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Condition Monitoring of Back to Back HVDC Transmission System using Artificial Neural Network

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Abstract: Fault detection process is much more complex in HVDC systems as many circuits and accessories are involved in this system which is much than HVAC systems. Here an attempt is made to monitor the condition of whole HVDC system. The HVDC system not only involves converter and inverter but have other parts too which are; grid systems, firing circuits, filters, sensing units, protections system and transmission lines. The condition monitoring involve overall present situations of entire system which ultimately ease the operation and maintenance of system and prevent unpredicted breakdowns. The proposed work is a condition monitoring system for back to back HVDC system using artificial neural network.

Keywords: Artificial Neural Network, Faults, HVDC System, Training.

I. INTRODUCTION

HVDC systems have a long history in electrical engineering. In the early age of electricity, all distribution systems were DC. However, as the electrical grid grew there was an increasing demand for higher voltage and power levels, making HVAC systems the norm . In more recent years however, HVDC systems have seen an increase in popularity, and is a popular choice for several applications. These are mainly bulk power transmission across long distances, and the interconnection of HVAC systems operating at different frequencies from one another, known as asynchronous networks. HVDC is also often preferred over HVAC for use in cables, as this drastically decreases voltage loss. So far all HVDC systems, with a few exceptions, are point to point systems, meaning the power transfer is merely between two converter stations, either connected with cable or overhead line. With recent increase in power demand and production, and especially the increasing renewable share, serious effort has been devoted to examine the feasibility of more complex HVDC systems with several converters interconnected. Such a system is known as a Multi Terminal HVDC (MTDC) system. There are a few in current operations, with the three converter Canadian Quebec-New England connection being amongst the first.

II. HVDC SYSTEM CONFIGURATION

- **Monopolar System**

In Monopolar systems, each converter station consists of a single converter. The resulting maximum system voltage and power is thus equal to the maximum rating of the converter. Monopolar systems further distinguished as either asymmetrical or symmetrical.

- **Bipolar System**

If voltage and power rating is to be increased beyond what is possible for a single converter, two converters can be connected together in a bipolar configuration,. The bipolar configuration is basically two Monopolar systems operating in parallel, at equal voltage levels but with opposite polarity from one another. The bipolar system is similar to the symmetrical monopole, but the extra converter operating in parallel ensures increased redundancy, allowing the system to continue operation at half the rated voltage in case of a fault on either pole. Bipolar systems are grounded at the DC midpoint between the converters to provide a neutral point. The neutral points of each converter can be connected together with metallic return, but during normal operation of both poles the neutral current will be zero.

III. DIFFERENT GRID TOPOLOGIES

An HVDC grid can be imagined both as an independent grid, or as an overlay grid alleviating the strain on existing HVAC grids which are close to their maximum operating point.

There are several advantages for choosing HVDC over HVAC for the future expansion of the high voltage power transmission:

- Lower number of cables and reduced visual impact
- Enables power exchange between asynchronous networks
- Lower losses over long distances
- Improves performance in parallel HVAC grid

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IV. PROPOSED WORK

The proposed work is divided in two section first one is problem domain and last one is solution domain. Figure 1.1 shows the configuration of HVDC system which is going to simulate through mat lab enviuorment. Figure no 1.1 shows the algorithm for problem domain and figure no 1.3 shows the algorithm for solution domain

