; Ahmed, K.H.1; Adam, G.P.1; Aboushady, A2
1University of Aberdeen, United Kingdom; 2Arab Academy for Science & Technology, Egypt
Several papers have been published recently on TPS control of dual active bridge (DAB) converter, however, no complete study of the converter operation behaviour exists, that takes into account all switching modes in both charging and discharging (bidirectional) power transfer. In this paper, six switching modes and their complements with opposite power transfer direction are defined with their operational constraints. Exact expressions for power transferred are derived with no fundamental frequency assumptions and range of power transfer for each mode is also defined to characterize mode limitations. Detailed constraints for zero voltage switching (ZVS) are also obtained. A new definition for converter reactive power consumption is introduced. This is based on calculation of inductor apparent power which avoids fundamental frequency approximations as well as the vague negative (back flowing) power definitions in recent papers. All known DAB phase shift modulation techniques including conventional, dual and extended phase shift, represent special cases from triple phase shift, therefore the presented analysis provides a generalised theory for all phase shift based modulation techniques.

A Novel Two Stage LED Driver Compatible with Electronic Transformers for MR16 Lamp
Liu, Wei1; Wang, Yuxi1; Yang, Zhansen1; Ma, Hao1; Wen, Wei2
1Zhejiang University, China; 2Opple Lighting Co. Ltd, China
In this paper, a novel two stage LED driver scheme used in the MR16 system is proposed. A peak current control boost converter is adopted in the front stage to avoid the capacitive load problem. By adding a low pass filter (LPF) unit in the front stage control loop, the inrush current problem is solved. The proposed approach is well compatible with the electronic transformers (ETs). The second stage can be a buck or buck-boost converter depending on the output voltage of LED lamps. The effect of the dc link voltage ripple is eliminated by adding the second stage circuit. The proposed LED driver presents a considerably good compatibility with
different kinds of electronic transformers. Moreover multi LED drivers can be parallel in the
system without the over current problem. Furthermore, the power factor can be significantly
improved with the proposed two stage scheme. 3W LED drivers are built and tested. The
experimental results verify the theoretical analysis.

A Practical Core Loss Calculation Method of Filter Inductors in PWM Inverters Based on the
Modified Steinmetz Equation
Tang, Yunyu; Zhu, Fan; Ma, Jiong; Ma, Hao
Zhejiang University, China
In this paper, a practical core loss calculation method based on the modified Steinmetz
equation is proposed. It calculates the low-frequency losses and the high-frequency losses
separately. By utilizing the curves of permeability versus DC bias provided by core vendors
instead of plenty tests, the paper establishes a relation between the DC bias and the core
losses. A novel model of minor loops is proposed to calculate the high-frequency losses based
on the simulation results and Steinmetz parameters of cores. The low-frequency loss is
analyzed in depth from the hysteresis curves in the B-H plane. The calculated results are
verified by measuring the core losses of the filter inductor in a three-level NPC inverter. The
proposed model can be derived without any test. Meanwhile, the detailed low-frequency loss
calculation is presented. Moreover, the influence of DC bias is also taken into consideration to
improve the accuracy. The proposed method is practical and accurate to predict the core
losses.

A Novel Resonant LLC Soft-Switching Buck Converter
Jabbari, Masoud; Kazemi, Habib; Hematian, Nahid; Shahgholian, Ghazanfar
Islamic Azad University, Iran
A new LLC resonant DC–DC buck converter is presented. The employed multi-resonant tank
provides soft-switching conditions for all semiconductor devices independent from the
operating voltages and the load current. The proposed converter enjoys useful advantages
such as low element count, unconditional soft switching operation, self short-circuit
protection, high efficiency and low EMI. Circuit analysis and important relations are presented
in this paper. Experimental results from a 60W laboratory prototype confirm the presented
theoretical analysis.

2nd June, Monday
09:00-11:20 at Elmas
MoA4 Power Electronics II
Session Chair : Hao Ma, Zhejiang University
Co-Chair : Rijil Ramchand, NIT Calicut

Sliding mode control of a three-phase three-wire LCL rectifier
Biel, Domingo; Doria-Cerezo, Arnau; Repecho, Victor; Fossas, Enric
Universitat Politècnica de Catalunya, Spain
This paper presents a dynamic analysis and the control design for a three-phase three-wire
unity power factor rectifier with a LCL filter. The control algorithm is based on the sliding mode control techniques that provides good tracking performance and robustness with respect to parameter variations, and a PI controller to regulate the DC voltage. The sliding control design uses a decoupling matrix to solve the algebraic constraint on the grid currents. The control law has been tested in numerical simulations with satisfactory results.

**Low cost linear current limiter for Stop & Start vehicles**

Chiappori, Guido; Moigne, Philippe Le; Delarue, Philippe; Chemin, Michael

1L2EP- EC Lille, France; 2Valeo, France

This article presents a Linear Current Limiter (LCL) specially meant for \( \mu \)-hybrid vehicles using the Stop-Start function. The LCL limits the current mainly during the start-up of the Internal Combustion Engine (ICE) in order to maintain the battery voltage stable. Its main advantages is the low price and the fact of avoiding EMC perturbation since it is composed of MOSFETs working in linear mode [1]. The concept is validated limiting the charging current of a capacitor by simulation and comparing with experimental results.

**Finite Set Model Predictive Current Control with Reduced and Constant Common Mode Voltage for a Five-phase Source Inverter**

Iqbal, Atif; Alammar, Rashid; Mostafa, Mosa; Abu-Rub, Haitham

1Qatar University, Qatar; 2Texas A&M University At Qatar, Qatar

Multiphase drives are now becoming serious competitor to traditional three-phase drives due to reasons of better fault tolerant property and reduced per-phase converter rating that are especially suited to high power drives application. One of the major factor of widespread research on multiphase drive are the availability of high computational power of control platforms such as DSP and FPGAs. With availability of such computationally powerful tool of DSP/FPGA leads to the adoption of model predictive control (MPC) in electric drive. This paper present current control of a five-phase inverter using MPC with the aim of achieving constant common mode voltage. By achieving constant common mode voltage (CMV), bearing current can be greatly reduced. This is achieved by proper selection of space vectors and analysis of drop in voltage gain is presented. Simulation results are supported by experimental approach.

**Wireless Current Sharing Scheme Considering Phase Synchronization Requirement for Paralleled Online UPS Inverters**

Lin, Liao; Zhang, Ning; Wang, Xiaorui

Zhejiang University, China

In this paper, a wireless current sharing Scheme for paralleled online uninterruptible power system (UPS) inverters is proposed, based on which effective power sharing under phase locking condition and fast dynamic response of sharing load are obtained. The output impedance of UPS inverter is designed to be resistive, and the droop method based on resistive output impedance is employed. Moreover, an adaptive virtual resistor is added to regulate the magnitude of the output impedance according to the requirement of reactive power sharing, which makes the power sharing less sensitive to frequency change. Besides, the root-mean-square (RMS) loop is adopted to improve the output voltage quality. And the secondary P-V droop method is put forward to decrease the amplitude deviation and improve the dynamic performance of current sharing. Simulation and experimental results are
presented to demonstrate the validity of the proposed scheme.

**Indoor WiFi Energy Harvester with Multiple Antenna for Low-power Wireless Applications**

Abd.Kadir, Ermeey; Hu, Aiguo Patrick; Biglari-Abhari, Morteza; Aw, Kean C

*The University of Auckland, New Zealand (Aotearoa)*

This research proposed a WiFi energy harvester for low-power wireless applications. The proposed system harvests energy using three antennas to cover three ISM (Industrial, Scientific, and Medical) channels with central frequencies at 2.412 GHz, 2.439 GHz, and 2.462 GHz. For each channel, a coplanar waveguide antenna is designed to harvest energy from indoor WiFi transmitters. FR4 substrate with relative permittivity of 4.3 and loss tangent of 0.025 is used to form the antennas. The output from each harvester antenna is then connected to a seven-stage multiplier circuit. The multiplier circuit is to rectify and boost the harvested energy to a higher voltage level and then stored temporarily in a super capacitor. A dc-dc boost-charger circuit with battery management is used to increase the output voltage level to 2 V. An experiment with the proposed system has been conducted using transmitted energy from available WiFi transmitters. The power density at the harvesting antenna front is between -80 dBm and -50 dBm. The proposed harvester system takes about 6 to 7 hours to charge up the first stage super capacitor up to the minimal threshold voltage (0.45V). This minimal threshold will start the boost-charger circuit charging the secondary storage device. This research demonstrates that the proposed system can supply energy for low-power wireless sensors that operate with an input power less than 1 mW.

**Modeling, Simulation and Implementation of Single Phase Five Level Inverter Fed from Renewable Energy Sources**

K, Biju¹; Ramchand, Rijil²

¹College of Engineering Munnar, India; ²NIT Calicut, India

At present, the whole world is going through a severe energy crisis due to the nonreplenishable nature of fossil fuels which are major sources of energy conventionally. In addition to limited availability of conventional energy sources, they also contribute heavily towards environmental pollution. In this scenario, renewable energy sources has got significant role to play in meeting global energy demand. Solar and wind energy systems are the most popular types of grid connected renewable energy systems. In this paper we are presenting a new system configuration for interfacing the hybrid solar and wind energy system to the grid. This configuration is flexible and it allows these two renewable energy sources to supply the load together or independently depending upon their availability. The configuration proposed here uses a modified five-level inverter for converting DC voltage generated from renewable energy sources to AC voltage at desired frequency. The usage of five-level inverter reduces Total Harmonic Distortion (THD) in output voltage and helps in eliminating bulk filters required at the output side. Simulation study of the proposed system is carried out using MATLAB Simulink. Experimental verification is carried out by implementing control algorithm using AT89C52 microcontroller. Both simulation and hardware results are provided in this paper.

**Frequency Adaptive Repetitive Controller for Grid-Connected Inverter with an All-Pass Infinite Impulse Response (IIR) Filter**
The repetitive controller is widely employed in grid-connected inverters to improve the power quality. Its resonant frequencies are predesigned to the nominal grid frequency and its harmonics to achieve excellent reference tracking and disturbance eliminating. However, the performance degrades when the grid frequency varies. In this paper, a frequency adaptive repetitive controller with a specially designed all-pass infinite impulse response (IIR) filter is proposed to improve the steady-state performance considering grid frequency variation. The IIR filter approximates a fractional delay. By adjusting the delay, the resonant frequencies can be corrected to the actual grid fundamental and harmonic frequencies. The filter design is based on the Thiran formula, which is simple with a closed form, and online real-time computation burden is highly reduced. The IIR filter has a wide band of linear phase region with low order. As the system stability is independent on the IIR filter for its all-pass characteristic, the system synthesis is simplified. Results from a single-phase grid-connected inverter are provided to validate the effectiveness of the proposed control scheme.

2nd June, Monday  
09:00-11:00 at Sedef  
MoA5 Power Electronics III  
Session Chair: Woojin Choi, Soongsil University  
Co-Chair: Guozhu Chen, Zhejiang University

Fully Integrated High Accuracy Continuous Current Sensor For Switching Voltage Circuits
Hussein, Ahmed I.; Mohieldin, Ahmed N.; Hussein, Faisal; Eladawy, Ahmed
Cairo University, Egypt

This paper presents the design of a novel integrated continuous current sensor (CCS) circuit for class-D audio amplifier and current mode controlled DC-DC converter. The proposed current sensor has the capability of sensing either positive or negative current of off-chip inductor continuously. Additionally, fast transient response with low quiescent current has been achieved. Furthermore, a calibration technique has been developed and attached to current sensor circuit to eliminate performance deterioration due to process, supply, and temperature (PVT) variation. The proposed CCS has been implemented using TSMC 65nm technology. Simulation results show that the proposed CCS is able to operate with switching frequency up to 1MHz at only 75 μA quiescent current. The overall accuracy of proposed CCS is greater than 95% over all process corner sand temperature variation from -40 °C to 125 °C, and supply variation from 2.5V to 2.9V.

Development of the Intelligent Charger with Battery State-Of-Health Estimation Using Online Impedance Spectroscopy
Nguyen, Thanh-Tuan; Tran, Van-Long; Choi, Woojin
Soongsil University, Korea (South)

In this research, a novel intelligent charger with battery diagnosis function is proposed. The
diagnosis function is implemented by way of impedance spectroscopy achieved by controlling the charger to create a frequency swept excitation voltage at the battery terminals with no additional hardware. The impedance variation of battery according to the degradation over the life is measured and used for evaluating the State-of-Health (SOH) of the battery. The voltage perturbation and the current response of the battery are measured by the digital lock-in amplifier embedded in the digital signal processor (DSP) in order to calculate the impedance of the battery. The parameters of the equivalent circuit model for the lead-acid battery are extracted by using the complex non-linear least square method and compared to the reference values to estimate the SOH of the battery. The design procedure of the proposed charger is detailed and the feasibility of the system is verified by the experiments.

**A generic approach to implementing finite-set model predictive control with a fixed switching frequency**

Tomlinson, Males; Mouton, Toit; Kennel, Ralph; Stolze, Peter

1Universiteit Stellenbosch, South Africa; 2Technische Universität München, Germany

This paper presents a generic approach to practically implementing a finite-set model predictive control strategy with a fixed switching frequency for high sampling rates. With conventional FS-MPC methods, the equations for describing the predictions of the controlled variables are derived specifically for each given topology. In this paper, a more generic approach is presented by using established state space control theory to develop a method for modelling and implementing an arbitrary topology. Numerical methods and the use of a symbolic computational toolbox is used for the calculation of off-line prediction equations and using a lookup table to reduce on-line computation time. An implementation scheme for an FPGA is discussed and experimental results are provided to confirm a successful design.

**New Topology Three Phase Multilevel Inverter for Grid-Connected Photovoltaic System**

Alyan, Ahmad; Rahim, Nasrudin Abd.; Mubin, Marizan; Eid, Bilal M.

1University of Malaya, Malaysia; 2King Abdulaziz University, Saudi Arabia

This paper presents a new schematic for three phase seven-level inverters. The proposed topology minimizes switching, reduces short circuiting, is easy to control, and can mask through upper-level switches the work of lower levels. System improvements include low ripple-current, high power conversion and minimized switching, which are verified in simulations using the Matlab/Simulink software package. Experimental results are obtained through the use of field programmable gate arrays (FPGA), and the pulse generation is carried out using the SPARTAN 3A DSP board. The proposed topology has been experimentally implemented for both five-level and seven-level pulse width modulated laboratory inverters.

**High Precision Control Strategy for Three-Phase Four-Wire Shunt Active Power Filter**

Xu, Qunwei; Zhong, Xiaojian; Yao, Wenxi; Chen, Guozhu

Zhejiang University, China

Three-phase four-wire Shunt Active Power Filters (SAPFs) can not only compensate the harmonics and reactive power for kinds of unbalanced nonlinear loads, but also suppress the neutral current. According to the disadvantages of conditional control strategies in dq0 frame for APF systems, a control strategy based on abc frame for three-phase four-wire SAPFs is presented. It achieves the control of DC-bus voltage and compensation currents in time
domain and there is no coupling among each phase. What’s more, the selective harmonic
detection method based on Discrete Fourier Transformation (DFT) algorithm and the
compound current control strategy consists of Proportional-Integral (PI) controller and
repetitive controller are adopted. Consequently, excellent compensation performances both in
balanced and unbalanced load are achieved. Experimental results of a 16.5-kVA laboratory
prototype prove its efficiency and feasibility.

A Variable DC Link Approach for High Power Factor Three-Level Single-Stage PFC Converter
Dusmez, Serkan; Akin, Bilal
University of Texas at Dallas, USA
To reduce the cost of the conventional two-stage power factor correction (PFC) converters,
single-stage PFC (SSPFC) converters have been studied in literature. Most commonly, the
SSPFC converters are operated at DCM mode due to the simplicity of the control, non-
existence of the reverse recovery losses. For ac/dc converters supporting universal input
voltage range, DCM operation with relatively low dc link voltage results in highly distorted
input current. In multi-level SSPFC converters, the dc link voltage can be adjusted in a larger
window between 400V-800V thanks to the reduced voltage stresses on the switches. Thus,
with an integrated controller adjusting dc link voltage with respect to line voltage, power
factor at high line voltage can be improved. However, in DCM mode, the efficiency of the
converter slightly decreases at high dc link voltage. In this paper, the tradeoff between the
efficiency and the input factor is analyzed for a new integrated three-level PFC converter.

Modeling and Analysis of Switching Frequency Circulating Current in Three-Phase Parallel
Inverters
Ma, Hao; Lin, Zhao; Dong, Liang; Guo, Qian
Zhejiang University, China
There are circulating currents among the parallel inverters. Based on the existing researches
on circulating currents, an accurate model of switching frequency circulating current is
proposed in this paper. Moreover, the relationships between the circuit parameters and
switching frequency circulating current are investigated and analyzed in detail. Based on the
analytical results, favorable design guidelines to restrain the switching frequency circulating
currents are further presented. The simulation by means of Matlab is well developed to
describe the proposed mathematical model and validates the effectiveness of the theoretical
analyses.

Operating Region Comparison of Symmetric and Asymmetric Multilevel Shunt Active Power
An operating region comparison is performed between a symmetric and an asymmetric CHB Multilevel Shunt Active Power Filter aimed to simultaneously compensate linear and nonlinear currents. The symmetric approach considers that all the power cells injects the same voltage; while the asymmetric case consists in the inclusion of two types of power cells; one of them meant for fundamental reactive power compensation and the other to cancel out the distortion power. Using steady state equations, the modulating signals of the H-bridges are calculated for a wide range of load conditions. This is used to identify when the converters lie in over-modulation and thus, the allowable operating region is found. Different values for the system parameters are considered in order to identify the compensation capabilities of both approaches. The presented results are supported with theoretical developments and simulated analyses.

A Different Inductor Cell for AC Multilevel Current Generation

Capilla, Adrian; Lopez, Hector; Vazquez, Nimrod; Hernandez, Claudia

Instituto Tecnologico de Celaya, Mexico

DC/AC converters are widely used in several applications; traditionally they can be classified in two types: the voltage source inverters (VSI) and the current source inverters (CSI). Their use depends on the application; however some of them are common for both types of converters. Other possibility for the DC/AC conversion is the multilevel configuration, there have been proposed different topologies for multilevel current source inverter (MCSI); in this paper is proposed a different inductor cell to produce more levels with less components. The operation and simulation results are shown.

Model Predictive Control of Three Phase Voltage Source Converters with an LCL Filter

Yoo, Dae Keun1; Wang, Liuping1; Rogers, Eric2; Paszke, Wojciech3

1Royal Melbourne Institute of Technology, Australia; 2University of Southampton, United Kingdom; 3University of Zielona Gora, Poland

Industry regulations and standards are placing ever increasing limitations on the individual and total harmonic distortion levels that can be injected into the grid and hence an LCL circuit becomes an attractive option to interconnect an inverter to the utility grid. However, despite the benefits of LCL filter in reducing the switching harmonics, the inherent resonance present in this filter can cause a closed-loop stability problem due to increased grid current distortion. This paper develops a model predictive based current control for a three phase grid connected converter with an LCL filter. The objective is to provide fast tracking response of the desired system reference coupled with suppression of the resonance disturbance caused by the LCL filter.

FPGA-based design of a Step-up Photovoltaic Array Emulator for the test of PV Grid-Connected Inverters

Chavarria, Javier; Biel, Domingo; Guinjoan, Francesc; Poveda, Alberto; Masana, Francesc; Alarcon, Eduard
In this work, a proof of concept prototype for a photovoltaic array emulator based on a DC-DC Boost converter is presented. This design arises from the need to study in the laboratory new PV inverters based on Silicon Carbide (SiC) devices in order to evaluate their performances. The lack of space for installation of real photovoltaic panels and the high costs of the commercial emulators lead to alternative systems which allow the reproduction of the characteristic curves of the panel arrays as well as their dependence on changing environmental conditions. The control algorithm designed for the emulator prototype is implemented by means of a field programmable gate array (FPGA). Experimental results confirm the proper operation of the PV emulator which is applied to a full-bridge single phase grid-connected inverter.

Controller Area Network for Fault Tolerant Small Satellite System Design
Kimm, Haklin; Jarrell, Matt
East Stroudsburg University, USA
The Controller Area Network (CAN) is a message based event triggered communication bus mostly used in the automotive industry. In this paper, however, the CAN bus is tested for being applicable to small satellite systems in order to provide better fault-tolerance. The CAN bus connects several independent CAN modules and allows them to communicate and work together asynchronously and/or synchronously. The CAN modules were designed to decrease weight and cost while improving stability and power consumption compared to current small satellite systems. We present advantages to using the CAN bus over existing satellite bus systems, design and propose a CAN protocol for CubeSats.
under assumption that the absolute acceleration information makes WOB more effective to estimate disturbances in work-space in some cases. To evaluate the accuracy of the tip-position control using the estimated values of the acceleration information, some kinds of simulations and experiments are conducted in this research.

Error Analysis of a Charge-balancing Capacitive Sensor Interface with Resistive Reference
Yang, Ruimin; Nihtianov, Stoyan
Delft University of Technology, Netherlands
This paper presents a detailed error analysis of a charge-balancing capacitive sensor interface (CSI), which is based on resistor-capacitor (R-C) comparison. Precision resistive and time references can be utilized in the CSI to achieve high-precision capacitance-to-digital conversion. However, having precision references is not sufficient for the CSI to perform a precision measurement. The comparison of the measured capacitance with the reference introduces additional errors and instability. As a result, the errors of the comparison circuit degrade the performance of the CSI. For this reason, an in-depth error analysis is performed to identify the error sources and their impacts on the final measurement results. Based on that, error budgets can be properly allocated according to specific requirements. Besides, several circuit techniques are proposed to reduce the corresponding errors. A design example is presented, which achieves a thermal drift as low as 6ppm/°C.

Use of Antagonistic Shape Memory Alloy Wires in Load Positioning Applications
Antonello, Riccardo1; Pagani, Sebastian1; Oboe, Roberto1; Branciforte, Marco2; Virzi, Maria Celvisia2
1University of Padova, Italy; 2STMicroelectronics, Italy
This paper is concerned with the analysis of an actuation system for load positioning applications based on a pair of antagonistic shape memory alloy wires. In this system, the restoring force required to stretch a wire in martensitic phase can be actively controlled by modulating the power provided to its antagonistic element. For the generation of controlled repeatable motions, this is an undoubted advantage over a configuration based on a single wire, where the restoring force is generated by a passive element such as a constant load or a spring. In order to ease the comprehension of the actuation principle based on antagonistic shape memory wires, this paper reports at first the derivation of a lumped parameter mathematical model of the actuation system. Then, the behaviour predicted by the model is used to support the analysis of the experimental results obtained with a special test bench consisting of two antagonistic NiTi wires driving a low-friction slider mounted on a linear guide.

Long Range Ultrasonic Inspection of Aircraft Wiring
Parthipan, Thayaparan1; Jackson, P.1; Chong, Alvin2; Legg, M.2; Mohimi, Abbas2; Moustakidis, Serafeim3; Hrissagis, K.3
1Plant Integrity Ltd., United Kingdom; 2Brunel University, United Kingdom; 3Centre for research & Technology, Greece
Inspecting complex aircraft wiring by means of ultrasonic non-destructive testing has been addressed. This paper discusses the progress on the development of software and hardware that enable a novel technique of Long Range Ultrasonic Testing—a subset of ultrasonic non-
destructive testing to be implemented for the inspection of complex aircraft wires insulation. A representative aircraft wire was modelled to identify appropriate wave modes that can be utilized for the inspection. The modelling work was validated via laser interferometry. The sensor array was driven with the Teletest® pulser-receiver unit used in laboratory conditions to produce data for signal processing. Signal processing algorithms that combine baseline subtraction and anti-correlation algorithms were deployed to detect features as well as defects on cable insulation. Further work on validating the hardware, software and system integration is planned.

**Design of a robust H-infinity repetitive control system with time-delay**

Shao, Zhen¹; Xiang, Zhengrong¹; Karimi, Hamid Reza²

¹Nanjing University of Science and Technology, China; ²University of Agder, Norway

This paper investigates the problem of designing a robust H-infinity repetitive control system with periodic time-delay. Firstly, a continuous-discrete two-dimensional (2D) model with time-delay is constructed to describe the control and learning actions of the system. Then, by choosing an appropriate Lyapunov functional, LMI-based sufficient stability conditions for asymptotic stability and satisfactory H-infinity tracking performance of the 2D model is derived. Finally, a numerical example is given to illustrate the effectiveness of the proposed method.

**Impulsive control on the synchronization for a class of chaotic Systems**

Karimi, Hamid Reza¹; Wang, Bo²; Shi, Peng³,⁴

¹University of Agder, Norway; ²Xihua University, China; ³The University of Adelaide, Australia; ⁴Victoria University, Australia

In this paper, the impulsive control problem on the synchronization for a class of chaotic systems is discussed. Based on Lyapunov stability theory, the new impulsive synchronization strategy is presented to realize the chaos synchronization and possesses the wider scope of application. Finally the numerical simulation examples are given to demonstrate the effectiveness of our theoretical results.

**On the stability analysis for impulsive switched system with time-varying delay**

Karimi, Hamid Reza¹; Wang, Bo²; Shi, Peng³,⁴

¹University of Agder, Norway; ²Xihua University, China; ³The University of Adelaide, Australia; ⁴Victoria University, Australia

This paper focuses on the stability and stabilization problem for a neutral impulsive switching system with time-varying delay. Based on LMI method and optimization technologies, some stability criteria are derived for this kind of system. Some example and numerical simulation are given to demonstrate the effectiveness of our theoretical results.
Phase-Equalization-System (PES) Design Utilizing New Phase-Error Function

Qin, Wei\textsuperscript{1}; Ito, Noboru\textsuperscript{2}
\textsuperscript{1}Dalian Polytechnic University, China; \textsuperscript{2}Toho University, Japan

This paper derives a new phase-error function for designing digital all-pass (AP) phase-equalization-system (PES) that is useful in digital communications and various electronic appliances including biomedical devices. Since the phase-error is a highly non-linear function with respect to the AP PES coefficients, the AP PES design is a challenging task. After deriving the phase-error function, we formulate the AP PES design as an iterative linear-programming (LP) problem and achieve the final PES design through iterating the LP procedure. We will use a design example to show that the proposed iterative LP formulation can achieve higher performance PES design than other existing design methods.

Fast Generation of Generalized Autoregressive Moving Average Processes

Ferdi, Youcef
University of Skikda, Algeria

This paper presents a new fast algorithm for synthesizing sequences of generalized Autoregressive Moving Average (GARMA) processes. These can be used to model time series which exhibit both short-range and long-range dependencies, as well as periodic behavior. The proposed synthesis scheme is based upon parameterizing the Gegenbauer coefficients by ARMA models using well-established signal modeling techniques such as Pade, Prony, Shanks, or Steiglitz-Mcbride methods. The proposed method is computationally efficient, sufficiently accurate, and very simple to implement. The generated sequences can be used in simulation studies such as network traffic.

The Design of a10-Gsps Analog-to-Digital Converter Board For the Radio Astronomy Community

Jiang, Homin; Liu, Howard; Guzzone, Kim
Institute of Astronomy & Astrophysics, Taiwan

A 4-bit, 10 gigasamples per second (Gsps) analog-to-digital converter (ADC) printed circuit board (PCB) was designed and manufactured for digitizing radio telescopes. Associated with the field-programmable gate array (FPGA) platform developed by the Collaboration for Astronomy Signal Processing and Electronics Research (CASPER) community, the developed PCB provides data acquisition systems with a wider bandwidth and simplifies the intermediate frequency (IF) section. The wider ADC bandwidth enables down converters in the IF section to be simplified, thereby saving resources. The current version of the PCB possesses an analog bandwidth of up to 5.9 GHz, whereas the chip possesses an analog bandwidth of to 18 GHz. This facilitates second and third Nyquist sampling using the revised PCB.
On The Implementation Of 2-D Separable-In-Denominator Recursive Filters
Wang, Dali1; Bai, Ying2; Zilouchian, Ali3
1Christopher Newport University, USA; 2Johnson C. Smith University, USA; 3Florida Atlantic University, USA
Realization and implementation of a class of two-dimensional (2-D) separable-in-denominator recursive digital (SDRD) filters are discussed in this paper. First, we present five modular structures of 2-D SDRD filters which possess a high degree of modularity, parallelism and regularity in their building blocks for easy hardware and software implementation. Second, we analyze the performance of each realization in term of computational complexity and data throughput delay for both parallel and serial processing. This work provides a comprehensive framework on the selection of realization structures and implementation techniques for any 2-D SDRD filters.

Bacterial Foraging Optimization Approach to the Controller Tuning for Automotive Torque Motors
Precup, Radu-Emil1; Borza, Andrei-Leonard1; Radac, Mircea-Bogdan1; Petriu, Emil M.2
1Politehnica University of Timisoara, Romania; 2University of Ottawa, Canada
This paper proposes the Bacterial Foraging Optimization (BFO)-based tuning of controllers for a pancake DC torque motor in the framework of a Diesel engine exhaust gas recirculation valve as a representative automotive torque motor actuator. The validation of the position of bacteria only if the control system response is in a valid range is inserted in the BFO algorithm. PID and sliding mode controllers are optimally tuned by the BFO algorithm focused on solving an optimization problem that minimizes an objective function expressed as the weighted sum of overshoot plus the integral of squared error. The parameters of these two controllers belong to the vector variables of the objective function. A case study that deals with the shaft angle control of an automotive torque motor actuator is included to validate our approach by simulation results. The comparison of control system performance is carried out.

Print-and-Scan Counterattacks For Plastic Card Supports Fourier Watermarking
Riad, Rabia1,2; Harba, Rachid2; Douzi, Hassan1; Elhajji, Mohamed1; Ros, Frederic2
1Ibn Zohr University, Morocco; 2University of Orleans, France
In recent past years, Fourier based watermarking techniques have been developed to deal with the print-and-scan attack. In this work, print-and-scan counterattacks for Fourier watermarking are proposed in the context of an industrial application where identity (ID) images are printed and scanned on a plastic card support. The counterattacks are within two stages. The first stage concerns the reduction of image blurring that occurs during the print-and-scan process. Blind restoration and unsharp filters already proposed elsewhere are compared to a Wiener filter adapted to the print-and-scan channel. The second stage deals with the color corrections. These image counterattacks are applied before the watermark retrieval. The proposed method has been experimentally tested on a set of 100 ID images. Results show that the adapted Wiener filter outperforms the blind restoration and unsharp filters in terms of detection rate and distance between empirical probability density functions of correlation values from marked and unmarked images. Finally, the color correction allows a noticeable increase of the overall performances of the method.
PV/Battery Hybrid Energy System via a Double Input DC/DC Converter For Dynamic Loads
Tavlasoglu, Yakup; Akar, Furkan; Vural, Bulent
Yildiz Technical University, Turkey
In this work, the utilization of a Photovoltaic (PV) array and a battery pack in parallel via a double input DC/DC converter including a coupled inductor is reported. The dynamic performance of this proposed hybrid energy system is analyzed in detail through the switching model created in MATLAB® Simulink® environment by using PLECS® power components under different solar irradiance and demanded load levels.

Performance Evaluation and Comparison of Single-Phase and Two-Phase Interleaving Flyback Micro- Inverters for Grid Connected PV Systems
Kavurucu, Semih; Hava, Ahmet M.
Middle East Technical University, Turkey
Flyback converter based single-stage, micro-inverters are attractive solution for interfacing individual PV modules to the grid due to their low cost, high performance, ease of implementation, and galvanic isolation. In such applications, discontinuous conduction mode (DCM) of operation and interleaving techniques bring additional size and performance advantages such as eliminating reverse recovery loss, switching stress, EMI radiation, and improving efficiency. This paper focuses on performance evaluation of flyback micro-inverters achieving single-phase and interleaving operations with DCM operation. Design and implementation of 200 W single-phase and two-phase interleaved flyback micro-inverters are realized, detailed laboratory tests are conducted and benefits of interleaving technique are demonstrated.

Series Active Filter Based Resonance Damping of High Power Three-phase, LCL Filtered, Grid Connected Voltage Source Inverters
Usluer, Nadir S.1; Hava, Ahmet M.2
1ASELSAN INC., Turkey ; 2Middle East Technical University, Turkey
A series active filter (SAF) based method for the damping of resonant harmonics created by the LCL-filter of the grid connected PWM-VSI is proposed. Oscillations in multi-megawatt rated high power inverters with LCL-filters are damped with resistors which create undesired power losses typically up to 1% of the rated power of the system. The method stated in this paper overcomes the stability/oscillation problem while providing a solution to the resistive power loss. The proposed SAF compensated system performs satisfactorily under rated load conditions and the transition from passive damping to SAF is flawless. Adaptability of the proposed method to dynamic loads is also advantageous as opposed to passive damping
methods. Simplified circuit diagrams and schematics are provided through the paper. Mathematical model of the passively damped filter is compared and contrasted with the SAF compensated system. The validity of the proposed method is proven via simulations.

**Evaluation of Selective Harmonic Elimination and Sinusoidal PWM for Single-Phase DC to AC Inverters under Dead-Time Distortion**

Jahmeerbacus, Iqbal; Sunassee, Mevin  
*University of Mauritius, Mauritius*

The switch-mode operation of dc to ac inverters produces undesirable harmonics in the voltage and current outputs. Pulse Width Modulation (PWM) schemes based on Selective Harmonic Elimination (SHE) and carrier-based modulation are commonly used to address the harmonic reduction problem, and to provide adjustable inverter output fundamental components. The implementation of each scheme requires introduction of dead-time delays in the power switches of each inverter leg to cater for nonzero switching times of power semiconductors. In this paper we investigate the effect of dead-time distortion on the performance of SHE and sinusoidal PWM techniques for single phase dc to ac inverters with unipolar voltage switching. The modulation schemes are evaluated based on the harmonic distortions in the output currents and voltages, and on the power efficiencies when the inverters are operated at comparable switching frequencies.

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**A Novel Lithium-Ion-Polymer Battery Model for Hybrid/Electric Vehicles**

Ceylan, Murat; Sarikurt, Turev; Balikci, Abdulkadir  
*Gebze Institute of Technology, Turkey*

Lithium-ion polymer batteries are getting popular in both renewable energy systems and electric vehicles thanks to their high power and energy density. Therefore, accurate battery models are vital in design and simulation of hybrid/electric vehicle propulsion systems. In this work a novel equivalent circuit-mathematical battery model whose parameters were extracted from experimental data is proposed. The simulation results were compared with actual results obtained from a series of experiments carried out using an automotive-grade 11 Ah Kokam SLBP lithium-ion polymer battery. The model exhibits consistent behaviour.

**A Low Cost High Performance UPQC for Current and Voltage Harmonics Compensations**

Trinh, Quoc-Nam; Lee, Hong-Hee  
*University of Ulsan, Korea (South)*

This paper introduces a low cost high performance three-phase unified power quality conditioner (UPQC) by using four-switch three-phase inverters. In the proposed UPQC, both
shunt and series active power filters (APFs) are developed by using four-switch three-phase inverters so that the number of switching devices in the proposed topology is reduced from twelve in the traditional UPQC down to eight devices. In addition, by inserting an additional capacitor in series with the shunt APF, the DC-link voltage in the proposed UPQC can also be greatly lessened. As a consequence, by using a smaller number of power switches with lower rating voltage in the proposed UPQC system, we can greatly reduce the system cost of the UPQC without degrading the harmonic compensation performance. Design of passive components for the proposed UPQC to achieve a good performance is discussed in detail in this paper. Simulation studies are performed to verify the effectiveness of the proposed topology.

**Analysis and Design of Distributed DC Power System with Modular Three-port Converters**  
Zhang, Junjun\(^1\); Wu, Hongfei\(^2\); Cao, Feng\(^1\); Xing, Yan\(^1\); Ma, Xudong\(^2\)  
\(^1\)Nanjing University of Aeronautics and Astronautics, China; \(^2\)Southeast University, China

Flyback converter based single-stage, micro-inverters are attractive solution for interfacing individual PV modules to the grid due to their low cost, high performance, ease of implementation, and galvanic isolation. In such applications, discontinuous conduction mode (DCM) of operation and interleaving techniques bring additional size and performance advantages such as eliminating reverse recovery loss, switching stress, EMI radiation, and improving efficiency. This paper focuses on performance evaluation of flyback micro-inverters achieving single-phase and interleaving operations with DCM operation. Design and implementation of 200 W single-phase and two-phase interleaved flyback micro-inverters are realized, detailed laboratory tests are conducted and benefits of interleaving technique are demonstrated.

**Control Strategy for Microgrid Inverter under Unbalanced Grid Voltage Conditions**  
Guo, Xiaoqiang\(^1\); Geng, Hua\(^2\); Guerrero, Josep\(^3\)  
\(^1\)Yanshan University, China; \(^2\)Tsinghua University, China; \(^3\)Aalborg University, Denmark

This paper presents the theoretical analysis of the inherent reason of current harmonic and power oscillation phenomena in case of operating the microgrid inverter under unbalanced grid voltage conditions. In order to flexibly control the current harmonic and power oscillation, a new stationary frame control strategy is proposed. It has a simple control structure due to no need of a phase-locked loop and voltage/current positive/negative sequence extraction calculation. The coordinate control of power and current quality is achieved, which enhances the operation performance of microgrid inverter. Finally, the performance evaluation tests are carried out under unbalanced grid voltage conditions. Results verify the effectiveness of the propose method.

**Space Vector Based PWM of Dual Full-Bridge VSI fed Two-Phase Induction Motor Drive**  
Kumar, Bharat; Srinivas, Srirama  
Indian Institute of Technology Madras, India

Two-phase induction motor (TPIM) can be controlled using a 4-leg voltage source inverter (VSI) topology. A space vector based space vector pulse width modulation (SVM) is proposed in this
paper for the 4-leg VSI by decomposing it into a dual single phase full-bridge VSIs. The
switching algorithm is envisaged by exploiting the principles of SVM of three-phase VSIs. The
implementation of the proposed SVM exploits the use of effective-time period concept and is
entirely based on instantaneous magnitudes of the four phase reference voltages
corresponding to the actual reference space vector. The use of effective time concept obviates
the need for sector identification and reduces the execution time thus making the whole task
of modulation fairly simple. The proposed SVM is simulated first using MATLAB/Simulink and
are experimentally verified on a 1/4 hp TPIM controlled with V/f control in the linear
modulation range.

Comparative Study of Series-Series and Series-Parallel Compensation Topologies for Electric
Vehicle Charging

Aditya, Kunwar; Williamson, Sheldon
Concordia University, Canada

Loosely coupled inductive power transfer (IPT) systems have recently gained enormous
attention for electric vehicle (EV) battery charging. For EV battery charging, a constant-current
source is required. Numerous published papers suggest that the secondary of loosely coupled
IPT systems, if series compensated, can act as constant-voltage source; and, if parallel
compensated, it can act as constant-current source. In this paper, the authors prove that both
series as well as parallel compensated secondary can act as constant-current source as well as
a constant-voltage source, depending on the nature of power supply. Hence, either of the
topological options can be utilized efficiently for EV charging. The authors intend to present
the work for the case where primary is in the form of a long track, such as in a mono-rail or
electric traction metro system. Hence, the primary is always considered to be series
compensated.

2nd June, Monday
14:00-16:00 at Elmas
MoB4 Power Electronics VII
Session Chair : Yen-Shin Lai, National Taipei Institute of Technology
Co-Chair : TBD

A Comprehensive Analysis of Matrix Converters: Bidirectional Switch, Topology, Modelling
and Control

Rmili, Lazhar1; Rahmani, Salem1; Vahedi, Hani2; Al-Haddad, Kamal2
1University of Tunis El-Manar, Tunisia; 2Universite du Quebec, Canada

Matrix Converters (MCs) are popular due to direct AC/AC conversion applications without the
need of bulky, lifetime limited DC links capacitors. In this paper the mostly used MC topologies
are explained. Each topology is also modeled and described as well. Moreover, various types
of bidirectional switches required for building a MC are studied and compared to show their
advantages and drawbacks. As well, some controlling methods associated to MCs are also
Multi-Source Converter for Energy Harvest in an Internal Combustion Engine Vehicle and Its Power Distribution Control

Lai, Yen-Shin¹; Chen, Wen-Shyue¹; Lee, Fong-Cyuan¹; Shei, Tsung-Wei²; Chang, Shin-Hung²; Lin, Chun-Chen²

¹National Taipei Institute of Technology, Taiwan; ²ITRI, Taiwan

The paper will present a converter with multiple sources for energy harvest of internal combustion engine vehicle. The energy sources include solar panel, regeneration energy during braking and thermal electrical generator. Since these three energy sources have different power rating, a power distribution control method is proposed in this paper. The proposed power distribution control provides effectively specific power distribution control while requiring less feedback signals and thereby reducing the cost of AD converter etc. The specifications of the converter include: input voltage ranging extends from 16 V to 60 V, output power is around 1.32 kW and output voltage is 12 V. Details of the controller design, simulation and experimental results will be presented to confirm the effectiveness of the proposed multi-source converter and power distribution control method. The results show that the output voltage can be well regulated. All the power distributions among different energy sources can be achieved. The prototype is designed and experimental results are included for confirmation.

Analysis and Characterization of Power MOSFETs for Power Converters Energy & Reliability-Aware-Design

Capua, Giulia Di¹; Femia, Nicola¹; Toledo, Davide¹; Abbatelli, Luigi²; Bazzano, Gaetano²

¹University of Salerno, Italy; ²STMicroelectronics, Italy

This paper discusses the impact of Power MOSFETs (PMs) Capacitance-Voltage (C-V) characteristics on switching losses in power converters. A fast and robustly convergent numerical technique is adopted to analyze the sensitivity of PMs power losses with respect to their C-V shapes. Such technique helps both in identifying desirable specifications for PMs design, and in achieving appropriate selection of PMs for power converters energy & reliability aware design. The results presented in this paper, concerning loss analysis and experimental verification for a 85V to 170V@0.5A dc-dc boost converter, highlight the PMs C-V curves impact and the valuable support of the proposed technique in PMs design.

FAΘPSO Based Fuzzy Controller to Enhance LVRT Capability of DFIG with Dynamic References

Beheshtaein, Siavash

Isfahan University of Technology, Iran

With increasing demand for energy, there is a growing tendency to employ renewable sources such as wind energy. Using large amounts of energy from wind arouses critical issues such as voltage variation and poor quality power supply. Several papers have been published on suggestions to improve performance of wind turbines during grid fault; however, to the authors’ knowledge only a few papers address this problem with dynamic references. This paper presents the fuzzy adaptive theta particle swarm optimization (FAΘPSO)-based fuzzy
controller applied to a doubly fed induction generator (DFIG) to operate at medium voltage. The proposed method attempted to determine required reactive power reference and active power amplification factors based on recommendations presented by the German Transmission Code 2007 and capability limits of the DFIG. Optimum values of membership functions were obtained by utilizing an FA PSO algorithm. This method improves voltage profile at the first instant besides during the grid fault. Moreover, aforementioned method also acts as an additional controller that could emerge with different inner controllers in the DFIG.

**Optimal Hysteresis Based DPC Strategy for STATCOM to Augment LVRT Capability of a DFIG Using Dynamic References**

Beheshtaein, Siavash; Farzanehfard, Hossein
*Isfahan University of Technology, Iran*

The recent trend in energy supply according to grid codes means that wind turbines need to connect to grids in both normal and abnormal conditions. It is therefore necessary to implement a fast and efficient method that enables a wind turbine to safely ride through faulty conditions. This paper employs optimized double decouple synchronous reference frame phase locked loop (ODDSRF-PLL) to correctly detect amplitude of grid voltage, then based on the output of ODDSRF-PLL, dynamic reactive power references are derived via fuzzy logic controller (FLC) and fed into a hysteresis based direct power control (H-DPC). To improve performance of static synchronous compensator (STATCOM) fuzzy adaptive particle swarm optimization (FAPSO) algorithm is used to determine optimal bands of H-DPC; furthermore, a reactive power reference correction (RPRC) is utilized to assign right values to reactive power references. This structure is implemented in MATLAB. The results demonstrate that the voltage profile is effectively improved during normal and grid fault conditions. Along with a proposed control scheme, it provides the wind generator the ability to remain connected during voltage sag and, at the same time, to fulfill the demanding reactive power requirements imposed by recent grid codes.

**Design of Laboratory Course for Learning Power Converters at Taipei Tech**

Chen, Wen-Shyue; Lai, Yen-Shin
*National Taipei University of Technology, Taiwan*

The main theme of this paper is to present the laboratory course design for magnetic components learning and hands-on. These magnetic components which are widely used in power conversion applications include inductor, drive transformer, and transformer with and without center-tapped windings for power conversion. The designed course is based upon modular concept and these modules include forward converter module for inductor and transformer with center-tapped winding, flyback converter module for transformer with air-gap acting as inductor and transformer, push-pull converter module for transformer with center-tapped winding and full-bridge converter module for drive transformer. The specifications for all modules are the same and the designed modular course has been applied to R & D Master Program sponsored by the industry. As acknowledged by the students, the designed modular course provides practical training and covers the wide range of magnetic components in power conversion applications.
Sensorless Interior Permanent Magnet Synchronous Motor Drive System for Air Conditioners
Liu, Tian-Hua; Tseng, Shao-Kai; Chen, Jui-Ling
National Taiwan University of Science and Technology, Taiwan
This paper proposes a new rotor position estimating method by detecting the stator currents under each PWM switching state for an interior permanent magnet synchronous motor drive system. The proposed sensorless drive system can be applied in an air conditioner without injecting any high-frequency sinusoidal or cosine voltage signal. The operating speed range can be effectively extended because the maximum available voltage is increased when compared to the high-frequency sinusoidal or cosine voltage injection method. A digital signal processor, TMS-320-F-2812, is used to execute the rotor position estimator and controller. Several experimental results are included to evaluate the theoretical analysis. The experimental results show that the proposed sensorless method can provide satisfactory performance for a closed-loop interior permanent magnet synchronous motor drive system applied in an air conditioner.

A Novel Technique for Online Partial Discharge Pattern Recognition in Large Electrical Motors
Sureshjani, Samaneh Abbasi; Kayal, Maher
Ecole Polytechnique Federale de Lausanne, Switzerland
In this paper, a fully automated system for source detection of the partial discharges (PD) as an online diagnosis test in rotating machineries is proposed. This technique uses a modified version of the Expectation Maximization-based (EM) clustering technique to separate the multi-source Phase-Resolved Partial Discharge (PRPD) measurements into multiple single-source clusters. Afterwards, the fuzzy rule-based classifier determines the degree of membership of individual clusters to the possible PD origins based on the extracted features and exploiting expert knowledge. For the first time, the concept of cluster analysis is introduced for separation of PD data coming from different sources. Interestingly, the results demonstrate the robustness of the proposed technique in classifying multi-source data even in presence of strong noise in online measurements. Among 5 available datasets with multiple PD sources, the proposed technique were successful in correct classification of 90% of the sources.

