A New Faulted-Phase Identification Technique for Overhead Distribution System

Eyada A Alanzi *, Mahmoud A Younis
ELECTRICAL POWER ENGINEERING
COLLEGE OF ENGINEERING
UNIVERSITI TENAGA NASIONAL
43009 KAJANG, SELANGOR, MALAYSIA
* E-mail of the corresponding author: ealanezi@yahoo.com

ABSTRACT
An identification of faulted phase in overhead distribution System is presented in this paper. This technique is accomplished by two steps. First, to identify the type of fault polarity (grounded or ungrounded). Then, determine the faulted-phase type. The proposed method takes the advantage of the special features of Clarke modal transformation and wavelet transform to explore the type of fault occurring along the distribution power system. MATLAB software is used for implementation of modal and wavelet transformation. ATP/EMTP is used for simulation results of the sample distribution system for demonstration and testing of the proposed method.

Keywords: Fault-phase classification, wavelet transform, phase-shift angle and overhead distribution system

1. INTRODUCTION

Classification of fault in over head distribution system is vital for economic operation. Accurate fault classification helps in fast repair, reduce operating costs, quick system restoration and significantly improve system availability and reliability. Fault classification is established for two main reasons, first, identification of the faulted phase type, e.g., single-phase-ground fault, phase-phase fault, etc. In this case the protection relays can select the suitable algorithm element to deal with various fault conditions. The second reason is determining of the faulted phase to maintain a single-phase tripping and auto-reclosing decisions [1]. Wavelet Transform (WT) is a valuable tool in analyzing transient voltage and current signals related to faults both in frequency and time domain. Recent fault classification techniques were based on the variation of the current or voltage samples of the three phases or phasor quantities of power frequency information [2]. Wavelet transform is also used for fault classification based on maximum detail coefficient, signal energy and ratio of energy change of three phase current signals [3]. Voltage and current waveforms are used by wavelet transform to classify faults in a double line network for only single-phase-ground faults [4]. Spectral energy tested at certain thresholds by wavelet transform. The current magnitude, phase angle difference and spectral energy of coefficients are analysed for detection of fault types. The threshold value is to be modified in each case with new actual data [5]. Also, Wavelet transform algorithm with three phase currents at one end of the line is used with a rule base to be set for each test case. Three-phase fault was not identified due to high impedance of the line [6]. For radial power system wavelet transform method is used to detect phase-phase-ground faults from three phase currents at both ends of the line [7]. Another approach of wavelet transform and generic algorithm (GA) is used with current signals collected at one end of the line. The approach did not result with same classification accuracy for all faulted phase cases [8]. Other researchers proposed a technique of wavelet transform with neural networks to detect faulted phase in different situations. Results of these approaches depend highly on the accuracy of current signals extracted from the system [9, 10].

In this paper, a new fault phase identification technique for overhead distribution system is proposed using Clarke Modal and wavelet transformations. The technique utilizes only voltage waveform (pre-fault and post-fault) from one end of the distribution line (main substation). This will eliminate the effect of CT behaviour during fault period on fault-phase type classification. In fact, during the fault period, current transformers do not operate properly due to transient state and over voltage of the power system. The problem of CT saturation and inaccurate measurement of current will increase the cost of protection of distribution system.The approach is divided into two parts. First, identify the grounded and the ungrounded faults by the modal transform method. Second, determine the faulty phase by Discrete Wavelet Transform (DWT).

2. MODAL TRANSFORM

In the proposed approach, to determine whether the fault is grounded or ungrounded, the modal components are extracted from the phase domain signals by the modal transformation matrix. In this study, all overhead distribution line models are assumed to be fully transposed, and therefore the well known Clarke's constant and real transformation matrix will be used for this purpose. The matrix is given by [11] and stated as follows:

$$T = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 2 & -1 & -1 \\ 0 & \sqrt{3} & -\sqrt{3} \end{bmatrix} \tag{1}$$

The phase signals are transformed into their modal components by using this transformation matrix as in (2).

$$S_{mode} = T \; S_{phase} \tag{2}$$

where,

$$S_{mode} = \begin{bmatrix} \alpha \\ \beta \\ 0 \end{bmatrix} \quad \text{and} \quad S_{phase} = \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix}$$

