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Selection of Optimal Mother Wavelet for Transmission Line Protection

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***Abstract*— The current and voltage signals of the system experience transients when faults in transmission lines occur. Wavelet analysis can be used to analyse these transients in order to locate, classify, and detect faults. In this study, travelling wave theory is used to locate the line's flaw. In order to determine the best mother wavelet for transmission line protection, this study also compares four distinct mother wavelets, including the Daubechies, Haar, Symlet, and biorthogonal wavelets. The outcome suggests that the suggested method is very straightforward, quickly detects defects, and is also able to classify faults and properly pinpoint the fault's location.**

***Index Terms*—Biorthogonal wavelet, Daubechies wavelet, Maximum norm value, Mother wavelet, Travelling wave theory, Threshold detail coefficient.**

I. INTRODUCTION

An electric power system comprises of three components, namely generation, transmission and distribution. Among these components, transmission line protection is an important task in safeguarding the power system. To deliver electricity to the users, these transmission lines cover hundreds of kilometers. Due to their exposure to the environment, there is a very high likelihood that a transmission line accident may develop. In an electric power system, the fault is any abnormal flow of electric current. Unbalanced and balanced faults are the two basic categories for transmission line faults.

The most prevalent of these faults, single-phase to ground problems, are caused by lightning strikes, tree collisions with power lines, mechanical failure of the insulator string due to fog, salt spray, and snow loading, and lightning strikes. The three-phase fault is most severe whereas single phase to ground fault is least severe. Faults may also occur due to natural reasons which are beyond the control of mankind. Various methods have been employed for fault detection and classification. Few of the techniques are Wavelet Transform [1], Fuzzy Logic [2], Artificial Neural Network (ANN)[3], Support Vector Machines (SVM) [4], [5]. Combined techniques have already been used, such as WT with ANN [6], [7], WT with Fuzzy [8]. Though the popularity of ANN, it has been widely criticized because it requires a considerable amount of training [9]. Techniques such ANN, and Fuzzy logic are dependent on training for knowledge representation based on a large sample, leading to large computational time [10].

The wavelet transforms based approaches have been quite successful in detection of fault with classification due to its ability to express a faulted signal both in time and frequency. The Continuous Wavelet Transform (CWT) is more complicated to implement because the information of interest is frequently a combination of features that are well localised temporally or spatially, and the CWT is calculated by varying the size of the analysis window, moving the window in time, and multiplying the signal.

This necessitates the employment of analytical techniques that are sufficiently flexible to handle signals in terms of their localization in time and frequency [11]. Proposed a transmission line protection using the DWT, [12] Describes that DWT based technique is an excellent online tool for relaying applications. [13], Selecting the optimum mother wavelet is the one main challenge in using wavelet transform, if different mother wavelets are applied to the matching signal, it may produce different results. According to [14], detecting power system transients was equally effective using the db4, coiflet, and b-spline.

The type of fault, the grounding resistance, the load circumstances, and system running away are all factors that are taken into consideration by existing methods for fault location, such as detecting changes in impedance or voltage and current of the line before and after a problem occurred. This paper represents the location of the fault method based on travelling wave theory. If a fault on line occurs, an unexpected change in voltage or in current at the fault point produces a high-frequency signal called a travelling wave [15].

This travelling wave moves away from the fault location along the line in both directions. Using the difference in the arrival times of a fault wave at two ends of a faulted line, the travelling wave fault location method can be used to determine the location of a fault. Although each study enhances the ability to identify, classify, and locate transmission line faults to some level, they all have disadvantages as well.

This paper evaluates four different mother wavelets: Daubechies (db6 & db4), Symlet 5, Bior 5.5 and Haar (db1) families in order to choose the most appropriate wavelet for fault detection, classification and location purpose. Decomposition on a single level is used because it contains the most information compared to decomposition on levels 2, 3, and so on. The more levels you go up, the more information you lose because each level's frequency component is halved. Computational time is decreased by using single level decomposition.

