IEEE PEDS 2013
The IEEE 10th International Conference on Power Electronics and Drive Systems (PEDS)

Kitakyushu International Conference Center
Kitakyushu, Japan
22 - 25 April 2013

Conference Guide
IEEE Fukuoka Section PELS Chapter
IEEE Singapore Section Joint IAS/PELS Chapter

2013 IEEE 10th International Conference on Power Electronics and Drive Systems (PEDS)

PEDS 2013

Program

April 22-25, 2013
Kitakyushu, Japan
Welcome to PEDS2013, Kitakyushu, Japan

On behalf of the organizing committee, we are pleased and honored to invite and welcome you to the 10th IEEE International Conference on Power Electronics and Drive Systems (PEDS2013) in Kitakyushu.

It is an occasion of great significance to us, as this is the first time PEDS is being held in Japan. We are honored at having the opportunity to host this bi-annual conference and hope to bring together researchers, developers, academics, and industry experts to share their new ideas and experiences.

The conference has generated much interest, attracting 356 paper submissions from academic and industry from 25 countries. Assigned with hard work of heading the Technical Program Committee, Program Chairs Masahito Shoyama and Hisao Kubota have produced a three-day excellent program which includes 255 contributed papers to be held in 164 lecture presentations in 44 lecture sessions and 91 poster presentations covering 9 technical topics and special sessions.

We have never experienced such a time as today that integration of power electronics and drive system is required. In this conference we collected most recent research achievements from the most emerging topics in the power electronics and drive system, such as integrating power electronics, power converters, nonlinear phenomena in power electronics, control of power converters, motor drives, power electronics applications, noise and power quality, renewable energy, and other power electronics and drive system topics. We hope in this conference, you will meet with very exciting innovations and ideas in the power electronics and drive system topics. In Japan, we have experienced the Tohoku-Pacific Ocean Earthquake two years back, from which we keenly noticed importance of innovation in power technology. The Kitakyushu City is one of the main industrial cities of Japan and it is a center of energy saving and environmental technologies of the world. As a world leading and authoritative international conference on power electronics and drive system, we are proud to host most relevant conference in this city today.

This significant technical program is attributed to the effort of many people including organizing committee, technical program committee, international advisory boards, reviewers, authors, and other contributors. We would like to thank them all for contributing to this great conference.
Kitakyushu is famous industrial city in Japan. It is known as city of energy saving and environmental technology today. This city has lots of tourist spots and provides delicious foods. I hope you can enjoy both the exciting conference and visit to Kitakyushu. Finally, thank you for joining us and wish you a wonderful experience of PEDS 2013.

Fujio Kurokawa and Tadashi Suetsugu
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Conference Committees

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Track Chairs

1. Integrated Power Electronics
   - Ke-Horng Chen, National Chiao Tung University, Taiwan
   - Yung C. Liang, National University of Singapore, Singapore
   - Motoaki Hara, Tohoku University, Japan

2. Power Converters
   - Akshay Kumar Rathore, National University of Singapore, Singapore
   - Hoshihiko Neba, Fukuoka University, Japan
   - Adrian Ioinovici, Sun Yat-Sen University, China
   - Junichi Itoh, Nagaoka University of Technology, Japan
   - Masayoshi Yamamoto, Shimane University, Japan
   - Nobukazu Hoshi, Tokyo University of Science, Japan
   - Tomokazu Mishima, Kobe University, Japan

3. Nonlinear Phenomena in Power Electronics
   - Hiroo Sekiya, Chiba University, Japan

4. Control of Power Converters
   - Yen-Shin Lai, National Taipei University of Technology, Taiwan
   - Kouji Higuchi, The University of Electro-Communications, Japan

5. Motor Drives
   - King J. Tseng, Nanyang Technological University, Singapore
   - Jung I. Ha, Seoul National University, Korea
   - Kozo Ide, Yasukawa Electric Corporation, Japan
   - Kan Akatsu, Shibaura Institute of Technology, Japan
   - Kazuhiro Ohyama, Fukuoka Institute of Technology, Japan

6. Power Electronics Applications
   - Tsorng-Juu Ling, National Chung Kung University, Taiwan
   - Noriyuki Kimura, Osaka Institute of Technology, Japan
   - Masahito Onishi, Panasonic Corporation, Japan
   - Akihiko Katsuki, Kyushu Institute of Technology, Japan
   - Hideki Omori, Osaka Institute of Technology, Japan
   - Toshimitsu Morizane, Osaka Institute of Technology, Japan

7. Noise and Power Quality
   - Yoshiaki Okui, Sanyo Denki, Japan
   - Hitoshi Haga, Nagaoka University of Technology, Japan
   - Shigenori Inoue, Hitachi, Ltd., Japan
   - Koji Kato, Sanken Electric Co., Ltd., Japan
8. Renewable energy

- **Sanjib K. Panda**, National University of Singapore, Singapore
- **Tomonobu Senju**, University of the Ryukyus, Japan
- **Tadatoshi Babasaki**, NTT, Japan

9. Other Power Electronics and Drive Systems Topic

- **Yoichi Ito**, Sanken Electric Co., Ltd., Japan
- **Makoto Hagiwara**, Tokyo Institute of Technology, Japan
- **Kazuasa Iwaya**, TDK Lambda Corporation, Japan
- **Shinnichirou Nagai**, Pony Denki K. K., Japan
- **Keiji Wada**, Tokyo Metropolitan University, Japan
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Keynote Speeches

**Keynote Speech 1: Tuesday, April 23, 9:20-10:00**

**Powering Critical Loads — A Taiwan Experience**

Prof. Po-tai Cheng  
*National Tsing Hua University, Taiwan*

Chair: Hisao Kubota, *Meiji University, Japan*

**Abstract:**
High tech industries, like semiconductor foundries, display panel manufacturers, etc. play a critical role in the economy of Taiwan. These facilities have many automatic equipment and processes, any unscheduled shut-downs due to electric power interruptions results in significant productivity and financial losses. This presentation will explain how various power electronics technologies are utilized to maintain the power quality and the reliability in these facilities, including dynamic voltage restorers, solid state transfer switches, and uninterruptible power supplies (UPSs). Advanced research based on field experiences will also be reported.

**Biography**

Po-Tai Cheng received his BS degree from National Chiao Tung University, Taiwan in 1990, and PhD degree from University of Wisconsin-Madison, USA in 1999. Since then, he has been with the Department of Electrical Engineering, National Tsing Hua University, Taiwan, where he currently holds the position of Professor. His research interest includes renewable energy systems, smart grid, and high power converters.

Dr. Cheng is an active member of IEEE Industry Applications Society and Power Electronics Society. He served as an associate editor for transactions of both societies. He was also the Technical Program co-Chair of Energy Conversion Congress and Exposition (ECCE) 2012. He received of the IEEE Industry Applications Society Transactions Prize Paper Award in 2009, and the IEEE IAS Industrial Power Converter Committee Prize Paper Award in 2012.
Keynote Speech 2: Tuesday, April 23, 10:00-10:40
Large Capacity Power Electronics Contributing to Realize a Better Future
Dr. Noriko Kawakami, TMEIC, Japan
Chair: Hisao Kubota, Meiji University, Japan

Abstract:
We are now focusing on the global environment because of its warming tendency. We feel that daily life is in a critical situation to be sustained in future. In this context, power electronics is one of the key technologies for the low-carbon industrial revolution leading to a sustainable society through renewable energy, efficient operation of power systems and the greening of the industry. The renewable generation facilities are now scaled up above the megawatt range. HVDC, SVC and STATCOM are contributing to realize the flexible and efficient operation of power systems. The greening is now expanding to industries consuming power above the megawatt range. Then, the speech focuses on very high-capacity power electronics trends for such fields. The speech will introduce the power conditioning system (PCS) for photo-voltaic generation, the back to back converter for wind power and PCS for battery energy storage systems. The speech will also introduce high-efficiency UPS for the Green IT, extra-large converters rated at several tens of MW for the Green Factory, and converters for FACTS. Owing to the recent development of power semiconductors and control devices, even in these high power ranges, the converter efficiency and the operation flexibility have been remarkably improved compared with the old generation.

Biography
Noriko Kawakami received her B.S. degree in physics from the Sophia University in 1982. In 1982, she joined Toshiba Corporation and has been engaged in developing and designing of power electronics equipment. In 2003, she moved to Toshiba Mitsubishi-electric Industrial Systems Corporation TMEIC, which succeeded the industrial systems business from two major Japanese companies. She earned her Ph.D. degree in engineering from the Tokyo Institute of Technology based on her works of control systems for large capacity self-commutated converters. Recently, she engages in developing power conditioners for wind turbines and for battery energy storage systems. She received the IEEJ Technical Development Award in 2000, and the IEEJ Paper Award in 2010.
Keynote Speech 3: Tuesday, April 23, 11:00-11:40
The evolution of interior permanent synchronous machines and their sensorless control strategies
Prof. Faz Rahman the University of New South Wales, Australia
Chair: Masahito Shoyama, Kyushu University

Abstract:
This talk will trace the evolution of the interior permanent magnet (IPM) synchronous machine since it became viable from the mid-1990s. Its strength, weaknesses and its continual development to-date, particularly for the automobile/traction market, will be presented. The recent trend towards fractional-slot, concentrated-winding machine with different stator and rotor poles will also be discussed. The control of the IPMSM in the rotor dq reference frame analysis and the direct torque and flux control in the stator reference frame will be reviewed. The operating performance of the machine at very low speed when a rotor position sensor is not used will be reviewed. The performance of the high-frequency injection scheme at very low speed and the direct torque control approach at high speed will be examined. Current and future trends of controlling the IPM machine sensorless and with high dynamic response for the conventional and the fractional-slot IPM machines will be overviewed.

Biography
Faz Rahman graduated in Electrical Engineering in 1972 from the Bangladesh University of Engineering and Technology, Dhaka. He obtained his Masters and Ph.D. in 1975 and 1978, respectively, from University of Manchester Institute of Science and Technology, U.K. He worked as a Systems Design Engineer in Microprocessor Applications at the General Electric Company (U.K.) since September 1978, until joining the National University of Singapore in September 1980. He joined the University of New South Wales, Australia, in 1988 as a Senior Lecturer, where he is currently a full Professor. His research interests during the past 20 years have been mainly in the interior permanent magnet synchronous machines and their sensorless control techniques. His research interests also include bi-directional power converters, matrix converters and z-source inverters.
Keynote Speech 2: Tuesday, April 23, 11:40-12:20
High Power-Density DC-DC Converters in HVDC Power Distribution Systems for Data Centers
Prof. Tamotsu Ninomiya, Nagasaki University, Japan.
Chair: Masahito Shoyama, Kyushu University

Abstract:
Recently the rapid growth of internet traffic has increased the number of ICT equipment in data centers. This results in the increase of electric power consumption in telecommunication buildings including data centers. The conventional data center utilizes the power distribution system based on the combined power lines of AC and 48VDC. On the other hand, the power distribution system using High-Voltage Direct-Current (HDVC) e.g. 400V, has several advantages such as higher efficiency due to smaller number of conversion stages, and easier installation due to finer power cables. Recently this HVDC power distribution system has been researched and discussed worldwide. However, some difficulties have to be solved concerning a high power-density isolated DC-DC converter for energy and space saving, and a semiconductor circuit breaker for system protection.

This article presents the development of the high power-density isolated DC-DC converters, where two types of converters are discussed. Firstly a full-bridge type has a problem of surge-voltage occurrence related to diode's recovery characteristics. This surge voltage deteriorates or breaks down the diodes. In order to realize a high power-density converter, the optimum selection of surge snubber and diodes through the surge-voltage evaluation is necessary. Secondly an LLC current-mode resonant converter has prominent features of high efficiency and low noise due to Zero-Voltage Switching (ZVS) of primary-side switches and Zero-Current Switching (ZCS) of secondary-side diodes. On the other hand, the operation characteristics are related to many components such as resonant inductor and capacitor, transformer's magnetizing and leakage inductances, and so the circuit design seems to be complicated. Here, through considerations based on analytical and experimental results, two breadboards with the power rating of 1kW (380V/2.7A), the maximum efficiency of 97.5%, and the maximum power-density of 13.4W/cm³ have been fabricated.

Biography
Tamotsu Ninomiya received the B.E., M.E., and Dr.Eng. degrees in electronics from Kyushu University, Fukuoka, Japan, in 1967, 1969, and 1981, respectively. Since 1969 he had been associated with the Department of Electronics, Kyushu University, and since 1988 he had been Professor. In March 2008, he retired from Kyushu University, and has moved to Nagasaki University, Japan as Professor of TDK endowed chair. He has been a specialist in the field of power electronics, including the analysis of switching power converters and their electromagnetic interference problems. He has served as a member of Program Committee for Power Electronics Specialists Conference (PESC) sponsored by IEEE Power Electronics Society (PELS) for many years, and as General Chairman for 1998 PESC. In January 2001, he was awarded as IEEE Fellow for contributions to the development of high-frequency switching power converters.
### Program at Glance - Talks

<table>
<thead>
<tr>
<th>Time</th>
<th>Track: Power Electronics Applications</th>
<th>Track: Control of Power Converters</th>
<th>Track: Motor Drives</th>
<th>Track: Renewable Energy</th>
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<tbody>
<tr>
<td>09:00-10:40</td>
<td>Chr: Akihiko Katsuki, Yao-Ching Hsieh</td>
<td>Chr: Tamotsu Ninomiya, Ken-Iti Jin'No</td>
<td>Chr: Noriyuki Kimura</td>
<td>Chr: Kazuo Honda</td>
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<tr>
<td>10:40-12:20</td>
<td>Chr: Hiroo Sekiya, Masahito Shoyama</td>
<td>Chr: Makoto Hagiwara, Abdul Motin Howlader</td>
<td>Chr: Tatsuya Nakajima</td>
<td>Chr: Shigeru Taniguchi</td>
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<td>09:00-10:40</td>
<td>Chr: Adrian Ioinovici, Junichi Itoh, Chin-Sien Moo</td>
<td>Chr: Yen-Shin Lai, Ching Hsieh</td>
<td>Chr: Masayoshi Yamamoto</td>
<td>Chr: Atsushi Yona</td>
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<td>11:00-12:40</td>
<td>Chr: Ching Hsieh, Hiroo Sekiya, Christi An Cheng</td>
<td>Chr: Tatsuya Kawakami, Kei Wada</td>
<td>Chr: Sanjib Panda, Kan Akatsu, Kozo Ide</td>
<td>Chr: Tsorng-Juu Liang</td>
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<td>09:00-10:40</td>
<td>Chr: Suttichai Premrudeep, Yen-Shin Lai</td>
<td>Chr: Masayoshi Yamamoto, Ching Hsieh</td>
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### Program at Glance – Posters

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<tr>
<th>Time</th>
<th>Event Hall</th>
<th>Track</th>
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<tbody>
<tr>
<td>Wednesday, Apr 24th, 2013 14:00-15:40</td>
<td>Event Hall</td>
<td>Integrated Power Circuits and Systems III Che: Motoaki Hara, Hirooki Soori</td>
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<td>Control of Power Converters Che: Nobukazu Hoshi, Takeshita Takeshita</td>
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<td>Nonlinear Phenomena in Power Electronics and Devices Che: Yushi Miura, Feel-Soon Kang</td>
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<td>Power Converter and Applications I Che: Kozo Ide, Jung-Ik Ha</td>
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<td>Power Converter and Applications II Che: Akihiko Katsumi, Teruhiko Kohama, Monobu Senjyu</td>
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<td>Other Power Electronics and Drive Systems Che: Koji Kato</td>
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Conference at Glance

April 22, 2013 (Monday)
9:00-12:40  Morning Tutorial
14:00-17:40 Afternoon Tutorial
18:00-20:00 Welcome Reception

April 23, 2013 (Tuesday)
9:00-9:20  Opening Ceremony
9:20-10:00 Keynote Speech (1)
10:00-10:40 Keynote Speech (2)
10:20-11:00 Coffee Break
11:00-11:40 Keynote Speech (3)
11:40-12:20 Keynote Speech (4)
12:40-14:00 Lunch
14:00-15:40 Lecture Sessions
15:40-16:00 Coffee Break
16:00-17:40 Lecture Sessions
18:00-21:00 Evening Mojiko Tour (Optional)

April 24, 2013 (Wednesday)
9:00-10:40  Lecture Sessions
10:20-11:00 Coffee Break
11:00-12:40 Lecture Sessions
12:40-14:00 Lunch
14:00-15:40 Poster Sessions
15:40-16:00 Coffee Break
16:00-17:40 Lecture Sessions
19:00-21:00 Conference Banquet

April 25, 2013 (Thursday)
9:00-10:40  Lecture Sessions
10:20-11:00 Coffee Break
11:00-12:40 Lecture Sessions
12:40-14:00 Closing Ceremony
Registration Hours
The PEDS 2013 registration desk will be open during the following hours:

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Hours</th>
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<tbody>
<tr>
<td>Monday</td>
<td>April 22</td>
<td>8:00-18:00</td>
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<td>Tuesday</td>
<td>April 23</td>
<td>8:00-17:40</td>
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<td>Wednesday</td>
<td>April 24</td>
<td>8:00-17:40</td>
</tr>
<tr>
<td>Thursday</td>
<td>April 25</td>
<td>8:00-12:40</td>
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</table>

Lecture Presentations
The duration of a presentation slot is **25 minutes**. You will have 20 minutes for the presentation itself and 5 minutes for questions from the audience.

Only a LCD projector & computer (Windows, MS Powerpoint & Adobe Acrobat Reader) will be available in every session room for regular presentations.

Speakers should arrive in their session room 15 minutes BEFORE the start of their session to report to the chair person. A proctor will also be available in case you need technical assistance.

Speakers are strongly encouraged to visit the Speaker Preparation room in advance of their presentation to avoid any last minute problems. The Speakers' Preparation room will be open during the sessions from Monday afternoon through Thursday.

Speaker Preparation Room
Speaker Preparation Room is located in the Conference Room 32C at 3rd floor, Kitakyushu International Conference Center. It will be open during the following hours:

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Hours</th>
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<tbody>
<tr>
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<tr>
<td>Thursday</td>
<td>April 25</td>
<td>8:00-12:40</td>
</tr>
</tbody>
</table>
**Poster Presentations**
Poster Area is located in the Event Hall at 1st floor, Kitakyushu International Conference Center. It will be open during the following hour:

Wednesday      April 24      14:00-15:40

**Best Paper Award**
The Best Paper Award will be presented at the closing ceremony in the International Conference Room, 2nd floor, Kitakyushu International Conference Center. The Closing Ceremony will be open during the following hour:

Thursday      April 25      12:40-14:00

**Social Programs**

**Welcome Reception**
Date: Monday, April 22  
Venue: Flamingo Café, Asia-pacific Import Mart (AIM) Building  
Ticket includes one beverage and foods. Additional beverage will be served by 500JPY per one glass.

**Conference Banquet**
Date: Wednesday, April 24  
Venue: 4F Royal Hall, Rihga Royal Hotel Kokura

**Evening Mojiko Tour (Optional, Free)**

Date: Tuesday, April 23  
Venue: Mojiko Historical Area

Reservation is not required. Free bus will take you to Mojiko Retro (Historical) Area. Bus will leave Conference Center at 18:00. There is no guide and dinner. Please walk around Mojiko Area and take dinner by yourself. Returning bus will leave from Mojiko at 21:00. You can also come back by yourself using JR train. Mojiko to Kokura is 12 minutes and 270 Yen. Every train leaving from Mojiko Station will stop at Kokura station.
Exhibits
Exhibition date:

Monday  April 22  12:00-18:00
Tuesday April 23  8:00-17:40
Wednesday April 24  8:00-17:40
Thursday April 25  8:00-12:40

Tutorials

Morning Tutorials
April 22, 2013 (Monday), 9:00-12:40
H1 Development of Standard Models for Power Electronics Simulations
H2 Optimal Operation of Photovoltaic Power Conversion Systems: Maximum Power Point Tracking Approach

Afternoon Tutorial
April 22, 2013 (Monday), 14:00-17:40
H4 Microgrids operation and planning for highly available power supply

Full Day Tutorial
April 22, 2013 (Monday), 9:00-17:40
F1 Control of Grid Connected Power Converters
**H1  Development of Standard Models for Power Electronics Simulations**

Dr. Noda  
Researcher of the Central Research Institute of Electric Power Industry (CRIEPI), Japan,  
Prof. Ishikawa  
Associate professor of Gifu University, Japan  
Dr. Fukushima (Researcher of the Central Research Institute of Electric Power Industry (CRIEPI), Japan  
Prof. Noriyuki Kimura  
Osaka Institute of Technology, Japan

Simulations today are used for the design of real power-electronic converters and also for solving real-world problems related to power electronics. If standard simulation models of power-electronic converters and related components are provided, simulations including power-electronics converters become much easier. Especially, time for preparing a simulation data case can be significantly reduced. Considering this, the Industry Applications Society of IEEJ (Institute of Electrical Engineers of Japan) has launched a study group for developing standard simulation models of power-electronic converters and related components which will be used in simulations related to Smart Grids and motor drives. This tutorial gives an overview of the standard model development activities.

**H2  Optimal Operation of Photovoltaic Power Conversion Systems: Maximum Power Point Tracking Approach**

Dr. M. VEERACHARY  
Professor, Dept. of Electrical Engineering, Indian Institute of Technology Delhi, INDIA

As the quantum of available fossil fuels are decreasing day-by-day the world is going towards the use of renewable energy sources either to supplement the existing utility supply are replace completely to mitigate the global warming related problems. Photovoltaic (PV) power generation is one among these renewable sources and has tremendous potential and going to play a key role in the future power generation systems.

In view of this it is now becoming essential to look into various aspects of the PV energy conversion into electric energy of form that is suitable to integrate to the conventional utility systems and to drive the versatile electric loads. As the solar radiation/insulation is hanging continuously, right from morning to evening, and hence its power output also changes. Further, the photovoltaic cells/modules exhibits non-linear volt-ampere characteristics and hence their power output also depends on the type of load connected to it. In order to extract the available power from the PV module and to improve the overall power conversion efficiency it is essential to use an intermediate suitable power electronic converter and then it must be controlled in such a way that the extracted power from the PV module must be maximum at all solar insulations/operating points. However, there are several issues that arises during the process of converter control while tracking power, of which the important ones are: (i) selection of suitable power electronic converter depending on the downstream load and/or nature of power requirement (ac or dc), (ii) the best suitable tracking strategy depending on the type of power conversion system, stand-alone or utility assisting system, (iii) constraints/limitations on the loads ranges, (iv) effect of multi-loop strategies on the overall PV conversion, (v) issues in battery charging in case of stand-alone PV systems, etc. In all the above cases the power electronic systems together with control theory plays a vital role in realization of optimal photovoltaic power conversion system. In view of this, there is a need for the design engineers/researchers/academicians to know more about these renewable energy generation and
integration issues and their application aspects in the up-coming area of photovoltaic power conversion. This tutorial is formulated considering these requirements and the details of topics to be delivered to the participants are:

- Review of Photovoltaic power conversion and it’s global state of art.
- Overview of control theory aspects which are used in the photovoltaic power conversion.
- State of art and overview of power electronic converters for PV power processing.
- Modeling of photovoltaic components used in power generation.
- Detailed discussion on front-end Power Electronic Converters selection and classification.
- Maximum Power Point Theory, discussion of different tracking scheme, selection, advantages and their limitations. Intelligent control applications in the PV power conditioning systems and digital solutions.
- Benchmark maximum power point tracking control problems, programming aspects/examples.
- Typical computer-aided simulation examples (PSIM/MATLAB/SIMULINK) of interfacing PV conversion/ Power Electronic Processors and Maximum Power Point Trackers.
- Comparison of various power tracking controllers, implementation issues and future directions.

H4 Microgrids operation and planning for highly available power supply
Alexis Kwasinski
Assistant Professor at the Department of Electrical and Computer Engineering at The University of Texas at Austin, USA

This tutorial discusses operational and planning approaches for achieving a highly available power supply through microgrids. The tutorial begins by presenting the motivation for using microgrids for highly available power supply: improving power supply availability during natural disasters and in their aftermath. In order to explain the use of microgrids in this application, the tutorial introduction presents the basic characteristics of conventional electric power grids that make them fragile systems with inherent limitations when trying to achieve a sufficient availability level in disaster conditions. Then, it is explained how microgrids present a paradigm change that may address the limitations found in conventional power grids in order to achieve high availability during disasters and their aftermath. However, in extreme conditions microgrids are a suitable solution for conventional grids only when they are planned and operated in a suitable way. Hence, the rest of this tutorial explains how to plan and operate a microgrid in a suitable way in order to achieve high power supply availability in disaster conditions. The rest of the tutorial is divided in the following modules:

- Microgrid basics: Definition of microgrids and basic description of their fundamental technologies, including local distributed power generation sources—both renewable energy and non-renewable energy ones—energy storage devices, power electronic interfaces, and power distribution architecture.
- Planning: Presentation of basic definitions of reliability theory, discussion of basic methods to calculate microgrids availability, and description of availability models for microgrids and its components, including local power generation sources—renewable energy and non-renewable energy ones—lifelines of non-renewable energy sources, power electronic interfaces, and energy storage.
- Power electronic interfaces: Description of basic circuit topologies for high available power supply with focus on circuits for integration of diverse sources and for interfacing energy storage devices. Autonomous controls: Focus on droop control in microgrids.
- Examples: Application of microgrids in disaster condition and case studies using data and information from recent notable disasters.
In the application field of electric drives, connecting rotating machines to networks of various sizes, the industry requires more and more robustness regarding network unbalance and sags, involving a special development effort on the control itself. Being more and more confronted to weak networks, a particular effort must be done on synchronisation, harmonic rejection, with a particular attention on fulfilling standards. The purpose is served through dedicated control on the power converter side and careful identification of network perturbations.

This tutorial is a shortened version of a doctoral course given at EPFL, Lausanne, Switzerland. It is aiming to give intuitive understanding on the issues related to the control of power converter connected to any kind of grids in a general context of multiplication of decentralized power generation and microgrids. A special focus will be provided on the control of drives connected to weak or isolated networks.

The covered topics will include converter control techniques in the fixed and synchronous reference frames (Proportional-Resonant control, multivariable control, state control) with a focus on single-phase application introducing the fictive axis emulation (FAE). In the afternoon the covered topics will include grid synchronization (grid modelling, strength, handling of weak networks with disturbances) and handling of asymmetric grids (control techniques for decoupling disturbances). The tutorial will contain design and simulation examples supported by industrial experience and academic approach.
Special Sessions

SS-1 Advanced Motor Drive for AC Machine
Organizer Kan Akatsu (Shibaura Institute of technology) and Kozo Ide (Yaskawa Electric)
Session Code: B2L-C
Location: Conference Room 21AB
Date & Time: Wednesday April 24, 2013 (11:00 - 12:40)
Chair: Kan Akatsu, Kozo Ide

SS-2 PV system utilization and control issues
Organizer Tomonobu Senju (University of the Ryukyus)
Session Code:  B1L-A
Location: Conference Room 11
Date & Time:  Wednesday April 24, 2013 (09:00 - 10:40)
Chair: Suttichai Premrudeep, Yen-Shin Lai

SS-3 Digital Control Technique
Organizer Prof. Kohji Higuchi (The University of Electro-Communications) and Prof. Yen-Shin Lai
(National Taipei University of Technology)
Session Code:  B1L-A
Location: Conference Room 11
Date & Time:  Wednesday April 24, 2013 (09:00 - 10:40)
Chair: Suttichai Premrudeep, Yen-Shin Lai

SS-4 High-Frequency Resonant Power Converters and Soft-Switching Technologies
Organizer Prof. Tomokazu Mishima (Kobe University)
Session Code:  A2L-A
Location: Conference Room 11
Date & Time:  Tuesday April 23, 2013 (16:00 - 17:40)
Chair: Tomokazu Mishima

SS-5 Contactless power transfer and its related topics
Organizer Prof. Hiroo Sekiya (Chiba University) and Prof. Hirohito Funato (Utsunomiya University)
Session Code:  B4L-A
Location: Conference Room 11
Date & Time:  Wednesday April 24, 2013 (16:00 - 17:40)
Chair: Hiroo Sekiya, Hirohito Funato
Technical Program Sessions

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<td><strong>Neural Networks Approach for Wind-Solar Energy System with Complex Networks</strong></td>
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<td><strong>Behavioral Modeling of Class E Amplifiers Based on Modified Nodal Analysis Formulation</strong></td>
<td>Yuichi Tanji, Hiroto Kamei</td>
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<td><strong>Stability Analysis of an Interrupted Circuit with Fast-Scale and Slow-Scale Bifurcations</strong></td>
<td>Hirohiko Asahara¹, Kazuyuki Aihara², Takuji Kousaka³</td>
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<td><strong>Voltage Converter by Using Printed Distortion Spiral Inductors</strong></td>
<td>Yuji Tanada, Takahiro Kuroko, Masayuki Yamauchi</td>
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We investigate the performance of the method for the WS model. From the results, if the power grid has strong randomness, the electric power is well distributed in the power grid. In this paper, we evaluate the method for various topologies of the complex networks. Then, results clearly show that there are strong dependency between the network topologies and distribution of the power in the power grid.

