ELECTRIMACS 2019 Salerno

The 13th
International Conference
of IMACS TC1 Committee

Salerno, Italy
20th-23rd May 2019

CONFERENCE PROGRAMME

Monday 20th May 2019

12:00 – 13:40	Registration UNISA, Campus di Fisciano
14:00 – 15:00	TUTORIALS - part 1 UNISA, Campus di Fisciano
15:20	COFFEE BREAK
15:40 – 16:40	TUTORIALS - part 2 UNISA, Campus di Fisciano
17:00 – 17:40	
18:00 – 18:40	Registration at GHS
19:00 – 21:00	Welcome reception (Grand Hotel Salerno)

Tuesday 21st May 2019

	Room VIETRI	Room FURORE	Room POSITANO	Room MAIORI
08:00	Registration (Foyer Conca)			
09:00	Opening			
09:30 – 10:10	Plenary session P1			
10:30	COFFEE BREAK			
11:00 – 12:40	TT1-A	TT2-A	SS5-A	SS2-A
13:00 – 14:00	LUNCH			
14:20 – 16:00	TT1-B	TT2-B	SS9-A	TT4-A
16:20	COFFEE BREAK			
16:40 – 18:40	TT1-C	TT3-A	SS8	TT4-B
19:00				

Wednesday 22nd May 2019

	Room VIETRI	Room FURORE	Room POSITANO	Room MAIORI
08:00	Registration (Foyer Conca)			
08:30 08:50 09:10 09:30 09:50 10:10	TT1-D	SS1-A	SS5-B	SS11
10:30	COFFEE BREAK			
11:00 11:20 11:40	TT3-B	SS1-B	TT4-C	SS6-A
12:00 12:20 12:40	Plenary session P2			
13:00 13:20 13:40 14:00	LUNCH			
14:20 14:40 15:00 15:20	IF Industry Forum	SS3	IMACS TC1 meeting	
15:40	COFFEE BREAK			
16:00 16:20 16:40 17:00	SS2-B	SS6-B	IMACS TC1 meeting	SS7
17:20 17:40 18:00 18:15	Meeting point for social dinner (bus service) Grand Hotel Salerno lobby, 18:15			
18:30 23:30	**Social dinner** ***Hotel CETUS, Cetara***			

Thursday 23rd May 2019

	Room VIETRI	Room FURORE	Room POSITANO
08:00	Registration (Foyer Conca)		
08:30 08:50 09:10	TT1-E	TT2-C	Battery 2030+ Forum
09:30 09:50 10:10	Plenary session P3		
10:30	COFFEE BREAK		
11:00 11:20 11:40 12:00 12:20 12:40	TT1-F	TT2-D	SS9-C
13:00	Closing		
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ELECTRIMACS 2019 Salerno

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Welcome to ELECTRIMACS 2019

On behalf of the Organising committee, it is a great pleasure and an honour to welcome you in Salerno for the 13th international conference of the IMACS TC1 Committee, better known as ELECTRIMACS! For the first time since the first edition in 1984, ELECTRIMACS conference comes to Italy!

ELECTRIMACS 2019 Salerno is an international conference on theory and application of modelling, simulation, analysis, design optimization, identification and diagnostics in electrical power engineering. The conference is a meeting point for researchers to share ideas and advances in the broad fields of electric machines and electromagnetic devices, power electronics, transportation systems, smart grids, electric and hybrid vehicles, renewable energy systems, energy storage, batteries, supercapacitors and fuel cells.

The technical programme includes three tutorial sessions, hosted at the University of Salerno, Fisciano Campus, three plenary sessions with thought leaders from academia and research centres, four technical tracks, and two forums. The conference programme is enriched by nine special sessions on fast modelling (SS1), applications and challenges in the field of photovoltaics (SS2, SS3), energy storage, batteries, supercapacitors, and fuel cells (SS5, SS8, SS9), graphene-based devices (SS7), resilient high-power quality renewable systems (SS6), and, finally, safety issues in electrical installations (SS11).

The conference hosts 133 oral presentations of papers, selected among 169 submissions received. The review process involved at least three reviewers per paper. In addition, six abstracts were accepted for presentations in the framework of SS9. These talks mainly focus on technological aspects of supercapacitors and batteries. Two small forums, including presentations from businesses (Mathworks, Ansys, and Bitron) and from Battery 2030+ initiative, enrich the scientific programme. In total, **ELECTRIMACS 2019 Salerno** will host 149 talks by speakers from 27 countries.

For this edition, a MATCOM special issue will collect invited post-conference full papers fitting the scope of the journal. Authors will be invited to submit conference-related full papers after the conference, and these will be peer reviewed. For the first time in this 13th edition, two Springer books in the series *Lecture Note in Electrical Engineering* will be associated to the conference. They will collect conference papers particularly focussed on electrical engineering simulation aspects and innovative applications. Thus, all papers presented at the conference will appear in one of the aforementioned publications, after a selection process conducted at the end of the conference.

Now, it is time to acknowledge all the individuals and institutions that contributed to the organisation of **ELECTRIMACS 2019 Salerno.**

We are grateful to the local organising committee and the administrative secretariat, the technical programme chairs, the track and special session chairs, the plenary spe-

akers, the tutorial presenters, the members and honorary members of the ELECTRIMACS international committee (IMACS TC1), and the reviewers for their fundamental contribution to the conference. In particular, we would like to thank the chairman of the IMACS TC1 international committee, Prof. Benoit Robyns, the Vice Chair, Prof. Ramon Blasco-Gimenez, the previous Chair, Prof. Eric Monmasson, for their help and continuous support to the organisation of ELECTRIMACS 2019 Salerno. We also thank our colleague Prof. Giovanni Spagnuolo, who continuously shared this experience with us.

We are truly indebted to the President of IMACS, Dr. Rosa Maria Spitaleri, for her long standing support to ELECTRIMACS, and for dedicating a special issue of the Elsevier MATCOM journal to the 13th edition of the conference. We also thank Springer Managing Editor Maria Bellantone and Sam Harrison for their support in the definition of the new Springer publication associated to the conference.

We would like to thank our institutional sponsors for their contribution to the success of the conference. In particular, the Dipartimento di ingegneria dell'Informazione ed Elettrica e Matematica Applicata (DIEM), Università degli studi di Salerno, Italy. We also thank IEEE Industrial Electronics Society (IES) for the technical co-sponsorship and involvement in the organisation of the conference, as well as for the Student and Young Professional Assistance programme activated for ELECTRIMACS 2019. We also thank the Institut Français – Italia, and the Ambassade de France en Italie for the co-sponsorship in the framework of Programma CASSINI.

A warm thanks goes to our sponsors: Ansys, Bitron, MathWorks, and Opal-RT, as industrial leaders in important areas of interest for the ELECTRIMACS community.

Last but not least, we thank all the ELECTRIMACS 2019 authors, attendees and exhibitors, because the success of **ELECTRIMACS 2019 Salerno** surely belongs to them.

Enjoy the Conference, enjoy Salerno!

Walter Zamboni and Giovanni Petrone
ELECTRIMACS 2019 General chairs

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F. Labrique, *Belgium*
R. Le Doeuff, *France*
J.P. Louis, *France*
J. Peracaula, *Spain*

■ Technical tracks

TT1 - Modelling and simulation

Efstratios Batzelis, Imperial College, London, *United Kingdom*
Maria Carmela Di Piazza, ISSIA-CNR Palermo, *Italy*
João Pedro Trovão, University of Sherbrooke, *Canada*

TT2 - Control and power management

Carlos Andres Ramos Paja, Universidad national de Colombia, *Colombia*
Seiichiro Katsura, Keio University, *Japan*
Eftichios Koutroulis, Technical university of Crete, *Greece*

TT3 - Design and optimisation

Mario Cacciato, Università degli studi di Catania, *Italy*
Bruno Sareni, ENSEEIHT, *France*
Dmitri Vinnikov, Tallinn University of Technology, *Estonia*

TT4 - Identification and diagnosis

Federico Baronti, Università di Pisa, *Italy*
Pavle Boskoski, Jožef Stefan Institute, Ljubljana, *Slovenia*
Marie-Cecile Pera, Université de Franche-Comté, *France*

SS1 – Fast modelling approaches for electromagnetic devices analysis and design

Yacine Amara, GREAH, Université Le Havre Normandie, *France*
Georges Barakat, GREAH, Université Le Havre Normandie, *France*

SS2 – Innovative Modelling and Simulation Approaches for new technologies in Photovoltaic Systems

Martha Lucía Orozco Gutierrez, Industrial Control Research Group, Universidad del Valle, *Colombia*
Patrizio Manganiello, Photovoltaic Department, IMEC/EnergyVille, Genk, *Belgium*

SS3 – Emerging Challenges in Fault Detection, Diagnosis and Prognosis in Photovoltaic Applications

Patrizio Manganiello, Photovoltaic Department, IMEC/EnergyVille, Genk, *Belgium*
Martha Lucía Orozco Gutierrez, Industrial Control Research Group, Universidad del Valle, *Colombia*
Ioannis Tsanakas, Photovoltaic Department, IMEC/EnergyVille, Genk, *Belgium*

SS5 – Energy storage systems: new power electronics topologies, high-performance control techniques, and hardware emulation

Massimiliano Luna, National Research Council (CNR-INM), Palermo, *Italy*
Alexandre De Bernardinis, SATIE / IFSTTAR, *France*

SS6 – Future power electronics for resilient high-power-quality grid-connected renewable energy systems: design, modelling and control

Hadi Y. Kanaan, Saint-Joseph University of Beirut, *Lebanon*
Maurice Fadel, Laplace Laboratory, INP Toulouse, *France*

SS7 – Graphene-based devices: modelling and experimental results

Patrizia Lamberti, Università degli studi di Salerno, Fisciano (SA), *Italy*
Polina P. Kuzhir, Research Institute for Nuclear Problems, Belarusian State University, Minsk, *Belarus*

SS8 – Advancements on models, methods and devices for monitoring and diagnosis of fuel cells

Pierpaolo Polverino, DIIN, Università degli studi di Salerno, Fisciano (SA), *Italy*
Samuel Simon Araya, Department of Energy Technology, Aalborg University, Aalborg, *Denmark*

SS9 – Challenges in battery and supercapacitor technologies

Francesca Soavi, Department of Chemistry “Giacomo Ciamician”, University of Bologna, *Italy*
Silvia Bodoardo, Dipartimento di Scienza Applicata e Tecnologia, Politecnico di Torino, *Italy*

SS11 – Safety related issues in electrical installations

Fabrizio Marignetti, DIEI, University of Cassino and South Lazio, *Italy*
Piergiacomo Cancelliere, Italian National Fire Rescue and Service, Ministry of Interior, *Italy*

■ Plenary speakers

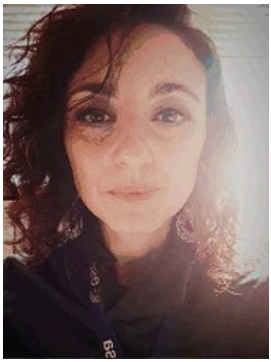
Nicola Femia is Professor at the University of Salerno, Italy, where he teaches Power Electronics, Energetic Intelligence, and Green Energy Digital Control in the Electronic Engineering and Computer Engineering Master Programs. His research activities encompass circuit theory and applications, design and optimization of switching power supplies, magnetic power components modeling and optimization, power electronics and control techniques for photovoltaic systems, wireless power transfer systems. He is co-author of more than 180 scientific papers, one book and six patents. He leads the Power Electronics and Renewable Sources Laboratory of the Computer and Electrical Engineering and Applied Mathematics Department of the University of Salerno. In the last two decades he has directed and developed many research and education projects on power electronics, in collaboration with worldwide leader companies, including National Semiconductor, Texas Instruments, National Instruments, STMicroelectronics, Power-One/ABB, Whirlpool, Coilcraft, Wurth. He held more than 50 invited lectures, courses and seminars on Power Electronics Design and Education for universities and industries over Europe, United States, China and India.

In 2014 he has been Visiting Professor in the Electrical Engineering Department of the Stanford University, Stanford, CA, where he taught Power Electronics Control and Energy Aware Design in the Electrical Engineering Enhanced Master Program. He is the author and co-creator of the Texas Instruments Power Management Laboratory Kit (TI-PMLK), of the Texas Instruments Power Electronics board for National Instruments Elvis III, of the TI-PMLK BUCK-Wurth Elektronik Edition, and relevant curricula, which are worldwide used nowadays in universities and industries for power electronics education and training.

Seddik Bacha was born in Ighram, Algeria in 1958. He received the Engineering and Magister degrees from the National Polytechnic School of Algiers, Algiers in 1982 and 1990, respectively. He joined the Grenoble Electrical Engineering Laboratory (G2Elab) and received the PhD and HDR degrees in 1993 and 1998, respectively. His research interests are based on the modeling and the control of electrical energy processes: Renewable energy systems, Intelligent buildings, V2G, microgrids and HVDC supergrids.

He served as Assistant Professor during six years in Algeria at the National Polytechnic School of Algiers and University of Bgayet-Bejaïa. In 1993 he has been appointed as Assistant Professor at Grenoble University and got Professor position in 1998. He has recently co published a book on Grid Optimal Integration of Electric Vehicles. He is an Associate Editor of IEEE Transactions on Industrial Electronics since 2015. His personal work deals with the optimization of energy flows in microgrids, the integration of renewable energies, the real-time control of unconventional loads (V2G, Intelligent Building) and finally HVDC systems.

He is currently Program Scientific Director and Scientific Council Chair at the SuperGrid Institute of Energy Transition (France), and Research Officer within Grenoble Electrical Engineering of Grenoble.



Mariel Triggianese, of Italian Nationality, took the degree in Electronics Engineering in 2004 at Università della Campania Luigi Vanvitelli, where she also pursued Ph.D. in "Conversione dell'energia elettrica" in 2007. In 2008 she started a post-doct in Space power electronics at European Space Agency (ESA), in the European Space Technology and Research Centre (ESTEC) in Noordwijk, The Netherlands. From 2010 she is working as Power Conditioning Engineer in the Electrical Department in ESA/ESTEC, supporting Space Projects and new Research and Development activities.

■ Tutorial venue

Tutorials will be held at:

Edificio E (blue block)
Università degli studi di Salerno
Campus di Fisciano
Via Giovanni Paolo II 132 – 84084 Fisciano (SA)

Urban bus lines 7 and 17 connects Fisciano Campus with Salerno city centre and train station. The bus takes from 20 to 30 minutes to go from Salerno to Fisciano.

Registration desk:	**SALA VIDEOCONFERENZA** FSTEC-05P01056 (first floor)
Tutorial 1:	Aula Maurizio Mangrella FSTEC-05P01053 (first floor)
Tutorial 2:	Laboratorio T25 FSTEC-05PTE022 (ground floor)
Tutorial 3:	Aula multimediale 118 FSTEC-06P01038 (first floor)


UNIVERSITÀ DEGLI STUDI DI SALERNO
Campus di Fisciano
INGRESSO NORD
(da raccordo SA-AV/A30)
INGRESSO SUD
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BUS TERMINAL
MENSA
RESIDENZE
ADISU
PIAZZA DEL SAPERE
SEGRETERIA
CHIOSTRO DELLA PACE
PIAZZA DE ROSA
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PARCHEGGIO MILITARE

■ Conference venue

About Salerno

Salerno is located in Campania region, very close to the wonderful Amalfi Coast (UNESCO World Heritage Site) and to Pompeii and Paestum (famous archaeological sites).

It is easy to get to Salerno from Napoli International Airport as well as from other Italian cities connected by TAV (high speed trains). More information is available ot the Travelling to Salerno web page.

Conference venue

The conference will be held at

Grand Hotel Salerno
Lungomare Clemente Tafuri 1
84127 Salerno, Italy
http://www.grandhotelsalerno.it/

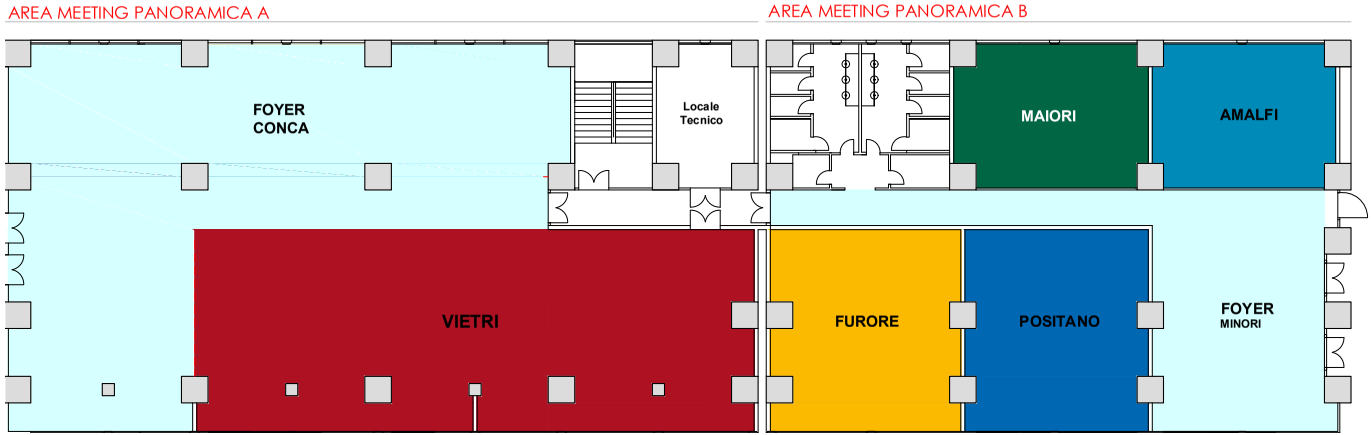
The hotel and conference centre is located on Salerno seafront, close to the main train station (walking distance: 7 min) and the city centre.

Internet connection

Internet connection will be available to Conference delegates in the GHS conference centre.

Wifi name: CAMERE
user id: utente
password: ghssalerno

ELECTRIMACS 2019 Salerno Meeting area
Grand Hotel Salerno - First floor



■ Social events

Welcome cocktail

Sala Atena, Grand Hotel Salerno
Monday 20th May 2019, 19:00-21:00

Social Dinner at Hotel Cetus

Hotel Cetus
Cetara, Amalfi Coast
Wednesday 22nd May 2019, 18:15-23:30
Meeting point for bus service: Grand Hotel Salerno lobby, 18:15

The conference participants will enjoy the social dinner in the magnificent venue of Hotel Cetus, near Cetara, the historic fishing village. Set on a promontory that overlooks an enchanting bay, the Hotel Cetus commands a breathtaking view on the beautiful Amalfi Coast. The elegant décor and the refined atmosphere is inspired by the tradition of Vietri ceramics. The Purple Tie quintet will liven up the event.

SCIENTIFIC PROGRAMME

■ Programme at a glance

Monday 20th May 2019

12:00 – 13:40	Registration *UNISA, Campus di Fisciano*
14:00 – 15:00	TUTORIALS - part 1 *UNISA, Campus di Fisciano*
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13:00	Closing		
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17:20 17:40 18:00 18:15 18:30 23:30			

Monday 20th May 2019
Aula Maurizio Mangrella | 14:00

TU1 – Tutorial 1

14:00 Smart transformer: its impact on distribution grid

■ *Rongwu Zhu*

The LV electric distribution grid is experiencing new challenges in terms of voltage and current limits violation, low inertia and low power quality due to the steadily increasing penetration of distributed generators and EV charging stations, leading to required reinforcement in electric grid. DC distribution and more controllability can reduce the needed reinforcement, and the Smart Transformer enables both. This tutorial introduces the Smart Transformer concept, considering architectures and power converter topologies aiming at high efficiency and reliability. Control strategies for the LV-grid to increase the distribution grid hosting capacity of the renewables and charging stations as well as innovative faulty management functionalities to ensure the continuity services are introduced.

Rongwu Zhu is a post-doctoral researcher associate at the Chair of Power Electronics of the Christian-Albrechts Universität zu Kiel, Germany. He received the PhD degree from Aalborg University, Demark, Dec. 2015. Since 2016, he joined the ERC Grant project “Highly Reliable And Efficient smart Transformer (HEART)”. He has published over 60 technical papers (about 20 of them in international peer-reviewed journals) and held two granted and one pending patents. He is member of IES and has organized several special sessions on the topic of Smart Transformer at the international conferences.

Monday 20th May 2019
Laboratorio T25 | 14:00

TU2 – Tutorial 2

14:00 Advanced control strategies dedicated to power electronics systems

Serge Pierfederici, Jean-Philippe Martin and Babak Nahid-Mobarakeh

Design of passive storage elements in power electronics systems are closely bound to dynamical performances of the systems. Improvement of these dynamical performances can be realized thanks to advanced control strategies applied to power electronics systems. Another way to decrease costs of power electronic systems, is to develop sensoreless control using a reduce numbers of sensors. Ended it is possible to remove mechanical or electrical sensors to cheaper systems or for reliability purposes.