II. WAVELET TRANSFORM

A novel mathematical method called the Wavelet transform was created in 1980. Power system protection and power quality analysis are the two main applications of WT[16]. Excellent characteristics of wavelet transformations include their ability to create small waves that have finite energy and integrate to zero. Wavelet transform offers numerous basis functions that can be employed as the mother wavelet as opposed to Fourier analysis, which depends on a single basis function. The short time Fourier transform utilises a single fixed window, whereas the wavelet transform uses short windows at high frequencies and long windows at low frequencies. This is the main distinction between the two transforms.By using wavelet transform, non stationary signals, i.e., whose frequency response varies with time can be analysed, whereas Fourier transform is not suitable. Signals can be analysed using the wavelet transform concurrently in the time and frequency domains. There are several different mother wavelet types available for use in wavelet analysis. When multiple Mother wavelets are used to analyse the same signal, the outcomes will vary. Mother wavelets typically exhibit characteristics including orthogonality, compact support, symmetry, and vanishing moment. Properties of the mother wavelet are taken into account while choosing a mother wavelet based on earlier studies. However, it's common to find many mother wavelets with the same characteristics. To get around this, when choosing a mother wavelet, the similarity between the signal and the mother wavelet is taken into account. Discrete Wavelet Transform (DWT) and Continuous Wavelet Transform (CWT) are the two types of wavelet transform (DWT).

A. Discrete Wavelet Transform:

The DWT was founded in 1976 by Croiser, Esteben, and Galand, who created a method for breaking down discrete time signals [3]. In DWT, a digital filtering technique is used to generate a time-scale representation of a discrete signal. The signal that has to be analysed is run through a unique filter with a unique cutoff frequency at various scales. The discrete time-domain signal is successively low-pass and high-pass filtered before being used to calculate the DWT. In single level decomposition, the signal is decomposed as D1 and A1, with the frequency band of $f_s/2-f_s/4$, $0-f_s/4$. In the second level decomposition, the low pass filter, A1 is split into D2 and A2 as the frequency band D2 is $f_s/4-f_s/8$ and A2 is $0-f_s/8$. The wavelet coefficient energy can be calculated as shown below equation (1),

$$E_w = \sum_{k=1}^{N_w} [d_w(k)]^2 \tag{1}$$

Where, $d_w(k)$ is the wavelet coefficient of w^{th} window and N_w may be the window length which is calculated as, $N_w = N_s/2$, here N_s may be the samples of any number.

III. DESCRIPTION OF PROPOSED TRANSMISSION LINE FAULT ANALYSIS METHOD

The simulink's power block set was used to build a simulation model that generates the transient signals of three-phase current. To find, categorise, and identify the defect, a discrete wavelet transformation is used with single level decomposition for three-phase current signals.

A. Fault Detection Module

Three basic steps make up the application of the suggested method. The fault is first identified, then the fault is classified, and the fault's location is finally determined. The three phase current signals of the transmission line used in this suggested system are accepted as input, decomposed using the discrete wavelet transform, and compressed using the remove near zero approach to provide the maximum norm value and threshold detail coefficient values. The maximum norm value is used for fault detection and threshold detail coefficient is used for classification purposes. In this paper, different mother wavelet such as d6, db4, haar (db1), sym 5, bior 5.5 is used in order to select the optimal wavelet for transmission line protection. Maximum norm values are calculated for all different types of fault using the wavelet tool box. The highest acceptable standard value for a normal state is used as a benchmark when comparing it to an aberrant one. A problem is identified if the signal's maximum norm value exceeds the value for a normal state. The norm of detail coefficient (d_1) can be calculated as,

$$d_1 = [\sum_{k=1}^{nd} d_1(k)]^{1/2} \tag{2}$$

Where nd may be the No. of detail coefficient.

B. Fault Classification Module

For fault classification purpose, the threshold detail coefficient values are considered. A phase's threshold value will be higher than its typical condition value in the event of a single phase to ground (A-G) fault, but the other two phases are unaffected (remains same). When there is a double phase (AB) fault, the threshold values for phases A and B will be equal but higher than they would be under normal circumstances. Phases A and B's threshold values will not be equal in value, but rather higher than those for a normal situation in the case of a double phase to ground fault (AB-G) scenario. A threshold value for each phase will be greater than the value for each phase's normal state in the case of a three phase fault (ABC).