The behavioral model of class E amplifiers on the steady state are given based on the modified nodal analysis (MNA) formulation. The MNA formulation is a method for producing circuit equations which is adopted in general purpose circuit simulators as SPICE. Hence, even though the circuit configuration is changed, the behavioral model can be obtained. To make the behavioral model, the MOSFET including in the class E amplifier is replaced with an ideal switch. Each dynamical system depending on “on” and “off” states of the switch is categorized into the predictor system in control community. Then, the behavioral model of the class E amplifiers is obtained based on control theory.

In this paper, we analyze stability of the fast-scale and slow-scale dynamics in an interrupted electric circuit. We mathematically show that the period-doubling bifurcation, which occurs in the fast-scale dynamics, does not directly affect the stability of the slow-scale dynamics.

In this study, some distortion spiral inductors are made on the printed boards, and we call the spiral inductor a printed distortion spiral inductor (PDS-Inductor). Shape of our PDS-Inductors is like an egg. We propose a thin and light transformer which is constructed by using two PDS-Inductors, and a voltage conversion system with the transformer. In our transformer, one of the two egg shape PDS-Inductors can rotate. Therefore, a magnetic flux leakage quantity between the PDS-Inductors is changed. In other words, the mutual inductance between PDS-Inductors is changed, and conversion or transmission efficiency is changed. Furthermore, our voltage conversion system can measure the rotation angle, because the efficiency of the transformer is changed by the rotation angle.
14:00 Applying Coupled Inductor to Step-Up Converter Combining KY and Buck-Boost Converters
K. I. Hwu, W. Z. Jiang
National Taipei University of Technology, Taiwan

In this paper, a novel voltage-boosting converter is presented, which combines one charge pump and one coupled inductor. The corresponding voltage gain is greater than that of the existing step-up converter combing KY and buck-boost converters. Since the proposed converter possesses one output inductor, the output current is non-pulsating. As a result, both the output current ripple and the output voltage ripple can be reduced significantly. After some mathematical deductions, an experimental set-up with 12V input voltage, 72V output voltage, and 60W output power is used to verify the effectiveness of the proposed converter.

14:25 Potential Power Analysis and Evaluation for Interleaved Boost Converter with Close-Coupled Inductor
Shota Kimura, Jun Imaoka, Masayoshi Yamamoto
Shimane University, Japan

Interleaved boost converter with close coupled inductor is widely employed in drive system for Hybrid electric Vehicle (HEV) or in renewable energy system, in order to achieve high power density of the converter. For further high power density of magnetic components, this paper presents calculation method for potential power of the magnetic components in interleaved boost chopper circuit with close coupled inductor. As a result of analysis, CRM control scheme is effective for miniaturization of the magnetic components. Finally, potential power of the interleaved boost converter with close coupled inductor is discussed from theoretical and experimental results.

14:50 Analysis and Implementation of a Bidirectional Double-Boost DC-DC Converter
Hsiu-Hao Liang, Tsorng-Juu Liang, Shih-Ming Chen, Kai-Hui Chen
National Cheng Kung University, Taiwan

This paper presents a novel bidirectional DC-DC converter with high conversion ratio for the renewable energy systems. The proposed converter uses the coupled-inductor technique to achieve high conversion ratio. Besides, this converter has simple circuit topology and simple control technique. In the discharging mode, the proposed converter likes two stage boost converters and only needs to control one active switch that can achieve high voltage step-up ratio conversion. When the charging mode, it likes two buck converters in cascaded, and the active switches are operated in the same duty cycle that can achieve high voltage step-down ratio conversion. This paper has analyzed the proposed converter operating principles, steady-state circuit characteristics. Eventually, a prototype circuit with conversion voltage 24 V/ 200 V and output power 200 W is implemented to verify the feasibility of the proposed converter. The maximum efficiency is about 94.3 % and 91.6% at discharging and charging mode respectively.

15:15 Quadratic Boost Converter with Switched Capacitor and Coupled Inductor for PV System Applications
Yuang-Shung Lee, Zih-Han Chou, Sian-Siou Huang, Shih-Yong Huang
1ASE Institute / Fu Jen Catholic University, Taiwan; 2Fu Jen Catholic University, Taiwan

A quadratic boost converter topology based on a high conversion ratio dc/dc converter with an active zero-voltage switching (ZVS) snubber circuit is developed for PV system application. Combined with a reboost inductor, a coupled inductor and charge-pump circuits are proposed to achieve high voltage gain with quadratic function. A front inductor is proposed to reboost the voltage gain to make the output voltage higher. The converter operating principle of the proposed conversion scheme is described in the detailed converter analysis. Simulation and experimental results are used to verify and validate the performance of
the quadratic boost converter with the fuzzy maximum power point tracking controller (MPPT) in the PV inverter system.
14:00 Integral Backstepping Sliding Mode Control of a Magnetic Ball Suspension System
Huann-Keng Chiang$^2$, Wen-Te Tseng$^2$, Chun-Chiang Fang$^3$, Chien-An Chen$^1$
$^1$Automotive Research and Testing Center, Taiwan; $^2$National Yunlin University of Science and Technology, Taiwan

This paper the uncertainty problem of nonlinear system using the backstepping control with sliding surface implemented in magnetic ball suspension system. The classical backstepping control is a systematic, methodical recursive nonlinear feedback control method, which is fit to design a controller of high order complicated system. For the reason of improving both effect and robustness, an integrator and a sliding surface are added in design process. The magnetic ball suspension system is employed to validate the proposed controller. The experimental result shows that the integral backstepping sliding mode controller is successful solving the uncertainty of nonlinear system and the steady error of classical backstepping control method.

14:25 Load Variation Characteristic of Magnetically Levitated Vehicle with Hybrid Magnets
Toshibo Kakinoki, Hitoshi Yamaguchi, Naoya Yoshinaga, Eiichi Mukai, Hiroyuki Nishi
Sojo University, Japan

This paper reports the experimental results of the load variation characteristics (weight test change) of a magnetically levitated vehicle with hybrid magnets, which we studied in place of street cars and conveyor systems. Magnetically levitated systems have the following advantages: no bearings, no wheels, no noise, no air pollution and low maintenance. We propose new constructive electromagnets and magnetic rails. Their practical use is facilitated by their low construction cost and low maintenance. Magnetic levitated vehicles with hybrid magnets have a major advantage over street cars and conveyor systems.

14:50 Scaling of Magnetically Levitated Homopolar Hollow-Shaft Machines
Claudius Zingerli$^1$, Ivan Coray$^1$, Jonathan Weber$^1$, Thomas Nussbaumer$^2$, Johann Walter Kolar$^1$
$^1$ETH Zürich, Switzerland; $^2$Levitronix GmbH, Switzerland

In this paper, we analyze scaling issues that arise when the size of a magnetically levitated hollow-shaft machine is varied, but the output power is kept constant. Reducing the size by a factor of two leads to a required increase in speed by a factor of about three. Because the losses of previously used topologies did not scale well we suggest and analyze a different topology: the combined homopolar magnetic bearing (CHB). The proposed design methodology has been experimentally verified in a prototype product.

15:15 Self-Sensing Electromagnetic Levitation System Taking Account of Ripple Currents Excited by PWM Amplifier
Kohei Matsuda, Tetsuso Sakamoto
Kyushu Institute of Technology, Japan

This paper presents a multirate linear model for self-sensing magnetic levitation (maglev) system. We consider one degree of freedom maglev system composed of a suspended object and an electromagnet driven by a pulse width modulated (PWM) switching power amplifier. The proposed model makes use of the embedded airgap information in the coil current which detects two times during the switching frequency. We design a controller based on the model, and show that proposed model performs well using closed loop simulations.
14:00  Investigation of Various Operating Modes of Fuelcell/Ultracapacitor/Multiple Converter Based Hybrid System
Latha K1, Umamaheswari B1, Rajalakshmi N2, Dhathathreyan K.S. 
1Anna University, India; 2ARCI, India
Fuel cells (FC) suffer with low energy density and hence required to be hybridized with Energy Storage Systems (ESS) like ultra capacitors (UC) or batteries to cater to load profiles that have periodic demands for higher power. Generally converters are connected to each ESS and hence they idle most of the time as they are operated only during peak demands. This paper proposes various operating modes in which the converters can be used in interleaved or isolated configurations upon predetermined load demand patterns. This paper analyses various operating modes and proposes control strategy to utilize the converters effectively. A multi objective energy and power management algorithm is derived based on predicted/predefined load pattern to meet tight load regulation, regeneration and protect fuel cell from starvation. The merits of the proposed configuration are illustrated through theoretical and experimental investigation.

Noboru Katayama, Sumio Kogoshi
Tokyo University of Science, Japan
In our previous study, it is developed the method to smooth the output power of fuel cells (FCs) by combining with electrical double layer capacitors (EDLCs). This study proposes an energy control method to maintain the voltage of the EDLCs within the specified range and to reduce the fluctuation of the FC output power at the same time, using an additional PI control loop and a digital filter to gradually vary the reference voltage of the FC voltage. The control parameter is determined using the simplified numerical model that is also constructed. The simulation result obtained from the model that used the determined control values showed that the system works stable and the movement of the operating point of the FC is controlled under the load condition where the duty ratio of the square-wave load current is changed. Finally, in consideration of vehicle applications, simulations using the large scale model is demonstrated and its results are evaluated.

14:50  Supersession of Large Penetration Photovoltaic Power Transients Using Storage Batteries
Emad Hussein Abdelkarim1, Mohamed M. Aly1, Mamdouh Abdel-Akher2, Zakaria Ziadi2, Tomonobu Senjyu2
1Aswan University, Egypt; 2University of the Ryukyus, Japan
This paper treats the impact of output fluctuations caused by cloud transients on the distribution power systems fed by large photovoltaic system. The PV power support may lose most of its power within a short period. For that, the interconnection standards for inverter based PV generation has been proposed. A control strategy for the PHEVs battery is developed in which the PV generation scheduled power is prepared based on clear sky assumption. The results include analysis for 33-node radial distribution feeder which has PV generation plants with PHEVs charging stations. Three models of the PV interface inverter are used.

15:15  Optimal Scheduling Method of Controllable Loads in Smart House Considering Forecast Error
Akihiro Yozza, Abdul Howlader, Kosuke Uchida, Atsushi Yona, Tomonobu Senjyu
University of the Ryukyus, Japan
Photovoltaic generation is getting attention in distribution systems. Then, houses with PV and heat pump can profit by time-of-day electricity price system. If fixed battery and electric vehicle can be introduced in the houses, the electricity cost would be more reduced. Home energy management system is needed for optimization of the coordinated operation of these appliances, but renewable energy often fluctuate from forecasted data. Hence, optimal schedule of these appliances may not be available due to the uncertainty of
weather. In this paper, we propose that optimal scheduling method of controllable loads considering forecasted error in the smart house.
14:00 Leakage Current Suppression in the Variable Capacitance Device for the Use in AC Power Converters
Akihiko Katsuki¹, Takuya Oki²
¹Kyushu Institute of Technology, Japan; ²Kyushu Institute of Technology, Japan

Ac leakage current in the Variable Capacitance Device is discussed. For varying its capacitance, this device utilizes nonlinear characteristics of dielectric. Therefore, the ac leakage current flows from the capacitor to a dc control voltage source when ac capacitor voltage is high. Here, techniques for suppressing ac leakage current are proposed. An example of its application is introduced about ac power supply. Influence of leakage current on distortion in current waveforms is also investigated.

14:25 GaN HEMTs Power Module Package Design and Performance Evaluation
Chung-Hsiang Ho, Po-Chien Chou, Stone Cheng
National Chiao Tung University, Taiwan

This paper described the electronic performance of power module packaged high-power AlGaN/GaN high electron mobility transistors on silicon substrate. Twelve GaN devices are mounted on AlN substrate. Each device is wire-bonded in parallel connection to increase the power rating. Both DC and pulsed current-voltage characteristics are measured for different connection and sizes of devices, at various of power densities, pulse lengths, and duty factors. The packaged GaN HEMTs exhibit the pulsed drain current, 0.43 A/mm. Performance of multichip GaN HEMTs module package is studied. The GaN HEMTs power module exhibit a drain current of 0.512 A/mm, which indicates that connecting three GaN HEMTs in parallel can effectively improve the drain current.

14:50 Differential Mode EMI Filter Design for Ultra High Efficiency Partial Parallel Isolated Full-Bridge Boost Converter
Ishtiyaq Ahmed Makda, Morten Nymand
University of Southern Denmark, Denmark

This paper presents a practical method to design a Differential Mode (DM) EMI filter. Unlike the other methods presented in literature where often the noise information is needed beforehand in order to design EMI filter, this paper allows one to calculate the DM noise analytically. A 3kW/400V partial parallel isolated dc-dc boost converter has been chosen to implement the filter. As the input voltage of the converter is very low with very high input dc and ripple currents such as in the fuel cell application and since the EMI limits also does not change for these applications hence it calls for a carefully optimized filter. Moreover, the negative impedance of the converter is extremely low thus it is a very challenging task to satisfy the output impedance condition of the filter. Simulation and hardware results of the DM filter are recorded and published.

15:15 A VLLMS Based Harmonic Estimation of Distorted Power System Signals and Hybrid Active Power Filter Design
Pravat Kumar Ray¹, Bidyadhar Subudhi²
¹NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA, India; ²National Institute of Technology, Rourkela, India

This paper presents a Variable Leaky Least Mean Square (VLLMS) based algorithm for harmonics estimation in distorted power system signals. Further, for mitigation of these harmonics a Hybrid Active Power Filter (HAPF) with modified Pulse Width Modulation (PWM) control technique has been designed. Both simulation and experimental studies are carried out for evaluating the estimation and filtering performances. VLLMS provides improved performance in estimation compared to LMS and Variable Step Size LMS (VSSLMS).
Further, HAPF exhibits improved harmonics filtering performance compared to both active and passive power filters.
A1L-F  Control of Power Converter I
Time:  Tuesday, April 23, 2013, 14:00 - 15:40
Place:  Conf. Room 32AB
Chair:  Tamotsu Ninomiya, Nagasaki University
        Kenya Jin'No, Nippon Institute of Technology

14:00  A New Control Strategy for Power Supply on Chip Using Parallel Connected DC-DC Converters
Takayuki Yamamoto\textsuperscript{1}, Jungo Rikitake\textsuperscript{2}, Satoshi Matsumoto\textsuperscript{2}, Tamotsu Ninomiya\textsuperscript{3}, Seiya Abe\textsuperscript{4}
\textsuperscript{1}International Center for the Study of East Asian Development, Japan; \textsuperscript{2}Kyushu Institute of Technology, Japan; \textsuperscript{3}Nagasaki University, Japan

In recent years, power supply on chip (SoC) attracts the attentions because it can realize higher electric power density and lower manufacturing cost. However, it is necessary to connect parallel at heavy loading conditions because of small capacity per chip. In addition, high-frequency switching of more than 10MHz is required. In such a scheme, the traditional analog based PWM will face the problems and the new control strategy is required. This paper propose a new control strategy of the power-SoC based on parallel connection of dc-dc converters by digital control.

14:25  SoPC Based Digital Current-Mode Control of Full-Bridge Phase-Shifted DC/DC Converters with Fast Dynamic Responses
Gun-Sen Ho, Chiao-Chin Lin, Shin-Hau Hsu, Ying-Yu Tzou
National Chiao Tung University, Taiwan

This paper proposes a system-on-a-programmable-chip (SOPC) solution for the digital current-mode control of a fullbridge phase-shifted (FB-PS) DC-DC converter to achieve fast dynamic response and high efficiency. The proposed digital current-mode control scheme is realized with a MCU-based mixed-signal FPGA A2F200 from Microsemi SmartFusion. A digital phase-shifted PWM generator is designed for the generation of programmable phase-shifted PWM signals with adjustable switching frequency. A digital controller with adjustable control parameters is synthesized to achieve a fast dynamic response of the output voltage. Synchronous current sampling scheme is developed to avoid switching noises and induced current spikes. Implementation issues of digital PWM controller using SOPC based mixed-signal FPGA has been addressed. Experimental results are given to verify and show the feasibility of the proposed control scheme to a 800W, 400V to 12V DC-DC dc-dc converter in applications to high-performance server power supplies.

14:50  Modeling and Control of Isolated Full Bridge Boost DC-DC Converter Implemented in FPGA
Fazel Taeed, Morten Nymand
University of Southern Denmark, Denmark

In this paper an Isolated Full Bridge Boost converter (IFBC) is modeled. In the modeling part, small signal equivalent circuit of the converter is used. From the small signal model the converter transfer function is derived. Based on the obtained transfer function, challenges of controller design are discussed. In the next step, a digital PI controller is designed and implemented in FPGA to control the output voltage. Using injection transformer method the open loop transfer function in close loop is measured and modeling results are verified by experimental results.

15:15  Control Characteristics of Novel Digital Peak Current Mode DC-DC Converter
Fujio Kurokawa\textsuperscript{1}, Kazuhiro Kajiwara\textsuperscript{1}, Yuichiro Shibata\textsuperscript{1}, Yoshihiko Yamabe\textsuperscript{3}, Toru Tanaka\textsuperscript{2}, Keiichi Hirose\textsuperscript{2}
\textsuperscript{1}Nagasaki University, Japan; \textsuperscript{2}NTT Facilities, Inc., Japan

Control characteristics of a novel digital peak current mode dc-dc converter are presented. First, this paper shows the proposed method can obtain good regulation characteristics in the operation range. Second, it is revealed that the proposed method has a superior transient response. As a result, the convergence time of output voltage is shortened to about one half to the conventional method. The overshoot of output voltage is also improved to one third.
14:00 Applying VRB-ESS in the DC Micro-Grid for Green Building Electricity Supply: Constructive Suggestions to Improve the Overall Energy Efficiency
Zhen Lu1, Jiyun Zhao2, King Jet Tseng2, Kian Wee Ng1, Yimin Rao1
1JTC Corporation, Singapore; 2Nanyang Technological University, Singapore

This paper proposes comprehensive methods to improve the overall energy storage efficiency of the vanadium redox flow battery energy storage system (VRB-ESS) as well as the overall energy efficiency of the DC micro-grid. It includes three components: firstly, a novel design concept of the bi-directional (charge/discharge) DC/DC converter circuits linking the VRB with the DC micro-grid is presented, together with the principle of how to set the nominal voltage of the VRB as well as how to control these circuits’ parallel operation; secondly, a scheme of multi-purpose operation is presented after analysing three main functions of the VRB-ESS in the DC micro-grid for green housings; thirdly, several improvement measures for establishment and operation of the VRB-ESS are suggested.

14:25 Simple Student Experiments Including Power Electronics Technology
Noriyuki Kimura, Toshimitsu Morizane, Hideki Omori
Osaka Institute of Technology, Japan

In this paper, experiments using a miniature motor and a chopper circuit for students are shown. These experiments are aimed to introduce the basic principle and characteristics of the motor and some control method to the sophomore (second grade) students. They learn not only the principles but also know-how of construction of experimental setup and measurement.

14:50 A Problem Oriented Model for Teaching Power Electronic Circuits
Wei Jiang, Fangyan Yu, Yueping Mo
Yangzhou University, China

In this paper, the features and the challenges in power electronics teaching activities are identified, and a problem-oriented teaching model is proposed. This model is comprised of well-designed problem-set, which is mapped to specific analytical techniques. Two theorems, four analytical methods and eight critical problems are proposed and incorporated in this teaching model. The teaching outcomes indicate that the proposed teaching mode is very engineering-oriented, which covers most of the analytical techniques and methods in undergraduate power electronics education. In the meantime, this teaching approach can foster students’ analytical thinking and re-innovation.
A2L-A  SS-4 High-Frequency Resonant Power Converters and Soft-Switching Technologies
Time:  Tuesday, April 23, 2013, 16:00 - 17:40
Place:  Conf. Room 11
Chair:  Tomokazu Mishima, Kobe University

16:00  Experimental Evaluations of a Five-Element Multi-Resonant DC-DC Converter with an Improved PFM Control Range
Tomokazu Mishima1, Hiroto Mizutani1, Mutsuo Nakaoka2
1Kobe University, Japan; 2Kyungnam University, Korea, South

The full-bridge inverter link LLC multi-resonant DC-DC converter with anti-resonant circuit (LLC-LC) is presented in this paper. The five-element dc-dc converter can realize the output voltage and power regulations by pulse frequency modulation (PFM) under soft switching conditions. And then, this proposed dc-dc converter is suitable for renewable and sustainable energy applications such as battery chargers. In this paper, the design guideline of circuit parameters is proposed, then experiment results on the soft-switching performances and steady-state characteristics are described, then the practical effectiveness is verified.

16:25  Consideration of Current Resonant Converter Topology for Bi-Directional Applications
Seiya Abe1, Toshiyuki Zaitsu4, Junichi Yamamoto4, Shinji Ueda4, Sihun Yang3, Masahito Shoyama2, Tamotsu Ninomiya3
1International Center for the Study of East Asian Development, Japan; 2Kyushu University, Japan; 3Nagasaki University, Japan; 4Texas Instruments Japan Ltd., Japan

This paper investigates the topology selection of the current resonant converter for bidirectional applications. The current resonant converter has several topologies which categorized switch network construction and resonant network construction. It is important that the topology is selected suitable for each application from several circuit topologies. In this paper, the operating characteristics are discussed in detailed in order to evaluate the appropriateness for each application. Moreover, the applicable topology is selected from detail operating characteristics.

16:50  Full SiC Soft Switching Inverter - Stability Performance for False Turn on Phenomenon
Masayoshi Yamamoto
Shimane University, Japan

The purpose of this paper is to evaluate the performance the false turn on phenomenon using SiC power semiconductor devices in both the conventional hard switching and the soft switching inverter. The power efficiency and the gate-source voltage were analyzed using comparative experimental data between the soft switching and hard switching full SiC inverter. It was found that the soft switching method improves stability operation in case of SiC applications. Furthermore, the soft switching method allows the inverter system higher frequency operation because of its controlled switching losses. The experimental test results indicate that the soft switching method is suitable for the wide band-gap semiconductor applications from the efficiency and stability point of view.

17:15  Characteristic Evaluation for Bi-Directional DC-DC Converter with Soft Switching
Shinichiro Nagai
Pony Electric Co., Ltd., Japan

In recent years, power generation utilizing solar power or wind power which generation ripple is large has been being great attractive for effective utilization of electrical energy. This report presents an evaluation of an isolated bi-directional DC-DC converter composed of a bi-directional boost chopper circuit and full-bridge-type LLC converter. As an evaluation method, a circuit which has two different types of voltage spec and electric power capacity is covered, and the confirmation of circuits operation and waveforms, measurement of conversion efficiency, and loss analysis are carried out. Furthermore, it is confirmed that the conversion efficiency changes when the switching timing which affects ZVS level changes.
**A2L-B  Power Converters I**

**Time:** Tuesday, April 23, 2013, 16:00 - 17:40  
**Place:** Conf. Room 22  
**Chair:** Adrian Ioinovici, *Sun Yat-Sen Univ*  
Kichiro Yamamoto, *Kagoshima University*

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### 16:00  Design and Implementation of a Interleaved Single-Phase Power Factor Correction Zeta Converter

Ke-Ming Chen, Tsorng-Juu Liang, Shih-Ming Chen, Kai-Hui Chen  
*National Cheng Kung University, Taiwan*

This paper presents a single-phase power-factor-correction (PFC) AC-DC step-up/down Zeta converter. It is operated in discontinuous conduction mode (DCM) to achieve unity power factor and step-up/down DC output voltage. The proposed converter is suitable for universal line voltage (90 ~ 264 V) and wide output power range. The operating principle and steady-state analyses of the voltage gain and the boundary operating condition are discussed. Finally, a 400 W / 200 V prototype sample is built in the laboratory to verify the feasibility and performances of the proposed converter.

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### 16:25  A Fixed-Frequency LCL- Type Series Resonant Converter with Capacitive Output Filter Using a Modified Gating Scheme

Nagendrappa Harischndrappa, Ashoka Bhat  
*University of Victoria, Canada*

A fixed frequency, modified series resonant converter (or LCL-type) with capacitive output filter using modified gating scheme is proposed. Steady-state analysis of the converter using approximate complex ac circuit analysis method is presented. Based on the analysis, a simple design procedure is given and illustrated with a design example of a 22 to 41 V DC input, 1 kW, 380 V output converter. Due to the increased number of switches operating with zero-voltage switching, this converter with the modified gating scheme gives higher efficiency as compared to that with the regular phase-shift gating scheme. With minimum input voltage this converter requires a narrow variation in pulse-width for a wide variation in the load current while the peak current through the switches decrease with the load current. Detailed PSIM simulation results are presented to substantiate the performance of the designed converter for varying input voltage and load conditions.

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### 16:50  A Novel Soft-Switching Single-Phase Three-Arm AC Voltage Regulator

Maoh-Chin Jiang, Wei-Shiang Wang, Kao-Yi Lu, Bing-Jyun Shih  
*National Ilan University, Taiwan*

A novel soft-switching single-phase three-arm AC voltage regulator (SSTAVR) is proposed in this paper. The proposed AC voltage regulator (AVR) uses a three-arm topology that operates as a rectifier and an inverter. The rectifier arm is switched at high switching frequency, to perform power factor correction and simultaneously transfer the power demand for the load to the DC link capacitor. The inverter arm is also switched at high switching frequency, for regulation of the output voltage. In order to achieve low switching losses and high efficiency, the common arm is switched at the line frequency. Using simple resonant units, the rectifier arm and the inverter arm are operated at zero-voltage-switching (ZVS) turn-on, while the auxiliary switches are operated at zero-current-switching (ZCS) turn-off. The three-arm topology reduces the number of switching devices. As a result, the system is also more reliable and cheaper. The proposed AVR can deliver a sinusoidal input current with unity power factor and good output voltage regulation. Some experimental results for the proposed SSTAVR, rated at 500 W and operated at 40 kHz, are presented for verification.
A2L-C  Optimal Design for Motor Drive or Generator System  
Time:      Tuesday, April 23, 2013, 16:00 - 17:40  
Place:    Conf. Room 21AB  
Chair:    King Tseng, Nanyang Technological University

16:00  Output Characteristics in Direct-Link Wave Power Generating System Considering Place of Installation  
Kenta Okano, Masayuki Sanada, Shigeo Morimoto, Yukinori Inoue  
Osaka Prefecture University, Japan

Recently, from a viewpoint of environmental problem, renewable energy such as wind energy and solar energy, attracts attention in the world. The energy density of wave power is higher than some other renewable energy sources. In this research, for the purpose of miniaturization of generator and high output, the wave power generating system named “direct-link” h wave power generating system is proposed. In this system, the generator is rotated by a buoys up-and-down movement with rack and pinion, so this is a favorable system to be higher efficiency, and smaller structure system. This research investigates output characteristics considering place of installation.