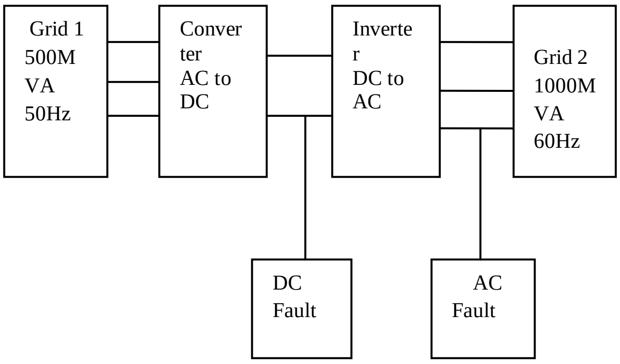

Figure no 1.1 HVDC system

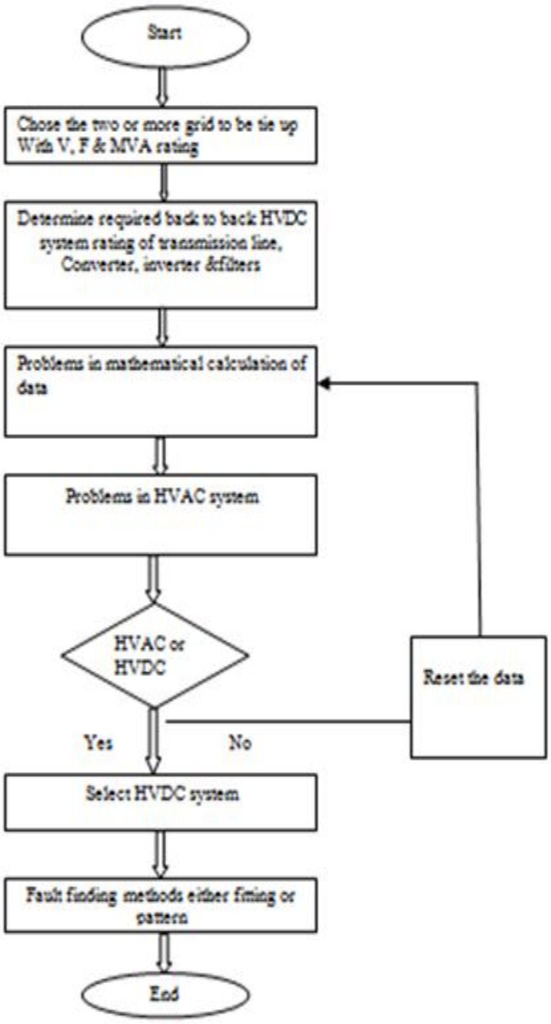

Figure no 1.2Problem Domain Algorithm

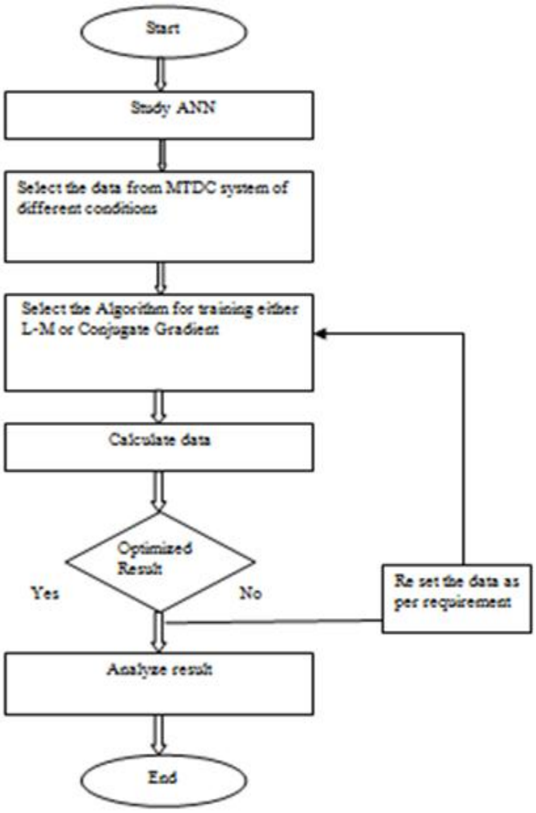

Figure no 1.3 solution Domain Algorithm

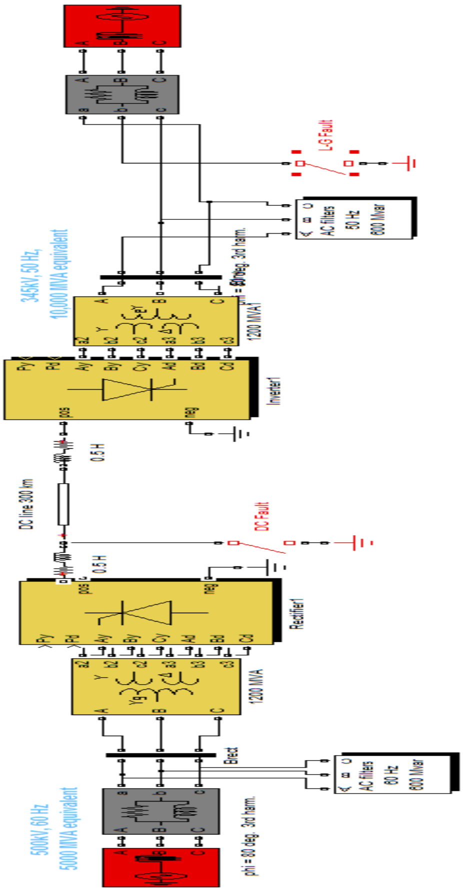

Figure 1.4 HVDC model in Simulink

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The HVDC system for the transfer of electricity is chooses because of ease of frequency matching and grid tie ups is flexible operative schedules as per the requirements. The proposed work is divided in two parts; first part is for creating the HVDC system in Simulink.

