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

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***Abstract*— Detection of High Impedance Faults mainly in distribution systems is a troublesome and challenging task that has caught researcher's attraction over past years. The random behavior of HIF current, as well as its low magnitude, causes difficulties in the detection of faults by conventional fault detection methods. Conventional distance relays, overcurrent relays, and ground fault relays cannot be used for HIF detection due to its sensitivity and selectivity issue owing to the low value of fault current. There are several Signal processing techniques available for HIF detection such as Fourier transforms, wavelet transforms but this paper mainly focuses on application of Fast Fourier Transform (FFT) for feature extraction from the voltage signals of a power system network. The pattern of the extracted features has been observed thoroughly and the results indicate that all the types of faults can be correctly identified irrespective of the magnitude of fault resistance. In this paper, different types of High Impedance Faults (HIFs) have been simulated at different locations of the transmission line. All the simulations have been done in MATLAB.**

Keywords*— Fast Fourier Transform (FFT), Feature extraction, Fault resistance, High Impedance Fault (HIF)

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. This study proposes the application of fuzzy assessment tree (FAT)-based short-time modified Hilbert transform (STMHT) as a new multiclass detection and classification technique, for a distributed generation (DG)-based microgrid. The time varying non-stationary power signal samples extracted near the target DG are initially de-noised by passing through the morphological median filter and then processed through the proposed STMHT technique for disturbance detection. Further based on the overlapping in the target attribute values, an FAT has been incorporated, which significantly classifies the different multiclass disturbances on a standard IEC microgrid model simulated in MATLAB/Simulink environment with highest precision in accuracy [1]. Smart grid (SG) containing clean distributed generation (DG) has gained intensive research for reliable digital protection against fault conditions. The main objective of this study is to develop and validate a fast and efficient fault detection and classification algorithm taking into account the dynamic behaviour of DG units. The proposed algorithm does not require additional measurements as it based only on the synchronized measured three-phase currents through the communication facilities available in SG. The advanced communication technologies in SG are currently utilized for efficient and real-time data transfer from the protective relays to the monitoring and protection center. The transferred data are processed for fault diagnosing before taking the necessary trip actions. In the proposed algorithm, the statistical cross-alienation coefficients are calculated for the measured current signals at sending and receiving ends of each feeder. Fault detection and classification process will be achieved taking into account the changes in the synchronized and discretized waveform of current signals within a movable window of (1/4 cycle). The proposed algorithm is tested on real system to detect and classify the different fault condition. The results indicated that the proposed technique is fast and reliable for SG digital protection schemes [2]. Signal processing techniques have provided an alternative approach of fault diagnosis in overhead transmission lines. These techniques are fast, accurate and convenient. There are multiple signal processing tools are available like Fast Fourier Transform (FFT), Wavelet Transform (WT) and S-Transform. Extensive research work has been done and published in many

literatures as given in [3]-[7]. 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

The Fast Fourier Transform does not refer to a new or different type of Fourier transform. It refers to a very efficient algorithm for computing the DFT. The time taken to evaluate a DFT on a computer depends principally on the number of multiplications involved. DFT needs principally on the number of multiplications involved. DFT needs N2 multiplications. FFT only needs Nlog2(N). The central insight which leads to this algorithm is the realization that a discrete Fourier transform of a sequence of N realization that a discrete Fourier transform of a sequence of N points can be written in terms of two discrete Fourier transforms of length N/2Thus if N is a power of two it is possible to recursively apply. Thus, if N is a power of two, it is possible to recursively apply this decomposition until we are left with discrete Fourier transforms of single points. The FFT of a signal x[n] is given by is given by Equation (1):

$$x[k] = \sum_{n=0}^{N-1} x[n] e^{-j2\pi kn/N} \qquad (1)$$

III. SIMULATION OF POWER SYSTEM NETWORK

A. Simulation of power system network

The single line diagram of the power system network considered in this study has been simulated in MATLAB and shown in Fig .1. The specifications of the system shown in Fig.1. have been provided in TABLE I.

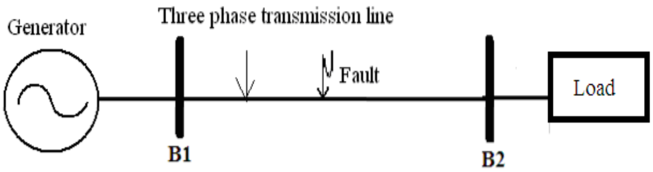


Fig. 1. Single Line diagram of 400 kV, 50 Hz, 3-phase power system network

The parameters of the system are given in TABLE I. The voltage signals have been simulated for a 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

The following ten types of faults have been simulated in steps of 10 Km from sending end (B1) of power system network as shown in Fig.1. The fault resistance has been considered to be 500 ohms.