16:25  Design of Multi-Parallel Drive Technique for System with Numbers of Permanent Magnet Synchronous Motors  
Tsuyoshi Nagano, Jun-Ichi Itoh  
Nagaoka University of Technology, Japan

This paper discusses a multi-parallel drive system, which uses two type inverters, a main inverter with V/f control and numbers of auxiliary inverter with vector control and damping control to control multiple numbers of Permanent Magnet Synchronous Motors (PMSMs). In addition, in PMSMs, the auxiliary windings for damping control are placed in the slots together with the conventional windings. The auxiliary inverter is applied with damping control to suppress the torque vibration when the motor speed is converged. From the simulation and experimental results, the proposed system achieves a stable operation with two parallel connected PMSMs, and the output power of the auxiliary inverter is less than 10% of the output power of the main inverter. Moreover, the experimental results are demonstrated the effectiveness of the proposed system like the simulation results.

16:50  Multi-Dimensional Feedback Quantized Modulation Used in Three-Phase PMSM Motor Current Control  
Hung-Chi Chen¹, Keng-Yuan Chen², Wei-Yu Chen³, Jwu-Sheng Hu³  
¹National Chiao Tung University, Taiwan; ²Yuan Ze University, Taiwan

Three current controllers are introduced in this paper. The simulations are conducted to compare the switching number, THD and power efficiency of the three controllers. Among the three current controllers, PI-MDFQM has the highest inverter power efficiency because of the lowest switching number. And the proposed MDFQCC achieves the highest overall power efficiency due to the reduced phase shift between the output voltage and the output current of the inverter.

17:15  A Calculation Method of Reference Flux to Realize Maximum Torque Per Ampere Control in Direct Torque Controlled Permanent Magnet Synchronous Motor Drives  
Atsushi Shinohara, Yukinori Inoue, Shigeo Morimoto, Masayuki Sanada  
Osaka Prefecture University, Japan

This paper proposes a reference flux calculation method to realize maximum torque per ampere (MTPA) control in the Direct torque controlled PMSM drives without using look-up table. This method is based on PMSM model in the d-q frame, therefore it can leverage existing inductance identification methods. Experimental result shows that proposed method can realize MTPA control when the inductance is modeled as a function of armature current.
A2L-E Battery Charging and Balance Techniques
Time: Tuesday, April 23, 2013, 16:00 - 17:40
Place: Conf. Room 33
Chair: Junichi Itoh, Nagaoka University of Technology
Chin-Sien Moo, National Sun Yat-sen University

16:00 A Battery Power Bank of Serial Battery Power Modules with Buck-Boost Converters
Chih-Hao Hou, Chun-Ti Yen, Tsung-Hsi Wu, Chin-Sien Moo
National Sun Yat-sen University, Taiwan

The operation of a battery power bank with buck-boost battery power modules (BPMs) connected in series is studied. With serial configuration, the average output currents of all BPMs are the same. However, the battery currents can be scheduled to meet the load requirements in accordance with the state-of-charge (SOCs) by adjusting the duty-ratios of the power converters for balanced discharging. With such a configuration, in addition to charge equalization capability, those BPMs with completely exhausted or damaged batteries can be isolated from the battery power bank without interrupting the system operation.

16:25 Contactless Energy-Transfer System Design for Lithium Iron Phosphate Battery-Charging Circuits
Shyh-Jier Huang, Yui-Jhe Li, Bo-Ge Huang, Tzyy-Haw Huang, Tsong-Shing Lee
National Cheng Kung University, Taiwan

This paper proposes a contactless energy-transfer system (CETS) for lithium iron phosphate battery-charging circuits. In the study, the design flow of contactless transformers and compensated circuit are investigated through the analysis of their impedance-matching and resonant features, by which the appropriate inductive coils can be optimally determined such that the power transmission efficiency can be significantly increased. Moreover, an algorithm of charging strategy is suggested to embed into the microcontroller, further facilitating the charging process. In order to validate the effectiveness of the method, both theoretical analysis and hardware realization help support the proposed approach for the lithium iron phosphate battery-charging applications.

16:50 Study of Importance of Charge Equalization for LiFePO4 Battery Pack
Chih-Chiang Hua, Yi-Hsiung Fang
National Yunlin University of Science and Technology, Taiwan

In this paper, four LiFePO4 batteries in parallel are charged to 3.65V and pauses 30 minutes for rest. Afterwards, the LiFePO4 batteries are connected in series and discharged with different C-rates. The voltage of each battery is sampled and analyzed. Finally, the necessary conditions and limitations for designing the charging equalization circuit are presented.

17:15 Proposal and Improvements of Voltage Equalizers for EDLCs
Hlaing Kyi Pyar Khant, Keiju Matsui, Masaru Hasegawa
Chubu University, Japan

EDLCs may be anticipated in the realm of energy storage devices, such as those used in electric vehicles or electric power stabilization in power systems, etc. However, since the voltage limit is low of the devices, it is necessary to connect them in series or parallel. In addition, it is required that they be used in the region of their critical voltage limit or capacity limit. In order to apply them efficiently, the devices should be used with balanced voltage. In this paper, a novel voltage equalizer and modified versions are presented, employing a CW (Cockcroft-Walton) circuit.
**16:00** Novel On-Line Parameter Tuning Method for Digital-Controlled Boost PFC with Transition Current Mode  
Yen-Shin Lai, Kung-Min Ho  
National Taipei University of Technology, Taiwan

A new on-line parameter tuning method for digital-controlled PFC with transition current mode control is proposed in this paper. The proposed method copes with the parameter variation issue which results in discontinuous current mode operation and larger current ripple. The proposed method is to give one more current sample in one sampling period in order to estimate the inductance of boost inductor on line and thereby tuning the parameter of controller. It will be shown by experimental results that the proposed on-line parameter tuning method can retain transition current mode operation even under full load condition and slightly increase the converter efficiency.

**16:25** A Method of Searching PID Controller's Optimized Coefficients for Buck Converter Using Particle Swarm Optimization  
Xutao Li, Minjie Chen, Yoshihara Tsutomu  
Waseda University, Japan

Discussed the problem that the found coefficients can be too large so that output voltage will diverge when using PSO to search PID controller fs coefficients for digital Buck converter.

**16:50** Centralized Digital Controller for Two-Input Integrated DC-DC Converter  
Mummadi Veerachary, M. Madan Mohan, B. Amarendra Reddy  
Indian Institute of Technology Delhi, India

A new two-input integrated DC-DC converter suitable to draw power from two different dc sources, sources can be either dc or photovoltaic (PV), and then feeding a common dc-bus is proposed in this paper. This is a two-switch converter belongs to third-order family and performs bucking operation together with both bucking as well as boosting feature with the second source. The salient feature of the proposed converter is that both the sources either individually or simultaneously supply power to the downstream load. This feature is particularly attractive for photovoltaic power processing applications. A digital voltage-mode controller is designed for downstream dc-bus regulation while the current controller enforced to draw the power from the second weak source. A 24 V, 100 Watt converter performance is analyzed and compared with the experimental observations.

**17:15** Effect of Time-Duration of Neural Network Based Control on Transient Response of DC-DC Converter  
Hidenori Maruta, Masashi Motomura, Fujio Kurokawa  
Nagasaki University, Japan

In this paper, we study a neural network based digital control method for dc-dc converters. In particular, we consider the time duration effect of the neural network control term on the improvement of the transient response of dc-dc converter. The neural network is trained to improve the transient response of output voltage of converters by modification in a conventional PID control. The training process of neural network proceeds repeatedly until the enough suppression of the output voltage against the load change is obtained. We also investigate the optimal duration of the reference modification by the neural network control, simultaneously. As a result, the undershoot of the output voltage is considerably suppressed from 3.4% to 1.8% compared with the conventional PID method. The convergence time is suppressed to 48% compared with conventional method fs one. Therefore, it is confirmed that the presented method has the superior performance to control dc-dc converters compared to the conventional method.
B1L-A SS-3 Digital Control Technique
Time: Wednesday, April 24, 2013, 09:00 - 10:40
Place: Conf. Room 11
Chair: Suttichai Premrudeep, Chiang Mai University
Yen-Shin Lai, National Taipei University of Technology

9:00 Design of Robust Digital Controller for Interleave PFC Boost Converter
Yoshihiro Ohta¹, Yuto Adachi², Yohei Mochizuki², Kohji Higuchi²
¹Mitsubishi Electric Corporation, Japan; ²University of Electro-Communications, Japan

Improving of power factor and reducing harmonic distortion in electrical instruments are needed. In general, a current conduction mode interleave boost converter is used for an active PFC (Power Factor Correction). In the interleave PFC boost converter, if a duty ratio and a load resistance are changed, the dynamic characteristics are varied greatly. In this paper, the robust digital controller for suppressing the output voltage variation at a load sudden change with high power factor and low harmonic is proposed. Experimental studies demonstrate that the proposed controller is effective to improve power factor and to suppress the output voltage variation.

9:25 A Current-Mode Buck Converter with a Pulse-Skipping Soft-Start Circuit
Pang-Jung Liu¹, Yi-Chieh Hsu¹, Yi-Hsiang Chang²
¹National Taipei University of Technology, Taiwan; ²National Taiwan University of Science and Technology, Taiwan

This paper presents a soft-start circuit that adopts a pulse-skipping control to prevent inrush current and output voltage overshoot during the start-up period of dc-dc converters. The purpose of the pulse-skipping control is to significantly restrain the increasing rate of the reference voltage of the error amplifier. Thanks to the pulse-skipping mechanism and the duty cycle minimization, the soft-start-up time can be extended and the restriction of the charging current and the capacitance can be relaxed. The proposed soft-start circuit is fully integrated on chip without external components, leading to a reduction in PCB area and cost. A current-mode buck converter is implemented with TSMC 0.35-µm 2P4M CMOS process. Simulation results show the output voltage of the buck converter increases smoothly and inrush current is less than 300 mA.

9:50 Inductor Saturation Detection with Anti-Saturation Control Strategy Applied
K. I. Hwu¹, C. W. Hsiao¹, Jenn-Jong Shieh²
¹National Taipei University of Technology, Taiwan; ²Ta Hwa University of Science and Technology, Taiwan

In this paper, detection of inductor saturation, together with anti-saturation control, is presented, which is applied to a synchronously-rectified (SR) buck converter. Since the inductor maybe sometimes work in a saturation situation, such as overload. In theory, as the inductor is saturated, the corresponding current slope in the inductor will be increased, and such a phenomenon can be used to judge whether the inductor is saturated or not. However, as this phenomenon occurs, variations in current are not easy to obtain because of limitations of slope detection speed and effects of noise interruption. Therefore, the detection of the inductor current ripple amplitude and the load current, together with the input voltage information, is used to judge whether the inductor is saturated or not. Afterwards, once the inductor is saturated, the proposed anti-saturation control strategy is applied to make the inductor work far from saturation. In this paper, some experimental results are provided to verify the proposed detection and compensation of inductor saturation.
10:15  Design and Implementation of Digital-Controlled Bi-Directional Converter for Scooter Applications
Yen-Shin Lai², Yong-Kai Lin¹
¹Industrial Technology Research Institute, Taiwan; ²National Taipei University of Technology, Taiwan

The main theme of this paper is to present the design and implementation of a digital-controlled bidirectional converter for scooter applications. The contribution of this paper is to explore the details of digital controller design and implementation. Moreover, as compared to previous research results which provide constant voltage mode only, for the presented digital-controlled converter the battery can be charged by either regenerative load or fuel cell in constant current mode to reduce the charging current ripple and thereby prolonging the battery life.
B1L-B  DC/DC Converters II
Time:  Wednesday, April 24, 2013, 09:00 - 10:40
Place:  Conf. Room 22
Chair:  Masayoshi Yamamoto, Shimane University

9:00  Series-Connected Isolated-Switched-Capacitor Tapped-Inductor Boost Converter
      Jong-Ho Jang, Do-Hyun Kim, Jung-Won Seo, Joungh-Hu Park
      Soongsil University, Korea, South

Depletion of natural resources, renewable energy sources such as photovoltaics(PV) has been brought to recent interest. In the photovoltaic power generation technology, the photovoltaic power control unit essentially requires a high-step-up DC-DC converter. The conventional step-up DC-DC converter has low efficiency and limited step-up ratio. To overcome these problem, proposing a new DC-DC converter topology. In this paper, novel high-step-up DC-DC converter using an Tapped-Inductor and on isolated switched capacitor is proposed.

9:25  Analysis, Modeling, Design and Implementation of Average Current Mode Control for Interleaved Boost Converter
      Sandeep Kolluri, Lakshmi Narasamma N
      Indian Institute of Technology Madras, India

In high power applications, parallel operation of boost converters is recommended. These paralleled boost converters can be operated in interleaved mode. Interleaved mode of operation improves the steady state and dynamic performance of the system. In this work, small signal modeling approach is used to develop an analytical model for average current-mode controlled interleaved boost converter. The controller is designed and implemented for a 500 W interleaved boost converter prototype. The experimental results are presented to evaluate the derived model and performance of designed controller.

9:50  Low Voltage DC-to-DC Converter Combining Flyback and Boost Converter for Charging an Auxiliary Battery in Hybrid Electric Vehicle
      J. Y. Lee, Feel-Soon Kang
      Hanbat National University, Korea, South

It presents a low voltage dc-to-dc converter (LDC), which needs to charge an auxiliary battery in a hybrid electric vehicle. LDC locates between an inverter and a main battery. Because it is always on board, a small and light design is very important to increase fuel efficiency and performance. The proposed LDC integrates a boost converter into a flyback converter. It substitutes the primary of a transformer for a boosting inductor. When supplying a low dc voltage to electric field systems, LDC operates in a step-down mode. On the other side, when starting, it operates in a step-up mode to supply a high dc voltage. According to operational modes, theoretical analysis is done and proven by computer-aided simulation using PSIM.

10:15 Two-Stage Boost Converter Using a Tapped Inductor for a High Voltage Amplitude Modulation
      Kidu Kim, Feel-Soon Kang
      Hanbat National University, Korea, South

It presents a two-stage boost converter to achieve a high voltage amplitude modulation ratio. To obtain a higher voltage boosting rate, the proposed converter uses a tapped inductor, and a double boosting stage. Thanks to this circuit configuration, the proposed converter increases a low input dc voltage to a high output dc voltage reducing a limitation on a duty-ratio. At the same time, an input battery and output filter capacitors connect in series. It reduces the number of battery stacks resulted in improvement on structural stability and reliability. Theoretical analysis for the proposed converter is proven by computer-aided simulations.
9:00  The Study on the PMSM Sensorless Control Using the Sub-Optimal Fading Extend Kalman Filter
Chongwu Wang, Yuyao He, Hong Li
Northwestern Polytechnical University, China

With the varying temperature the PMSM parameters usually change significantly and make the residual series in EKF is not the autocorrelation Gaussian white noise anymore, which brings out that EKF lose tracing state variables ability and even divergence in worst case. A sub-optimal fading extend Kalman filter-SFEKF is adopted to estimate speed and it can forces the output state variables to tracing the gradual or step changing parameters. The SFEKF overcomes varying parameter impacts caused by the temperature, improving the dynamic characteristics and tracking precision. The simulation and experiment results show that the SFEKF has the more simple arithmetic, moderate calculation and good robustness.

9:25  DC Motor Control Using an Optimal Control System with a Dual-Sampling Rate Method Based on a Kalman Filter and a Disturbance Observer
Hiromitsu Ogawa, Ryo Tanaka, Takahiro Murakami, Yoshihisa Ishida
Meiji University, Japan

This paper describes an optimal control system with dual-sampling observer. The proposed system design is independent of the plant sampling rate and it controls the plant as high sampling rate although the plant has the low sampling rate. It can be applicable to the plant that has the low sampling rate and the proposed method can apply in various types of the plant. The proposed method has revolutionary features that are the robustness compared with conventional method and high accuracy.

9:50  Observer-Based Automatic Control Loop Tuning for Servo Motor Drives
Sheng-Ming Yang, Jin-De Lin
National Taipei University of Technology, Taiwan

Accurate servo drive tuning requires motor electrical and mechanical parameters such as torque constant, moment of inertia, and frictional torque coefficient. In this paper, an observer-based auto-tuning scheme for servo motor drives is presented. The main element in this scheme is a state estimator which generates a motor parameter-related disturbance torque. Following the disturbance estimator, two adaptive controllers are used to adjust the drive inertia and frictional torque to their correct values. The servo control loops are tuned automatically with the parameters identified. Motor torque constant is also identified and used in the disturbance estimator. The experimental results verified that the proposed scheme can accurately identify motor parameters and tune the servo control loops.

10:15  Rotor Position Estimator Using Non-Linear Observer of Surface Permanent Magnet Synchronous Motor
Tsuyoshi Hanamoto¹, Hiroaki Yamada², Ryuichi Kawano¹, Yoshihiro Okuyama²
¹Kyushu Institute of Technology, Japan; ²Shimadzu Corporation, Japan

In this paper, a position estimator for surface permanent magnet synchronous motors (SPMSMs) at start-up is proposed. The initial position of a SPMSM is not able to be estimated theoretically, hence DC excitation is used at start-up. While the rotor of SPMSM is vibrating during DC excitation, the rotor position is immediately estimated from the induced voltage. Because the motor model consists of nonlinear terms involving the Coulomb friction torque and trigonometric function, we propose an estimation method using the modified Euler method.
B1L-D  Power Control in Distribution Line
Time:  Wednesday, April 24, 2013, 09:00 - 10:40
Place:  Conf. Room 21CD
Chair:  Atsushi Yona, University of the Ryukyus

9:00  A Comparison of Electric Power Smoothing Control Methods for the Distributed Generation System
Tomoyuki Kanehira, Akiko Takahashi, Jun Imai, Shigeyuki Funabiki
Okayama University, Japan

Renewable energy such as solar light has attracted attention as an alternative energy source to fossil fuel. The output power in photovoltaic generation systems changes steeply. The change in the output power influences the electric power quality of the power system. Therefore, a system that can smoothen the fluctuation of the output power is desired. In this study, we applied the methods of moving average and exponential smoothing to the electric power smoothing control schemes for distributed generation systems and compared their effects.

9:25  Effectiveness of Constant Power Factor Control of Mega-Solar System for Voltage Regulation with Long Distribution Line
Kouichiro Kouno¹, Masatsugu Hirose², Wataru Hashimoto², Tadao Nagase³, Masahide Hojo⁴, Tokuo Ohnishi⁵
¹Nissin Electric Co., Ltd., Japan; ²Shikoku Electric Power Co., Inc., Japan; ³Shikoku Research Institute Inc., Japan; ⁴University of Tokyo, Japan

This paper reports a result examined by numerical analysis and an experiment using a real system about mitigating the voltage variation by applying the reactive power control based on constant power factor control of the PCS in a large-scale photovoltaic system. It is investigated that the loss change on a distribution line influences the results of the reactive power control, especially when the large-scale photovoltaic system is interconnected with a long distance from a substation. This paper reveals that it is possible to mitigate a voltage variation sufficiently with the distance of about 5km from a substation to the interconnection point.

9:50  Implementation and Design of Hybrid Power Module for DC Power Grid in Paralleled Applications
Wei-Shih Liu, Jiann-Fuh Chen, Tsorng-Juu Liang, Te-Lun Lai
National Cheng Kung University, Taiwan

This paper presents storage-ability hybrid modules for DC paralleled grid system for flexibility and expansibility applications. A novel two-cascoded hybrid module is integrand with the renewable source and battery to achieve optimum power flow control. A two-loop positive feed-forward voltage control strategy in each module is proposed to manage the power flows in paralleled grid. The power flows are discussed and demonstrated under different operation modes. The experimental results from the power grid system is implemented to verify the theoretical analysis.
A Novel Single-Stage High-Power-Factor LED Driver for Street-Lighting Applications

Chun-An Cheng, Chien-Hsuan Chang, Fu-Li Yang, Tsung-Yuan Chung
I-Shou University, Taiwan

This paper proposes a novel single-stage LED driver for street-lighting applications with high levels of power factor. The presented driver integrates a modified bridgeless power-factor-correction (PFC) AC-DC converter with a half-bridge-type LLC DC-DC resonant converter into a single-stage conversion circuit topology. The proposed AC-DC resonant driver provides input current shaping, and its offers attributes of lowered switching losses to the soft-switching functions obtained on two power switches and two output rectifier diodes. The proposed driver features cost-effectiveness, high circuit efficiency, high power factor, low input current ripples and a reduced components count. A prototype driver is developed to supply a 144W LED street-lighting module with a 110V utility-line input voltage. Experimental results demonstrate the functionalities of the proposed circuit.

A High-Power-Factor LED Driver with Zero-Voltage Switching-On Characteristics

Hung-Liang Cheng¹, Wei-Chen Lin¹, Yong-Nong Chang³, Yao-Ching Hsieh²
¹I-Shou University, Taiwan; ²National Dong Hwa University, Taiwan; ³National Formosa University, Taiwan

This paper proposes high-efficiency LED driver consisting of interleaved buck-boost and buck converters. Without using any auxiliary reactive components, the active switches can operate at zero-voltage switching on (ZVS). The buck-boost converter is operated at discontinuous-conduction mode (DCM) to perform the function of power-factor correction (PFC). The buck converter regulates the output voltage to drive LEDs. A prototype 60-W LED driver is built and tested. Experimental results show that the switching losses can be effectively reduced by operating the active switches at ZVS. The measured power factor and circuit efficiency are as high as 0.99 and 93%, respectively.

The Development of Single Stage Asymmetric Half Bridge Converter with PFC Used in ZCS Dimmable LED Lighting Equipment

Chin-Yuan Hsu, Ren-Wei Huang, Yu-Liang Chang
National Kaohsiung University of Applied Sciences, Taiwan

This thesis focuses on the analysis and design of single stage asymmetric half bridge converter with PFC used in ZCS dimmable LED lighting equipment. At first, the operation mode and parameter design of single stage asymmetric half bridge converter with PFC will be analyzed in this thesis. Then, the analysis and design criteria are provided for the ZCS LED Dimming Driver in order to make the circuit design easier. Finally, a prototype 60W AC-DC power converter and ZCS LED Dimming Driver are implemented. The efficiency of the front stage asymmetrical half-bridge converter with PFC can reach 89.6%, and the maximum efficiency of the rear stage ZCS LED Dimming Driver is 98%.

RGB LED Backlight Driving System with Dynamic Voltage Regulation Capability

Jing-Hsiao Chen¹, Shun-Chung Wang², Yi-Hua Liu³, Yu-Shan Cheng³, Zong-Zhen Yang¹
¹Industrial Technology Research Institute, Taiwan; ²Lunghua University of Science and Technology, Taiwan; ³National Taiwan University of Science and Technology, Taiwan

Advantages including higher luminance efficacy, local dimming capability, wider color gamut, faster response, longer operation life and lesser environmental issues makes RGB LED backlight system suitable for high-end display units. For RGB LEDs, the forward voltages for the red, green and blue LEDs are different. Therefore, dynamic voltage regulation (DVR) can be applied to optimize the power stage design. In this paper, a RGB LED backlight driving system is proposed. The proposed system consists of a power factor correction pre-stage and a digitally-controlled LLC resonant converter. The output voltage of the presented
LLC resonant converter is adjusted by a digital controller so that RGB LED maintains the desired string current; this will improve the efficiency of the driving system. According to the experimental results, the presented system can adjust the output voltage of the LLC resonant converter according to the requirements of the RGB LED string.
9:00 Study of Warming Method for Secondary Battery by Charging and Discharging
Masayuki Kubota, Mami Mizutani, Yukitaka Monden
Toshiba Corporation, Japan

The output power of secondary batteries has a tendency to decrease because the internal resistance is high under the low temperature. This paper describes a method of evaluating temperature increase characteristics by measuring internal resistance and verifies warming effects caused by charging and discharging of secondary batteries and by heater. As the results, energy loss of the method by charging and discharging is smaller than that of the method by heater. Experimental results show that charging and discharging method keeps inner resistance differences of cells in a smaller range, and warms up the module faster.

9:25 A High Accuracy Regressive-Derived Winding Loss Calculation Model for High Frequency Applications
Mohammad Amin Bahmani, Torbjörn Thiringer
Chalmers University of Technology, Sweden

When operating higher up in frequency, the copper losses in transformer windings will significantly rise due to enhanced skin and proximity effect. This leads to a high need to propose and develop new methods to accurately evaluate winding losses at higher frequencies. This paper investigates the effect of different geometrical parameters at a wide range of frequencies in order to propose a pseudo-empirical formula for winding loss calculation in high frequency transformers. A comprehensive analysis of the edge effect and AC resistance is done by performing more than 12300 2-D finite element simulations on foil and round conductors. Unlike previous studies which mostly focused on specific case studies with limited applications, this model provides very high accuracy, especially where the most common analytical models drastically underestimate the winding losses. Moreover, the model has a wide-range applicability which could be of interest for designers to avoid time consuming FEM simulation without compromising with the accuracy.

9:50 Optimal Inductor Setup for a Power-Hardware-in-the-Loop Machine Emulator
Christian Nemec, Oliver Lehmann, Martin Heintze, Jörg Roth-Stielow
Universität Stuttgart, Germany

This paper presents investigations on the inductor setup within the power electronic stage of a machine emulator. The emulator draws currents from a drive inverter, equivalent to a real electrical machine, by a setup of a multiphase interleaved-switched inverter and inductors. The influences of the inductor setup on the emulator’s output current slew rate as well as on the current controller are investigated with respect to the desired application. Based on these results, an optimal inductor setup is extracted by using a control block diagram of the topology.

10:15 Dynamic Feedrate Control Based on the Feedback of Path Curvature and Real-Time Contour Error
Kuan-Chen Lin, Shyi-Kae Yang
Far East University, Taiwan

This paper studies the dynamic feedrate control problem for mechanical stages performing contouring actions. In modern researches, feedrate is considered as a dynamic factor instead of simple constant value in the traditional methods. A result of a sophisticated dynamic feedrate control design is proposed where the system feedrate is real-time determined based on both the feedback of the path curvature and the measured contour error. Experiments and comparative studies for free-form paths are conducted, and the results show that the proposed design indeed can provide significant precision improvement in overall contouring performance in contrast to the traditional method.
9:00  **Adaptive Pulse Skipping and Adaptive Compensation Capacitance Techniques in Current-Mode Buck-Boost DC-DC Converters for Fast Transient Response**  
Andreas Ehrhart\(^1\), Bernhard Wicht\(^2\), Moris Lin\(^1\), Yung-Sheng Huang\(^1\), Yu-Huei Lee\(^1\), Ke-Horng Chen\(^1\)  
\(^1\)National Chiao Tung University, Taiwan; \(^2\)Reutlingen University, Germany

In this paper a fast transient (FT) current mode buck-boost DC-DC converter with adaptive pulse skipping (APS) and adaptive compensation capacitance (ACC) is proposed. The buck-boost DC-DC converter cannot only use the whole battery range from 2.5 V to 4.2 V but also has a good response time with a low voltage undershoot/overshoot at load current variations. Additionally, it can handle load transitions and keep the system stable in buck-boost mode.

9:25  **An Ultra-Low Input Flyback Converter with Wide Conversion Ratio Utilizing Zero-Current Switching Techniques**  
Chang-I Chou, Tse-Hsu Wu, Jiann-Jong Chen, Yuh-Shyan Huang, Cheng-Chieh Yu  
National Taipei University of Technology, Taiwan

An ultra-low input flyback converter is proposed in this paper. Instead of the conventional flyback topology, the improved topology is able to reduce more power consumption to achieve high efficiency by replacing the output diode with a power transistor.

9:50  **A Single-Inductor Dual-Output Step-Down DC-DC Converter**  
Guan-Shiau Lin, Hwai-Pwu Chou, Wei-Shau Liu  
National Tsing Hua University, Taiwan

A single-inductor dual output (SIDO) step down DC-DC converter with continuous conduction mode (CCM) operation is proposed to improve efficiency and reduce cost for power management. The supply voltage is from 2.7 V to 3.3V, with dual output at 1.8V and 1.2V. Pulse frequency modulation (PFM) technique is employed to reduce cross regulation between dual outputs. The proposed SIDO converter is implemented with 0.35um IC process for a system-on-chip (SoC) design.

