

FAULT ANALYSIS OF HVDC TRANSMISSION SYSTEMS

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ABSTRACT

This paper analyzes the behaviour of a Voltage Source Converter Based HVDC system under DC pole to ground fault & AC faults for 2-level VSC-HVDC & 12-pulse VSC-HVDC system in order to better understand the system under such faults. DC line faults on HVDC systems utilising Voltage Source Converters (VSC) are a major issue for HVDC systems in which complete isolation of the faulted system is not a viable option. The occurrence of pole-to-ground faults on DC link is the most common fault in HVDC system. It was observed that with the occurrence of DC pole to ground faults leads to substantial over current in the AC grid system which may lead to damage of the converter valve. Simulation of 2-level VSC-HVDC under AC fault is carried out. The fault current magnitude is attempted with the mathematical analysis & which was found to be the same as the simulated result. This paper also compares the performance of the conventional 12-pulse (CSC) HVDC system with the PWM based 2-level VSC-HVDC & 12-pulse VSC-HVDC system.

Key words: CSC-HVDC, Fault Analysis, IGBT, PWM, THD, VSC


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1. INTRODUCTION

In India, with the rapid increase in energy demand, grid integration of renewable energy sources has become very essential [1], [2]. In the different renewable energy sources, wind energy benefits from HVDC technology for power transmission to enhance the system performance [3]. There are two technologies of HVDC transmission

Fault Analysis Of Hvdc Transmission Systems

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Norrga, Remus Teodorescu**



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Fault Analysis and Protection System Design for DC Grids Abhisek Ukil, Yew Ming Yeap, Kuntal Satpathi, 2020-04-13 This book offers a comprehensive reference guide to the important topics of fault analysis and protection system design for DC grids at various voltage levels and for a range of applications. It bridges a much needed research gap to enable wide scale implementation of energy efficient DC grids. Following an introduction DC grid architecture is presented covering the devices operation and control methods. In turn analytical methods for DC fault analysis are presented for different types of faults followed by separate chapters on various DC fault identification methods using time frequency and time frequency domain analyses of the DC current and voltage signals. The unit and non unit protection strategies are discussed in detail while a dedicated chapter addresses DC fault isolation devices. Step by step guidelines are provided for building hardware based experimental test setups as well as methods for validating the various algorithms. The book also features several application driven case studies.

AC-DC Power System Analysis J. Arrillaga, Bruce Smith, 1998 A graduate level textbook that can also serve as a reference for engineers and researchers working on problems in modern power systems. Emphasizes incorporating HVDC converters and systems into the analysis of power systems but describes algorithms that can be extended to other industrial components such as drives and smelters and to the flexible AC transmission systems technology. Considers only system studies influenced by steady state or transient converter control and not fast transients such as lightning. Annotation copyrighted by Book News Inc. Portland OR

Hvdc Transmission +1: Vsc Hvdc Based Mmc Topology In Power Systems Chan-ki Kim, Seung-il Moon, Kyeon Hur, Jang-mok Kim, Gilsoo Jang, 2021-04-09 HVDC grids and super grids have sparked so much interest these days that researchers and engineers across the globe are talking about them, studying them, supporting them, or questioning them. This book provides valuable information for researchers, industry, and policy makers. It explains why HVDC is favorable over AC technologies for power transmission, what the key technologies and challenges are for developing an HVDC grid, how an HVDC grid will be designed and operated, and how future HVDC grids will evolve. The book also devotes significant attention to nontechnical aspects such as the influence of energy policy and regulatory frameworks. This book is a result of collaboration between industry and academia. It provides theoretical insights into the design and control of MMC technology and investigates practical aspects of the project planning, design, manufacture, implementation, and commissioning of MMC HVDC and multi-terminal HVDC transmission technologies, filling the knowledge gap between the technology specialists and VSC HVDC project developers and key personnel involved in those projects.

Design, Control, and Application of Modular Multilevel Converters for HVDC Transmission Systems Kamran Sharifabadi, Lennart Harnefors, Hans-Peter Nee, Staffan Norrga, Remus Teodorescu, 2016-10-17 Design, Control, and Application of Modular Multilevel Converters for HVDC Transmission Systems is a comprehensive guide to semiconductor technologies applicable for MMC design, component sizing, control, modulation, and application of the MMC technology for

