Fault Detection, Classification and Location on Transmission Lines using Fundamental Phasor Based Approach

Kumarraja Andanapalli, Nazeer Shaik, Srinivas Vudumudi, Bhanu Chandar Yenugu

Abstract: The intent of this paper to instigate a fault detection, classification and location scheme for two terminal long transmission lines network using fundamental phasor based approach. This method utilizes the voltage and current signals are measured from the relay and phasor quantities are estimated with the aid of DFT (discrete fourier transform) a signal processing technique. The proposed algorithm uses absolute current phasor values for fault detection algorithm from three phase quantified current signals from the relay end. After, fault detection, utilization of one cycle information about post fault data of absolute current phasors provides clear discrimination between faulted phase and healthy phase. Zero sequence absolute current phasors shows the involvement of ground during fault condition. Later, an fault location algorithm is developed to locate the fault for faster repair and bring back into service using impedance algorithm. The entire algorithm is tested on 400 kV, 50 Hz two terminal bus system by considering different events like variation of resistance, distance, angle of inception and type of the fault. Performance investigation is done under various fault situations through MATLAB/SIMULINK and results show the accuracy of the algorithm.

***Index Terms*: Transmission lines, DFT (Discrete Fourier transform), Fault detection, Classification, Location, Sequence components.**

I. INTRODUCTION

In power systems, transmission and distribution networks play an important role in transmitting power from generating points to the load centers. In long transmission line the power flow will be discontinued due to broken of the line conductors, occurrence of the faults may be temporary or permanent type, overload on the transmission line may affect the reliable operation by tripping of the line. Occasionally unwanted tripping of the relays during stressed conditions also leads to disturbance in reliable operation. In order to mitigate in these situation, relays are to be designed with proper detection during fault condition only. For fast repair and immediate get back into service, therefore the relay has to identify the affected phase and also should trace the fault location. Several years researchers are focusing on developing different fault detection, classification and location algorithms in transmission lines to protect the health system from fault events and also to maintain reliable operations. These algorithms have to detect the fault as quickly as possible prior to classification and location. Identification of fault type and location leads to quick repair and maintenance. Fault zone detection and classification on transmission lines were opt by using wavelet transform, support vector machine, Artificial neural network, the Naïve Bayes approach for series compensated line [1-5]. But those approaches need large amount of training data is required. A new Harmony search algorithm based technique has been proposed to discriminate transmission line faults in [6-7]. This method offers high computaional burden. Signal processing techniques are also used to detect the fault, identify the fault type and locate the fault by Hilbert huang transform [8], Cumulative Sum-Based approach [9], and wavelet transform [10-12]. These methods are able to detect and classify the fault accuaratеly, but computational burden is high. In [13], fuzzy based fault location estimation is developed but it requires more number of inputs and accurate rule formation.

Intelligence schemes were proposed for fault detection, classification by ANN [14-19], Back propagation method [20], Radial basis function neural network (RBFNN) [21-22], Feed forward ANN (FFNN) [23]. Intelligent based approaches detect, classify and locate the fault accurately but it requires huge amount of large data for training patterns. In [24], PNN is used for the protection of series capacitor compensated multi bus extra high voltage transmission system. This method is not considered for uncompensated lines. Hybrid comination of signal processing techniques and intelligence application are able to detect the fault, classify the fault and locate the fault is given in [25], wavelet transform & ANN combination. In [26], travelling wave theory has been presented for the protection of ultra high voltage transmission line.In [27], a hybrid method of combing wavelet singular entropy and Euclidean norm has been applied for the detection and classification of faults. In [28], wavelet singular entropy (WSE) is used for the detection and classification of transmission line faults. The classification of fault has been done using the Euclidean norm value of all the phases. The above [25-28] approaches uses hybrid combination give accurate results but it needs high computational procedures.

In this paper a fundamental phasor based approach is applied for detection, classification and location

Revised Manuscript Received on June 01, 2019.
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algorithm on single circuit transmission lines during fault phenomenon is presented. Discrete fourier transform (DFT) is used for extraction of fundamental phasor components of measured signals from the relay point. The proposed algorithm involves two stage of operation. Firstly the absolute current phasors of three phase current signals measured from relay end is used to develop the fault detection and fault classification algorithm. Fault location estimation is implemented by taking one cycle data after the fault clearance is applied to impedance algorithm. The entire algorithm is tested on 400KV, 50 Hz two terminal three bus system by considering different fault events like fault resistance, fault distance, fault inception angle and fault type. Performance of the algorithm is also tested on two terminal lines with four bus system. is evaluated through MATLAB/SIMULINK under various fault conditions and results show the efficacy of the algorithm.

