Application Of Artificial Neural Network In Fault Detection Of Hvdc Converter

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Abstract

The aim of this paper is to examine the suitability of artificial neural network for fault detection of HVDC converter. As the neural network has the capability to map complex and non-linear input-output behaviour the approach is widely used for fault detection of ac-dc system. Also the neural network is used to learn patterns and relationships in data. On the basis of all advantageous features of neural network,. an attempt has been made to detect the faults in HVDC converter using artificial neural network.

1. Introduction

The transmission and distribution of electrical energy started with direct current. But at that time conversion between reasonable consumer voltages and higher dc transmission voltages could only be realized by rotating dc machines. In case of ac, voltage conversion is simple with the help of ac transformer. It is a simple device with little maintenance. Further a three-phase synchronous generator is superior to a dc generator in every respect. For these reasons, ac technology was introduced in early stage in the development of electrical power system. It was soon accepted as the only feasible technology for generation, transmission and distribution of electrical energy. But still for long transmission lines ac has some limitations as the reactance of the line is inversely proportional to the power per circuit which leads to stability problems. The limitations of ac over long transmission led to the use of dc for bulk power transmission over long distance.

On the other hand, artificial neural networks are nonlinear information processing devices which are built from interconnected elementary processing devices called neurons. Neural networks are the type of artificial intelligence that attempts to imitate the way a human brain works. Artificial neural networks use mathematical foundations which can be helpful to investigate input output relations of provided data and give the desired results. Hence in this paper we have tried to investigate whether the neural networks successfully detect the faults that may occur in converter or not.

2. HVDC System Model

A dc link allows power transmission between ac networks with different frequencies or networks, which cannot be synchronized, for other reasons. Inductive and capacitive parameters do not limit the transmission capacity or the maximum length of dc overhead line or cable. The conductor cross section is fully utilized because there is no skin effect. The transmission of electric power for the distances less than breakeven distances ac transmission is economical but beyond the breakeven distances the dc transmission is economical. The HVDC transmission system is basically environment-friendly because improved energy transmission possibilities contribute to a more efficient utilization of existing power plants. It can be said that an HVDC system is highly compatible with any environment and can be integrated into it without the need to compromise on any environmentally important issues. Therefore we can say that the HVDC transmission is advantageous than AC in technical, economical and environmental point of view. Converter is the most important part of the HVDC system. For proper operation of HVDC system it is necessary that the converter should operate properly.

Continuous operation of converter requires fast detection of faults that may occur in it and application of appropriate control actions. Therefore, this paper focuses on fault detection of HVDC converter using neural network. To detect the faults the HVDC system is designed using MATLAB software.

The HVDC system model is designed for 12-pulse 1000MW. 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.

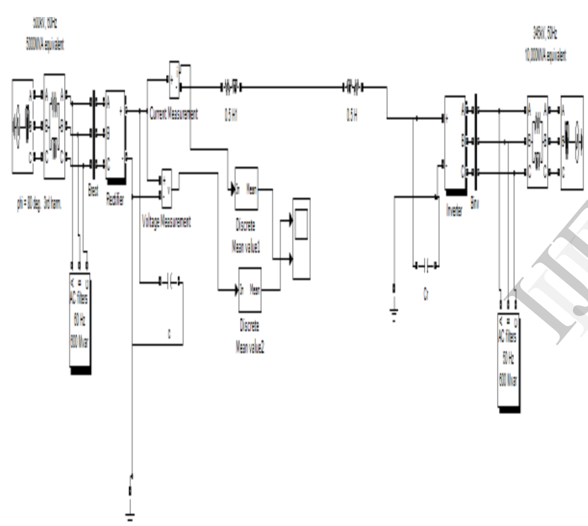
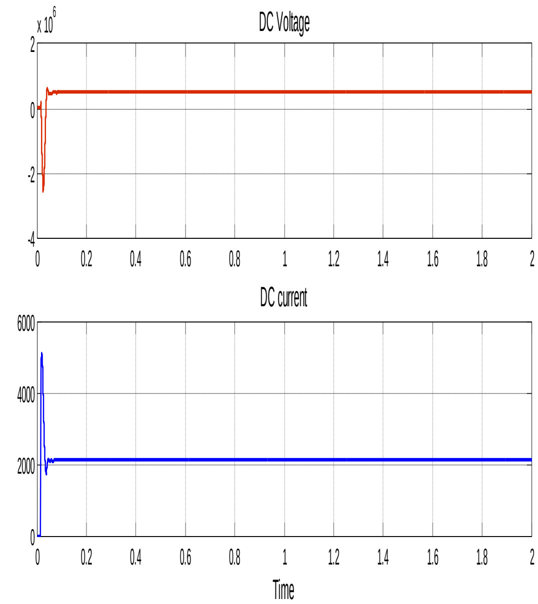


Figure 1: HVDC system model

Results of simulation of HVDC system model shown in fig.1 are stated below.



