Device Level Control of Power Electronics Systems

IEEE IECON 2018 Tutorial

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ABSTRACT

Significance and Objectives:

This tutorial provides a fundamentally different perspective to control of switching power electronic systems. It is based on controlling the time evolution of the switching states (i.e., switching sequences) as well as controlling the switching transition of the power semiconductor device of the solid state electronic system. The former – i.e., switching-sequence based control (SBC) yields rapid response under transient condition, optimal equilibrium response, and yields seamless transition between the two states of dynamics. The first part of the tutorial will primarily focus on SBC for power electronics systems. By enabling integration of modulation and control, SBC precludes the need for ad-hoc offline modulation synthesis. In other words, an optimal switching sequence for the power converter is generated dynamically without the need for prior determination of any modulation scheme (which generates a pre-determined switching sequence) in typical conventional approaches.

One of the fundamental distinctions between SBC and conventional model predictive control (MPC) is that SBC ensures optimal determination of the switching sequence of the power converter under stability bound. The tutorial will provide the mechanism to carry out SBC and MPC control syntheses and demonstrate the differences between SBC and MPC. Several device, converter, and network level implementations (e.g., microinverter, microgrid, parallel inverters, multilevel converter, aircraft power system) of the SBC will be provided encompassing author's multiple years of project experience encompassing leading advanced defense and energy industries.

Finally, the tutorial will focus on switching transition control (STC). The primary objective of STC is to demonstrate how key power electronic system parameters including dv/dt and di/dt stress, switching loss, electromagnetic noise emission can be controlled dynamically by modulating the dynamics of the power semiconductor devices. Both electrical and newly developed optical control mechanisms to achieve STC will be demonstrated. In the context of the latter, mechanisms for monolithic integration of switching sequence control as well as switching transition control will be outlined and the revolutionary impact of such a novel integration on system performance will be demonstrated with practical applications.

Tutorial Topics Outline:

The comprehensive tutorial is arranged in four parts.

1. Need for next-generation power-electronics control
   - 1.1. Overview of need
   - 1.2. Control elements and their current limitations
     - 1.2.1. Beyond averaged modeling
     - 1.2.2. Overview of existing equilibrium stability approaches: scope and limitations
     - 1.2.3. Limitations of conventional control approaches
   - 1.3. New control propositions based on SBC, MPC: similarities and differences

2. Switching-sequence-based control (SBC)
   - 2.1. Conditions for orbital existence of power electronics systems
     - 2.1.1. Demonstrative results
   - 2.2. SBC control formulation and optimization
     - 2.2.1. SBC results for standalone, high-frequency-link, and networked power electronics systems

3. Outline of switching-transition control (STC)
   - 3.1. Control of a power electronics system at the semiconductor device level
   - 3.2. Real-time implementation and results for simultaneous control of system switching loss, dv/dt and di/dt stress, and electromagnetic noise of an optically-triggered power electronics system

4. Review of key concepts and conclusions

Intended Audience:

This tutorial is intended for a wide spectrum of researchers and industry professional reflecting the typical distribution of IECON audience.

Duration of the Tutorial:

The intended duration of the tutorial is 3 hours. However, the duration can be modified as desired by the program committee.

INSTRUCTOR BIO

Sudip K. Mazumder:

Dr. Mazumder is a Professor at the University of Illinois and also the President of NextWatt LLC and also serves as the Director for the Laboratory of Energy and Switching-Electronics Systems. He received his Ph.D. from Virginia Tech in 2001. He is a Fellow of IEEE (2016) and a Distinguished Lecturer for IEEE Power Electronics Society (2016).

He has over 25 years of professional experience and has held R&D and design positions in leading industrial organizations. His current areas of interests are optimal switching-sequence based control and stability analysis of power electronic device, converters, and networks; renewable and alternative energy based high-frequency-link conversion systems; and photonic and wide-bandgap devices and applied technologies. He has over 200 publications, 10 book/book chapters, and 11 patents, and has worked on about 50 sponsored research projects.

Dr. Mazumder received the following prestigious awards: One of the 2 best papers for May’18 issue of IEEE Transactions on Power Electronics (2018), Inventor of the Year Award (2014) from the University of Illinois, Chicago, University Scholar Award (2013) from the University of Illinois, NSF CAREER Award (2003) and ONR Young-Investigator Award (2005), IEEE PELS Transaction Prize Paper Award (2002), Best Paper Award at IEEE PEDG Conference (2013), Outstanding Paper Award at IEEE AINA Conference (2007), and IEEE Future Energy Challenge Award (2005).

He was the first Editor-in-Chief for Advances in Power Electronics and recently served as the Guest Editor-in-Chief for IEEE PELS and IEEE IES Transaction Special Issues. Currently he is also serving as a Lead Editor for IEEE IES Special Issue on Special Issue on Sliding mode control and observation for complex industrial systems and as an Associate Editor for IEEE IES and IEEE PELS. He is also the Chair for IEEE PELS TC on Sustainable Energy Systems, and served/will serve as a Plenary Chair for ECCE 2015, TPC Chair for 2019 IEEE IDEAS, and Chair for IEEE PEDG 2021.

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