Identification and Classification of Faults in HVDC System using Wavelet Transform and Artificial Neural Network

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Abstract:

Over the years, the HVDC system has become virtually mature, but there are still some protective issues to be addressed, such as the circuit breaker (CB) being selective not to travel if the transient is temporary, such as overcurrent due to load change. This paper is based on the measuring the DC line current (Idc) signal. Then that measured signal is preprocessed to remove the noise and Creates number of frames of the measured current signal by the window method. The values of currents are measured and modified accordingly and are ultimately fed into the wavelet transform as inputs. Then wavelet transform can decompose that current signal into approximation and detail coefficients up to level10.

Keywords: HVDC, Circuit Breaker (CB), DC Line Current (Idc) Signal, Wavelet Transform, Window Method.

1. Introduction

Electrical energy transmission and distribution began with direct current in 1882, a 50-km-long 2-kV DC transmission line was constructed in Germany between Miesbach and Munich. Conversion between sensible customer voltages and higher DC transmission voltages could only be accomplished by rotating DC machines at that moment. Conversion of voltage in an AC scheme is easy. An AC transformer enables elevated concentrations of energy and elevated concentrations of insulation within one unit, with small losses. It is a tool that is comparatively easy, requiring little maintenance. In addition, in all respects, a synchronous three-phase generator is superior to a DC generator. For these reasons, in developing electrical power systems, AC technology was implemented at a very early point [8]. For the lengthy transmission of high-voltage electricity, direct present (HVDC) is the best choice for it throughout the globe. It is also known as an electric superhighway or superhighway. It will provide various characteristics such as power flow control, economy while transmitting bulk energy over very lengthy distances, reduced transmission losses and lack of stability problems. All of these benefits make the HVDC system more appealing than the HVAC system. For the secure and optimal operation of energy systems, the fast-acting HVDC systems in AC energy systems can quickly detect fault. To make the right protective control choices, it is very essential to identify precise and quick classification of the fault [9,10]. This paper provides identification and classification of different faults on HVDC transmission line using WT and ANN.

2. Literature Survey

One of the main components of the energy scheme is the HVDC transmission lines. Due to the smallest loss of transmission between grids, this line is of great significance. Due to the introduction of DC Micro grids, in which DC supply is the energy for consumer loca tions, the HVDC transmission line is also relevant. Mathematical morphology is a kind of nonlinear technique of assessment that has an benefit in the filter and signal detection abrupt shift point [1]. ZHANG Jie et al. [2] recommends a rapid Bob mathematical morphology detection technique, using a multi-resolution morphological gradient for fault transient voltage traveling wave, and a range measurement method for fault line identification is proposed. Hilbert Huang transform is a fresh technique of signal processing that has a clear physical importance in handling nonlinear and non-stationary signals. The literature [3] by Hilbert Huang's algorithm detects the Bob and then calculates the distance of the fault. The literature [4] demonstrates that, according to the signal itself, Hilbert Huang can adapt the decomposition in the time domain.

Rommel Aguilar et al. [5] present a method of orthogonal decomposition comparable to a discrete transformation of Fourier. This technique is used to obtain the data produced after a fault from the present transient signals. A set of EOFs are applied to fault data and are intended to obtain appropriate information from the fault current signals in the first milliseconds. The technique suggested by Zhixiong Li et al [6] is that it presented the ICA-wavelet properly to perform precise extraction of fault features and real engineering information. The Guangzhou HVDC system was used to check the system's efficiency. This system uses Wavelet-base to introduce independent component analysis (ICA) feature extraction and a neural network fault classifier. Liu Yue[7] has high voltage direct current (HVDC) detection of ground fault location transmission line. The method of error location based on the algorithm of fast independent component analysis (Fast ICA). The FastICA is used in this proposed system to isolate traveling wave fault voltage feature signals from direct current transmission line voltage signals from multi-channel high voltage. The first and second traveling wave heads are acknowledged at the measuring stage, as is the polarity of the two wave heads.