Section II presents the brief explanation of the methodology and simulation results are presented in section III and conclusion are followed in the next section.

II. METHODOLOGY

The proposed methodology deals the fault detection, classification and location on the two terminal transmission line as shown in figure.1.

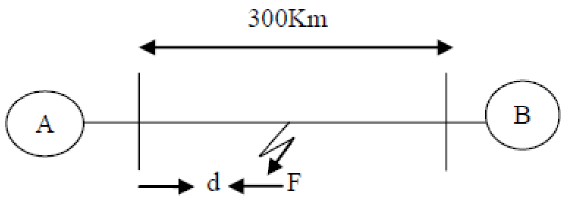

Fig. 1. A 400 kV, 50 Hz Two terminal transmission line.

The procedure of the method involves four steps

A. DFT based phasor extraction.
B. Fault detection algorithm.
C. Fault classification algorithm.
D. Fault location estimation using two end measurement

A. Extraction of Phasors using DFT

In a power system network the voltage and current signals are quantified at the relay point. These signals are converted into phasor quantities utilizing Discrete Fourier Transform (DFT) which extract the fundamental phasor values. Discrete Fourier Transformation (DFT) is utilized to convert the time domain digital samples to frequency domain utilizing congruous sample space depends on the sampling frequency of the signal. Computational process is very simple compared to other techniques such as cosine and least squares algorithm. DFT is calculated over one cycle information of voltage and current signals utilizing equation-1.

$$I_{DFT} = \frac{2}{N}\sum_{i=1}^{N} i_n e^{\frac{-2\pi jn}{N}} \quad (1)$$

Using the above equation estimate voltage phasors in a similar manner.

B. Fault detection algorithm

Fault detection would be the primary process in relay design and it is to be performed exactly for power system reliability. Consider the three phase currents from both relay ends and find the absolute current phasor quantities for fault detection criteria. Under the mundane condition, the absolute current phasor values appears as diminutive during healty condition and with the occurrence of fault, its value change significantly and treated it as fault detection index. This index utilizes to detect faults efficaciously in a small interval of time. A fault is registered if, any one of the phases exceeds threshold parameter h.

$$|Ia_i(k)| > h \quad (2)$$

Where ‘i’ indicates the phases of ‘A’, ‘B’ & ‘C’ of corresponding phase current signals respectively.

C. Fault classification

Secondly, Fault classification procedure is followed after the completion of fault detection task. One cycle of absolute current phasors data is considered after the clearance of the fault are used for the fault classification process. The magnitude of the absolute current phasors of any phase exceeds a certain threshold values then particular phase is involved with faulted phase otherwise, healthy phase. Another important issue is that fault initiated with the involvement of ground or not. To identify it, ground current has to be calculated with the avail of three phase currents phasors using equation.3.

$$Ig = (Ia+Ib+Ic)/3 \quad (3)$$

Absolute values of ground current phasor are greater than particular threshold value h1 using equation.4, then fault is said to be grounded fault otherwise ungrounded fault.

$$|I_g(k)| > h1 \quad (4)$$

D. Fault location

Two-ended fault location procedure is used in this study using impedance based algorithm. The algorithms make use of quantified data capture at both relay ends of a transmission line to obtain accurate location of the faul. Adscititious quantifications from the end points cessation of a transmission networks are habituated in order to eliminate any kind of error caused by impact of fault resistance, load current, or system non-homogeneity, fault type relegation is additionally not required. This technique surmises that quantifications from both terminuses of a transmission line are unsynchronized to a general time reference via global processing system (GPS).

