Application of FFT for Detection of Low Impedance Faults in Power System Network

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***Abstract*— Detection of the types of Fault conditions in overhead transmission lines is a troublesome and challenging task that has caught researcher's attraction over past years. Conventional ways of fault analysis require the detail information of system parameter that may not be always accessible to the user. Hence, signal processing techniques have provided an alternative opportunity for fast, convenient and accurate fault detection in power system network. There are several signal processing techniques available for LIF detection such as Fourier transforms, wavelet transforms but this paper mainly focuses on Fast Fourier Transform. The objective of the present work is to detect the type of fault condition for different locations on the transmission line and different values of ground resistances. The ground resistance is liable to change depending on the soil condition and topographical features. Hence, the faults involving the transmission line and the ground are needed to be studied for different values of ground resistances. All the simulations and the programming have been done in MATLAB.**

Keywords*— *Fault, Fast Fourier Transform (FFT), Feature extraction, Ground resistance.

I. INTRODUCTION

Fast detection of faults allows the relays to isolate the faulty part from the rest of the power system in order to protect the assets of the faulty part and to continue power supply to the healthy part. In addition, the accurate classification of faults provides necessary information regarding fault location that expedites the required repair works. Consequently, fast and reliable fault detection and classification have become an essential operational requirement of modern electricity grids. The electrical power system is very large, complex and spread over a large geographical area. The electrical power system consists of a generator, transformer, transmission lines and load. A fault in a circuit is the disturbance or failure, which interfere the normal system operation. Fault usually occurs in a power system due to insulation failure, flashover, physical damage such as wire blowing together in the wind, an animal coming in contact with the wire. Fault usually causes the flow of excessive current, abnormal voltages, induce overvoltage on neighboring equipment and cause hazards to human, animals, etc. Fault analysis is generally needed to select the size of circuit breaker fuse and characteristics, setting of the relay. Fuse, circuit breaker, relays, lighting power protection device are some of the faults limiting devices.

Extensive research work has been done and published in many literatures as given in [1]-[13]. The present work involves detection of type of fault condition using Fast Fourier Transform (FFT) based on feature extraction. The rest of the paper is organized as follows. A brief overview of FFT is discussed in section II. The simulation of the power system and the different fault conditions have been described in section III. The method of feature extraction using FFT has been discussed in section IV.

Results and discussions have been given in section V. The conclusion and future scope of work have been explained in section VI.

II. OVERVIEW OF FAST FOURIER TRANSFORM

FFT is the algorithm for implementing Discrete Fourier Transform on a time domain signal. FFT works quite fast in converting a time domain signal into the frequency domain and is independent of the number of samples of the signal. Also, it is immune to noise. The magnitudes of harmonic components and their phase angles remain unaffected in presence of noise. In case of transient disturbances of power system network, the time domain signal is not enough to recognize the type of the fault/disturbance. But the frequency spectrum of the same signal contains enough information to detect a particular fault condition of the network. Hence, in this paper FFT has been implemented for obtaining suitable characteristic features of the voltage signals obtained from the sending end of the network. The method of feature selection has been explained in the next section.

III. SIMULATION OF POWER SYSTEM NETWORK

A. Simulation of power system network

A three-phase power system network has been simulated in MATLAB for obtaining different fault conditions. Fig. 1 shows the single line diagram of the same network

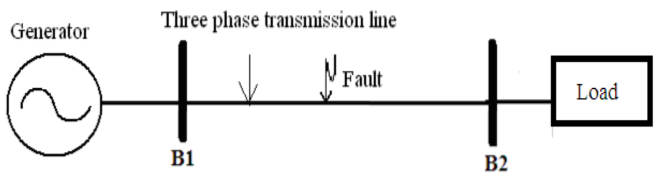


Fig. 1. Single Line diagram of 400 kV, 50 Hz, 3-phase power system network

The TABLE I shows the system parameters. The signals have been simulated with the total time period of 0.04 sec.

