Next-Generation High-Frequency-Link Inverters for Sustainable Energy Systems

EPE 2011 Tutorial Proposal

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TITLE OF TUTORIAL:

Next-Generation High-Frequency-Link Inverters for Sustainable Energy Systems

ABSTRACT:

A. Significance and Objectives:

Photovoltaic (PV), wind, and fuel-cell (FC) energy are the front-runner renewable- and alternate-energy solutions to address and alleviate the imminent and critical problems of existing fossil-fuel-energy systems: environmental pollution due to high emission level and rapid depletion of fossil fuel. The framework for integrating these "zero-emission" alternate-energy sources to the existing energy infrastructure has been provided by the concept of distributed generation (DG) based on distributed energy resources (DERs) which provides an additional advantage: reduced reliance on existing and new centralized power generation, thereby saving significant capital cost. DERs are parallel and standalone electric generation units located within the electric distribution system near the end user. DER, if properly integrated can be beneficial to electricity consumers and energy utilities, providing energy independence and increased energy security. Each home and commercial unit with DER equipments can be a micropower station, generating much of the electricity it needs on-site and sell the excess power to the national grid. The projected worldwide market is anticipated to be $50 billion by 2015.

A key aspect of these renewable-/alternative-energy systems is an inverter (note: for wind, a front-end rectifier is needed) that feeds the energy available from the energy source to application load and/or grid. Such power electronics for next-generation renewable-/alternative-energy systems have to address several features including (a) cost, (b) reliability, (c) efficiency, and (d) power density. Conventional approach to inverter design is typically based on line-frequency-transformer architecture. A problematic feature of such an approach is the need for a line-frequency transformer (for isolation and voltage step-up), which is bulky, takes large footprint space, and is becoming progressively more expensive due to the increasing cost of copper. As such, recently, there has been significant interest in high-frequency (HF) transformer based inverter approach to address some/all of the above-referenced design objectives. In such an approach, a HF transformer (instead of a line-frequency transformer) is used for galvanic isolation and voltage scaling, resulting in a compact and low-footprint design. The HF transformer can be inserted in the dc/dc or dc/ac converter stages for multi-stage power conversion. For single-stage power conversion, the HF transformer is incorporated into the integrated structure. Based on these HF architectures, several high-frequency-link (HFL) topologies, being developed at the University of Illinois at Chicago and rest of the world, will be described which have applications encompassing photovoltaics, wind, and fuel cells. Some have applicability for energy storage as well. The work will incorporate several patented and patent-filed technologies at University of Illinois at Chicago in high frequency link power systems.

B. Intended Audience:

This tutorial is intended for researchers, industry professionals, and academicians engaged in

design and development of power conversion systems for PV, wind, fuel cell, and storage applications. The tutorial will require basic knowledge of power electronic topologies, devices, and systems. However, an initial overview will be provided to engage and encompass those who have recently engaged in this area or even business developmental audience.

C. Tutorial Outline:

1. **Introduction (35 minutes)**
   a. **Role and applications of inverters and power conversion systems in renewable and alternative energy systems**
   b. **Overview and limitations of existing technologies.**

2. **High-Frequency-Link (HFL) Topologies (100 minutes)**
   a. **Outline of overall approach and core topological differences with conventional approaches**
   b. **Role and incorporation of next-generation wide-bandgap power semiconductor devices and high-frequency magnetics**
   c. **Fixed-dc link and pulsating-dc link HFL converters: design approaches and key differences**
   d. **Operational and design details of single- and split-phase HFL systems**
   e. **Operational and design details of three-phase HFL systems**
   f. **Topological scalability for high power and distributed applications**

3. **Modulation and Control (70 minutes)**
   a. **Overview of existing approaches for standalone and grid connected operations**
   b. **Outline and operational details of next-generation hybrid modulation technologies that achieve soft switching and loss mitigation without auxiliary circuits**
   c. **Outline and operational details of new innovations in linear and nonlinear controls for HFL power converters while operating in standalone and clustered (e.g. microgrid, smart-grid) operations for high reliability and performance of sustainable source and overall system**
4. **Conclusions (35 minutes)**
   a. **Review of key concepts and scope, applicability, and tangible benefits**
   b. **Other emerging concepts and towards universal power conditioning**
   c. **Overview and impact of new standards**

D. Duration of Tutorial:

The intended duration of the tutorial is 4 hours. However, the duration can be modified as desired by the program committee.

1. LEAD INSTRUCTOR:
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2. AUTHOR BIO:

Sudip K. Mazumder is the Director of Laboratory for Energy and Switching-Electronics Systems (LESES) and an Associate Professor in the Department of Electrical and Computer Engineering at the University of Illinois, Chicago. He received his Ph.D. from Virginia Tech and M.S. from RPI. He has over 15 years of professional experience and has held R&D and design positions in leading industrial organizations. His current areas of interests are stability and stabilization of interactive power-electronics networks, renewable and alternative energy systems, and photonic and wide-bandgap devices and applied technologies.

Dr. Mazumder received the 2008 and 2006 Faculty Research Awards from the University of Illinois, Chicago for Outstanding Research Performance and Scholarly Activities. For his work, closely related to this Tutorial, he received the ONR Young Investigator Award and NSF CAREER Award in 2005 and 2003, respectively and the Prize Paper Award from the IEEE Transactions on Power Electronics in 2002. Dr. Mazumder was the Editor-in-Chief for International Journal of Power Management Electronics between 2006 and 2009. He is also an Associate Editor for the IEEE Transactions on Industrial Electronics since 2003, Associate Editor for the IEEE Transactions on Aerospace and Electronics Systems since 2008. He has published over 100 refereed and invited journal and conference papers, has 3 US patents, and is a reviewer for 6 international journals. He has been invited by IEEE, ASME, leading industries and universities, and national laboratories for keynote, plenary, and invited lectures and presentations. Dr. Mazumder was the Co-Chair for IEEE Power Electronics Society Technical Committee on Sustainable Energy Systems and is the Vice Chair for IEEE Power Electronics Society Technical Committee on Distributed Generation and Renewable Energy. He was the Chair for Student/Industry Coordination Activities, IEEE Energy Conversion Congress and Exposition (ECCE), for 2009 and 2010.