Synchronizsing procedures is expalined using sequence components of voltage and current signals of post fault data are utilized for fault location computation as follows [29]. Utilizing the equation (1), obtain the phasor quantities of voltages and currents for two end measurments. After mining of phasors quantities and inditing the equation of voltage from fault point i.e. the positive-sequence voltage at the fault point F, viewed in

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between the bus-S and bus-R as shown in figure.1.

$$V_F^S = V_F^R \quad (5)$$

$$V_F^S = V_S e^{j\delta} \cosh(\gamma l d) - Z_c I_S e^{j\delta} \sinh(\gamma l d) \quad (6)$$

$$V_F^R = V_R e^{j\delta} \cosh(\gamma l(1\text{-}d)) - Z_c I_R e^{j\delta} \sinh(\gamma l(1\text{-}d)) \quad (7)$$

Solving the equations (5) - (7) for both positive and negative sequence components (during symmetrical fault phenomenon consider incremental positive sequencecomponents), gives

$$A(e^{j\delta})^2 + Be^{j\delta} + C = 0 \quad (8)$$

Realizing the equation.8 provides the two distinct values of synchronization angle 'δ', out of which valid 'δ'need to be selected from the condition given in equation.9.

$$| e^{j\delta} | > 0.9 \text{ or } | e^{j\delta} | < 1.1 \quad (9)$$

Finally, signals are synchronized with help of selected accurate synchronizing angle 'δ' is proceeding to find the accurate location using equation.10.

$$d = real \left(\frac{V_s e^{j\delta} - (V_R - Zc\ IS)}{Zc\ (I_s e^{j\delta} + I_R)} \right) \quad (10)$$

The terms Vs, Vr, Is and Ir are the sending end and receiving end of voltage & current phasors respectively. Zc is the characteristic impedance of the transmission line and 'd' represents the fault distance between fault initiated point and measured relay end. The entire algorithm is explained clearly in the flow chart as shown in figure.2.

III. SIMULATION RESULTS

A 400 kV, 50 Hz transmission line network as shown in fig.1 is considered for performance evaluation of the proposed detection, classification and location method. System data is make available in Appendix. A sampling frequency rate of 80 kHz and number of samples per cycle is 1600. The rigidness of the proposed method is established by creating several fault events like impact of fault resistance, fault inception time, fault location. The following representative cases specify the accuracy of the proposed method.

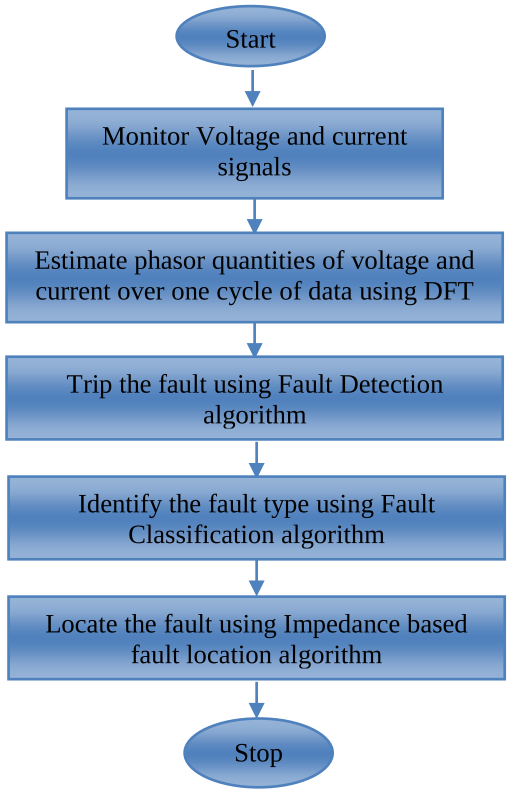

Fig. 2. Flow chart of Fault detection, Fault classification and loction algorithm.

a. Close- in fault condition

A single line to ground fault is simulated at a distance of 10 km with negligible fault resistance of 0.01Ω and fault incepted time is 0.02 s is considered. The corresponding results as shown in fig.3. The following subplots 3.a, 3.b, 3.c, 3.d represents the quantified three phase voltage and current signals of both sending end & receiving end respectively. Figure 3.d denotes the fault detection plot using absolute current phasors crosses the threshold 'T1' and figure 3.e represents the post fault absolute current phasors helps in identifying the type of fault by exceeding the threshold 'T2' value. It clearly identifies that absolute current phasor values are very less during normal conditon and were insignificant values at the time of a fault condition. As a result, the index values are higher than a threshold 'T1' it gives decision to relay for tripping within 2.2 ms after fault inception. Similarly using post fault data if phase-A and ground signals exceeds the value 'T2' then A-G fault is identified. Later using impedance based algorithm the estimated location is 10.2539 kms .