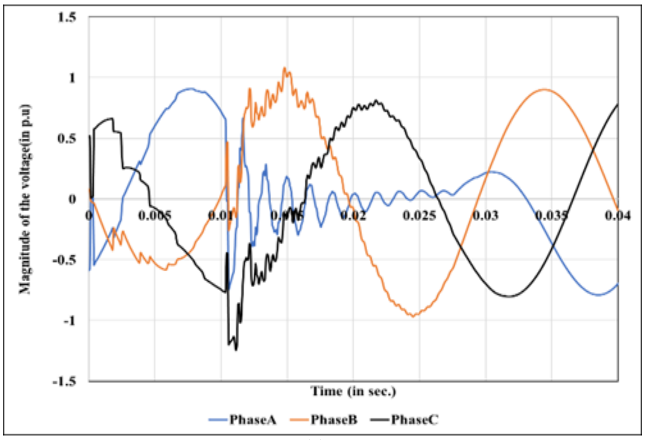
TABLE I. SYSTEM PARAMETERS

System Components	**Specifications**
Generator	Impedance = (0.2+j4.49) Ω, X/R ratio = 22.45.
Transmission Line	Length: 300 Km, R1 = 0.02336Ω/km, R2 = 0.02336Ω/km, R0 = 0.38848Ω/km, L1 = 0.95106mH/km, L2 = 0.95106mH/km, L0 = 3.25083mH/km, C1 = 12.37nF/km, C2 = 12.37nF/km, C0 = 8.45 nF/km
Balanced Load	Load Impedance = (720+j11) Ω, p.f.= 0.9, MVA rating = 200

B. Simulation of power system faults

Short circuit shunt faults have been simulated in the network involving several combinations of the three phases of the transmission lines and the ground. For e.g., AG, BG and CG faults refer to Phase A, B and C shorted to ground respectively. Similarly, ABG symbolize the phases A and B shorted to ground and so on.

As the objective is to simulate low impedance faults, the fault resistance is 0 ohm but the ground resistance for all the faults has been considered as 5-ohm, 10-ohm, 15-ohm, 20-ohm. The voltage wave forms of all the simulated faults at a particular condition have been shown in Fig.2.



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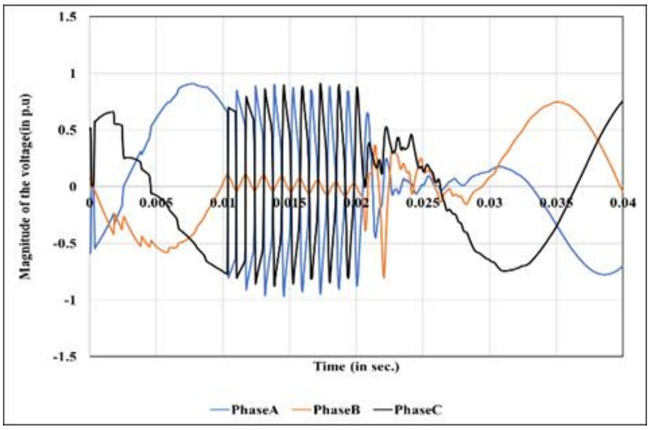

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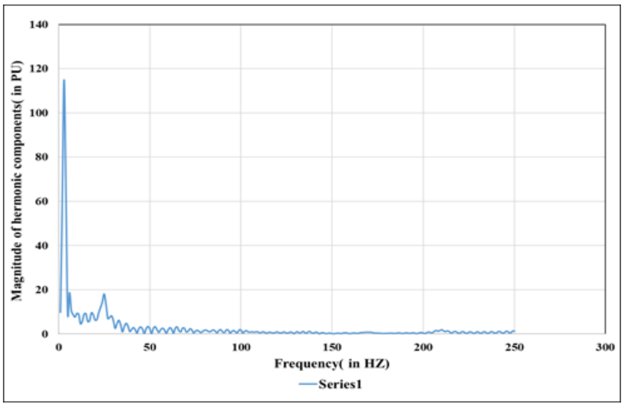
Fig. 2. Plots of Three phase voltage waveform during (a) AG type (b) ABCG type of fault occurring at 100 Km from B1 in the power system network with Ground Resistance=5ohms

IV. APPLICATION OF FFT FOR FEATURE EXTRACTION

A. Selection of features

FFT has been implemented on the voltage waveform of each phase simulated at the sending end of the network during different types of fault condition. The output of the FFT is a complex matrix. The absolute value of the FFT matrix is obtained which is referred to as the frequency spectrum of the voltage waveform. The frequency spectrum of voltage during AG and ABG kind of fault shown in Fig 3.



