Guest Editorial
Special Section on
Control Theory and Technology

CONTROL theory and technology pertains to an interdisciplinary branch of engineering and mathematics that deals with the analysis and synthesis of dynamical systems that can be automatically regulated. With its origins in positioning systems such as clocks, valves, and thermostats and their precise regulation, this interdisciplinary topic and its scope of application have significantly broadened over the years to include industrial process control, flight control, control of power systems, and automotive control, and more recently for the control of problems in robotics, biological systems and micro-nano systems. The overarching principle that is common to the application of control to all these systems is feedback—the process by which information is gathered, processed, and used to make decisions that drive the closed-loop behavior of these systems.

One of the main features of the smart grid is the introduction and use of information and communications technologies pertaining to renewable generation, consumption, and storage, in an automated fashion, to improve the efficiency, reliability, economics, and sustainability of the generation and distribution of electricity. As such, smart grid becomes an apt application area for control, as it opens up a variety of possibilities for gathering information, designing feedback strategies, and making decisions, i.e., for closing loops. This role of control is explored in this Special Section on Control Theory and Technology for the IEEE TRANSACTIONS ON SMART GRID.

The closing of loops is subject to various challenges. The first pertains to the type of information that is available. Often this information is available at various time-scales and therefore suitable classification, modeling, and processing methods have to be developed based on the time-scales. The second pertains to intermittencies and uncertainties associated with both generation, especially due to renewable energy sources and load. Suitable modeling of these components as well as the type of constraints associated with them has to be carried out for control design. The third pertains to the distributed nature of the underlying components, including storage. Information and decision making are highly distributed in nature, which requires careful modeling, analysis, and design of coordination, cooperation, synchronization, and optimization strategies in order to meet the goals of the power grid. Last and most importantly, the act of feedback, where decisions are made using information available and in turn the information gathered is affected by the decision-making, can introduce destabilization. The role of control theory and technology is to provide guidelines for circumventing instability and any other undesirable effects and meet the goals of security, efficiency, and reliability in the power grid. The fourteen papers that appear in this Section illustrate various approaches to meet these challenges.

Control theory and technology applied to smart grid is a topic that has attracted tremendous attention in the smart grid and control communities. Several workshops and special sessions have been held in control conferences such as the IEEE Conference on Decision and Control and the American Control Conference with standing-room-only audiences. Several smart grid conferences including the IEEE Innovative Smart Grid Technologies conference and Smart GridComm routinely dedicate several sessions to control-centric topics. This Section is the first of its kind in a major journal to focus on this topic and help underscore the important contributions that control can make in the area of smart grid.

In response to the call for papers, we received 79 abstracts for this Special Section from all over the world. After a quick round of reviews, 50 abstracts were accepted for full paper submission. 33 papers were submitted all of which underwent a very rigorous peer review process. We finally selected 14 full papers for this Special Section.

The papers in this Section can be broadly organized into three main categories: i) architectures for economic dispatch; ii) demand response strategies using heating, ventilation, and air conditioning (HVAC); iii) algorithms for distributed generation and storage; and iv) micro-grid based validation of distributed architectures.

Papers in category i) are concerned with strategies for economic dispatch of various generation resources so as to ensure power balance while also ensuring efficiency and reliability. The paper by Yang and Hug-Glanzmann seeks to improve the utilization of transmission assets, even as increased variations in power flows occur with increasing penetration of renewables, using a risk constrained economic dispatch. The paper by Zhu and Hug-Glanzmann proposes a stochastic approach based on model predictive control (MPC) for economic dispatch of generation and storage in the presence of uncertainties in generation and demand. The paper by Kiani, Annaswamy, and Samad proposes a transactive control architecture that includes a dynamic economic dispatch strategy combined with decision making for active control at the secondary and tertiary levels to address uncertainties in renewables and load.

Papers in category ii) are concerned with efficient demand response algorithms for dispatching building HVAC loads. The paper by Hao, Lin, Kowli, Barooah, and Meyn proposes a feed-forward control architecture to tap into the thermal storage potential in commercial buildings and use the energy for providing ancillary services to the grid. The paper by Zheng and Cai uses a queuing model and Lyapunov optimization to develop a dis-

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tributed demand response strategy for dispatching HVAC loads. The paper by Goddard, Klose, and Backhaus proposes a reduced-order model to represent the dynamics of a large-scale commercial HVAC system and develop a fast demand response control.

Papers in category iii) are concerned with issues that arise due to distributed generation and storage especially in the presence of high penetration of renewables. The paper by Chang, Gorinevsky, and Lall addresses the analysis and engineering of inverter-connected distributed generation by providing guidelines for the stability of the underlying interconnected distributed system. The paper by Larsen, van Foreest, and Scherpen addresses the problem of combined heat and power balance in a distributed network of households using distributed MPC. The paper by Rowe, Yunusov, Haben, Singleton, Holderbaum, and Potter considers the problem of reinforcing a low voltage distribution in the presence of increasing demand using an algorithm for distributed energy storage and load forecast. The paper by Stetz, Diwold, Kraiczy, Geibel, Schmidt, and Braun addresses the possibility of increasing the hosting capacity of low voltage grids with high photovoltaic penetration using autonomous voltage control and coordinated control approaches. The paper by Juelsgaard, Andersen, and Wisniewski considers optimization of consumption in a community with high demand response and solar energy resources while minimizing active losses in the grid using a coordinated control strategy.

Finally, papers in category iv) address validation of various concepts using a microgrid. The paper by Crisostomi, Liu, Raugi, and Shorten addresses the use of algorithms in distributed communication networks for optimizing distributed energy resources in a microgrid. The paper by Delfino, Minciardi, Pampararo, and Robba propose a multi-level decision architecture based on MPC to address the interactions between distributed energy resources, renewables, and storage in a microgrid. Finally the paper by Igualada, Corchero, Cruz-Zambrano, and Heredia addresses cost savings in a microgrid using an optimization model for the management of charging spots for plug-in electric vehicles.

It should be mentioned that a Special Section simply provides a snapshot into the field taken at a particular point in time. Due to the standard page limitations of a Transactions issue, it can only include a relatively small number of papers. As a result, its coverage is by no means complete despite our best efforts.

Many individuals contributed to the success of this Special Section. I would like to thank all the authors for their submissions and all the editors for orchestrating all of the reviews. I am also indebted to a small army of referees who have put in the hard work and the long hours to review each paper in a timely and professional way. Editorial Administrator Cheryl Koster provided enormous and valuable assistance. Last, but not least, I am indebted to the Editor-in-Chief, Mohammad Shahidehpour, for offering me this opportunity.

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