In this tutorial, we will follow the following outline:

- Motivation: we will show throw practical examples the effect of control laws on the design of passive elements.
- Controller design using Energetic approaches: Flatness based control and Passivity based control applied to power electronics and drive
- Observer design in power engineering: from extended Kalman Filter to non-linea observers applied to power electronics and drive.

Serge Pierfederici received the Dipl.-Ing. degree in electrical engineering from the Ecole Nationale Supérieure d'Electricité et de Mécanique (ENSEM) of Institut National Polytechnique de Lorraine (INPL), Nancy, France, in 1994, and the Ph.D. degree from the Institut National Polytechnique de Lorraine (INPL), Nancy, in 1998. Since 1999, he's working at the Lorraine University, where he is currently a Full Professor. His research activities deals with the stability study of distributed power system, the control of DC and AC microgrids and the design of power electronic converters for specific applications like fuel cells systems, electrolyser.

Jean-Philippe Martin received the graduation degree from the University of Nancy, Nancy, France, and the Ph.D. degree from the Institut National Polytechnique de Lorraine (INPL), Nancy, in 2003. Since 2004, he is an Assistant Professor at University of Lorraine and member of the lemta since January 2018. His research interests include DC and AC microgrid with centralized or decentralized control, multi-vector microgrid combining electrical, thermal and hydrogen vectors, stability study of distributed power system, static converter architectures and their interactions with fuel cell and photovoltaic system.

Babak Nahid-Mobarakeh received the Ph.D. degree in electrical engineering from the Institut National Polytechnique de Lorraine (INPL), Nancy, France, in 2001. From 2001 to 2006, he was at the Centre de Robotique, Electrotechnique et Automatique, University of Picardie, Amiens, France. In September 2006, he joined the Ecole Nationale Superieure d'Electricite et de Mecanique, Université de Lorraine, Nancy, where he is currently a Professor. Dr. Nahid-Mobarakeh is the author or coauthor of more than 250 international peer reviewed journal and conference papers as well as several book chapters and patents. He has been the recipient of several IEEE awards. Dr. Nahid-Mobarakeh was the General Co-Chair of the 2015 IEEE Transportation Electrification Conference and Expo (ITEC). Between 2012 and 2017, he served as Secretary, Vice Chair and Chair of the Industrial Automation and Control Committee (IACC) of the IEEE Industry Applications Society (IAS). Currently, he is the Past Chair of the IACC. He is also the IACC Committee Administrator. His main research interests include nonlinear and robust control design of power converters and drives, fault detection and fault-tolerant control of electric systems, and design, control and stabilization of microgrids.

TU3 – Tutorial 3

14:00 Design, modelling and control of linear induction motors

Marcello Pucci, Ion Boldea

The main subject of the tutorial are linear induction motors (LIMs). Starting from a brief structural description of such motors, their main applications will be exposed in the tutorial with specific reference to MAGLEV (Magnetically Levitation) vehicles, urban people movers, X-Y planar motion industrial platforms, launchers, actuators for industry and automotive. As a first step, the main differences between rotating and linear induction motors will be highlighted, focusing on the aspects of static and dynamic end effects as well as transversal edge effects. The typical structure of LIMs will be treated, with specific reference to secondary sheet and primary winding configurations. Single-sided LIMs (S-LIMs) and Double-sided ones (D-LIMs) will be described, focusing on normal force effects. Design criteria of LIMs will be specifically exposed, emphasizing the main differences with the classic rotating induction motor design, caused by the presence of large air-gaps, high leakage inductances as well as the end effects. The static and dynamic models of LIMs will be introduced, including the so called end-effects. Suitable parameter estimation methods will be then described. Afterwards, control techniques specifically devised for LIMs, like field oriented control, input-output feedback linearization control and active disturbance rejection control will be introduced. Finally, sensorless techniques specifically developed for LIMs will be shown.

Table of contents:

- Intro on linear motors (LIMs)
- Main applications of LIMs
- Linear Induction Motors (LIMs)
- Main differences between LIMs and RIMs
- Structures of LIMs and differences with RIMs
- Secondary sheet and primary winding configurations
- Design criteria of LIMs and differences with RIMs
- Mathematical Models of LIMs (static and dynamic)
- Parameter Estimation of LIMs
- Control Techniques for LIMs

Marcello Pucci received the Laurea and Ph.D. degrees in electrical engineering from the University of Palermo, Palermo, Italy, in 1997 and 2002, respectively. In 2000, he was a Host Student with the Institute of Automatic Control, Technical University of Braunschweig, Braunschweig, Germany, involved in the field of control of ac machines, with a grant from the German Academic Exchange Service. From 2001 to 2018, he has been with the Institute of Intelligent Systems for Automation, National Research Council of Italy. He is currently a Senior Researcher with the Institute of Marine engineering, National Research Council of Italy. His current research interests include electrical machines, control, diagnosis, and identification techniques of electrical drives, and intelligent control and power converters. Dr. Pucci is currently an Associate Editor for the IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS. He is a member of the Editorial Board of the Journal of Electrical Systems.

Prof. Ion Boldea, IEEE Life Fellow, worked and published extensively (patents, papers, books), delivered keynote addresses, intensive courses in EU, USA, Brazil, S. Korea etc on “Rotary and linear electric machines drives and MAGLEVs design control and testing”. He is the recipient IEEE 2015 Nikola Tesla Award.

Tuesday 21st May 2019
Room VIETRI | 09:00

OS – Opening session

09:00 Conference opening

- *Giovanni Petrone and Walter Zamboni – General Chairs*
- *Benoît Robyns – IMACS TC1 Committee (ELECTRIMACS) Chairman*

Tuesday 21st May 2019
Room VIETRI | 09:30

P1 – Plenary session 1

Chair: Éric Monmasson

09:30 From Power Electronics to Energetic Intelligence: an evolutionary challenge for designers and educators

- *Nicola Femia*

Power Electronic Circuits provide electrical energy to all the objects making our life more comfortable, safer and funnier, like smart phones and watches, aircraft and automobiles, implanted prostheses and magnetic resonance machines, blenders and microwave ovens, robots and drones, digital TV sets and personal computers.

The Design of Power Electronic Circuits is an exciting intellectual dare for students and educators, as it stimulates insight of interdisciplinary knowledge, understanding of new technologies, exploration of unconventional modeling and design solutions, discovery of the power of mathematics, reinforcement of problem solving capability, intelligent use of the energy and ultimately preservation of the environment and of the Earth's resources. Power Electronic Circuits have today to implement much more enhanced energy processing functions than in the past. University education and industry training has to coherently enhance, to proactively drive this evolution and to guide talented students and designers towards the achievement of powerful professional skills. The presentation intends to overview modern power electronics design issues and to propose a vision of the knowledge, methods and tools needed to bridge power designers to the land of Energetic Intelligence.

TT1-A Modelling and simulation

Chairs: Maria Carmela Di Piazza and Efstratios Batzelis

11:00 Comparison of two dynamic models for a DC railway electrical network including a power electronics based bi-directional power station

N'Guessan Kouassi, Khaled Almaksour, Nicolas Navarro, Christophe Saudemont, Bruno François, Lionel Taunay, Tony Letrouvé, Benoît Robyns

ID 131 – To face environmental issues, SNCF, the French railway operator, has chosen to improve the energy efficiency of its power network by investigating solutions for regenerative braking. With the contribution of Railenium, a research and test center in the railway area, they aim to recover the braking energy by setting up a reversible inverter at the DC power station "Masséna". In this paper, the modelling of the railway electrical network including the reversible station is addressed by using AC and DC equivalent sources. The results of this modelling are then compared with the ones obtained from Esmeralda, the SNCF professional software. A first configuration is led without inverter and gives certified Esmeralda results. It is used as a validation of the discussed model despite some gaps in powers and voltages due to differences in input data. A second comparison with the inverter is also achieved. Indeed, a strategy considers the inverter as a storage system in order to reproduce its operation. The proposed model as it includes the real power electronic inverter and its associated control system allows the refinement of the Esmeralda results. For the case study, the recovered energy evolves from 17 kWh with Esmeralda to 8.5 kWh.

11:20 Topological modelling and simulation of gas networks for multi-energy applications

Enrico Vaccariello, Pierluigi Leone, Flavio Canavero, Igor Simone Stievano

ID 72 – This paper addresses the generation of a topological model of a gas network to be used in an integrated multi-carrier energy co-simulation framework. The study is based on a set of three real gas networks and emphasis is put on both a unified graph-based description and a steady-state simulation carried out via an electrical circuit analogy and classical tools for circuit analysis. An isothermal assumption is also considered and validated. The proposed approach turns out to be a first step toward a simple and viable solution for the efficient co- simulation of a possibly complex energy scenario involving renewables, electrical and gas networks.

11:40 Enhanced DC Microgrid Control for a Fast and Stable DC Bus Voltage

Sonia Moussa, Manel Jebali-Ben Ghorbal, Ilhem Slama-Belkhodja

ID 89 – DC microgrids are the new trend for renewable energy distributed systems due to their high efficiency and more suitability to new load appliances. However, some problems are still open to discussion as it is an emerging concept. In a DC microgrid, a very important issue consists on an enhanced control of the DC bus voltage.

This control should be reliable especially towards power flow variations which can be caused distributed sources generation or by abrupt load demand. These oscillations are also caused by special load type called Constant Power Loads (CPL) when connected to the DC bus voltage due to the negative impedance they induce between source converter and load side. To overcome the above mentioned problems, this paper investigates two primary level controls to ensure a constant DC bus voltage with good performances firstly when a CPL is connected and secondly when a power flow change occurs from the source side or even the load one. The first control is based on cascaded PI regulators and the second one is a nonlinear control. Both controls performances are compared for different load points using PSIM and simulation results are presented and discussed.

12:00 Integrated design process and sensitivity analysis of a hybrid electric propulsion system for future aircraft

Matthieu Pettes-Duler, Xavier Roboam, Bruno Sareni

ID 91 – This paper is situated in the framework of future hybrid electric aircrafts which embedded weight minimization and maximization of power efficiency are the key challenges to address fuel reduction and environmental constraints. In the first part, the integrated design process aiming the overall power train optimization is described. The second part presents models specifically oriented towards the integrated design. Finally, a sensitivity analysis is carried out at the power train system level to study the influence of both electric components specific powers and efficiencies on the Maximum Take Off Weight (MTOW) and on the fuel burn of the hybrid propulsion aircraft.

12:20 Optimization of offshore wind farms with HVAC and HVDC transmission networks

Asma Dabbabi, Salvy Bourguet, Mohamed Machmoum, Rodica Loisel

ID 134 – Recently, offshore wind farms have attracted more and more attention because of their greater energy capacity. To get the best performances of a wind farm park, a technical and economic compromise between energy yields and overall investment must be established. In this paper, a study was done on Borssele I & II offshore wind farm with HVAC and HVDC transmission technologies to compare their performances with different transmission distances.

12:40 Forecasting of renewable energy-related time series by NARX ANN for electrical grid management

Annalisa Di Piazza, Maria Carmela Di Piazza, Giuseppe La Tona, Massimiliano Luna

ID 155 – Forecasting of meteorological variables is crucial for accurate planning and management of electrical power grids, aiming at improving overall efficiency and performance. In this paper, an artificial neural network (ANN)-based technique is investigated for short-term forecasting of the hourly wind speed and solar radiation. Specifically, the non-linear autoregressive network with exogenous inputs (NARX) ANN is considered, compared to other models, and then selected to perform multi-step-ahead forecasting. Different time horizons have been considered in the range between 8 and 24 hours ahead. The main advantage of the proposed method is that it reconciles good forecasting performance with a very simple network structure, which is potentially implementable on a low-cost processing platform.

TT2-A Modelling and simulation

Chairs: Seiichiro Katsura, and Giovanna Adinolfi

11:00 Electrical Load Forecasting by means of Echo State Network in view of Demand Response Programs

Muhammad Mansoor · Francesco Grimaccia · Sonia Leva · Marco Mussetta

ID 148 - The electrical load forecasting is a fundamental technique for load prediction of consumers for a utility. The accurate load forecasting is crucial to Demand Response (DR) programs in the paradigm of smart grids. Artificial Neural Network (ANN) based techniques have been widely used in recent years and applied to predict the load with high accuracy to participate in DR programs for commercial, industrial and residential consumers. This research work is focused on the use of two ANN based load forecasting techniques, i.e. Feed-Forward Neural Network (FFNN) and Echo State Network (ESN), on a data set related to commercial buildings, in view of a possible DR application. The results of both models are compared based on the load forecasting accuracy measures.

11:20 Integration of Consumers' Sensitivities and Preferences in Demand Side Management

Benoit Durillon, Florentin Salomez, Arnaud Davigny, Sabine Kazmierczak, Hervé Barry, Christophe Saudemont, Benoît Robyns

ID 47 – To address the new challenges arising from the higher penetration of renewable energy in electrical grid, Demand Side Management (DSM) and Demand Response (DR) aim to involve the residential as well as industrial consumers in the grid equilibrium. Ensuring benefits for both utility and users requires the consumers sensitivities to be understood and then included in the Energy Management System (EMS). For this purpose, the cost is the predominant and most often only factor taken into account in the literature, although in the residential sector other concerns influencing electricity consumption behaviour has been observed. This paper presents an EMS based on a neighbourhood of consumers modelled at the level of their appliance and incorporating 6 consumption profiles along three sensitivities: cost, environment and appliances shifting comfort. A multi-agent optimization is lead by a central aggregator but performed locally by the household using multi-pass Dynamic Programming (DP), thus ensuring privacy protection for the stakeholders.

11:40 Neural Network based predictive algorithm for peak shaving application using behind-the-meter battery energy storage system

Nicolas Mary, Louis Dessaint

ID 71 - In this paper, a predictive peak shaving algorithm is proposed. Based on neural networks, the power management system aims to minimise the operation cost of a behind-the-meter battery storage system applied to a university campus with a really versatile load combined of residential, commercial and institutional profiles. An emphasis has been made on the necessity of predictions and the challenges that come with their uncertainty. Two artificial neural networks are developed and combined to an error-based correction to predict 24-h ahead load demand. Objective function is quickly explained along with a complete architecture of the system. The results show considerable minimisation on operation costs and the impact that errors in load forecasting can have on them.

12:00 Blended antilock braking system control method for all-wheel drive electric sport utility vehicle

Andrei Aksjonov, Valery Vodovozov, Klaus Augsburg, Eduard Petlenkov

ID 27 - At least two different actuators work in cooperation in regenerative braking for electric vehicles. Torque blending is an important area, which is responsible for better manoeuvrability, reduced braking distance, improved riding comfort, etc. In this paper, an intelligent fuzzy logic controller for electric vehicle blended antilock braking system is promoted. The principle prioritizes usage of electric motor actuators to maximize recuperation energy during deceleration process. Moreover, for supreme efficiency it considers battery's state of charge for switching between electric motor and conventional electro-hydraulic brakes. To demonstrate the functionality of the controller under changing dynamic conditions a hardware-in-the-loop simulation with real electro-hydraulic brakes test bed is utilized. In particular, the experiment is designed to exceed the state of charge threshold during braking operation, what leads to immediate switch between regenerative and friction brake modes.

12:20 Management strategy of an electric vehicle charging station under power limitation

Dian Wang, Hongwei Wu, Fabrice Locment, Manuela Sechilariu

ID 63 - The rapid development of electric vehicles increases the power demand, which causes an extra burden on public grid, and most importantly increases the load fluctuations to the public grid. In the proposed management strategy, a charging station is empowered by a DC microgrid and the charging power can be limited according to power availability. Such a DC microgrid consists of electric vehicles, electrochemical storage systems, a public grid connection, and photovoltaic sources, which help to reduce greenhouse gas emissions. This paper focuses on the management strategy of an electric vehicle charging station under power limitation, presents the topology of the electric vehicle charging system, and discusses the common problems during electric vehicle charging process. The simulation results obtained under MATLAB/Simulink verify the feasibility of the management strategy that presents good performance in terms of precise control.

SS5-A Energy storage systems: new power electronics topologies, high-performance control techniques, and hardware emulation

Chairs: Massimiliano Luna and Alexander Kuznietsov

11:00 Direct determination of a single battery internal resistances distribution using a heterogeneous model

Maxime Juston, Nicolas Damay, Christophe Forgez, Stephane Vivier, Karrick Mergo Mbeya, Bogdan Vulturescu, Guy Friedrich

ID 25 – Lithium-ion batteries are getting larger due to the expansion of transportation and mass storage markets and they can now contain up to thousands of cells. However, a sole damaged cell can significantly impact the whole battery pack efficiency. Thus, the diagnosis of a single cell remains critical for those systems. Many methods exist in which the cell is considered homogeneous. We recently developed a heterogeneous equivalent circuit model that considers a distribution of internal resistances to better represent a real single cell behavior. This resistances distribution (RD) may bring valuable information about a single cell internal quality, but only if it is determined with a sufficient accuracy. In this paper, we propose an algorithm that allows a responsive determination of the RD. The results are compared to other determination methods. This resistances distribution (RD), which is determined thanks to the preliminary construction of a homogenous model and a single discharge, is also valid for other operating conditions. This proves the relevance of the determination method and it should now be usable to detect abnormal evolution of the RD during a single cell lifetime. Although this work is developed for a single cell, it can also be used for several cells connected in parallel and may thus be used to detect a damaged cell inside a battery pack.

11:20 Spatial and Temporal Temperature Homogenization in an Automotive Lithium-Ion Pouch Cell Battery Module

Markus Gepp, Vincent Lorentz, Martin März, Fanny Geffray, Elsa Guyon, Fabrice Chopard

ID 52 – A battery system with a thermally optimized module design with regard to boundary conditions in automotive applications is developed. Measures for spatial and temporal temperature homogenization are realized. High thermal conductive Pyrolytic Graphite Sheets as heat spreaders replace conventional metallic cooling sheets in a lightweight module design. Efficient space utilization with a novel Phase Change Material for thermal peak-shaving enables benefits in thermal management and lifetime. Heat conductive adhesives and elastomer based gap filler sheets further reduce the thermal resistance and the rise in temperature. Measurements showed a maximum temperature difference between the cells of 4.3 K, and a maximum thermal resistance between cells and coolant 0.12 K/W. By integrating thermal solutions, the gravimetric and volumetric overhead was reduced by 25% and 10% referred to the state of the art.

11:40 Lithium-Ion Capacitors: Characterization and Modeling at Both High and Low Temperatures

Zeineb Chabrak Payet, Alexandre De Bernardinis, Pascal Venet, Richard Lallemand

ID 15 – The Lithium-Ion Capacitor is a recent energy storage component. Although it has been commercialized for several years, its hybridization still requires further investigation to characterize it. The literature has investigated some of its characteristics focusing on experimentation at positive temperatures. This paper aims to enlarge the tests to include very low temperatures, showing the difference between Nyquist plots at 65°C and -30°C. It also presents the Ragone plot for several temperatures, with a comparison between three storage systems: a battery, a supercapacitor and the lithium-ion capacitor. Finally, a model of the LIC is proposed, for low and high temperatures, with experimental validation.

12:00 On-board impedance spectroscopy of Lithium-Ion Batteries in electrical Vehicles: Comparative Analysis of injected Signals and practical Implementation

Alexander Kuznietsov, Tilman Happek, Aleksej Kiselev

ID 139 – This paper presents a fast spectroscopy of Lithuim-Ion batteries using a modified SinC excitation signal whose power spectrum covers frequency range of interest within given duration in the time domain. The proposed generation method allows the realisation of an impedance spectroscopy as a part of an on-board battery management system (BMS) in an electric vehicle. The current injection can be performed in a still-stand of an vehicle without influencing the movement of the motor.

12:20 Luenberger observer for lithium battery State-Of-Charge estimation

Stefano Barsali, Massimo Ceraolo, Jianjing LI, Giovanni Lutzemberger, Claudio Scarpelli

ID 181 – One of the main concerns regarding energy storage systems during their normal operation is the possibility to perform an accurate State-Of-Charge estimation. This cannot be done by simple ampere-hour counting, unless drift correction means are put in place to avoid accumulation of measurement errors over time. In this paper, a State-Of-Charge estimation algorithm is widely analysed and tested on a nickel manganese cobalt oxide (NMC) lithium cell. The algorithm is based on the utilisation of an equivalent electrical circuit battery model, and on the consequent use of a Luenberger-style technique for a runtime correction, from the measure of current and voltage at battery terminals. Although application of Luenberger-style estimation is not new in literature for application to batteries, new expressions of battery model parameters and more detailed simulations are shown, to imply much higher estimation accuracy than in the past. After setting the model parameters, different test cycles have been considered, to evaluate the robustness of the proposed technique.

