Artificial intelligence for assessing the security of electricity supply

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Overview

Potential losses in the reliability of electricity supply are often listed as concerns about the phase-out of nuclear energy use and coal-fired power generation. Today, the scenario space under consideration expands to include phase-out scenarios for natural gas use for power generation in the context of potential supply disruptions. At the same time, the complexity of the energy system is increasing due to the expansion of supply-dependent decentralized generation plants as well as the advancing sector coupling. Against this background, security of supply assessment requires the analysis of a large number of possible future scenarios in order to adequately evaluate the resilience of the power system. However, previous methods are extremely complex and thus resource-intensive and severely limited in the number of scenarios that can be investigated [1], [2]. We are therefore developing new approaches based on methods from the field of artificial intelligence (AI) in order to accelerate these analyses and thus to be able to cover the future uncertainty space regarding the security of supply in the power system as comprehensively as possible. A special focus is the collaboration with the project's advisory board, in which the four German transmission system operators and the Federal Network Agency participate.

Methods

We combine the aforementioned solution approaches into a coherent model pipeline in Figure 1. Starting with raw data from multiple sources, the data needs to be consolidated and missing and incorrect data needs to be added and corrected. Such tasks can be performed with the help of machine learning. Based on a single input data set of historical, ideally measured or reported data, data forecasting may be required when analyzing a future scenario. For this, machine learning-based models can outperform traditional statistical modeling approaches, especially if a large set of explanatory variables are being processed. Lastly, design of experiment (DOE) can be combined with metamodeling to efficiently increase the scope of energy system analyses.

