ADVANCED COMPUTATIONAL METHODS TO INTEGRATE REAL-TIME SYSTEM DATA FOR SMART GRID CONTROL CENTER OPERATIONS

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With the emerging innovations to the electricity infrastructure (referred to as the smart grid), high levels of penetration of renewable energy, and an emphasis on information and communication technologies, and competitive pricing, it will become necessary to optimize the safety margins presently allowed, and use existing equipment as optimally as possible. Maintaining reliable service and implementing emergency defense plans during major unintended disturbances and intended attacks is critical with the growth of the electric power network and its information infrastructure.

Intelligent communication, computation and control (IC^3) technologies needed for distributed modeling, sense-making, situational awareness/intelligence, decision-making, control and optimization in smart grid real-time control centers is the emphasis of this position paper. The smart grid can be viewed as a digital upgrade of the existing electricity infrastructure that minimizes the cost of energy and reduces emissions. The monitoring, optimization and control systems for smart grids will require scalable computerized intelligent systems to handle the increased variability and uncertainties caused by increased penetration of intermittent renewable energy resources. What principles will govern the design of such systems and where do we find them? [1] Do we have the technologies today to grow and ripe the fruits (*reduced* cost *of energy and emissions*) of the smart grid promises at a large scale?

A vast amount of data is generated and must be processed, so that the pertinent information is communicated to the appropriate control centers in time for necessary decisions to be made and adaptations to take place. All that will depend on the development of computerized intelligent systems, or computational systems thinking machines (CSTMs). Such CSTMs will have to have three basic capabilities: sense-making, decision-making and adaptation [2]. Realization of those capabilities will depend in turn on subsystems that continuously improve their *knowledge* of grid dynamics and not just gather data. Using traditional methods, however, it is difficult or impossible to model, control and optimize power systems because of their nonlinearity, spatial and temporal complexity, ever-changingness, and uncertainties. The smart grid is a complex cyber-physical electric energy generation-delivery system.

The optimization and control systems for cyber-physical power system (CPPS) will require dynamic information and computational capabilities to handle the uncertainties and variability that exist especially with distributed and renewable energy integration. These technologies must be scalable and real-time data driven given the complexity of a smart grid especially that of the United States of America. The development of reliable and scalable intelligent monitoring and control algorithms, and situational intelligence (*beyond situational awareness (SA)*) technologies are needed as synchrophasor measurement devices (such as phasor measurement units (PMUs)) and other advanced metering infrastructure (AMI) are deployed for operational sense-making, decision-making and implementing actionable controls. These PMU and AMI data can be used in online model validation, improving models used in state estimators, and many real-time EMS applications.

The next question is the vulnerability of control center operations with these cyber data, and what is the trust level? Cybersecurity will need to be integrated to make the nation's control centers secure to deliver stable, reliable and efficient real-time operations.

References:

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[2] Venayagamoorthy GK, "Dynamic, Stochastic, Computational and Scalable Technologies for Smart Grid", *IEEE Computational Intelligence Magazine* (*Special Issue on Smart Grid*), Vol. 6, No. 3, August 2011, pp. 22-35