The HVDC model is choses from basic model given in demo system of Simulink. This HVDC model is tie up with different grids of different power rating and frequencies. The second step is toward condition monitoring of same system under different condition using ANN. The input and training data for ANN is generated from the Simulink model and feed it into ANN input.

Figure 1.5 shows the fault current waveform under normal operating condition:

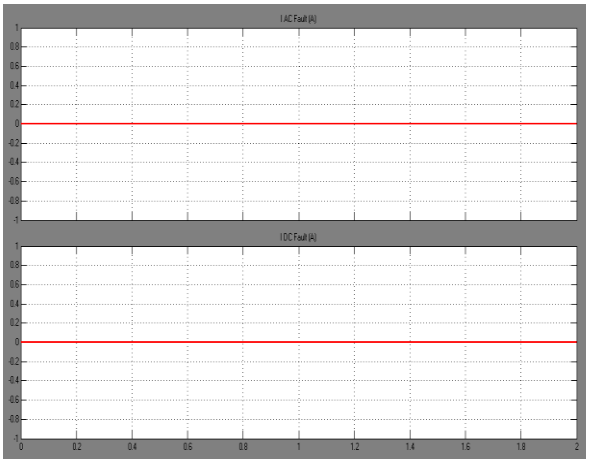

Figure 1.5 AC & DC fault current wave form under normal condition

Figure 1.6 shows the waveform under only DC fault condition:

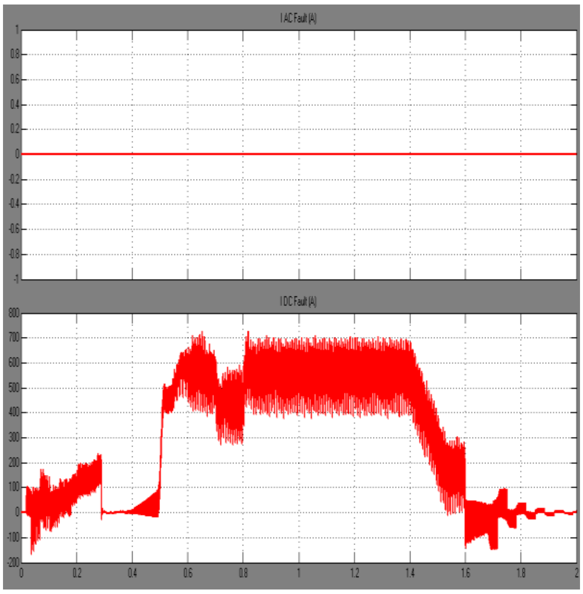

Figure 1.6 AC & DC fault current wave form under DC fault condition

Figure 1.7 shows the waveform under only AC fault condition:

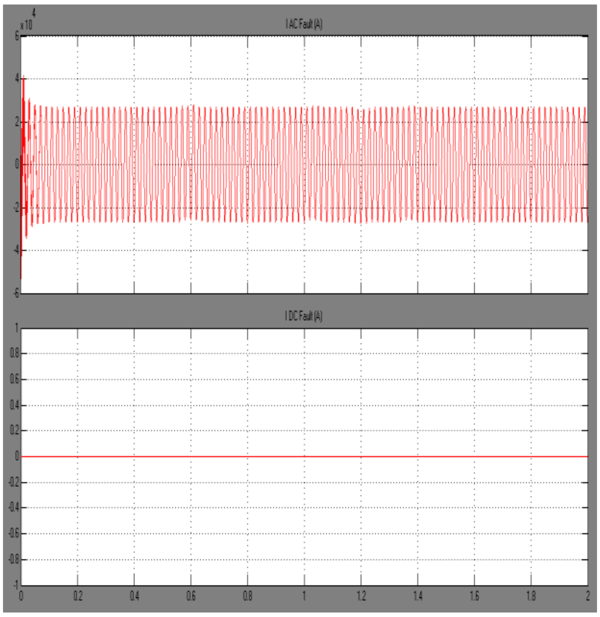

Figure 1.7 AC & DC fault current wave form under AC fault condition

Figure 1.8 shows the waveform under both DC & AC fault condition:

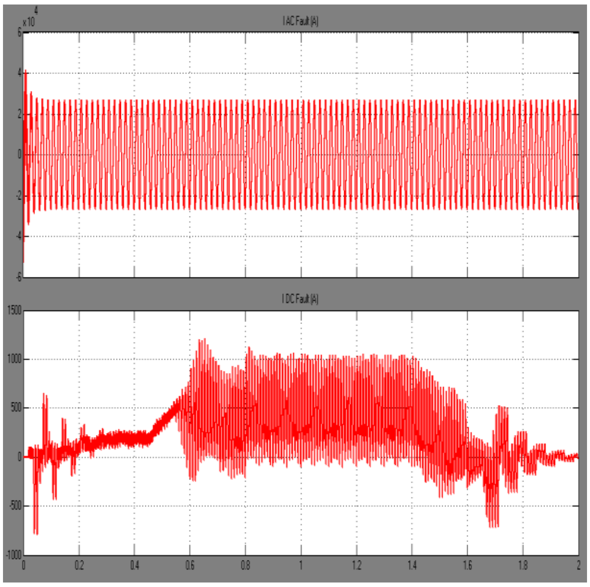

Figure 1.8 AC & DC fault current wave form under DC & AC fault condition

V. FAULTS IN HVDC SYSTEM AND DETECTION USING ANN

Mat lab is selected for applying ANN in HVDC system for fault detection. Here back propagation type neural network is chooses for the fault detection. This type of ANN is a supervised learning for which the data received from the simulation of HVDC model is used to feed as input. The

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ANN using fitting tool is chooses for fault detection and a network is created of six input layer, 25 hidden layer and two output layers. Figure 1.8 shows the fitting neural network:

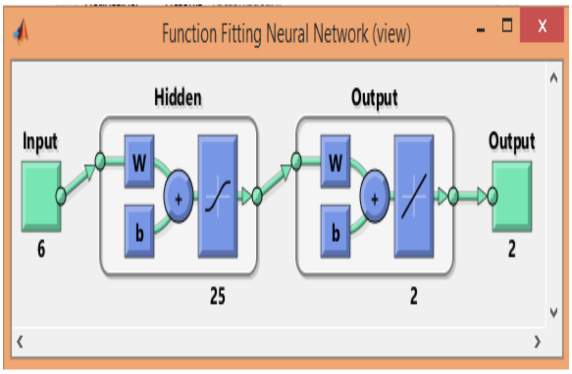


Figure 1.8 Neural Network architecture for fitting tool

Figure 1.9 shows the pattern recognition network

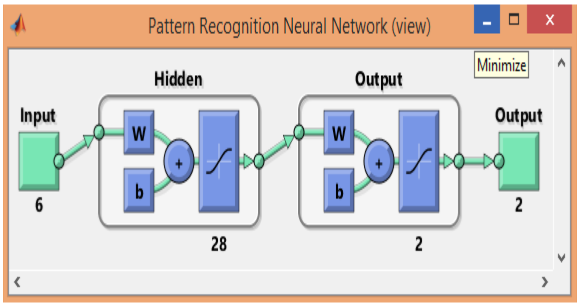
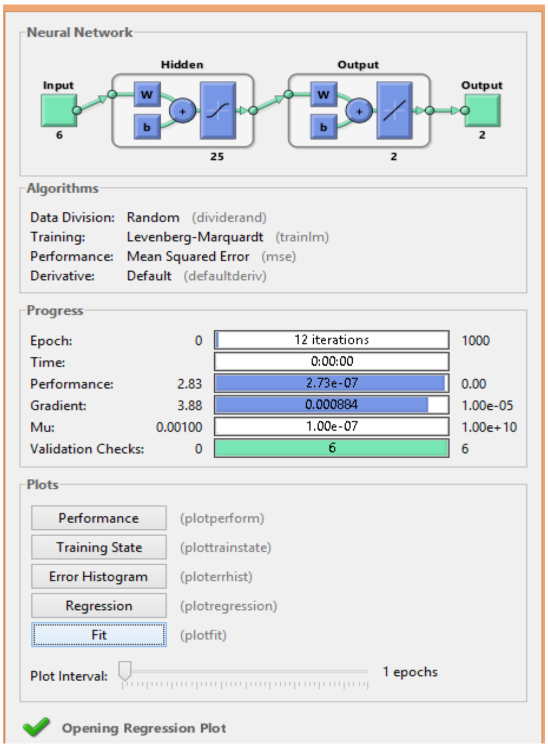