12:40 Off-line method of the separation of the electrodes equilibrium state of the Li-ion batteries

Karrick Mergo Mbeya, Nicolas Damay, Guy Friedrich, Christophe Forgez, Maxime Juston

ID 46 – To ensure better performances of the Li-ion batteries in applications such as electric vehicles, the monitoring of their state with a BMS (Battery Management System) is required. To this end, non-invasive tools are needed to perform monitoring of the battery at the electrode scale. In this paper, we propose a method to extract from charge and discharge of the battery, the electrodes informations (equilibrium potentials, capacities and lithiation rates as functions of the battery state of charge). A pseudo-OCV model has been used to determine these informations. The proposed method allows to reduce the bias related to the battery overvoltage. Evaluated on a LFP/graphite lithium ion battery, the needed parameters were obtained with an accuracy of about 1 mV on the pseudo-OCV average (between discharge and charge) measurements of the battery. This method can be used for any battery chemestry.

SS2-A Innovative modelling and simulation approaches for new technologies in photovoltaic systems

Chairs: Patrizio Manganiello and Francisco José Sánchez Pacheco

11:00 Computation of the Lambert W function in photovoltaic modelling

Efstratios Batzelis, Georgios Anagnostou, Chandan Chakraborty, Bikash Pal

ID 5 – Recently, the Lambert W function has emerged as a valuable mathematical tool in photovoltaic (PV) modeling and other scientific fields. This increasing interest is because it can be used to reformulate the implicit equations of the single-diode PV model into explicit form. However, the computation of the Lambert W function itself is still not clear in the literature; some studies use the iterative built-in functions in MATLAB or other computational platforms, while others adopt their own approximation formulae. This paper takes a deeper look at the ways the Lambert W function is evaluated in PV models and carries out a comparative study to assess the most commonly used methods in terms of accuracy, computational cost and application range. These alternatives are implemented in a modern computer and a typical microcontroller to evaluate their performance in both simulations and embedded applications. The analysis concludes that some series expansions are good options for PV modeling applications, requiring less execution time than the built-in MATLAB lambertw function and exhibiting negligible approximation error.

11:20 Experimental verification of a method to model the operation of PV modules during irradiance transitions

Kari Lappalainen, Seppo Valkealahti

ID 16 – Photovoltaic (PV) systems are prone to deep, steep and frequent irradiance fluctuations, mainly originated from overpassing cloud shadows, which cause fluctuations in PV power production. These irradiance transitions have been modelled by using a mathematical function to study their behaviour in a systematic way. Although the used methods and obtained results seem to be reliable, the simulation model has not been verified in detail. In this paper, the accuracy of the used theoretical model for irradiance transitions has been verified experimentally. The results show that the simulation model is accurate enough to study the irradiance transitions caused by moving clouds and their effects on the operation of PV systems.

11:40 Optimal power dispatching in the DC microgrid with clear sky irradiance model

Hongwei Wu, Wenshuai Bai, Fabrice Locment, Manuela Sechilariu

ID 54 – The optimization of power dispatching has been proved to be useful for reducing the operation energy cost of a microgrid based on photovoltaic source. However, the formulation of the optimization problem needs the weather forecast to predict photovoltaic generation. The current hourly forecast is always available and often lacks accuracy. Thus, this work proposes the optimization based on a clear sky model to predict the solar irradiance. This model has the advantage of simplicity, since it depends only on the

geographical coordinates. The analyses have been done to compare the weather data during five months and the validation of the proposed model is carried out by simulation. The results show the optimization results of the proposed model is slightly better than a common hourly forecast weather provided by a meteorological website.

12:00 Annual Energy Yield Simulation Toolbox and its Application to Floating Bifacial Photovoltaic Modules with Reflectors

Rudi Santbergen, Zidan Wang, Julen Garro Etxebarria, Elias Garcia Goma, Hesan Ziar, Olindo Isabella, Miro Zeman

ID 120 – Bifacial photovoltaic (PV) modules harvest additional energy from the light incident on their rear side. The conventional annual yield simulation tools use relatively simple models for predicting the rear side irradiance and therefore cannot take into account the effects of for example reflectors, added for boosting the rear side irradiance. In this work we introduce our simulation toolbox that contains more advanced optical models and can take the effects of reflectors into account. Ray-tracing simulations are used to generate a so-called sensitivity map of the front and rear side of the PV module, taking into account shading and reflections from nearby object as well as the spectral and angle resolved response of the PV module to incoming light. In order to predict the PV module's power output for every hour of the year, this sensitivity map is combined with sky, thermal and electrical models. We then use this toolbox to analyze the annual energy yield of floating PV modules, in which the performance of different designs, including bifacial PV modules with and without reflectors, is analyzed. This shows that adding a white reflector increases the annual energy yield of floating bifacial PV modules by as much as 18%.

12:20 Optimizing scattering behaviour of encapsulant for maximum PV energy yield

Hans Goverde, Imre Horvath, Patrizio Manganiello, Bader Aldalali, Filip Duerinckx, Arvid van der Heide, Eszter Voroshazi, Jozef Szlufcik

ID 132 – Nowadays, material manufacturers are engineering module materials to optimize the energy production of the PV modules. One of the elements which can be influenced is the optical scattering of a material. In this study, we quantified the effect of a scattering front encapsulant on the energy production of PV modules. First, a wavelength dependent scattering model was developed in the ray-tracing software PVlighthouse. This model was used to find the optimal scattering conditions, looking at the photo-generated current for a glass-glass PV modules with flat front surface. It was shown that a gain of +0.63 mA/cm2 can be obtained for optimal scattering conditions. The scattering is mostly beneficial when the light strikes the module surface at a perpendicular angle. The outcome of the optimization study was implemented in IMEC's energy yield simulation framework. This framework was used to estimate the energy gain of PV module with scattering front encapsulant when installed in Kuwait's desert. It was shown that an energy production gain of 1.8% can be expected in case of a glass-glass module with flat front surface and ARC coating.

12:40 Matlab/Simulink interface design and implementation for PV arrays reconfiguration

Mariana Durango Florez, Luz Adriana Trejos Grisales, Daniel Gonzalez Montoya

ID 10 – One of the major problems in photovoltaic (PV) arrays operation is the mismatching effect due to partial shading; it produces significant drops in the power delivered by the PV system. The power losses due to partial shading for a given operating condition can be mitigated in part by changing the scheme connection of the PV array. This paper introduces a solution to reconfigurate a 3x3 PV array by means of a graphic interface using Matlab and Simulink. A mathematical model is used to calculate the configuration which provides the maximum power under a given operating condition. Then, a connection matrix is identify and the connections on the PV array are implemented by using an ARDUINO DUE and a relay based reconfiguration board. The proposed solution is validated by comparing the power vs voltage (P-V) characteristics of different configuration schemes obtained from experimental tests.

TT1-B Modelling and simulation

Chairs: Efstratios Batzelis, and Xavier Roboam

14:20 Modelling of photovoltaic systems for real-time hardware simulation

Harshavardhan Palahalli, Yujia Huo, Giambattista Gruosso

ID 3 – The Real-time simulation is a valid help to test electrical systems when a physical device is not available. This is even more true when used in Hardware and Software co-simulation environment, where it is possible to connect the emulator to a real sub-system to test or validate it. In this paper, a model of photovoltaic system is presented, that can be implemented within a hardware simulator to be able to interface it with a real circuit. The hardware simulator used is National Instruments RIO system.

14:40 Deep learning based forecasting of aggregated CSP production

Jorge Segarra-Tamarit, Emilio Pérez, Eric Moya, Pablo Ayuso, Hector Beltran

ID 53 – This paper introduces deep-learning-based forecasting models for the continuous prediction of the aggregated production generated by CSP plants in Spain. These models use as inputs the expected top of atmosphere irradiance values and available weather conditions forecasts for the locations where the main CSP power plants are installed. The performances of the forecast models are analysed and compared by means of the computation of the most extended metrics in the literature for a whole year of CSP energy production.

15:00 High granularity model of a photovoltaic array under complex shadow condition

Luis Garcia-Gutierrez, Michael Bressan, Antonino Sferlazza, Fernando Jimenez, Salvador De-Las-Heras, Corinne Alonso

ID 126 – This paper presents a model of Photovoltaic (PV) array under complex partially shading conditions integrating characteristics of shadow area and combination of direct and indirect radiations. The area of the shadow on PV module is deducted through of image processing. The Hybrid Bond-Graph (HBG) facilitates the energy exchange between the different parts of the PV module justifying the high granularity of the tool. The proposed model is validated through experimental tests under shading conditions.

15:20 Mathematical Albedo Modelling and Simulation Approach for Solar Engineering Applications

Hesan Ziar, Furkan Sonmez, Olindo Isabella, Miro Zeman

ID 112 – We present a physical model for albedo component of solar irradiation. The model solves the complexity issue of albedo and illustrates how to simulate and obtain minutely local albedo values at each location on Earth. The model accurately predicts the daily change and variations of albedo. For the studied case, the obtained Root Mean Square Error (RMSE) between measured and modelled ground albedo was as low as 0.34%. The model has the potential to be used not only in Urban Integrated Photovoltaics (UIPV) and Building Integrated Photovoltaics (BIPV) but also in any field of science which relates to albedo including meteorology, astronomy, urban architecture, and agriculture.

15:40 Soc-Based Real-Time Simulation of Highly Mismatched PV Strings

Antonio Guarino, Éric Monmasson, Giovanni Spagnuolo

ID 117 – The real time simulation of photovoltaic arrays is a main tool for monitoring and diagnostic purposes as well as for model-based control strategies implementation. Under the hypothesis that all the cells in the modules and that all the modules of the array operate in the same conditions, the single diode model can be used at any level of granularity, from the single cell up to the whole array. It is only needed that the circuit parameters are suitably scaled at the desired level. Unfortunately, when mismatching effects have to be taken into account, including partial shadowing phenomena, the simulation is not as simple as in the previous case. In this paper a numerical method, which has been recently presented in literature, is engineered in order to simulate in real time a large mismatched photovoltaic array by using a low cost system-on-chip device available on the market. Implementation results show that the chosen algorithm ensures a computation time that fits with what is needed by on-site applications.

TT2-B Control and power management

Chairs: Giovanni Spagnuolo and Francisco José Sánchez Pacheco

14:20 Enhanced dead-beat predictive control using power harmonic components for DFIG wind system under asymmetrical grid voltage sags

Meriem Ghodbane-Cherif, Sondes Skander-Mustapha, Ilhem Slama-Belkhodja, Azeem Khan

ID 26 – This paper focuses on an enhanced dead-beat predictive control technique for a variable speed wind system based on a doubly fed induction generator under asymmetrical grid voltage sags. By using the proposed control strategy, the mechanical stress on the generator can be reduced by decreasing electromagnetic torque ripples. The main idea of the proposed improved control technique is to introduce a new calculation of the rotor currents references for the dead-beat predictive controllers. This calculation uses power harmonic components to extract current harmonic components from the conventional rotor currents references. The obtained references are used, by the dead-beat predictive controllers, to forecast the optimum voltage vector. Fast dynamic responses are ensured by using the dead-beat predictive controllers. A doubly-fed induction generator model is presented in both positive and negative reference frames to allow harmonic analysis of the wind system under the unbalanced grid voltages. A theoretical analysis is used to develop the proposed control technique. Detailed simulation tests have been conducted using the PSIM software and the results are presented to demonstrate the effectiveness of the proposed control technique and its ability to mitigate the unbalanced operation effects.

14:40 Performances Analysis of a Micro-Grid System Composed of Renewable Energies Sources with Hybrid Energy Storage System

Salah Tamalouzt, N. Benyahia, Abdelmounaïm Tounzi, Kassa Idjdarene

ID 98 - The present paper focuses on the study of the generated power smoothing performances of hybrid renewable energy sources dedicated to the application of a micro-grid. The latter is constituted of a variable speed wind turbine (VSWT) based on a doubly Fed induction generator (DFIG), a PV system and a hybrid energy storage system. The DFIG rotor side is powered by a three-level inverter, instead of two inverters, and controlled by a flexible algorithm based on the Direct Reactive Power Control (DRPC) technique. This topology is chosen to improve the quality of the output power and current injected into the grid. The hybrid storage system is made of a combination of batteries banks (BBs) and supercapacitors (SCs). The main purpose of the work is to manage the energy used by the system and to control the active and reactive powers flowing through the micro-grid. Also, the use of the DFIG with its converter as a local reactive power compensator is considered. In addition, to mitigate fluctuations due to random changes in wind speed and solar radiation, an energy management algorithm is introduced. The latter must also ensure the smoothing of the output power, the control the discharge depth of the batteries and the continuity of service. Simulation results, performed under Matlab / Simulink, are presented and analysed.

15:00 Efficient Power Management Strategies for High Energy Demanding Industrial Plants

Libero Paolucci, Mostafa Abdollahi, Francesco Grasso, Alberto Reatti, Fabio Corti

ID 143 - Power efficiency and its management is of crucial importance when dealing with high energy demanding industrial plants. In this paper, a feasibility study of a power distribution system in an industrial plant is presented. The aim of the project is to increase overall system efficiency by supplying the plant with a DC bus and by integrating grid power with a PV plant. System efficiency is improved by minimizing conduction losses in the DC bus while a better power management is achieved by avoiding the DC-AC conversion stages of the PV plant. As a case study a galvanization plant with PV solar roof is took under consideration. A comparative study of several possible configuration is presented, and the pros and cons of the different solutions are highlighted.

15:20 H-infinity controller design for grid forming Offshore Wind Power Plants Connected to a HVDC-Diode Rectifier system

Jaime Martínez-Turégano, Antonio Sala, Ramon Blasco-Gimenez

ID 153 - The use of Diode Rectifiers units (DRU) is an alternative for the HVDC connection of off-shore wind power plants to the on-shore grid. DRUs are passive converters, therefore, grid forming wind turbine generators (WTG) are required for their operation. This paper shows how H-infinity synthesis can improve both WTG dynamic response and harmonic mitigation. The designed stationary frame H-infinity controller achieves zero steady state error to sinusoidal voltage references at the synchronous frequency. The response of the proposed controller is compared with that of a reasonably designed proportional-resonant controller, both in terms of dynamic response and on harmonic mitigation. The results have been validated by means of detailed PSCAD simulations.

15:40 Configuration and Management of Smart Transformer-fed Distribution Grid

Rongwu Zhu, Marco Liserre

ID 137 - Compared to the conventional power transformer, Smart Transformer, which is based on the solid-state transformer, can not only provide the DC connectivity but also reduce the reinforcements potentially required by the integration of EV charging station and distribution generators. Due to the flexible voltage and power control capability of Smart Transformer, high potential to improve grid performances and reliability can be obtained by meshing the LV distribution grid structure and optimizing operation modes, when Smart Transformer is involved. Therefore, this paper thoroughly analyses the advanced configurations of LV distribution grid and optimized operation of Smart Transformer.

SS9-A Challenges in battery and supercapacitor technologies

Chairs: Francesca Soavi and Silvia Bodoardo

14:20 Recent results on industrial-scale energy storage with Vanadium Redox Flow Battery

Andrea Trovò, Piergiorgio Alotto, Monica Giomo, Federico Moro, Massimo Guarnieri

ID 30 – Vanadium Redox Flow Batteries are increasingly being considered as one of the most interesting options for the storage of large quantities of energy due to their unique advantages. Their development and future diffusion largely depend on the research on new materials, such as electrolyte solutions, membrane and electrodes, which are typically developed on laboratory scale devices. An extensive literature on these topics already subsists. However, even the technological development plays an important role in view of the effective application of VRFBs in large plants. Despite that, very few investigations are reported in the literature on the technology of large scale VRFB systems. This paper presents the design and installation of a test facility for industrial-sized vanadium redox flow batteries, named IS-VRFB. As preliminary positive result, a peak power of 8.9 kW was obtained with a specific stack power of 77 W kg-1. Based on the fact that modeling and simulations are also crucial issues to obtain a comprehensive understanding of the key factors affecting VRFB performance, for the first time, this paper presents a complete dynamic model, able to simulate the thermal behavior of Vanadium Redox Flow Batteries in standby, i.e. without power and reactant flow, and during operating conditions. The proposed model has been validated by using the IS-VRFB facility.

14:40 Innovative electrolyte components for safer electrochemical energy storage devices

Giovanni Battista Appetecchi

ID 170 – Ionic liquids (ILs), salts molten at room temperature or below, display very interesting properties as high thermal/chemical/electrochemical stability, good ion transport properties and high specific heat in combination with non-measurable vapor pressure and non-flammability. Because of these unique peculiarities, ILs have been proposed as electrolyte components for replacing the hazardous and volatile organic solvents used in commercial electrochemical devices, particularly in rechargeable lithium batteries (RIBs). The last are excellent candidates for the next generation power sources because of their high gravimetric and volumetric energy with respect to other cell chemistries. However, the safety, but also the performance and life, of lithium batteries is affected by their storage and operative temperature. Also, RIBs can experience “thermal runaway”, especially if improperly handled or defectively manufactured. In this scenario, the electrolyte plays a key role. In the last fifteen years ionic liquid-based electrolytes, in combination with lithium battery electrodes, were extensively investigated with the aim to realize safer devices without depleting their electrochemical performance. Here, an overview of best promising uses of ionic liquid-based electrolytes, liquid or solid, in lithium battery systems is reported and discussed.

15:00 The impact of non conventional electrolytes on the performance of electrochemical double layer capacitors: a critical analysis

Andrea Balducci, Christoph Schütter, Lars Henning Heß, Jakob Krummacher, Annika Bothe

ID 174 – Electrochemical double-layer capacitors (EDLCs) are nowadays considered among the most important energy storage devices. EDLC are characterized by high power densities (ca. 10 kW·kg-1), long cycle-life (> 500.000 cycles) and have a superior efficiency especially for shortterm use (discharge time of some seconds to minutes) compared to commercially used Lithium-Ion-Batteries (LIBs). In EDLCs the energy is stored through a physical process -the double-layer formation- occurring at the surface of the electrodes. This process, although guarantee high power, is limiting the energy of these devices and EDLCs can only provide about a tenth of the energy density of batteries, which are devices relying on a chemical storage process taking place in the bulk of the electrodes. Activated carbon are the most used electrode materials in EDLCs, while the state-of-the-art electrolytes are based on organic solvents (propylene carbonate (PC) or acetonitrile (ACN)) with asymmetric quaternary ammonium conductive salts (mostly tetraethylammonium tetrafluoroborate (Et4NBF4). This electrode-electrolyte combination allows operative voltages in the order of 2.8-3.0 V. Several studies indicate that if the energy of EDLCs would increase from the actual 5-8 Wh·kg-1 to 12-15 Wh·kg-1, the number of applications, and thus the market, of these devices would increase dramatically. Consequently, great efforts have been dedicated toward the realization of high voltage EDLCs, and it has been shown that one of the most effective strategies to achieve this goal is to realize high voltage systems. Since the state-of-the art electrolytes are not suitable for the realization of stable high voltage EDLCs, the search and development of innovative electrolytes is essential for the future of the EDLC´s technology. In the last years many efforts have been made toward the development of advanced electrolyte components, solvents and salts, able to fulfil all requirements needed for the realization of high energy EDLC. The innovative electrolyte components (for non-aqueous systems) proposed so far for the realization of high voltage, high energy EDLCs can be divided in three main categories: new solvents, new salts and ionic liquids (ILs). In this work the impact on these novel electrolytes on the performance of EDLCs will be critically analysed. Initially, the energy and power of EDLCs containing nonconventional electrolytes will be considered and compared to that of state-of-the-art devices. Afterwards, the influence of these alternative electrolytes on the stability at high voltage and on the self-discharge of EDLCs will be analysed. Finally, the possibility to introduce alternative electrolytes in commercial devices will be exploited.

15:20 Comparison and modeling of commercial supercapacitors via standardized potentiostatic electrochemical impedance spectroscopy

Filippo Gherdovich, Giuseppe Taddia, Sandro Maria Tenconi, Alessandro Lampasi, Maria Luisa Di Vona, Miguel Pretelli, Francesca Soavi

ID 81 – The main scope of the study is the characterization of the capacitive and resistive behavior of two supercapacitors samples and one hybrid supercapacitors sample available on the market, through tests of potentiostatic electrochemical impedance spectroscopy (PEIS). The PEIS tests were performed by applying to all samples the same voltage perturbation in the same frequency range. In a first phase, the instrumentation used for the acquisitions was optimized, with particular care to the connections between the potentiostat and the supercapacitive cell. The Nyquist diagrams obtained for each sample are compared and capacitance/frequency graphs are deduced. The technological differences between various devices are then discussed in relation to the results. The characterization of the sample cells and the collected data are used to propose the corresponding models conceived for circuit simulation. These models are based on simple electronic components available in the standard circuit simulation software tools.

