

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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Power System Stability and Control Leonard L. Grigsby, 2017-12-19 With contributions from worldwide leaders in the field, *Power System Stability and Control* Third Edition, part of the five-volume set *The Electric Power Engineering Handbook*, updates coverage of recent developments and rapid technological growth in essential aspects of power systems. Edited by L. L. Grigsby, a respected and accomplished authority in power engineering and section editors Miroslav Begovic, Prabha Kundur, and Bruce Wollenberg, this reference presents substantially new and revised content. Topics covered include Power System Protection, Power System Dynamics and Stability, Power System Operation and Control. This book provides a simplified overview of advances in international standards, practices, and technologies such as small signal stability and power system oscillations, power system stability controls, and dynamic modeling of power systems. This resource will help readers achieve safe, economical, high-quality power delivery in a dynamic and demanding environment. With five new and 10 fully revised chapters, the book supplies a high level of detail and, more importantly, a tutorial style of writing and use of photographs and graphics to help the reader understand the material. New Chapters Cover Systems Aspects of Large Blackouts, Wide Area Monitoring and Situational Awareness, Assessment of Power System Stability and Dynamic Security, Performance Wind Power Integration in Power Systems, FACTS Devices. A volume in the *Electric Power Engineering Handbook* Third Edition. Other volumes in the set: K12642 *Electric Power Generation, Transmission and*

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 and Control Third Edition 9781439883204 K12650 Electric Power Substations Engineering Third Edition 9781439856383
 K12643 Electric Power Transformer Engineering Third Edition 9781439856291 **Advanced Power Applications for
 System Reliability Monitoring** Hongming Zhang, Slaven Kincic, Sherrill Edwards, 2020-11-13 This book examines real time
 models and advanced online applications that enhance reliability and resilience of the grid in real time and near real time
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Development E. Muljadi, Abraham Ellis, National Renewable Energy Laboratory (U.S.), 2012 *Future Power Network and Smart Energy Systems, Volume 2* Rahul Sharma, Amit Kumar, Anmol R. Saxena, 2025-09-26 This book features high quality peer reviewed papers from the International Conference on Future Power Network and Smart Energy Systems Issues and Challenges FPNSSES 2023 Organized by the Department of Electrical Engineering at the National Institute of Technology Kurukshetra it includes contributions from academicians technologists entrepreneurs and research scholars The content is designed to benefit engineers students and researchers working in the fields of power networks and smart energy systems

Green Entrepreneur Handbook Eric Koester, 2016-04-19 Written by a practicing business attorney with startup experience in the environmental and technology sectors this comprehensive handbook assists entrepreneurs in tackling the wide variety of opportunities to go green A one stop resource for entrepreneurs it helps readers incorporate clean technology environmental practices and green business approaches into the work environment The book discusses how to sell to utilities explores fundraising outlets for green businesses covers government incentives presents key startup tools aimed at green businesses and addresses challenges of many new businesses such as raising money and making sales Additional resources are available on the book s website

An Introduction to the Wind Power Industry in the United States J. Paul Guyer, P.E., R.A., 2021-06-03 Introductory technical guidance for professional engineers and others interested in wind powered generation of electric power energy Here is what is discussed 1 INTRODUCTION 2 INSTALLATION TRENDS 3 INDUSTRY TRENDS 4 TECHNOLOGY TRENDS 5 PERFORMANCE TRENDS 6 COST TRENDS 7 WIND POWER PRICE TRENDS 8 POLICY AND MARKET DRIVERS

Meeting Electricity Demand in the West Through Responsible Development of Energy Rights-of-way on Federal Lands United States. Congress. House. Committee on Resources. Subcommittee on Water and Power, United States. Congress. House. Committee on Resources. Subcommittee on Forests and Forest Health, 2006