HVDC transmission Separated into three distinct parts the first offers an overview of MMC technology including information on converter component sizing Control and Communication Protection and Fault Management and Generic Modelling and Simulation The second covers the applications of MMC in offshore WPP including planning technical and economic requirements and optimization options fault management dynamic and transient stability Finally the third chapter explores the applications of MMC in HVDC transmission and Multi Terminal configurations including Supergrids Key features Unique coverage of the offshore application and optimization of MMC HVDC schemes for the export of offshore wind energy to the mainland Comprehensive explanation of MMC application in HVDC and MTDC transmission technology Detailed description of MMC components control and modulation different modeling approaches converter dynamics under steady state and fault contingencies including application and housing of MMC in HVDC schemes for onshore and offshore Analysis of DC fault detection and protection technologies system studies required for the integration of HVDC terminals to offshore wind power plants and commissioning procedures for onshore and offshore HVDC terminals A set of self explanatory simulation models for HVDC test cases is available to download from the companion website This book provides essential reading for graduate students and researchers as well as field engineers and professionals who require an in depth understanding of MMC technology

High Voltage Direct Current Transmission, an Annotated Bibliography, 1966-1968 United States Boneville Power Administration, 1968

HVDC Transmission Chan-Ki Kim, Vijay K. Sood, Gil-Soo Jang, Seong-Joo Lim, Seok-Jin Lee, 2009-07-23 HVDC is a critical solution to several major problems encountered when trying to maintain systemic links and quality in large scale renewable energy environments HDVC can resolve a number of issues including voltage stability of AC power networks reducing fault current and optimal management of electric power ensuring the technology will play an increasingly important role in the electric power industry To address the pressing need for an up to date and comprehensive treatment of the subject Kim Sood Jang Lim and Lee have collaborated to produce this key text and reference Combining classroom tested materials from North America and Asia HVDC Transmission compactly summarizes the latest research results and includes the insights of experts from power systems power electronics and simulation backgrounds The authors walk readers through basic theory and practical applications while also providing the broader historical context and future development of HVDC technology Presents case studies covering basic and advanced HVDC deployments headed by world renowned experts Demonstrates how to design analyze and maintain HVDC systems in the field Provides updates on new HVDC technologies such as active power filters PWM VSC and 800 KV systems Rounds out readers understanding with chapters dedicated to the key areas of simulation and main circuit design Introduces wind power system interconnection with HVDC Arms readers with an understanding of future HVDC trends Balancing theoretical instruction with practical application HVDC Transmission delivers comprehensive working knowledge to power utility engineers power transmission researchers and advanced undergraduates and postgraduates in power engineering programs The book is also a useful

reference to for engineers and students focused on closely related areas such as renewable energy and power system planning

The proceedings of the 10th Frontier Academic Forum of Electrical Engineering (FAFEE2022) Qingxin Yang, Xuzhu Dong, Weiming Ma, 2023-08-13 This book includes the original peer reviewed research papers from the 10th Frontier Academic Forum of Electrical Engineering FAFEE 2022 held in Xi an China in August 2022 It gathers the latest research innovations and applications in the fields of Electrical Engineering The topics it covers include electrical materials and equipment electrical energy storage and device power electronics and drives new energy electric power system equipment IntelliSense and intelligent equipment biological electromagnetism and its applications and insulation and discharge computation for power equipment Given its scope the book benefits all researchers engineers and graduate students who want to learn about cutting edge advances in Electrical Engineering

Artificial Intelligence Applications in Electrical Transmission and Distribution Systems Protection Almoataz Y. Abdelaziz, Shady Hossam Eldeen Abdel Aleem, Anamika Yadav, 2021-10-21 Artificial intelligence AI can successfully help in solving real world problems in power transmission and distribution systems because AI based schemes are fast adaptive and robust and are applicable without any knowledge of the system parameters This book considers the application of AI methods for the protection of different types and topologies of transmission and distribution lines It explains the latest pattern recognition based methods as applicable to detection classification and location of a fault in the transmission and distribution lines and to manage smart power systems including all the pertinent aspects

FEATURES Provides essential insight on uses of different AI techniques for pattern recognition classification prediction and estimation exclusive to power system protection issues Presents an introduction to enhanced electricity system analysis using decision making tools Covers AI applications in different protective relaying functions Discusses issues and challenges in the protection of transmission and distribution systems Includes a dedicated chapter on case studies and applications This book is aimed at graduate students researchers and professionals in electrical power system protection stability and smart grids

Protection of Wind Turbine Generators Using Microcontroller-Based Applications Nagwa F. Ibrahim, Sobhy S. Dessouky, Hossam E. Mostafa Attia, Ali H. Kasem Alaboudy, 2022-02-08 Protection of Wind Turbine Generators Using Microcontroller Based Applications focuses on the application of microcontrollers in the protection of wind turbine generators The book looks at the design and implementation of a versatile digital overcurrent OC OV UV OF UF and negative sequence relays and addresses the dynamic behaviour of a wind driven induction generator IG connected to a power system grid through a transmission line The transient responses of protective devices associated with the IG are also studied Modelling of the digital relay for wind turbine generator protection using MATLAB Simulink consider most of the aerodynamic and mechanical effects that can influence instantaneous output voltage current and power Coverage also includes different AC fault types a detailed theoretical analysis of fault and protection strategy in AC fault and the different types of fault detection algorithms to maintain power system reliability

