IEEE Control Systems Society (CSS)

Proposal for

Technical Committee on Smart Grids (TC-SG)

Proposed TC Chair: S. Massoud Amin, Department of Electrical and Computer Engineering, University of Minnesota, amin@umn.edu

Proposed TC Co-Chair: Tariq Samad, Honeywell Labs, tariq.samad@honeywell.com

1.0 Background

The term "smart grid" refers to the use of computer, communication, sensing and control technology which operates in parallel with an electric power grid for the purpose of enhancing the reliability of electric power delivery, minimizing the cost of electric energy to consumers, and facilitating the interconnection of new generating sources to the grid.

Recent policies in the U.S., China, India, EU, and other nations, combined with potential for technological innovations and business opportunities, have attracted a high level of interest in smart grids. Smart grids are seen as a fundamentally transformative, global imperative for helping the planet deal with its energy and environmental challenges. The ultimate goal is for an end-to-end electric power system (from fuel source, to generation, transmission, distribution, and end use) that will:

- Allow secure and real-time 2-way power and information flows
- Enable integration of intermittent renewable energy sources and help decarbonize power systems
- Enable energy efficiency, effective demand management, and customer choice
- Enable the secure collection and communication of detailed data regarding energy usage to help reduce demand and increase efficiency.

In 2007, the United States Congress passed the Energy Independence and Security Act outlining specific goals for the development of the nation's smart grid. Section 1301 of this Act states that, "It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:

1. Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.
2. Dynamic optimization of grid operations and resources, with full cyber-security…"

Smart Grid is a concept and a range of functionalities: It is designed to be inherently flexible, accommodating a variety of energy production sources and adapting to and incorporating new technologies as they are developed. It allows for charging variable rates for energy, based upon supply and demand at the time. In theory, this will incentivize consumers to shift their heavy uses of electricity (such as for heavy-duty appliances or processes that are less time-sensitive) to times of the day when demand is low (called peak shaving or load leveling). As an example of these range of functionalities, in 2008, U.S. Department of Energy (DOE) defined functions of a smart grid as:

- "Self-healing" from power disturbance events
- Enabling active participation by consumers in demand response
- Operating resiliently against physical and cyber attacks
- Providing power quality for 21st century needs

• Accommodating all generation and storage options
• Enabling new products, services, and markets
• Optimizing assets and operating efficiently.

The concept of smart grids, pertinent R&D programs aimed at developing self-healing grids, and the associated terminology, date back to the 1990s. Of particular interest is a large-scale research program conducted jointly by the Electric Power Research Institute (EPRI) and the U.S. Department of Defense (DOD) during 1998 – 2002, titled Complex Interactive Networks/ Systems Initiative (CIN/SI). 108 professors and over 240 graduate students in 28 U.S. universities participated, along with 52 utilities and grid operators. Several leading controls researchers led and/or participated in project teams. This work provided the mathematical foundations and simulations for the smart self-healing grid and showed that the grid can be operated close to the limit of stability given adequate situational awareness combined with better secure communication and controls.

Smart grid conceptualization and development is occurring internationally. Some information for activities in the EU and in China, for example, is available at http://www.smartgrids.eu/ and http://www.juccce.com/program_events/juccce_china_smart_grid_cooperative respectively.

2.0 Why does CSS need this TC?

Societal and governmental visions for the smart grid will require the engagement of the controls community for their realization. Feedback, optimization, estimation, dynamics, stability... these and other control system concepts are core to smart grid technology. In many ways, the smart grid is a control problem!

Control systems are needed across broad temporal, geographical, and industry scales—from devices to power-system-wide, from fuel sources to consumers, from utility pricing to demand response, and so on. With increased deployment of feedback and communication, opportunities arise for reducing consumption, for better exploiting renewable sources, and for increasing the reliability and performance of the transmission and distribution networks. At the same time, however, closing loops where they have never been closed before, across multiple temporal and spatial scales, creates control challenges as well.

The proposed TC will provide technical resources and collaboration opportunities for numerous researchers world-wide engaged in smart grids, in academic institutions, government laboratories, and industrial companies. Numerous companies with control system products and services are aggressively developing solutions for smart grids (e.g., ABB, GE, Honeywell, Siemens).

The TC will make particular effort to reach out to CSS members globally. Suggestions from CSS leaders for interested members to involve would be appreciated.