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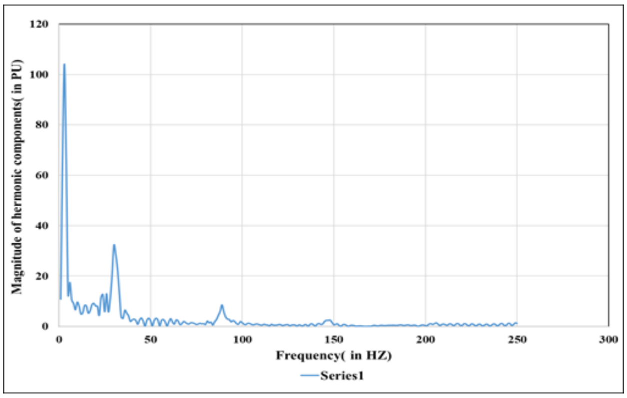

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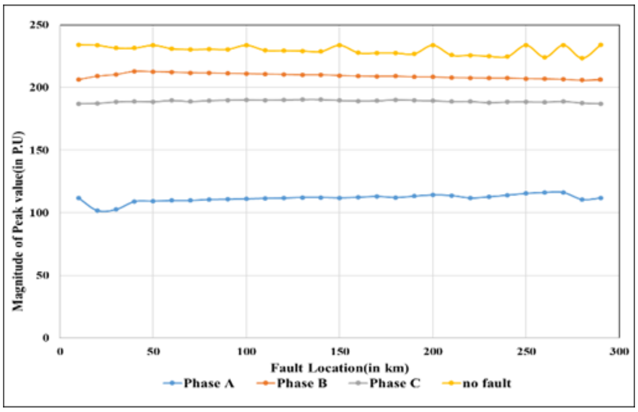
Fig. 3. Frequency spectrum of the voltage signal of phase A during (a) AG fault (b) ABG fault occurring at 100 km from the sending end of the power system with Ground Resistance = 5 ohms

The features have been selected from the frequency spectrum of each voltage signal by the following steps:

- The maximum value of the harmonic component from the frequency spectrum is noted as an important feature for classification of fault in the present study.
- The process is repeated for all the types of faults at different locations of the transmission line.

The plots of the features of four types of fault conditions are shown in Fig.4. to Fig.5. The observations from these plots have been tabulated in TABLE II.



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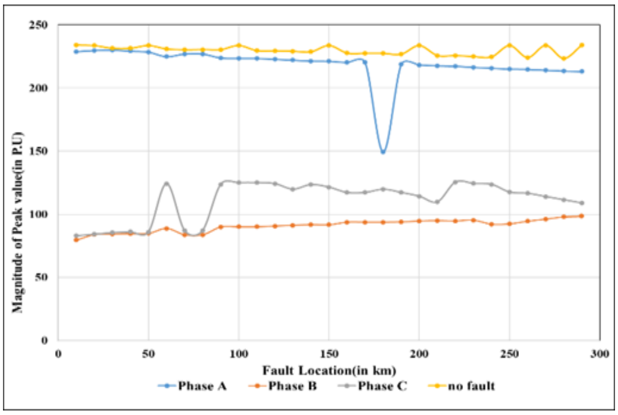

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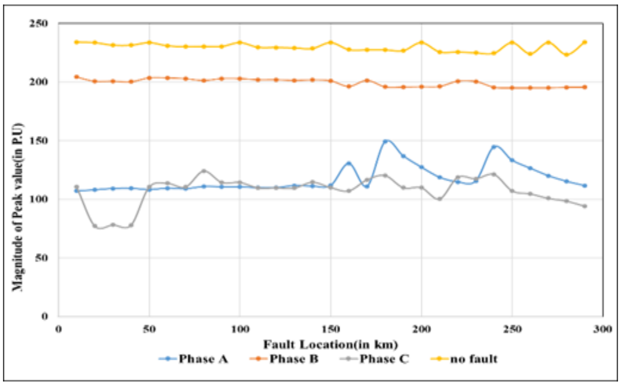
Fig. 4. Plot of magnitude of features obtained from FFT with respect to fault location in case of (a) AG fault (b) BCG Fault occurring at 100 km from B1 in the power system network with ground resistance = 5 ohms



