POWER ELECTRONICS SOCIETY NEWSLETTER

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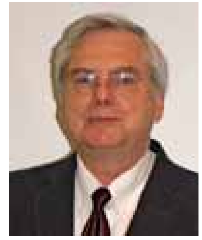
John M. Miller



The Power Electronics Society newsletter has the charter to offer recent news and events along with technical content of general interest to all our members. To this end I appeal to our members to please consider submitting an article of brief technical content on a product new to market, on tips and tricks for the application of power electronic components and other relevant items of interest. Advertisers are encouraged to submit a brief technical synopsis of products offered on the market that will help users gain an appreciation of its application. The newsletter is also an excellent venue for members on the move. Please send a short notice of your new position along with a photo to the newsletter editor at pelsnews@ieee.org.

In this issue there are several recent events being recognized. The winners of the 2007 international future energy challenge are announced and will be congratulated at the APEC 2008 banquet. Please plan to attend and congratulate winners of both Topic A Universal Adapting Battery Charger and Topic B Integrated Starter Alternator Motor Drive for Automotive Applications. Prof. Fahimi, general chair of the Vehicle Power and Propulsion Conference, VPPC2007, held 9-12 September 2007 in Arlington, TX reports on that meeting. Prof. Frede Blaaberg, Editor-in-Chief for PEL's Transactions reports that the meeting held in Aalborg, Denmark was an overwhelming success with more than 1,000 participants attending from 50 countries. Prof. Bimal K. Bose a Life Fellow of the IEEE offers a very comprehensive survey of the power electronics field and why it is so exciting.

The newsletter editorial staff looks forward to providing timely announcements and late breaking news for our membership. But we need your help to keep current with developments in members on the move, articles of interest and meeting announcements. Please submit your comments, news items, and meeting announcements to the EIC. If we don't know about an upcoming event it will not be included in the newsletter so please send those announcements.

John M. Miller, EIC
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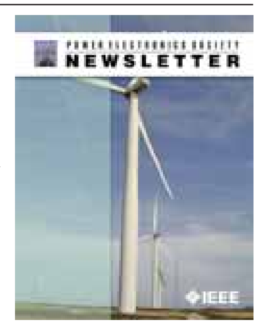
Large Turbine Test Site of the Danish Wind Energy Research. Turbine ratings of 1.5 MW to 4.6 MW under test from various manufacturers



IEEE Power Electronics Society Officers

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News Items should be sent to: Dr John M. Miller, PELS Newsletter, Editor-in-Chief, J-N-J Miller Design Services, PLC, 3573 East Gatzke Road, Cedar, MI. 49621, USA; TEL:+1 231 228 5011; EMAIL: pelsnews@ieee.org. Deadlines for copy are March 15, June 15, September 15 and December 15. Email submission of items in MS-Word or plain-text format are preferred. MS-Word and plain-text (straight ASCII) submissions on CDROMs are welcome and should be accompanied by a backup hardcopy. Fax submissions are acceptable, but are least desirable. Include caption with all photos identifying event and individuals in a back-row, left to right, front-row, left to right, etc method. Full-page calls for papers and announcements of PELS-supported conferences are welcome and should be sent as both high-quality hardcopy and MS-Word files. Please indicate all trademarked items, such as INTELEC®, APEC® with the registered trademark symbol, "®".
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September 24, 2007
2007 IFEC Awards Announced

Prof. Ali Emadi

We have concluded the 2007 final competition and the award winners have just been announced. I would like to thank Drs. Phil Krein, Babak Fahimi, Antonello Monti, and Ms. Lee Myers for their work in organizing the 2007 competition. I would also like to thank our sponsors, reviewers, judges, industry collaborators, MPC Products Corporation, and Texas Instruments. We had many difficult challenges this year including late formation of the Organizing Committee. Therefore, we have planned to begin the process for the next competition as early as possible. Based on the committee meeting at PESC'07, the IFEC Organizing Committee had selected Dr. Babak Fahimi as the Chair of the 2009 IFEC, Dr. Grahame Holmes as the Topic A Coordinator of the 2009 IFEC, and Dr. Antonello Monti as the Topic B Coordinator of the 2009 IFEC. The PELS AdCom has formally endorsed the three IFEC Organizing Committee Officers. Please join me in extending our support to Babak, Grahame, and Anto and thanking them for taking the lead in organizing the next competition.

Congratulations to the following winners.

Topic A:
- Outstanding Performance Award (for $7,000) – Federal University of Mato Grosso do Sul, Brazil
- Outstanding Engineering Achievement Award (for $5,000) – Monash University, Australia
- PSMA Outstanding Innovation Award (for $5,000) – Huazhong University of Science and Technology, China
- Outstanding Undergraduate Educational Impact Award (for $2,500) – Bangladesh University of Engineering and Technology, Bangladesh
- Outstanding Teamwork Award (for $2,500) – University of Texas at Arlington, USA
- Outstanding Technical Presentation Award (for $2,500) – Institute for Power Electronics and Electrical Drives of the RWTH Aachen, Germany, and Institute for Automation of the University of Applied Sciences Cologne (FH Köln), Germany
- Outstanding Technical Report Award (for $2,500) – Virginia Tech, USA

Topic B:
- Outstanding Educational Impact and Undergraduate Teamwork Award (for $8,000) – University of Colorado at Boulder, USA, and Indian Institute of Technology at Delhi, India
- Performance Achievement Award (for $5,000) – University of Padova, Italy
- Innovation Award (for $3,000) – University of Padova, Italy
- Outstanding Presentation/Report Award (for $3,000) – University of South Carolina, USA, and University of Nebraska, USA

The 2007 IFEC Awards Recognition is planned for the 2008 IEEE Applied Power Electronics Conference (APEC'08), February 24-28, 2008, in Austin, Texas, USA (http://www.apec-conf.org/). Formal award presentations are scheduled at the banquet of APEC'08. Award winners are invited to attend the banquet to accept their certificates. Please note that there will be no travel support from the 2007 International Future Energy Challenge.

Ali Emadi
Chair,
2007 International Future Energy Challenge

INTELEC® Fellowship

Dr. Hui Li

The INTELEC® Advisory and Conference Executive Committees sponsor the Joseph J. Suozzi INTELEC Fellowship in Power Electronics. This fellowship is named in honor of the late Dr. Joseph Suozzi, a founder and longtime leader of INTELEC. This grant of $15,000 is made annually to an electrical engineering graduate student studying in an area of power electronics applicable to communications systems. Such systems include wireline, optical, wireless or combinations of such systems such as the Internet or embedded telecommunications infrastructures. Alternative energy systems for communications networks or network elements is also a suitable area.

This fellowship is international and is therefore open to electrical engineering graduate students in all countries. It is a one-time grant to an individual and is not renewable.

Interested electrical engineering graduate students should submit:
- an essay not exceeding one page in length that explains how his/her proposed project can be applied to powering of communications systems
- a transcript of his/her grades
- a letter of support from his/her Faculty Advisor.

These materials should be sent by 1 February 2008 to the Chair of the IEEE Power Electronics Society Educational Activities Committee:

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The recipient of the 2008 INTELEC fellowship will be notified by 1 May 2008.

PESC Student Travel

Dr. Hui Li

The IEEE Power Electronics Society has a travel reimbursement program for student members who present a paper at the Power Electronics Specialists Conference in Rhodes, Greece, June 15-19, 2008. This program will reimburse up to $800 of travel expenses associated with the conference for up to 50 students. To be eligible for this program, students must:

- Have a paper accepted at PESC 2008 and present the paper.
- Be an IEEE student member and a PELS member.

Interested students should complete the application found online at the PESC 2008 website (www.pesc08.org). This form is to be completed and faxed or sent by e-mail to the chair of the Education Activities Committee. Reimbursement of costs will be done after the conference has concluded and students have sent in the necessary reimbursement forms and receipts. The application deadline is April 15, 2008. Students will be notified if they have been approved for travel reimbursement on May 15, 2008.

In case there are more than 50 applicants for travel reimbursement, preference will be given to the best papers according to the review rating and to students who have not previously been part of this travel program.

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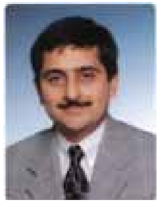


IEEE Joint IAS/PELS/IES German Chapter meets during international event in Denmark

Dr. Omid Forati Kashani

Using the opportunity to have a meeting with other chapters out of Germany, the Joint IAS/PELS/IES German chapter met with the Joint IAS/PELS/IES Danish Chapter, the PES German Chapter and the European Power Electronics (EPE) Chapter on Wind Energy during the 12th European Conference on Power Electronics and Applications (EPE 2007) from 2nd to 5th of September in Aalborg, Denmark. This was a good opportunity for these Chapters from two countries, namely Germany and Denmark, to have a common meeting to improve the networking aims of IEEE.

As a result of the cooperation of these Chapters, a high level technical program around an actual subject, i.e. wind energy, with a multitude of presentations and up to 150 attendees was offered on the Joint EPE and IEEE Wind Day. Many presentations and discussions were dealing with power electronics in wind energy conversion. Power electronics is a key technology in this field to feed the electrical energy supplied by variable speed wind generators into the grid. Because of the presence of the PES German Chapter in this program, the joint technical meetings gave an opportunity to have an intersociety (IAS/PELS/IES/PES) event. Such intersociety cooperation leads to a better understanding between the world of power electronics and power engineering which is essential to find viable technical solutions for integration of distributed generation in the grid. Another aspect was the combination of academic and industrial contributions to the various sessions, which let each side to be informed of the knowledge and activities of the other side.

