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A Review on Different ANN Based Fault Detection Techniques for HVDC Systems

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ABSTRACT

Neural Network has been one among few best choices for the detection of faults in electrical systems. HVDC transmission system has no doubt first choice for the long transmission of electricity all over the world. This paper presents a use of different artificial neural network for the fault detection & classification in HVDC transmission system. Here an attempt is made to cite the scholarly work done and available on renounced journals with excellent review on their work. The work is valuable and may be light house for beginners in the same field.

Keywords

Artificial Neural Network, Wavelet Transform, Faults, HVDC System, Travelling Waves

1. INTRODUCTION

An HVDC Transmission has very efficient means of transferring power in bulk over long distances due to rapid technical advancement in power electronics [34]. For the stable & reliable operation of HVDC system, the fault classification & location & clearance of fault in the HVDC lines are very important. Fault classification and location of HVDC transmission system is currently afford by the function of repeater stations [12]. Reliable operation of HVDC transmission system depends on fast detection and clearing the fault [7]. An Artificial Neural Network (ANN) has been used for fault detection in HVDC system. Only four types of faults including, short circuit in DC transmission system, single line to ground (SLG), double line to ground (DLG) & three phase fault in AC system has been detected[7]. Artificial Neural Networks (ANNs) is a mathematical model inspired by biological neural networks [15]. ANNs have been. Artificial Neural Networks (ANNs) are powerful in pattern recognition and classification. They possess excellent features such as generalization capability, noise immunity, robustness & fault tolerance [23]. ANN based techniques have been used in power system protection & encouraging results are obtained [23]. This paper aims to investigate pattern of the over current due to different cases, for instance, fault & load change. The fault taking place on HVDC transmission lines may cause instability of power system & therefore a large economic loss. Travelling wave based methods are widely used for the detection of faults in HVDC system. But it has disadvantage such as it is easily affected by noise, difficulty in accurate detection of wave head, requirement of complex & expensive equipment, vulnerable to interference of external signals etc. [b]. With the rapid advance of microelectronics technology and microcomputer protection, travelling wave theory has been implemented and adopted in HVDC transmission line successfully [24]. Neural Network (NN) gives the best results in fault detection and classification [b]. Travelling wave, which is a kind of non-stationary signal with mutation, spread along the line when HVDC transmission line fault happens [12]. The objective of this paper is to propose an HVDC transmission line fault localization algorithm based on radial basis function neural network with wavelet packet decomposition. The effectiveness of wavelet transform [WT] in identifying & locating the fault has been discussed [2]. In this paper an ANN based approach is used & an accurate fault classifier and locator algorithm is designed.

2. ARTIFICIAL NEURAL NETWORK (ANN)

ANNs are non linear information (signal) processing devices, which are built from interconnected elementary processing devices are called neurons. The arrangement of neurons into layers & the pattern of connection within & in-between layer are generally called as the architecture of the net. [35]. ANNs have been used for the protection of power transmission lines. The excellent pattern recognition and classification abilities of neural networks have been cleverly utilized to address the issue of transmission line fault location.

Artificial neural network (ANN) can be applied to fault detection and classification effectively because it is a programming technique, capable to solve the non linear problems easily [3]. They are widely accepted and used in the problem of fault detection and fault classification because of the following features:

- The ANN output is very fast, reliable and accurate depending on the training, because its working depends upon a series of very simple operations.
- The conditions of the electrical power system change after each and every disturbance. Hence a neural network is capable to incorporate the dynamic changes in the power systems.

The values of the pre fault and post fault voltage and current of respective three phases are very different and are governed by the type of fault. Thus, the fault classification method required a neural network that allows it to determine the type of fault from the patterns of pre fault and post fault voltages and currents, which are generated from the values measured from a three phase transmission line of an electrical power system at one terminal. The neural network is based upon the total six numbers of inputs, i.e. the voltages and currents of respective three phases. The neural network is trained by using these six inputs. The total number of outputs of the neural network is four in numbers, i.e. three phases A, B, C and fourth is ground of three phase transmission line.

3. TRAVELLING WAVE PHENOMENON

Travelling wave fault location methods are usually more suitable for application to long lines. Travelling wave methods for transmission lines fault location have been reported since a long time. It is well known that when a fault occurs in overhead transmission lines systems, the abrupt changes in voltage and current takes place, at the point of the fault. When a fault occurs on the HVDC line, according to travelling wave theory, voltage and current travelling waves transmits on the line. During the occurrence of a fault, travelling waves carry the information about the fault which can be used for fault detection and line protection [38]. If the times of arrival of the travelling waves in the two ends of the transmission line can be measured precisely, the fault location then can be determined by comparing the difference between these two arrival times of the first consecutive peaks of the travelling wave signal. Travelling-wave-based line fault location principle has been successfully applied to transmission line fault location in the conventional HVDC systems with two terminals [37].

4. WAVELET TRANSFORM

A wavelet is a waveform of effectively limited duration that has an average value of zero [37]. Wavelet transform has received greater attention in fault analysis due to its ability in analyzing the travelling waves than conventional methods of analysis. The method using wavelet transforms for detecting a HVDC Transmission line faults is proposed after simulating the HVDC system for various faults. The simulation results show that the application of wavelet technique leads to a more reliable solution for recognition of faults and provides a good basis for the new protection scheme for the HVDC lines.

