

# Brain Science and Living Neuronal Networks for Smart Grids

G. Kumar Venayagamoorthy<sup>1</sup> and Steve M. Potter<sup>2</sup>

<sup>1</sup>Real-Time Power and Intelligent Systems Laboratory Department of Electrical and Computer Engineering Missouri University of Science and Technology, Rolla, MO 65409 <sup>2</sup>Laboratory for Neuroengineering Coulter Department of Biomedical Engineering Georgia Institute of Technology and Emory University, Atlanta, GA

The objective of this multi-disciplinary collaborative research is to infuse more neurobiology into control systems, to make them more brain-like and better able to carry out real-time control of complex systems. This project has two research thrusts, 1) neurobiology-based and 2) neuroengineering-based.

On the neurobiology side, a novel in vitro neural system is used to explore new learning mechanisms that may underlie the massively parallel real-time control capabilities of the brain. Brains are exquisitely good at adaptive real-time interaction with the world. This requires spatially and temporally coordinated activity of many neurons to accomplish. Although much is known about how neurons function, comparatively little is known about how networks of them, along with glial cells, produce the kinds of emergent brain properties we call memories, thoughts, decisions, associations, or perceptions. How do neural systems adapt and learn to be highly effective at time-critical control problems? In this project, we are approaching this question by studying small living neuronal networks (LNNs) in culture, which have fewer uncontrolled parameters than intact brains, and are much more amenable to detailed observation and manipulation. LNNS of ~50,000 neurons (and glial cells) from rodent cortex are grown in culture, using multi-electrode array culture dishes (MEAs).

The neuro-engineering activity takes advantage of advances in the neurobiology thrust to develop technologies for real-time control and decision making, aimed at revolutionizing nonlinear adaptive optimal control of large complex critical infrastructures such as, but not limited to, the smart electric power grid.

Living neuronal networks (LNNs) in Atlanta, GA are trained to predict the responses of several different Real-Time Digital Simulator (RTDS) models of power networks in Rolla, MO. In parallel, the results from the LNNs are used to develop new types of biologically-inspired artificial neural networks (BIANNs). The BIANNs are then to be used (instead of existing neural network architectures structures) in several closed loop control applications scattered throughout a power system, firstly by simulation, and then on hardware testbeds.

The findings of this research shall provide a better understanding of multiple-time base system identifiers and controllers, and their interactions and scalability for large

systems. Neurocontrol of the power grid with new architectures and algorithms will therefore increase real-time responsiveness to changing power loads and component failures, improve the dynamic and transient behavior of the power network, and improve grid reliability, ensuring local and wide area stability, reduce greenhouse gas emissions and assisting human experts in control rooms.