A New Permanent-Magnet Vernier Machine Using A Single Layer Winding Layout for Electric Vehicles
Abdel-Khalik, Ayman1; Ahmed, Shehab2; Massoud, Ahmed3
1Alexandria University, Egypt; 2Texas A&M University at Qatar, Qatar; 3Qatar University, Qatar
Permanent magnet (PM) vernier machines have shown promise in electric vehicle applications as they offer high torque density and low speed/high torque operation by introducing flux-modulation poles that modulate the high-speed armature rotating field and the low-speed PM rotor field. The non-overlap single layer windings provide a cost-effective design variation that eases manufacturing, reduces torque ripples, enhances voltage quality, and provides fault tolerant capability due to the negligible coupling between phases. The performance of such machines depends mainly on the proper selection of the pole and slot numbers. The preferred slots per phase per pole (SPP) ratios eliminate the effect of low order harmonics in the stator MMF, and thereby the vibration and stray loss are reduced. This paper proposes a new three-phase winding configuration based on the 20 slots/18 poles five-phase PM vernier machine which exploits the advantages of multiphase machine, including higher torque density and lower torque ripples, while fed from an off-the-shelf three-phase power converter. 2D Finite element analysis is used to verify the proposed design.

Pulsating Signal Injection-Based Sensorless Initial Rotor Position Detection of PMSM Using Three Symmetrical Injection Axes

Tang, Qipeng; Shen, Anwen; Luo, Xin
Huazhong University of Science and Technology, China

This paper investigates the performance limits of pulsating carrier signal injection method in detecting the initial rotor position of permanent magnet synchronous motors (PMSMs). To eliminate the influence of motor parameter variations and signal delays, a novel signal extraction algorithm by simultaneously demodulating the two orthogonal response currents in the estimated rotor frame is proposed. On this basis, an improved method using three symmetrical injection axes (0°, 120° and 240°) is presented to determine the rotor shaft position, which not only accelerates the detection procedure but also minimizes the dead zone effects without any compensation strategies. Besides, to identify the magnetic polarity, the magnetic saturation effects on the saliency is considered. Finally, the effectiveness of the improved approach is verified by experiments when the motor is at standstill.

2nd June, Monday
14:00-15:40 at Topaz
MoB6 Electrical Machines and Drives II
Session Chair : TBD
Co-Chair : TBD

A Rapid and High-Accuracy Control Scheme of Starting Torque for Elevators Without a Weight Transducer

Liu, Feng; Shen, Anwen; Zhang, Yinnan; Fu, Wenbiao
Huazhong University of Science and Technology, China

In order to reduce the cost of the elevator traction system and to provide a comfortable riding experience for the passengers, a rapid and high-accuracy control scheme of starting torque for elevators without a weight transducer is proposed in this paper. A main problem on how to
provide an electromagnetic torque to balance the load torque is considered as the one how to maintain a zero velocity during brake releases. Firstly, we propose an approach to obtain a high-accuracy speed measurement from a quadrature encoder. Then as a feedforward compensation, an estimated load torque based on a reduced-order observer is introduced to improve the dynamic performance of the motor. The impact of different moment of inertia used in the observer and in the real system has been analyzed as well. Moreover, an adjusting method of the PI controller is established to suppress the speed overshot. Finally, results of experiments on a permanent magnet synchronous motor are provided to illustrate the validity and improvement of the scheme.

**Performance Study of Switching Frequency Signal Injection Algorithm in PMSMs for EV Propulsion: A Comparison in Stator and Rotor Coordinates**

Lara, Jorge; Chandra, Ambrish  
*University of Quebec, Canada*

This paper studies the performance of the switching frequency signal injection (SFSI) algorithm to estimate the rotor position in permanent magnets synchronous machines (PMSM) intended for electric vehicle (EV) propulsion. A simple and effective demodulation algorithm is proposed to carry out this estimation by using only current measurements. As opposed to recent literature on the subject, the proposed algorithm is not based on the inductance matrix from the high-frequency impedance model of the PMSM, therefore neither voltage sensors nor voltage reconstructions from the inverter switching states are necessary, thus reducing the system complexity. The analytical expressions in both stationary (αβ) and rotating (dq) reference frames are consistently derived. A performance comparison of sensorless control of PMSM in stator and rotor coordinates is carried out considering the dynamics model of a 1,200 Kg mass car. The simulation results obtained through MATLAB® SimPowerSyste™ demonstrate the effectiveness of the proposed demodulation algorithm and its superiority in the rotating frame.

**An Automatic Efficiency Optimizer for Fractional-Horsepower Appliance Motors**

Hanson, Stephen; Lopez-Tello, Carlo; Mohammad, Zeeshan; Baghzouz, Yahia;  
Ginobbi, Paolo  
*University of Nevada, Las Vegas, USA*

It is a known fact that when an AC motor operates below its rated load, its efficiency can be improved by reducing the supply voltage to an appropriate level. This paper proposes an automatic voltage controller that optimizes the efficiency of fractional-horsepower motors when operating under variable load conditions. The scheme is based on perturbing the supply voltage (by controlling the firing delay angle of a triac) and observing the power drawn by the motor, and the process is repeated until minimum power is reached—thus referring to it as a Minimum Power Point Tracker (MPPT). Due to the simple convex property of the motor power-voltage curve for a given mechanical load, the method always reaches the optimal solution even under severe waveform distortion. The proposed method is validated by laboratory tests on fractional horsepower motors of major home appliances.

**Capacity Estimation of Large-scale Retired Li-ion Batteries for Second Use based on Support Vector Machine**
Capacities of li-ion batteries are difficult to estimate quickly and accurately when second use batteries are in large scale with dispersed parameters. This may result in costing too much time and money to reuse batteries. By analyzing the capacity and resistance characteristics, there is no functional relationship between them. In order to solve this nonlinear problem, a SVM model with 3 parameters (i.e. penalty coefficient, kernel function parameter and loss function parameter) is established. The inputs are five calculated values of resistance and the output is the capacity value of batteries. Data of 70 battery modules are adopted to train the model while data of other 30 battery modules are used to test the model. In this process, two parameters optimization methods using genetic algorithm have been proposed. By comparison, the coefficient of determination (COD) value of method 2 is higher than method 1 both in training model and testing model. The average error of method 2 between measured values and estimated values is 0.67% whereas that of method 1 is 1.35%. In method 2, 90% of the estimation errors are under 2.5%. The results provide valuable insights for large-scale retired li-ion batteries into second use.


Paula, Geyverson T. de; Monteiro, Jose Roberto B. de A.; de Almeida, Thales E. P.; Santana, Marcelo P. de; Pereira, William C. A.

Universidade de Sao Paulo, Brazil

This work deals with the influence of magnetic saturation on machine’s parameters of a surface mounted permanent magnet synchronous machine driven by an ideal six step three-phase inverter. In order to investigate and describe each machine’s parameter, a review on Frozen Permeability Method is developed. Further, a general machine design characteristics are presented. At last, some simulation by means of finite element method with Frozen Permeability Method are carried out taking into account that the machine is driven by an ideal square current waveform. The results for line inductance, flux-linkage waveform and its harmonic contents are shown and analyzed.

Observer-based Adaptive Control of PMSMs with Disturbance Compensation and Speed Estimation

Chaoui, Hicham¹; Sicard, Pierre¹; Miah, Suruz²

¹Universite du Quebec a Trois-Rivieres, Canada; ²University of Ottawa, Canada
In this paper, an observer-based adaptive control strategy is presented for permanent magnet synchronous machines (PMSMs). The adaptive control scheme achieves accurate tracking using the machine’s inverse dynamics and an observer to approximate disturbance and speed used as feedback. The adaptive controller is validated through a set of simulations. Results show high speed tracking and estimation accuracy.

Identification of induction motor parameters for self-commissioning procedure: a new algorithm and experimental verification

Peresada, Sergei¹; Kovbasa, Sergey¹; Prystupa, Dmitriy¹; Lyshevski, Sergey Edward²

¹National Technical University of Ukraine, Ukraine; ²Rochester Institute of Technology, USA

A new identification procedure to identify unknown parameters of induction motors for self-commissioning of vector controlled electrical drives is developed, substantiated and experimentally verified. Our algorithm uses a full-order adaptive observer to estimate stator fluxes and motor parameters: rotor resistance, stator (rotor) inductances, and, magnetizing inductance. Experiments demonstrate that the adaptive observer provides accuracy of identified parameters, asymptotic convergence of estimation errors to zero, and, fast convergence. The proposed solution is of a particular importance in high performance electromechanical systems with speed measurements as well as sensorless vector controls.

Improved Load Modelling for Switching Power Supplies in Electrified Vehicles

Lindenthaler, David; Neumayer, Markus

Graz University of Technology, Austria

The trend for hybrid powertrain concepts has led to a widespread application of electric drives and electronic inverters in electrified vehicles. The operating principle of switched mode power supplies causes different motor excitations with respect to the excitation signals under stationary conditions. I.e. the motor is driven by fast transient switching signals instead of single harmonic signals, respectively. The simulation based prediction of occurring side effects like resonances becomes a matter about the accuracy of the load model. In this paper we present improved load modelling for electric motors in electrified vehicles to cover occurring side effects due to switching power supply excitation.

Low Switching Frequency Explicit Model Predictive Control of Induction Machines Fed by an NPC

Jofre, Matias; Silva, Cesar

Universidad Tecnica Federico Santa Maria, Chile

This paper proposes a low switching frequency predictive control scheme for the induction machine, employing a3L-NPC. The mismatch between sampled and average current is modeled and compensated. The control strategy is implemented as an explicit model predictive controller with PWM, considering a sampling time of 1[ms], which results in a 500[Hz] switching frequency. The results show that the controller achieves a fast dynamic response and an excellent steady state current tracking.

Segmental Rotor Axial Field Switched Reluctance Motor with Single Teeth Winding

Wang, Bo; Lee, Dong-Hee; Ahn, Jin-Woo
A novel 12/10 axial field SRM with segmental rotor and single teeth stator is investigated, which is proposed for high torque performance within reducing copper volume. This paper presents the machine topology, which base on the axial field to permits use of short pitched windings placed around a single teeth stator. This concept improves the torque capability of the previous design, but uses much less copper volume. The theoretical basis and FEM is established base on the software of Maxwell and Matlab-Simulink. Experiment results are presented for the machine operating as a drive, indicating the viability of the concept which is much suitable for the low speed and high torque application.

Towards a Novel Direct Online Speed-Torque Curve Plotter for Three Phase Induction Motor

Murali, Ashwin; Gupta, Arushi; Rao, Madhava
Microsemi India Pvt. Ltd., India; BITS, Pilani, India

The measurement of induction motor air-gap flux and rotor speed using flux search coils along with stator windings is a known technique used for variable speed operation of three phase induction motor. The use of stator windings as search coils for sensing air-gap flux was not well received in the industry due to difficulties in signal processing of the sensed rotor voltage signals. This paper discusses various components of air-gap flux wave caused by rotating magnetic flux due to the rotor and stator excitation, and the harmonic components due to motor construction and rotor current. This paper proposes a new method for recovering the Electromagnetic Field (EMF) signal induced by the air-gap flux in stator windings to sense the rotor current (I2) and rotor current frequency (fR). As an extension, a Digital Signal Processing (DSP) based algorithm for extracting the rotor current and rotor speed information from the recovered signal to calculate torque, speed, slip of the induction motor (IM) online has been discussed. This has been validated by simulation and experimental data through an off-line plotting of torque – speed (slip) characteristics of Induction motor using the proposed method.

2nd June, Monday
14:00-16:00 at Ballroom1
MoB8 Power Converters, Control, and Energy Management for Distributed Generation I
Session Chair : Akshay K. Rathore, National University of Singapore
Co-Chair : Concettina Buccella, University of L'Aquila

Integrated Voltage Control and Line Congestion Management in Active Distribution Networks by Means of Smart Transformers

Carne, Giovanni De1; Liserre, Marco1; Christakou, Konstantina2; Paolone, Mario2
1Christian-Albrechts-University of Kiel, Germany; 2EPFL, Switzerland

Within the context of Active Distribution Networks (ADNs), smart transformers represent very powerful devices able to provide fast and efficient control actions with respect to different ADNs ancillary services. This paper discusses the benefits, in terms of ADNs voltage and line flows controls, achieved by interfacing distributed generators with the power grid by means of
a smart transformer. Among several benefits, these devices allow for a phase-per-phase control of the generators active and reactive power injections. This peculiarity enables to deploy new control schemes that are analyzed and discussed in the paper with reference to a case study based on a modified IEEE 34 node test distribution feeder.

Agent-based Distributed Unbalance Compensation for Optimal Power Quality in Islanded Microgrids

Meng, Lexuan¹; Dragicevic, Tomislav¹; Guerrero, Josep¹; Vasquez, Juan¹; Savaghebi, Mehdi²; Tang, Fen³
¹Aalborg University, Denmark; ²Islamic Azad University, Karaj Branch, Iran; ³Beijing Jiaotong University, China

In microgrids, the distributed generators (DG) can be used as distributed compensators so as to compensate the voltage unbalances in the critical bus. However, the power quality disturbance in generator sides and local buses may be affected and exceeds the limit. It can be more convenient to implement tertiary control so as to adjust the compensation efforts among DGs and ensure the acceptable power quality in local buses. Moreover, as centralized control methods have certain disadvantages, such as low flexibility, expandability and heavy computation burden, this paper proposes an agent-based distributed hierarchical control method. Communication links are required between neighboring units. Consensus algorithm and optimization algorithm are implemented in tertiary control for global information discovery and local optimal decision making respectively. The tertiary control gives lower level controller a tertiary compensation gain to adjust the local DG compensation effort so as to ensure the acceptable power quality in the local bus while keeping the best power quality in critical bus. Simulation results are shown to demonstrate the effectiveness of the method.

Naturally Commutated and Clamped Soft-switching Current-fed Push-pull Voltage Doubler Based Solar PV Inverter

Rathore, Akshay K.; Pan, Xuewei
National University of Singapore, Singapore

The photovoltaic (PV) residential power system is an important application of renewable energy. In this paper, a novel soft-switching current-fed push-pull front-end converter based inverter is proposed. Push-pull converter has only two primary devices with common ground to supply and results in simple and reduced gating requirement. The device voltage is clamped naturally by secondary modulation without active clamping circuit or passive snubbers. Zero-current switching (ZCS) or natural commutation of primary devices and zero-voltage switching (ZVS) of secondary devices is achieved. Soft-switching is inherent owing to proposed secondary modulation, load independent, and is maintained during wide variation of input voltage and power transfer capacity, and thus is suitable for PV applications. A 250 W laboratory prototype is built and tested to demonstrate the converter performance over wide variations in input voltage and output power for PV applications.

On Flatness-based control for Series-Connected VSC for Voltage Dip Mitigation

Buccella, Concettina; Cecati, Carlo; Khalid, Hassan Abdullah; Ul-Haq, Azhar
University of L’Aquila, Italy

The grid connected series converter is a custom power device that is mainly used for
mitigation of voltage sags. In this paper a novel direct flatness-based control (FBC) in cascade configuration, constituted by an outer voltage and an inner current controller, is presented. It can absorb and inject active and reactive power into the grid. Simulation model includes the practical limitation of voltage source converter output voltage and computational delay. Then, the simulations results for the FBC under balanced voltage dips are presented and compared with traditional proportional integral controller. Finally, the sensitivity analysis of the FBC for grid frequency, phase angle jump and inaccurate knowledge of system parameters are presented.

**Frequency Restoration in Microgrids by Means of Distributed Control With Minimum Communication Requirements**

Serban, Ioan  
*Transilvania University of Brasov, Romania*

This paper presents a solution for improving the functionality and reliability of the frequency restoration process in autonomous microgrids (MG), which is known as secondary control. The main advantage of the proposed method consists in not requiring extensive communication between the involved regulating units. Due to the integrative action of the secondary control level, the distribution of multiple controllers throughout the system is unpractical, without a synchronization mechanism, and therefore the most adopted solution is a centralized control with communication links with the associated regulating units inside the MG. However, the reliability of the control process strongly depends of the communication infrastructure. For this reason, this paper tackles the distributed control method and improves it to make it practical and minimizing the communication requirements. The proposed concept is assessed on a laboratory experimental microgrid.

**P and Q Control Strategy for Single Phase Z/qZ Source Inverter Based on d-q Frame**

Roncero-Clemente, Carlos¹; Romero-Cadaval, Enrique¹; Husev, Oleksandr²; Vinnikov, Dmitri²  
¹*University of Extremadura, Spain*; ²*Tallinn University of Technology, Estonia*

This paper explains a new control strategy for controlling active and reactive powers in a single phase Z or qZ source inverter to increase the active functions of these converters when they are interfacing with distributed energy resources. The proposed strategy is based on a d-q synchronous reference frame and it is validated by simulation in a single phase three-level neutral-point-clamped topology. Both steady and transient states are studied under different conditions.
A Novel Sensorless Field Oriented Controller for Permanent Magnet Synchronous Motors
Aygun, Hilmi; Gokda, Mustafa; Akta, Mustafa; Cernat, Mihai
Karabuk University, Turkey
In this paper, a Particle Swarm Optimization based PI controller (PSO-PI) is used for control the speed and the torque of a Permanent Magnet Synchronous Motor (PMSM) while a Model Reference Adaptive System (MRAS) based on an Artificial Neural Network (ANN) estimation mechanism is applied to estimate sensorless the speed.
In order to show the capability of the proposed PSO-PI controller, it is compared with a Fuzzy-Logic PI controller and with a classical PI controller. The simulation results prove the usefulness of the proposed PSO-PI controller.

Modeling of Wheel and Rail Slip and Demonstration the Benefit of Maximum Adhesion Control in Train Propulsion System
Sadr, Sajad1; Khaburi, Davood Arab1; Shiri, Abbas2; Moghadam, Davoud Esmaeil3
1 Iran University of Science & Technology, Iran; 2 Islamic Azad University-Hadishahr Branch, Iran; 3 Technische Universität Dresden, Germany
This paper presents an introduction toward train movement as well as relationship among wheel and train’s speeds, and defines the notion of wheel slip including two different operation regions designated as creep and wheelspin areas holding stable and unstable characteristic, respectively. Since the equations of movements must be solve simultaneously, the model of wheel and slip is derived by integrating the corresponding equations of movements. Besides, the block diagram of train’s speed control is shown in this paper. As wheels and rails are constructed from iron, the friction among them is weak. Consequently, the operation point of speed control system may be in either creep or wheelspin areas regarding the values of driving torque compared to the value of maximum adhesion torque. Simulation results demonstrate the advantages of maximum adhesion control in train’s propulsion system minimizing the acceleration time as well as the wheel and rail sublation.

Sliding Mode abc Current Control for PMSM Drives with an Enhanced High Frequency Injection Algorithm for Sensorless Operation
Repecho, Victor; Biel, Domingo; Arias, Antoni
Universitat Politecnica de Catalunya, Spain
A high frequency injection (HF) based sensorless Sliding Mode Control (SMC) for Permanent Magnet Synchronous Machines (PMSMs) is designed. An analytical analysis, which demonstrates that the HF band is perturbed under sensorless operation, is addressed. Further increase of the sensorless control dynamics is achieved by removing the perturbed signals by means of compensation terms, which also estimate the PMSM $\alpha\beta$ inductance value. Numerical simulation results are presented, confirming the proper speed sensorless control at low speed reversal with load impact.

Direct-Torque Control of a PMSM using Four-Switch Three-Phase Inverter
Kashif, Syed Abdul Rahman; Saqib, Muhammad Asghar; Hassan, Mustafeez ul
University of Engineering and Technology, Pakistan
This paper presents the direct-torque control of a permanent magnet synchronous motor
using four-switch three-phase inverter. The control of the four-switch inverter was developed based upon the orientation of four-switch space-vectors in the plane of six-switch inverter. The proposed inverter was successfully used in the direct-torque control of a PMSM. A dynamic model of a machine gives deep insight for designing the efficient control scheme for its control. A model based estimator was used for the sensing of currents. The control scheme was implemented using TMS320F2812 and TMS320F28835, and the results have been presented for the demonstration of efficient control of PMSMs using four-switch inverters.

**Different Topologies of Active Front Ends for High Power Induction Motor Drives**

Marino, Pompeo; Rubino, Luigi; Brando, Gianluca; Pizzo, Andrea Del

1University of Naples, Italy; 2Second University of Naples, Italy

The paper analyzes and compares main features and performance of two different kinds of active front ends employed in high power induction motor drives. The two considered topologies of Voltage Source Rectifiers (VSR) are: A) two-level four-wire; B) three-level three-wire in Neutral Point Clamped configuration. Reference is made to a Direct Torque Control strategy, which can produce critical unbalanced voltages on dc-link capacitances.

Preliminary, the paper describes the control strategies used for both PWM-VSR topologies, suitable to obtain good dynamic performance and high level of power quality indexes. These control techniques are implemented both in simulation software and on a real-time experimental platform linked to a preliminary laboratory test-bench. The corresponding numerical and experimental investigations are carried out in order to highlight and compare performance of the two considered configurations, taking into account also their different circuit complexity.

**Design and Hardware Implementation of PMSM Sliding Mode Control in SISO and MIMO Cases**

Hassaine, Said; Moreau, Sandrine; Bensmaine, F.

1University of Ibn Khaldoun, Algeria; 2University of Poitiers, France

This paper introduces the principle and the implementation of two nonlinear control strategies for Permanent Magnet Synchronous Motor (PMSM) based on sliding mode theory. The Sliding Mode Control (SMC) strategy presents good performances in transient regime and robustness in respect with system uncertainties. The first adopted approach uses a (MIMO) feedback controller in order to control speed and stator direct current. The second one relays on a (SISO) approach and consists in controlling the electromagnetic torque and stator direct current by means of sliding mode. Moreover, an IP algorithm is used to control the rotor speed. The simple and practical control scheme is easily implemented on a PMSM driver using TMS320LF2407 DSP. The comparative effectiveness of the two proposed speed control approaches are validated experimentally.
A Novel Approach for Efficiency and Power Density Optimization of an Axial Flux Permanent Magnet Generator through Genetic Algorithm and Finite Element Analysis

Taran, Narges; Ardebili, Mohammad
K. N. Toosi University of Technology, Iran

This study puts forth a multi-objective optimization of the efficiency and power density of a low speed Axial Flux Permanent Magnet (AFPM) synchronous generator with the output power and rated speed amplitude of 1 kW and 100 rpm. Firstly, a brief review of different AFPM machine topologies has been provided and double sided interior slotted stator (known as TORUS-S) structure has been selected as the most suitable structure for the current application. The optimization problem was formulated by means of general sizing equations and then genetic algorithm was utilized. Innovatively, this study introduces a novel fitness function as its original contribution which offers a tool for ascertaining the priority of objective functions. This fitness function includes two variables whereby an increase in either of them leads to more improvement in one of the objective functions than in the other. The merits of this method are especially palpable in situations where it is necessary to prioritize the objective functions as is indeed the case with generators used in wind turbines which should have not only a high efficiency but also a reduced weight and volume. Finally, the results are verified through the three dimensional Finite Element Method.

Design Considerations of Electromagnetic Brakes for Servo Applications

Yasa, Yusuf1; Sincar, Eyyup2; Ertugrul, Baris Tugrul2; Mese, Erkan1
1Yildiz Technical University, Turkey; 2ASELSAN Inc., Turkey

Servo motors have increased popularity in industrial and robotics applications. Also, servo motors employ electromagnetic brakes for holding and emergency braking. So, electromechanical brakes found numerous fields due to operation and emergency requirements. The design procedure of an electromagnetic brake requires multidisciplinary approach in terms of mechanical, electrical and thermal aspects. This paper focuses on design, development and experimental verification of an electromagnetic brake. The electromagnetic and thermal design is handled in both FEA and analytical models. Electromagnetic brake prototype is produced and design aspects are experimentally verified. Good agreement between the test results and the prototype is achieved.

A Practical Method for Calculation of Overexcited Region in the Synchronous Generator Capability Curves

Moghadam, Davoud Esmaeil1; Shiri, Abbas2; Mardalizadeh, Morteza3
1Technische Universitat Dresden, Germany; 2Islamic Azad University- Hadishahr Branch, Iran; 3Islamic Azad University- South of Tehran Branch, Iran
The capability curves are used for loading the synchronous generators as a useful and essential tool. Moreover, one of the important applications of the capability curves is setting the relays. The main purpose of the proper loading and accurate setting of the relays is stable operating of the synchronous generators in desired margins. Therefore, the accurate calculation of the curves is significant. Although in the papers some methods and formula for calculating and drawing the capability curves have been presented, the obtained results do not coincide with the original capability curves provided by the manufacturers. It could be potentially because of disregarding the real conditions of synchronous generators such as saturation, temperature, mechanical considerations, altitude and etc. Also, there is no complete source about the capability curves which cover all parts of the curve.

In this paper, in addition to briefly assess all parts of the capability curve, the latter is precisely calculated by taking into account all parameters and operational conditions of the generator. The results in the armature current limit and the under-excitation limit are in agreement with the original capability curves provided by the manufacturers. In spite of this coincidence, the over-excitation part of the graph drawn on the basis of the above-mentioned considerations and calculations does not follow the manufacturer's curves, although the conditions and limitations of the generator are considered. Accordingly, in this paper, a new simple and applicable procedure is proposed for calculating the over-excitation part of the curve, based on authors' experience in designing the synchronous generators. The results of the calculations are in good agreement with over-excitation limit of the manufacturers' curves. Simplicity, fast calculation time, precision and error minimization main features of this method.

**Rotor Eddy Current Determination Using Finite Element Analysis for High-Speed Permanent Magnet Machines**

El-Hasan, Tareq
Zarqa University, Jordan

This paper is concerned with the determination of the eddy current losses in each part inside the rotor of the High-Speed Axial Flux Permanent Magnet (AFPM) Machine (starter/generator) that delivers a power of 18 kVA. The research is based on modeling and Finite Element (FE) simulation techniques using ANSYS where a quarter of the machine is modeled with the appropriate boundary conditions in order to minimize the simulation run time. Optimistic results were obtained which unlocked the potential for further research to validate the results via experimental setup and develop an appropriate analytical model that can facilitate a quick and accurate eddy current losses prediction in similar machines.

2nd June, Monday
16:20-18:00 at Kahrribar
MoC3 Signal Processing and Computational Intelligence II
Session Chair : TBD
Co-Chair : Predrag Ninkovic, University of Belgrade
A Novel Real-Time Magnitude and Frequency Estimation Method Using DFT Zero-Crossings

Ninkovic, Predrag

University of Belgrade, Serbia

This paper presents a novel method for calculation of magnitude and frequency of single-phase voltage sources in hard real-time applications. It is developed for supervision of renewable power sources. A Forward-Facing Hybrid Vehicle Simulation Tool Breces, both for converter and grid side. The method is based on Discrete Fourier Transform (DFT) of input signal, but it avoids the DFT errors due to off-nominal frequency operation. Steady-state error and second-harmonic oscillations in output signal are decreased within acceptable levels for all frequencies of interest. Accuracy of 20mHz for frequency and 0.2% for magnitude without harmonic content in input signal is obtained. The method described is applied on ARM7TDMI microcontroller platform and verified by experiments.

Placement of STATCOM to Improve the Power Quality of a DG Integrated Building Energy System in Virtual Environment

Khadem, Shafiuuzzaman Khan¹; Basu, Malabika²; Kerrigan, Ruth³; Basu, Biswajit¹

¹Trinity Collge Dublin, Ireland; ²Dublin Institute of Technology, Ireland; ³Integrated Environmental Solutions, United Kingdom

In this paper, the placement of Custom Power Devices (CPDs) to improve the power quality of a distributed generation (DG) integrated building energy system (BES) has been analyzed. A typical residential building energy has been modeled in a Virtual Environment (VE) simulator. The extracted energy demand is generated by input load demand and hourly operating information. Based on the electrical energy demand for a typical day, a DG integrated BES (DG-BES) is then simulated in MATLAB to extract the current/voltage disturbance information into the network. Outcome of this simulation shows the voltage/current waveform along with the disturbances at different locations in the building. Finally a CPD is placed into the network and simulation in MATLAB shows the performance of the device by improving the power quality of the DG-BES. The city of Dublin, Ireland has been chosen as a geographical location and VE-Pro software has been used to develop the virtual environment simulation for the building energy system.

Regularization Parameter of Normalized Subband Adaptive Filter

Jeong, Jae Jin; Koo, Gyogwon; Kim, Seung Hun; Kim, Sang Woo

Pohang University of Science and Technology, Korea (South)

The stability and performance of the normalized subband adaptive filter (NSAF) algorithm is influenced by the regularization parameter. However, in various noise environments, the regularization parameter is difficult to be determined. The basic idea of this paper is to eliminate the effects of the noise in filter estimation. Simulation results show the proposed method has valid results in various noise environment.

A Radial Configurations Search Algorithm for joint PFC and DFR Optimization in Smart Grids

Storti, Gian Luca; Paschero, Maurizio; Rizzi, Antonello; Mascioli, Fabio Massimo

Frattale

University of Rome, Italy

The power loss reduction is one of the main targets for any electrical energy distribution
company. In this paper the problem of the joint optimization of both topology and network parameters in a real Smart Grid is faced. A portion of the Italian electric distribution network managed by the ACEA Distribuzione S.p.A. located in Rome is considered. It includes about 1200 user loads, 70 km of MV lines, 6 feeders, a Thyristor Voltage Regulator and 6 distributed energy sources (5 generator sets and 1 photovoltaic plant). The power factor correction (PFC) is performed tuning the 5 generator sets and setting the state of the breakers in order to perform the distributed feeder reconfiguration (DFR). About the DFR, in this paper we introduce a simplified graph representation of the electrical network and we propose a new algorithm to find all the radial network configurations. The PFC and the DFR optimization is faced by defining and solving a suited multi-objective optimization problem adopting a genetic algorithm. Tests have been performed by feeding the simulation environment with real data concerning dissipated and generated active and reactive power values. First results are very interesting, showing that considering all the possible admissible network configurations can help the optimization procedure in finding better solutions.

Classification Method for Faults Diagnosis in Reluctance Motors Using Hidden Markov Models

Bouchareb, Ilhem¹; Bentounsi, Amar¹; Lebaroud, Abdeslam ²

¹University of Mentouri 1, Algeria; ²University of Skikda, Algeria

The Switched Reluctance Machine (SRM) is ideal for safety critical applications due to its superior fault-tolerance characteristics. The switched reluctance drive is known to be fault tolerant, but it is not fault free. Fault diagnosis of SRM in the critical applications is often a difficult and daunting task. Thus, finding efficient and reliable fault diagnostics methods especially for SR machines is extremely important. This paper focuses on the development, and application of modern statistical classifier method, namely Hidden Markov Model (HMM) associated with a smoothed ambiguity plane Time-Frequency Representation (RTF) for the diagnosis based classification of electrical faults in this particular machine. The RTF-HMM Technique is composed of two steps: the Feature Extraction step based on the smoothed ambiguity plane designed for maximizing the separability between classes using Fisher's discriminant ratio and Hidden Markov Model algorithm applied for the classification step. The algorithm of each step is well developed. Classifier development and training data is carried out by the HMM using a set of fault scenarios, between healthy, single and combined faults, in terms of torque at different load level in order to deduce the fault severity. Parameter training of Hidden Markov Models generally need huge a mounts of historical data. Experimental results proves that the use of RTF-HMM based approaches is a suitable strategy for the automatic classification of new sample independent from de type of fault signal.
An Analysis Approach for Optimization Based Reconfiguration in Photovoltaic Arrays
Karakose, Mehmet\textsuperscript{1}; Baygin, Mehmet\textsuperscript{1}; Baygin, Nursena\textsuperscript{2}

\textsuperscript{1}Firat University, Turkey; \textsuperscript{2}Kafkas University, Turkey

Partial shading in photovoltaic (PV) arrays is an important factor that decreases the performance of the system. The reconfiguration process that uses to change of panel connections in array aims to increase of efficiency of PV array in partial shading conditions. However, optimal layout of panels with partial shading and number of switching matrixes cannot be determined exactly. In this study, an analysis approach for reconfiguration process based on optimization of panel layout and switching matrix according to partial shadings in PV array has been proposed. The reconfiguration process changes mainly connections with a switching matrix between adaptive panels and rows of fixed panels in array. Proposed approach finds continuously to energy efficiency optimal panel layout and optimal number of switching matrix according to shading conditions. Simulation results have been given to verify of proposed approach in different shading conditions and efficiency of about 15% has been obtained.

Autonomous Hole Quality Determination Using Image Processing Techniques
Kuzu, Ahmet\textsuperscript{1,2}; Kuzu, Ali\textsuperscript{1}; Rahimzadeh, Kaveh\textsuperscript{1}; Gokasan, Seta\textsuperscript{1}; Bogosyan, Metin\textsuperscript{1}; Bakkal, Mustafa\textsuperscript{1}

\textsuperscript{1}Istanbul Technical University, Turkey; \textsuperscript{2}Tubitak Bilgem Bte, Turkey

This paper introduces a technique which evaluate performance of hole quality after drilling process. Hole making is one of the most time consuming process in industry. For some applications the quality of holes are very crucial and be expected of tight tolerance from manufacturer. One of the most common device used by manufacturers to investigate the hole quality is coordinate measurement machines. However investment cost of coordinate measurement instrument machines are very high. Therefore a new image processing technique is proposed in this paper and coordinate measurement machine and image processing technique results were compared.

Reconfigurable Architecture For Computing Histograms in Real-Time Tailored to FPGA-based Smart Camera
Maggiani, Luca\textsuperscript{1,2}; Salvadori, Claudio\textsuperscript{1}; Petracca, Matteo\textsuperscript{2}; Pagano, Paolo\textsuperscript{2}; Saletti, Roberto\textsuperscript{3}

\textsuperscript{1}TeCIP Institute, Scuola Superiore Sant’Anna, Italy; \textsuperscript{2}National Laboratory of Photonic Networks, CNIT, Italy; \textsuperscript{3}University of Pisa, Italy

The design and development of distributed innovative services leveraging pervasive smart
camera network solutions requires the use of reconfigurable low-cost smart cameras. In this respect, FPGA based Smart Cameras enabled to wireless communication that follow the Internet of things paradigm area promising solution. The paper proposes an optimized design of the histogram extractor algorithm targeted to low-complexity and low-cost FPGA based Smart Cameras. The proposed solution is the basis for a wide range of distributed computer vision applications. We first define a general architecture for the image histogram core, then we evaluate its performance with a real implementation.

**Capacity Constrained Hazard Awareness Navigation in a Fire Emergency: A Heuristic Approach**

Dinesh, H. G. Chinthaka P; Kolamunna, Harini D.

The Institution of Engineers Sri Lanka, Sri Lanka

We propose a novel heuristic algorithm for directing victims during a fire emergency within a building. We considered the capacity constraints of evacuation paths and the effect of hazard spreading for our algorithm. The main objective of the proposed algorithm is to maximize the number of evacuated victims at each time step. Therefore, we model the evacuation problem as the standard universal maximum flow problem by integrating unavailability of nodes and links over time due to hazardous conditions. The proposed solution is a heuristic approach instead a linear programming method. We compared the performance of our approach against two most relevant alternative heuristic approaches in order to experimentally demonstrate that our algorithm outperforms the alternatives.

**Broken rotor bars detection via Park vector approach based on ANFIS**

Zarei, Jafar\(^1\); Hassani, Hossein\(^1\); Wei, Zuolong\(^2\); Karimi, Hamid Reza\(^2\)

\(^1\)Shiraz University of Technology, Iran; \(^2\)University of Agder, Norway

Many attempts have been made on fault diagnosis of induction motors based on frequency and time domain analysis of stator current. In this paper, first the Park’s vector transformation and frequency analysis for fault detection of induction motors are introduced. Then a smart approach using Adaptive Neuro Fuzzy Inference System (ANFIS) is proposed. This approach uses the time domain features derived from the Park’s vector transformation of stator current. By the proposed method, a partial break including 5 mm crack on a bar, one broken bar and two broken bars using experimental data are investigated. It will be shown that features derived from Park’s vector compared to features obtained from a phase current, have better results.

**Induction motors broken rotor bars Fault diagnosis by pattern recognition based on noise cancelation**

Zarei, Jafar\(^1\); Tajeddini, Mohammad Amin\(^1\); Karimi, Hamid Reza\(^2\)

\(^1\)Shiraz University of Technology, Iran; \(^2\)University of Agder, Norway

Current signal monitoring (CSM) can be used as an effective tool for diagnosing broken rotor bars fault in induction motors. In this paper, fault diagnosis and classification based on artificial neural networks (ANNs) is done in two stages. In the first stage, a filter is designed to remove irrelevant fault components (such as noise) of current signals. The coefficients of the filter are obtained by least square (LS) algorithm. Then by extracting suitable time domain features from filter’s output, a neural network is trained for fault classification. The output vector of this
network is represented in one of four categories that includes healthy mode, a 5 mm crack on a bar, one broken bar, and two broken bar modes. An optimum structure of the neural network is obtained via particle swarm optimization (PSO) algorithm.

**Case Study: Restoration of a Blast Furnace Stoves Safety Automation**

Soressi, Ernesto¹; Consonno, Federico¹; Giordano, Miro¹; Grisolia, Paolo²; Tornielli, Giampiero¹; Mantovani, Giorgio¹

¹Nidec-ASIC C.so, Italy; ²Nidec-ASIC Consultant C.so, Italy

Iron making is one of the most impressive processes in the metal industry. The process of heat and weight in a not stoppable continuous transformation. The authors were involved in the revamping of the complete automation system of a huge blast furnace, see Figure 1. The restoration consisted in the replacement of a vintage discrete relay based automation with a modern PLC based system and included the development of the safety system dedicated to the management of the blast furnace stoves.

The aim of the paper is to describe the development process of the stoves safety system.

**Analysis of Risk Mitigation by Decentralized Ordering in Multi-tier Supply Chain**

Mori, Masakatsu¹; Kobayashi, Ryoji²; Samejima, Masaki²; Komoda, Norihisa²

¹Yokohama Research Laborator, Hitachi, Ltd., Japan; ²Osaka University, Japan

We address developing the simulator for multi-tier supply chain to evaluate the effect of risk mitigation by decentralized ordering. A simulator for 2-tier supply chain has been developed through our research. Because the relationship between the suppliers in the multi-tier supply chain is similar to the relationship between the retailer and the supplier in the 2-tier supply chain. In order to realize the simulation for the multi-tier supply chain, we combine the simulator for the 2-tier supply chain with the functions of price decision and updating the probability distribution of the downtime of the suppliers. Applying the simulator to the multi-tier supply chain model, we discuss the effect of the risk mitigation by decentralized ordering.

**Aggregated Time-Critical MAC Protocol for Factory Automation**

Reinhold, Rafael; Underberg, Lisa; Kays, Ruediger

Dortmund University, Germany

Communication in industrial applications like wireless factory automation demands high reliability and low latency. Due to the fact that state of the art wireless sensor networks do not entirely fulfill the high requirements, new approaches have to be developed. An ultrawideband system in combination with a MAC protocol for time-critical applications seems to be a promising approach. This paper introduces an optimized MAC protocol to guarantee the
stringent real-time requirements of factory automation. Based on a realistic network scenario and IEEE 802.15.4 impulse-radio ultra-wideband physical layer simulations, both reliability and latency are examined. Moreover, the impact of retransmissions is analyzed. The proposed MAC protocol minimizes the resulting latency meeting entirely the requirements of factory automation.

**Design and Implementation of Hybrid Circuit/Packet Switching for Wearable Systems**

Derogarian, Fardin; Ferreira, Joao Canas; Tavares, Vitor M. Grade

*Universidade do Porto, Portugal*

This paper presents a network router and transceiver for wearable, low-power, high-speed Body Area Networks (BAN) applications running in a mesh network of sensors embedded in textiles and connected to each other with conductive yarns functioning as bidirectional transmission channels. The routing of data packets from sensor nodes to a sink node is based on hybrid circuit and packet switching. In comparison with pure packet switching, hybrid routing decreases end-to-end delay, power consumption and buffer size. The proposed design uses independent sender, receiver and circuit switching modules, thereby allowing the nodes to simultaneously send and receive data. The simulation results show that circuit and hybrid switching modes significantly increase the performance of the system. In addition, implementing the complete packet process on FPGA, instead of using an external microcontroller as in previous work, enables a much faster routing process. The results are based on a Verilog description of the system, which has been synthesized for a low-power IGLOO FPGA with Libero Project Manager and simulated with ModelSim. The implementation operates successfully at a data rate of 20 Mbps.

**Communication Support for Petri nets based Distributed Controllers**

Silva, Edgar M. 1,2; Campos-Rebelo, Rogerio 1,2; Hirashima, Takahiro 3; Moutinho, Filipe 1,2; Malo, Pedro 1,2; Costa, Aniko 1,2; Gomes, Luis 1,2

1Universidade Nova de Lisboa, Faculdade de Ciencias e Tecnologia, Portugal; 2UNINOVA, Centro de Tecnologia e Sistemas, Portugal; 3Osaka University, Japan

This paper addresses the distributed execution of IOPT Petri nets models supported by a network of distributed controllers. Each controller is associated with a sub-model. Sub-models use communication channels to exchange events allowing global evolution. Whenever controllers are interconnected through some kind of network, communication channels are implemented by communication nodes associated with each distributed controller. Communication nodes are characterized in terms of layers and buffers allowing their use with different types of communication and topologies. Their usage in a simple application example composed by a network of distributed controllers interconnected through a serial ring topology network is presented. Arduino boards are used as implementation platforms for proof-of-concept purposes.

**Simulative Comparison of Parallel Redundant Wireless Systems with OMNet++**

Rentschler, Markus 1; ElSayed, Ahmed T. 2; Nagui, Alia H. 2; ElShenawy, Mohamed M. 2; Tawfik, Karim N. 2; ElMansoury, Mohamed 2; Hendawy, Mostafa 2; Halawa, Hassan H. 2; Daoud, Ramez M. 2; Amer, Hassanein H. 2; ElSayed, Hany M. 2

1Business Unit Networking, Balluff GmbH, Germany; 2American University in Cairo,
Parallel redundant point-to-point transmission utilizing a dual-radio wireless infrastructure has been identified as a powerful approach to improve the performance of wireless communication. This method can be applied for every existing wireless standard, but has not been deeply researched so far. To fill this gap, an OMNet++ simulation model for IEEE 802.11g (Wi-Fi) and IEEE 802.15.4 (ZigBee) is developed and some simulation scenarios performed to get a better understanding of the comparative performance characteristics of parallel redundant operation for these wireless standards.

A study of using nonnegative matrix factorization to detect solder-voids from radiographic images of solder

Mouri, Motoaki¹; Kato, Yoichi²; Yasukawa, Hiroshi²; Takumi, Ichi³
¹Aichi University, Japan; ²Aichi Prefectural University, Japan; ³Nagoya Institute of Technology, Japan

Accurate detection of voids in solder bumps on ball grid arrays (BGAs) is important for improving device quality. Radiographic imaging is commonly used to inspect BGA packages incorporate into LSI circuits. In the case of conventional method, imaging is normally done four times, and the images obtained are averaged to reduce noises. We have developed a nonnegative matrix factorization method for detecting solder-voids using only three radiographic images. Computer simulation demonstrated that it has the same level of accuracy as the conventional method.

Phase Stability Index of AC Furnace Arc Based on RMS and THD

Kim, Kyuhwan¹; Jeong, Jae Jin¹; Lee, Baek²; Jung, Byungkyu²; Kim, Sang Woo¹
¹Pohang University of Science and Technology, Korea (South); ²Pohang Iron and Steel Company, Korea (South)

In this paper, a method to calculate the phase stability index of AC furnace arc is proposed. To find the period of distinguished arc, root mean square (RMS) values of phase voltage and current are used. Also, to detect the distortion of phase voltage and current, total harmonic distortion (THD) are employed. Then, two indices are combined to complement each other. Finally, simulation results verify the performance of the indices.

Automated in-Line Defect Classification and Localization in Solar Cells for Laser-Based Repair

Rodriguez-Araujo, Jorge; Garcia-Diaz, Anton
AIMEN Technology Center, Spain

Defective crystalline silicon solar cells may be repaired using laser-based techniques if the
problem is properly identified and characterized. This paper presents a novel system for the automation of solar cells repair that carries out the following tasks: 1) It detects and localizes cracks and shunts in solar cells from electroluminescence images; 2) It takes a decision on the laser process to repair faulty cells; 3) It automates the operation of a laser machine for processing solar cells. Regarding the analysis of electroluminescence images of solar cells, the proposed solution is able to discriminate the type of defect, which means a step-forward compared to state-of-the-art approaches. Moreover, it is to our knowledge the first solution that takes the results of such analysis to automate a process of laser-based repair. The proposed system paves the way for waste reduction in the production of solar cells by using repaired cells in custom-made solar modules.

A Tool for Diagnosis in Industrial Valves Based on ISA Standards
Silva, Diego; Silva, Jorge; Germano, Amanda; Venceslau, Allan; Guedes, Luiz
Universidade Federal do Rio Grande do Norte, Brazil
This paper shows the implementation of a software of valves evaluation in accordance with ANSI/ISA specifications and the use of a model which simulates the static friction for validation. The assessment is generated from the execution of standardized tests. For this purpose, the software is able to generate input signals for each specific test considering user-defined parameters, allowing flexibility and execution of tests in different types and sizes of valves. The test results are displayed graphically by plotting the input signal and position of the valve stem as variables. The analysis of these data is done to extract the parameters that reflect the current state of each instrument. The results section at the end of the paper shows some screens running tests where such information can be extracted.

Towards the Use of Place/Transition Net Tools for Analysis of IOPT Models
Barros, João Paulo¹; Gomes, Luís²
¹Instituto Politécnico de Beja, Portugal; ²Uninova-CTS, Portugal
This paper proposes a translation from IOPT nets, a class of non-autonomous Petri nets, to Place/Transition nets. The translation removes most of the non-autonomous extensions in IOPT net models using a set of behaviorally equivalent submodels. The resulting model is complemented by additional models, which specify the non-autonomous parts, namely signals and events. All models are composed together using net addition, a composition operator. The translation allows the application of analysis and verification Place/Transition tools to IOPT net models. The translation preserves the initial model structure allowing a mapping between the generated model and the initial one, and brings to evidence the level of compactness made possible by IOPT nets.

2nd June, Monday
16:20-18:20 at Akik
MoC7 Robotics and Mechatronics I
Session Chair : Kiyoshi Ohishi, Nagaoka University of Technology
Co-Chair : Ming-Tzu Ho, National Cheng Kung University
Lyapunov Function--Based Adaptive Chaos Anti Control of Robot Manipulators
   Moreno-Valenzuela, Javier
   Instituto Politecnico Nacional-CITEDI

Anti control of chaos is a problem that has been studied in recent years. It consists in injecting a chaotic behavior by means of a control scheme to a system, which in natural form does not present any strange behavior. This paper explores the anti control of chaos of robot manipulators. In particular, by using the Lyapunov function framework, an adaptive chaos anti controller is proposed. The proposed scheme has been experimentally tested in a two degrees–of–freedom direct–drive robot, which corresponds to the configuration of fully actuated rotational pendulum.