15:40 Lifetime expectancy of LFP and NMC batteries in residential PV applications

Pablo Ayuso, Hector Beltran, Jorge Segarra-Tamarit, Emilio Pérez Soler

ID 49 – This paper analyses the ageing experienced by different types of Li-ion batteries when used under various operation modes in a household. The study is performed by means of annual simulations that use actual consumption and PV production values as well as semi-empirical ageing models that are proved to be accurate. Therefore, the work provides lifetime expectancies for the different batteries that can be profitable for future financial analyses.

16:00 Economic Analysis of Hybrid Storage System Associated to a PV Source and Supervised by Fuzzy Logic power management

Xingyu Yan, Dhaker Abbes, Antoine Labrunie, Youssef Krim, Benoît Robyns

ID 96 – This study concerns a grid-connected Photovoltaic (PV) system associated with an hybrid storage system made up of lithium NCA battery (energy source) and Maxwell super-capacitor (power source). Two supervision algorithms have been proposed for Energy Management System (EMS): a Boolean and a fuzzy logic EMS. Moreover, a comparative study between both supervision algorithms especially in terms of storage components lifespan and system Levelized Cost of Energy (LCOE) has been carried out. The economic analysis is done with two different planned PV power production profiles : one with a “clear sky” bell curve and a second with an ideal forecast. The supervisor based on Boolean method is simple and easy for understanding, while the fuzzy logic method offers more flexibility in supervision. It improves a little batteries lifespan and system performances and reduces significantly the system penalties. The simulation results show for all scenarios the achievement of the desired objectives in terms of compliance with production program while respecting the various constraints of electric grid manager with a LCOE below 130 €/MWh.

TT4-A Identification and diagnosis

Chairs: Éric Monmasson and Marcello Pucci

14:20 A Fault Localization Method for Single-phase to Ground Faults in LV Smart Distribution Grids

Nikolaos Sapountzoglou, Bertrand Raison, Nuno Silva

ID 14 – A fault localization method for single-phase to ground short-circuit (SC) faults in low voltage (LV) smart distribution grids is presented in this paper. Both the use of rms voltage phase measurements and an analysis of symmetrical components of the voltage were investigated and compared in this study. Phase measurements were found to be more suitable for single-phase to ground faults. The described method is a three-step process beginning with the identification of the faulty branch, followed by the localization of the sector in which the fault occurred and concluding with the estimation of the fault distance from the beginning of the feeder. Fault resistance values of 0.1, 1, 5, 10, 50, 100, 500 and 1000 Ω were tested. An heterogeneity analysis was performed to test the effect of the use of various conductors on the method. Faults in all three phases were implemented and simulated on a real-case of a semi-rural LV distribution network of Portugal, provided by Efacec. Finally, the method presented an average estimation accuracy of 89.33% and an increased accuracy of 93.11% for low impedance faults (up to 10 Ω of fault resistance).

14:40 Comparison between ig Integration and vgs Derivation methods dedicated to fast Short-Circuit 2D-Diagnosis for Wide Band Gap Power Devices

Yazan Barazi, Nicolas Rouger, Frédéric Richardeau

ID 17 – This paper presents and compares two original high speed protection circuits, ig integration and vgs derivation methods against Short Circuit (SC) types, Hard Switch Fault (HSF) and Fault Under Load (FUL). Since the gate-drain capacitor Cgd of power device depends on vds, it can become an original native sensor to monitor the switching operation and so to detect unwanted vds transition or absence of vds transition by monitoring only vgs. Using only low-voltage monitoring is an essential step to integrate fast and embedded new detection methods on an ASIC gate driver. This Cgd capacitor plays a major part in the two detection methods. The first method is based on a dedicated two dimension monitoring the gate charge transferred in a time interval combined with the gate voltage monitoring. The second method consists on the reconstruction of the dvgs/dt by means of a capacitive current sense to provide the vgs derivation combined with also the vgs monitoring. Comparison and simulation of the methods based on a C2M0025120D SiC MOSFET device under LTspice™ are made to verify the validity of the methods. In terms of detection speed of the SC, a detection time of 300ns is obtained for both methods. Both methods are easy to design, and to integrate. However, the robustness and the speed of detection trade-off of all these methods will be analyzed and compared relatively to the critical functionalities.

15:00 Estimation of control voltage disturbances for induction machine drive using LPV observer with convex optimization

Xuefang Lin-Shi, Paolo Massioni, Jean-Yves Gauthier

ID 73 - This paper presents a Linear Parameter-Varying (LPV) observer for an Induction Machine (IM) under control voltage disturbances. The observer estimates not only the IM state variables, but also the disturbances. As the extended IM model depends on the stator angular speed ωs and the rotor angular speed ωr, the proposed observer is designed by convex optimization to induce a convergence of the observer for a predetermined range of ωs and ωr. The estimated disturbances can be used to compensate for the real disturbances. The simulation results show the effectiveness of the observer, and experimental validations have been made on a 1.5 kW test-bench.

15:20 A New Approach for Effective Position/Speed Sensor Fault Detection in PMSM Drives

Saïda Ben Slimen, Manef Bourogaoui, Houda Ben Attia Sethom

ID 80 – This study presents a new fault detection approach for Permanent Magnet Synchronous Motors (PMSMs), based on the Park Currents Vector (PCV), which addresses the total loss position/speed information fault in electric motor drives. Two PMSMs were considered, a 53kW PMSM was adopted for simulations whereas experimental validation was performed using a 1kW PMSM. Effective position/speed sensor fault detection was achieved using the proposed PCV-based approach, which validity and feasibility are proved by simulation and experiment results.

15:40 PRBS-Based Identification of Multiple Control Loops in DC Microgrid Power Converters

Aram Khodamoradi, Guangyuan Liu, Paolo Mattavelli, Tuomas Messo

ID 85 – This paper presents the application of an on-line identification technique to rapidly evaluate the control loop gains of the dc microgrid power converters. The technique consists of injecting orthogonal pseudo-random binary sequences (PRBSs) into different control loops of switched-mode power converters, and measuring the frequency response of the loops, simultaneously. The obtained models contain the full picture of the control performance, and can determine, for example, the stability margins of each loop. The proposed approach is applied to an experimental dc microgrid prototype composed of three droop-controlled converters, and the identified models are discussed. The reported experimental results confirm the applicability of this method to the dc microgrid power converters.

16:00 Smart Sensors in Smart Cities Collaborate for Indoor Air Quality

Erina Ferro, Paolo Barsocchi, Paolo Baronti, Fabio Mavilia, Lucanos Strambini, Massimo Piotto

ID 51 – This paper presents an example of collaboration between two different air quality monitoring systems, one developed for indoor usage, the other one used in some regions in Italy as an example of citizens' collaborative work for monitoring the air quality. The exchange of information between the two systems (the inner one and the external one) allows taking a weighted decision for improving the inner air quality. By evaluating the relationship between the inner air quality and the external one, a reasoner decides the best policy to be automatically adopted to improve or, at least, not worsen, the indoor air quality.

TT1-C Modelling and simulation

Chairs: Efstratios Batzelis and Mattia Ricco

16:40 Low-side MOSFET current sensing technique for Automotive Applications

Patrik Varecha, Giacomo Scelba, Mario Cacciato, Matej Pacha, Pavol Makys

ID 136 – This paper deals with analysis and simulation of a current sensing technique based on the estimation of the current flowing in the low-side MOSFETs of an inverter. In this case the power MOSFET is utilized as a current sensor, by estimating its internal on-state resistance. Due to the temperature dependency of the internal on-state resistance, the temperature of MOSFET die has been also estimated. by measuring the internal body diode forward voltage of the power MOSFET. The proposed low-side MOSFET current sensing method will be used as current sensing in three-phase inverters for automotive applications.

17:00 Modelling and Analysis of Equivalent SISO D-Q Impedance of Grid-Connected Converters

Qi Xiao, Paolo Mattavelli, Aram Khodamoradi, Poh Chiang Loh

ID 145 – Impedance-based stability analysis in d-q reference frame has been widely used in three-phase grid-connected converters. Due to the multi-input multi-output (MIMO) property of the d-q model, the generalized Nyquist stability criterion (GNC) is usually adopted to evaluate the eigenvalues of the return ratio matrix, which is the ratio between the source subsystem and the load subsystem impedances. This paper presents an equivalent single-input single-output (SISO) model for the d-q impedance of grid-connected converters. Thus, the system stability can be assessed by directly analysing two impedance ratios of d- and q-axis with classic Nyquist stability criterion (NC), making the analysis intuitive and simple. The equivalence between the stability criteria given by the original MIMO d-q impedance model and the SISO representation is verified by comparing their stability conditions. The proposed modelling method is finally validated by Matlab/Simulink simulations.

17:20 An Analytical Method of Switching Waveform Design for Selective Harmonic Elimination

Sraddhanjoli Bhadra, Hirak Patangia

ID 149 – The paper proposes an analytical approach for design of switching waveforms to eliminate harmonics and improve Total Harmonic Distortion (THD) in power converters. Generally, numerical solutions are used to obtain the switching angles to eliminate targeted harmonics and the solution requires guessing of an initial value and a valid modulation index, m. Both of these values affect convergence. Such difficulties are absent in analytical solutions. The closed-form solutions obtained through the analytical approach also determine the range of m. Due to the closed form, this method is suitable for real-time applications where a microcontroller can be programmed, thus making it attractive for low-cost applications. The approach requires solution of transcendental equations associated with Fourier coefficients of a periodic waveform. An even-odd symmetry waveform has been selected to minimize the complexity of the solution. Chebyshev expansion is used to convert the Fourier equations to power-sum non-linear polynomials. A successive polynomial reduction method has been used that lead to a set of elementary functions in closed-form, which are used to generate a polynomial and its roots are the desired optimal switching angles. In this paper, the proposed approach has been examined through a fourth-order, three-phase systems for bipolar and multistep waveforms. Simulation results verify the harmonic cancellations.

17:40 Potential contribution from photovoltaic panels on electric and hybrid vehicles

Francesco Antonio Tiano, Matteo Marino, Gianfranco Rizzo, Sourav Mondal, Luca Bonci

ID 190 – In the paper, an extensive analysis of the potential contribution harvested from photovoltaic panels mounted onroad vehicles is performed, considering realistic solar data for a large set of world locations. Different options are considered, ranging from almost horizontal position (i.e. on the roof and on the hood) to vertical position too, on the lateral sides and on the back side.

TT3-A Design and optimisation

Chairs: Dmitri Vinnikov and Mario Cacciato

16:40 Simulation Optimization of Generic Wind Turbine and Wind Farm Models

Alberto Lorenzo-Bonache, Raquel Villena-Ruiz, Andrés Honrubia-Escribano, Emilio Gómez-Lázaro

ID 43 - Generic wind turbine and wind farm models have been extensively developed and validated during the last years. International Standard IEC 61400-27-1, which defines these models, was firstly published in 2015. With the second edition under development, it is currently an interesting field for researchers to focus on the study of optimization techniques. Since generic wind turbine and wind farm models are intended to be used by system operators, it is crucial to guarantee that they can be used to conduct dynamic transient simulation analysis within the time margins in which they usually work. Generic wind turbine and wind farm models are defined to work in continuous time simulation. Nevertheless, it is well known that discrete simulation is usually faster for these cases. Furthermore, discrete simulation has advantages when compiling the model to run under an external target. Using MATLAB/Simulink^{\tiny\textregistered}, this work compares the simulation time of the continuous generic wind turbine models with the discretized ones. Later, the different simulation modes which Simulink offers (Normal, Accelerator and Rapid Accelerator) are tested, defining the boundaries in which each of them is the most proper. Hence, the aim of this work is to provide an optimization analysis of generic wind turbine and wind farm models, being of high interest to researchers and system operators.

17:00 Multi-objective Optimization of a DC-DC Boost Converter including Control Strategy and Stability Constraint

Davide Dell'Isola, Matthieu Urbain, Serge Pierfederici, Farid Meibody-Tabar

ID 66 - In this paper a procedure is proposed to optimally design a boost converter, (including its input filter and its control) for embedded applications where power density and high efficiency are crucial criteria. The load consists of a constant power load (CPL), which represents the most stringent case in term of stabiltiy issues. This optimization problem can be treated as a multi-objective one, which aims to maximize compactness and efficiency of the studied system. In order to find a trade-off between compactness and efficiency the two objective functions (volume and power losses), a genetic algorithm was implemented to generate the most convenient design solutions (Pareto front). The operating conditions includes both steady and fast output power load transients (step up and step down) . Since CPL transients may lead to large deviations of the output voltage from its nominal value, the control strategy is discussed as well and included in the design procedure. The presence of a differential input filter is likely to interact with the constant power load and cause some instability issues. A constraint function excludes solutions that do not respect the magnetic saturation or the stability constraints.

17:20 Impact of Photovoltaic Power Uncertainties on Generation Scheduling and Cost of an Urban Micro Grid

Xin Wen, Bruno Francois, Dhaker Abbes

ID 101 - In electrical systems, the main objective is to ensure that users demand is met at the least cost without having imbalance between generation and consumption. Thus, the uncertainty of photovoltaic (PV) power production must be considered in generation planning. In this paper, the optimal generation scheduling including the operating reserve (OR) provision are developed under stochastic characteristics of PV renewable energy in an urban microgrid. With a prescribed risk level of unbalancing, a dynamic programming (DP) algorithm sets the operational planning of conventional generators. Then, the operational cost and available operating reserve can be calculated. The effect of PV power uncertainty into UC is then analyzed by considering forecast intervals of PV forecasting. The proposed methods considers PV prediction uncertainties with a 95% confidence level. The unit commitment is then recalculated as well as new generator set points with same criteria. Hence, variations of the targeted minimized costs and obtained OR is analysed according to the considered uncertainty.

17:40 Hybrid DC-DC Converters with Topology Morphing Control and Post-Fault Operation Capability

Dmitri Vinnikov, Andrii Chub, Oleksandr Korkh, Andrei Blinov, Elizaveta Liivik

ID 109 - This paper discusses an alternative realization approach of the reconfigurable full-bridge/voltage-doubler rectifier for implementation in hybrid DC-DC converters, i.e., the power electronic converters that can adaptively change the power circuit topology for optimization of performance or enabling the post-fault operation. The proposed rectifier is characterized by the reduced number of semiconductor components and the ability of independent use of its capacitors for forming the series resonant tank and output voltage filtering. Paper explains the derivation and operation principle of the reconfigurable rectifier and discusses the experimental results obtained by the help of 350 W laboratory prototype. Finally, the fully-controlled version of the proposed rectifier is presented, which features the excellent control and reconfiguration possibilities in both directions of power flow and, therefore, could be used as a power electronics building block for hybrid DC-DC converters.

18:00 Matrix approach based on Quadripole for quality analysis in Aircraft Electrical Power Distribution System

Bernard Makhraz, Hubert Piquet, Xavier Roboam, Jérome Mavier

ID 164 - HVDC bus based electrical network architectures have shown to be relevant for More Electric Aircrafts. Today, adequate standards of power quality and stability must be set and even optimized: these design constraints have to allow the system integrator to guarantee the safe operation of the network, without excessive cost for the equipment provided by the suppliers, especially regarding weight penalty. In this context, this paper proposes a specific methodology to analyze the power quality constraints in an HVDC networks. A matrix approach, based on Quadripole analysis of the power distribution is especially focused. It aims at achieving sensitivity analysis of any electrical quantity (regarding its harmonic content) of any network, with respect to selected inputs and properties (topology, parameters). One major advantage of our proposition is that the modeling approach is analytically developed, based on symbolic calculation. All the building parts of the system are represented as four-terminals (quadripole) devices, connected together according to the network topology. The calculations are performed at very high speed in the frequency domain. An application of this approach on a relevant aircraft electrical power distribution is shown to highlight its benefit on the path of optimizing new HVDC quality standards.

SS8 Advancements on models, methods and devices for monitoring and diagnosis of fuel cells

Chairs: Pierpaolo Polverino and Samuel Simon Araya

16:40 Parameters identification of fuel cell model by using interval arithmetic

Giovanni Petrone, Raffaele Siano, Giovanni Spagnuolo, Walter Zamboni

ID 178 - A new approach for identifying the parameters of a fuel cell equivalent circuit is described in this paper. The proposed method exploits the Interval Arithmetic for formulating the system equations directly as interval functions. A branch and bound technique is then used to find the intervals of feasible parameters values. The experimental spectra of the fuel cell impedance, acquired by means of the Electrochemical Impedance Spectroscopy method, is used as constraint. In order to speed-up the parameters identification process, the initial parameter search space is divided in sub-intervals by applying an enhanced branching method. It allows to discard the unfeasible sub-intervals and preserve only the ones that bound the experimental spectrum. The proposed approach is able to account for uncertainties affecting the impedance measurements and provides directly the parameter ranges for a given tolerance assigned to the fuel cell impedance spectrum. The method has been validated by using experimental spectra acquired in different fuel cell operating conditions.

17:00 Data-driven multi-fault diagnosis for H2/O2 & H2/air PEMFCs

Raffaele Petrone, Didier Chamagne, Marie-Cécile Pera, Daniel Hissel

ID 84 - Enhance the Proton Exchange Membrane Fuel Cells' systems (PEMFCs) lifespan and reliability is a sensible point for the FCs' manufacturers. In this framework, the Health-Code project works contribute to improve the on-board monitoring and diagnostic tool for on-board state-of-health assessment to prevent improper operating conditions, that can severely affect the stack performance. The diagnosed faulty conditions are: the improper water management (drying and flooding), the reactants' starvations (fuel and oxidant) and the fuel quality contaminations (poisoning). The developed methodologies are mainly based on the use of the Electrochemical Impedance Spectroscopy (EIS) measurements oriented to multi-fault detection purposes. Experimental activity was performed both on H2/O2 PEMFC and H2/Air PEMFC technologies. Experimental data are used for methods learning and validation, while the final tool is validated on-board, directly on real systems. The developed data-driven approach is presented in this paper. Particularly, the procedure development related to the relevant features extraction and the algorithm learning are reported. Finally, the algorithm off-line validation results are presented.

17:20 Probabilistic deconvolution of solid oxide fuel cell impedance spectra

Boštjan Dolenc, Gjorgji Nusev, Pavle Boškoski, Bertrand Morel, Julie Mougin, Đani Juricić

ID 119 - Higher exploitation of the fuel cell technologies can be achieved employing effective maintenance and condition monitoring tools. Electrochemical impedance spectroscopy (EIS) is a common way for state-of-health characterisation of fuel cells. However, parameters of an equivalent circuit models (ECM) used to describe the EIS seem to be more convenient and informative. Usually, an ECM structure is selected a priori, and an optimisation problem is formulated to fit the parameters of the model, and gain their corresponding point estimates. However, for more precise reasoning, better information about the parameters is desirable. This can be achieved through Bayesian inference. In this paper Bayesian inference is employed to estimate model parameters and so to obtain the posterior marginal density functions of the model's parameters. It is shown how point estimates may be misleading. The approach is demonstrated on solid-oxide fuel cell (SOFC) short stack.

17:40 ECM-based algorithm for on-board PEMFCs diagnosis

Ennio Andrea Adinolfi, Marco Gallo, Pierpaolo Polverino, Davide Beretta, Samuel Simon Araya, Cesare Pianese

ID 150 - This work aims at implementing an advanced monitoring and diagnostic tool for μ-CHP PEM fuel cell systems running on-board. Such a tool is able to determine the FC current status (condition monitoring) to support stack failures detection. Six faults are investigated: fuel starvation, air starvation, flooding, drying, CO contamination and sulphur poisoning. The developed methodology is based on the use of the Electrochemical Impedance Spectroscopy (EIS) measurements and Equivalent Circuit Model (ECM) approach to infer on them. Experimental data from HEALTH-CODE project are exploited for training and to finally validate the model-based algorithm. The fault detection and isolation algorithm, which works on the relevant features extracted from EIS data is herein reported. Eventually, the off-line validation results of the algorithm are presented.

18:00 Electrochemical impedance parameter extraction for online control of reformed methanol high temperature PEM fuel cells

Sobi Thomas, Samuel Simon Araya, Simon Lennart Sahlin, Søren Knudsen Kær

ID 188 - This work focuses towards online control strategy for detecting fuel and oxidant starvation and predicting an optimal stoichiometry for operation under different fuel compositions using electrochemical impedance spectroscopy (EIS) parameter extraction method. The tests involve three fuel compositions namely dry hydrogen, dry re-formate (H2, CO, CO2 and N2) and wet reformate (H2, CO CO2, and H2O). The characterization of the anode and cathode stoichiometry (both low and high) are carried out with each fuel composition by measuring electrochemical impedance spectroscopy (EIS) and current-voltage (IV) curves. The results suggest a positive effect with humidified gas on the fuel cell stack performance. The changes in the mass transport due to excess gas or gas starvation both on the anode and cathode could only be deduced using the EIS method. online is measurement seems useful in deducing the optimal stoichiometric ratio as the IV curves are unable to show the changes in the mass transport. Thus, to operate the fuel cell stack under an optimal fuel and oxidant utilization, an online EIS with parameter extraction algorithm needs to be implemented online. This would ensure a better fuel and oxidant utilization which thereby will improve the system efficiency.