10:15  **Novel Structure of Deep Trench Capacitor with Higher Breakdown and Higher Capacitance Density for Low Dropout Voltage Regulator**  
Ashif Aminulloh, Vikash Kumar, Shao-Ming Yang, Gene Sheu  
Asia University, Taiwan

This paper discusses a novel structure of deep trench capacitor with breakdown voltage of 10V and capacitance density of 527nF/mm\(^2\), serving for Low Dropout Voltage regulator in IC power management. The structure is presented using 3D & 2D Sentaurus Synopsys simulation, with RIE etching and high quality LPCVD is deployed on the equivalent process. Higher breakdown is achieved by choosing low-k, high band-gap dielectric material. Higher capacitance density is achieved by implementing deeper trench using state of the art etching technology with aspect ratio of 1:50. After forming trench in a 75 um deep trench in an Arsenic doped silicon substrate, an oxide growth of 5 nm is presented following by continuous LPCVD of 0.5 um polysilicon and 10 nm oxide, stacked 3 times. The LPCVD polysilicon is arsenic-doped to form a good electric conductivity and to reduce ESR. A further study on RF performance shows an effective result on ESR and ESL.
SS-2 PV system utilization and control issues

Time: Wednesday, April 24, 2013, 11:00 - 12:40
Place: Conf. Room 11
Chair: Tomonobu Senju, University of the Ryukyus

11:00 Load Balancing of Active Distribution Systems with High Photovoltaic Power Penetration
Zakaria Ziadi\(^2\), Atsushi Yona\(^2\), Tomonobu Senju\(^2\), Mahmoud Abdel-Akher\(^1\)
\(^1\)Aswan University, Egypt; \(^2\)University of the Ryukyus, Japan

This paper treats the problem of voltage control and balancing of the unbalanced three-phase loads in distribution systems with Distributed Generators (DG) and tap change transformers. The DGs considered here are based on Photovoltaic (PV) generators. The proposed method aims to balance the three-phase loads and control the voltage using the available reactive power generated from the DG through PV interfaced inverters. Newton Raphson method is used solve the unbalanced three phase power flow equations. Twenty-four-hour data are used to simulate a 14-bus distribution system with unbalanced three-phase loads in 7 nodes to verify the effectiveness of the method.

11:25 Coordinated Charging of Plug-in Hybrid Electric Vehicle for Voltage Profile Enhancement of Distribution Systems
Abdel-Fatat Ali\(^1\), Mahmoud Abdel-Akher\(^1\), Zakaria Ziadi\(^2\), Tomonobo Senju\(^2\)
\(^1\)Aswan University, Egypt; \(^2\)University of the Ryukyus, Japan

This paper presents a new technique for charging PHEVs in real time controlled charging. The developed control strategy aims to keep the system voltage in secure operation irrespective of the number of vehicles and their place along the distribution feeder. The developed control strategy uses real-time network voltage and the PHEV state of charge as the main inputs of the fuzzy logic controller. The output is then used by the bi-directional converters of each PHEVs to decide the desired level of charging. This ensures secure operation of distribution systems during charging whatever the number of connected PHEVs to the grid.

11:50 Operational Method of DC Power System Including Photovoltaic and Solid Oxide Fuel Cells
Hiroya Yajima, Akiko Takahashi, Tadatoshi Babasaki
Nippon Telegraph and Telephone Corporation, Japan

It is difficult to repair equipment in a short time after a strong earthquake. Therefore, the power supply to shelters becomes problematic. To solve this problem, a small-scale power system without being dependent on commercial power supplies is needed. We experimentally investigated a power supply system that includes photovoltaic and fuel cells to solve the above-mentioned problem. In this paper, we discuss an efficient operational scheme of the system based on measurement results. We also examined the use of the battery. By effectively using the amount of generated electricity from the photovoltaic cell by using the battery, the fuel cell was able to reduce generation quantity.
### Analysis of a New Soft Switching Converter with Three Resonant Tanks

Bor-Ren Lin\(^2\), Chia-Hung Chao\(^2\), C. H. Chien\(^1\), Y. H. Wang\(^1\)

\(^1\)National Cheng Kung University, Taiwan; \(^2\)National Yunlin University of Science and Technology, Taiwan

This paper presents a new zero-voltage switching (ZVS) DC/DC converter with three resonant tanks for high input voltage applications. Two series half-bridge legs and two split capacitors in order to limit the voltage stress of active switches at a half of input voltage. These resonant circuits are operated by an interleaved PWM scheme to reduce the output current ripple. The output sides of these resonant circuits are connected in parallel to evenly distribute the input power, lessen current stresses on rectifier diodes and reduce copper losses of transformers. The ZVS turned on through power switches and zero-current switching (ZCS) turned off for rectifier diodes are accomplished through the three series resonant tanks. Finally, experiments are provided to verify the performance of the proposed converter.

### Three-Phase Series-Parallel LCC-Type DC-DC Converter with Capacitive Output Filter Including the Effect of HF Transformer Magnetizing Inductance

Mohamed Almardy, Ashoka Bhat

University of Victoria, Canada

A three-phase LCC-type dc-dc resonant converter with capacitive output filter including the effect of the HF transformer magnetizing inductance is presented. The equivalent ac load resistance is derived and the converter is analyzed by using approximate analysis approach. Base on the analysis, design curves have been obtained and a 300 W converter design example is given. Intusoft simulation results and experimental verification of the designed converter performance are given for variations in input voltage and load conditions. The simulation and experimental results show a reasonable match to the theoretical analysis. It is shown that the converter operates in zero-voltage switching (ZVS) at various input voltage and different load conditions.

### Intelligent High Efficiency Controller for 2-kW Interleaved Series Resonant Converters

Poki Chen, Yu-Kang Lo, Kuan-Cheng Chiu, Kun-Hung Lin, Ting-Yu Tsai, Wei-Chen Lin

National Taiwan University of Science and Technology, Taiwan

An interleaved SRC with a secondary-side resonant tank is presented in this paper to solve the resonant component design problem caused by small characteristic impedance (Zo). To support interleaving operation, two SRCs are connected in parallel with a 90° phase shift between the gating signals. Without the direct support of commercial ICs, a full-custom interleaved SRC controller is designed instead. A 2-kW laboratory prototype with a 12-V input and a 200-V output is realized and tested to verify the feasibility of the proposed converter. The controller was fabricated in a TSMC 0.35μm 2P4M 3.3/5V CMOS process.

### An Interleaved Bidirectional DC-DC Converter with Zero-Voltage-Switching

Yao-Ching Hsieh, Kun-Ying Lee, Kuo-Fu Liao

National Dong Hwa University, Taiwan

An interleaved DC-DC bidirectional zero-voltage switching converter is presented in this paper to have small current ripple and voltage ripple. The proposed converter employs an inductor LS to achieve zero-voltage switching. This converter replaced diode with N-MOSFET to reduce the power consumption of components.
11:00 Synthesis and Analysis of Time-Optimal Current Trajectory Based on Final-State Control for IPMSM
Takayuki Miyajima\textsuperscript{2}, Hiroshi Fujimoto\textsuperscript{2}, Masami Fujitsuna\textsuperscript{1}
\textsuperscript{1}Denso Corporation, Japan; \textsuperscript{2}University of Tokyo, Japan

This paper investigates time-optimal current trajectory of an interior permanent magnet synchronous motor (IPMSM) and achievable performance limitations. The analysis with linearized IPMSM model shows that time-optimal trajectory under voltage limit has q-axis current undershoot, d-axis current overshoot, and torque overshoot/undershoot. These achievable performance limitations are verified with final-state control which describes current response under the voltage limit with linear matrix inequalities.

11:25 Sensorless Control of AC Machines at Carrier Frequency Signal Injection Using Analog Filter Circuit
Sungho Jung, Jung-Ik Ha
Seoul National University, Korea, South

The saliency measurement method using analog filter circuit is proposed at sensorless AC machine drives. Where high frequency injection signal is used, Signal-to-Noise Ratio can be diminished by large machine reactance and then the sensorless control performance drops easily. Using analog filter circuit, the current feedback signal at injection frequency is amplified before Analog to Digital Converter. But, the introduction of the filter cause voltage distortions at carrier frequency injection. The signal distortion factor is analysed and new sensorless method with angle distortion compensater is proposed. The injection voltage level can be reduced significantly using this method.

11:50 Motor Control Methods with a Behavior Model Based on FEA Results
Makoto Usui, Noriya Nakao, Kan Akatsu
Shibaura Institute of Technology, Japan

In this paper, some motor control methods by using a behavior model which is created by the FEA results are proposed. A real time simulator with the behavior model is worked with the real time motor control, especially the torque ripple control and the current sensorless control are performed and verified by the experiments.

12:15 Wide Rand and Fast Response Control of PMSM by Using Model Predictive Control
Shinji Doki, Takya Sakamoto
Nagoya University, Japan

This paper describes our proposed torque control for PMSM drive system by using model predictive control (MPC). The MPC control system is possible to drive PMSM with fast response torque response in wide speed rage by utilizing overmodulation and rectangular-wave mode of inverter. In this paper, the performances are evaluated by simulation in various drive patterns.
B2L-D  Wind Generator Control
Time:  Wednesday, April 24, 2013, 11:00 - 12:40
Place:  Conf. Room 21CD
Chair:  Sanjib Panda, National University of Singapore

11:00  Smoothing of Output Power of PMSG-Based WECS and Enhancing FRT During Grid Faults
Alok Pratap, Naomitsu Urasaki, Tomonobu Senjyu
University of the Ryukyus, Japan

This paper presents a smoothing of an output power of wind energy conversion systems (WECS) with permanent magnet synchronous generator (PMSG) and enhancing the fault-ride through (FRT) capability during grid faults. It uses three main control methods: pitch angle control method, inertia of the wind turbine and DC-link voltage control. The generator-side converter is used to control the PMSG torque for achieving stable power smoothing of the WECS while the grid-side inverter is used to control the DC-link and grid voltages. For the proposed method, the torque smoothing is effective for the reduction of torque difference and is controlled by the inertia of the wind turbine. The FRT requirement is imposed on a wind power generator so that it remains stable and connected to the grid during faults. The effectiveness of the proposed method is verified by the numerical simulations.

11:25  Control Strategies for Wind Farm Based Smart Grid System
Abdul Motin Howlader1, Naomitsu Urasaki2, Atsushi Yona2, Tomonobu Senjyu2, Ahmed Yousuf Saber1
1Operation Technology, Inc, United States; 2University of the Ryukyus, Japan

The paper deals with wind farms based smart grid. The smart grid composes of wind farms, smart houses, grid side energy storage system. A electric double layer capacitor (EDLC) based energy storage system is considered in this system. The surplus power of the smart houses sends back to the grid, and grid side energy storage system ensures to supply a smooth power to the grid. Effectiveness of the proposed method is verified by the numerical simulations using MATLAB/SIMULINK.

11:50  Instantaneous Frequency and Voltage Control of PMSG-Based WECS Using Controllable Load
Alok Pratap, Naomitsu Urasaki, Tomonobu Senjyu
University of the Ryukyus, Japan

Due to the power fluctuations from the renewable resources, such as wind; voltage and frequency variations are the biggest issues. This paper presents an instantaneous frequency and voltage control with distribution lines using controllable load. The wind energy conversion system (WECS) adopts AC-DC-AC methods, i.e., AC-DC (generator-side converter) and DC-AC (grid-side inverter). The pitch angle control method is used to control the output power of permanent magnet synchronous generator (PMSG). The generator-side converter controls the PMSG torque for achieving stable power smoothing of WECS. The grid-side inverter is used to control the DC-link voltage and grid voltage. The voltage control after the distribution line can be possible by reactive power control connected to the controllable load in the demand-side. Similarly, the frequency control can be controlled by active power of the controllable load. The effectiveness of the proposed method is validated by simulation results in Matlab/SimPower Systems.

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11:00  **PSO-Based Fuzzy Logic Optimization of Dual Performance Characteristic Indices for Fast Charging of Lithium-Ion Batteries**
Chun-Liang Liu, Shun-Chung Wang, Shao-Shan Chiang, Yi-Hua Liu, Chien-Hung Ho

In order to maximize the available performance of the Li-ion batteries, in this paper, a searching strategy based on the particle swarm optimization (PSO) conducted with a fuzzy-deduced fitness evaluator (FDFE) is proposed to find the best multistage charge current pattern. Experimental findings show that the obtained charge pattern is capable of charging the batteries to over 90% available capacity within 50 minutes. Comparing with the conventional constant current-constant voltage (CC-CV) method, the devised scheme has the performance enhancements of more than 80% charging time reduction, 21% more life cycles, and over 0.4% charging efficiency increase.

11:25  **Power Control Method Using Time Delay Compensation Scheme Based on Smith Predictor for Flywheel Power Leveling System**
Kenta Tanaka, Jun-Ichi Itoh, Soya Matsuo, Noboru Yamada

This paper introduces the performance of a power leveling system with a 3.0-MJ, 9500-r/min flywheel energy storage. In term of the cost reduction, this system uses low cost flywheel and the general purpose products. Therefore, the time delay of the measurement device limits the control performance. In order to overcome this problem, the time delay compensation scheme based on Smith predictor is applied in the control in order to improve the control performance of the power regeneration. As a result, the overshoot of the regeneration power is eliminated by applying the compensation. In addition, the effectiveness of the power leveling control in a prototype is evaluated by experiment. As a result, it is confirmed that the power fluctuation is reduced by 84.6%.

11:50  **A Combined PDM and AVC Control for Induction Cooking Appliances**
Jirapong Jittakort, Samart Yachiangkam, Anawach Sangswang, Sumate Naetiladdanon, Chayant Koompai, Saichol Chudjuarjeen

This paper presents a combined pulse density modulation (PDM) and asymmetrical voltage cancellation (AVC) control for induction cooking appliances. The average output power can be adjusted by the varying output voltage waveform, which achieves the zero-voltage switching (ZVS) condition, and reduced the power losses on the IGBT switches. The proposed control improves the efficiency at the low power level as well as increases the power range operation. The simulated results using the PSPICE program verify the proposed control scheme.
B2L-F Other Drive Systems

Time: Wednesday, April 24, 2013, 11:00 - 12:40
Place: Conf. Room 32AB
Chair: Koji Kato, Sanken Electric Co.

11:00 The Use of a Heuristic Approach to Localise Faulty Lines in Induction Motor
Hubert Razik², Edison Da Silva¹, Mauricio Corrêa¹
¹Universidade Federal de Campina Grande, Brazil; ²Université Lyon 1, France

As the induction motor takes a larger place than ever in industrial process, it is necessary to monitor this process. The motor can be connected to the lines or supplied by a voltage inverter converter. Even if the induction motor is robust several stresses could affect its live span. So it has to be monitored in order to prevent the operator of any dangerousness. Many technics appeared which were based on the spectral analysis using the fast Fourier transform. Thus, we propose in this paper to have a stand-alone process to track the faulty lines using a heuristic approach. This technic is based on particles swarm optimization. This one is tested on real data acquisitions of a defective induction motor having a problem with its squirrel cage.

11:25 Experimental Verification of the Resolver Dynamic Model and Control Designs
Chung-Chuan Hou, Ying-Hsuan Chiang, Chi-Pong Lo
Chung Hua University, Taiwan

Resolver is an absolute angle measurement and is mounted on the motor shaft to get the motor’s absolute angular position. This study proposes an equivalent circuit of the resolver. The transfer function of the resolver is proposed. Furthermore, the frequency response of the resolver is measured by a dynamic signal analyzer to obtain the adequate frequency of resolver's reference signal. Test results are presented to validate the performances of the resolver.

11:50 Energy Optimized Speed Regulation of Permanent Magnet Synchronous Motors for Driving Roller Conveyors
Mohjtaba Masoudinejad, Sascha Feldhorst, Fatemeh Javadian, Michael Ten Hompel
Technische Universität Dortmund, Germany

This paper provides a method to optimize the power consumption of permanent magnet synchronous motors (PMSM) in the field of material handling. Therefore, a mathematical model of the PMSM power consumption during constant speed packet handling is defined and an approach to determine the optimum speed according to the packet weight is presented. Based on this method a potential saving margin for a pilot roller conveyor system is offered. The proposed method is qualified by a simulation model including a vector controller for speed control and a hysteresis current controller.

12:15 Design and Analysis of Two-Degree-of-Freedom Actuator Using PMSM and LSM
Wataru Kitagawa, Masaki Mori, Takaharu Takeshita
Nagoya Institute of Technology, Japan

This paper presents the design and analysis of two-degree-of-freedom actuator that can move in rotary and linear direction. The proposed actuator is moved in principles of permanent magnet synchronous motor and linear synchronous motor. The structure of the actuator is robust to use the ring magnets that magnetized in axial direction. Moreover, the stator of the actuator has the salient pole in axial direction for improvement of thrust density. Characteristics of the actuator are analyzed by three-dimensional finite element method. As a result, the actuator is obtained characteristics that the average torque is 61.8 mNm in rotary motion and the average thrust is 9.00 N in linear motion.
Development of a New Package for Next Generation Power Semiconductor Devices: Toward High Temperature and High Voltage Applications
Keisuke Koyanagi¹, Akinari Yamane², Masahiro Kozako³, Ichiro Omura³, Masayuki Hikita¹, Zarel Valdez-Nava², Sorin Dinculescu³, Thierry Lebey²
¹Kyushu Institute of Technology, Japan; ²Université Paul Sabatier, France

This paper deals with I-V characteristics of SiC-SBD and rectifying capabilities of four SiC-SBD using a new package under the temperature up to 300 °C. As regards the I-V characteristics, as the temperature increases, the threshold voltage decreases and the reverse current increases dramatically. This increase of the reverse current of the diodes under study leads to the limitation of the rectifying characteristics of the proposed packaging. This study demonstrates the ability of the later to be used in a harsh environment ones the components problems will have been solved.

Thermal Analysis and Electrical Performance of Packaged AlGaN/GaN Power HEMTs
Po-Chien Chou, Stone Cheng, Wei-Hua Chieng, E.Y. Chang, Hsin-Ping Chou
National Chiao Tung University, Taiwan

This work presents thermal resistance constitution evaluation and electrical experiments for AlGaN/GaN HEMTs packaging device. The investigation of thermal resistance is based on the closed-form expression heat transfer model. Real multi-fingers structure and thermal resistance was modeled. The Infrared thermography is utilized to observe heat distribution of the packaged GaN device by measuring the temperature of the active region in the operation. The simulation result is verified by comparing with experimental observations.

Influences of Gate Drive on Pulsed Current Collapse Recovery in AlGaN/GaN Power HEMTs
Yuling Li, Yung C. Liang, Ganesh S. Samudra, Huolin Huang, Yee-Chia Yeo
National University of Singapore, Singapore

The slow recovery in pulsed drain current in AlGaN/GaN power HEMTs caused by high voltage stress during off-state becomes an important research topic in power electronic switching applications. To further investigate this phenomenon, the influence of gate drive towards the drain current recovery is investigated in this paper. The gate drive current can influence the de-trapping process along the AlGaN device surface, and then in turn affects the 2DEG conductivity for the on-state current recovery. The effect is analysed through the physical model and 2D T-CAD Sentaurus simulations, and verified by the experimental measurement. This proposed work is able to assist engineers in gate drive design for AlGaN/GaN power HEMT devices for fast current recovery in high-frequency switching.

Integrated Matrix Converter Switch
Alberto Castellazzi, Tianxiang Dai, Jianfeng Li, Adane Kassa Solomon, Andrew Trentin, Pat Wheeler
University of Nottingham, United Kingdom

This paper presents the reliable design, assembly and test of integrated power switches for matrix converter development. The design is based on a built-in reliability approach and is verified experimentally by both functional and reliability tests. The assembly is based on a fully bond-wire-less double-sided cooling packaging solution featuring device stacking. As compared with standard technology solutions, the proposed intergation approach brings along significant improvements in electro-magnetic and electro-thermal performance, as well as power density and reliability, by relying on a fully bond-wire-less double-sided cooled packaging concept.
An Omnipotent Li-Ion Battery Charger with Multi-Mode Controlled Techniques
Hong-Yi Yang, Tse-Hsu Wu, Jiann-Jong Chen, Yuh-Shyan Huang, Cheng-Chieh Yu
National Taipei University of Technology, Taiwan

The omnipotent Li-Ion battery charger with multi-mode controlled techniques is presented in this paper. This technique can reduce the damage of Li-Ion battery. The design of structure, which creates an omnipotent charger, combines with the reversible three-stage charger; that is adapts to any Li-ion batteries.

Thermal-Mechanical Design of Sandwich SiC Power Module with Micro-Channel Cooling
Shan Yin, K.J. Tseng, Jiyun Zhao
Nanyang Technological University, Singapore

A sandwich packaging structure of SiC power module for HEV application has been designed and numerically investigated by CFD study. The design has a micro-channel heat sink integrated in the back Cu-layer of DBC substrate. Double-side cooling is adopted and liquid coolant (ethylene glycol, 105°C) flows in opposite directions in the two heat sinks. Compared with wirebonding packaging, the proposed sandwich structure can almost double the cooling efficiency (thermal resistance 0.11 K/W and temperature-distribution uniformity. Finite element analysis of thermal stress was further carried out to check that the CTE mismatch in the packaging has been minimized.

Digitally Controlled Boost Converter with Digital DLL Based Calibration
Jen-Hou Wu, Shao-Ku Kao
Chang Gung University, Taiwan

This paper presents the all digital controlled boost converter with delay locked loop (DLL) to enhance the resolution. We propose two novel circuits: all digital ramp generator for coarse tuning and DPWM with build-in DLL for calibration. This circuit is designed in 0.35μm CMOS process. The input voltage range is from 3.3V to 4.2V with output voltage of 5V. The maximum efficiency is 90% at loading current to be 500 mA.

Improved Transient Response Using HFFC in Current-Mode CFCOT Control for Buck Converter
Wen-Wei Chen\textsuperscript{1}, Jiann-Fuh Chen\textsuperscript{1}, Tsorng-Juu Liang\textsuperscript{1}, Jian-Rong Huang\textsuperscript{1}, Wei-Yuan Ting\textsuperscript{2}
\textsuperscript{1}National Cheng Kung University, Taiwan; \textsuperscript{2}Chang Gung University, Taiwan;

In this paper, improved transient response using high-frequency feedback control (HFFC) in current-mode constant frequency constant on-time (CFCOT) control for Buck converter is proposed. The concept uses HFFC to filter out the Vout at the load transient to dynamically change the width of on-time to prevent the Vout from dropping markedly. Finally, HFFC is implemented using the experimental results and SIMPLIS simulation results to verify its viability and superiority.

Design of Fast Stabilized LED Driver IC with Low Overcurrent
Yuan-Ta Hsieh, Jian-Fu Wu, Chiao-Li Fang, Hann-Huei Tsai, Ying-Zong Juang
Chip Implementation Center, Taiwan

This paper proposes an LED overcurrent suppression method capable of extending the lifespan of LEDs. The simulation and experimental results demonstrate that the efficacy of the proposed LED driver in reducing overcurrent in LEDs under various current limits. The proposed design extends the PWM dimming frequency range, making it suitable for LED dimming systems.
Design of Novel Normally-Off AlGaN/GaN HEMTs with Combined Gate Recess and Floating Charge Structures
Huolin Huang\textsuperscript{1}, Yung C. Liang\textsuperscript{2}, Ganesh S. Samudra\textsuperscript{2}, Chih-Fang Huang\textsuperscript{1}
\textsuperscript{1}National Tsing Hua University, Taiwan; \textsuperscript{2}National University of Singapore, Singapore

Normally-off operation is strongly desired for safety and efficient power switching in order to make the HEMT devices compatible with the currently used Si based devices. Combination of partially gate recess etching and gate insulator interface or floating gate charges in MIS structures is proposed and demonstrated for the first time to realize the normally-off mode. Partially gate trench using wet etching can effectively reduce 2DEG density and shift threshold voltage (Vth) to positive without degradation in 2DEG channel conductance, while gate insulator interface or floating gate charges can further increase Vth at a relatively low charge density and thus maintain normally-off mode at a much longer time. A positive Vth of larger than 3 V is demonstrated by employment of gate recess with 5~10 nm barrier leftover in combination of gate dielectric charging with a low sheet density of $\sim 10^{12}$ cm$^{-2}$. The proposed structures are very promising in future power switching applications due to the large positive Vth and the low gate leakage current density by adjusting the gate insulator thickness.
Prony-Based Technique for Voltage Envelope Extraction and Estimation of Instantaneous Flicker Level
Cheng-I Chen^2, Yeong-Chin Chen^1, Chao-Nan Chen^1, Ru-Huei Liang^1
^1Asia University, Taiwan; ^2National Central University, Taiwan

The accurate extraction of voltage envelope is an important process for the flicker estimation. According to the latest IEC standard for design of flickermeter, the factor of fundamental frequency deviation is necessary to be taken into account. Therefore, a Prony-based technique is proposed in this paper. With the characteristic of high-frequency resolution in this method, the extraction of voltage envelope can be accurately performed for the time-varying power signals.
Study on the Improved Modeling of the Linear Motor System for Linear Compressor Considering the Magnetic Nonlinearity
Sungan Kim, Sang-Geon Lee, Dae-Geun Park, Sang-In Byun, Yun-Hyun Cho  
*Dong-A University, Korea, South*

The high performance linear Compressor system is being studied due to ozone depletion caused by refrigerant. In this paper, the improved modeling of the linear compressor system is researched considering the magnetic nonlinear. The strategy for modeling the Linear Compressor considering the magnetic nonlinear is conducted in two steps. Frist, nonlinear inductance values of the linear compressor are calculated by electromagnetic field analysis using the FEM(Finite Element Method). Secondly, modeling of the controller is performed by analysis of the loss factor of the linear compressor system. The loss estimation of nonlinear modeling of the linear compressor system is verified through experiments under load conditions.

Design Procedure of Single Phase PWM DC-AC Inverter by Divided Optimization Algorithm
Kazuya Morita, Takuya Kurihara, Takuya Shindou, Kenya Jin'No  
*Nippon Institute of Technology, Japan*

We consider a design procedure of a single phase PWM DC-AC inverter by using our proposed divided optimization algorithm (abbr. DOA). For the single phase PWM DC-AC inverter, the switching operation is the most important component. The DOA can optimize the switching angle effectively. The design procedure of the switching angle evaluates the total harmonic distortion and the effective value of the output. The proposed evaluation function restricts the scope to evaluate of the harmonic components. Based on our numerical simulation results, we confirm that the performance of proposed design procedure is improved comparing with the conventional sinusoidal PWM procedure. The simulation result indicates that the proposed algorithm exhibits better performance than the conventional sinusoidal PWM DC-AC inverter.
A Novel High Step-Up Converter
K. I. Hwu1, Y. T. Yau2, Jenn-Jong Shieh2
1National Taipei University of Technology, Taiwan; 2Ta Hwa University of Science and Technology, Taiwan

A high step-up converter is presented herein, which is constructed mainly by stacking bootstrap capacitors combined with inductor-coupled boost converter with active voltage clamp. Above all, this converter can be implemented based on low turns ratio with the relatively small number of components used. Furthermore, under different input voltages and different output currents, the variations in voltage stress for each component are slight. In this paper, some experimental results are provided to verify the feasibility and effectiveness of the proposed topology.

Implementation of an Interleaved Three-Level PWM Converter with ZVS/ZCS Functions
Bor-Ren Lin, Chia-Hung Chao, Bo-Ren Hou
National Yunlin University of Science and Technology, Taiwan

An interleaved three-level PWM converter is presented in this paper to achieve the functions of zero voltage switching (ZVS) for all power switches and zero current switching (ZCS) for all rectifier diodes. Three-level hybrid DC converter is adopted to reduce the voltage stress of power switched at half the DC bus voltage and automatically balance the two input capacitor voltages. Therefore, MOSFETs with 600V voltage stress can be used at the second DC/DC converter after the three-phase power factor correction (PFC) circuit. The fixed frequency pulse-width modulation (PWM) is used in the three-level PWM series resonant converter to regulate output voltage. Finally, experiments are provided to verify the effectiveness of the proposed converter.