C. Fault Location module

The algorithm for fault location is performed after the completion of fault detection and classification process. In this process, different fault current signal are taken which are obtained from a simulated power system model, and it is transformed into the modal signal using Clarke modal transformation. Then these modal signals are decomposed using DWT with different mother wavelet such as d6, db4, haar (db1), sym 5, bior 5.5 in order to choose the ideal wavelet. After the decomposition, the peak magnitude of current signal at the lowest scale of the detail coefficient is used to determine the location of the fault. The location of fault is calculated by formula,

$$x = v(t_a - t_b)/2 \tag{3}$$

Where t_a and t_b are corresponding to the time at which the modal signal wavelet coefficient at lowest scale, show their peak values. If the spread value of the signal is identified, then the gap of the fault is easily found. Wave propagation speed is influenced by line parameter values like inductance (L) and capacitance (C). Where $v = 1/\sqrt{LC}$ is the velocity of propagation.

IV. RESULTS AND DISCUSSIONS

The suggested algorithm has been tested for all types of Single Phase to Ground Faults, but only Phase A to Ground is shown here. It has also been tested for all types of Double Phase Faults, with or without ground, but only Double Phase AB and Double Phase AB-G are shown here.

A. Description of Line Diagram of Test System

The system under study consists of a 220 KV transmission circuit with sections measuring 200 km for section 1, 120 km for section 2, and 110 km for section 3. These sections are connected to sources at both ends. The power system model developed in power system is given in Fig. **1**.

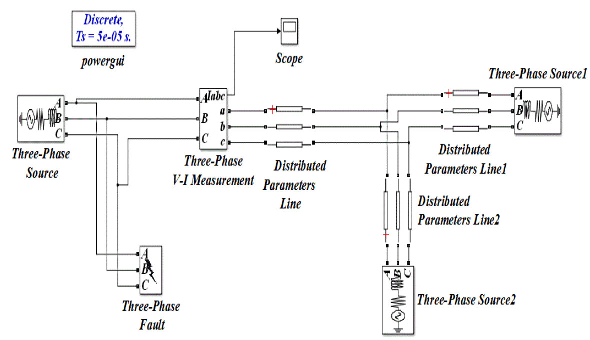

Fig. 1. Simulated Power System Model.

The corresponding Thevenin sources on either side of the line are estimated to have a short circuit capacity of 1.25 GVA and an X/R ratio of 10. Table 1 displays the transmission line parameters for the test system.

TABLE I
TEST SYSTEM TRANSMISSION LINE PARAMETERS

Positive sequence resistance R1, Ω/km	0.018
Zero sequence resistance R0, Ω/km	0.218
Positive sequence Inductance L1, H/km	0.000929
Zero sequence Inductance L0, H/km	0.00328
Positive sequence Capacitance C1, F/km	1.2571e-008
Zero sequence Capacitance C0, F/km	7.8555e-009

B. Performance of the Programmed Fault Signals

1) Normal Condition

Fig. 2 displays the three-phase current signal under ideal conditions. Here, using DWT and various mother wavelet types, including db6, db4, haar (db1), sym 5, and bior 5.5, the maximum norm value and threshold detail coefficient values are determined for this circumstance. Maximum norm and threshold detail coefficient of three phases at normal condition using db6, db4, haar (db1), sym 5, bior 5.5 wavelet are shown in Table 2, 3, 4, 5 & 6. These calculated values are taken as reference for further detection and classification purposes.

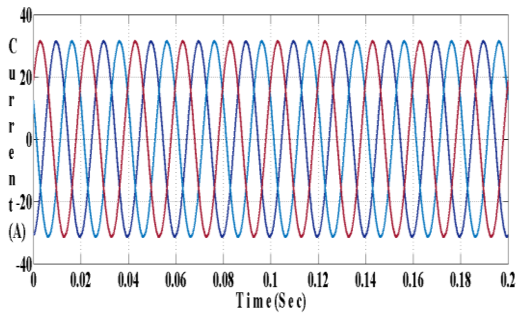

Fig. 2. Simulated Result for Normal Condition.

