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Monitoring and Analysis of PQ Parameters Using Wavelet Transforms

D.Nivetha[1], M.Karunakaran[2]

P.G. Student, Department of Power System Engineering, S.K.P Engineering College, Tiruvannamalai, TN, India[1]

Assistant Professor, Department of Electrical and Electronics Engineering, S.K.P Engineering College, Tiruvannamalai, TN, India[2]

ABSTRACT: The issues of many non-linear loads cause severe disturbances like voltage sag, voltage swell, harmonics in the distribution line of present power system. It affects the power quality thereby decreasing the overall efficiency, performances, accuracy, instabilities in output. The important issue among the power quality is harmonics that becomes the major concern in the power system network. This survey mainly discusses the causes and effects of harmonics in the electrical network. It also discusses the various detection techniques that detects and analyzes the presence of harmonics in the system. In addition to this, this survey also discusses the new technique called EWT AND RDWT to detect the harmonics in the real signal.

KEYWORDS: Harmonics, Power Quality, EWT, RDWT.

I. INTRODUCTION

Electric power quality (PQ) has become the concern of utilities, end users, manufacturers, and all other customers. Power quality is the set of parameters defining the properties of power supply delivered to the users in normal operating conditions in terms of continuity of supply and characteristics of voltage (magnitude, frequency, symmetry, waveform etc.). Modern electronic equipments and devices, such as microprocessors, microcontrollers, telecommunication equipment and sensitive computerized equipments etc. are susceptible to PQ problems. Poor PQ has become a more important concern of both power suppliers and customers [1],[2].The application of non-linear loads in the industrial and commercial environment increases in large amount nowadays. These loads increase the losses and heating of the equipments and devices that are connected in the power system network. It mainly induces the harmonics, which is the greatest concern among the power quality issues such as swell, sag, flicker, etc. into the system. These harmonics mainly arises from electronic equipment such as fluorescent lamps, adjustable speed drives, uninterruptible power supply, Television, etc. The operation of machines at fixed speed for prolonged time is a great strange thing. Therefore, there is a need for adjusting the speed of the machine, which provokes the adjustable speed drives. These Adjustable Speed Drives (ASDs) adjusts the speed according to the demand, fluctuation of the load. These ASDs introduces the fifth, seventh and higher order of harmonics into the power system network that damages the much equipment mainly motor. The source of harmonics in the adjustable speed drives is the converter used at the input side [3].

This paper compares the various methods of detection of voltage sag and swells in real time on the basis of detection time, magnitude, effect of windowing and effect of sampling frequencies. The RMS, Peak, Fourier transform and Missing Voltage algorithm are introduced and discussed in them for real time implementation [4]. DFT particularly estimates the flicker source location in power systems. The output signal from the state estimation is applied to half wave rectifier and filtered by series filter to gasbag the voltage and current. But, by use of this state estimation such as Weighted Least Square Method will bring down the affectivity of FPA [5]. Moreover S-transform is employed to study the power quality signals and to observe, assort the disturbance in time frequency representation (TFR) and also it can perform with different time duration to check the accuracy [6]. Later DWT is used to represent the non stationary components which consists of bi orthogonal 5/3 spline filter that gives a better linear response and clear the data expansion problem by Huffman coding in MATLAB. For automatic detection and classification of single and hybrid

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PQ disturbances DWT and Modular probabilistic neural network is used based on MRA techniques for feature extraction of PQ waveforms. In MRA, both time and frequency information are available. A SVWT is a three phase approach mostly used to examine PQ disturbances with the help of dyadic transformation of DWT with multi resolution signal decomposition method which fails to find gradual changing events [7-9]. In [10] the authors have employed FFT demodulation method with flicker power algorithm to extract the particular flicker component of input signal without farming the non- modulating component on frequency spectrum, as well as the voltage and current envelope that compiled of all the flicker components can be separated from the vacillated voltage waveform. It neglects the negative frequency components and identifies the flicker source location accurately by the combination of FPA with FFT demodulation method. In [11] FFT has more or less disfavor such as an aliasing effect, spectrum leakage, picket- fence effect, which lead to error in results. To overcome the above drawbacks FFT algorithm with adaptive Kaiser self convolution window method is used which treats the time varying harmonic and attain higher accuracy parameters beneath asynchronous sampling condition. Using WT the signal is de-noised first and expands a signal in different scales in different regions known as mother wavelet [12, 13]. Voltage sag can be analyzed at starting and ending points based on energy coefficient and the values are monitored by using MATLAB simulink model. The characteristics of voltage sag such as 'Magnitude', 'Phase Angle Jump', 'Duration' are analyzed and monitored by implementing DWT and ZCDT[14]. It also detects the disturbed waveform like voltage sag, swell, and harmonics by extracting energy from the distorted signal. The mathematical modeling for measuring active power in real time measurements is based on WT and also Hilbert-Huang Transform to separate the operating modes and results that by use of PV plants will affect the time-domain signal [15]. A HHT disintegrates a difficult set of nonlinear and non stationary data into individual oscillatory modes such as (IMF) Intrinsic mode functions [15]. Section II discusses the sources of harmonics used to find out the load contributing the harmonics among the various loads connected in the distribution network. Section III discusses the power quality disturbances. Section IV brief out the real time measurement techniques to find out the presence of harmonics in the system. Section V introduces the new techniques to detect the harmonics with the results obtained.