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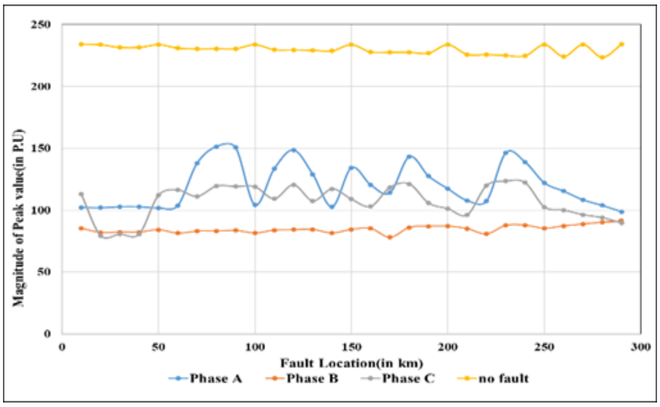

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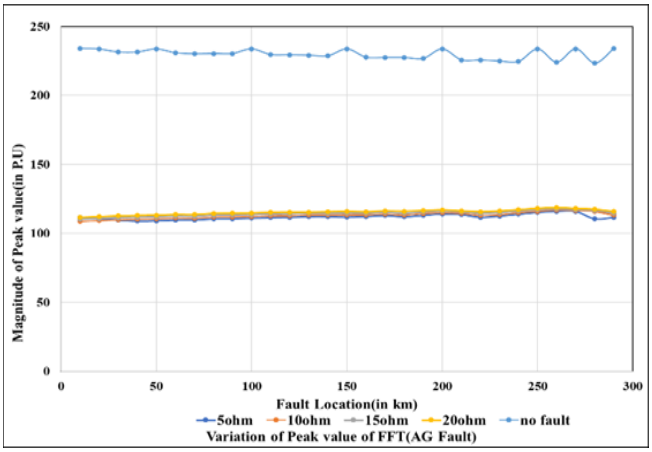
Fig. 5. Plot of magnitude of features obtained from FFT with respect to fault location in case of (a) CAG fault (b) ABC Fault occurring at 100 km from B1 in the power system network with ground resistance = 5 ohms

B. *Effect of ground resistance*

In this section, the features obtained from FFT have been plotted with respect to fault location for different values of ground resistances. The Figures 6-7 show the profile of the features of only the faulty phase for some particular fault conditions. It is observed from the plots that the variation in ground resistance has almost no effect on the magnitudes of the features. Hence, the method suggested for identification of the type of fault is independent of the magnitude of ground resistance.



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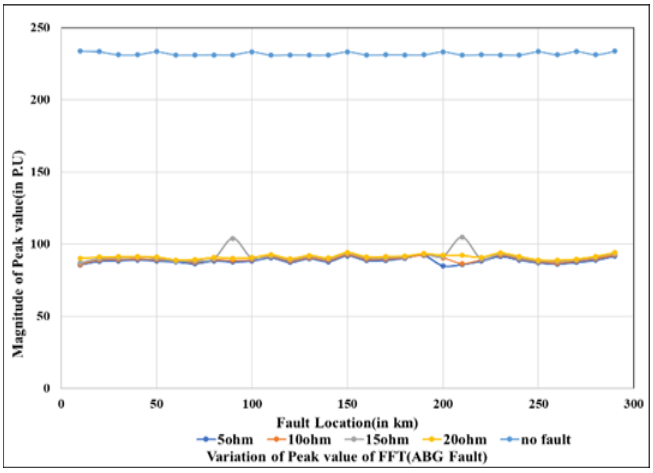