3. HVDC System

We understand that the generating station generates AC power. This should be transformed to DC first. Using the rectifier, the conversion is performed. The DC energy is going to flow through the overhead lines. This DC must be converted into AC at the end of the user. An inverter is put at the receiving end for this purpose [10]. The Power devices with high voltage direct present (HVDC) use D.C. for transmission over lengthy distances of bulk energy. HVDC lines are less costly for long-distance power transmission, and losses are lower compared to AC transmission. It interconnects networks with distinct frequencies and features [11]. Figure a shows the parts of HVDC system and functions of the HVDC Transmission System are; Converters: The conversion of AC to DC and DC to AC is performed by the converters. It involves bridges for transformers and valves, Smoothing Reactors: Each pole is made up of smoothing reactors made up of inductors linked to the pole in sequence. It is used to prevent inverter switching failures, to reduce harmonics and to avoid discontinuation of current for loads, Electrodes: in fact, they are conductors used to link the system to the earth, Harmonic Filters: Used to minimize the harmonics of the converters used in voltage and current, DC Lines: Cables or overhead lines can be used. Reactive energy supplies: more than 50% of the total transferred active energy could be the reactive power used by the converters. The shunt condensers therefore provide this reactive power AC Circuit Breakers: The circuit breakers clear the fault in the transformer. It also disconnected the DC connection [10].

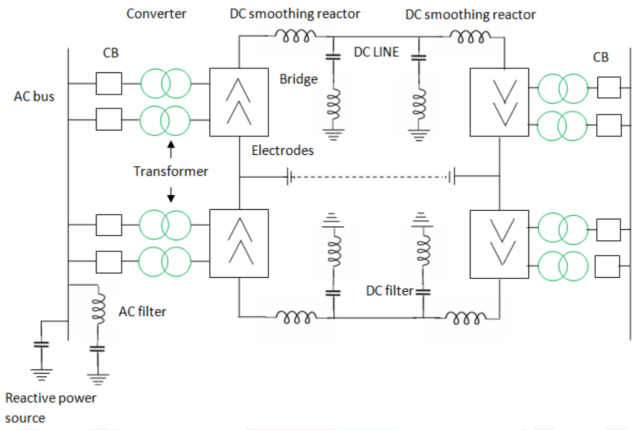


Figure 1 HVDC Components [10]

4. Fault Case Study

a) L-G Fault

Now we can detect the occurrence of a fault on a transmission line and also classify the fault into the various fault categories. Three possible single line – ground faults exist (A-G, B-G, C-G), corresponding to each of the three phases (A, B or C) with the ground being faulted.