PELS President Prof. Akagi and PELS Past President Prof. De Doncker with other high ranking personalities in the meeting on technical and coordinating issues

Besides the technical meetings a Board Meeting attended by

some personalities such as PELS President Prof. Hirofumi Akagi, PELS Past President Prof. Rik W. De Doncker, IAS Past President Prof. Robert D. Lorenz, EPE Wind Energy Chapter Prof. Tore M. Undeland, Chairman of IEEE Joint IAS/PELS/IES Danish Chapter Prof. Remus Teodorescu, Chairman of IEEE Germany Section and of IEEE PES German Chapter Dr. Andreas Luxa and the Past Chairman of IEEE Joint IAS/PELS/IES German Chapter Prof. Andreas Lindemann. This meeting has strengthened networking within the societies and chapters generally and regionally. Besides technical key issues some other topics such as coordinated organization of conferences have been addressed.

The Joint EPE and IEEE Wind Day was complemented with some technical excursions such as visiting the Danish Wind Energy Research large turbine test site of Vestas Wind Systems for testing of multi-megawatt wind turbines in Høvsøre, Denmark, on 6th of September.

The last meeting of IEEE Joint IAS/PELS/IES German Chapter in 2007 will be held in November in Hannover and Hameln, Germany. For more details please visit our website at: http://www.ewh.ieee.org/r8/germany/ias-pels/index.html.

Dr.Omid FORATI KASHANI is with Siemens AG in Nuremberg and Public Relations Chair of the IEEE Joint IAS/PELS/IES German Chapter.

Large Turbine Test Site of the Danish Wind Energy Research. Turbine ratings of 1.5 MW to 4.6 MW under test from various manufacturers

European Power Electronic conference in Aalborg, Denmark - 1000 participants discussing the future energy technologies

Frede Blaabjerg, Stig Munk-Nielsen, Aalborg University, Institute of Energy Technology, Pontoppidanstraede 101, D-9220 Aalborg East, Denmark

The European Power Electronics and Adjustable Speed Drives conference with technical sponsorship of IEEE Industrial Electronic Society has been held in Aalborg, Denmark, during the first days of September 2007 with an overwhelming success and participation. It was hosted by Aalborg University's Institute of Energy Technology.

The conference had a major technical programme. It received more than 950 synopsis and about 600 papers were selected and received for publication in the field of power electronics and its application. More than 1000 participants from 50 countries all over the world enjoyed Aalborg and the spirit of EPE'2007 as one of the leading power electronics conferences. Germany, Denmark, France and Japan were the most frequent represented countries with more than 100 from each country.

Denmark is one of the frontiers in renewable energy supplies and distributed generation. Today about 20 % of all electrical energy is produced by wind turbines and further 30 % is covered by small combined heat and power plants, which is a record in this scale. Further due to a strong national energy savings pro-grammes the use of electricity has almost been 25 years even though the production has doubles and the population have increased. Europe has set up new targets for renewable energy and Denmark has the goal to remain one of the leading countries in the world. These issues were also addressed at the EPE 2007 conference.

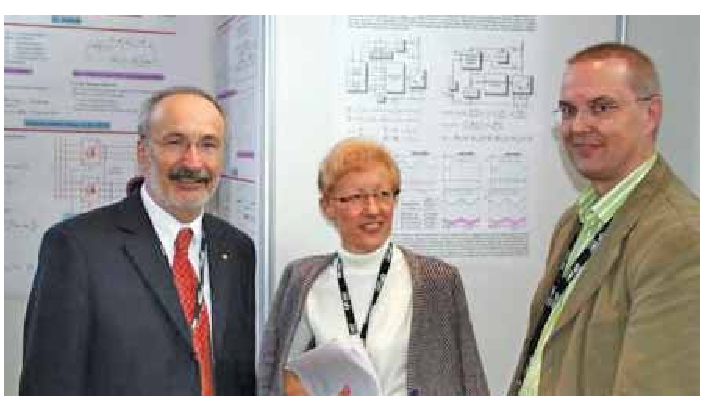
The conference started with 5 tutorials on Modeling and Control of Permanent Magnet Synchronous Motors, Propulsion systems for hybrid and fuel cell electric vehicles, Superjunction devices &

Conference chairman Frede Blaabjerg at the Welcome reception.

technologies - Benefits and Limitations of a revolutionary step in power electronics, Power Electronics and Control for Renewable Energy Systems, Grid Requirements, Monitoring, Synchronization and Control of Wind Turbines under Grid Faults. The participance was record high with special attraction to renewable energy systems and their interconnection.

During the three days of main conference 160 papers were presented as lecture sessions – done in the morning through six parallel tracks. In the afternoons 440 posters were presented. The quality was in general high and it has always been an important event for the previous EPE conferences. As the conference has so high participation, the poster sessions had a high attendance and all posters were discussed in details with benefits for the presenters.


The lecture sessions were well-attended.


Conference participants at the dialogue session.

One of the real highlights was on the first day with many high levels technical papers on wind turbines and wind power system technology with interesting contributions from several leading manufacturers. Dr Philip Kjaer, Vestas Wind Systems and Prof. Tore Undeland organized this event. The more than 100 papers received in this field highlighted the present technological importance of wind turbines and the importance to think into complete systems when integrating a high level of wind power into the power system. Also other fields in adjustable speed drives, switched mode power supplies, automotive, custom power systems, new power devices were thoroughly represented through highly interesting papers. Two key-note presentations on multi-level converters for utility applications and Silicon Carbide Components were also held in the mornings. The last presentation concluded that Silicon Carbide is really moving towards interesting applications.

On top of those activities, several workshops were held in power electronics, power systems, the future of education as well as a project match-making workshop was organized in order to facilitate joint research projects for international R&D programmes.

To spice the renewable energy spirit further, at the entrance of the conference site a full scale Vestas 3 MW wind turbine nacelle was placed for inspection – and inspiration. The weight was more than 70 tonnes.


Participants from Japan and the Conference Chairman Frede Blaabjerg in front of the 3 MVA Vestas Nacelle situated at the conference site

A commercial exhibition with 24 exhibitors was organized new products could be seen and prolonged discussions with fellow specialists in the field of Power Electronics and Drives were possible. The aim of the exhibition was to promote technical exchanges and business contacts and it was placed in the same area as the posters.

Conference chairman Frede Blaabjerg at the Opening Session.

The conference had three Danish companies as main sponsors which were Vestas Wind Systems A/S. Danfoss A/S and Grundfos A/S which supported the conference significantly. Furtheron sponsors like Emotron, Gamesa, Siemens Wind Power, Mitsubishi, DEIF and Eon also demonstrated the industrial importance of the EPE'2007-event.

After the conference three industrial tours were organized with visits to Vestas Wind Systems (www.vestas.com) which was very attractive for the participants. It was a joint activity with the German IEEE PELS/IES/IAS chapter which was a very rare possibility for researchers to see how large wind turbines are manufactured. Also a special wind turbine site visit was arranged demonstrating how much wind power really is explored in Denmark. A third trip was a visit to Aalborg University Campus (Institute of Energy Technology) to see state of the art power electronic facilities and energy systems.

All papers will very soon be available for the IEEExplore database. Details about which papers were presented can be seen at www.epe2007.com. The next two conferences in the EPE history will be EPE-PEMC in Poznan, Poland in 2008 and EPE'2009 in Barcelona, Spain.

2007 IEEE Vehicle Power and Propulsion Conference (VPPC)

September 9-12, 2007, Sheraton Hotel, Arlington, Texas, USA

The third IEEE vehicle Power and Propulsion Conference (VPPC) was held during September 9-12, 2007 at Sheraton Hotel and Resort in Arlington, TX. This event was a remarkable success from every aspect. During the four day program experts from academia, industry, and government who gathered from 16 different countries exchanged views on various aspects of vehicular power and modern propulsion concepts and technologies. Compliment to a strong technical program comprised of 132 technical presentations, VPPC 2007 featured a series of distinguished educational tutorials, plenary speeches, and keynote speeches by the world leading experts. One of the main attractions of this year's conference was the special invited sessions on various important topics of research related to vehicle power electronics, advanced energy storage techniques, and state-of-the-art electromechanical energy conversion, and sensors.

At the gala dinner, the past chairman's of the VPPC were acknowledged for rendering their expertise for furthering the objectives of this conference. In addition, the best paper awards for VPPC 2006 (Windsor, UK) and VPPC 2007 (Arlington, USA) were presented at the gala dinner.

As the general chairman of the VPPC 2007, I would like to take this opportunity and thank all the support that we have received from IEEE Power Electronics and Vehicular Technology Societies. My particular gratitude is extended to the members of the international advisory committee, team of technical reviewers, graduate students from University of Texas at Arlington and Illinois Institute of Technology for their relentless support and enthusiasm without which VPPC 2007 could have not enjoyed its current level of professionalism and technical quality.

On behalf of the steering committee of IEEE-VPPC, it is my pleasure to invite you to attend the next year VPPC which is to be held in Harbin, China under the leadership of Prof. C.C. Chan.

Babak Fahimi
General Chairman,
IEEE-VPPC 2007

Past, present, and future Chairman's of VPPC at gala dinner

Presentation of the best paper awards by Dr. Economou

Educational tutorial presented by Dr. Nigel Schofield

POWER ELECTRONICS – Why the Field is so Exciting?

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***Abstract*–Power electronics has recently emerged as an important, exciting and complex discipline in electrical engineering due to many inventions in power devices, converters, PWM techniques, analytical and simulation methods, and advanced control and estimation techniques during the last three decades. It is now playing a dominant role in modern industrial automation, energy conservation, and environmental pollution control trends of the 21st century.**

***Index Terms* – Power electronics, motor drives, energy, energy efficiency, conservation, environmental pollution.**

I. INTRODUCTION

What is power electronics? Power electronics deals with conversion and control of electrical power using power semiconductor devices that operate as high speed electronic switches. Modern devices include diode, thyristor, triac, GTO (gate turn-off thyristor), power MOSFET, IGBT (insulated-gate bipolar transistor), and IGCT (integrated gate-commutated thyristor). The level of power may be from several watts to kilowatts and megawatts (even giga-watts) compared to typical micro-watts to milli-watts level that is handled by signal electronics. The traditional power engineers find it difficult to comprehend how such tiny devices can handle so large power and so fast in comparison with electro-mechanical circuit breakers, transformers, and other bulky apparatus in power system. A power electronic apparatus can be looked upon as a high-efficiency switching mode power amplifier, where the efficiency may approach as high as 98 to 99 percent. While switching large voltage and current **so** fast (high *dv/dt* and *di/dt*) and at high switching frequency at the command of microchip-based signal electronics, the equipment generates severe EMI (electromagnetic interference) and harmonics that create difficult problems in the environment.