The S_{mode} and S_{phase} are the modal and phase signals (voltages or currents) vectors respectively. Clarke's transformation is real and can be used with any transposed line. If the studied line is not transposed, then an eigenvector based transformation matrix, which is frequency dependent, will have to be used. This matrix should be computed at a frequency equal or close to the frequency of the initial fault transients. Recorded phase signals are first transformed into their modal components. The first mode (mode α), is usually referred to as the *ground* mode, and its magnitude is significant only during faults having a path to ground. The second mode (mode β) is also known as the aerial mode. Therefore, the fault type problem is formulated based essentially on the ground mode α, making use of the ground mode magnitude for the purpose of distinguishing between grounded and ungrounded faults situations.

3. WAVELET TRANSFORM

Wavelet Transform (WT) is mathematical tool that can be used effectively for analysis of transient current and voltage signals [2, 3]. WT has much more features than conventional signal processing methods because of the efficient analysis of the signal in both frequency and time domains. In WT, the band of analysis can be adjusted so that low frequency and high frequency components can be detected accurately. Results of WT provide time and frequency information in different resolution. Discrete Wavelet Transform (DWT) is used in analyzing transient voltage of faults on the distribution system by two scale factor. For any function (f), DWT is written as,

$$DWT(m,n) = \frac{1}{\sqrt{2^m}} \sum_k f(K)\Psi\left(\frac{n-k2^m}{2^m}\right) \tag{3}$$

Where, Ψ is mother wavelet. The decomposition for three levels is shown Fig.1.

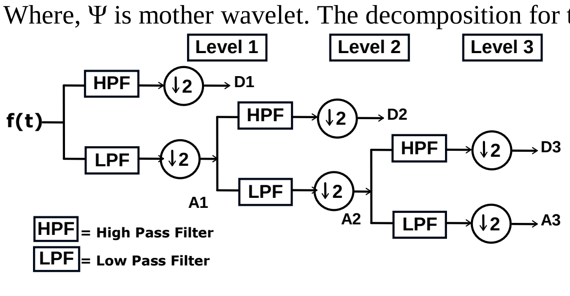

Fig.1. Three level signal decomposition diagram.

In this paper, DWT is used to classify the type of fault either when fault is grounded or ungrounded. In the grounded fault situation, faulted phases of SLG, LLG and LLLG will be distinguished. Similarly, for ungrounded fault situation, LLF and LLLF phases will be determined.

4. PHASE-SHIFT ANGLE

Phase shift is a change in voltage phase angle associated with fault occurrence. The characteristics of particular faults at certain locations are determined by the type of fault in addition to other factors [12]. Phase shift during the fault occurrence can be obtained by calculating the difference between the pre-fault voltage waveform angle and the during-fault voltage waveform angle. A phase shift can be expressed either as a time (in milliseconds), or as an angle (in degrees or radians), and may have a negative or positive values.

5. FAULT TYPE CLASSIFICATION

The proposed approach of fault type classification consists of two steps: (1) use of modal transformation to identify if fault is grounded or ungrounded. (2) DWT implementation with angle phase shift to classify the faulted phase type.

5.1. Identification of Grounded and Ungrounded Faults

After reading the faulted voltage waveforms, the signals undergo a low-pass filtration and a size reduction for readiness to the modal transform. Next, using the faulted voltage waveforms (Va, Vb, Vc) in (2) to calculate the modal signals (α, β, 0). Fig.3 shows the flow chart for identifying the grounded and ungrounded faults by modal transform. For proper differentiation between grounded and ungrounded situations, a threshold value is proposed. When absolute value of the sum of signal α is calculated, it was found that for grounded cases the value is over 30 except for three phase-to-ground faults the value was slightly more than 0.01.On the other hand, for ungrounded faults the values was below 0.009. As a result it was decided to set a certain threshold value (ε) as 0.01 for definite selection between the two types.

