# A New Fault Detection Method for Protection of a Two Terminal Transmission Line System

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***Abstract:*** *This paper illustrates a new approach to detect different types of faults occurring in a two terminal transmission line network. In this proposed method, current phasors are estimated using discrete Fourier transform and a Euclidean distance based fault index is designed to detect faults. The basic idea of any detection algorithm is simply detection of variation of network signal when system subjected to random changes. But this leads to unnecessary trip signal during non fault events like frequency deviation, load changes, noise, power swing, CT saturation etc. if the algorithm is effective then it will handle different situations in an accurate manner. The proposed method detects different types of normal faults, faults with high impedance, faults locating at remote ends and some of the non fault events. The method also discriminate non fault cases from faults. All above situations and a suitable limit value which classifies faults from non fault events. Results are verified in MATLAB-SIMULINK software.*

***Key words:*** *Transmission line protection, Discrete Fourier transform, Euclidean distance, High Impedance Fault*

## 1. Introduction.

Transmission line is a part of power system which connects generating units and load centers. Transmission line protection is a challenging issue in the area of power system components and their protection because it is the critical component where the probability of occurrence of faults maximum. In general power is sending from generating stations to consumers through proper transmission system and it carries current which is a pre determined value when the system operates under normal condition. When any short circuit taking place with one of the phase of the transmission line to ground or another phase, it leads to abnormal change in the magnitude of the power system signals like current, voltage and power[1]-[3].

Initially Wavelet transform was introduced in 1980s and applied in many electrical engineering problems such as power quality, protection etc. Wavelets were extensively applied in many papers by considering several operating conditions [4-5].Artificial intelligent based techniques like Fuzzy logic [11], artificial neural networks (ANN) [6-7, 9], and Support Vector machines (SVM) [8, 10] were developed and these techniques were applied for power system protection area for fault Detection, classification and location. Phasor estimation techniques were also implemented for detection and to estimate location [12-13]. In this paper a combined method is implemented and successfully applied for two terminal transmission line system using matlab simulink. The paper organizes as follows: chapter 1 includes introduction, chapter 2 consists proposed method with flow chart, chapter 3 consist system studied, and simulation results for different cases which includes several fault cases and non fault events. Chapter 4 is discussions and final chapter consist conclusion with future scope.

## 2. Proposed Method

In the last few years, several methods were proposed based on the mathematical background. Here a new strategy is analyzed with current phasor as input. Discrete Fourier transform (DFT) is used for estimation of current phasor. DFT is the most commonly used technique in power system relaying. In general, extraction of a particular frequency component is done using Fourier transform. However, in relay environment, sampled data at discrete time step is available for processing [12]. Therefore, the Fourier-transform calculation is also done in discrete environment and is termed as Discrete Fourier Transform or DFT. Equation 1 shows the frequency domain sample of I for i[n].

$$I(j\omega) = \sum_{n=-\infty}^{+\infty} (i[n]).e^{-j\omega n}$$

For a pure sinusoidal current or voltage signal,

$$I(t) = I_m.\cos(2\pi ft+\theta)$$

The discrete representation of the signal of N samples is given by

$$I[n] = Im.\cos(2\pi \frac{n}{N} +\theta)$$

$$I = \frac{2}{N}\sum_{n=0}^{N-1} I_m.\cos(2\pi \frac{n}{N} + \theta)e^{-j2\pi \frac{n}{N}}$$

By using Euler identity, the above equation can be modified as

$$I = \frac{1}{N}\sum_{n=0}^{N-1} I_m.(e^{j(2\pi n/N+\theta)} + e^{-j(2\pi n/N+\theta)}).e^{-j2\pi \frac{n}{N}}$$

The above equation includes both real and imaginary parts $I_{real}$, $I_{img}$ and the amplitude of the phasor is given by

$$Iamp = \sqrt{(I_{real}^2 + I_{img}^2)}$$

After calculating magnitude of current phasor, a Euclidean distance measure is calculated for side by side samples. Euclidean distance (ED) is defined as the ordinary distance between two points that is deduced with the Pythagorean Theorem. To obtain the distance between two points A and B at $i^{th}$, $(i+1)^{th}$ instants, in coordinates (K (i), $I_{amp}$ (i)) and (K (i+1), $I_{amp}$ (i+1)) respectively, is:

ED(AB) =

$$\sqrt{(I_{amp}(i+1) - I_{amp}(i))^2 + (K(i+1) - K(i))^2}$$

For effective detection, cummulative addition of ED is calculated and which is taken as a final fault index to decide any fault occurs or not.

$$ED(k) = ED(k-1) + \max(ED(k) - \lambda, 0)$$

Here ED(k), ED(k-1) are the euclidean distances of side by side samples for k, k-1 instants/samples. $\lambda$ is the pre-fixed value obtained in normal operation of the system. Finally decision is made by the following equations.

If ED(k) > I, then there exist fault, otherwise there is no fault in the system.

## 3. System Studied and Simulation Results

The proposed Algorithm is tested by considering different typical cases which not only includes normal faults but also switching transients and High Impedance faults etc. however many traditional methods are effectively.

### 3.1 System Studied

A 230-kV, 50-Hz two terminal transmission line systems has been chosen to assess the performance of proposed fault detection method. The transmission line length is 300 Km. the sending end area operated at 10 degrees angle and receiving end area is operating at 0 degrees. In general any fault detection technique is verified for different situations like normal faults like LG, LL, LLG, LLL and LLLG, faults with different inception angles and faults with high impedances. In this paper the proposed method is tested under following cases.

### 3.2. Performance during Different faults

The basic objective of any fault detection algorithm is detection of different types of faults. In general there are two catagories of faults known as symmetrical and asymmetrical faults. In three phase power system, several faults like line to ground faults, line to line faults, line to line to ground faults and three phase faults are occuring at different locations of transmission line of the power system network. In this paper, the proposed algorithm is tested under Different faults. Figue 1 represents the detection indices for normal A-G fault located at 20 km from sending end. Figure 2 represents detection plot for A-B type fault located at 20 km from sending end with different inception. Similarly figures 3 and 4 represents BCG, ABC faults. From all the results it is concluded that the proposed algorithm effectively detects all types of faults located at different locations of transmission line system with different fault resistances incepted at different angles.

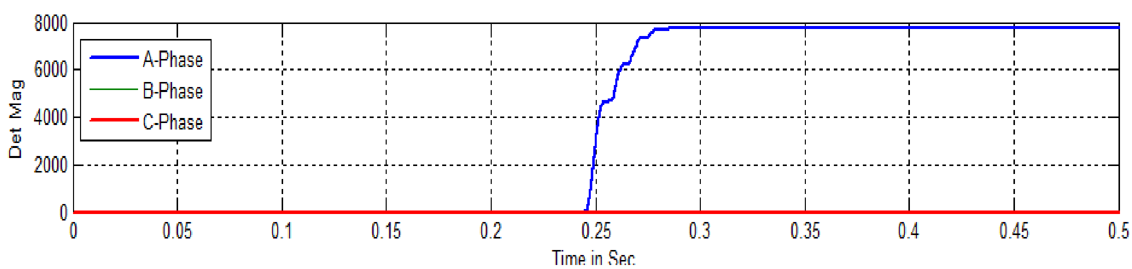


Figure 1: Fault Detection Index for L-G (A-G) fault

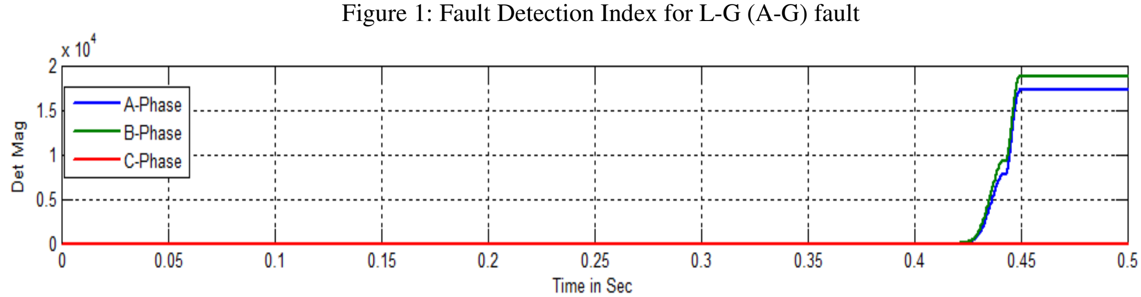


Figure 2: Fault Detection Index for L-L Fault type (A-B)