1. Single line to Ground -AG, BG, CG (e.g., AG- Phase A to Ground)
2. Double line faults - AB, BC, CA
3. Double line to ground fault- ABG, BCG, CAG
4. Three phase short circuit fault -ABC

All the faults have been simulated in steps of 10 km on the transmission line from the sending end(B1) of the power system. As the objective is to simulate high impedance faults, fault resistance is taken to be 500 Ohm.

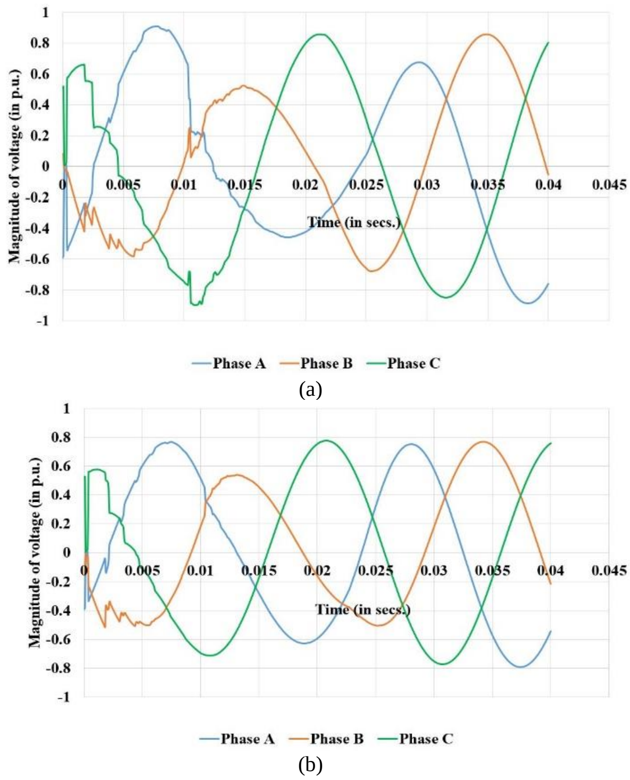


Fig. 2. Plots of Three phase voltage waveform during (a) AB type (b) ABG type of fault occurring at 100 Km from B1 in the power system network with Fault resistance=500ohms

IV. APPLICATION OF FFT IN ANALYSIS OF HIGH IMPEDANCE FAULTS

A. Method of feature extraction

FFT has been implemented on the voltage waveform of each phase simulated at the sending end of the network during a 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 ABG kind of fault shown in Fig. 3.

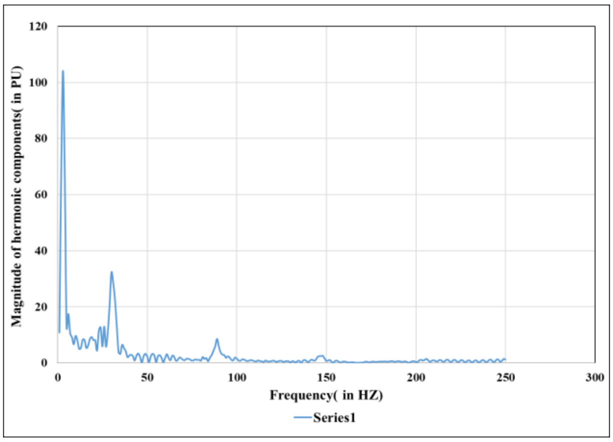
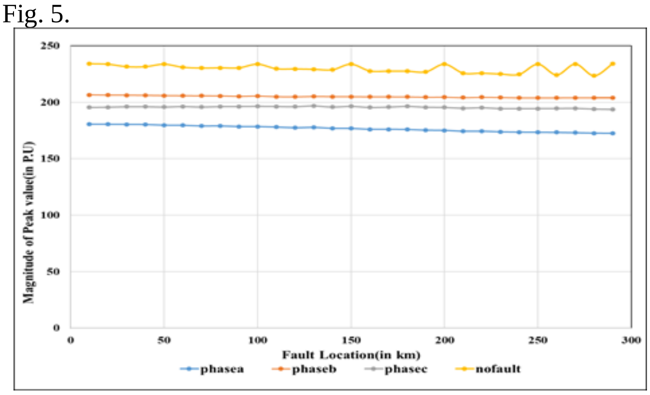
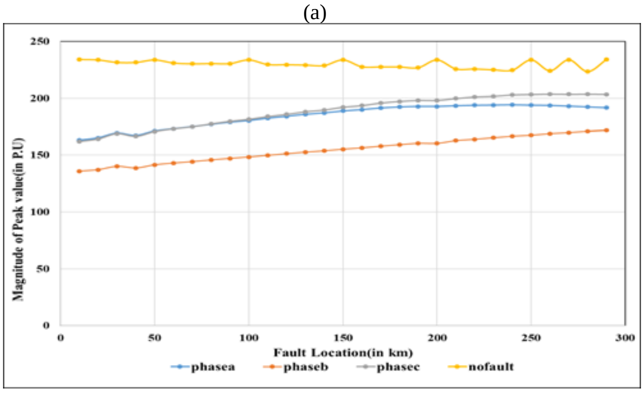