TT4-B Identification and diagnosis

Chairs: Marcello Pucci and Éric Monmasson

16:40 Automation architecture for Multi-Terminal DC grid

Gaurav Kumar Roy, Philipp Joebges, Ferdinanda Ponci, Antonello Monti, Rik W De Doncker

ID 86 – The Multi-Terminal DC (MTDC) grid is one of the solutions to accommodate the increasing distributed energy resources (DERs) capacity in the distribution grid. An MTDC grid consists of devices from different manufacturers with a proprietary protocol, which is a challenge for the automation system. This paper addresses the challenge by proposing a flexible automation architecture of MTDC grid consisting of three levels based on IEC 61850 substation protocol, which are field level, bay level and station level. Furthermore, in this paper, latency tests prove that the proposed architecture meets the latency requirements for P2, P3, P4, P5 and P6 class of monitoring, protection and control applications according to the IEC 61850 standard.

17:00 Detection of magnetization loss in a PMSM with Hilbert Huang transform applied to non-invasive search coil voltage

Jian Zhang, Abdelmounaïm Tounzi, Abdelkader Benabou, Yvonnick Le Menach

ID 87 – This paper presents a novel method for demagnetization fault detection of permanent magnet synchronous machine (PMSM). Demagnetization fault is a common problem existing in PMSM which deteriorates the machine performance and can lead to serious secondary machine damages. Unlike the most popular method for detecting this fault which is based on the analysis of the machine current, the approach proposed in this paper analyses the voltage signal of a non-invasive search coil by means of Hilbert Huang transform. Simulations are carried out with a two dimensional finite element analysis (FEA) for different demagnetization levels to verify the proposed method.

17:20 ISO26262-compliant Development of a High Dependable Automotive Powertrain Item

Jacopo Sini, Massimo Violante, Riccardo Dessì

ID 11 – In the automotive domain, the electric and electronic items are playing day after day a more central role. Since most of these units are in charge of safety-relevant functionalities, a strict development process is required. The ISO26262 automotive functional safety standard describes a mandatory process to design, validate, and verify items designs. The aim of this work is to describe a suitable way to overcome some safety lifecycle issues. The description starts from the concept phase, with the Hazard Analysis and Risk Assessment, in where the safety goals are defined, and an Automotive Safety Integrated Level is assigned to each of them. After that preliminary phase, it will be shown how it is possible to check the reliability of the obtained hardware design keeping into account the failure detection and mitigation capabilities of both hardware and software. To achieve this goal, a simulation-based Failure Mode and Effect Analysis assessment technique is applied to assess the hardware design possible sources of failures and to analyse detection, isolation, and mitigation capabilities. To achieve this result, the hardware model and the embedded software has been implemented using the Model-Based Software Design approach. This approach has been demonstrated on an electric vehicle powertrain design.

17:40 Enhanced Kalman filter-based identification of a fuel cell circuit model in impedance spectroscopy tests

Danilo Flammia, Antonio Guarino, Giovanni Petrone, Walter Zamboni

ID 176 – Model parameters identification plays an important role in enhancing the currently available diagnosis techniques for fuel cells. In this work, the Dual Kalman Filter (DKF) has been used for the parametric identification of a Randles circuit model. The fuel cell has been stimulated with typical EIS input signals and the results of the identification have been validated by using the impedance spectra produced by the Fouquet impedance model. The obtained results allow to infer a functional relation between the filter settings and the input signal, thus enabling the possibility of detecting faults by inspecting the deviation of model parameters.

TT1-D Modelling and simulation

Chairs: Efstratios Batzelis and Ilhem Slama-Belkhodja

08:30 An Integrated electro-thermal model for pouch lithium ion batteries

Simone Barcellona, Luigi Piegari, Simone Scorrano

ID 107 – Lithium ion batteries are spreading in many applications. One of their major weaknesses is in their sensitive to temperature. Indeed, their safety and their aging strongly depend on their temperature. In order to control cell temperatures, usually, each cell in a battery pack is equipped with thermal sensors. In this paper, an integrated electro-thermal model is proposed capable of predicting the thermal behaviour of a battery cell only on the basis of the knowledge of its current and of the ambient conditions. The proposed model has been tuned and validated by means of experimental results. The obtained precision is good to predict the battery temperature with an acceptable accuracy also considering the low complexity of the proposed model.

08:50 Hardware-in-the-loop simulation of high power modular converters and drives

Christian Dufour, Karthik Palaniappan, Brian J. Seibel

ID 6 – This paper explains several industrial cases involving the HIL simulation of MW-range drives and inverters using CPU cores with FPGAs to compute model equations. The use of HIL simulators is common today in the industry to accelerate design cycles, mitigate financial and human risks and support software updates through the products life cycle. The first case is a 2-level inverter scheme in which increasing power specifications are met by adding parallel IGBT-modules. The second case is a multi-level motor drive with low harmonic injection on the AC-side. The 3rd case is a modular multi-level converter in a grid application. We also discuss a new T-type inverter model that uses an industry PV-to-grid power converter. In each case, all power system modelling was done using Simulink and SimPowerSystems in conjunction with the SSN solver from the ARTEMiS blockset together with code generation for CPU execution at time step in the 20-50us range, with an exception for MMC models on FPGA. In all cases the firing accuracy of the IGBTs remains in the nanosecond range using time-stamping techniques and an FPGA board. In the case of the parallel 2-level inverters, there is significant difficulty regarding the small firing delays (typical <500 nanoseconds) between modules that create circulating currents. These circulating currents are rendered correctly on the HIL bench. Also discussed in the paper are the various optimisations, solvers and methods that enable these performances.

09:10 Concept and Implementation of a Rotor Position Detection Method for Permanent Magnet Synchronous Machines based on Linear Halls

Yuchen Wang, Liu Kai, Wei Hua, Xiaofeng Zhu, Baoan Wang

ID 39 – The purpose of this paper is to propose and implement a novel rotor position detection method for permanent magnet synchronous machines (PMSMs) based on linear Halls, which are embedded inside of stator of PMSMs. A three-phase 9-slots/8-poles PMSM is exampled to verify the method. Firstly, a special point located in stator yoke (back-iron) is found by 2-dimensional finite element analysis (2D-FEA), where the open-circuit flux-density due to permanent magnets versus rotor position (BPM) shows a high amplitude and good linearity, while the armature-reaction flux-density(Barmature) due to armature currents exhibits a low amplitude and good linearity versus armature currents. Then, an analytical model is built and the analytical relationship between armature currents and the Barmature is derived. Based on the analytical mode, BPM can be obtained by separating the Barmature from the synthetic magnetic field (BSynthetic). Thereafter, the resultant BPM can be used to detect the rotor position information with differential-type piecewise-linear analytical method. The feasibility of the proposed detection method is verified by co-simulations and experiments. The simulation results show that the novel linear Hall-based angle sensor can achieve the accuracy equivalent to 3000-line. The experimental results indicate that compared with an encoder, the maximum error of electric angle position at different speeds is less than 0.3%.

09:30 Direct Torque Control Applied to DFIG Supplied Via Three Level-Inverter Under Random Behavior Wind Speed

Salah Tamalouzt, Nabil Benyahia, Mariama Said Mohamed, Angel Scipioni, Bernard Davat

ID 105 – A DFIG driven by a variable speed wind turbine (WT) is presented in this paper. The DFIG is partially interfaced by its rotor via a back-to-back converter This one is supplied via a three-level inverter in the rotor side and controlled with a flexible algorithm based on DTC technique, to ensure mastery of this generator. The main aim of this contribution is to analyze the performances and robustness of the proposed control technique. The aim of this structure is to obtain at the generator output AC sine waveforms signals with a constant frequency and a low THD, as well as minimum output voltages ripples, regardless of the variation of the wind speed. Indeed, the main objectives of this work are the performances analysis of the DTC applied to a three-level inverter in the rotor side of the DFIG, considering some constraints that reflect the real operation of wind turbine generator, such as the randomness behavior of the wind speed, allowing all modes operation of this generator. These operation modes are carried out with a successive and continuous manner, while showing synchronous and overspeed modes. Simulation results, performed under Matlab / Simulink, are presented and analyzed.

09:50 Sensorless control strategy for Switched Reluctance Traction Drive based on high frequency injection

Pavel Sovicka, Giacomo Scelba, Pavol Rafajdus, Vladimir Vavrus

ID 130 – This paper deals with the implementation of a sensorless control strategy devoted to Switched Reluctance Motor Drives used in the traction drive of a small truck. The sensorless technique operates at low and zero speed. In the proposed approach an additional high frequency magnetic field is injected into the machine and a suitable demodulation algorithm is exploited to extract useful information on the rotor position and speed. The feasibility of the implementation is verified by simulations.

10:10 Input-State Feedback Linearization of a Boost DC/DC Converter

Andrea Cervone, Gianluca Brando

ID 194 – The paper presents a procedure to achieve an input-state feedback linearization on a bidirectional Boost DC/DC converter connected to a passive load. The system linearization is achieved by a proper state-space/output transformation performed on a non-dimensional form of the analytical model. The resulting system is then controlled through a standard linear regulator. An online load estimation technique is also provided to overcome the transformations parameter dependency. The proposed approach has been numerically tested and compared with a standard two-loop controller.

SS1-A Fast modelling approaches for electromagnetic devices analysis and design

Chairs: Yacine Amara and Georges Barakat

08:30 3-D Generic Magnetic Equivalent Circuit Taking Into Account Skin Effect: Magnetic Field and Eddy-Current Losses

Youcef Benmessaoud, Frédéric Dubas, Mickael Hilairet

ID 18 – In this paper, a three-dimensional (3-D) generic magnetic equivalent circuit (MEC) in Cartesian coordinates considering the skin effect is developed. This model has been applied to a U-cored static electromagnetic device. The main objective is to compute the magnetic field behaviour in massive conductive parts (viz., aluminium) and to predict the impact of the eddy-current magnetic fields in the neighbouring non-conductive parts. The classical magnetomotive force (MMF) distribution has been modified by integrating the MMF produced by the eddy-currents that occur in massive conductive regions. The eddy-current MMF was introduced by formula which derived from magnetodynamic Maxwell's equations. Both Experimental tests and three-dimensional (3-D) finite-element analysis (FEA) have been used to prove the validity of the proposed approach.

08:50 Air-gap reluctance function for MEC dynamic models of smooth rotor machines

Juliana Fernandes Cardoso, Marylin Fassenet, Christian Chillet, Laurent Gerbaud, Lamya Belhaj

ID 42 - This paper presents a method which describes the air-gap reluctance for machines with smooth cylindrical rotors. The method links the air-gap reluctance model to the machine's geometric parameters through use of the Fermi-Dirac integral as an analytical approximation of the magnetic flux waveform in the air-gap. Mathematical and physical limitations of the approach are studied and an adapted version for use in dynamic Magnetic Equivalent Circuit (MEC) models is presented. For this study, the real rotor is replaced by an ideal smooth rotor to eliminate the spurious effects and focus the study on the air-gap. The results are benchmarked against Finite Element (FE) simulation, showing maximum error of 1.1%. This represents an improvement of 5.6% compared to a discontinuous linear model.

09:10 Effects of synchronous motors parameters variations on efficiency maps

Habibou Lawali Ali, Abed Al Kader Al Asmar, Amina Bensalah, Yacine Amara, Georges Barakat

ID 106 - This contribution presents a study of the effect of synchronous motors losses parameters variations on the machines behaviour. In particular, the effects on efficiency maps are investigated. The goal is to identify parameters sets allowing improving energy efficiency for a given application.

09:30 2-D Analytical Model of Conventional Switched Reluctance Machines

Walid Belguerras, Youcef Benmessaoud, Fréderic Dubas, Kamel Boughrara, Mickael Hilairet

ID 61 - In this paper, we present a two-dimensional (2-D) analytical model of a conventional switched reluctance machines (SRMs). This model has been applied to a 8/6 conventional SRM supplied by conventional excitation (viz., standard asymmetric H-bridge). The goal is to determine the electromagnetic performances. The proposed analytical model is based on solving the partial differential equations (PDEs) due to Maxwell's equations in each domain of the studied machine (viz., air-gap, rotor and stator slots). A parametric study by using the developed analytical model has been compared with that obtained by numerical computations in linear and no-linear conditions. The results showed that the analytical and numerical results are in good agreements in linear conditions. However, in no-linear conditions, the developed model over-estimates the performances. Indeed, to pre-design the machine, this model can be incorporated in optimization environments where savings in computation time are needed.

09:50 Study of Magnets and Pole Pieces Openings in Coaxial Magnetic Gearbox by Reluctance Network

Mohammed Naïdjate · Nicolas Bracikowski · Tianbo She · Luc Moreau · Xiangyu Yang · Nicolas Bernard

ID 192 - The magnetic gearboxes has received much attention in the last few years. Their numerous advantages, such as: low vibration, reduced acoustic noise and minimum maintenance, are attracting considerable interest for sectors of a high-growth like wind turbines and electric vehicles. The present paper aims to study the effect of the magnet and pole pieces opening on the torque of coaxial magnetic gears (CMG) in order to optimize the latter. It is also about providing a fast and accurate model based on reluctance network method capable of describing the correct electromagnetic behavior of CMG. The confrontation of the obtained results to those calculated by finite element show a good agreement while guaranteeing a considerable gain in computation time. The proposed model was adopted to optimize the CMG design using parameter-scanning method.

10:10 Weight-function identification for the Preisach model of laminated steels using concentric hysteresis loops

Reza Zeinali, Dave Krop, Elena Lomonova

ID 198 - This paper proposes a new methodology to obtain the weight function of the Preisach model for non-oriented laminated steels using concentric hysteresis loops. In this methodology, first the experimental weight function is obtained from measured concentric hysteresis loops and a mathematical technique is applied to remove the existing negative values. Based on the shape of the modified weight function, a new analytic function is proposed as a weight function for the Preisach model. The proposed analytic function is more advanced than the conventional probability functions proposed in literature, such that it is able to better mimic the actual shape of the weight function. The unknown parameters of the analytic weight function are identified by minimizing the error between the Preisach model and the modified measurements. Using the proposed analytic weight function, the minimum rms-error is reduced to less than 0.5% and a decent agreement is achieved between the model and the measurement.

SS5-B Energy storage systems: new power electronics topologies, high-performance control techniques, and hardware emulation

Chairs: Massimiliano Luna and Alexander Kuznietsov

08:30 Theoretical analysis of six-phase interleaved boost converter based on SiC semiconductor and inverse coupled inductor for fuel cell electric vehicle application

Hanqing Wang, Arnaud Gaillard, Daniel Hissel

ID 41 – This paper deals with the theoretical analysis of the proposed six-phase Interleaved Boost Converter (IBC) based on Silicon Carbide (SiC) semiconductor and inverse coupled inductor aimed at Fuel Cell Electric Vehicle (FCEV) application. According to the comparison analysis, the proposed converter is attractive to reduce the fuel cell stack current ripple and extend its lifespan. Then, the total volume and weight of magnetic component has been decreased due to the inverse coupled inductor. Furthermore, benefiting from the SiC semiconductor, high switching frequency has been selected and low switching loss has been obtained. The power loss of proposed converter has been reduced while the reliability, efficiency, thermal performance and power density have been increased.

08:50 Preliminary Design of Ultrafast Charging Station for Electrical Vehicles

Diego Iannuzzi, Pasquale Franzese

ID 193 – The paper proposes a design methodology of ultrafast charging station based on Load Levelling power management. The target of EV ultrafast charge time is 10 minutes. This means a significant increasing of electric power requirement fed by the grid. The paper suggests dc micro-grid concepts for modular ultrafast charging station based on integration of intermediate power buffer. This latter is composed by energy storage system (ESS) in order to reduce the peak power of grid during the EV charging. The choice of ESS size depends on number of EV to charge at same time, the type EV battery capacity and their initial state of charge. The paper presents an analytical approach based on simplified battery model in order to design the capacity and maximum power rating of ESS taking into account the cell technology of battery and their life cycle.

09:10 A non-dissipative Li-ion battery hardware emulator based on a hybrid dynamic model

Massimiliano Luna, Maria Carmela Di Piazza, Giuseppe La Tona, Angelo Accetta, Marcello Pucci

ID 156 – More and more applications encompass battery energy storage systems (BESSs) based on Li-ion batteries. However, when designing the BESS power converter or when studying the interaction between BESSs and other application components, relying on a real battery makes the process cumbersome, expensive, and time-consuming. Moreover, the battery could even be damaged. In this paper, a Li-ion battery emulator that is capable of both sourcing and sinking power at kilowatt scale is designed, built, and experimentally validated. Unlike other similar devices available in the market or proposed in the technical literature, it is low-cost, it injects power into the grid during sink operation, and it can reproduce battery dynamics. Design criteria are given, and several test results are presented, validating the design. The obtained device allows reducing the cost, time, and complexity of performing system tests of Li-ion BESS applications.

09:30 A two-level Fuzzy Logic Machine based control algorithm for resilient microgrids in ICT applications

Giovanni Brunaccini, Marco Ferraro, Davide Aloisio, Giorgio Dispenza, Nico Randazzo, Francesco Sergi, Vincenzo Antonucci

ID 125 – Resilient microgrids have been determining growing interest from ICT service providers, since the revenue of their services is critically affected by the service availability. Among ICT systems, in landline and radio base stations, to assure service availability even in case of grid fault due to bad weather conditions, an internal storage capacity as uninterruptible power supply is used. However, such storage equipment represents an unavoidable cost in terms of initial investment, maintenance, and operational efficiency. In this work, starting from a previous development of a prototype supply system for a landline station, the control algorithm of the storage devices was investigated to optimize the cost/benefit ratio. Based on Fuzzy Logic, the system controller was developed in order to exploit the revenue opportunities offered by the energy market, by converting a passive load (landline station) in an active system that exchanges power through the grid. Beside this, a fuel cell generator was integrated to assess the further benefits in terms of system resiliency against grid supply fault and battery design optimization. The simulation results indicated that the developed algorithm had well reactive behaviour both for energy price, battery State of Charge, and grid fault probability variations.

09:50 Thermal analysis of the power distribution system as part of an underwater compressed air energy storage station

Océane Maisonnave, Luc Moreau, René Aubrée, Mohamed Fouad Benkhoris, Thibault Neu

ID 82 – This paper deals with sizing and reliability of the power electronics equipment embedded in an offshore compressed air energy storage station. In this system, the power grid is distributed through a DC bus between 10 identical electro-pneumatic power conversion units. Each unit is also divided in 2 parallel variable speed drive devices which operate with large power fluctuations. From a transient thermal model of IGBT modules, the thermal behaviour of power converters is described over cyclic fluctuations. Thermal results analysis shows that the sizing of the system could be considered downwards. Then, the main grid side converter sizing is discussed according to two operating configurations. Finally, considering thermal results, the temporal interleaving of the power units operation allows to reduce current rating of IGBTs as well as thermal stress of the semiconductors.

10:10 JADE Based Multi-Agent Decentralized Energy Management System of a hybrid Marine-Hydrogen Power Generation System

Mahmoud Barakat, Boubekeur Tala-Ighil, Hamid Gualous, Daniel Hissel

ID 40 – This paper presents the decentralized JADE (Java Agent Development Environment) based Multi-Agent System (MAS) oriented to the energy management and balance of the hybrid marine-hydrogen power generation system. The proposed hybrid marine-hydrogen system consists of a fixed pitch direct drive tidal turbine, a MegaWatt (MW) scale proton exchange membrane electrolyzer, and fuel cell and a Li-ion battery stack. The different components are coupled together on a DC-link via different topologies of power electronics converters for feeding a residential load as isolated system architecture. The MW scale electrolyzer and fuel cell systems represent the main elements of the hydrogen energy storage system. An isolated mode of operation is programmed to evaluate the MAS capability of energy management and balance considering the marine current intermittency and the demand-side variations. The proposed energy management system considers the safe operations of the electrolyzers, fuel cell and battery by considering their constraints and dynamics.

SS11 Safety related issues in electrical installations

Chairs: Fabrizio Marignetti and Piergiacomo Cancelliere

08:30 A low-cost monitoring and fault detection system for stand-alone photovoltaic systems using IoT technique (from TT1)

Adel Mellit, Amor Hamied, Alessandro Massi Pavan, Vanni Lughi

ID 67 – In this paper we developed a prototype device for smart monitoring and fault detection of a stand-alone photovoltaic system (SAPVS), using an Internet of Things approach. An electronic sensing board has been designed and a web based application has been developed in order to monitor the data (current and voltages delivered by the SAPVS, as well as air temperature and solar irradiance) in real time. The prototype has been tested experimentally at the Renewable Energy Laboratory of Jijel University, Algeria. The experimental results show the capability of the prototype to monitor data, detecting and singling out possible faults based on the output PV power, and inform users via website about the state of the system. The faults that have been investigated are: open circuit, shading effect, and dust accumulation on PV modules. The prototype is cost-effective and very easy to be implemented without any additional circuits and efforts.