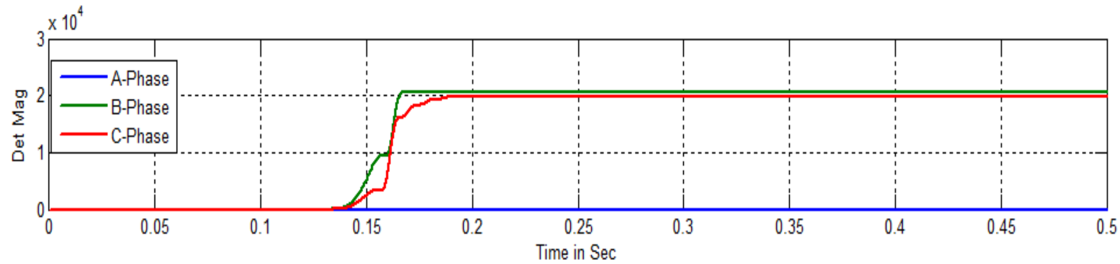

Figure 3: Fault Detection Index for L-L-G fault (B-C-G)

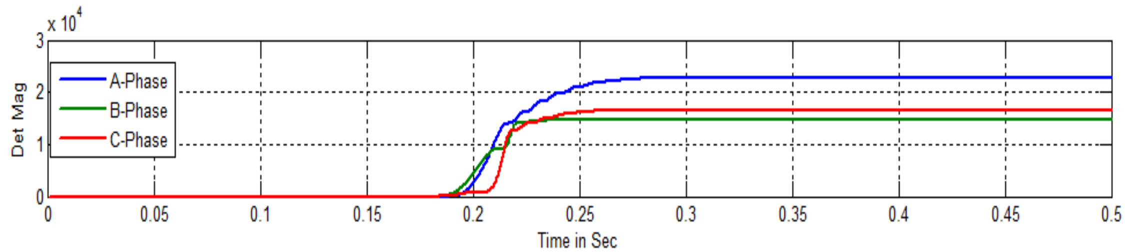

Figure 4: Fault Detection Index for L-L-L fault (A-B-C)

The magnitude of fault index is nearly 40000 for faults occurring nearer to sending end where current and voltage measurements are placed. The magnitude of fault index is nearer to 3000 when faults locating far away from measuring units. However in both cases the magnitude is enough to detect faults.

**3.3 Performance during fault conditions**

Transmission lines are the only components of power system where the probability of occurence of faults is maximum due to its explosure into atmosphere. In this paper, the proposed method is verified under different faults occurring at different lengths, faults with different inception angles and different times etc. this method is tested under faults with high impedances. Generally many fault detection algorithms are failed if the signal consists less disturbance even the magnitude changes drastically. Another important issue in protection of transmission lines is detection of faults occurring far away from the sending end. These types of drawbacks are also eliminated by using proposed method. From figures 1-4, all types of faults are detected by proposed method irrespective of location fault, inception of fault etc., All the above mentioned cases are tested using given test system and results are mentioned in the following tables 1-3.

***3.4. Performance during Non Fault events***

Designing of fault detection algorithm is purely based on either current signals or voltage signals or both signals of operating system. Because if the power system operating under normal operating condition, the voltage and current signals are purely sinusoidal. If any fault occurs at any section of system then corresponding voltage and current signals deviates from their normal operating conditions. Detection of such deviation is enough to design a fault detection algorithm. There are certain situations in power system where unnecessary operation of relay takes place. In situations like capacitor switching, noise, load changes, spikes and frequency deviation etc , there is a chance of deviation operating signals of relay there by unnecessary tripping and interruption of electrical power will occur. But power supply without interruptions is also important with protection. So the reliability of any detection algorithm is purely depends on its handling capacity with fault conditions as well as no fault events. In this paper, the technique proposed by the authors is very effective under fault conditions and it is most suitable under most of the non fault events. Figure 5 represents detection plot of proposed method under switching transients. Consider initially system operates under normal condition with current magnitude $I_s$ and there is a sudden disturbance due to capacitor switching, many traditional algorithms are failed and unnecessary tripping will Produce, but the proposed method will isolate this case from fault cases by increasing threshold value with small amount and it improves the reliability of the given algorithm. Another important non fault events are spike and capacitor switching. Fig 6 shows a current wave form with spikes. Fig 8 represents the detection plot of proposed method under spikes. In final detection plot, the detection indices varies between 10 to 400 and at sending end side it is completely eliminated.

