Euclidean Metric based Fault Diagnosis in Power Transmission Line

Manohar Kintali, Srinivasa Rao Sura, Nageshwara Rao Pulivarthi, Aravind Kumar Kondaji

Abstract:*This article proposes a unique algorithm for the saf ety of the* power transmission line.*In real time power transmission line has abnormal situations include such as sudden load changes, transient switching operations and so on etc., In the process of protecting power transmission line with associated power system equipment normal electromechanical relays are not reliable for faults protection as they fail to detect faults accurately. So, the euclidean distance technique approach can work effectively even at transient situations. The recommended methodology is progressively precise to recognize faults in the electrical transmission line. With help of MATLAB / SIMULINK software for a 300km,400kv electrical tra nsmission line, the accuracy of the proposed scheme was evaluate d by varying fault index and fault resistances.*

Keywords : Euclidean distance, power transmission line, protection , transient switching operations, faults

I. INTRODUCTION

Power transmission lines are very important in Power transmission lines are significant in real-time power systems as it empowers transferring of power from generating systems to load systems.. Power transmission line faults occurs frequently, which interrupts continuity of power supply and connected power system equipments

Some faults are very low in magnitude which may not affect the transmission line.

Transient faults interrupts continuity of power supply and damages linked power system equipments in power transmission line. Fault detection and classification are very important tasks in power transmission line protection. These tasks must be achieved quickly and accurately to protect the power transmission line and restore the power system. For the speedy operation of power system protective relays, accurate information about the type of fault is provided with in half a cycle.

In the earlier stage of fault classification, several techniques are formulated based on voltage and current samples considered from load and source ends of power transmission line. Later the artificial intelligence like ANN had been replaced as novel techniques to identify the faults types. There are different approaches that are considered for the fault classification in three phase power transmission line [1],[4].

Mohanty *et al.* proposed a cumulative sum-based technique [1]. Wang *et al.* proposed a protection scheme using computational intelligence-based classification algorithm using fault incidence angle effect [2]. Silva *et al.* proposed new fault detection algorithm using wavelet transform [3]. Bandaru *et al.* proposed an algorithm based on alienation coefficients to detect and classify faults [4],[5].

This article is categorized into five sections Section-2 pre sents the Euclidean distance technique, section 3 explains th e suggested algorithm, section 4 illustrates the detection and classification of power transmission line and paper with resu lts and analysis was concluded in section 5. with results and analysis.

II. EUCLIDEAN DISTANCE TECHNIQUE

In this research article we have considered a Euclidean distance method to identify different power transmission line faults and diagnose type of fault. In this work we have considered current signals for the detection of the fault.

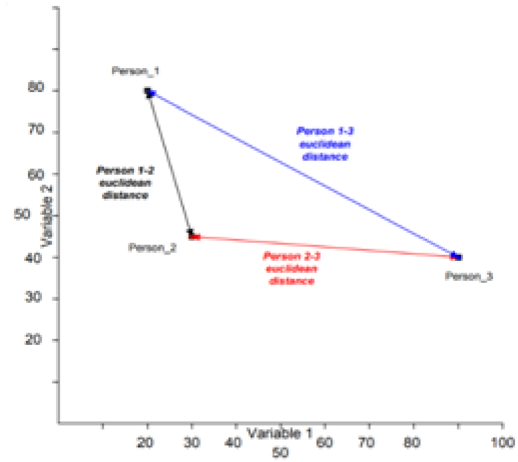

Fig. 1. Euclidean distance between two points

This Euclidean distance technique is accurate technique even in the conditions like sudden changes in load, transient switching operations etc., in which the normal relays may not detect at these conditions. This procedure is utilized to order and identify a wide range of faults in power transmission line. This method is tested with the MATLAB/SIMULINK

Euclidean distance technique is a technique for identification and classification based on euclidean metrics, which corresponds to trial and error, where the distance between the points relates length of the line between them. The Euclidean distance is calculated using the Pythagorean formula.

