

A Review on HVDC Transmission Line Fault Location Detection with Different ANN Techniques

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Abstract:

As uninterrupted power supply is the prime demand by all consumers. However, faults in power system will leads to the interruption in power supply and it will make system vulnerable towards system outage/collapsing and will lead to damage various electrical peripheral of switch gear/ electrical equipment.

Hence all faults are required to be detected and clear as soon as possible to restart power supply to consumer. Having an accuracy knowledge of fault location will come very handy in reducing system outage time and they're by improving continuity and reliability of system.

Various research has been done previously towards finding accurate result. In this paper location detection using various artificial neural network (ANN) techniques is presented. The goal of the work is to prepare a model which can somehow manage to give accurate fault location on HVDC line thus helps in improving the system performance.

In this study we are proposing a model formed using ANN model for the purpose of fault location approximation in HVDC transmission line using the information of sending end and receiving end voltage. This proposed work is performed with the help of MATLAB/Simulink environment and simulation using PSCAD/EMTDC software. The results show the superiority in efficiency and precision of present model in fault location detection using ANN than other tools.

1. Introduction:

Transmission system plays the vital role in connecting generation station to load. It has the

responsibility to supply continuous power from one and two other. Any type of damage to transmission line will lead to an interruption in power supply but in the present era of power system deregulation providing good power quality with continuous supply is main its main priority of all electric utility companies. Hence for this reason focus should be paid in the field of system protection and a proper planning is expected to deal with any unwanted situation.

Relay and circuit breakers play key part in preventing system during any fault condition. Faults are responsible for creating system malfunctioning and their immediate diagnosis is expected is expected to increase reliability.

Normally distance relays are used for locating fault. The working of distance relay is based upon the measured value of impedance between fault point and relay location (that is ratio of voltage and current between these two points) [29]. Now this should be giving accurate results, but due to the presence of series capacitor banks for compensation problem will somehow tarnish the accuracy of relay.

Capacitor banks are used because they help in balancing reactive power in transmission line thus helping in increasing line loadability, reducing line losses and increase in system stability [29] [30].

2. Literature Review

Govind Kant Mishra, Yaduvir Singh [1] in 2021 discussed that protection programs against DC faults in the HVDC Networks play a critical role in the development and expansion of integrated HVDC networks. When DC fault happens in HVDC network, every passing second counts huge

power loss which makes a fast-executing fault detection system necessary. Traditional fault detection methods either lacks accuracy or consume significant time in execution. The proposed method utilizes frequency dependent transmission line characteristics and travelling wave wavefront information for determining location of fault. The proposed method's functionality is tested in PSCAD simulation with realistic models. The results have been further compared with existing fault location methods and the proposed method shows suitable accuracy and significantly faster execution.

Shuping Gao Zhenxi Xu Guobing Song Mingxing Shao Yuanyue Jiang [2] in 2021 discussed that to reduce the impact of traveling wave velocity, wave head recognition, and LMD (Local Mean Decomposition) end effect and mode mixing on location accuracy, this paper presents a fault location method based on improved LMD for hybrid three-terminal HVDC transmission lines, which is not affected by wave velocity. Firstly, the improved LMD is used to get the time when the fault traveling wave first arrives at the four measuring terminals. Then the fault branch is identified according to the ratio of the time of the fault traveling wave arriving at the measuring terminal. Finally, the equation is listed according to the principle of traveling wave location and the measurement equation which is not affected by the wave velocity is deduced. A hybrid three-terminal HVDC transmission system model is built by PSCAD to simulate various faults and output fault data under various fault conditions. MATLAB is used to process the fault data and verify the location algorithm. The simulation results show that the location method proposed in this paper is not affected by fault distances, fault types, infeed levels and transition resistances.

Qing Huai, Liang Qin Kaipei LiuHuaDingXiaobing LiaoTianyuan Tan [3] in 2020 discussed that a combined algorithm based on traveling wave (TW) theory and time-frequency characteristics is proposed to estimate the DC line fault location in modular multilevel converter-high voltage direct current (MMC-HVDC) systems. The relationship between instantaneous frequency and TW propagation velocity is analysed, and the local voltage signal is utilized to extract fault features. The instantaneous frequency of the TW front is

obtained via ensemble empirical mode decomposition and Hilbert-Huang transform. The fault location is predicted with the detected TW arrival times and corresponding TW propagation velocity. The effectiveness and superiority of this method are verified through simulations in PSCAD/EMTDC and computation in MATLAB.

