Fault Identification Of Hvdc Converter Using Artificial Neural Network

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Abstract

This paper explores the suitability of using artificial neural networks for fault identification of HVDC converter. An important application of artificial intelligence is the diagnosis of faults of mechanisms, systems, in general. Based on the ability of this network to distinguish reliably between different types of faults that may occur in converter, the feature can be suitably integrated with artificial neural network based algorithms to improve the dynamic performance of AC-DC power system. In this paper back propagation algorithm is used to identify the faults in HVDC converter.

1. Introduction

Remote generation and system interconnections lead to a search for efficient power transmission at increasing power levels. The problem of AC interconnections particularly in long distance transmission has led to the development of DC transmission. HVDC allows power transmission between unsynchronised AC distribution systems, and can increase system stability by preventing cascading failures due to phase instability from propagating from one part of a wider power transmission grid to another. HVDC transmission system has become a mature and well accepted technology. It is recognize as an effective and efficient means of transmitting bulk power over long distance [6]. The main circuitry comprises of converter transformers, converter bridges, smoothing reactors and filters. For safe operation of AC-DC systems requires the monitoring of appropriate system signals and accurate and rapid classification of any perturbations so that protective control decisions can be made. Power system reliability improves when HVDC converter faults are detected and eliminated before they deteriorate to severe state.

Artificial neural networks are found to be suitable for above requirements. Neural networks are massively parallel distributed processors that has natural propensity for storing experimental knowledge and making it available for use. An important feature of fault diagnosis using neural networks is that they can interpolate among the training to give an appropriate response for cases described by neighbouring or noisy input data. In this paper neural networks are used to identify the faults in HVDC converter [8].

2. HVDC System and Its Model

The most common reason for choosing HVDC over AC transmission is that it is more economical than AC for transmitting large amount of power point to point over long distances. A long distance, high power HVDC transmission scheme generally has lower capital cost and lower losses than an AC transmission link. Even though HVDC conversion equipment at the terminal station is costly, overall savings in capital cost may arise because of significantly reduced transmission line costs over long distance routes[7]. HVDC needs fewer conductors than an AC line, as there is no need to support three phases. Also, thinner conductors can be used since does not suffer from the skin effect. Depending on voltage levels and construction details, HVDC transmission losses are quoted as about 3% per 1000 km, which is less than typical losses in an AC transmission system. Changes in load that would cause portions of an AC network to become unsynchronised and separate would not similarly affect a DC link, and power flow through DC link would tend to stabilize the

AC network. The magnitude and direction of power flow through DC link can be directly commanded, and changed as needed to support the AC networks at either end of the DC link this has caused many power system operators to contemplate wider use of HVDC technology for its stability benefits alone.

The HVDC system modelled is a 12-pulse, 1000 MW (500 kV-2kA) 50/60 Hz HVDC transmission system. Two 6-pulse bridges in series constitute a 12-pulse converter. Complete HVDC system is modelled in a SIMULINK platform with MATLAB as a computational engine.

HVDC system model is shown in figure (1), where power is transmitted from 500kV, 60Hz, 5000MVA system to 345kV, 50Hz, 10,000MVA system. Subsystem 1 is the sending or rectifier end ac system. AC filters for the 5th, 7th, 11th, and 13th harmonics are provided. The remaining reactive power demand of the converter is supplied by a shunt capacitor bank. Subsystem 2 is a dc system. The rectifier is connected to the inverter via two o.5H smoothing reactors. There is no dc line in case of back to back tie. Subsystem 3 is the receiving or inverter end ac system. AC filters are provided here for 5th, 7th, 11th, and 13th harmonics.

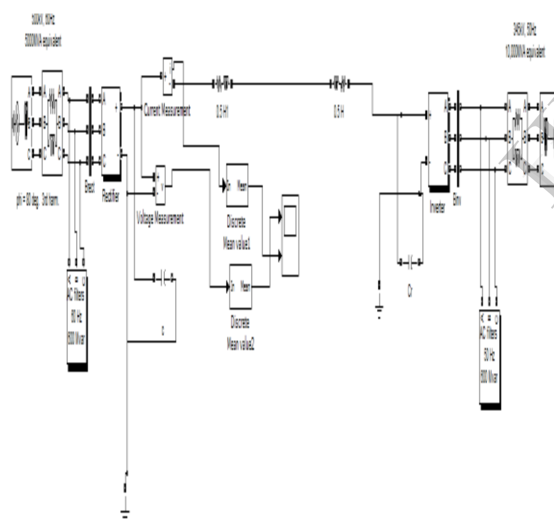
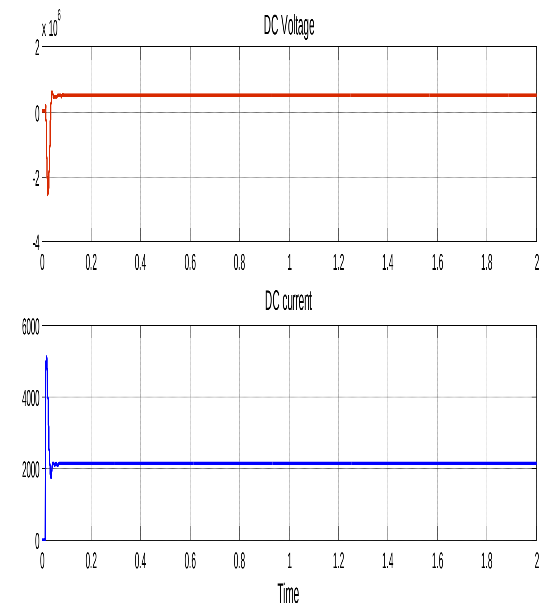


