FUNDAMENTALS OF HARMONICS AND ITS EFFECT ON POWER SYSTEM A CASE STUDY

Ritesh Dash[1] Aryadhara Pradhan[2]

Manas Ranjan Sarangi[3] Pratik Ranjan Behera[4]

Dr. S.M Ali[5]

[1,2,3,4,5]School Of Electrical Engg. KIIT University

Abstract

With the globalisation of industry the quality of power is changing day by day. In recent years power engineers are more concerned about harmonics and about their typical behaviour in electrical power system. The application of power electronics in day to day life has increased the efficiency of the system and at the same time they are also responsible for the production of harmonics. Non-linear loads basically contribute to zero sequence harmonic current in the neutral conductor and which is tripplen the current harmonics. The generated harmonic components again affect the voltage and current wave shape. This problem can be solved by the proper use of suitable filter, mostly LC filter. It not only nullifies the zero sequence harmonics but also some other harmonics present in the system. Power factor is improved and as a result the total harmonic distortion is also reduced. This paper gives a detailed theoretical presentation of harmonics and a matlab simulation to proof the concept.

Keywords: Harmonics, THD, Filter, Non linear

I. Introduction

Harmonics distortion is increasing day by day due to rapid industrialization and huge amount of power electronics devices. Thus reduction of power system harmonics has bagged a great condition in recent days. Harmonics are broadly classified into three categories namely positive sequence harmonics, negative sequence harmonics and zero sequence harmonics. Positive sequence harmonics consists of 7^{th} 13^{th} 19^{th} harmonics, where as negative sequence harmonics has 5^{th} 11^{th} and 17^{th} harmonics and that of zero sequence harmonics has 3^{rd} 9^{th} and 15^{th} harmonics. In a three phase four wire system the zero sequence harmonics flows through the neutral wire and hence leads to the overheating of the conductor. In power system, measurement of inter harmonics inside the harmonic is a great challenge and in recent year it drags the focus of many engineers. Inter harmonics are those harmonics whose frequencies are close to the harmonics. DFT is basically used to analyse the harmonics and inter harmonics components.

II. Concept Of Fourier Transform

Fourier transform and fourier series became very popular after its first invention in the year 1830 by jean baptiste joseph fourier. For signal processing Fourier transform is a tool to connect the time domain and frequency domain. All kinds of signal analysis are become very easy with frequency domain than that of time domain analysis.

ISSN: 2278 – 7798

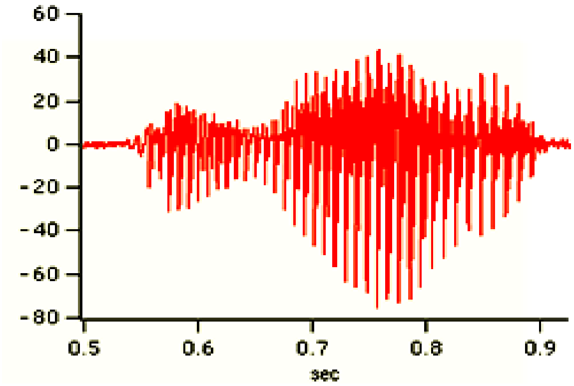

Fig:1 Voice Signal

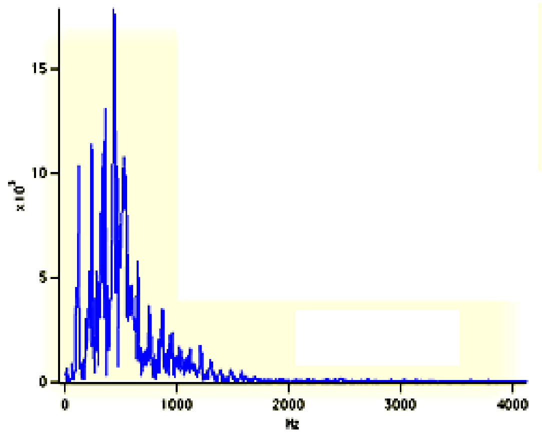

Fig:2 Frequency domain representation of voice signal

Figure :1 shows the voice signal and from which it is very difficult to predict the information content in the signal . however from figure :2 one can easily predict the signal that it contain one voice signal whose magnitude is about 600Hz. Thus it is necessary to transform a signal into its frequency domain so as to calculate the information.

The power system harmonics can be solved by fouries series as it is a technique to solve non-sinusoidal wave form. Trigonometric function such as sin(x) and cos(x) has a period of 2π. Similarly sin(nx) and cos(nx) has a period of 2π/n. Then the linear combination of these two function or multiply a constant will produce a periodic signal of 2π. According to fourier any periodic signal f(x) can be expressed as a sum of sinusoidal function

$$f(x) = a0 + \sum_{m+1}^{\infty}\big(amcos(mx) + bmsinmx$$

For any periodic function f(x) with period 2π f(x)=f(2π+x) becomes

$$f(x) = \frac{a0}{2} + \sum_{m+1}^{\infty}\big(amcos(mx) + bmsinmx$$

Using the orthogonality property

$$am = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)\cos(mx)dx$$

$$bm = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)\sin(mx)dx$$

$$a0 = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)dx$$

By considering the function

$$f(x) = \begin{cases} 1 & 0 < x < \pi \\ -1 & -\pi<x<\pi \end{cases}$$

The solution for the above function becomes

$$f(x) = \frac{4}{\pi} X \left(\frac{sinx}{1} + \frac{sin3x}{3} + \frac{sin5x}{5} + \dots\right)$$

In the above expression the higher order harmonics are neglected while the 3rd , 5th and 7th harmonics needs more attention .

