International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Fault Analysis of HVDC Transmission System.

Sasi Kowshik. M [1], Dr. Rajesh Babu. D [2]

[1]***Student***, *GMR Institute of Technology, Rajam, India*
[2]***Assistant Profesor***, *GMR Institute of Technology, Rajam, India*

A B S T R A C T

This document discusses transmission line and system functioning, detection, categorization, and location. An investigation of the HVDC reaction under DC circumstances is carried out since a defect impacts the converter station and converter's performance. Performance checks and precise and fast fault detection are made possible by the DC's accuracy and efficacy. Appropriate protection systems are presented when the fault transient characteristics are analyzed. DC connections fail most HVDC transmission lines, which employ the voltage source converter (VSC). The usage of MMCs, or modular multilevel converters, is currently common. The use of flexible direct current transmission technology to connect sustainable energy sources with enormous capacities to the power grid is a successful strategy. But because DC pole-to-ground faults frequently occur in HVDC systems, increasing the overcurrent in the AC grid system and damaging the Voltage Source Converter valve, failures in these systems are frequent and cannot be isolated. It has been confirmed that the scheme can survive resistance to transitions and has a quick action time and good dependability. For simulation, PSCAD software is utilized, and this is verified by fault analysis.

Keywords: Internal fault, DC, HVDC, AC, Fault Detection, Protection Schemes, External fault, Fault classification.

INTRODUCTION

India's increasing energy demand has made the integration of renewable energy into the country's power infrastructure imperative. The alternating current (AC) grid is connected to remote renewable energy sources through the use of high-voltage direct current (HVDC) transmission technologies. There are two types of HVDC gearbox systems: VSC-based systems that use IGBTs with PWM technology and traditional (CSC) HVDC systems that use thyristor valves for line commutation. These techniques make it possible to link small-scale renewable energy installations to the main AC grid at a reasonable cost.

VSC-HVDC systems are the preferred technology for seamless integration into the grid. These systems enable swift and autonomous control of active and reactive power flow bidirectionally, minimizing harmonic generation to enhance power quality and overall system stability. Among the challenges encountered in HVDC systems, AC faults such as L-G, L-L, and LLL, along with DC pole-ground faults on DC links, are widespread issues.

A breakdown in the ground connection of a DC pole results in a rapid decline in DC voltage, leading to significant overcurrent. To protect HVDC Converters from potential damage caused by excessive AC grid current through freewheeling diodes during DC faults, protective measures are imperative. Ensuring the security of these systems involves emphasizing operational protocols, redundancy, and contingency plans for failure scenarios. Fault detection employs the feature extraction method, a proven approach that withstands transitional resistance, exhibits quick response times, and provides high reliability.

1. FAULT IN HVDC

A short circuit is a situation in a transmission line where electric current flows through an unintended and shorter pathway.

TYPES OF FAULTS

In today's context, ensuring the security of the system against transmission faults and failures is of utmost significance. This research delves into various types of faults and the corresponding protective measures, shedding light on the strategies already implemented for device security. These protective techniques encompass Line protection, Back-Up protection, Morphological Gradient protection, and Differential protection.

The HVDC system is susceptible to a diverse array of faults, including:

- Fault between the Positive pole and ground
- Fault between the Negative pole and ground
- Fault between the Positive pole and negative line

- Fault among Positive pole, negative line, and ground

Various measures are in place to address these potential issues and safeguard the integrity of the system.

2. FAULT DETECTION IN HVDC

This section of the passage explores the essential principles underpinning diverse fault detection approaches for high-voltage direct current (HVDC) grids. Essentially, DC fault detection techniques fall into two main categories: single-ended and double-ended. Single-ended approaches predominantly depend on local measurements, whereas double-ended approaches integrate local measurements with remote measurements acquired from the opposite end of the transmission line. Regardless of the approach, these methods analyze the gathered measurements to identify the fault's location and assess whether intervention is necessary in response to the fault.

2.1 FAULT DETECTION METHODS CAN BE CLASSIFIED INTO UNIT PROTECTION AND NON-UNIT PROTECTION

Methods for safeguarding systems that don't rely on individual units often employ inductors placed at both ends of each line to define protection boundaries. Moreover, the inductor in series serves as a current limiter, constraining the speed at which fault current (di/dt) increases. In contrast, protection strategies based on units, such as current differential or directional protection, do not rely on series inductors. Essentially, fault detection techniques with two ends are also classified as unit protection strategies, distinctly outlining protection zones. These approaches are considered selective means for DC protection.

