Power Electronics Laboratory

About

Power Electronics Laboratory at the Department of Electrical and Computer Engineering at Baylor University leads for advanced smart-grid or micro-grid and energy-efficient power electronic technologies for alternative green energy conversion and industrial automation industries. Our experiences are in designing, simulating and implementing power converters, power supplies, motor drives, and power electronics systems. We are responsible for key technical solutions on a wide range of design and development projects in power electronics systems. We also utilize design feasibility and tradeoff analyses for proof of concept and prototype systems and develop funded contract programs with detailed designs through life-cycle engineering.

Research Areas:

- Modeling, analysis, design, implementation and test of alternate energy power conversion systems for smart-grid/Micro-Grid using Real-Time Digital Simulator (RTDS)
- Intelligent universal transformers for micro-grids
- Design and control of wind power/ water turbine Permanent magnet generators
- High energy efficient power converters and switched-mode power supplies
- LED lighting driver and power factor correction
- Advanced electric vehicle propulsion drive systems and their digital controllers
- Compact pulsed power system and energy storage system solutions for medical devices and defense applications

People

- Faculty
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Education:
• Ph.D., Virginia Tech, 2001.
• M.S., Chungnam National Univ., 1988.
• B.S., Chungnam National Univ., 1986.

Teaching Interests:
Power Electronics, Automatic Control Systems, Advanced Power Grid Interface Techniques

- **Current Students**

  - **Mohammad Reza Abedi**

Mohammad Reza Abedi received his B.S. degree in Power Systems from Iran University of Science and Technology, and his M.S. degree in Power Electronics and Drives from Sharif University of Technology, Tehran, Iran, in 2006 and 2009, respectively. He is currently pursuing his Ph.D. Degree at Baylor University. His research interests include advanced power electronics control techniques, high-power grid-connected converters, and high-efficiency inverters for renewable energy application.
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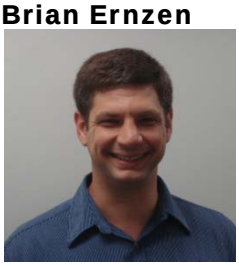
  - **Brian Ernzen**



Brian Ernzen received his B.S. degree in Electrical Engineering from Texas A&M University in 2003. He also studied mechanical engineering from 2003 to 2005 at Texas A&M University. He has experience over 5 years in design and implementation in the field of power supplies. He has worked in dc/dc converter design, avionics design, and aircraft integration. He is currently pursuing his Masters Degree at Baylor University. His research interests include power electronics modeling and control.
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  - **Bochuan Liu**

Bochuan Liu received his B.S. degree in Electrical Engineering from Anhui University of Technology in 2009. Since 2009, he is currently pursuing his

Master Degree at Baylor University. His research interests include intelligent universal transformers, high-power grid-connected converters, and high-efficiency inverters for renewable energy application.
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- **Robert Antle**

Robert Antle is currently pursuing his B.S. in Electrical and Computer Engineering from Baylor University. His research interests are DSP/FPGA digital controllers in the field of power electronics.
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Research Interests:

Our research focuses on modeling, simulation and analysis of renewable energy conversion systems using advanced power electronics technologies. The foundation we have built while developing our real-time digital simulation environment will be coupled with the Power and Energy Systems Laboratory (PESL) initiated by Dr. Kwang Y. Lee. This research collaboration can not only demonstrate our ability to extend the power electronics technologies to smart-grid and micro-grids, but also our capability to recognize and advance the engineering frontier. We desire to perform system integration that incorporate both the power and control, theory and experimental, to establish industrial tools leading to further understanding of advanced power electronics solutions. In addition, we want to extend our research collaboration activities that will be conducted in partnership with the private sector, state and local governments, DOE national laboratories, and universities in the USA as well as other universities in the world.

Topic 1: Renewable Energy Conversion Systems and Their Power Grid Interface

In the United States, utilities are facing major challenges concerning smart grids and micro-grids served by distributed power generation from renewable energy sources. There are many issues concerning grid interconnections between distributed generation (DG) systems and the utility grid. Distributed generation (DG) systems such as micro-turbines, wind-turbines, photovoltaics (PV), and fuel cells will play major roles in smart grids and micro-grids. The DC power from the renewable energy conversion systems must be converted to synchronized AC power for delivery to the utility grid. The power conditioning system (PCS) is introduced to control energy flow from the DC source to the AC grid. For effective power transfer to the grid, the advanced PCS will be developed. At present research is being carried out to develop a PWM DC/AC voltage source inverter (VSI) and its control algorithm. Furthermore, advanced digital controller will be developed to extract maximum power from the renewable sources.