Adaptive Reaction Torque/Force Observer Design II
   Sariyildiz, Emre; Ohnishi, Kouhei
   Keio University, Japan

This paper completes the proposal of a new adaptive reaction torque/force observer (RTOB/RFOB) design method. In the first paper, a new adaptive RTOB/RFOB design method is proposed when environmental impedance is considered as pure damping or stiffness. The proposed method can be used in several motion control applications, e.g., stiff model of environmental impedance is widely used in industrial applications. However, the exact adaptive RTOB/RFOB design method, in which environmental impedance is modeled by using damping and stiffness, has not been proposed yet. In this paper, a new adaptive RTOB/RFOB design method is proposed when damping and stiffness are considered in the model of environmental impedance. In the proposed method, not only the force control gain, but also the bandwidths of a disturbance observer (DOB) and a RTOB/RFOB and the ratios between uncertain and nominal inertias are adjusted automatically to improve the stability and performance of the robust force control system. Environmental impedance is modeled by using lumped parameters, and they are estimated by using an online recursive least-mean-square error algorithm. The validity of the proposal is verified by simulation and experimental results.

Performance Analysis and Experimental Verification of Solenoid Actuator
   Mahajan, Deepak Pitambar; Narayanaswamy, Renukaprasad; Bavisetti, Siva
   Honeywell Technology Solutions, Inc, India

Typical application of solenoid that is discussed in this paper is to operate pneumatic valves under harsh aerospace environmental conditions and high endurance requirements. A thorough analysis of force balance is required to ensure that solenoid will function under all worst operating conditions. A numerical simulation based on finite element (FE) methods is used for evaluating electromagnetic force generated from solenoid at different stroke conditions. FE modeling is done considering practical non-idealities that exist due to manufacturing and assembly process along with worst case solenoid geometry. Low carbon steel material that is used in this solenoid is experimentally characterized for its nonlinear BH properties. This BH curve is fed to the FE Analysis (FEA). 2D static, 2D transient, 3D static FE analysis methods along with different mesh sizes are compared. Experimental verification of the force generated from solenoid is used to validate the methods of finite element analysis.
Balance Control of a Unicycle Robot
Ho, Ming-Tzu; Rizal, Yusie; Chen, Yi-Lung
National Cheng Kung University, Taiwan
This paper presents the design and implementation of balance control for a unicycle robot. The robot consists of a wheel, a body frame, and a reaction wheel. The wheel enables the robot to move forward or backward to obtain longitudinal stability, while the reaction wheel is used for obtaining lateral stability. Control of this system is a challenging task because of inherent nonlinearity, instability, and underactuation. A detailed dynamic model of the system is derived for control design. By retaining the predominant nonlinear terms and neglecting the high-order coupling terms, the system model is simplified to two decoupled systems. Sliding mode control and feedback linearization are then used to design the stabilizing controllers for the simplified models. The robot is constructed and the designed control schemes are realized through a digital signal processor. The effectiveness of the control schemes is demonstrated through experimental studies.

A Comparison Study for Force Sensor and Reaction Force Observer based Robust Force Control Systems
Sariyildiz, Emre; Ohnishi, Kouhei
Keio University, Japan
In this paper, two disturbance observer (DOB) based explicit robust force control systems, in which a force sensor and a reaction force observer (RFOB) are used to detect contact forces, are compared in terms of stability, robustness and performance. A force sensor detects contact forces implicitly by estimating the strains of a strain gauge. The compliancy of a force sensor degrades the stability and performance of a force control system. Besides, noise is another challenging issue in a force sensor based force control implementation. Against a force sensor, a RFOB detects contact forces explicitly by using the acceleration and force/torque signals of a servo system. Inasmuch as a RFOB detects contact forces explicitly, the stability and performance of an explicit force control system are improved intrinsically. However, a RFOB has a model based control structure; therefore, the stability and performance of the robust force control system may deteriorate by the imperfect identification of system uncertainties. New analysis and design tools are provided for the DOB based robust force control systems. Simulation and experimental results show the viability of the proposals.

Movement Safety Control Method of a Haptic Device for Minimally Invasive Surgery
Saafi, Houssem; Laribi, MedAmine; Zeghloul, Said; Ibrahim, Yousef
1PPRIME Institute, France; 2Monash University, Australia
The overall objective of this work is to develop a system composed of master, slave and a control system for special medical applications. A PROMIS (Pprime RObot for Minimally Invasive Surgery) system is designed to be cost-effective with a less complication of use and an application-specific for collaborative operations between the surgeon and the robot. This paper focuses on the introduction of a motion safety control methodology for a haptic device. The haptic device is used as a master with a parallel spherical architecture (SPM). The introduced control methodology is based on the workspace of the medical application. Three
areas of the workspace are defined with a consideration of the degree of security. An algorithm that constantly keeps the mobile platform in a safe region, when the surgeon moves it, is presented and explained. The developed algorithm runs in real-time using a programmable logic controller (PLC). The control strategy of the haptic device was successfully tested and validated experimentally.

2nd June, Monday
16:20-18:00 at Ballroom1
MoC8 Building Automation Control and Management I
Session Chair : Milos Manic, University of Idaho
Co-Chair : Kasun Amarasinghe, University of Idaho

The effect of smart appliances and smart gateways on network loads
Wenninger, Joseph; Haase, Jan
Vienna University of Technology, Austria

Smart appliances and smart gateways (between private households and energy providers) are a hot topic, due to the promises of more convenience, more energy saving, less cost. This paper focuses on the impact of such devices on the load of networks, i.e. the view of energy providers. This is achieved by implementation of a simulator framework for sets of households (arranged in big buildings or even small villages) which considers social and environmental factors. The framework is presented in detail.

Neural Network Based Downscaling of Building Energy Management System Data
Amarasinghe, Kasun; Wijayasekara, Dumidu; Manic, Milos
University of Idaho, USA

Building Energy Management Systems (BEMSs) are responsible for maintaining indoor environment by controlling Heating Ventilation and Air Conditioning (HVAC) and lighting systems in buildings. Buildings worldwide account for a significant portion of world energy consumption. Thus, increasing building energy efficiency through BEMSs can result in substantial financial savings. In addition, BEMSs can significantly impact the productivity of occupants by maintaining a comfortable environment. To increase efficiency and maintain comfort, modern BEMSs rely on a large array of sensors inside the building that provide detailed data about the building state. However, due to various reasons, buildings frequently lack sufficient number of sensors, resulting in a suboptimal state awareness. In such cases, a cost effective method for increasing state awareness is needed. Therefore, this paper presents a novel method for increasing state awareness through increasing spatial resolution of data by means of data downscaling. The presented method estimates the state of occupant zones using state data gathered at floor level using Artificial Neural Networks (ANN). The presented method was tested on a real-world CO2 dataset, and compared to a time based estimation of CO2 concentration. The downscaling method was shown to be capable of consistently producing accurate estimates while being more accurate than time based estimations.
Hierarchical concept for IP-based resilient communication in building automation
Krammer, Lukas; Bunyai, Dominik; Kastner, Wolfgang
Vienna University of Technology, Austria

In building automation, IP-based communication is commonly used. However, availability and reliability recently gained importance in this domain since even safety critical applications (e.g., fire alarm systems) are integrated in building automation networks. Usually, IP-based communication systems, as they are used in functional buildings, do not provide redundancy mechanisms. However, redundancy and deterministic behavior is crucial for a reliable communication system. For different reasons, building automation networks facilitate standard network technologies and components. Nevertheless, such networks are required to be flexible and scalable ranging from small buildings up to areas of buildings by additionally being efficient regarding communication overhead.

This paper presents a new hierarchical system concept which provides a homogeneous communication infrastructure to the automation devices. The concept is based on physical Ethernet ring topologies which represent the bottom level. However, the design and selection of such protocols is out of scope. The rings are connected by a special kind of Router in a redundant way which represents the next level. To establish a connection between dislocated network segments, a reliable backbone communication mechanism is introduced, that can be seen as top level of the hierarchy. In contrast to other technologies, this concept can be statically configured and does not need dynamic reconfiguration in case of a fault. It tolerates one single fault per ring and provides deterministic and local fault handling. The concept is theoretically analyzed; a proof-of-concept shows the feasibility.

Improving Energy Efficiency of Buildings Using Data Mining Technologies
Zucker, Gerhard¹; Malinao, Jasmine¹; Habib, Usman¹; Leber, Thomas²; Preisler, Anita¹; Judex, Florian¹
¹Austrian Institute of Technology, Austria; ²Vienna University of Technology, Austria

Building automation systems record operation data including physical values, system states and operation conditions. This data is stored, but commonly not automatically evaluated. This historic data is the key to efficient operation and to quick recognition of errors and inefficiencies, a potential that is not exploited today. Instead, today the evaluation during operation delivers only alarming in case of system failures. Analysis is commonly done by the facility manager, who uses his experience to interpret data. Methods from data mining and data analysis can contribute to a better understanding of building operation and provide the necessary information to optimize operation, especially in the area of Heating, Ventilation and Air Conditioning (HVAC) systems. Increases in energy efficiency and can be achieved by automated data analysis and by presenting the user energy performance indicators of all relevant HVAC components. The authors take a first step to examine operation data of adsorption chillers using the X-Means algorithm to automate the detection of system states.

High Order Line Filters for Grid Connected AC-DC Converter Parameters Selection and Optimization
Szymon, Piasecki
Warsaw University of Technology, Poland

In this paper three types of the high order line filters dedicated for AC-DC Grid Connected
Converter (GCC) are analyzed and compared. According to selected power quality standard and passive components minimization a design procedure is proposed for each described filter topology. Typical LCL filter is compared to LCL with Trap and LLCL line filters with use of analytical calculations and simulation study. Optimization parameters and performance indices for analyzed filters are introduced.

3rd June, Tuesday
09:00-11:20 at Opal
TuA1 Control Systems and Applications III
Session Chair : TBD
Co-Chair : TBD

WC-SWFA algorithm in the application of constant tension control of the yarn
Su, Quan; Huang, Jiye; Gao, Mingyu; He, Zhiwei; Ma, Guojin; Liu, Yuanyuan
Hangzhou Dianzi University, China
The aim of constant tension control of the yarn is to keep the yarn’s tension to be consistent during the winding process by controlling the speed of the motor according to the output voltages of the tension sensor. The mechanical structure of spinning machines such as the winding machine makes the fluctuation of the yarn’s tension changes rapidly. In this paper, we propose a new tension control algorithm, which is called the weighted curve sliding window filtering algorithm (WC-SWFA). According to this algorithm, the brushless direct current (DC) motor can be controlled to operate stably and efficiently, and the yarns will be shaped well. Theoretical analysis is firstly carried out to verify its effectiveness. Laboratory experiments are then put in force. In the experiments, an arbitrary waveform generator (AFG3252) is used to generate the simulated fluctuation signals of the tension, and an STM32 micro-controller is used to control the rotation of the motor, with the proposed WC-SWFA served as the control algorithm. Practical experiments on the winding machine show that the proposed algorithm works effectively.

Evaluation Criteria of Biological Artifacts Removal Rate from EEG Signals
Jafarifarmand, Aysa; Badamchizadeh, Mohammad Ali; Seyedarabi, Hadi
University of Tabriz, Iran
EEG is one of the most important bioelectrical signals that plays a vital role in investigation of brain activities in clinical applications as well as Brain-Computer-Interface systems. The major facing obstacle is that the EEG signals are often affected by a variety of large signal contaminations or artifacts, which reduce their usefulness. Various approaches have been introduced to remove the artifacts from EEG signals, but since the artifact-free EEG signal is practically not accessible as a comparison referent so the precise evaluation of the artifact removal level is not possible, which makes it impossible to realize how useful the obtained EEG signal is. However, several metrics have been proposed to measure the EEG artifact removal success rate. Various evaluation criteria are presented and analyzed in this paper.
Adaptive Integral Sliding Mode Controller for Offshore Steel Jacket Platform
Sola, Hamid Nouri; Ahmadi, Bahar; Ghaemi, Sehraneh
University of Tabriz, Iran
This paper is concerned with active control for an offshore steel jacket platform subject to nonlinear wave-excited forces and parameter perturbation by using an adaptive control law and combining it with sliding mode control scheme. This novel control scheme is an adaptive integral sliding mode controller (AISMC). Then by considering vibration frequencies uncertainties and damping ratio uncertainties of offshore steel jacket platform, we have designed (RAISMC) control scheme. It is shown through simulation results, compared with some existing control schemes, this controller has a better performance in reducing oscillation amplitudes of the three floors of offshore platform with much less control force.

Application of Posicast Control Method to Generator Excitation System
Ghorbani, Hamidreza; Candela, J. Ignacio; Luna, Alvaro; Rodriguez, Pedro
Technical University of Catalonia. BarcelonaTech, Spain
Application of Posicast control method to generator excitation system is presented in this paper. Presented control method is one of the simplest control design methods which can be installed in generators excitation to damp the oscillations caused by changing the excitation reference signal. Stability of the designed controller is shown using extensive time domain simulations. Performance of Posicast controller in IEEE power system standard models with presence of PV power plant is evaluated in MATLAB/Simulink environment.

REST Client Pattern
Upadhyaya, Bhim P.
Walgreens Co., USA
Service oriented architecture (SOA) is a common architectural practice in large enterprises. There are numerous technologies to support SOA including web services. The IT industry is moving toward REST based design for its simplicity and productivity. Apache CXF, Apache Axis, JBoss RestEasy, and Jersey frameworks support REST based services and client side implementation. Based on our observation in health care, manufacturing, and retail domains a reoccurring solution can be put into practice so as to minimize code duplication. This paper presents such a solution in the form of a design pattern that promotes design re-use. The REST client pattern houses common service operations in the top of class hierarchy so that re-use is promoted by inheritance. The service specific call preparations are implemented by subclasses. This pattern is being used by three iconic companies in above mentioned domains using three different open source frameworks—CXF, RESTEasy, and Jersey.

Enterprise Service Delegation Pattern
Upadhyaya, Bhim P.
Walgreens Co., USA
Enterprise architecture is an emerging field of study. There are multiple areas that provide building blocks for this discipline including information technology and business management. Information technology plays a vital role in shaping the direction of business. In a granular level, business processes can be mapped to hardware and software automated processes. Service oriented architecture (SOA) is a popular architecture for providing business services in
the form of software and hardware services. A software service can represent a business service partially or fully. Developing architectural building blocks is a common practice recommended by open group. This paper presents one such building block in the form of software design pattern. The enterprise service delegation pattern provides a structure to arbitrate service calls. This pattern is being used to construct enterprise service buses.

Stabilization of a DC Electrical Network via Backstepping Approach

Hamache, Djawad1; Fayaz, Akram2; Godoy, Emmanuel1; Karimi, Charif1
1École superieure d’electricite(Supelec), France; 2Conservatoire national des arts et metiers (CNAM), France

It is known that a constant power load connected to DC electrical network may lead to instability problems on the DC-link variables. This paper addresses this problem of instability. To do this, a supercapacitor which is an energy storage element connected to the network is used to stabilize. To achieve this goal, a nonlinear control law based on backstepping approach is synthesised and robustness tests relatively to parameters variation have been realized. Simulation results confirm the good performances and robustness of the using approach.

3rd June, Tuesday
09:00-11:20 at Turkuaz
TuA2 Control Systems and Applications IV
Session Chair : Mario E. Salgado, Universidad Tecnica Federico Santa Maria
Co-Chair : Mohammad Bilal Malik, National University of Sciences & Technology

Dynamics of Partner Network
Kangilaski, Taivo; Shevtshenko, Eduard
Tallinn University of Technology, Estonia

Communication is a crucial element in business environment. It ties companies together to work on a common business goal, as well as destroys existing business connection. Thus it is important to understand dynamics of partner networks. The current article analyses Partner Network lifecycle and it maturity aspects.

Transient simulation of fixed-speed wind turbine with grid fault variety in real wind farm
Mehrshad, Mahdi1; Effatnejad, Reza2; Mohammadpour, Asad1
1Science and Research Islamic Azad University, Iran; 2Islamic Azad University, Iran

Wind turbine with proportion of its design and control concept, can produce electricity in different actual mode. This enables turbine to show a certain reaction in different faults. This operation, can be analyze and provide a suitable plan for construct, and also add to turbine control mechanism as necessity. The main goal of this paper is analyzing the stability of a fixed-speed wind turbine during grid fault occurrence in different period and gets the reaction of wind turbine during its operation in a sample wind farm. Beside the analysis, the innovative solutions on how to build wind farms are mentioned to reduce these effects in matter. Also
some electrical and mechanical solution adds to wind turbine structures to get best result in wind farm operation.

**Application of Sampled Data LQR Control Scheme for Grid Tie Inverter**

Ali, Rahat; Malik, Mohammad Bilal; Salman, Muhammad; Malik, Fahad Mumtaz  
*National University of Sciences and Technology, Pakistan*

In this paper, we present closed loop sampled-data linear quadratic regulator (LQR) based control scheme. Suggested scheme is applied on a practical linear system of a grid tie inverter for tracking a reference signal in the presence of external disturbance. LQR functions on the basis of minimization of a well-defined cost function. Prior knowledge about the external disturbance is utilized by the control scheme. This information is effectively used in defining cost function to minimize the disturbance effects and providing smooth tracking of a reference signal. Through computer simulations, a comparison is also drawn between the proposed sampled-data control scheme and the corresponding continuous time control scheme applies on third order grid tie inverter plant. We note that sampling time and weighing parameters of the cost function in sampled-data control schemes play pivotal roles in defining its performance.

**Optimal design of P and PI controllers for simple SITO plants. Cases study**

Vega, Felipe N.; Salgado, Mario E.  
*Universidad Tecnica Federico Santa Maria, Chile*

In this paper an optimal PI design approach is developed and illustrated for the control of plants with one input and two outputs (SITO). The idea is applied to simple discrete-time SITO plants amenable to be stabilized with P and/or PI controllers. Simple linear discrete-time systems are considered, and a 2-norm minimization is used.

**Online energy efficiency assessment in serial production - statistical and data mining approaches**

Cupek, Rafal¹; Drewniak, Marek²; Zonenberg, Dariusz²  
¹*Silesian University of Technology, Poland; ²AIUT, Poland*

Due to increasing energy costs and the demand to lower CO₂ emissions in the production, companies try to apply energy efficient technologies in green (new installations) and brown (modernized installation) production systems. Hence, the procedures of energy efficiency assessment have to be integrated with production systems on the machine control level. Presented work compares the energy efficiency assessment based on statistical analysis with an approach based on data mining and cluster analysis. Experimental results have shown limitations and possible application fields for both methods. Even though the presented methodology was conducted on compressed air consumption monitoring system, it can also be easily applicable for other types of consumed energy.

**Adaptive Fuzzy Tracking Control of Unmanned Quadrotor Via Backstepping**

Yacef, Fouad¹; Bouhali, Omar²; Hamerlain, Mustapha¹  
¹*Center for Development of Advanced Technologies, Algeria; ²Jijel University, Algeria*

This paper presents an adaptive fuzzy control scheme for quadrotor trajectory tracking. A fuzzy system is employed to approximate a model based control law developed using backstepping
techniques. The adaptive laws for tuning the adjustable parameters of the fuzzy system are derived based on the Lyapunov synthesis approach. The proposed controller yields asymptotic tracking, while keep the stability of the closed loop dynamics of the quadrotor and boundedness of approximation errors. Numerical simulation results are provided to illustrate the good tracking performance of the proposed adaptive control approach.

**Offline Measurement of 2-axis platform tilt and its Soft Compensation**

Hina, Aminah; Malik, Muhammad Bilal; Akhtar, Muhammad Usman

*National University of Sciences & Technology, Pakistan*

In many applications, platforms/turn tables have to be leveled before they can be used for instrumentation or other purposes. In this paper, we introduce a soft leveling technique, which is based on error compensation rather than physical leveling. The tilt in the platform is modeled, which is then estimated using an inclinometer. A least squares approach minimizes discrepancy due to measurement noise. The results of the proposed scheme as implemented on a physical system demonstrate the utility and accuracy of the method.

**3rd June, Tuesday**

09:00-11:20 at Kahribar

TuA3 Robotics and Mechatronics II

Session Chair : Kiyoshi Ohishi, Nagaoka University of Technology

Co-Chair : Huei-Yung Lin, National Chung Chung University

**Robust Position Control of Delta Parallel Mechanisms Using Dynamic Model and QFT**

Kenmochi, Masanori; Avci, Ebubekir; Kawanishi, Michihiro; Narikiyo, Tatsuo;

Kawakami, Shinji; Saitou, Yumi

1Toyota Technological Institute, Japan; 2OMRON Corporation, Japan

This paper presents a solution to the residual vibration of 3-DOF Delta parallel robots. As the parallel mechanism is highly nonlinear, inverse dynamics analysis in explicit form by using Lagrangian formulation is proposed to linearize the system. To apply the Lagrangian method to the parallel mechanism, the structure is divided to sub-chains by imaginary open tree method. After deriving inverse dynamics in analytical form, system is linearized. To control the linearized system, Quantitative Feedback Theory is applied and vibration suppression during the high-speed motion is achieved. Usefulness of the linearization and QFT method to control the high-speed parallel mechanism is shown through experiments.

**An Experimental Validation of Electro-hydraulic Transmission for Haptic Teleoperation - Comparison with Thrust Wire**

Bechet, Francis; Ohnishi, Kouhei

*Keio University, Japan*

This paper proposes an experimental validation of electro-hydraulic transmission for haptic teleoperation. Haptic teleoperation is an emerging technology that is designed to transmit position and force sensations of a distant environment to the human hand. Heretofore, it has
been considered in several applications such as plant reparation, space exploration or laparoscopic surgery. So far, flexible actuator using thrust wire is one of the most efficient way of transmitting haptic sensations. However, compensations of friction and backlash caused by deflection and shape changes of wire remain veritable issues. In this paper, we propose to connect two syringes through a hydraulic tube in order to achieve position tracking and force transmission between an electromagnetic motor and a remotely located end-effector. By that mean, flexibility of thrust wire is replaced by the flexibility of hydraulic tube, mechanical friction is replaced by viscous friction, and backlash is avoided by incompressibility of fluid. The validity of the proposal is verified experimentally.

Active Stereoscopic Camera to Build an Occupancy Grid for Autonomous Navigation

Barcelos, Andre de Oliveira Palmerim; Vidal, Fabio Silveira; Rosa, Paulo Fernando Ferreira

1Military Institute of Engineering, Brazil; 2Federal Institute of Tocantins, Brazil

Using a SLAM technique, known as Rao-Blackwellized particle filter (RBPF), and this work proposes to compare the performance of this solution in two situations: (a) using a rangefinder laser sensor to build an occupancy grid, as done in previous works in literature, and (b) using an active stereoscopic camera. This will allow to generate an occupancy grid, simultaneously while doing the robot’s localization, using only one device, reducing the payload and costs for this task. A future work will be performed to resolve the problems observed in this work.

Localization and Tracking of a 3-D Object Based on Multi-View Image Acquisition

Chuang, Yao-Cheng; Lin, Huei-Yung

National Chung Cheng University, Taiwan

This paper presents a 3-D object localization and tracking technique based on the CAD model and multi-view image captures of the object. From the given projected 2-D pose model in the image, the matching lines between the model contour and the object’s edge feature are used for nonlinear 3-D pose computation. The object location information in the real world is then identified. The method presented in this work has been validated on several experiments with various test objects. The results demonstrate that the proposed approach is robust to the partial occlusion and provides accurate positioning of the real object.

3D Instrument Localization and Tracking with the Integration of Image-Based and Electromagnetic Techniques

Yang, Shih-Feng; Lin, Huei-Yung; Wang, Min-Liang

1National Chung Cheng University, Taiwan; 2IRCAD-Taiwan, Taiwan

In this paper, we present an improved marker for optical tracking. The proposed IR pattern can accept up to 50% of occlusion so that we can reduce the requirement of line-of-sight during the instrument tracking. To provide the accurate instrument tracking results for surgeons to manipulate minimally invasive surgery, we integrate both optical tracking and electromagnetic tracking methods into an image guided surgery system. Furthermore, we use a sensor fusion algorithm to fuse the measurements from these subsystems to make the measurement of the system more stable.
Proposal of Friction and Force Transmission Compensator for Cancer Hardness Measurement System Using Flexible Actuator

Ogawa, Kenji; Francis, Bechet; Ohnishi, Kouhei
Keio University, Japan

The rate of death by cancer is higher than any other diseases in Japan. In order to prevent the number of death by cancer from increasing, it is necessary to find a solution as soon as possible. However, nowadays’s diagnosis technology has a limitation in cancer detection. Therefore, some kinds of cancer cannot be detected. In addition, diagnosis is done only qualitatively by looking the condition of organs. From above reasons, quantitative cancer hardness measurement system based on palpation has been developed. However, it is difficult to measure the cancer hardness collectly because of force attenuation. Therefore, it is necessary to consider compensation methods. In this paper, friction and force transmission compensator for cancer hardness measurement system is proposed. Friction is compensated in real time by a linear square method and force transmission is compensated by a mapping function. The efficiency of the proposal is verified experimentally.

Impedance Control based Two-Channel Architecture in Time Delayed Teleoperation System

Yoshimura, Nobuto; Ohnishi, Kouhei
Keio University, Japan

This paper proposes a two channel control architecture based on impedance transmission in time delayed teleoperation system. In conventional research, bilateral teleoperation is widely researched and bilateral control is used to obtain remote force information. However the performance is degraded and destabilized by time delay. Conventional approaches like smith predictor, communication disturbance observer (CDOB), and three-channel architecture improved stability of position control and reduced operational force caused by time delay, yet force control is still not stable. Damping injection can stabilize the force control, but law of action-reaction was not achieved. To achieve teleoperation using force feedback, law of action-reaction should be achieved. From the point of view, experiments are conducted and validity of the proposed method is confirmed.

3rd June, Tuesday
09:00-11:20 at Elmas
TuA4 Wireless Sensor Networks for Embedded Industrial Applications I
Session Chairs : Gerhard P. Hancke Jr., University of Pretoria
Reza Abrishambaf, University of Minho, Portugal

An Energy Sentient Methodology for Sensor Mapping and Selection in IoT Systems

Huang, Zhenqiu1; Lin, Kwei-Jay1,2; Han, Lina3
1University of California, Irvine, USA; 2Intel-NTU Connected Context Computing Center, Taiwan; 3Tongji University, China

This paper presents an energy sentient methodology for mapping and deploying IoT applications on sensor devices installed in a target environment. The deployment decision
support is part of the WuKong intelligent middleware which is designed to automatically discover and man-age smart sensor devices. Given a pre-defined flow-based service process, WuKong will select and set up the most efficient configuration for the application using the service-oriented paradigm. The sensor selection methodology re-portad in this paper is to minimize the total communication energy consumption and to balance the energy costs on all devices in order to increase the system lifetime. We define the service collocation problem model, develop algorithms based on the Integer Linear Programming (ILP) model, and study the algorithm performance by simulation.

A Wireless Sensor Network for Collision Detection on Guardrails

Miranda, Jorge; Gomes, Tiago; Abrishambahf, Reza; Loureiro, Filipe; Mendes, Jose; Cabral, Jorge; Monteiro, Joao Luís
University of Minho, Portugal

This paper presents a real-time system based on Wireless Sensor Network (WSN) capable of detecting collisions of vehicles with motorways' guardrails. The system is based on Service Oriented Architecture (SOA) with web services, where the WSN and other applications, like alarm systems and management of WSNs, are connected. It is also presented a simulation based mathematical model using finite element methods, in order to improve the reliability of collision detection.

An Intelligent Home Automation Control System Based on A Novel Heat Pump and Wireless Sensor Network

Brito, Joao; Gomes, Tiago; Miranda, Jorge; Monteiro, Leonel; Cabral, Jorge; Mendes, Jose; Monteiro, Joao Luís
University of Minho, Portugal

One of technology’s main goals is to providing comfort to humans. However, in order to be an aid, it has to be easy to install, use and maintain. The ever growing complexity of technological systems can only be achieved by converging different technologies. This is usually expressed as Cyber-Physical Systems (CPS), previews the symbiosis of several technologies in order to make them more accessible. This paper attempts to demonstrate the integration between two technologies such as: Heat-pump System and Wireless Sensor Network (WSN) to provide a new control mechanism for new building generations so-called smart houses. The proposed control architecture ben-efits from our developed WSN hardware platform. It enables the user to control and monitor the ventilation system using our developed mobile application and/or a personal computer. Also, the performance of the proposed hardware platform is measured in three different environments in order to observer the coverage area of the WSN.

An Industrial Wireless Sensor Networks Framework for Production Monitoring

Bal, Mert
Miami University, USA

This paper presents design and implementation of a spatially distributed measurement system using Wireless Sensor Networks (WSN) for real-time condition and performance monitoring of industrial machines in a manufacturing system setting. Main focus in this study was given to applications in small-to-medium size metalworking industry, where most of the machinery are conventional and do not support modern digital
data communication technologies common for factory networking. The general procedure and the details of implementation are presented through a prototype implementation performed in a metalworking industry. A multi-platform and multi-layer sensor platform has been utilized using ZigBee-based TelosB and SunSPOT motes for enhancing the wireless communication quality in a factory environment. A distributed decision making scheme was used in order to provide real-time reliable machine utilization information.

Development of Pseudo Autonomous Wireless Sensor Monitoring System for Water Distribution Network

Kondratjevs, Kaspars; Zabasta, Anatolijs; Kunicina, Nadezhda; Ribickis, Leonids
Riga Technical University, Latvia

Water distribution networks require long term autonomous monitoring solutions, integrated, reliable and cost effective data transfer methods. This paper investigates the data delivery infrastructure of water distribution network sensor equipment used for network monitoring and billing of the subscribers. Water distribution network usually apply sensors to measure water flow, pressure and temperature. The main goal is to offer a wireless sensor system architecture comprising simplified and cost effective design for large scale deployments, maximizing autonomous running time and data transmission reliability. The proposed solution offers a periodic data acquisition system by removing the need of drive-by scenarios commonly used for water meter readouts collection. The idea of pseudo autonomous wireless sensor monitoring system is also discussed in the conclusion.

Industrial Applications of Collaborative Wireless Sensor Networks: A Survey

Bal, Mert
Miami University, USA

The objective of this paper is to summarize the recent literature and application examples of the use of Wireless Sensor Networks (WSN) in the industry. Main focus in this paper is primarily on the use of collaborative wireless sensor networks for condition and performance monitoring of the industrial machines and plants. Current challenges and potential future research issues are outlined for design of WSN-based industrial monitoring systems in order to provide guidelines to researchers and application developers.

Dynamic Spectrum Allocation for Smart Meter Networks and WSNs in the Presence of Household Consumer Networks

Hancke Jr., Gerhard P.1,2; Mbuya, Colman F.1
1University of Pretoria, South Africa; City University of Hong Kong, Hong Kong

The spectrum used by wireless sensor networks and smart metering networks is becoming increasingly crowded due to the increasing deployment of IEEE 802.11b/g and Bluetooth devices as well as other co-located wireless sensor networks. Using an energy detection application, this paper presents the statistics of the interfering power levels from typical IEEE 802.11b/g devices, Bluetooth devices and wireless sensor networks. This paper also discusses a possible channel characterization and selection criteria based on the interfering power level statistics. It is found that while the energy detection application is not optimal, it is good enough to detect occupancy levels of a channel and can provide a base from which dynamic spectrum access WSNs can designed and implemented. The application can also be used by
smart metering networks to avoid interference.

Fuzzy Energy Control Strategy of Through-To-Road Hybrid Electric Vehicle
Moghbeli, Hassan¹; Niasar, Abolfazl Halvaei²; Fallahi, Naser²
¹Arak University of Technology, Iran; ²University of Kashan, Iran

New energy management strategies for hybrid electric vehicles (HEV) play an important role on HEV's future. In order to achieve high performances, less fuel consumption and pollution, and higher efficiency, modern strategies should be employed. Fuzzy approach is one of the most popular and powerful techniques in energy management and optimization which are developed for HEVs. On the other hand, separated-axle or through-to-road (TTR) parallel HEV has the simplest structure among other type of HEVs in addition to desirable performance. Shaheb 2 is a TTR parallel HEV type based on Pride platform that has been manufactured and designed in university of Kashan. This paper presents a new energy management strategy with two fuzzy controllers for battery state-of-charge (SOC) and developed torque of Shaheb 2. A comprehensive model of Shaheb 2 as well as its control strategy has been developed using ADVISOR. Low fuel consumption, high efficiency, and simple control strategy are the other benefits among various energy management strategies. Simulation results confirm the advantages of proposed fuzzy controller rather than conventional on/off strategy.

Hybrid City Bus Design Evaluation Using System Level Simulations
Halmeaho, Teemu; Rahkola, Pekka; Pippuri, Jenni; Tammi, Kari
VTT Technical Research Centre of Finland, Finland

Effects of different design parameters on the performance of a hybrid city bus were studied. A system simulation model of the hybrid city bus was developed and used for studying the effects of drive motor torque and vehicle mass on vehicle performance, fuel consumption and stability during regenerative braking. Increasing the maximum torque by 60% from the nominal value was found to improve the fuel efficiency by 8.3 % when the vehicle was driven on Braunschweig cycle. On the other hand, vehicle stability during regenerative braking was analysed to understand the influence of the braking torque on vehicle stability. This is particularly important when operating at limited traction conditions. In situations where only regenerative braking was applied, the stability was found insufficient.

An Analytical Battery State of Health Estimation Method
Sarikurt, Turev; Ceylan, Murat; Balikci, Abdulkadir
Decrease in state of health (SoH) of a battery is a measure of end of battery life. Also available battery capacity is dependent on battery life either. Thus accurate estimation of SoH and cycle number of a battery are very important. In this study a method was proposed in order to estimate battery cycle number using ECE 15 driving cycle. Also another method to obtain SoH of a battery using the cycle number is introduced. The results of both methods are compared with the outputs of an experimental setup.

Fabrication and Characterization of Composite Electrodes for Lithium-ion Batteries
Prosini, Pier Paolo; Cento, Cinzia; Masci, Amedeo; Carewska, Maria

This paper reports the preparation and the characterization of composite electrodes based on TiO₂ and LiFePO₄. The electrodes were studied by using XRD, SEM, and charge/discharge cycles. The electrochemical tests comprised low rate cycling and cycling at different rates. The electrodes were used for the fabrication of lithium-ion batteries. Battery cells were assembled and electrochemical tested at various discharge rates to evaluate cell capacity and capacity retention as a function of the discharge rate.

An Enhanced Performance IPT Based Battery Charger for Electric Vehicles Application
Abdelhamid, Eslam¹; Abdelsalam, Ahmed²; Massoud, Ahmed³; Ahmed, Shehab³

1. Arab Academy for Science And Technology, Egypt; 2. Qatar University, Qatar; 3. Texas A&M University, Qatar

World-wide scientists/engineers were motivated to research in the area of renewable energy resources and to reduce the consumption of fossil fuels. Hence, electric and hybrid vehicles have won the attention of many researchers and vehicles manufacturers. Electric vehicle requires a charging system having a high degree of reliability and robustness and to run maintenance-free. This brings the inductive power transfer (IPT) systems to play a significant role in electric vehicle battery chargers applications. IPT system has proved its capability to be a safe, convenient, and efficient electric vehicle battery charger through its features, such as operating in a harsh environment, high efficiency at reasonable power levels, and decreasing equipment maintenance through operating without any mechanical contacts. This paper presents an enhanced performance IPT system, which is particularly suitable for electric vehicle battery charging application. The proposed system is slightly affected by the small tolerance between sender (track coil) and receiver (pickup coil). Relation between application, transformer configuration selection, and power converter controller is discussed in details. The proposed system effectiveness is investigated, in addition to simulation, by an experimental set-up.

A Forward-Facing Hybrid Vehicle Simulation Tool Based on Multi-Physics Lumped Circuit Approach
Paschero, Maurizio; Frattale Mascioli, Fabio Massimo

University of Rome "Sapienza", Italy

In this paper it is described a research project concerning the derivation and the development of a novel forward-facing hybrid vehicle simulation tool based on Multi-physics lumped circuit approach. Sub-components are modelled as multi-port systems. Each port is characterized by
means of an intensive and an extensive quantity complementary in power. This approach allow to model the mutual influence of the interconnection among blocks resulting in a more accurate simulation. A variational Lagrangian approach is used to derive analitical models. Equations are interpretated from a circuital point of view. The resulting circuit is then implemented and tested using the SimScape toolbox available in Matlab/Simulink environment.

A Superior Hybrid Fuel Cell Vehicle Solution for Congested Urban Areas: Modeling & Analysis

Youssef, Mohamed1; Abu-Mallouh, M.2; Salah, M. 2; Hamdan, M. 2; Abdelhafez, E. 2; Surgenor, Brian3

1University of Ontario Institute of Technology, Canada; 2Hashemite University, Jordan; 3Queen’s University, Canada

This paper presents a promising solution to the problem of the bad environmental impacts and the high operating cost of the Internal Combustion Engine (ICE) gasoline powered vehicles. In Toronto, the capital of Ontario, the traffic jam is becoming a regular flavor of every day’s commute that make the driving pattern featured with low speed and a lot of stops and goes. This driving pattern increases the pollution problem that already exists due to the large number of vehicles in Toronto streets and reduces the lifetime of the engine and the brakes leading to a more running cost. This study investigates the performance of a hybrid Fuel Cell (FC)/battery vehicle configuration, which is considered as one of the most promising clean vehicles in comparison with the traditional ICE vehicles. In this study, a model of an ICE mid-size vehicle was developed and validated against experimental acceleration tests. The ICE vehicle model was modified by replacing the ICE power-train with a FC and battery power-train while keeping the other vehicle parameters the same. A comparison between ICE and hybrid FC/battery vehicle configurations was conducted using a representative alignment load cycle in Toronto. It was found that the hybrid FC/battery configuration is much better than the ICE version in terms of emission, fuel economy, efficiency and speed tracking error due to the faster response of the control system.

3rd June, Tuesday
09:00-11:20 at Topaz

TuA6 Automotive Applications of Hybrid and Electric Propulsion
Systems II
Session Chair: Gianluca Fabbri, Drive the Innovation in Energy Storage
Co-Chair: Ezio Santini, “Sapienza” University of Rome

Innovation Management of a High-Technology Academic Start Up: the case of DINESTO

Fabbri, Gianluca1; Tarquini, Gabriele1; Pasquali, Luca1; Antonucci, Massimo2; Frattale Mascioli, Fabio Massimo 1

1Drive the Innovation in Energy Storage(DInESto), Italy; 2BIC Lazio, Italy

An academic spin-off is a new company born by the idea of merging the competences of different academic or institutional research groups. The main goal of a spin-off is to transfer
and commercialize technological innovations. This article describes a high-technology Italian innovative spin-off named DInESto, (Drive the Innovation in Energy Storage); the core business of this company is in the field of electrochemical energy storage systems and in particular in the production of lithium iron phosphate (LiFePO4) as cathode material in lithium ions batteries. The development of an efficient energy storage system is very crucial both for its use in renewable energy production systems and in the automotive sector. One of the limitations of the extensive employment of these batteries concerns the cathode materials. The activities of the spin-off are described as case study including discussion of issues and innovations related to management aspects, risk taking and related consequences. Moreover a summary of the new Italian legislative framework for Start-ups is given and a new tool to improve self awareness of future entrepreneurs named PES, Promoting Entrepreneurship Skilful, is described.

**Bonifica 2.0 : an Integrated Territorial System of Sustainable Mobility and Micro Smart Grids**

Fabbri, Gianluca; Dessi, Marco; Frattale Mascioli, Fabio Massimo; Paschero, Maurizio; Sgreccia, Simone; Anniballi, Luigi; Nardecchia, Stefano  
*Sapienza University of Rome, Italy*

The main objective of this paper is to illustrate an Integrated Territorial System of Sustainable Mobility and Micro Smart Grids developed by the Pole for Sustainable Mobility (POMOS) and its partners, in the framework of a regional R&D project named “Bonifica 2.0”. This project aims at the touristic exploitation of the Pontine territory, a large naturalistic area in the region of Lazio in Italy, configuring mixed routes (waterways, channels and bicycle/pedestrian paths) out of the road network paths and expanding the concept of land sustainable mobility to waterways and coastal lakes that characterize all the Pontine area. One of the main targets is the restoration of historical, archaeological and natural zones in an innovative way and with the use of new technologies and environmentally sustainable means of transportation. A mobility system integrated with the mainland has been studied and will be implemented. The system will allow to manage the fleet and the infrastructures assuring safe routes and the exploitation of historical / cultural sites. The system and its main components are described in this paper illustrating what has been achieved till now. In particular a prototype of an innovative electric boat to be used to navigate shallow waters is presented.

**Automotive Application of Lithium-ion batteries: Control of Commercial Batteries in Laboratory Tests**

Dell’Era, Alessandro1; Fabbri, Gianluca2; Pasquali, Mauro3; Santini, Ezio3  
1University Guglielmo Marconi, Italy; 2Drive the Innovation in Energy Storage(DInESto), Italy; 3“Sapienza” University of Rome, Italy

In this work the behavior of commercial lithium-ions batteries for auto-motive sector usage have been analyzed. Through laboratory tests the loss of the nominal capacity in a battery has been studied. In particular the three basic causes of this phenomenon such as the amount of power required during the discharge phase, the aging due to high number of cycles and the poorly management of a battery pack have been examined in order to try to identify and define a method to recover battery packs poorly managed.

**Home Energy Management with PSO in Smart Grid**

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In this paper, a real-time optimal appliance usage strategy is proposed based on binary particle swarm algorithm, participated by both energy suppliers and end users. Under the multi end-users and time-of-use electricity prices circumstances, the total electricity bills can be generated with different appliance usage pattern: random, single optimal objective and double optimal objectives, resulting in different load curves. Considering the characteristics of the appliances and living habits, the appliances are classified into three categories. Matlab is used as the simulation tool to perform the experiments to prove that the load shifting, energy saving and energy supply efficiency enhancement can be achieved with multi-objectives with particle swarm optimization.

Diagnostic methods for the evaluation of the state of health (SOH) of NiMH batteries through electrochemical impedance spectroscopy

Galeotti, Matteo¹; Giammanco, Corrado¹,²; Cina, Lucio¹,²; Cordiner, Stefano¹; Carlo, Aldo Di¹,²

¹University of Rome Tor Vergata, Italy; ²Center for Hybrid and Organic Solar Energy (CHOSE), Italy

In this work, we have characterized single nickel metal hydride (NiMH) cells with Electrochemical Impedance Spectroscopy (EIS) technique to determine online the state of the batteries. Studying the variations of the obtained impedance spectra at specific frequencies, which correspond to part of the spectra that change mostly during the charge and discharge processes of the batteries, we have constructed and interpreted diagnostic diagrams through a mathematical model based on Dempster-Schafer Theory of Evidence in order to determine the SOH.

Impact of V2G/G2V Technologies on Distributed Generation Systems

Fabbri, Gianluca¹; Odoardi, Simone¹; Tarquini, Gabriele²; Pasquali, Luca²; Teodori, Sabrina¹; Santini, Ezio¹

¹Sapienza University of Rome, Italy; ²Drive the Innovation in Energy Storage (DiNESto), Italy

This paper investigates the current status and implementation impact of V2G/G2V (Grid-to-Vehicle) technologies on Distributed Generation (DG) systems, requirements, benefits, challenges and strategies for interfaces of both individual vehicles and fleets.

Novel File System with ASN.1 Support for Java Card Applications

Imam, Mostafa¹; Sobh, Mohamed²

¹Softlock Company, Egypt; ²Ain Shams University, Egypt

By the release of Java Card 3.0 Connected version and the rapid evolution of ubiquitous computing, many embedded software applications have been proposed recently to exploit the benefits of the new technology. These recent research and software development activities make it inevitable to defend the new applications in the open untrusted environments through proposing parallel research in securing embedded software platforms. This paper proposes a novel File System Applet for existing Java Card systems that provides highly secure storage for
security-critical objects of the other residing Applets. The new file system Applet depends on PKCS15 and ISO7816 standards and features new built-in ASN.1 parser to prevent intended/unintended leakage of sensitive information.

Grid Inertial Response with Lithium-ion Battery Energy Storage Systems
Knap, Vaclav; Sinha, Rakesh; Swierczynski, Maciej; Stroe, Daniel-Ioan; Chaudhary, Sanjay
Aalborg University, Denmark

The increased grid-penetration levels of energy produced by renewable sources, which have almost no inertia, might have a negative impact on the reliable and stable operation of the power system. Various solutions for mitigating the aforementioned problem were proposed in the literature. The aim of this paper is to evaluate the technical viability of utilizing energy storage systems based on Lithium-ion batteries for providing inertial response in grids with high penetration levels of wind power. In order to perform this evaluation, the 12-bus system grid model was used; the inertia of the grid was varied by decreasing the number of conventional power plants in the studied grid model while in the same time increasing the load and the wind power penetration levels. Moreover, in order to perform a realistic investigation, a dynamic model of the Lithium-ion battery was considered and parameterized. All the studies were performed in real time on a laboratory setup composed of RTDS and dSPACE platforms.

An Adaptive Fuzzy Logic Based Energy Management Strategy for Electric Vehicles
Zhou, Wenhao; Li, Mian; Mian, He; Ma, Chengbin
Shanghai Jiao Tong University, China

One of the key issues for electric vehicle (EV) development is the energy management strategy, especially for those with hybrid energy storage systems. A fuzzy logic based energy management strategy (FEMS) is proposed in this work to determine the power split between two energy storage sources: a battery tank and an ultracapacitor tank. Fuzzy logic control is chosen because of the nonlinearity of the EV plant and real-time control issue. The FEMS is further improved to be adaptive for better control performance. The underlying principle of this adaptive fuzzy logic control is to maximize the system efficiency, to maintain ultracapacitor charge state, and to minimize the battery current variation. NetLogo is used to assess the performance of the proposed methods. Simulation results show that the proposed control method produces better and balanced performance in terms of comparison criteria.

Sinusoidal Ripple Current Charging System with PLL Function
This paper proposed a sinusoidal ripple current charging system with PLL (Phase-Locked-Loop) function, which is used to charge the battery with battery resonant charging frequency. The proposed system uses a resonant frequency tracker, which is mainly constructed by the phase-locked-loop, so that the features of detecting, tracking and locking in the resonant charging frequency can be achieved. Finally, a prototype is simulated to verify the performance.

A robust contactless capacitive communication link for high power battery systems

Wenger, Martin; Filimon, Radu; Lorentz, Vincent; Marz, Martin

Fraunhofer IISB, Germany

Large Li-ion battery systems are being used in a growing number of applications. Due to lack of standards and various requirements, the battery systems have to be specifically designed for each application. This need for a specific design also affects the battery monitoring circuit. In order to reduce design effort, distributed battery monitoring systems integrated into the cells were proposed. Economies of scale allow these circuits to be produced at low cost per unit as they will be needed in every single battery cell. One of the major challenges of the distributed battery monitoring concept is the communication link for the monitoring circuits: it has to be robust, reliable, and easy to install. As a possible solution, a capacitively coupled data transmission link for a battery system consisting of up to 100 smart battery cells is investigated by simulation and experiment. Relevant influence factors of the physical implementation on a capacitive voltage divider determining the transmitted data signal are identified and evaluated, considering application specific constraints. As a result, a suitable signal conditioning circuit using frequency shift keying (FSK) modulation is proposed and experimental results obtained with a prototype implementation of the proposed circuit are presented.