fig.(1) 12-pulse, 1000MW, 50/60Hz HVDC system model

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



3. Neural Network

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous system process information. It is composed of large number of highly interconnected processing elements called neurons working in unison to solve specific problems. This highly connected, parallel interface forms the hardware of the ANN. One of the major advantages associated with the use of neural network is the parallel processing capability. The high degree of parallel connectivity of an artificial neural network also brings about desirable properties such as noise reduction and fault tolerance [8].

The processing units or neurons of ANN consist of three main components; synaptic weights connecting the nodes, the summation function within the node and the transfer function. Synaptic weights characterize themselves with their strength, which corresponds to the importance of the information coming from each neuron. In other words, the information is encoded in these strength-weights. The summation function is used to calculate a total input signal by multiplying their synaptic weights and summing up all the products. The artificial neuron model is shown in fig. (2):

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 3, March - 2013

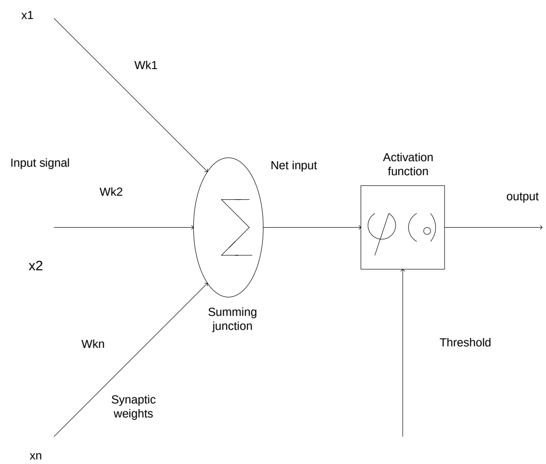


Fig. 2 Neuron model

Each neuron could receive several inputs from neighboring neurons through interconnections. The net input of the neuron is the weighted sum of inputs into the neuron and then neuron uses net input, together with information on its current activation state to determine its new state of activation. The activation function is used to calculate the output response of a neuron.

Neural network computing characteristics are distinguished from conventional pattern recognition by their ability to map complex and highly non linear input-output patterns. A neural network can be trained to perform a pattern association or classification. It can respond to input data and provide output that can provide quantitative information about the system.

4. Fault Identification

HVDC converter faults are mainly depends upon the operation of the converter valve and conduction pattern of the valve. Fault identification is based on valve parameter. Fault identification method is treated as a problem of input data pattern recognition and pattern recognition is well handled by artificial neural networks. Fault identification will be done using back propagation algorithm.

Back propagation is a systematic method for training multilayer artificial neural networks. It has a mathematical foundation that is strong if not highly practical. It is a multi-layer forward network using extend gradient-descent based delta-learning rule, commonly known as back propagation rule. It provides computationally efficient method for changing the weights in a feed forward network, with differentiable activation units, to learn a training set of input-output examples.

Here we created a fault in the converter valve using a breaker which is shown below in fig. (3)

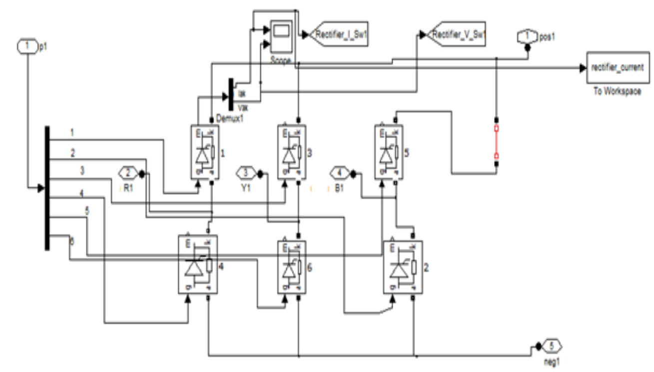


Fig.3. Six-pulse Bridge showing fault at valve 5

The figure (3) shows a six-pulse converter bridge having six thyristor valves. Three valves (1, 3, 5) on upper side and three valves (4, 6, 2) on lower side. Gate pulses are provided to each thyristor. Here valve current is taken as an important parameter for the detection of fault in converter. Breaker is inserted at thyristor 5, as a result the current fails to commutate to next thyristor.