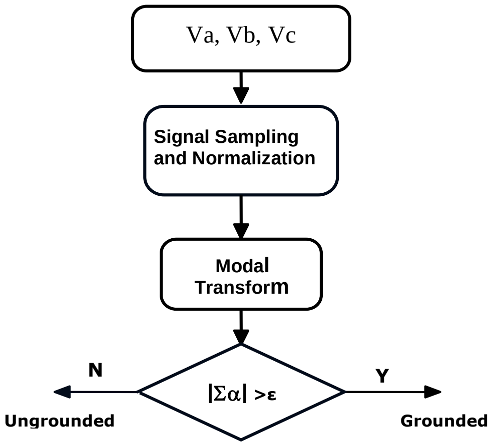

Fig.2. Identification of grounded or ungrounded faults
Based on Modal Transformation of voltages signals

5.2. Determination of Fault Phase Type

The faulted phase is determined by using two types of data, results of discrete wavelet transform for each voltage phase (Wv_a, Wv_b , Wv_c) and the phase-shift angle (θ_A, θ_B, θ_C) of each recorded voltage waveforms. Therefore, fault phase type can be determined as per the following sequence:

a. Reading/recording of voltage signals at main substation (V_a, V_b, V_c).

b. Calculation of phase-shift angle for each voltage phase waveform (θ_A, θ_B, θ_C).

c. Apply of Discrete Wavelet transform (DWT) and use of data (Wv_a, Wv_b, Wv_c) of (db8) at level 1.

The grounded faults scheme is performed in the following steps (as shown in Fig.3):

1. If $|WVa| < |WVb|$ & $|WVc|$ AND $\theta_A > \theta_B$ & θ_C then fault type is single phase-to-ground (AG).
2. If $|WVb| < |WVa|$ & $|WVc|$ AND $\theta_B > \theta_A$ & θ_C then fault type is single phase-to-ground (BG).
3. If $|WVc| < |WVa|$ & $|WVb|$ AND $\theta_C > \theta_A$ & θ_B then fault type is single phase-to-ground (CG).
4. If $|WVa|$ & $|WVb| < |WVc|$ AND θ_A & $\theta_B > \theta_C$ then fault type is double phase-to-ground (ABG).
5. If $|WVa|$ & $|WVc| < |WVb|$ AND θ_A & $\theta_C > \theta_B$ then fault type is double phase-to-ground (ACG).
6. If $|WVb|$ & $|WVc| < |WVa|$ AND θ_B & $\theta_C > \theta_A$ then fault type is double phase-to-ground (BCG).
7. Otherwise, the fault type is three phase-to-ground fault (ABCG).

Similarly, the ungrounded faults scheme is performed in the following (as shown in Fig.4) steps:

1. If $|WVa|$ & $|WVb| < |WVc|$ AND θ_A & $\theta_B > \theta_C$ then fault type is double phase fault (AB).

2. If $|WVa|$ & $|WVc| < |WVb|$ AND θ_A & $\theta_C > \theta_B$ then fault type is double phase fault (AC).
3. If $|WVb|$ & $|WVc| < |WVa|$ AND θ_B & $\theta_C > \theta_A$ then fault type is double phase fault (BC).
4. Otherwise, the fault type is three phase fault (ABC).