Reza Rohani, AmangaldiKoochaki [4] in 2020 discussed that one of the most important issues with HVDC systems are the occurrence of various faults that can lead to considerable electrical power losses, serious damage to expensive equipment and huge financial losses. Hence, it is highly required to design an accurate and automatic fault location method in HVDC systems for maintaining uninterrupted supply of energy and protecting sensitive equipment such as rectifiers and inverters. Accordingly, this paper proposes a new hybrid system based on adaptive neuro-fuzzy inference system (ANFIS) with optimal parameters and Hilbert-Huang (HH) transform for fault location in voltage sourced converter-HVDC (VSC-HVDC) systems.

Dong Wang, Haishan Yang, Mengqian Hou, Yifei Guo [5] in 2020 discussed the fault location problem of hybrid multi-terminal high-voltage direct-current (HVDC) transmission systems based on the line-commutated converter (LCC) and modular multi-level converter (MMC). Two issues are addressed in this study: (i) the travelling wave (TW)-based fault location principle and (ii) the method of capturing the high-frequency TW signals. Finally, a typical ± 400 kV hybrid three-terminal LCC-MMC-HVDC system is used for the case study to verify the high accuracy of the proposed method. Furthermore, its robustness against different fault locations, fault resistances and fault types are also investigated.

Jianzhong Xu, Yu Lü, Chengyong Zhao, Jun Liang [6] in 2020 discussed that accurately determining the location of DC pole-to-pole short-circuit faults in modular multilevel converter (MMC) based multi-terminal HVDC (MTDC) systems is key issue in ensuring fast power recovery. This paper proposes an effective DC fault location scheme for the MMC-MTDC that uses an estimated R-L representation of the transmission lines. By using the measured voltage and current data from both ends of the faulted DC line, the proposed fault

location formulas can calculate the location of the fault with high accuracy. The simplified R-L representation greatly reduces the computation burden of the fault detection algorithm. Electromagnetic transient (EMT) simulations of a four-terminal MMC-MTDC system on PSCAD/EMTDC are used to confirm the effectiveness of the proposed approach.

Daniel Marques da Silva, Flavio B. Costa, Vladimiro Miranda, Helder Leite [7] in 2019 discussed the qualitative and quantitative analysis of the traveling waves induced by faults on direct current (DC) transmission lines of line-commutated converter high-voltage direct current (LCC HVDC) systems for detecting the wavefront arrival times using the boundary wavelet coefficients from real-time stationary wavelet transform (RT-SWT). The qualitative analysis takes into account the steady-state operation and the detection of the inception times of both first and second wavefronts at the converter stations. An algorithm designed to run in real-time and able to minimize the factors that hamper the performance of traveling wave-based protection (TWP) methods is proposed to detect the first and second surge arrival times. Quantitative results are achieved based on the accuracy of one- and two-terminal fault location estimation methods, and indicate the proper operation of the presented algorithm.

Sheng Lan, Mou-Jie, Chen Duan-Yu, Chen [8] in 2019 discussed that due to the difficulty in locating high-resistance grounding faults, this paper proposes a novel fault location method for HVdc transmission lines by considering double-end unsynchronized using Hilbert-Huang transform and one-dimensional convolutional neural network (1D-CNN).

The trained CNN can then be used to achieve fault location effectively. Electromagnetic transient simulation software PSCAD/EMTDC has been used to carry out various types of fault simulation on the ± 500 kV HVdc transmission system. The results show that the proposed method can reliably and accurately locate line faults under fault resistance up to 5200Ω .

Debani Prasad Mishra et al in [9] discussed how in any interconnected power system's transient stability is heavily affected by any fault on transmission line. Hence, as soon as fault occurs in

transmission line, that line is disconnected to restore stability. According to author the current and voltage signal are sufficient to recognize the location and type of fault in any line with the help of some signal processing tools along with other techniques. Author discussed how relay and circuit breaker are used to detect abnormality in transmission system and how they disconnect the faulty part. Along with these different techniques are discussed which can be used for fault location detection in brief.

Avagaddi Prasad et al in [10] presents a detailed survey over different techniques for fault location estimation. Type of fault detection and classification is of great importance for both relaying circuits and distance protection. The work of author is divided in two parts, in first author has discussed some introductory part of faults in transmission line and in second it has discussed some newly developed techniques for solving same problem with great accuracy and efficiency.