II. SOURCES OF HARMONICS

In power system, there are many loads connected to the supply from where the loads receive the power. It is difficult to find out the harmonic contribution load among the various loads connected at the supply. The following techniques find out the load generating the harmonics. The paper [16] introduced the data correlation technique to determine the impact of individual load harmonics. This technique followed the idea of cause and effect relationship and used the data of measured voltage and current values. The exact source was identified from the behavior of each load and the degree of association.

The single point strategy method proposed in [17] used the concept of decision-making rules. This paper did not involve the spectral analysis of the parameters such as voltage and current. The comparison of Fryze's reactive power, the fundamental reactive power, and Sharon's quadrature reactive power at the same load provided the harmonic content of that load. The decision-making rules found out the source producing the harmonics.

The paper [18] presented the Bayesian approach for finding out the harmonic source. This method took out the input as measured quantities and theoretic information of the system. The power spectral density provides value of the harmonic currents of each load and Bayesian approach decides the harmonic source.

The state estimation technique proposed in [19] used to measure the effect of harmonics at the point of common coupling. This technique includes three steps.1) Raw data collection. 2) Use of extended Kalman filter, a linear Kalman filter, and a constrained recursive least-squares algorithm for data processing. 3) Estimation of total harmonic contribution index that find out the correct source of harmonics.

The modified data correlation method was the advancement of data correlation method. It took the details of load harmonic impedance in calculating the harmonic contribution. The long-term measurement data found out the harmonic contribution of industrial loads and short-term data found out the effectiveness of this method [20].

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III. POWER QUALITY DISTURBANCES

The PQ disturbances are usually characterized in terms of the effect upon the system voltage and supply frequency. They can be broadly classified according to voltage magnitude variations, frequency variations and transients.

A. VOLTAGE SAG

The voltage sag is the most common type of PQ disturbances which is usually lasting from 0.5 to 10 cycles within the consumers' premises. The sag is usually associated with the short circuit faults such as single-line to ground (LG), line to line (LL), double-line to ground (LLG), three-phase (LLL), and three-phase to ground (LLLG) faults. The voltage sag can also be created owing to the energization of heavy loads such as starting of large motors [21, 22].

B. VOLTAGE SWELL

The voltage swells are also associated with the short circuit faults on power system. In a single line to ground fault, the sag is created on the phase in which fault is occurred while the swell is produced on the non-fault phases. The swell can also be created by switching-off a heavy load or energizing a large capacitor bank [21, 22].

C. INTERRUPTION

The complete loss of the supply voltage for a period of time not exceeding 1 minute is known as an interruption. The supply voltage is decreased to 10% of the nominal value. The power system faults, equipment failure, and control functions are the consequences of the interruption [21, 22].

D. HARMONICS

The harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the fundamental frequency (50 or 60Hz). The harmonics are mainly caused by the nonlinear loads such as rectifiers and inverters and other static power conversion equipment [21, 22]

IV. REAL-TIME MEASUREMENT TECHNIQUES

Fourier algorithm

The Fourier algorithm (FA), which is based on the Fourier series, is a conventional method for phasor computation by virtue of low computational complexity. The performance of the FA was studied by considering it as band pass filtering through sine and cosine filters [23, 24]. Owing to the implicit rectangular window, the magnitude frequency properties (MFPs) of the orthogonal filters were not identical, were asymmetric and had side lobes. As a consequence, the result of phasor computation oscillates severely in the presence of frequency deviation, harmonics and decaying DC offsets. To overcome this defect, the rectangular window in the FA was replaced by other types of windows [24, 25]; the modified orthogonal filters achieved desirable measurement accuracy in various service conditions. However, the new windows were longer than the rectangular window and thus the dynamic responses of the modified filters were slower. In addition, the computational complexities also increased significantly owing to the lack of a recursive algorithm.