TABLE II
MAXIMUM NORM AND THRESHOLD DETAIL COEFFICIENT OF THREE PHASE AT NORMAL CONDITION USING DB6 WAVELET.

Parameter	Phase A	Phase B	Phase C
Max Norm	0.0102	0.0844	0.0741
Threshold	0.0134	0.1109	0.0974

TABLE III
MAXIMUM NORM AND THRESHOLD DETAIL COEFFICIENT OF THREE PHASE AT NORMAL CONDITION USING DB4

Parameter	Phase A	Phase B	Phase C
Max Norm	0.0135	0.0985	0.0849
Threshold	0.0225	0.1643	0.1417

TABLE IV
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT NORMAL CONDITION USING HAAR.

Parameter	Phase A	Phase B	Phase C
Max Norm	0.2458	0.1719	0.1724
Threshold	0.1738	0.2432	0.2439

TABLE V
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT NORMAL CONDITION USING SYMLET 5.

Parameter	Phase A	Phase B	Phase C
Max Norm	0.0118	0.0978	0.0859
Threshold	0.0164	0.1354	0.1190

2) Single Phase to Ground

The three current signals of phase A to Ground fault are given in Fig. 3. Maximum norm and threshold detail coefficient of 3 phases of single phase to ground fault condition using db6, db4, haar (db1), sym 5, bior 5.5 wavelet are shown in Tables 7, 8, 9, 10, 11. Each phase maximum norm value and threshold detail coefficient value of A-G fault is compared with the normal condition value.

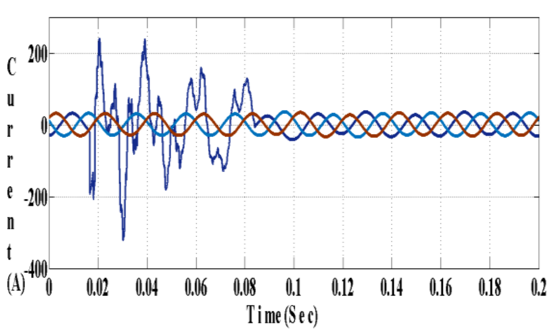

Fig. 3. Simulated Result for Phase A to Ground Fault.

TABLE VII
MAXIMUM NORM AND THRESHOLD DETAIL COEFFICIENT OF THREE PHASE AT SINGLE PHASE TO GROUND FAULT USING DB6 WAVELET.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase A-G	Max Norm	0.2941	0.0844	0.0741
	Threshold	0.3073	0.1109	0.0974
Phase B-G	Max Norm	0.0102	0.2683	0.0741
	Threshold	0.0134	0.3047	0.0974
Phase C-G	Max Norm	0.0102	0.0844	0.3142
	Threshold	0.0134	0.1109	0.3095

TABLE VIII
MAXIMUM NORM AND THRESHOLD DETAIL COEFFICIENT OF THREE PHASES AT SINGLE PHASE TO GROUND FAULT USING DB4.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase A-G	Max Norm	0.2902	0.0988	0.0846
	Threshold	0.3100	0.1648	0.1412
Phase B-G	Max Norm	0.0145	0.2245	0.0860
	Threshold	0.0243	0.2903	0.1435
Phase C-G	Max Norm	0.0130	0.0989	0.2707
	Threshold	0.0218	0.1651	0.3122

TABLE IX
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT SINGLE PHASE TO GROUND FAULT USING HAAR.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase A-G	Max Norm	0.2198	0.1722	0.1707
	Threshold	0.3108	0.2435	0.2414
Phase B-G	Max Norm	0.1710	0.2128	0.1710
	Threshold	0.2418	0.3010	0.2419
Phase C-G	Max Norm	0.1715	0.1707	0.2203
	Threshold	0.2426	0.2414	0.3115