A Buck-Type Power-Factor-Correction Circuit
Ching-Ran Lee, Wen-Tien Tsai, Hwei-Shung Chung
Industrial Technology Research Institute, Taiwan

A buck-type power-factor-correction (PFC) circuit is proposed for low dc voltage applications. To achieve a high power factor, a conventional buck correction is cascaded by an auxiliary flyback conversion circuit to continue drawing current from the ac line source at the vicinity of zero crossing. The PFC circuit consists of only an active power switch, and thus has a high efficiency and can easily be accomplished by a simple control circuit with pulse width modulation. A laboratory circuit designed for a 48 V, 30 W dc load is built and tested to verify the theoretical analyses. Experimental results demonstrate that a power factor of 0.99 and a circuit efficiency of 92.5 % can be achieved.

Development of Single-Phase Current Source Inverter with Power Decoupling Function
Masaki Saihso1, Tsuyoshi Harimoto1, Hideki Hayashi2, Makoto Saito2
1Kyushu Electric Power Co., Inc., Japan; 2Shibaura Institute of Technology, Japan

Authors have developed a single-phase current source inverter with power decoupling function, applying a matrix converter. The inverter achieved high efficiency since the step-up chopper circuit is not required, and realized the circuit structure that enabled size reduction and longer service life without a electrolytic capacitor for smoothing DC voltage. This paper describes the circuit structure, characteristics and control method of the single-phase current source inverter with power decoupling function, followed by the charge and discharge simulation results.
High-Frequency Link DC for Power Quality Improvement of Stand-Alone PV System in Cascaded Multilevel Inverter
Muhammad Sadikin, Tomonobu Senjuy, Atsushi Yona
University of the Ryukyus, Japan

Multilevel inverters are emerging as a new breed of power converter options for power system applications. Recent advances in power switching devices enabled the suitability of multilevel inverters for high voltage and high power applications because they are connecting several devices in series without the need of component matching. Usually, a transformerless battery energy storage system (BESS) based on a cascaded multilevel inverter, is used as a measure for voltage and frequency deviations. System can be reduced in size, weight, and cost of energy storage system. This paper presents a DC-DC type high-frequency link DC (HFLDC) stand-alone photovoltaic(PV) system in cascaded multilevel inverter. Each converter cell is implemented a control strategy for two H-bridge inverters that are controlled with the same multi-carrier pulse width modulation (PWM) technique. The proposed cascaded multilevel inverter generates lower voltage total harmonic distortion (THD) in comparison with conventional cascaded multilevel inverter. Digital simulations are carried out using PSCAD/EMTDC to validate the performance of the proposed cascaded multilevel inverter.

Analysis and Design of a Novel Interleaved Single-Stage LLC Resonant AC-DC Converter
Chien-Hsuan Chang, Chun-An Cheng, Hung-Liang Cheng, Ching-Fu Lin
I-Shou University, Taiwan

This paper proposes a novel interleaved single-stage LLC resonant ac-dc converter. Two derivative buck-boost typed power-factor-correctors (PFCs) with interleaved operation are integrated with an LLC resonant converter to form the presented circuit. The proposed single-stage converter has the features of simple circuit structure, balance switch currents, low dc-bus voltage, low input current harmonics, and high system reliability. Both the active switches can turn on with zero voltage switching (ZVS), and both the output rectifier diodes can turn off with zero current switching (ZCS), which results in lower switching losses. Circuit derivations, operation principles, and circuit analysis of the proposed converter are addressed. Finally, a laboratory prototype with an 110Vrms utility-line voltage is implemented correspondingly. The experimental results have verified the validity of the theoretical predictions and the feasibility of the proposed circuit.

Loss Evaluation for ARCP Matrix Converter
Syotaro Nagafuchi, Takashi Abe, Tsuyoshi Higuchi
Nagasaki University, Japan

A Matrix Converter (MC) is an AC-to-AC conversion device that has various advantages compared to the PWM inverter. The auxiliary resonant commutated pole (ARCP) method, a variation of the soft switching technology, is applied to a MC and ARCPMC has been proposed in previous paper. The ARCP soft switching technology is able to reduce the switching loss of main switches. However, the conduction loss of main switches and the loss of auxiliary switches are not reduced. This paper aims to clarify the switching and conduction loss of main switches and auxiliary switches. And also, those loss characteristics are compared with the loss of conventional MC.

Comparative Study on Efficiency and Switching Noise of Bridgeless PFC Circuits
Kiyoshi Masumoto¹, Kewei Shi², Masahito Shoyama³, Satoshi Tomioka³
¹Kyushu University, Japan; ²TDK-Lambda Corporation, Japan

Recently, efficiency improvement has been noted with the rapidly increasing consumption of energy. The diode losses is the main cause of efficiency decrease in bridge rectifier of conventional PFC circuit, it can not be neglected. Therefore bridgeless PFC circuit has been focused. In this research, the various bridgeless PFC circuits are analyzed. The results of switching noise are compared and efficiency improvement is verified.
**Charge-Pumped and Switched-Capacitor Flyback Series-Connected with Tap-Inductor Boost Converter**

Do-Hyun Kim, Jong-Ho Jang, Joung-Hu Park  
*Soongsil University, Korea, South*

This paper proposes novel high-step-up DC-DC converter using charge pump switched capacitor cell. The proposed converter uses the tapped transformer, coupled-inductor, and switched-capacitor techniques. The output of the tap-inductor boost, flyback, and switched-capacitor cell are connected in series connection for high-step-up. A prototype circuit with 15-35V input voltage, 340V output voltage, and 100W output power is implemented to verify the performance of the proposed converter.

**The Pursuit and Analyses for Optimum Chopper**

Yuhta Ando, Keiju Matsui, Masaru Hasegawa  
*Chubu University, Japan*

For rectifier circuits with power factor correction, boost converters are generally used, however, the output voltage becomes limited. To expand the controlled voltage range, buck-boost converter types should be utilized. In such a way, a variety of choppers can be discussed and utilized to a suitable application. Our research group have been studying and discussing on circuit configuration in pursuit of optimum chopper by a third type of converter. In this paper, a novel type of converter is presented and discussed in terms of the mechanisms and the characteristics based on an unique power flow chart which can resolve and explain power flow mechanism.

**Bilateral Chopper of Resonant Converter Employing Zero Current Switch with Saturable Inductor**

Keisuke Kuwabara, Keiju Matsui, Takanori Asaba, Masaru Hasegawa  
*Chubu University, Japan*

As a characterized orthodox technology, a variety of chopper circuits are used for the electric vehicles, etc. Such technologies have a tendency to go out of vogue as power supplies for like electric trains. However, as a boost chopper for the battery charger for an electric vehicle and the like, those technologies become a main stream, where a bilateral function is required. With the foregoing in mind, the authors have devised and analyzed the bilateral chopper using the soft-switch technology, where as a resonant component, a novel saturable inductors is proposed and discussed.

**Implementation and Analysis of a Half-Bridge Series-Parallel LLC Loaded Resonant DC-DC Converter for Low Power Applications**

Mazliza Abdul Halim, Muhamad Nabil Hidayat, Mohammad Nawawi Seroji  
*Universiti Teknologi MARA, Malaysia*

This paper presents an implementation and analysis of a half-bridge series-parallel loaded resonant DC-DC converter. This paper covered theoretical studies that proven with simulation and prototype work. MATLAB/SIMULINK 2011 had been used to carry out simulation results that will be used to compare with prototype results. The converter designed is targeted for low power applications at 30mW.

**A Comparative Study of on-Board Bidirectional Chargers for Electric Vehicles to Support Vehicle-to-Grid Power Transfer**

Chris Gould, Kalhana Colomboage, Jiabin Wang, Dave Stone, Martin Foster  
*University of Sheffield, United Kingdom*

A comparative study of On-Board Bidirectional Chargers for Electric Vehicles has been undertaken to enable Vehicle-to-Grid power transfer. Mains-frequency motor inverter topologies are compared to high frequency DC-DC converters with respect to efficiency, weight and cost.
Differential Flatness Based Control of Supercapacitor Substation for DC Grid System
Phatiphat Thounthong¹, Suwat Sikkabut¹, Matheepot Phattanasak¹, Panarat Sethaku¹, Serge Pierfederici², Bernard Davat²
¹King Mongkut's University of Technology North Bangkok, Thailand; ²Université de Lorraine, France

This paper presents a new control approach for dc-link stabilization that use supercapacitors (SC) as the energy storage substation. A 4-phase parallel converter with interleaved switching technique is presented as a 2-quadrant SC converter. Using a nonlinear control approach based on the flatness property, we propose a straightforward solution to dynamic and stabilization problems in the power electronics systems. This is the key contribution in this paper. We analyze a prototype small-scale network (700-W dc main generator and a 100-F SC bank). The utility of the control algorithm is validated using experimental results measured during load cycles.

Modified Elman Neural Network Control for PMSM Direct-Driven PMSG/Battery Renewable Energy System
Chih-Hong Lin, Ren-Jeng Wu
National United University, Taiwan

The modified Elman neural network (NN) controller to be used for the voltage control of the permanent magnet (PM) synchronous generator/battery renewable energy system is proposed to improve control performance. Because the PM synchronous generator/battery renewable energy system is a nonlinear time-varying system, three sets on-line trained modified Elman NN controllers are developed for the voltage tracking controllers of DC bus voltage of rectifier, AC voltage of inverter and DC voltage of battery storage system in order to improve output performance. Finally, experimental results are verified to show the effectiveness of the proposed control scheme.

T-S Fuzzy Lighting Control for an Unknown Arranged LED Array
Chian-Song Chiu, Jay Sh Lin, Ya-Ting Lee
Chung Yuan Christian University, Taiwan

This paper presents T-S fuzzy lighting control of an unknown arranged LED (Light Emitting Diode) array for universal adaptable applications. In order to driving and lighting an unknown arranged LED array, a boost converter is applied to adjust the input voltage of the LED array. Based on the proposed T-S fuzzy model based control, exact LED lighting current control is achieved without searching the arrangement and turn-on voltage of the LED array. By solving linear matrix inequalities (LMIs), the T-S fuzzy LED lighting controller is guaranteed with asymptotic convergence and high robustness to uncertainty and disturbance. Moreover, the satisfactory performance is shown from experimental results.

A Novel PWM Control Method for DC-DC Converter with Fast Transient Response
Min Lin¹, Satoshi Tomioka², Takashi Nabeshima³, Terukazu Sato³, Kimihiro Nishijima¹
¹Oita university, Japan; ²TDK-λambda Corporation, Japan

A novel PWM control method with constant switching frequency for DC-DC converters is proposed. The proposed control method has excellent control characteristics and is suitable for the low-voltage high-current dc-dc converter which requires a fast transient response. The transfer function of the proposed controller is obtained by small signal ac analysis, and the dynamic characteristics of the regulator are examined by simulation and experiments. The results show the proposed method provides excellent dynamic performance and stable switching action without using an error amplifier in the controller.
Control of Single-Phase AC to DC Converter for Hybrid Microgrid
Chanlit Tarasantisuk, Viboon Chunkag, Phatiphat Thounthong
King Mongkut’s University of Technology North Bangkok, Thailand

The paper presents a current control using the DQ synchronous reference frame for single-phase ac to dc converter. The control method transforms an orthogonal current by the actual single-phase input current and a \( T/4 \) delay current, from a stationary to a rotating frame. The steady state current components become direct current instead of alternating current values. The advantage of this method is zero steady state error and easily for power calculation. A full bridge single-phase converter is implemented for bidirectional power flow in hybrid microgrid. The results consist of simulation result in Matlab/Simulink and converter experiment result controlled with DS1104 interface card.

Digital-Analog Hybrid Controlled Converter with Interleaved PWM Method
Takayuki Kuroki, Terukazu Sato, Kimihiro Nishijima, Takashi Nabeshima
Oita University, Japan

This paper presents a novel digital control method that improves both phase margin and jitter of a dc-to-dc switching converter. The proposed method has two controlled pulses, one is generated by digital control and the other by analog control. The resulted switching frequency is twice of analog control and digital control frequency, which results in smaller ripple currents in the converter. It is clarified that the proposed control method greatly contributes to improve the stability and the dynamic performance compared to the conventional PID control by the examinations of the frequency response and the transient response.

Chienru Lung, Hiroaki Kakigano, Yushi Miura, Toshifumi Ise
Osaka University, Japan

Nowadays, the distributed generation system with energy storage can be operated in stand-alone operation. In this case, the electrical power is supplied to ac loads in houses by a single-phase 3-wire inverter. Low distortion output waveform under many kinds of load conditions is required. In this paper, we proposed the sigma-delta modulation control scheme for a single-phase 3-wire inverter. Some experiments to demonstrate the validity of this control scheme were carried out and results of inverter losses and the total harmonic distortion of load voltage were compared with conventional proportional and resonant control under several sampling frequency conditions.

Study of Decentralized Collaboration Power Control for Spacecraft
Minoru Iwasa, Shuuehi Shimada, Hitoshi Naito, Hiroaki Kusawake
JAXA, Japan

Spacecraft have many components required for existence in orbit, e.g. subsystems for electrical power, thermal control, communication & data handling and attitude control, which are known as “BUS systems”. To increase the ratio of mission payloads in spacecraft, a compact and lightweight BUS system is demanded, in response to which JAXA has been studying the establishment of decentralized and collaboration power control. In this paper, we describe an algorithm of decentralized and collaboration power control and a test of an experimental model.

Estimation of Optimized Switching Points for on-Off Module Control in Paralleled Converter System
Teruhiko Kohama, Masahiro Momono, Satoshi Tsuji
Fukuoka University, Japan

This paper proposes estimation method of optimized switching points for on-off module control to improve overall power conversion efficiency of paralleled converter system. On-off module control changes the number of active modules according to load current. The main concern of the control is to determine the on-off points of converter modules. Optimized switching points for on-off control are estimated by simple
manner. Experimental results show the effectiveness of proposed estimating method to improve the efficiency.
Robust Backstepping RWNN Control for a Linear Synchronous Motor Drive
Chih-Hong Lin, Wai-Jun Wong
National United University, Taiwan

The robust backstepping control system using adaptive recurrent wavelet neural network (RWNN) uncertainty observer is proposed to control LSM drive for the tracking of periodic reference inputs. First, the field-oriented mechanism is applied to formulate the dynamic equation of the LSM servo drive. Then, the robust backstepping control system using adaptive RWNN uncertainty observer is developed to control LSM drive under the occurrence of parameter variations. With the proposed robust backstepping control system, the mover position of the LSM drive possesses the advantages of good transient control performance and robustness to uncertainties for the tracking of periodic reference trajectories. Moreover, to further increase the robustness of the LSM drive, an adaptive RWNN uncertainty observer is proposed to estimate the required lumped uncertainty. The effectiveness of the proposed control scheme is verified by the experimental results.

Design and Analysis of a Family of Speed and State Sliding Mode Observers with Compound Manifolds for the Induction Motor Drive
Mihai Comanescu
Penn State Altoona, United States

The paper discusses the problem of speed and state estimation for the induction motor (IM) drive and presents the design of a family of Sliding Mode (SM) observers that are constructed using compound manifolds. Generally, given the stationary reference frame model of the IM, several methods can be used to estimate the speed and the states. In particular, if estimation is done with SM methods, it is typical to use simple manifolds (usually, the current mismatches). However, SM observers with compound manifolds have very interesting properties. The paper examines a specific observer that uses a discontinuous speed estimate; then, it attempts to design similar SM observers with alternative compound manifolds. Three observers are attempted and their convergence and estimation properties are investigated. The paper finds that the original observer offers the only viable design. The theory is supported by simulations.

Design of a Sliding Mode Algebraic Speed and Rotor Position Observer for the PMSM Drive
Hernan Arroyo, Mihai Comanescu
Penn State Altoona, United States

The paper presents a method to estimate the speed and the rotor position of the permanent magnet synchronous motor (PMSM) drive. The development is done using sliding mode theory. The method proposed is based on the model of the PMSM in the stationary reference frame and uses two sliding mode (SM) observers to estimate the variables of interest: the states, the rotor position and the motor speed. A distinct advantage of the proposed approach is that speed is obtained algebraically - some previous speed estimation methods described in the state of the art use adaptation theory; however, this is usually not reliable. In the development, the motor voltages and currents are measured. A first SM observer estimates the EMFs of the PMSM model. Then, these are fed into a second SM observer which estimates the derivatives of the EMFs. The equivalent controls of the two observers are used to compute the speed. The paper discusses some of the approaches available to estimate the speed with known EMFs. The theoretical developments are supported with simulations.
Simulink/Modelsim Co-Simulation of EKF-Based Sensorless PMSM Drives
Ying-Shieh Kung, Nguyen Trung Hieu
Southern Taiwan University of Science and Technology, Vietnam

Based on Simulink/Modelsim co-simulation technology, the design of sensorless PMSM drives using EKF (Extended Kalman Filter) is presented in this paper. Firstly, the estimation of the rotor flux position and rotor speed based on EKF is applied to the sensorless speed control for PMSM drives. Secondly, the VHDL adopted to describe the behaviour of EKF. Thirdly, a simulation work is performed by Simulink and ModelSim co-simulation mode. The PMSM, inverter and speed command are performed in Simulink and the sensorless speed control of PMSM drives is executed in ModelSim. Finally, the co-simulation results validate the correctness and effectiveness of the EKF-based sensorless PMSM control system.

Performance Evaluation of High Power and Low Torque Ripple Structure of Rare-Earth Free PMASynRM with Ferrite Magnet
Masahiro Obata, Shigeo Morimoto, Masayuki Sanada, Yukinori Inoue
Osaka Prefecture University, Japan

Currently, it is required that the use of rare-earth permanent magnet should be reduced. This paper proposes a permanent magnet assisted synchronous reluctance motor (PMASynRM) with a ferrite magnet that does not use rare earth materials. The performance of the proposed PMASynRM is evaluated based on the 2-D finite element method and an experiment using a prototype machine. The analysis results reveal that the proposed PMASynRM has the same power density and equivalent efficiency as conventional rare-earth permanent magnet synchronous motors for HEV driving. Moreover, asymmetric structure of flux barrier in order to reduce torque ripple is discussed.

Characteristics Comparison of PMASynRM with Bonded Rare-Earth Magnets and IPMSM with Sintered Rare-Earth Magnets
Hiroki Nishiura, Shigeo Morimoto, Masayuki Sanada, Yukinori Inoue
Osaka Prefecture University, Japan

This study investigated characteristics of PMASynRM with Dy-free bonded rare-earth magnets and IPMSM with sintered rare-earth magnets. Maximum torque of PMASynRM and IPMSM is almost equal at rated current. PMASynRM has the wide operating range, while the maximum output power of IPMSM and PMASynRM is equal. Loss of PMASynRM was larger than that of IPMSM because the copper loss was large.

Space-Vector Based Current Control of Permanent-Magnet Synchronous Motor/Generator Drive Applied to Flywheel Energy Storage System
Yuan-Chih Chang, Jan-Cheng Chen, Jui-Teng Chan, Kun-Han Sun
National Chung Cheng University, Taiwan

This paper develops a 5kW permanent-magnet synchronous motor/generator drive applied to flywheel energy storage system. To develop the PMSM/G drive for charging and discharging the flywheel, the dynamic model is established in advance. According to the derivation of the proposed space-vector based feed-forward current control scheme, the PMSM/G parameters including back-EMF constant, winding inductance and winding resistance are required. The parameter estimation of the PMSM is completed via experimental tests. The proposed current control algorithm can be implemented in both motor mode and generator mode. In addition, the switching times of the three-phase full-bridge power switched in the PMSM/G drive are decreased to reduce the switching losses. The digital control of the PMSM/G drive system is fulfilled by the microcontroller. To verify the driving performance of the PMSM/G drive, some experimental results are measured. This PMSM/G drive can be operated at different rotational speeds and output powers.
Improved Internal Model Control Based on Optimal Control for Servo System with Dead Time
Hiromitsu Ogawa, Ryo Tanaka, Takahiro Murakami, Yoshihisa Ishida
Meiji University, Japan
This paper describes an improved internal model control based on PID control for servo system with dead time. The internal model control works for more stability of disturbance. The proposed system uses the feedback based on internal model control and PID control when the disturbance occurs. The proposed method can be applied to not only servo stable plant with dead time but also unstable plant with dead time. It can be applicable to both simulation and actual DC motor control. The proposed method has good robustness compared with general PID design method.

Evaluation of IPMSMs with Concentrated Windings Using Powder Magnets for High Torque
Kyohei Hayakawa, Masayuki Sanada, Shigeo Morimoto, Yukinori Inoue
Osaka Prefecture University, Japan
In this research, IPMSMs with concentrated windings using powder magnets that have higher coercive force are examined and discussed regarding rotor structures for high torque. When sintered magnets was replaced to powder magnets in same rotor structure, maximum torque decreased to 75% of sintered magnet structure. As the number of layer increased with respect to flat shape and V shape structure, Tr of the flat shape structure increased but that of the V shape structure slightly increased. As a result, the three-layer flat shape structure has the highest torque and it is the 85% of sintered magnet structure.

Influence of Magnet and Flux Barrier Arrangement for IPMSM with Concentrated Winding
Junka Okamoto, Masayuki Sanada, Shigeo Morimoto, Yukinori Inoue
Osaka Prefecture University, Japan
This study was carried out by changing the flux barrier angle about the influence that the stator configuration for IPMSM with concentrated winding used the ferrite magnet gives to the reluctance torque. In five models, the structure with middle opening angle shows the maximum reluctance torque and average torque. Moreover, asymmetrical structure with the slanted magnet shows the average torque and the ratio of reluctance torque are greater than all other structures in this study. It needs further consideration of the structure that the ratio of torque of the winding form is improved in order to increase the average torque.

Basic Experimental Evaluation of Three-Dimensional Air Gap Structure for Torque Improvement in Electric Motors
Keisuke Yakushijin, Shigeo Morimoto, Masayuki Sanada, Yukinori Inoue
Osaka Prefecture University, Japan
A three-dimensional (3-D) air gap structure of the motor was proposed to improve the torque characteristics. In this study, the effect of 3-D air gap structure is evaluated from experiment. The measured torque of 3-D air gap structure models was higher than that of the flat air gap structure models. However, the measured iron loss of 3-D air gap structure models was higher than that of the flat air gap structure models. When using PWM inverter, the iron loss of 3-D air gap structure models was increased.

Implementation of BLDCM Sensor-Less Controller
Chin-Yuan Hsu, Shin-Chang Hsu, Guo-Xiang Hung
National Kaohsiung University of Applied Sciences, Taiwan
The purpose of this paper is to use the sensor-less controller to achieve the speed control of brush-less DC motor. This paper proposes an important starting method. The principle of this starting method is to add the flux angle control mode between the constant acceleration control mode and the Back-EMF control mode in the sensor-less controller, to make the starting of the brush-less DC motor more stable and reliable. At first the MATLAB/Simulink is used to establish the brush-less DC motor model, and to simulate the speed control of the brush-less DC motor, using the sensor-less controller, to confirm the feasibility of the starting theory. Finally a prototype brush-less DC motor is built, using the sensor-less controller, to compare the difference
between the simulation and the real system. The sensor-less controller can achieve the starting of the brush-less DC motor, forward and reverse rotation and speed control.

Magnet Losses of Fractional Number Slots Per Pole PMSM in Flux Weakening Operation
Istvan Szenasy
Szechenyi University, Hungary
A newly applied method for control the PMSM is the flux weakening operation for extending the region over nominal speed but on nominal voltage. This paper deals with these questions and its impacts. The method is a very well elaborated theory and process for about twenty years and applied with success in up-to date drives of electrical vehicles. The one of proved methods is increasing the torque angle and with this the d axis directed component of the stator current vector for reduce the main flux, however the loss developed in magnets as a heat increase the temperature. Theses impacts and its reduction need several investigations. Our work can indicate the possibilities and limits of flux-weakening for a given PMSM, battery and demands of use.

Design of Vibration Suppression Controller for High Order Resonance System by Mutation-Type Grouping PSO
Hidehiro Ikeda2, Shoichi Ueda2, Tsuyoshi Hanamoto1
1Kyushu Institute of Technology, Japan; 2Nishi-Nippon Institute of Technology, Japan
In this paper, a new design method of vibration suppression controller for 6-mass resonance system is proposed. The proposed method is possible to suppress the mechanical vibrations of all mode. The controller consists of a modified-PI-PD controller for speed loop and a PI controller for current minor loop. The seven controller gains are determined by CDM. And then, we propose Mutation-Type Grouping PSO to design a Coefficient Diagram. Comparing with the conventional design algorithm, the proposed technique is able to shorten the time of the controller design to a large extent and to obtain accurate results.

Analysis on the Torque Characteristics Due to Outer Rotor Displacement in the Double Rotor Switched Reluctance Machine
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The paper presents an influence on the torque characteristics of the outer rotor displacement in the double rotor reluctance motor. At the first stage the magnetic equivalent circuit of the machine is developed based on the magnetic circuit of the machine in each of the parts that describes their own reluctances. From the equivalent circuit at the particular position the net reluctance is calculated. The magnetic circuit reluctances include due to the iron core of the stator, the rotor and that of the air gaps. The air gap reluctance in different rotor position influences predominantly the torque characteristics as the torque development highly dependent upon the flux linkages at any position. The changing of the pole arc essentially improves the extended flux linkage capability. Hence an investigation into the variations on the displacement of the rotor pole is imperative. In this investigation attempt is made only on the displacement of the outer rotor pole with respect to that of the inner rotor pole. From the results it is inferred that displacing the outer rotor by 3 degrees evolve an improvement in the torque characteristics through the analytical evaluations.

Diagnosis of Multi-Turn Faults of Induction Motor by Direct Detection of Asymmetry Admittance Component
Toshiji Kato, Kaoru Inoue, Keisuke Yoshida, Takashi Itokawa
Doshisha University, Japan
This paper proposed a new diagnostic method of a stator winding fault of an induction motor. It can detect positive/negative sequence voltages/currents directly by the LS analysis and can estimate and diagnose faulted phases and turns according to estimated asymmetry admittances. It is difficult to process the
two-phase fault model analytically because the model has stronger structural asymmetry, however, it is possible to simulate the model numerically and flexibly by describing it in an hardware description language, for example, in VHDL-AMS. The proposed method is investigated for its validity by simulation and experiment of a 0.75kW induction motor. It is validated for diagnosis not only of one-phase faults but also of multi-phase faults by tracing asymmetry admittance variations.
**Method of Feedback Detection for Loosely Coupled Inductive Power Transfer System with Frequency-Tracking Mechanism**

Shyh-Jier Huang1, Tsong-Shing Lee2, Fu-Sheng Pai2, Tzyy-Haw Huang3

1National Cheng Kung University, Taiwan; 2National University of Tainan, Taiwan

This paper proposes a feedback signal detection method and frequency-tracking control approach for inductive power transfer (IPT) systems. The power delivery efficiency is increased by utilizing a resonance compensation circuit and frequency-tracking control. Yet, the resonance characteristics of IPT systems are observed to be easily influenced by load impedance and coil gap, hence motivating the integration of frequency-tracking control with the microprocessor control unit-based controller to closely lock the operation frequency with the primary current phase. Moreover, a voltage across RDS(on) of the power MOSFET is utilized to compensate the resonance features of IPT system in the circuit design, by which the system efficiency is improved while the zero-voltage switching is simultaneously achieved. This proposed system has been tested under several scenarios. Test results help confirm the feasibility of the proposed IPT module for the application.

**Inductive Power Transmission Technology for Li-ion Battery Charger**

Chih-Chiang Hua, Hau-Ran Chen, Yi-Hsiung Fang

National Yunlin University of Science and Technology, Taiwan

This paper proposes a contactless electromagnetic induction power transmission technology. The induced condition of resonant coupling and the non-resonant coupling is discussed and applied to Li-ion battery charger. The primary side and secondary side produce electromagnetic induction to achieve the purpose of power transmission through the half-bridge converter generate an alternating current, and the rectifier filter input to the buck converter to obtain a stable voltage supply Li-ion battery for charging. The Simulation analysis in this paper can be seen the inductive effect of the resonant coupling architecture is better than non resonant coupling structure, and the experimental used resonant coupling structure to verify its induction characteristics.