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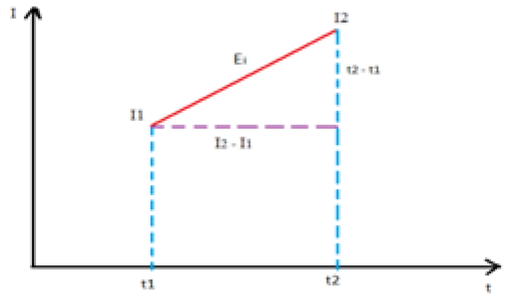

Fig. 2. Euclidean distance between two current samples

.In euclidean system consisting of two points labelled as x and labelled as y if x=(x_1,x_2,….,x_n) and y=(y_1,y_2,….,y_n) then the distance(E_i) between the points x and y is given by Pythagorean formula.

$$d=\sqrt{((q_1-p_1)^2+(q_2-p_2)^2+\cdots+(q_n-p_n)^2)} \quad (1)$$

$$d=\sqrt{\sum_{i=0}^{n}(q_n-p_n)^2} \quad (2)$$

In the present paper we are considering the two-dimensional euclidean distance between two progressive current samples. Here let us consider two successive current samples I_1 ,I_2 at the time t_1 ,t_2 respectively. So the Euclidean distance technique is the distance between the successive current samples that is I_1 and I_2 current samples at respective time instansts t_1 and t_2. Which is calculated using the Pythagorean formula as show below in Fig. 2.

$$E_i=\sqrt{((t_2-t_1)^2+(I_2-I_1)^2)} \quad (3)$$

where E_i is the Euclidean distance between I_1 and I_2 .

This approach makes to detect all the types of faults in the transmission line. It can also be worked under the conditions like sudden load changes, switching operations etc., .By this approach we can have the fault classification even for very high impedance faults i.e., up to 50 ohm. At different lengths of line any location on transmission line the fault can be detected by using this technique. In this paper we have tested this approach at any location of fault and for different lengths of lines and at different fault resistances and for different types of faults.

III. PROPOSED ALGORITHM

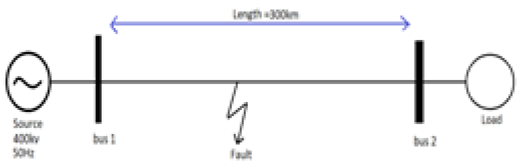

Fig. 3. Single line diagram of proposed model

The proposed Euclidean separation method has been researched on a power transmission framework model as appeared in Fig.3.

300km and having a transmission line system source voltage of 400kv,50HZ frequency[1]. Positive sequence parameters such as resistance, inductance and capacitance of the transmission line are 0.023Ω,0.95mH and 12. The negative sequence parameters are same as the positive sequence parameters. zero sequence parameters are 0.388 Ω,3.25mH and 8.45µF.Positive and negative sequence of source impedance (Z_s) are (0.45+j5) Ω per phase and the zero sequence impedance is one-and-half times positive sequence impedance.

The methodology for this technique is determined as shown in the Fig. 4. Initially a power transmission line is simulated in the MATLAB/SIMULINK. In the flow chart given below the N_a, N_b , N_c are the maximum Euclidean distance between two successive current samples of phase A,B,C respectively during healthy condition i.e., during no fault. These values are read and used as a reference for the fault classification.

Here we are considering e_a, e_b, e_c are the Euclidean distance between the two successive current samples at a step time change (we considered step time change or sampling time as 0.001sec half cycle time data) of phase A, phase B and phase C respectively in healthy condition.