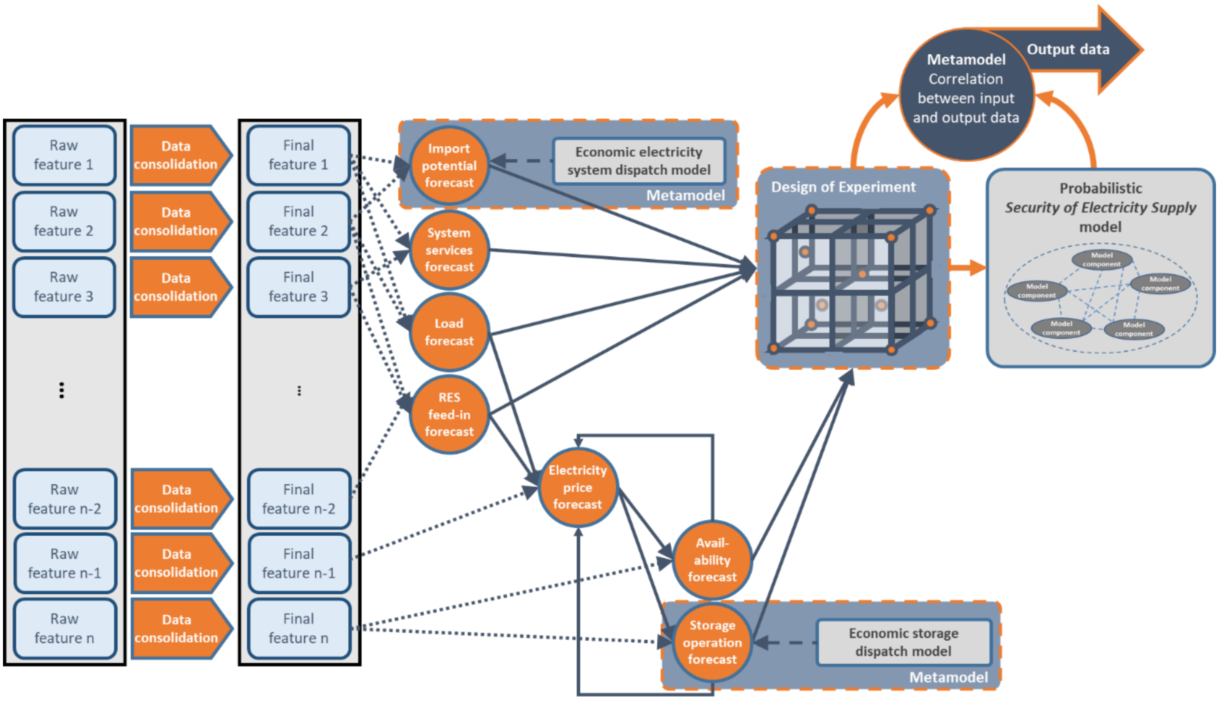

Figure 1: Link of the different fields of application of machine learning and design of experiment methods in the context of the assessment of security of supply.

Results

AI provides necessary tools to tackle the “complexity dilemma” in energy system analysis as stated by Nolting and Praktiknjo [3]. According to the authors, in the case of resource adequacy assessment, the "complexity dilemma" describes the situation where increasingly sophisticated research questions lead to increasingly complex models whose accuracy then becomes more and more dependent on the quality of the input data. However, the more comprehensive these input data are, and the further ahead assumptions have to be made for them, the more they are subject to uncertainties. AI-based methods for forecast input data for resource adequacy assessment models that outperform traditional forecasting methods can, therefore, increase the quality and reliability of such analyses and thereby tackle the “complexity dilemma".

A further dimension of the complexity dilemma is the limitation of covering future uncertainty when working with highly complex and therefore computationally resource intensive models [4]. The European Agency for the Cooperation of Energy Regulators (ACER) formulates that requirements for resource adequacy assessments to be a probabilistic analysis in terms of stochastic influences such as weather conditions [5]. Also, an optimization-based assessments is required, leading to very high computational requirements per analyzed scenario. Therefore, the requirements by ACER to deal with further uncertainties such as the progress in capacity expansion of renewable energies need to be considered only to a very limited extent. This dilemma between complexity of the analysis and coverage of the uncertainty space can be resolved using metamodeling and design of experiment (DOE) approaches (see Figure 1).

Our preliminary results show that AI-based time series forecasting for long-term resource adequacy assessments shows to be a promising approach to adequately consider future changes in the power system and other uncertainty factors. We also find out that complex metamodels can better represent the nonlinear behavior of underlying probabilistic model. Metamodels based on neural networks are able to approximate the original model with high accuracy. At the same time, the metamodels are capable to simulate a new scenario (based on 30 weather years) in a few seconds, instead of 4 hours as before with the probabilistic model.

Conclusion

As the necessity for and complexity of assessments of resource adequacy increase, combining AI-based methods with an adequate design of experiments offers the possibility for efficient metamodeling of complex energy system models. Hence, a broad variety of scenarios can be investigated and prevailing limits regarding runtime and hardware requirements can be efficiently circumvented while maintaining high degrees of accuracy.

References

[1] Priesmann, J., Münch, J., Ridha, E., Spiegel, T., Reich, M., Adam, M., Nolting, L., Praktiknjo, A. (2021). Artificial Intelligence and Design of Experiments for Assessing Security of Electricity Supply: A Review and Strategic Outlook. CoRR abs/2112.04889. PREPRINT (Version 2)

[2] Nolting, L., Spiegel, T., Reich, M., Adam, M., Praktiknjo, A. (2020). Can Energy System Modeling Benefit from Artificial Neural Networks? Application of Two-stage Metamodels to Reduce Computation of Security of Supply Assessments, Computers & Industrial Engineering, 142

[3] Nolting, L., Praktiknjo, A. (2022). The Complexity Dilemma – Insights from Security of Electricity Supply Assessments. Energy, 122522. [ScienceDirect]

[4] Priesmann J, Nolting L, Praktiknjo A. Using metamodels for conducting large-scale scenario analyses: The case of security of electricity supply. In: 13. Internationale Energiewirtschaftstagung an der TU-Wien (IEWT 2023); 2023.

[5] ACER. Methodology for the European resource adequacy assessment: in accordance with Article 23 of Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity. [April 19, 2021].