TABLE X
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT SINGLE PHASE TO GROUND FAULT USING SYMLET 5.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase A-G	Max Norm	0.2333	0.0978	0.0859
	Threshold	0.3061	0.1354	0.1190
Phase B-G	Max norm	0.0118	0.2552	0.0859
	Threshold	0.0164	0.2963	0.1190
Phase C-G	Max Norm	0.0118	0.0978	0.2688
	Threshold	0.0164	0.1354	0.3105

TABLE XI
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT SINGLE PHASE TO GROUND USING BIOR 5.5

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase A-G	Max Norm	0.2329	0.0794	0.0691
	Threshold	0.3091	0.0973	0.0847

Phase B-G	Max Norm	0.0117	0.2459	0.0691
	Threshold	0.0143	0.2986	0.0847
Phase C-G	Max Norm	0.0105	0.0795	0.2403
	Threshold	0.0128	0.0975	0.3124

If the maximum norm value exceeds a usual situation value means, a fault is noticed. From the below tables it is clear that under the A-G Fault condition, maximum norm value of phase A is greater than the normal condition value, so it is detected as phase A is faulted. Similarly, a threshold value of phase A is greater than the normal condition value of phase A and the other two phase values are equal to the normal condition values. This indicates that phase A to Ground fault is detected.

3) Double Phase Fault

The three-phase current of phase A-B fault are shown in Fig. 4.

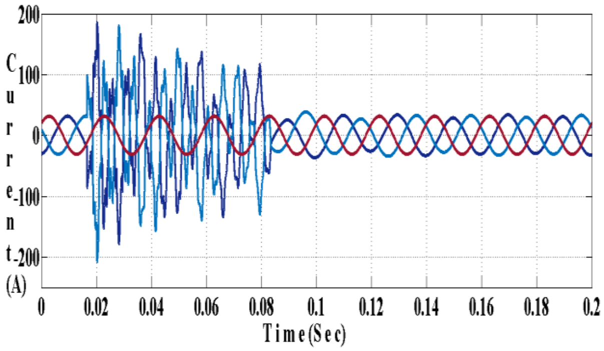

Fig. 4. Simulated Result for Phase A to B Fault.

Maximum norm and threshold detail coefficient of three phases of double phase fault condition using db6, db4, haar (db1), sym 5, bior 5.5 wavelet are shown in Table 12,13,14, 15,16. Maximum norm value and threshold values of each phase under AB fault are compared with normal condition values. From the below tables it is clear that the maximum norm value of A and B phase is greater than normal situation values of phase A and B, this indicates that phase A and B is affected. Similarly, a threshold value of phase A and B are same in value, but greater than the normal condition value of phase A and B. This indicates that phase AB is not connected to Ground.

TABLE XII
MAXIMUM NORM AND THRESHOLD DETAIL COEFFICIENT OF THREE PHASE AT DOUBLE PHASE FAULT USING DB6 WAVELET.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase AB	Max Norm	0.3509	0.3059	0.0741
	Threshold	0.3167	0.3167	0.0974
Phase BC	Max Norm	0.0102	0.3046	0.3046
	Threshold	0.0134	0.3157	0.3157
Phase AC	Max Norm	0.2876	0.0844	0.2876
	Threshold	0.3179	0.1109	0.3179

TABLE XIII
MAXIMUM NORM AND THRESHOLD DETAIL COEFFICIENT OF THREE PHASES AT DOUBLE PHASE FAULT USING DB4.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase AB	Max Norm	0.2289	0.2289	0.0849
	Threshold	0.3119	0.3119	0.1417
Phase BC	Max Norm	0.0135	0.2848	0.2848
	Threshold	0.0225	0.3147	0.3117
Phase AC	Max Norm	0.2608	0.0985	0.2608
	Threshold	0.3195	0.1643	0.3156