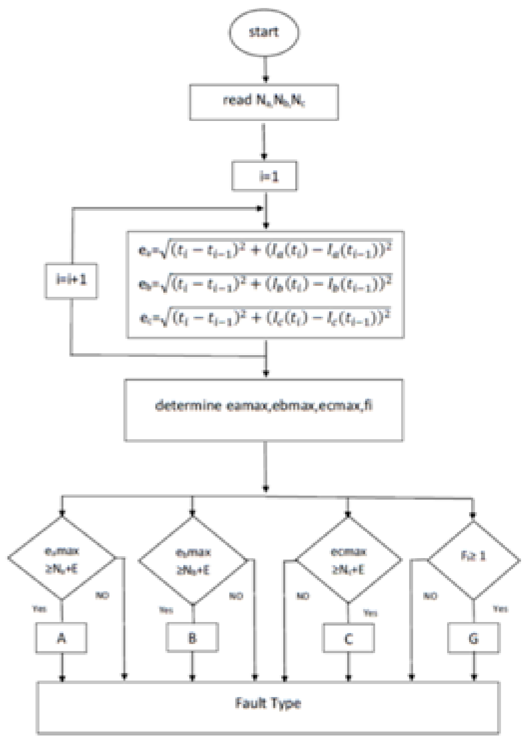

Fig. 4. Euclidean distance based fault detection algorithm

So these ea, e_b, e_c are calculated along the time period and $e_a$max, $e_b$max, $e_c$max are the maximum values of Euclidea distance between any two successive current samples along the time period i.e., among the e_a, e_b, e_c for all the samples for phases A,B,C respectively. Now the fault is detected if any of them $e_a$max, $e_b$max, $e_c$max is greater than the N_a,N_b,N_c with a error correction factor E i.e.,($e_a$max>N_a+E, $e_b$max>N_b+E, $e_c$max>N_c+E).

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Here error correction factor E is considered in order to ignore the disturbances and false faults. In this which maximum euclidean distance is greater than the maximum euclidean distance during no fault condition with a sum of error correction factor that phase is considered as faulty phase. By this we can detect the type of fault along with faulty phases.

IV. DETECTION AND CLASSIFICATION OF POWER TRANSMISSION LINE FAULTS

To determine whether the attained fault is ground fault or not, we consider an index called fault index (F_i).Fault index [3] is the maximum value of sum of all the phase currents at a particular time interval that is given in the equation (4).,

$$F_i=\max(Ia+Ib+Ic) \quad (4)$$

Ia, Ib, Ic are individual phase currents of phase A, phase B and phase C .. If the value of F_i greater than 1 , it indicates that as ground fault, or if F_i is less than 1 then it indicates that as phase fault.

Table-I: Fault index(F_i) for phase faults

Nature of fault	For R_f=1Ω	For R_f=10Ω	For R_f=25Ω	For R_f=50Ω
	F_i	F_i	F_i	F_i
ABC	$2.48e^{-13}$	$3.41e^{-13}$	$3.30e^{-13}$	$2.41e^{-13}$
AC	$5.006e^{-4}$	$5.006e^{-4}$	$5.006e^{-4}$	$5.006e^{-4}$
BC	$5.18e^{-4}$	$5.18e^{-4}$	$5.18e^{-4}$	$5.18e^{-4}$
AB	$4.92e^{-4}$	$4.93e^{-4}$	$4.94e^{-4}$	$4.93e^{-4}$

Table-II: Fault index(F_i) for ground faults

Nature of fault	For R_f=1Ω	For R_f=10Ω	For R_f=25Ω	For R_f=50Ω
	F_i	F_i	F_i	F_i
AG	30.678	25.026	18.55	13.105
BG	21.208	19.98	17.0427	12.8588
CG	21.1846	19.8344	17.1774	12.9404
ABG	17.4523	15.5932	13.2229	10.4610
BCG	14.7305	14.0889	12.7407	10.3732
ACG	17.0339	15.0288	12.4646	10.3192

The power transmission line is simulated in MATLAB/SIMULINK environment to classify various power transmission line faults with a various faulty resistances i.e., 50 Ohm, 25Ohm, 10 Ohm, 0.001Ohm. in power transmission line. Faulty phase of transmission line has more maximum euclidean metrics than healthy phase of power transmission line. Maximum Euclidean distances for different fault types in power transmission line are tabled as shown below.