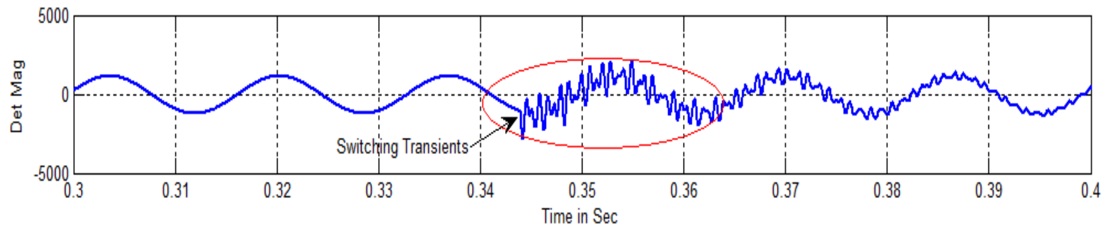


Figure 5: Instantaneous current in case of switching transients

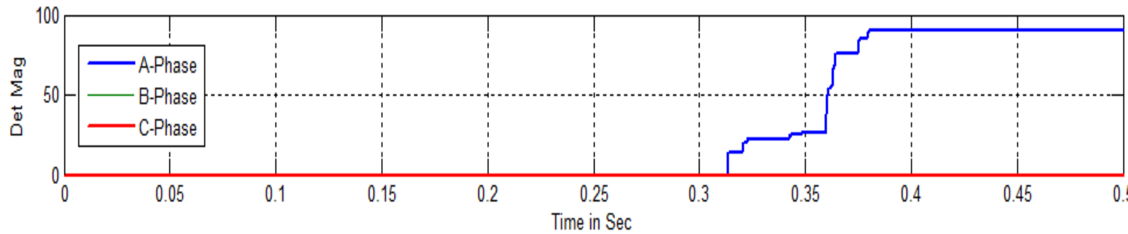


Figure 6: Fault Detection Magnitude in case of capacitor switching

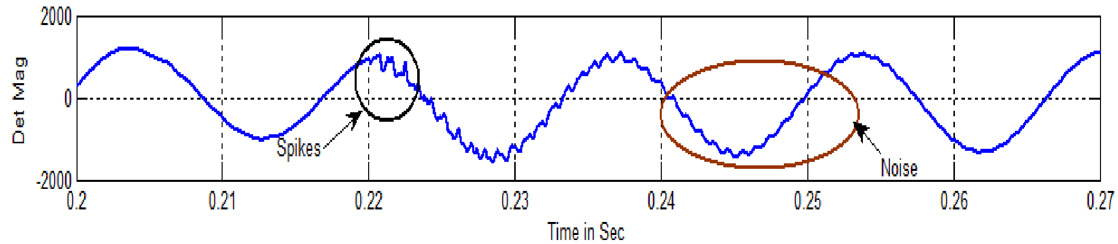


Figure 7: Current waveform with spikes and noise

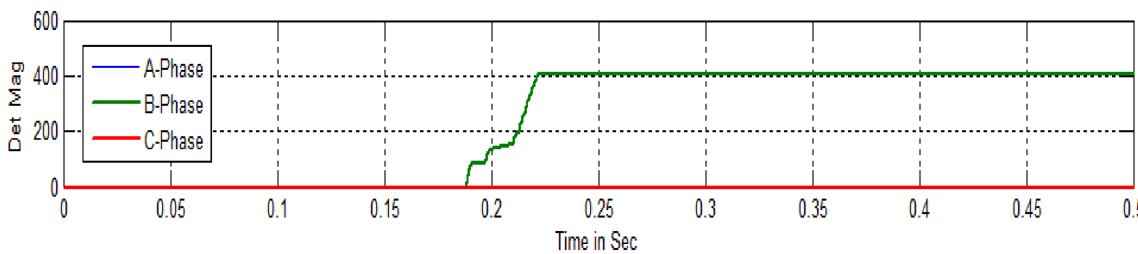


Figure 8: Fault Detection Index for spike Noise

### 3.5. Performance during High Impedance faults

The original signal under fault consist two parts namely normal and disturbance part. The fault detection is easily achieved as the disturbance part of the signal produces an irregular shape compared to the shape produced from the normal part of the signal. By selecting suitable threshold value the starting point of irregular part can be found. But in case of HIF the disturbance part is closely equal to normal signal and the detection of these types of faults are difficult with conventional algorithms. But the proposed method is effectively detects high impedance faults with fault impedance of 100Ω. But the magnitude of fault index is relatively low when compared to normal faults. The magnitude for an LG type fault with $R_f$= 30Ω is 3000 which is approximately equal to FDI of normal faults locating at F2 point. The magnitude for an LG type fault with $R_f$= 100Ω is 600 which is approximately larger than FDI of non fault events. The maximum possibility of detection of high impedance faults is of order 120Ω.

