DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

Guest lecture 1:

UCI Power Electronics Laboratory and its Research Related to Modernizing Power System

by

Prof Keyue Ma Smedley, University of California, USA

and

Guest lecture 2

by

Prof Carlo Cecati, Università degli Studi dell'Aquila, L'Aquila, Italy

April 10 2014, 10:00 – 12:00

Aalborg University, Department of Energy Technology, Pontoppidanstræde 101, room 21

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Abstract, lecture 1

In this presentation, Dr. Smedley will give a brief introduction to some of the research activities in the UCI Power Electronics Laboratory. She will also talk about her effort in modernizing the US power grid related to development of universal One-Cycle Control technology for fast, accurate, and stable control of three-phase power converters for power system applications aiming to minimize grid loss, alleviate grid congestion, improve grid stability, and enable high penetration of renewables.

In the last two decades, semiconductors have revolutionized the IT and communication world; with proven speed and controllability, Dr. Smedley believes that high power semiconductors are ready to revolutionize the power system.

About the lecturer

Keyue Ma Smedley, received her Ph.D. in electrical engineering from the California Institute of Technology. She is currently a professor in the Department of Electrical Engineering and Computer Science at the University of California at Irvine, the Director of the UCI Power Electronics Laboratory, and a cofounder of One-Cycle Control, Inc.

Dr. Smedley's research includes high-efficiency dc-dc converters, high-fidelity class-D power amplifiers, single-phase and three-phase PFC rectifiers, active power filters, inverters, V/VAR control, energy storage system, and utility-scale fault current limiters. She is an inventor of One-Cycle Control and the Hexagram power converter.

Dr. Smedley's work has resulted in 150 technical publications, 10 US/international patents, two start-up companies, and numerous commercial applications. Dr. Smedley is a recipient of UCI Innovation Award 2005. She was selected to be a IEEE Fellow in 2008 for her contributions in high-performance switching power conversion. Her work with One-Cycle Control, Inc., has won Department of the Army Achievement Award in the Pentagon in 2010.

Abstract, lecture 2

Due to the high demand of intelligence in control of electrical energy and of power systems, a new reseach group, "ICT for Energy" has been very recently started at DISIM-UAQ, i.e. the Department of Information Engineering, Computer Science and Mathematics at the University of L'Aquila, L'Aquila, Italy.
Currently, this research group includes electrical engineers, a control theorist, a mathematician and a physician, but it is expected to rapidly grow incorporating also computer science and telecommunications experts; moreover, the group has already estabilished cooperations with national and foreign research groups.
Its main research activities aim to cover some important topics, primarily in the field of integration of renewable energy sources with the existing power system (i.e. distributed generation), electromobility, smart grids. The speech, after a general overview of the researches underway, will be focused on two distinct topics, in the field of harmonics elimination in multilevel converters and non linear control of LLC DC/DC resonant converters. These topics have a common factor which is the optimization of conversion of

energy produced by renewable energy, in particular photovoltaic energy and is part of a large project which is under definition aiming at developing a high power smart recharging infrastructure for electric vehicles, based on PV energy and full integration within the grid.

With reference to first part of presentation, multilevel converters offer many advantages over conventional two level converters, but are still affected by significant harmonics caused by modulation. Selective Harmonic Elimination (SHE) and Selective Harmonic Mitigation (SHM) have recently attracted the attention of several researchers over the world, due to clear advantages deriving by elimination of low order harmonics without use of passive filters thus allowing the use of light filters tuned at high frequencies. Current literature reports many distinct methods for selective harmonic elimination/mitagation but all of them cannot be implemented in real-time due to complex calculations, which are practically implemented using a mix between off-line calculations and real-time implementation through look-up tables. These usually require huge amount of memory for obtaining the necessary precision and even in this case do not provide exact solutions.

Some analytical procedures for computation of all valid pairs of switching angles used for pattern generation in five-levels H-Bridge cascaded inverters have been developed at DISIM-UAQ aiming at removing a single harmonic (SHE) or a group of harmonics (SHM). These procedures are completely analytical and, for each harmonic, returns the exact boundaries of all valid modulation index intervals. Due to their simple mathematical formulations, they can be easy implemented in real-time using a Digital Signal Processor or a Field Programmable Gate Array. The exact solutions are given for modulation angles, which is a unique features of the developed methods. After a detailed description of the methods, some experiments are shown demonstrating the quality of achievable results.

Another part of the speech will deal with the use of Extended Describing Functions (EDF) in control of LLC DC/DC resonanat converters operating under wide input voltage and load variations. A nonlinear model for a LLC resonant converter was developed using the EDF method; then, based on the derived model, a nonlinear observer-based controller was designed and implemented using a Digital Signal Processor (DSP). Obtained transient experimental responses, under disturbances from both the output and the input, show that the proposed controller is capable to stabilize the output effectively even in case of large input/output variations, which is very important in photovoltaic systems, while not yet obtained conventional control methods in resonanat converters. A traditional Proportional-Integral-Derivative (PID) controller was also implemented for the purpose of comparison. Experimental results show superiority of the proposed observer-based controller over the conventional PID controller.