**Development of Portable Power Supply Units Applying Li-ion Batteries**

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1Koyo Electric Industrial Co.,Inc., Japan; 2Kyushu Electric Power Co.,Inc., Japan

Conventionally, generators with diesel engines have been used for electrical or civil engineering work at night or work inside manholes where there is no permanent power supply unit. Since a generator produces noise, careful consideration for the surrounding environment must be taken, especially when it is used at night. To address these issues, portable power supply units that use Li-ion batteries were developed. This paper summarizes the characteristics of the portable power supply units, Li-ion battery monitoring and management technology, and various measures to improve the serviceability, followed by the results of the system performance experimental tests.

**Artificial-Lighting Sources for Plant Growth**

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1Cheng Shiu University, Taiwan; 2Far East University, Taiwan; 3Industrial Technology Research Institute, Taiwan

This study examines the use of artificial-lighting sources for indoor photosynthesis and proposes a novel indoor plant-lighting scheme in which red LEDs, blue LEDs and CCFLs are combined to work as effective light sources. The lighting combinations confirmed in this study have been proven effective in improving the
growth uniformity of Anoectochilus Formosanus Hayata. Furthermore, the study has also demonstrated that lowered growth racks contribute to higher yield per unit area.

**Design and Implementation of a Digitally-Controlled LLC Resonant Converter for Battery Charging Applications**

Chun-Liang Liu, Yi-Hsun Chiu, Yi-Feng Lo, Shun-Chung Wang, Yi-Hua Liu

1Industrial Technology Research Institute, Taiwan; 2Lunghua University of Science and Technology, Taiwan; 3National Taiwan University of Science and Technology, Taiwan

In this paper, a digitally-controlled LLC resonant converter is developed for LEV battery charging applications. LLC resonant converter boasts the advantages of high efficiency and wide input voltage range; therefore is a suitable candidate for medium power battery charging applications. To enhance the performance of the developed battery charger, five-step constant current (CC) charging method is implemented in the proposed digital controller. Experimental results show that the proposed charger can successfully realize the five-step CC charging, and the measured conversion efficiencies of the designed LLC converter are all higher than 88% under all output voltage and load conditions.

**Analysis on Parallel Operation of Boost-Type Battery Power Modules**

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1MIRDC Metal Industries Research & Development Centre, Taiwan; 2National Sun Yat-sen University, Taiwan

Battery power modules (BPMs) with boost converters are connected in parallel to accomplish a large load current. The paralleled BPMs are strongly interactive with each other. Nevertheless, the analyzed results indicate that the inherent internal resistance may alleviate the mutual interaction. The discharging currents of the batteries can be individually controlled but are coordinated to execute a full amount load current. The experiments are carried out on three boost-type BPMs to confirm the theoretical analyses and to demonstrate the feasibility of balanced discharging.

**Bidirectional Converter Uniﬁying AC-to-DC Power Factor Corrected Converter and Buck-Boost DC-to-DC Converter for a V2H Application**

Seong-Hye Kim, Feel-Soon Kang

Hanbat National University, Korea, South

A single-stage bidirectional converter, which is available for a grid-connection with an inverter and a battery charger of PEV (plug-in electric vehicle), is presented by employing a buck-boost with two switch elements. The proposed bidirectional converter combines a front-end H-bridge ac-to-dc converter with a back-end buck-boost dc-to-dc converter. To explain how the proposed converter works, we divide into four operational modes according to circuit functions. Mode 1 and mode 2 operate when a battery charges from the grid. While mode 3 and mode 4 work when a battery discharges to the grid. Each mode is illustrated and explained in detail. To verify the validity of the proposed approach, we carry out computer-aided simulations using PSIM.

**Differential Flatness Based Control of Hybrid Power Plant Based on Supercapacitor Storage Energy for AC Distributed System**

Suwat Sikkabut, Nisai Fuengwarodsakul, Matheepot Phattanasak, Phatiphat Thounthong, Azeddine Houari, Serge Pierfederici, Bernard Davat

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This paper presents a control law for distributed ac generation supplied by a dc main source and supercapacitor; a nonlinear control algorithm based on the flatness properties of the system is proposed. Using the flatness property, we propose simple solutions to hybrid energy management. To validate the proposed method, a simulation system and a hardware system are implemented. Simulation results and real experimental results in a laboratory corroborate the excellent control scheme during load cycles.
Integrated Motor Drive and Non-Isolated Battery Charger Based on the Torque Cancelation in the Motor
Saeid Haghbin, Isabel Serrano Guillen
Chalmers University of Technology, Sweden

For a plug-in vehicle, the traction circuit components like electric motor, inverter, and sensors are not used during the battery charging. So there is a possibility to use them in the battery charger circuit that is called an integrated motor drive and battery charger which can be galvanically isolated or non-isolated from the grid utility. A novel integrated motor drive and non-isolated battery charger is presented and described. The drive system is based on a split-phase PM motor that has a double set of stator windings. The motor windings are reconfigured by a relay for the traction and charging operation. One important challenge to use the motor as three inductors in charger circuit is to have it in stand-still during the battery charging. Simulation and experimental results are provided to verify proper operation of the system. The results shows that the system has a good performance and the developed torque is negligible during the battery charging.

A New PFC Implementation for Small Wind Power System
Jun-Hua Chiang, Bin-Da Liu, Shih-Ming Chen, Hong-Tzer Yang
National Cheng Kung University, Taiwan

This paper presents an algorithm for implementing the nonlinear-carrier (NLC) control method by adapting NLC law with variable slope ramps for power factor correction (PFC) without input voltage sensing circuits. The proposed method not only achieves a high power factor, but also efficiently simplifies complexity of integrated circuit realization, especially for multi or three phase PFC converter. A three-phase wind power system higher than 1 kW is implemented to verify the performance of the proposed NLC control.

Quasi-Resonant Converter for Induction Heating in High Temperature Applications
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3Rajamangala University of Technology Krungthep, Thailand

The paper describes quasi-resonant converter for induction heating in high temperature application. Converter is implemented by using IGBT as its switching. The switching loss is minimized by operating the IGBT in the zero voltage resonance modes. The output power can be adjust by varying the switching frequency of converter. The prototype is tested under load-parameter variation during the heating process and it is rated at approximately 1000 W, with operating frequency ranging from 5-7 kHz. The operation principles of quasi- resonant are investigated and validity is verified by simulation and experimental results.
Influence of Power Semiconductor on-Voltage on Iron Loss of Inverter-Fed
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The influence of power semiconductor on-voltage on iron loss of inverter-fed electrical steel is made clear through the experimental data. In this work, one-phase full bridge inverter is used for the iron loss evaluation, where a bipolar transistor, MOSFET and IGBT are selected as a power semiconductor in the inverter circuit. When maximum magnetic flux density is adjusted to be 1 tesla in electrical steel, the measured iron loss is different from the three kinds of power semiconductors.

Application of D-Q Axis Transformation Control Strategy for Three-Phase AC/DC Converter
Gwo-Jen Chiou, Jeng-Yue Chen, Tsung-Cheng Chen, Bo-Xin Chen
National Formosa University, Taiwan

In the paper, a single phase three-switch AC/AC converter is implemented. The converter consists of three power switches, input and output inductors, three capacitors, and an output filter capacitor. Two operation modes, half-bridge rectifier mode and half-bridge inverter, are adopted. Use state equations of traditional single phase full-bridge rectifier to derive the ratio of capacitor and control strategy of the converter. By TMS320F2812 and control software VisSim, the digital close-loop control is achieved to get unity power factor, sinusoidal input current, adjustable output voltage, and adjustable output frequency, etc.. Finally, some experimental results verify the feasibility of converter.

An Implementation Algorithm of a Carrier-Based PWM Technique for Three-Phase Four-Leg Voltage Sag Generator with Microcontroller
Worrakaj Muangjai, Suttichai Premrudeepreechacharn, Kosol Oranpiroj, Wichan Jantee, Kohji Higuchi
1Chiang Mai University, Thailand; 2Rajamangala University of Technology, Thailand; 3University of Electro-Communications, Japan

This paper presents an implementation of a carrier-based PWM (CBPWM) technique for three-phase four-leg voltage sag source generator with microcontroller. Recently, the implementation of the 3D SVPWM for three-phase four-leg voltage source it seems to be the easiest way to generated voltage sag and it might be a software and hardware burden even for recent digital signal processor (DSP) systems but needs quite a bit of digital logic and computational power. Therefore, this paper presents a simple sag algorithm CGBPWM technique for three-phase four-leg voltage sag source generator its very simple design, low-cost and can be easily develop and operate hardware structure. The proposed technique can be implemented with microcontroller and testing algorithm compare with 3D SVPWM tecnique. The performance of proposed CGBPWM strategy has been investigated and verified through simulations and experimental results for three-phase four-leg voltage source generator.

Application of D-Q Axis Transformation Control Strategy for Three-Phase AC/DC Converter
Gwo-Jen Chiou, Tsung-Cheng Chen, Jeng-Yue Chen, Bo-Xin Chen
National Formosa University, Taiwan

In this paper, a new control strategy for three-phase AC/DC converter has proposed. Basically the proposed converter adopts three-phase full-bridge circuit and has several advantages such as sinusoidal input current, unity power factor and energy regeneration. For closed-loop control, three phase AC signals are transformed to DC signals by using the D-Q axis transformation such that the converter has faster dynamic response. The general solution of switching duty ratio is obtained by using the state space averaging technique. Based on the solution, a dead-band control modulation is implemented to drive the proposed converter. The effectiveness of the control can reduce 1/3 times switching number and switching losses successfully.
Consequently, the efficiency and voltage utilization of the converter can increase. Both TI DSP TMS320F28335 and VisSim software are employed to achieve digital control successfully. The advantages of the converter include size-reduced and easily adjusting for control parameters. Finally, some experimental results are presented to verify feasibility of the proposed control strategy.

**Digitally Controlled Multi-Phase Electronic Current Sink**

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\(^1\)Gunma University, Japan; \(^2\)Yangzhou University, China

In this paper, a digital-controlled multi-phase electronic current sink is proposed. The wide Safe Operation Area (SOA) MOSFETs are used as the power dissipating device, which are regulated to the saturation region by filtered PWM gate signals. Due to the inherent limitation of switching frequency and sampling rate in digital systems, interleaved multi-phase PWM scheme is proposed to provide active current ripple mitigation. The power stage and signal conditioning peripherals are designed and modeled; the digital controller is implemented to provide regulation for constant current and pulsed current sink modes. The digital signal controller dsPIC33FJ64GS606 is used to provide four-phase interleaved high-precision PWM and real time control for the prototype. The experimental test results indicate that the proposed system performs well in the steady-state and dynamic testing, and is applicable to the future digitalized testing equipments.

**Automatic Variable Frequency Asymmetrical Control of Half-Bridge Series Resonant Inverters for Low-Cost Domestic Induction Cooking**

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This paper presents a digital implementation of power control for induction cooking appliances with domestic low-cost vessels. The proposed control strategy is based on the asymmetrical duty-cycle with automatic switching-frequency tracking control employing a digital phase locked-loop (DPLL) control on high performance microcontroller. With the use of a phase locked-loop control, this method ensures the zero voltage switching (ZVS) operation under load parameter variation and power control at any power levels. Experimental results have shown that the proposed control method can reach the minimum output power at 15% of the rated value.

**A High Efficiency of a Class-D Resonant Inverter High Power Factor for Induction Heating Multi-Coils Hardening Application**

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This paper presented a high efficiency Class-D resonant inverter high power factor for induction heating multicoils hardening application. The main function of the Class-D resonant inverter is to provide high frequency AC from bridge rectifier and LC filter input voltage. The advantages of this technique, the power switched are operated under the zero voltage switching condition and the transformer leakage inductance the LLC resonant can be used. A prototype Class-D operating at a 102 kHz fixed frequency, 730 W maximum input power. Experimental results, induction hardening had a near unity power factor, total harmonic distortion of the input current THDi 6.5 %, it can be heat up 2 work pieces a same size diameter 9.5-mm from room temperature to 400 oC within about 1 minutes and 92 %efficiency at full power.

**A Magnetron Power Supply with Transition-Mode ZVS Inverter**

Yueh-Ru Yang

*Ming Chi University of Technology, Taiwan*

This paper designs a transition-mode zero-voltage-switching inverter for cooker magnetrons. The inverter drives a leakage transformer to generate high voltage and stabilize current. While switch is ON, pulsating
input voltage magnetizes the transformer. And, while switch is OFF, the transformer resonates with a parallel capacitor. For achieving zero-voltage switching, a transition-mode driver L6561 is utilized to detect the ending of resonance and drives an insulated-gate-bipolar transistor. The ON time of transistor is controlled to regulate the magnetron power and is set to be inversely proportional to the input voltage. To demonstrate the analyses and designs of this paper, a 1kW ZVS inverter is implemented.

**Autonomous Power System Control by Decentralized Controllable Loads**
Yoshihisa Kinjyo, Michael Damien Palmer, Atsushi Yona, Tomonobu Senjyu
*University of the Ryukyus, Japan*

In recent years, amount of renewable energy facilities using wind turbine generator and photovoltaic power system have been increased due to natural environment and resource depletion. However, due to the fluctuating power from renewable energy sources and loads, fluctuations of grid frequency and distributed voltage become problematic. This paper presents a methodology of control system frequency and distributed voltage by distributed controllable loads such as heat pump and electric vehicles. By applying power consumption controller using distribution control for HP and droop characteristics for battery, fluctuations of grid frequency and voltage are suppressed around desired value.
Single-Stage Controlled PV Micro-Inverter with Symmetrical Phase-Shift Modulation
Ming-Tsung Tsai, Ching-Lung Chu, Jhe-Yu Lin
Southern Taiwan University of Science and Technology, Taiwan

This paper focuses on digital signal processor based technique to achieve a grid-connected photovoltaic power generation system with single-stage controlled algorithm. The researched system consists of a full-bridge high-frequency DC/DC converter with the proposed symmetric phase-shift modulation to achieve the ZVS switching function, and a DC/AC inverter which can have two operating methods depending on the applied situation, respectively, for the two-stage DC - AC inverter and a single-stage DC - AC inverter. It replaces the traditional two stages of independently control algorithms with the integrated single-stage control to obtain high conversion efficiency. Finally, a prototype of 350W system with the maximum power point function is settled to verify the proposed idea.

Nonlinear Power Source Booster Suitable for Photovoltaic Cell
Teruhiko Kohama, Yuki Sogawa, Satoshi Tsuji
Fukuoka University, Japan

This paper proposes nonlinear power source booster which amplifies voltage and current in small size of nonlinear power source such as photovoltaic (PV) cell and wind power generator. The booster simulates large size of nonlinear power source by using a small PV cell, a flyback converter, and a control circuit including variable current source. Principle of proposed booster is described at first. Prototype of the booster is built and tested to confirm the effectiveness of the booster.

Simulation of Grid Connected HVDC Offshore Wind Farm Topologies
Firas Obeidat, Xu Lie, Yongdong Li
Tsinghua University, China

This paper presents two topologies to connect HVDC offshore wind farm into the grid, the offshore part consist of five units; in the first topology, each unit contains PMSG connected to 3L-NPC, The offshore platform consists of a half bridge connected in series. The second topology, each unit contain PMSG connected to 3-phase to 3-phase matrix converter, The offshore platform consists of HFT and bridge rectifier. MMC is used in the onshore side to integrate the wind far into the grid.

Power System Vulnerability Assessment Considering Energy Storage Systems
Jen-Hao Teng\textsuperscript{1}, Chia-Yen Chen\textsuperscript{3}, Ivan Curtis Martinez\textsuperscript{2}, Chi-Fa Chen\textsuperscript{1}
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Vulnerability assessment is one of the main issues for power system planning and operation. Recent research reveals that Energy Storage Systems (ESSs) have a great potential to be used to mitigate power system vulnerability. A vulnerability assessment is proposed in this paper to calculate the impact factors for power systems based on generator and line outages. A Bus Impact Severity (BIS) analysis is then designed and used to find the vulnerable buses in the power system. The buses with larger BIS values as defined in this paper can be considered as the better locations for ESS placement. Test results show that the ESS placement in the vulnerable buses can mitigate system vulnerability effectively.
An LVRT Control Strategy for Reducing DC-Link Voltage Fluctuation of a Two-Stage Photovoltaic Multilevel Inverter
Chih-Ming Lin¹, Chung-Ming Young³, Wei-Shan Yeh³, Yung-Hsiang Liu²
¹Ming Chi University of Technology, Taiwan; ²Motech Industries, Inc., Taiwan; ³National Taiwan University of Science and Technology, Taiwan

This paper proposed a LVRT strategy to suppress the fluctuation of the dc-link voltage by injecting the reactive current to meet the LVRT requirement with available real power to the grid. Under the proposed method, the dc-link voltage increase rapidly and then returns to normal value faster than only providing reactive current. A simulation was conducted to verify the validity of the proposed method.

The Economic Operation of Building with Multi Energy and Electric Vehicles
Qian Dai, Shanxu Duan, Tao Cai, Changsong Chen, Ling Huang
Huazhong University of Science and Technology, China

nowadays the distributed generation (DG) including renewable energy generations (mainly wind and solar resources), micro turbine (MT), and energy storage system (ESS) can reduce carbon emission. As the plug-in electric vehicles (EVs) being gradually accepted by social place, EVs’ electricity energy demand will increase. This paper focuses on using the concept named vehicle to building (V2B) to make EVs as mobile energy storage to reduce the ESS’s capacity. A building energy management system (BEMS) is proposed, taking into optimal sizing and economic operation of ESS in the building. The BEMS is capable of PV power forecasting, EVs coordinating charging, economic dispatch. The sizing of ESS is formulated based on the yearly operation cost of building and determined by global search. Finally, simulation results are presented to verify the feasibility of the proposed methodology.

Harmonic Current Characteristic Analysis for Wind Turbines
Chuo-Yean Chang¹, Shun-Yu Chan¹, Jen-Hao Teng², Rong-Ceng Leou¹
¹Cheng Shiu University, Taiwan; ²National Sun Yat-Sen University, Taiwan

This paper analyzes the harmonic current characteristic of wind turbines. Field measurement, data sorting, and analysis are conducted for wind turbine. Most wind turbines at present use a power converter and are equipped with harmonic filters, the control results of these equipments will become highly stochastic as wind speed changes. Even if there is a slight difference in the wind speed, harmonic output of wind turbine will be quite different. If harmonic currents are segmented and the probability density distributions are calculated, then different viewpoints as can be observed. Although harmonic currents of the wind turbine are stochastic, the probability density distributions are close to normal distribution. A stochastic harmonic current predictor is then proposed in this paper based on the probability density distributions of harmonic current. Test results show that the harmonic currents of a wind turbine in long-term operation can be effectively analyzed by the established probability density distributions.

An Analytical Overpotential Model of a Direct Liquid-Feed Fuel Cell
Yu-Jen Chiu, Jing-Lun Sun
Taipei Chengshih University of Science and Technology, Taiwan

Direct liquid-feed fuel cells are considered potential devices that provide power for portable electronic applications. Fuel crossover is one of the key issues in such a low-temperature fuel cell. Fuel crossover confines the fuel cell performance and makes mass transfer mechanisms and electrochemical reactions more complex. It is thus essential to investigate the mass transfer behavior and the concentration distribution of the reactants and products before analyzing this kind of fuel cells. In this paper, an analytical overpotential model of a direct methanol fuel cell (DMFC) is introduced based on our pre-established fuel crossover model, which provides fuel crossover fluxes and fuel concentration profiles. By acquiring polarization data of a DMFC, parameters in the model are fitted meanwhile a variety of overpotentials are recognized. The resultant model is represented as explicit functions of significant operating variables: temperature, fuel concentration, and current density. The proposed approach can serve as the basis of system control strategies and adopted for fuel cell characterization to enhance fuel cell efficiency.
An Active Clamp Flyback Converter Using Constant Power Control Method for Improving Output Power Under Partial Shading Conditions in PV Arrays
S.-Y. Tseng, H.-Y. Wang, C.-T. Huang
Chang Gung University, Taiwan

This paper presents a PV power system using constant power control method to improve output power of the PV arrays. In this research, each PV array connects an active clamp fly-back converter using constant power control method to control its output power, while all of output terminals of converters are connected in series to supply power to load. Moreover, a perturb-and-observe method is adopted in each converter control to achieve a maximum power point tracking (MPPT) of the PV arrays. Its control circuit is implemented by an microcontroller. Finally, a prototype using two PV modules to implement the PV power system for improving output power of PV arrays.

A MPPT Control Method of Thermoelectric Power Generation with Single Sensor
Hiroaki Yamada1, Koji Kimura2, Tsuyoshi Hanamoto2, Toshihiko Ishiyama3, Tadashi Sakaguchi1, Tsuyoshi Takahashi1
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In this paper, we describe a MPPT control method for thermoelectric power generation with single sensor. Estimating the output of the thermoelectric power module (TM) using state space averaging method, the MPPT controller can track the maximum power point. Analyzing the thermoelectric power generation system with boost chopper by state space averaging method, the output of the TM estimates with only current sensor. A prototype experimental model is constructed and tested. The experimental results demonstrate that the proposed MPPT controller can track the maximum power point perfectly.

Dual-Output Photovoltaic Inverter Applied in Reverse Osmosis Desalination
Fei Zhang, Zheng Xu, Libao Shi, Pijiang Zeng
Tsinghua University, China

Photovoltaic reverse osmosis desalination has great significance not only in solving fresh water shortage, but also in providing a new way for solar energy utilization, especially in the remote area where electricity is unavailable. As one of the most important components of photovoltaic powered reverse osmosis desalination (PVRO) system, the design and application of inverter directly affect the whole system performance. In this paper, a new kind of dual-output photovoltaic inverter was designed to drive the lift pump and high pressure pump in the reverse osmosis device and control the rotational speed of pumps in accordance with the variation of solar radiation to realize the maximum power point tracking (MPPT). An experimental PVRO system was also built to evaluate the performance of the inverter. Furthermore, a practical optimization model is proposed to provide useful reference for the configuration and optimal design of PVRO systems.

Current Estimation Based Maximum Power Point Tracker of Grid Connected PV System
Byunggyu Yu1, Ahmed G. Abo-Khalil1
1Almajmaah University, Saudi Arabia; 2Kongju National University, Korea, South

This paper proposes a novel sensorless maximum power point tracking (MPPT) algorithm for PV systems. The method is based on divide the operating time into several intervals in which the PV terminals are short circuited in one interval and the calculated short-current of the PV is obtained and used to determine the optimum operating point where the maximum output power can be obtained. The proposed MPPT algorithm has been introduced into a current-controlled boost converter whose duty ratio is controlled to the maintain MPP condition. The same sequence is then repeated regularly capturing the PV maximum power. The main advantage of this method is eliminating the current sensor. Meanwhile, this MPPT algorithm reduces the power oscillations around the peak power point which occurs with perturbation and observation algorithms. In addition, the total cost will decrease by removing the current sensor from the PV side. Finally, simulation results confirm the accuracy of the proposed method.
Energy Management and Coordinated Control of Energy Storage System in Microgrids
Changsong Chen, Baoqi Liu, Shanxu Duan, Qian Dai
Huazhong University of Science and Technology, China

This paper concentrates on the control and energy management of energy storage system (ESS) in microgrids (MGs). The control design for the energy storage systems employs a new compound control strategy so that energy storage systems can operate in different modes. An energy management algorithm is implemented to coordinate the operations of the energy storage systems to maximize the value of the microgrid for both grid-connected and islanded operations. The design concept is verified through various test scenarios to demonstrate the operational capability of the proposed energy storage system and the results obtained are discussed.

Performance of Wind Driven Generators Under Wind Speed Variation and Grid Faults
Mahmoud Saleh, Mona Eskander
Electronics Research Institute, Egypt

In this paper the dynamic behavior of a double-output induction generator (DOIG) driven by wind turbine under wind speed variation and during and after grid faults, is investigated. Two damping methods are tested to reduce the high transient values of currents and voltages at different parts of the wind energy conversion system. First, connecting 3-phase capacitors in the rotor circuit did not reduce the high transients due to wind speed variations, but only improved the system power factor. In the second method, 3-phase inductance is connected in series with the stator terminals. This method reduced these transients by 50% and improved the system power factor. The inductance value has to be limited to avoid deteriorating the generation system performance. Fault ride through is investigated after symmetrical and unsymmetrical faults by insertion of inductance at the stator terminals. This method led to suppress the induced over-voltages and, hence, over-currents in the rotor windings and converters.

A Real-Time Linearized Maximum Power Point Tracker for Photovoltaic System
Raseswari Pradhan, Bidyadhar Subudhi, Pravat Ray
National Institute of Technology, Rourkela, India

This paper proposes a novel linearized maximum power point tracking method for a photovoltaic system. This method involves first the linearization of the photovoltaic (PV) module and the DC-DC converter. Hence, difficulty in switching control due to highly non-linear and time-variant characteristics of PV module is removed. That results in. Further, for an efficient maximum power point tracking (MPPT) performance of the PV system. Then the MPPT operation can be accomplished efficiently with a simple PI-controller. The proposed linearized maximum power point tracking method has been tested using one mono-crystalline (BP350) and other multi-crystalline (SSI-M6-205) solar panels over varying environmental conditions over various practical operating regions of the solar module like solar radiations of 200 to 1000 watt/m2 and temperatures of -25 to 500C. The effectiveness of the proposed linearized maximum power point tracking method has been validated by experimental results of Opal-RT.
Controller Design for Music Playing Robot - Applied to the Anthropomorphic Piano Robot
Yen-Fang Li¹, Li-Lan Chuang¹
¹Chang Gung University of Science and Technology, Taiwan; ²Ming Hsin University of Science and Technology, Taiwan

In this paper, a hierarchical control structure, host controller (PC) and local controller (FPGA), is proposed to implement the anthropomorphic piano robot control with parallel controlling of two hands and ten fingers. The host PC is in charge of to integrate and encode the music codes of playing music to command the robot via the local controller, namely FPGA controller or distributed control module. The host controller is programmed with an intelligent algorithm to generate the music control code and an interactive man-machine interface. The intelligent algorithm will generate a series of optimum positions commands for the hands and fingers of the piano robot to play the piano. The series of optimum positions commands are programmed with crashing protection and minimum movement for the hands and fingers to anthropomorphize the robot.

In situ Capped GaN-Based Metal-Insulator-Semiconductor Heterostructure Field-Effect Transistor
Ping-Chuan Chang¹, Kai-Hsuan Lee²
¹Kun Shan University, Taiwan; ²National Synchrotron Radiation Research Center, Taiwan

In this study, AlGaN/GaN HFET with Mg-doped GaN cap layer was fabricated and characterized. Without activation, the Mg-doped GaN film is highly resistive and shown to reduce leakage current in AlGaN/GaN heterostructure. The enhancement of channel current and transconductance indicates that Mg-doped GaN is suitable to serve as semi-insulator beneath the gate and protect any surface modification which unavoidably resulted from air exposure or during the processing. It is promising for high-frequency and high-power applications towards the next-generation electronics.

The PC Based Human Interface for Arm Strength Training Machine
Tze-Yee Ho³, Po-Hung Chen², Chih-Hao Chiang³, Yuan-Joan Chen³, Mu-Song Chen¹
³Da-Yeh University, Taiwan; ²Feng Chia University, Taiwan; ³Ling Tung University, Taiwan

The establishment of interactive communication between ASTM and the people, will make the exercise and rehabilitation therapy become more friendly. This paper presents a friendly human interface for an arm strength training machine, in such a way to reduce the occurrence of improper operation of exercise machine by real time monitoring. The system hardware consists of a UART communication, ADC converter, Personal Computer (PC), and a PMSM motor drive which is basically realized by a microcontroller for simulating the weight stack. The system software for human interface is developed under PC and written in C language. The firmware of motor drive is programmed based on the MPLAB development tool by Microchip technology incorporate. Finally, a prototype of human interface arm strength training machine is realized and demonstrated. The experimental results show the feasibility and fidelity of the complete designed system.