A Battery Modeling Method Based on Percentage of Discharge (POD)

He, Zhichao¹; Yang, Geng¹; Chen, Yingjie¹; Lu, Languang¹; Wang, Zhanjiang²; Sun, Xiaofeng²

¹Tsinghua University, China; ²Yanshan University, China

Modeling the discharge characteristics of every cell in a battery pack individually is the basic issue for battery management systems (BMS). This paper proposes a simple method for modeling the constant current discharge curves with POD. With this method, precise model of a cell can be built with typical discharge curves, and characteristics of other cells can be estimated. This method can also be used to evaluate the consistency of the cells in a battery pack. The method is verified with experiments on valve-regulated lead-acid (VRLA) batteries and LiFePO₄ lithium-ion batteries.

Ageing Law for Supercapacitors Floating Ageing

German, Ronan¹; Sari, Ali¹; Venet, Pascal¹; Zitouni, Younes¹; Briat, Olivier²; Vinassa, Jean-Michel²

¹Université de Lyon, Université Lyon 1, France; ²Univ. Bordeaux, France

Supercapacitors are energy storage systems appreciated as high power short duration power sources. As any electrochemical devices, supercapacitors are subject to ageing processes.
Ageing is characterized by supercapacitors electrical performances loss (capacitance fades and Equivalent Series Resistance increases). In this article, we focus on capacitance fade with time for different sets of floating ageing constraints (constant temperature and voltage). This article deals with the best way for modeling capacitance fading with time for supercapacitors. Firstly, we present the approach of Eyring which predicts time for failure apparition. Then, we study two recent and uncommon ways for predicting capacitance evolution based on Langmuir isotherms and on the growth of a surface electrolyte interface. According to our study surface electrolyte interface approach appears more suitable for floating ageing modeling.

Energy Management and Control Algorithms for Integration of Energy Storage Within Microgrid

Zamora, Ramon\textsuperscript{1,2}; Srivastava, Anurag K.\textsuperscript{1}

\textit{Washington State University, USA; Syiah Kuala University, Indonesia}

This paper discusses energy management and control algorithms of microgrid with energy storage. Specific management framework within microgrid presented here includes: a) help prioritizing the renewable energy sources (RES) to provide power to local loads, b) manage battery to avoid deep-discharging and overcharging, c) maintain dc link voltage at a specified value, and d) regulate ac voltage buses at nominal voltage and frequency. The system analyzed here is adopted from Consortium for Electric Reliability Technology Solutions (CERTS) microgrid test bed. While the generation priority is from RES, the system also has a thermal generation unit to compensate for renewable energy variability and intermittency. Depending on battery state of charge (SOC) and power difference between photovoltaic (PV) and the load, the energy management can work with several modes: charging, discharging, export power, import power, and halt. The system is simulated in PSCAD platform and shows that energy management and control algorithms work as expected.

Wavelet-based Adaptive Nonlinear Power System Excitation Control

Yousef, Hassan; Al-Badi, Mohammad; Soliman, Hisham M.

\textit{Sultan Qaboos University, Sultanate of Oman}

This paper presents a new adaptive excitation control for power system based on wavelet network. An application of wavelet networks to nonlinear excitation control of a power system is presented in this manuscript. A wavelet network is constructed as an alternative to a neural network to approximate a nonlinear system. Based on this wavelet network approximation, suitable adaptive control and appropriate parameter update algorithm are developed to force the nonlinear unknown power system to track a prescribed trajectory with desired dynamic performance. It is shown that the effects of approximation errors can be attenuated to a
specific attenuation level using the proposed adaptive wavelet network control scheme. A single machine infinite bus system with uncertain fault location is presented to illustrate the proposed design procedure and exhibit its performance.

**Power Sharing for Efficiency Optimisation into a Multi Fuel Cell System**

Garcia, Jorge E.1,2,3; Herrera, Daniel F. 1,2,3; Boulon, Loic1,2,3; Sicard, Pierre1,2,3; Hernandez, Andres I. 4

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This paper presents a power splitting algorithm in order to optimize the efficiency of a multi fuel cell system. Versus a single fuel cell, such a system is modular, allows a better efficiency curve and reduces the risk of general failure. The results of the algorithm are easy to implement into a real time controller. This work presents simulation results based on an experimental power vs efficiency curve.

**Fuzzy Deception Game using Ant-Inspired Meta-Heuristics**

Kouzeghar, Maryam; Badamchizadeh, Mohammadali A.

University of Tabriz, Iran

Deception plays a significant role in many intelligent systems whether natural (insect colonies, animal colonies etc. to human beings) or artificial ones. In order to make artificial deception near the one existing in the real world, fuzzy theory seems a reasonable tool since it is the theory of mind through which the uncertainties can be modeled. In this work a hide and seek problem is considered in a maze imaginable in any form between two robots one of which is trying to deceive the other. Fulfilling the deception, the deceiver is supposed to use two signals (track and smell), the second of which is inspired from natural ants. The deceiver is free to choose whether or not to leave a track on the way and also it is the one who decides on the amount of smell deposited in order to confuse the robot under deception (the mark). After the deceiver decides where to go, the robot under deception (the mark) (on each cross-road) is to decide which path to choose based on a utility function calculated within a fuzzy inference system whose inputs are the value of deception signals. The results show that the robot under deception faces high utilities when coming across the roads the deceiver wants him to enter (less-beneficial roads to the deceiver) and consequently is convinced to do the thing desired by the deceiver.

**Intelligent Control Design of Anticipation and Relaxation Behavior in Real Traffic Flow**

Ghaffari, Ali1; Khodayari, Alireza2; Hosseinkhani, Niloofar1; Salehinia, Saeed2

1 K. N. Toosi University of Technology, Iran; 2 Islamic Azad University, Iran

Car following and lane change are the most common driving behavior in urban roads and highways. Although these two maneuvers have been studied extensively, the effects of lane change on car following maneuver remain elusive. This effect, which is called anticipation and relaxation, is a transient state between two cars following maneuvers happening due to the lane change of new leader. During this behavior, immediate follower deviates from common car following models to accommodate the lane changer ahead. Previous studies for anticipation and relaxation proposed equation-based models for this behavior. These models
are only matched to the rest cases and are not reliable. Unlike previous studies, in this paper an intelligent controller based on the behavior of real drivers is proposed. This controller aims to regulate the acceleration of follower vehicle in a way that the control system mimics the behavior of real drivers. Afterwards, its performance is compared with human driver data. The results show that the intelligent controller offers safer and more comfortable drive than real drivers.

Longitudinal and Lateral Movement Control of Car Following Maneuver Using Fuzzy Sliding Mode Control

Ghaffari, Ali; Khodayari, Alireza; Gherehpapagh, Bahar; Salehinia, Saeed

1K. N. Toosi University of Technology, Iran; 2Islamic Azad University, Iran

Nowadays, car following models, as the most popular microscopic traffic flow modeling, are increasingly being used by transportation experts to evaluate new Intelligent Transportation System applications. The control of the car following is essential to its safety and its operational efficiency. For this purpose, this paper builds fuzzy sliding mode control (FSMC) system for car following maneuver. The aim of designing of this FSMC system is to obtain a controller that maintain safe longitudinal distance and minimizes the lateral movement of the vehicle with its leader vehicle. These goals were reached by producing proper composite torque and steering angle in car following maneuver. This control system has both advantages of sliding mode and fuzzy logic methods. Also, a nonlinear dynamics model with three degrees of freedom has been used to define sliding surfaces in sliding mode control method. The FSMC’s performance was evaluated based on real observed traffic data. The simulation results show that the FSMC controller has a behavior much safer than that of real drivers, and it can provide a pleasant trip for passengers. The designed control system keeps a safe longitudinal distance from its leader and makes much less lateral displacement than the real driver.

Decouple PID Control System of Ultra-Compact Binary Power Generation Plant Considering Larger Number of Manipulated Variables

Han, Kun-Young; Lee, Hee-Hyol

Waseda University, Japan

Modeling of an ultra-compact binary power generation plant by using temperature difference of thermal energy between hot water and cold water and designing of its control system are consider in this paper. First, linearized transfer function models of the ultra-compact binary power generation plant are deduced. Also a decouple PID control system is designed. Furthermore, control performance of the control system that has a larger number of manipulated variables than the number of controlled variables is investigated.
Physiological Estimation of Body Balance for Affinitive Personal Vehicle

Ajisaka, Shimon¹; Nakamura, Sosuke²; Kubota, Takashi¹; Hashimoto, Hideki²

University of Tokyo, Japan; Chuo University, Japan

Recently, personal vehicles have received a lot of attention to expand our mobility for low carbon society and diversification of individual mobility. So far several small vehicles have been developed. However a new thesis of designing and controlling personal vehicles is required, because there are some difference between general vehicle-used environment and personal vehicle-used environment like mixed traffic. In such new kinds of environment, vehicles should have close relationship with drivers. To have closer relationship, personal vehicles must be smaller and lighter. In addition, designing personal vehicle’s motion by considering driver’s psychological evaluation, we can provide more comfortable vehicle’s interface. The author defined these kinds of personal vehicle as Affinitive Personal Vehicle and focused on driver’s sense of balance to estimate driver’s psychological evaluation. In this paper, author shows that change of vehicle’s motion effects on driver’s sense of balance, and there is relation between driver’s sense of balance and Kaisei evaluation.

A Novel Fast Search Motion Estimation Algorithm In Video Coding

Alvar, Saeed Ranjbar; Abdollahzadeh, Milad; Seyedarabi, Hadi

University Of Tabriz, Iran

Full search (FS) motion estimation algorithm compares the current block with every possible block of the reference block to find the most accurate motion vector (MV) with the least matching error by the mean square error (MSE). Using FS motion estimation algorithm in real time applications is impractical because of the cumbersome computations. In order to decrease the amount of significant computation on a FS motion estimation algorithm a fast search algorithm is proposed. A fast search algorithm samples a few possible locations in a search block in order to find local minimum MSE. A fast search algorithm improves the processing time and also gives a good quality performance in terms of the quality in the reconstructed frame. The proposed fast search algorithm aims to remove computational redundency by eliminating most highly impossible candidate locations. Experiments show that proposed algorithm reduces the computations greatly up to 99% and 22% compared to FS and diamond search (DS).

Towards an Artificial Immune System for Scheduling Jobs and Preventive Maintenance Operations in Flowshop Problems

Tayeb, Fatima Benbouzid-Si; Belkaaloul, Wahiba

Laboratoire des Methodes de Conception de systemes (LMCS), Algeria
This paper investigates permutation flowshop problem with preventive maintenance (PM). The objective functions are to minimize the total completion time for the production part and the total earliness/tardiness for PM part. The resolution consists of two steps: the one consists on scheduling production jobs using an artificial immune algorithm (AIA); the second one consists on deploying PM operations, taking the production schedule as a mandatory constraint of resources unavailability in the resolution of the problem. Furthermore, we use the principles of vaccination and receptor editing in order to strengthen search ability. The efficiency of the proposed AIAs with respect to minimization of makespan for the production part and performance loss after PM insertion, is compared to some referred in the related scheduling literature metaheuristics. Simulation results on both standard PFSP problems and non-standard integrated PFSP with PM problems show the superiority of our proposed algorithms.

Efficient discrete wavelet representation of electrical power disturbances by measuring energy concentration in the tiled time-frequency plane
Torres, Jose Eduardo; Valtierra-Rodriguez, Martin; Juarez, Mario Alberto; Vazquez, Gerardo
Instituto Tecnologico Superior de Irapuato (ITESI), Mexico
In this paper, it is proposed to treat the square wavelet coefficients as a probability density function in order to be able to measure energy concentration/dispersion in the tiled time-frequency plane. The proposed measure is the average distance to the center of mass of the tiled time frequency plane. This measure not only indicates energy concentration/dispersion in the tiled time-frequency plane but also hints that near symmetric orthogonal wavelets detect better the different electrical disruptions such as: transients, harmonics, interharmonics, voltage disruptions as well as sag and swell. To better illustrate the usefulness of the proposed approach a synthetic signal is generated containing the above mentioned electrical disruptions. The following wavelets are used to see which one concentrates better the energy in the tiled time-frequency domain: Daubechies, Coiflets, Symlets, Haar and the discrete Meyer wavelet.

Adaptive median filter based on ANFIS for impulse noise suppression
Selmani, Anissa; Seddik, Hassene; Ben braiek, Ezzedine
University of Tunis, Tunisia
Image enhancement and restoration in a noisy environment are fundamental problems in image processing. Various filtering techniques have been developed to suppress noise in order to improve the quality of images. Among diverse de-noising techniques, median filter is a well-known filter to deal with impulse noise in digital images. However, due to some limitations associated with the standard median filtering approach, several new improved versions of the median filtering method have been proposed by researchers. In this study, a new approach based on adaptive neuro-fuzzy inference system (ANFIS) was presented for restoring digital images corrupted by salt and pepper noise by a dynamic median filter that will adapt itself to the local noise intensity. Simulation results indicate that the proposed approach shows a high-quality restoration of filtered images than those using static median filter or others filters, in terms of peak signal-to-noise ratio (PSNR).
A Hybrid Method to the Reconstruction of Contour Lines from Scanned Topographic Maps
Hancer, Emrah1; Samet, Refik2; Karaboga, Dervis1
1Erciyes University, Turkey; 2Ankara University, Turkey

This paper addresses with the problem of contour line reconstruction extracted from scanned topographic maps since contour lines play a significant role on construction of Digital Evaluation Models (DEMs) and 3D simulations in serious fields. In this way, a semi-automatic hybrid method based on simple geometrical properties is proposed. The proposed hybrid method is designed by combining the two previously presented methods such as advanced and highly advanced methods in the literature. The contribution of the proposed hybrid method is to increase the accuracy of the advanced method and is to improve the run-time of highly advanced method in the process of reconstruction. The effectiveness of the algorithm is demonstrated by comparing it with the five popular methods in the literature. The implementation results show that the proposed hybrid method outperforms the others and can be efficiently employed in reconstruction process of contour lines.

3rd June, Tuesday
14:00-16:00 at Kahribar
TuB3 Power Electronics for AC and DC Microgrids I
Session Chair : Yan Xing, Nanjing University of Aeronautics and Astronautics
Co-Chair : Marko Gulin, University of Zagreb

Droop-Control-Based State-of-Charge Balancing Method for Charging and Discharging Process in Autonomous DC Microgrids
Lu, Xiaonan1; Sun, Kai2; Guerrero, Josep M.3; Vasquez, Juan3; Huang, Lipei2
1University of Tennessee, USA; 2Tsinghua University, China; 3Aalborg University, Denmark

In this paper, a droop control based state-of-charge (SoC) balancing method in autonomous DC microgrids is proposed. Both charging and discharging process have been considered. In particular, in the charging process, the droop coefficient is set to be proportional to $SoC^n$, and in the discharging process, the droop coefficient is set to be inversely proportional to $SoC^n$. Since the injected/output power is in inverse-proportion to the droop coefficient, with the proposed method, the energy storage unit (ESU) with higher SoC absorbs less power in the charging process and delivers more power in the discharging process. Meanwhile, the ESU with lower SoC absorbs more power in the charging process and delivers less power in the discharging process. Eventually, the SoC and injected/output power in each ESU are equalized. The exponent $n$ for SoC is employed to regulate the balancing speed of the SoC and injected/output power. It is demonstrated that with higher exponent $n$, the balancing speed is higher. Simulation model comprised of three ESUs is implemented by using MATLAB/Simulink. The proposed method is verified by the simulation results.

A Novel Multi-Port Bidirectional Converter for Interfacing Distributed DC Micro-Grid
Zhang, Junjun1; Wu, Hongfei1; Huang, Jun1; Xing, Yan1; Ma, Xudong2
A novel multi-port bidirectional DC-DC converter (MPBDC) is proposed for a stand-alone renewable power system which is composed of multiple distributed DC sub-systems. With the proposed MPBDC, the DC buses of these sub-systems can be interconnected with single stage and step-up/-down power conversion. The MPBDC is derived by interconnect multiple bidirectional buck/boost switching cells via DC-link inductors. The equivalent circuit between any two of the DC buses is a H-Bridge step-up/-down converter, which achieves single stage conversion. Compared with the conventional common DC-bus-based solution, the bulky DC-link capacitors have been eliminated with the MPBDC, which benefits reduced size, lower cost and better reliability. The operational principles, power management and pulse width modulation scheme are presented in detail. A prototype is built with experimental results given to verify the topology and control.

Sustainability of grid-connected Community Microgrid based on micro-wind generation system with storage

Mariam, Lubna; Basu, Malabika; Conlon, Michael F.

Dublin Institute of Technology, Ireland

In recent years, emphasis has been given on Renewable Energy based Microgrid (μGrid) systems because of their few advantages over Micro-generation (μGen) systems in terms of power quality, stability, reliability, economics etc. But the commercial installation of μGrid system is not yet progressing significantly. This paper presents the techno-economic aspects of μGen and μGrid system towards the sustainability study of grid connected Community Based Microgrid (C-μGrid) system. Emphasis has been given to identify the technical stability by introducing storage system and economical benefits of C-μGrid over the individual μGen system. As a case study, wind turbine based μGen and C-μGrid system both grid connected and off-grid have been considered. Ireland has been chosen as a geographical location where wind based μGen system is not yet very popular with Government REFIT (Renewable Energy Feed-in-Tariff) policy.

Mitigating low frequency ripple in Multiply Micro Sources inverter system with waveform control method

Wang, Hao Ran¹; Zhu, Guo Rong¹; Fu, Xiao Bin¹; Liu, Wei Xing¹; Xiao, Cheng Yuan¹; Tan, Siew Chong²

¹Wuhan University of Technology, China; ²The University of Hong Kong, Hong Kong

DC power systems comprising single-phase DC/AC inverters draw low-frequency AC ripple currents at twice the output frequency from the DC input. Such a 100/120 Hz ripple current may create instability in the DC clean energy system, lowers its efficiency, and shortens the lifetime of the DC source. This paper presents a general waveform control method that can mitigate such a low-frequency ripple current being drawn from the multiply micro sources in micro grid while it delivers AC power to the load regardless of the number of inverters connected in series at the AC side. With the application of waveform control, the double frequency pulsation power can be confined to the AC side (between the capacitors and the AC load), while the average DC output power is supplied by the multiply micro sources. Theoretical analysis and results are provided to explain the operation and showcase the
performance of the approach. Results validate that the proposed solution can achieve significant mitigation of the pulsation power as well as high quality output voltage without the need for extra hardware.

**Dynamical Behaviour Analysis of a DC Microgrid in Distributed and Centralized Voltage Control Configurations**

Gulin, Marko; Vasak, Mario; Pavlovic, Tomislav  
*University of Zagreb, Croatia (Hrvatska)*

In majority of cases residential microgrids are constituted of renewable energy sources, energy storage systems, and of power converters representing control points that by proper operation assure overall system stability and quality of power supply. In this paper we present simulation based analysis of dynamical behaviour of a residential DC microgrid laboratory setup in distributed and centralized voltage control configurations. It is shown that these control configurations have several inherent limitations, like overload of microgrid components during rapid load changes which can affect components lifetime. In order to overcome such limitations, the cause of such behaviour is assessed and control concepts to overcome that are proposed. Microgrid is simulated on electrical level using equivalent electrical models of all components involved: photovoltaic array, electrochemical batteries, fuel cells stack and power converters.

**Model-In-The-Loop Real-Time Simulation in Phasor Domain**

Jalili-Marandi, Vahid; Belanger, Jean; Ayres, Fabio Jose  
*OPAL-RT Technologies Inc., Canada*

The ePHASORsim tool offers real-time phasor domain simulations for large-scale power systems. Applications include contingency studies, testing control devices, operator training, and SCADA system tests. This paper describes a new application of this tool for Model-In-the-Loop simulations. Two test experiments are shown in this paper to demonstrate the accuracy and advantages of utilizing ePHASORsim for this purpose. The Matlab SimPowerSystems® toolbox is used to validate the results.

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**Neural Networks based approach for inverse kinematic modeling of a Compact Bionic Handling Assistant trunk**

Melingui, Achille¹; Merzouki, Rochdi¹; Mbede, Jean Bosco²; Escande, Coralie¹; Benoudjit, Nabil³  
¹Laboratoire d’Automatique, Genie (LAGIS), France; ²The University of Yaounde I, Cameroon; ³University of Batna, Algeria
A common approach to resolve the problem of inverse kinematics of manipulators is based on the Jacobian matrix. However, depending on the complexity of the system to model the elements of the Jacobian matrices may not be calculated. To overcome intrinsic problems related to Jacobian matrix based methods, a new inverse kinematic modeling approach capable to approximate the inverse kinematics of a class of hyper-redundant continuum robots, namely Compact Bionic Handling Assistant (CBHA) is proposed in the present work. The proposed approach makes use of Multilayer Perceptron (MLP) and Radial Basis Function (RBF) Neural Networks as approximation methods. A validation using a rigid 6 DOF industrial manipulator demonstrates the effectiveness and efficiency of the proposed approach.

Mobile Robot Navigation System Based on Probabilistic Road Map with Halton Sampling of Configuration Space

Velagic, Jasmin; Delimustafic, Dada; Osmankovic, Dinko
University of Sarajevo, Sarajevo, Bosnia and Herzegovina

The paper uses Probabilistic Road Map (PRM) based path planning algorithm which composes Halton point sets to improve mobile robot navigation capabilities. The Halton set obtains a good coverage of robot environment with points that is better than using grid based methods. Within PRM learning phase Halton point sets are used to randomly generate the robot configurations which constitute probabilistic road maps. The shortest path between an initial and a final configuration was founded out using A* algorithm adopted for query phase of PRM. The influence of number of Halton points and a distance between adjacent nodes for the current configuration to the path planning are analyzed. For purpose of map building of an unstructured environment a new histogramic based method is applied. In order to implement PRM based planning algorithm the whole navigation system is designed and implemented. The effectiveness of the proposed navigation system was demonstrated in both simulation and experimental modes.

Three-Dimensional Contour Tracking Control of a Parallel Manipulator: Comparison of Two Control Techniques

Uzunovic, Tarik; Baran, Eray A.; Golubovic, Edin; Sabanovic, Asif
Sabanci University, Turkey

In this paper a novel design for three-dimensional (3-D) contour controller is proposed. This design relies on dynamics projection to the moving Frenet-Serret frame defined for each point on reference trajectory. Contour controller consists of independent joint controller and additional sliding mode controller, added as corrective term. Control task is defined as contour tracking with constant tangential velocity. Contour controller was compared with independent joint controller designed as acceleration controller with first order disturbance observer. Reference trajectory is generated using time based spline approximation to provide smooth reference trajectory. Experimental results showed significant improvement that contour controller provides over independent joint control with relatively high velocity references.

Wireless Sensor Networks and Safe Protocols for user tracking in Human-Robot Cooperative workspaces

Vicentini, Federico; Ruggeri, Massimiliano; Dariz, Luca; Pecora, Alessandro; Maiolo, Luca; Polese, Davide; Pazzini, Luca; Tosatti, Lorenzo Molinari
Workers protection in collaborative industrial robotics application represents the predominant aspect of robot safety in production systems. Flexible production systems and multimodal human-robot interactions often encompass cooperative tasks that are performed in fenceless configurations. Collaborative open workspaces enable, in fact, a workflow of continuously interchangeable tasks done by operators or by robot at close distance or using hand-guided modes. Layout and workflow optimization may, in fact, require a co-presence in some shared spaces whose safeguarding (e.g. robot speed limitations, distances) is conservatively restricted by the current standards. In such scenarios, the tracking of operators is mandatory for the overall assessment of the system safety. In this work, a combination of wireless sensing technologies, highly robust wireless protocols and safe computation over a standard ethernet IP (black channel) concur to improve the functional safety of a cooperative robotic system. The system architecture and data framework are in particular discussed with reference to the properties of the communication protocols implementing the safety layer.

Desktop Microfactory for High Precision Assembly and Machining

Zhakypov, Zhenishbek; Uzunovic, Tarik; Nergiz, Ahmet Ozcan; Baran, Eray A.; Golubovic, Edin; Sabanovic, Asif
Sabanci University, Turkey

This work presents a modular and reconfigurable desktop microfactory for high precision machining and assembly of micro mechanical parts. Miniature factory is inspired by the downsizing trend of the production tools. The system is constructed based on primary functional and performance requirements such as miniature size, operation with sub-millimeter precision, modular and reconfigurable structure, parallel processing capability, ease of transportation and integration. Proposed miniature factory consists of several functional modules such as two parallel kinematic robots for manipulation and assembly, galvanometric laser beam scanning system for micromachining, camera system for inspection, and a rotational conveyor system for sample part delivery. The overall mechanical structure of the proposed microfactory facilitates modularity and reconfigurability, parallel processing, flexible rearrangement of the layout, and ease of assembly and disassembly of the whole structure. Experiments involve various tasks within a single process such as pick-place of the 3 mm diameter metallic ball, marking a 2D sub-millimeter image on the ball surface with high power laser, and inspection along with verification of the image by means of microscopic camera. Results have shown the possibility of implementation of the desktop microfactory concept for machining and assembly of tiny mechanical parts with micro-precision.

Developing Fusion Strategy of Ultrasonic and Omnidirectional Data for On-Line Maze Mapping

Arthaya, Bagus¹; Pratama, Alfrans Setyo²; Wu, Mellisa²
¹Parahyangan Catholic University, Indonesia; ²Alumni of Parahyangan Catholic University, Indonesia

Mapping is one of typical tasks carried out by an Autonomous Mobile Robot (AMR). Unknown
maze is a good example for mobile robot to exercise its ability to perform mapping task. Other fields also need this application such as in exploring an unknown environment such as desert, forest, new setup building, etc. When performing an exploration task, AMR normally is equipped with ranging sensors to scan its surrounding condition and communication facility to continuously report its finding to the computer control system. Ultrasonic sensor is often used to monitor the surrounding condition but it mainly detects its current position which is considered late in some certain situations. Meanwhile omnidirectional sensor is other type of sensor that is capable of providing advanced information of robot environment. When ultrasonic data and omnidirectional data are combined then the speed to carry out mapping task may become faster and more reliable. This research introduces the basic strategy in implementing data obtained from omnidirectional sensor to an AMR equipped with ultrasonic sensor.

3rd June, Tuesday
14:00-16:00 at Sedef
TuB5 Digital Control in Power Converters and Drives I
Session Chair : Marcelino Santos, Universidade de Lisboa
Co-Chair : Janis Zakis, Riga Technical University

Multiple Output Battery Charger based on the Novel Time Division Multiple Control Method for Electric Vehicle Charge Applications
Tran, Van-Long; Tran, Ngoc-Tham; Nguyen, Trung-Thanh; Choi, Woojin
Soongsil University, South Korea
Multiple Output Converters (MOCs) are widely used in electronic equipment for industrial, commercial, and military application such as the voltage regulator modules in portable electronic devices, multiple output power supplies, and multiple output charger due to their advantages in cost, volume, and efficiency. However, most of the MOCs developed so far have limitations in terms of the number of outputs, the tight regulation of all the outputs, the simplicity of the structure and the ease of control. In this paper, a novel Time Division Multiple Control (TDMC) method which can regulate all of the outputs with high precision is proposed. The proposed method is simple in its control and structure. In addition, it provides an even degree of tight regulation for all the outputs. The validity and the feasibility of the proposed method are verified by applying it to a multiple output battery charger for the EV charge applications.

Mixed cells modular multilevel converter
Adam, G.P.1; Ahmed, K.H.2; Williams, B.W. 1
1University of Strathclyde, UK; 2University of Aberdeen, UK
This paper uses a scaled down version of the mixed cells modular multilevel converter (MMC) to discuss its modulation and capacitor voltage balancing method, and investigates its AC and DC fault ride-through capability. It has been found that the mixed MMC is resilient to both AC and DC network faults, which are necessary for next generations of highly meshed multi-
terminal HVDC grids. The power losses comparison conducted in this paper has shown that the mixed cells MMC and three-level cells MMC achieve DC fault reverse blocking capability at reduced on-state losses than full-bridge MMC and alternative arm MMC.

Predictive Control of a Variable-Speed Multi-Pump Motor Drive
Bakman, Ilja; Gevorkov, Levon; Vodovozov, Valery
Tallinn University of Technology, Estonia
This paper addresses performance improvement of the centrifugal pumps running in variable-speed applications. Focus is on the system operation in the best-efficiency region. The impact of various factors affecting the pumping efficiency in the single-pump and multi-pump environments is described. A method for the multi-pump drive predictive control is proposed.

Implicit Current DC-DC Digital Voltage-Mode Control
Moreira, Carlos¹; Santos, Marcelino¹,²
¹Instituto Superior Técnico, Universidade de Lisboa, Portugal; ²SiliconGate, Portugal
Analog circuits have been dominating the switching power supplies control due to simplicity and low implementation cost. However, digital control presents important advantages to meet the increasingly stringent future processors power requirements. This study focuses in the fact that, sensing only a buck converter output voltage, a digital control can be built to implicitly implement a Current Mode Control (CMC), without sensing the inductor current while maintaining a fast response to load variations.
A solution that consist on a Digital Linear-Quadratic Regulator with a Kalman Estimator (DLQRwKE) is compared with two new digital control laws: Digital Voltage-Mode Current Control (DVMCC), based on the last cycle output voltage change, and Digital Voltage-Mode Averaged Current Control (DVMACC) that also takes into account the previous duty-cycle. This last original control solution is proven to present state-of-art load and line transients and robust stability, even in the presence of changes in the operation conditions. The propose DVMACC is shown to be a promising alternative to current analog and digital control methods.

Two Predictive Control Techniques for Output Voltage Control and Improvement of the Source Currents in an Indirect Matrix Converter
Rivera, Marco¹; Rodriguez, Jose²; Espinoza, Jose³; Olloqui, Alex⁴; Wheeler, Patrick⁵; Zanchetta, Pericle⁵; Baier, Carlos¹; Munoz, Javier¹
¹Universidad de Talca, Chile; ²Universidad Tecnica Federico Santa Maria, Chile; ³Universidad de Concepcion, Chile; ⁴Tecnologico de Monterrey (ITESM), Mexico; ⁵University of Nottingham, UK
This paper presents and compares two strategies to generate sinusoidal output voltage waveforms and unitary displacement power factor on the input side using predictive control with an indirect matrix converter. These objectives are accomplished using two different predictive control schemes on the input side: minimization of instantaneous reactive power and imposed input sinusoidal currents. Predictive control calculates the future values of the variables to be controlled in order to choose the switching state that produces the minimum error between the variables and their references. Both methods have been tested and compared in simulation, obtaining sinusoidal output voltage and achieving unitary input displacement factor, with a THD of less than 2% for both the input currents and the output
voltages.

Application of a time-varying switching line in the cascade sliding-mode speed control of the induction motor drive

Tarchala, Grzegorz; Orlowska-Kowalska, Teresa
Wroclaw University of Technology, Poland

This paper deals with the sliding mode application in the control of the induction motor speed. The equivalent control method, in which the control signal consists of two parts: continuous and discontinuous is used. In order to ensure identical dynamics of the speed transients and system robustness during the switching line reaching phase, regardless of the external and parametric disturbances, the time-varying switching line is introduced.

3rd June, Tuesday
14:00-16:00 at Topaz
TuB6 Digital Control in Power Converters and Drives II
Session Chair: Istvan Nagy, Budapest University of Technology and Economics
Co-Chair: Jinjun Shan, York University

Accurate State Estimation in DC-DC Converters Using a Proportional–Integral Observer (PIO)
Alavi, S.M. Mahdi; Saif, Mehrdad; Shafai, Bahram
University of Oxford, UK; University of Windsor, Canada; Northeastern University, USA

This paper focuses on state estimation of DC-DC converters in the presence of a biased duty-cycle which is very common in practice. It is shown that the commonly used Proportional (P-) observer fails to estimate the state of the converter when an unknown biased duty-cycle is present. To address this issue, a Proportional-Integral (PI-) observer is proposed, and its design is formulated as a $H_\infty/L_2$ problem. A sufficient condition is derived by using the Lyapunov stability theorem and linear-matrix-inequality (LMI) design tool, guaranteeing the convergence of the observer’s estimation error. The effectiveness and robustness of the proposed technique is verified and is compared with the P-observer observer through an experimental test on a step-down buck converter.

High speed fixed point DSOGI PLL implementation on FPGA for synchronization of grid connected power converters
Cossutta, Pablo M.; Aguirre, Miguel P.; Engelhardt, Mathias Angelico; Cao, Andres D.; Valla, Maria I.
Instituto Tecnologico de Buenos Aires, Argentina; Universidad Nacional de La Plata, Argentina

Power converters are the subject of extensive research because of their ability to work under different operating conditions, providing bidirectional power flow, high dynamic range and fast response. These advantages allow them to be used as an interface between the electric grid and many high power applications such as motors, energy storage, active filters and renewable energy sources. To be able to connect to the utility grid, every power converter must be
provided with a synchronization method. The synchronization algorithms are mostly based on the well known Synchronous Reference Frame Phase Locked Loop (SRF-PLL) plus some pre-filter stage that can be achieved by different algorithms of variable complexity, usually implemented on Digital Signal Processors (DSP) or Microcontrollers. In this paper a simple and highly effective Field Programable Gate Array (FPGA) implementation of a Phase Locked Loop (PLL) algorithm based on a Dual Second Order Generalized Integrator PLL (DSOGI-PLL) is presented in detail, along with the auxiliary circuitry needed to acquire the grid voltage information. Using a fast-prototype high-level synthesis tool, design time is drastically reduced without the need of any Hardware Description Language (HDL) code. Both simulation with MATLAB Simulink and experimental results on a Xilinx FPGA, show a robust behaviour even against frequency steps, severe distortion and unbalances in the power input.

**Comparison of two Sampling Techniques of SVM Applied in Sensorless Field Oriented Controlled IM Drive**

Stumpf, Peter; Jardan, Rafael K.; Nagy, Istvan; Vajk, Istvan

1Budapest University of Technology and Economics, Hungary; 2MTA-BME Control Engineering Research Group, Hungary

Field Oriented Control (FOC) technique is one of the mostly applied algorithm to control the speed and the flux of a three-phase electric drive. The paper focuses on high speed or high-pole count motor FOC drives when both the sampling over reference frequency ratio $F$ and the carrier over reference frequency $m_f$ is low. The paper presents that the stability range of a speed sensor-less FOC motor drive can be extended by recalculating the reference signal of the Space Vector Modulation (SVM) algorithm at the negative peak of the carrier signal as well by approximating the rotor flux angle change over one half carrier period. The result was verified by computer simulations and laboratory measurements.

**Discrete Synchronism Methods for Polluted Single Phase and Unbalanced Three-Phase Systems**

Rohten, Jaime; Espinoza, Jose; Villarroel, Felipe; Munoz, Javier; Melin, Pedro; Baier, Carlos; Perez, Marcelo

1University of Concepcion, Chile; 2Universidad de Talca, Chile; 3Federico Santa Maria University, Chile

Due to the proliferation of distributed power systems, renewable energy sources and systems working in islanding mode, the issue of grid frequency variations has come to be an important topic. In this paper, two single-phase and one three-phase phase-locked loop methods are studied. The resulting PLLs algorithms are completely developed in the discrete plane in order to be directly applied on digitals systems as DSPs or FPGAs. The objective is to get PLLs as simple as it can be accomplished, with the purpose to reduce the computing time. Weak network supply systems and systems working in islanding mode have usually poor short circuit capacity. In addition, the source impedance leads to a much polluted voltage supply signal in the presence of nonlinear loads. In order to get an appropriate synchronization, a Rectangular Windows Filter (RWF) is employed as a noise rejecter. For unbalanced systems, two approaches to get synchronism are presented, where the unbalanced system can be due to sensors failures or power problems in the grid voltage.
Computationally efficient fixed-parameter digital control of power converters
Vu, Tue T.1; O’Driscoll, Seamus2; Ringwood, John V.1
1National University of Ireland Maynooth, Ireland; 2Texas Instrument Limited Cork, Ireland
This paper studies the effect of variable sampling frequency on the dynamic of the fixed-parameter digital compensator in switched-mode power supplies. Based on the resulting analysis, we propose a simple technique to design a computationally efficient adaptive predictive functional controller (PFC) which can be implemented in a low-cost microcontroller. While the approach should have general applicability to systems where the sampling/switching frequency is varied, in this paper we use the example of a flyback power converter operating in discontinuous conduction mode (DCM). The performance of the proposed controller is verified with both simulation and experimental results.

Feedback/Feedforward Control for Hysteresis-Compensated Piezoelectric actuators in High-Speed Scanning Applications
Liu, Yanfang1; Shan, Jinjun2
1Harbin Institute of Technology, China; 2York University, Canada
This paper presents a control scheme for piezo-electric actuators (PEAs) in high-speed triangular trajectory scanning applications. Nonlinear hysteresis is compensated using a Maxwell resistive capacitor model. Based on the frequency response of the identified linear model, the feedforward compensation is proposed. This feedforward strategy is then combined with a proportional plus integral (PI) feedback controller for high-speed triangular trajectory tracking using piezoelectric actuator. Fast and precise tracking results are demonstrated through experiments. Moreover, it is found that the feedback loop does not always improve the tracking accuracy. When the input frequency exceeds a certain value, feedforward control only will result in better control performance.

3rd June, Tuesday
14:00-16:00 at Akik
TuB7 Digital Control in Power Converters and Drives III
Session Chair : Magdi S.Mahmoud, King Fahd University of Petroleum and Minerals
Co-Chair : Giovanni Spagnuolo, Universite de Cergy-Pontoise

Hardware Implementation of Balance Control for Three-Phase Grid Connection 5-Level Cascaded H-Bridge Converter using DSP
Taha, Othman A.1; Pacas, Mario2
1University of Mosul, Iraq; 2University of Siegen, Germany
The objective of this paper is the implementation of a three phase 5-level cascaded H-bridge inverter connected to the grid. A voltage oriented control (VOC) based on space vector pulse width modulation technique (SV-PWM) is used for the control of the converter by using only a single DSP. A feedforward modulation index compensation is applied to overcome the problem of voltage imbalance among the different phases. Simulation and experimental results of a
system with a 5-level CHB (Cascaded H-Bridge) inverter and grid connection are presented to validate the proposed topology and control method.

**Minimum Computing Adaptive MPPT Control**

Massimiliano, De Cristofaro; Femia, Nicola; Mario, Migliaro; Petrone, Giovanni

*DIEM - University of Salerno, Italy*

This paper discusses an adaptive Maximum Power Point Tracking (MPPT) control involving minimum computing effort, suitable for implementation with low cost microcontrollers. The runtime multiple optimal setup of the Perturb&Observe MPPT algorithm, is achieved by exploiting the correlation existing among the MPPT efficiency and the onset of a permanent 3 level quantized oscillation around the MPP. As no operations on measured voltage, current and power are required, the adaptive MPPT control is achievable with very cheap digital devices. Experimental test results are presented in the paper, regarding a 70W LED lighting system fed by a photovoltaic source, including an energy storage device.

**Global Tracking Passivity--Based PI Control for power converters : An application to the Boost and Modular Multilevel converters**

Cisneros, Rafael¹; Ortega, Romeo¹; Pirro, Matteo²; Ippoliti, Gianluca²; Bergna, Gilbert¹,³; Cabrera, Marta Molinas³

¹Supelec, France; ²Universita Politecnica delle Marche, Italy; ³Norwegian University of Science and Technology, Norway

This paper deals with the problem of trajectory tracking of a class of power converters. To analyze the stability of these systems we consider the bilinear structure they admit. First, we propose the theoretical framework for which it is possible to ensure global tracking of trajectories. To do so, a construction of an output signal respect to which the incremental model becomes passive is carried out. This leads to a simple linear PI controller for the plant. Then, we apply this result in a realistic simulation for two well-known converters systems: the boost and the modular multilevel converter (MMC).

**Effects analysis of model parameters uncertainties on battery SOC estimation using H-infinity observer**

Xue, Li; Jiuchun, Jiang; Caiping, Zhang; Weige, Zhang; Bingxiang, Sun

*Beijing Jiaotong University, China*

The accurate estimation of the state-of-charge (SOC) of battery is the basic premise for the effective energy management and the important guarantee for the safe and efficient operation in electric vehicles. To improve SOC estimation accuracy and robustness, the paper analyzes the effects of different initial SOC errors and parameters variation on SOC estimation accuracy and robustness with H-infinity observer. A model in Matlab/Simulink is established to make calculation process come true, which is based on a new battery with nominal capacity of 90Ah. The simulation and experiment aresults indicate that the H-infinity observer based SO estimation can converge to the true values quickly even if at the set maximum initial error and its steady error can be controlled within 2%. The effects of model parameters change resulted from battery degradation including SOC-OCV relationship, capacity and internal resistance on H-infinity observer are investigated. It’s concluded that SOC estimation accuracy with H-infinity observer largely depends on the accurate of the curve of SOCCV (Open circuit voltage, OCV),
which provide a foundation for battery management.

**Direct Power Control of Brushless DC Motor Drive**
Moghbeli, Hassan\(^1\); Niasar, Abolfazl Halvaei\(^2\); Shahrbak, Mozghan Behzadi\(^2\)
\(^1\)Arak University of Technology, Iran; \(^2\)University of Kashan, Iran

Due to significant increase in the demand of electric motors, design and manufacturing of high efficiency motors and related variable speed drives has been a major interest by many suppliers. Brushless DC (BLDC) motor has many advantages including high torque capability. In this paper, the possibilities of direct power control (DPC) of BLDC motors fed by voltage source inverter have been studied. BLDC motor has been driven with three control methods. It is shown that DPC method enjoys all advantages of direct torque control method including fast response and ease of implementation, without its lacks. Theoretical analysis and performance of the developed controller is confirmed via simulation under various conditions.

**Two-level Control for Improving the Performance of MicroGrid in Islanded Mode**
Mahmoud, Magdi S.; Al-Buraiki, Omar
Kfupm, Saudi Arabia

In this paper, a two-level coordinating control approach is developed for the islanded operation of a microgrid system. The microgrid includes \(n\) parallel connections of distributed generation (DG) units. These units and the load are connected to the common coupling point (PCC). In the islanded operation of the microgrid, the master DG unit handles the voltage and frequency control of the load, and the slaves DG units regulate their power components based on utilizing the conventional dq-current control strategy. It is shown that the parallel connection of \(n\) DG units in islanded mode forms an interconnected control system which is conveniently controlled in a two-level coordinating scheme. MATLAB simulations of a typical microgrid system have illustrated the effective performance under the developed control strategy.

**3rd June, Tuesday**
**14:00-16:00 at Ballroom1**
**Post A**
**Session Chair:** Guozhu Chen, Zhejiang University  
**Co-Chair:** Yi-Hung Liao, National Penghu University of Science and Technology

**Fault Detection and Classification Approaches in Transmission Lines Using Artificial Neural Networks**
Ben Hessine, Moez; Jouini, Houda; Chebbi, Souad
University of Tunis, Tunisia

This paper studies a new approach based on the artificial neural networks (ANN) for the fault detection and classification, in real time, in transmission lines to extra high voltage (EHV) which can be used in the production system digital protection. This approach is based on the
treatment of each phase current and voltage. The outputs of the ANN indicate the fault presence and it type. The ANN detector and classifier are tested in various fault types, various locations, different fault resistances and various inception angle. All the test results show that the fault suggested detector and classifier can be used to support a new system generations of protection relay at high speed.

**Comparative Study of Single-phase PLLs and Fuzzy Based Synchronism Algorithm**

Brasil, Thiago A.; Caicedo, Jorge; Aredes, Mauricio  
*Federal University of Rio de Janeiro, Brazil*

The correct current or voltage phase angle of a power electronics equipment is an essential information, especially in those connected to grid as: thyristor rectifiers, active power filters and distributed generation systems. For this reason, up to this day there are several Phase-Locked Loop (PLL) algorithms presented. However, those algorithms usually suffer from unsatisfactory dynamic response when phase angle jumps or harmonic distortion are presented. In this paper, 2 (two) single-phase PLL strategies will be discussed and compared to a novel PLL based on Fuzzy Logic theory. From this, it will be possible to evaluate the dynamic behavior of each of the PLLs.

**Interval Type-2 Takagi-Sugeno-Kang Fuzzy Logic Approach for Three-Tank System Modeling**

Maalej, Imen; Rekik, Chokri; Ben Halima Abid, Donia; Derbel, Nabil  
*University of Sfax, Tunisia.*

This paper concerns the use of fuzzy structures to model nonlinear dynamic systems. An interval type-2 Takagi Sugeno Kang fuzzy logic systems (IT2 TSK FLSs) is proposed. The proposed approach is a combination of IT2 fuzzy system and TSK fuzzy models and it presents an extension of the type-1 Takagi Sugeno Kang fuzzy logic system (T1 TSK FLSs). The interval type-2 fuzzy sets provide additional degrees of freedom and offer the capability to directly handle uncertainties. Different steps of this approach are described. The performance of the IT2 TSK FLSs is compared to the traditional T1 TSK FLSs. Simulation results performed on three tank system illustrate the efficiency of the suggested method.

**Observer-Based Nonlinear Control of Space Vehicles with Multi-Mass Fuel Slosh Dynamics**

Hervas, Jaime Rubio; Reyhanoglu, Mahmut  
1*Nanyang Technological University, Singapore; 2*Embry-Riddle Aeronautical University, USA

This paper studies the problem of observer-based control of space vehicles with fuel slosh dynamics in a zero gravity environment. Multi-mass-spring models are considered for the characterization of the most prominent sloshing modes. The control objective is to control the translational velocity vector and the attitude of the spacecraft, while attenuating the sloshing modes. A full-state feedback that uses a reduced-order observer for the estimation of the slosh states is proposed to achieve the objective. The effectiveness of the proposed observer-based control law is illustrated through a computer simulation.

**PID Controller Design for Unmanned Aerial Vehicle Using Genetic Algorithm**

Noshahri, Hengameh; Kharrati, Hamed  
*University of Tabriz, Iran*
Control of unmanned aerial vehicles (UAVs) is challenging due to inherent nonlinearities and its coupled dynamics. In this paper, an improved proportional-integral-derivative (PID) controller is proposed for UAV motion control with 6 degrees of freedom (DOF). A genetic algorithm is employed to find suboptimal coefficients of PID controller to optimize performance of the closed-loop control system. Simulation results are presented to verify the effectiveness of the proposed control system and also to compare with previous works.

**Multi-Network Neural model for Nonlinear Systems Modeling**

Turki, Amina; Chtourou, Mohamed  
*University of Sfax, Tunisia*

This paper proposes a Multi-Network Neural Model (“MNNM”) to deal with complex systems modeling. Indeed, the training of this architecture was performed using a parallel algorithm consisting on training simultaneously all local neural networks. The obtained results show the effectiveness of the “MNNM” compared to the Single-Network Neural Model (“SNNM”). This work will be supported by two examples: a second order nonlinear system and a chemical reactor.