AG at rectifier side

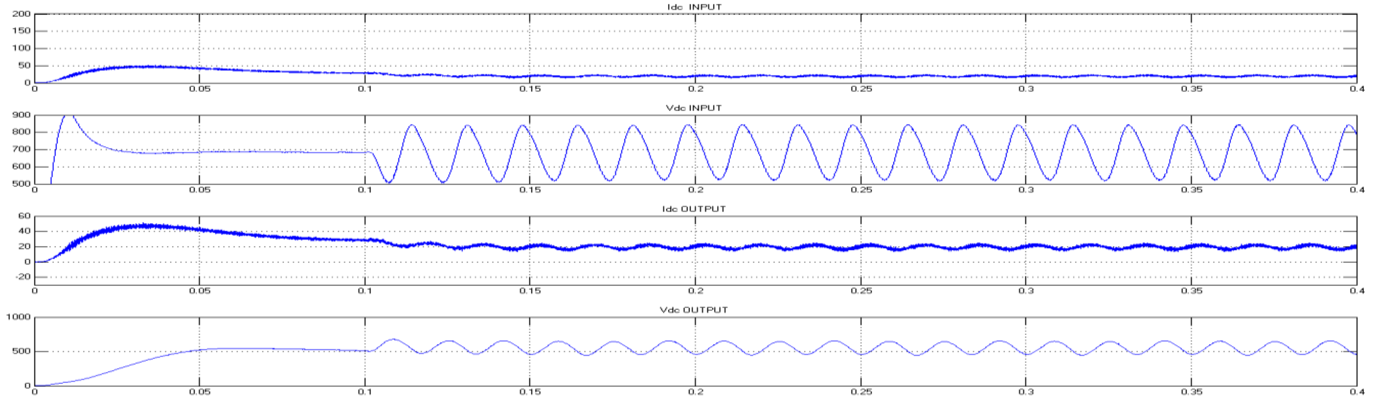
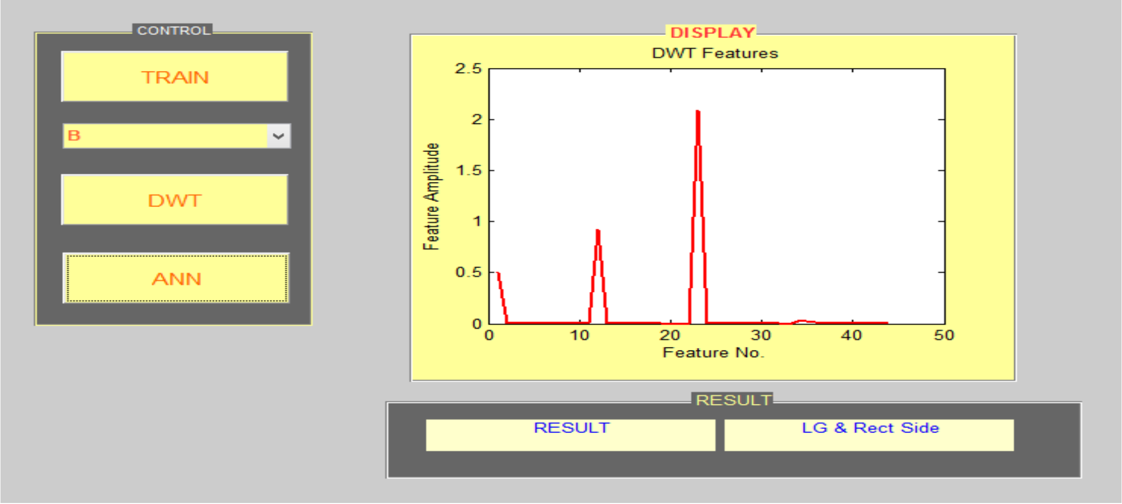


Figure 2 DC Current and Voltage in line for AG at rectifier side between 0.1-0.4 sec.



