IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 15, Issue 1 Ser. I (Jan – Feb 2020), PP 16-21
www.iosrjournals.org

Relative Exploration of High Voltage Direct Current on Artificial Intelligence and Machine Learning.

Mrs. Poornima H S[1], Bhargav R[2], Harshitha M S[3],Aishwarya M Magi[4] , Sudheer M Naik[5]

[1](*Assistant Professor,Electrical and Electronics Department, The National Institute Of Engineering,Mysuru, INDIA)*
[2](*Student, Electrical and Electronics Department, The National Institute Of Engineering,Mysuru, INDIA)*
[3](*Student, Electrical and Electronics Department, The National Institute Of Engineering,Mysuru, INDIA)*
[4](*Student, Electrical and Electronics Department, The National Institute Of Engineering,MysuruINDIA)*
[5](*Student, Electrical and Electronics Department, The National Institute Of Engineering, Mysuru, INDIA)*

Abstract:
In thisstudy, due to the lowsensitivity in existing high voltage DC (HVDC) evolutionaryalgorithmanalysis leads to aim in the application for detection and localization of faults in HVDC system. The advancement of power electronics in recentyearpaved the waves for particularimplementation of HVDC system. A comprehensivesurvey of researchliteratureusingvariousalgorithm has been proposed in thispaper. For faultdiagnosis in HVDC system and itcanbeobservedthat a new machine learningalgorithmslike K-NearestNeighbor (KNN) and Support Vector Machine (SVM), Extreme Learning Machine (ELM), protective performance of travelling wave protection, voltage protection, geneticalalgorithmartificial neural network basedresearchmethods are proposed in thispaper and all these are modeled in simulatingplatformwith MATLAB, PSCAD.

Key Word*:HVDC, KNN, SVM, ELM, MATLAB, PSCAD, ANN, PSO.*

Date of Submission: 13-01-2020 Date of Acceptance: 29-01-2020

I. Introduction

Alternating Current (AC) is preferred for electrical transmission everywhere as it can be stepped up to a high voltage and back, easily through transformers. We transmit power in high voltage because when we increase voltage to a very high magnitude the current for transmitting the same power is reduced which in turn reduces the power lost in the transmission cables (i.e. I ^2 * R loss). But High voltage AC (HVAC) has its limitations, that being, its transmission capacity, Reactive Power loss, Skin Effect, Corona effect, and transmission grids of two different frequencies can't be interconnected. Recent advancements in High Voltage DC (HVDC) systems have led to efficient ways of converting power to High voltage DC. The above-mentioned demerits of HVAC transmission are not that much significant when it comes to DC and Reactive power loss is completely nil so no Reactive power loss. The advantages of DC transmission are higher power transmission capacity with the same copper size and less net losses compared to HVAC system.

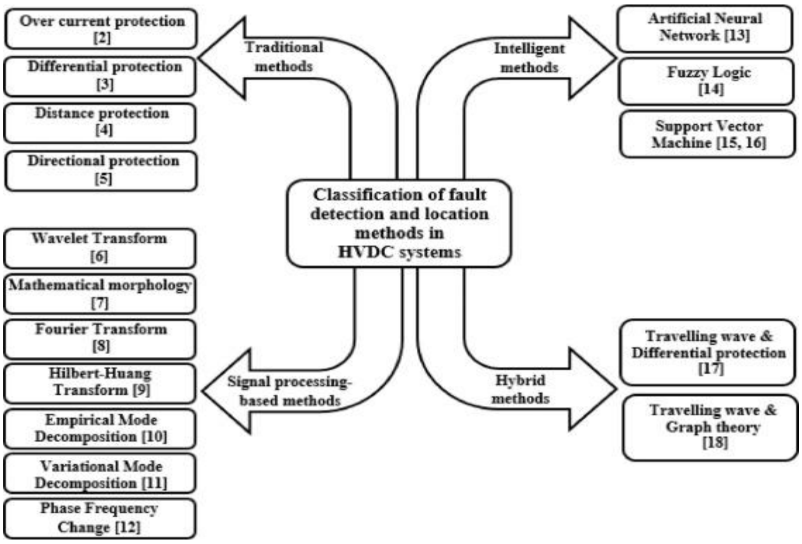
In a combined AC and DC system, generated AC voltage is converted into DC at the sending end. Then, the DC voltage is converted (inverted) to AC at the receiving end, for distribution purposes. Thus, equipment for the conversion and inversion process are also needed at the ends of the line. HVDC transmission is economical only for long distance transmission lines and for underground cables. In generating substation, AC power is generated which can be converted into DC by using a rectifier. In HVDC substation or converter substation rectifiers and inverters are placed at both the ends of a line.