In view of practical realization, a grid-connected multi string photovoltaic system with a three level voltage source converter using double closed loop control strategy has been considered. The outer DC voltage control loop regulates the DC bus voltage. The inner current control loop synchronizes the output current with the grid voltage, thus ensuring unity power factor. In the proposed configuration, LLC resonant DC-DC converter is used to extract the maximum power and to boost the photovoltaic array voltage. It is intrinsically isolated by a high frequency transformer, so that the parasitic capacitance of the photovoltaic panels to ground could not be of concern; furthermore, because of soft switching technique, LLC converter operates at high frequency with low switching losses. Size and cost of the magnetic components and DC-link capacitor are decreased compared

with traditional boost converters. An incremental conductance method integrated within PI controller is also used to extract maximum power by photovoltaic panels. Simulation studies confirm that the control design approaches taken are robust and the dynamic performance of the proposed system during fast solar irradiation changes is acceptable.

Finally, in view of development of high efficiency power converters, a Simulink model of Silicon Carbide devices has been developed, obtaining a library block capable of precise simulation of next generation power converters.

About the lecturer

Carlo Cecati (IEEE Fellow) was born in Lanciano, Italy.
In 1983 he received the degree in Electrical Engineering from the Università degli Studi dell'Aquila, L'Aquila, Italy. In the same year, he joined the Department of Electrical and Information Engineering of the same university, where he was a consultant (1984-1986), a Researcher (1987-1990), a Senior Researcher (1990-2001), an Associate Professor (2001-2006) and, since 2006, he is a Full Professor in Industrial Electronics and in Electrical Drives.

Since 2005, he is the Rector's delegate for high level learning programs developed in partnership with the regional universities (University of Teramo and University "G. D'Annunzio, Chieti-Pescara) supported by European funds ("P.O. Abruzzo"), a large program consisting of several educational activities addressed to Ph.D. and to graduated and undergraduated students, a technological transfer program for increasing regional companies competitiveness, and for increasing the number of students of scientific anf technological faculties.

From 2006 to 2008, he has been the executive director of "SistemAbruzzo" a 4.2 million euro project consisting of 28 masters and some tenth of shorter courses in partnership with the University of Teramo, the University "G. D'Annunzio" and several learning agencies and regional companies. In his position, until now, has been responsible of fund well over 20 million euro.

His research and technical interests cover several aspects of power electronics and electrical drives including control techniques, fault diagnosis, microprocessor applications and industrial networks. He authored more than 100 papers published on international journals (mainly IEEE Transactions on Industry Applications, Industrial Electronics, Industrial Informatics, Power Electronics, Sustainable Energy, Industrial Electronics Magazine and others), some books (published in Japan, Germany and Netherlands) and on highly qualified international conferences with referee.

On these topics, for several times he has been a guest editor of IEEE Transactions of Industrial Electronics, IEEE Transactions of Industrial Informatics, and IEEE Industrial Electronics Magazine .

Since 2009, he is a Co-Editor in Chief of IEEE Transactions on Industrial Electronics; since 2004 he has been an Associate Editor of the same journal and from 2006 to 2008 he has been an Editor of IEEE/ASME Transactions on Mechatronics. He has been and he is a

reviewer of the most important international journals in the field of power electronics and drives.

Since 1990 he has been an active member of the IEEE Industrial Electronics, IEEE Industry Applications, IEEE Power Electronics,IEEE Control System societies. From 2000 to 2004 he has been an AdCom member of the IEEE Industrial Electronics Society. From 2005 to 2006 he has been a Vicepresident of the IEEE Industrial Electronics Society. From 2007 he is a Senior AdCom member of IEEE Industrial Electronics Society; from 2007 to 2008 he has been the IEEE Region 8 Coordinator for the same society.

He has been General Co-Chair of the conferences IEEE-ISIE2002 (L'Aquila, I), IEEE-ISIE2004 (Ajaccio, F) , IEEE-ISIE2008 (Cambridge, UK) and Honorary Co-Chair of IEEE-ISIE2010 (Bari, I). He has been Technical Program Co-Chair of IEEE-ISIE2007 (Taipei, Taiwan). Since 1997 he has been a Track Co-Chair (power electronics, mechatronics, sensors and actuators), Special Session Co-Chair and Tutorial Co-Chair of many international conferences (IEEE-ISIE, IEEE-IECON, IEEE-ICIT, ECCE Europe EPE-PEMC). He has been a Publication Chair of IEEE-IECON 1994.