RESULT LG & Rect Side

Figure 3 DWT Features for AG at rectifier side and Their Result

BG at inverter side

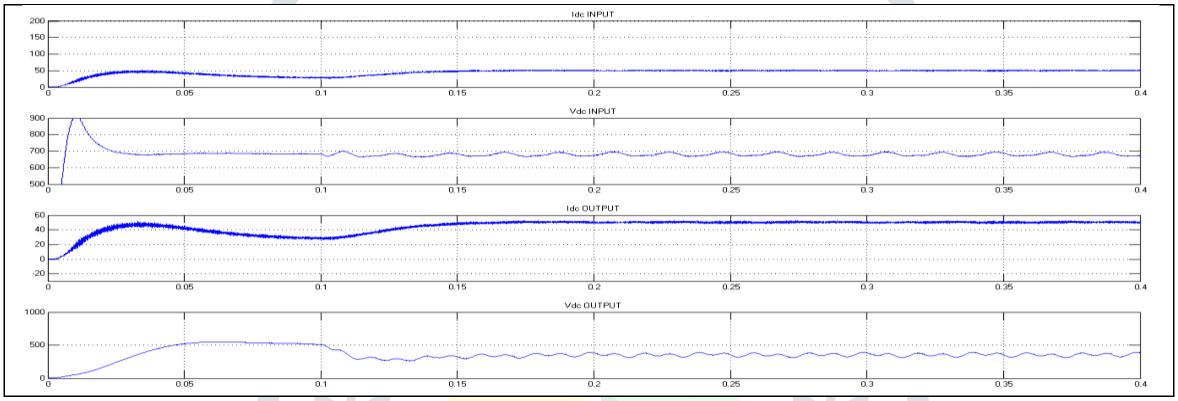
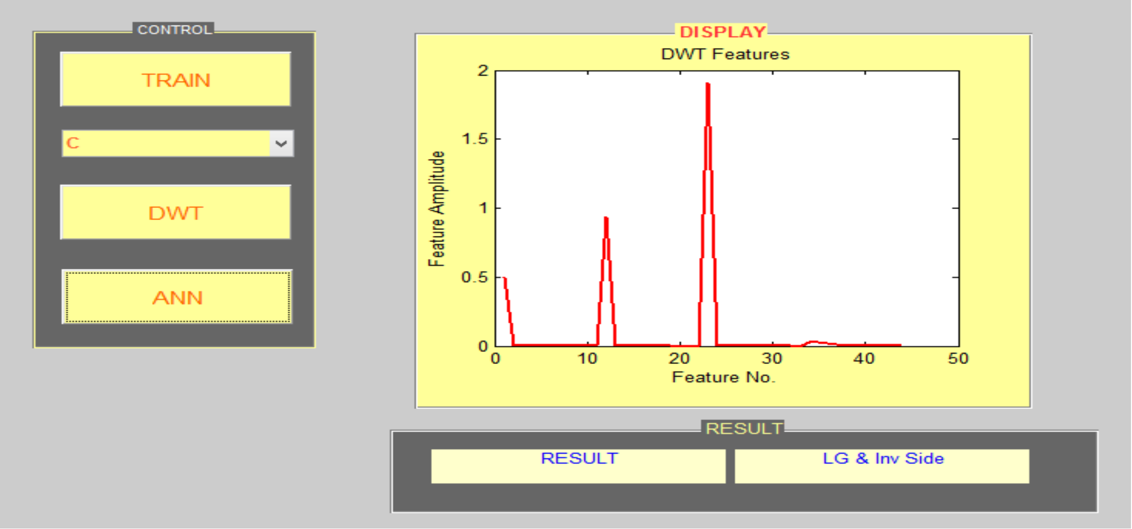


Figure 4 DC Current and Voltage in line for BG at inverter side between 0.1-0.4 sec.



RESULT LG & Inv Side

Figure 5 DWT Features for BG at inverter side and Their Result

CG at rectifier side

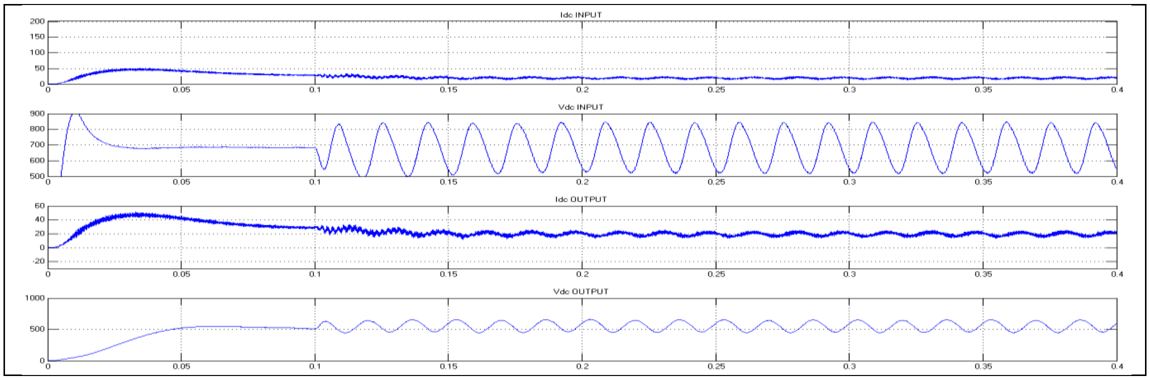
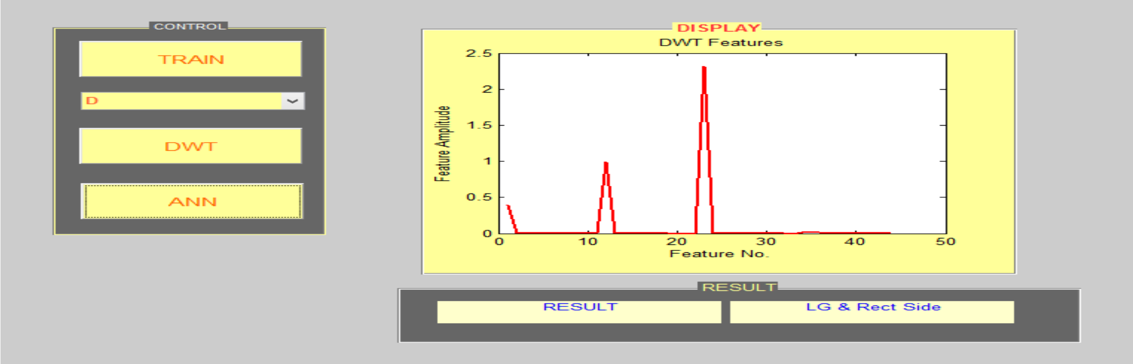


