STOCHASTIC MODELING OF GAS-FIRED POWER PLANT AVAILABILITY: A SEMI-MARKOV APPROACH LEVERAGING EMPIRICAL DATA

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Overview

The decarbonization of the European energy system potentiates the critical role of flexible power plants in complementing the growing shares of fluctuating and weather-dependent renewable generation to manage high residual loads and withstand prolonged periods of low renewable generation [1]. As a result of the decarbonization of energy systems, electricity demand and its dependence on weather is increasing, and simultaneously, dispatchable power plants have to phase out due to economic competition and political regulations. Low-carbon generation units (e.g., combined-cycle gas turbines) are perceived as a pivotal component of flexibility measures in future energy systems due to their ability to operate short start-up times and steep generation ramps [2]. With a shrinking dispatchable power plant fleet, the dependence on the availability of dispatchable power plants grows. In general, the availability of dispatchable power plants is affected by technical failures, operational errors, and context factors. Resulting power plant outages cause significant economic, political, and social costs and are a key uncertain factor that has to be considered in decision-making problems, especially when analyzing the security of supply [3,4]. Given the increasing uncertainty and critical role of dispatchable power plants, the need for detailed examinations to assess the dynamics and dependencies of their availability has become paramount.

In resource adequacy assessments, forced outages of power plant groups are simulated with Markov models [5,6] or time series models [7]. Planned maintenance schedules are usually deterministically optimized or based on given maintenance profiles. These approaches neglect relevant fundamental influences on forced outages. Further studies use recursively convoluted probability functions of individual power plants or groups of power plants, considering fundamental factors but lacking consideration of temporal dependencies or individual power plant characteristics [8–10].

However, comprehensive evidence of the dynamics and dependency of the availability of dispatchable power plants remains missing. Therefore, this paper aims to provide valuable insights into the descriptive data characteristics of the availability of gas-fired generation capacity in key European countries. This paper focuses on peak-load power plants fueled by natural gas to design a stochastic approach using a semi-Markov model for suitable usage in future resource adequacy assessment or capacity expansion planning. In addition, the comprehensive examination encompasses the evaluation of extant studies.

Methods

First, the availability of gas-fired power plants in key European countries is examined by leveraging a large publicly available dataset on power plant outages from 2019 to 2024 given by the ENTSO-E Transparency Platform. In a comprehensive analysis the availability of these essential power plants and influencing fundamental factors are conducted using econometric methods. Furthermore, an event-based semi-Markov model is designed to simulate the availability of individual gas-fired power plants in Germany. In contrast to existing studies, the model considers relevant fundamental factors determined in the initial examination. The semi-Markov model is evaluated using selected statistical measures for suitable usage resource adequacy assessments.

Expected Results

As this is a work in progress, only expected results can be shared at the current stage. First examinations demonstrate that the availability of gas-fired power plants exhibits seasonal fluctuations that increase during winter, resulting from the heat supply obligations of combined heat and power plants. In addition, the electricity demand and gas prices have a high impact on the availability of gas-fired power plants in Germany. While most power plant outages last less than 24 hours, rare enduring outages have the highest impact on their availability. Preliminary findings indicate that complete outages, whether planned or forced, cause most unavailable energy. Therefore, the semi-Markov model reflects the availability of power plants as a binary variable.

Conclusions

Amid the transition to decarbonize the European energy system, dispatchable power plants must contribute essential electricity during hours with high residual load and resource droughts. This comprehensive examination of publicly available data on the availability of gas-fired power plants provides valuable insights into their ability to fulfill this role. The semi-Markov model simulates the availability of gas-fired power plants subject to planned and forced outages, considering relevant fundamental factors applicable in resource adequacy assessments or capacity expansion planning.

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