Although the name Power Electronics starts with "Power," and some people mistakenly identify it with power engineering , power electronics is, in fact, far distant from the traditional power area based on 50/60 Hz. The term "power" tends to scare away a large segment of graduate students in universities, who dislike traditional power engineering. Basically, the name "power electronics" comes from "electronics" that handles high power. Some people define power electronics as "enabling technology," or power processing apparatus that normally remains hidden from the public eye **and, therefore**, general public is not familiar with power electronics, unlike, for example, with computers. Truly speaking, power electronics has now established itself more important than computers in modern industrialized society. Once, I was responsible to make a U.S. national survey on familiarity of power electronics among politicians and senior policy makers. To my surprise, I found that they are familiar with terms "power" and "electronics," but none of them heard the term "power electronics" before.

Power electronics is essentially a hybrid high-tech area that embraces multiple disciplines. The area of motor drives (or motion control) is usually amalgamated with power electronics, because the complexity and characteristics in motion control are mainly due to power electronics that control the machines. In recent years, a new hybrid discipline, called "Mechatronics", has emerged that blends power electronics with signal electronics, machine drives, and mechanical systems. The area of power electronics (including machine drives) has gone through dynamic technology evolution during the last three decades, because of relentless R&D that have resulted many inventions in power semiconductor devices, converter topologies, pulse width modulation (PWM) techniques, analytical and simulation techniques, advanced control and estimation methods, digital signal processors (DSP), and ASIC (application specific integrated circuit) chips. It has now grown as a vast, complex, and interdisciplinary technology. The excitement and R&D challenges in power electronics have attracted large segment of researchers from the traditional power, electrical machines, and control engineering communities over the number of years, and most of them now take pride in identifying themselves as power electronic engineers. It has now emerged as a major discipline in electrical engineering that is evident by the large number of education and research programs in universities all over the world, and large number of IEEE and non-IEEE conferences and publications in this area. The dramatic cost and size reduction of power electronic apparatus, along with performance improvement in recent years, is promoting widespread applications of power electronics in industrial, commercial, residential, transportation, aerospace , utility, and military environments. It is interesting to note that according to the estimate of EPRI (Electric Power Research Institute **of USA**), roughly 60% of electricity consumed in USA is now flowing through power electronics, and eventually, this figure will increase to 100%.

II. POWER ELECTRONICS APPLICATIONS

Let us first discuss applications of power electronics before discussing its importance, challenges, and technology evolution. Fig. 1 summarizes the general applications of power electronics. At one end

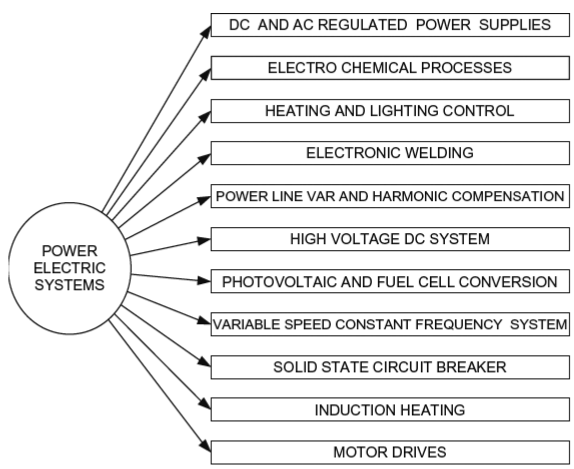

Fig. 1. Power electronics applications

of the spectrum, it consists of dc and ac regulated switching-mode power supplies (SMPS). The dc supplies are widely used in electronic equipment, such as computers, radios, TVs, VCR/DVD players, and tele-communication equipment. The ac supplies can be used, for example, in UPS (uninterruptible power supply) systems and portable battery-fed converters for ac motor drives. Electrochemical processes in industry, such as electroplating, anodizing, metal refining, production of chemical gases (hydrogen, oxygen, chlorine, etc.), and metal reduction require controllable dc from ac supplies through power electronic converters. Electrical heating, lighting, and welding control require power electronic converters. It is interesting to note that incandescent lamp (now tending to be obsolete) dimming normally requires phase-controlled ac supply (50/60 Hz), whereas modern fluorescent lamps need high frequency ac (tens of kHz) supply that not only permits higher luminous efficiency, longer life, soothing light, but light dimming capability as well. Power electronics based static VAR generators (SVG), or static VAR compensators (SVC), or static synchronous compensators (STATCOM) can generate controllable leading or lagging reactive power (similar to over- or under-excited synchronous machines at noload) that help to improve system power factor and regulate utility bus voltage. High power STATCOMs are essential elements for controlling active and reactive power flow in modern utility system (often called FACTS or flexible ac transmission system). Harmonics, generated by power electronics (normally thyristor-type converters) on ac system, can be combated by active harmonic filters (AHF) that are also based on power electronics. Often, active and passive filters are hybrided for economical filter size and improved system performance. Power electronics based high voltage dc (HVDC) transmission is often used for long distance in order to improve power efficiency and system stability. In this case, three-phase ac is converted to dc for transmission, and then inverted back to ac at the receiving end. HVDC inter-tie is also used to connect two power systems with different frequencies (for example, Japan uses both 50 Hz and 60 Hz power). Photovoltaic (PV) arrays generate dc at variable voltage that requires conversion to ac by power electronics, before connecting to the utility grid. Similarly, fuel cells generate dc that requires conversion to ac. Wind, PV and fuel cell generation systems are getting increasing attention now-a-days, which will be further discussed later. Variable speed constant frequency (VSCF) system consists of variable voltage variable frequency (VVVF) ac power generation from variable speed wind turbines or aircraft engines, and then converting it to fixed frequency regulated voltage ac for feeding to utility grid or local supply, respectively. Power electronic switches can be used to construct dc and ac circuit breakers in wide power range. Such breakers are extremely fast compared to electromechanical circuit breakers, and can be synchronized to open or close at a precise operating point of voltage or current wave. High frequency converters are often used for induction heating of metals for heat treatment or general processing. An important application of power electronics (not shown in the figure) is conversion of power for bulk storage of electrical energy in battery, superconducting magnet, or flywheel. Unfortunately, utility energy storage is not yet economical by these methods.

The largest possible applications of power electronics are in dc and ac motor drives. Although, traditionally, dc motors have been used in motion control, but recently, they are being replaced fast by ac motor drives. The ac machines include induction and synchronous types, and the drive applications include servo and computer peripherals, machine tools and robotics, pumps and compressors, home appliances (blenders, mixers, drills, washing machines, etc.), paper and textile mills, transportation systems (electric and hybrid vehicles, subway trains, and locomotives), air conditioning and heat pumps, wind generation systems, rolling and cement mills, ship propulsion, etc.

Let us now discuss several application examples briefly in order to make our ideas clear.

1. Three-Phase UPS System with 60 Hz Line Back-Up

The utility power system is not very reliable. There may be interruption (blackout), brownout (or sag), or other power quality problems, such as voltage unbalance, waveform distortion, or frequency deviation. Critical loads, such as computers, tele-communication equipment, emergency lights, fire and security systems, etc. demand reliable power supply. An UPS system, shown in Fig. 2, satisfies this requirement. The three-phase critical UPS load can be supplied either directly from the utility system, or by the battery-backed inverter, as shown in the figure. Electronic circuit breaker (CB), consisting of anti-parallel thyristors, can help the transfer in sub-cycle period. In the system, the inverter normally supplies the load with the line CB remaining open. The system consists of three-phase diode rectifier, single-phase thyristor-based battery charger, storage battery, LC filter, PWM IGBT bridge inverter (shown with BJT) , output LC filter, and CB. The inverter generates high quality 60 Hz power supply from the inferior and unregulated line supply at the input. The thyristor Q is basically a switch, which remains open in the normal condition. While the converter system supplies the load, the battery gets trickle charging current from the charger that boosts the supply dc voltage (V_d) by V_R , as shown in the figure. At utility power interruption, Q is turned on and the battery takes over the supply to the inverter. When the line supply is restored, the battery supply is withdrawn by turning off Q. If there is a problem in the inverter system, the load is transferred to the ac line directly with a short interruption time (assuming the interruption is permitted). Alternately, the line can be the primary source of power, where the inverter system remains as the standby. The dc link can have a boost chopper (single IGBT dc-dc converter) that will shape the line current sinusoidal at unity power factor and maintain V_d at a desired level. For prolonged power interruption, if battery storage is exhausted, an engine-generator or fuel cell power supply can take over.