By developing a computer program using back propagation algorithm we can able to identify or detect the fault. In this method valve current is taken as input to the neural network.

Program using back propagation algorithm is stated as follows:

```
yaxis1=rectifier_current_healthy.signals.values;
yaxis2=rectifier_current.signals.values;
xaxis1=rectifier_current_healthy.time;
xaxis2=rectifier_current.time;

figure
subplot(2,1,1);
plot(xaxis1,yaxis1,'k-');
title('Healthy Rectifier Current Plot');

subplot(2,1,2);
plot(xaxis2,yaxis2,'r-');
title('Faulty Rectifier Current Plot');

 yaxis_trunc1=yaxis1([37000:40000],1);
yaxis_trunc2=yaxis2([37000:40000],1);

y_max1=max(yaxis_trunc1);
yaxis_n1=yaxis_trunc1/y_max1;
y_max2=max(yaxis_trunc2);
yaxis_n2=yaxis_trunc2/y_max2;

feature1abs=yaxis_n1;
feature2abs=yaxis_n2;
```

```
figure
subplot(2,1,1);
plot(feature1abs,'k-');
title('Healthy Rectifier Feature Plot');

subplot(2,1,2);
plot(feature2abs,'r-');
title('Faulty Rectifier Feature Plot');

%   ANN IMPLEMENTATION by Training
Parameters Set
%___________________________________________
_____________

S2=2; % Total No of Patterns to be recognized

annINPUTpattern=[feature1abs feature2abs];
[row column]=size(annINPUTpattern);

for i=1:row
   if annINPUTpattern(i,1)==annINPUTpattern(i,2)

annINPUTpattern(i,2)=annINPUTpattern(i,1)+0.00001;
   else
   end
end

 targets=[1 0;0 1];

  DEFINING THE NETWORK
%    ===================

%    The neural network will have 200 neurons in its
hidden layer.

S1 = 200;
net = newff(minmax(annINPUTpattern),[S1
S2],{'logsig' 'purelin'},'traingdx');

% net =newff(minmax(annINPUTpattern),[S1
S2],{'logsig' 'purelin'},'trainlm');

TRAINING THE NETWORK
%
==================================

net.performFcn = 'sse';       % Sum Squared Error
performance function
net.trainParam.goal = 0.01;     % Sum-squared error
goal.
net.trainParam.show = 20;      % Frequency of progress
displays (in epochs).
net.trainParam.epochs = 5000;  % Maximum number of
epochs to train.
net.trainParam.mc = 0.95;      % Momentum constant.

   Training begins...please wait...

P = annINPUTpattern;
T = targets;

[net,tr] = train(net,P,T);

echo off


annOutput = sim(net,P);

[T annOutput]
```

In this programming method we have 40000 values of rectifier current used for training purpose. Then these values are truncated from 37000 to 40000 to get better performance and to reduce errors. These values are then normalised as it involves simplification of entities and minimization of duplication of data. The target is decided as [1 0] for healthy system and [0 1] for faulty system. The network has 200 neurons in its hidden layer. The network is trained maximum up to 5000 epochs. The momentum constant allows the net to perform large weight adjustment. The main purpose of momentum is to accelerate the convergence of error propagation algorithm.

After running the program and the whole HVDC model together we can see the result which is shown below.

```
 ans =

   1.0000         0    0.9788    0.0571

        0    1.0000   -0.0227    1.0663
```