TABLE XIV
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT DOUBLE PHASE FAULT USING HAAR.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase AB	Max Norm	0.2212	0.2202	0.1706
	Threshold	0.3128	0.3114	0.2441
Phase BC	Max Norm	0.1738	0.2230	0.2224
	Threshold	0.2458	0.3154	0.3145
Phase AC	Max Norm	0.2257	0.1719	0.2238
	Threshold	0.3191	0.2432	0.3166

TABLE XV
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT DOUBLE PHASE FAULT USING SYMLET 5.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase AB	Max Norm	0.2561	0.2561	0.0859
	Threshold	0.3197	0.3034	0.1190
Phase BC	Max Norm	0.0118	0.2729	0.2729
	Threshold	0.0164	0.3157	0.3146
Phase AC	Max Norm	0.2288	0.0978	0.2288
	Threshold	0.3233	0.1354	0.3233

TABLE XVI
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT DOUBLE PHASE USING BIOR 5.5

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase AB	Max Norm	0.2480	0.2480	0.0691
	Threshold	0.3104	0.3104	0.0847
Phase BC	Max Norm	0.0108	0.2314	0.2314
	Threshold	0.0133	0.3144	0.3144
Phase AC	Max Norm	0.2458	0.0792	0.2458
	Threshold	0.3207	0.0970	0.3162

4) Double Phase to Ground

The three phase current signals of phase AB to Ground fault are shown in Fig. 5.

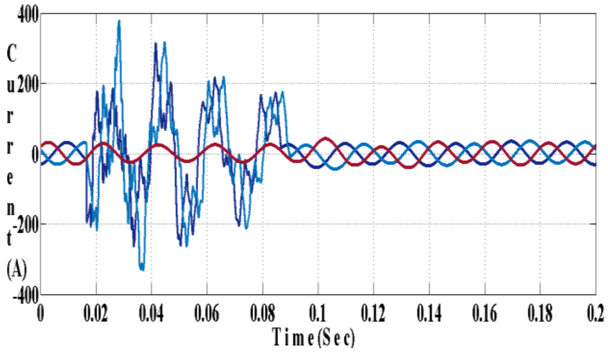

Fig. 5. Simulated Result for Phase AB to Ground Fault.

Maximum norm and threshold detail coefficient of three phases at phase AB to ground fault condition using db6, db4, haar (db1), sym 5, bior 5.5 wavelet are shown in Table 17, Table 18, Table 19, Table 20, Table 21. Maximum norm value and threshold values of each phase under AB to Ground fault are compared with normal condition values. From the below tables it is clear that the maximum norm value of phases A and B is greater than normal condition values of phase A and B, this indicates that phase A and B is affected.

TABLE XVII
MAXIMUM NORM AND THRESHOLD DETAIL COEFFICIENT OF THREE PHASE AT DOUBLE PHASE TO GROUND FAULT USING DB6 WAVELET.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase AB-G	Max Norm	0.2683	0.2942	0.0741
	Threshold	0.3190	0.3109	0.0974
Phase BC-G	Max Norm	0.0102	0.3137	0.2688
	Threshold	0.0134	0.3127	0.3133
Phase AC-G	Max Norm	0.2932	0.0842	0.2438
	Threshold	0.3140	0.1109	0.3146

Similarly, a threshold value of phase A and B are greater than the normal condition value of phase A and B but the values of phase A and phase B are different. This indicates that phase AB is connected to ground.

TABLE XVIII
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT DOUBLE PHASE TO GROUND FAULT USING DB4.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase AB-G	Max Norm	0.2445	0.2600	0.0864
	Threshold	0.3190	0.3163	0.1442
Phase BC-G	Max Norm	0.0139	0.2698	0.3197
	Threshold	0.0232	0.3132	0.3149
Phase AC-G	Max Norm	0.2753	0.0997	0.2785
	Threshold	0.3164	0.1663	0.3147

TABLE XIX
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT DOUBLE PHASE TO GROUND FAULT USING HAAR.