Table-III: Maximum Euclidean distance of all phases for fault resistance of 0.001ohm

Fault type	R_f=0.001		
	eamax	Ebmax	ecmax
AG	8.3740	3.3008	3.2616
BG	3.2223	8.4993	3.2616
CG	3.2222	3.3008	8.0990
ABG	13.4646	10.2294	3.2618
BCG	3.2223	12.9601	10.0702
ACG	10.0750	3.3008	13.0663
AB	12.7800	9.8270	3.2618
BC	3.2223	12.3990	9.3679
AC	9.8282	3.3009	12.9858

Table-IV: Maximum Euclidean distance of all phases for fault resistance 1ohm

Fault type	R_f=1		
	eamax	ebmax	ecmax
AG	8.3834	3.3008	3.2616
BG	3.2223	8.4977	3.2616
CG	3.2222	3.3008	8.1378
ABG	13.4603	10.4492	3.2618
BCG	3.2223	12.9143	10.2473
ACG	10.3187	3.3008	13.115
AB	13.0073	10.0811	3.2618
BC	3.2223	12.4747	9.4411
AC	9.9804	3.3009	13.1379
ABC	13.7513	13.0172	12.7897

Table-V: Maximum Euclidean distance of all phases for fault resistance 10ohm

Fault type	R_f=10		
	eamax	ebmax	ecmax
AG	8.2426	3.3008	3.2616
BG	3.2223	8.3551	3.2616
CG	3.2222	3.3008	8.2370
ABG	12.5134	10.6227	3.2618
BCG	3.2223	12.1254	10.4583
ACG	10.9057	3.3008	12.2701
AB	12.6143	10.0581	3.2618
BC	3.2223	12.2383	9.6783
AC	10.0197	3.3009	12.3042

ABC	12.8336	12.4962	12.7605

Table-VI: Maximum Euclidean distance of all phases for fault resistance 25ohm

Fault type	R_f=25		
	eamax	Ebmax	ecmax
AG	7.7449	3.3008	3.2616
BG	3.2223	7.9884	3.2616
CG	3.2222	3.3..8	7.7837
ABG	10.1310	9.7623	3.2618
BCG	3.2223	9.9791	9.7862
ACG	9.7250	3.3008	10.0525
AB	10.3481	8.4394	3.2618
BC	3.2223	10.2357	8.4282
AC	8.4346	3.3009	10.5227
ABC	10.8248	10.7250	10.6472

Table -VII: Maximum Euclidean distance of all phases for fault resistance 50ohm

Fault type	R_f=50		
	eamax	Ebmax	ecmax
AG	6.9304	3.3008	3.2616
BG	3.2223	7.0125	3.2616
CG	3.2222	3.3008	6.9506
ABG	7.6496	7.9073	3.2618
BCG	3.2223	7.7416	7.9969
ACG	7.9310	3.3008	7.8092
AB	7.8087	6.8745	3.2618
BC	3.2223	7.8744	6.7508
AC	6.8062	3.3009	7.8632
ABC	8.2964	8.2540	8.2391

V. RESULTS AND ANALYSIS

The results are considered for the fault resistance 0.001(R_f) to the simulated transmission line model. In this approach we are considering the positive difference as the fault(i.e., greater than maximum Euclidian distance during healthy condition),we are consider the negative difference as maximum euclidean distance at healthy condition(i.e., the Euclidean distance less than maximum euclidean distance at normal condition means that no fault).So by this assumption we will get a normal straight line during healthy condition. The results are taken out between the euclidean distance of a current sample with its post sample and the time of the current sample. The fault is given at 150km of distance from the source at a time 0.12sec.The results for different faults are shown below.

A. No Fault

In this condition the waveform for all the three phases are in a straight line without any fluctuations in the waveform. This results that the all the three phases are clear without any fault. The results for no fault are as shown below.