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 3, March - 2013

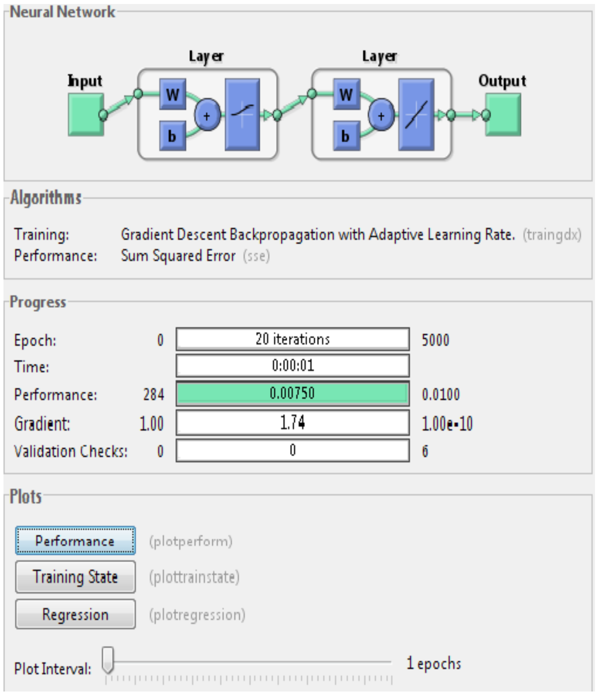
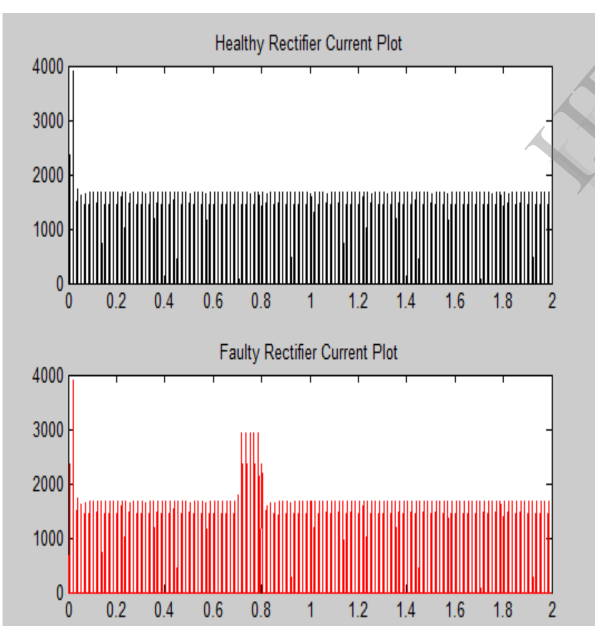


Fig.(4). Training of neural network



(5) current plot of healthy and faulty rectifier

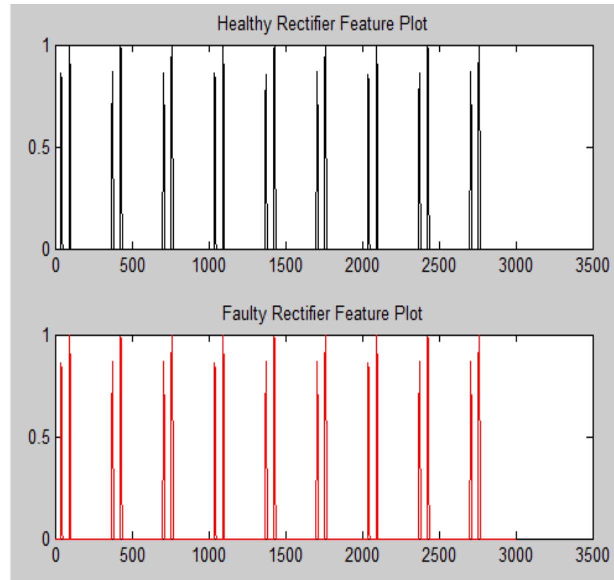


Fig.(6) Healthy and faulty rectifier feature plot

The commutation failure in a six pulse bridge is characterized by significant reduction of ac phase current amplitudes where as the current on the dc side is subject to an increase. We can observe from above figures that the dc side current is increasing which indicates the faulty condition. Hence we can conclude that there is commutation failure takes place inside the converter.

At a detected commutation failure the protection is blocked for a time corresponding to the longest fault clearing time for ac faults. At all commutation failures, instantaneous advancing of firing angle in faulty converter will be done to improve the recovery.

5. Results of Convertor Diagnosis

This paper has focused on the ability of the system to correctly diagnose the fault condition. Fault current is taken as input to the neural network and provide output pattern accurately. The different input patterns and output fault conditions derived for normal and abnormal conditions to train the neural network and we can see that neural network effectively detect the abnormal or faulty condition occur in HVDC converter.

An important advantage of neural network based diagnosis is its performance in real time environment and under the influence of noisy or varied input data, thus exhibiting resilience.

6. Conclusion

Due largely to technical advances in high voltage converters and other high voltage apparatus, HVDC transmission become available means for transferring power over long distance. The reliability of HVDC system has always been of primary concern in planning and operation of power system. The total reliability of HVDC system depends upon the components in the line and at the stations. In this paper, application of neural network for fault detection of thyristor power converter is discussed. As neural networks can handle large amount of data, fast and efficiently they can be used in solving complex power system problems. Also they are fault tolerant. Back propagation algorithm is used here to identify the commutation failure occur in HVDC converter. The aim of back propagation network is to train the network to achieve a balance between the ability to respond correctly to the input patterns that are used for training and ability to provide good responses to the input. Therefore, by developing a computer program using back propagation algorithm and integrate it with HVDC system mode,l we can identify the fault and improve the reliability of the system.

7. References

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