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HARMONIC IDENTIFICATION IN DISTRIBUTION SYSTEM USING GENETIC ALOGORITHM

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ABSTRACT

Voltage and current waveforms of a distribution or a transmission system are not pure sinusoidal. There are distortions in these waveforms that consist of a combination of the fundamental frequency, harmonics and high frequency transients. This work presents an approach of a harmonic identification method for distorted waveforms in electrical Power Systems. The proposed method is based on a Fast Fourier Transform.

Keywords- Harmonics, Harmonic Analysis, FFT.

1. INTRODUCTION

Harmonic pollution is a growing concern in recent years with more nonlinear loads being supplied to power systems. A nonlinear load injects harmonic currents into connected power system network. The voltage at the point of common coupling (PCC) will be distorted even if the power supply voltage is purely sinusoidal. At the same time linear loads connected to the PCC will absorb distorted currents because of the distorted voltage. The harmful effect of harmonics includes overheating in the transformers, cables and rotating machines that reduces the life time of such equipment; telephone interference; improper operation of protective relays; and neutral line overloading due to the zero–sequence nature of the triplen harmonics.

Voltage and current waveforms of a distribution or a transmission system are not pure sinusoidal. There is a presence of distortions in these waveforms that consists of a combination of the fundamental frequency, harmonics and high frequency transients. By definition, harmonics are periodical high frequency current and voltage distortions. Their frequencies are multiples of the fundamental system frequency. The fundamental system frequency (first harmonic) of the Indian electric power system is 50Hz, the second harmonic is 100Hz, the third harmonic is 150Hz, and so on. Such distortion occurs in a steady state system and it will be present at least for a few seconds after the occurrence of the event. The harmonics can be associated to the continuous operation of a load with non-linear characteristics of power electronic equipment, such as inverters, rectifiers, AC and DC converters. The source of these distortions may be internal or external. Individual harmonic frequencies may vary in amplitude and phase angle, depending on the harmonic source.

According to [2], the evaluation of harmonic distortion is a very important task for the correct operation of a system. The difficulty in measuring harmonics comes from the fact that the generating sources of harmonics are from a dynamic nature.

The harmonics produced have time varying amplitudes. Consequently, they demand fast methods concerning measurements and estimation. So the need of harmonic elimination arises, but first the harmonics spreading in the power network have to be determined and analyzed.

2. HARMONICS

2.1. Harmonics

Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is designed to operate, that combine with the fundamental voltage or current, and produce waveform distortion.

2.2. Causes

In a normal alternating current power system, the voltage varies sinusoidal at a specific frequency, usually 50 or 60 hertz. When a linear electrical load is connected to the system, it draws a sinusoidal current at the same frequency as the voltage (though usually not in phase with the voltage).

When a non-linear load, such as a rectifier, is connected to the system, it draws a current that is not necessarily sinusoidal. The current waveform can become quite complex, depending on the type of load and its interaction with other components of the system. Regardless of how complex the current waveform becomes, as described through Fourier series analysis, it is possible to decompose it into a series of simple sinusoids, which start at the fundamental power system frequency and occur at integer multiples of the fundamental frequency.

2.3. Mitigation of harmonics

There are a variety of solutions available to reduce the effects of power system harmonics. Passive filters are widely used to control harmonics and are a simple solution, but over time may lose effectiveness as their components age, and may also become overwhelmed by harmonic sources throughout the network.

3. HARMONIC ANALYSIS

Harmonic analysis is the process of calculating the magnitudes and phases of the fundamental and higher order harmonics in power system. Various digital signal processing techniques have been suggested for measurement and estimation of power system harmonics. Traditionally, the harmonic analysis can be based on the theories of static and dynamic estimation. Some of the theories used are examples of static estimation: Least-Squared Method (LSM), the Discrete Fourier Transform (DFT) and the Fast Fourier Transform (FFT). On the other hand, the Kalman Filter is an example of a dynamic estimation. In both methods, static and dynamic, the presence of incorrect data in the measurements (input data) has a significant effect in the performance of the estimation.

The LS technique is based on the minimization of the mean square error between the estimated and the measured values of a function. In power systems, the state variables estimated are the voltage and current magnitudes and phase angles. For a non-linear model of the system, this technique results in a reasonable estimation of the parameters.

The DFT technique is based on the theory of orthogonal functions, where the waveform measured consists of a fundamental component increased by an infinite number of harmonics. However, misapplication of the DFT algorithm can lead to incorrect results. The computational cost of the algorithm is very low, but its performance can be affected by the DC component present in the signal.

