The smart grid is expected to support an interconnected network of self-contained microgrids. Nonetheless, the distributed integration of renewable generation and demand response adds complexity to the control and optimization of smart grid. Forecasts are essential due to the existence of stochastic variations and uncertainty. Forecasting data are spatio-temporal, which means that the data correspond to regular intervals, say every hour, and the analysis has to take account of spatial dependence among the distributed generators or locations. Hence, smart grid operations must take account of, and in fact benefit from the temporal dependence as well as the spatial dependence. This is particularly important considering the buffering effect of energy storage devices such as batteries, heating/cooling systems and electric vehicles. The data infrastructure of smart grid is the key to address these challenges, however, how to utilize stochastic modeling and forecasting tools for optimal and reliable operation and control of smart grid remains an open issue.

Utilities are seeking to become more proactive in decision-making, adjusting their strategies based on realistic predictive views into the future, thus allowing them to sidestep problems and capitalize on the smart grid technologies, such as energy storage, that are now being deployed at scale. Predictive analytics, capable of managing intermittent loads, renewables, rapidly changing weather patterns and other grid conditions, represent the ultimate goal for smart grid capabilities. Within this framework, this dissertation develops high-performance analytics, such as predictive analytics, and ways of employing analytics to improve distributed and cooperative optimization software which proves to be the most significant value-add in the smart grid age, as new network management technologies prove reliable and fundamental.

Proposed optimization and control approaches for active and reactive power control are robust to variations and offer a certain level of optimality by combining real-time control with hours-ahead network operation schemes. The main objective is managing spatial and temporal availability of the energy resources in different look-ahead time horizons. Stochastic distributed optimization is realized by integrating a distributed sub-gradient method with conditional ensemble predictions of the energy storage capacity and distributed generation. Hence, the obtained solutions can reflect on the system requirements for the upcoming times along with the instantaneous cooperation between distributed resources. As an important issue for smart grid, the conditional ensembles are studied for capturing wind, photovoltaic, and vehicle-to-grid availability variations. The following objectives are pursued:

- Spatio-temporal adaptive modeling of data including electricity demand, electric vehicles and renewable energy (wind and solar power)
- Predictive data analytics and forecasting
- Distributed control
- Integration of energy storage systems

Full distributional characterization and spatio-temporal modeling of data ensembles are utilized in order to retain the conditional and temporal interdependence between projection data and available capacity. Then, by imposing measures of the most likely ensembles, the distributed control method is carried out for cooperative optimization of the renewable generation and energy storage within the smart grid.
Damla Turgut, Electrical & Computer Engineering
Mariana Pensky, Mathematics
Aman Behal, Electrical & Computer Engineering
George Atia, Electrical & Computer Engineering

Approved for distribution by Zhihua Qu, Committee Chair, on May 31, 2016.

The public is welcome to attend.