**Sensor Fault Observer Design for Uncertain Nonlinear Systems**

Aouaouda, Sabrina; Boukhnifer, Moussa; Bouhali, Omar  

1*University of Souk Ahras, Algeria; 2ESTACA of Paris, France; 3University of Jijel, Algeria*

This article is dedicated to the problem of fault detection observer design for uncertain Takagi-Sugeno (T-S) models with unknown bounded disturbances. The aim is to synthesize a sensor fault observer minimizing the perturbation effect by means of $H_{\infty}$ criterion. The considered observer is used to estimate states and faults simultaneously. Using the technique of descriptor system representation new sufficient condition is proposed in terms of Linear Matrix Inequalities (LMIs) by considering the sensor fault as an auxiliary state variable. An example is given to illustrate the effectiveness of the proposed approach.

**New Robust Feedback Linearization Method Based on Nonlinear Disturbance Observer**

Azizi, Askar; NouriSola, Hamid; Bibak, Sirus; Ghaemi, Sehraneh  
*University of Tabriz, Iran*

Nowadays the feedback linearization and backstepping techniques are introduced as methods for linearization of a system with coordinate transformation and nonlinear designing, respectively. The feedback linearization and backstepping techniques are robust methods, however this study indicates that combining of them and adding nonlinear disturbance observer increases the system robustness. In this paper, the system linearization with backstepping process has been studied. Combining of above mentioned techniques has been used for linearization in this method. The systems have been practically exposed to disturbances and uncertainties. Nonlinear disturbance observer has a good ability to estimate disturbances and nonlinear dynamics, so it is useful method for increasing performance of control methods, reducing the effects of disturbances and system uncertainties. The presented control method with nonlinear disturbance observer improves the system robustness against different types of uncertainties, so this method is a modified technique. The proposed design process consists of two steps: First, the nonlinear disturbance observer has been designed to
estimate the uncertainties and external disturbances applied to system. Second, a controller has been designed using combined feedback linearization-backstepping method that used prior estimations to decrease the effects of external disturbances and uncertainties in the control input.

**Passivity Based Voltage Controller-Observer Design with unknown load disturbance for Permanent Magnet Synchronous Motor**

Achour, Abdelyazid; Mendil, Boubekeur  
*University of Bejaia, Algeria*

This paper introduces a design strategy that utilizes the passivity concept in order to develop a combined controller-observer system for Permanent-Magnet synchronous Motor (PMSM) speed control using only rotor position measurement and voltage applied to stator windings. The load torque is unknown, therefore it must be estimated. To this end, first a desired energy function for the closed loop system is constructed, and then a combined controller-observer system is constructed such that the closed loop system matches this energy function. A damping term is included to ensure asymptotic stability of the closed loop system. The interesting feature of this approach is the fact that it establishes a duality concept between the controller and observer design strategy. Such a duality feature is unique for nonlinear systems. Simulation tests on the combined controller-observer design and adaptive law to estimated load torque are provided to show the feasibility and the performance of this method.

**A Singular System Approach to Robust and Non-Fragile Filtering Design for Continuous-Time Semi-Markovian Jump Systems**

Wei, Yanling; Wang, Nan; Qiu, Jianbin; Gao, Huijun  
*Harbin Institute of Technology, China*

This paper proposes a singular system approach to robust and non-fragile $H_{\infty}$ filtering design for a class of continuous-time semi-Markovian jump linear systems (S-MJLSSs) with norm-bounded uncertainties. By a singular model transformation approach and a semi-Markovian Lyapunov function, a sufficient condition for robust $H_{\infty}$ performance analysis is firstly derived and then the non-fragile filter synthesis is developed. It is shown that by a linearisation technique combined with sojourn-time partitioning idea, a unified framework can be developed such that both the full-order and reduced-order filters can be obtained by solving a set of linear matrix inequalities. Finally, simulation studies are provided to illustrate the effectiveness of the proposed method.

**Development and Analysis of a Single-Stage Converter for Small-Scale Wind Power System**

Liao, Yi-Hung¹; Yang, Li-Ching¹; Chuang, Ying-Chun²  
¹National Penghu University of Science and Technology, Taiwan; ²Kun Shan University, Taiwan

In this paper, analysis of single-stage ac/dc converter for small-scale wind power generation system is proposed. The harmonic currents of wind generator are reduced so as to decrease the wind turbine noise. The proposed three-phase wind converter has zero-voltage switch in the active switches. Compared with a traditional two-stage converter, high efficiency and high step-up voltage ratio are also accomplished. In addition, based on the proposed wind
A Novel Battery Charger Circuit with An Improved Parallel-Loaded Resonant Converter for Rechargeable Batteries in Mobile Power Applications

Chuang, Ying-Chun; Chuang, Hung-Shiang; Liao, Yi-Hung; Yang, Chun-Hsiang; Wang, Yung-Shan

Kun Shan University, Taiwan; Kao Yuan University, Taiwan; National Penghu University of Science and Technology, Taiwan; Industrial Technology Research Institute, Taiwan

This work proposes a novel battery charger circuit with an improved parallel-loaded resonant converter use in rechargeable batteries in mobile power applications. The proposed topology is composed of an improved parallel-loaded resonant inverter and a bridge rectifier. The output voltage of the improved parallel-loaded resonant converter is filtered by an electrolytic capacitor. This topology has advantages over the traditional parallel-loaded resonant converter of smaller size, lower weight and lower cost. The operating principles of the proposed charger circuit are thoroughly analyzed. A prototype charger circuit with the improved parallel-loaded resonant converter implemented for a 12V 12000mAh rechargeable battery of mobile power is constructed and tested to verify the theoretical predictions. The measured energy conversion efficiency of the improved parallel-loaded resonant topology reaches up to 91.2%. The test results demonstrate that the novel topology provides a satisfactory performance. The improved parallel-loaded resonant converter has great potential for use in power-related devices in electronic products, such as standby power supplies for laptop computers, communication equipment, consumer electronics, and telecom power supplies.
Thus, the size, weight and passive component loss of the proposed inverter can reduce. This paper presents the operating principles, power loss analysis, simulation and experimental results, and compares with those of the conventional Switched LZ-source inverters.

**Research on An Active Double Auxiliary Resonant Commutated Pole Soft-switching Inverter**

Chu, Enhui; Huang, Liang; Fu, Zhiqiang  
*Northeastern University, China*

Aiming at overcoming the problem that the auxiliary switches in an improved auxiliary resonant communicated pole (ARCP) inverter may not realize zero-voltage-switching (ZVS) turning off in practical application if there is parasitic inductance in the wiring process, this paper proposes an active double ARCP inverter topology. In novel topology, the auxiliary capacitor and the auxiliary switch are in parallel closely. This connection avoids the influence of parasitic inductance in the wire, and it ensures the auxiliary switch to realize ZVS turning off reliably. The proposed inverter not only inherits all advantages of the improved ARCP inverter, but also improves its reliability. According to the equivalent circuits in different operation modes, this paper analyzes the circuit operation principle and soft-switching implementation condition. Finally, a 10 kW 16 kHz double ARCP inverter prototype with insulated gate bipolar transistor-based switches has been built. Experimental results are given to demonstrate the validity and features of the proposed inverter.

**Control Strategy for Three Phase Four PWM VSI Parallel Connected in UPS Applications**

Kommers Jappe, Tiago; Lazzarin, Telles Brunelli; Arbugeri, Cesar Augusto; Mussa, Samir Ahmad  
*Federal University of Santa Catarina, Brazil*

In UPS applications VSI parallel connected is a very common solution to improve the power capability and the reliability of the system, however, a strategy to share the load current should to be used. In this work a control strategy, with communication, is proposed for three–phase four–wire VSIs parallel connected.

**Non-Linear Sliding Mode Control of Three-Phase Buck-Boost Inverter**

Said, Mohamed1; Elserougi, Ahmed1; Abdel-Khalik, Ayman1; ElArabawy, Ibrahim1; Massoud, Ahmed1,2; Ahmed, Shehab3  
1*Alexandria University, Egypt*; 2*Qatar University, Qatar*; 3*Texas A&M University at Qatar, Qatar*

The development of static power converters capable of transforming DC energy obtained from alternative sources into AC has become one of the main challenges in renewable energy systems. In this context, the buck-boost inverter is advantageous for being capable of providing an AC output voltage higher or lower than the input DC voltage in a single power conversion stage. In this paper, a controller based on the non-linear sliding mode theory is proposed for a three-phase buck-boost inverter to track a desired AC reference voltage. Unlike conventional linear sliding mode controllers that depend on the errors of the state variables, the control law used here depends only on the input and output voltages of the converter without the need to the inductor current measurement, which reduces the system complexity and cost. The proposed controller can not only track the desired reference quickly and accurately, but also achieve a high immunity to external perturbations, such as input voltage
and output load disturbances. Several simulation studies are presented in order to investigate the performance of the proposed controller.

**New Modeling Approach and Validation of a Thermoelectric Generator**
Karami, Nabil; Moubayed, Nazih
Lebanese University, Lebanon

In this paper, a mathematical modeling of a Thermoelectric Module (TEM) is presented. The modeling is based on several studies presented in literature with some correction of mistaken equations. The presented model is developed using different approach taking into consideration the modeling of the Maximum Power Point (MPP) and the maximum efficiency of a TEM. The proposed approach is validated and simulated using a Simulink model.

**A novel Single-Phase Interleaved Bi-directional Inverter for Grid-Connection Control**
Hwang, Jong-Chin\(^1\); Liu, Chuan-Sheng\(^1\); Chen, Po-Cheng\(^2\); Chen, Liang-Rui\(^3\)
\(^1\)National Taiwan University of Science and Technology, Taiwan; \(^2\)National Formosa University, Taiwan; \(^3\)National Changhua University of Education, Taiwan

This paper propose a novel single-phase interleaved bi-directional inverter topology. The bi-directional inverter can operate in the grid connection mode (GC) or the power factor correction mode (PFC). The Interleaved Inverter have several advantages such as the increase of the power capacity, the reduction of the current ripple, the decentralized power switching component losses and heat dissipation. In this new topology, we can choose the lower current stress for power switch component and increase the switching frequency and system bandwidth for the reduction of the output filter size and cost. The predictive current control strategy improves the total current harmonic distortion on the grid side. Finally, The topology and current control strategy is verified by using the simulation program.

**Unbalance, Flicker, Harmonic, Voltage and Reactive Power Compensation of the Distribution Grid Using a Universal Converter**
Farokhnia, Naeem\(^1\); Mohammad, Muneer\(^1\); Rezanezhad Gatabi, Iman\(^2\); Ehsani, Mehrdad\(^1\)
\(^1\)Texas A&M University, USA; \(^2\)California Nano Devices, USA

Power electronic converters are actively involved in many parts of the power grid as active power filters and FACTs devices. They are employed to actively control the absorbed/injected reactive power of the fixed capacitor banks. These devices have the ability to regulate the voltage of distribution systems. In this paper, some novel features are added to the controller of the compensator without adding any hardware to make the device a universal tool. Having said that, the unbalance of the grid is compensated using the proposed dq0 transformation developed for both positive sequence and negative sequence components. A 5 Hz flicker produced by the dynamic load can be perfectly compensated by the converter. This makes the converter a universal tool that is able to correct the power quality indices of the grid. The MATLAB DSTACOM model is used for the implementation of the proposed features. The simulation results are presented to show the effectiveness of the proposed controller.

**A Novel Standstill Position Detection Method of PMSM for Electric Vehicles Based on Carrier Phase-shifted PWM Technology**
This paper presents the application of carrier phase-shifted PWM technology in the position detection for permanent magnet synchronous motor at standstill position. At the same time, it gives the polarity identification in the rotary frame with detected position from the neutral voltage. The new technique describes the method of carrier phase-shifted PWM technology with neutral voltage. It can detect the motor position from simple measurements of the neutral point voltage of the motor influenced by the variation of inductances with respect to rotor position. Theoretical studies have been carried out and experimental results are implemented to vary rotor position over one electrical cycle for position detection.

Discrete-Time Sliding Mode Direct Power Control for Grid Connected Inverter with Comparative Study

Huseinbegovic, Senad; Perunicic, Branislava; Hadzimejlic, Nijaz
University of Sarajevo, Sarajevo, Bosnia & Herzegovina

This paper presents a design of a digital direct power control strategy for a three-phase grid-connected inverter combining the discrete-time sliding mode control and the space vector modulation. Using the discrete-time state-space model of the controlled system, a discrete-time sliding mode control system is designed. Its output is a control vector which minimizes the instantaneous active and reactive power displacement from their reference values. The control vector is computed from the samples of voltages and currents and then converted to a switching sequence using space vector modulation. The period of modulated signal is equal to the sample period. A correction of the control vector is defined with aim to eliminate the influence of the system uncertainties using predicted values of the active and reactive powers. In this way a robust control system with a constant switching frequency is designed. Its digital hardware implementation is very simple. This control system is tested on a simulation model and compared with other similar approaches.

Hybrid Parallel Three-Level Converter Topology for Large Wind Turbin Generation Systems

Lee, June-Seok; Lee, Eunsil; Lee, Kyo-Beum
Ajou University, South Korea

This paper proposes a hybrid parallel three-level converter topology for large wind turbine generation (WTG) systems and its control method. The proposed topology focuses on a machine side of a back-to-back converter. It consists of one conventional three-level neutral-point clamp (NPC) converter and numerous reduced-part converters, which are connected in parallel depending on rated power of a WTG system. In comparison with a conventional parallel three-level converter topology, in the proposed topology, switching devices are reduced by using reduced-part converters. Moreover, the proposed topology achieves the existing advantages of the parallel converter topology. The reduced-part converter guarantees the sinusoidal current at a particular power factor which does not become a unity power factor. Therefore, a power factor compensation control is performed in one conventional three-level NPC converter to mitigate the disadvantage related with the power factor. The simulation of 2-parallel three-level converters topology is conducted to identify the practicality
of the proposed topology and validity of its control method.

A Study of Chaos and Bifurcation of a Current Mode Controlled Flyback Converter

Ghosh, Arnab1; Banerjee, Subrata1; Basak, Saptarshi2; Chakraborty, Chandan2

1National Institute of Technology, India; 2Indian Institute of Technology, India

This paper describes the complex behaviors (i.e. Chaos and Bifurcation) of flyback converter under peak current-mode control. Firstly, an iterative map based converter model is developed from its on and off states equations to study these complex dynamics. Then primary bifurcation parameters of converter like reference current, input voltage, load resistance, inductance and output capacitance are varied to investigate the converter dynamics. According to quantitative increasing or decreasing of these bifurcation parameters the logistic behavior of converter has been attained fundamental periodic oscillation to chaotic oscillation through period-doubling bifurcation. The iterative map based model of converter is simulated and the changes of the converter dynamics with variation of primary bifurcation parameters have been reported in this paper.

Simple Fault Diagnosis and Fault-Tolerant Strategy Based on Model Predictive Control for Matrix Converter

Lee, Eunsil1; Lee, Kyo-Beum1; Yoon, Young-Doo2

1Ajou University, South Korea; 2Myongji University, South Korea

This paper presents a simple fault detection method and fault-tolerant strategy based on the model predictive control theory. The proposed fault detection method can detect and locate a failed switch with current error signals dedicated to each switch, based on the position of space vectors. Following the fault detection, the proposed fault-tolerant control strategies are developed to produce three-phase balanced sinusoidal output voltages/currents with only normally functioning bidirectional switches. Therefore, the developed control technique for the matrix converter can preserve continuous operation even after the failure of switches and improve reliability of the drives. Simulation results are provided to validate the effectiveness of the applied detection and control strategy.

A Hybrid AC and DC Power Source for the Tests of an HTS Tapes

Stepien, Mariusz A.; Grzesik, Boguslaw

The Silesian University of Technology, Poland

The structure and the results of measurements of a hybrid supplying system for the tests of an HTS tapes carrying the high amplitude AC current with DC offset is described in the paper. The system is dedicated to an examination of the second generation (2G) superconducting tapes operating under dynamic conditions (the transition between superconducting and resistive state). The tapes are bifilarly arranged and immersed in LN2. The system for the tests consists of the high current transformer (up to 500 A_{RMS}) and the controlled DC supply (up to 200 A). The load current in the superconducting tape is a sum of the current of the transformer (sinusoidal shape) and the DC supply (constant value). The frequency of AC component is a grid frequency (50 Hz). The structure of the system is described in the paper. Some details of the transformer geometry and parameters are presented. The results of measurements are used to estimate the power distribution in the system. Operation at different regimes (different DC to AC amplitude ratio) is analyzed. Some representative results of measurements
Improvement of driver to gate coupling circuits for SiC MOSFETS
Balcells, Josep; Mon, Juan; Lamich, Manuel; Laguna, Alberto
Universitat Politecnica de Catalunya, Spain

This work presents a study of the influence of different gate driver circuits on the switching behavior of SiC MOSFET devices used in a buck converter. The paper is based on several tests performed to determine the switching times and switching losses, using different reverse bias $V_{GS}$ voltage levels and different passive RCD (Resistance Capacitor Diode) circuits to interface the driver to the SiC MOSFET gate.

A Frequency Adaptive Strategy for Composite Current Controller of Shunt Active Power Filters
Qu, Yingnan; Chen, Guozhu
Zhejiang University, China

Shunt Active Power Filters (APFs) are effective to eliminate harmonic current generated by nonlinear load. Many current control strategies including composite controller are proposed but the current control performance when grid frequency fluctuates is rarely discussed. This paper presents a frequency adaptive strategy for composite controller which can change sampling frequency of the controller automatically to track the grid frequency, so that excellent grid current compensating performance can be obtained in spite of grid frequency variation. To obtain both high compensation precision and fast dynamic response, the current composite control system includes an external repetitive control loop and an inner PI control loop. The frequency adaptive capability is achieved by the use of a special phase-locked loop. Simulation and experimental results verify the validity and feasibility of the schemes proposed by this paper.

HFL Micro-Inverter with Front-End Diode Clamped Multi-Level Inverter and Half-Wave Cycloconverter
Nayanasiri, Dulika$^1$; Vilathgamuwa, Mahinda$^2$; Maskell, Douglas$^1$
$^1$Nanyang Technological University, Singapore; $^2$Queensland University of Technology, Australia

A high-frequency-link (HFL) micro inverter with a front-end diode clamped multi-level inverter and a grid-connected half-wave cycloconverter is proposed. The diode clamped multi-level inverter with an auxiliary capacitor is used to generate high-frequency (HF) three level quasi square-wave output and it is fed into a series resonant tank to obtain high frequency continuous sinusoidal current. The obtained continuous sinusoidal current is modulated by using the grid-connected half-wave cycloconverter to obtain grid synchronized output current in phase with the grid voltage. The phase shift power modulation is used with auxiliary capacitor at the front-end multi-level inverter to have soft-switching. The phase shift between the HFL resonant current and half-wave cycloconverter input voltage is modulated to obtain grid synchronized output current.

Maximum Power Point Tracking for Photovoltaic Systems with Boost Converter Sliding Mode Control
Tracking the Maximum Power Point (MPP) of the photovoltaic array is very difficult due to the nonlinearity of its I-V characteristic which is dependent to the temperature and irradiation conditions. In this paper we propose a new method called sliding mode control (SMC) to maximize the PV array output power. With this method, the PV array output power is used to directly control the dc/dc converter, thus reducing the complexity of the system. The Boost-type dc/dc converter is controlled by the DS1104 R&D controller board. This method has several advantages in comparison to others conventional methods such as best accuracy, good convergence speed and high efficiency. The proposed controller is robust to weather condition changes. Simulation and experimental results are shown.

Linear current source as a power generator for the spark erosion process
Mysinski, Wojciech
Cracow University Of Technology, Poland
This article discusses common circuit designs for power supplies used in spark erosion machines. The author proposes the use of a linear current source as a generator. Moreover, he presents several solutions of electronic controlled current sources based on an operational amplifier and a power Mosfet transistor. One of the solutions has been selected for further tests, including verification with the LTspice simulation program. This article also presents DC analysis as well as transient analysis results, based on which it can be concluded that the circuit selected can be employed as a pulse generator for a spark erosion machine. Moreover, the author looks at results of laboratory tests performed on a current source prototype and discusses the advantages and disadvantages of the proposed solution relative to a typical transistor-based power supply unit.

LED-Based Electronic System to Support Plant Physiology Experiments
Almeida, Camila; Almeida, Pedro; Monteiro, Nicolas; Pinto, Milena; Braga, Henrique
Federal University of Juiz de Fora, Brazil
This paper proposes an electronic system intended to provide a simplified and efficient alternative for plant physiology experiments, as well as to be used in greenhouse conventional processes. The text starts with a description regarding the interaction between artificial lighting and cultivation of vegetables, either for agricultural-oriented purposes or to help the interpretation of plants behavior in botanical studies. This first study helps to characterize the main radiometric quantities of interest, with a predominant orientation for growing vegetables when artificial lighting is used as a supplement or as a sole lighting source. Hence, based on some previous works, it is proposed a standalone system intended to drive a lighting fixture consisting of white power LEDs or mixed-color LED unities. Moreover, the paper also includes some preliminary radiometric experiments concerning a possible commercial LED, which is intended to be used in association with the proposed lighting fixture. The results should indicate if the LED brands are enough to excite a good photosynthetic response. Hence, the most relevant parameters are measured, such as the photosynthetic photon flux, luminous flux, lamp color rendering and color correlated temperature. It is expected that the developed prototype be able to present features that add flexibility, automation and radiometric relevance to some selected vegetable crops.
An Intelligent MPPT Approach based on Neural-Network Voltage Estimator and Fuzzy Controller, Applied to a Stand-alone PV System

Bendib, Boualem¹; Krim, Fateh²; Belmili, Hocine¹; Almi, M.Faycal¹; Bolouma, Sabri¹

¹Unité de développement des équipements solaires (UDES)/EPST-CDER, Algeria;
²University of Setif 1, Algeria

This paper presents an intelligent maximum power point tracking (MPPT) method for a stand alone photovoltaic (PV) system using artificial neural networks (ANN) modelling and a fuzzy logic controller (FLC). The ANN is trained for various conditions of solar irradiance and temperature to estimate the MPP voltage. This voltage is then used by the FLC as a reference voltage to generate the appropriate control signal for the DC-DC converter. The proposed technique is implemented in Matlab/Simulink and compared with the conventional method of incremental conductance (IncCond). Simulation results show a good performance of the ANN based fuzzy MPPT controller.

3rd June, Tuesday
16:20-18:00 at Opal
TuC1 Modular Multilevel Converters and other Multilevel Converter Topologies and Applications I
Session Chair : Samir Kouro, Universidad Tecnica Federico Santa Maria
Co-Chair : Sebastian Rivera, Ryerson University

A Brushless Generation System for Microgrid Operation Utilizing Dual Stator Induction Generator

Basak, Saptarshi; Chakraborty, Chandan
Indian Institute of Technology Kharagpur, India

Modern micro-grid needs to integrate all possible and economically attractive renewable energy resources. In many cases these generations are not smooth in nature and are situated in remote locations where regular maintenance is difficult. This paper proposes a brushless generation system using a dual stator winding induction generator (DSWIG). The power winding of the DSWIG is connected to the grid by rectifier-inverter system, whereas, the excitation winding is fed from an inverter. The generator is controlled in a way to enable terminal voltage regulation of the main winding by controlling the rotor flux through the excitation winding. Preliminary results show the capability of the system to regulate voltage and maintain constant frequency at the micro-grid. Simulations results show usefulness of such systems for micro-grid operation.

Post-Fault Reconfiguration for a Versatile and Hybrid 4 Leg NPC-Flying Capacitor Topology

Ben Abdelghani, Hafedh¹;²; Ben Abdelghani, Afef Bennani²; Frederic, Richardau³; Jean-Marc, Blaquiere³; Frank, Mosser³

¹University of Tunis El Manar, ENIT-L.S.E., Tunisia; ²University of Carthage-LSE-INSAT, Tunisia; ³University of Toulouse-LAPLACE-CNRS-INPT-UPS, ENSEEIHT, France
Enhancing power converter reliability is an important issue for multilevel converters. With 2 level topologies, one IGBT failure leads to the whole system breakdown. Since multilevel converters are featured by a high number of semiconductor switches, it is possible to reshuffle the topology when an IGBT failure occurs. Remedial measurements are then possible and a safe continuity operation after a power device failure is guaranteed. This paper investigates a hybrid 4 Leg NPC-FC converter: it is composed by 3-level NPC-based 3 phases and a fourth FC-based one. The FC leg regenerates an active neutral point and, consequently, avoids bulky capacitors bank. When one or more IGBTs are damaged, the FC leg is controlled in order to ensure a post-fault operation. An appropriate LC filter is proposed to connect this leg to the NPC inverter. Experimental results show the effectiveness of the proposed LC filter design methodology. A loss-based comparison study between healthy and faulty operating modes is carried out.

Control of MMC-HVDC System based on Local Variables
Lizana, Ricardo; Perez, Marcelo A.
Universidad Tecnica Federico Santa Maria, Chile
The search for new energy sources has led to the installation of renewable energy plants located far away from the centers of consumption. In this scenario, the transmission of electrical energy over long distances has become a key issue and high voltage DC (HVDC) transmission systems have demonstrated to be the best cost effective solution. Among the different HVDC technologies, modular multilevel converters (MMC) provide the highest power quality, modularity, reliability and availability. In this paper, the control of two HVDC stations based on MMC is proposed. A set of power and voltage limits are defined for each station and the control scheme is designed to work inside these limits. Due to this operation mode, the controller in one station does not require information from the other station. The different operating modes of the MMC-HVDC transmission system are analyzed and simulation results are obtained, in order to validate the proposed control strategy.

Resonant Control for H-Bridge Topologies based on Single-Phase Current-Source Inverters
Rohten, Jaime1; Melin, Pedro2; Espinoza, Jose1; Silva, Jose1; Espinosa, Eduardo3; Munoz, Javier3; Sbarbaro, Daniel1
1University of Concepcion, Chile; 2Universidad del Bio-Bio, Chile; 3Universidad de Talca, Chile
This work deals with the control of a single-phase Current Source Inverter (CSI) in a three-phase array which can be used for both power drives and PV applications. Unlike in three-phase inverters, where the Fortescue Transform or Park Transformation can be applied in order to simplify the design of the controllers, for single-phase systems they cannot be directly applied making the control a difficult task if a rotating reference frame is chosen. On the other hand, Resonant Control (RC) is a control strategy that allows working with sinusoidal references and ensuring zero steady state error. This paper studies the resonant control of a single-phase CSI in a three-phase array, considering a design in continuous as well as discrete time domain. The resonant control is justified because the current sources should not be considered equals at all times, leading to independent control in each phase, or each cell, where the current source value and the load current can be feed-forward into the controller both of them disturbances, making the load voltage control in each cell easier to accomplish.
To corroborate the mathematical analysis, the proposed control scheme is tested under different conditions and disturbances, including a stability study.

**Distributed DC Bus EV Charging Station using a Single DC-link H-Bridge Multilevel Converter**

Rivera, Sebastian\(^1\); Wu, Bin\(^1\); Kouro, Samir\(^2\)

\(^1\)Ryerson University, Canada; \(^2\)Universidad Tecnica Federico Santa Maria, Chile

This paper proposes a novel architecture for Plug-in Electric Vehicles (PEVs) dc charging stations, through the use of a single dc-link 3-level h-bridge (HB) converter as the grid interface. This feature is achieved by the use of an open-ended secondary windings transformer at the grid side. The proposed solution enables fast charging for PEVs concentrating several charging units into a single grid-tied converter. The selected topology provides a three-level waveform without any balancing requirements, enabling a stable dc-bus. Finally, because of the simple nature of the converter, it can be implemented with off-the-shelf components, enabling a low cost alternative for the grid connection of Level III fast chargers.

3rd June, Tuesday
16:20-18:20 at Turkuaz
TuC2 Intelligent Robotic Control and Motion Planning I
Session Chair : Qinyuan Ren, National University of Singapore
Co-Chair : Artur Saudabayev, Nazarbayev University

**Depth Image based Terrain Recognition for Supervisory Control of a Hybrid Quadruped**

Saudabayev, Artur; Kungozhin, Farabi; Nurseitov, Damir; Varol, Huseyn Atakan
Nazarbayev University, Kazakhstan

This paper presents the depth image based locomotion strategy selection framework for a hybrid mobile robot. Terrain recognizer is a major component of a supervisory controller which classifies depth images into terrain types in real-time and selects different locomotion mode sub-controllers. In order to design the terrain recognizer, a database consisting of five terrain types (uneven, level ground, stair up, stair down and not traversable) is generated. Confidence based filtering is applied to enhance depth image data. The accuracy of the terrain classification for the testing database in five class terrain recognition problem is 96.71\%. Real-world experiments conducted in mixed terrain environment evaluate both locomotion and terrain recognition capabilities of the robot in real-time. Experimental results show that a consumer depth camera might serve as an effective instrument for terrain recognition and thus locomotion strategy selection for hybrid robots with multiple locomotion modes.

**Intelligent Vision Guide for Automatic Grommet Tube Insertion on Human Tympanic Membrane**

Gao, Wenchao; Tan, Kok Kiong; Liang, Wenyu; Gan, Chee Wee; Lim, Hsueh Yee
National University of Singapore, Singapore

Otitis Media with Effusion (OME), a worldwide common ear disease, occurs in adults and children when the middle ear is infected. The current treatment is to surgically insert a
grommet tube onto the Tympanic Membrane (TM) to bypass the Eustachian tube in raining fluid. A robotic device allowing fast and automatic grommet tube insertion has been designed in an earlier work. However, the part of the membrane where the malleus bone is attached to the inner surface is to be avoided so as not to touch or hit the bone during the insertion process. To solve this problem, an endoscope is used to provide the vision guide for the device. Thus, to locate a suitable target spot for tube insertion and plan the working channel trajectory by tracking the malleus from the endoscopic views form crucial steps for a safe and effective OME surgery. This paper mainly focuses on an incorporative optical flow based gradient vector flow active contours algorithm to achieve an online tracking of malleus to guide the working channel to conduct the surgery appropriately and automatically. Pre-clinical tests are carried out to verify the feasibility and efficacy of the proposed approach.

**Motion Control of a Multi-joint Robotic Fish Based on Biomimetic Learning**

Ren, Qinyuan; Xu, Jianxin; Guo, Zhaoqin; Ru, Yi  
*National University of Singapore, Singapore*

In this paper, a biomimetic learning approach is applied for motion control of a multi-joint robotic fish. In the learning approach, a general internal model (GIM) is employed to learn coordinated fish-like locomotion from observing live fish swimming. Owing to the scalabilities of the GIM, the learning approach is able to regenerate similar swim patterns with different temporal/spatial scales in the robot. Through experimental analysis, we find out that the motion states, namely speed and orientation, can be controlled by tuning the GIM parameters as well. Based on this control mechanism, feedback control strategies are designed to achieve desired motion. Finally, the effectiveness of the proposed motion control approach is verified by experiments.

**Control-oriented modeling of flight demonstrations for quadrotors using higher-order statistics and dynamic movement primitives**

Fang, Zhou; Wang, Guofang; Li, Weirong; Li, Ping  
*Zhejiang University, China*

In this paper, we present a novel method for parsing demonstrations, and further characterizing the segments as sub-actions which are easy to implement by low-level motion controllers. Demonstration data’s attributes of Gaussianity and linearity are linked to teacher’s control manners and intentions, and Hinich’s Gaussian and linear tests with higher-order statistics are adopted for segmentation. Wigner spectrum tools are applied to locate the rhythmic phases. Having parsed the demonstration into segments based on the test results, segmental features are parametrically represented in different ways, among which dynamic movement primitives (DMPs) are used to unifiedly model the nonlinear and rhythmic segments. For the multi-dimensional demonstrations, rules of selecting suitable variables for characterization are presented for both linear and nonlinear cases. The adverse effects brought about by inter-axis couplings are discussed and recognized using heuristics. For the case of multiple demonstrations, three-leveled feature consistency problem is also addressed. The proposed techniques are integrated into a whole for learning from flight demonstrations, and evaluated in simulations by modeling a quadrotor’s axial roll maneuver. Results show the effectiveness of our method.
On Trackability of a Moving Target By Fixed-wing UAV Using Geometric Approach
He, Zhirong¹; Xu, Jianxin²; Yang, Shiping²; Ren, Qinyuan²; Deng, Xin³
¹Sichuan University, China; ²National University of Singapore, Singapore; ³Chongqing University of Posts and Telecommunications, China
This paper addresses the trackability for a fixed-wing unmanned aerial vehicle (UAV) to track a dynamic target. To achieve the tracking task, the UAV needs to fulfill two objectives, i.e., keep synchronous motion with the target, and minimize the relative distance between itself and the target. Thus, to ensure the successful path planning, the UAV dynamics and sensor coverage range must be taken into consideration. By adoption of a geometric approach, systematic path planning algorithms are developed based on the ratios between the speeds of UAV and moving target. Meanwhile, a sufficient condition on sensor range is derived for the target to be non-escape from the UAV field of view (FOV). Finally, an application example is presented to demonstrate the efficacy of the developed algorithms.

Linear Time-varying Control Law for Stabilization of Hopping Robot during Flight Phase
Miah, Suruz¹; Chaoui, Hicham²; Sicard, Pierre²
¹University of Ottawa, Canada; ²Universite du Quebec a Trois-Rivieres, Canada
The well-known Brockett's theorem revealed that nonholonomic systems, hopping robots, for example, can not be stabilized by smooth time-invariant state feedback controllers. In this manuscript, we propose a linear time-varying state feedback controller for stabilizing a nonholonomic hopping robot during flight mode in finite time. The current approach is novel in the sense that we modify the Pontryagin's minimum principle to formulate the linear state feedback control law. The existence of such a control law and its necessary conditions are presented in detail. The theoretical results are also validated through computer simulations.

3rd June, Tuesday
16:20-18:20 at Kahribar
TuC3 Distributed Intelligent Systems in Industrial Environments I
Session Chair : TBD
Co-Chair : Paulo Leitao, Polytechnic Institute of Braganca

Security risk analysis for smart grid automation
Sierla, Seppo¹; Hurkala, Marcin¹; Charitoudi, Konstantinia²
¹Aalto University, Finland; ²University of South Wales, UK
The reliability theory used in the design of complex systems including electric grids assumes random component failures and is thus unsuited to analyzing security risks due to attackers that intentionally damage several components of the system. In this paper, a security risk analysis methodology is proposed consisting of vulnerability analysis and impact analysis. Vulnerability analysis is a method developed by security engineers to identify the attacks that are relevant for the system under study, and in this paper, the analysis is applied on the communications network topology of the electric grid automation system. Impact analysis is then performed through co-simulation of automation and the electric grid to assess the potential damage from the attacks. This paper makes an extensive review of vulnerability and
impact analysis methods and relevant system modeling techniques from the fields of security and industrial automation engineering, with a focus on smart grid automation, and then applies and combines approaches to obtain a security risk analysis methodology. The methodology is demonstrated with a case study of fault location, isolation and supply restoration smart grid automation.

Smart Indoor Lighting Control: Power, Illuminance and Colour Quality

Baniya, Rupak1; Maksimainen, Mikko1; Sierla, Seppo1; Pang, Cheng2; Yang, Chen-Wei2; Vyatkin, Valeriy2

1Aalto University, Finland; 2Luleå University of Technology, Sweden

This paper investigates the correlation between color quality and energy efficiency of indoor lighting control. The color quality, in terms of visual performance and comfort, is quantified using three measurements: illuminance, Color Rendering Index, and Correlated Color Temperature. Several experiments have been conducted to evaluate the potential energy savings of using different portions of light spectrum to obtain the optimal color quality. In particular, Light-Emitting Diodes are used as the lighting sources of the experimental luminaire. Moreover, the above quantification method and experimental results have been incorporated into a previously developed simulation framework for Building Automation and Control Systems, and smart lighting is used to adjust the tradeoff between comfort and energy consumption based on the presence of occupants. The results can be used to evaluate the viability of advanced lighting automation.

Compatibility and Coalition Formation: Towards the Vision of an Automatic Synthesis of Manufacturing System Designs

Feldmann, Stefan; Legat, Christoph; Kernschmidt, Konstantin; Vogel-Heuser, Birgit

Technische Universität München, Germany

The increasing demand for manufacturing systems’ flexibility and adaptability enlarges the complexity in engineering. Engineering efficiency must be increased by reusing existing components. However, large component libraries complicate a modular approach as identifying and selecting components can be time consuming and inefficient. To overcome this challenge, the vision of an automatic synthesis of manufacturing system designs is illustrated. It is shown how this vision can be mapped to checking the compatibility of components from a library and how coalition formation of software agents can provide possible means towards realizing this vision.

Energy efficient traffic-based street lighting automation

Nefedov, Evgeny1; Maksimainen, Mikko1; Sierla, Seppo1; Yang, Chen-Wei2; Flikkema, Paul3; Kosonen, Iisakki1; Luttinen, Tapio1

1Aalto University, Finland; 2Luleå University of Technology, Sweden; 3Northern Arizona University, USA

The emerging LED technology enables intelligent street lighting that is based on sensing individual vehicles and dimming street lights accordingly. The potential energy savings are considerable, exceeding 50% on roads with low traffic. A possible reason why such applications are not yet emerging are financial uncertainties about the size of the savings, which are needed to motivate the investment. Another barrier to adoption are uncertainties about
whether proposed approaches meet standards and regulations for traffic safety. In this paper, an energy efficient street lighting design that meets regulations for rural roads is implemented with the IEC 61499 distributed function block architecture. The intelligent lighting is co-simulated against a traffic simulation using cellular automata. Virtual metering in the IEC 61499 application is used to quantify energy savings in simulation scenarios with different traffic volumes. Across a range of traffic volumes representative of rural roads, our simulations indicate that smart dimming can deliver energy savings of 14% to 70%, with savings increasing as traffic density decreases.

Adaptive Scheduling based on Self-organized Holonic Swarm of Schedulers
Leitao, Paulo; Barbosa, Jose
Polytechnic Institute of Braganca, Portugal

Scheduling plays an important role in the companies’ competiveness, dealing with complex combinatorial problems subject to uncertainty and emergence. In particular, in the ramp-up phase of small lot-sizes of complex products, scheduling is more demanding, e.g. due to late requests and immature technology products and processes. This paper presents the principles of a distributed scheduling architecture based on holonic and swarm principles and implemented using multi-agent system technology. In particular, it is described the coordination among the network of the swarm of schedulers and analysed the impact of embedded self-organization mechanisms.

JBoss ESB Sniffer: Message Flow Visualization for Enterprise Service Bus
Vrba, Pavel; Kadera, Petr; Myslik, Martin; Klima, Martin
1Czech Technical University in Prague, Czech Republic; 2Certicon a.s., Czech Republic

The paper presents a tool called JBoss ESB Sniffer, which was developed within the frame of the European project ARUM. The project is focused on optimization of the ramp-up and small lot production processes that are facing constant disturbances and error events. The proposed solution applies the Enterprise Service Bus (ESB) technology for integration of heterogeneous tools and legacy systems. In such a distributed environment with multiple interacting services it is of crucial importance to have the overview of the flow of messages to help monitoring and understanding of the overall state of the system. A new visualization tool developed for the JBoss ESB message bus is presented in the paper. Additionally, the mechanism for description of service interfaces and interactions based on WSDL and FIPA standards is presented.

3rd June, Tuesday
16:20-17:40 at Elmas
TuC4 Distributed Intelligent Systems in Industrial Environments II
Combined with Control and Filtering for Networked Systems I
Session Chair : Luca Ferrari, Politecnico di Milano
Co-Chair : Thomas Strasser, Austrian Institute of Technology

Requirements for Smart Grid Simulation Tools
Due to the ongoing changes in the power systems and their evolution towards Smart Grids they will become tremendously complex. Those systems will contain many different components and actors that are connected among each other and located on different technological as well as conceptual levels. Analyzing the influences and impacts of new components or changes of parameters becomes more and more challenging. For that reason the importance of simulation is continuously increasing. However, Smart Grids impose new requirements on supporting tools that today’s technologies are no longer suitable for. In this paper such requirements from selected Smart Grid use cases and projects are analyzed and discussed.

A Distributed Model Predictive Control approach for the integration of flexible loads, storage and renewables
Ferrarini, Luca\textsuperscript{1}; Mantovani, Giancarlo\textsuperscript{1}; Costanzo, Giuseppe Tommaso\textsuperscript{2}
\textsuperscript{1}Politecnico di Milano, Italy; \textsuperscript{2}Technical University of Denmark, Denmark

This paper presents an innovative solution based on distributed model predictive controllers to integrate the control and management of energy consumption, energy storage, PV and wind generation at customer side. The overall goal is to enable an advanced prosumer to auto-produce part of the energy he needs with renewable sources and, at the same time, to optimally exploit the thermal and electrical storages, to trade off its comfort requirements with different pricing schemes (including real-time pricing), and apply optimal control techniques rather than sub-optimal heuristics.

Line-Interactive UPS System Applied to Three-Phase Four-Wire Systems with Universal Filtering Capabilities
Modesto, Rodrigo A.\textsuperscript{1}; Oliveira da Silva, Sergio\textsuperscript{1}; Albano de Oliveira Junior, Azauri\textsuperscript{2}
\textsuperscript{1}Federal Technological University of Parana, Brazil; \textsuperscript{2}University of Sao Paulo—USP-EESC, Brazil

This paper proposes a three-phase line-interactive Uninterruptible Power Supply (UPS) scheme, which is applied to three-phase four-wire systems, allowing harmonic suppression and reactive power compensation of the load, resulting effective power factor correction. The proposed UPS system is composed of two PWM converters, where one of them is placed in parallel with the load and the other one is placed in series between the power source and the load. Both the converters share the same DC-bus, which is composed of a battery bank. The parallel converter is implemented by using a four-leg VSI topology and it is controlled to operate as a sinusoidal voltage source, while the series converter is implemented by means of a three-leg topology and it is controlled to operate as a sinusoidal current source. The proposed scheme allows the voltage level reduction of the DC bus, when compared to the use of two three-leg split-capacitor topologies for performing the series-parallel conditioning. In addition, the number of switches is also reduced when it is compared to the use of two four-leg topologies. Both the UPS voltage and current controllers are implemented in the synchronous rotating reference frame ($dq0$-axes), and the PWM converters are modulated by
using three-dimensional space vector modulation. Simulation results are presented in order to validate the theoretical development and confirm the performance of the UPS system.

**Fuzzy Networked Control Systems Design Considering Frequency Transmission and Bounded Delays Restrictions as Local Phase Problem**

Benitez-Perez, Hector; Esquivel-Flores, Oscar

*I.I.M.A.S., U.N.A.M., Mexico*

Nowadays network control systems present a common approximation when connectivity is the issue to be solved based on time delays coupling from external factors. However, this approach tends to be complex in terms of time delays and the inherent local phase missing. Therefore, it is necessary to study the behavior of the delays as well as the integration onto differential equations of these bounded delays. The related time delays needs to be known a priory but from a dynamic real time behavior in order to understand dynamic phase behavior. The objective of this paper is to show a way to include data frequency transmission and time delays that are bounded as parameters of the dynamic response from real-time scheduling approximation considering local phase situation. The related control law is designed considering fuzzy logic approximation for nonlinear time delays coupling. The main advantage is the integration of this behavior through extended state space representation keeping certain linear and bounded behavior leading to a stable situation during events presentation based on accurate data transmission rate. What is expected is to conform the basics local phase missing as result of local bounded time delays from the lack of tide synchronization as modeling approximation.

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**3rd June, Tuesday**

**16:20-18:20 at Sedef**

**TuC5 Machine Vision, Control and Navigation I**

Session Chairs : Laurentiu Acasandrei, Instituto de Microelectronica de Sevilla

Oleg Sergiyen, Autonomous University of Baja California

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**Machine Vision supported by Artificial Intelligence Applied to Rotatory Mirror Scanners**

Flores-Fuentes, Wendy; Rivas-Lopez, Moises; Sergiyenko, Oleg; Gonzalez-Navarro, Felix F.; Rodriguez-Quinonez, Julio C.; Hernandez-Balbuena, Daniel; Rivera-Castillo, Javier

*University Autonomos of Baja California, Mexico*

A performance evaluation of different artificial intelligence methods for machine vision using a rotatory mirror scanner is presented. This assessment concludes importance results, in order to properly select a method for the development of a precise optical scanning system for machine vision, with application in Structural Health Monitoring and Robot Navigation task.

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**Face Identification Implementation in a Standalone Embedded System**

Acasandrei, Laurentiu1; Barriga, Angel1; Quintero, Manuel2; Ruiz, Alejandro2

1*Instituto de Microelectronica de Sevilla, Spain*; 2*Universidad de Sevilla, Spain*
In this paper is described an embedded system for face identification. The system, running on FPGA, is built around LEON3 processor and consists of several IP (Intellectual Property) modules designed as AMBA bus peripherals. The face detection is accelerated with the help of a hardware module while the face recognition is entirely executed in software. The face detection hardware accelerator module is reconfigurable and can share its internal resources (memory, multiplier, integer square root unit) with the LEON3 processor. The system has been designed on the criteria of resources optimization, low power consumption and improved operation speed.

**Acceleration measurement improvement by application of novel frequency measurement technique for FDS based INS**

Murrieta-Rico, Fabian N.; Petranovskii, Vitalii; Sergiyenko, Oleg; Hernandez-Baluena, Daniel; Molina, Mayra; Hipolito, Juan Ivan Nieto; Pestryakov, Alexey; Tyrsa, Vyra

1Center for Scientific Research and Higher Education of Ensenada, Mexico; 2National Autonomous University of Mexico, Mexico; 3Autonomous University of Baja California, Mexico; 4Tomsk Polytechnic University, Russian Federation; 5Kharkiv National Automobile and Highway University, Ukraine

Inertial navigation systems have as sensing elements gyroscopes and accelerometers. The accelerometers with a frequency output domain have some outstanding characteristics like output of quasi-digital signals, high sensitivity, high resolution, wide dynamic range, anti-interference capacity and good stability. This work explains how this sensor works inside an inertial navigation unit and how the measurement of acceleration can be improved through a novel frequency measurement principle. Also it is examined how in a common accelerometer the frequency measurement by principle of rational approximation can be easily implemented with low cost-affordable components. The error analysis in the measurement process is introduced.

**Structural Health Monitoring Based on Optical Scanning Systems and SVM**

Rivera-Castillo, Javier; Flores-Fuentes, Wendy; Rivas-Lopez, Moises; Nieto-Hipolito, Juan I.; Sergiyenko, Oleg; Hernandez-Baluena, Daniel; Platt-Carrillo, Jesus A.

1University Autonomous of Baja California, Mexico; 2University of Sonora, Mexico

This paper presents a new approach for damage detection in Structural Health Monitoring (SHM) Systems, which is based on Optical Scanning and Support Vector Machine (SVM) models. Optical Scanning Systems provide position measurements for SHM task by a novel method based on automatic geodetic measurements. Precise measurement of plane spatial angles are performed in the optical energy signal centre by the optical signal function geometric centroid calculation, however these scanners usually have non-linear variations in their measurement, and normally these variations depend on the position of the light emitter on the structure under monitoring in relation to the scanner. In this paper, SVM Regression is proposed as a machine learning technique to predict measurement errors and to adjust this non-linear variation for measurement accuracy enhancement.