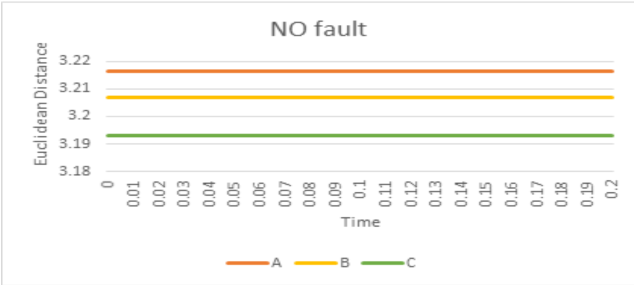

Fig.5. Euclidean distance at no fault condition.

B. AG Fault

In this condition the phases B, C are in a straight line without any disturbances. But the phase A has a high rise in magnitudes if euclidean distance that results to a high deflection in AG fault. This outcome tells that phase A has a fault in contrast with phase A and Phase B. Outcome of AG fault is demonstrated as follows.

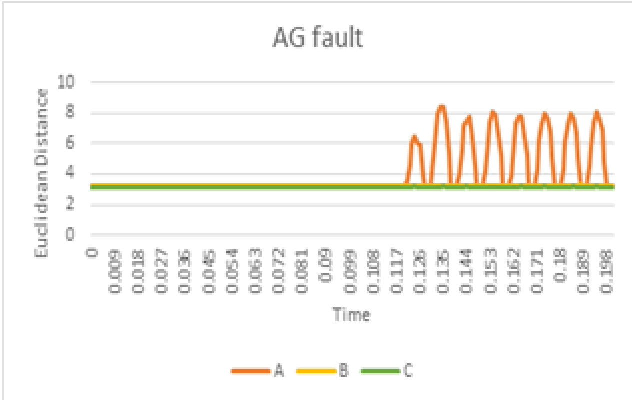

Fig.6. Euclidean distance at AG fault condition.

C. BG Fault

In this condition the phases A,C are in a straight line without any disturbances. But the phase B has a high rise in magnitudes if Euclidean distance that results to a high deflection in it . This results that the phase B has a fault in it.

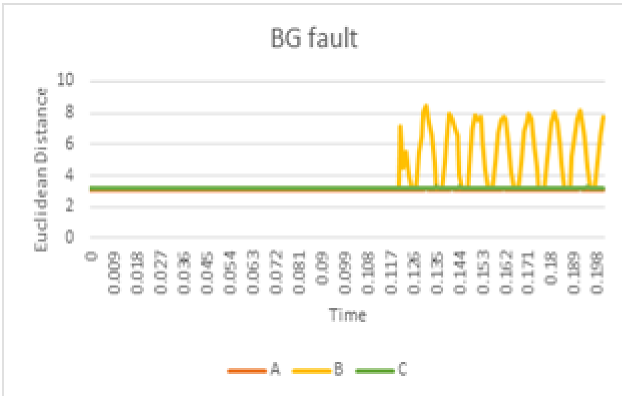

Fig.7 Euclidean distance at BG fault condition.

The results for the BG faults are as shown below.

D. CG Fault:

In this condition the phases A,B are in a straight line without any disturbances. But the phase C has a high rise in magnitudes of euclidean distances that results to a high deflection in it .This results that the phase C has a fault in it. The results for the CG faults are as shown below.

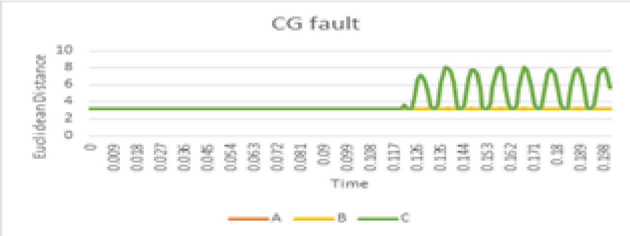

Fig.8 Euclidean distance at CG fault condition.

E. AB Fault

In this condition the phases C are is in a straight line without any disturbances. But the phase A and B has a positive change in magnitudes in their euclidean distances that results to a deflection in both the phases. This results that the phase A and B has a faults. Here the phase A has a high rise in magnitude deflection than phase B and the fault index is less than 1. So this indicates AB fault. The results for the AB faults are as shown below.

