

HVDC Converter Fault Discrimination based On Artificial Neural Network

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Abstract: *This paper investigates the possibility of using artificial neural network to detect the faults occur in HVDC converter. Neural networks are inherently not fault tolerant and hence they can be used to differentiate the faults that may occur in converter. Also they are capable of handling huge amount of data fast and efficiently. Therefore, taking into account all the advantageous features of neural network an attempt has been made to detect the fault in HVDC converter using artificial neural network.*

Keywords: HVDC system, HVDC system model, HVDC converter, artificial neural network, fault discrimination.

1. Introduction

The growing trend towards the rapid increase of load and present development systems have made it necessary to transmit more power over longer distances to cope with the demands. Today's designs, although technically safe, are not necessarily the most economical. The inherent simplicity and economic considerations have urged the power engineers to think in terms of DC at high voltage for power transmission.

It has been proved that AC is better from generation and utilization points of view while DC is preferable for transmission over very long distances. In a combined AC and DC system, generated AC voltage is converted into DC voltage at sending end. Then the DC voltage is inverted to AC voltage at the receiving end for distribution purpose. Thus in combined system conversion and inversion equipment is also needed at the two ends of the line. HVDC systems are quite reliable and converter control allows flexibility in the system operation. One of the reasons for safe operation of HVDC system is to detect and clear the converter faults as fast as possible. HVDC technology has reached a level of maturity and is contributing to the improved performance of AC systems. Hence there is a need to protect such system from the faults to achieve the desired level of power transfer. The current interest in neural networks is largely a result of their ability to mimic natural intelligence. Neural network have emerged as a powerful technique for pattern classification, function approximation, optimization, prediction and automatic control. They exhibit mapping capability also possess the capability to generalize. They can process the information in parallel at high speed and in distributed manner. Also abstract the features from inputs containing irrelevant data. As the neural networks can handle large amount of data fast and efficiently they can be used for fault detection application as stated above.

2. HVDC System and Its Model

HVDC technology has become popular and widespread due to the advantages it provides over AC transmission. Advantages of HVDC over AC transmission include lower net cost for long distance, greater power per conductor, and

possible use of ground as a return path, hence each conductor can be operated as an independent circuit. Besides that, it doesn't require any charging current, no skin effect; hence the line doesn't require reactive compensation, elimination of system synchronization and simpler transmission towers.

A HVDC transmission lines are mainly overhead transmission lines lay over long distances. The existence of fault on the transmission line may lead to the tripping of the transmission line. As the HVDC is a bulk power transmission system the short duration faults may lead to the total block out of the region. Therefore, reliability of HVDC systems has always been of primary concern in planning and operation of power systems. The total reliability of HVDC system depends on the components in the line and at the station.

The HVDC system model is designed for 12-pulse 1000MW, with the help of MATLAB software. A 1000 MW (500 kV, 2kA) DC inter connection is used to transmit power from a 500 kV, 5000 MVA, 60 Hz network to a 345 kV, 10,000 MVA, 50 Hz network. The rectifier and the inverter are 12-pulse converters using two 6-pulse thyristor bridges connected in series. At both the ends, at rectifier end as well as at inverter end AC filters are installed. Filters are installed to filter out the harmonics also to provide reactive power to the converter. Rectifier and inverter are connected via two 0.5H smoothing reactor. The HVDC system model is shown in figure (1) below.

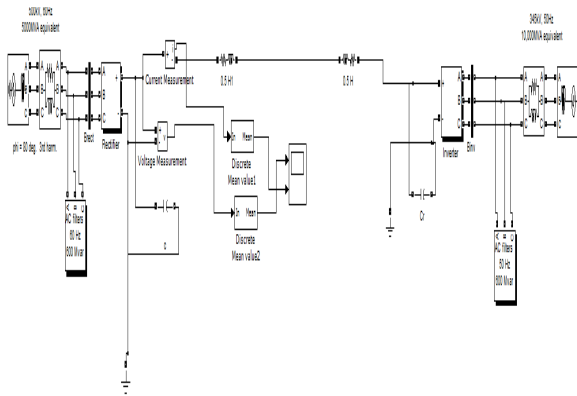


Figure 1: HVDC system model

Direct voltage and direct current that results after simulation of the HVDC system model are shown in figure (2).