3.0 Targets and foci

The electric power network, combined with overlaid networks of sensing, communication and control constitutes a complex dynamical network, geographically dispersed, nonlinear, and interacting both among its components and with its human owners, operators, and users. No single entity has complete control of these multi-scale, distributed, highly interactive networks, nor does any such entity have the ability to evaluate, monitor, and manage them in real time.

There are several technical areas that the controls community can contribute to and that the proposed TC will cover, for example:

- Optimization of demand response under variable pricing
- Integration of distributed generation and storage in automation and control strategies
- Integration of plug-in electric and hybrid-electric vehicles

- Distributed state estimation of power systems, and elements thereof, with limited sensing and communication
- Cybersecurity in smart-grid control systems
- New power market designs that exploit feedback and information integration
- Stability issues, especially given latency and uncertainty in communication networks
- Self-monitoring and self-healing in intelligent transmission systems
- Modeling and analysis of multi-scale, complex grids
- The broader systems question: how can we engineer (and retrofit) a stable, secure, robust and resilient grid with large numbers of unpredictable power sources and variable demand

Structure of the TC

After consultation with CSS volunteers interested in participating in the TC on Smart Grid, we anticipate forming several working groups. A preliminary structure is as follows:

- *Demand-side optimization and control.* 90+% of the electricity generated in developed nations is consumed in residential, commercial, and industrial premises. Energy efficiency and peak load reduction are required to reduce overall electricity consumption, to minimize use of expensive peaking plants, and to fully exploit renewable sources. Automation and control systems in homes, buildings, and industrial plants will be needed to minimize consumption and cost.
- *Intelligent transmission and distribution.* New sensors and power-flow-management devices can, in principle, promise the fulfillment of the long-standing promise of self-healing grids. Key research needs include estimation, observers, and modeling under partial and uncertain information.
- *Policies and pricing mechanisms for real-time power markets.* Smart grids will result in new business and market structures. Issues related to information sharing, real-time or near-real-time dynamic pricing, fairness of access, and others must be resolved. Modeling, control, optimization, will be crucial.
- *Automation aspects of integrating distributed generation and storage.* Future power systems are likely to have substantially larger contribution from renewable sources such as wind and solar, which are characterized by intermittency of operation and a lack of ability to dispatch. Integrating such sources in an automation and control system is therefore challenging, since balance between instantaneous supply and demand must always be maintained. Storage technologies—and their control—will be crucial in this respect. Plug-in electric (including hybrid) vehicles must also be considered.

4.0 Collaboration with TC on Power Generation and Control

We also foresee synergies between this TC and one proposed on Power Generation and Control. The energy space is too broad and important for the controls community to be covered with one TC, but close collaboration between energy-related TCs is crucial.

In addition to TC-specific activities, it is suggested that the two proposed energy TCs collaborate on the organization of some CSS events—e.g., special issues of CSS journals/magazine, *IEEE Transactions on Smart Grid* (CSS is a partner in this new journal, the first issue of which is expected in June 2010), and *Proceedings of the IEEE*. Collaboration on symposia, conferences, and for the organization of special topic workshops in ACC, MSC, and CDC is also suggested.

5.0 About the proposed TC chair

S. Massoud Amin holds the Honeywell/H.W. Sweatt Chair in Technological Leadership, directs the Technological Leadership Institute (TLI), is a University Distinguished Teaching Professor and a professor of electrical and computer engineering at the University of Minnesota.

Dr. Amin is an expert in and teaches graduate courses in smart grids and leads the Minnesota Smart Grid Coalition. As Director of the Technological Leadership Institute, he leads a team of 52 senior faculty members from across the University and industry executives, who develop local and global leaders for technology enterprises.

He has worked with military, government, universities, companies, and private agencies, focusing on theoretical and practical aspects of reconfigurable and self-repairing controls, electric power and national energy systems, infrastructure security, risk-based decision making, system optimization, and differential game theory for aerospace, energy, and transportation applications.

Prior to joining the University of Minnesota in March 2003, Dr. Amin held positions of increased responsibility including the Area Manager of Infrastructure Security, Grid Operations/Planning, Energy Markets, and Risk and Policy Assessment at the Electric Power Research Institute (EPRI) in Palo Alto, California. In the aftermath of the tragic events of 9/11, he directed all security-related R&D at EPRI. Prior to 9/11, for four years he served as head of mathematics and information sciences where he developed and led the CIN/SI program referred to above.

Prior to joining EPRI in January 1998, he was an associate professor of systems science and mathematics and associate director of the Center for Optimization & Semantic Control at Washington University in St. Louis, Missouri. During his twelve years at Washington University, he was one of the main contributors to several projects with several government and industry sponsors.