Our past research activities provide us with an overall understanding of research trends in power and energy, these trends include the need to develop new control methods to improve the power quality and energy efficiency. Our research has included development of new control algorithms for effective power interface between the utility grid and the local loads.

Topic 2: Energy Efficient Power Electronic Converters

Another area of research interest for us is energy efficient power electronics converters. The current research includes the development of a multiple-input single-output DC-DC converter and its digital controllers. These areas can continuously provide advanced power electronics solutions to the industry.

In recent years, the demand for electric vehicles (EVs) has increased rapidly as an attractive alternative method of transportation that is energy efficient and environmentally friendly. The use of these vehicles can improve the air quality by decreasing the amount of harmful emissions given off by gasoline and diesel engines. Thus, advanced electric motor drives have emerged in various electric vehicles (EV), such as hybrid electric vehicles (HEV) and plug-in hybrid electric vehicles (PHEV). Since the power electronics will be one of the key enabling technologies to EVs, we focus on the development of bidirectional DC/DC converters, DC/AC inverters, digital controllers and battery chargers. Most recently, the demand of a new charging system for vehicle-to-grid (V2G) electric vehicles (EVs) has been increasing rapidly with renewable energy resources such as wind and solar.

Our Vision:

Our power electronics research program will be cross-disciplinary in nature with the industry and the university's major research goals. The variety of engineering activities at Baylor will allow for both graduate and undergraduate students to actively participate in the groundbreaking research developments. Also, it will be vital in providing short-term solutions to satisfy the industry's immediate needs while having the potential to contribute towards long-term fundamental knowledge and technology as well. Here are our three strategies to achieve our successful research accomplishments.

(a) Supporting the local and the federal governments' research projects and industry's research initiatives for the development of technologies (applied research) that will advance national power and energy solutions: smart-grid and energy efficient renewable power conversion systems.
(b) Enhancing the engineering educational curriculum that combines both contemporary and traditional teaching methodology to effectively engage the classroom setting and instill a passion for learning among this generation of engineers. The curriculum will be based on finding strategies for incorporating fundamental concepts.
(c) Extending our research collaboration activities that will be conducted in partnership with the private sector, state and local governments, DOE national laboratories, universities in USA as well as other universities in the world. Our research group can demonstrate a leadership role in developing and conducting the cross disciplinary research effort in power electronics societies.

On-Going Research Activities

- Micro-grid system design and key component development

- Intelligent charging system for vehicle-to-grid (V2G)
- New hydrokinetic energy capturing system for micro-grid
- Power grid interface for fuel-cell/gas-turbine power plant
- LED lighting driver with power factor correction
- Permanent magnet motor/generator design and simulation
- PV Interconnection to grid

Publications

1) E. S. Kim, B. M. Song, and S. Lee, "An Effective Control Algorithm for a Grid-connected Multifunctional Power Converter," *International Journal of Modern Engineering*, vol. 10, no. 2, pp. 10-16, April 2010.
2) B. M. Song, S. Lee, and M. H. Kye, "Practical Soft-Switching High-Voltage Dc-Dc Converter for Magnetron Power Supplies," *International Journal of Engineering Research & Innovation*, vol. 2, no.1, pp. 30-35, May 2010.
3) S. Lee, B. M. Song, and T. H. Won, "Evaluation of a Software Configurable Digital Controller for the Permanent Magnet Synchronous Motor using Field-Oriented Control," *International Journal of Engineering Research & Innovation*, vol. 2, no.2, Nov. 2010 (accepted).
4) B. M. Song, R. McDowell, A. Bushnell, and J. Ennis, "A Three-Level DC-DC Converter with Wide-Input Voltage Operations for Ship-Electric-Power-Distribution Systems," *IEEE Transactions on Plasma Scienc*e, pp. 1856-1863, Oct. 2004
5) B. M. Song and J. Ennis, "Component Technologies of Pulsed Power System," *Korea Power Electronics Journal* (*Special Issue - Pulsed Power Technology, Invited Paper*), pp. 26-31, Feb. 2004,
6) H. Yu, B. M. Song and J. S. Lai, "Design of a Novel ZVT Soft-switching Chopper," *IEEE Transactions on Power Electronics*, Vol. 17, No. 1, January/February 2002, pp. 101-108.
7) X. Jia, Q. Li, J. S. Lai, and B. M. Song, "Analysis of Poly-phase Brushless Exciter," *IEEE Transactions on Industry Applications,* vol. 37, no. 6, pp. 1720-1726, Nov./Dec. 2001.
8) J. S. Lai, B. M. Song, R. Zhou, A. R. Hefner, Jr., D. W. Berning, and C. C. Shen, "Characteristics and Utilization of a New Class of Low On-Resistance MOS-Gated Power Device," *IEEE Transactions on Industry Applications,* vol. 37, no. 5, pp. 1182-1289, Sep./Oct. 2001.
9) B. M. Song, J. H. Kim, J. S. Lai, K. C, Seong, H. J. Kim, and S. S. Park, "A Multilevel Soft-Switching Inverter with Inductor Coupling," *IEEE Transactions on Industry Applications,* vol. 37, no. 2, pp. 628-636, Mar./Apr. 2001.
10) B. M. Song and J. S. Lai, "A Novel Two-Quadrant Soft-Switching Converter with One Auxiliary Switch for High Power Applications," *IEEE Transactions on Industry Applications,* vol. 36, no. 5, pp. 1388-1395, Sep. / Oct. 2000.
11) S. K. Kwon, B. M. Song, and J. S. Lai, "Design Optimization of the ZVT Soft-Switching Inverter for High Power AC Motor Drives," in *Journal of Electrical Engineering and Information Science*, vol. 4, no. 4, pp. 507-513, Aug. 1999.