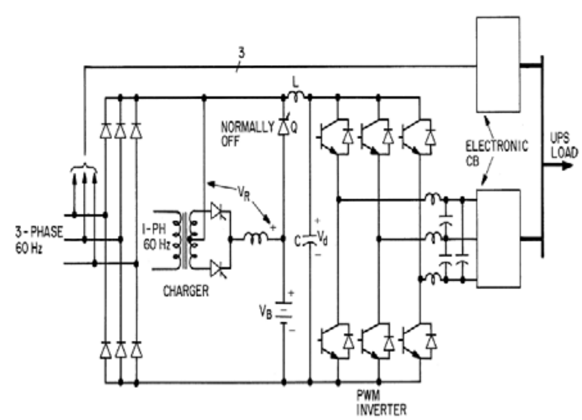

Fig. 2. Three-phase UPS system with 60 Hz line back-up

2. Modern Bullet Train Drive (Shinkansen system) in Japan [5]

The high speed Shinkansen system for railway transportation is a pride of Japan, and it has gone through evolution over a period of more than 30 years. Fig. 3 shows the modern drive system that has been added in some sections since 1999. The overhead catenary has a single-phase 25 kV, 60 Hz power supply that is connected to the primary of a multi-winding transformer on the vehicle. The lower end of the primary is returned to ground (track) through the wheels. There are three identical drive units in each carriage, which are fed by the stepped-down transformer secondary windings as shown. The 60 Hz power is rectified by a PWM H-bridge three-level IGBT rectifier, and then converted to variable voltage variable frequency power by a three-phase three-level inverter for speed control of four parallel-connected identical induction motors (275 kW each). The three-level converter permits improved voltage sharing of the IGBTs and gives better PWM quality compared to the traditional two-level converter. Each machine is connected to an axle, and the characteristics of all the four machines along with their wheel diameters are matched properly for parallel operation with equal load sharing. The drive has vector (or field-oriented) control in constant torque and field-weakening regions. In the regenerative braking mode of the four-quadrant drive, the inverter operates as rectifier, and the rectifier operates as inverter, to pump braking energy to the 60 Hz line. Sinusoidal PWM operation of the line-side converter permits sinusoidal line current at unity power factor, which can also compensates the line voltage sag. The maximum speed of the train is around 180 miles/hr.

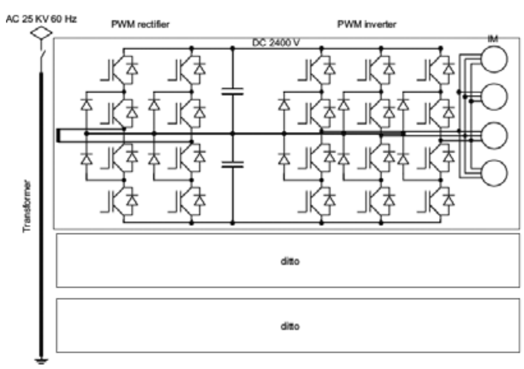

Fig. 3. Modern bullet train drive system in Japan

3. Hybrid Electric Vehicle (HV) Drive by Toyota [6]

A hybrid electric vehicle (often called hybrid vehicle or HV) drive system is powered by an engine (IC or diesel) as well as an energy storage device (Ni-MH or Li-ion battery). The HV can have a large drive range like that of a gasoline car, but the mileage/gallon is higher and the engine size is smaller. The primary function of the battery is to recover the braking energy (which is otherwise wasted in mechanical brake), and assist the engine during acceleration and grade climbing. It can also drive the car independently in electric vehicle (EV) mode for low-range city driving that can eliminate the urban pollution problem. Fig. 4 shows the simplified block diagram of HV drive system by Toyota (Prius-II). The vehicle has been available commercially from 2004. The power to the drive axle is supplied jointly (parallel-hybrid) by the ac electric motor (50 kW, permanent magnet (PM) synchronous) and IC engine (57 kW) as shown. The engine is also connected to an ac generator (PM synchronous) that supplies the surplus engine power to charge the battery (Ni-MH, 201.6 V, 21 kW, 1.2 kWH) through a rectifier and dc-dc converter. When the car is in the garage, the battery can also be charged from the grid by a rectifier (defined as plug-in hybrid), but there is no such provision in the Prius because the battery energy storage is small. The battery voltage is boosted to 500 V by a dc-dc converter for feeding the inverter (not shown in detail).The same converter system is used for charging the battery. During regenerative braking, the drive motor acts as a generator and the battery recovers only part of the braking energy through the converter system. Since energy storage in the battery is small, the control does not permit pure EV (electric vehicle) mode of operation. In steady highway driving, the HV is essentially a gasoline car. The battery requires replacement several times in the life of the car. Although HV is more expensive, and the pollution problem remains as usual, it became somewhat popular recently because of high gasoline price. Currently, the technology of HV yet remains immature.

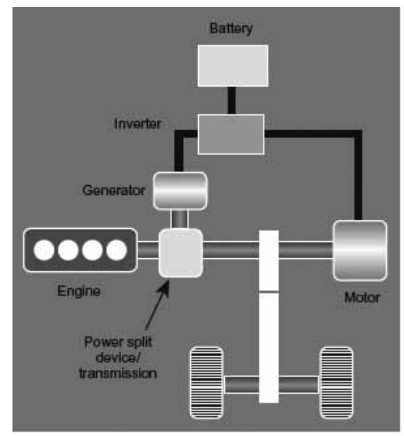

Fig. 4. Hybrid electric vehicle drive (Toyota Prius)

4. Renewable Energy Systems

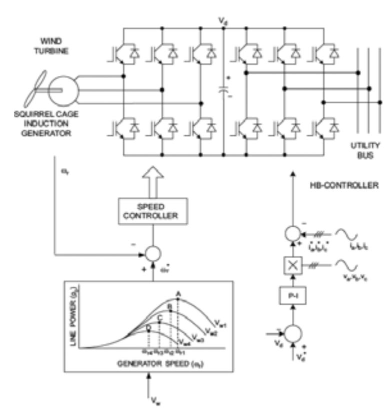

Fig. 5. Wind power generation system with two-sided PWM converter

Renewable energy sources, such as wind and PV, are being emphasized recently, as mentioned before. They are environmentally clean, safe and abundant in nature. Fig. 5 shows a simplified wind power generation system with a cage type induction generator and two-sided PWM voltage-fed converter using IGBTs. The variable speed wind turbine is coupled to the machine shaft. The variable voltage variable frequency power output of the generator is converted to dc by the PWM rectifier, and then pumped to the utility bus through the PWM inverter. The machine excitation current (i_{ds}) is supplied by the rectifier that maintains the flux constant. Both ids and the torque component of current (i_{qs}) are sinusoidal, and are controlled (not shown here) by vector control within the speed control loop. The command speed ω_r* is programmed with wind velocity V_W to extract maximum output power. This means that the optimum operating speeds are ω_{r1}, ω_{r2}, ω_{r3}, ω_{r4} for wind velocities V_{w1}, V_{w2}, V_{w3}, and V_{w4}, respectively, as shown in the figure.

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POSITIONS AVAILABLE

MIXED SIGNAL ENGINEER

Description Design of state-of-the-art frequency synthesizers and mixed signal products. Responsibilities will include: Lead board designer, mentor and provide technical guidance to department, share lessons learned, solicit feedback from assignment managers, and identify training opportunities. May be asked to contribute to department process improvement by actively participating in the department's Process Deepening meetings and as an active core member of the department's Preventive Action Board (PAB).

Required Skills Candidate must have proven design skills in the areas of frequency synthesis and mixed signal boards. Ideal candidate should be familiar with all aspects of frequency synthesis including PLL design and performance trades, fractional-N design, clock recovery loop and direct digital synthesizer design. Ideal candidate should also be familiar with mixed signal board design including application of analog components, digital components, RF/IF components, feedback control, and board development, test, and integration. Candidate should have experience in all phases of product development including specification development, design, verification, and validation. Higher levels of hardware integration support and proposal experience are a plus.

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MIXED SIGNAL BOARD & UNIT DEVELOPMENT ENGINEER

DESCRIPTION Mixed signal board and unit Responsible Design Engineer (RDE). Candidate must have an active DOD secret clearance.

Required Skills Mixed signal and high-speed digital (GHz) board & unit development for communications subsystems. Perform circuit design and analysis. Requires knowledge of the electronics development process, including product design, manufacturing, and test/troubleshooting. Must be effective in multi-disciplinary team setting, and be able to generate and perform to execution plan.

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SR. ELECTRICAL POWER ELECTRONICS — POWER CONVERTERS

Description Develop DC/DC power converters destined for state-of-the-art spacecraft. Tasks include, but are not limited to, requirements generation including spec writing, power system architecture trade studies, circuit design including magnetics, analysis & simulation using PSpice, design verification testing, orchestrating design reviews, and flight hardware production support; in addition, participate in the specification, evaluation, selection, and procurement of power converters from external sources. The selected candidate will work closely with personnel from other disciplines including mechanical packaging, systems engineering, reliability, procurement, manufacturing, integration and test, etc. This position may involve project cost & schedule oversight as well as providing technical direction to other engineers as a team leader. Final grade determination shall be based on experience.

Required skills This position requires a BSEE (MSEE preferred) and 10+ years of relevant hands-on experience developing high-reliability DC/DC power converters for aerospace applications. A thorough knowledge of power switching topologies, magnetics design & analysis, feedback controls loops, and applicable military standards is required; experience with Point of Load Converter designs and applications is especially desired. The selected candidate must also demonstrate knowledge of correctly applying high-reliability power components including MOSFETs, rectifiers, magnetics, filters, and controller ICs. He or she must be an innovative thinker that can perform with minimal supervision, be able to provide technical guidance to others, interface effectively with personnel across multiple disciplines, and demonstrate excellent written and verbal communication skills. US citizenship required; active security clearances highly desired.

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MIXED SIGNAL IC TEST SECTION HEAD

Description Computer controlled mixed signal test development experience. High and low level software programming experience. Familiar with test equipment required to test mixed signal ICs. Candidate must have strong leadership skills to lead and manage engineers. Must be proficient with Microsoft Project and working EVMS knowledge. Must have good communications skills to interface with management, personnel from other areas, and project management. Strong process knowledge along with process improvement experience highly desired. BSEE required with 8 years applicable experience. Current active security clearance required and must be able to obtain SSBI.

Required Skills Section Head for Test Engineers to develop Mixed Signal hardware and software required for high speed electrical testing. Products include Mixed Signal Products space flight-qualified Mixed Signal high speed GaAs/Indium Phosphide A/D's, D/A's, and digital chips. Responsibilities include mentoring and guiding test engineers to perform the following: evaluate electrical test requirements, work with chip designers to create test plans, create the test methodology, and plan the development schedule. Will be responsible for ensuring engineers follow processes and works to continuously improve those processes. Section Head will be responsible for budgeting cost and schedule along with managing resources to adhere to them. Must have strong technical skills and hands-on experience with developing automated rack and stack test sets along with Automated Test Equipment, such as Verigy 93000. Must have good presentation and communication skills to effectively interface with customers. Candidate will be responsible for staffing, performance appraisal, proposal support and IRAD support activities. Candidate must have strong leadership skills to manage, mentor, and develop test engineers. Must have good communications skills to interface with management, customers, personnel from other areas, and project management. Strong process knowledge along with process improvement experience highly desired. The Section Head will be an active participant to assist in implementing the 6 Sigma initiatives for the test development process. Good knowledge of MIL-STD-883 requirements for testing class S microelectronics required. BSEE required with 8 years applicable experience. Previous IC or circuit design.