Table 1 Comparison of different dc fault detection methods[6]

Method	**Overcurrent**	**Undervoltage**	**Travelling waves**	**DV/DT**	**di/DT**	**Current differential**	**Directional protection**	**Wavelet Transform**
Use of reactor	A reactor is used to limit fault current	The reactor is used for selectivity	A reactor is used to define boundaries	A reactor is used to define boundaries	A reactor is used to define boundaries	Not needed	Not needed	A reactor is used to define boundaries
Use of comms	NO	NO	NO	NO	NO	YES	YES	NO
Main/backup protection	Part of main protection OR Backup protection	Part of main protection OR Backup protection	Main OR part of main protection	Main OR part of main protection	Main OR part of main protection	Main or busbar protection	Main	Main OR part of main protection
Advantages	Simplicity, availability of current measurements	Simplicity, availability of voltage measurements	The use of the first incident wave provides high-speed protection	The use of the first incident wave provides high-speed protection	The use of the first incident wave provides high-speed protection	High selectivity, directionality, very robust	High sensitivity, directionality, and reduced transmission requirements	Very fast, WT can be used to detect singularities
Disadvantages	Selectivity issues, limited speed	Cannot distinguish between forward and backward faults\	The protection margin is reduced for very long lines	Susceptible to noise, selectivity is limited by low cable impedance	Susceptible to noise, selectivity is limited by low cable impedance	Communication delays need for synchronized measurements	Communication delays, limitations against high resistive faults	Extensive simulations or analysis is needed to set the thresholds

2.2 PROTECTION SCHEME

A novel pilot protection system for a hybrid HVDC (High Voltage Direct Current) transmission line is recommended, leveraging the distinctive polarity characteristics of current fault components. In the design of this system, careful consideration has been given to the guiding principles and standards that govern the operation of each individual unit. The following description provides an insight into the comprehensive framework of principles and standards that underpin the proposed protection system for efficient and reliable hybrid HVDC transmission line operation.

3. FAULT ANALYSIS IN HVDC

The suggested protection method underwent testing through simulations conducted on the PSCAD (Power Systems Computer-Aided Design) platform. MATLAB was employed to implement the proposed differential protection technique. The testing was carried out on a power system featuring a 500 kV HVDC voltage. Its specifications are detailed in Table 1.

3.1 INTERNAL FAULT ANALYSIS

Analyzing internal faults in an HVDC (High Voltage Direct Current) transmission line is crucial for ensuring the reliability and safety of the system. Internal faults refer to abnormalities that occur within the components of the HVDC transmission line, such as converters, cables, or other equipment.

- POSITIVE-POLE-TO-GROUND FAULT OCCURS NEAR TERMINAL R
- NEGATIVE-POLE-TO-GROUND FAULT OCCURS AT THE MIDDLE POINT
- POLE-TO-POLE FAULT OCCURS NEAR TERMINAL I

3.2 EXTERNAL FAULT ANALYSIS

- EXTERNAL FAULT OCCURS OUT OF THE TRANSMISSION LINE
- EXTERNAL FAULT OCCURS AT TERMINAL R
- EXTERNAL FAULT OCCURS AT THE TERMINAL I

4. HVDC TRANSMISSION SYSTEM

When managing significant electricity transmission requirements over vast distances, the benefits of utilizing a High-Voltage Direct Current (HVDC) system become evident. HVDC systems provide cost-effective and more efficient options for transmitting power across long distances compared to Alternating Current (AC) transmission. Moreover, they facilitate the connection of networks with different frequencies and unique characteristics. In a power generation substation, alternating current (AC) is generated and can be converted into direct current (DC) using a rectifier. In high-voltage direct current (HVDC) or converter substations, rectifiers and inverters are positioned at each end of the transmission line. The rectifier end changes AC to DC, while the inverter end transforms DC back into AC. The direct current (DC) travels through overhead lines and is converted back to alternating current (AC) at the user's end using inverters in the converter substation. The power remains constant at both the transmission and receiving ends, making DC transmission advantageous for long-distance power transfer by minimizing losses and enhancing efficiency. A configuration consisting of more than two converter stations and a solitary transmission line is denoted as a 'two-terminal DC system' or simply a 'point-to-point system.' Similarly, if a substation incorporates more than two converter stations along with interconnected DC terminal lines, it is categorized as a multi-terminal DC substation.