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase AB-G	Max Norm	0.2257	0.2239	0.1580
	Threshold	0.3192	0.3167	0.2234
Phase BC-G	Max Norm	0.1592	0.2235	0.2236
	Threshold	0.2251	0.3161	0.3162
Phase AC-G	Max Norm	0.2230	0.1592	0.2242
	Threshold	0.3154	0.2252	0.3170

TABLE XX
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT DOUBLE PHASE TO GROUND FAULT USING SYMLET 5.

Fault Type	Parameter	Phase	Phase B	Phase C
Phase AB-G	Max Norm	0.2535	0.2478	0.0859
	Threshold	0.3187	0.3178	0.1190
Phase BC-G	Max Norm	0.0118	0.2756	0.2447
	Threshold	0.0164	0.3140	0.3165
Phase AC-G	Max Norm	0.2914	0.0978	0.2523
	Threshold	0.3126	0.1254	0.3203

TABLE XXI
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT DOUBLE PHASE TO GROUND FAULT USING BIOR 5.5

Fault Type	Parameter	Phase A	Phase B	Phase C
Phase AB-G	Max Norm	0.2408	0.2561	0.0694
	Threshold	0.3180	0.3161	0.0851
Phase BC-G	Max Norm	0.1119	0.2347	0.2327
	Threshold	0.0137	0.3215	0.3152
Phase AC-G	Max Norm	0.2291	0.0801	0.2559
	Threshold	0.3183	0.0982	0.3195

5) Three Phase Fault

The three phase current signals for this case is shown in Fig. 6.

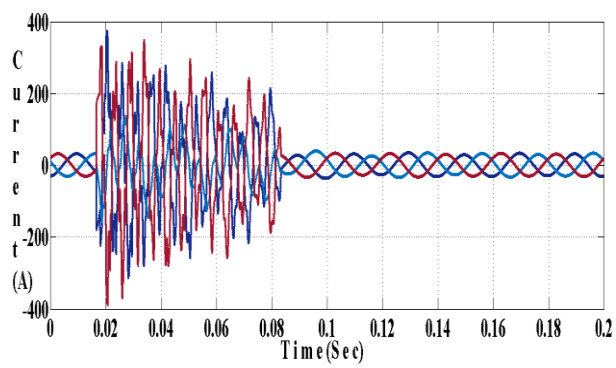

Fig. 6. Simulated Result for Three Phase Fault.

Maximum norm and threshold detail coefficient of three phases at three phase fault condition using db6, db4, haar (db1), sym 5, bior 5.5 wavelet are shown in Table 22, Table 23, Table 24, Table 25, Table 26.

TABLE XXII
MAXIMUM NORM AND THRESHOLD DETAIL COEFFICIENT OF THREE PHASE AT THREE PHASE FAULT USING DB6 WAVELET.

Parameter	Phase A	Phase B	Phase C
Max Norm	0.2711	0.2400	0.3070
Threshold	0.3134	0.2994	0.3230

TABLE XXIII
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT THREE PHASE FAULT USING DB4.

Parameter	Phase A	Phase B	Phase C
Max Norm	0.2642	0.2220	0.2555
Threshold	0.3176	0.3054	0.3188

TABLE XXIV
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT THREE PHASE FAULT USING HAAR.

Parameter	Phase A	Phase B	Phase C
Max Norm	0.2245	0.2198	0.2236
Threshold	0.3175	0.3108	0.3162

TABLE XXV
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT THREE PHASE FAULT USING SYMLET 5.

Parameter	Phase A	Phase B	Phase C
Max Norm	0.2365	0.2234	0.2339
Threshold	0.3246	0.3001	0.3154

TABLE XXVI
MAXIMUM NORM AND THRESHOLD DETAILS OF THREE PHASE AT THREE PHASE FAULT USING BIOR 5.5

Parameter	Phase A	Phase B	Phase C
Max Norm	0.2447	0.2428	0.2633
Threshold	0.3140	0.3083	0.3130

From the below tables it is clear that the maximum norm value of all the three phases (ABC) is greater than normal condition values of all the three phases. Similarly, a threshold value of all the three phases is greater than normal condition values.

