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Power System Fault Analysis Using Signal Processing Technique – A Review

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Abstract: The power quality is a very important issue in electrical power system. Electrical transmission lines are one of the vital components of this power system which play important role in power quality during electricity transmission. These transmission lines are exposed to faults most of time due to atmospheric conditions as well as due to overload. Various methods are established for fault analysis occurs on transmission lines. The study of these methods is necessary for performance improvement as well as to maintain the reliability and stability of the power system in any critical event. This paper presents a review on the signal processing tools used to analyze the behavior of a power system and evaluate the performance of the system for different scenarios

Keywords: Power system, Fault analysis, S-transform, Fourier, MRA, MMG, MUDW, wavelet.

I. INTRODUCTION

Transmission line faults are the most widespread faults, triggered by falling trees across lines, lightning strikes or insulator strings to flash over. Economic and consistent operation of a power system requires quick fault location and quick fault clearing. Concepts of availability, efficiency and superiority have an increasing importance nowadays due to the new marketing policies which can be directly interpreted as a cost reduction or a profit increasing. Conventional methods use basic components of voltage and current. Fundamental component during pre-fault and fault are used in these methods to estimate the apparent impedance viewed from the measurement point and then fault location. However, the estimation of fundamental components of voltage and current signals requires application of robust algorithms against the undesired effects of generated transient components after occurrence of the fault. This is the essential problem which limits the operation speed of conventional techniques for identification of the faults [1-3]. Traveling wave algorithms are based on the fact that an abrupt change of voltage and current at the fault point results in transient waves which propagate along the transmission line in both directions away from the fault point close to the light velocity. These high frequency waves carry useful information associated to the relevant fault. [4-5].

II. RELATED WORK

The rapid growth of Digital Signal Processing technique enabled the analysis of a system and its signals so as to identify the performance of the system. DSP tools used for the analysis of a system are the tools operating either on Time Domain or Frequency Domain. Having its own identity the Wavelet Analysis operates both on Time and Frequency Domain. This thesis is organized in 6 chapters to analyze the performance of a given system. The literature presented in a systematic manner to give a light on the recent trends in identifying the performance of the system using DSP tools, especially Mathematical Morphology. Petros Maragos et al presented a morphological system for multi dimensional signal processing. It reviews the basic theory and applications of a set theoretic approach to image analysis called mathematical morphology. The goals of the paper are; to show how the concepts of mathematical morphology can quantify geometrical structure in signals and to illuminate the ways that morphological systems can enrich the theory and applications of multidimensional signal processing. The topics covered include: applications to non-linear filtering (morphological and rank-order filters, multi scale smoothing, morphological sampling, morphological correlation); applications to image analysis (feature extraction, shape representation and description, size distributions, and fractals); and representation theorems, which show how a large class of nonlinear and linear signal operators can be realized as a combination of simple morphological operations. Hochong park et al for image processing systems that have a limited size of region of support, say 3 x 3, direct implementation of morphological operations by a structuring element larger than the prefixed size is impossible. The decomposition of morphological operations by a large structuring element into a sequence of recursive operations, each using a smaller structuring element, enables the implementation of large morphological operations. The decomposition of arbitrarily shaped (convex or concave) structuring elements into 3 x 3 elements, optimized with respect to the number of 3 x 3 elements are presented. The decomposition is based on the concept of factorization of a structuring element into its prime factors. For a given structuring element, all its corresponding 3 x 3 prime concave factors are first determined. From the set of the prime factors, the decomposability of the structuring element is then established, and subsequently the structuring element is decomposed into a smallest possible set of 3 x 3 elements. Examples of optimal decomposition and structuring elements that are not decomposable are presented.

III. FOURIER TRANSFORMS

There are number of transformations, among which the Fourier transforms are probably by far the most popular. Fourier series have a few drawbacks, they require periodicity in all the time functions involved and also location of transient in all time axis is lost. The Fourier transform only retrieves the global frequency content of a signal. Therefore, the fourier transform is only useful for stationary and pseudo-stationary signals. The Fourier transform does not give satisfactory results for signal that are highly non-stationary, noisy, a periodic, etc.

IV. FFT

FFT for determination of fault location using frequency domain data obtained by transformation of transient response measured on one terminal of transmission line is proposed. Fault distance is detected by processing transient voltage and current waveforms transformed into the frequency domain using Fast Fourier Transform [6], considering the frequency of travelling wave with lower frequency. Simulation result show that the accuracy of the method is about %1 and phase angle at fault instant and fault resistance do not affect the accuracy of the method. [7] Discusses the detection capability of DFT & EDFT for low-level harmonics and sub-harmonic. The STFT can be used to achieve much accuracy in fault classification. STFT is a means of signal processing in which a Fourier transform (FT) is performed by setting a window function with a constant size. STFT have the limitations of fixed window width and it will consume more time in transient location [8]

V. S-TRANSFORM

The extension of Fourier transform and short time Fourier transform is the S-transform (ST). S-transform overcomes the disadvantage of short time Fourier transforms. A Key feature of the S-transform is that it uniquely combines a frequency dependent resolution of the time-frequency space and absolutely referenced local phase information. [9] Shows comparative analysis of short time Fourier transform and S-transform for analyzing power quality disturbances.