**Closed-Form Solution 3D Points for Estimating Extrinsic Parameters of Camera and Laser**
Sensor
Hoang, Van-Dung; Hernandez, Danilo Caceres; Park, Han-Sung; Jo, Kang-Hyun
University of Ulsan, Korea
Integration systems based on cameras and laser rangefinders has been applied in many researches on robotics, autonomous navigation vehicles, and intelligent transportation systems. Relative information between sensors is usually required for systems using multiple sensors. This paper will present a method for recovering extrinsic parameters of a system based on an omnidirectional camera and laser rangefinder. The calibration method uses a discontiguous calibration pattern, which emphasizes laser information of range. It supports to extract corresponding feature points between camera images and laser range scans. A closed-form solution is also presented for estimating 3D image points based on the PnP technique. Finally, corresponding 3D points are used to recover extrinsic parameters of location and direction of a camera with respect to a laser rangefinder.

Scanning for Light Detection and Energy Centre Localization Methods Assessment in Vision Systems for SHM
Rivas-Lopez, Moises1; Flores-Fuentes, Wendy1; Sergiyenko, Oleg1; Hernandez-Balbuena, Daniel1; Rodriguez-Quinonez, Julio C. 1; Rivera-Castillo, Javier1; Taddei-Bringas, Jorge L. 2
1University Autonomous of Baja California, Mexico; 2Strategic engineering University of Sonora, Mexico
In this research, six Energy Centre Localization Methods are assessed by Wilcoxon Signed Rank Test. Due to SHM is an upcoming tendency of determining the integrity of structures and development of strategies to prevent undesirable damage, it is necessary to detect a light emitter mounted on the structure under monitoring and calculate the energy centre localization. After a short introduction to the energy centre localization methods, a machine learning technique was applied to predict measurement errors and adjust non-linear variation for measurement accuracy improvement. An Optical Scanning System was enhanced by measurement at the optical signal energy centre and error adjustment by SVM algorithm. The theoretical methods principles, experimental development and validation are presented.

3rd June, Tuesday
16:20-18:00 at Topaz
TuC6 Continuous Learning in Engineering and Industrial Technologies
Education I
Session Chair: Joao Martins, Universidade Nova de Lisboa
Co-Chair: Luiz Gomes, Universidade Nova de Lisboa

Industrial Internet Education: Issues and Opportunities
Pimentel, Juan R.1; Rojas-Moreno, Arturo2
1Kettering University, USA; 2Universidad de Ingenieria y Tecnologia, Peru
We propose an approach for addressing the challenges and meeting the needs of industrial
networking education. The approach is based on using open source resources, key networking technologies, and an experimental framework to revolutionize the way industrial networking ought to be taught at higher learning institutions around the world. Based on the approach a new type of industrial networking course has been designed, developed, and offered with positive outcomes.

**Benefit of an e-learning environment including real and simulated plants for teaching mechanical engineering freshman in programming C**

Rehberger, Sebastian; Frank, Timo; Mayer, Felix; Vogel-Heuser, Birgit  
*Technische Universitat Munchen, Germany*

Practical aspects of a lecture are important to increase motivation and performance of students, especially in teaching programming for mechanical engineers. In this paper we present an approach and first experience to include plant programming into the software engineering and programming lectures at the Technische Universitat Munchen. To demonstrate common engineering practice and broaden the prospects for exercises this concept is adapted to control simulated systems instead of real hardware programming. The architectural concept for the web based e-learning with real hardware and the co-simulation framework is presented as well as the students’ performance.

**A new teaching tool for fault detection in the induction machine**

Assuncao, Renato1; Delgado-Gomes, Vasco2; Pires, Vitor Fernao3,4; Martins, Joao1,2  
1*Universidade Nova de Lisboa, Portugal;* 2*CTS-UNINOVA, Faculty of Sciences and Technology Campus, Portugal;* 3*ESTSetubal - Instituto Politecnico de Setubal;* 4*INESC-ID Lisboa, Portugal*

The study of fault detection and diagnosis of electrical machines is nowadays a very important issue, particularly regarding induction machines. However giving students or engineers practical experience in this field requires a large investment from teaching institutions. This paper presents an experimental system used to provide students or engineers with some practical experience in induction machine’s fault detection. The major advantage of the described tool is that it can work with a standard healthy induction machine. This system is based on only one machine that will be operated under faulty operation modes, allowing testing several fault types, such as stator winding faults, bearing faults or broken bars. A human machine interface with several options is also presented. This interface allows not only controlling the induction machine but also to perform some learning exercises as well providing documentation about the induction machine and fault detection procedures.

**Cloud based development framework using IOPT Petri nets for embedded systems teaching**

Gomes, Luis; Costa, Aniko  
*Universidade Nova de Lisboa, Portugal;*

A model-based development flow based on IOPT Petri nets models and its insertion in a digital system design course is presented. The IOPT-Tools framework is used to support a cloud en-abled design automation flow, including specification of system’s behavior, state space based verification, and automatic code generation (C and VHDL) leading to implementation deployment into reconfigurable computing platforms.
Teaching flow method is presented, supported by reconfigurable platforms (FPGA based boards and Arduino devices) giving adequate flexibility for exercising different implementation strategies and allowing laboratory prototyping during classes. The proposed approach was fully validated during a course on Digital Systems Design offered to Electric and Computer Engineering MSc course, and student’s assessment on usage of cloud based development IOPT-Tools framework is analyzed.

**Power quality and long life education**

Cardoso, Tiago¹; Pereira, Pedro¹; Pires, Vitor Fernao²; Martins, Joao¹

¹Universidade Nova de Lisboa, Portugal; ²ESTSetubal - Instituto Politecnico de Setubal & INESC-ID, Portugal

This paper presents a remote laboratory linked with mobile devices for real data analysis on the field of power quality. A global system was developed from the power quality analyzer into the human machine interface devoted to the m-learning system. This m-learning system is intended to be used in a long life learning perspective. The developed remote laboratory is a good opportunity for people, even without deep knowledge on the field, to learn power quality principles in an applied way. Since the system is based on real data, is a good approach to give trainees practical knowledge on the field.

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**3rd June, Tuesday**
**16:20-18:00 at Akik**
**TuC7** Haptics for Human Support I

Session Chair: Kiyoshi Ohishi, Nagaoka University of Technology
Co-Chair: Tomoyuki Shimono, Yokohama National University

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**Motion-Copying System of a Different Master-Slave Mechanism with Variable Reproduction Speed**

Phuong, Thao Tran; Ohishi, Kiyoshi; Yokokura, Yuki

Nagaoka University of Technology, Japan

This paper presents a motion-copying system of different master-slave mechanism in variable speed of motion reproduction. The motion-saving system is performed by bilateral control algorithm to preserve arbitrary motions of human operator to a data memory. The slave actuator is affected by friction; hence, a friction-free disturbance observer is employed for force estimation on the slave side. The motion-loading system is able to reproduce human motion saved in data memory with changeable speed of motion reproduction. To improve the performance of motion-loading system, a displacement-based reproduction correction is used to eliminate the effect of unpredictable disturbances in variable speed of motion regeneration. The effectiveness of the proposed method is confirmed by simulation results.

**Motion Navigation in Haptic Bilateral System Based on Vision-based Force Compliance Controller Taking Object Coordinate into Account**

Jamaluddin, Muhammad Herman¹; Shimono, Tomoyuki²; Motoi, Naoki²
This paper addresses a solution for solving the object’s rotational effect during the navigation process by the haptic bilateral control system. The system utilizes the vision-based guidance which depends on the virtual force generated by the vision-based force compliance controller (VFCC). During object’s navigation, the virtual force is generated and affected to the manipulator’s horizontal trajectory movement. In this paper, the different rotational angle of an object’s trajectory which reflects to different movement direction of produced force, will be studied and evaluated. The details concerning the implementation of this method will be discussed. Two sets of experiments are conducted to evaluate the effectiveness of the proposed technique.

Multilateral Control-Based Motion Copying System for Haptic Training
Kebude, Dogancan\textsuperscript{1}; Morimitsu, Hidetaka\textsuperscript{2}; Katsura, Seiichiro\textsuperscript{2}; Sabanovic, Asif\textsuperscript{1}
\textsuperscript{1}Sabanci University, Turkey; \textsuperscript{2}Keio University, Japan
This paper proposes a new motion-loading method that utilizes a multilateral control-based scheme for the motion-copying system. The motion-copying system refers to human operator’s motion, tracks and preserves it only for being able to reproduce the same result of the motion. Conventionally, only slave system was used for motion-loading phase. The method proposed in this paper offers a way to enable more than one slave side actuator at the phase. With the proposed system, the operator at loading phase can grab the master system which the manipulator was holding at the saving phase. The performance analyses of proposed system are made with the bode plots, and the experiments are held with two degrees-of-freedom actuators. The newly proposed haptic informational reproduction technique can be applied in many areas, especially as the training purposes.

A Classification Method of Motion Database Using Hidden Markov Model
Matsui, Ayaka; Nishimura, Satoshi; Katsura, Seiichiro
Keio University, Japan
This paper proposes a classification method of a stored motion–data. Robotic technology has made progress, and robots are demanded to cooperate with human. To realize the human and robot exist together, a motion recognition system is needed. In the conventional method, the stored motion–data is classified in advance to search the motion quickly and accurately. However, the task of the classification will be very complex when the stored data is increased. Therefore, the classification system of stored data automatically is required. Since the human motion is time series information and unsteady signal, a hidden Markov Model is used as the probability models. Additionally, this paper shows that Kullback–Leibler divergence indicates the similarity index of the stored motion. At this time, the motion is classified according to the acceleration information, which includes the pure force and position information. The validity of the proposed method is confirmed by simulations.

Reduction of an Operational Force in a Simultaneity Realized Bilateral Telecommunication System
Nishimura, Satoshi; Katsura, Seiichiro
Keio University, Japan
The paper proposes a method to reduce an operational force in a bilateral control system that
realizes simultaneity property under communication delay. A bilateral control that realizes simultaneity property is previously proposed, which is achieved by delaying the own force information. It focused on the fact that the force information is the pure information that actuates the motor, therefore, timing of the force information input is corrected. However, the control system requires large force when operator tries to operate the system. In this paper, the problem is solved by utilizing the delayed position information of the own system. The proposed control system is designed to mix present and buffered position information to reduce the operational force. The delayed information can easily affect the stability problem, therefore, phase compensator and the velocity feedback is used. The validity of the proposed method is confirmed by experiments.

3rd June, Tuesday
16:00-18:00 at Ballroom1
Post B
Session Chair: Touhami Rachida, University of Science and Technology Houari Boumediene
Co-Chair: Maria Carmela Di Piazza, Consiglio Nazionale delle Ricerche (CNR)-Istituto di Studi sui Sistemi Intelligenti per l’Automazione (ISSIA)

Vector Control of Current Source Inverter-Fed Axial-Flux Permanent Magnet Motors with Space Vector Pulse Width Modulation
Tsai, Ming-Fa1; Lee, Ti-Chung1; Tseng, Chung-Shi1; Syu, Wei-Syuan1; Chen, Yu-Yuan2; Peng, Wen-Yang2
1Minghsin University of Science and Technology, Taiwan; 2Industrial Technology Research Institute of Taiwan, Taiwan
This paper presents the vector control design of an axial-flux permanent magnet motor (AFPM) driven by a current source inverter (CSI), which is considered as having many advantages over the voltage source inverter. The control system consists of a 2-DOF speed controller, a multi-loop current controller, and an SVPWM modulation block, which can offer a faster dynamic response, an instantaneous adjustment of the modulation index, and a precise control of the ac motor current magnitude and phase. To evaluate the effectiveness of the proposed control system, computer simulation in PSIM were performed. The speed response of the proposed 2-DOF controller can quickly track the step speed command and reach the steady state even if the load torque is suddenly added to the system.

High Performance Backstepping Control of a Five-phase Induction Motor Drive
Echeikh, Hamdi1,3; Trabelsi, Ramzi1,2; Mimouni, Faouizi Med1,3; Iqbal, Atif4; Alammari, Rashid4
1Monastir National Engineering School, Tunisia; 2High Institute of Applied Sciences and Technology, Tunisia; 3Research Unit: Etude des Systèmes Industriels et des Energies renouvelables ESIER, Tunisia; 4Qatar University, Qatar
Multiphase electric drives have been investigated and proposed for applications where the
highest overall system reliability and the reduction in the total power per phase are required. This paper deals with the high performance Backstepping control strategy which is based on laws allowing an explicit control of system stability in closed-loop operation of five-phase induction motor drives. This control focuses on the transient analysis in nonlinear adaptive control which allows tending asymptotically the process to a reference model. The reference model is established from the desired performances of the drive system in the closed-loop mode of operation system. This paper presents the Backstepping control technique (BC) and compared with the indirect rotor flux oriented control of a five phase IM drives. Simulation results are provided to support the findings and validate the control scheme.

**EMI Filter Design in Motor Drives with Common Mode Voltage Active Compensation**

Di Piazza, Maria Carmela; Giglia, Graziella; Luna, Massimiliano; Vitale, Gianpaolo

Consiglio Nazionale delle Ricerche (CNR)- Istituto di Studi sui Sistemi Intelligenti per l’Automazione (ISSIA), Italy

In this paper the design issues of input electromagnetic interference (EMI) filters for inverter-fed motor drives including motor Common Mode (CM) voltage active compensation are studied. A coordinated design of motor CM-voltage active compensator and input EMI filter allows the drive system to comply with EMC standards and to yield an increased reliability at the same time. Two CM input EMI filters are built and compared. They are, designed, respectively, according to the conventional design procedure and considering the actual impedance mismatching between EMI source and receiver. In both design procedures, the presence of the active compensator is taken into account. The experimental evaluation of both filters’ performance is given in terms of compliance of the system to standard limits.

**Analysis of Three-Phase Induction Machines with Combined Star-Delta Windings**

Misir, Onur; Ponick, Bernd

Institutfur Antriebssysteme und Leistungselektronik, Germany

Combined Star-Delta windings in electrical machines result in a higher fundamental winding factor and cause a smaller harmonic content. This leads to an increased efficiency. In this paper, a calculation method is presented to determine these $I^2R$ losses for three-phase induction machines with combined star-delta windings. An important calculation tool is the field damping factor in order to consider the rotor’s influence on the magnetic field excited by the stator. As the magnetomotive force in the star and delta winding is different, more harmonic contents are generated, but with rather load amplitudes. The method presented here also considers the additional harmonic content by determining the corresponding winding factors.

**Adaptive Fuzzy Logic Control Structure of PMSMs**

Teiar, Hakim; Boukaka, Salim; Chaoui, Hicham; Sicard, Pierre

Universite du Quebec a Trois-Rivieres, Canada

In this work, a fuzzy logic control system is proposed for PMSMs without knowledge of the machine’s parameters. The scheme consists of two adaptive fuzzy controllers, respectively for velocity and direct current control. The control scheme stability is proven by the Lyapunov stability theory and its performance is validated through a set of simulations on an experimentally validated PMSM model. The control design achieves low sensitivity to torque
disturbances and machine’s parameter variations.

**Sensorless control system of induction machine with the Z-type backstepping observer**  
Morawiec, Marcin; Guzinski, Jaroslaw  
*Gdansk University of Technology, Poland*

The paper presents the sensorless control of induction machine based on multi-scalar variables in which the rotor angular speed is estimated by the novel structure of the speed observer. The novel speed observer structure is constructed by using the backstepping approach. This observer structure is named Z-type observer backstepping. A comparison between the standard adaptive backstepping and the Z-type observer backstepping is made. The experimental results show the properties of the control system and in particular the Z-type observer backstepping.

**Model Predictive Control of Stator Currents in Switched Reluctance Generators**  
Kiani, Morgan  
*Texas Christian University, USA*

Control of phase current is an integral part of operation in Switched Reluctance Generators (SRG). Since machine windings experience a substantial back-emf during generation, stator phase currents tend to increase even after the phase is turned off. This in turn necessitates an oversized converter, thereby increasing the cost and overall size of the system. Moreover, due to variations in speed of the prime mover, the power electronic converter should be designed for the worst possible case. This will magnify the additional cost and size issues. Furthermore, implementation of a current profiling scheme for specific reasons such as active vibration cancellation, etc. requires an online estimation of the motional back-emf. In the present paper, a novel method for controlling the current in SRG is proposed. This method enhances the cost and size of the power electronics converter. In addition, using an online estimation of motional back-emf, it makes current profiling in the stator windings possible. This will pave the way for advanced applications of SRG in automotive, aerospace and other challenging places. It must be noted that this method does not require any extra circuitry or memory for its implementation.

**Nonlinear Model of Synchronous Generator for Autonomous Electrical Power Systems Analysis**  
Michna, Michal; Kutt, Filip; Racewicz, Szymon; Ronkowski, Mieczyslaw  
*Gdansk University of Technology, Poland*

This paper presents the nonlinear lookup table model for synchronous generator (SG) analysis. The saturation effects of the SG magnetic circuit have been considered. The saturated characteristic of the SG magnetic circuit are based on the open circuit saturation curve for magnetizing inductances. The model has been implemented into the Synopsys/Saber software using the MAST modelling language. To implement the no-load voltage characteristic of SG into the MAST model the table look-up tool has been used. Normal and fault operation of SG can be effectively studied. Developed model exhibits a network with the same number of external terminals as the real SG and represents its behaviour in terms of the electrical and mechanical variables as well. Accuracy and robustness of the nonlinear lookup table modelling approach has been confirmed by measurements performed on the 3 kVA synchronous generator.
Predictive Position Control of the Induction Two-Mass System Drive
Serkies, Piotr; Szabat, Krzysztof
Wroclaw University of Technology, Poland
In the paper, a model predictive controller (MPC) for the position control for an induction motor drive with an elastic connection is presented. The control methodology enables the drive’s safety and physical limitations to be directly incorporated into control synthesis. The effect of the predictive horizon on the drive performance is examined. The theoretical consideration are supported by experimental results.

Diagnosis of Stator High-Resistance Connections in Wound Rotor Induction Machines for WECS
Gritli, Yasser1,2; Rossi, Claudio1; Zarri, Luca1; Mengoni, Michele1; Filippetti, Fiorenzo1; Casadei, Domenico1; Capolino, Gerard-Andre3
1University of Bologna, Italy; 2University of Tunis El Manar-ENIT, Tunisia; 3University of Picardie "Jules Verne", France
Design of modern Wind Energy Conversion Systems (WECSs) must take into account two crucial aspects: efficient control strategies and reliable monitoring and diagnosis techniques. Wind turbine generators based on Wound Rotor Induction Machine (WRIM) is actually the preferred technology mainly because of the lower rating of the power converter connected to the rotor side. With the association of a back-to back converter on the rotor side a Stator-Flux-Oriented-Control (SFOC) system can be used to obtain a decoupled control of the active and reactive power on the stator side with high efficiency. Faults detection at incipient stage in this power-generation system is mandatory to prevent unscheduled downtimes. In this paper, a convenient time-frequency analysis of the rotor modulating signals is confirmed by experimental results. The proposed system is suitable to be easily embedded in the power-converter digital control system at very low cost.

2-Phase Direct Torque Controlled IM Drive using SVPWM with Torque Ripple Reduction: Motoring and Regenerating
Laskody, Tomas; Dobrucky, Branislav; Kascak, Slavomir; Prazenica, Michal
University of Zilina, Slovak Republic
The paper deals with design and simulation of 2-phase direct torque controlled induction motor (IM) drive using space-vector modulation (SVPWM). The IM drive is supplied 2-phase full bridge inverter. The control system uses direct torque control method with PI controllers of torque and flux denoting by reduced torque ripple. Simulation results in both motoring and regenerating modes are given in the paper.

Surviving the Digital Transition: Maintaining UHF Microphone Systems for the Future
Hewitt, Christopher1; Wang, Dali2
1Thomas Jefferson National Accelerator Facility, USA; 2Christopher Newport Universiy, USA
A direct sequence spread spectrum implementation was developed in an effort to extend the operational lifetime of legacy analog wireless audio equipment. These legacy devices have an uncertain future due to spectrum reallocation and repurposing in the United States. Through
the development of a drop-in module incorporating spread spectrum techniques, aging analog equipment can benefit from audio integrity preservation and isolation from other devices and services operating on the UHF band. By extending the operational lifetime of existing wireless equipment, this approach could reduce electronic waste.

**Feature Extraction Techniques Based on Power Spectrum for a SSVEP-BCI**

Castillo, Javier\(^1\)\(^2\); Muller, Sandra\(^1\); Caicedo, Eduardo\(^2\); Bastos, Teodiano\(^1\)

\(^1\)Federal University of Espirito Santo, Brazil; \(^2\)University of Valle, Colombia

This paper presents a comparison among three methods for Steady-State Visually Evoked Potentials (SSVEP) detection. These techniques are based on Power Spectral Density Analysis (PSDA) and Canonical Correlation Analysis (CCA). The first method estimates the signal-to-noise ratio of the power spectrum in each stimulus frequency using PSDA, which is called Traditional-PSDA. The second analysis estimates the relation between the difference of the stimulus frequency and its neighbor frequencies, using the power spectrum in these neighbor frequencies, and seeks the neighbor frequency which present the lowest relation value. This technique is referred to Ratio-PSDA. The third and final technique called Hybrid-PSDA-CCA. The performances of the methods were evaluated using a database of electroencephalogram (EEG) signals. The EEG signals were recorded from 19 volunteers, from which six people present disabilities. They were stimulated with visual stimuli flickering at 5.6, 6.4, 6.9 and 8.0 Hz. The system performance was evaluated considering the accuracy and the Information Transfer Rate (ITR) for each stimulus frequency. The results showed that the Hybrid-PSDA-CCA method achieved the best result with an average accuracy of 91.44%.

**Comparison of New Techniques Based on EMD for Control of a SSVEP-BCI**

Tello, Richard M. G.\(^1\); Muller, Sandra Mara Torres\(^2\); Bastos-Filho, Teodiano\(^1\); Ferreira, Andre\(^1\)

\(^1\)Universidade Federal do Espirito Santo, Brazil; \(^2\)Centro Universitario Norte do Espirito Santo, Brazil

This paper presents the comparation of three different feature extraction techniques based on the Empirical Mode Decomposition (EMD) for a SSVEP-BCI. This approach based on the characterization of the signal by EMD, is proposed as a novel alternative to other techniques and it was demonstrated that it exceeds both in accuracy rate and Information Transfer Rate (ITR). The experiments were performed in an offline way, and seven volunteers participated of the study. The stimuli were generated both by LCD and LEDs. The frequencies used were 8, 11, 13 and 15 Hz. The results here reported such represent the average of the seven participants, achieving a success rate of 81% and ITR of 23.32 bits/min of the total set of cases analyzed. It is further confirmed that the highest success rates and ITRs were obtained for stimulation by LEDs.

**Neuro-genetic classifier applied to road detection**

Bahri, Mohamed Amine; Seddik, Hassene; Selmani, Anissa

École nationale d'ingénieurs de Tunis (ENSIT), Tunisia

Image classification has gained an important role in many applications (landscape planning or assessment, meteorology, biodiversity, etc...). This operation aims to separate different regions of an image having various properties in different classes. In this paper, a back-
propagation clustering network is proposed for efficient image classification. Our goal is to be able to determine with accuracy some (ROI) regions of interest in a gray level image. To this end, we introduce a new approach that optimizes network performance and improve its learning using genetic algorithms (GA). GAs are applied to optimize internal parameters of the network structure (weights and bias) through a fitness function. The proposed approach generates classification results with high accuracy and reliability. A comparison study is conducted and proved that the combination between a feed forward neural network and genetic algorithm generates better results than other recent methods in the literature based only on neural network trained with back-propagation algorithm.

**Arabic Sign Language Recognition using the Leap Motion Controller**
Mohandes, M.; Aliy, S.; Deriche, M.
King Fahd University of Petroleum & Minerals, Saudi Arabia

Sign language is important for facilitating communication between hearing impaired and the rest of society. Two approaches have traditionally been used in the literature: image-based and sensor-based systems. Sensor-based systems require the user to wear electronic gloves while performing the signs. The glove includes a number of sensors detecting different hand and finger articulations. Image-based systems use camera(s) to acquire a sequence of images of the hand. Each of the two approaches has its own disadvantages. The sensor-based method is not natural as the user must wear a cumbersome instrument while the image-based system requires specific background and environmental conditions to achieve high accuracy. In this paper, we propose a new approach for Arabic Sign Language Recognition (ArSLR) which involves the use of the recently introduced Leap Motion Controller (LMC). This device detects and tracks the hand and fingers to provide position and motion information. We propose to use the LMC as a backbone of the ArSLR system. In addition to data acquisition, the system includes a preprocessing stage, a feature extraction stage, and a classification stage. We compare the performance of Multilayer Perceptron (MLP) neural networks with the Naive Bayes classifier. Using the proposed system on the Arabic sign alphabets gives 98% classification accuracy with the Naive Bayes classifier and more than 99% using the MLP.

**Cost-effective Redundancy for Ethernet Train Communications using HSR**
Zuloaga, Aitzol; Astarloa, Armando; Jimenez, Jaime; Lazaro, Jesus; Araujo, Jose A.
University of the Basque Country UPV/EHU, Spain

In this work a novelty use of the High-availability Seamless Redundancy (HSR) in the Train Communication Network (TCN) is presented. Nowadays, the 10 years old TCN standard is being renewed toward an Ethernet-based solution, but it is necessary to accomplish some special restrictions for such a critical application. The HSR standard can help solve the redundancy required in train communications.

**Joint sensor fault detection and recovery based on virtual sensor for walking legged robots**
Hashlamon, Iyad; Erbatur, Kemalettin
Sabanci University, Turkey

This paper presents a novel method for joint sensor faults detection and faulty signal reconstruction. It uses the Virtual Joint Sensor (VJS). The model structure of the VJS consists of two interconnected models: The simple Linear Inverted Pendulum Model (LIPM) and the robot
leg kinematics model (LKM). Kalman filter based on LIPM estimates the Center of Mass (CoM) position of the biped. The LKM uses the estimated CoM position to calculate the joints angles. A faulty signal model is formed to detect the faults, based on an adaptive threshold, and recovers the signal using the VJS outputs. The sensor abrupt, incipient, and frozen output faults are studied and tested. The validity of the proposed method was confirmed by simulations on 3D dynamics model of the humanoid robot SURALP while walking on a flat terrain.

An optimal estimation of feet contact distributed normal reaction forces of walking biped
Hashlamon, Iyad; Erbatur, Kemalettin
Sabanci University, Turkey
The motion of a walking biped has rich information about the contacts with the environment. This paper presents an optimal estimation method of the distributed normal reaction forces at the contact points on the feet soles of walking bipeds. The motion is acquired by employing the inertial measurement unit (IMU) and the joint-encoder readings into Newton-Euler dynamic equations without using any force sensor model. The quadratic programming optimization method is used. The validity of the proposed estimation method was confirmed by simulations on 3D dynamics model of the humanoid robot SURALP while walking.

Traveling Surface Characteristics Extraction Equipment for Optical Mouse based Mobile Robot Velocity Estimation
Kim, Sungbok
Hankuk University of Foreign Studies, South Korea
This paper presents the design and analysis of the traveling surface characteristics extraction equipment for the mobile robot velocity estimation using optical mice. For effective and reliable extraction of the statistical parameters of a given traveling surface, the traveling surface characteristics extraction equipment is proposed, in which a traveling surface sample is rotating relative to stationary optical mice. First, the conceptual design of traveling surface characteristics extraction equipment is explained. Second, the velocity kinematics of the optical mouse based mobile robot velocity estimation and the traveling surface characteristics extraction equipment are derived. Third, the parameter setting of the traveling surface characteristics extraction equipment is described. Finally, experimental results using the prototype are given.

A Review Of Piezoelectrical Energy Harvesting And Applications
Lopes, Carolina M. A.; Gallo, Carlos A.
Uberlandia, Brazil
The main objective of this work is to review the most important experiments and applications that have been studied in the last few years in the area of converting mechanical energy from the environment to usable electrical energy using piezoelectric materials.

Very High Throughput Evaluation of Emerging mmWave WLANs
Mohammed Zakarya, Zaaimia1; Rachida, Touhami1; M.C.E, Yagoub2
1University of Science and Technology Houari Boumediene, Algeria; 2University of Ottawa, Canada
This paper investigates the achievable very high throughput (VHT) of the emerging IEEE 802.11ad standard operating at 60 GHz ISM band. The specified modulation and coding schemes are evaluated in a 60 GHz conference room channel. Two IEEE 802.11ad physical layers were considered namely, orthogonal frequency division multiplex (OFDM) physical layer and single carrier (SC). Evaluation was conducted by link level simulations in terms of packet error rate (PER) and throughput. Simulation results highlighted the tradeoffs and limitations of most modulation and coding schemes based on SC and OFDM physical layers.

**Distribution level SiC FACTS devices with reduced DC bus capacitance for improved load capability and solar integration**

Wolfs, Peter; Yang, Fuwen; Han, Qing-Long

*Central Queensland University, Australia*

FACTS devices, such as STATCOMs and UPFCs can be directly applied in the low voltage distribution system to regulate the sequence voltages within a network while simultaneously cancelling zero and negative sequence currents that are introduced by load unbalance or by high levels of distributed photovoltaic generation. Instantaneous reactive power theory shows that for FACTS devices the DC-bus capacitor power will fluctuate at twice mains frequency during unbalanced operation. High rating non-polarized bus capacitors can be applied if the double frequency fluctuations are restricted. In combination with silicon carbide devices it becomes possible to produce compact pole mounted systems. This paper proposes control methods that allow distribution level or dFACTS compensators with finite rating to best allocate its capacity to voltage, current balancing and reactive power compensation.

**Digital observer based current loop control for buck converters - Prototype implementation on an FPGA**

Mezger, Florian; Killat, Dirk

*Brandenburg University of Technology, Germany*

This paper presents an approach for current sensing in digital controlled buck converters. From the several possible techniques for current sensing an observer based algorithm in a digital implementation is used as it has the advantage of not needing an additional sensor or shunt in the circuit which causes additional power losses and costs. The system concept used herein works without additional A/D-converters (ADC) besides these, which are already available in the system. By making use of this sensorless current mode (SCM) concept a current signal is obtained, which is fed to the current loop of the controller. The working principle of this current sensing technique is investigated with system level simulations in ScicosLab and with a prototype based on an FPGA implementation of the algorithm. The controller together with the observer algorithm to estimate the inductor current was written in VHDL and implemented on a Xilinx Spartan 6 FPGA with a Digilent Nexys 3 board. In the simulations a noise floor of $V_{pp} = 20$ mV (peak-to-peak voltage) is added to the measured signals in order to account for the always present noise in real world systems.

**Passive Fault Tolerant Control Design of Energy Management System for Electric Vehicle**

Oubellil, Raouia; Boukhnifer, Moussa

*ESTACA - École d'Ingénieurs, France*

In this paper, we present a passive fault tolerant control energy management for two-
converter parallel configuration in electrical vehicle system. The passive FTC is based on $H_infinity$ approach ($H_infinity$ infinity full order and fixed $H_infinity$ structure); this PFTC is coupled with the optimal control to optimize the consumption of the FC fuel. This architecture is proposed to ensure the stability with an acceptable performance of the system in the faulty mode. To test this architecture, we introduce a fault in the DC bus voltage sensor, and we compare the behavior of the system in the case of a PI controller and robust fault tolerant controller. The simulation results proved the effectiveness of the $H_infinity$ FTC synthesis and the two kinds of $H_infinity$ synthesis are discussed.

**Design and FPGA Implementation of an All-Digital Two-Quadrant General Pulse-Width Modulator**

Di Piazza, Maria Carmela; Luna, Massimiliano; Vitale, Gianpaolo

Consiglio Nazionale delle Ricerche (CNR)- Istituto di Studi sui Sistemi Intelligenti per l'Automazione (ISSIA), Italy

This paper proposes an all-digital general pulse-width modulator (ADGPWM) that is an improvement of the general pulse-width modulator (GPWM). The ADGPWM allows overmodulation and negative carrier and reference signals to be managed. The proposed all-digital implementation is suited both to serial/concurrent data processing platforms and to integrated circuit implementation, to realize several control algorithms for switching power converters. The VHDL design of the ADGPWM is synthesized and tested on a board which is based on a commercial field-programmable-gate-array (FPGA). Several details of the all-digital implementation are discussed thoroughly and experimental results are given in order to assess its validity.

**Digital Observer-Based Control Technique for an AC/DC Converter with a very Fast Voltage Loop**

Pahlevani, Majid; Eren, Suzan; Bakhshai, Alireza; Jain, Praveen

Queen’s University, Canada

This paper presents a novel approach to control an AC/DC converter without using any current sensors. The AC/DC converter is based on the well-known boost PFC topology. Due to the particular structure of the boost PFC AC/DC converter, sensorless control of the converter is very challenging. As illustrated in this paper, the converter loses its observability for some operating points. This is the reason that the sensorless control of the boost PFC entails special attentions. A very simple and practical senseless scheme is proposed in this paper, which is able to accurately estimate the inductor current for the entire operating range of the converter. In addition, a very simple and practical closed-loop control approach is proposed in order to improve the transient response of the single-phase boost PFC converter. This approach eliminates the need for filtering double frequency ripple from the output voltage, which allows increasing the bandwidth of the external voltage loop. Simulation and experimental results validate the feasibility of the proposed technique and confirm its superior performance compared to the conventional control system.

**Optimal and Secure Protocols in the IETF 6TiSCH communication stack**

Accettura, Nicola; Piro, Giuseppe

Politecnico di Bari, Italy
In order to cope with large multi-hop resource-constrained and IPv6-compliant Low-power and Lossy Networks (LLNs), based on IEEE802.15.4 radios, novel protocols have been standardized within the IETF. More recently, the IEEE802.15.4e Timeslotted Channel Hopping (TSCH) MAC amendment has been designed to meet the requirements of industrial applica-tions, by reducing idle-listening and improving reliability in the presence of narrow-band interference and multi-path fading. To integrate this new powerful MAC within the framework of IPv6-based LLN protocols, a new IETF working group has been defined, namely “IPv6 over the TSCH mode of IEEE 802.15.4e” (6TiSCH). In a timely way, this paper presents our contribution to the early standardization efforts required to define (i) an optimal distributed scheduling technique able to allocate resources between any couple of neighbors, while seconding the minimal bandwidth requirements and avoiding collisions, and (ii) a scalable framework supporting setting-up and maintenance of secured domains. Supported by the scientific interest to this reasearch topic, we strongly believe that the 6TiSCH stack will be a viable solution for a wide gamut of optimal and secured IoT applications in industrial environments.

Modeling The Undulatory Locomotion of C. elegans Based On The Proprioceptive Mechanism

Deng, Xin\textsuperscript{1,2}; Ren, Qinyuan\textsuperscript{2}; Du, Ying\textsuperscript{1}; Wang, Guoyin\textsuperscript{2}; Wu, Rongkun\textsuperscript{1}; Si, Xiang\textsuperscript{1}

Chongqing University of Posts and Telecommunications, China; National University of Singapore, Singapore

This paper provides an undulatory locomotion model of C. elegans to implement the chemotaxis behaviors based on the proprioceptive mechanism. The nervous system of C. elegans is modeled by a dynamic neural network (DNN) that involves two parts: head DNN and motor neurons. The body of C. elegans is represented as a multi-joint rigid link model with 11 links. The undulatory locomotion behavior is achieved by using the DNN to control the lengths of muscles on ventral and dorsal sides, and then using the muscle lengths to control the angles between two consecutive links. The propagation of undulatory wave is achieved by using proprioceptive mechanism, for which the cooperation between muscles and motor neurons is needed. Owing to the learning capability of DNN, a set of nonlinear functions that are designed to represent the chemotaxis behaviors of C. elegans are learned by the head DNN. The testing results show good performance of the locomotion model for the chemotaxis behaviors of finding food and avoiding toxin, as well as slight and Ω turns.

Capability Analysis of a D-STATCOM Integrated to Single-Phase to Three-Phase Converter for Rural Grids

Scapini, Rafael Z.; Rech, Cassiano; Marchesan, Tiago B.; Schuch, Luciano; de Camargo, Robinson F.; Michels, Leandro

Federal University of Santa Maria, Brazil

This paper presents a capability study of a static converter system to provide balanced three-phase four-wire with grounded neutral from single-phase network. The system is connected in parallel with the single-phase grid, that matches one of the output three-phase terminal. The converter absorbs active power from single phase grid to produce two additional phases of the three-phase system. Furthermore, it allows the voltage compensation or power factor correction through reactive power injection. This system also allows the connection of alternative sources to DC bus.
An Improved Extremum-Seeking Based MPPT for Grid-Connected PV Systems with Partial Shading

Elnosh, Ammar¹; Khadkikar, Vinod¹; Xiao, Weidong¹; Kirtely Jr., James L.²
¹Masdar Institute, United Arab Emirates; ²Massachusetts Institute of Technology, USA

This work deals with single-stage three-phase grid connected Photovoltaic (PV) systems with a focus on developing an efficient Maximum Power Point Tracking (MPPT) technique under partial shading conditions. As partially shaded PV arrays exhibit a multi-modal behavior on their Power-Voltage (P-V) characteristics with a number of possible patterns, the MPPT strategy under such conditions is a complex and challenging task. An Extremism-Seeking Control (ESC) based method is proposed in this paper to track the global power peak under non-uniform irradiance conditions. It relies on the measurements of power and estimation of the power gradient to iteratively determine the segment of the P-V characteristics in which the global peak lies, without converging at the other local maxima. The proposed method is compared to the sequential ESC-based MPPT method presented in the literature. Different test scenarios of partial shading show that the proposed method can reach the global peak with a faster convergence rate and higher tracking efficiency than conventional approaches.

The New FLC-Variable Incremental Conductance MPPT with Direct Control Method Using Cuk Converter

Radjai, Tawfik¹; Gaubert, Jean Paul²; Rahmani, Lazhar¹
¹Setif university 1, Algeria; ²Poitiers University, France

Maximum power point tracking (MPPT) is a necessary function for all photovoltaic (PV) systems. The classical incremental conductance (IncCond) maximum power point tracking (MPPT) with direct control is widely applied in many papers. The IncCond algorithm is prone to failure during high changes in the irradiance. This paper deals with a new algorithm based on variable step size to eliminate all drawbacks of the classical IncCond algorithm with direct control. We use fuzzy logic controller to adjust the duty cycle change, therefore, the reach of MPP is quick and accurate simultaneously during the dynamic and steady state conditions compared to conventional IncCond MPPT with direct control method, a controlled Cuk dc–dc converter was used and connected to a SunTech STP085B in order to verify the results. We used Matlab Simulink for simulation, the results clearly indicate the improvement of the proposed method.

A Magnetron Driver with LLC Resonant Converter for Microwave Oven

Yang, Yueh-Ru
Ming Chi University of Technology, Taiwan

This paper depicts a magnetron driver with half-bridge LLC resonant converter for microwave ovens. The designed driver contains a diode rectifier, a half-bridge switching inverter, an LLC transformer resonant tank and a diode-capacitor full-wave voltage doubler. Input voltage and output current are sensed and sent to a 16 bit digital signal controller for power control. The controller varies the switching frequency to regulate output current and achieve zero-voltage switching. Its output is similar to a current source. To verify the analysis and design, a one-kilo watts half-bridge driver is built. Experimental results demonstrate the LLC converter suits this application.
Application of SOM Artificial Neural Network to Fault Diagnosis in Nuclear Power Plant

Yang, Xuhong
Shanghai University of Electric Power, China

In this article, the SOM artificial neural network Method, which is advanced in no require of pre-setting goals, respond differently according to different inputs, automatic classification and so on, is used in a nuclear power plant for detecting the typical fault of the secondary condensate feed water system.

A modified technique for 3D camera calibration

Badalkhani, Sajjad; Badamchizadeh, Mohammadali
University of Tabriz, Iran

In this paper a modified technique for 3D camera calibration is applied on a stereo-camera, in order to get accurate depth information of a desired object on the scene. The technique requires observing a scene or a planar pattern with known geometry at some different orientations. A curvature based corner detection technique is applied to detect both fine and coarse features at low computational cost to obtain the intrinsic and extrinsic parameters of cameras and achieve the translation between the world and image coordinates. SURF matching approach is aimed for optimizing the translation rule from the image to spatial coordinates by using a set of rotation-invariant interest points on stereo images. The result together with accuracy and calculation speed is reported.

4th June, Wednesday
09:00-11:20 at Opal
WeA1 Advanced Power Electronics for Power Quality Improvement in Distributed Generation Systems I
Session Chair: Hadi Y. Kanaan, Saint-Joseph University
Co-Chair: Kamal Al-Haddad, University of Quebec

A Review of Modulation and Control Strategies for Matrix Converters Applied to PMSG Based Wind Energy Conversion Systems

Nasr El-Khoury, Catherine1,2; Kanaan, Hadi Y.1; Mougharbel, Imad2
1Saint-Joseph University, Lebanon; 2Lebanese University, Lebanon

This paper presents a review of modulation and control strategies for matrix converters applied to permanent magnet synchronous generator (PMSG) in wind power generation systems. Modulation techniques already discussed in scientific literature for the command of matrix converters are mostly divided into three categories: the scalar modulations, the pulse width modulations and the predictive control modulations. These modulation methods are combined with maximum power point tracking (MPPT)-based control strategies to secure and improve the performance of the overall system. Control strategies are combinations of two elementary blocs: the MPPT algorithms and the regulation approach. MPPT algorithms are crucial for the improvement of wind harvest and regulation approaches are generally based on
adaptive, non-linear or linear automatic methods that are responsible for current control or field oriented control or reactive power control.

**4-Leg Shunt Active Power Filter with Hybrid Predictive Fuzzy-logic Controller**

Fahmy, Abdullah¹; Abdelsalam, Ahmed¹; Kotb, Abdelsamea²

¹Arab Academy for Science and Technology, Egypt; ²AL-Adzhur University, Egypt

This paper presents a 4-leg shunt active power filter (APF) featuring reactive power compensation, line current harmonics mitigation, neutral-current reduction and system load-currents balancing. The authors propose hybrid controller for the 4-leg shunt APF: Fuzzy Logic Control (FLC) for the DC-link voltage and predictive control for the grid current. The DC-link voltage FLC handles the system uncertainties and nonlinearities, hence improving the transient performance. In addition, the proposed predictive current control technique features phase locked loop (PLL) independency. Moreover, the proposed hybrid controller necessities sensing only the grid voltage and current, hence less number of sensors are required. In addition, implementation simplicity and cost reduction are achieved. The proposed controller is simulated using Matlab/Simulink® package. For effectiveness verification, system performance is investigated under several loading conditions.

**A single-phase transformerless active filter with reduced DC-link voltage**

Javadi, Alireza; Al-Haddad, Kamal

University of Quebec, Canada

This paper proposes a Hybrid series active filter (HSeAF) without interfacing transformer. The compensator improves power quality issues of a single phase system. A control algorithm to compensated current harmonics of a nonlinear load to propagate into the single-phase system, while protecting loads from voltage perturbations initiated from the power system is studied. The exclusion of the series transformer reduces complexity and overall costs of this configuration. The compensation of current harmonics and load voltage distortions are analyzed together with the influence of gain and delays in the controller stability. The detailed operation of the proposed topology is presented and analyzed in a comparative study with conventional series active filters. Validation by simulations of the system dynamic for different load and supply conditions is presented.

**Cascaded Multilevel Inverter with Multicarrier PWM Technique and Voltage Balancing Feature**

Vahedi, Hani; Al-Haddad, Kamal; Labbe, Philippe Alexandre; Rahmani, Salem

University du Quebec, Canada

Multilevel inverters generate low harmonic waveforms at the output, which makes them suitable for high voltage energy conversion scheme to deliver efficient high power to the loads from renewable energy sources like photovoltaic systems which are penetrating to the electric grid nowadays, significantly. In this paper a single-phase hybrid multilevel inverter based on cascading full bridge and half bridge cells is introduced. Moreover the associated switching technique with multicarrier PWM is designed to generate five-level voltage at the output. As well, the designed switching technique allows the capacitors of the half bridge cell to have balanced voltage despite load changes. Furthermore, this study is extended to more cells using unequal DC sources to produce more voltage levels. Simulations have been performed on two
and three cells to demonstrate the efficiency of the presented cascaded inverter with equal and unequal DC sources and switching technique.

**Selective Harmonic Elimination Modulation Technique Applied on Four-Leg NPC**
Sharifzade, Mohammad¹; Vahedi, Hani²; Sheikholeslami, Abdolreza³; Ghoreishy, Hoda¹; Al-Haddad, Kamal²
¹Babol Noshirvani University, Iran; ²University du Quebec, Canada

In this paper the selective harmonic elimination pulse width modulation (SHE-PWM) technique is proposed to control the three-level four-leg neutral point clamped (NPC) inverter in order to have both advantages of low switching frequency of SHE and neutral point of fourth leg in four wire systems. In this proposed method, the obtained switching angles of inverter phase legs are used to eliminate the non-triplen, 5th to 23th harmonics orders from the output voltage. As well, switching angles calculated for the fourth leg are considered to eliminate the triplen harmonics containing 3th, 9th, 15th, 21th and 27th orders from phase voltage. The efficiency of the proposed modulation technique is verified by simulations of a four leg NPC inverter as an UPS feeding different types of dynamic and unbalanced loads.

**Power Quality Enhancement by Power Electronic Generation Interface under Non-Ideal Voltage Conditions**
Jelani, Nadeem
Norwegian University of Science and Technology, Norway

Distributed generation (DG) interfaced to the grid through power electronic (PE) interface can be used to provide reactive power for voltage stability in a power system they are part of. Furthermore, they can be used to minimize the harmonic issues caused by the PE non-linear loads present at the distribution level. This article investigates the possibility of using a generation side PE interface for shunt active filtering in addition to supply the active power demand to the consumers under non-ideal source voltage conditions. Reference signal generation techniques for shunt compensator are based on instantaneous reactive power (IRP) p-q theory and the theory of current’s physical components (CPC), in rotating synchronous reference frame (SRF). Converter control is based on vector control method. IRP p-q theory based reference signal generation technique uses filters to extract the desired current components. CPC utilizes frequency domain methods to compute the current references. Simulation results show that the generation interface performs shunt active filtering very efficiently. However, it is observed that the source current distortion is further increased due to the reduction of fundamental current component in the source current when generation interface supplies the active power to the power network.

**A Survey on Modeling, Control, and dc-Fault Protection of Modular Multilevel Converters for HVDC Systems**
Sleiman, Mohammad¹; Al-Hage Ali, Ali²; Fortin Blanchette, Handy¹; Al-Haddad, Kamal¹; Piepenbreier, Bernhard²; Kanaan, Hadi Y.³
¹Ecole de Technologie Superieure, Canada; ²University of Erlangen, Nuremberg; ³Saint-Joseph University, Lebanon

The modular multilevel converter (MMC) is becoming one of the most promising topology in multilevel converter series especially for high-voltage and high-power applications. This
valuable features, nominates MMCs to interface high-voltage and high-power renewable energy resources into modern HVDC electric grids for more penetration of renewable energy. This paper investigates recent modeling, control, and dc-fault protection techniques that have been applied to MMCs.