Modelling, Control and Stability Analysis of Photovoltaic Systems in Power System Dynamic Studies Gustav Lammert, 2019 This thesis investigates the impact of i the low voltage ride through and dynamic voltage support capability ii the active current recovery rate iii the local voltage control 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 *Power System Analysis and Design* Mr. Rohit Manglik,2023-06-23 This book offers a detailed exploration of power system analysis and design focusing on key concepts methodologies and practical implementations relevant to modern engineering and technology practices *Power System Control and Stability* Vijay Vittal,James D. McCalley,Paul M. Anderson,A. A. Fouad,2019-10-15 The third edition of the landmark book on power system stability and control revised and updated with new material The revised third edition of Power System Control and Stability continues to offer a comprehensive text on the fundamental principles and concepts of power system stability and control as well as new material on the latest developments in the field The third edition offers a revised overview of power system stability and a section that explores the industry convention of q axis leading d axis in modeling of synchronous machines In addition the third edition focuses on simulations that utilize digital computers and commercial simulation tools it offers an introduction to the concepts of the stability analysis of linear systems together with a detailed formulation of the system state matrix The authors also include a revised chapter that explores both implicit and explicit integration methods for transient stability Power System Control and Stability offers an in depth review of essential topics and Discusses topics of contemporary and future relevance in terms of modeling analysis and control Maintains the approach style and analytical rigor of the two original editions Addresses both power system planning and operational issues in power system control and stability Includes updated information and new chapters on modeling and simulation of round rotor synchronous machine model excitation control renewable energy resources such as wind turbine generators and solar photovoltaics load modeling transient voltage instability modeling and representation of three widely used FACTS devices in the bulk transmission network and the modeling and representation of appropriate protection functions in transient stability studies Contains a set of challenging problems at the end of each chapter Written for graduate students in electric power and professional power system engineers Power System Control and Stability offers an invaluable reference to basic principles and incorporates the most recent techniques and methods into projects **Human Interface and the Management of Information. Interaction, Visualization, and Analytics** Sakae Yamamoto,Hirohiko Mori,2018-07-09 This two volume set LNCS 10904 and 10905 constitutes the refereed proceedings of the 20th International Conference on Human Interface and the Management of Information HIMI 2018 held as part of HCI International 2018 in Las Vegas NV USA in July 2018 The total of 1170 papers and 195 posters included in the 30 HCII 2018 proceedings volumes was carefully reviewed and selected from 4373 submissions The 56 papers presented in this volume were organized in topical sections named information visualization multimodal interaction information in virtual and augmented reality information and vision and text and data mining and analytics **Advances in Modelling and Control of Wind and Hydrogenerators** Amir Ebrahimi,2020-04-01 Rapid deployment of wind and solar energy generation is going to result in a series of new problems with regards to the reliability

of our electrical grid in terms of outages cost and life time forcing us to promptly deal with the challenging restructuring of our energy systems Increased penetration of fluctuating renewable energy resources is a challenge for the electrical grid Proposing solutions to deal with this problem also impacts the functionality of large generators The power electronic generator interactions multi domain modelling and reliable monitoring systems are examples of new challenges in this field This book presents some new modelling methods and technologies for renewable energy generators including wind ocean and hydropower systems Ivanpah Solar Electric Generating System ,2010 *Missouri River Master Manual* United States. Congress. Senate. Committee on Indian Affairs (1993-),2004 *Wind Power in Power Systems* Thomas Ackermann,2012-04-23 The second edition of the highly acclaimed *Wind Power in Power Systems* has been thoroughly revised and expanded to reflect the latest challenges associated with increasing wind power penetration levels Since its first release practical experiences with high wind power penetration levels have significantly increased This book presents an overview of the lessons learned in integrating wind power into power systems and provides an outlook of the relevant issues and solutions to allow even higher wind power penetration levels This includes the development of standard wind turbine simulation models This extensive update has 23 brand new chapters in cutting edge areas including offshore wind farms and storage options performance validation and certification for grid codes and the provision of reactive power and voltage control from wind power plants Key features Offers an international perspective on integrating a high penetration of wind power into the power system from basic network interconnection to industry deregulation Outlines the methodology and results of European and North American large scale grid integration studies Extensive practical experience from wind power and power system experts and transmission systems operators in Germany Denmark Spain UK Ireland USA China and New Zealand Presents various wind turbine designs from the electrical perspective and models for their simulation and discusses industry standards and world wide grid codes along with power quality issues Considers concepts to increase penetration of wind power in power systems from wind turbine power plant and power system redesign to smart grid and storage solutions Carefully edited for a highly coherent structure this work remains an essential reference for power system engineers transmission and distribution network operator and planner wind turbine designers wind project developers and wind energy consultants dealing with the integration of wind power into the distribution or transmission network Up to date and comprehensive it is also useful for graduate students researchers regulation authorities and policy makers who work in the area of wind power and need to understand the relevant power system integration issues **Utility Scale Solar Forecasting, Analysis and Modeling** Kay Stefferud,2017 **Smart Cyber-Physical Power Systems, Volume 2** Ali Parizad,Hamid Reza Baghaee,Saifur Rahman,2025-03-07 A practical roadmap to the application of artificial intelligence and machine learning to power systems In an era where digital technologies are revolutionizing every aspect of power systems *Smart Cyber Physical Power Systems Volume 2 Solutions from Emerging Technologies* shifts focus to cutting edge solutions

for overcoming the challenges faced by cyber physical power systems CPSs By leveraging emerging technologies this volume explores how innovations like artificial intelligence machine learning blockchain quantum computing digital twins and data analytics are reshaping the energy sector This volume delves into the application of AI and machine learning in power system optimization protection and forecasting It also highlights the transformative role of blockchain in secure energy trading and digital twins in simulating real time power system operations Advanced big data techniques are presented for enhancing system planning situational awareness and stability while quantum computing offers groundbreaking approaches to solving complex energy problems For professionals and researchers eager to harness cutting edge technologies within smart power systems Volume 2 proves indispensable Filled with numerous illustrations case studies and technical insights it offers forward thinking solutions that foster a more efficient secure and resilient future for global energy systems heralding a new era of innovation and transformation in cyber physical power networks Welcome to the exploration of Smart Cyber Physical Power Systems CPPSs where challenges are met with innovative solutions and the future of energy is shaped by the paradigms of AI ML Big Data Blockchain IoT Quantum Computing Information Theory Edge Computing Metaverse DevOps and more

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