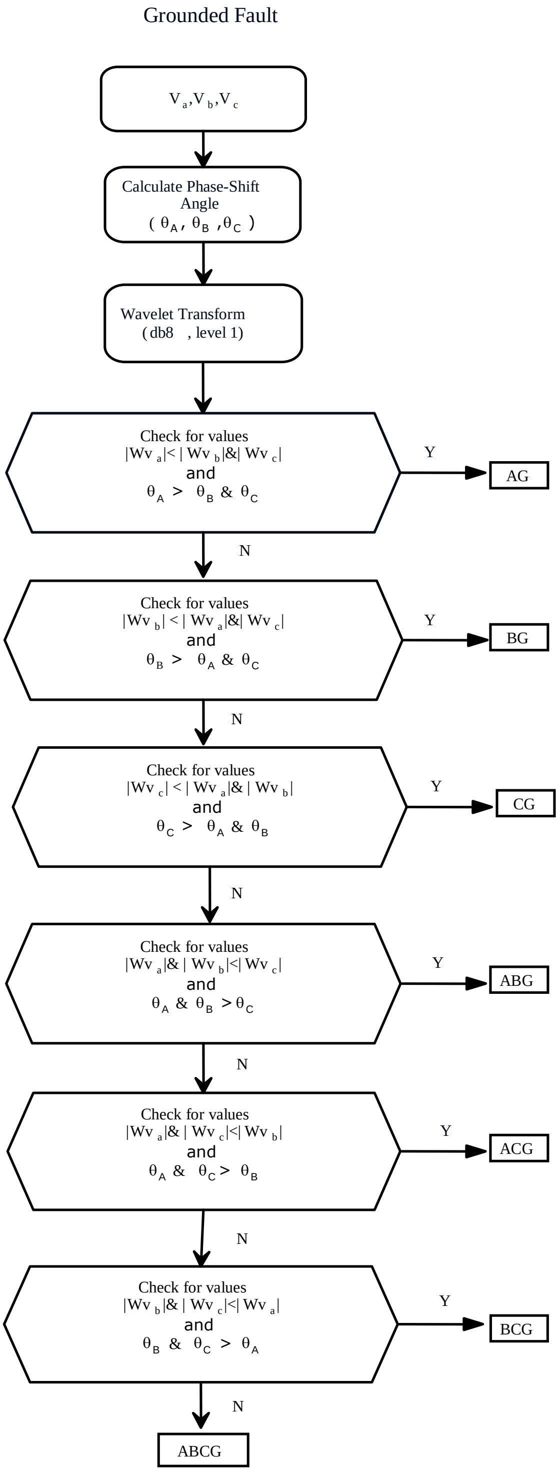

Fig.3 Flowchart of identification of fault phase type for the grounded faults

Ungrounded Fault

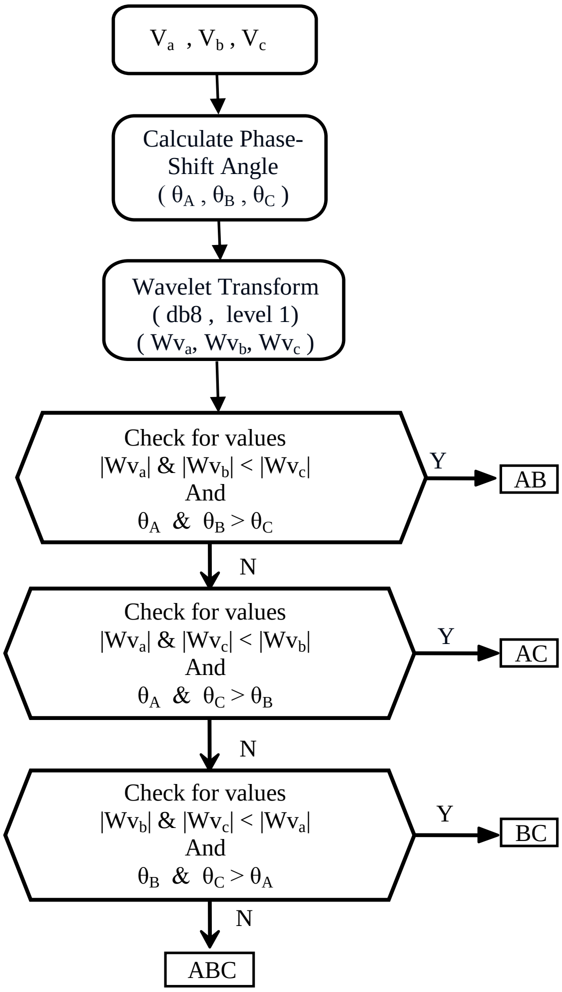

Fig.4 Flowchart of identification of fault phase type for the ungrounded faults

6. SIMULATION STUDY FOR FAULT PHASE TYPE CLASSIFICATION

In this paper, estimation of fault phase type classification is performed on a power system simulation as shown in Fig.5. The simulation of transient signals of the overhead distribution system is performed using ATP/EMTP program [13]. The power system is consisting of single power supply of 33kv, 50Hz and a radial over head distribution system of 20 km with three lateral branches of 5 km each and loads. The faults are simulated on 7 points (T1-T7) on the power system. Faulted phase types simulated with different fault impedances (R_f) (0Ω-100Ω) and different inception angles (A_i) (0°, 45°, 90°) of faults are studied. For each case, the summations of the first level (L1) coefficients of mother wavelet (db8) are determined. It is found that even these values are different; however, values are close for one fault type (SLG, LL, LLG, LLL or LLLG) with different impedances and inception angles. The simulation time is 60 ms with time step 1.0μs and total of 1200 samples.