VI. WAVELET TRANSFORMS

With the time-frequency localization characteristics embedded in wavelets, the time and frequency information of a waveform can be presented as a visualized scheme. This feature is very important for non-stationary signals analysis such as the ones generated from power system disturbances. Unlike the Fourier transform, the wavelet transform approach is more efficient in monitoring fault signals as time varies [10]. Unlike Fourier analysis, which relies on a single basis function, wavelet analysis uses basis functions of a rather wide functional form such as Haar wavelet and Daubechies wavelet. This new form of signal analysis is far more efficient than Fourier analysis whenever a signal is dominated by transient behavior or discontinuities. The Wavelet Transform (WT) of a continuous signal x(t) is defined as

$$WT(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t) g\left(\frac{t-b}{a}\right) dt$$

Where a and b are the scaling and translation parameters respectively and g is the mother wavelet function. The DWT is defined by

$$DWT[m,k] = \frac{1}{\sqrt{a_0^m}} \sum_n x[n] g\left[\frac{k - na_0^m}{a_0^m}\right]$$

Where g[n] is the mother wavelet, and the scaling and translation parameters a and b are functions of an integer parameter m.The selection of mother wavelet is discussed in [11]. For time intervals where the function changes rapidly, this method can zoom in on the area of interest for better visualization of signal characteristics. [12]-[13] gives an overview of wavelet application in power systems. A case study on analysis of system transients using wavelets is given in [14]. Wavelet based fault detection and categorization in transmission lines using Daubechies level 1 wavelet, MRA has been discussed in [15]. The Modulus Maxima of Wavelet transform provides a valuable technique for extracting the individuality of various transient travelling waves generated by a power system fault. The characteristics of both the forward and reverse travelling waves are extracted using the Modulus Maxima (MM) of the wavelet transform [16]. WT in conjunction with AI/Fuzzy/Expert system/SVM based techniques have the advantage of fast response and increased accuracy in fault type and location identification. [17] Discusses the detection and classification of faults on 220 KV transmission line using wavelet transform and neural network. The detection and classification is carried out by using energy of the detail coefficients of the phase signals, used as input to neural network to classify the faults on transmission lines [18] Proposes a new technique using Discrete Wavelet Transform (DWT) and support vector machines (SVM) to classify the fault types on transmission systems. The DWT is used to detect the high frequency components from fault signals. Positive sequence current signals are used in fault detection decision algorithm. The variations of first scale high frequency component that detects fault are used as an input for the SVM. Wavelet & Fourier transforms have shown faster time response [19]-[21].

In the study involved computer simulation of some power quality disturbances on power systems, and DWT analysis of the resulting current and voltage waveforms to detect the various types of power quality problems under consideration. This feature of WT comes from its ability to separate power quality problems which overlap in both time and frequency domains. [22-23] harmonic analysis, and can extract the fundamental wave in a very good tracking harmonic changes, thus the wavelet theory in harmonic monitoring is promising.[24] A circuit that represents a real distribution system, 13.8 kV, from CPFL (Cia Paulista de Força e Luz – a Brazilian utility) was simulated through the software ATP (Alternative Transients Program) for purposes of this study. Finally, a comparison with real-life data recorded at the distribution system was performed in order to validate the present simulation. Other than the mentioned ones wavelet transforms proved to be an efficient tool for representing an voltage flicker [25] ,partial discharges[26], load forecasting[27], auto-reclose schemes[28], transients due to capacitor switching[29], Transformer protection. However wavelet transforms have the drawback of high computational burden and high sampling rate to detect a fault. The type of basic wavelet employed affects the effectiveness in identifying the transient elements. Mathematical morphology combined with Hilbert- Huang Transform is a proposed technique which is used to analyze both stationary and non-stationary signals [30]

VII. MATHEMATICAL MORPHOLOGY

MM based tools have been proposed to monitor power quality events, detect power system disturbances, estimate harmonics, detect CT saturation, and distinguish magnetizing inrush from internal faults in power transformers. MM based tools have also been proposed for fault detection, transmission line protection, digital relaying, and extraction of the transient component from a fault waveform. The overview of mathematical morphology in power systems & the effect of sampling rate for various applications of MM for power quality , transformer inrush & internal fault classification in power transformers, identification of CT saturation using morphological wavelets& for distribution system protection has been discussed in [31]. An fault detector based on MMG for adaptive distance relaying is presented in [32] . [33] Proposes an improved fault detection method in transmission lines using MUDW scheme compared to MMG based fault detection.in [34] also explains the selection of the length of structuring element in quick and effective detection of a power swing as well as symmetrical fault during a power swing. The tool is tested atdifferent swing frequencies with different fault locations at different inception angles, and different fault resistances using PSCAD/EMTDC and proves less computational burden and low sampling rate unlike wavelet transforms. The effectiveness of MMG is based on the selection of structuring element for morphological operators. [35] gives the guidelines for the selection of structuring element for morphological tools of fault detection in power systems.

VIII. CONCLUSION

The Fourier, ANN, fuzzy logic, genetic algorithm, SVM and wavelet based techniques have been quite successful but are not enough for the present time varying network configurations, power system operating conditions and events. hence, it seems that there is a major scope of research in AI techniques which can simplify the complex nonlinear systems, understand the cost effective hardware with proper modification in the learning tactic and preprocessing of input data and which are computationally much simpler. This article is an effort to present the most comprehensive set of references on the subject of recent techniques in power system applications.

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