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Continuous wavelet transform

Recently, the continuous wavelet transform (CWT) has been used for real-time measurement of power phasor in non stationary waveforms. Because a wavelet function has a band pass frequency property, the CWT based on a complex wavelet function acts essentially as complex band pass filtering and, analogous to the FA, it extracts the complex phasor of a selected component in the non stationary waveform, and the instantaneous amplitude, phase angle and frequency can be further estimated [26, 27, 28]. There are common harmonic detection methods.

FFT (Fast Fourier Transformation) algorithm:

Step 1: using fast Fourier transform; Step 2: after the transformation, we can get the current signal, then remove the fundamental component; Step3: we will inverse transform the remaining components. Then we can get time domain signal of the harmonic current.

i) Improved Fourier Series Method:

The theoretical basis is calculating current fundamental component by Fourier transform, then subtracting fundamental component from the load current.

ii) The Instantaneous Reactive Power Method:

Using the ideas of transformation from three-phase to two-phase, we will transform three-phase voltage and three-phase current to the two orthogonal system, so as to calculate the instantaneous active power and reactive power; DC component can be obtained by passing a low-pass filter, then we can get two phase fundamental wave current by transforming the DC component, next, transforming two phase to three phase after inverse transform, so we can get the fundamental wave current. Finally harmonic current can be obtained after the total current minus the fundamental wave current.[30] The harm of harmonic of power system is very serious. Real-time and accuracy of detection method have a great influence on harmonic governance.[29]

V. RESULTS AND DISCUSSION

EWT:

The various techniques discussed above do not detect the minute amount of harmonics. This section proposes a new method that measures even a very minute amount of harmonics to a higher order harmonics present in power system. It is cost-effective, reliable in any environment. The following block diagram of fig.1 explains the proposed method. Empirical Wavelet Transform is an adaptive method using this method it is able to separate the nonlinear and non-stationary part of the signal. This method is effective for find out the amplitude modulated – frequency modulated that means AM –FM component of a signal. This AM – FM components have a Fourier spectrum and that spectrum is centered around a specific frequency. In this method first we take the Fourier spectrum of the image and this whole spectrum is divided into a number of segments known as modes. This segmentation provides adaptability to this wavelet transform. Therefore the segmentation of Fourier spectrum is an important task. The representation of Empirical Wavelet Transform is similar to that of classical wavelet Transform. This wavelet also contains an approximation coefficient and a detail coefficient [31]. And also the signal is reconstructed.

RDWT:

The RDWT is approximately shift invariant and totally discrete transform [32]. By using RADWT, due to the oscillatory behaviour of signal of interest, the Q-factor of wavelet bases can be adjusted and an optimum representation of signals can be obtained. The frequency and time domain representations of low and high Q-factor wavelets employed in the proposed method are seen in Figure 2. As noticed, when high Q-factor filters are used, oscillatory wavelets similar to wheeze signals in the time domain and better frequency resolution for low and middle frequency bands in frequency domain can be achieved.

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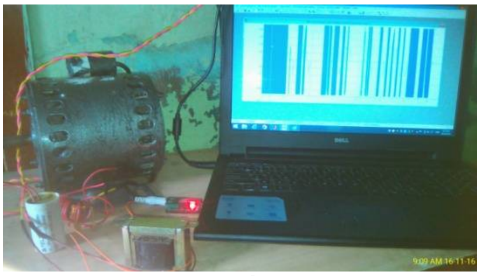

Fig.1 Experimental setup

Fig.2 Experimental setup

VI. CONCLUSION

Harmonics becomes a major concern in today's electrical network. This paper discussed the various sources of harmonics from which it arises and propogates through the network. It also discussed the impacts of harmonics on various components such as transformer, cables,etc. The various detection techniques to find out the harmonics present in the power system network are also discussed. In addition to this, a new method that was previously used only in bio-medical field called as EWT AND RDWT is proposed to detect the harmonics. The data analyzed through this algorithm in MATLAB. The transferred signal can be viewed from SIGVIEW software.

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