Proceedings of the 33rd European Safety and Reliability Conference (ESREL 2023)
Edited by Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio

doi: 10.3850/978-981-18-8071-1_P636-cd

Reliability analysis of European power system assets

Andrej Stankovski [a]

Reliability and Risk Engineering Laboratory, Institute of Energy and Process Engineering, Department of Mechanical and Process Engineering, ETH Zurich, Switzerland. E-mail: andrejst@ethz.ch

Blazhe Gjorgiev [a]

Reliability and Risk Engineering Laboratory, Institute of Energy and Process Engineering, Department of Mechanical and Process Engineering, ETH Zurich, Switzerland. E-mail: gblazhe@ethz.ch

Joé Wengler [a]

Reliability and Risk Engineering Laboratory, Institute of Energy and Process Engineering, Department of Mechanical and Process Engineering, ETH Zurich, Switzerland. E-mail: wenglerj@ethz.ch

Sinan Sencan

Reliability and Risk Engineering Laboratory, Institute of Energy and Process Engineering, Department of Mechanical and Process Engineering, ETH Zurich, Switzerland. E-mail: ssencan@student.ethz.ch

Giovanni Sansavini *

Reliability and Risk Engineering Laboratory, Institute of Energy and Process Engineering, Department of Mechanical and Process Engineering, ETH Zurich, Switzerland. E-mail: sansavig@ethz.ch

[a] *These authors had equal contribution to this work.*
* *Corresponding author*

Large interconnected systems can be severely destabilized due to failures of interconnector lines and large generating units. Therefore, identifying the failure behavior of critical assets can be invaluable for modeling and research purposes. In this work, we analyze outages of European generation and transmission system assets, obtained from the ENTSO-E transparency platform. We analyze the data using Markov chain and analytical methods. Our results show that the reliability of generating units is primarily impacted by the technology type and country of origin. Nuclear and fossil units have the lowest availability, resulting from their high unavailability due to planned and forced outages, respectively. Furthermore, we observe that units with high frequency of planned transitions, tend to have a low frequency of forced transitions, and vice versa. This emphasizes the positive impact of preventive maintenance measures in ensuring the safe and reliable operation of generating units. Regarding transmission system assets, we find that AC interconnectors are substantially more reliable than DC interconnectors. Additionally, we observe that internal lines, transformers, and substations are more available compared to interconnector lines. The results obtained from this work can provide important insights for the operation of European assets, helping system operators and researchers identify key vulnerabilities.

Keywords: European power system; transmission assets, generating units; availability; transition rates.

1. Introduction and Methodology

Operating a safe and reliable power system is imperative for the unobstructed supply of consumers. Being more interconnected than ever, modern power systems are susceptible to failures of interconnector lines and large generating units. Although work has been done in the field of power system component reliability, most of the literature focuses on North American generating units (NERC 2023). Therefore, identifying the failure behavior of critical European assets can be invaluable for modeling and research purposes. In this work, we analyze outages of generation and transmission system assets, obtained from the ENTSO-E transparency platform (ENTSO-E 2022; Hirth, Mühlenpfordt, and Bulkeley 2018). We utilize cleaning and clustering techniques to process the data, resulting in a dataset of 7’675 transmission asset events, and a second dataset of 39’529 generating unit events. Each event contains information about the asset, the country of origin, date, time, and the type of the failure (planned or forced). The assets in question include generating units, interconnectors, internal lines, substations, and transformers. We use this data to calculate the transition rates and steady-state probabilities of the assets using Markov chain analyses. The Markov model for transmission assets is comprised of three states: operational, planned outage and forced outage. Generating units can also be in a derated state, in which they operate with reduced capacity. Therefore, for this analysis, we use a model with five states: operational, planned derated, forced derated, planned outage, and forced outage. The steady-state probabilities obtained with this method help us perform component availability analyses based on the methods defined in the IEEE Std 762™-2006 standard (IEEE 2006).

Results and Discussions

Our results show that the technology and country of origin of the generating units play an important role in their availability. Fossil and nuclear units have the lowest availability of all technology types, with 78.3% and 75.8%, respectively. In the case of fossil units, this is a result of their high unavailability due to forced outages, while nuclear units have the highest unavailability due to planned outages. We observe the best performance indicators for solar and wind units, although it should be noted that their sample size in our analyses is significantly smaller. Analyzing the frequency of forced outages, hard coal units in Spain have the worst performance with 0.16 transitions per hour. On the other hand, we observe the highest frequency of planned outages in hydro reservoir units in France, with 0.12 transitions per hour. Our results show that units with high planned transition rates tend to have low forced transition rates, and vice versa. This observation is valid for most countries, emphasizing the positive effects of preventive maintenance measures.

Analyzing transmission system assets, we identify interconnectors as the worst performing asset with an availability of 96.2%. The interconnection with the highest frequency of planned transitions is between Sweden and Germany, with an average of 0.005 transitions per hour. Regarding forced transition rates, the Finland-Russia interconnection is the worst performing with 7.7 10^{-4} transitions per hour. According to our results, DC interconnectors more frequently experience outages compared to AC interconnectors. We observe the highest availability of 99.5% in substation components, followed by transformers with 99.1%. Internal lines also have a high availability with 98.7%. For this type of components, we observe the highest frequency of forced transitions in Lithuania and Spain.

The results presented in this work provide key operational indicators for assets in the European transmission system. These indicators can be beneficial to operators, researchers, and regulatory bodies to identify vulnerabilities and ensure the safe operation of the European power system. In our future publications, we will further explore this topic and present the steady state probabilities for the observed assets.

References

ENTSO-E. 2022. “ENTSO-E Transparency Platform.” Retrieved November 9, 2022 (https://transparency.entsoe.eu/).

Hirth, Lion, Jonathan Mühlenpfordt, and Marisa Bulkeley. 2018. “The ENTSO-E Transparency Platform – A Review of Europe’s Most Ambitious Electricity Data Platform.” *Applied Energy* 225:1054–67. doi: 10.1016/j.apenergy.2018.04.048.

IEEE. 2006. *IEEE Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity*. doi: 10.1109/IEEESTD.2007.335902.

NERC. 2023. “Generating Availability Data System.” Retrieved March 17, 2023 (https://www.nerc.com/pa/RAPA/gads/Pages/Reports.aspx).