The FFT algorithm is also used to estimate the harmonic content for waveforms varying in time and it is an optimized version of the TDF.

The Kalman filter is based on a dynamic estimation of the signal and it has the ability to identify, analyze and locate the harmonic content in a non-stationary tri-phase signal. Despite presenting accurate results, previous statistical analysis of the signal is necessary.

4. FAST FOURIER TRANSFORM

4.1. Basics of Fourier analysis

Fourier analysis are generally classified as Fourier series and Fourier transform Fourier series are applied for continuous time and discrete time period signal whereas the Fourier transform are applied for continuous time and discrete time aperiodic signal.

4.2. Fourier Transform

Fourier transform is a versatile tool used in many fields of science as a mathematics.The Fourier transform decomposes a signal or a function into a sum of sines and cosines of different frequencies which sum up to the original signal or function. The main advantage of Fourier transform lies in its ability to transfer the signal from its time domain to the frequency domain which usually contains more information about the analyzed signal. As power system disturbances are subject to transient and non-periodic components, the DFT alone may fail to provide an accurate signal analysis. Theoretically DFT can be applied to any serried of values but in practice for large series it takes considerable time to perform the required computations, the time taken being proportional to the square of the number of points in the series. A much faster algorithm was developed around 1965 called the Fast Fourier transform (FFT).

5. THE HARMONIC MODEL

A signal can be represented in terms of its fundamental frequency and harmonic components, expressed as a sum of sinusoidal waveforms referred to as the Fourier Series. Each frequency is an integer multiple of the fundamental system frequency. In order to obtain an approximation of such waves, mathematical models are employed.

Consider a voltage waveform with harmonic components, written as Equation

$$V(t) = V_0 + \sum_{i=1}^{N} V_{si}(t)\sin(i\omega t + \phi_{si}) \qquad (1)$$

Where i is the harmonic order,
V_0 is the dc component,
V_{si} is the voltage magnitude of the i^{th} harmonic component,
φ_{si} is the phase of the corresponding i^{th} voltage component,
N is the highest harmonic order

6. RESULT AND DISCUSSION

6.1. Performance of FFT in harmonic analysis

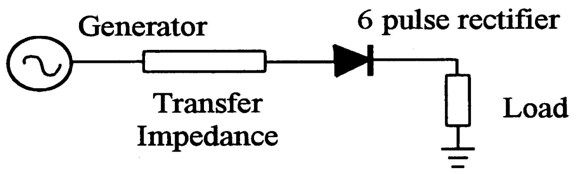

Fig. 2. Sample system a two-bus architecture with six pulse full wave bridge rectifier supplying the load.

This is the sample system with six pulse rectifier supplying the non linear load gives the distorted voltage and current waveforms to analyze the harmonics which are present in that system.

6.2. Without compensation Input Voltage

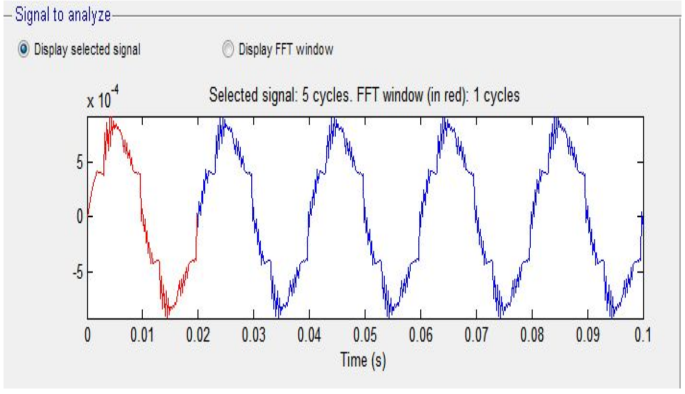

Fig.1. Input Voltage Vs Time

This waveform shows the input voltage of selected signal to analyze harmonics present in that signal.