Figure 6 DC Current and Voltage in line for CG at rectifier side between 0.1-0.4 sec.



RESULT LG & Rect Side

Figure 7 DWT Features for CG at rectifier side and Their Result

- **LL-G Fault**

Now we can detect the occurrence of a fault on a transmission line and also classify the fault into the various fault categories. Three possible Double line – ground faults exist (AB-G, BC-G, AC-G), corresponding to any two phases (A, B or C) with the ground being faulted.

ABG at rectifier side

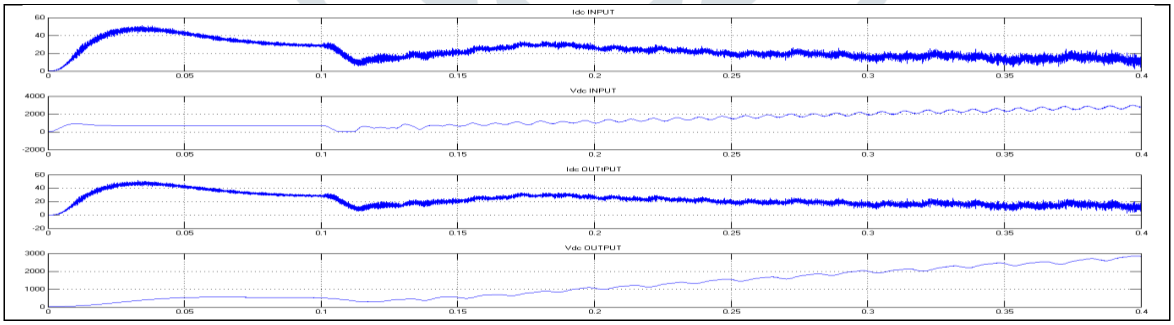
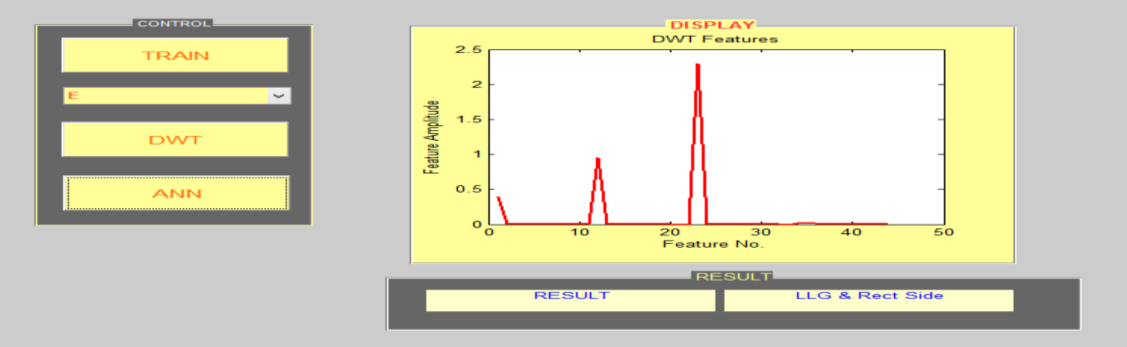


Figure 8 DC Current and Voltage in line for ABG at rectifier side between 0.1-0.4 sec.