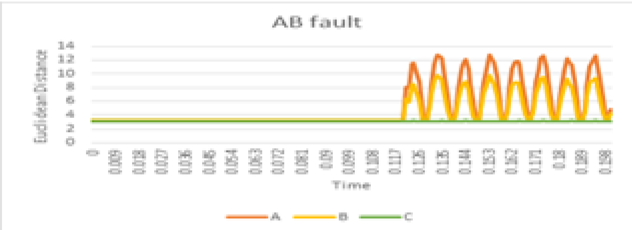

Fig. 9. Euclidean distance at AB fault condition.

F. BC Fault

In this condition the phases A are is in a straight line without any disturbances. But the phase B and C has a positive change in magnitudes in their Euclidean distances that results to a deflection in both the phases. This results that the phase B and phase C has a fault. Here the phase B has a sky scraper rise in magnitude deflection than phase C and the fault index is less than 1. So, this indicates BC fault. The results for the BC faults are as shown below. Fig.10. Euclidean distance at BC fault condition.

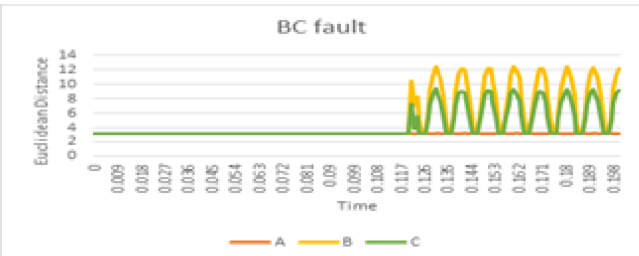

Fig.10. Euclidean distance at BC fault condition.

G. AC Fault

In this condition the phase B are is in a straight line without any disturbances. But the phase A and C has a positive change in magnitudes in their euclidean distances that results to a deflection in both the phases. This results that the phase A and C has a faults. Phase C has a high rise in magnitude deflection in comparision with phase A and the fault index is less than 1. So this indicates AC fault. The results for the AC faults are as shown below.

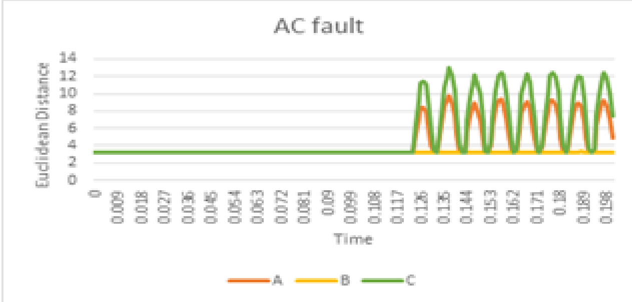

Fig.11. Euclidean distance at AC fault condition.

H. ABG Fault

In this condition phase C is in a straight line without any disturbances. But phase A and B has a positive change in magnitudes in their euclidean distances that results to a deflection in both the phases. This results that the phase A and B has a fault. Here the phase A has a high rise in magnitude deflection than phase B and the fault index is greater than 1. So, this indicates ABG fault. The results for the ABG faults are as shown below.

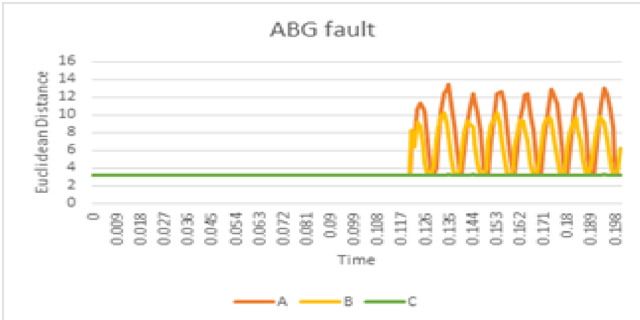

Fig. 12. Euclidean distance at ABG fault condition.