% Magnitude of input voltage

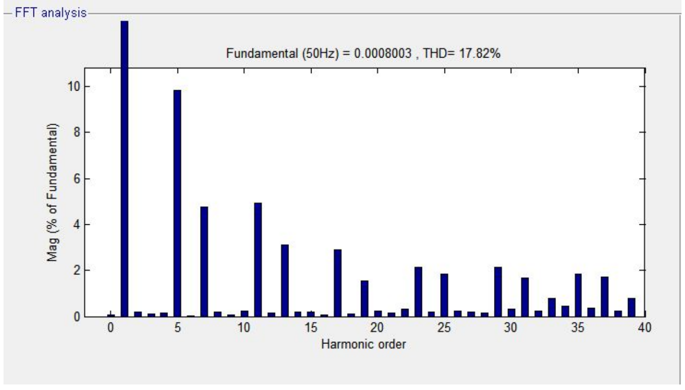

Fig.2. % Magnitude of input voltage Vs Harmonic order

Fig.2. shows that the input voltage of selected signal and their corresponding %magnitude of input voltage for the sample system

Input Current

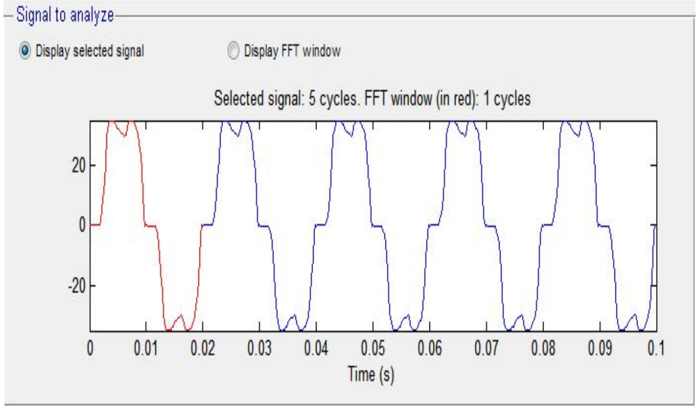

Fig.3. Input Current Vs Time

This waveform represents the input current of selected signal

%Magnitude of Input current

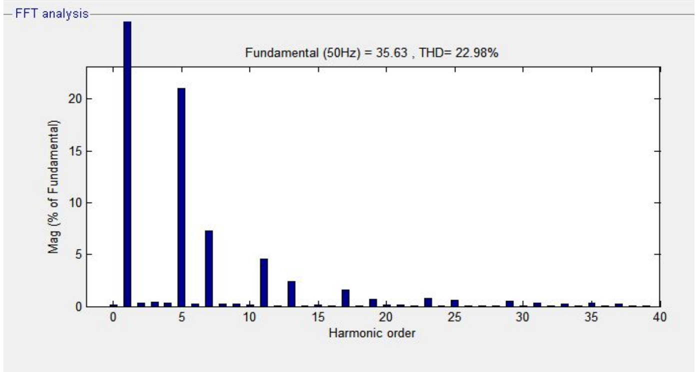

Fig.4. %Magnitude of Input current Vs Harmonic order

The above waveform shows that the %magnitude of input current with respect to the Harmonic order

6.3. With compensation -High Pass Filter

Input voltage

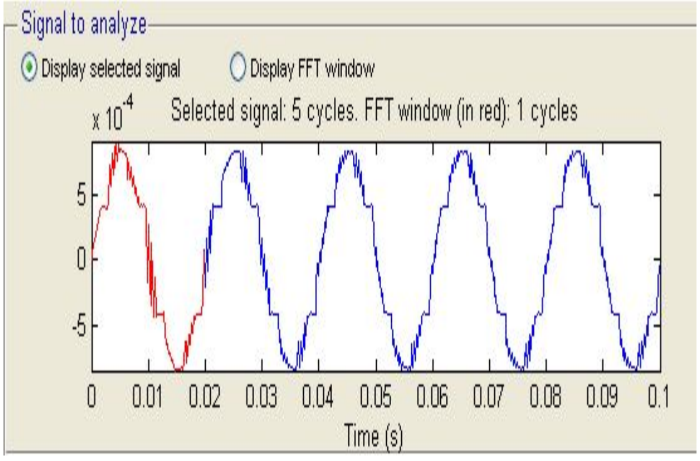

Fig.5. Input voltage Vs Time

%Magnitude of input voltage

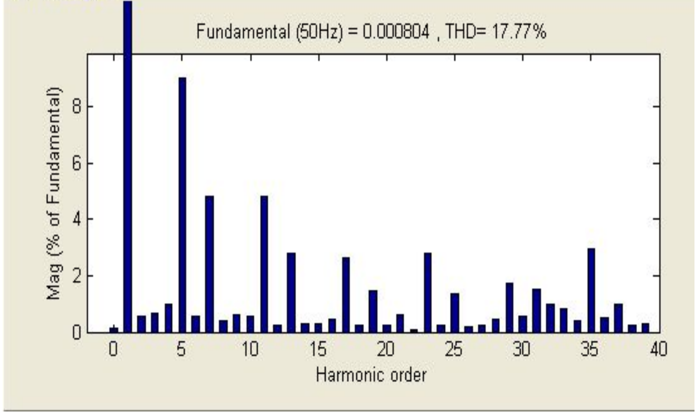

Fig.6. %Magnitude of input voltage Vs Harmonic order

The above waveform shows the input voltage of selected signal with filter. In this the high pass filter is used to reduce the effect of 7th harmonics present in the voltage waveform.