Direct Current Fault Protection Isik

C. Kizilyalli,Z. John Shen,Daniel W. Cunningham,2023-05-23 The lack of effective DC fault protection technology remains a major barrier for the DC paradigm shift In addressing the key challenges Direct Current Fault Protection Basic Concepts and Technology Advances starts with an introduction to the advantages of DC power systems before moving on to an in depth review of DC fault protection technologies including mechanical circuit breaker MCB solid state circuit breaker SSCB hybrid circuit breaker HCB converter based breakerless protection and fault current limiter FCL Coverage includes a comprehensive comparison of various DC fault interruption technologies and their suitable applications state of the art DC fault protection concepts and advances in research identification of fundamental challenges and future directions in the field and commercialization aspects This book will be a valuable reference for practicing engineers researchers and graduate students in the field of power electronics and DC power systems

HVDC Power Transmission Systems K. R. Padiyar,1990 Hvdc Transmission Technology Is Fast Advancing And Its Applications Are Rapidly Expanding This Book Presents The Various Aspects Of Hvdc Technology In Sufficient Depth To A Beginner In Addition It Also Includes The Analysis And Simulation Of Ac Dc System Interactions Which Are Of Importance In The Planning Design And Operation Of Hvdc Systems The Book Gives Up To Date Information And Integrates Material That Has Been Scattered In Several Journals The Book Is Divided Into Two Parts The First Part Has 9 Chapters And Covers The Techniques And Components Of Hvdc Systems In Detail The Emphasis Is On The Unique Components Of Hvdc Systems Such As Thyristor Valves Converters Control Protection And Harmonic Filters One Chapter Each Is Devoted To Each Of These Items Reactive Power Control And Multiterminal Dc System Operation Are Also Included As Two Separate Chapters Static Var Systems Used For Reactive Power Control In Converter Stations Are Also Discussed The Second Part Of The Book Deals With The Modelling Analysis And Simulation Of Ac Dc Systems Seven Chapters Are Included In This Part Which Cover Component Models Power Flow Transient Stability Dynamic Stability And Power Modulation Harmonic And Torsional Interactions Simulation Of Converters And Hvdc Systems The Coverage Is Fairly Detailed And Includes Some New Information Not Published Before The Book Should Be Of Interest To Graduate Students Researchers And Engineers From Utilities Industries Who Are Involved With Hvdc Power Transmission

Machine Learning, Advances in Computing, Renewable Energy and Communication Anuradha Tomar,Hasmat Malik,Pramod Kumar,Atif Iqbal,2021-08-19 This book gathers selected papers presented at International Conference on Machine Learning Advances in Computing Renewable Energy and Communication MARC 2020 held in Krishna Engineering College Ghaziabad India during December 17 18 2020 This book discusses key concepts challenges and potential solutions in connection with established and emerging topics in advanced computing renewable energy and network communications

The Proceedings of the 19th Annual Conference of China Electrotechnical Society Qingxin Yang,Zhaohong Bie,Xu Yang,2025-01-27 This book compiles exceptional papers presented at the 19th Annual Conference of the China Electrotechnical Society CES held in Xi an China from September 20 to 22 2024 It encompasses a wide range of topics