Fig. 3. Frequency spectrum of the voltage signal of phase A during ABG type of fault occurring at 100 km from the sending end of the power system with fault resistance = 500 ohms

The maximum value of every 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 location of the transmission line. The plots of the features of four types of fault conditions are shown in Fig. 4. to Fig. 5.

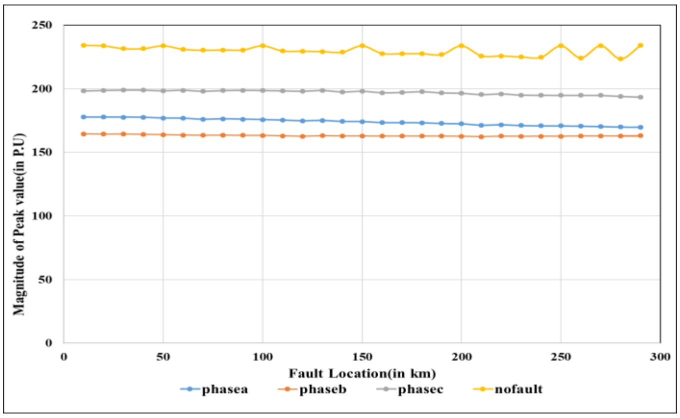


(a)

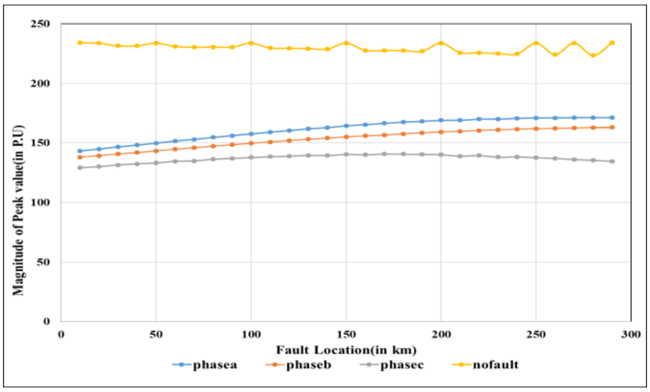


(b)

Fig. 4. Plot of magnitude of features obtained from FFT with respect to fault location in case of (a) AG fault (b) AB Fault occurring at 100 km from B1 in the power system network with fault resistance = 500 ohms



(a)



(b)

Fig. 5. Plot of magnitude of features obtained from FFT with respect to fault location in case of (a) ABG fault (b) ABC Fault occurring at 100 km from B1 in the power system network with fault resistance = 500 ohms

V. DISCUSSIONS

The following observations have been made from the profile of features shown in Fig.4. to Fig 5.

TABLE II. COMPARISON OF THE MAGNITUDES OF FEATURES OF THREE PHASES DURING DIFFERENT TYPES OF FAULT CONDITIONS WITH THOSE OF PHASES DURING NORMAL CONDITIONS WITHOUT NOISE

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	Higher than normal value	Higher than normal value
BG	Higher than normal value	Lowest	Higher than normal value
CG	Higher than normal value	Higher than normal value	Lowest
AB	Lowest	Lowest	Higher than normal value
BC	Higher than normal value	Lowest	Lowest
CA	Lowest	Higher than normal value	Lowest
ABG	Lower than normal value	Lower than normal value	Higher than normal value
BCG	Higher than normal value	Lower than normal value	Lower than normal value
CAG	Lower than normal value	Higher than normal value	Lower than normal value
ABC	Lower than normal value	Lower than normal value	Lower than normal value

VI. CONCLUSION

In the present work, different types of High Impedance Faults have been simulated with fault resistance of 500 ohm at different locations of the transmission line. Suitable features have been selected from the voltage signals by using FFT under no fault and different fault conditions. The voltage signals of the three phases at a single terminal of the power system network have been considered for feature extraction. FFT works quite fast as a signal processing tool and is independent of the number of the samples of a signal. The features have been thoroughly studied and it has been observed that the fault conditions can be accurately identified at every location.

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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