Smart Grids, Renewable Energy, & Data Analysis

Organizers

Prof. Anthony Kuh: University of Hawaii: kuh@hawaii.edu
Prof. Danilo Mandic: Imperial College, London: d.mandic@imperial.ac.uk
Dr. Dora Nakafuji: Hawaiian Electric Company: dora.nakafuji@heco.com

I. MOTIVATION AND SYNOPSIS

We live in a time and age when technologies are so ubiquitous that they affect many, if not all, aspects of our lives. The twentieth century was marked by numerous technological innovations, with *electrification* topping the list of Greatest Engineering Achievements in the Twentieth Century[1], and *computers* and the *Internet* are both included among the top fifteen on that list. As the world continues to progress, technologies will continue to evolve, facilitated by various forms of innovations. The technology that makes the existing electric power grid smarter is among the technological innovations that will most likely have profound impact on our lives, for the legacy grid desperately needs major improvements on its efficiency and dependability, and on reducing negative environmental impacts.

Developing a *smart grid* is a compelling national and global technological challenge. It is compelling not only because of the need for reliable energy sources, but also because of environmental reasons. While the amount that renewable energy sources should contribute to the entire power generation portfolio is often a political decision, one thing is clear: we must develop and embrace technologies that improve the efficiency, reliability, and security of power generation, distribution, and consumption. The integration of information and communication technology with power systems engineering provides a promising path to the development of smart grid technology. However, such integration requires innovative research to address many challenges presented by the desired features of smart grid, including timely demand response, self-healing, etc. Employing off-the-shelf technologies is most likely not adequate.

The key features of the smart grid include active participation by consumers, accommodation of generation and storage options, enable new tools, products, services, and market, provide power quality, optimize asset utilization and operate efficiently, enable self healing, and resiliency to attacks and natural disaster. This tutorial will start with basics of those smart grid features and vision, the key technologies and infrastructure required for that development including PHEV, communication, and distributed sensing and estimation. We shall present basic principles, benefits, costs, and politics of various forms of renewable energy and their integration into the grid. We shall also cover issues relevant to demand response, privacy and security, and the social, commercial, and regulatory implications of the development of smart grid technology. We also discuss how techniques in machine learning and signal processing can be effectively applied to smart grid and renewable energy integration.

II. LECTURE TOPICS

1. Smart grid basics –
   - what is smart grid and why;
   - objectives and main features of smart grid;
   - key terminologies;
   - applications and potential impacts.
2. Energy resources – are we running out of fuel?
   - renewable energy: solar, wind, hydropower, biomass, geothermal, ocean wave, biofuels;
   - benefit, costs, and government policies of renewable energy;
   - renewable sources integration;
   - centralized vs. distributed generation;
   - storage systems technology;
   - microgrids.

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[1] http://www.greatachievements.org/ (U.S. National Academy of Engineering)

3. Plug-in Hybrid Electric Vehicle (PHEV) –
   - history of EV;
   - PHEV challenges and potential solutions;
   - EV and electric power grid;
   - PHEV charging infrastructure, challenges and solutions;
   - PHEV as an energy storage device and an energy source (V2G).
4. Monitoring the smart grid –
   - environment sensor network data
   - data interpretation and visualization
   - wide-area monitoring system (WAMS), SCADA and PMU;
   - advanced metering infrastructure (AMI);
   - smart metering;
   - state estimation, multi-area state estimation, forecast-aided state estimation;
   - distributed estimation and smart grid system monitoring;
   - self-healing;
   - privacy – how much?
5. Demand Response and demand-side management –
   - load profile of the power grid;
   - market pricing;
   - peak shaving and valley filling;
   - load forecasting;
   - regulations and policies.
6. Communication infrastructure for smart grid –
   - power line communications;
   - wireless communications, basic principles and standards;
   - M2M communications;
   - home area networks;
   - security in communications.
7. State-of-the-Art – test beds/field trials, what has been done and where?

III. REFERENCES AND READING MATERIAL

1. J. Duncan Glover, Mulukutla S. Sarma, and Thomas J. Overbye, *Power System, Analysis and Design*, 4th Ed., Stamford, CT: Cengage Learning, 2008.
2. Jan Machowski, Janusz Bialek, and James R. Bumby, *Power Systems Dynamics, Stability and Control*, 2nd Ed. New York, New York: John Wiley, 2008.
3. B. Droste-Franke, et al., *Balancing Renewable Electricity – energy storage, demand side management, and network extension from an interdisciplinary perspective.* Heidelberg, Germany: Springer, 2012.
4. David J.C. MacKay, *Sustainable Energy – without the hot air*.
5. Charles Weiss and William B. Bonvillian, *Structuring an Energy Technology Revolution*. Cambridge, Massachusetts: MIT 2009.
6. T. Ackermann, Ed., *Wind Power in Power Systems*. New York, New York: Wiley, 2005.
7. M. Ehsani, Y. Gao, S. E. Gay, and A. Emadi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design*. New York, New York: CRC Press, 2005.
8. William Stallings, *Wireless Communications & Networks*, 2nd Ed. Upper Saddle River, NJ: Prentice-Hall, 2005.
9. John B. Anderson and Rolf Johannesson, *Understanding Information Transmission*. Piscataway, NJ: IEEE Press, 2005.
10. *Smart Grid Communications and Networking*, Edited by Ekram Hossain, Zhu Han, H. Vincent Poor, Cambridge University Press, 2012.
11. *The Smart Grid: An Introduction*, http://www.oe.energy.gov/SmartGridIntroduction.htm, Department of Energy, 2008.
12. TiE Oregon's Clean Energy SIG Focus on the Smart Grid: http://www.slideshare.net/irhicks2/ti-e-smart-grid-overview-rh-5-05-09

IV. JUSTIFICATION FOR TUTORIAL

In the Computational Intelligence Society (CIS) there has been much interest in applying algorithms and methods developed in our society to the smart grid and energy areas. There have been numerous special sessions at IJCNN on smart grids and energy. At the SSCI conference there have been workshops on computational intelligence analysis of the smart grid (CIASG). There is also a current call for papers for a special issue of the IEEE Transactions on Neural Networks and Learning Systems Applications in Smart Grid.