### 4th June, Wednesday

09:00-11:00 at Turkuaz

**WeA2** Advances in Energy Storage II

**Session Chair:** Walter Zamboni, Universita degli Studi di Salerno

**Co-Chair:** Roberto Saletti, Universita di Pisa

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**An SOH Estimation System Based on Time-Constant-Ratio Measurement**

Dung, Lan-Rong; Wu, Sung-Han; Yuan, Hsiang-Fu


The SOH of batteries is critical information for electric vehicle (EV) and hybrid electric vehicle (HEV) systems. This paper proposes an SOH estimation system based on time constant-ratio measurement. There are two reasons of choosing time-constant as aging criterion. First, time-constant represents the response speed of terminal voltage during charging and discharging. Second, time-constant represents the change of internal chemical reactions. The proposed estimation resolves the issues of traditional SOH estimations. There are two widely used SOH estimations. The first one is full-charge-capacity (FCC) estimation. Unfortunately, to access FCC information need to take a long-term charging and discharging test. Therefore, FCC estimation fails to be a fast SOH estimation. The second estimation is internal impedance estimation. However, this SOH estimation may cause large error due to the effect of environmental impedance. For improving the above issues on different SOH estimations, this paper proposes an SOH estimation system based on time-constant-ratio measurement. The time-constant-ratio is a novel criterion for aging effect. The use of this novel criterion for SOH estimation helps to achieve the purpose of an environmental-impedance-free and fast SOH estimation. The proposed estimation is 0.14% the measured time of FCC estimation based on 1C charging and discharging. The measured results have average error below 1% and maximum error below 2%.

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**Analysis and Design of a Dual-Bridge Series Resonant DC-DC Converter for Capacitor Semi-Active Battery-Ultracapacitor Hybrid Storage System**

Chen, Hao; Bhat, Ashoka

*University of Victoria, Canada*

Electrical power systems in electrical vehicles require high energy density sources such as battery ultra capacitor hybrid storage system. In order to draw energy from the source as well as recharging the ultra-capacitor during regenerative breaking, a dual-bridge series resonant DC-to-DC converter with modified gating scheme is proposed. The switches on the primary side of the transformer are controlled using the modified gating scheme, and the switches on
the secondary side of the transformer are controlled using normal gating scheme having phase-shift with respect to the primary voltage. The use of modified gating scheme increases the number of switches operating in zero voltage switching, thus increasing the overall efficiency as well as reducing component stress. Moreover, the direction of the power flow is determined by the polarity of the phase shift between the primary and secondary sides of the converter. The proposed converter is analyzed using approximate ac equivalent circuit analysis for both ac impedance load and voltage source load. Based on the analysis, a design procedure and design curves are given. Finally, a 200 W converter with input voltage ranging from 64 V to 96 V and output voltage ranging from 88 V to 104 V is designed, and PSIM simulation and experimental results are shown to verify the theoretical values.

Quantitative Analysis on Energy Efficiency of A Battery-Ultracapacitor Hybrid System
Zhao, Chen; Yin, He; Noguchi, Yohei; Ma, Chengbin
1Shanghai Jiao Tong University, China; 2Nippon Chemi-Con Corporation, Japan
This paper provides a quantitative analysis on the energy efficiencies of the battery-ultra capacitor hybrid energy storage system and the lithium-ion-battery-only system under the JC08 driving cycle. There are two control parameters selected in the analysis, the efficiency of the DC-DC converter and the internal resistance of the battery pack. The analysis shows that compared to the battery-only system the battery-ultra capacitor hybrid energy storage system is less sensitive to the internal resistance of the battery pack. Meanwhile, the energy loss of the DC-DC converter is a key factor to the overall efficiency of the battery-ultra capacitor hybrid energy storage system. With a high-efficiency DC-DC converter, the battery-ultra capacitor hybrid energy storage system can achieve a similar or higher efficiency than the battery-only system.

Control Strategy for Bidirectional HBCS Converter with for Super capacitor Applications
Garcia, Jorge; Capponi, Fabio Giulii; Borocci, Gabriele; Garcia, Pablo
1University of Oviedo, Spain; 2University of Roma “La Sapienza”, Italy
This paper proposes the basic average model and the design of the control system for the Half Bridge Current Source (HBCS) Bidirectional DC to DC Converter. This converter is intended to interface a High Voltage DC link and a Low Voltage DC Storage Device in transportation applications. Firstly, the basics of the converter operation, high-level control and the simplified modeling are presented. Then, a cascaded control approach for the whole system is discussed and validated through simulations.

Cost Benefit Analysis of Individual Cell Control in Batteries for Electric Vehicles
Ozkurt, Celil; Camci, Fatih; Esat, Burak; Toker, Onur
1Antalya International University, Turkey; 2Fatih University, Turkey
Battery technologies have been receiving great attention in recent years with increased pressure on green energy. Electric Vehicle (EVs) is one of the most important applications that is considered to be a potential contributor for the global green energy target. Battery technologies play critical role in deployment of the EVs. Batteries in EVs require storing high energy, which can be achieved to use huge number of battery cells in the battery pack. Monitoring and management of high number of cells in battery packs for EVs are important aspects of Battery Management System (BMS). This paper analyzes the cost of monitoring and
management of each cell in a battery pack for a Plug in Hybrid Electric Vehicle (PHEV). A battery management system that can control individual cells by allowing individual charge/discharge ability is proposed. The extra cost that the battery management system brings and its potential benefits are discussed.

Experimental Validation of an Efficient Charge Equalization System for Lithium-Ion Batteries
Baronti, Federico¹; Roncella, Roberto¹; Saletti, Roberto¹; Zamboni, Walter²

¹Università di Pisa, Italy; ²Università degli Studi di Salerno, Italy

The experimental validation of a Battery Management System (BMS) provided with an innovative high-efficiency active balancing circuit is described in this paper. Charge equalization among the series connected battery cells is achieved with a cell to cell balancing topology. The balancing circuit consists of a switch matrix for the individual access of each cell and a bidirectional DC-DC converter to transfer a controlled amount of charge from a cell to a super capacitor and back to another cell. The balancing algorithm and the experimental setup are also described. The experiments show the functionality of the balancing circuit that restores a fully balanced battery consisting of eleven 40 Ah Lithium-ion cells. For instance, if one of the cells is 17.7 % imbalanced, battery equalization lasts around 25 h and only costs 1 % of the battery energy. It allows the recovery of the full battery charge, otherwise limited to 82.3 %, with an energy saving factor of 6, if compared with passive balancing. The efficiency of the process, calculated by measuring the energy lost during balancing, is higher than 75 %.

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**4th June, Wednesday**

**09:00-11:20 at Kahribar**

**WeA3**  
**Machine Vision, Control and Navigation II Combined with Real Time Simulations on Electrical Systems I**

**Session Chair:** Rajesh Gupta, M.N National Institute of Technology Allahabad

**Co-Chair:** Kang-Hyun Jo, University of Ulsan

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**Vision-Based Heading Angle Estimation for an Autonomous Mobile Robots Navigation**

Caceres Hernandez, Danilo; Hoang, Van-Dung; Filonenko, Alexander; Jo, Kang-Hyun

*University of Ulsan, Korea*

Autonomous mobile robots navigation and control systems are still hugely important in real time robotic applications. When moving towards fully autonomous navigation, guidance plays a vital task for successful autonomous navigation. In this paper, the authors propose real time guidance fuzzy logic application based on edge and color information surrounding the road surface by using Omni directional cameras. Autonomous navigation systems must be able to recognize feature descriptors from both edge and color information. Firstly, it was proposed to extract the longest segments of lines from the above mentioned methods. Secondly, Random Sample Consensus (RANSAC) curve fitting method was implemented for detecting the best curve fitting given the data set of points for each line segment. Thirdly, the set of intersection points for each pair of curves were extracted. Fourthly, the Density-based spatial clustering of applications with noise (DBSCAN) method was used in estimating the vanishing point (VP).
Finally, to control the mobile robot in an unknown environment, a fuzzy logic controller facilitated by the VP was implemented. Preliminary results were gathered and tested on a group of consecutive frames undertaken at the University of Ulsan (UoU) to prove their effectiveness.

**Improve Laser Detection in CCD for Integrated Photogrammetry - Laser Scanner**

Rodriguez-Quinonez, Julio C.; Sergiyenko, Oleg; Hernandez-Balbuena, Daniel; Rivas-Lopez, Moises; Flores-Fuentes, Wendy; Basaca-Preciado, Luis C.

*University Autonomous of Baja California, Mexico*

The specified properties of both the close-range photogrammetry and laser-scanning have their advantages and specific limitations. In this paper we are going to expose such advantage and combine this methods to exploit their natural synergy, additionally a new pre-processing technique to realize a quick identification of the laser centroid and edges detected by a CCD is presented, this technique can be used in a combination with edge detection techniques as Canny and Prewitt methods to obtain more defined edges in an image. Finally the experimentation is presented to see the stability of the identified centroid in the laser reflection at different thresholds using the proposed technique in an Integrated Photogrammetry-Laser Scanner.

**An approach for dynamic triangulation using servomotors**

Lindner, Lars¹; Sergiyenko, Oleg¹; Tyrsa, Vera²; Mercorelli, Paolo³

¹*University of Baja California, Mexico*; ²*Automobile and Highway University, Ukraine*; ³*Leuphana University of Luneburg, Germany*

A novel principle of dynamic triangulation was developed at the institute of engineering UABC. This method of coordinate measurement uses stepping motors for laser positioning and an open loop controlled DC motor for signal detection. The present paper describes an approach for use of servomotors in cascade control loop, optimized with the amplitude optimum in the frequency domain. These approach results in a short rising time of the step response without overshoot. Simulations of the complete system approves the theoretically values.

**Implementation of a Microgrid model for DER Integration in Real-Time Simulation Platform**

Mentesidi, Konstantina¹; Rikos, Evangelos²; Kleftakis, Vasilis³; Kotsamnopoulos, Panos³; Santamaria, Mikél; Aguado, Monica⁴

¹*Public University of Navarra, Spain*; ²*Department of Photovoltaics and Distributed Generation CRES, Greece*; ³*University of Miyazaki, Japan*; ⁴*Grid Integration Department CENER Pamplona, Spain*

Comprehensive analysis of Distributed Energy Resources (DER) integration requires tools that provide computational power and flexibility. In this context, throughout this paper PHIL simulations are performed to emulate the energy management system of a real micro grid including a diesel synchronous machine and inverter-based sources. Moreover, conventional frequency and voltage droops were incorporated into the respective inverters. The results were verified at the real micro grid installation in CRES premises. This research work is divided into two steps: A) Real time in RSCAD/RTDS and PHIL simulations where the diesel generator’s active power droop control is evaluated, the battery inverter’s droop curves are simulated and the load sharing for parallel operation of the system’s generation units is examined. B) micro
grid experiments during which various tests were executed concerning the diesel generator and the battery inverters in order to examine their dynamic operation within the LV islanded power system

**Power Hardware-in-the-Loop Implementation and Verification of a Real Time capable Battery Model**

Seitl, Christian; Kathan, Johannes; Lauss, Georg; Lehfuss, Felix  
*AIT Austrian Institute of Technology, Austria*

For this contribution a generic and real time capable battery model was implemented within a dedicated Power Hardware-in-the-Loop (PHIL) simulation environment. This was done in order to investigate its implement ability and accuracy for PHIL simulations. PHIL simulations offers major benefits to battery inverter tests as reproducibility increases and the preparation time can be reduced significantly. Following a discussion of real time capable battery models, the implemented model is validated with measurement data of a real battery. Finally a PHIL simulation of a battery model is carried out and its applicability is shown.

**Solar Array System Simulation using FPGA with Hardware Co-Simulation**

P., Rajesh; S., Rajasekar; Gupta, Rajesh; Samuel, Paulson  
*M.N National Institute of Technology Allahabad, India*

In this paper an attempt has been made to realize the solar photovoltaic (PV) characteristics and its control through solar array simulation system designed using field programmable gate array (FPGA) with hardware co-simulation. This facilitates the virtual test bench to test the I-V and P-V characteristics of the solar PV module and performance of the maximum power point tracking (MPPT) algorithm. The test system consists of boost DC-DC power converter, which is controlled by Xilinx/FPGA based control unit to demonstrate the perturb and observe (P&O) MPPT algorithm employed for the solar PV module. The results of the simulated solar PV module are verified with the practical solar PV module characteristics. The results of the MPPT verify the performance of the proposed solar array simulation system. The real time simulation study is carried with Xilinx System Generator (XSG) and Matlab/Simulink simulation environment.

**Compensation of CM Voltage in Systems Consisting Interleaved AC-DC Converters**

Smolenski, Robert¹; Jasinski, Marek²; Jarnut, Marcin¹; Bojarski, Jacek¹; Cecati, Carlo³  
¹University of Zielona Gora, Zielona Gora, Poland; ²Warsaw University of Technology, Warsaw, Poland; ³University of L’Aquila, L’Aquila, Italy

Presented in this paper are the results of research connected with common mode (CM) interference generated by parallel-connected AC-DC power electronic interfaces (PEIs), that are increasingly being used, e.g., in the fast charging infrastructure for electric vehicles or in PV systems. Thanks to parallel connection of lower power AC-DC converters high power capability and modularity would be obtained. Designer can focus only on parameters optimization for one Power Electronic Building Block (PEBB) and predict the necessary features for parallel operation. It is relatively well known that the use of interleaved AC-DC converters aids the reduction of generated Electromagnetic Interference (EMI). However, the aim of this paper is to present a novel approach in the development of a passive CM voltage compensator, dedicated to systems consisting of AC-DC interleaved converters. The presented analyses have
shown that the interleaved modulation used for DC-link voltage ripple reduction brings about additional benefits in the context of passive CM voltage compensation. In the presented case CM voltage compensators for individual converters have been replaced by only one, smaller and cheaper CM compensator for all of the parallel-connected interleaved converters.

Optimal Placement of Phasor Measurement Units in Power Grids Using Memetic Algorithms

Linda, Ondrej¹; Wijayasekara, Dumidu¹; Manic, Milos¹; McQueen, Miles²
¹University of Idaho, USA; ²Idaho National Laboratory Idaho Falls, USA

Wide area monitoring, protection and control for power network systems are one of the fundamental components of the smart grid concept. Synchronized measurement technology such as the Phasor Measurement Units (PMUs) will play a major role in implementing these components and they have the potential to provide reliable and secure full system observability. The problem of Optimal Placement of PMUs (OPP) consists of locating a minimal set of power buses where the PMUs must be placed in order to provide full system observability. In this paper a novel solution to the OPP problem using a Memetic Algorithm (MA) is proposed. The implemented MA combines the global optimization power of genetic algorithms with local solution tuning using the hill-climbing method. The performance of the proposed approach was demonstrated on IEEE benchmark power networks as well as on a segment of the Idaho region power network. It was shown that the proposed solution using a MA features significantly faster convergence rate towards the optimum solution.

Clustering of electric network for effective management of Smart grid

Belyaev, Nikolay A.¹; Korovkin, Nikolay V.¹; Frolov, Oleg V.²; Chudny, Vladimir S.¹
¹Saint Petersburg State Polytechnical University, Russia; ²Joint Stock Company «Scientific and Technical Center of Unified Power System», Russia

The paper proposes a new approach to monitor operating states of electric power systems (EPS). Optimization of parameters of EPS control elements, including Smart grid elements, has been studied. The main features of influence zones of Smart grid elements have been described in the paper and an inventive approach has been proposed regarding the network clustering based on nodes cross-influence.

Controlling a Grid-Connected T-type Three Level Inverter System Using a Sliding Mode Approach

Pires, Vitor Fernao¹; Sousa, Duarte²; Martins, Joao³
¹ESTSetubal/Instituto Politecnico Setubal, Portugal; ²IST / Universidade de Lisboa,
In this work a multilevel inverter based grid connected photovoltaic system is presented. It is used a T-type multilevel inverter. This inverter is based on a classic three-phase voltage source inverter. However, in order to increase the number of voltage levels, three extra bi-directional switches are used. These switches are connected between the three-phase terminals of the inverter and a common point of the two DC capacitors. The inverter is connected to the photovoltaic panel through a DC/DC converter and to a three-phase transformer. The DC/DC converter and the multilevel inverter are controlled using a sliding mode controller. At the output of the controller associated to the multilevel inverter is used a vectorial modulator. This modulator will also be used to ensure the DC voltage balancing of the capacitors connected to the inverter. A maximum power point tracking algorithm associated to the photovoltaic generator is also presented. Several results are presented in order to confirm the characteristics of the proposed system.

Hierarchical Energy Management Scheme for Multiple Battery-Based Smart Grids

Chaoui, Hicham; Sicard, Pierre

Universite du Quebec a Trois-Rivieres, Canada

In this paper, a supervisory energy management strategy is presented for multiple battery units. The use of several energy storage devices such as batteries makes their maintenance costly and management a difficult task to undertake. The proposed supervisory approach aims to equilibrate the state of charge (SOC) and hence energy usage, which extends the life of batteries and reduces their heavy maintenance. The energy management strategy yields a high efficient operation of the overall system.

Oscillatory Current Management for DC Microgrids with High Penetration of Single-Phase AC Loads

Hamzeh, Mohsen; Ghazanjfari, Amin; Ashourloo, Mojtaba; Karimi, Houshang

1Shahid Beheshti University, Iran; 2University of Alberta, Canada; 3Polytechnique de Montreal, Canada

This paper presents a comprehensive control scheme for the autonomous operation of a dc microgrid with high penetration of single-phase and unbalanced ac loads. An oscillatory component is introduced into current of dc microgrid through inverter-connected single-phase ac or three-phase unbalanced loads. In such a condition, a conventional droop controller cannot appropriately share the oscillatory components of loads among distributed generation (DG) units. The main merit of this paper is to present an effective control strategy to share the high frequency current among the power sources of dc microgrid. The DG units are considered as reliable hybrid power conversion system which can meet load demands and support transients. The proposed control system consists of a two control blocks. A multiloop voltage control unit is employed to regulate the microgrid voltage. Furthermore, a virtual impedance loop is implemented to share dc current and oscillatory components among power sources. The effectiveness of the proposed control scheme is verified by using digital time-domain simulation studies in the PSCAD/EMTDC software environment.

Remote Monitoring of High-Voltage Disconnect Switches in Electrical Distribution Substations
An autonomous, wireless multi-variable smart sensor is presented able to gather, validate, and locally process data on both position alignment and temperature in remotely operated high-voltage disconnect switches, as part of an instrumentation system which, integrating small, smart, and deeply embedded ‘field’ devices in large numbers, may address the data requirements placed by new sophisticated asset management criteria applied to primary distribution substations in smart electrical grids.

A Stationary Frame Current-Control for Inverter-Based Distributed Generation with Sensorless Active Damped LCL Filter using Kalman Filter

El-Deeb, Hisham\textsuperscript{1}; El-Serougi, Ahmed\textsuperscript{2}; Abdel-Khalik, Ayman\textsuperscript{2}; Ahmed, Shehab\textsuperscript{3}; Massoud, Ahmed\textsuperscript{1}

\textsuperscript{1}Qatar University, Qatar; \textsuperscript{2}Alexandria University, Egypt; \textsuperscript{3}Texas University, Qatar

Due to the large variety of renewable power sources, power electronics play an important role in energy conversion. Different power converter topologies are used to interface distributed power generation systems (DPGS) with the utility network. Introduction of power electronics for DPGS provide several advantages such as energy optimal operation by employing a control algorithm to extract the maximum available power. In addition, load control, reduced noise, controllable active and reactive power and improved power quality. Using a LCL filter to ensure that high quality power is delivered comes at the expense of degraded stability unless mitigation procedures are followed. In this paper, a stationary frame current control for inverter-based distributed generation (IBDG) with sensorless active damped LCL filter is proposed. The Kalman filter sensorless-based technique not only mitigates the stability problem regarding the resonance of the LCL filter, but it improves the overall stability margins. The concluded assumptions were simulated through Matlab/Simulink and verified experimentally with a laboratory prototype.

Three-Port Micro-Inverter with Power Decoupling Capability for Photovoltaic (PV) System Applications

Hu, Souhib Harb Haibing\textsuperscript{1}; Kutkut, Nasser\textsuperscript{1}; Batarseh, Issa\textsuperscript{3}; Harb, Ahmad\textsuperscript{2}

\textsuperscript{1}University of Central Florida; \textsuperscript{2}German Jordanian University, Jordan; \textsuperscript{3}Princess Sumaya University, Jordan

This paper proposes a new single-phase inverter topology for Photovoltaic (PV) applications. The capability of decoupling the double-line-frequency ripple, using a small capacitance, is the
main feature of the proposed topology. This allows for using a film capacitor instead of an electrolytic capacitor, resulting in higher inverter reliability. Additionally, no extra circuitry is needed to manage the transformer leakage energy.

Fuzzy Logic Controller Design for Battery Energy Management in a Grid Connected Electro-Thermal Microgrid

Arcos-Aviles, Diego\textsuperscript{1}; Guinjoan, Francesc\textsuperscript{2}; Marroyo, Luis\textsuperscript{3}; Sanchis, Pablo\textsuperscript{3}; Vega, Christian\textsuperscript{1}

\textsuperscript{1}Universidad de las Fuerzas Armadas, Ecuador; \textsuperscript{2}Universitat Politecnica de Catalunya, Spain; \textsuperscript{3}Universidad Publica de Navarra, Spain

A fuzzy logic controller strategy for battery energy management in a grid connected electothermal residential microgrid is presented. The fuzzy control policy manages the power of the microgrid storage elements in order to minimize a set of quality indices involving, among others, the power profile exchanged with the mains. Numerical simulations using real measured data generation and consumption are provided to both validate the control design and to highlight the benefits of including thermal elements in the overall energy management strategy of the system.

Hybrid low-power Wind Generation and PV grid-connected system with HPC, PC and MPPT control

Rosa, Carlos\textsuperscript{1}; Vinnikov, Dmitri\textsuperscript{2}; Romero-Cadaval, Enrique\textsuperscript{3}; Pires, Vitor Fernao \textsuperscript{4}; Martins, Joao\textsuperscript{5}

\textsuperscript{1}CTS/UNINOVA, Portugal; \textsuperscript{2}Tallinn University of Technology, Estonia; \textsuperscript{3}University of Extremadura, Spain; \textsuperscript{4}Escola Sup. Tecnologia Setubal / Instituto Politecnico Setubal, Portugal; \textsuperscript{5}Universidade Nova de Lisboa, Portugal;

This paper presents a hybrid grid-connected low-power Wind Generator (WG) and Photovoltaic (PV) system with Hybrid Power Control (HPC), Power Control (PC) and Maximum Power Point Tracking (MPPT) control modes. This system mainly focuses on household applications. Due to legal restrictions, these three control modes will be implemented in order to assure that no power is injected into the electrical grid and, at the same time, that the system has an optimized performance. The PC mode will be active when home’s consumed power is lower than the system’s maximum available power \(P_{\text{WGmax}}+P_{\text{PVmax}}\) in MPPT mode, the HPC mode will be enabled when the home’s power is higher than \(P_{\text{WGmax}}\) but lower than \(P_{\text{WGmax}}+P_{\text{PVmax}}\) and the MPPT mode will be used when the consumed power is higher than \(P_{\text{WGmax}}+P_{\text{PVmax}}\). With these control modes, the system’s controller plays the most important role, which is to decide which control mode should be active in order to supply the maximum possible power, without power injection into the grid.

Point of Common Coupling Voltage Regulation with Photovoltaic Power Plant Infrastructures

Minambres-Marcos, Victor; Guerrero-Martinez, Miguel Angel; Romero-Cadaval, Enrique; Gonzalez-Castrillo, Pedro

Universidad de Extremadura, Spain

This paper presents a point of common coupling voltage regulation technique by using a photovoltaic power plants generation system for controlling not only the injection active power but also the balance reactive power. The need of this functionality becomes true when
some countries propose the use of renewable energy to help the grid when a sag is detected as a new standard. However, the idea is extensible to Smart-Grids where the power balance must be provided by the distributed generation. Active power injection is developed by a reference power point tracking and reactive power regulation by controlling the node voltage, both with $dq$ current control with the different power priority possibilities. The studied topology is based on a single-stage traditional inverter but the control algorithm philosophy is valid for any topology. The whole system has been simulated in order to validate the control algorithm and tune the controller for obtaining the best transient response with zero steady state.

Distributed Smart Metering Integration into Power Electronics Systems

Navas-Matos, Francisco Martin; Romero-Cadaval, Enrique; Milanes-Montero, Maria Isabel; Minambres-Marcos, Victor

*University of Extremadura Badajoz, Spain*

The main objective of this paper is to develop a monitoring system and to integrate it into existing power electronics equipment. In that way, they will have one smart meter in any point of the grid where a power electronics system exists, taking advantage of the sensor that these systems already have for implementing their operation strategies. The proposed algorithm is integrated in a previously developed Photovoltaic Array Emulator with the principal aim of monitoring important quality parameters that will be sent to a central repository (by using UDP protocol), where they will be available as pen data.

A Simple Modular Active Power Electronic Transformer

Roasto, Indrek; Strzelecki, Ryszard

*1Tallinn University of Technology (TUT), Estonia; 2Gdynia Maritime University, Poland*

The current project was originally initiated by the marine industry, where bulky low-frequency transformers have become a growing problem. The need for an alternative that is more flexible and would also support the micro grid concept has become a priority. The active power electronic transformer (APET) is likely to be the most suitable candidate for that. In the complex power electronic systems modularity is one of the key factors to success. Modular power electronic building blocks (PEBB) enable complex power electronics systems to be built and reconfigured quickly and reliably by just connecting several PEBBs together, without considering the physical realization inside the PEBB. As a result, reduced costs, losses, weight, size and less engineering effort could be achieved. In this paper a new type of the PEBB for the APET is proposed. The performance of the system was verified by computer simulations using PSIM simulation software. Finally, a 3D model of the demonstrator is presented.

Modeling Harmonics of Networks Supplying Nonlinear Loads

Lamich, Manuel; Balcells, Josep; Corbalan, Montserrat; Sainz, Luis; Fernandez, Cristian

*Universitat Politecnica de Catalunya, Spain*

This work presents the development and validation of a model for electric networks supplying nonlinear loads (NLL). The model is based on Neural Networks (NN) and its purpose is the prediction of harmonic currents sank by the loads, in case of supply impedance changes caused by the insertion or releasing of neighboring loads or by the voluntary insertion of filters to reduce such harmonic currents. The NN is trained using data obtained from several Matlab
simulations and the model is validated using the same network with different supply impedances and load conditions.

4th June, Wednesday
09:00-11:20 at Topaz
WeA6 Multi-phase Power Conversion and Control I
Session Chair: Emil Levi, Liverpool John Moores University
Co-Chair: Atif Iqbal, Qatar University

Dual Matrix Converters Based Seven-phase Open-end Winding Drive
Sk, Moin Ahmed¹,²; Abu-Rub, Haitham³; Salam, Zainal²; Iqbal, Atif³
¹Texas A&M University at Qatar, Qatar; ²Universiti Teknologi Malaysia; ³Qatar University, Doha, Qatar
This paper presents a novel seven-phase open-end winding drive system supplied by the dual non-square matrix converter. The input to each of the matrix converter is three phase utility grid system and the output is seven phase voltages with variable voltage and frequency. The two matrix converters feeding the seven-phase open-end load are supplied from a common single three-phase utility source of 50 Hz. Simple carrier-based PWM algorithm is developed to control the seven phase open-end load. A simple R-L load is considered in the paper. The paper presents the analytical approach to obtain the expression of modulating signals that are used to generate the switching pulses for the matrix converter. Simulation results are presented to support the idea of the proposed modulation scheme.

An Integrated Battery Charger for EVs Based on a Symmetrical Six-Phase Machine
Subotic, Ivan; Levi, Emil
Liverpool John Moores University, U.K.
A new topology for integrated on-board battery charging is proposed in this paper. A symmetrical six-phase machine and inverter, which are used for propulsion, are incorporated into the charging process. The configuration achieves power transfer through the machine without developing an average torque in it during the charging mode. Additional degrees of freedom of six-phase machines are explained and it is shown how they can be utilized to transfer a part of the excitation from the torque producing plane into the non-flux/torque producing plane of the machine, so that rotation does not take place. The advantage is that the motor does not have to be mechanically locked during the charging process. The configuration is operated with a unity power factor and the appropriate control scheme is introduced for this purpose. Theoretical considerations are validated by simulations for both charging and vehicle-to-grid (V2G) modes of operation.

Five-phase induction motor drive with sine-wave filter
Stec, Pawel¹; Guzinski, Jaroslaw¹; Strankowski, Patryk¹; Iqbal, Atif²; Abduallah, Ahmad Anad²; Abu-Rub, Haitham³
¹Gdansk University of Technology, Poland; ²Qatar University, Qatar; ³Texas A&M
The paper presents closed-loop ac drive with 5-phase induction motor operating with voltage source inverter and sine-wave filter. The motor supply voltages and currents have sinusoidal shape. For well-known adjustable electric drives the field oriented control method with flux and speed control can be applied. In the presence of output filter both control and estimation algorithms should be modified due to sine-wave filter installation. The major advantage of the drive with speed observer is an operation without motor speed sensor based on inverter currents and voltage embedded sensors. In this paper sensorless operation of a five-phase induction motor drive with inverter output filter is accomplished. The validation of the drive operation was proved by simulation and experiments. The test bench was developed with prototype of 5-phase 4.3 kW induction motor and inverter with DSP control and sine-wave filter is designed and built.

Design Considerations on Current Control Feed-forward in Grid-Tie-Inverters with Kalman Tracking Filters

Ramos, Joao Cunha; Araujo, Rui Esteves
Middle East Technical University, Turkey

With the increasing pressure on modern power converters towards higher efficiency and smaller volume, power electronic specialists are now even more obliged to power converter optimization. In this study, the optimal design of an 800W, hard switched step down converter is targeted. Switching frequency (f) and inductance (L) are selected as parameters for optimization. Interleaving, a technique widely utilized due to the benefits it introduces to the converter that it is applied to, is also taken into consideration; phase number (N) is an optimization parameter for the analysis to utilize interleaving with the optimal phase number. A laboratory prototype of the targeted 800W converter is implemented in view of the efficiency and volume analyses. Comparison of analytical and practical results is provided.

Common-Mode Voltage Control through Vector Selection in Three-To-Five Phase Matrix Converter

Rahman, Khaliqur1; Aware, M.V.1; Iqbal, Atif1; Al-Ammari, Rashid1; Abu-Rub, Haitham2
1Qatar University, Qatar; 2Texas A&M University at Qatar, Qatar

Multi-phase matrix converters (more than three phase) are distinctively advantageous as because of reduced per-phase current and unity power factor operation. The electrical motors supplied through these converters do have the common mode voltage problem. In this paper, an approach to reduce the common-mode voltage is presented through appropriate vectors selection. An availability of the \(3^5\) 243 states gives selection freedom within the constraints. The useful ninety three vectors with ninety active and three zero vectors are implemented in conventional space vector modulation technique in matrix converter. The space vector control technique is used with selective large and medium vectors with their disposition in d-q plane having controlled mapping in x-y harmonics plane to reduce the common-mode voltage is discussed. Two operating modes, one within the linear range and another with non-linear range (ten stepping mode) is presented with their performance. The common mode voltage (CMV) voltage reduction with rms voltage gain is observed in ten step operation. The effectiveness of these control algorithms are presented through simulation and verified by
implementing it on 2 kVA matrix converter.

**Vector Controlled Five-Phase Permanent Magnet Synchronous Motor Drive**
Hosseyni, Anissa¹,³; Trabelsi, Ramzi¹,²; Mimouni, Med faouzi¹,³; Iqbal, Atif⁴

¹Monastir National Engineering School, Tunisia; ²High Institute of Applied Sciences and Technology, Tunisia; ³Research Unit : Etude des Systemes Industriels et des Energies renouvelables ESIER, Tunisia; ⁴Qatar University, Qatar

This paper establishes the vector control of a five phase permanent magnet synchronous motor (PMSM). First, the mathematical model of a five-phase PMSM is described in a decoupled space with two orthogonal components. Next, space vector modulation (SVM) algorithm is presented to obtain high performance vector control drive. The vector control principle of a five-phase PMSM is developed to prove the effectiveness of this control strategy. This paper deals with the simulation results of SVM and the vector control of a five-phase PMSM.

**Design and Implementation of a 800W Step Down Converter with Optimized F-L-N Parameters**
SAhin, ILker; Hava, Ahmet M.

Middle East Technical University, Turkey;

With the increasing pressure on modern power converters towards higher efficiency and smaller volume, power electronic specialists are now even more obliged to power converter optimization. In this study, the optimal design of an 800W, hard switched step down converter is targeted. Switching frequency (f) and inductance (L) are selected as parameters for optimization. Interleaving, a technique widely utilized due to the benefits it introduces to the converter that it is applied to, is also taken into consideration; phase number (N) is an optimization parameter for the analysis to utilize interleaving with the optimal phase number. A laboratory prototype of the targeted 800W converter is implemented in view of the efficiency and volume analyses. Comparison of analytical and practical results is provided.

**4th June, Wednesday**
**09:00-11:20 at Akik**
**WeA7 Power Converters, Control, and Energy Management for Distributed Generation II**
**Session Chair :** Masoud Karimi-Ghartemani, Mississippi State University
**Co-Chair :** Peter Palensky, AIT Austrian Institute of Technology

**A linear constant current LED driver with no off-chip inductor or capacitor**
Wang, Chenyang; Xi, Jianxiong; He, Lenian

Zhejiang University, Hangzhou, China,

This paper presents a linear constant current LED driver with no off-chip inductor or capacitor. The proposed circuit consists of a main controller and constant current sources to drive the LED array. An improved control method is used for lighting the LED array step by step, shaping
the output current in proportion to the input voltage. Each constant current source has functions of temperature compensation and over voltage protection. A prototype of a 7×7 LED array has been built to verify the control method. The chip is designed and implemented by using CSMC’s 1 μm 700V process. The post-layout simulation results indicate that under the 220Vrms 50Hz utility voltage, the system can realize a high power factor of 99.76% and a maximum power conversion efficiency of 90.68%.

**Galvanically isolated differential data transmission using capacitive coupling and a modified Manchester algorithm for smart power converters**

Niedermeier, Markus¹; Wenger, Martin¹; Filimon, Radu²; Sedlacek, Victor²; Lorentz, Vincent¹; Fort, Charles³; Marz, Martin¹; Ferrieux, Jean-Paul⁴; Frey, Lothar¹

¹ Fraunhofer IISB, Germany; ² University of Erlangen/Nuremberg, Germany; ³ CEA – LETI, France; ⁴ University Grenoble Alpes, France

In our work we have elaborated the assessment of the student’s performance in engineering modules. In order to maximize the usefulness to the student, such assessments should be individualized and accompanied with helpful and guiding feedback. To this end we have developed a methodology and a system that project the assessment information on independent (vertical) but complementary cognitive planes which form the educational status. This leads to understand in a more effective and deep manner the student’s educational needs, his learning style and eventually his profile. The context has been the engineering courses.

**Universal Control Method for Single Phase Grid-connected and Islanded Converters**

Karimi-Ghartemani, Masoud¹; Khajehoddin, Sayed Ali²

¹ Mississippi State University, Mississippi, USA; ² University of Alberta, Alberta, Canada

A universal control method to operate the single phase inverters was proposed recently. The proposed method can operate the inverter regardless of whether it is connected to a stiff grid, to a weak grid, or to a load. Moreover, the transition between these modes of operation can be performed seamlessly. This feature makes the proposed method promising for smart microgrid applications where flexible and autonomous operation of the inverter is required. The proposed method is self-synchronizing and does not need a dedicated phase-locked loop (PLL). There are no switching actions required in the proposed control structure when the system’s operational modes change. This paper expands on the concept by incorporating the case where the output filter of the inverter is an LCL filter. Moreover, a current limiting mechanism is proposed to avoid over-current caused by grid voltage magnitude drops.

**Multiphase matrix converter for power system application**

Szczepanik, Jerzy

Cracow University of Technology, Poland

A matrix NxM Multiphase Converter (MC) is a very simple structure incorporating NxM bi-directional switches, connecting N input phases to M output phases and able to convert input voltages into output voltages of any shape and frequency. However, commutation problems and complicated control algorithms keep it from being utilized on a large scale. This paper shows a new application field for multiphase matrix converters and its practical realization.
Practical applications of multiphase matrix converter in power system require the study of application requirements, possible converter topologies and the development of new, reliable control algorithms. The MC is working as a connection device between power systems or as an interconnection device within the power system. The proposed tasks performed by the MC in power system are power flow control and power flow oscillations dumping. The device can be viewed as new FACS device- series power system connector, based on straight forward energy conversion.

Analytical Approach for Simultaneous Optimal Sizing and Placement of Multiple Distributed Generators in Primary Distribution Networks

Shahzad, Mohsin1; Ullah, Ikram1; Palensky, Peter1; Gawlik, Wolfgang2

1AIT Austrian Institute of Technology, Austria; 2Technical University of Vienna, Austria

This paper presents a novel analytical expression for finding optimum sizes of multiple Distributed Generators (DGs) simultaneously in order to minimize the power loss reduction ratio. The optimal power factor based on active and reactive power demands by the load is considered for sizing multiple DGs. The generalized analytical expressions for finding optimum sizes of two DGs simultaneously are presented considering mutual coupling factor to reduce the computation time. A brief description of both Exhaustive Load Flow (ELF) method and Improved Analytical (IA) methods are also presented. Systems with varying size and complexity were used for testing and validating the proposed analytical expressions for simultaneous optimal sizing and placement of DGs for active power loss reduction. The test results of IEEE 14 and 30 bus systems using the proposed methodology were compared with ELF and IA methods. Results proved the effectiveness of the proposed method in comparison to the ELF and IA methods.

An Advanced Energy Management of Microgrid System Based on Genetic Algorithm

Elsied, Moataz1; Oukaour, Amrane1; Gualous, Hamid1; Hassan, Radwan2; Amin, Amr2

1University of Caen Basse-Normandie, France; 2Helwan University, Egypt

Immense growth has happened in the field of microgrid (MG) and the energy management system (EMS) methods in the past decade. It is estimated that there is still a huge potential of growth remaining in the field of EMS in the coming years. The main role of EMS is to autonomously determine hour-by-hour the optimum dispatch of MG and main grid energy to satisfy load demand needs. This paper is focused on developing an advanced EMS model able to determine the optimal operating strategies regarding to energy costs minimization, pollutant emissions reduction, MG system constraints and better utilization of renewable resources of energy such as wind and photovoltaic through daily load demand. The proposed optimization model of EMS is formulated and solved based on genetic algorithm (GA). The efficient performance of the algorithm and its behavior is illustrated and analyzed in detail considering winter load demand profile.

Distributed Energy Resources with Home Energy Management in Smart Grid

Zhou, Yimin1,2; Chen, Yanfeng1,2; Xu, Guoqing1,2

1Chinese Academy of Sciences, China; 2The Chinese University of Hong Kong, China

In this paper, an optimal real-time home energy management to regulate the residential appliances is proposed considering renewable energy resources included in the grid. The
appliances can be classified into different groups, where the time shiftable appliances are participated in the scheme to schedule their operational period via the price incentive. An improved binary swarm optimization algorithm is introduced to optimize the usage of household appliances. The parameter settings in the particle location of the algorithm are improved to increase the global searching capability and convergence speed. Besides, the renewable energy resources such as PV panel and wind turbine output are discussed. Simulation experiments are performed to prove the efficacy of the proposed algorithm.
controller implementation.

Securing IEEE 1588 Messages with Message Authentication Codes based on the new SHA-3 Hash Function implemented on FPGAs

Moreira, Naiara; Astarloa, Armando; Kretzschmar, Uli; Lazaro, Jesus; Molina, Elias
University of the Basque Country, Spain

Having a common sense of time is a key factor for many Smart Grid functions, such as the Sampled-Value (SV) process bus operation. The IEC 61850 family of standards recommends the Precision Time Protocol (PTP) for substation communication networks. This protocol allows accuracies in the nanoseconds range using conventional Ethernet networks. But security is only defined as an optional extension and presents several vulnerabilities. In particular, the cryptographic algorithms specified in the standard are suboptimal due to latency and area cost and hence, in this paper, the implementation of the new SHA-3 based MAC in programmable devices is proposed to improve the impact of security on PTP performance.

Power Consumption of Multicore Digital Signal Processor: Theoretical Analysis and Real Applications

Fryza, Tomas; Mego, Roman
Brno University of Technology, Czech Republic

This paper presents the power consumption measurement performed on the multi-core digital signal processor. The selected processor TMS320C6678 from Texas Instruments is suitable for high performance computing, and it is based on very long instruction word architecture. Each core consists of 8 functional units, but the processor’s instruction packets do not require specific operations for all functional units at every CPU cycle. Both theoretical and real-world applications are proposed in the paper and the measurement results show, how power consumption can be affected by using different functional units, as well as the different types of instructions. A model of power consumption on this platform has been proposed for a particular instruction setup.

A Scalable FPGA-based Architecture for Digital Controllers and a Corresponding Rapid Prototyping Design Methodology

Economakos, Christoforos; Tzamtzi, Maria; Economakos, George
1Technological Educational Institution of Sterea Ellada, Greece; 2National Technical University of Athens, Greece

Recent advances in embedded automation applications require quality of results in terms of speed and computational complexity, along with strict time-to-market schedules. To cope with these demands, the design industry is searching for novel approaches. Performance is sought by utilizing modern FPGA devices, offering hundreds of GFLOPs with maximum power efficiency. Productivity is enforced with modern design methodologies like High-Level Synthesis and Electronic System Level design that offer an efficient abstraction level to boost-up early prototyping. This paper presents a scalable architecture and a corresponding design methodology for the design of digital controllers, as a reference for modern control applications. The advantages of the proposed methodology are: (a) improved performance through hardware acceleration of demanding application cores, (b) improved quality of results with floating point calculations, (c) flexibility and integration of common peripheral devices
supported by a RISC microcontroller, (d) low-overhead scalability from single core to multi core architectures and (e) improved designer productivity by working with C level design descriptions only. Experimental results show that the proposed System-on-Chip architecture is an efficient rapid prototyping platform for digital control applications, with very promising future extension capabilities.

Virtualization of FPSoC-based Instruments - An Application Example

Molanes, Roberto Fernandez; Farina, Jose; Rodriguez-Andina, Juan J.
University of Vigo, Spain

This paper analyzes the issues associated to the virtualization of instruments based on Field-Programmable System-on-Chip hardware platforms, with emphasis on communication issues. The main steps for virtualization are described through a real application example, intending to provide designers with guidance through the tasks involved in the process. This avoids the need for them to directly dealing with large amounts of generic documentation and specialized terminology, allowing development and debugging time to be reduced. Experimental results are presented to highlight the usefulness of the virtualized instrument.

A Finite-Time Convergent Algorithm for Systems of Relative Degree More Than One

Basin, Michael; Ramirez, Pablo Rodriguez
Autonomous University of Nuevo Leon, Mexico

This paper presents a data-driven homogeneous continuous super-twisting algorithm for systems of relative degree more than one, which is globally convergent to the origin for a finite time for any initial condition and also robust with respect to disturbances with a bounded changing rate. The designed technique generalizes the seminal continuous supertwisting algorithm, which was proven to be highly effective for stabilization of both system state and its derivative, to systems of relative degree more than one. This advance leads to a possibility of applying a continuous finite-time stabilization control law to technical plants, where a conventional sliding mode control cannot be reliably employed due to effects pertinent to its discontinuous nature, such as short circuiting. Typical examples of industrial electronics devices where the designed technique could be used include induction motors, anti-lock braking systems, vibration attenuators, and many others. This paper presents a homogeneous continuous super-twisting algorithm for systems with relative degree more than one.

Wireless Networked Control System Design: An Overview
Mahmoud, Magdi S.
King Fahd University of Petroleum and Minerals, Saudi Arabia

Wireless networked control systems (WNCS) are attracting an increasing research interests in the past decade. This is particularly relevant for the areas of communication, control and computing where successful design of WNCS brings about new challenges to the researchers. The primary motivation of this survey paper is to examine the design issues, identifying recent guidelines for the issues and to provide directions for successful implementation of WNCS. The paper also as well reviews some simulation tools for such systems.

Control for Discrete-time Fuzzy Markov Jump Systems with Mode-dependent Antecedent Parts
Zhang, Lixian\textsuperscript{1,2}; Yang, Ting\textsuperscript{1,2}; Wu, Fen\textsuperscript{2}
\textsuperscript{1}Harbin Institute of Technology, China; \textsuperscript{2}North Carolina State University, USA

This paper is concerned with the control problem for a class of discrete-time fuzzy Markov jump systems (MJSs). Unlike the common assumption in the existing literature, the antecedent parts of fuzzy rules are mode-dependent, i.e., the premise variables and/or their fuzzy partitions can be different in different modes. Based on a fuzzy basis- dependent and mode-dependent Lyapunov function, the existence conditions of the desired mode-dependent state feedback controller are derived such that the closed-loop system is stochastically stable and achieves a guaranteed performance in the H-infinity sense. Two examples, including a practical example of robot arm, are used to demonstrate the applicability of the obtained theoretical results.

A Review of Thermal Analysis Methods in Electromagnetic Devices
Mohammadi, Rahim\textsuperscript{1}; Mozaffar, Alireza\textsuperscript{2}; Mardaneh, Mohammad\textsuperscript{1}; Darabi, Ahmad\textsuperscript{2}
\textsuperscript{1}Shiraz University of Technology, Iran; \textsuperscript{2}Islamic Azad University, Iran

This paper reviews different methods of thermal analysis, highlighting advantages, drawbacks, and limits. It represents the basics for both analytical methods and numerical ones; which the analytical method is discussed more in detail, including thermal coefficients relevant issues. Also, different applications are investigated, and related analytical and numerical techniques are represented. The aim is to give an exhaustive treatise of the various aspects concerning the thermal analysis. The key issues in thermal problem are represented. This paper is aimed as a tutor for designers who may be unfamiliar with this particular type of concepts; also they are leaded to some useful references for more details and investigation.

A New Adaptive Selective Harmonic Elimination Method for Cascaded Multilevel Inverters Using Evolutionary Methods
Mohammadi, Hamid Reza; Akhavan, Ali
University of Kashan, Iran

In this paper, a new approach for modulation of an 11-level cascaded multilevel inverter using selective harmonic elimination (SHE) is presented. The dc sources feeding the inverter are considered to be varying in time. In this approach the switching angles are obtained offline for different dc source values. Then an artificial neural network (ANN) is trained to determine the switching angles that correspond to the real-time values of the dc sources in each phase. In fact, each one of the dc sources can have different values at any time, but the output
fundamental voltage will stay constant and the harmonic content will still meet the desired specifications. Mathematical methods for harmonic elimination are presented in some of the literatures but solving a non-linear transcendental equation set describing the SHE problem using these methods are not suitable for high level inverters. In this paper, the genetic algorithm (GA) and the particle swarm optimization (PSO) are applied to obtain the switching angles. These techniques can be applied to cascaded multilevel inverters with any number of levels. This paper gives details on the both evolutionary methods. Finally, the results obtained using GA and PSO are compared together and an ANN is trained by the best answer between GA and PSO.