In HVDC system, the main protection scheme is travelling wave protection; the derivative and differential protection are background protection. The voltage in DC Converter station is should not drop to a low value as it creates problem for controlled rectifier. So, it is necessary to detect, classify and clear the faults as fast as possible. Thus, there is a need to study the faults in the transmission lines to improve and optimize present HVDC systems. This study focuses on DC side fault how it can be analyzed using latest technologies like Machine learning and Artificial Intelligence. These modern techniques can help to analyze the HVDC system in faults and helps to make quick decision regarding what has to done under such cases. In this report we see how various Machine learning and Neural Network methods and be implemented in HVDC fault Detection system.

II. Methodology.

HVDC system is developing over the years but it is still met with some protection issues, for example, the circuit breaker (CB). So, in order to identify various faults and fault parameters in the HVDC systems we can implement modern techniques such as Machine learning and Artificial intelligence which have proven to be effective. The various methods and techniques involved in fault detection and fault identification are explained in this section.

ELM was introduced by Huang [1], for single layer feed forward neural networks (SLFNs) which randomly chosen hidden layers and numerically determines the output weights of SLFN. SLFN simply considered as a linear system and outputs of SLFN can be determined by generalized inverse operation of hidden layer output matrix in case of activation functions in the hidden layer are infinitely differentiable. The voltage and current values of the transmission lines are monitored, when a fault occurs this voltage and current signals are collected. For these signals we apply Wavelet transform typically Discrete Wavelet Transform (DWT) or Continuous Wavelet Transform (CWT) and from this transform data we acquire certain features of the fault signal like signal energy and Shannon Entropy etc. The Extreme Learning Machine algorithm has to trained with known faults and the features of extracted fault signals and should undergo testing process. Finally, ELM would be capable of detecting the fault location if enough data is provided for training the ELM.



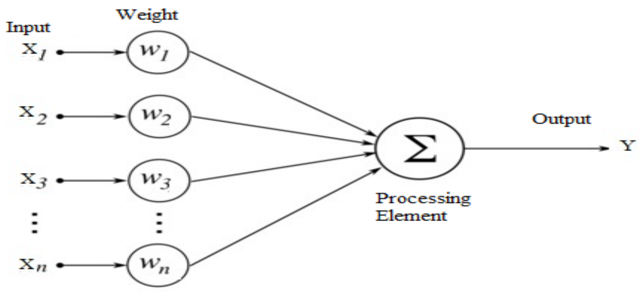
Considering a HVDC transmission system consisting of two terminals, converter and transmission lines as in [4], when a fault is caused the rectifier side will detect a sudden change in the voltage. Obtaining this information for different fault locations and resistance we train machine learning methods K-Nearest Neighbor (KNN) and Support Vector Machines (SVM).So, in the case of a fault anywhere within the HVDC system we can obtain the voltage data from rectifier side and feed it to these two Machine Learning algorithms which could identify the fault location. The accuracy of the fault location determined by the Machine learning method depends on the data set it is trained with.

The wavelet transform is a mathematical tool [2], like Fourier transform for signal analysis. The WT breaks up a signal into many pieces or many small signals and shifted, scaled versions of the original (or mother) wavelet, allowing for simultaneous time and frequency analysis. The continuous wavelet transforms (CWT). The discrete wavelet transforms (DWT). The multi resolution signal decomposition (MSD) are different types of wavelet transform which could be used depending upon the use case.

