EPClimate: A New Probabilistic Simulation Model for Assessing Impacts of Climate Change on Power Systems

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Background and Purpose: Climate change is undoubtedly one of the most serious threats facing the U.S. power grid today. Two important factors contribute to this observation: wind, solar and hydropower are all susceptible to a climate that is becoming less predictable and increasingly more intense and more frequent weather events driven by climate change. Some of the adverse manifestations of climate change include prolonged heat wave, increased precipitation and flooding, more frequent and extensive wildfires, and sea level rise among many others. The purpose of this paper is to describe Argonne's new probabilistic simulation model that has been used to help power system planners as well as emergency responders more accurately predict the impacts of climate change on power system performance, thereby enabling them to formulate better mitigation and adaptation measures to protect critical electric assets. To illustrate the mathematical logic and usefulness of the tool, a specific application involving a wildfire scenario threatening a real system is presented and discussed in this paper.

Approaches and Activities. EPClimate utilizes the Monte Carlo framework to simultaneously account for stochastic nature of the various climate-induced threats in combination with the uncertainties on asset operational status due to forced outage rates. For the wildfire application, the model provides a mechanism to link a comprehensive database of fire-ignition probability raster maps with the regional electric infrastructure spatial layers to quantify risk to the individual assets as well as the entire electric grid. Embedded within the model are sets of fragility curves (damage functions) that relate wildfire hazard intensity to probable damage levels as well as functionality degradation of affected assets. The model is applied to a real system operating in southern California. EPClimate employs a grid simulator that estimates the geographic extent of power outage and system loss due to the disruption of assets affected by the wildfire. It also uses an optimal power flow module to re-route power and search for a new stable operating point for the system.

Results and Lesson Learned. The study has shown that the Monte-Carlo-based wildfire threat model within EPClimate is capable of quantifying the potential impacts of wildfire threat to an actual system in a probabilistic fashion. Impacts are depicted via probability distribution curves, failure probability exceedance plots, and heat maps for region-wide impact depictions. In addition, the model reports the individual transmission lines, substations, and generators that are most at risk of being damaged by the wildfire, as well as those which are at risk of disruption due to cascading failures which result from the initial impact The generated likelihood - consequence chart for this particular scenario after 500 Monte Carlo iterations indicates a MW loss ranging from 0 to 2,000 MW along the high-likelihood-of-fires region of the chart. These values appear consistent with past historical observations in the consequence space. Similar observations can be made on the likelihood space. Further work can be done to enhance the significance of the results gathered so far. Probabilistic outcomes such as the expected geographic outage area can be estimated using the output of the Monte Carlo simulation and methods from spatial analysis. Similarly, unserved energy can also be estimated by combining this model with an existing tool developed by Argonne which models system restoration and determines potential recovery time.