A Novel Gate Driver with Output Possessing Triple Input Voltage and Negative Double Input Voltage
K. I. Hwu, Y. T. Yau
National Taipei University of Technology, Taiwan

This paper presents a gate driver, whose output possesses triple the input voltage and double the negative input voltage under only one positive-voltage source required. Such a gate driver can reduce the transient period of the gate driver and hence can reduce the corresponding switching loss. In addition, since double the negative input voltage is imposed on the input of the power switch during the turn-off period, the leakage current can be reduced, and hence the undesired energy loss can be decreased. The detailed
operating principles are illustrated and some simulated and experimental results are provided to verify the effectiveness of the proposed scheme.

**A Low Power Precise Current Balance LED Driver with -0.228% ~ 0.198% Imbalance Among Three Output Channels**
Yao-Chen Wang, Fajar Budiman, Ya-Ying Li, Poki Chen
*National Taiwan University of Science and Technology, Taiwan*

In this paper, a 3-channel LED driver with precise current balance is proposed. Artful layout topologies instead of complicated circuit structure are created and analyzed to achieve accurate current balance among LED channels with excellent insensitivity to PVT variations and small standard deviation for trimming-free bandgap reference voltage. With a high yield rate of 99.5%, the maximum imbalance among LED driving currents for 199 test chips is measured to be merely -0.228% ~ 0.198% which is not only much better than 2% deviation of the conventional one [1] but also very close to the simulated imbalance of -0.18% ~ 0.09% under gradients up to the 2nd-order. In addition, the 1.21V bandgap reference voltage accomplishes inaccuracy of 3.78% only. This circuit was fabricated in a Vanguard 0.5um 5V and 12V 2P3M process with a chip size of 1.25mm2. Except for the LED driving and setting currents, the power consumption is measured to be 340uW only.

**Frequency Characterizations of Voltage and Current Transducers for Evaluation of Phasor Measurement Units**
Saytaro Kon, Tatsuji Yamada
*National Metrology Institute of Japan / National Institute of Advanced Industrial Science and Techno, Japan*

This paper describes a phasor measurement unit (PMU) evaluation method and presents the measurement results of the frequency characteristics of an inductive voltage divider (IVD) and a current transformer (CT). Frequency characteristics up to 3 kHz of an IVD and a CT were evaluated in terms of PMUs, which play an important role in smart grids. The frequency characteristics of IVDs were found to be sufficient for the evaluation of PMUs, the results show that improvements in the frequency characteristics of current transducers are needed for successful PMU evaluation.

**Novel Transistor Composed of LED and Photodiode**
Kensho Okamoto, Junichi Fujita
*Kagawa University, Japan*

Bipolar junction transistor, such as PNP and NPN transistor, was invented by W. B. Shockley in 1948. Since the birth of transistor, the operation of such bipolar transistor have been explained by the behavior of electrons and positive holes in the emitter, base and collector regions for more than sixty years. Contrarily to this conventional theory on the junction transistor, the author has dared to establish a novel hypothesis that the operation of transistor can be explained by light emission and photovoltaic effect at the PN and NP junctions in the transistor.

**Phase Control Dimming Circuit Used the "Diristar" Composed of an LED and a Photodiode**
Junichi Fujita, Tetsuo Hattori, Kensho Okamoto
*Kagawa University, Japan*

Prof. Kensho Okamoto, who is one of the authors, has recently dared to establish a novel hypothetical theory that the operation of the bipolar junction transistor (BJT) can be explained by the light emission and the photovoltaic effect between the two junctions in the BJT. On the basis of this new hypothesis, he invented a novel amplifier consists of an infrared LED and a silicon photodiode[1-4]. He named the original amplifier “DISTAR or distar”. Also, Okamoto found that the distar became a thyristor under a certain condition and he named the novel thyristor “DIRISTAR”. This paper introduces the Diristar and its application.
**B4L-A  SS-5 Contactless power transfer and its related topics**

**Time:** Wednesday, April 24, 2013, 16:00 - 17:40  
**Place:** Conf. Room 11  
**Chair:** Hiroo Sekiya, Chiba University  
Hirohito Funato, Utsunomiya University

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**16:00  Fundamental Verification of a Single-to-Single Phase Direct Power Converter for Wireless Power Transfer Systems**  
Yuki Nakata, Yoshiya Ohnuma, Koji Orikawa, Goh Teck Chiang, Jun-Ichi Itoh  
Nagaoka University of Technology, Japan

This paper proposes a single-to-single phase power converter based on the indirect matrix converter, an active buffer and boost chopper. PDM control which can achieve zero voltage switching, is applied to the inverter. From the simulation results, the operation to compensate the power ripple is confirmed because the DC link current is controlled approximately 0.5 A constantly. However, there is the 35% of the current ripple because of the quantization error. Additionally, the THD of the output voltage and input current are 4.9% and 42.7% respectively. As a result, a validity of the proposed circuit was confirmed.

Yasuyoshi Kaneko, Shigeru Abe  
Saitama University, Japan

A wireless power transfer system is desirable for the recharging of electric vehicles. The system for electric vehicles requires a high efficiency, a large air gap, and a good tolerance to lateral misalignment and needs to be compact and lightweight. This paper describes the characteristics of wireless power transfer system, the subject and solution in the case of applying to electric vehicles. Especially, the difference of characteristics of single-sided winding transformer and double-sided winding transformer is detailed. And new trends of the wireless power transfer system for electric vehicles are introduced.

**16:50  Analysis of Transfer Power of Capacitive Power Transfer System**  
Hirohito Funato, Hiroya Kobayashi, Tatsuaki Kitabayashi  
Utsunomiya University, Japan

Inductive power transfer (IPT) is currently the most popular way to realize wireless power transfer. There is another way called capacitive power transfer (CPT) using electric field. There are only few studies about CPT because of small power density due to small coupling capacitance. In order to overcome this problem, a lot of CPT system were proposed using LC resonance. The authors have proposed a CPT system using one pulse switching active capacitor (OPSAC). In this paper, transfer power of CPT system is analyzed with comparison between CPT with LC resonance and CPT with OPSAC.

**17:15  Numerical Derivations of Locking Ranges for Injection-Locked Class-E Oscillator**  
Tomoharu Nagashima, Xiuqin Wei, Hisa-Aki Tanaka, Hiroo Sekiya  
1Chiba University, Japan; 2Fukuoka University, Japan; 3University of Electro-Communications, Japan

This paper presents numerical derivations of locking ranges for the injection-locked class-E oscillator with various injection-signal waveforms. The class-E oscillator achieves high-power-conversion efficiency at high frequencies by satisfying the class-E ZVS/ZDS conditions. The operating frequency of the class-E oscillator is synchronized with the frequency of a injection signal into MOSFET gate terminal, if the signal falls within the locking range. Locking ranges are investigated and discussed by injecting various types of injection signals. It is seen from the results that the locking range becomes wide as the fundamental-frequency component of the injection-signal waveform is large.
16:00  Phase-Shifted PWM Strategy of a Seven-Level Single-Phase Current Source Inverter for Grid-Connection Systems  
Napaphat Lekgamheng, Yuttana Kumsuwan  
Chiang Mai University, Thailand

This paper presents a detailed analysis of a seven-level single-phase current source inverter for grid-connection systems. The aim of this research was to control high power factor operation, injecting a sinusoidal current flowing into the utility grid. The proposed two-stage power conversion strategies consisted of a dc-dc multilevel converter and a current source inverter, which operated with high switching and line frequency. A proposed topology is used to produce a seven-level current output with a phase-shifted PWM technique. A simple method is presented to improve the total harmonic distortion and power factor requirement. The feasibility of the proposed method was verified by simulation and experimental results.

16:25  Fabrication and Evaluation of SiC Inverter Using SiC-MOSFET  
Akinari Yamane, Keisuke Koyanagi, Masahiro Kozako, Kiyotaka Fuji, Masayuki Hikita  
Kyushu Institute of Technology, Japan

In this paper, device characteristics of SiC-MOSFET (600V, 10A) and efficiency characteristics of SiC inverter when the motor is driven were performed as compared respectively with Si-MOSFET and Si inverter. As the result, it was found that the on-resistance of SiC-MOSFET is smaller than that of Si-MOSFET, and the switching loss of SiC-MOSFET is approximately 1/3 compared with Si-MOSFET. Also, it was found that the SiC inverter is operated at high efficiency about 7.3% than the Si inverter at the switching frequency of 100kHz.

16:50  A New Dual Mode Current Phasor-Controlled ZVS High-Frequency Resonant Inverter for Induction Heating  
Tomokazu Mishima1, Chikanori Takami2, Mutsuo Nakaoka2  
1Kobe University, Japan; 2Kyungnam University, Korea, South

novel soft-switching high-frequency (HF) resonant (HF-R) inverter for induction heating (IH) is presented in this paper. By adopting the phase shift (PS)-based current phasor (CP)-controlled, the IH load resonant current can be continuously regulated under the wide-range soft-switching conditions. In order to improve the conversion efficiency in the light load region, the pulse-density-modulation (PDM) is employed for the CP-controlled HF-R inverter, thus creating PS & PDM dual mode CP-control scheme. The essential performances on the output power regulation and soft-switching operations are demonstrated in experiments using a 1kW-60kHz prototype, and then its topological validity is evaluated from the practical point of view.
B4L-C  Switched Reluctance Motor Drives
Time:  Wednesday, April 24, 2013, 16:00 - 17:40
Place:  Conf. Room 21AB
Chair:  Kan Akatsu, Shibaura institute of technology

16:00  A Study of Rotor Position Control for Switched Reluctance Motor
Yoshitaka Niwa, Takashi Abe, Tsuyoshi Higuchi
Nagasaki University, Japan

Switched Reluctance Motor (SRM) has a lot of attention and many research institutions investigate actively
in vehicle applications. If assuming the application to servo system, the SRM has many advantageous. Our
research group starts to build up the position control system for SRM. This research aims to clarify the
position control capability at the arbitrary rotor position. This paper explains the experimental position
control system and verifies this system using conventional position control method and non-complement
drive method. And the experimental results shows the position control capability at arbitrary rotor position.

16:25  On the Improvement Performance of a Dual Rotor Segment Type SRM
Yuma Yoshimaru, Tsuyoshi Higuchi, Yuichi Yokoi, Takashi Abe
Nagasaki University, Japan

The authors proposed a dual rotor segment type novel switched reluctance motor to decrease the copper
loss. We calculated the characteristics of the motor by using 2-Dimensional (2-D) and 3-D finite element
method (FEM). As a result, The average torque of the 3-D model was decreased to comparing with the 2-D
model because of the influence of the leakage flux coil end. In this paper we propose the performance
improvement method and confirm it using the FEM analysis.

16:50  Precise Pulewise Current Drive of SRM Under PWM Control
Yu Kuwahara1, Takahiro Ono2, Takashi Kosaka3, Nobuyuki Matsui4, Hiroshi Shimada5
1Fuji Electric Co. Ltd., Japan; 2Nagoya Institute of Technology, Japan

In this paper, a precise pulsewise current drive for SRM under sub-harmonic PWM control with 8kHz carrier
frequency and fixed bus voltage is presented. The sub-harmonic PWM control requires adequate voltage
reference, that is, PWM duty ratio according to given operating condition. In the proposed control, the
adequate voltage reference is calculated based on an analytical model of non-linear magnetizing curves of
target motor. Some experimental investigations using 20kW SRM into drive performances in terms of torque
ripple and noise are demonstrated.

17:15  PWM-Based Instantaneous Current Profile Tracknig Control for Torque Ripple Suppression in
Switched Reluctance Servomotors
Hiroaki Makino1, Takashi Kosaka1, Nobuyuki Matsui1, Masayuki Hiyama3, Motomichi Ohto2
1Nagoya Institute of Technology, Japan; 2Yaskawa Electric Corporation, Japan

This paper presents PWM-based tracking control of instantaneous current profile for torque ripple
suppression of the developed four-phase SR servomotor. In the proposed method, the controller determines
the instantaneous current profile for a given torque command and rotor position, which minimizes torque
ripple. Then, the controller calculates the instantaneous applied voltage command which is determined
based on the voltage equation derived from non-linear magnetizing curve model. The instantaneous
applied voltage reference is realized under conventional PWM control. Experimental studies using the
developed four-phase test motor show that the measured current waveforms can accurately track the
instantaneous reference current profiles.
An improved quick detection method for fundamental wave and harmonics in single-phase AC source is presented. Single-phase inverter produces amount of harmonic, which directly affects the quality of electric energy[1-3]. This paper propose an improved method, which can fully detect the fundamental wave and harmonic. The method applies orthogonal transformation theory. The principle is demonstrated, and the results of Matlab simulation is presented to verify the validity of proposed theory.

When distributed generators are connected to the grid, it is required that the system withstand to the voltage dip caused by the grid failure. This is known as low voltage ride through (LVRT). It is no evidence that the PLL behaves correctly at voltage dip, since the input voltage of the PLL vanishes. The VSG model itself can behaves like PLL, since the electromagnetic torque is determined by synchronizing torque of the VSG. In this paper, a VSG control without PLL is proposed. Using this control, the operation of inverter can be continued if a severe voltage dip.

A finite-time settling response with three sampling periods in case of the LCL filter is considered as a time-optimum response. We have already developed a simple deadbeat current control scheme with both accuracy and high responsiveness for a grid-connected inverter with an LCL filter. The manipulated value i.e. the inverter output voltage is simply calculated using the state feedback equation. In this paper, the features of the deadbeat control are summarized.
Multi-level and Multi-phase Converters

Time: Wednesday, April 24, 2013, 16:00 - 17:40
Place: Conf. Room 33
Chair: Yi-Hua Liu, National Taiwan University of Science and Technology
Noriko Kawakami, Toshiba Mitsubishi-Electric Industrial systems corporation

16:00 Modular Multilevel Matrix Converter for Low Frequency AC Transmission
Yushi Miura, Tomoya Mizutani, Michitaka Ito, Toshifumi Ise
Osaka University, Japan

The modular multilevel matrix converter (MMMxk) that consists of a number of H-bridge cells as bidirectional switches is one of very promising ac-to-ac converters for the frequency converter of low frequency ac transmission system (1 Hz~20 Hz), because a high voltage and high power converter is easily realized by connecting H-bridge cells in series. In this paper, a new scheme of power and capacitor voltage control for the MMMxk is proposed and its characteristics are investigated especially under low frequency operation. In addition, experiments are carried out to verify the proposed control schemes using a 1 kW class laboratory setup.

16:25 Analysis and Implementation of a Three-Phase Voltage-Doubler Soft-Switching Active Power Filter
Maoh-Chin Jiang, Jing-Jhu Jhan, Bing-Jyun Shih, Kao-Yi Lu
National Ilan University, Taiwan

The system analysis and circuit implementation of a three-phase voltage-doubler soft-switching active power filter (Vdssapf) comprising four main switches and four auxiliary switches is proposed in this paper. All main switches in the proposed Vdssapf operate at zero-voltage-switching (ZVS) turn-on, while the auxiliary switches operate at zero-current-switching (ZCS) turn-off. The reduction in the number of switches can also increase the reliability, since the control circuits are thereby reduced to two sets. Moreover, the proposed Vdssapf can compensate the current harmonics, improve the power factor and balance the unbalanced load. Additionally, the dedicated control circuit required for soft-switching active power filter operation is implemented using a FPGA circuit, reducing overall system cost and complexity. Finally some experimental results for a 500 W prototype are presented to verify the theoretical analysis and system performance.

16:50 Design and Implementation of Power Converters for Wind Generator with Three Phase Power Factor Correction
Chih-Chiang Hua, Yi-Hsiung Fang, Wei-Tze Chen, Lyu-Jhih Wang
National Yunlin University of Science and Technology, Taiwan

The implementation of power converter for wind generator controlled by digital signal processor is presented in this paper. The proposed system is composed of a wind generator, lead-acid batteries, a three phase ac/dc full-bridge semicontrolled boost rectifier, a dc/dc single-ended primary inductance converter (SEPIC), a bi-directional converter and a full-bridge inverter. The wind generator is used as the main power source, and lead-acid batteries as the auxiliary power source. The proposed system adopts power factor correction to achieve unit power factor and maximum power point tracking (MPPT) to implement available maximum power, thus to improve the overall system performance. In addition, the bi-directional converter provides charging and discharging compensation to dc bus by controlling the duty cycle of switches. Finally, the full-bridge inverter produces a stable ac output with feedback.
B4L-F  Control of Power Converter III
Time:  Wednesday, April 24, 2013, 16:00 - 17:40
Place:  Conf. Room 32AB
Chair:  Fujio Kurokawa, Nagasaki University

16:00  A Novel PWM Strategy of Bidirectional AC/DC Converters for Micro Grid System
Yi-Hung Liao¹, Ming-Chieh Cheng²
¹National Penghu University of science and Technology, Taiwan; ²National Tsing Hua University, Taiwan

In this paper, a novel simplified PWM strategy is proposed for the bidirectional ac/dc single-phase converter in the micro-grid system. Then, the operation mechanism of the novel simplified PWM is clearly explained. It is obvious that the switching numbers of the novel simplified PWM strategy are only one-fourth that of the conventional unipolar PWM and bipolar PWM. Based on the novel simplified PWM strategy, a feasible feed-forward control scheme is also developed to achieve better performance in both rectifier mode and inverter mode operation compared with the conventional dual control scheme. In addition, the proposed simplified PWM strategy with proposed feed-forward control scheme possesses lower total harmonic distortion than bipolar PWM, and higher efficiency than unipolar and bipolar PWM. Finally, a prototype system is constructed, and the control scheme is implemented using FPGA Spartan-3E XC3S250E. Both simulation and experimental results verify the validity of the proposed PWM strategy and the control scheme.

16:25  Input Power Factor Control of Bi-Directional AC/DC Converter
Balaji Veerasamy, Wataru Kitagawa, Takaharu Takeshita
Nagoya Institute of Technology, Japan

The paper describes the method for the control of the input power factor for a variable voltage AC/DC converter under different output voltage conditions. The proposed PWM strategy also suppresses the output voltage ripple with a reduced number of commutations. The proposed control method is verified by the experimental results.

16:50  Seamless Dynamic Model for Bi-Directional DC-DC Converter
Yasutaka Imamura, Husam A. Ramadan, Sihun Yang, Gamal M. Dousoky, Masahito Shoyama
Kyushu University, Japan

In this paper, a bi-directional DC-DC converter is analyzed using a seamless dynamic model with an independent voltage source and an independent current source, which polarity depends on the direction of the power flow. In the seamless dynamic model, the independent voltage source represents a battery and an independent current source represents the load or energy source. A small signal model is derived using a state space averaging method. Simulated results about the transient response characteristics are presented.

17:15  Regulation Characteristics of Fast Response Digitally Peak Current Controlled DC-DC Converter
Fujio Kurokawa, Haruki Tamenaga, Yuichiro Shibata, Yoshihiko Yamabe
Nagasaki University, Japan

This paper discusses regulation characteristics of proposed fast response digitally peak current controlled DC-DC converter. In the proposed method, the peak current is able to be detected in real time by using the voltage controlled oscillator (VCO) which is very low cost and a high speed A-D converter. In simulation and analysis results, it is revealed that the proposed control circuit has the sufficient resolution of the output voltage. In addition, the analysis give close agreement with the simulation results.
Design of Sliding Mode Observers with Single Compound Manifolds for State Estimation of the Induction Motor Drive
Mihai Comanescu
Penn State Altoona

The paper discusses the problem of state/rotor flux angle estimation for the induction motor (IM) drive and presents a series of Sliding Mode (SM) observers that are constructed using compound manifolds. The observers use the model of the IM in the stationary reference frame - their behavior and estimation properties are discussed. Observers with compound manifolds have not been widely investigated because they cannot be designed using a standard procedure; however, they have interesting properties. The paper shows candidate manifolds and explains the approach for designing IM observers with compound manifolds. A class of observers and their versions are presented. In the paper, several sensed SM observers are presented first. Then, it is attempted to transform them into sensorless observers by replacing the measured speed with a speed estimate (which is assumed inaccurate). The paper finds a certain design has desirable properties — using an improper speed value, its estimated fluxes are in phase with the real fluxes. Using direct field orientation, the rotor flux angle obtained is accurate and this can be used for sensorless field orientation.

Design of a Double Manifold Sliding Mode Observer for Speed and State Estimation of the Induction Motor
Vadim Kachkovskiy, Mihai Comanescu
Penn State Altoona, United States

The paper discusses the problem of speed and state estimation for the induction motor (IM) drive and presents a double-manifold Sliding Mode observer. This is obtained by adding extra feedback terms to a single-manifold observer design. Both designs are based on the model of the IM in the stationary reference frame. The observer uses compound manifolds which are constructed as a combination of the estimated states and mismatches. Observers with compound manifolds have not been widely investigated because they cannot be designed using a standard procedure; however, they may have very interesting properties. The paper investigates the behavior of a single-manifold observer first; it is shown that this only converges partially and provides an approximate speed estimate. Based on this, a double-manifold observer is designed. This estimates the fluxes, drives the current mismatches to zero and yields an accurate speed estimate. The method is applicable in a sensorless IM drive control algorithm where the speed, the flux magnitude and the rotor flux angle are needed. The theoretical developments are supported with simulations.

Optimal Torque and Rotating Speed Trajectories Minimizing Energy Loss of Induction Motor Under Both Torque and Speed Limits
Kaoru Inoue, Keito Koteru, Yuji Asano, Toshiji Kato
Doshisha University, Japan

In order to drive the electric machines using the motors efficiently, the energy loss should be minimized during its operation. It has been reported that the design methodology of the optimal torque and rotating speed trajectories to minimize the energy loss of the induction motor (IM) drive system when the operation time, rotating speed, and rotational angle are given as drive conditions. However, the amplitude of the obtained optimal torque trajectory may exceed the maximum rating torque of the motor. The obtained optimal rotating speed trajectory also may exceed the maximum acceptable rotating speed of IM. This paper proposes a design methodology of the optimal trajectories for IM drive system by means of the variational method and the Newton-Raphson iteration when both the torque amplitude and the rotating
speed limits are given simultaneously. The drive condition of the rotating speed will be relaxed to a case that the initial and the objective rotating speed can be set as the arbitrary values.

17:15 A Novel Single to Two-Phase Matrix Converter for Driving a Symmetrically Designed Two-Phase Induction Motor
Yuji Kudoh¹, Nobuyuki Otsuka², Kenji Mizutani², Toshimitsu Morizane¹
¹Osaka Institute of Technology, Japan; ²Panasonic Corporation, Japan

We propose a novel single to two-phase matrix converter (iS2MC) for driving a symmetrical two-phase induction motor. Matrix converter (MC) technology is already used in industrial applications, but is limited to three-phase induction motor with three-phase power line. The iS2MC, which consists of 8 bi-directional switches, enables a two-phase induction motor to be driven by single-phase power line without smoothing capacitors for the first time. The iS2MC generates independent two phase voltages controlled by a simple switching algorithm, which is designed to hold the switching state for a period of the output source to decrease switching loss. The two-phase motor driven by iS2MC eliminates start-run capacitors and produces more torque than the three-phase motor. The performance of the iS2MC system with symmetrical two-phase induction motor was confirmed by both simulation and experiment. The full paper will present the conversion efficiency, the torque for various loads, and the effective range of the rotational speed for the iS2MC system.
**C1L-A  DC/DC Converter Control**

**Time:** Thursday, April 25, 2013, 09:00 - 10:40  
**Place:** Conf. Room 11  
**Chair:** Ashoka Bhat, University of Victoria

### 9:00  
**A New Digital Soft Start Circuit for Parallel Current Mode DC-DC Converter**  
Fujio Kurokawa, Suguru Sagara  
Nagasaki University, Japan

This paper presents a new digital soft-start circuit for parallel current mode dc-dc converter. For soft-start operation, it is important to detect the load. In the conventional method, the fixed parameter of the soft-start circuit must be set. In the proposed control, the load can be calculated with the output voltage and output current. The optimal upper limit of the digital feedback can be decided by load value. Compared with the optimal upper limit to the digital feedback value, the digital value of the switching signal is determined. It is confirmed that the proposed digital control method has superior soft-start characteristics from the simulation results.

### 9:25  
**Digital Dead-Time Control for Two Phase Double-Ended Forward Converter**  
Yonezawa Yu, Nakao Hiroshi, Tomotake Sasaki, Nakashima Yoshiyasu, Tsugito Maruyama  
Fujitsu Laboratories, Japan

A two-phase double-ended forward converter is suitable for a more than 2-kW high-efficiency power supply. A feature of a double-ended forward converter is low surge voltage on the primary-side FET that enables the use of low-voltage FETs with low resistance. They reduce the resistive loss. However, there is an issue of the circuit, that the body diode of synchronous rectifier FETs have power loss. To reduce the dead-time loss, we propose a precise digital dead-time control method. The loss at half load was reduced from 59 W to 53 W which correspond to estimated loss reduction effect.

### 9:50  
**Digital Voltage-Mode Controller for Zero-Current Transition Fourth-Order Boost Converter**  
Mummadi Veerachary, Mallesham Myla  
Indian Institute of Technology Delhi, India

In this paper a robust digital voltage-mode controller is designed for a Zero Voltage Transition fourth-order boost converter. The proposed boost converter has low source current ripple together with conventional boost converter voltage gain property. Additionally, it exhibits reduced switching losses on account of zero voltage transition behavior. This converter circuit exhibits seven different modes of operations in one switching cycle and also results in zero-voltage transition to the switching devices. As there are several operating modes in one switching cycle the small-signal z-domain transfer functions are formulated using MATLAB based system identification toolbox, and then used in the direct digital controller design. A pole-zero placement technique is adopted to arrive at final digital voltage mode controller and then an edge theorem is employed for testing the robustness of the controller. Closed-loop converter performance is predetermined for a 24 to 42 V, 50 W prototype in simulation and then compared with experimental measurements. Experimental measurements are in close agreement with simulations.

### 10:15  
**Robust Digital Controller for Fourth-Order Bidirectional Charger/ Discharger**  
Mummadi Veerachary, Praveen Kumar Veeravalli  
Indian Institute of Technology Delhi, India

A 4th order bidirectional converter for charger/ discharger (BCDR) applications is proposed and then robust controller is designed. The advantages and limitations of the proposed converter are compared with the conventional charger/dischargers. Discrete-time modeling and the expressions for small-signal transfer functions of the proposed BCDR are derived using state-space analysis. Based on the discrete-time models controllers for both the charging and discharging modes are designed. Then the robustness of the designed controllers is verified and necessary and sufficient conditions on nominal performance, robust stability and the robust performance conditions are obtained. Robustness of the designed controllers is verified through time-domain simulations and then compared with experimental results.
C1L-B  Soft Switching DC/DC Converters II
Time: Thursday, April 25, 2013, 09:00 - 10:40
Place: Conf. Room 22
Chair: Kimihiro Nishijima, Oita University

9:00  Push-Pull Zero-Voltage Switching Resonant DC-DC Converter Based on Half Bridge Class-DE Rectifier
Ratchuruethai Thippayanet1, Chainarin Ekkararodom1, Kamon Jirasereamornkul1, Kosin Chamnongthai2, Marian K. Kazimierczuk4, Kohji Higuchi3
1King Mongkut's University of Technology North Bangkok, Thailand; 2King Mongkut's University of Technology Thonburi, Thailand; 3University of Electro-Communications, Japan; 4Wright State University, United States

This paper presents an analysis of parasitic capacitances in resonant rectifier which has significant impact on the operating point of the resonance circuit, which the junction capacitance is to decrease the resonant current and DC output voltage in the circuit at switching frequency less than resonant frequency. This can be represented by simplified series resonant equivalent circuit and voltage transfer function versus normalized operating frequency at varied values of resonant capacitor. The step-up resonant push-pull DC/DC converter was used as design example. The design procedure is based on the principle of the half bridge class-DE resonant rectifier. All power switches are operated under the zero-voltage switching conditions, resulting in higher overall system efficiency. The prototype of resonant DC/DC converter was operated at 62-88 kHz variable frequency, the input voltage of 12-VDC, the output voltage of 380-VDC and the output power rated of 150 W. The experimental results have shown that 92.97% efficiency at full power. The experimental results are presented to verify the theoretical analysis.