RESULT: LLG & Rect Side

Figure 9 DWT Features for ABG at rectifier side and Their Result

BCG at inverter side

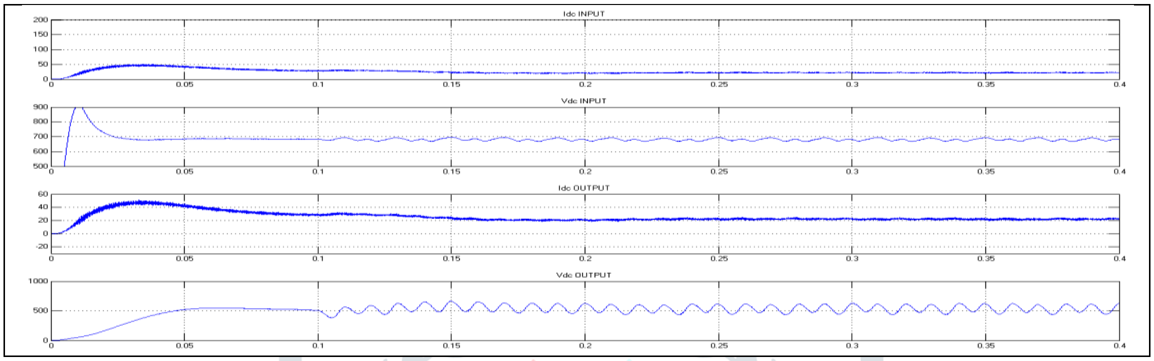
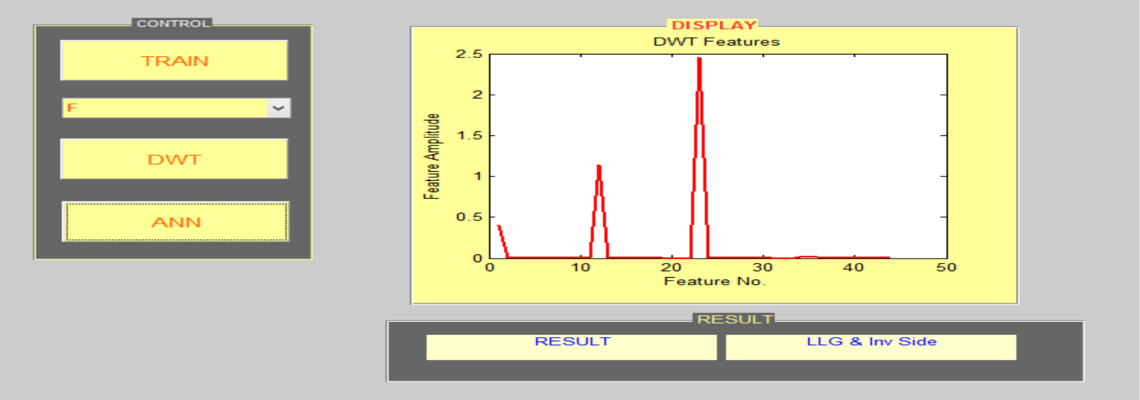


Figure 10 DC Current and Voltage in line for BCG at inverter side between 0.1-0.4 sec.