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EPS MTS POSITION

Description Job tasks include documenting & tracking EPS subsystem requirements, supporting trade studies to aid EPS architecture definition and design optimization, coordinating technical aspects of EPS interfaces to other subsystems, performing worst case analyses (including energy balance), defining and performing subsystem testbed and flight subsystem test verifications, supporting development of flight EPS algorithms and supporting flight launch, activation and calibration for the power system once in orbit. Occasional travel may be required.

Required Skills 2-5 years experience in an EPS-related discipline plus BSEE or equivalent is required. Candidate shall have working knowledge of spacecraft electrical power subsystems and electronics units. Also requires design experience with one of the following: solar arrays, batteries, power conditioning and control circuits and/or PWM power converters. Knowledge of orbital mechanics, flight software, EPS algorithm generation or EGSE is a plus. The preferred candidate must be a self-starter that can work with minimal supervision, be team oriented, interface effectively with engineers across multiple disciplines, and demonstrate good written and verbal communication skills, including the ability to verbally articulate technical presentations. Candidate must be proficient with Microsoft WORD, EXCEL, PowerPoint and Project applications and one type of engineering analysis software (SPICE, Simulink, MathCAD, etc.). Knowledge of computer programming languages such as C/C++ is a plus. This position is for a MTS spacecraft EPS Engineer and the grade will be commensurate with experience, qualifications and demonstrated ability to learn quickly. US Citizenship required. Active DOD or restricted clearance is also a plus.

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ELECTRICAL POWER SUBSYSTEM ENGINEER

Description Job tasks include synthesizing power system designs from system requirements, performing required trade studies to support design optimization, performing all required analyses including energy balance, defining and performing system testbed and flight subsystem test verifications, performing flight algorithm developments, and performing all aspects of flight launch, activation and calibration support for the power system. Candidate shall have responsibility for defining technical requirements and overseeing design for a team of 10 - 25 engineers in support of a spacecraft power subsystem design.

Required Skills 10 years experience required. Candidate shall have broad experience with spacecraft electrical power subsystems and electronics units. Knowledge of solar arrays, batteries, power conditioning and control and PWM power converters is required. Familiarity of orbital mechanics, flight software, EPS algorithm generation or EGSE is required.

The preferred candidate must be a self-starter that can lead a team, interface effectively with engineers across multiple disciplines, and demonstrate good written and verbal communication skills, including the ability to verbally articulate technical presentations. Candidate must be proficient with Microsoft WORD, EXCEL, PowerPoint and Project applications and one type of engineering analysis software (SPICE, Simulink, MathCAD, etc.).

This position is for a senior spacecraft EPS Engineer and the grade will be commensurate with experience, qualifications and demonstrated ability to learn quickly. US Citizenship required. Active DOD or restricted clearance is required.

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The line-side converter is responsible to maintain the dc link voltage V_d constant as shown. The sinusoidal line phase voltages v_a, v_b, and v_c are sensed, and the corresponding co-phasal (unity power factor) line current commands i_a^*, i_b^*, i_c^* are generated by multiplying them by the output of V_d control loop as shown. The phase currents are then controlled by hysteresis-band (HB) PWM current control. If the generator output power tends to increase the dc link voltage, the line currents will tend to increase so that a balance is maintained between the turbine power and line output power.

III. WHY POWER ELECTRONICS IS SO IMPORTANT?

The applications of power electronics discussed so far have possibly demonstrated adequately the importance of power electronics. Modern solid-state power electronic apparatus has very high efficiency compared to old and traditional motor-generator (M-G) sets, saturable-core magnetic amplifiers, mercury-arc converters, and gas tube electronics. The equipment is static, free from audio noise, and has low cost, small size, high reliability, and long life. The device switching frequency in the apparatus is normally high that reduces the size of passive components, such as filters and transformers. Power electronics is very important in modern power processing plants (such as UPS, HVDC, SVC, FACTS, etc.), as discussed before. Power electronics based control has established more importance than hydraulic and pneumatic controls in industrial systems. Power electronics in motion control systems gives high industrial productivity with improved product quality. In modern automated industrial environment, power electronics and computers work closely, where the former can be looked upon as a brawn (or muscle), and the latter is the brain. In a modern automobile plant, for example, power electronic controlled robots are routinely used for assembling , material handling, and painting. In a steel-rolling mill, motor drives with high-speed DSP-based control, produce steel sheets in high volume with precision control of width and thickness. In a broad perspective, power electronics helps industrial competitiveness of a nation that provides improved quality of life. In this age of Internet communication, geographically remote countries of the world are now in close proximity, and we now live practically in a global society. In the trade barrier-free world of the future, the nations will face fierce industrial competitiveness in order to improve living standard of the people. In the highly automated industrial environment, it appears that two technologies will be most dominant: power electronics with motion control and computers. It is no wonder that power electronics is now spreading fast from the industrially advanced nations to developing countries of the world.

There is another important role of power electronics. Power electronics is now playing an increasingly important role in energy conservation and environmental pollution control trends of the 21st century. Globally, electrical energy consumption is increasing by leaps and bounds in order to improve our living standard. This is particularly true for USA, where the energy appetite is voracious. Most of the world's electricity is produced in fossil and nuclear power plants. Fossil fuels cause environmental pollution that includes generation of greenhouse gases for global warming problem, whereas nuclear plants have safety and waste disposal problems. Power electronics helps energy conservation by improved efficiency of utilization. According to the estimate of EPRI, around 15% of grid energy can be saved by widespread applications of power electronics. Saving energy not only provides the direct economic benefit, but also helps solving the environmental problem and preserving our dwindling fossil fuel reserves. Currently, there is a growing trend towards using environmentally clean and safe renewable energy sources, such as wind and PV, which are heavily dependent on power electronics. Fuel cell power generation, which is based on hydrogen (H_2) fuel, also uses power electronics extensively.

It is interesting to note that the world has abundant wind and solar energy resources. European Wind Energy Association has estimated [8] that tapping only 10% of available wind energy economically can supply the electricity needs of the whole world. Currently, wind energy is economical (~6 cents/kWH), and almost comparable to fossil fuel power, but PV power is very expensive (~25 cents/kWH). Unfortunately, wind and solar power availability is sporadic in nature and, therefore, they require back-up power from the grid. Bulk storage of electricity, generated from wind and PV sources, that is heavily dependent on power electronics, is not yet economical, as mentioned before. Wind and solar power are particularly important for people of emerging nations, who are not tied to electric power grids. It has been estimated that currently around one-third of the world population (2 billion) is isolated from power grids. Currently, we are talking about "hydrogen economy" of the future that will mainly utilize wind energy for generation of electricity, and then produce hydrogen fuel by electrolysis of water. Hydrogen can be easily stored as compressed gas or in cryogenically cooled liquefied form. Of course, H_2 can also be produced at zero emission by using PV, nuclear, or coal gasification (with CO_2 sequestration and underground storage), as they become economical.

Let us now expand our understanding of energy saving by power electronics with some specific example applications. Rheostatic control of power is well-known and yet common in many developing countries. Rheostatic speed control of dc motor drive in a subway train or tram car is still common in many parts of the world. Replacing rheostat by switching mode dc-dc converter saves large amount of energy. According to the estimate of EPRI, roughly 60% to 65% of generated electrical energy in USA is consumed in motor drives, and 75% of these are pump, fan, and compressor type drives. Majority of the pumps and fans are used in industrial environment for control of fluid flow. In such applications, traditionally, induction motor operates at constant speed and the fluid flow is controlled by throttle opening, where a lot of energy is wasted because of fluid turbulence. In contrast, variable speed operation of the motor with the help of power electronics at full throttle opening is highly efficient, and can save up to 30% energy at light load. Again, most of the machines operate at light load most of the time. Motor-converter efficiency at light load can be improved by reduced flux operation (flux programming efficiency optimization), instead of operating with the rated flux. Flux programming at light load increases copper loss, but decreases iron loss. However, the total loss is reduced. Air conditioners and heat pumps are traditionally controlled by on-off switching of thermostats. However, power electronics based variable speed load-proportional control can provide energy saving of as much as 30%. With variable speed drive, the equipment cost may increase, say, by 20% to 30%, but energy saving recovers this cost in a period depending the cost of energy. For example, in Japan, the cost of electricity may be three to four times higher than that of USA. For this reason, most of the Japanese homes use variable speed air conditioners to save energy. One very popular area of application growth is large power (multi-MW) variable speed drives for ship propulsion. The main motivation for this application is saving of large amount of diesel fuel. It has been estimated that around 20% of generated electricity in USA is consumed in lighting. Power electronics based high frequency fluorescent lamps can be three to four times more efficient than incandescent lamps. These lamps have additional advantages, such as long life, soothing light, and easy dimming capability. It is interesting to see that incandescent lamps are recently being widely replaced by compact fluorescent lamps.

Another large and potentially growing area of power electronics applications is electric and hybrid vehicles, which have been discussed before. EV/HV not only saves oil-based energy consumption, compared to gasoline cars, but also solves urban pollution problem (not so in Toyota Prius). A simple calculation indicates that approximately 20% of the coal-based energy is supplied to the wheels of EV, whereas only 10% of oil well energy goes to ICE vehicle wheels [9]. For a plug-in hybrid car (with grid charging of battery), the corresponding figure will be somewhat intermediate. Note that in EV, the urban pollution of IC engine vehicle is replaced by central power station pollution, which is somewhat easier to control. A fuel cell based electric car, on the other hand, may not use any fossil fuel and, therefore, does not create any pollution problem.