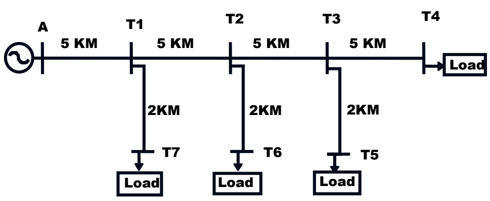

Fig.5 Overhead Distribution System used for the study

System parameters are typical to Kuwait network at Wafra area with generator source resistance 0.89Ω and source inductance of 12.37mH. Overhead distribution line parameters for main line and lateral branches are shown in Table.1.

Sampling of three-phase of voltage waveforms is shown in Fig.6, Fig.7 and Fig.8 during the occurrence of single-line-to-ground (phase-A-to-ground), double-line-to-ground (phases-AB-to-ground) and line-to-line (phase-A-to-phase-B) faults, respectively.

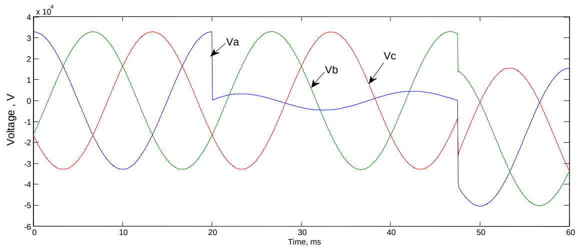

Fig.6 Three phase voltage waveforms during SLG-AG fault at T2 on the distribution system

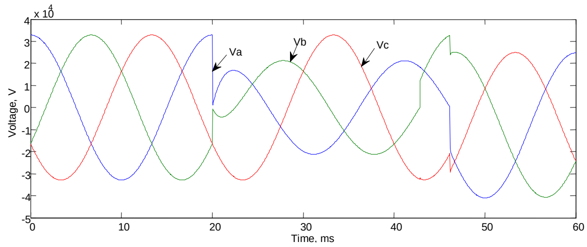

Fig.7 Three phase voltage waveforms during DLG-ABG fault at T2 on the distribution system

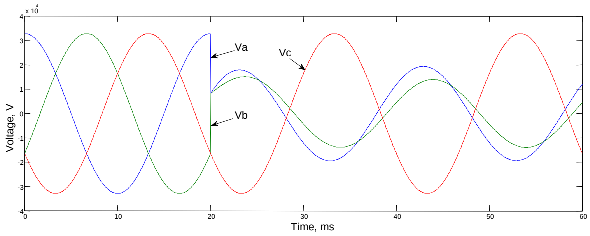

Fig.8 Three phase voltage waveforms during Line-Line (AB) fault at T2 on the distribution system

TABLE.1
Overhead Distribution line parameters

Parameters of main line	
R1	0.11763 Ω/km
R0	0.22961 Ω/km
X1	0.3712 Ω/km
X0	1.0717 Ω/km
C1	3.1 µF/km
C0	1.5 µF/km
Parameters of lateral branches	
R1	0.227 Ω/km
R0	0.04122 Ω/km
X1	0.3654 Ω/km
X0	0.1601 Ω/km
C1	3.1 µF/km
C0	1.3 µF/km

7. RESULTS AND DISCUSSIONS

The data of system shown in Fig.5 is used by the proposed algorithm for classification of fault phase type resulted at different locations on the power system. The voltage waveforms are taken from one side of the line at substation A for all occurred faults. MATLAB software is used for calculation of data in both methods, modal and wavelet transforms [14].

7.1 Identification of Grounded and Ungrounded Faults

Table.2 and Table.3 show the results of modal transformation of faulted voltage waveforms for different types of fault phases at different fault locations on the power system with fault resistance $R_f = 0\Omega$. It is concluded from tabulated results that the value of selected threshold is met for both schemes (grounded and ungrounded). For grounded condition the threshold value is > 0.01and for ungrounded condition the threshold value is < 0.01.