3. Artificial Neural Network

Neural Networks can operate on multidimensional data that humans may not be able to recognize due to their limited three dimensional views. Artificial neural networks are especially appropriate and powerful when used to find relationships that are difficult to describe explicitly. The training sets used for ANNs need to encompass the complete solution space. Neural networks exhibit some of the same properties that biological system exhibit. A neural network forms its own logic and stores the knowledge in its weights and instead of being given rules, the neural network learns them by training examples. Performance is improved overtime by iteratively updating the weights. ANNs appear to learn underlying rules (like input-output relationships) from given collection of representative examples.

A learning algorithm refers to a procedure in which learning rules are used for adjusting the weights and biases. The purpose of learning rule is to train the network to perform some task. In this paper, back propagation training algorithm is used for fault detection purpose. Back propagation neural network is a multilayer feed forward network. Back propagation training algorithm is the most widely used ANN model for nonlinear control of a power system. Back propagation neural network has the ability to respond correctly to the input patterns that are used for training and the ability to provide good responses to the input.

4. Fault Detection Scheme

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. The faults such as valve short circuit, misfire and arc through faults are discussed in this paper.

Valve Short Circuit:

When valve short circuit occurs high amplitude current developed on secondary of converter transformer which is conducted by a faulty valve and thereby a healthy valve which is attempted to commutate. This is avoided by fast detecting the fault and order blocking without bypassing pair before the next valve is fired. The valve short circuit is detected when the dc current goes to zero and ac current tends to increase. Here the valve short circuit fault is created in a six pulse converter bridge using breaker across valve 1 shown in figure 2.

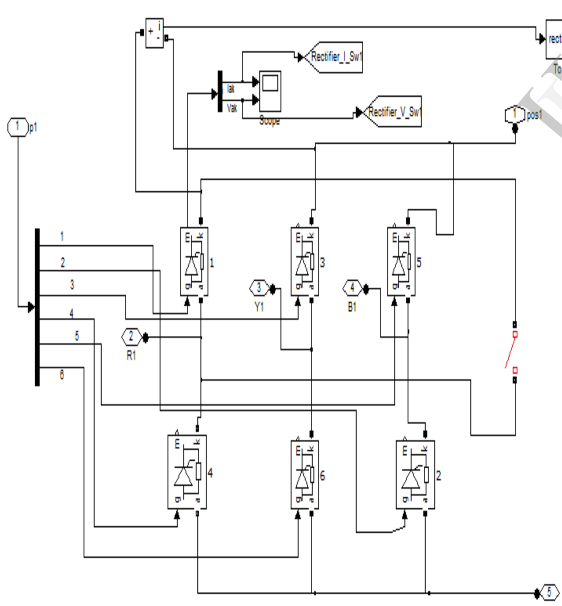


Figure 2: Valve short circuit fault

For detecting all these three faults an M-file program is developed using back propagation training algorithm. After execution of this program we get the results for valve short circuit fault which are shown below:

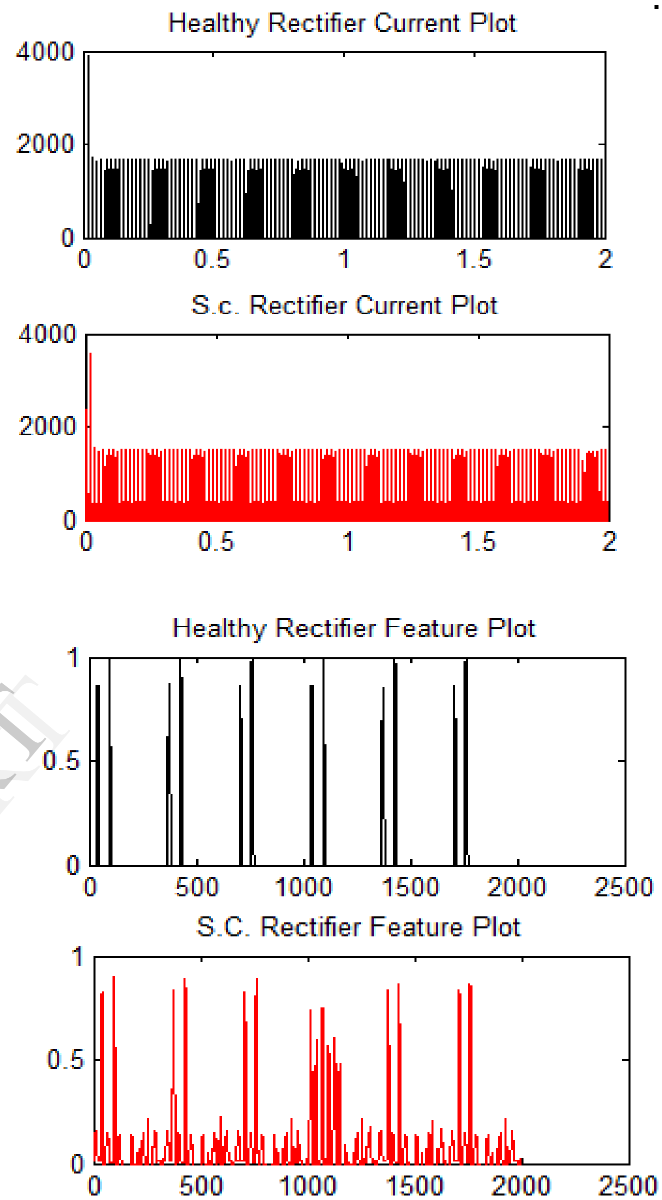


Figure 2(a): Healthy and Faulty feature plot

During valve short circuit fault there are disturbances in the rectifier current which is clearly visible from the rectifier current feature plot. Also the current through the valve during short circuit goes to zero which is shown in figure 3.

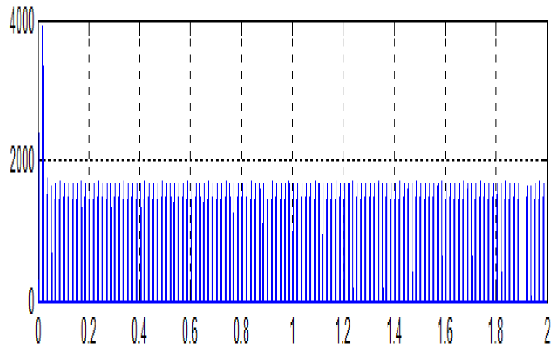


Figure 2(b): valve 1 current during short circuit

Misfire fault:

A misfire is when a valve fails to take over the conduction at its programmed instant although its voltage has the correct polarity. For a single valve misfire fault, the normal valve conduction sequence of the rectifier will be disturbed once in a cycle and reappear in every cycle if the fault is sustained. As a result, a harmonic current in rectifier side of the system frequency will be induced on dc line.

Misfire fault created in a six pulse converter bridge is shown in figure 4.