5. CONVERTER FAULTS IN HVDC SYSTEM

HVDC system considered for analysis is shown in Figure 1 which consists of rectifier at sending end and inverter at receiving end. Converters are connected with a DC transmission line represented by a resistance and DC inductor on either side of the line [32].

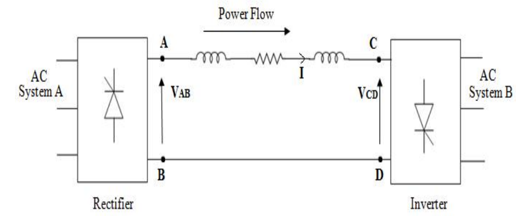

Figure 1 HVDC system model

The common malfunctions reported for the HVDC thyristor converters are:

i. Backfire: It is conduction in the reverse direction.
ii. Fire-through: It is conduction during blocking.
iii. Misfire: It is failing of conduction in spite of the positive gate and anode to cathode voltages.
iv. Commutation Failure

6. FAULT CLASSIFICATION

Fault Detection is also followed here in terms of the design & development of the classifier neural network. The designed network takes in the sets of six inputs (the three phase voltages and currents values normalized with respect to their corresponding pre-fault values) [3]. The neural network has four outputs, each of them corresponding to the fault condition of each of the three phases & one output for the ground line. Hence output are either 0 or 1 denoting the absence or presence of a fault on the corresponding line (A, B, C or G where A, B, C denote the respective 3 phases of the transmission line system & G denotes the ground). The proposed neural network should be capable to accurately distinguish between the ten possible categories of faults [3].

In HVDC, external fault is either at the rectifier stations or at the inverter stations. The external fault identified by using the value of current. The nominal value of terminal currents is 1 per unit (pu). Whenever fault occurs, this value changes. If the values of terminal currents are greater than the nominal value, fault will be at inverter side. If the value of those currents is less than the nominal value, fault will be at rectifier side [36].

The faults that occur in an HVDC line are mainly of two types. These faults can be identified easily by analyzing the current data. Current at the two terminals A & B of the DC transmission line are different in each type of fault [36]. There are two types of fault.

1. **Open Circuit Fault**: In this fault the line breaks and an open circuit fault occurs. Both terminal currents are zero.
2. **Pole to Ground Fault**: In this fault the values of terminal currents are not equal to zero. The value of terminal current I_A will be greater than I_B.

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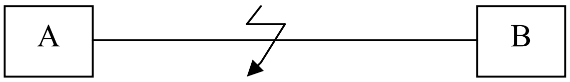

Figure 2 pole to ground fault

7. HVDC FAULT DETECTION

In this paper, wavelet transform is used for detection of faults and artificial neural network is used for classification of faults. The neural network is provided with six inputs during the fault detection process. The inputs are three voltages of respective three phases and three currents of the respective three phases. The value of input voltages and input currents are normalized with respect to the pre-fault values of the voltages and currents respectively. The output of the neural network is in simple yes or no form, i.e. 1 or 0, which indicates whether the fault has been occurred or not [3].

The 12 pulse HVDC system model is studied for various faults like (a) DC line short circuit, (b) short circuit on the AC side of inverter station and (c) normal operation as reference case. The short circuit faults on the AC side of the inverter are Single Line to Ground fault (LG fault), Line to Line fault (LL fault), Triple line (symmetrical) fault on the AC side of the inverter (LLL fault). It is not easy to identify the faults and to make correct protection decision within 3-5ms by using traditional methods, as the fault generated travelling waves, will be similar in nature. It is even more difficult if there is noise [38]. If the converter fault is considered then Fault detection of HVDC converter is based on the fact that every operation of the converter valve is associated with a set of conduction pattern of the valves. Fault detection is basically treated as a problem of pattern recognition and neural networks are extensively used where pattern recognition is needed. Therefore, by integrating the neural network algorithm with HVDC system model the faults in converter can be detected [33]. The faults such as valve short circuit, misfire and arc through faults are discussed in this paper. With the help of ANN and wavelet transformation, the fault is easily classified and detected respectively. Wavelet analysis expands functions not in terms of trigonometric polynomials but in terms of wavelets, which are generated in the form of translations and dilations of a fixed function called the mother wavelet. Compared with Fourier transform, wavelet can obtain both time and frequency information of signal, while only frequency information can be obtained by Fourier transform. Each wavelet is created by scaling and translation operations in a special function called mother wavelet. A mother wavelet is a function that oscillates, has finite energy and zero mean value [32]. When fault occurs on a DC line, the travelling waves propagate along the line and are reflected at discontinuous points of surge impedance. This leads to an abrupt change in the voltage and current and hence in the reverse voltage travelling wave. The sudden changes are the edges in signal processing. The wavelet theory is used to detect the sudden changes, and the fault location can be identified along with the recognition of the fault by obtaining the time delay Δt in seconds between the two absolute maximum values of the wavelet coefficients. By denoting

$$L = \frac{v \times \Delta t}{2}$$

Where,

v is the velocity of travelling wave in km/s and

L is the fault distance in km from the measuring point

The time delay between the first two maximum wavelet coefficients of the reverse voltage travelling wave is Δt = 0.00102 seconds, thus the fault location from the measuring terminal can be calculated and is equal to 151 km. One of the fault commutation failures can be identified clearly from the HVDC line fault with the polarity change of wavelet coefficient.

8. CONCLUSION

Here an attempt is made to gather the collection and review the work done on same and allied areas by scholars. The conclusion might be the ANN and similar techniques are capable to detect analysis and classify the different faults in HVDC systems and accessories.

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