including electrical technology power systems electromagnetic emission technology and electrical equipment The book highlights innovative solutions that integrate concepts from various disciplines making it a valuable resource for researchers engineers practitioners research students and interested readers Advances in Artificial Intelligence Application in Data Analysis and Control of Smart Grid Xin Ning,Imr Fattah,Praveen Kumar Donta,Mohamed M.F. Darwish,2023-11-23 Smart grid SG is considered a form of intelligent system that allows the electric grid to perform its functions efficiently The SG is a network that allows for the flow of electrical energy and data where the data is used to make intelligent decisions in the operation of the electric grid Artificial intelligence AI techniques such as expert system ES Machine Learning ML and deep Learning DL have brought an advancing frontier in power electronics and power engineering with their powerful data processing capabilities The SG relies on the flow of data to make its intelligent control therefore AI technology is a perfect fit for the SG The application of AI technology in the SG has the potential to improve the intelligence of the SG This research topic is focused on ways of improving the data analysis and control of SG by leveraging technologies Manuscripts with the progress made in solving a range of miscellaneous and critical problems in SG by leveraging AI methods such as ES ML and DL methods are welcome Reviews and original research that describe the latest developments in this field are considered for publication in this research topic The scope of this Research Topic will include the following themes but are not limited to 1 Data driven and artificial intelligence approaches to enhancing flexibility and resilience of SG 2 Expert system Machine Learning and Deep Learning reinforcement learning and transfer learning for applications in SG 3 AI for development in ensuring high reliability and stability of electric power system with high penetration of renewable energy 4 AI for studies in operation protection integrated planning and control of SG systems 5 AI for development in diagnostics and diagnostics for SG 6 Health monitoring of a modern wind generation system using an adaptive neuro fuzzy system 7 Space vector fault pattern identification of a smart grid subsystem by neural mapping 8 Control techniques mathematical programming methods optimization techniques and metaheuristics applied in SG 9 AI and optimization techniques for green energy and carbon footprint 10 Novel applications of AI based smart grids in smart cities smart transportation smart healthcare and smart manufacturing The proceedings of the 16th Annual Conference of China Electrotechnical Society Xidong Liang,Yaohua Li,Jinghan He,Qingxin Yang,2022-04-22 This book gathers outstanding papers presented at the 16th Annual Conference of China Electrotechnical Society organized by China Electrotechnical Society CES held in Beijing China from September 24 to 26 2021 It covers topics such as electrical technology power systems electromagnetic emission technology and electrical equipment It introduces the innovative solutions that combine ideas from multiple disciplines The book is very much helpful and useful for the researchers engineers practitioners research students and interested readers *Adaptive Switching Control of Large-Scale Complex Power Systems* Yang Liu,Qing-Hua Wu,2023-04-30 This book presents the latest research on switching control adaptive switching control and their applications in the transient stability control and analysis

of large scale complex power systems In large scale complex power systems renewable power generators flexible power electronics converters and distributed controllers are widely employed Due to the poor overcurrent tolerance capability of power electronics converters and lacking of coordination mechanism stability control in events such as natural disasters cascaded faults and severe disturbances is viewed as the key challenge in the operation of these systems High performance self coordinated controllers are needed for the control of important power sources and power electronics converters Adaptive switching controllers are a group of controllers designed by the authors for the control of various renewable power generators synchronous generators and modular multilevel converters These controllers operate in a self coordinated manner and aim to employ the largest transient control energy of converters and power sources Imbalance between power generation and consumption is largely filled by the application of these controllers and transient stability of power systems can be significantly improved This book covers both the preliminary knowledge and key proofs in the design and stability analysis of adaptive switching control systems and considerable simulation and experimental results are presented to illustrate the application and performance of the controllers This book is used as a reference book for researchers and engineers in fields of electrical engineering and control engineering

The Theory of Fault Travel Waves and Its Application Xinzhou Dong, 2022-03-19 The book starts from the existed problems in fault analysis of the lumped parameter circuit model It firstly introduces the basic electromagnetic phenomenon uniform transmission line guided electromagnetic waves multi conductor system guided electromagnetic waves fault generated travelling waves then it introduces series of the traveling waves based protections which includes principle technology and application in practical power grid it also discusses the travelling waves based fault location and the travelling waves based fault feeder selector in China It systemically reveals the essential features of the fault traveling wave and concludes the analytical solutions of the transient fault traveling waves and the modulus maxima representation of the dyadic wavelet transform of fault traveling waves Finally the book analyzes the acquisition of traveling waves and the sensor s characteristics A unique fault travelling wave test device has been invented based on the theories of the book and will be applied in real systems

Advances in Renewable Energy and Electric Vehicles Sanjeevikumar P., Nagesh Prabhu, Suryanarayana K., 2021-08-20 This book presents select proceedings of the International Conference on Advances in Renewable Energy and Electric Vehicles AREEV 2020 and examines related emerging trends feasible solutions to shape and enable the development of mankind The topics covered include renewable energy sources electric vehicles energy storage systems power system protection security smart grid and wide band gap semiconductor technologies The book also discusses applications of signal processing artificial neural networks optimal and robust control systems and modeling and simulation of power electronic converters The book will be a valuable reference for beginners researchers and professionals interested in power systems renewable energy and electric vehicles

Intelligent Technologies and Applications Imran Sarwar Bajwa, Tatjana Sibalija, Dayang Norhayati Abang

Jawawi,2020-05-08 This book constitutes the refereed proceedings of the Second International Conference on Intelligent Technologies and Applications INTAP 2019 held in Bahawalpur Pakistan in November 2019 The 60 revised full papers and 6 revised short papers presented were carefully reviewed and selected from 224 submissions Additionally the volume presents 1 invited paper The papers of this volume are organized in topical sections on AI and health sentiment analysis intelligent applications social media analytics business intelligence Natural Language Processing information extraction machine learning smart systems semantic web decision support systems image analysis automated software engineering **High Voltage Direct Current Transmission** ,1968

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