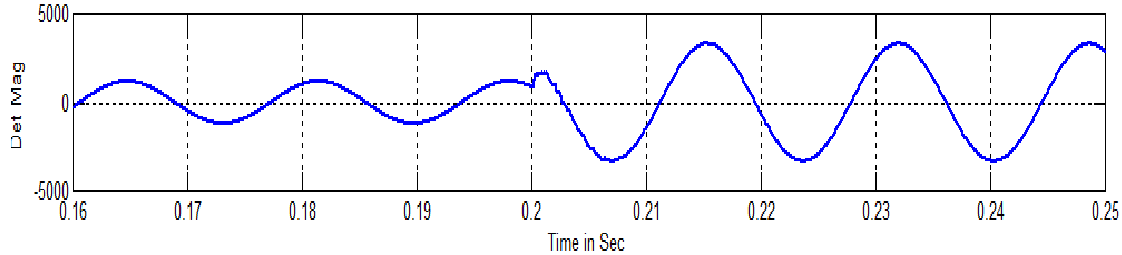


Figure 12: Current waveform in case of HIF

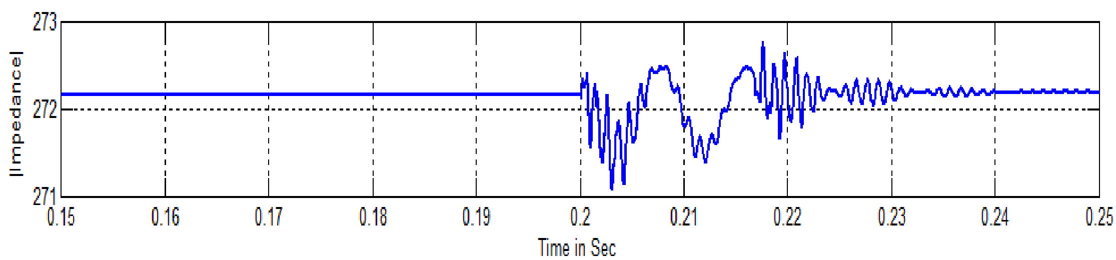


Figure 13: magnitude of Impedance seen by DFT method

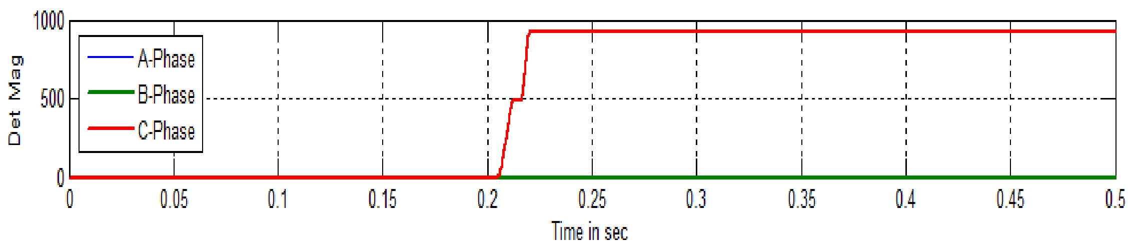


Figure 14: Fault Detection Index for L-G fault with HIF

## 4. Discussions

Several cases were examined in this paper including normal faults of 11 types by varying fault inception, fault location and fault impedance. Table 1 shows the detailed list of magnitudes of fault index for faults occurring at F1 and F2. F1 is point which is away from 20 Km from bus A whereas F2 is point which is located at 280 km from sending end bus A. The index magnitude gradually reduces if the location of faults moves away from relay position A. Table 3 show fault indices for high impedance faults with impedance values 30Ω, 50Ω, 80Ω and 100Ω. FDI's of other non fault events are also mentioned in table 3. From all tables listed above, it is evident that there is a clear differentiation between normal faults locating at nearer to the relay point and faraway from relay point so it can be extended for finding fault location also.

**Table1: Detection indices for various faults at Sending end**

| Type of fault | **Location: 20 Km from A (F1)** | | |
|---|---|---|---|
| | Sa | Sb | Sc |
| *A-G* | **1.999e+4** | 0 | 0 |
| *B-G* | 0 | **1.334e+4** | 0 |
| *C-G* | 0 | 0 | **1.586e+4** |
| *A-B* | **2.872e+4** | **2.757e+4** | 0 |
| *B-C* | 0 | **1.910e+4** | **1.789e+4** |
| *C-A* | **3.043 e+4** | 0 | **3.134e+4** |
| *A-B-G* | **3.275 e+4** | **2.471e+4** | 0 |
| *B-C-G* | 0 | **2.077e+4** | **2.036e+4** |
| *A-C-G* | **3.188 e+4** | 0 | **3.109e+4** |
| *A-B-C* | **3.867 e+4** | **2.476e+4** | **2.955e+4** |
| *ABCG* | **3.867 e+4** | **2.477e+4** | **2.954e+4** |

**Table 2: Detection indices for various faults at receiving end**

| Type of fault | **Location: 20 Km from B (F2)** | | |
|---|---|---|---|
| | Sa | Sb | Sc |