Automated fault detection method in process data based on cluster analysis
Belic, Filip\textsuperscript{1}; Hocenski, Zeljko\textsuperscript{2}
\textsuperscript{1}Tvornica elektro opreme, Croatia; \textsuperscript{2}University Josip Juraj Strossmayer in Osijek, Croatia
This article presents a method for detecting changes in behavior of data. It is based on cluster analysis, which is a common name for methods that group data in segments called clusters, based on similarities and differences of data itself, without supervision of human observer. The data analyzed by clustering techniques are commonly met in process industry: locally constant process values with a lot of noise and sudden changes to completely different values. The experimental application was developed for evaluation of proposed method and gained results prove its quality for several data patterns. This method can be used for automated fault detection applied to industrial process data when data errors are more complex than simple breaching of data limits or minimum and maximum.

Data-Driven Self-Tuning Feedforward Control by Iterative Learning Control
Noack, Rene\textsuperscript{1}; Jeinsch, Torsten\textsuperscript{1}; Sari, Adel Haghani Abandan\textsuperscript{1}; Weinhold, Nick\textsuperscript{2}
\textsuperscript{1}University of Rostock, Germany; \textsuperscript{2}Department Powertrain Mechatronics Gasoline Engine Systems, Germany
In this paper, a data-driven iterative learning control (ILC) based approach for the self-tuning of an existing feedforward controller with fixed structure of a nonlinear system is proposed. Compared to the standard ILC-based approaches, the proposed method consists of two main steps: the first step is the calculation of an input variable, based on an ILC algorithm, and the second step is the optimization of the given parameters of the feedforward controller. The performance and effectiveness of the proposed method are shown using a simulation model of a one stage turbocharged gasoline motor with wastegate.
Real World Battery Diagnostics Model Based and Prius Case Study
Leijen, Peter
AECS Ltd., New Zealand
A new method of diagnosing failure within large series connected battery packs is presented taking the Toyota Prius as a specific case study. The new method involves plotting battery minimum and maximum block number against battery current in a histogram type plot. Failures such as corroded sensing wires, “bathtub” type capacity fading throughout the battery pack and individual module of block failures can be easily identified using this method. A relationship between Cbulk of the two capacitor model and the capacity of the battery module is also briefly presented and confirmed using a measurement of the slope of the discharge curves. The two capacitor model is then built to confirm the new method with good results.

Data-driven estimation of air mass using Gaussian mixture regression
Kolewe, Bjoern; Sari, Adel Haghani Abandan; Beckmann, Robert; Jeinsch, Torsten; Noack, Rene
University of Rostock, Germany
The modelling and calculation of charge cycles with conventional intake manifold pressure based extensions is difficult to implement in real-time for combustion engines with extra actuators in valve train (VVT - variable valve timing) on current control units. Additionally, there is a high parametrization effort due to a variety of engine characteristics of this approach. In this paper we will analyse a cycle based calculation of the air mass with regard to an applicability for estimation in real time on the engine unit as well as varying options of actuators and sensor equipment components of combustion engines. We present a physical based, zero-dimensional model and the problem of its real-time realization is discussed. Furthermore, we will introduce a data-driven alternative for estimation of air mass using Gaussian Mixture Regression (GMR). The GMR allows a flexible data-driven modelling with a high input space dimensions together with a perspective of possibilities of adaption and local optimisation. Subsequently, the proposed method will be applied to a current Volkswagen (VW) Otto engine and the results discussed.

A data-driven fault detection approach for static processes with deterministic disturbances
Luo, Hao1; Ding, Steven X.1; Zhang, Kai1; Yin, Shen2
1University of Duisburg-Essen, Germany; 2Harbin Institute of Technology, China
Based on the well-established model-based fault detection techniques, in this paper, a data-driven fault detection approach for static processes with deterministic disturbances is proposed. The basic idea behind this approach is, first identify the maximum influence of the unknown input on the measurement using the fault-free recorded data, and then apply the existing model-based schemes to solve the fault detection problem. The performance and effectiveness of the proposed scheme are demonstrated through a laboratory continuous stirred tank heater (CSTH) setup.
A Subspace Based Fault Diagnose Method And Its Application On Mechatronics Systems

Wei, Zuolong¹; Yin, Shen²; Karimi, Hamid Reza¹

¹University of Agder, Norway; ²Harbin Institute of Technology, China

The mechatronics systems are widely used in modern society. This paper presents a novel data-driven scheme which can be used for fault diagnose of mechatronics systems. The proposed method is based on the subspace identification of parity vector. By constructing the output observer, critical variables can be acquired by soft sensors. This makes the fault diagnoses free from the limitation of online measurement. A diagnose observer is designed directly from the parity vector. Finally, the proposed scheme is tested by the Simulink benchmark of vehicle suspension and shows its good performance.

RUL prediction based on a new similarity-instance based approach

Khelif, Racha; Malinowski, Simon; Morello, Brigitte; Zerhouni, Noureddine

FEMTO - ST Institute, France

Prognostics is a major activity of Condition-Based Maintenance (CBM) in many industrial domains where safety, reliability and cost reduction are of high importance. The main objective of prognostics is to provide an estimation of the Remaining Useful Life (RUL) of a degrading component/system, i.e. to predict the time after which a component/system will no longer be able to meet its operating requirements. This RUL prediction is a challenging task that requires special attention when modeling the prognostics approach. In this paper, we proposes a RUL prediction approach based on Instance Based Learning (IBL) with an emphasis on the retrieval step of the latter. The method is divided into two steps: an offline and an online step. The purpose of the offline phase is to learn a model that represents the degradation behavior of a critical component using a history of run-to-failure data. This modeling step enables us to construct a library of health indicators (HI’s) from run-to-failure data which are then used online to estimate the RUL of components at an early stage of life, by comparing their HI’s to the ones of the library built in the offline phase. Our approach makes use of a new similarity measure between HIs. The proposed approach was tested on real turbofan data set and showed good performance compared to other existing approaches.

Characterizing Leakage Current on Polluted Insulators by Measuring Nonlinearity

Sokolowski, Peter; Li, Xiangjun; Yu, Xinghuo; Feng, Yong

RMIT University, Australia

A new approach based on a nonlinearity measure to study the leakage current signature is proposed. Using this approach profiles for clean insulators, contaminated insulators with various contamination levels in dry and wet conditions are established. The nonlinearity measure captures a range of magnitudes for leakage currents exhibiting different signatures.
The insulator nonlinearity measure decreases when the insulator is either wetted, contaminated or both wetted and contaminated. The change in this measure is significant in identifying the ‘health state’ of contaminated insulators and in flashover prediction, especially since contamination is one of the main causes of insulator failure, which thereafter may cause power system outages and threaten life. Further, this approach has the added advantage of application in identifying other types of disturbance waveforms which model-based and spectrum analysis methods lack.

**Improving the Performance of Speed Sensorless Induction Motor Drive with Rotor Broken Bar Failure by Stator Current Signature Analysis**

Verma, Vimlesh; Chakraborty, Chandan

*Indian Institute of Technology, India*

This paper proposes a new method to improve the performance of indirect vector controlled speed sensorless induction motor (IM) drive under rotor bar fault. When a rotor bar fault occurs, the parameter of the system is altered. This creates a mismatch between estimated speed and actual speed of the drive. The difference magnifies with load and with more number of rotor bar failures. As the drive is speed sensor free, there is no direct way to find the deviation in speed. However, indirect estimation is possible through sensing the stator currents. Occurrence of rotor bar fault produces oscillating component in the torque-producing-component of stator current. Frequency of this oscillation is estimated using the proposed method and is used to calculate the actual rotor speed. This results in improvement of the drive performance. A newly proposed X-MRAS based speed sensorless algorithm is used. However, the proposed algorithm can also be used for other existing speed sensorless drive. The proposed approach is simulated in MATLAB/Simulink and experimentally validated through a dSPACE-1104 based laboratory prototype.

**Performance Analysis of IEEE 802.15.4 real-time Enhancement**

Dariz, Luca; Malaguti, Giorgio; Ruggeri, Massimiliano

*IMAMOTER-CNR, Italy*

The IEEE 802.15.4e amendment provides different modalities over which Wireless Sensor Networks (WSNs) can be deployed, even with strict requirements in terms of latency and determinism; still, there seems to be room for improvement. This paper proposes two enhancements for IEEE 802.15.4e LLDN mode: (1) allowing a reduced and more predictable configuration time and (2) focusing on the worst-case latency for high-priority traffic. A comparison with standard LLDN is then performed and evaluated, either through Monte Carlo simulations or analytically.

4th June, Wednesday
14:00-15:40 at Sedef

**Web5 Photovoltaic Converter Topologies and Control I**

Session Chair : Haitham Abu-Rub, Texas A&M University at Qatar

Co-Chair : Giovanni Spagnuolo, Universita degli Studi di Salerno
Impedance Design of 21-kW Quasi-Z-Source H-Bridge Module for MW-Scale Medium-Voltage Cascaded Multilevel Photovoltaic Inverter

Liu, Yushan1,2; Abu-Rub, Haitham2; Ge, Baoming1,3; Peng, Fangzheng4
1Beijing Jiaotong University, China; 2Texas A&M University at Qatar, Qatar; 3Texas A&M University, USA; 4Michigan State University, USA

An impedance parameter design of quasi-Z-source (qZS) H-bridge inverter module applied to megawatt (MW)-scale medium-voltage Photovoltaic (PV) power system is proposed. A double-line-frequency (2ω) voltage and current ripple model of qZS network with PV panel is established. The effects of qZS inductance and capacitance as well as PV panel terminal capacitance on 2ω voltage and current ripples are investigated by using the built model. Elaborate designed prototype parameters are to buffer those low-frequency ripples. Simulations are carried out on a 21-kW single-phase qZS PV inverter to verify the proposed 2ω-ripple model and impedance design method.

Multi-dimension Diode Photovoltaic (PV) Model for Different PV Cell Technologies

Soon, Jing Jun; Low, Kay-Soon; Goh, Shu Ting
Nanyang Technological University, Singapore

Different types of photovoltaic (PV) cell technologies have been commercially used for various applications. These cell technologies can be categorized as multicrystalline, mono-crystalline and thin film. Due to the differences in PV cell technologies, a single PV model is unable to model all the output characteristics. The single and double diode PV models have been widely used for modeling the output characteristic of a PV module. This paper introduces a generalized multi-dimension diode PV model which can be used to select the most suitable dimension for a particular PV cell technology. The results confirm that the single diode PV model is suitable for the multi-crystalline and mono-crystalline PV modules. For the thin film PV module, a multi-dimension diode PV model is required to achieve a low modeling error.

Asymmetric Cascaded Converter for Solar PV Applications

Perez, Marcelo A.; Kouro, Samir
Universidad Tecnica Federico Santa Maria, Chile

Solar photovoltaic energy systems have received increasing attention during the last years due mainly to the cost reduction of solar panels and the availability of power converters specifically designed for these applications. Small scale photovoltaic plants have been installed to fed houses and small business whether connected to the grid or stand-alone. In the latter case, the converter must provide a high quality output voltage even with non-linear loads. In this paper the design and control scheme of an asymmetric cascaded converter for small scale PV applications is shown. The converter proposed is based on a main stage which provides the active power to the load and a secondary stage that generates the reactive power compensation. It is shown that this asymmetric converter can work with higher voltage ratios than previously published asymmetric converters and can generate high quality output voltages for both linear and non-linear three-phase loads. The proposed converter is analysed and design guidelines are given. Results that shown the performance of the converter and its control system are presented.
About the Criteria for triggering the Reconfiguration of a Photovoltaic Array

Spagnuolo, Giovanni¹; Petrone, Giovanni¹,²; Manganiello, Patrizio¹; Carotenuto, Pietro Luigi¹

¹Università degli Studi di Salerno, Italy; ²Seconda Università degli Studi di Napoli, Italy

The dynamical reconfiguration of the photovoltaic array is a feasible method for maximizing the electrical power it produces in presence of partial shading. Although in literature some algorithms aimed at determining the best configuration to be settled for a given shadowing pattern have been presented, no indications about the electrical conditions that can trigger the reconfiguration procedure have been discussed. In this paper some criteria for understanding if the photovoltaic array working conditions have changed, so that a new electrical connection among the modules can increase the produced power, are discussed. Moreover, some conditions revealing that the reconfiguration process can be delayed are analyzed as well. Simulation results are used for achieving the results shown in the paper and give some indications for improving the criteria formulated herein.

Analysis of Short Term and Long Term Characteristics of PV Power Production

Perez, Marcelo A.; Zapata, Jaime

Universidad Tecnica Federico Santa Maria, Chile

Solar photovoltaic (PV) energy has one of the fastest growth among renewable energies, reaching an installed capacity of 100 GW in year 2012, mainly due by the cost reduction of PV panels. However, one of the main disadvantages of this kind of energy source is their highly variability. The main source of variability is, of course, the day/night cycle. Nevertheless, short-term effects such as cloud shadowing and supply interruptions and long-term effects such as dust accumulation; seasonal variation and ageing of panels will also appear as sources of variability. The combined effect of all these variability sources makes the analysis of the power production data very complex. The reliability and accuracy of this data analysis could become significant because it is required to expand the PV plant size, to design a new one, to incorporate energy storage for power smoothing or to economically evaluate the PV system. This work presents a methodology to obtain statistically consistent data from a PV plant, in order to evaluate all the mentioned effects separately. The method is based on the correlation of PV power production data with an ideal value of solar power obtained from geographical and astronomical data. The proposed methodology is applied to data obtained from a PV plant located in northern Chile.

4th June, Wednesday
14:00-16:00 at Topaz
WeB6 Power Converters, Control, and Energy Management for Distributed Generation III
Session Chair : Akshay K. Rathore, National University of Singapore
Co-Chair : Hisham Mahmood, The University of Western Ontario

Harmonics and Interharmonics Estimation of DFIG based Standalone Wind Power Plant
Detection of harmonics and inter-harmonics produced by wind power plant is very challenging task for the modern power system researchers. This paper presents estimation of harmonics produced by wind generator under variable wind speed by sliding window ESPRIT and sliding window Root-MUSIC algorithm. The series of simulation results demonstrate advantages of the sliding window ESPRIT over the sliding window Root MUSIC in estimation of harmonics and inter harmonics generated by standalone doubly fed Induction Generator.

A New Power Management Control Strategy for a MV Microgrid with Both Synchronous Generator and Inverter-Interfaced Distributed Energy Resources

Hamzeh, Mohsen2; Zangeneh, Mohsen2; Mokhtari, Hossein1; Karimi, Houshang3

1Sharif University of Technology, Iran; 2Shahid Beheshti University, Iran; 3Polytechnique de Montreal, Canada

Control strategies of a microgrid which includes both synchronous generators and converter-based distribution generation (DG) units must be designed such that effective operation of the microgrid is achieved. The main objective of this paper is to develop a high performance control strategy for an islanded medium voltage (MV) microgrid consisting of inverter and non-inverter interfaced DG units. A new control method for the synchronous generator in an islanded microgrid is proposed based on a virtual droop scheme. The proposed strategy can effectively manage the real and reactive powers of the microgrid among the inverter and non-inverter based DG units. The steady state and dynamic responses of the MV microgrid is significantly improved by using the proposed power management scheme. The performance of the proposed control strategy is verified by using digital time-domain simulation study in the PSCAD/EMTDC software environment.

A Control Strategy of a Distributed Generation Unit for Seamless Transfer Between Grid Connected and Islanded Modes

Mahmood, Hisham; Jiang, Jin

The University of Western Ontario, Canada

In this paper, a control strategy for a distributed generation (DG) unit that provides a seamless transition between grid connected mode and islanded mode is presented. Instead of switching between current control and voltage control modes as commonly proposed in the literature, a voltage control mode is used in both grid connected and standalone modes. The output voltage and frequency are controlled to regulate the reactive and real power injected into the grid, respectively. In the islanded mode, the output voltage and frequency of the DG unit are regulated at their nominal values. Therefore, transition between operation modes is achieved by switching the voltage and frequency references of the same voltage controller. When the grid is interrupted, the DG unit supplies only the load automatically with no abrupt transients in the local load voltage and current, even before the islanding is detected. The principle and implementation of the control strategy to detect the grid conditions and islanding, and to switch seamlessly between the two operating modes are developed. The control strategy is validated through simulations using a detailed switching models in the PSCAD/EMTDC environment.
Design of a Pitch Controller using Disturbance Accommodating Control for Wind Turbines under Stochastic Environments

Cheon, Jongmin\textsuperscript{1}; Kwon, Soonman\textsuperscript{1}; Choi, Youngkiu\textsuperscript{2}

\textsuperscript{1}Korea Electrotechnology Research Institute, South Korea; \textsuperscript{2}Pusan National University, South Korea

This paper describes a design of a wind turbine pitch controller based on the disturbance accommodating control (DAC) theory. Wind turbine systems generally operate under stochastic environments, such as random wind inputs and noise corrupted sensor signals. Especially wind inputs can be treated as persistent disturbances and DAC can play a role in reducing effects of wind disturbances. By doing this, wind turbines suffer less from mechanical fatigue loads and their lifespan can be increased. Because wind disturbances we must accommodate are stochastic, we design DAC for stochastic plants and compare with other controllers not considering stochastic conditions to verify the performances of our proposed controller.

Comparison of Bi-directional Voltage-fed and Current-fed Dual Active Bridge Isolated Dc/Dc Converters Low Voltage High Current Applications

Rathore, Akshay K.; Pan, Xuewei

National University of Singapore, Singapore

This paper presents a comparison of two potential soft-switching bi-directional high-frequency transformer isolated voltage-fed and current-fed dual active bridge dc/dc converters for fuel cell vehicle application. The comparison and discussion are conducted over the suitability of these two converters acting as a front-end dc/dc converter for a fuel cell inverter from the perspective of the circulating and peak currents, RMS currents through the devices, components’ ratings, size, losses, and efficiency. Software package PSIM 9.0.4 has been utilized to justify the merits of current-fed converter over voltage-fed converter for the given application. Experimental results of current-fed converter have also been provided. Switching losses are reduced significantly owing to zero-current switching (ZCS) of primary switches and zero-voltage switching (ZVS) of secondary switches, which allow high switching frequency operation resulting in a compact and low cost system.

Improvement of Grid Current Performance for Grid-Connected DG under Distorted Grid Voltage and Nonlinear Local Loads

Trinh, Quoc-Nam; Lee, Hong-Hee

University of Ulsan, Korea

The presence of grid voltage distortion and nonlinear local load are badly impact on the performance of grid-connected distributed generation (DG). This paper introduces an enhanced current control strategy to improve the grid current performance of grid-connected DG under such scenario. The proposed current controller is designed in the synchronous reference frame and composed of a proportional-integral (PI) controller and three resonant controllers tuned at 6n (n = 1, 2, 3) of fundamental frequency. The proposed controller is operated without demand of local load current measurement, which means that no extra hardware is required to achieve good performance of the grid current. The DG with the proposed current controller can transfer a sinusoidal current into the utility grid despite the presence of distorted grid voltage and/or nonlinear local load. Various test cases are
considered and experimental results are given to verify the effectiveness of the proposed current controller.

Towards a Smart Walker Controller for Physiotherapy and Rehabilitation Purposes
Valadao, Carlos¹; Bastos, Teodiano¹; Frizera, Anselmo¹; Carelli, Ricardo²
¹Federal University of Espirito Santo, Brazil; ²National University of San Juan, Argentina

Mobility-aid is a very important research field with studies being made in several institutions around the world. People who suffer lack of mobility have problems in their daily tasks and those who still have remaining forces have a strong indication to work with their residual forces in physiotherapy sessions. The proposed Smart Walker is designed to help people who need to undergo physical rehabilitation and work these remaining locomotion potentials. It is called UFES’S Smart Walker and uses a laser sensor to detect the user’s gait and has a control system to ensure the user’s distance and angle related to the walker.

Mobile Robotics: A Tool for Interaction of Children with Autism
Goulart, Christiane M.; Castillo, Javier; Valadao, Carlos; Caldeira, Eliete; Bastos-Filho, Teodiano F.
Federal University of Espirito Santo, Brazil

This paper presents an implementation with mobile robot to generate actions to interact with children with autism. The robot is able to detect the child localization and approach him/her, keeping a safe proximity minimum (interaction distance). The mobile robot is equipped with laser sensor to obtain distances and an embedded control system for the interaction. The implementation allows two modes of interaction, depending on the degree of interaction with the child. The system here developed can help children with autism in the process of social evolution and be a tool for professionals and researchers of the area.

Intelligent algorithm for music playing robot -Applied to the anthropomorphic piano robot control
Li, Yen-Fang; Lai, Chi-Yi
Ming-Hsin University of Science and Technology, Taiwan

Simple and friendly operation interface, intelligent calculation, high performance control and driving circuit, and precision and reliable plant are necessary conditions for intelligent robot design. In this paper, an intelligent algorithm is proposed for the piano robot control with an interactive program and an automatic control code generator. The interactive program of man-machine interface makes the musical score input is simple and friendly as the piano
keyboard playing. This interactive program can identify the musical beat and note automatically while the user plays the keyboard on PC monitor. The interactive program of man-machine interface makes the musical score input is simple as the piano keyboard playing. This program can identify the musical beat and note automatically while the user plays the keyboard on PC monitor and then the musical score is built. The control code generator, an intelligent algorithm, will convert the musical score to generate a series of optimum positions commands accordingly for the hands and fingers of the piano robot to play a piano. The optimum positions commands are programmed with crashing protection and minimum movement for the hands and fingers to anthropomorphize the robot. Via the algorithm operation, the music control codes are generated automatically to replace the situation of manual coding and give the ability of intelligent thinking for the piano robot.

**Damping of the torsional vibration using adaptive fuzzy control system with different recurrences**

Knyczas, Sebastian; Derugo, Piotr; Szabat, Krzysztof

*Wroclaw University of Technology, Poland*

In the paper an adaptive control system with the different type of the neuro-fuzzy speed controller for drive system with flexible joint is proposed. A model reference adaptive control structure (MRAC) is used. The comparative analysis of the system performance with Mamdami and TSK type with different recurrent feedbacks is presented. The tensional vibrations are successfully suppressed in the control structure with only one basic feedback from the motor speed. The damping ability of the proposed system has been confirmed for a wide range of the system parameters.

**Modeling, Design and Fault Analysis of Bidirectional DC-DC Converter for Hybrid Electric Vehicles**

Al-Sheikh, Hiba¹; Bennouna, Ouadie¹; Hoblos, Ghaleb¹; Nazih, Moubayed²

¹IRSEEM ESIGELEC, France; ²Lebanese University, Lebanon

This paper presents modeling, design and analysis of a bidirectional half-bridge DC/DC converter suitable for power electronic interface between the main energy storage system and the electric traction drive in hybrid electric vehicles. A hybrid energy storage system composed of a battery unit and an ultra-capacitor pack is considered. A parallel dc-linked multi input converter with a half-bridge bidirectional DC/DC cell topology is chosen to link the battery/ultra-capacitor storage unit with the dc-link. The paper focuses on modeling the proposed converter for both dynamic and steady state analysis. Averaging and linearization techniques are applied to obtain the averaged state space models and small signal models of the converter in both boost and buck operation modes. A criterion for sizing the converter passive components based on the imposed design specifications and constraints is illustrated. Simulation results of the buck-boost converter during normal functioning and under faulty conditions are presented. In particular, short-circuit fault sand open-circuit faults of diodes and transistors are analyzed.

**Sinusoidal PWM Modulation Technique of Five-Phase Current-Source-Converters with Controlled Modulation Index**

Elgenedy, Mohamed A.¹; Abdel-Khalik, Ayman¹; Elseroughi, Ahmed A.¹; Ahmed,
Applications such as multiphase machine drives and wind energy conversion systems are normally based on voltage source converters (VSCs) which feature a convenient and familiar control scheme. In high-power medium voltage drives, three-phase current source converters (CSCs) are widely used owing to its simple topology, motor-friendly waveforms, power reversal capability, and short-circuit-inherited protection. Although controlling CSCs in three-phase is a troublesome, multi-phase CSCs gating generation and control are challenging. In this paper, a sinusoidal PWM-based controlled modulation index gating signal generator is introduced for five-phase CSCs. Two different simulation models have been built, using MATLAB/SIMULINK, to verify the proposed concept on rectification and inversion modes of the CSCs. The proposed controller provides a controllable linear modulation index with the availability of over modulation.

**Design of the Traction Battery for a Formula SAE Racing Car**
Baronti, Federico; Calderini, Daniele; Caposciutti, Gianluca; Gassani, Andrea; Moras, Riccardo; Saletti, Roberto
*University of Pisa, Italy*

This paper describes the design of the traction battery for the new electric Formula SAE vehicle of the University of Pisa. A model based design methodology extended to the mechanical, electrical and thermal domains was applied to find the best trade-off between the battery weight and the maximum power available at the wheel. The designed battery configuration was validated by means of electrical and thermal simulations.

**The Optimized Capacity for Lithium Battery Balance Charging/Discharging Strategy**
Chang, Yong-Nong\textsuperscript{1}; Shen, Yu-Siang\textsuperscript{1}; Cheng, Hung-Liang\textsuperscript{2}; Chan, Shun-Yu\textsuperscript{3}
\textsuperscript{1}National Formosa University, Taiwan; \textsuperscript{2}I-Shou University, Taiwan; \textsuperscript{3}Cheng Shiu University, Taiwan

This paper proposed an optimized strategy to enhance the capacity of a cascaded Lithium battery pack. An active balance system is used to elongate the life cycle of Lithium battery pack. The proposed techniques cover active balance circuit, digital balance control module and Lithium battery pack capacity optimized control strategy. By integrating E-class series resonant circuit, shunted multi-winding transformer, balance control switch and digital control module, the cell charging/discharging process will be divided into ten intervals. Every interval has its own linear voltage versus surplus charge capacity relationship with corresponding slope. Different proper balance factor is defined for each interval to determine the action of balance switch. The cell with voltage is below the average. The experiment is performed by using Lithium battery pack 16S1P to investigate the charging/discharging behavior of each cell and define balance factor to switching action of balance control switch. The battery pack function will be measured when experiencing charge imbalance and optimized strategy is employed to complete the balance requirement.

**A Mathematical Lithium-Ion Battery Model Implemented in an Electrical Engineering Simulation Software**
Rael, Stephane; Urbain, Matthieu; Renaudineau, Hugues
Université de Lorraine, France

This article presents some applications for our mathematical model of lithium-ion battery. This model is based on Newman’s works, and includes migration and diffusion of species and charges in electrodes and electrolyte, electric double layer capacitance, and solid-electrolyte interface layer. Using electrical analogies of transport phenomena, it is directly implemented in standard simulation software used in electrical engineering. The paper recalls the fundamental model of lithium ion battery. Then, it briefly explains how the analog model is obtained from mass and charge transport equations. At last, some examples of simulation are shown (lithium plating abacus, electrochemical impedance spectroscopy, including SEI) to demonstrate the advantages of our modeling method.

Influence of Thermal Cycling on Supercapacitor Performance Fading During Ageing Test at Constant Voltage

Ayadi, Mohamed1,2; Briat, Olivier1; Lallemand, Richard 2; Coquery, Gerard 2; Vinassa, Jean-Michel1

1Univ. Bordeaux, France; 2IFSTTAR, LTN, France

In this paper, we focus on impacts of thermal cycling ageing on super capacitors performances at a constant voltage. We compare obtained results with those coming from simple calendar ageing at constant temperature and voltage. The comparison is based on physics modeling parameters evolution based on results from experimental measurements during calendar ageing up to 10000 h and 6000 h, 8000 h for thermal cycling tests. Finally, the impacts of thermal cycling interval is highlighted and quantified.

Implementation on MicroBlaze of AES Algorithm to Reveal Fake Keys Against Side-Channel Attacks

Lumbiarres-Lopez, Ruben1; Lopez-Garcia, Mariano2

1Universitat Politecnica de Catalunya, Spain; 2Universitat Rovira i Virgili, Spain

This paper presents a new proposal for hiding the cryptographic key, when the so-called side-channel attacks (SCAs) are applied to break the security of AES-128. The algorithm was executed on Micro Blaze, but the proposed method is generic and can be extended to any other microprocessor. SCAs are based on examining the correlation produced between the data and operations performed by the microprocessor and its actual power consumption. Traditionally, such weakness is counteracted by introducing countermeasures addressed to reduce as much as possible this correlation, making data and power consumption independent. On the contrary, the proposal presented in this paper introduces some modifications in the AS algorithm. These changes aim at concealing the true key by reinforcing the correlation coefficient in such a way that a classical attack leads to a false key. This way, the system misleads the attacker and apparently behaves as an unprotected system that, in fact, reveals a false positive. The complete system was built on a Virtex-5 FPGA. Experimental results show the strength of our implementation, which is capable of successfully hiding the true cryptographic key.

Comparative Analysis of Boost and Quasi-Z-Source Converters as Maximum Power Point Trackers for PV Panel Integrated Converters

Zakis, Janis; Rankis, Ivars; Ribickis, Leonids
This paper analyzes two maximum power point tracking (MPPT) converter topologies that are part of an interface converter for the integration of photovoltaic (PV) in the grid. Two different MPPT converter topologies (boost converter and quasi-Z-Source (qZS) converter) were selected and compared. Theoretical comparison includes an analysis of regulations for obtaining continuous source current and comparison of necessary parameters of the reactive elements of the systems. 270 W experimental prototypes of both converters were built and experimentally compared. Theoretical and experimental efficiency estimation is proposed and discussed. Also, the losses in diodes and MOSFETs are evaluated taking into account technical data from datasheets.

Analysis and Control of Seven-Phase Permanent-Magnet Bearingless Motor with Single Set of Half-coiled Winding

Li, Bingnan; Huang, Jin; Liu, He; Hou, Zhaowen
Zhejiang University, China

In this paper, a seven-phase inset-type permanent magnetic bearing less motor is proposed with characters as the treble frequency suspension force compensation and elimination of the affection of the third plane to the suspension plane. The winding configuration and harmonic distribution are presented. Then, the analysis formulations of inductance and suspension force of the proposed motor are presented and verified by Finite Element Analysis (FEA). Furthermore, the control system is proposed based on the derived voltage model, torque model and suspension force model with the rotor eccentricity being considered. Finally, the Simulink simulation is provided on a prototype motor to verify the validity of the analysis.

Reliability assessment in the design of interleaved converters under multi-physical constraints

Bendali, Mahraz1; Larouci, Cherif1; Azib, Toufik1; Marchand, Claude2
1ESTACA Engineer School, France; 2Paris Sud University, France

This paper presents the integration of the reliability assessment in a pre-design approach of interleaved converters for embedded automotive applications. This approach’s based on a multi-physic optimization to pre-size the entire converter and its components. The design constraints are progressively integrated, in addition the reliability aspect of power components is considered in the early steps of the design. The proposed method is applied to an Interleaved Buck Converter IBC. It allows to pre-size converter determining the optimal number of cells under multi-physics constraints such as electric, efficiency, thermal, volume and in particularly there liability, which is considered in same level of pre-design to eliminate all risk of feasibility. This paper describes the reliability assessment approach of the converter using the FIDES methodology for components reliability. Therefore, this approach takes account of mission profile associated with operating conditions to assess the lifetime of power converter.

Stability analysis and effects of dampers on Series active compensator

Javadi, Alireza; Hamadi, Abdelhamid; Al-Haddad, Kamal
University of Quebec, Canada

Although, series compensators including dynamic voltage restorer and series active filters in
general are considered reliable, a stability analysis of their configuration and their control algorithm is mandatory before their large propagation in the power system. The stability study of three-phase controllers applied in drives and Active filters seems complex and unusual. Thus, this paper presents a comprehensive approach to evaluate the stability of a typical control algorithm by means of Laplace transforms in frequency domain. Furthermore, the paper focus on the stability of LC filters implemented in series compensators to eliminate high frequency harmonics of the power converter. Then, the effect of passive dampers is evaluated. This frequency domain interpretation of three-phase passive filter could be used in stability analysis of various three-phase systems. Moreover, simulation and experimental results are presented to validate the theoretical approach.

Voltage Stability Study of Micro-grid with Asynchronous Wind Turbine in Islanding Mode

Sun, Hai; Han, Min-Xiao; Luo, Chao; Xia, Huang-Rong
North China Electric Power University, China

In islanding mode, the surge current during startup and shutdown of asynchronous wind turbine and its power fluctuations can be a significant challenge to the stable operation of micro-grid. Energy storage based micro-grid stability controller has been proved effective for micro-grid control. This paper analyses the performance of the micro-grid stability controller considering its capacity, the control strategy and the line impedance. The minimum necessary capacity of the energy storage and maximum line impedance limitation for micro-grid voltage stability are presented theoretically and verified by simulation. Finally, the transient process of grid-connection and disconnection of asynchronous wind turbine are studied with the developed micro-grid stability controller by field experiment.

Development of Students’ Activity through On-Lecture Assessment in Electrical Engineering

Vodovozov, Valery; Raud, Zoja; Gevorkov, Levon
Tallinn University of Technology, Estonia

The analysis of the promoted innovative setups and practices of educational systems revealed the necessity to develop an active learning approach. On-lecture assessment methods developed in the active learning context and introduced into Electronics, Power Electronics, and Electrical Drives promote ultimately students’ progress increasing the quality of learning. To motivate students, specific self-assessment modules were prepared in the scope of the institutional learning content management system. They encourage the students to acquire the methods, skills, and experience related to the real power electronics and drives equipment in a manner that is very close to the way they are being used in industry. This approach helps the teachers to interact with students and to utilize their practical experience and knowledge to improve course applicability and attraction.

Generalized Classification of PV Modules by Simplified Single-Diode Models

Cannizzaro, Stefano; Di Piazza, Maria Carmela; Luna, Massimiliano; Vitale, Gianpaolo
Consiglio Nazionale delle Ricerche (CNR)-Istituto di Studi sui Sistemi Intelligenti per l’Automazione (ISSIA), Italy

This paper proposes a theoretical study supporting the use of simplified single-diode photovoltaic (PV) models to accurately reproduce the behavior of PV generators. In particular, a newly defined parameter is introduced, which allows to classify PV modules according to the
possibility to neglect either the series- or the shunt resistance in the circuit model. On such a basis, equations allowing to identify the non-neglected resistance and the other unknown model parameters, are derived. The resolution of such equations is non-iterative, therefore, the proposed approach is suitable for on-line parameter identification, for example for supporting a maximum power point tracking circuit. The accuracy of the proposed method is assessed by practical cases of PV model parameter extraction.

**Optimal L2-L Infinity Filtering for Markovian Jump Repeated Scalar Nonlinear Systems**

Zheng, Zhong; Hu, Zhongrui; Li, Fanbiao; Wu, Ligang
Harbin Institute of Technology, China

This work studies the optimal L2-L Infinity filter design problem for discrete-time Markovian jump repeated scalar nonlinear systems. The design focus is full- and reduced order filters which guarantee the filtering error system to be stochastically stable with a prescribed weighted L2-L Infinity performance. Firstly, both the mode dependent Lyapunov function approach and the positive definite diagonally dominant Lyapunov function technique are employed to establish a sufficient condition that guarantees the Markovian jump repeated scalar nonlinear system to be stochastically stable with an induced L2-L Infinity disturbance attenuation performance. Secondly, the corresponding full-order filter design is transformed into a convex optimization problem, which can be efficiently handled using standard numerical algorithms. Finally, a numerical example is presented to show the effectiveness of the proposed design.

**A Novel SVPWM Scheme for Vienna Rectifier without Current Distortion at Current Zero-crossing Point**

Yao, Wenxi; Lv, Zhengyu; Zhang, Ming; Lin, Zhuang
Zhejiang University, China

Vienna rectifier is one of the most popular topologies for three-phase PFC converter. DC voltage, grid current double loop controller and three-level SVPWM are normally used to control the Vienna rectifier. Accurately detecting the current zero-crossing point is required to achieve the correct SVPWM signals since the output level of Vienna rectifier is also decided by the direction of the phase current. The error of the duty ratio’s decided by the error time of the current zero-crossing point detecting and the duty ratio before and after the current zero-crossing point. It can be concluded that the impact of current zero-crossing will be eliminated if the switches near current zero-crossing point are kept “on”. To achieve this goal, a novel SVPWM scheme is proposed by using the certain state combinations of short vectors in each sector. In this method, the calculation of duty ratio will not be affected by the direction of phase current near the zero-crossing point, and therefore the distortion of current caused by current zero-crossing detection error will be eliminated. Simulations and experiments are conducted to verify the presented method.

**Harmonic Mitigation Performance of the Power Inverter based DG in a AC Microgrid**

Geng, Hua; Lv, Qing; Yang, Geng
Tsinghua University, China

Harmonic impedance is important issue for voltage quality of the micro grid when nonlinear load exists. The distributed generator (DG) unit with different control frame and parameters
would have different harmonic impedance. This paper compares the harmonic mitigation property of the current-controlled DG (CC-DG) and voltage controlled DG (VC-DG) unit. The paper clears following results with analysis and simulations.

**Improved Switched Boost Inverter with Reducing Capacitor Voltage Stress**

Nguyen, Minh-Khai¹; Hoang, An-Quoc¹; Le, Tuan-Vu²; Park, Sung-Jun²; Choi, Joon-Ho²; Kim, Se-Jin²; Lim, Young-Cheol²

¹University of Technical Education, Vietnam; ²Chonnam National University, Korea

This paper presents an improved switched boost inverter (SBI) with reducing the capacitor voltage stress. The improved SBI topology has the same component to the conventional SBI. Operating principles, analysis and comparisons with the conventional inverters are presented. A prototype based on a TMS320F28335 DSP is built to verify the operating principle of the improved SBI.

**H-Infinity Loop shaping Controller Design of Micro-Source Inverters to Improve the Power Quality**

Bouzid, Allal El Moubarek; Cheriti, Ahmed; Sicard, Pierre

Université du Québec à Trois-Rivières, Canada

The introduction of micro grids in distribution networks based on power electronics facilitates the use of renewable energy resources, distributed generation (DG) and storage systems while improving the quality of electric power and reducing losses thus increasing the performance and reliability of the electrical system. The main objective of this paper, is designing $H_\infty$ controllers for a control scheme based on decoupled models, which includes an inner current loop and an outer voltage loop for micro-source grid-connected inverter. The robust controller is designed for the grid-forming using structured uncertainties to improve the performance of the system facing parametric uncertainties. The controller is evaluated by simulation to demonstrate the performance of the proposed strategy for the nominal case and perturbed parameters cases.

**Single-Phase Grid-Tied Photovoltaic System with Boost Converter and Active Filtering**

Oliveira da Silva, Sergio; Sampaio, Leonardo; Campanhol, Leonardo

Federal Technological University of Parana, Brazil

This paper deals with a single-phase grid-tied photovoltaic system, which can operate, simultaneously, as shunt active power filter and injecting active power into the grid. The photovoltaic system is composed of DC/DC step-up (boost) converter and full-bridge DC-AC converter, performing both reactive power compensation and harmonic current suppression generated by nonlinear loads. The photovoltaic system is implemented utilizing an equivalent electric model, and its maximum power point is tracked by means of P&O algorithm, which is used to control the DC-DC step-up converter. The algorithm adopted to obtain the current reference of the DC-AC converter is based on the synchronous reference frame (SRF) method. Furthermore, an anti-islanding technique is implemented, in order to guarantee the safe operation of photovoltaic system. Simulation results are present to validate the proposed control strategy, and to verify the system feasibility.

**Tracking Control of Class E Inverter for the Duty Cycle Control**
Class E resonant inverter is often applied to design a high frequency AC power source. Based on the zero voltage switching (ZVS) operation, the class E converter has high converting efficiency even the converter works at high frequency. In general, the output power needs to be controlled for practical application. The power output of class E inverter can be adjusted by regulating the duty ratio of the switch turn on. Unfortunately, the ZVS operation will fail while the operated duty ratio changes without adaptive tuning the switching frequency. Based on the Fourier series expansion, the fundamental component of load current is analyzed for the class E inverter while it is controlled by duty cycle and switching frequency. The phase shifting of the load current is an important message for ZVS examining. Without complicated mathematical model and numerical iteration, a close form formula has been proposed to calculate the phase shifting from the duty ratio and switching frequency. By the obtained phase shifting, a tracking controller is proposed to achieve the close loop control for keeping the class E inverter works on ZVS operation while the operated duty ratio is regulated. To illustrate the proposed method, both the examples of theoretical simulation and circuit simulation are given.

Integration of a Large-Scale Photovoltaic Plant Using a Multilevel Converter Topology and Virtual Synchronous Generator Control

Torres, Miguel¹; Espinoza, Jose¹; Moran, Luis¹; Rohten, Jaime¹; Melin, Pedro²
¹Universidad de Concepcion, Chile; ²Universidad del Bio-Bio, Chile

This work investigates the integration of large-scale photovoltaic (PV) plants to the grid. In particular it presents a case study where a cascaded H-bridge topology based on single phase current-source inverters (CHB-CSI) is used as the grid interface of the PV plant and a control technique named virtual synchronous generator (VSG) is used in order to contribute to the stability of the grid by providing inertial response and primary frequency control to the PV plant. For all the three simulated cases the proposed control strategy for the PV plant was always capable to perform the VSG functions (inertial response and damping), even when one of the PV arrays output power went down to 10 %. However, simulation results also showed that in some cases the voltage variations were close to 100 % and even 300 % of its nominal value. Even though the execution of the VSG was always successful, the obtained results indicate that voltage loops are needed in order to keep the output voltages at a safe level.

Dual Stator Induction Generator with Controllable Reactive Power Capability

Basak, Saptarshi; Chakraborty, Chandan; Sinha, Avinash K.
Indian Institute of Technology Kharagpur, India

Dual stator winding induction generators (DSWIG) can provide controlled excitation and hence offer a brushless alternative to traditional synchronous machines or doubly fed induction machines (where a 2nd supply is injected to the rotor through a converter-inverter systems). These generators are a potential candidate for extraction of power from renewable energy resources such as wind, micro-hydro etc. as these are very robust and require the least maintenance. Such systems are also suitable for on-grid/off-grid operation in a micro-grid. This paper deals with a model reference adaptive system based reactive power controller. The excitation winding of the DSWIG is fed from an inverter and controlled in synchronism with the
power winding to achieve rotor flux orientation and direct reactive power control. Extensive simulations on SIMULINK validate the proposed method.

An optimal pole placement state feedback with feed forward digital control applied to a three-level NPC inverter implemented in FPGA
Pedroso, Marcelo Dias; Nascimento, Claudinor Bitencourt; Kaster, Mauricio dos Santos; Tusset, Angelo Marcelo
Federal University of Technology of Parana, Brazil
This paper presents an Optimal-Pole-Placement Control (OPPC) combined with feedforward (FF) scheme to control a 1φ-3L-NPC-Inverter. The OPPC is an optimal linear state feedback control that improves the transient response time with controlled input/output current and voltage overshoot. The inclusion of a feedforward branch between the reference signal and duty-cycle strategy ensures null steady state error and it reduces the output voltage distortion as well as the response time of the DC bus capacitor voltage balancing. To verify the performance of the NPC-Inverter, the proposed control is compared to a dual PI voltage and current control loops strategy. For both control schemes, the system uses just a voltage sensor, with the current calculated from the voltage. Simulations results using the Altera DSP Builder software in a Matlab/Simulink environment are presented to demonstrate the NPC-Inverter performance implemented in FPGA.

Sensorless Operation of an Active Front End Converter with LCL filter
Wrona, Grzegorz; Malon, Kamil
Warsaw University of Technology
In this paper sensorless control method for an Active Front End (AFE) converter is presented. Developed algorithm’s based on Voltage Oriented Control (VOC), extended by additional Voltage Dips Compensation (VDC) module. Moreover improved Virtual Flux (VF) estimator based on SOGI-QSG for LCL filter has been shown. This new sensorless control method can assure sinusoidal and balanced grid currents even during strong voltage dips. To avoid large current overshoots, new universal startup procedure has been developed. Operation relies on turning the zero vector on for a short time and measuring the currents growth. This allows synchronize and soft starts with and without load connection at any grid voltage condition. Simulation and laboratory results illustrate operation of the developed control method in steady states and transients.

Fault diagnosis of the continuous stirred tank heater using fuzzy-possibilistic c-means algorithm
Yin, Shen; Zhang, Jingxin
Harbin Institute of Technology, China
This paper mainly introduces a practical algorithm called fuzzy-possibilistic c-means (FPCM) clustering algorithm. It is based on fuzzy c-means (FCM) clustering algorithm and possibilistic c-means (PCM) clustering algorithm. FPCM algorithm figures out the existing problems of the above two algorithms and produces both memberships and possibilities simultaneously. For example, FPCM algorithm works out the inconsistency problem of FCM algorithm and overcomes the coincident clusters problem of PCM algorithm. Then this paper applies FPCM algorithm to the fault detection and diagnosis of the continuous stirred tank heater CSTH). The
effect of the fault diagnosis approach is demonstrated on the CSTM benchmark.

Start-up Control With Constant Precharge Current for the Modular Multilevel Converter

Li, Binbin; Zhang, Yi; Xu, Dianguo; Yang, Rongfeng

Harbin Institute of Technology, China

One specific issue associated with the modular multilevel converter (MMC) is that the capacitors of the submodules (SMs) need to be precharged before MMC begins its normal operating. Otherwise, a large inrush current will occur if these SM capacitors were not charged to the rated value. This paper proposes a novel start-up control scheme for MMC, in which the closed-loop control is adopted to regulate a constant rms precharge current with a unity power factor. As such, the SM capacitors will be linearly precharged to the rated value without any inrush current and much shortened charging time. Moreover, this scheme requires no extra power supply and is very flexible as it can be easily implemented into any MMC application regardless of the power rating and the number of SMs. Finally, a three-phase MMC prototype has been built in the laboratory to verify the effectiveness of the proposed start-up control scheme.

Prototype Design and Experimental Verification of Modular Multilevel Converter Based Back-to-back System

Li, Binbin; Xu, Dandan; Xu, Dianguo; Yang, Rongfeng

Harbin Institute of Technology, China

This paper presents the design and control methods for a modular multilevel converter (MMC) based back-to-back (BTB) system. A 20kW, 50Hz three phase downscaled prototype is constructed to show the working principles, hardware design procedures, and control circuits implementation. In this prototype, there are two MMC stations, namely the inverter and the rectifier, each consisting of 18 full-bridge (FB) sub-modules (SMs). Each station is controlled by an independent controller. Moreover, the management and communication methods of these sub-modules are also illustrated. Further, the control principles for the MMC based BTB system are presented as well to achieve power regulation and balance all the SM capacitor voltages. Finally, experimental results are given to verify the validity of the circuit design and show the effectiveness of the control methods.
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