Input current

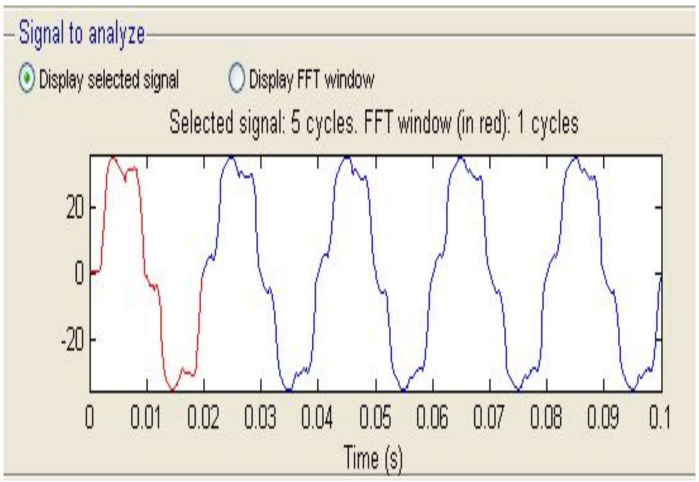

Fig.7. Input current Vs Time

%Magnitude of input current

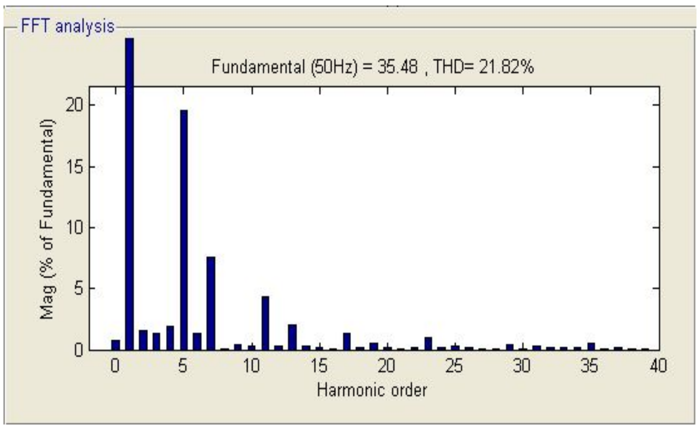

Fig.8. %Magnitude of input current Vs Harmonic order

The above waveform shows the input current and their corresponding %magnitude with respect to harmonic order.