TABLE.2
Results of Modal Transform ($|\Sigma\alpha|$) for SLG, LLLG and LLL faults
at different locations on the distribution system with $R_f = 0\Omega$.

Fault Location (Terminal #)	AG	BG	CG	LLLG	LLL
T1	70.396	32.197	37.760	0.0102	0.009
T2	70.055	31.996	37.611	0.0114	0.009
T3	69.704	31.785	37.459	0.0126	0.009
T4	69.342	31.563	37.304	0.0137	0.009
T5	69.688	31.775	37.452	0.0132	0.009
T6	70.040	31.987	37.604	0.0120	0.009
T7	70.381	32.188	37.753	0.0109	0.009

TABLE.3
Results of Modal Transform ($|\Sigma\alpha|$) for grounded (LLG) and ungrounded (LL) faults
at different locations on the distribution system with $R_f = 0\Omega$.

	Grounded Faults			Ungrounded Faults		
Fault Location (Terminal#)	ABG	ACG	BCG	AB	AC	BC
T1	37.607	32.245	69.823	0.006	0.009	0.009
T2	37.459	32.046	69.475	0.006	0.009	0.009
T3	37.311	31.839	69.120	0.006	0.009	0.009
T4	37.162	31.625	68.756	0.006	0.009	0.009
T5	37.303	31.830	69.101	0.006	0.009	0.009
T6	37.451	32.037	69.458	0.006	0.009	0.009
T7	37.599	32.236	69.806	0.006	0.009	0.009

7.2 Determination of Fault Phase Type

The results of employing the data of DWT and Phase Shift Angle are stated in this section. Table.4 shows results data for SLG (AG) and LLG (ABG) with fault resistance $R_f = 0\Omega$ at different fault locations on the distribution system. For AG condition it is clear from tabulated data that all values of $|Wv_a|$ are less than the values of $|Wv_b|$ and $|Wv_c|$; and the value of phase shift angle θ_A is more than the values of phase shift angles θ_B and θ_C for all fault locations. Similarly, for ABG, the values of $|Wv_a|$ and $|Wv_b|$ are less than the value of $|Wv_c|$; and the value of phase shift angles θ_A and θ_B are more than the value of phase shift angle θ_C for all fault locations. In Table.5, The results of LL (AB) faults are tabulated. It is clear that for all fault locations the values of $|Wv_a|$ and $|Wv_b|$ are less than the value of $|Wv_c|$; and the phase shift angles values of θ_A and θ_B are more than the phase shift angle value of θ_C and the condition criteria satisfied for AB ungrounded fault.

TABLE.4
Results of Voltage Wavelet Transforms (Wv) and phase shift angles (θ)
for grounded phases (SLG and LLG) at (R_f =0Ω).

Fault Type	Fault Location (Terminal#)	$\|Wv_a\|$	$\|Wv_b\|$	$\|Wv_c\|$	θ_A	θ_B	θ_C
SLG (AG)	T1	0.0019	0.0123	0.0134	0.838	0	0.001
	T2	0.0022	0.0123	0.0134	0.788	0	0.001
	T3	0.0024	0.0123	0.0134	0.742	0	0.001
	T4	0.0026	0.0123	0.0134	0.7	0	0.001
	T5	0.0024	0.0123	0.0134	0.74	0	0.001
	T6	0.0022	0.0123	0.0134	0.786	0	0.001
	T7	0.0019	0.0123	0.0134	0.836	0	0.001
LLG (ABG)	T1	0.0019	0.0054	0.0134	0.837	0.73	0.001
	T2	0.0022	0.0056	0.0134	0.786	0.68	0.001
	T3	0.0024	0.0058	0.0134	0.74	0.64	0.001
	T4	0.0026	0.0060	0.0134	0.698	0.61	0.001
	T5	0.0025	0.0058	0.0134	0.738	0.64	0.001
	T6	0.0022	0.0056	0.0134	0.784	0.68	0.001
	T7	0.0019	0.0054	0.0134	0.835	0.73	0.001

TABLE.5
Results of voltage wavelet transforms (Wv) and phase shift angles (θ)
for ungrounded phases (LL) at (R_f =0Ω).