Figure 1.9 Neural Network architecture for pattern reorganization fitting tool



Data Division: Random (dividerand)
Training: Levenberg-Marquardt (trainlm)
Performance: Mean Squared Error (mse)
Derivative: Default (defaultderiv)

Epoch: 0 | 12 iterations | 1000
Time: 0:00:00
Performance: 2.83 | 2.73e-07 | 0.00
Gradient: 3.88 | 0.000884 | 1.00e-05
Mu: 0.00100 | 1.00e-07 | 1.00e+10
Validation Checks: 0 | 6 | 6

Plot Interval: 1 epochs

Opening Regression Plot

Fig. 1.10 ANN training

The fitting tool uses Levenberg-Marquardt algorithm for training the system. This algorithm is fast in nature gives the result in less time. Figure 1.10 shows its training details

Figure 1.11 shows the regression curve

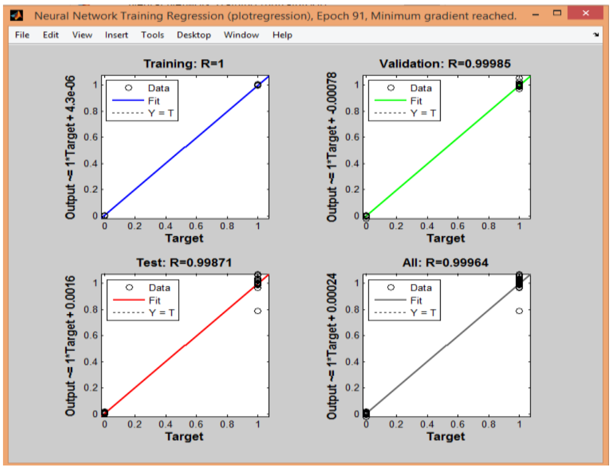


Fig. 1.11 ANN Regression curve

The comparative results show the actual condition of fault values either 0 or 1 and artificial neural network detection in every condition. Here we chooses eight samples for each type of fault to locate here while during training and input feeding we select 50 samples of each conditions

Table 1.1 Comparative Result of DC Fault

Sample no	DC Fault	BP ANN using Fitting Tool detection	Error in %	BP ANN using Pattern Tool detection	Error in %
1	0	0.01712	-0.01712	0.00013	-0.00013
2	0	0.00474	-0.00474	0.00012	-0.00012
3	0	0.00696	-0.00696	0.00011	-0.00011
4	0	0.00914	-0.00914	0.00011	-0.00011
5	1	0.91702	0.08298	0.99971	0.00029
6	1	0.93306	0.06694	0.99971	0.00029
7	1	0.94306	0.05694	0.99972	0.00028
8	1	0.95809	0.04191	0.99972	0.00028

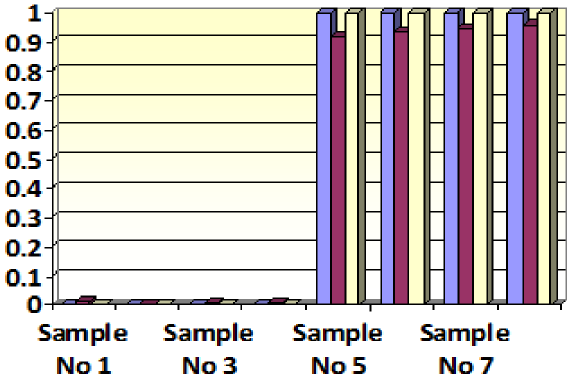


Fig. 1.12 Comparative chart of DC Fault

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Table 1.2 Comparative Result of AC Fault