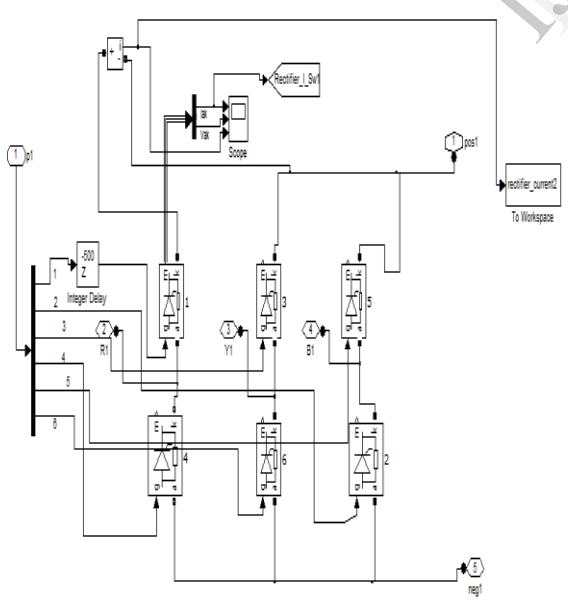


Figure 3: Misfire Fault

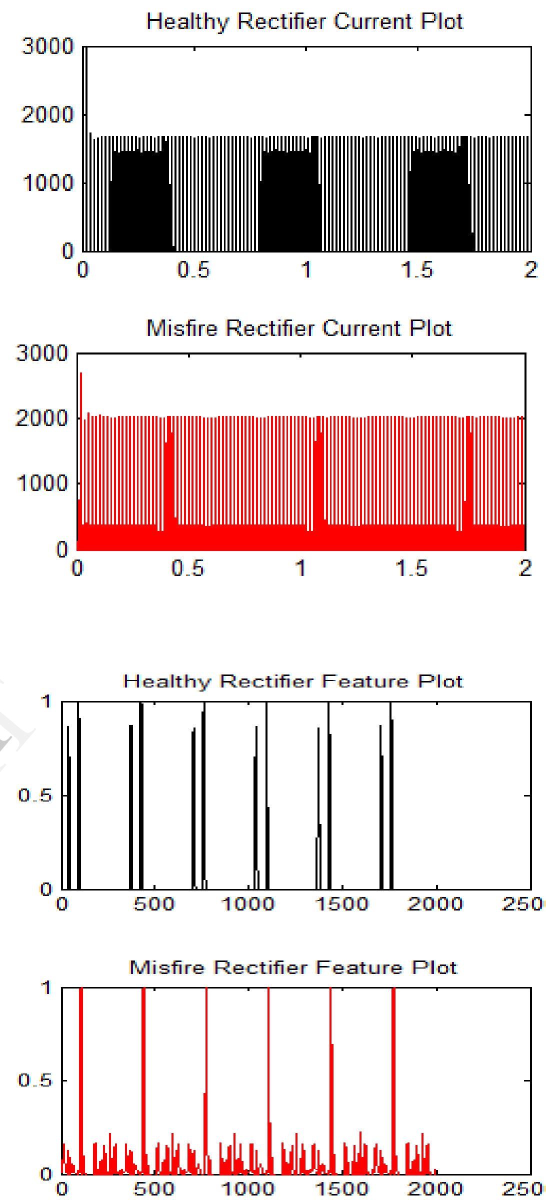


Figure 3(a): Healthy and Faulty feature plot

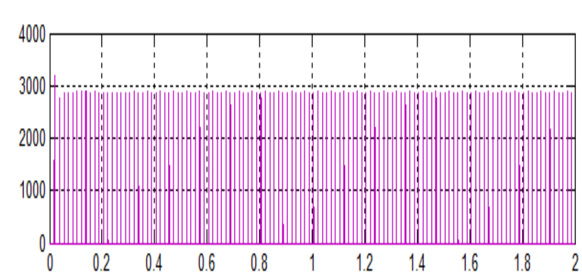
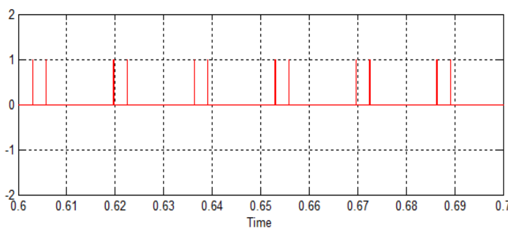
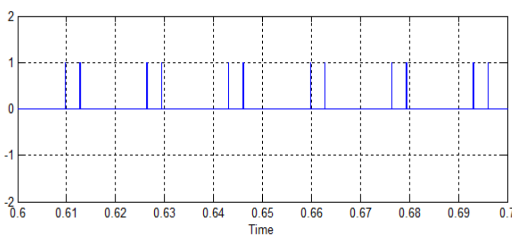


Figure 3(b): Valve current during misfire fault

From fig. 5 we can see that the current through the valve during misfire fault suddenly increase and there are small disturbances in rectifier current. During this fault the normal conduction sequence is disturbed which is shown in figure 3(c).



Nornal conduction sequence



Faulty conduction sequence

Figure 3(c): Normal and Faulty conduction sequence

Arc Through Fault:

Arc through fault occur when the valve fails to block the conduction at its programmed instant i.e. the valve is continuously is in ON state. Due to this reason the conduction sequence will be disturbed. Arc through fault in six pulse bridge is shown in figure 4.

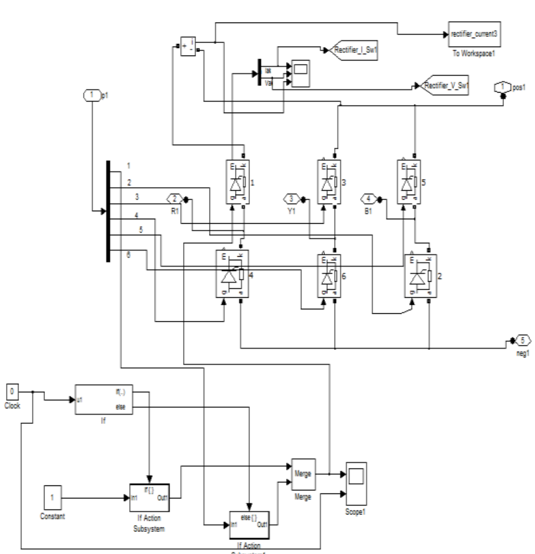
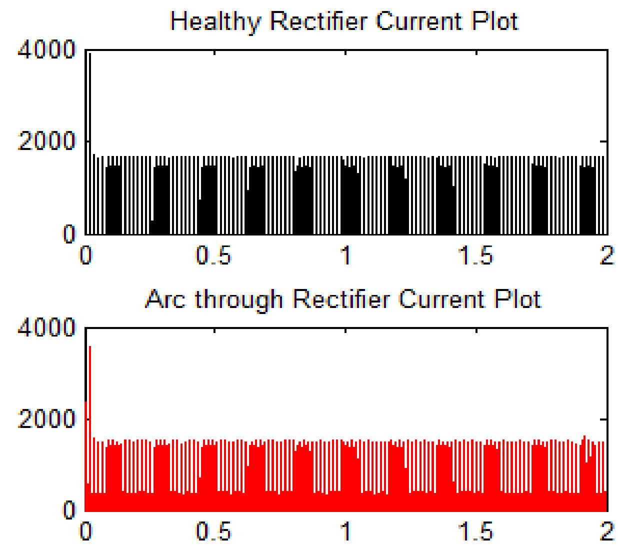