The WT generates wavelet coefficient for two cases, phase-to-ground fault and load change, which allows or recognizes the change in rising time in clearer manner. Before the fault the coefficients of WT will remain almost close to 0, but in case of a line to ground fault several spikes are noticeable, indicating the occurrence of fault for that duration, and simultaneously the wavelet coefficient becomes zero as soon as the fault is cleared. The load change waveform experiences less turbulent change in rising time. The DC line-to-ground fault is investigated using wavelet analysis. Under normal operation, the wavelet coefficients are aligned along the x-axis, the wavelet coefficient is near to zero. A very high wavelet coefficient appears representing the onset of DC fault. The capability of wavelet coefficient as the solid indicator to detect the wrong or the immediate change caused by either fault or load change is proven.

The faults in HVDC system is identified by also using Artificial Neural Network (ANN). The complete ANN structure and design procedure is explained in [7] [9]. ANNs simulate the natural systems behavior by means of the interconnection of processing basic units called neurons. Neurons are related by means of links.

The neurons can receive the signals coming from other neurons affected by a factor called weights. The proposed Neural Network (NN) based Fault Classifier (FC) is called Rms Pre-Processed (RPP) method. In the 3 phase AC voltages, dc line current and ground current are used as inputs obtained from fault simulations in HVDC systems. The ground current is essential for the NN-based FC to distinguished between unsymmetrical and symmetrical faults. The NNs can be built from either static NN or recurrent NNs. In static NNs the neurons are connected only on the forward direction. In this type of construction the neurons implement the past inputs or uses it as the feedback and thus introduces the dynamic behavior into the static NN. Using dynamic FNN structure with 3 layers. Each input voltages, dc line current or ground current is combined with its four consecutive values of past history terms.



In [6], AkadiuszBurek and JacekRezmer presents Evolutionary algorithm i.e. Genetic Algorithm for fault detection. Transient wave is produced in the DC lines whenever a fault occurs. This transient contains very low frequency components which could almost be interpreted as aperiodic signal. There is a special relation between the amplitude of this aperiodic component of transient wave and the fault location from the converter station from which this transient wave is measured. The Amplitude is also sensitive to the fault resistance. In order to effectively extract the fault location, we use Genetic Algorithm (GA). Genetic Algorithm is reasonable compromise between the solution space and use of earlier results. The transform of the current transient obtained due to fault is given to the GA algorithm which process the information and extracts the fault location data.

The ANN based fault identification is explained in different schemes in [8]. In first method the inputs to the ANN are valve current and relative gate firing pulse. This method of ANN uses single layer perceptron with two inputs. The training technique used here is called the perceptron-learning rule. The second method is proposed which is independent of the overlap angle. This method uses the valve current and gate firing pulse as input. In the third scheme Neural model is proposed to avoid fault in a system and normal pulse zone and current zone is used. This same as the second method but it is advanced than the previous method for fault identification. This scheme even identifies the fault such as double successive commutation failure, double not successive commutation failure. In method four, it is same as above methods but the simple concurrent inputs are assumed and that is used to detect correct sequence.

The fault in HVDC system is also be identify by Radial Basis Function (RBF) which is the application of ANN. This is explained briefly in [5]. This type of NN uses the Gaussian RBF for identification. The fault patterns are classified using an adaptive filter with a fixed time window which uses the Least Square (LSQ) approximation to track the proportional values of original and to that of the system values signals at each time interval. These signals are then send to the RBFNN via signal conditioner to perform the fault identification. RBFNNs share the features of Back Propagation (BP) NNs for pattern recognition and it uses a Gaussian transfer function in the hidden layer and a linear function in the output layer. The output of the signal conditioner follows the proportional tracked values and provides a non disturbing signal for the RBFNN to proceed with the fault identification within one cycle.

The ANN is also used to find the fault in Multi Terminal-HVDC system and this is explained in [13]. The rate of change of faulty current will help to increase discrimination between internal and external faults. And the energy indices is measured. Here the ANN is consist of 3 layers: input layer, output layer, hidden layer which contains neurons. Discrete Wavelet Transform is used which captures the lot and high energy transients.

The fault can be classified using Optimal Probabilistic Neural Network and this is explained in [11]. The Optimal Probabilistic Neural Network is used for fast and accurate fault classification where a Particle Swarm Optimization (PSO) is employed to achieve optimal smoothening factor to improve performance and accuracy of PNN.