Sample no	AC Fault	BP ANN using Fitting Tool detection	Error in %	BP ANN using Pattern Tool detection	Error in %
1	0	**0.00346**	-0.00034	0.00098	-0.00098
2	0	**0.00581**	-0.00581	0.00058	-0.00058
3	0	**0.00841**	-0.00841	0.00042	-0.00042
4	0	**0.00918**	-0.00918	0.00034	-0.00034
5	1	**0.99804**	0.00196	0.99873	0.00127
6	1	**1.09882**	-0.09882	0.9987	0.0013
7	1	**0.99513**	0.088484	0.99973	0.00027
8	1	**1.22757**	-0.22757	0.99845	0.00155

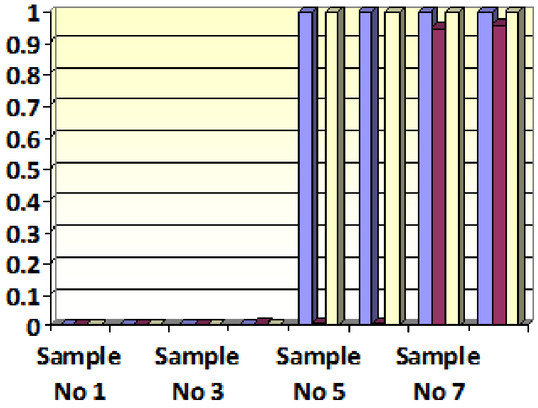

Fig. 1.13 Comparative chart of AC Fault

Table 1.3 Comparative Result of DC & AC Fault

Samp. no	DC Fault	AC Fault	BP ANN using Fitting Tool detection		Error in %		BP ANN using Pattern Tool detection		Error in %	
			AC	DC	AC	DC	AC	DC	AC	DC
1	1	1	1.003	0.96541	-0.003	0.03459	0.99999	0.99994	0.00001	0.00001
2	1	1	0.98708	0.99339	0.01292	0.00661	0.99996	0.99999	0.00001	0.00001
3	1	1	1.00316	0.96258	-0.00316	0.03742	0.99999	0.99993	0.00001	0.00001
4	1	1	0.98860	0.99341	0.0114	0.00659	0.99996	0.99999	0.00001	0.00001
5	1	1	1.00347	0.96007	-0.00347	0.038993	0.99989	0.99992	0.00001	0.00001
6	1	1	0.99044	0.99164	0.00956	0.00836	0.99994	0.99999	0.00001	0.00001
7	1	1	1.00383	0.95660	-0.00383	0.0434	0.99988	0.99991	0.00001	0.00001
8	1	1	0.99240	0.99145	0.0076	0.00855	0.99992	0.99999	0.00001	0.00001

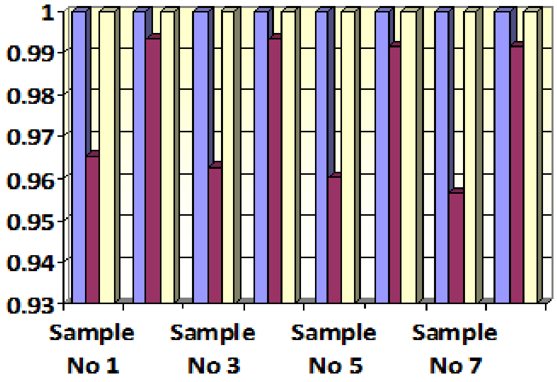

Fig. 1.14Comparative chart of DC & AC Fault

VI. CONCLUSION

The paper tries here to present the fult classification and detection for HVDC system using ANN. The HVDC model is presented here for the condition monitoring of overall system either it is AC or DC and artificial neural network is a modern technique which is capable to give fast and accurate results; the need of present time so the selected algorithm gives batter result for condition monitoring of HVDC system. Following conclusion are drawn from the presented work:

1. Two different grids are selected for the tie up of HVDC transmission system.
2. The grid configuration for first grid is 5000MVA, 500KV, 60Hz
3. The grid configuration for second grid is 10000MVA, 345KV, 50Hz
4. There are four conditions are choses here for HVDC system simulation healthy system, DC fault, AC fault, AC & DC both type of fault.
5. For each type of fault 50 samples are used for training and testing ANN.
6. For validation there are 8 samples are selected for each case
7. In each case no fault and faulty conditions both were validated through ANN techniques using pattern recognition and fitting tool
8. In both training algorithms results gave error less than 1%

Fitting tool is very fast in computation while pattern recognition is more accurate in result but its speed is comparatively slow and require more iterations

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