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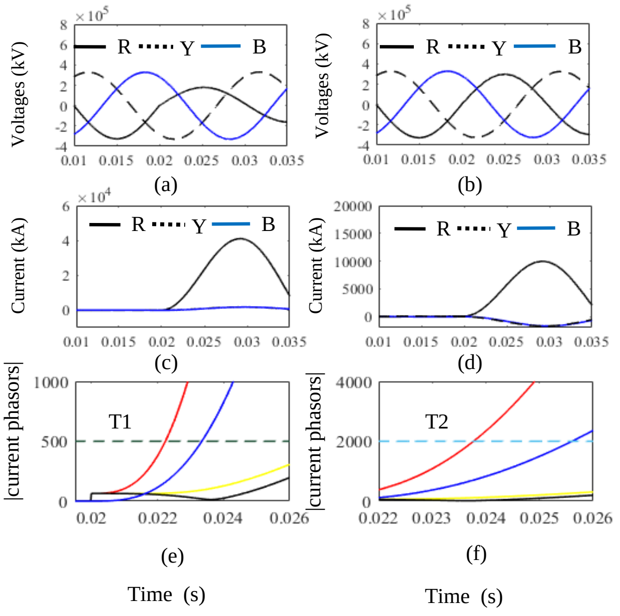

Fig. 4. Represent ofr AG fault during close –in fault conditon

b. High resistance condition

A double line to ground fault is simulated at a distance of 150 km with a fault resistance of 25Ω and fault incepted time is 0.0225 s is considered.

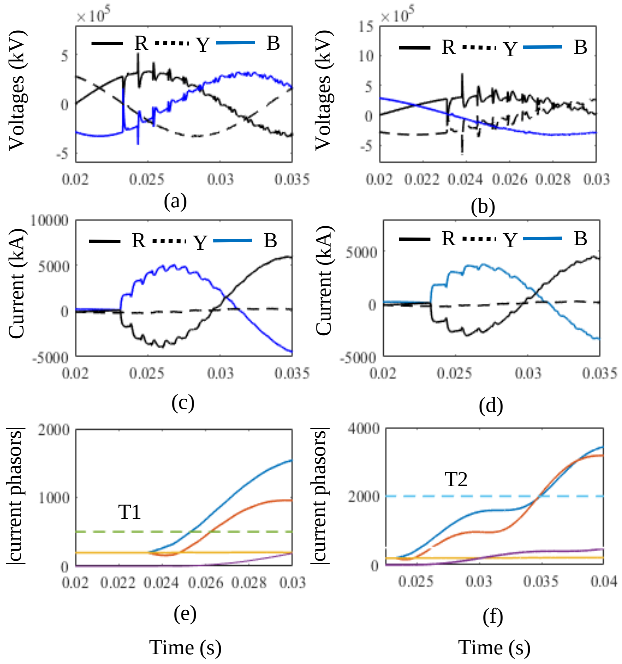

Fig. 5. Represent ofr ABG fault during High resistance fault conditon

Figure.4 represents the following subplots 4.a, 4.b, 4.c, 4.d represents the quantified three phase voltage and current signals of both sending end & receiving end respectively. Figure 4.d denotes the fault detection plot using absolute current phasors crosses the threshold 'T1' and figure 4.e represents the post fault absolute current phasors helps in identifying the type of fault by exceeding the threshold 'T2' value. It clearly identifies that absolute current phasor values are very less during normal condition and were insignificant values at the time of a fault condition. As a result, the index values are higher than a threshold 'T1' it gives decision to relay for tripping within 3.2 ms after fault inception. Similarly using post fault data if phase-A and ground signals exceeds the value 'T2' then A-G fault is identified. Later using impedance based algorithm the estimated location is 149.4856 kms .

c. Far end faults

A Three phase fault is simulated at a distance of 250 km with a fault resistance of 50Ω and fault incepted time is 0.0245 s is considered. The corresponding results as shown in fig.5. The following subplots 5.a, 5.b, 5.c, 5.d represents the quantified three phase voltage and current signals of both sending end & receiving end respectively. Figure 5.d denotes the fault detection plot using absolute current phasors crosses the threshold 'T1' and figure 5.e represents the post fault absolute current phasors helps in identifying the type of fault by exceeding the threshold 'T2' value. It clearly identifies that absolute current phasor values are very less during normal condition and were insignificant values at the time of a fault condition. As a result, the index values are higher than a threshold 'T1' it gives decision to relay for tripping within 3 ms after fault inception. Similarly using post fault data if phase-A and ground signals exceeds the value 'T2' then ABCG fault is identified. Later using impedance based algorithm the estimated location is 249.88 kms.