The identification of fault in Line Commuted Converter HVDC (LLC-HVDC) system is explained in [14]. ANN is used when different AC side faults and DC faults are identified using Back Propagation algorithm. In this algorithm a desired firing angle is generated as output and fault is rectified.

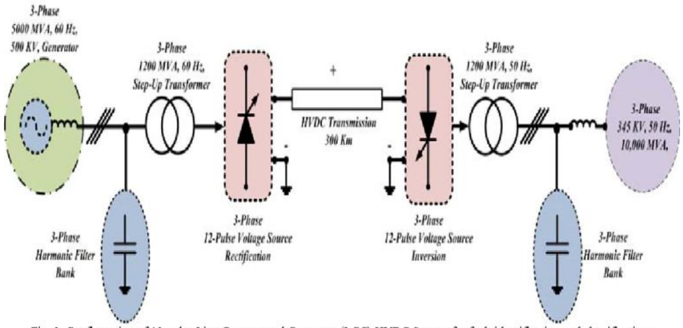
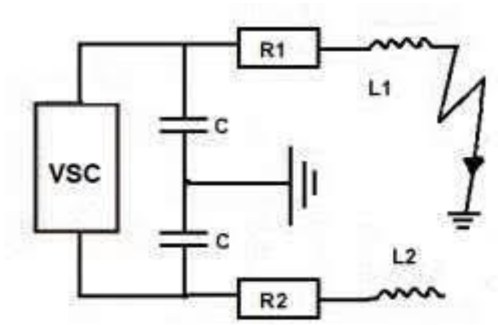


Fig. 2. Configuration of 12-pulse Line Commutated Converter (LCC) HVDC System for fault identification and classification

As mentioned in [3], when a fault occurs in the DC lines a travelling wave of voltage and current are present in the lines, these contain plenty of information about the fault which could be extracted by travelling wave protection system. Protective performance to fault location, here we monitor rate of change of voltage and amplitude at the same time, if both are exceeding its limit, we check for current travelling wave and if this also increases beyond its limit, the travelling wave protection is enabled. The idea of detecting fault location is that the rate of change of these current and voltage signals near say rectifier side will be relatively greater than that of a fault further away considering these changes are measured from the rectifier side. Similarly, the same observations can be made for protective performance of fault resistance here when subjected to different fault resistances the lower resistance fault exceeds its rate of change voltage and current limits faster than relatively higher resistance faults.

Fault Location Estimation for VSC-HVDC System Using Artificial Neural Network. This is explained briefly in [12]. A fault location technique on a 200 km two terminal VSC-HVDC system using wavelet transform (WT) and artificial neural networks (ANN). The fault of concern is pole to pole fault. The simulation is repeated by varying fault resistance and location, to test the influence of these two parameters on the proposed fault location method. The development in power electronics has helped to the development of VSC based HVDC system, eg. Its high power application insulated-gate bipolar transistor (IGBT) is used in the convert to AC into DC and vice-versa.



Fault Identification in VSC

A Novel HVDC Double Terminal Non-Synchronous Fault Location Method Based on Convolution Neural Network is explained briefly in [15]. One-dimensional convolution neural network (1D-CNN). The fault voltage line mode component is extracted from the conversion and inversion side. Signals are processed through Empirical Mode Decomposition (EMD) and used to train a CNN. Then the CNN's classification mechanism is used to achieve fault location. PSCAD/EMTDC software was used to establish the HVDC transmission model. The simulation shows that this algorithm can successfully recognize faults.

Artificial Intelligence Based Short Circuit Fault Identifier for MT-HVDC Systems is explained briefly in [17]. For clearing the faults in addition to the recovery of the network the AC circuit breakers are adopted. A new artificial intelligence (AI) MT-HVDC precise fault identifier is proposed to identify the fault lines and define both of the fault type and the precise fault location through recognizing the impact of travelling waves. The mutual effects of the fault current travelling waves, will identify the faulted pole using current sensors. Measured current data is analyzed via a discrete WT (DWT). A fuzzy classifier further categories the wavelet data into pattern classes, and finally trained neural networks (NNs) recognise the patterns of the impact of the travelling waves on the wavelet data.

