

Time Series Power Flow and Contingency Analysis with Weather Adjusted Line Ratings: A Synthetic WECC Case Study

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Abstract— This paper presents a time series power flow and contingency analysis with weather adjusted line ratings (WALR). The objective is to evaluate the impact weather conditions have on a transmission system's thermal limits under different loading scenarios. Hourly time series power flow and contingency analysis are performed on the synthetic 10,000-bus WECC case over a year to identify the critical contingencies and corresponding overloads. WALR are calculated using ambient temperature, wind speed and direction, and solar radiation as inputs. Sensitivities of these inputs on transmission line ratings are also evaluated. In comparison to conventional static ratings, WALR is effective at increasing transmission capacity and reducing regularity and severity of overloads. This detailed perspective enables system planners to propose effective and reliable mitigation solutions. The paper also discusses the challenges and limitations of applying WALR in practice, including data availability, forecasting accuracy, and regulatory issues.

Keywords— Time series, power flow, contingency analysis, ambient-adjusted rating, dynamic line rating.

I. INTRODUCTION

In the era of energy deregulation and a strong push for clean energy transition, our power grids are becoming more complex and dynamic. Unlike the scheduling-based, conventional resources dominated grid of the past, today's power system operations are faced with numerous moving parts, posing significant challenges for engineers and system operators. Traditional peak-only operation studies often fail to provide a clear picture of what to expect in real-time. Time series analysis can offer a deeper and more dynamic view of the grid, thereby enhancing situational awareness for system operators. When laying out the blueprint for our future power infrastructure, planners need to understand not only if or where a reliability issue may occur, but the regularity and severity of that occurrence. Time series analysis can provide these insights, empowering Transmission Owners (TOs) to make strategic and informed grid investment decisions. In addition, a granular view of the grid, which time series analysis provides, enables planners to access and compare the effectiveness of different mitigation options, which include transmission expansion and grid-enhancing technologies (GETs).

Time series analysis is an effective tool for studying the impact of transmission line ratings. In today's power systems, common transmission line rating approaches include static ratings, seasonal ratings, ambient adjusted ratings (AAR), and dynamic line ratings (DLR) [1]. Static ratings are designed to reflect the ratings under the most severe ambient conditions. Seasonal ratings, on the other hand, adjust line ratings according to the season, such as summer and winter. Both AAR and DLR fall under the category of weather adjusted line ratings (WALR), which allow for more frequent rating changes. DLR distinguishes itself from AAR by incorporating a wider range of weather and line-specific factors into the rating determination. As mandated by Order 881 [2], transmission providers under FERC's jurisdiction must implement AAR in their transmission operations by July 2025.

Research has been conducted to study the impact of transmission line ratings. A method for calculating DLR and an economic optimization model were proposed in [3] to assess the impact of DLR on wind power integration. A comprehensive design framework for DLR and was discussed in [4], along with an algorithm to identify critical line spans for optimal placement of DLR sensors, considering the sag limit and the correlation between the dynamic thermal rating and the actual line rating. The rating accuracy is crucial when implemented in real-time. A method was proposed in [5] to estimate the line ampacity using sensor data. The authors of [6] used data collected from a DLR system installed on line segments located in southern Alberta, Canada to quantify the rating improvement. More recent work [7] evaluated the impact of DLR on ERCOT's system using a security constrained DCOPF model with contingency screening. The study in [8] identified that establishing a reliable communication path to relay DLR data back to the Energy Management System (EMS) may not always be economically practical. A list of AAR and DLR simulations and real-world installations is summarized in [9]. As highlighted in [10], incorporating DLR in microgrid planning can lead to a reduced installation capacity requirement. However, applying this model to transmission planning should be proceed with caution as the objectives and risk exposures can differ significantly.

This paper presents a comprehensive study framework that examines the impact of WALR on the thermal capacity of a transmission system. The output provides a detailed view of the

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Power System Dynamic Modelling and Analysis in Evolving Networks Babak Badrzadeh, Zia Emin, 2024-07-31 This Green Book is an essential resource for power system engineers seeking comprehensive information on contemporary power system dynamic modelling and analysis. With today's rapid adoption of inverter-based resources and the resulting changes in power system dynamics, this book compares conventional power systems with evolving power systems characterized by high shares of grid-connected and distributed inverter-based resources. It covers dynamic phenomena analysis methods, simulation tools, and enablers required for secure and reliable system planning and operation. Starting with an overview of power system studies and associated analysis tools, the book provides modelling requirements for various power system components, including existing and emerging technologies. It includes practical examples from real-world power systems worldwide that act as step-by-step study guides for practising engineers and provides knowledge to apply in their day-to-day tasks. Additionally, the book emphasizes the importance of power system model acceptance testing and validation, providing practical examples of various testing methods. Written with practising power system engineers in mind, this book minimizes the use of advanced mathematics. However, relevant sources for those interested in learning more about mathematical concepts are provided. Overall, this book is an invaluable resource for power system engineers navigating contemporary power systems. Readers who would like to comment on any of the published books or identify errors to the editorial team, please contact cigregreenbooks@springer.com.

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and iv the plant level voltage control of large scale photovoltaic systems on short term voltage stability and fault induced delayed voltage recovery as well as transient and frequency stability The power system dynamic performance is analysed using state of the art methods such as phasor mode time domain simulations and the calculation of the critical clearing time that determines the stability margin Moreover the recently developed Kullback Leibler divergence measure is applied to assess the quality of the voltage recovery Drawbacks of this metric are outlined and a novel metric the so called voltage recovery index is defined that quantifies the delayed voltage recovery more systematically The studies are performed with a generic photovoltaic system model and typical model parameters are used that were determined in collaboration with a manufacturer The stability analysis is performed in DIgSILENT PowerFactory using i a one load infinite bus system and ii an IEEE multi machine voltage stability test system namely the Nordic test system The results show that with the adequate control of photovoltaic systems power system dynamic performance can be significantly improved

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