08:50 Behavioral Modeling of Wireless Power Transfer System Coils (from TT1)

Kateryna Stoyka, Gennaro Di Mambro, Nicola Femia, Antonio Maffucci, Salvatore Ventre, Fabio Villone

ID 169 – This paper discusses the behavioral modeling of mutual inductance for rectangular-shaped coils used in Wireless Power Transfer Systems (WPTSs), for different types of coils misalignment. A Multi-Objective Genetic Programming (MOGP) algorithm has been adopted to discover behavioral models offering optimal trade-off between accuracy and complexity, starting from a large set of mutual inductance data evaluated by using literature analytical model. The proposed behavioral models express the dependence of the mutual inductance on the axial and lateral misalignments of the two coils and on their reciprocal rotation angle. The resulting mutual inductance values are in good agreement with the adopted analytical model predictions and with full 3D Finite Element numerical simulations.

09:10 Multicast routing protocol for LoRa mesh networks in safety critical communications

Roberto Di Stefano, Fabrizio Marignetti

ID 76 – The risk reduction, in case of catastrophic events, is strongly conditioned by the possibility of performing mechanical actuation in extreme conditions and without electric energy. Many devices, which implement security features and fulfill these specifications, are on the market, however the capability to transfer data and information through reliable technologies is also required in order to monitor and coordinate the safety systems. A possible candidate that could provide a communication link, even in the absence of electricity, is LoRa technology, even if it has some problems and limitations mainly due to the topological configuration of the LoRaWAN communication network and the increasing number of devices and users. This paper reports a proposal to improve the reliability of LoRa data transfer in very severe environmental conditions and on large areas. Some experiments, conducted on a number of devices, make it possible to verify the effectiveness of the proposed communication strategy.

09:30 A Quasi-3D Methodology for the Assessment of AC Interference Induced on Buried Metallic Pipelines in Complex Right-of-Ways

Arturo Popoli, Andrea Cristofolini, Leonardo Sandrolini

ID 146 – This paper proposes a novel methodology aimed at providing a tool for assessing the levels of current and voltage induced on metallic buried pipelines by overhead power lines. The developed technique employs a Finite Element Analysis to define multiport electrical components, that represent segments of the corridor shared by the overhead power line and the pipeline. These components can be integrated into a network embodying the physical characteristics of the whole corridor. In this way, the circuital analysis is used to extend the capabilities of a standard two-dimensional field analysis. The applicability of the method is demonstrated by simulating two cases of interference, showing that the methodology is suitable for the assessment of complex routings of the considered metallic conductors.

09:50 Investigation on the fire hazards of Li-ion cells

Paola Russo, Maria Luisa Mele, Giovanni Longobardo, Michele Mazzaro, Cinzia Di Bari

ID 183 – Li-ion batteries had a great development in recent years, and their use has grown massively because of their higher energy and power density with respect to traditional ones. However, their high energy density imply great danger in the event of malfunctions or failures, due to the emission of toxic and highly flammable substances. In the worst case, thermal runaway can occur. It is a chain reaction where unwanted reactions take place that leads to an uncontrolled and unstoppable increase in temperature. It can cause uncontrolled combustion and then explosion with great danger. In order to identify the conditions that lead to the thermal runaway and to limit its occurrence, thermal stability of Li-ion batteries is here investigated. Thermal abuse tests are performed on Lithium Nickel Manganese Cobalt oxides cells from Panasonic in a ISO 5660 cone calorimeter. Heat release rate is measured by changing the state of charge (SoC) of the cells and the radiant power of the cone calorimeter. The relationship between the SoC and the onset of the heat release is clearly revealed.

10:10 Fire safe transformers using natural esters liquid insulations

Massimo Pompili, Luigi Calcara, Michele Mazzaro, Domenico De Bartolomeo, Piergiacomo Cancelliere

ID 162 – The use of natural esters in power transformers is increasing considerably thanks to their different advantages such as high flash/fire points, lower toxicity, higher biodegradability and possibility of recycling. In this paper are reported some experimental activities carried out within an Italian Working Group on natural esters on the different fire behavior of natural esters and mineral oils. As an example, some similar tests carried out at international level are also re-ported. The results shown in the present paper give a contribution to ascertain that the use of natural ester transformer may positively contribute to a significant reduction of risks to humans and environment.

TT3-B Design and optimisation

Chairs: Mario Cacciato Dmitri Vinnikov

11:00 Performance testing of a piezoelectric device for extracting energy from vibrations

Giorgia Leonardi, Fabio Passacantilli, Carmen Galassi, Daniele Dessi

ID 92 – Energy harvesting from ambient sources is an interesting opportunity for wireless and self-powered electronics, increasing research efforts toward the development of new devices. Among all the energy sources, vibrations seem particularly convenient for this kind of application. Piezoelectric resonant systems, though offering configurations well suited to recovery energy from vibrations, suffer from narrow operational bands, and for this reason new solution to enhance performances at off-design excitation conditions are sought. In this paper a piezoelectric resonant energy harvester is developed, focusing the attention on both ceramics production method and support material choice in order to maximize the oscillation amplitudes, and consequently the energy production. The device produced at ISTEC laboratories is then compared with a commercial product under harmonic excitations. Results relative to power output show that the in-house assembled device has better performance than the commercial one in the considered tested conditions both in absolute terms and with respect to the active piezoelectric volume of the two devices.

11:20 High Frequency Injection-based Sensorless Position Estimation in Permanent Magnet Synchronous Machines

Cyril Spiteri Staines, Kris Scicluna, Reiko Raute

ID 102 – This paper is concerned with the application of a pulsating high frequency voltage together with a Search based Online Commissionable (SONIC) sensorless position observer for Surface Mounted Permanent Magnet Synchronous Machines. The proposed algorithm is based on an iterative search of position dependent saliency maps commissioned online with the aim to make the technique also applicable to machines with non-ideal sinusoidal saliencies. Experimental results for estimation at low and zero speed are shown.

11:40 Generator Topologies for Horizontal Axis Tidal Turbines

Mohammad Rafiei, Francesco Salvatore, Fabio Giulii Capponi

ID 121 – Over the last decade, research on technologies to exploit tidal currents kinetic energy for renewable electricity generation has had a significant growth. Megawatt-scale horizontal axis marine current turbines have been deployed worldwide. However, as to date, there is not a consensus worldwide standard Power Take-Off (PTO) systems, due to the current immaturity of tidal energy converters technologies. In most cases, mechanical/electrical power conversion follows well proven technologies derived by the mature wind-energy sector. However, the peculiarities of tidal energy resource impose ad-hoc technology solutions. In this paper, different generator topologies and recent developments for marine tidal energy systems are reviewed and compared. The aim is to provide an overall perspective and identify areas for further development. Among considered technologies, the direct-drive permanent magnet synchronous generator (DDPM) represents an appealing solution, for reduced system complexity and maintenance requirements and possibility to develop smart Maximum Power Point Tracking (MPPT) strategies.

SS1-B Fast modelling approaches for electromagnetic devices analysis and design

Chairs: Georges Barakat and Yacine Amara

11:00 Graphical predetermination of optimal machine designs by iso-performance configuration modeling

Stephane Vivier

ID 93 - This paper presents a methodological procedure for optimization assistance in general and for the optimal design of electrical machines in particular. This approach tries to address the multiple weaknesses presented by "classical" direct optimization techniques. In particular, the tools implemented by this methodology offer the opportunity to understand more finely, typically through 2D graphical representations, the complexity of the optimization design problems. This work is an attempt to find an intermediate configuration between the pure optimization approach and the one based solely on modeling. The application of this approach is illustrated by the presentation of the main steps of the optimal design of a Permanent Magnet Synchronous Machine.

11:20 Pre-optimisation of hybridisation ratio of hybrid excitation synchronous machines based on electrical circuits modelling

Yacine Amara, Sami Hlioui, Hamid Ben Ahmed, Mohamed Gabsi

ID 122 - Hybridisation ratio α is an additional degree of freedom offered by the hybrid excitation principal in the design of electrical machines. This contribution presents a study of the effect of some design parameters, or variables, on the values of the hybridisation ratio α.

11:40 A novel passive force sensor based on Villari effect

Valerio Apicella, Carmine Stefano Clemente, Daniele Davino, Damiano Leone, Ciro Visone

ID 163 - This paper deals with the development of a novel force sensor exploiting a cylindrical sample of Galfenol, a giant magnetostrictive Iron-Gallium alloy, as the active core. The aim is to develop a device able to measure slow force profiles with good accuracy, by exploiting an extremely simple transduction principle. In fact, the well known Villari effect is exploited to construct a force map taking into account both flux density and effective magnetic field experienced by the sample during the operations. Therefore, a preliminary calibrating characterization is carried out, followed by tests performed with the aim of validating the device working principle and to estimate its performance.

TT4-C Identification and diagnosis

Chairs: Benoît Robyns and Paolo Mattavelli

11:00 Fractional Order System Identification Method for Online Monitoring of Humidity of Electrochemical Hydrogen Pumps

Gjorgji Nusev, Pavle Boškoski, Gregor Dolanc

ID 113 – Electrochemical hydrogen pump (EHP) is promising technology capable of extracting hydrogen from miscellaneous gas mixture and compress it to very high pressures. The basic working principles are similar to that of a proton exchange membrane (PEM) fuel cell. Consequently, its performance is heavily dependant on humidity level of the membrane. Unlike PEM fuel cells where water is generated as a by product, in the case of EHP the humidity has to be delivered via external humidifier. Therefore, it is paramount to have accurate information regarding the humidity in order to achieve optimal exploitation. Inaccessibility of the membranes makes it almost impossible to perform direct humidity measurements. Addressing this issue, this paper presents a method for online estimation of humidity levels based on the parameters of an equivalent circuit model (ECM). The parameter estimation is performed through a combination of evolutionary algorithm and simplex optimisation. The method is evaluated on a market ready EHP device with capacity of pumping 1.4118 stl/min of H2.

11:20 Report on Lithium-ion Battery Ageing Tests

Rocco Morello, Roberto Di Rienzo, Roberto Roncella, Roberto Saletti, Federico Baronti

ID 173 – Lithium-ion battery ageing modelling and prediction is one of the most relevant topic in the energy storage research field. The development and assessment of reliable solutions are not straightforward, because of the necessity to acquire information on the cell ageing processes by employing very time-consuming tests. During these tests the cells are subjected to different profiles, usually based on the repetition of several charge/discharge cycles, in order to reproduce the ageing effects in laboratory. This paper aims at accelerating the advancement in this research field by discussing a dataset containing three different ageing tests and making it available to be used by other research groups. The tests are accurately described and a preliminary analysis of the obtained results is carried out.

11:40 Simplified Parameters Estimation for the Dual Polarization Model of Lithium-Ion Cell

Claudio Rossi, Carlo Falcomer, Marco Bertoldi, Davide Pontara

ID 189 – This paper describes a method for determining the parameters of the 'Dual Polarization Model' for Lithium-Ion battery cell from the result of a standard pulsed discharge test. The paper introduces a sequence of computations that, starting from the acquired data, step by step, gives the parameters of the look-up tables used in the model. The combination of the very common Dual Polarization Model, or two RC network, with this tuning method allows to define a procedure that can be applied to a wide range of Lithium-Ion cells. The use of a normalized cell model and the application of a search function with pre-determined boundary conditions guarantees the certainty of the results, regardless of the cell size and type. The proposed procedure is suitable for future adaptions of the model to cell temperature variation and aging derating. The resulting model is also proposed as the reference model used for the State Of Health (SOH) estimation.

SS6-A Future power electronics for resilient high-power-quality grid-connected renewable energy systems: design, modelling and control

Chairs: Hadi Y. Kanaan and Maurice Fadel

11:00 Structural Analysis and Modular Control Law for Modular Multilevel Converter (MMC)

Pierre-Baptiste Steckler, Jean-Yves Gauthier, Xuefang Lin-Shi, François Wallart

ID 118 – This paper proposes an in-depth analysis from the control point of view of dynamic models of a Modular Multilevel Converter (MMC) for high-voltage direct current (HVDC) application. Firstly, a generic method of analysis is presented for a natural arm-level state-space model. Its structural analysis highlights the decoupled nature of the MMC. Secondly, the well-known sum and difference of the upper and lower arm state and control variables is considered to obtain a sigma/delta model. This transformation leads to a coupling between state and control variables and to an increase of the system complexity. Using the analysis results of the natural model and the sigma/delta model, an original arm-modular control is finally proposed. The simulation results show the effectiveness of the proposed control, which is simpler to design compared to a conventional sigma/delta control.

11:20 Static Switch Activation Algorithm for Energy Storage System Grid-Connection and Disconnection

Manel Jebali-Ben Ghorbal, Marwa Ben Said-Romdhane, Jihen Arbi Ziani, Sondes Skander-Mustapha, Ilhem Slama-Belkhodja

ID 127 – One of the most important problems for residential rooftop photovoltaic systems with energy storage is grid voltage synchronization control under balanced grid conditions and fast and appropriate disconnection from the distribution electrical network if inacceptable voltage variation occurs. Connection and disconnection of such a system is performed through a static switch denoted K. This paper deals with an activation algorithm of the static switch K connecting and disconnecting a battery energy storage system (BESS) to and from the main grid. The BESS is dedicated to areas where grid is not available all the time, but where photovoltaic (PV) is available to ensure non interruptible supply of residential loads. The BESS is connected to the grid via a DC-AC converter which hosts the proposed algorithm. Fast detection of special grid conditions is first ensured, to allow a fast disconnection from the grid but keeping a good power quality for connected loads. Finally, simulation and experimental results are given to validate the effectiveness of the proposed method.

11:40 Coordinated control of supercapacitors-Battery tandem by Smart Converters in microgrid scenario

Giovanna Adinolfi, Roberto Ciavarella, Giorgio Graditi, Angelo Merola, Maria Valenti

ID 157 – Microgrids represent a promising energetic scenario applicable in different contexts, especially in residential clusters. In this paper, authors propose a novel control logic to implement a coordinated management of generators, loads and Hybrid Energy Storage Systems (HESS) in a microgrid by means of a hierarchical Smart Converters architecture. The innovative algorithm is embedded in a Master Converter. It allows the online management of energetic fluxes in cooperation with Slave Converters distributed among the microgrid resources. They carry out a smart coordination of microgrid generation, absorption and battery-supercapacitor storage systems with the aim to improve the availability of the storage systems for providing ancillary services to the power grid. The effectiveness of the control is tested applying the Smart Converters Master-Slave architecture, including the combined management BESS-Supercapacitor algorithm, to a grid-connected residential microgrid.

P2 - Plenary session 2

Chair: Giovanni Spagnuolo

12:00 The plugin electric vehicle: grid disturbances provider or a mean to improve the grid operation?

Seddik Bacha

The Plugin Electric Vehicle (PEV) has attracted increasing interest from the public, the manufacturers and finally from the grid operators. It is due to public policies and/or ecological concerns, business and sometimes to its potential threat for the grid operation.

The PEV first interesting characteristic is its randomized multidimensionality: state of charge of the battery, location, times of arrival and departure. To increase the complexity, one can add the human in the lop. All of these factors make the PEV a source of multidisciplinary locks. The first actor to be impacted will the power grid because the PEV is necessarily an additional burden and consequently it will be necessary to add new resources. If there is no planed actions, the grid will be disturbed and will suffer disturbances, congestions and serious impacts on voltage and frequency behaviors.

However, with a four quadrants on-board charger, the PEV can be used as a flexible mean of storage, then can provide various grid functionalities, facilitate the integration of renewable energy, furnish a provision of primary reserves for the frequency and voltage or even shape the overall load curve.

If these features are interesting, needless to say that these functions are strongly constrained by the Grid structural limits, by the PRVs availability, by regulations and finally by the economic viability of the corresponding business model. This presentation will attempt to explain all of these points and will propose a few avenues for reflection.

Industry Forum

Chairs: Paolo Mattavelli and Massimiliano Luna

14:20 Power Electronics Control Design in MATLAB and Simulink

Francesco Alderisio
MathWorks
Via Bertola, 34 Torino, Italy

In the current era of electrification, power electronics control systems are becoming more and more popular, but at the same time their complexity is also increasingly growing. One of the major applications is represented by hybrid and electric vehicles, where electrical systems are starting to replace, either partially or totally, conventional propulsion systems based on combustion engines. For such complex systems, modelling and simulation tools are essential to experiment many variants and combinations of powertrain concepts, design control algorithms, test logical integration of control units, monitor temperature, and analyse power quality of the electrical network. In this presentation you will find out how MATLAB, Simulink and Simscape can be used to model and simulate analog and digital components of a power electronics system. The design of a hybrid electric vehicle and some of its components, such as the DC/DC power converter and the battery, will be shown. Particular focus will be given onto the design and implementation of a battery management system (BMS). You will see how physical modelling tools can help you correctly size electrical components, serve as the fundamental element to implement control strategies, and introduce faults to perform “what-if” analysis to test and validate your supervisory control logic.

15:00 Electric motor design: focus on NVH and Thermal Management

Davide Frigerio
ANSYS
Via G.B. Pergolesi, 25 Milano, Italy

In the design of electric motors, the engineering challenge is in keeping the maximum performance of the active part by controlling losses, heat, and discomfort due to vibrations in the package. ANSYS supports e-motor design with a comprehensive workflow for all the stages: during the presentation, we will show how the ANSYS multiphysics approaches help to have complete control of the Noise Vibration and Harshness and the Thermal management of the motors.

15:20 Challenges in EV fast charging

Francesco Galiano
Bitron
Grugliasco (TO), Torino, Italy

Bitron is a multinational manufacturing company, active in industry sectors such as Home Appliance, Automotive, Energy, HVAC. The presentation will outline some successful research and development projects, in sectors where evolution is faster, like fast chargers for electric vehicles.

SS3 Emerging challenges in fault detection, diagnosis and prognosis in photovoltaic applications

Chairs: Patrizio Manganiello and Mattia Ricco

14:20 Real-Time procedure to detect losses in photovoltaic generators using the instantaneous and the translated Performace Ratio

Francisco José Sánchez Pacheco, Llanos Mora-López, Mariano Sidrach-de-Cardona, Michel Piliougine, Juan Heredia-Larrubia

ID 4 – The energy yield of a photovoltaic plant depends on the performance of each of its single photovoltaic modules. In this paper, a methodology is presented that allows calculating the losses produced in a module and identifying if it is operating properly according to given climatic conditions. The proposed model is based on the comparison between the theoretical performance ratio of a module and the resulting experimental one under given climatic conditions. The results obtained allow estimating the losses that affect a module non operating properly. By means of real-time monitoring at module level, the herein described experimental system together with the proposed methodology allows to quantify the module losses. The immediate corrective actions will avoid further losses in the generated energy.

14:40 Reliability of explicit methods to identify the parameters of PV panels with degraded series resistance: an experimental comparison

Giovanni Petrone, Luigi Orza, Francisco José Sánchez Pacheco, Michel Piliougine, Llanos Mora-López, Mariano Sidrach-de-Cardona

ID 111 - In this paper a comparison of some explicit methods, used for parameters identification of the photovoltaic single-diode model, has been carried out. The analysis is aimed at understanding the level of reliability of the methods when applied for photovoltaic model-based diagnostic functionalities. The study is focused on the series resistance variation since this is the parameter mainly related to the photovoltaic degradation phenomenon. Although in online detection of PV degradation the explicit methods are preferred for their simplicity, the experimental results demonstrated that is not recommended to adopt only these methods because the higher the series resistance the higher error is introduced, thus affecting the diagnosis results.

15:00 An approach to the cell-level diagnosis of malfunctioning events in PV panels from aerial thermal maps

Antonio Pio Catalano, Pierluigi Guerriero, Vincenzo d'Alessandro, Lorenzo Codecasa, Santolo Daliento

ID 141 - This paper presents an innovative approach to the cell-level diagnosis of malfunctioning events in photovoltaic (PV) panels from the processing of temperature maps taken from low-flying drones. The application of a detailed power balance equation allows deriving the electrical power generated or dissipated by each cell with a reasonable degree of accuracy. The method is tested by emulating the experimental temperature maps through accurate 3-D thermal simulations of the panel for some cases of interest.

15:20 Diagnose Algorithm and Fault Characterization for Photovoltaic Arrays: A Simulation Study

Luis D. Murillo-Soto, Carlos Meza

ID 187 - Performance of photovoltaic installation is highly affected by faults in single modules. Faults in photovoltaic arrays are difficult to detect, locate and diagnose due to the way in which modules are configured. Given that photovoltaic arrays are formed by modules in series, a fault in a single module affects the whole system. Therefore, the technology to detect and diagnose faults inside solar arrays is emerging, the present paper proposes several expressions that help to detect and diagnose failures using a proposed algorithm. The expressions were obtained by an inductive approach based on the analysis of simulation cases were different faults were tested. The array model used for the simulation was built in Spice software base on the five parameter model of a solar module.