Inter area oscillation is one of the main challenges for the secure and stable operation of a large-scale interconnected AC/DC power system. This is explained briefly in [20]. As the voltage source converter high voltages direct current (VSC-HVDC) transmission system. This features the fast and flexible power regulation capability, and supplementary damping controller (SDC). It can be designed for VSC-HVDC to suppress inter area oscillation in a large-scale AC/DC power system. The SDC exports an additional signal to the control system of the HVDC, which can modulate the power flow of DC transmission line and improve the dynamic performance of the system significantly.

III. Result.

SL.NO	ALGORITHMS	INFERENCE
01	Extreme Learning Machine (ELM).	ELM was introduced for Single layer Feed Forward Network, which uses Wavelet Transform for the fault identification in the signals. It is compared with the conventional neural network.
02	K-Nearest Neighbor (KNN) and Support Vector Machine (SVM).	If the transmission power system fails, the rectifier detect the change in the electrical parameters and this algorithm helps in identifying the fault by data send by the rectifier.
03	Wavelet Transform (WT).	The WT breaks up a signal into pieces of signal and shifted, scaled versions of the original (or mother) wavelet, allowing for simultaneous time and frequency analysis, by this it identify the fault location.
04	Rms Pre-Processed Method (RPP).	The 3 phase AC voltages, dc line current and ground current are used as inputs, these inputs are combined to give larger inputs, using this method the inputs identify the fault location.
05	Genetic Algorithm (GA).	Genetic Algorithm it uses earlier results. The transform of the current transient obtained due to fault is given to the GA which process the information and extracts the fault location data.
06	Radial Basis Function (RBF).	In This algorithm, fault patterns are classified using an adaptive filter with a fixed time window which uses the Least Square (LSQ) approximation which produces the signal, further this algorithm uses the signal for fault identification.

IV. Conclusion.

The HVDC transmission system can be encouraged if the present issues regarding faults detection are solved effectively. The current Artificial Intelligence Methods like Machine learning and Neural networks can present a way to effectively detect and analyze the faults. The complex math like wavelet analysis involved in finding the fault parameters could easily be achieved by these methods. Once the Machine learning or Artificial Neural Network algorithms are trained to detect the fault parameters like fault resistance and fault location, it can be used to detect further faults in future. The various Machine learning algorithms like Extreme Learning Machines (ELM), K-nearest Method (KNM), Support Vector Machine and Neural Networks like Radial Basis Function Neural Network (RBFNN) and Neural Fuzzy Logics provide means to analyse the faults and detect fault data like fault location and fault resistance automatically with reliable accuracy. Thus, by implementing these methods in HVDC systems we can improve its applicability in practical transmission systems which will solve many problems faced by conventional HVDC transmission systems.

References

[1]. FatihUnal , Sami Ekici "A Fault Location Technique For HVDC Transmission Lines Using Extreme Learning Machines" Dept of energy systems engineering, faculty of technology, Firat University, turkey, ICSG, Instanbul ,IEEE 2017.

[2]. Yew Ming YEAP, AbhisekUkil "Wavelet Based Fault Analysis In HVDC System" School of Electrical and electronic Engineering, Nanyang Technological University (NTU), Singapore, IEEE 2014.

[3]. Han Kunlun, CaiZexiang, Liu Yang, "Study On Protective Performance Of HVDC Transmission Line Protection With Different Types Of Line Fault" School of Electric Power, South China University Of Technology, Guangzhou, China, IEEE 2011.

[4]. Mou-Jie Chen, ShenLan, Duan-Yu Chen, "Machine Learning Based One-Terminal Fault Areas Detection IN HVDC Transmission System" College of Electrical Engineering and Automation Fuzhou University, Fuzhou, China IEEE 2018.

[5]. K. G. Narendra, V. K. Sood , K. Khorasani R. Pate1 "Application of Radial Basis Function (RBF) Neural Network for Fault Diagnosis in a HVDC System". IEEE Trans. on Power Systems, Vol. 13, No. 1, February 1998.