Figure 4: Arc through fault



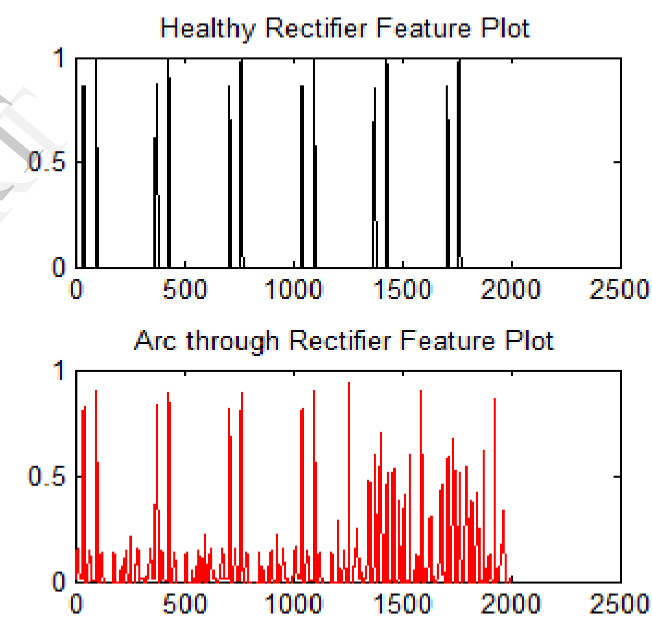
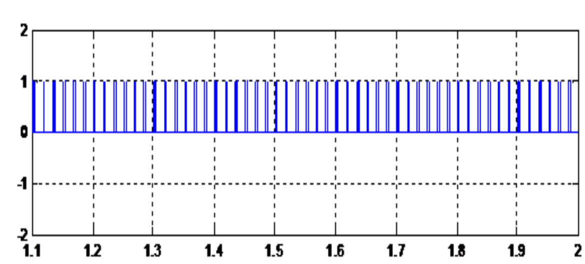
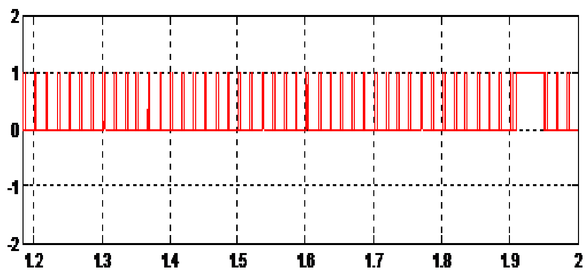


Figure 4(a): Healthy and Faulty feature plot



Normal conduction



Conduction during fault

Figure 4(b): Normal and Faulty conduction

The figure 4(b) shows that between the instant 1.91 and 1.95 the valve fails to block the conduction and it is continuously in ON state.

Single arc through is self clearing if the causes led to it are removed. In case of persistent arc through fault differential protection scheme is used. The basic protection against all the converter faults is provided by valve group differential protection, which compares the rectified current on the valve side of converter transformer to the dc side current measured on the line side of the smoothing reactor. The differential protection is employed because of its selectivity and fast detection. The overcurrent circuit is used as a back-up. The level of overcurrent required to trip must be set higher than that of the valve group differential protection to avoid tripping with faults outside the station.

5. Conclusion.

The results of different types of faults that may occur in HVDC converter have been discussed above. Fault investigation has been done using back propagation neural network based training algorithm. The back propagation neural network training algorithm is well suited for the fault detection application. The training algorithm is integrated with HVDC system to achieve the desired results. It may be concluded that the performance of back propagation training algorithm was found to be satisfactory for this application.

6. References

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