| *A-G* | **4460** | 0 | 0 |
| *B-G* | 0 | **3143** | 0 |
| *C-G* | 0 | 0 | **3304** |

| | | | |
|---|---|---|---|
| *A-B* | **7853** | **6711** | 0 |
| *B-C* | 0 | **6085** | **4909** |
| *C-A* | **7250** | 0 | **8265** |
| *A-B-G* | **8889** | **6090** | 0 |
| *B-C-G* | 0 | **6624** | **4938** |
| *A-C-G* | **7744** | 0 | **8046** |
| *A-B-C* | **1.052e+4** | **7279** | **7384** |
| *ABCG* | **1.052e+4** | **7279** | **7384** |

**Table 3: Detection indices for various cases**

| Type of Fault | S | Case Study | S |
|---|---|---|---|
| *A-G Rf=30* | **3244** | *Noise in A* | **106.4** |
| *B-G Rf=30* | **2882** | *Noise in B* | **98.45** |
| *C-G Rf=30* | **3079** | *Noise in C* | **73.8** |
| *A-G Rf=50* | **1885** | *Spikes & Disturbances* | **444.1** |
| *B-G Rf=50* | **1702** | *Spikes & Disturbances* | **338.5** |
| *C-G Rf=50* | **1823** | *Spikes & Disturbances* | **388.9** |
| *A-G Rf=80* | **935.6** | | |

## 5. Conclusions

A new fault detection method is presented in this paper for protection of two terminal transmission line systems which is extended for phase selection also. Initially the method is tested for detection of all types of normal faults by varying point of location and inception of fault. The technique presented here, detects all types of normal faults like many conventional methods. Unlike several techniques, the proposed method works very effectively under high impedance faults of range around 120Ω when fault locating point is very far away from relay point. In the system studied, the location of fault and relay points are F2, A respectively. The major advantage of proposed approach is detection and classification of most of the non fault events from fault cases. This classification is not possible with many techniques. Hence the proposed method is one of the effective approaches for fault detection and phase selection.

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