IV. AN INTERDISCIPLINARY TECHNOLOGY

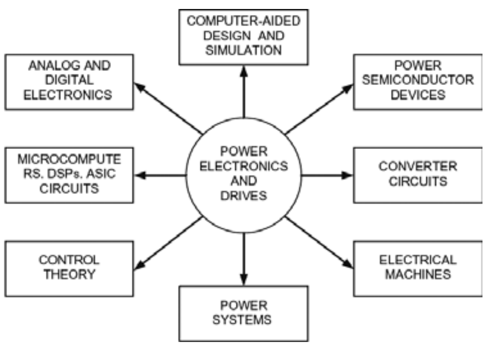

Fig.6 Power electronics – an interdisciplinary technology

Power electronics is an exciting, but complex technology, because of its multi-disciplinary nature, as indicated in Fig. 6. In general, an engineer specializing in power electronics, should have in-depth knowledge of power semiconductor devices, converter circuits, electrical machines, control electronics, microprocessors and DSPs, ASIC chips, control theories, power systems, and computer-aided design and simulation techniques. Of course, intimate knowledge in passive components (inductors, capacitors, transformers, etc.), EMI and harmonics, heat transfer, and the interfacing equipment is also essential. Very recently, the advent of artificial intelligence (AI) techniques, such as expert systems (ES), fuzzy logic (FL), artificial neural networks (ANN or NNW), and genetic algorithms (GA) (also called evolutionary computation) are advancing the frontier of the technology [14], and creating new challenge to the traditional power electronic engineers. Again, most of these component disciplines are advancing rapidly and, therefore, power electronic engineers are required to keep abreast with these developments. It is interesting to mention here that there is a class of power electronic engineers who spend their life-time in SMPS area, and consider that the domain of power electronics is basically confined to SMPS only. If an engineer, on the other hand, attempts to develop a modern high performance ac motor drive, he has to be knowledgeable in all the component disciplines mentioned above.

Solid state power semiconductor devices, as mentioned before, constitute the heart of modern power electronics. In-depth knowledge of the devices is essential to make the equipment reliable, efficient, and cost-effective.

The selection of optimum converter topology depends on the equipment power rating, performance requirement, interaction with the load and supply, and various other trade-off considerations. Since electrical machines are normally used in close loop drive system, their dynamic mathematical model along with precision parameter information is essential, and these are often very complex and operating condition dependent. The control is generally nonlinear, discrete-time, and multivariable. Therefore, computer-aided design and extensive simulation study are often required before translating into practice. The complexity of control and signal estimation demands the use of microcomputers/DSPs that are going through endless evolution in recent years. A good knowledge of power system is mandatory, because of interaction of power electronic equipment with the utility supply.

V. POWER ELECTRONICS EVOLUTION

The history of power electronics evolution goes back to more than 100 years. Peter Cooper Hewitt of USA invented (1901) the glass-bulb mercury-pool rectifier, while doing experiment with arc lights for ships. Prior to this, M-G sets were mainly used for power conversion and control. It is interesting to note that Ward-Leonard speed control with dc machines was introduced in 1891. Copper oxide and selenium rectifiers were invented in 1927 and 1933, respectively. Interestingly, New York subway first installed grid-controlled mercury-arc rectifier (3000 kW) in 1930 for dc traction motor drives. Around the same time (1931), German railways introduced mercury-arc cycloconverters (50 Hz to 16 2/3 Hz) for universal motor traction drives. Gradually, as shown in Fig. 7, the evolution went through gas tube electronics, such as ignitrons, phanotrons and thyratrons (that gives the name thyristor) in 1930;s, and saturable core magnetic amplifiers in 1940's and 1950's. Historically, the first variable speed (synchronous) motor drive (400 hp) was installed (1934) in U.S. Logan power station for boiler induced draft (ID) fan using thyratron cycloconverter.

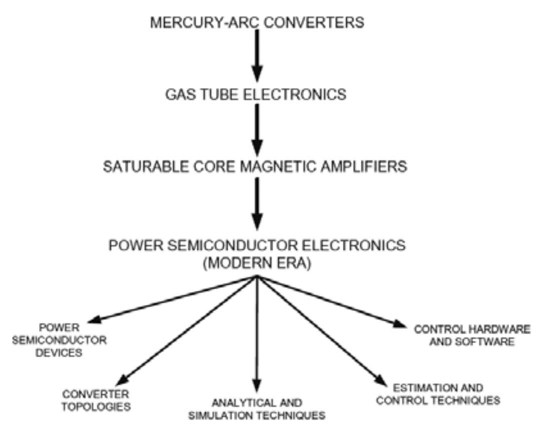

Fig. 7 Evolution of power electronics

The modern era of high density solid state power electronics started with the invention of PNPN triggering transistor by Bell Labs (1956), which was later translated to commercial thyristor (1958) by GE. Since then, there has been a vast expansion of the technology with the R&D radiating in different directions as shown in the figure. It is interesting to note that the name "Power Electronics" emerged systematically from the early 1970's. Earlier, it was included as a part of Industrial Electronics.

The R&D for power devices consisted of studies of different semiconductor materials, processing, fabrication and packaging techniques, device modeling and simulation, characterization, and development of modern intelligent power modules (IPM). Many new and improved devices emerged as a result of the research. Devices with new large band-gap materials, such as silicon carbide (SiC), are showing extremely high promise for the future. Many new converter topologies emerged along with advanced PWM techniques, and analytical and computer simulation methods. Many advanced control and signal estimation methods for ac motor drives were introduced. The control techniques include vector or field-oriented control, DTC control, sliding mode control, sensorless control, and many AI-based intelligent control methods. Advanced DSPs and ASIC chips, along with the modern software tools, permitted implementation of complex control and estimation algorithms of power electronic systems. The advent of powerful PCs also contributed to this evolution.

VI. CONCLUSION AND FUTURE SCENARIO

The paper has attempted to demonstrate how the field of power electronics is so important, exciting and challenging, and thus, attracting large number of professionals from other areas of electrical engineering. With relentless R&D for a period of more than three decades, it has now emerged as a major discipline in electrical engineering. This is evident by the large number of education and research programs in the universities around the world, large number of conferences and publications, and extensive industrial applications. Power electronics has now established as an indispensable tool for industrial automation, high efficiency energy systems, and energy conservation trends of the 21st century. It can play a dominant role in saving the world from impending global warming problem. As members of our proud profession, we need to educate the public, politicians, and national policy makers in power electronics so that their familiarity and awareness in this area can be utilized effectively in framing the industrial and energy policies of the country.

What is the future scenario of the technology? Is the technology tending to saturate? What are the directions of future R&D in this area? Generally, in the author's opinion, the answer is "yes" to the saturating trends of the technology. However, it is difficult to predict the future course of a technology. Our past experience can only guide us for prediction of the future. Any major invention can alter the course of a technology. In the history of power electronics evolution, we have seen this many times. With the present technology trends, some of the future R&D areas can be outlined as follows: Besides improvement of the current Si-based power semiconductor devices, the devices based on large band-gap power semiconductor materials are expected to bring renaissance in power electronics. The material is difficult to process and, therefore, R&D in this area is expensive and time-consuming. The device research, in fact, does not fall in the mainstream power electronics area. Like devices, research in batteries, fuel cells, photovoltaic cells, microchips, ultra-capacitors, SMES (superconducting magnet energy storage), etc. will impact power electronics evolution. At the other end of the spectrum, AI–based intelligent control and estimation techniques will significantly impact power electronics evolution. The application of different NNW topologies for innovative problem solution requires major exploration. Besides, hybrid AI techniques, such as neuro-fuzzy, neuro-genetic, neuro-fuzzy-genetic, etc. require further exploration. Development of large NNW ASIC chips is required for economical and fast implementation of intelligent systems. On-line precision estimation of machine variables, (particularly position and speed estimation near zero frequency), and equivalent circuit parameters require further R&D, although significant advances have been made recently in these areas.. On-line diagnostics of converter and machine faults, and the corresponding fault-tolerant control are important R&D topics for reliability improvement of power electronic systems. The control, estimation, monitoring, fault diagnostics, and fault tolerant control will eventually be implemented on a single powerful DSP/ASIC chip. In addition, converter, control and machine will eventually be integrated as an intelligent machine. There are, of course, myriads of application-oriented R&D topics.

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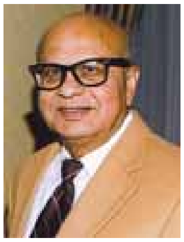

Biography of Dr. Bimal K. Bose

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Tel: (865) 974-8398
E-mail: bbose@utk.edu

Dr. Bimal K. Bose (Life Fellow, IEEE) has held the Condra Chair of Excellence (Endowed Chair) in Power Electronics in the University of Tennessee, Knoxville since 1987, where he was responsible for teaching and research program in power electronics and motor drives. Concurrently, he served as Distinguished Scientist (1989-2000) and Chief Scientist (1987-89) of EPRI-Power Electronics Applications Center, Knoxville. Prior to this, he was a research engineer in General Electric Corporate R & D Center (now GE Global Research Center) , Schenectady, NY for 11 years (1976-87), an Associate Professor of Electrical Engineering, Rensselaer Polytechnic Institute, Troy, NY for 5 years (1971-76), and faculty member of Bengal Engineering College (now Bengal Engineering and Science University), India for 11 years (1960-71). Dr. Bose has extensive teaching and research experience in power electronics and motor drives that includes power converters, PWM techniques, microcomputer/DSP control, electric/hybrid vehicle drives, renewable energy systems, and artificial intelligence (expert system, fuzzy logic and neural network) applications in power electronics and motor drives. He has been a power electronics consultant in a large number of industries. He holds Honorary Professorships in Shanghai University (1991), China University of Mining and Technology (1995), Xian Mining University (also Honorary Director of Elec. Engg. Inst.) (1998), Huazhong Univ. of Science and Technology (2002), and Honorary Adviser of Beijing Power Electronics R&D Center(1990).