To validate the performance of the proposed method total 1050 case were simulated and give accurate results. Few test cases were presented in the table-1.

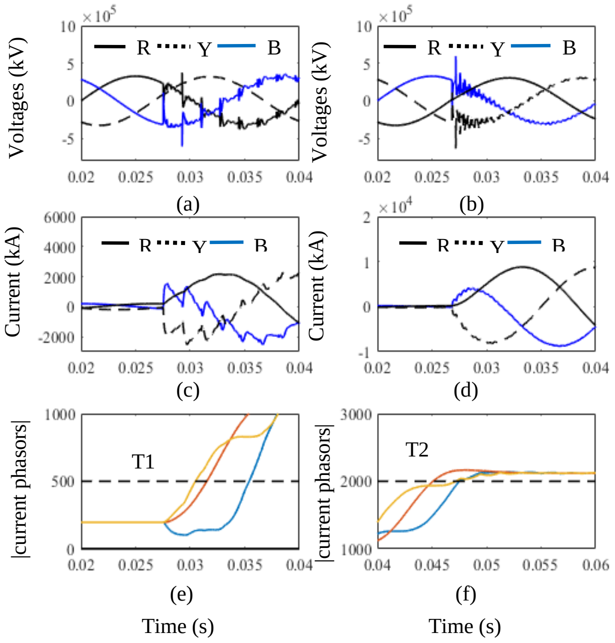

Fig. 6. Represent ofr ABCG fault during Far end fault conditon

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TABLE I. **PROPOSED METHIOD RESULTS**

S.I . no	***Fault distance in (kms)***	***Fault resistance***	***Fault inception time (msec)***	***Results of Proposed methods***		
				F.D (msec)	***F.C***	***F.L***
1	50	0.01	20	22	AG	46.511
2	150	25	21.7	23	CG	149.44
3	50	50	23.3	24.5	BG	46.511
4	240	0.01	25	26.2	ABC	239.56
5	10	25	26.7	28	BC	9.9736
6	90	50	28.3	30.7	CA	89.043
7	150	0.01	20	22	ABG	149.44
8	170	25	21.7	23	BCG	167.565
9	180	50	23.3	24.5	CAG	179.456
10	190	0.01	25	26.2	ABC	188.145
11	10	25	26.7	28	AG	9.9736
12	250	50	28.3	30.7	ABG	248.465
13	170	0.01	20	22	AB	167.565
14	260	25	21.7	23	BC	259.48
15	10	50	23.3	24.5	ACG	9.9736

IV. CONCLUSION

Fault detection, classification and location algorithm using fundamental phasor based approach. DFT is applied for extraction of fundamental phasors. Several years ago different approaches have been developed earlier to detect such faults but still they were facing drawbacks. The entire algorithm is tested on 400 kV, 50 Hz two terminal bus system by considering different fault events like fault resistance, fault distance, fault inception angle and fault type. Performance of the algorithm is also tested on two terminal lines system evaluated in MATLAB/SIMULINK under various fault conditions. Simulation results visualize the accuracy of the proposed method under different fault conditions and claims the capable of detecting any type of faults very quickly and reliably, identify and locate.

APPENDIX

System data: 400 kV, 50 Hz
$V_S = 400\angle 0^0$ kV, $V_R = 400\angle 5^0$ kV
length of line: L: 300 km.
Transmission Line Parameters:
ZL1: 0.03293 + j 0:3184 Ω/km, C1: 0.01136 µF/km ,
Z0: 0.2587 + j 1.1740 Ω/km, C0: 0.00768 µF/km,
Sampling frequency = 80 KHz.
Source parameters:
ZS1=ZR1= 0.06979 + j 1.99878 Ω/km
ZS0 =ZR0 = 0:2094 + j 5.9963 Ω/km

ACKNOWLEDGMENT

The author would like to acknowledge the college of SRKR Engineering, for providing the research facilities to complete this work. I, also thank to my co-authors for their support regarding fulfillment of this work.

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