RESULT: LLG & Inv Side

Figure 11 DWT Features for BCG at inverter side and Their Result

ACG at rectifier side

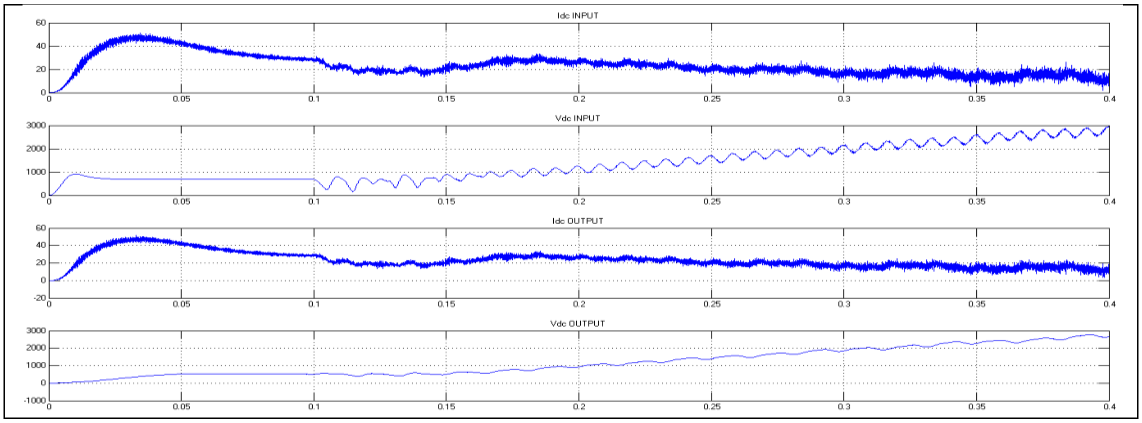


Figure 12 DC Current and Voltage in line for ACG at rectifier side between 0.1-0.4 sec.

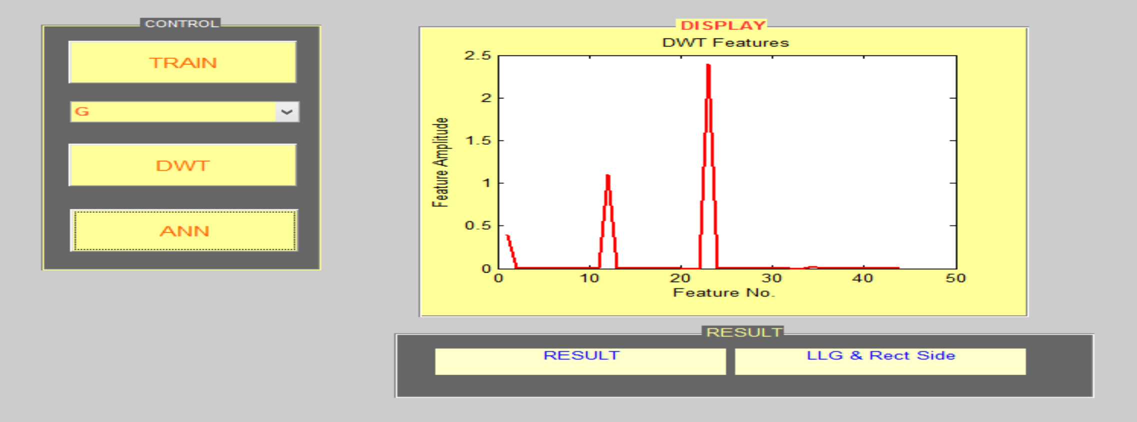


Figure 12DWT Features for ACG at rectifier side and Their Result

5. Simulation Results for Fault Classification

In this section, the HVDC system model has been simulated for various operating conditions such as DC line faults, AC faults on the rectifier and inverter side and normal operating condition as a reference case for the fault classification by creating faults in HVDC system at AC side as well as DC line faults for the duration of 0.1-0.4 sec. The proposed HVDC Fault Classification scheme is based on the measuring the DC line current (I_{dc}) signal. Then that measured signal is preprocessed to remove the noise and Creates number of frames of the measured current signal by the window method. The values of currents are measured and modified accordingly and are ultimately fed into the wavelet transform as inputs. Then wavelet transform can decompose that current signal into approximation and detail coefficients up to level10 that means we get 10 detail Coefficients and one approximation Coefficient. After that DWT can calculates the features by using db4 mother wavelet. Here four features can be calculated such as wavelet energy, variance and waveform length, entropy.So we get 44 values of coefficients for 13 different conditions including normal condition, 11 values of coefficients for wavelet energy, 11 values of coefficients for variance, 11 values of coefficients for waveform length, 11 values of coefficients for wavelet entropy. Then these calculated features can be given to the ANN as a input for the fault classification. The following table 1 shows the DWT features for various conditions of fault classification and figure 2 shows their comparison.