Dr. Bose has authored more than 190 technical papers, and holds 21 U.S. patents. He has authored/edited seven books in power electronics: Power Electronics and Motor Drives-Advances and Trends (Academic Press,2006), Modern Power Electronics and AC Drives (Prentice-Hall, 2002), Power Electronics and AC Drives (Prentice-Hall, 1986), Power Electronics and Variable Frequency Drives (John Wiley, 1997), Modern Power Electronics (IEEE Press, 1992), Microcomputer Control of Power Electronics and Drives (IEEE Press, 1997), and Adjustable Speed AC Drive Systems (IEEE Press, 1981). He was the Guest Editor of the Proceedings of the IEEE "Special Issue on Power Electronics and Motion Control" (August 1994). He has been a member of the Editorial Board of the Proceedings of the IEEE since 1995. He has served as Distinguished Lecturer of both Industry Applications and Industrial Electronics Societies of the IEEE. He has given tutorials, keynote addresses and invited lectures extensively throughout the world, particularly in IEEE sponsored conferences.

Dr. Bose has served the IEEE in various capacities, that include the U.S. Energy Policy Committee, Fellow Committee, Lamme Medal Committee, IAS Outstanding Achievement Award Committee, Chairman of the IEEE IE Society Power Electronics Council, Associate Editor of the IEEE Trans. on Industrial Electronics, IEEE IECON Power Electronics Chairman, Chairman of the IA Society Industrial Power Converter Committee, IAS member of the Neural Network Council, Vice-Chairman of IAS Distinguished Lecture Program, Vice-Chair of IEEE Medals Council, etc. etc.

Dr. Bose is the recipient of a number of Awards/Honors that include:

(1) IEEE Power Electronics Society Newell Award (2005) " for outstanding achievements in the interdisciplinary field of power electronics".
(2) IEEE Millennium Medal (2000) "for outstanding contributions in power electronics",
(3) IEEE Meritorious Achievement Award in Continuing Education (1997) "for exemplary and sustained contributions to continuing education",
(4) IEEE Lamme Gold Medal (1996) "for contributions in power electronics and drives",
(5) IEEE-Industrial Electronics Society Eugene Mittelmann Award (1994) "in recognition of outstanding contributions to research and development in power electronics and lifetime achievement in the area of motor drives".
(6) IEEE Region 3 Outstanding Engineer Award (1994) "for outstanding achievement in power electronics and drives technology",
(7) IEEE-Industry Applications Society Outstanding Achievement Award (1993) "for outstanding contributions in the application of electricity to industry",
(8) IEEE Life Fellow (1996) (Fellow in 1989) "for contributions in power electronics and drives technology".
(9) Distinguished Alumni Award (2006) from Bengal Engineering and Science University "for outstanding contribution to the profession and the Alma Mater"

He is also the recipient of Calcutta University Premchand Roychand Scholarship and Mouat Gold Medal (1970), GE Silver Patent Medal (1986) and GE Publication Award (1985).

Dr. Bose received the B.E. (Calcutta University), M.S.(University of Wisconsin) and Ph.D. (Calcutta University) degrees in 1956, 1960 and 1966, respectively.


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Meetings of Interest

SAICA 2007 the 2nd Seminar for Advanced Industrial Control Applications will take place from 5-6 November 2007 at the Fundacion Gomez-Pardo, Madrid, Spain. More information can be found by visiting the website at: http://www.ieeecss.org/cgi-bin/CAB/conferences.cgi

23rd Annual Applied Power Electronics Conference and Exposition (APEC2008) is announced for 24-28 Feb 2008 at the Austin Convention Center, Austin, TX. APEC2008 is co-sponsored by IEEE PEL's, IAS and PSMA. For more updates visit the website at: www.apec-conf.org

I&CPS 2008 the Industrial and Commercial Power Systems conference is scheduled for 4-8 May 2008 at the Sheraton Sand Key hotel in Clearwater Beach, FL. The meeting site is near Tampa, FL on the Gulf side. For more information please visit: www.ieee.org/icps2008

OPTIM-2008 venue: Biannual (in same Mountain Resort), on Power Electrical and Electronics Enginnering; May 22-24, 2008, Brasov, Romania and technical co-sponsored by IEEE – IAS, IES, and PEL's. For details please visit: http://info-optim.ro and http://optim.8m.com. Also, see the announcement in this issue.

39th IEEE Power Electronics Specialists Conference, PESC08 will take place on the island of Rhodes, Greece from 15-19 June 2008. Form more information please visit PELs website or contact PESC08 General Chair, Dr. Stefanos Manias (IEEE IAS/PELs/IES Greece Section Chair) at National Technical University of Athens, manias@central.ntua.gr

43rd Industry Applications Society annual meeting is announced for 5-9 October 2008 at the Weston, Edmonton, Alberta, Canada. Author's deadlines are abstract and digest by 15 Jan 2008 followed by notice of acceptance by 31 March 2008. For more information on the conference and technical program visit the website at: http://www.ieee.org/ias2008

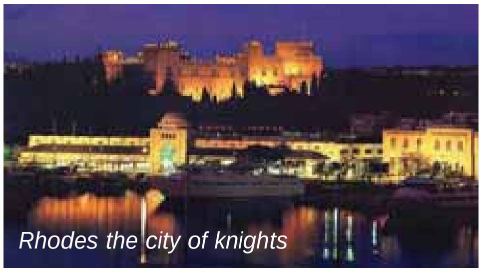
5th Vehicle Power and Propulsion (VPPC2008) Conference is announced for 3-5 September 2008 in Harbin, China. Correspondence may be directed to: vppc2008@hit.edu.cn. VPP'08 general chair: Prof. C.C. Chan, Harbin Institute of Technology. Abstracts with contact details should be submitted by 1 March 2008. VPP'08 is co-sponsored by PEL's. For more information visit the website at: www.vppc2008.com

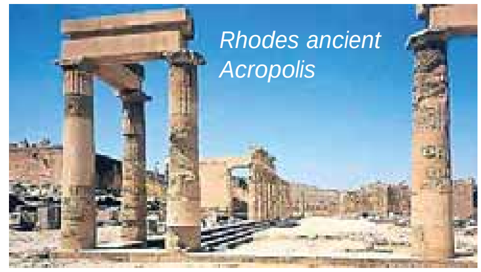
1st Annual Energy Conversion Congress and Exposition (ECCE2009) is announced for 20-24 September 2009 at the Double Tree Hotel at 2050 Gateway Place in San Jose, CA. For more information on ECCE2009 visit the conference website: www.ecce2009.org

44th Industry Applications Society annual meeting is announced for 4-9 October 2009 in Houston, Texas. This will be a new meeting format following the transition of IAS committees to ECCE2009 with more emphasis on tutorials and workshops. For more information visit the website at: www.ieee.org/ias2009

PESC08

39th Power Electronics Specialists Conference
June 15-19, 2008
Island of Rhodes, Greece





PESC is an annual international conference providing a forum for research results, which advance fundamentals and principles of power electronics technologies. PESC includes: technical sessions, tutorials, and informal discussion sessions. Topics cover design, control, analysis, modeling, and simulation of power electronics systems, power converters, motor drive systems, power semiconductor devices and technologies, magnetic devices and materials, energy storage systems, emerging power electronic topologies, and all other aspects of the field. A highlight of this conference would be specially planed sessions showcasing state-of-the-art industrial applications including energy efficiency technologies.

The IEEE Power Electronics Specialist Conference for the year 2008 will take place in the island of Rhodes in Greece and will be co-sponsored by the National Technical University of Athens chaired by Dr. Stefanos Manias and Dr Vassilios Agelidis.

The island of Rhodes is considered to be one of the most popular summer resorts of Europe. Rhodes is gifted with unprecedented natural beauty, blessed with innumerable archaeological sites of unique value and pulsing with numerous non-identical settlements. The island of Rhodes is situated at the cross roads of two major sea routes of the Mediterranean between the Aegean Sea and the coast of the Middle East. The meeting point of three continents, it has known many civilizations.

The conference will be held at the Sofitel Capsis Hotel & Convention Center, a 5-star deluxe fully equipped resort hotel, located at the beachfront of the Ixia Bay, 5 minutes from the Medieval City of Rhodes and 15 minutes from the Rhodes International Airport.

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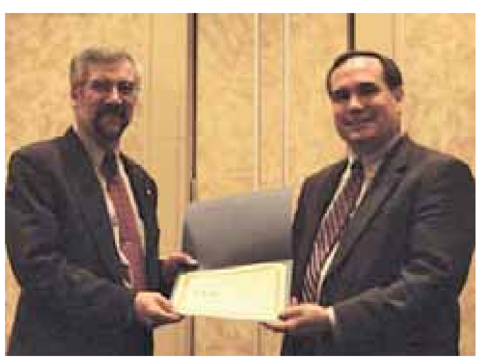
CPES proudly congratulates Prof. Tom Jahns – recipient of the 2007 IEEE Power Electronics Society Distinguished Service Award!

Congratulations to Dr. Tom Jahns, recipient of the 2007 IEEE Power Electronics Society Distinguished Service Award presented at PESC in Orlando on June 21, 2007!

The award was established to recognize long and distinguished service by members to the welfare of the Power Electronics Society at an exceptional level of dedication and achievement. Dr. Jahns is the second CPES professor to receive this prestigious award. The previous CPES recipient was Prof. Daan van Wyk, who was honored in 2006.



Kevin Felhoelter, PES Distinguished Service Award Subcommittee Co-Chair, presents award to Tom Jahns at PESC 2007

Dr. Jahns is a Fellow of IEEE. He received the 2005 IEEE Nikola Tesla Award "for pioneering contributions to the design and application of AC permanent magnet machines" and had earlier received the William E. Newell Award from the Power Electronics Society in 1999. Dr. Jahns has been recognized as a Distinguished Lecturer by the Power Electronics Society during 1998-1999 and the Industry Applications Society during 1994-1995.