Dr. Amin is the author or co-author of more than 180 refereed papers, the editor of seven collections of manuscripts, and serves on the editorial boards of six academic journals. At Washington University, students voted him three times Professor of the Year and awarded him the senior class' Leadership Award in 1995. Dr. Amin received Best Session Paper Presentation Awards (American Control Conference, 1997) and an AIAA Young Professional Award (St. Louis section, 1991). At EPRI he received several awards including the 2002 President's Award for the Infrastructure Security Initiative, 2000 and 2002 Chauncey Awards (the institute's highest honor, in March 2001 and 2003), and six EPRI Performance Recognition Awards during 1999-2002 for leadership in three areas.

He served as a member of the Board on Infrastructure and the Constructed Environment (BICE) at the U.S. National Academy of Engineering during 2001-2007, and a member of the Board on Mathematical Sciences and Applications (BMSA) at the U.S. National Academy of Sciences during 2006-2009. He served as a member of the IEEE Computer Society's Task Force on Security and Privacy in the aftermath of 9/11, and served on the Board of the Center for Security Technologies (CST) at Washington University (2002-2006). Dr. Amin holds B.S. (cum laude) and M.S. degrees in electrical and computer engineering from the University of Massachusetts-Amherst, and M.S. and D.Sc. degrees in systems science and mathematics from Washington University in St. Louis, Missouri.

IEEE activities

- Editorial Board Member, IEEE Control Systems Magazine (Jan. 1998-Jan. 2003)
- Editorial Board Member, IEEE Security and Privacy magazine (April 2002- Dec. 2006)
- Editorial Board Member, IEEE Power and Energy Magazine (Jul. 2006-present)
- Served as the IEEE Control Systems Society's Chair of Technical Committee on Control of Power Systems, 1998-2003. Organized/Chaired Sessions at various Control Systems and Power Engineering Societies' Conferences; Served as Guest Editor of:
    - Editor Special Issue of Proceedings of the IEEE on Energy Infrastructure Defense Systems, May 2005

    - Editor Special issues of IEEE Control Systems Magazine on Control of Complex Networks, February 2002
    - Editor Special issue of IEEE Control Systems Magazine on Power Systems and Markets, Aug. 2000
- Member-at-Large, IEEE Energy Policy Committee
- Served on IEEE Computer Society's Task Force on Security & Privacy, Apr. 2002- Jan. 2007
- Served as the IEEE Robotics & Automation Society's liaison to the Neural Network Council, 1992-'93.

6.0 Potential members of the TC

- Prof. Anuradha Annaswamy, Massachusetts Institute of Technology
- Dr. Kishan Baheti, National Science Foundation
- Prof. Aranya Chakrabortty, Texas Tech Univ.
- Prof. Joe Chow, Rensselaer Polytechnic Institute
- Prof. Chris DeMarco, Univ. of Wisconsin-Madison
- Prof. Eduardo Camacho, Univ. of Seville
- Prof. Ian Hiskens, Univ. of Wisconsin-Madison
- Dr. Paul Houpt, GE
- Prof. Marija Ilic, Carnegie Mellon University
- Prof. Bruce Krogh, Carnegie Mellon University
- Prof. Stephen Low, Caltech
- Prof. Prof. Toru Namerikawa, Keio University
- Dr. Jorge Pereira, European Commission
- Dr. Tariq Samad, Honeywell Labs
- Prof. Mohammad Shahidehpour, Illinois Institute of Chicago
- Prof. Sarosh Talukdar, Carnegie Mellon University
- Prof. Lefteri Tsoukalas, Purdue University
- Prof. Pravin Varaiya, UC-Berkeley
- Prof. George Verghese, Massachusetts Institute of Technology

With the exception of Dr. Samad, who has agreed to serve as the TC co-chair, the above individuals have not been approached as yet for their interest in participating in the TC. However, they are all active in related research activities and we are optimistic that the majority will enthusiastically agree to participate.

Contact information for the proposed TC chair:

Dr. S. Massoud Amin
Director, Technological Leadership Institute (TLI)
Honeywell/H.W. Sweatt Chair in Technological Leadership
Professor, Electrical & Computer Engineering
University Distinguished Teaching Professor

University of Minnesota
1300 South Second Street, Suite 510
Minneapolis, MN 55454 USA
Web: http://umn.edu/~amin