***ABSTRACT***

Power systems all over the world are drastically transforming in an effort to reduce carbon emissions,
increase efficiency, and become more resilient to extreme events. With a changing energy landscape comes the need for tools that allow utility planners and regulators to explore the future of the grid system and make informed, data-driven decisions on future investments. Namely, power system expansion planning models are developed to assist in this decision-making. Power systems are complex systems that are vulnerable to extreme meteorological events that can cause an insurmountable amount of damage to society economically, socially, and physically. Therefore, considerations towards infrastructure resilience within these power system expansion planning models must be made. Expansion planning models are typically long-term in nature and provide investment decisions into the future. While considering the long-term nature of the models comes the presence of uncertain parameters and assumptions in the model. Thus, expansion planning models must also take into account the uncertainties and several future scenarios must be evaluated. Long-term co-optimized
expansion planning (CEP) has previously been implemented to identify generation, transmission,
and distribution (GTD) investments over a planning horizon of 10-30 years.

The purpose of this dissertation is to extend the functionality of the CEP model such that it handles resilience and adaptation while also identifying processes that can be used in today’s electric infrastructure planning processes.

Extreme events - including hurricanes, flooding, tornadoes, earthquakes, and other natural disasters -
greatly affect the structural integrity of the power system and, as a result, the delivery of power to customers is disrupted. Therefore, it is vital to investigate how these extreme events affect our power system and how a power system that is resilient against such events can be achieved. This leads to the development of a long-term expansion planning model that explores capacity expansion and resilience investments within the GTD system. This model seeks to find the most cost-effective investment portfolios while incorporating the influence of extreme events on the system. This influence is reflected by using meteorological data, historical weather events, fragility curve analysis, and statistical failure data. In this work, this model is tested with a 315 bus representation of the power system in the islands of Puerto Rico. The model explores resilience and capacity investments made in a 20-year planning horizon with typical meteorological years (TMY) and extreme meteorological years (EMY). A sensitivity analysis is performed to assess the value of making generation investments at the distribution level versus the transmission level is performed. The AEP model is a stochastic-based CEP model that has the ability to handle uncertainties and future scenarios. This model is used on a reduced model of the Eastern Interconnection (EI) with emphasis on the Midcontinent Independent System Operator (MISO) planning region. Within this work, several fundamental steps are completed to develop and test the planning software. The first task is to develop a reduced model of the Eastern Interconnection via Kron Reduction methodology with an emphasis on the MISO network. Then a database of the EI generator and economic data is constructed to be used as input into the AEP planning model. Simultaneously, future scenarios and uncertain variables are identified to be used for the AEP model structure. The overall goal of this analysis is to evaluate the overall performance of the AEP model with the EI dataset and use this methodology to further evaluate the MISO Transmission Expansion Planning (MTEP) process. A plan validation technique, called the folding horizon simulation (FHS) is also implemented into this work. The FHS algorithm allows the planner to efficiently expose the AEP core solutions to ”out-of-sample” uncertainties and provide insight into the overall robustness of the plans. A connection
and comparison between the deterministic resilience-based CEP model and the AEP model are made. This allows for even further investigation within the investment portfolios to make a system more resilient and economically attractive. To accomplish this, a conceptualization of resilience-based uncertainties is introduced and discussed. Finally, an overview of how resilience should be introduced into traditional planning frameworks is discussed.

Lastly, the potential benefits of the tools and concepts presented in this work are discussed in the context of the MTEP process. Numerous tool enhancements and study framework considerations will be introduced to further improve today’s transmission planning processes. In doing so, long-term investment portfolios can be identified to develop a power system that is resilient to extreme events and adaptive to future uncertainties.