Fault Type	Fault Location (Terminal#)	$\|Wv_a\|$	$\|Wv_b\|$	$\|Wv_c\|$	θ_A	θ_B	θ_C
LL (AB)	T1	0.0049	0.0085	0.0134	0.973	0.960	0.0
	T2	0.0050	0.0084	0.0134	0.908	0.862	0.0
	T3	0.0050	0.0084	0.0134	0.850	0.759	0.0
	T4	0.0050	0.0084	0.0134	0.798	0.657	0.0
	T5	0.0050	0.0084	0.0134	0.848	0.755	0.0
	T6	0.0050	0.0084	0.0134	0.905	0.858	0.0
	T7	0.0049	0.0085	0.0134	0.970	0.956	0.0

7.3 Testing of Performance of Proposed Technique at Different Conditions

The proposed method is tested with different parameters and shows high accuracy and meeting the condition set for each case with different fault resistance (R_f) and inception angle (A_i), as illustrated in Tables (6 – 8). In Table.6, the resulted data of grounded and ungrounded faults are tabulated, where in Table.7 and Table.8 the resulted data for fault phase types based on wavelet transforms and phase shift angles for ABG and AC faults, respectively.

TABLE.6
Results of the Modal Transform (|Σα|) for ABG and BG faults at
different locations on the distribution system with different parameters

Fault Location (Terminal #)	ABG FAULT (R_f =10Ω, A_i =90°)	AC FAULT (A_i =45°)
T1	5.242861	0.005607
T2	5.188395	0.001258
T3	5.134361	0.002632
T4	5.080795	0.003279
T5	5.131809	0.004574
T6	5.185825	0.002965
T7	5.24028	0.007969

TABLE.7
Results of voltage wavelet transform (Wv) and phase shift angle (θ)
during ABG faults at R_f =10Ω and Ai = 90 °.

Fault Location (Terminal#)	$\|Wv_a\|$	$\|Wv_b\|$	$\|Wv_c\|$	θ_A	θ_B	θ_C
T1	0.00307	0.00857	0.01339	0.34570	0.28622	0.00096
T2	0.00305	0.00870	0.01339	0.33446	0.27793	0.00095
T3	0.00302	0.00881	0.01339	0.32391	0.27006	0.00094
T4	0.00299	0.00893	0.01339	0.31400	0.26258	0.00093
T5	0.00302	0.00882	0.01339	0.32345	0.26972	0.00094
T6	0.00305	0.00870	0.01339	0.33397	0.27758	0.00095
T7	0.00307	0.00858	0.01339	0.34519	0.28586	0.00096

TABLE.8
Results of voltage wavelet transforms (Wv) and
phase shift angles (θ) during AC fault at A_i = 45 °.

Fault Location (Terminal#)	$\|Wv_a\|$	$\|Wv_b\|$	$\|Wv_c\|$	θ_A	θ_B	θ_C
T1	0.00159	0.01234	0.01075	0.76690	0.00000	0.79574
T2	0.00117	0.01234	0.01116	3.13068	0.00000	0.75277
T3	0.00081	0.01234	0.01153	3.13068	0.00000	0.71328
T4	0.00050	0.01234	0.01184	3.13068	0.00000	0.67700
T5	0.00080	0.01234	0.01154	3.13068	0.00000	0.71159
T6	0.00116	0.01234	0.01118	3.13068	0.00000	0.75094
T7	0.00157	0.01234	0.01077	0.76293	0.00000	0.79375

8. CONCLUSION

This paper presents a proposed technique for classification of fault phase types in Overhead Distribution Systems with lateral branches. The new technique employed three methods namely, Clarke Modal Transform, Wavelet Transform and Phase Shift Angle criteria to establish a robust result for fault phase type identification utilising only three phase voltage waveforms at one end of the distribution line. The technique performance is successfully tested with data obtained during computer simulations with different types of sampled data at various situations (faulted resistance, inception angle and fault location). This proposed technique can be implemented in real time with actual data.