Dr. Jahns served as President of the Power Electronics Society during 1995-1996 and as Division II Director on the IEEE Board of Directors during 2001-2002. During his career, he has served in other Power Electronics Society leadership positions including At-Large AdCom member, Meetings Committee Chair, and Award Committee member. Dr. Jahns served as General Chair of the 1992 Applied Power Electronics Conference and as Technical Program Co-Chair of the 2003 International Electric Machines and Drives Conference. He is presently helping to organize the 2009 Energy Conversion Congress and Exposition (ECCE) as a Technical Program Chair.

Dr. Jahns is the leader of the CPES Sustainable Building Initiative, a new research initiative focused on the development and demonstration of advanced power electronics technology for building electrical systems. He served as CPES thrust leader for Integrated Motor Drive Systems (IMDS) and is a member of the CPES Education Committee.

Dr. Jahns is a Grainger Professor of Power Electronics and Electric Machines in the Department of Electrical and Computer Engineering at the University of Wisconsin-Madison, and Co-Director of the Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC).

SECOND ANNOUNCEMENT AND CALL FOR PAPERS

11th International Conference on

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- Romanian Academy, Romanian Academy of Technical Sciences,
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Topics:

Electrotechnics

- Electric Circuits and Networks, Electromagnetic Field, Electrostatic Processes, EMC/EMI,
- Magnetic Materials, Pasive Components and Materials
- Electromagnetic Processing of Materials, Electromagnetic heating
- High Voltage Technique: Discharges, Insulation
- Electric Arc, Electrical Apparatus: Modelling, Simulation, CAD
- Industrial and Commercial Power Systems: Transients, Short Circuits; Rural Electric Power
- Power Quality and Utility Applications, Power System Protection, Earthing, Lightning
- Lighting Applications

Power Electronics, Electrical Machines & Industrial Drives

- Rotary and Linear-Motion Electrical Machines and Drives, Electric Generators and their Control
- Power Electronics in Drives, Control in Power Electronics
- Electric Propulsion on Trains, Vessel, Urban People Movers
- High Power Converters, Low Power Converters, Switching Converters
- Automotive Power Electronics and Motor Drives, Automotive Electrical Equipment
- Mechatronics, Actuators, Robotics, Mobile Autonomous Systems

Industrial Automation and Control

- Control of Linear and Non-linear Systems
- Motion Control, Drive Control, Modelling, Simulation, Signal Processing
- Adaptive and Robust Control, Variable Structure Control, Petri Nets, Neural Networks, Intelligent Systems
- Industrial Informatics, Communication Systems, Process Control
- CAD Tools and Multimedia, Human-Machine Interface Technology
- Safety and Reliability in Automation

Applied Electronics

- Power Electronics Components and Devices: Modelling, Simulation; Discrete and Integrated Semiconductors,
- DSP and Microcontrollers for Power Electronics and Motion Control
- Electronic Circuits and Network Theory, Circuits & Systems, Microsystems
- Symbolic Approaches on Electronics
- Embedded Systems, Hardware & Software Co-Design
- Measurements and Data Acquisition, Metrology
- Audio and Video Signal Processing
- Reliability of Electronic Devices

Electrical Engineering Education

- Education in Electrical Technologies
- New Educational Tools including Information and Communication Technologies
- Introducing Information and Communication Technologies in the Laboratories
- Distance Learning, Continuous Learning, New Materials, New Methods
- University-Industry Collaboration

Special Sessions

- Optimization Algorithms in Power Electrical and Electronics Engineering
- Hybrid Vehicles, Fuel Cell Vehicles, Electric Vehicles, Control Techniques for Electric and Hybrid Vehicles
- Renewable Energy Conversion and Control
- Linear Electric Motor Drives and Maglevs
- Numerical Field Computation Methods in Electromagnetics
- Virtual and Remote Laboratories

Schedule for paper submission:

Full paper deadline:	January 15, 2008
Notification of acceptance:	February 15, 2008
Photo-ready copies and Registration fees:	April 5, 2008

Submission:

Selection will be based upon full length 6 or 8 A4 pages paper in IEEE double column format. Only contribution papers are accepted. Practical (experience based) contributions from industry are mostly welcome. Please make sure that your paper is the best it can be when you send it by Email. You will be invited to make corrections in accordance with reviewers' recommendations.

IEEE Authors Guide may be downloaded from the sites: http://www.ewh.ieee.org/soc/ias/pub-dept/style.html, (styles) and …/two-column.pdf (sample paper) or may be available on request from IEEE Publications Department, P.O. Box 1331, Piscataway, NJ 08855-1331 USA. **Important OPTIM corrections**: paper size A4; 3-3.5 cm top and bottom margins, 2.5 cm left and right margins; 5 mm space between the two equal width columns.

We expect to have again a conference with 170-200 papers or more (OPTIM '06 had 158 papers from 28 countries). The papers are planned to be presented in 3 parallel oral lines of sessions with poster sessions to cover for the rest of the papers. We will have 3-4 keynote addresses from world-renowned personalities and international high tech Companies, to be presented in special plenary sessions. There will be 2 full conference days (Thursday May 22 and Friday May 23) with day 3 (Saturday May 24, 2008) for cultural events for all participants.

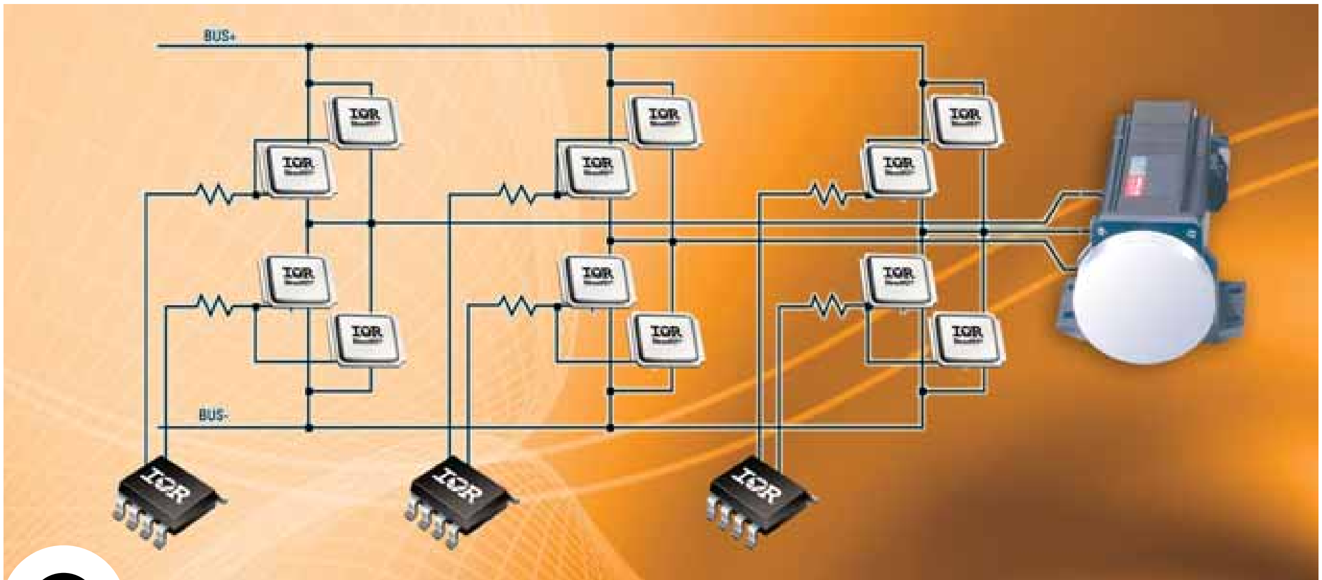
Load your submission on the site http://info-optim.ro. Please load blind (anonymized) files in Adobe Acrobat (.pdf). On the site you are invited to complete a form containing the title of the paper, the authors (names, affiliation, E-mail address, mailing address, phone and fax numbers), the corresponding author, and the topic area.

Accepted Papers:

All submitted papers will be reviewed by members of the International Steering Committee and the corresponding author will be notified of acceptance or rejection. Accepted papers must be presented at the conference (an author could present maximum two (2) papers) and will be published in the conference Proceedings.

The best (graded by the reviewers' scores) 20% of papers presented (the session and date will be mentioned) at OPTIM 2008, with the author's approval, will be sent by the organizers of OPTIM-06 and will considered for review for eventual publication in **IEEE Trans. Vol. IA, PEL, and IE**, provided their content falls into the scope of these Journals. More details will be given on site at OPTIM 2008. **This is a result of continuing technical sponsorship from IEEE-IAS, -PELS, and -IES.**

Papers from OPTIM '08. may also be considered, by author's initiative or by invitation, for final review and speedy publication in the new Internet-only international archival journal: "Journal of Electrical Engineering"; please visit: "www.jee.ro".



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IRS2001SPBF	SOIC8 Bulk					
IRS2001STRPBF	SOIC8 Tape & Reel					
IRS2003PBF	DIP8	UVLO, VCC	RoHS & PBF	290 mA / 600 mA	HIN, LIN/N	Deadtime
IRS2003SPBF	SOIC8 Bulk					
IRS2003STRPBF	SOIC8 Tape & Reel					
IRS2004PBF	DIP8	UVLO, VCC	RoHS & PBF	290 mA / 600 mA	IN, SD/N	SD Input & deadtime
IRS2004SPBF	SOIC8 Bulk					
	SOIC8 Tape & Reel					

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IRF6635	DirectFET	N	30	2.4	1.8	180	47.0	17.0	1.4	89
IRF6613	DirectFET	N	40	4.1	3.4	150	42.0	12.6	1.4	89
IRF6648	DirectFET	N	60		7.0	86	36.0	14.0	1.4	89
IRF6646	DirectFET	N	80		9.5	68	36.0	12.0	1.4	89

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