[6]. ArkadiuszBurek, JacekRezmer, Tomasz Sikorski "Evolutionary Algorithm For Detection and Localization of Faults in HVDC Systems" ABB corporate research center , Krakow, Poland, Wroclaw University Of Technology, Wroclaw, Poland, IEEE 2015.
[7]. A.J. Mazon, I. Zamora, J. Gracia, K.J. Sagastabeitia, J.R. Saenz K.J. Sagastabeitia "Selecting ANN Structures to Find Transmission Fault" IEEE Computer Applications in Power,Vol-14,Issue-3, Jul 2001.
[8]. NarendraBawane A.G. Kothari "Artificial Neural Network Based Fault Identification of HVDC Converter "Symposium on Diagnostics for Electric Machines, Power Electronics and Drives (SDEMPED 2003).
[9]. H. Etemadi, V.K. Sood, K. Khorasani, R. V. Patel "Neural Network Based Fault Diagnosis in an HVDC System" Concordia University, Electrical and Computer Engineering Dept, West Montreal, Quebec, University of Western Ontario, Electrical and Computer Engineering Dept, London, Ontario, IEEE 2000.
[10]. M Ramesh, A. Jaya Laxmi "Fault Identification in HVDC using Artificial Intelligence – Recent Trends and Perspective", IEEE 2012.
[11]. M.Khodaparastan, A.S.Mobarake, G.B.Gharephpetian, S.H.Fathi "Smart Fault Classification in HVDC System Based on Optimal Probabilistic Neural Networks" Amirkabir University of Technology, EEE Dept, Tehran, Iran, Sharif University of Technology, EEE Dept, Tehran, Iran, IEEE 2000.
[12]. SomasundaramVasanth, AbhisekUkil "Fault Location Estimation for VSC-HVDC System Using Artificial Neural Network", student member, senior member IEEE, 2016.
[13]. Ahmed E.B. Abu-elanien "An Artificial Neural Network Based Technique For Protection of HVDC Grids", ECE Dept, Dhofar University, Salalah, Oman, EEE dept, Alexandria University, Alexandria, Egypt, IEEE, 2019.
[14]. P. Sanjeevikumar, BenishPaily, MalabikaBasu, Michael Conlon "Classification of Fault Analysis of HVDC Systems Using Artificial Neural Network", School of Electrical and Electronics Engineering, Dublin Institute of Technology, Dublin, Ireland, IEEE,2014
[15]. Sheng Lan, Mou-Jie Chen, Duan-Yu Chen "A Novel HVDC Double-Terminal Non-Synchronous Fault Location Method based on Convolution Neural Network", Student members, IEEE,2018.
[16]. Mou-Jie Chen, ShenLan, Duan-Yu Chen, "Machine Learning Based One-Terminal Fault Areas Detection IN HVDC Transmission System" College of Electrical Engineering and Automation Fuzhou University, Fuzhou, China IEEE 2018.
[17]. Ahmed Hossam-Eldin , Ahmed Lotfy , Mohammed Elgamal, Mohammed Ebeed, "Artificial Intelligence-Based Short-Circuit Fault Identifier for MT-HVDC Systems", Electrical Engineering Department, Alexandria University, Alexandria, Egypt, Electrical and Control Engineering Department, Arab Academy for Science, Technology and Maritime Transport, Alexandria, Egypt, Operation Services Department, Arab Petroleum Pipelines Co.Sumed, Alexandria, Egypt, Electromechanical Maintenance Department, Alexandria Port Authority, Alexandria, Egypt, IEEE, 2018.
[18]. M Ramesh, A. Jaya Laxmi, "Fault Identification in HVDC using Artificial Intelligence-Recent Trends and Perspective", Research scholar, Member, IEEE,2012.
[19]. FatihUnal , Sami Ekici "A Fault Location Technique For HVDC Transmission Lines Using Extreme Learning Machines" Dept of energy systems engineering, faculty of technology, Firat University, turkey, ICSG, Instanbul ,IEEE 2017.
[20]. Yu Shen, Weibiao Chen, Wei Yao, Shiwu Liao, Jinyu Wen, "Supplementary Damping Control of VSC-HVDC for Interarea Oscillation Using Goal Representation Heuristic Dynamic Programming", State key Laboratory of Advanced Electromagnetic Engineering and Technology, Wuhan, Hubei Province, P.R.China, IEEE, 1995.

Mrs. Poornima H S, et.al."Relative Exploration of High Voltage Direct Current on Artificial Intelligence and Machine Learning."*IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 15(1), (2020): pp.16-21.