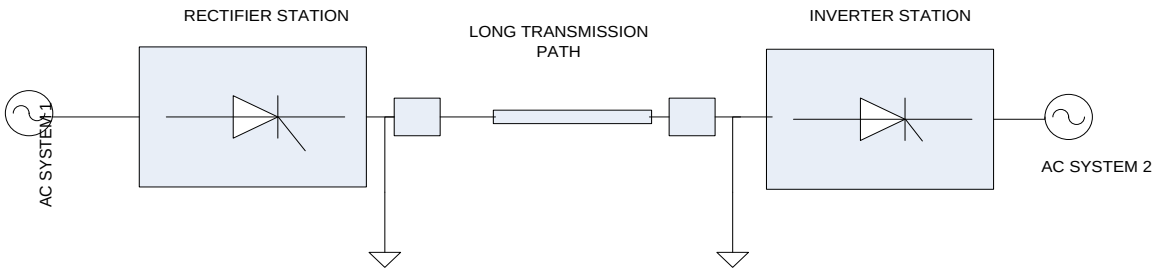

Fig 1 HVDC System model

5. CONCLUSION

This paper investigates techniques for the identification, classification, and detection of faults in transmission lines and distribution systems. The discussion encompasses various methods, accompanied by detailed illustrations. The study highlights the potential risks associated with DC pole-to-ground failures, emphasizing their ability to cause a notable surge in system overcurrent and potentially harm the converter valve. The review delves into diverse systems designed to detect DC faults in HVDC grids, each based on distinct principles, and compares protective measures. Two overarching categories are established for defect detection techniques: unit protection methods and non-unit protection methods. Non-unit protection involves the establishment of boundaries using DC reactors, facilitating the effective differentiation between internal and external issues. The investigation extends to addressing concerns within both internal and external HVDC transmission systems. The paper advocates for future research to evaluate the efficacy of these strategies and assess their impact on various grid features, such as grid complexity, converter technology, and the control systems governing DC grids and converters. This pragmatic approach aims to enhance comprehension and its relevance to engineering applications. Notably, the protective

principle outlined in the paper is deemed applicable to HVDC systems with multiple terminals and diverse converter structures, irrespective of converter types.

References

[1] Mujib J. Pathan and V. A Kulkarni, Fault Analysis of HVDC Transmission Systems. International Journal of Electrical Engineering & Technology, 7(3), 2016, pp. 106–116.

[2] S. K. Khairnar, S. S. Hadpe, R. G. Shriwastava, and S. S. Khule, "Fault detection and diagnosis of monopolar configured VSC based high voltage direct current transmission line," Glob. Transitions Proc., vol. 3, no. 1, pp. 43–54, Jun. 2022, doi: 10.1016/j.gltp.2022.04.010.

[3] K. Chen, C. Huang, and J. He, "Fault detection, classification and location for transmission lines and distribution systems: A review on the methods," High Voltage, vol. 1, no. 1. Institution of Engineering and Technology, pp. 25–33, 2016. doi: 10.1049/hve.2016.0005.

[4] S. Xue, J. Lian, J. Qi, and B. Fan, "Pole-to-ground fault analysis and fast protection scheme for HVDC based on overhead transmission lines," Energies, vol. 10, no. 7, 2017, doi: 10.3390/en10071059.

[5] Glasgow Caledonian University and Institute of Electrical and Electronics Engineers, 2018 53rd International Universities Power Engineering Conference (UPEC2018) : proceedings : 4th-7th September 2018, Glasgow, United Kingdom.

[6] A. M. Eltamaly, Y. Sayed, and A. A. Nasr ELGHAFFAR, "A SURVEY: HVDC SYSTEM OPERATION AND FAULT ANALYSIS".

[7] M. A. Jarrahi, H. Samet, and T. Ghanbari, "Novel Change Detection and Fault Classification Scheme for AC Microgrids," IEEE Syst. J., vol. 14, no. 3, pp. 3987–3998, 2020, doi: 10.1109/JSYST.2020.2966686.

[8] O. Dharmapandit, R. K. Patnaik, and P. K. Dash, "A fast time-frequency response based differential spectral energy protection of AC microgrids including fault location," Prot. Control Mod. Power Syst., vol. 2, no. 1, 2017, doi: 10.1186/s41601-017-0062-0.

[9] D. Naidoo and N. M. Ijumba, "A Protection System for Long HVDC Transmission Lines."

[10] M. Muniappan, "A comprehensive review of DC fault protection methods in HVDC transmission systems," Protection and Control of Modern Power Systems, vol. 6, no. 1. Springer, Dec. 01, 2021. doi: 10.1186/s41601-020-00173-9.