6) Fault Location results

The fault location is found for all different fault types using different mother wavelet such as d6, db4, haar (db1), sym 5, bior 5.5. The different mother wavelet is used in order to select the optimal wavelet. The location for each fault is calculated using the equation (3) and the results are shown in Table 27**.**

TABLE XXVII
FAULT LOCATION ON BUS 1 WITH RESPECT TO 2 IN Km

FAULT TYPE	Db6	Db4	Haar	Symlet 5	Bior 5.5
A-G	83.032	83.051	83.050	83.034	83.033
B-G	68.822	79.690	79.270	78.980	78.970
C-G	69.780	80.345	80.150	79.120	80.342
A-B	69.220	80.348	80.149	80.410	80.347
B-C	70.615	80.627	80.021	80.703	80.586
A-C	69.780	80.345	80.153	80.410	69.850
AB-G	72.990	83.551	83.295	83.556	72.788
BC-G	72.284	78.739	79.010	78.998	78.998
AC-G	76.449	80.416	80.414	69.648	80.414
ABC	69.782	80.344	80.413	80.414	69.648

B. COMPARISON PERFORMANCES OF DB6 WITH OTHER WAVELETS.

In this paper, different mother wavelet such as db6, db4, haar (db1), sym 5, bior 5.5 is used for transmission line fault protection. In fault classification, it is difficult to distinguish the double phase fault from double phase to ground fault condition while using db4, haar (db1), sym 5, bior 5.5 as a mother wavelet, whereas db6 wavelet gives a very accurate classification.

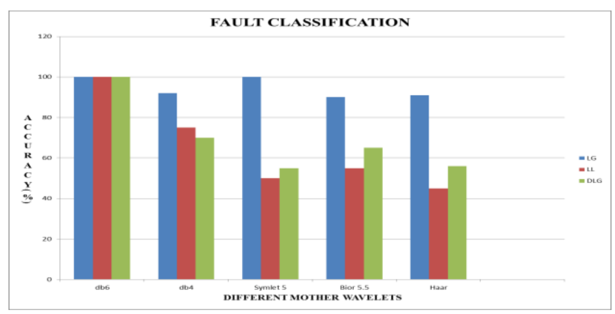

Fig. 7. Accuracy of fault classification using different Mother wavelets

The accuracy of fault classification using different mother wavelets is shown in Fig. 7. At fault location, the db6 as mother wavelet provide better accuracy than other wavelet such as db4, haar (db1), sym 5, bior 5.5. The accuracy of fault location is shown in Fig. 8. Overall db6 as a mother wavelet provides good accuracy in transmission line protection.

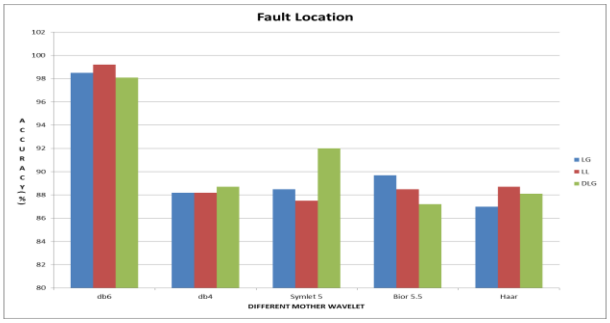

Fig. 8. Accuracy of fault location using different mother wavelet

V. CONCLUSION

The suggested system's Simulink model has been created, and fault analysis has been done using the Discrete Wavelet Transform with wavelets like db6, db4, haar (db1), sym 5, and bior 5.5. Maximum Norm and Threshold values, which are utilised for Fault Detection and Classification, are computed from DWT. By calculating the travelling-wave propagation periods, the fault location is identified. Among these wavelets, db6 is determined to be the most effective for transmission line protection, followed by db4, haar (db1), sym 5, and bior 5.5. Using db4, haar (db1), sym 5, and bior 5.5 wavelets for fault classification, it is challenging to discern between a double phase fault and a double phase to ground fault. For transmission line protection, the db6 mother wavelet is therefore the best option. The outcome demonstrates that the suggested system can accurately locate the issue, identify the fault type, and detect faults quickly.

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