REFERENCES

[1] Xinzhou Dong, Wei Kong, Tao Cui, “Fault classification and faulted-phase selection based on the initial current travelling wave,” IEEE Trans. Power Delivery, vol. 24, No.2, April 2009.
[2] O.A.S. Youssef, A modified wavelet-based fault classification technique, Elect. Power Syst. Res. 64 (2) (2003) 165–172.
[3] S. A. Shaaban, T. Hiyama, "Transmission Line Faults Classification Using Wavelet Transform", the 14th International Middle East Power Systems Conference (MEPCON’10), Cairo University, Egypt, December 19-21, 2010, Paper ID 225.
[4] Kajoijilertsakul, P., Asawasripongtom, S., Sanposh, P., Suwatthikul, J., Fujita, H., "Wavelet based fault detection, classification and location in existing 500 kV transmission line", Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2011 8th International Conference, pp. 873 - 876, Vol. 17-19 May 2011.
[5] Sawatpipat, P., Tayjasanant, T., "Fault classification for Thailand's transmission lines based on discrete wavelet transform", Electrical Engineering/Electronics Computer Telecommunications and Information Technology (ECTI-CON), 2010 International Conference on, pp. 636 - 640, Vol. 19-21 May 2010.
[6] U. D. Dwivedi, S. N. Singh, and S. C. Srivastava, "A Wavelet based Approach for Classification and Location of Faults in Distribution Systems", IEEE Conf. & Exhibition on Control, Communication and Automation (INDICON) , India, vol. 2 pp. 488-493, Dec. 11-13, 2008.
[7] P. Makming,S. Bunjongoti, A. Kunakorn, S.jiriwibhakorn and M. kando, "Fault Diagnosis in Transmission lines using Wavelet Transform Analysis", IEEE Transmission and Distribution Conference and Exhibition , pp.2246-2250,2002.

[8] J. Upendar , C. P. Gupta and G. K. Singh "Discrete wavelet transform and genetic algorithm based fault classification of transmission systems", Proc. 15th Natl. Power Syst. Conf. (NPSC), pp.323 - 328 , 2008.
[9] V. S. Kale, S. R. Bhide, R. P. Bedekar and G. V. K. Mohan, "Detection and classification of faults on parallel transmission lines using wavelet transform and neural network," International Journal of Electric and Electronics Engineering Vol. 1, pp.364-368, 2008.
[10] S. A. Ghafoor, and P. V. R. Rao, "Wavelet based fault detection, classification and location in transmission lines", First International Power and Energy Conference PECon, Putrajaya, Malaysia, Nov. 2006.
[11] A. M. Elhaffar, "Power transmission line fault location based on current traveling waves", Doctoral dissertation, Helsinki University of Technology, 2008.
[12] Djokic, S. Z., Milanovic, J. V., Advanced Voltage Sag Characterisation. Part I: Phase Shift, IEE Proc.-Gener. Transm. Distrb., Vol. 153, No. 4, July 2006
[13] H. Dommel, "Electromagnetic Transients Program", Bonneville Power Administration, Portland, OR, 1986.
[14] MATLAB User's Guide, The Math Works Inc., Natick, MA.

Eyada A Alanzi (M'97) received the B.E. and M.E. degrees, from Kuwait University in 1985 and 1996, respectively. He worked in the private sector for more than 20 years on design and construction of Electrical Projects. He is currently working on his research as PhD candidate in the Department of Electrical Power Engineering, Universiti Tenaga Nasional (UniTen). His research interest includes protection of power systems, neural networks, support vector machines and their application to fault locations. He is a member of IET (Chartered Engineer) and IEEE.

Mahmoud A. A. Younis was born in Gaza, Palestine. He receives the PHD in the Department of Electrical Engineering, UM, Malaysia 2009, the M.Sc. degree from UM Malaysia. in 2001, and B.Sc. degree from IIT, Bangladesh in 1997. Currently he is a lecturer in the Department of Electrical Power Engineering, University Tenaga Nasional (UNITEN), Malaysia. Dr. Mahmoud is active in Power Electronics research Group in UM and His research interest including, Power Electronics, Renewable Energy, distributed Generation and Fuel cell system.