SELECTED CONFERENCE PAPERS:

1) J. Y. Choi, J. M. Jang, and B. M. Song, "Design of a Direct-Coupled Radial-Flux Permanent Magnet Generator for Wind Turbines," *IEEE 2010 PES General Meeting*, July 2010, 2010GM1532.
2) B. M. Song, M. H. Kye, and R. Y. Kim, "Design of a Cost-Effective DC-DC Converter with High Power Density for Magnetron Power Supplies," *2010 International Power Electronics Conference (IPEC)*, 21-24 Jun. 2010, pp. 137-141.

3) B. M. Song, K. C. Chang, and S. Lee, “Design of an Outer-Rotor-Type Permanent Magnet Motor for Electric Scooter Propulsion Systems,” *2010 International Power Electronics Conference (IPEC)*, 12-24 Jun. 2010, pp. 2763-2742.
4) B. M. Song, B. Garner, and S. Steinbach, “Design Feasibility of a New Fluid Vortex Energy Capturing System,” *IEEE 2010 Green Technologies Conference (GTC)*, Apr. 15-16, 2010, pp. 1-4.
5) S. Lee, B. M. Song, and T. H. Won, “Evaluation of a Software Configurable Digital Controller for the Permanent Magnet Synchronous Motor using Field-Oriented Control,” *IEEE 2010 The Southeastern Symposium on System Theory* (SSST), Mar. 7-9, 2010, pp. 302-306.
6) G. H. Kim, Y. J. Kim, M. Park, I. K. Yu, and B. M. Song, “RTDS-based Real Time Simulations of Grid-Connected Wind Turbine Generator Systems,” *IEEE 2010 Applied Power Electronics Conference (APEC),* Feb. 22-25, 2010, pp. 2085 -2090.
7) E. S. Kim, B. M. Song, and K. Y. Lee, “Modeling and Analysis of a Grid-Connected Wind Energy Conversion System Using PSCAD/EMTDC,” *IEEE 2010 PES Conference on Innovation Smart Grid Technologies*, Jan. 19-21, 2010, pp. 1-6.
8) B. M. Song, K. Y. Lee, and S. Nikneshan, “The Cyber Security Solution for SCADA Power Systems using Software Defined Radio (SDR) Technology,” *National Workshop on New Research Directions for Future Cyber-Physical Energy Systems*, June 2009.
9) A. H. Bushnell, B. M. Song, J. Ennis, R. Miller, D. Johnson, and Maenchen, “Design Optimization of Linear Transformer Driver (LTD) Stage Cell Capacitors,” in *Conf. Rec. of IEEE International Power Modulator Conference*, May 2004.
10) B. M. Song, R. McDowell, A. Bushnell, and J. Ennis, “ Practical Design and Control of a ZVS 3-Level DC-DC Converter with Minimum Circulating Current,” in *Conf. Rec. of IEEE-IECON’2003*, pp. 726-731, Nov. 2003
11) J. B. Ennis, B. M. Song, A H. Bushnell, R. A. Cooper, J. Jichetti, F. MacDougall, R. McDowell, B. Andermatt, and J. Bates, “Custom Design of Components and Power Supplies for Pulsed Power Systems,” in *Conf. Rec. of IEEE-IECON’2003*, pp.87-92, Nov. 2003
12) B. M. Song, R. McDowell, and A. Bushnell, “A Three-Level DC-DC Converter with Wide-Input Voltage Operations for Ship-Electric-Power-Distribution Systems,” in *Conf. Rec. of IEEE-PPC’2003*, Dallas, TX, Jun. 2003.
13) D. W. Yoo, J. W. Baek, H. S. Son, G. H. Rim, and B. M. Song, “Full Digital 150V-1kA ZVS Converter for X-ray Power Applications,” in *Conf. Rec. of IEEE-PPC’2003*, Dallas, TX, Jun. 2003.
14) J. W. Baek, D. W. Yoo, G. H. Rim, and B. M. Song, “ A 2kV-40A Pulse Generator Using Boost Converter Array,” in *Conf. Rec. of IEEE-PPC’2003*, Dallas, TX, Jun. 2003.
15) B. M. Song, R. Kratz, and S. Gurol, “Contactless Inductive Power Pickup System for Maglev Applications,” in *Conf. Rec. of IEEE-IAS,* pp. 1586-1591, Oct. 2002.
16) B. M. Song, J. S. Lai, C. Y. Jeong, and D. W. Yoo, “A Soft-Switching High-Voltage Active Power Filter with Flying Capacitors for Urban Maglev System Applications,” in *Conf. Rec. of IEEE-IAS*, pp. 1461-1468, Oct. 2001.
17) H. Yu, W. Dong, B. M. Song, and J. S. Lai, “Variable Timing Control for Coupled-Inductor Feedback ZVT inverters,” in *Conf. Rec. of International Power Electronics & Motor Control Conference (IPEMC)*, Aug. 2000, pp. 1138-1143.
18) B. M. Song, N. Yadlapalli, and J. S. Lai, “A Novel Auxiliary Resonant Snubber Converter for Switched Reluctance Motor Drives,” in *Conf. Rec. of International Power Electronics Conference (IPEC) –Tokyo ’2000,* Apr. 2000, pp. 560-565.
19) B. M. Song, H. Zhu, J. S. Lai, and A. R. Hefner, Jr.,“ Switching Characteristics of NPT- and PT-IGBTs under Zero-Voltage Switching Conditions,” in *Conf. Rec. of IEEE-IAS,* Oct. 1999, pp. 722-728.