Danilo Pinto Moreira de Souza, et. al. in [11] has propounded that due to faults in transmission lines it is difficult to maintain power quality. Hence, it becomes important to find fault location. Such thing is to make sure that all maintenance work to be done on time. The work is mainly focused on proving that this problem can be solved using voltage signals only. The proposed method uses the time-based waveforms of parameters. These parameters are then used in an ARIMA model to predict the location of fault from the terminal from which the measurements of parameters are done.

Huibin Jia in [12] presented a method of locating fault location using travelling wave theory. In this work dispersion effect of travelling wave theory is considered as the main factor for calculating fault location. This because of the fact due to this effect the rise and fall time of waveform becomes longer which leads to increasing complexity in determining time and velocity of travelling wave, which gives wrong calculation of fault location. In order to reduce the effect of dispersion effect in this work a new double-ended fault location method has been proposed. The results obtained by author has surpassed the accuracy obtained with traditional methods.

Sunil Singh, D. N. Vishwakarma [14] in 2016 has developed a fault location estimation technique for a 300 km, 400 kV transmission line. Author has

performed fault analysis at various location of this transmission line in MATLAB environment and the data obtained during simulation at various fault location is stored. This data is then transformed using wavelet analysis for the sole purpose of feature extraction which then can be supplied to ANN for prediction of fault location. After obtaining results from ANN, author came to conclusion DWT and ANN model together are very efficient in predicting exact location of fault with very high accuracy.

Ankita Nag and Anamika Yadav [15] in 2016 author has proposed an ANN based protective scheme for the hybrid transmission system both overhead and underground. Author has discussed various advantages of AI has over primitive location detecting techniques like one based on phasor-based method which usually utilizes fundamental component of signal and other is traveling wave-based method which works on the basis of value of reflected waves. Author has developed and simulated 15-kilometer, 132 kV, 50 Hz transmission line with 3-kilometer underground cable and 12-kilometer overhead lines for a LG fault. After training and testing author came to conclusion that the output is very accurate compare to other techniques.

Qingqing Yang, Jianwei Li, Simon Le Blond, Cheng Wang [16] in 2016 has developed a model for DC microgrid fault detection and fault location using artificial neural network. The DC microgrid is modelled in PSCAD/EMTDC to simulate various faults. Author has discussed the importance of microgrid for present day power system in which penetration of renewable energy is increasing day by day leading to more unpredicted grid behavior and hence making control strategies more complicated. A total of 40 neurons are taken in input layer consisting of 20-20 data from both sending end and receiving end of dc microgrid. Author has obtained results from trained model with an accuracy of one percent error which is very accurate considering distance.

Nabamita Roy & Kesab Bhattacharya [17] in 2015 has presented a technique for detecting fault, classifying it had then forecast fault location. Various techniques author has used in this work is s-transform and wavelet transform for feature extraction purpose. Values of this features is used

for both classification and locating fault in this work. Author has concluded that above following techniques includes BPNN techniques has developed a model which has great speed of computation and very high accuracy. Author has utilized value of current and voltage parameter values for solving about problem and obtained error of maximum value of 4.35 percent.

Liang Yuansheng, Wang Gang, and Li Haifeng [18] in 2014 has discuss a noble algorithm to detect fault location. Author has performed a mix of travelling wave theory and Bergeron times domain fault location method. The value of voltage and current from both sides is taken as input parameters. In this study a self-adopted filter is also utilized which has ultimately improved performance of the algorithm. After the simulation and performing all tests related to fault at different location, author came to conclusion that this method is efficient for faults location detection for unsynchronized two end measurements on HVDC lines.

S. F. Alwash, Member, V. K. Ramachandaramurthy, and N. Mithulananthan [19] in 2013 has developed an algorithm for identification of all shunt type fault location. This work mainly presented a scheme where author has used impedance method for fault location. This method is tested for IEEE 34 bus distribution system designed and simulated in PSCAD/EMTDC software. In the study author has computed a method which has capability to identify fault's location irrespective of type of shunt fault. In this work while designing model for fault location estimation for both distributed generation and capacitive effect of lines are considered.

Jae-Do Park, Member, IEEE, Jared Candelaria, Liuyan Ma, and Kyle Dunn [20] in 2013 a DC microgrid system's fault location technique is proposed. In this work author has used intelligent electronic devices for the controlling and monitoring all nodes. The author has successfully implemented proposed algorithm/technique both in hardware and simulation experimentally.

3. Faults in HVDC system

Usually when any fault occurs in HVAC line, circuit breakers have the responsibility to disconnect the line from rest of the power system.

