Power Electronics

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Power Electronics Research Overview
The focus of our group is on advancing power electronics technology, and in applying power electronics to improve the performance of systems including renewable energy generation (solar), computation (microprocessor power delivery), communications (radio-frequency power amplifiers) and other areas.

1. Power Electronics for Photovoltaic Systems

Sponsors:
Enphase Energy, National Science Foundation, MIT Center for Integrated Circuits and Systems, FCRP Interconnect Focus Center

Project Staff:
Mr. Brandon Pierquet, Mr. Robert Pilawa, Mr. Aleksey Trubitsyn, Mr. Alexandar Hayman, Ms. Grace Cheung, Prof. David Perreault

There is a growing demand for power converters to interface between low-voltage photovoltaic (PV) sources and the ac grid. One component of our research in this area is development of converters that deliver energy (with maximum power point tracking - MPPT) from a single low-voltage PV panel to the ac grid. Such “microinverters” or “module integrated converters” must be capable of very high efficiency, while meeting challenging size and lifetime constraints. Our group has developed new circuit topologies and controls for realizing such grid interface power converters; these designs promise unprecedented levels of performance, and scale favorably with the evolution of semiconductor devices. One of our prototype designs has demonstrated CEC efficiency (weighted across power and voltage) of nearly 96%, with promise to achieve still higher efficiency. To date, the technology under development has resulted in two papers, which will be presented at the 2010 Energy Conversion Congress and Exposition. We have also submitted a provisional patent filing on this technology. A second component of our research in this area is developing techniques to allow power point tracking at the *individual cell* level, while enabling efficient power conversion at high output voltage levels. To achieve this, we are exploring the use of small, high-frequency CMOS power converters integrated together with PV cells to form “controlled cells”. Our initial efforts in this area, undertaken in collaboration with the Sullivan group at Dartmouth, suggest that the approach is feasible.

2. Very High Frequency Power Conversion

Sponsors:
National Semiconductor, Texas Instruments, FCRP Interconnect Focus Center, Charles Stark Draper Laboratory, MIT Center for Integrated Circuits and Systems

Project Staff:
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A principal means for improving performance and reducing the size of power electronics is through increases in switching frequency. However, conventional power converter designs are subject to a number of constraints that greatly limit their practical switching frequency. My research team and I are exploring new circuit architectures, topologies and ancillary technologies that overcome these constraints, greatly increasing the switching frequency range for which efficient dc/dc conversion is feasible. One approach being pursued is development of new resonant power converter topologies that mitigate the losses that limit the achievable operating frequency. Another approach under investigation is circuit architectures that separate voltage transformation and regulation to permit key portions of the circuit to run at very high frequency. This approach is particularly well suited for interfacing to low-voltage sources and achieving higher degrees of integration. Additional work in very high frequency (VHF) power conversion encompasses development of passive components and integration techniques needed for operation at increased frequencies. Aspects of this new technology have been the subject of several publications this year, including a paper in the IEEE Transactions on Power Electronics and upcoming papers at the IEEE Energy Conversion Congress and Exposition and the International Power Electronics Conference.

Publications

Journal Articles, Published

Pilawa-Podgurski, R.C.N., A.D. Sagneri, J.M. Rivas, D.I. Anderson, and D.J. Perreault, "High-Frequency Resonant Boost Converters," *IEEE Transactions on Power Electronics*, Vol. 24, No. 6, pp. 1654-1665, June 2009.

Godoy, P.A., D.J. Perreault, and J.L. Dawson, "Outphasing Energy Recovery Amplifier with Resistance Compression for Improved Efficiency, *IEEE Transactions on Microwave Theory and Techniques*, Vol. 57, No. 12, pp. 2895-2906, Dec. 2009.

Meeting Papers, Published

Chung, S., P.A. Godoy, T.W. Barton, E.W. Huang, D.J. Perreault, and J.L. Dawson, "Asymmetric Multilevel Outphasing Architecture for Multi-Standard Transmitters," *2009 IEEE Radio Frequency Integrated Circuits Symposium*, pp. 237-240, June 2009.

Sagneri, A.D., D.I. Anderson, and D.J. Perreault, "Optimization of Transistors for Very High Frequency dc-dc Converters," *2009 IEEE Energy Conversion Congress and Exposition*, pp. 1590-1602, Sept. 2009.

Pilawa-Podgurski, R.C.N., N.A. Pollo, W.R. Chan, D.J. Perreault, and I.L. Celanovic, "Low-Power Maximum Power Point Tracker with Digital Control for Thermophotovoltaic Generators," *2010 IEEE Applied Power Electronics Conference*, pp. 961-967, Feb. 2010.

Qiu, Y., D.J. Perreault, T.A. Keim, and J.G. Kassakian, "Optimal Cam Design and System Control for an Electromechanical Engine Valve," *2010 International Conference on Industrial Technology*, pp. 565-572, March 2010.

Qiu, Y., D.J. Perreault, J.G. Kassakian, and T.A. Keim, "A Custom-Designed Limited-Angle Actuator for an Electromechanical Engine Valve Drive Part I: Conceptual Design," *IET International Conference on Power Electronics, Machines and Drives*, April 2010.

Qiu, Y., D.J. Perreault, J.G. Kassakian, and T.A. Keim, "A Custom-Designed Limited-Angle Actuator for an Electromechanical Engine Valve Drive Part II: Fabrication and Evaluation," *IET International Conference on Power Electronics, Machines and Drives*, April 2010.

Theses

Han, Yehui, "Circuits and Passive Components for Radio-Frequency Power Conversion, Ph.D. Thesis, February 2010.

Li, Wei, "Design and Optimization of Automotive Power Electronics Utilizing FITMOS MOSFET Technology," S.M. Thesis, June 2009.

Trubitsyn, Aleksey, "High Efficiency DC-AC Power Converter for Photovoltaic Applications," S.M Thesis, June 2010.

Burkhart, Justin, "Design of a Very High Frequency Resonant Boost dc-dc Converter," S.M. Thesis, June 2010.

Hayman, Alexandar, "Development of a High-Efficiency Solar Micro-Inverter," M.Eng. Thesis, August 2009.

Cheung, Grace, "Development of an Automated Efficiency and Loss Measurement System for High-Efficiency Power Converters," M.Eng. Thesis, June 2010.

Patent Applications Filed

J.L. Dawson, D.J. Perreault, E.W. Huang, S. Chung, and P.A. Godoy, "An Asymmetric Multilevel Outphasing Architecture for RF Amplifiers," (Filed 10 November 2009; Pending).