SS2-B Innovative modelling and simulation approaches for new technologies in photovoltaic systems

Chairs: Patrizio Manganiello and Xavier Roboam

16:00 Centralized control in photovoltaic distributed maximum power point tracking systems

Ramón López-Erauskin, Ander González, Johan Gyselinck, Giovanni Petrone, Giovanni Spagnuolo

ID 56 – Photovoltaic energy harvest in distributed maximum power point tracking systems has demonstrated to be superior to the traditional photovoltaic systems under mismatch conditions. The distributed architecture usually consists of series-connected DC/DC converters forming a string, dedicated to process the power of individual photovoltaic panels. However, the classical approach assumes an independent control of the DC/DC converters preventing them from knowing the operating condition of the other converters in the string. The adoption of centralized algorithms allows full control of the variables in distributed maximum power point tracking systems and hence further increases the energy harvest. This paper proposes a novel centralized control that matches distributed and central maximum power point tracking functions, as well as an innovative functionality that improves the dynamic performance in photovoltaic applications.

16:20 Optimal PV panel reconfiguration using Wireless Irradiance Distributed Sensing

Antonino Laudani, Gabriele Maria Lozito, Martina Radicioni, Francesco Riganti Fulginei, Alessandro Salvini

ID 108 – The aim of this paper is to provide a dynamic reconfiguration method for partially shaded photovoltaic arrays. The implemented strategy is able to increase power production of the array with respect to the initial topology in real time and with any shading pattern. The array is supposed to be made of strings of modules interconnected in parallel and each module is constituted by series-connected photovoltaic cells. Irradiance values are calculated through a closed-form relation given the operating point of the modules, their temperatures and their equivalent circuit model. This procedure frees the system from the necessity of costly pyranometers. The implemented method has been validated in Matlab environment simulating random shading conditions and implemented on a low-cost 32 bit microcontroller with wireless connectivity capabilities. The results prove the efficiency of the proposed solution.

16:40 Unity Efficiency and Low Cost MPPT Method for Single-Stage Grid-Connected PV System

Yacine Triki, Ali Bechouche, Hamid Seddiki, Djaffar Ould Abdeslam

ID 116 – This paper presents a new maximum power point tracking (MPPT) algorithm based on the adaptive linear neuron concept. This method is designed to extract the maximum power in single-stage grid-connected photovoltaic (PV) systems configuration. The PV panel is directly connected to grid through a pulse-width modulation inverter. The control is achieved in the synchronous dq frame and the proposed MPPT estimates directly the optimal d-axis duty cycle component. Furthermore, in order to achieve a unity power factor operation, the q-axis reference current is set to zero. In this work, only one proportional integral controller is used to maintain the reactive power to zero value. To verify the effectiveness of the proposed method, the grid-connected system is built and simulated under MATLAB-Simulink software. The results are compared to those obtained by the conventional perturb and observe based MPPT technique under fast and slow irradiance changes. The simulation results show that the proposed method lead to achieve incomparable performances such as unity efficiency and no oscillations in the PV panel in both transient and steady state operations.

17:00 Distributed converters in large PV plants: performance analysis supported by behavioral models

Giovanni Nobile, Mario Cacciato, Giuseppe Scarcella, Giacomo Scelba, Ester Vasta, Agnese Giuseppa Federica Di Stefano, Giuseppe Leotta, Paola Maria Pugliatti, Fabrizio Bizzarri

ID 123 – This paper is aimed to assess the performance of distributed converters in large PV plants through the analysis of a case study represented by a 2 MW PV plant in Central Italy. The electrical layout of a 500 kW subfield has been modified performing the installation of DC/DC converters at string level in order to create an independent MPPT control for every string. This kind of performance analysis is usually carried out using data acquired by the plant datalogger. Unfortunately, the presence of partial unavailability, monitoring system faults, shutdown for maintenance activities, etc. can create several issue in data processing. To support data elaboration, a novel behavioural modeling approach has been developed and exploited in this work. This novel approach, based on an integrated state-space average model, can improve the performance analysis ensuring a satisfactory accuracy but keeping a low computation effort. Validation is performed considering real operating scenarios in case study.

SS6-B Future power electronics for resilient high-power-quality grid-connected renewable energy systems: design, modelling and control

Chairs: Maurice Fadel and Hadi Y. Kanaan

16:00 Paralleling Converters in DC Microgrids with Modified Lag I-V Droop Control and Voltage Restoration

Daniel Zammit, Cyril Spiteri Staines, Maurice Apap, Alexander Micallef

ID 7 - In stand-alone or islanded DC microgrids, load sharing between paralleled converters is usually obtained using the droop control method. There are two main types of droop control used with DC microgrids; the impedance (V-I) droop control method and the admittance (I-V) droop control method. Droop control permits load sharing between paralleled converters, but it creates a voltage deviation in the DC microgrid voltage. Voltage restoration control is then required to restore the DC microgrid voltage back to its preset value. This paper presents an alternative I-V droop control method using a modified lag compensator to obtain voltage control as well as load sharing between the paralleled converters within the DC microgrid. The control system consists of two nested controllers, an inner Proportional-Integral (PI) controller to control the current, and an outer modified lag compensator to control both the voltage and the droop. An addition outer loop is used for voltage restoration. The proposed control system was modelled in Simulink and the operation was tested by simulating two paralleled Buck converters operated in the continuous current mode while sharing a common resistive load.

16:20 Power management of a full DC microgrid for building self-consumption applications

Wenshuai Bai, Hongwei Wu, Manuela Sechilariu, Fabrice Locment

ID 58 - Microgrid is a small-scale power supply system that can support the intelligent energy management integrated with multi-source, multi-storage, and local demand side management in multiple operational modes, and most importantly make the microgrid achieve self-consumption. This paper presents an algorithm for a full DC microgrid, which combines grid-connected and islanded operational modes, with real-time demand side management optimization. Such a full microgrid consists of photovoltaic sources, a DC load, battery storage systems, a supercapacitor storage, a diesel generator and a public grid connection, which is based on a DC common bus. The proposed real-time power management focuses on building self-consumption and considers the power constraints imposed by the public grid as well as the sluggish dynamic of the diesel generator, self-discharging characteristic of the supercapacitor, and the load shedding optimization. The simulation results, obtained under MATLAB/Simulink, verify the real-time control algorithm can keep power balance in real-time.

16:40 A systematic design methodology for DC-Link voltage control of single phase grid-tied PV systems

Meriem Merai, Mohamed Wissem Naouar, Ilhem Slama-Belkhodja, Eric Monmasson

ID 140 - PI controllers are commonly used for the DC-link voltage control of single phase grid-tied inverters. This DC-link voltage is characterized by double-line frequency ripples, which are natural by-product of single phase AC systems. These ripples, if not controlled properly, can adverse the performances of the grid-tied PV system at the AC side, particularly the grid current THD. On the other hand, random and sudden changes of the active power produced by PV panels, during sudden shadow or lighting of PV panels, can lead to high DC-link voltage fluctuations. This paper presents a systematic design methodology to tune the gains of the PI-based DC-link voltage controller so that the DC-link voltage fluctuations as well as the grid current THD are reduced to tolerable limits. Several simulation results are presented and discussed to show the effectiveness of the proposed design methodology.

17:00 Simulation of an Islanded DC Microgrid Using Instantaneous and Average modeling approaches

Elie Hleihel, Maurice Fadel, Hadi Kanaan

ID 152 - With the proliferation of renewable energy sources and the adoption of several policies to reduce environmental risks caused by traditional polluting sources, the concept of microgrids is gaining nowadays an increased interest especially DC microgrids. In fact, most of Renewable Energy Sources (RESs) and loads are inherently DC type. Moreover, DC microgrids offer many merits over AC ones in terms of ease of control and efficiency. While most of researches address the control hierarchy and strategy in DC microgrids, this paper focuses on the modeling and simulation aspect. A typical configuration of an islanded DC microgrid is modelled in MATLAB/Simulink and a primary level control strategy is adopted where two approaches of converters modeling are tested: instantaneous and average model. The two approaches of modeling are compared in terms of precision of losses modeling, dynamic response of the system, simulation time and computational burden. Simulations tests are conducted and results show that, despite its accuracy, the instantaneous model can be applied only for short-term simulations due to many limitations while, average converter modeling presents a better solution for long time simulations since it ensures a tradeoff between model accuracy and simulation time which makes the application of the three levels of hierarchical control in DC Microgrids valid in one simulation model.

SS7 Graphene-based devices: modelling and experimental results

Chairs: Patrizia Lamberti and Giovanni Spinelli

16:00 An Impedance-based Life-Monitoring Technique for a Graphene Water Filter

Stefano Bellucci, Antonino Cataldo, Luigi Ferrigno, Samuele Giovannetti, Antonio Maffucci

ID 144 – The paper deals with the design and verification of a monitoring system for the analysis of the useful life of a water filter. The filter is made by pressed graphene nanoplatelets, obtained from commercial graphite with a low-cost fabrication procedure. The state of the filter is monitored by measuring the electrical impedance at the port of a suitable circuit embedding the graphene filter. It is demonstrated a good sensitivity of the impedance with respect to the saturation level of the pollutants into the filter. The technique is also shown to provide a high level of reproducibility and stability with environmental conditions.

16:20 Impedance spectroscopy characterization of a graphene based solar cell with improved contacts

Ilaria Matacena, Daniele Zocco, Pierluigi Guerriero, Nicola Lisi, Laura Lancellotti, Eugenia Bobeico, Paola Delli Veneri, Santolo Daliento

ID 160 – In this paper graphene on silicon solar cells, adopting either gold contacts or graphite contacts, are characterized by means of the impedance spectroscopy analysis. Experiments are described in terms of equivalent circuit model and lumped parameters allowing to reproduce experiments in the whole set of frequency and dc biases are given. From this analysis the C-V plot of the solar cell is extracted, and the barrier height of the graphene-silicon interface is derived.

16:40 Design of Experiments for Optimization of a Large-Signal Model of Graphene Field-Effect Transistors

Patrizia Lamberti, Vincenzo Tucci, Giovanni Spinelli, Francisco Pasadas, David Jimenez

ID 175 – In the last decade, experimental research into graphene-based field-effect transistors (GFETs) has rapidly increased and currently, due to its unique electronic structure favouring high carrier mobility, graphene is considered a promising material for use in high-speed electronic devices in the post-silicon electronic era. However, despite the continuous progress in the optimization of such devices many critical issues remain to be solved such as their reproducibility with guaranty and identical performances against possible variations of different nature. In fact, devices and apparatuses in all engineering fields are required to maintain their performances in prefixed limits even in presence of the unavoidably variations of either the constituent physical parameters or the operating conditions. In the present work, changes of the ID-VDS characteristics of a graphene-based device, caused by a 10% of tolerance in the fabrication process of the active channel (i.e. its length and width) and in the determination of the top oxide thickness are investigated in order to assess the reliability of such devices by using a Large-Signal Model of Graphene Field-Effect Transistors. Next to circuit simulations, Design of Experiments (DoE) is adopted with the aim to identify the most influential factors on the electrical performance of the device.

17:00 Investigation of electrical properties of graphene-based nanocomposites supported by Tunneling AFM (TUNA)

Giovanni Spinelli, Patrizia Lambertil, Vincenzo Tucci, Liberata Guadagno, Marialuigia Raimondo, Luigi Vertuccio

ID 180 – The present study concerns the electrical properties of epoxy/amine-based composites filled with two types of exfoliated graphite nanoparticles, i.e. partially exfoliated graphite (pEG) and carboxylated partially exfoliated graphite (CpEG) that differ in the exfoliation degree (56% and 60%, respectively) and hence for the content of carboxylate groups. The morphological analysis reveals that both graphene-based nanoparticles are homogenously dispersed within the epoxy/amine matrix. The amount of the two fillers influences the overall electrical performance of the resulting nanocomposites. In particular, it is found that the incorporation of CpEG leads to a very low percolation threshold (EPT) in the range [0.025-0.1] wt% and a relatively high electrical conductivity (about 0.096 S/m at 1.8 wt% of loading). These results are due to the higher exfoliation degree and the presence of carboxylate groups on the edges of the nanoparticles, which are responsible for weak attractive intermolecular bonds that favour the formation of the conducting network through a sort of self-assembled structure. In order to confirm this interpretation, Tunneling Atomic Force Microscopy (TUNA) analysis is performed. In particular, the topographic mapping of the local filler dispersion of the selected nanocomposites is carried out for supporting the DC electrical results.

TT1-E Modelling and simulation

Chairs: Maria Carmela Di Piazza and Benoît Robyns

08:30 Electro thermal characterization of double sided cooling Si power module

Sébastien Sanchez, Quang-Chuc Nguyen, Claudia Cadile, Jean-Pierre Fradin, Patrick Tounsi, Jean-Michel Reynes

ID 79 – This paper presents an electro-thermal characterization of a prototype double-sided cooling power module. The junction temperature Tj is an important parameter of power devices. Different methods exist for junction temperature measurement. In this work, an electrical method based on temperature sensitive electrical parameter (TSEP) is conducted to estimate the junction temperature of the power module. A 3D thermal model was built to better comprehend thermal behaviour within the module. A comparison between simulation and measurement results is analyzed. Results have shown that 3D numerical modeling help understanding several manufacturing defects (soldering, sintering, die defaults, etc).

08:50 On the Design of the Channel Region in 4H-SiC JBS Diode

Luigi Di Benedetto, Gian Domenico Licciardo, Alfredo Rubino

ID 99 – 4H-SiC Junction Barrier Schottky diodes are promising devices for their low on-state resistance and their high blocking voltage, resulting of very interest to scientific and industrial communities. The operating principle of a JBS diode is based on the potential barrier in the channel region, which is the n-type epilayer of the device surrounded by the p+-type regions. The channel can be completely depleted at equilibrium conditions, depending on geometry and doping concentration, and the developed electric fields at pn-junctions induce a potential barrier: its height can be higher than that of the Schottky built-in potential at the anode contact and can affect the electron flow from the cathode to the anode. Although they have been firstly developed in Silicon technology, 4H-SiC JBS diodes are easier to fabricate because 4H-SiC p-n junctions have wider space charge regions for the same values of the doping concentrations and of the channel geometry respect to Si JBS devices, resulting in a more relaxed constrains of design. In this paper we propose a tool for the design of the channel region in terms of the geometry and of the doping concentration. Based on an analytical model, comparisons with numerical simulations are shown.

09:10 Analytical model of a resonator for PCB-embedded power conversion

Yoann Pascal, Mickaël Petit, Denis Labrousse, François Costa

ID 168 - A comprehensive analytical model of the magnetism, electrostatic, and loss of a simple and economical structure of PCB-embedded magnetic component (coil, high leakage transformer or resonator) for electrical energy conversion is proposed. The predictions of this model were compared to Finite Element Simulations and to a prototype. A good match was obtained over a wide bandwidth (up to at least 10 MHz). The model was adapted to predict the electrical characteristics of the device used as a monolithic series-LC tank, with resonant frequency in the MHz-range. The model is intended to be used for power electronics converter design and optimisation.

TT2-C Modelling and simulation

Chairs: Seiichiro Katsura and Ramon Blasco-Gimenez

08:30 Voltage boost by neutral point supply of AC machine

Jean-Yves Gauthier, Xuefang Lin-Shi

ID 48 – A new concept of AC motor drive is proposed in this paper. It allows to boost voltage of an AC machine without supplementary components. The main idea is to wisely connect the neutral point of the AC machine to the DC power supply. With some modifications on the control algorithm, the proposed solution allows to supply the AC machine with a higher voltage than with classical inverters. The concept is general for different AC machines and different topologies of inverters. The case study of an induction motor driven by a three-phase two-level inverter is illustrated. In steady state, a factor gain up of 1.7 of maximum RMS voltage can be obtained with the proposed solution compared to a classical scheme. Experimental validation on an induction motor test-bench shows the effectiveness of the proposed concept.

08:50 Influence of the load angle on magnetic radial forces and torque ripple for different control strategies

Emre Uygun, Michel Hecquet, Abdelmounaïm Tounzi, Daniel Depernet, Vincent Lanfranchi, Serge Bruno, Thierry Tollance

ID 97 - This paper shows the impact of the shift phase angle ψ between phase currents and back-electromotive forces (back-EMFs) on torque and radial forces for a low power synchronous machine (20 W). Pressure harmonics versus space and frequency on our motor and torque are evaluated with different angle with finite element approach. The aim is to establish a good compromise between consumed current, harmonics of torque and harmonics of radial forces linked to the electromagnetic noise for two strategies: maximum torque per ampere (MTPA) control and field weakening (FW) control. The evolution of each harmonics versus ψ are compared for both strategies. Experimental measurements in sinusoidal case are detailed.

09:10 System-on-a-Chip Including Generic Framework of Motion Controller Using Disturbance Observer Based Acceleration Controller

Hiroki Kurumatani, Seiichiro Katsura

ID 62 - A system-on-a-chip (SoC) for a motion controller using an field-programmable-gate-array (FPGA) and ARM processors is developed and a task-partitioning technique is presented. Motion control requires fast and realtime input- output and the FPGA is a good tool to manage them. However, flexible and complex command-generations are difficult to implement. Here, the SoC FPGA is a good solution because it has processors beside the FPGA. In design on this platform, a feedback controller achieving high robustness is on the FPGA and a feedforward controller determining a motion is on the processor. Then, a disturbance observer (DOB), one of the 2 degree-of-freedom (DOF) controllers, and an acceleration controller are introduced to decouple these designs. The DOB is simple to design with a few parameters and then provides a general framework for motion control. Introduction of the SoC FPGA enables to attain both the high-robustness and the flexible command-generation.

SS9-B Battery 2030+ Forum

Chair: Silvia Bodoardo

08:30 Battery 2030+

Kristina Edström

Batteries have a central role to play in Europe's transition from fossil fuels to renewable energy. Versatile and high-performance electrochemical energy storage can reduce the carbon footprint of the transport sector, stabilise the power grid, and support a broad range of strategic industries, including medical device production, information and communication technologies, aerospace and advanced robotics. In nearly all aspects of modern life, batteries enable innovation. Europe could capture a battery market of up to €250 billion a year from 2025 onwards. The European Battery Alliance, launched by the European Commission Vice-President Maroš Šefčovič in October 2017, aims to establish a competitive battery industry in Europe. The Strategic Action Plan on Batteries, published by the European Commission in May 2018, calls for preparing an ambitious, large-scale and long-term research programme on batteries as a complement and support to the European Battery Alliance. Accordingly, the BATTERY 2030+ initiative proposes a 10-year visionary research programme on future battery technologies. As a long-term research programme, BATTERY 2030+ will complement the short-term industrial initiatives launched in the framework of the European Battery Alliance, as well as the short- to medium-term research and innovation programmes implementing the SET Plan roadmap. The vision for BATTERY 2030+ is to invent the batteries of the future, providing European industry with disruptive technologies and a competitive edge across the full value chain. BATTERY 2030+ will pursue ultrahigh-performance, reliable, safe, sustainable and affordable batteries, by a cross-disciplinary, transformational research approach, leveraging advances in artificial intelligence, robotics, sensors and smart systems. The groundbreaking science and technology developed by BATTERY 2030+ will have an invaluable impact on the ongoing transition towards a carbon-neutral and circular economy. The BATTERY 2030+ initiative will gather leading scientists in Europe, as well as the industry across the full value chain, to achieve a leap forward in battery science and technology.

For additional information and to endorse Battery2030+ initiative: battery2030.eu

P3 – Plenary session 3

Chair: Ramon Blasco-Gimenez

09:30 Space power system and electronics. Design, inspiring principles and challenges

Mariel Triggianese

Designing Space power system means dealing with several factors that make the difference with terrestrial world. The first constrains are due to Space environment effects, which impose the development and consequently the use of specific technologies. The additional and fundamental requirement of containment of failure propagation represents the challenge to face in power system engineering and power electronics design. Knowing that once launched, (usually) no repair is possible, the rule was born that "No single component failure shall result in a significant loss of spacecraft operation." This apparently "innocuous" statement has a very important consequence for the redundancy, reliability and performance aspects of the power-system. This constraint implies at least: modular concepts, redundancy schemes, which can be hot and/or cold, separation of critical sub-circuits (both mechanically and electrically) and additional features incorporated in each module to avoid failure propagation. Failure propagation in systems are caused by failures in circuits elements, therefore a list of failure modes of parts needs to be taken into account when performing a failure mode effects analyses (and design). Moreover, failures in circuits can cause short circuits, over current or over voltage conditions. Therefore protections need to be used.

In order to define requirements for performance, reliability and quality ESA standards (ECSS requirements, E-20, Q-60, Q-30) have been produced. They are the applicable reference documents for the space power designers.