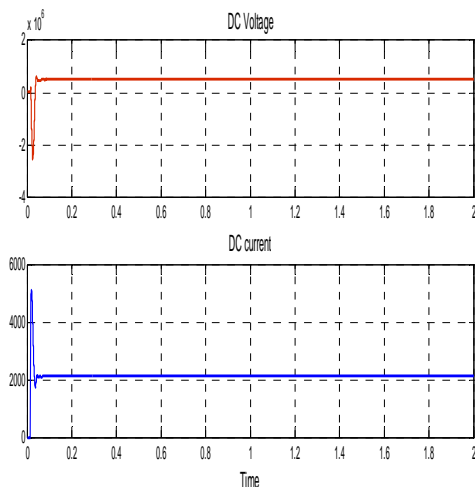


Figure 2: simulation results of HVDC system model

3. Neural Network

A neural network is a massive parallel-distributed processor that has natural propensity for storing experimental knowledge and making it available for use. An artificial neural network derives its computing power through, first, its massively parallel distributed structure and second, its ability to learn and therefore generalize. These two information-processing capabilities make it possible for neural network to solve complex problems that are currently intractable.

An artificial neuron is a computational model inspired in the natural neurons. These basically consist of inputs, which are multiplied by weights, and then computed by a mathematical function which determines the activation of neurons. Another function computes the output of artificial neuron. ANNs combine artificial neurons in order to process the information.

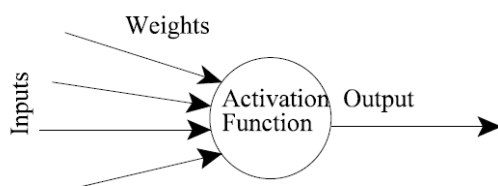


Figure 3: Artificial neuron model

The higher the weight of a neuron is, the stronger the input which is multiplied by it will be. By adjusting the weights of artificial neuron we can obtain the output we want for specific input. But when we have an ANN of hundreds or thousands of neurons, it would be quite complicated to find by hand all necessary weights. Therefore, there are algorithms which can adjust the weights in order to obtain the desired output from the network. This process of adjusting the weights is called learning or training. There are variety of ANNs used to study behavior of machines, systems etc and also for engineering purposes such as pattern recognition, feature abstraction, data compression, fault detection, forecasting etc. In this paper back propagation algorithm is used to detect the abnormal conditions in the converter.

4. Back Propagation Neural Network

The back propagation algorithm is used in layered feed forward artificial neural networks. This means that the artificial neurons are organized in layers, and send their signals “forward”, and then the errors are propagated backward. The network receives inputs by neurons in the input layer and output is given by the neurons on the output layer. There may be one or more intermediate hidden layers. The back propagation algorithm uses supervised learning, which means that we provide the algorithm with the examples of inputs and outputs we want the network to compute, and then the error is calculated. The back propagation algorithm reduces the error until the neural network learns the training data. The training begins with random weights, and the goal is to adjust them so that the error will be minimal. Back propagation training algorithm is used in this paper to detect the faults HVDC in converter.

5. Fault Discrimination Scheme

The identification of faults in HVDC converter will be done using back propagation training algorithm. Here we develop an M-file program in MATLAB software using back propagation algorithm to identify the faults that may occur in converter such as valve short circuit and arc through.

5.1 Valve short circuit

When valve short circuit occurs, high amplitude current developed as consequence of phase to phase fault on secondary of converter transformer, is conducted by faulty valve and by a healthy valve as it attempts to commutate. A valve short circuit is detected by comparing the AC and DC currents. In this case, the DC current goes to zero while AC currents tends to increase. Here short circuit across valve 1 is created using circuit breaker for 8ms which is shown in fig 4.

