

## 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 is two technologies of HVDC transmission

# Fault Analysis Of Hvdc Transmission Systems

**Almoataz Y. Abdelaziz, Shady Hossam  
Eldeen Abdel Aleem, Anamika Yadav**

## **Fault Analysis Of HvdC Transmission Systems:**

**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 Norrgr n, 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

**Design and Implementation of Voltage Source Converters in HVDC Systems** Nagwa F. Ibrahim, Sobhy S. Dessouky, 2020-09-12 This book looks at the control of voltage source converter based high voltage direct current VSC HVDC The objective is to understand the control structure of the VSC HVDC system and establish the tuning criteria for the proportional integral PI control of the converter controllers Coverage includes modeling of the VSC based HVDC transmission system using MATLAB and Simulink simulation package implementation of control strategies for the VSC based HVDC transmission system and analysis of the developed system behavior under different conditions normal and fault conditions The book provides researchers students and engineers working in electrical power system transmission and power electronics and control in power transmission with a good understanding of the VSC based HVDC transmission system concept and its behavior

**Applications of Superconducting Fault Current Limiters in Power**

**Electronics-Dominated Power Systems** Lei Chen, Hongkun Chen, Li Ren, Yuejin Tang, 2024-12-08 The book discusses superconducting fault current limiters and their applications in power systems exploring the principles simulations and engineering practices but focusing on systematic applications in traditional and renewable power systems It provides in depth studies on a number of major topics such as architecture of superconducting fault current limiter device design parameter optimization prototype testing co ordination control and performance evaluation It also describes multiple application cases of superconducting fault current limiters which are applied in high voltage direct current transmission systems active distribution networks and micro grids Offering a comprehensive and systematic overview of practical issues

the book is intended for readers wanting to learn practical approaches for developing superconducting fault current limiters. It also appeals to researchers, engineers and graduate students in various fields including high temperature superconducting materials, power system transient stability and control science and engineering. **AC/DC Hybrid Large-Scale Power Grid System Protection** Xinzhou Dong, 2022-10-15. System protection is laid between the defenses for power system protective relaying and the emergency control. Under the premise of ensuring the safety of electrical equipment, it strives to ensure the safety of the system, block the chain of occurrence and growth of cascading faults and effectively avoid the occurrence of large scale blackout catastrophes. This book systematically elaborates on the dealing technology of a special type of fault, the cascading fault in the AC/DC hybrid large scale power grid. The main contents include immunization distance protection for accident overload, distance protection that is immune to oscillation, inverter control technology to prevent long term or continuous commutation failure, DC participation emergency power flow control technology used to share the accident transfer overload caused by inverter lockout and overhead transmission line adaptive overload protection. The basis of English translation of this book from its Chinese original manuscript was done with the help of artificial intelligence machine translation by the service provider DeepL.com. A subsequent human revision of the content was done by the author.

**HVDC for Grid Services in Electric Power Systems** Gilsoo Jang, 2019-11-18. The modern electric power system has evolved into a huge nonlinear complex system due to the interconnection of thousands of generation and transmission systems. The unparalleled growth of renewable energy resources (REs) has caused significant concern regarding grid stability and power quality and it is essential to find ways to control such a massive system for effective operation. The controllability of HVDC and FACTS devices allows for improvement of the dynamic behavior of grids and their flexibility. Research is being carried out at both the system and component levels of modelling, control and stability. This Special Issue aims to present novel HVDC topologies and operation strategies to prevent abnormal grid conditions. **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

*HVDC Transmission* Chan-Ki Kim,Vijay K. Sood,Gil-Soo Jang,Seong-Joo Lim,Seok-Jin Lee,2009-04-27 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

**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

**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

**Proceedings of PURPLE MOUNTAIN FORUM 2019-International Forum on Smart Grid Protection and Control** Yusheng Xue, Yuping Zheng, Saifur Rahman, 2019-08-08 This book presents original peer reviewed research papers from the 4th Purple Mountain Forum International Forum on Smart Grid Protection and Control PMF2019 SGPC held in Nanjing China on August 17 18 2019 Addressing the latest research hotspots in the power industry such as renewable energy integration flexible interconnection of large scale power grids integrated energy system and cyber physical power systems the papers share the latest research findings and practical application examples of the new theories methodologies and algorithms in these areas As such book a valuable reference for researchers engineers and university students

**Proceedings of 2020 International Top-Level**

**Forum on Engineering Science and Technology Development Strategy and The 5th PURPLE MOUNTAIN FORUM (PMF2020)** Yusheng Xue,Yuping Zheng,Anjan Bose,2021-01-23

This book includes original peer reviewed research papers from the 2020 International Top Level Forum on Engineering Science and Technology Development Strategy the 5th PURPLE MOUNTAIN FORUM on Smart Grid Protection and Control PMF2020 held in Nanjing China on August 15 16 2020 Hot topics and cutting edge technologies are included Advanced Power Transmission Technology AC DC Hybrid Power Grid Technology eIoT Technology and Application Operation Protection and Control of Power Systems Supplied with High Penetration of Renewable Energy Sources Active Distribution Network Technology Smart Power Consumption and Energy saving Technology New Technology on Substation Automation Clean Energy Technology Energy Storage Technology and Application Key Technology and Application of Integrated Energy Application of AI Block Chain Big Data and Other New Technologies in Energy Industry Application of New Information and Communication Technology in Energy Industry Application of Technical Standard System and Related Research in Energy Industry The papers included in this proceeding share the latest research results and practical application examples on the methodologies and algorithms in these areas which makes the book a valuable reference for researchers engineers and university students

**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

*High Voltage Direct Current Transmission* ,1968 **Protection Principle and Technology of the VSC-Based DC Grid** Bin Li, Jiawei He,2020-08-13

This book discusses key techniques of protection and fault ride through in VSC HVDC grids including high speed selective protection DC fault current limitation converter restarting and DCCB reclosing strategies It investigates how high speed transient variable based protection can be used to improve grids acting sensitivity acting reliability and ability to withstand high transition resistance compared with traditional protection In addition it discusses the applicability of the pilot protections including the current differential protection and travelign wave based protection in the dc grid as well as the improved methods Furthermore it proposes several DC FCL topologies which are suitable for DC grids Lastly in the context of overhead line application conditions it explores converter restarting and DCCB reclosing strategies which not only identify

the fault property but also limit the secondary damage to the system improving the system's operation security and reliability. As such, the book offers a comprehensive overview of original and advanced methods and techniques for the protection of VSC HVDC grids.

**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.

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