But in case HVDC converter side this circuit breakers are of no use hence no mechanical way can be used to disconnect faulted part. When fault occurs in DC line fault protection devices signals the rectifier to operate in the inverter mode and there by discharges the line. It takes about 100ms for rectifier to re charge line. In the case of those faults which are irregular in nature the line recovers after 200ms and the line will again continue its transmission. But if the fault is constant in nature in that case if rectifier will try to re charge after 200ms than it may result in second fault. Th DC fault current is very smaller than that of AC fault current hence it takes short time to restart. Due to the fact that there is no mechanical action involved in case transmission link hence it is faster than that of a AC system.

Faults in HVDC can be classified on the basis of location of fault. Hence faults can be classified as DC faults, AC faults and converter station faults [25].

DC transmission line faults:

These faults are of our main interest since our study is primary focused on this type of faults. The main reason of DC transmission line faults are lighting strikes, high speed wind and other natural calamities and degraded line parts. These faults are permanent faults and they require quick repairing in order to restore transmission. DC transmission line faults are classified as

1) DC Line -Line faults

The reason of this type of fault is insulation failure due to which the capacitor of DC transmission line will be discharged rapidly. This type of fault very rarely occurs in power system. In case of such faults both side converter station should be blocked to protect system.

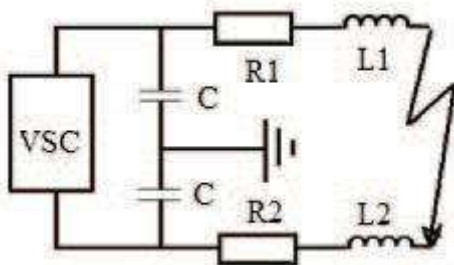


Fig. 3.1: Equivalent circuit of DC LL fault.

2) DC Line-Ground fault

This is a case when DC conductor comes in direct contact with ground or when the insulation between

the two is damaged. During this type of fault, the DC voltage drops constantly [18].

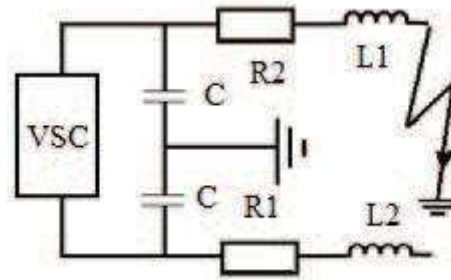


Fig. 3.2: Equivalent circuit of DC LG fault.

4. Proposed Methodology

Prior to ANN, the technique which is used to estimate the location of fault utilizes the travelling wave theory. In this theory it calculates the time of propagation of travelling wavehead from the fault point to the point of observation and this time implies the fault distance. This technique faces following technical problems:

- 1) This method is purely dependent on the detection of travelling wavehead. Any compromise in capturing it will directly lead to the failure in locating fault. Under many situations the transient wave signals are too weak to be detected resulting in no fault location detection.
- 2) The fault location is the product of travelling wave speed and time taken by wavehead to reach location of observation but the speed of wave is largely depending upon transmission line parameters.
- 3) Traveling wave theory is affected largely by interferences in signal. Hence if this interference somehow manages to overshadow the effect of wavehead than fault location will not be calculated. [12]

In light of such drawbacks Artificial Neural Network came in to lime light with its recent advancement in field of electrical engineering dew to its robustness to be unaffected by parameters such as travelling wave speed and type of fault and interference

Artificial Neural Networks (ANN) are computing systems or technique that are inspired by the learning architecture of human brain to discover the relations between the input and target variables of a system. Human brain consists of a

large set of structural constituents, known as neurons, which form a well-connected network to respond to an input signal to perform all its computations / calculations in a certain complex task such as image and voice recognition task and they do this with incredible speed and accuracy. Neurons are simple processing units, which has the ability to store experimental data and which work as parallelly distributed processor.

A network of connected artificial neurons can be designed, and a learning algorithm can be applied to train it. Signals (Input data) are passed between neurons over connection links and Each connection link has an associated weight, which in a neural network, multiplies the signal transmitted. The weights represent information being used by the network to solve a problem. Then the weighted sum is operated upon by an activation function (usually nonlinear), and output data are conveyed to other neurons. The weights are continuously altered while training to improve accuracy and generalize abilities.

5. Conclusion:

This paper presents a review on the method used for fault location detection in HVDC bipolar transmission lines and distribution systems. A variety of methods are introduced and representative works are presented in detail.

As surveys of fault location methods can be found in existing literature, we mainly present some fault location methods based upon artificial intelligence. We also put forward the possibility of using the latest machine learning models to facilitate the fault location tasks.

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