The lecture will address the common design and verification process for space power. In particular, it will deal with the basic concepts to ensure reliability in space (Redundancy, Protections, Autonomy, Derating), how to design and verify for reliability (First Design or Analyses?) and a short explanation of the required typical analysis document (FMECA, PSA, THA). Few (circuit) example will be shown.

TT1-F Modelling and simulation

Chairs: Efstratios Batzelis and Maria Carmela Di Piazza

11:00 Controllability insurance of the boost converters dedicated to fuel cell management system

Milad Bahrami, Jean-Philippe Martin, Gaël Maranzana, Serge Pierfederici, Farid Meibody-Tabar, Sophie Didierjean, Jérôme Dillet, Majid Zandi, Roghayeh Gavagsaz-Ghoachani

ID 2 – The lifetime of a fuel cell stack can be increased by controlling the cells separately. In such a topology, it is imperative to use a high voltage conversion ratio. The isolated step-up DC-DC converters can be a good solution but the efficiency is the major challenge. Connecting the output capacitors of classical converters like boost converters can cope with the problem of efficiency. However, the inequality of injected powers by different cells originated from the commands of the energy management system can lead to reducing the corresponding capacitor voltage. If the output capacitor voltage became lower than the corresponding converter input voltage, its controllability would be lost. An equalizer system that can send energy from the series connection to lower voltage cells is proposed in this paper to ensure the controllability of the boost converters in such a connection. The simulation and experimental results confirm the validity of the proposed equalizer.

11:20 A modified CHB multilevel inverter SHE-PAM technique

Concettina Buccella, Maria Gabriella Cimoroni, Carlo Cecati

ID 34 – In this paper a modified selective harmonic elimination pulse-amplitude modulation (MSHE-PAM) method is proposed for cascaded H-bridge (CHB) multilevel inverters fed by disequal dc voltage sources. For a fixed number of levels, the method fixes the switching angles, that remain constant and independent on modulation index m and generates an output voltage waveform characterized by very low total harmonic distortion (THD) that is constant with m. Without amplifying the magnitude of higher order harmonics, the proposed procedure deletes a significant number of harmonics as compared to conventional SHE and PAM methods. The presented method can be applied to inverter with high number of levels; a solution always exists for modulation index between 0 and 1 and low computational time is required for its implementation.

11:40 Mathematical procedure for harmonic elimination in CHB multilevel inverters with variable dc sources

Concettina Buccella, Maria Gabriella Cimoroni, Carlo Cecati

ID 35 – In this paper, a cascaded H-bridge (CHB) multilevel inverter having s dc sources and a number of levels l=2s+1 with s=2^n n=1,2,3,... is considered and a method to eliminate n+1 harmonics and their respective multiple from its output voltage waveform, is presented. The proposed procedure is compared with conventional selective harmonic elimination (SHE) technique and its better performances, in terms of Total Harmonic

Distortion (THD), are shown. The procedure requires low computational cost and low memory occupation, allowing real time implementation.

12:00 A Discrete-Time Robust MRAC Applied on Grid-Side Current Control of a Grid-Connected Three-Phase Converter with LCL Filter

Paulo Jefferson Dias de Oliveira Evald, Rodrigo Varella Tambara, Hilton Abílio Gründling

ID 59 - This paper proposes a discrete-time control strategy of grid-side currents of a three-phase grid-connected converter with LCL filter. The implemented control system, a RMRAC (Robust Model Reference Adaptive Control) by state feedback, presents robustness to parametric uncertainties and rejection of periodic disturbances. To demonstrate the controller performance, numerical simulation results, considering parameters of a real plant, are presented.

12:20 Modelling and Simulation of a Bidirectional SiC-based Battery Charger for V2G applications

Alex La Cognata, Giuseppe Aiello, Giacomo Scelba, Mario Cacciato, Giuseppe Scarcella, Alessandro Allegra

ID 129 - This work deals with the study of a bidirectional battery charger with SiC-MOSFETs devices, from the design, modelling and simulation stages to the realization of a laboratory prototype. The battery charger consists of a high efficiency 5 kW single-phase bidirectional power converter suitably designed for grid to vehicle and vehicle to grid applications. It is composed by two stages: an AC/DC PFC Synchronous converter and a insulated DC/DC Dual Active Bridge modulated in phase-shift. In order to optimize the design, an accurate model has been implemented and accurate simulations have been carried out able to evaluate the system performance in several operating conditions.

12:40 Parseval's Theorem Used for the Inductor Analysis in High-Frequency Boost Converters

Alonso Gutierrez Galeano, Emmanuel Marcault, David Tremouilles, Corinne Alonso, Jean-Pierre Laur

ID 142 - Todays, the tendency is to decrease the power converters size through the operation frequency increase. This requires the development of innovative methodologies for the selection and design of the associated inductors. This paper proposes a methodology for the inductor selection in power converters using the Parseval's theorem. The analysis provides a model to describe the relation between the inductor losses in the time domain and the frequency domain given the known parameters of the quality factor (Q) and the Self Resonance Frequency (SRF). The simulation study provides insights about the impact of the quality factor (Q) and the contribution of the inductor current harmonics to the total power losses.

TT2-D Modelling and simulation

Chairs: Ramon Blasco-Gimenez and Seiichiro Katsura

11:00 Digital control of a FFC NMR relaxometer power supply

António Roque, Duarte Sousa, Elamano Margato, Pedro Jose Sebastião, Rúben Lopes

ID 1 - Fast Field Cycling (FFC) Nuclear Magnetic Resonance (NMR) is a technique that allows to overcome a technical difficulty associated to the NMR signal-to-noise ratio (SNR) at low frequency spin-lattice relaxation measurements when using conventional NMR spectrometers. Constituting a step forward than the classical analog approaches, in this paper, a digital control system for a FFC-NMR relaxometer power supply was developed. The hardware and software were designed to allow for the modulation of the Zeeman field as required by this technique. Experimental results show that under digital control the system performs fast transitions between the high and low magnetic flux density, i.e., the switching times obtained are in the millisecond range, and, assures a good stability of the field during the steady states. Comparative proton relaxometry measurements in two compounds (liquid crystal 5CB and ionic liquid [BMIM]BF4) were made to assess the digital control system performance.

11:20 Study of interleaved PWM strategies applied to two back-to-back three-phase full bridges

Nicolas Patin, Zakaria Chmeit, Georges Salloum, Rita Mbayed

ID 77 - The aim of this study is to evaluate the impact of interleaved PWM strategies on the RMS current flowing through the DC link capacitor associated to two back-to-back three-phase full bridges (FB). Indeed, this value is usually the key-parameter for the sizing of this (or these) component(s), far above the capacitance, especially for aluminum electrolytic capacitors. Interleaving technique is applied on two different strategies: Unified Double Carrier PWM (dedicated to reduction of the RMS current for a single FB) and a classical (single carrier) space-vector PWM strategy.

11:40 Droop Control Strategy for Voltage Source Converters Containing Renewable Power Sources

Iván Andrade, Rubén Peña, Ramón Blasco-Gimenez, Javier Riedemann, Cristian Pesce

ID 161 - This paper presents a strategy to control the active and reactive power in the Point of Common Connection (PCC) of a wind generation system operating in islanded mode. A full back-to-back Voltage Source Converter (VSC) is connected between each wind generator and the PCC. The control scheme considers voltage and frequency regulation for each VSC. The voltage and frequency references are obtained from P-V and Q-f droop characteristics of the generators, where Q and P are the reactive and active power supplied by each VSC to the PCC. Proportional-Integral (PI) controllers process the voltage and frequency errors and set reference currents (in d-q frame) to be imposed by the converter. The strategy has been validated by mean of simulations and results are presented showing the performance of the control strategy proposed.

12:00 Eigenvalue and Dynamic Analysis of Numeric Iterative Decentralized Interleaving for Multicellular Converters

Miguel Mannes Hillesheim, Marc Cousineau, Guillaume Aulagnier, Guillaume Gateau

ID 94 - The decentralized control of multicellular converters is an alternative to the usual control techniques. Decentralized interleaving techniques simplify cases of leg withdrawal. These approaches have been proposed in the literature and implemented in concrete applications. However, the analytical study of stability and dynamic response of this closed loop device has not yet been conducted. This paper presents a behavioural model in a discretized space for a digitally implemented decentralized-interleaving device. This study gives the stability criteria and convergence speed to choose the application parameters. A modal decomposition technique dissociates the various types of differential interactions allowing to observe their time response. Validation simulations demonstrate that the system is unconditionally stable when all differential modes are properly damped.

12:20 Ripple Correlation Control MPPT scheme applied to a Three-phase Flying Capacitor PV system

Mattia Ricco, Manel Hammami, Riccardo Mandrioli, Gabriele Grandi

ID 114 - A ripple correlation control (RCC) scheme is presented in this paper to track the maximum power point (MPP) for a three-phase three-level Flying Capacitor photovoltaic (PV) system. RCC algorithm has been predominantly used for single-phase configurations and the implementation of the RCC maximum power point tracker (MPPT) in a three-phase system has not been presented yet in the literature. RCC MPPT algorithm adopts as perturbation the inherent oscillation of the PV current and voltage to track the MPP. The 3rd harmonic component of the PV current and voltage is adopted in the proposed algorithm for the estimation of the voltage derivative of the power dPpv/dVpv (or dIpv/dVpv), driving the PV operating point toward the MPP. Firstly, the modulation principle for this kind of converter is presented with reference to the sinusoidal carrier-based PWM. Then, the proposed RCC-MPPT algorithm is introduced. Several simulations are provided in MATLAB/Simulink of the proposed RCC scheme applied to a grid-connected photovoltaic generation system. The results show good performance in both steady-state and dynamic conditions under increase and decrease sun irradiance ramp.

12:40 Series hybrid Fuel cell/Supercapacitor Power source

Apinya Siangsanoh, Milad Bahrami, Wattana Kaewmanee, Roghayeh Gavagsaz-Ghoachani, Matheepot Phattanasak, Jean-Philippe Martin, Babak Nahid-Mobarakeh, Mathieu Weber, serge pierfederici, Gaël Maranzana, Sophie Didierjean

ID 115 - This article proposes a novel converter structure for a hybrid fuel cell/supercapacitor application in which the fuel cell is hybridized with a bank of supercapacitors. Its benefits include high efficiency and maximum use of supercapacitor energy. The operation and modeling of the converter are presented. Closed-loop controls by using an indirect-sliding mode technique for the inner current loop and the energy control in outer loop including a disturbance estimator are provided. Finally, simulation and experimental results are given to validate the proposed system.

SS9-C Challenges in battery and supercapacitor technologies

Chairs: Silvia Bodoardo and Francesca Soavi

11:00 Graphene-based electrodes for high-power Li-ion batteries

Vittorio Pellegrini

ID 186 – In this talk I will first show that a novel laminated silicon-graphene heterostructure provides superior performance as anode nanomaterial in half and full Li-ion cells. It is composed by dispersing carbon-coated polycrystalline silicon nanoparticles in between a few parallel oriented few-layers graphene flakes leading to high capacity values of around 1000 mAh/g at current values up to 3.5 A/g. On the cathode side, I will address a Lithium Iron Phosphate (LFP)-graphene nanohybrid obtained by a direct LFP crystal colloidal synthesis on few-layer graphene (FLG) flakes produced by LPE offering a specific capacity exceeding 110 mAh/g at 20 C, with no electrode damaging. On Lithium Sulphur batteries I will present a facile, non-aggressive and environmentally friendly strategy to perform a sulfur carbon composite material by simply dry a dispersion of elemental sulfur and graphene in ethanol solvent. The sample powder shows a suitable micrometric morphology capable to deliver 600 mAh/g of specific capacity for 500 cycles at the outstanding current rate of 2C = 3350 mAh/g.

11:20 Flow lithium batteries: A promising approach to develop high energy, next-generation batteries

Francesca De Giorgio, Francesca Soavi, Federico Poli, Alessandro Brilloni

ID 182 – The development of next-generation batteries is crucial to boost new global energy policies. The emerging flow lithium batteries (FLBs) combines in a unique solution the advantages of the high specific energy of lithium batteries and the design flexibility of redox flow batteries that, in turn, allow to decouple energy and power. Different kinds of FLBs have been proposed, including batteries featuring semi-solid anolytes and/or catholytes with Li-ion intercalation powders, such as LiFePO4 or Li4Ti5O12, dispersed in organic electrolyte, and Li/S and Li/O2 flow batteries. However, advancements in materials, cell design and concepts are still mandatory to boost the leap into the new battery generation. BETTERY, an Italian Innovative Startup, aims to bring into market a radically new battery concept, a NEw Semi-Solid flow lithium OXygen battery (NESSOX) that combines the high energy density of Li/O2 batteries with the flexible and scalable architecture of redox flow batteries. NESSOX, featuring a lithium metal anode and a semi-solid, flowable catholyte, displays the highest practical specific energy and energy density ever reported, up to 500 mWh cm-2, and current densities that are rather competitive with those featured by commercial Li-ion batteries (up to 4 mA cm-2). The flowable concept also permits a breakthrough in the battery field thanks to the fast recharge by “catholyte refueling”. Here we present and discuss the main technology challenges faced by BETTERY to bring NESSOX into market.

11:40 Enabling Post Li-ion Technologies through Composite Polymer Membranes

Julia Amici, Mojtaba Alidoost, Usman Zubair, Daniele Versaci, Carlotta Francia, Silvia Bodoardo, Nerino Penazzi

ID 171 – Nowadays, electrical energy storage is one of the most critical issue to answer global warming by effectively replacing fossil energies by renewable ones. The Li-ion technology, widely studied and available on the market for multiple application is now reaching its limits and does not represent, alone, a viable option toward energetic transition. Currently, two options are under study: enabling a safe use of metallic lithium and post Li-ion technologies exploiting the benefits of such anode. However, several issues associated to the use of metallic Lithium, such as dendrite growth and SEI instability, are still a challenge to overcome. In particular, the reactivity of lithium with oxygen and towards polysulfides is problematic in Li-Air and Li-Sulphur batteries, respectively. One interesting solution to enhance battery safety consists in protecting lithium by using either polymer membranes or composite polymer electrolytes specifically tailored for each application.

12:00 Negative Electrode Materials for Sodium Ion Batteries

Chiara Ferrara, Riccardo Ruffo, Piercarlo Mustarelli

ID 166 – The world annual consumption of energy is in the range of 100 TWh. The largest part of this energy is supplied by fossil fuels or nuclear plants. Both these technologies are nowadays considered as not sustainable, however the global energy demand is still increasing. In this dim picture, renewable energy supplied by sun, wind, earth crust heat, and sea represent a viable and environmental friendly alternative which is leading to the investigation, development, and commercialization of new technology such as solar cells, wind mills, heat pumps, etc. The full exploitation of the energy produced by these primary sources, which are intrinsically intermittent, represents another technological issue which is currently approached by the design of better energy distribution grids and the large use of energy storage devices. Moreover, an important part of the total energy consumption is related to the automotive field, where fossil fuels still play a predominant role. Just in the last few years the automotive market is showing an exponential growing interest in electrical power units to feed hybrid or full electrical vehicles. Electrochemical energy storage units are currently used in high or low tech portable devices. The most demanding high-tech tools require the use of high energy density system, such as lithium ion batteries. Smart grid developers or automotive engineers are looking with growing interest at the development of better batteries with higher performances, however, the figure of merits depends on the specific applications. Few years ago, due to the large use of lithium, several investigators are questioning about its availability and possible material shortness. There are several answers to this issue: the design of better lithium-based systems (lithium air, lithium sulfur), lithium recycling, actually non yet convenient, or the development of lithium-free battery technologies. Aim of the present contribution will be the description of the current researches performed at the Material Science Department of the University of Milano Bicocca on materials for sodium-ion secondary batteries, focusing in particular on the negative electrode. Usually, research efforts in this field are directed towards the production of optimized phases by a trial and error procedure focused on the electrochemical performances rather than a full understanding of the mechanism beyond the electrochemical reaction. In our case, however, the scope is to elucidate the structure properties correlations by combining SEM, TEM, XRPD, Raman and NMR mea-

surements with the electrochemical behaviour in half cells vs. metallic sodium. Several phases (e.g. black phosphorus, Fe/Ti based oxides) representative of different reaction classes have been investigated, which show different reaction mechanisms depending on their structure and physico-chemical properties.

12:20 Development of high capacity lithium sulphur batteries

Mariasole Di Carli, Margherita Moreno, Gabriele Tarquini, Alfonso Pozio, Annalisa Aurora, Livia Della Seta, Pier Paolo Prosini

ID 184 – In this paper we want to show some of the most recent results obtained in our laboratory concerning the fabrication of lithium sulphur batteries. For their construction we used two different binders and two carbons with different surface area, deposited directly on the separator. Sulphur was introduced mixed with the electrolyte in the form of polysulphide. The particular cell configuration has allowed to obtain stable specific capacities after numerous charge and discharge cycles of more than 800 and 1200 mAh g-1 and low cell resistances.

12:40 Electrode and Electrolyte Materials for the electrochemical storage of energy in Li-ion and post Li-ion Batteries

Maria Assunta Navarra, Sergio Brutti, Pietro Altimari, Francesca Pagnanelli, Stefania Panero

ID 185 – Electrochemical systems, such as batteries, that can efficiently store and deliver energy on demand in stand-alone power plants, as well as provide load levelling of the electrical grid in integrated systems, are playing a crucial role in the present energy economy. In addition, lithium ion batteries (LiBs) are seen as the power sources of choice for sustainable transport, able to guarantee the progressive diffusion of electric or hybrid vehicles. The most recent activities, carried out at the Chemistry Department of Sapienza University of Rome in the field of electrochemistry and materials recycling for LiB technologies, will be presented. Our approach in the search of novel ionic liquid-based electrolytes for lithium-ion and lithium-sulfur batteries, demonstrating superior performance in terms of safety and reliability with respect to conventional carbonates electrolytes, will be discussed. Our achievements in the development of high voltage spinel cathodes, combined with both conventional and ionic liquid-based electrolytes in lithium cells, will be also reported, revealing prolonged stability and fast charging ability. Finally, the possibility of recovery metal-based active materials from spent batteries will be presented and the case of electrodeposited cobalt and copper nanowire electrodes, with both faradaic and capacitive contributions to the total capacity, will be discussed.

Tuesday 21st May 2019
Room VIETRI | 13:00

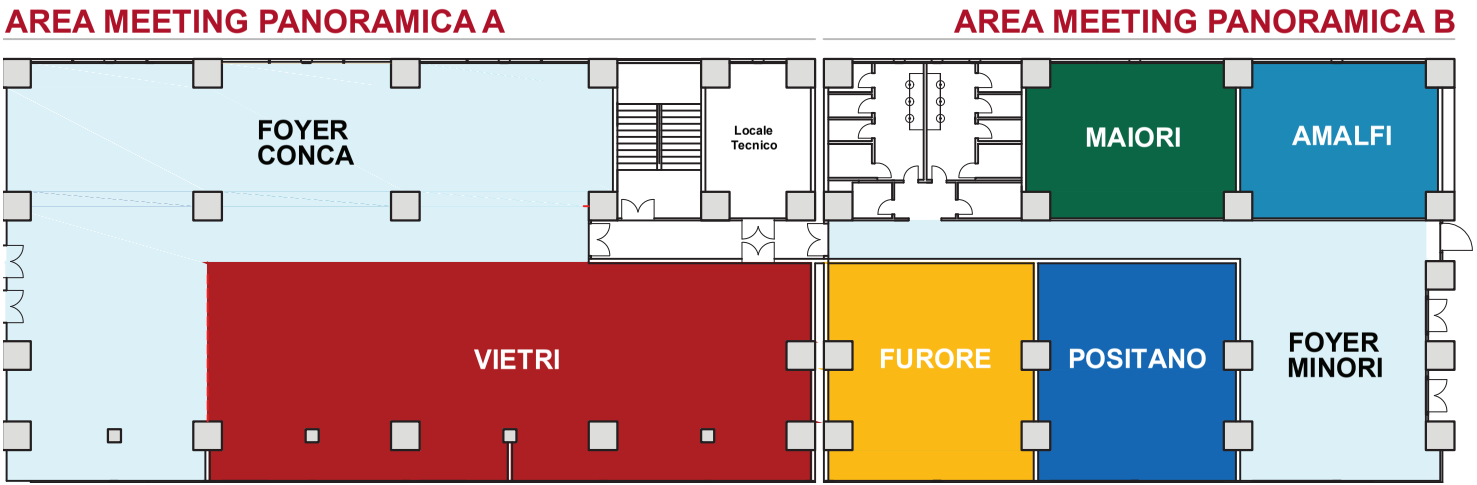
CS - Closing session

13:00 Conference closing

Giovanni Petrone and Walter Zamboni – General Chairs

ELECTRIMACS 2019 Salerno

Meeting Area
Grand Hotel Salerno - First Floor



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