Table 1 DWT features for various conditions of fault classification

Condition	Normal	AG	BG	CG	ABG	BCG	ACG	AB	BC	AC	PG	PP	PPG
Wavelet Energy	5E-02	5E-02	5E-02	5E-02	5E-02	5E-02	5E-02	5E-02	5E-02	5E-02	5E-02	5E-02	5E-02
Variance	1E-01	9E-02	1E-01	9E-02	9E-02	1E-01	1E-01	5E-02	7E-02	6E-02	5E-02	3E-02	3E-02
Waveform Length	2E-01	2E-01	2E-01	2E-01	2E-01	2E-01	2E-01	1E-01	2E-01	2E-01	4E-01	4E-01	4E-01
Wavelet Entropy	8E-03	6E-03	7E-03	6E-03	6E-03	6E-03	5E-03	5E-03	6E-03	5E-03	4E-03	4E-03	4E-03

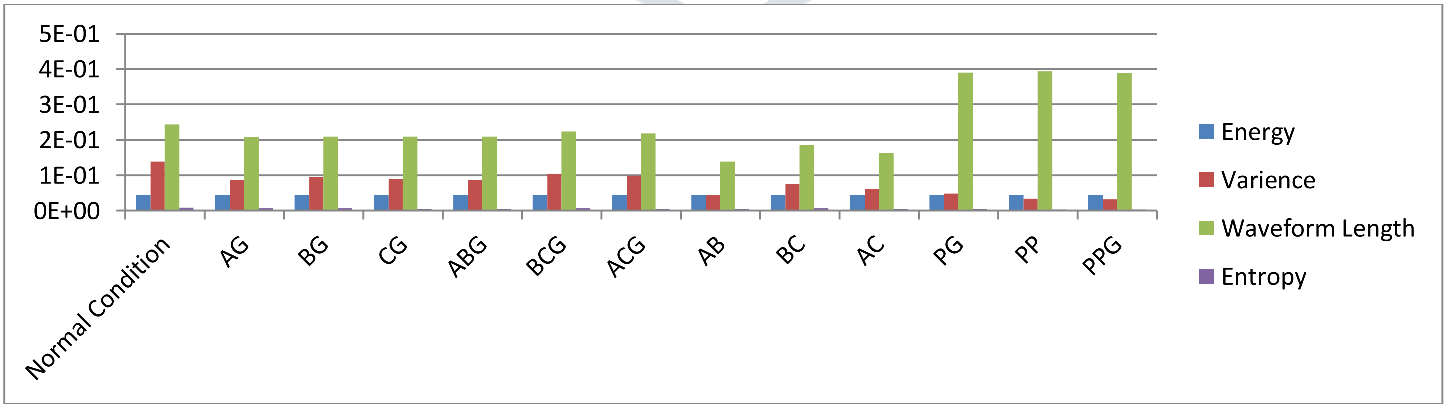


Figure 2 Comparative Analysis of DWT Features for Fault Classification

6. Conclusion

In this paper, a HVDC model is proposed for the analysis of various operating conditions. The faults generally occurred on the transmission line such as AC faults on the rectifier side and inverter side, the DC line fault on the transmission line at various distances have been analyzed using Artificial Neural Networks (ANN) and Wavelet Transforms(WT). Wavelet Transform is used to extract distinctive features from the measured current signals. The proposed scheme allows the protection engineers to increase the reach setting i.e. a greater portion of line length can be protected as compared to earlier techniques.

During the normal operating condition of the HVDC system, it will transmit power satisfactorily with both the voltage and currents observed to be at 1 p.u. During DC line faults, the line voltage at the rectifier is oscillating till the fault has been cleared. However the DC line current rises to 2 p.u. in 0.01sec. The system starts recovering after the clearance of the fault. During the AC faults on the AC side of the rectifier the DC line voltage is positive and is oscillating between 2p.u. and 0 p.u. The AC voltage on the inverter side has no significant impact due to this fault. However the currents on the AC side are almost zero at the time of fault.

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