20) B. M. Song, J. S. Lai, and S. K. Kwon, “Design Criteria of the Auxiliary Resonant Snubber Inverter Using Load-side Circuits for Electric Propulsive Drives” in *Conf. Rec. of ICPE’98*, Oct. 1998, pp. 145-150.
21) Y. Tang, H. Zhu, B. M. Song, J. S. Lai, and C. C. Chen, “EMI Experimental Comparison of PWM Inverter Between Hard- and Soft-switching Techniques,” in *Conf. Rec. of IEEE-WPET’98*, Detrorit, Oct. 1998,pp.71-77.
22) B. M. Song, S. R. Lee, and J. S. Lai “An improved Three-Phase auxiliary Resonant Snubber Inverter for AC Motor Drive Applications” in *Conf. Rec. of IEEE-PESC*, June 1998, pp. 423-428.
23) S. C. Oh, B. M. Song, Y. H. Cho, and H. D. Ha, “Design of New AC Power Train using 2 Quadrant Chopper as an Input converter,” in *Conf. Rec. of 12th Inte’l Electric Vehicle Symposium*, Anaheim, California, Dec. 1994, pp.634 - 639.

PROFESSIONAL SOCIETY ACTIVITIES:

- Senior member of IEEE
- Technical Program Committee Member & Paper Reviewer of IEEE 2010 Green Technologies Conference.
- Session Chair and Paper Reviewer of IEEE 2010 Southeastern Symposium on System Theory (SSST)
- Session Chair and Paper Reviewer of IEEE 2010 International Power Electronics Conference (IPEC)
- Paper Reviewer of IEEE 2010 Applied Power Electronics Conference and Exposition (APEC)
- Paper Reviewer of IEEE Transaction on Energy Conversion - 2010
- Session Chair and Paper Reviewer of IEEE 2010 International Power Electronics Conference (IPEC)
- Paper Reviewer of IEEE Industry Applications Society and Power Electronics Society
- Member of IEEE Power & Energy (PES), Power Electronics (PELS), and Industry Applications (IA) Societies.