I. BCG Fault

In this condition the phases A are is in a straight line without any disturbances. But the phase B and C has a positive change in magnitudes in their euclidean distances that results to a deflection in both the phases. This results that the phase B and phase C has a fault. Here the phase B has a very high rise in magnitude deflection than phase C and the fault index is greater than 1. So, this indicates BCG fault. The results for the BCG faults are as shown below.

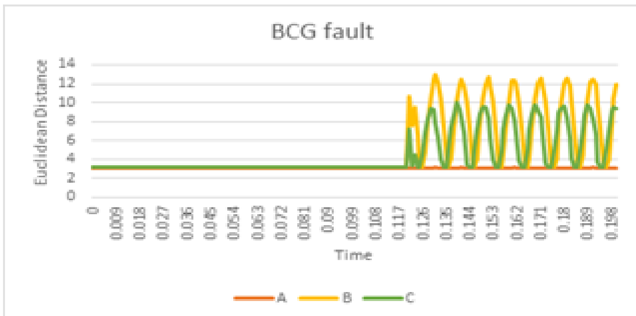

Fig.13. Euclidean distance at BCG fault condition.

J. ACG Fault

In this condition the phases B is in a straight line without any disturbances. But the phase A and C has a positive change in magnitudes in their euclidean distances that results to a deflection in both the phases. This results that the phase A and phase C has a fault. Phase C has a high rise in magnitude change compared to phase A phase B and the fault

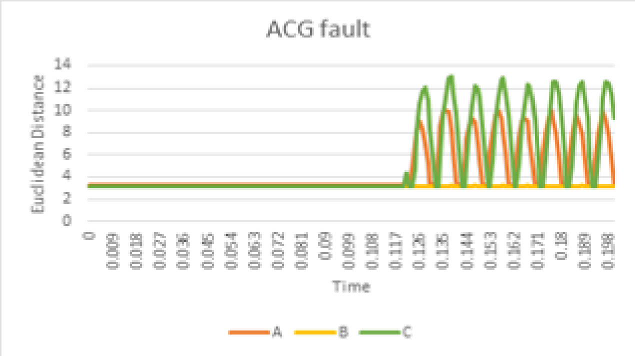

Fig.14. Euclidean distance at ACG fault condition.

index is greater than 1. So, this indicates ACG fault. The results for the ACG faults are as shown below.

K. ABC Fault

In this condition the waveform for all the three phases are having a high magnitude changes in the waveform. This means that all the three phases having high euclidean distances that results to the high rise in deflections in those wave forms. This results that the all the three phases are having faults. So this is the ABC fault condition. We know that the fault effect of ABC and ABCG are of similar or approximately equal. The results for the ABC faults are as shown below.

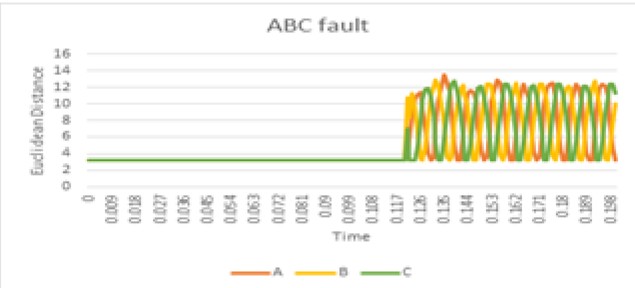

Fig.15. Euclidean distance at ABC fault condition.

VI. CONCLUSION

A euclidean distance method is proposed in the power tra nsmission line for identification of faults and classification o f faults. Current signals are used in euclidean distance technique approach for power transmission line fault detection. This approach considers the maximum euclidean distance between two successive currents samples during post fault as a reference. Based on the value of fault index (Fi) the proposed method detects the ground fault or phase fault. Simulation was done in MATLAB/SIMULINK for 400kv, 50Hz ,300km line length to check the results of the proposed technique. Simulation has been performed for various fault indexes, fault resistance and Power transmission system fault conditions. Results indicate the accuracy and speed in detection of fault during any transient condition.

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