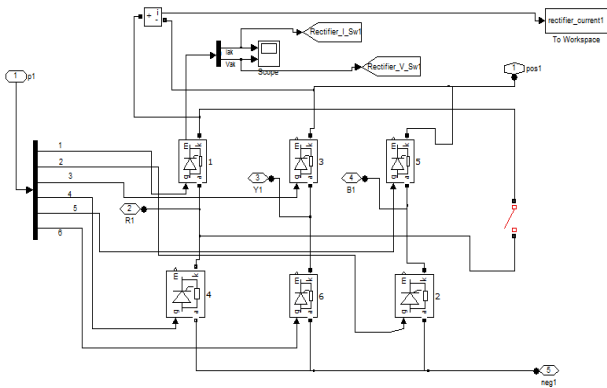


Figure 4: Valve short circuit across valve 1

Execution of the program results in training of neural network which is shown below:

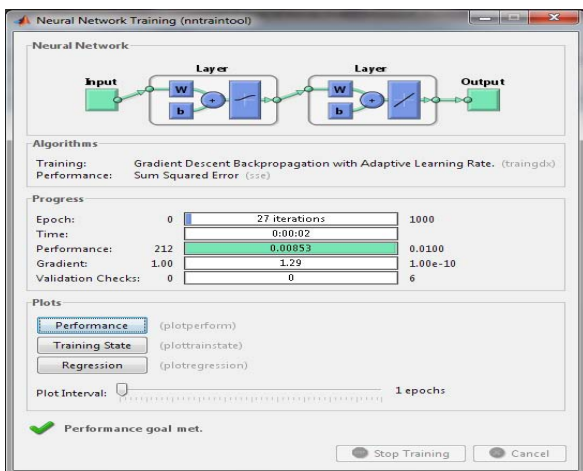


Figure 5: Training of neural network

After application of M-file program in MATLAB using back propagation algorithm following results are obtained:

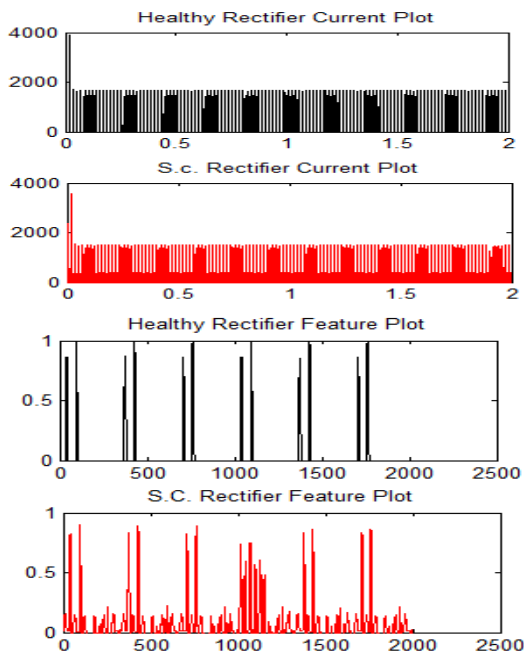


Figure 6 (a): Healthy and faulty rectifier feature plot

From the feature plot we can easily compare healthy and faulty system and we can see that there is disturbance for a short period due to valve short circuit.

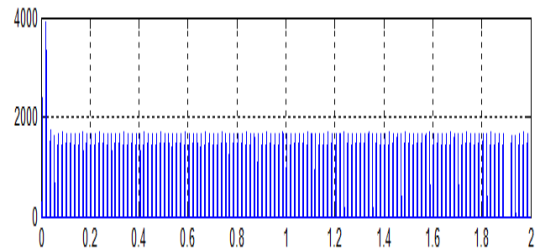


Figure 6 (b): current through short circuited valve 1

From the above figure it can be seen that there is a zero dc current for 8ms i.e. from 1.9sec to 1.908sec, which indicates that there is a short circuit across the valve.

Arc through fault

Arc through or fire through fault in HVDC converter is defined as the failure of the valve to block the conduction. This is mainly caused by an improper or malfunction of firing circuits. In this fault, the normal conduction sequence will be disturbed. It is the condition of valve with correct polarity for commutation before its programmed instant of conduction. Fire through in a valve is usually hard to be detected and may exist for a long time. When this fault occur bridge voltage falls from its rated value.

Arc through fault created in a six pulse converter bridge is shown below in fig.7 (a).