9:25  Design of Dimmable LED Lighting Driving Circuit for Battery Power Source
Yong-Nong Chang3, Chih-Ming Kuo3, Hung-Liang Cheng1, Ching-Ran Lee2
1I-Shou University, Taiwan; 2Industrial Technology Research Institute, Taiwan; 3National Formosa University, Taiwan

In this paper, the design of dimmable LED lighting driving circuit for battery power source is proposed. In this research, Class-E resonant converter is the electricity power conversion circuit for achieving high efficiency. By applying multiple series transformers with three windings to driving multiple LED lighting lamps which can improve current uniformity and increase operating reliability. Furthermore, integral cycle switching technique will be utilized to implement the dimming design. Finally, the simulation results show the dimming circuit which can promote the operating efficiency with dimmable control, which can effectively promote the operating efficiency.

9:50  Novel Zero-Current / Zero-Voltage Transition DC-DC Converter
Thilak Senanayake
Denso Corporation, Japan

A new class of zero-current transition (ZCT) and/or zero-voltage transition (ZVT) turn-on and turn-off switching together main switch of the DC-DC converter is presented. In addition, all semiconductor devices operate under soft-switching, and they are not experienced any additional voltage stresses. The new converter is capable of regulating the output voltage for a wide load and input voltage range, while maintaining the stability of the system. The theoretical analysis of a converter is presented and is verified by experiment of 60-600V/15V, 30-300mA DC-DC buck converter. The 18% increases of overall efficiency is achieved with compared to the hard-switching converter.

10:15  Modeling and Analysis of New Zero Current Transition SEPIC Converter
Mummadi Veerachary, Manasvi Goyal, Hemant Raghuwanshi
Indian Institute of Technology Delhi, India

In this paper, modeling and analysis of a new Zero current Transition (ZCT) SEPIC Topology is proposed. It gives reduction in the auxiliary elements current ratings, which leads to lower conduction losses and
improved converter efficiency. In addition, a reduction in size of auxiliary magnetic elements can be accomplished. The converter with the proposed ZCT soft-switching can operate with soft-switching for wide line and load ranges at considerably high frequencies. The operation principles, a detailed analysis and a soft switching resonant circuit design procedure of proposed zero current transition converter are presented. A 100 W, 50 kHz ZCT-SEPIC prototype circuit is built and tested. The proposed design methodology is verified both in simulation and experiments for different loading conditions. Measurement observations are in close agreement with the simulation and analytical predictions.
C1L-C  Motor Design
Time:  Thursday, April 25, 2013, 09:00 - 10:40
Place:  Conf. Room 21AB
Chair:  Kan Akatsu, Shibaura institute of technology

9:00  Study of the Further Reduction of Shaft Voltage of Brushless DC Motor with Insulated Rotor Driven by PWM Inverter
Yoshinori Isomura¹, Kichiro Yamamoto¹, Shigeo Morimoto², Tatsuo Maetani³, Akihiko Watanabe⁴, Keisaku Nakano⁴
¹Kagoshima University, Japan; ²Osaka Prefecture University, Japan; ³Panasonic Corporation, Japan

Authors succeeded in reduction of the shaft voltage of a motor with an insulated rotor driven by PWM inverter previously. This paper proposes a new method of further reduction of the shaft voltage of the motor with the insulated rotor. A non-grounding common-mode equivalent circuit of the motor is examined, and the effect of the further reduction by a new method is verified by calculation of the shaft voltage from the equivalent circuit and measurement of the shaft voltage of the motor.

9:25  A Study on the Rotor Design of the Synchronous Reluctance Motor for EV and HEV Propulsion
Taiki Satou, Shigeo Morimoto, Masayuki Sanada, Yukinori Inoue
Osaka Prefecture University, Japan

Flux barrier type SynRM has been studied remarkably to realize an inexpensive variable speed motor. This motor has slits in rotor and can use only the reluctance torque generated by the magnetic saliency of the rotor. For the application of an electric vehicle and a hybrid electric vehicle, high torque and high power density are required, thus the rotor of SynRM have to be designed optimally. In this paper, to find out how to realize a high torque SynRM for EV and HEV applications, influences of number of flux barrier layer, ratio of slit width to rib width, center rib width are analyzed using 2-D finite element method.

9:50  Analytical Prediction of EMF Waveform and Harmonics in Surface PM Machines with Radial Magnetization
Maxime Dubois
Université de Sherbrooke, Canada

An analytical expression is developed for predicting electromotive force (emf) waveforms and flux linkage resulting from permanent magnets (PM) in electrical machines. The expressions are based on a volume integral over the magnet volume, rather than the usual surface integral over the coil. The specific case of surface-mounted arc PM with radial magnetization is analyzed. A slotless stator with infinitely thin winding distribution is considered. The stator chording factor, slot factor and spread factor are included in the analytical expression. The emf waveform predicted analytically is validated by comparing with a computation using the finite element method and with experiment.

Mohammad Reza Zare⁵, Misron Norhisam⁵, Chockalingam Aravind Vaithilingam⁵, R.N. Firdaus⁵, Ishak Aris⁵, Norman Mariun³, Hioyuki Wakiwaka³
¹Shinshu University, Japan; ²Taylor’s University, Malaysia; ³Universiti Putra Malaysia, Malaysia

An optimal chopping strategy to enhance the ratio of pull-in thrust to input power for the high density transverse flux linear motor is presented. The high density transverse flux linear motor is a novel machine combining the characteristics of the high density linear motor and the transverse flux linear machines. If the ratio of the pull-in thrust to the input power is made higher then the machine performance can be improvised to a greater extent. In this investigation the single pulse given to the drive element is modulated for the reduction in the power consumption. Experimentation is performed under different load condition until the motor come to the standstill value. The results show that the utilization of the optimal chopping strategy improvised the ratio of pull-in thrust to power consumed during the start time is about 5.5% higher value while the input power consumed is reduced by 19.82%. The efficiency of motor under the optimal chopping mode is 5.52% higher than using the conventional nominal applied voltage.
Optimal Operation for Renewable Energy

Time: Thursday, April 25, 2013, 09:00 - 10:40
Place: Conf. Room 21CD
Chair: Tomonobu Senjyu, University of the Ryukyus

9:00  **Thermal Units Commitment with Demand Response to Optimize Battery Storage Capacity**
Ryosuke Kyoho, Tomonori Goya, Wang Mengyan, Tomonobu Senjyu, Atsushi Yona, Toshihisa Funabashi, Chul-Hwan Kim

Meidensha Corporation, Japan; Okinawa Electric Power Company, Japan; Sungkyunkwan University, Korea, South; University of the Ryukyus, Japan

Recently, the deregulation in power market increase competition in retail. Therefore, power company needs to reduce operational cost. For the operation of the thermal generating units, it is important to satisfy transmission constraint. One of the system to satisfy transmission constraint is the battery storage system. However, the battery storage system requires high cost, therefore, it is impossible to introduce the large capacity of the battery storage system to power system. This paper introduces the demand response system to the thermal units commitment program. The demand response system can reduce the additional battery storage system capacity to satisfy transmission constraint.

9:25  **Control Strategy of Solar/Wind Energy Power Plant with Supercapacitor Energy Storage for Smart DC Microgrid**
Suwat Sikkabut, Nisai H. Fuengwarodsakul, Panarit Sethakul, Phatiphat Thounthong, Serge Pierfederici, Melika Hinaj, Babak Nahid-Mobarakeh, Bernard Davat

France; King Mongkut’s University of Technology North Bangkok, Thailand; Université de Lorraine, France

This paper presents an original control algorithm for a hybrid energy system with a renewable energy source: a photovoltaic (PV) array and a wind turbine (WD). A single storage device, a supercapacitor (SC) module, is in the proposed structure. The very fast power response and high specific power of a SC complements the insufficient power output of the main sources. Experimental results with small-scale devices, namely, a wind turbine generator (500 W), a photovoltaic array (800 W, 31 A) manufactured by the Ekarat Solar Company and a SC module (100 F, 32 V), illustrate the excellent control-system during load cycles.

9:50  **Optimization of the VRB-ESS Integrated Hybrid Power System for Building Applications**
Wynn Chen, Jiyun Zhao, K.J. Tseng, Kian Wee Ng, Willie Tan Wee Lip, Rao Yimin

JTC Corporation, Singapore; Nanyang Technological University, Singapore

The vanadium redox flow battery energy storage system (VRB-ESS) has to date shown the greatest potential for large-scale energy storage applications, which is low cost, safe, environmental friendly. This paper investigates the economic performances of the VRB-ESS integrated hybrid power system (HPS) for a typical building in Singapore. The energy sources of the building include solar PV, VRB-ESS and the national grid power (NGP). This paper analyzes the interaction among components of hybrid power system, as well as the relative size of the components that is used efficiently at an optimum rate. Using developed Microsoft excel methodology, the different HPSs have been simulated for the building load profile and aim to optimize the levelized unit energy cost — US$ per kWh for each configuration of HPS.

10:15  **Optimal Operation of Thermal Generating Units and Smart Houses Considering Transmission Constraints**
Ryosuke Kyoho, Tomonori Goya, Wang Mengyan, Tomonobu Senjyu, Atsushi Yona, Toshihisa Funabashi, Chul-Hwan Kim

Meidensha Corporation, Japan; Okinawa Electric Power Company, Japan; Sungkyunkwan University, Korea, South; University of the Ryukyus, Japan

Fuel exhaustion and global warming is increasing, therefore, the renewable power plant is introduced to the power system. The generated power of the large capacity renewable energy plant reads to the violated
transmission constraint in thermal unit commitment program, therefore, the transmission constraint should be considered. This paper focuses on the optimal operation of the thermal units incorporated controllable loads such as electrical vehicle (EV) and heat pump (HP) considering the transmission constraints. The proposed method is compared with the power flow in thermal units operation without controllable loads and the optimal operation without the transmission constraints.
9:00  New AC/DC Converter Considering Both Inrush Current Limitation and Start-Up Time
Chien-An Lai, Yen-Shin Lai
National Taipei University of Technology, Taiwan

The main theme of this paper is to present a new AC/DC converter considering both inrush current limitation and start-up time. The presented converter consists of conventional power factor corrector, an auxiliary circuit and additional power device, e.g. MOSFET, which is connected in series with input capacitor of PFC. The power device operates in linear region during start-up process in order to limit inrush current and then is fully turned on to reduce conduction power loss. The effectiveness of the proposed new AC/DC converter, including inrush current limitation and start up time improvement, will be confirmed by simulation and experimental results. It will be shown that the inrush current is 2A and start-up time is less than 1 sec for 450 W AC/DC converter with input voltage = 230 V and output voltage = 12V.

9:25  Standby Consumption Reduction for Capacitive Power Supplies
Laurent Gonthier, Antoine Passal
STMicroelectronics, France

Most appliances, where a low current in the range of 10 mA to 50 mA is required to supply the control circuit, are still, even today, using capacitive power supplies. These appliances are for example, coffee machines, food processors, room heaters, hand dryers or low-end fridges. It is becoming more and more difficult to fulfill stand-by power standard requirements with such capacitive power supplies. We explain here how capacitive power supplies can be modified to better meet these requirements or to increase their output current capability while maintaining power consumption during stand-by operation mode at a low level.

9:50  Design of a PT-Based Resonant Inverter for Ozone Generation with Flexible Capacity Operations
Fu-Sheng Pai¹, Shyh-Jier Huang¹, Tsong-Shing Lee¹
¹National Cheng Kung University, Taiwan; ²National University of Tainan, Taiwan

This paper proposes a piezoelectric inverter of varying-capacity for ozone generations. It was known that the drawback of a piezoelectric transformer (PT) lies in its limited ability to transfer power, rendering it unable to provide sufficient current. Therefore, the study proposes a resonance topology with multiple modular parallel PTs using a PT-equivalent circuit derivation, anticipating reaching the flexible expansion of the output capacity while stabilizing the resonance characteristics and mechanical frequency. In addition, the study embeds an asymmetrical pulse width modulation (APWM) control into the microprocessor unit such that the operating power of the ozone generator can be well regulated. In order to confirm the effectiveness of this method, it was realized with hardware circuit verification. Experimental results demonstrate that the proposed inverter effectively drives the ozone generator system, regulates the operation power, and achieves the zero-voltage switching (ZVS). This design also ensures that the output current of each PT is evenly balanced, thereby facilitating the approach for industry applications.
9:00  An Improved DC Capacitor Voltage Balancing Strategy for PWM Cascaded H-Bridge Converter-Based STATCOM
Yichao Sun, Jianfeng Zhao, Zhendong Ji, Xiaojun Yao, Zean Zhu
Southeast University, China

An improved dc capacitor voltage balancing method for PWM cascaded multilevel STATCOM is proposed in this paper. Based on the principle of vector analysis, vector reconstruction technology is adopted to built up the whole control sheme, and result in a better performance than that using other balancing method which is proposed before. Moreover, the analysis results including control area are validated through simulation and experiment completely.

Wen-Jer Chang, Bo-Jyun Huang
National Taiwan Ocean University, Taiwan

A passive fuzzy controller design methodology is developed in this paper to achieve state variance constraint for a nonlinear synchronous generator system, which is modeled by a Takagi-Sugeno (T-S) fuzzy model. The proposed fuzzy controller is constructed by the concept of Parallel Distributed Compensation (PDC). Based on the Lyapunov theory, the sufficient conditions are derived to guarantee the stability of the closed-loop system. Besides, the passivity and variance constraints are also considered in this paper.

9:50  Direct Single Phase AC-AC Dynamic Voltage Restorer
Eimi Diyana Rosli, Muhamad Nabil Hidayat, Rahimi Baharom
Universiti Teknologi MARA, Malaysia

This paper focus on a study of a direct single phase dynamic voltage restorer (DVR) with direct alternating current (ac-ac) converters without the use of any storage element. Single Phase Matrix Converter (SPMC) is used to replace the inverter part in the conventional DVR system. The simulation was done using Matlab/Simulink software to observe the SPMC performance towards mitigating the voltage sag. In this project a single line to ground fault is used to create the disturbance to the load and a Sinusoidal Pulse Width Modulation (SPWM) strategy is used as the switching technique to control the switches.

10:15  Power Compensation Approach and Double Frame Control for Grid Connected Converters
Daniel Siemaszko, Alfred Rufer
École Polytechnique Fédérale de Lausanne, Switzerland

The handling of weak networks with asymmetric disturbances implies the accurate handling of the second harmonic component appearing under unbalanced networks. This paper proposes a two-step approach using classic vector control for operating the current controller from the network disturbance. First, both voltage and current must be described in the positive and negative sequence with a proper decoupling. The use of a double frame controller for forcing current balance proves to drastically reduce the second harmonic component in the DC-link voltage. As a second step, a current reference computing method is proposed for fully compensating power oscillations on the DC side that is applicable for phase voltage dips up to 50%.
C2L-A DC/DC Converters III
Time: Thursday, April 25, 2013, 11:00 - 12:40
Place: Conf. Room 11
Chair: Noboru Katayama, Tokyo University of Science

11:00 Research on the Gain Coverage of Boost DC/DC Converting Circuit Voltage
Xianmu Mu, Meifang Li, Fengchun Liu
Dalian University of Technology, China

The output voltage of boost DC/DC converting circuit will be increased when the duty ratio increased. Practically, when the duty ratio increased to a threshold value, the output voltage will be decreased with the increasing of duty ratio. The boost DC/DC converting circuit was analyzed through state-space average method. Furthermore, it analyzed the main factors influencing boost DC/DC converting circuit voltage gain and put forward the effective working range of duty ratio of boost DC/DC converting circuit. Taking the boost circuit for example, the effective range of voltage gain of boost circuit was studied to set up the circuit for experiment. The experimental result verified the theoretical analysis result.

11:25 PWM Switched Capacitor Voltage Divider with High Step-Down Ratio
Masatoshi Uno
Japan Aerospace Exploration Agency, Japan

Switched capacitor converters (SCCs) and switched capacitor voltage dividers (SCVDs) offer both high power density and high power conversion efficiency. However, since the voltage conversion ratio of conventional SCCs and SCVDs is fixed and not controllable, applications of such converters have been limited to unregulated applications. A PWM SCVD that achieves controllable high step-down voltage conversion ratio is proposed in this paper. The operation analysis is made, and the basic characteristics of the PWM SCDV are discussed on the basis of the comparison with a traditional buck converter. Experimental tests were performed on a 30-W prototype to demonstrate its performance.

11:50 Prototype Evaluation of Over 10W/cm³ High Power Density Converter for 400V-DC Power
Distribution System in Data Center
Seiya Abe¹, Sihun Yang², Masahito Shoyama³, Yoichi Ishizuka³, Tamotsu Ninomiya³, Masato Kaga⁴
¹International Center for the Study of East Asian Development, Japan; ²Kyushu University, Japan;
³Nagasaki University, Japan; ⁴NTT Facilities, Inc., Japan

This paper investigates the high power density design of LLC converter for 400V-DC power supply system for data center. The prototype experimental circuit of 12.5W/cm³, 1.25kW (rated load) can be achieved. Moreover, the circuit operation is examined by experimentally. As a result, the ZVS operation of primary side switch and ZCS operation of secondary side rectifier diode is confirmed. Furthermore, the power conversion efficiency can be achieved 97.4% @ half load. The parallel connection of LLC converter in order to achieve 5kW will be discussed in the full paper.

12:15 Medium Frequency Transformers for Solid-State-Transformer Applications - Design and Experimental Verification
Gabriel Ortiz¹, Michael Leibl¹, Johann Walter Kolar², Oscar Apeldoorn¹
¹ABB Switzerland, Switzerland; ²ETH Zürich, Switzerland

In solid-state-transformer technology, the voltage adaptation and input/output isolation is done through a medium-frequency AC link comprising a medium-frequency transformer. From the applications point of view, the main design targets in these transformers are power-density and efficiency in the case of traction and smart-grids respectively. An optimization procedure for different transformer concepts, comprising loss calculation and thermal modeling, among others, is described in this paper. The optimization procedure is applied to an air-cooled transformer with ferrite core and to a water-cooled transformer with nano-crystalline core in order to find the according Pareto fronts. The means to test these transformers under continuous power transfer and the results of this experimental testing are included in the paper.
Predicting Potential of 4H-SiC Power Devices Over 10 kV
Muhammad Nawaz
*ABB Corporate Research, Sweden*

This paper presents the theoretical assessment of conversion losses for 4H-SiC based power devices over 10 kV. A set of empirical and analytical equations are developed to predict the losses at different temperatures and over wide blocking voltage range. Basic data for empirical equations in terms of RON and knee voltage of bipolar devices (i.e., IGBTs, PIN diode) is also compared with the experimental results and shows fairly well qualitative agreement. The conduction and switching losses for SiC-IGBTs are far superior to Si based IGBTs up to 6.5 kV. Compared to MOSFETs, SiC-IGBTs show superior performance over 10 kV predicted from present simple analysis. These set of handy equations provide a quick insight and useful guidelines for designing converter valves/cells for high power ratings.

Short-Circuit Tests on SiC Power MOSFETs
Alberto Castellazzi¹, Tsuyoshi Funaki², Tsunenobu Kimoto³, Takashi Hikihara¹

¹Kyoto University, Japan; ²Osaka University, Japan; ³University of Nottingham, United Kingdom

This paper presents experimental results and a related discussion for the behaviour under short-circuit conditions of novel 1200V silicon-carbide (SiC) power MOSFETs. The study is based on commercially available devices and delivers important insights into specific device features which have no counterpart in high voltage silicon (Si) transistors. The main aim is to provide indications for reliable power system development and inform the progression of device design in a broad application scenario and device types (e.g., implementation of SiC based solidstate current limiters/regulators; development of SiC Smart Power technology).

Drive Loss Analysis and Comparison of Capacitor-Less Gate Drive Circuit for GaN FETs with Capacitor Type Gate Drive Circuits
Fumiya Hattori, Hirokatsu Umegami, Takashi Yoshida, Masayoshi Yamamoto
*Shimane University, Japan*

GaN FETs have been being great attractive for high frequency operation recently and have a possibility to realize downsizing and high-power density for power electronic equipment. On the other hand, a loss increases in high frequency operation. That is why a loss is substantially important tips. This paper investigates drive losses of the capacitor-less gate drive circuit for GaN FET. And also the loss is compared with the inverted circuit. In addition, a detailed loss analysis of the capacitor-less circuit is stated.
11:00 Position Estimating Method of IPMSM at Low Speed Region Using dq-axis Current Derivative Without High Frequency Component
Yuji Hosogaya, Hisao Kubota
Meiji University, Japan

Various methods have been proposed to identify the flux position in an IPMSM without the use of mechanical sensors. To achieve this, a method that uses both the back EMF and the saliency to identify the flux position in the IPMSM without the injection of high-frequency components at low speeds has been reported. We propose the extended method by controlling current derivative during zero voltage vector. Our method uses d-axis current derivative which has the unstable region where q-axis current derivative can be applied.

11:25 Investigation of Sensorless Direct Torque Control Using High Frequency Injection Apply to a Fractional-Slot Concentrated Winding Interior PMSM
Dai Nguyen, Rukmi Dutta, Faz Rahman
University of New South Wales, Australia

This paper presents the sensorless direct torque control based on the high frequency injection method for a fractional-slot concentrated winding Interior Permanent Magnet (FSCW IPM) Synchronous Machine. In the existing literature there are a number of papers which have discussed high frequency injection method have been applied to IPMSM with Distributed winding but similar approaches for the FSCW IPMSM have been scarcely explored. In this paper, the sensorless direct torque control scheme that uses high frequency injection signal was applied to a prototype FSCW IPM machine.

11:50 Position Sensorless Control for IPMSM Based on Extended EMF Using Voltage Injection Synchronized with PWM Carrier
Kousuke Uchida, Hisao Kubota
Meiji University, Japan

This paper proposes position sensorless control method for IPMSM, which is applied to both low speeds and high speeds. The proposed method is based on the extended EMF. At low speeds, the extended EMF is raised by voltage injection synchronized with PWM carrier. The same estimation algorithm is applied for low speeds and high speeds.

12:15 Maximum Torque Per Ampere Control Method for IPM Synchronous Motor Based on V/F Control
Jun-Ichi Itoh, Yuki Nakajima, Masakazu Kato
Nagaoka University of Technology, Japan

This paper proposes a maximum torque per ampere (mpta) control method based on v/f control for an interior permanent magnetic synchronous motor (ipmsm). The v/f control is inherently a position sensorless method. in addition, the mpta control can be achieved by controlling the reactive power without magnet pole position information. The proposed mpta control is able to achieve high efficiency because the copper loss becomes minimum. in this paper, the validity of the proposed method is confirmed by experimental results. in addition, from the experiment, the output current can reduce up to 76%.
### C2L-D  PV Energy (MPPT Control)

**Time:** Thursday, April 25, 2013, 11:00 - 12:40  
**Place:** Conf. Room 21CD  
**Chair:** Teruhiko Kohama, *Fukuoka University*

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| 11:00 | **Current Ripple-Free Module Integrated Converter (Mic) with More Precise Maximum Power Tracking Control for PV Energy Harvesting** | Ching-Tsai Pan$^1$, Ming-Chieh Cheng$^1$, Ching-Ming Lai$^2$  
$^1$National Tsing Hua University, Taiwan; $^2$UPE-Power Technology Co., Ltd., Taiwan |

Installation of photovoltaic (PV) energy harvesting system keeps a rather high growing rate in recent years. A switching power converter is usually required as a regulator for achieving the maximum output power of the PV energy harvesting system. However, the inherent current ripple of switching power converter indeed may cause significant impact on the output power. Hence, the major objective of this paper is focused on the further study of the quantitative output power reduction effect of the input current ripple of PV energy harvesting system as well as proposing ripple cancelling techniques to solve the above dilemmas.

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| 11:25 | **Stand-Alone Operation with a Centralized Controller for Multiple PV Module Converters** | Jungwon Seo, Sol Moon, Jong-Ho Jang, Joung-Hu Park  
*Soongsil University, Korea, South* |

In this paper, stand-alone control with Maximum Power Point Tracking (MPPT) control and output voltage of converter control method using Zigbee wireless communication for multiple module converters as a concept of the intelligent PV module of the photovoltaic power conditioning systems (PCS) is proposed. The proposed scheme integrates all the information under stand-alone condition for a single host controller to choose which one of the entire PCS group regulates the output dc-link voltage of the converters or regulates the input voltage for the MPPT control.

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| 11:50 | **Voltage control of PCS for Photovoltaic System Paper**            | Hitoshi Shiki$^1$, Tsuyoshi Harimoto$^2$, T. Akine$^3$, Y. Tsuda$^4$, Masanobu Koshio$^3$  
$^1$Kyushu Electric Company, Japan; $^2$Kyushu Electric Power Co., Inc., Japan; $^3$Mitsubishi Electric Corporation, Japan |

Large penetration of photovoltaic systems at the distribution network level can be one of the causes of high fluctuating voltage. In this study the authors present a voltage control method based on the modulation of the reactive power production of the power conditioning system of the PV. The study evaluate the efficiency if constant voltage control, proportional voltage control and constant power factor control in a test facility with a single PCS and 4 PCS connected in parallel. The test results confirm that the constant and proportional voltage control methods are the most effective solution to control the voltage in the distribution network.

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| 12:15 | **A Low-Cost Microcontroller-Based Maximum Power Point Tracking System with Multiple-String Connection for PV Stand-Alone Applications** | Uthen Kamnarn, Suparak Srita, Surasak Yousawat  
*Rajamangala University of Technology Lanna, Thailand* |

The aim of this paper is to design and implementation of a multiple-string connection using modular buck converter with Maximum Power Point Tracking (MPPT) for stand-alone PV solar energy system. A simple, highly-performance algorithm suitable to be implemented in a low-cost microcontroller (PIC 18F4431) has been developed in order to make photovoltaic arrays track and operate in their maximum power point. A 3kWp prototype distributed solar controller comprising 4-modular MPPT buck converters with the proposed control scheme has been designed and implemented. Experimental results confirm excellent tracking effectiveness and rapid dynamic response.
11:00  A Hysteretic PWM Control Operated in Double Switching Frequency of Clock Signal
Takaharu Morotomi, Terukazu Sato, Kimihiro Nishijima, Takashi Nabeshima
Oita University, Japan

This paper proposed a novel hysteretic pwm controller that consists of two comparators with hysteretic characteristics and or gates for a buck converter. The proposed controller operates in double switching frequency of the clock signal input for synchronization with keeping excellent dynamic performance of hysteretic pwm method. It was confirmed that the proposed method provides not only excellent steady-state characteristics but also fast transient response characteristics by experimental results.

11:25  A Flexible Low-Voltage Ride-Through Operation for the Distributed Generation Converters
Hsin-Chih Chen², Chia-Tse Lee², Po-Tai Cheng², Remus Teodorescu¹, Frede Blaabjerg¹, Subhashish Bhattacharya³
¹Aalborg University, Denmark; ²National Tsing Hua University, Taiwan; ³North Carolina State University, United States

This paper presents a control method for the grid-connected converter to meet the LVRT requirement during voltage sag. The proposed method synthesizes the current commands without exceeding the user-defined peak current limit. In the meantime, it operates the converter at the minimum DC-bus voltage ripple. In addition, the control structure is capable of the flexibility to inject the reactive current of both positive sequence and negative sequence to alleviate the unbalance of the grid voltages during LVRT. Simulation results validate the proposed method, and the preliminary hardware test results are also presented.

11:50  Space Vector Based Pulse Width Modulation Scheme for Multilevel Inverters Using the Concept of Multi-Valued Logic
Pankaj Sagar³, G Shiny³, M. R. Baiju¹
¹College of Engineering Trivandrum, India; ²Rajagiri School of Engineering and Technology, India

An N-level inverter has N discrete levels in the pole voltage, and hence multilevel inverter can be viewed as a multi-valued logic device. A space vector pulse width modulation (SVPWM) scheme for multilevel inverter is presented based on the principle of multi-valued logic. The multi-valued logic operations are utilized to realize a computationally efficient space vector PWM scheme. The algorithm used to realize the reference space vector are generated using multi-valued logic. The scheme is experimentally verified using a 3-level inverter in cascade configuration and experimental results are presented to validate the scheme.
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