Potential Impacts of Heat Waves and Coincident Drought on Electric Grid Reliability in the Eastern Interconnection

Jennie Rice, James Dirks, Michael Kintner-Meyer, Scott Morris, Timothy Seiple, Daniel Skorski

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Platform for Regional Integrated Modeling and Analysis

Introduction

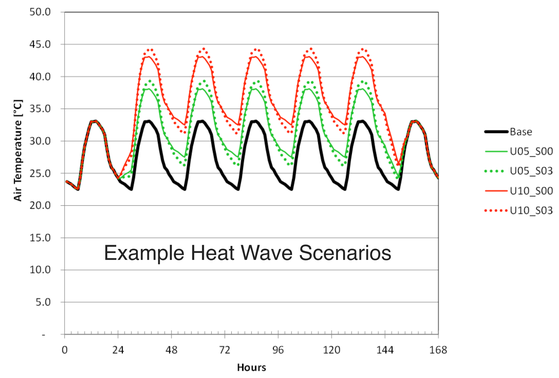
Recent droughts, heat waves, and severe storms have focused public attention on the vulnerability of the U.S. electricity system to climate change. This research explores the system reliability impact of increasingly severe heat wave scenarios coincident with power plant operational curtailments due to water-related constraints in the Eastern Interconnection (EIC).

Developing Heat Wave Scenarios

Uplift: the increase in the daily average temperature over the target period.
Spread: the increase in difference between the maximum and minimum temperatures in the day (spread can be positive or negative).
Duration: length of the heat wave event in days.

Scenario	Uplift (°C)	Spread (°C)	Duration (days)
1	0.0	0.0	5
2	5.0	−3.0	5
3	5.0	0.0	5
4	5.0	3.0	5
5	7.5	−3.0	5
6	7.5	0.0	5
7	7.5	3.0	5
8	10.0	−3.0	5
9	10.0	0.0	5
10	10.0	3.0	5

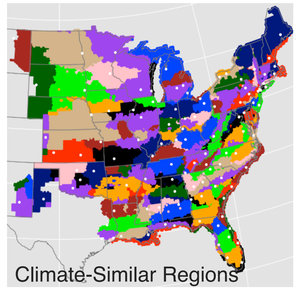
To get a clean heat wave signal, the scenarios were applied to a "typical day" constructed from the average hourly temperatures over a 28-day period in the last two weeks of July and first two weeks of August in 2005. The results were compared to historical temperature data (2000-2012) to verify their reasonableness.



Modeling Heat Wave Impacts on Electricity Demand

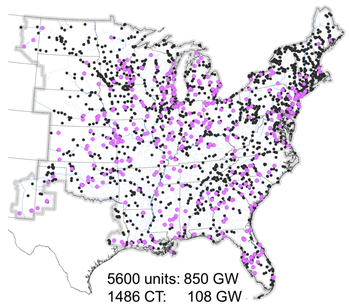
Under severe heat waves, the use of air conditioning can increase significantly, driving the demand for electricity up over the entire period, with the largest increases during the mid- to late-afternoon hours. To simulate hourly demands for each heat wave scenario, we used PNNL's Building ENergy Demand (BEND) model. BEND runs DOE's EnergyPlus model for unique building types within a census block and then statistically aggregates the hourly simulation results to a user-defined regional scale. BEND takes into account hourly weather conditions, building stock characteristics, building schedules, and population.

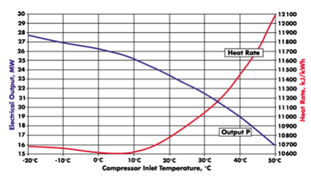
For this analysis, BEND simulated the hourly building loads for approximately 2000 unique buildings within each of the climate-similar regions shown at right and then aggregated the results to the 39 utility zones in the EIC used for the system reliability modeling. The total number of buildings simulated was approximately 2 million.


Climate-Similar Regions

Modeling Heat Wave Impacts on Electricity Supply

High ambient temperature conditions affect the output and efficiency of air-breathing gas combustion turbines (CTs) because of the reduced density of the air at higher temperatures--unless inlet cooling technologies are used. We used the function represented below to modify the output of each gas combustion turbine in the EIC for each heat wave scenario.



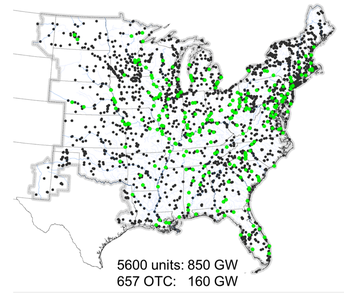


Generator output and heat rate versus compressor inlet air temperature for an SGT-600 industrial gas turbine (Siemens Westinghouse).

Modeling Drought Impacts on Electricity Supply

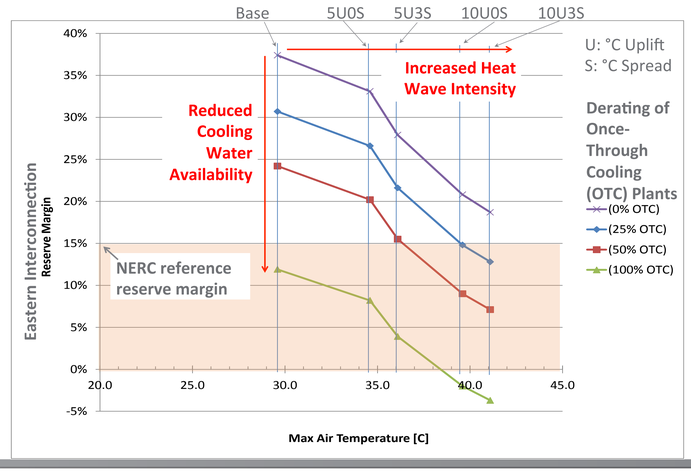
Droughts may affect both water quantity and water temperatures. Power plants utilizing once-through cooling (OTC) rely on the quantity and temperature of intake water. Clean Water Act regulations govern the water temperatures that result from discharging thermal effluent. Plant operations may need to be reduced or curtailed if temperature requirements in the mixing zone are not met (and a variance is not granted) or if water levels are reduced below intakes.

We performed a bounding analysis to represent potential drought impacts ranging from no impact on OTC power plant operations to 25, 50, and 100% shutdowns of all OTC plants in the EIC.



Results

We employed a commonly used production cost model, PROMOD, to simulate the operation of the power plants in the EIC to meet demand for each heat wave and drought scenario combination. The figure below shows how these scenarios affect system reliability as expressed by the reserve margin—the percent of capacity available above peak demand. The North American Electric Reliability Corporation (NERC) defines a reference reserve margin of 15%. All heat wave scenarios with 100% shutdown of OTC plants (green line) are below the reserve margin target, while in the 50% shutdown scenario (red line), the reserve margin is not met for peak temperatures above 35°C.



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