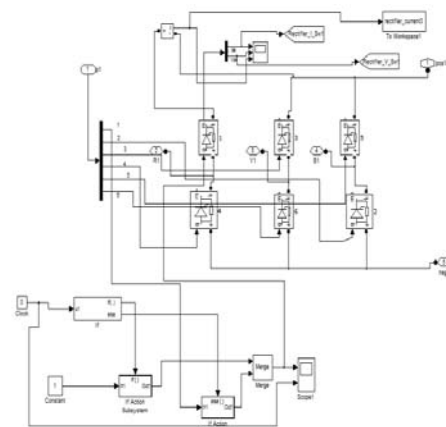


Figure 7 (a): Arc through in a 6-pulse bridge

The results of arc through fault after execution of program are shown below:

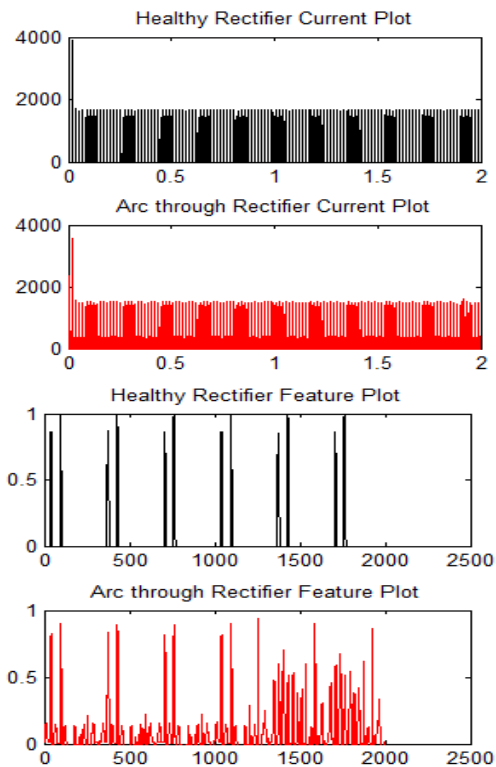


Figure 7 (b): Healthy and Faulty rectifier feature plot

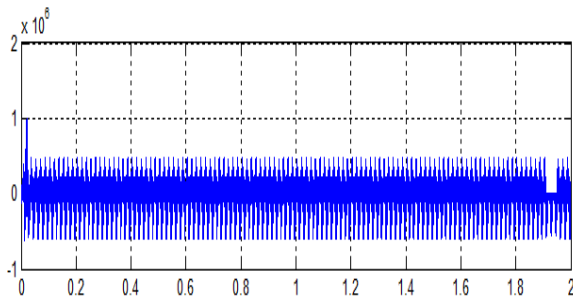


Figure 7 (c): Bridge Voltage

We can observe from fig. 7(c) that due to occurrence of arc through fault the voltage across the bridge falls from its normal value. Also it results into mis-conduction of the valve that can be seen from fig. 7(d).

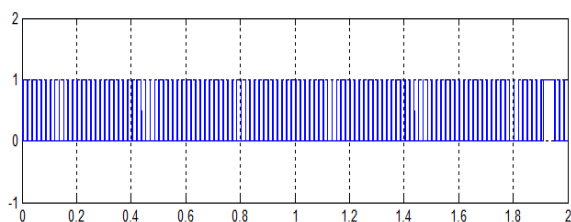


Figure 7(d): Mis-conduction due to arc through fault

Usually single arc through is self clearing. But arc through may recur and protection against this taken care by converter differential protection schemes. The short circuit across the valve is avoided by fast detecting the fault and order blocking without by-passing pairs before the next valve is fired. If the valve is unable to block the forward voltage, additional loops of over currents result and this can be avoided only by tripping AC breaker.

6. Conclusion

Safe operation of HVDC system depends on fast detection of faults. As neural network has capability to map complex and highly nonlinear input-output behavior, the approach is widely used to recognize patterns in electrical circuits, fault identification. Fault identification is basically treated as a problem of pattern recognition. Hence neural network has been used extensively where pattern recognition is needed. Based on this approach a back propagation neural network training algorithm is used in this paper to discriminate the HVDC converter faults. And from the results we get after training the neural network it is concluded that neural network can successfully discriminate the faults occur in converter and hence improve the performance of HVDC system.

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