V. BIOGRAPHIES

Anthony Kuh: He received his B.S. in Electrical Engineering and Computer Science at the University of California, Berkeley in 1979, an M.S. in Electrical Engineering from Stanford University in 1980, and a Ph.D. in Electrical Engineering from Princeton University in 1987. Dr. Kuh previously worked at AT&T Bell Laboratories and has been on the faculty in Electrical Engineering at the University of Hawai'i since 1986. He is currently a Professor in the Department and is also currently serving as director of the interdisciplinary renewable energy and island sustainability (REIS) group. Previously, he served as Department Chair of Electrical Engineering Dr. Kuh's research is in the area of neural networks and machine learning, adaptive signal processing, sensor networks, communication networks, and renewable energy and smart grid applications.

Dr. Kuh won a National Science Foundation Presidential Young Investigator Award and is an IEEE Fellow. He was also a recipient of the Boeing A. D. Welliver Fellowship and received a Distinguished Fulbright Scholar's Award working at Imperial College in London. Dr. Kuh was an Associate Editor for the IEEE Transactions on Circuits and Systems, served on the IEEE Neural Networks Administrative Committee, served on the IEEE Neural Networks for Signal Processing Committee, and was a Distinguished Lecturer for the IEEE Circuits and Systems Society. Dr. Kuh co-chaired the 1993 International Symposium on Nonlinear Theory and Its Applications (NOLTA) and served as the technical co-chair for the 2007 IEEE ICASSP both held in Honolulu. He co-chaired special sessions on energy and smart grids at IJCNN 2010, is a member of the CIS Task Force on Smart Grid, and contributed an article to the CIS magazine special issue on Computational Intelligence in Smart Grid in 2011. He is currently serving as the IEEE Signal Processing Society Regions 1-6 Director at Large, on the Board of Governors of the Asia Pacific Signal and Information Processing Association, and as a senior editor of the IEEE Journal of Selected Topics in Signal Processing Journal.

Danilo Mandic: He obtained his PhD in the area of nonlinear adaptive systems from Imperial College in 1999 and is currently a Professor of Signal Processing at the same institution. He has been working in the areas of nonlinear and multidimensional adaptive filters, complex- and quaternion-valued neural networks, time-frequency analysis and complexity science. His research has found applications in biomedical engineering (brain-computer interface), human-computer interaction (bodysensor networks), and renewable energy and smart grid. He has published two research monographs: "*Recurrent Neural Networks for Prediction*", Wiley 2001, and "*Complex Valued Nonlinear Adaptive Filters: Noncircularity, Widely Linear and Neural Models*", Wiley 2009, and has also co-edited a book on Data Fusion (Springer 2008) and has been a part-editor for Springer Handbook on Neuro- and Bio-informatics (Springer 2014). Dr Mandic has held visiting positions in RIKEN (Japan), KU Leuven (Belgium) and Westminster University (UK). Professor Mandic is a Fellow of the IEEE, has been a Publicity Chair for the World Congress on Computational Intelligence (WCCI) in 2013, Plenary Talks Chair at EUSIPCO 2013, European Liaison at ISNN in 2011 and a Program Co-Chair for ICANN in 2007. He has given keynote and tutorial talks at foremost conferences in Signal Processing and Computational Intelligence (ICASSP in 2013 and 2007, IJCNN in 2010, 2011, and 2012), and has been an Associate Editor for IEEE Transactions on Neural Networks and Learning Systems (since 2008), IEEE Signal Processing Magazine, and IEEE Transactions on Signal Processing. He is also a Co-Chair of the *Task Force on Complex Neural Networks* and a Member of the *Task Force on Smart Grid* (both within IEEE CIS), and the *Signal Processing Theory and Methods* technical committee within the IEEE SPS.

Dr. Mandic has won several Best Paper awards in international conferences in Computational Intelligence

(2010, 2009, 2006, 2004, 2002), and was appointed by the World University Service (WUS) as a Visiting Lecturer within the Brain Gain Program (BGP). His Ear-EEG device has been shortlisted for the Annual Brain Computer Interface Award in 2012. He has been granted patents and has had successful industrial collaborations in the areas of brain- and human-computer interface.

Dr. Mandic has great satisfaction in educating new generations of researchers and his PhD students and PDRAs have won Best Thesis awards at his home Department in 2007 and 2011, Best Student Paper awards in ISNN in 2010, MELECON 2004, and RASC in 2002, and Best Research poster in 2012.

Dora Nakafuji: Dr. Nakafuji is the Director of Renewable Energy Planning at Hawaiian Electric Company. With over 14 years of experiences in renewables, her division is responsible for spearheading and coordinating many of the renewable integration initiatives being undertaken by the island utilities. Integration efforts focus on reducing utility and customer risks. Efforts include operationalizing an advance real-time solar and wind integrated forecasting capability, assessing distributed generation impacts on the grids, developing data analysis/modeling and visualization, enhancing EMS integration of renewables, developing workforce and technical outreach with industry and academia. Dr. Nakafuji's team works with numerous industry leaders in forecasting, EMS integration, improving grid intelligence through technology and data informatics. Dr. Nakafuji has a PhD in Aero/Mechanical Engineering from UC Davis, holds a patent in advance blade control and is also an adjunct professor at the University of Hawaii at Manoa.