With compensation- Double Tuned Filter

Input voltage

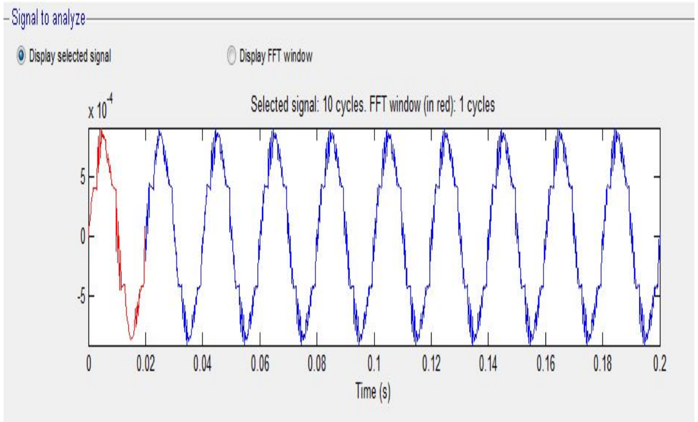

Fig.9. Input voltage Vs Time

%Magnitude of input voltage

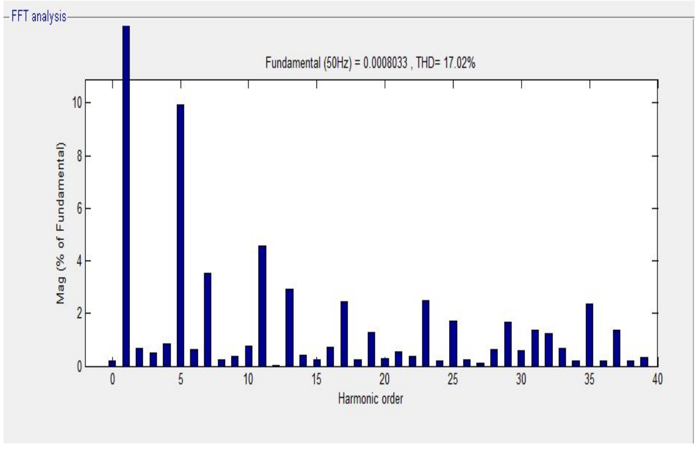

Fig.10. %Magnitude of input voltage Vs Harmonic order

Input current

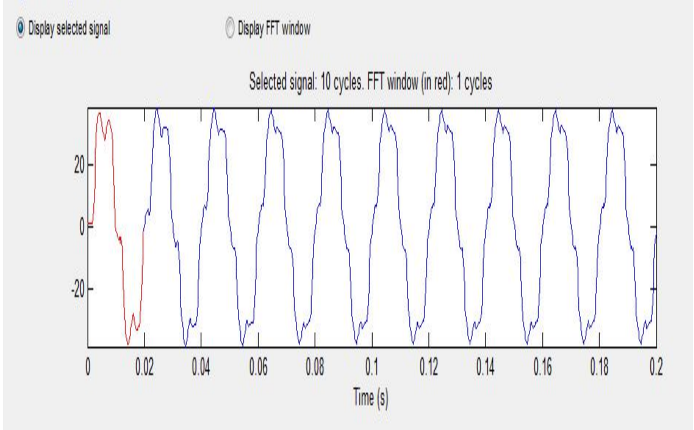

Fig.11. Input current Vs Time

%Magnitude of input current

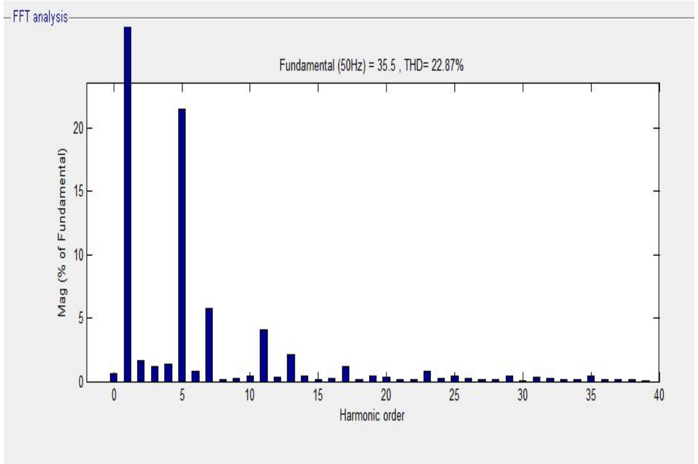

Fig.12. %Magnitude of input current Vs Harmonic order

The above four waveform shows that the input voltage and current waveform with double tuned filter and their corresponding %magnitude.

TABLE 1
Input measurements (% Magnitude)

Harmonic content	Without Filter	
	V	I
1	100	100
3	0.12	0.37
5	9.85	21.04
7	4.76	7.32
11	4.94	4.57
13	3.10	2.37
17	2.89	1.58
19	1.55	0.71
23	2.15	0.77
25	1.83	0.57

Table 1 gives the magnitude of input voltage and current of selected odd harmonics without compensation.

TABLE 2

Input measurements (%Magnitude)

Harmonic content	With Filter			
	High Pass Filter		Double Tuned filter	
	V	I	V	I
1	100.00	100.00	100.00	100.00
3	0.32	0.86	0.52	1.13
5	11.16	24.06	9.91	21.41
7	2.73	4.62	3.52	5.74

11	4.39	3.87	4.59	4.04
13	2.85	2.05	2.90	2.07
17	2.64	1.29	2.47	1.19
19	1.68	0.62	1.29	0.44
23	2.22	0.68	2.49	0.80
25	1.82	0.45	1.71	0.42

Table 2 gives the magnitude of voltage and current of selected odd harmonics using high pass and double tuned filter.

7. CONCLUSION

In this paper the authors proposed a solution procedure for measuring harmonics by FFT based method. The approach for calculating the correct system fundamental frequency is also described. The proposed method is tested using different examples.

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