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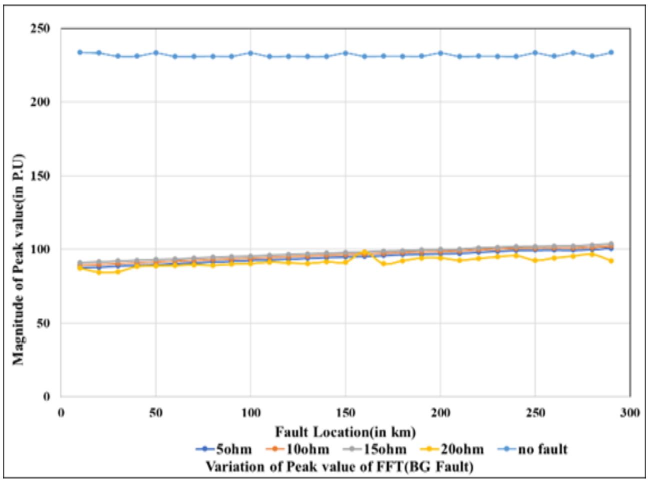
Fig. 6. Plots of magnitudes of features obtained from FFT with respect to fault location in case of (a) AG fault (phase A) (b) ABG fault (phase B) for different values of Ground resistances



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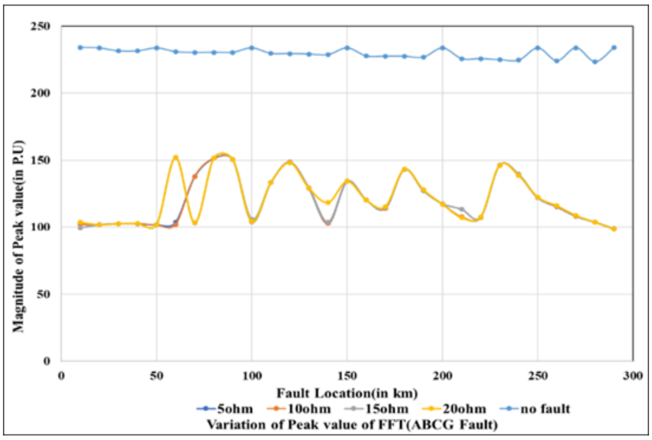

(b)

Fig. 7. Plots of magnitudes of features obtained from FFT with respect to fault location in case of (a) BG fault (phase B) (b) ABCG fault (phase A) for different values of Ground resistance

V. RESULTS AND DISCUSSIONS

The pattern of the features for different fault conditions has been studied in section IV and the observations have been enlisted in TABLE II. It has been observed in section 4 that the magnitudes of features remain almost unaffected with the change in ground resistance.

TABLE II. COMPARISON OF THE MAGNITUDES OF FEATURES OF THREE PHASES DURING DIFFERENT TYPES OF FAULT CONDITIONS WITH THOSE OF PHASES DURING NORMAL CONDITIONS

Nature of fault	**Magnitude of feature in comparison to the feature of the voltage signal during no fault condition**		
	Phase A	**Phase B**	**Phase C**
AG	Lowest	Lower than normal value	Lower than normal value
BG	Lower than normal value	Lowest	Lower than normal value
CG	Same as normal value	Lower than normal value	Lowest
AB	Lowest	Lowest	Same as normal value
BC	Same as normal value	Lowest	Lowest
CA	Lowest	Lower than normal value	Lowest
ABG	Lowest	Lowest	Lowest
BCG	Lowest	Lower than normal value	Lower than normal value
CAG	Lower than normal value	Lowest	Lower than normal value
ABC	Same as normal value	Lower than normal value	Lowest

VI. CONCLUSION

In the present work, different types of short circuit faults have been simulated with fault resistance 0 ohm and different values of Ground resistances, ranging from 5-ohm, 10-ohm,15-ohm and 20-ohm respectively. As the ground is involved, hence only L-G, LLG and LLG faults have been simulated. Suitable features have been selected from the voltage signals by using FFT under no fault and different fault conditions. FFT works quite fast as a signal processing tool. The features have been thoroughly studied and it has been observed that the fault conditions can be accurately identified. As the majority of the types of faults in overhead transmission lines involve ground, hence it is important to investigate the effect of ground resistance on the magnitudes of features extracted from FFT.It was noted that the magnitudes of features remain almost unaffected for different values of ground resistances. Hence, the suggested method for fault detection is independent of the magnitude of ground resistance.

In the future scope of work, the signal features that have been obtained would be used to train a suitable classifier involving neural network or support vector machine so that fault can be notified automatically under different conditions. The effect of noise on the voltage signals also requires to be studied. The study can be further extended by considering higher values of fault resistances and applying other signal processing tools like wavelet transform, for obtaining signal features.

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