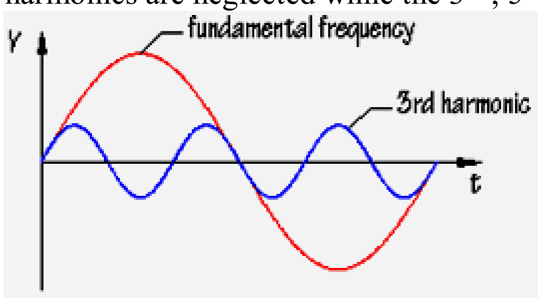

Fig:3 Fundamental and 3rd harmonics

ISSN: 2278 – 7798

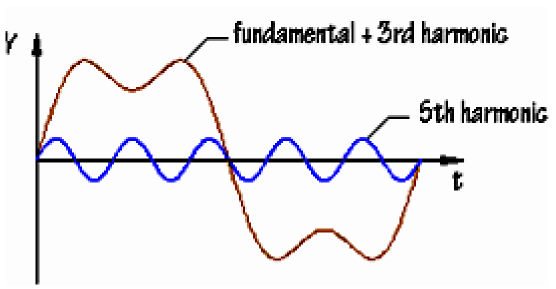

Fig:4 Mutual combination of Fundamental and 3rd harmonics with separate 5th harmonics

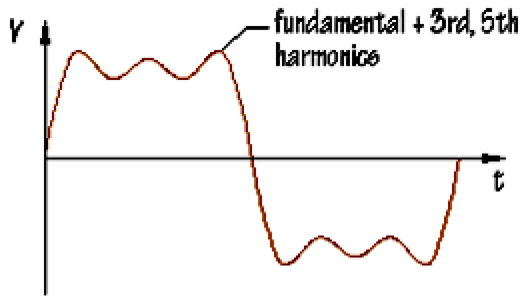

Fig:5 Mutual combination of Fundamental, 3rd and 5th harmonics

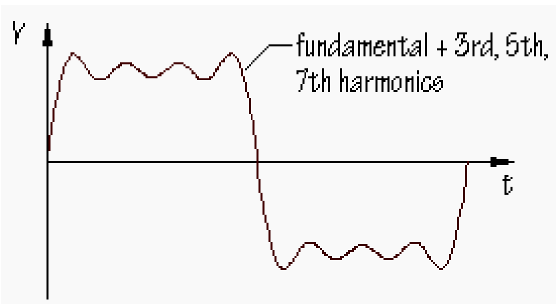

Fig:6 Mutual combination of Fundamental,3rd and 5th harmonics

From figure 3, 4, 5 and 6 it can be concluded that the higher order harmonics are neglected from the analysis. Harmonics always affect the flat top portion of the wave which ultimately creates some noise in the system.

III. MITIGATING THE HARMONICS

Harmonics can be limited either at the distribution side or at the end user side. Under light load condition the voltage rises and transformer produces more amount of harmonics. To mitigate this capacitor switching off can be applied. Harmonics in power system can be eliminated by either using passive filter or active filter. Active filter is a new concept where it restores the part of sine wave in the AC system. It basically uses an inductor and a capacitor. the inductor stores the charge and the capacitor stores the charge. Inductor will give supply to the AC system where it is necessary to insert the corresponding sine wave. The unique advantage of active filter over other filter is the avoidance of parallel resonance. It can address to more than one harmonics at a time.

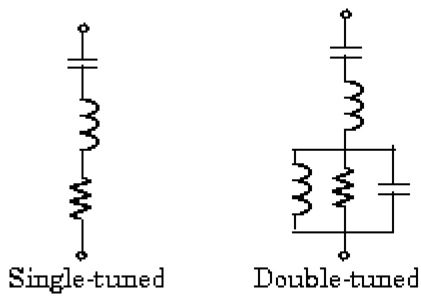

Fig:7 Single tuned & double tuned Filter

Passive filter are the most common type of filter used in the transmission system. Bur these type of filters usually suffers from parallel resonance so while designing the filter care must be taken to avoid the resonance. Depending upon the harmonic strength single tuned circuit or double tuned circuit is designed. Generally filters are applied in the system where the short circuit impedance is likely to be constant. Zero sequence harmonic can be filtered out by inserting a reactor in the neutral of the capacitor bank. Series passive filter is rarely employed because it has a limitation to multiple harmonic components. Therefore it is basically preferred for single phase circuits. Initially it provides a

ISSN: 2278 – 7798

high impedance path to the particular component of the harmonic current and hence can filter out only one harmonic component at a time from the system.

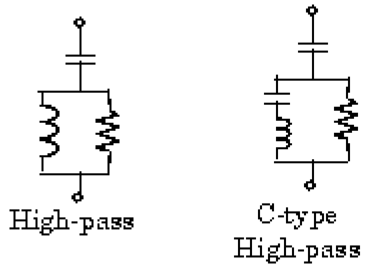

Fig:8 High pass & C type filter

Some times C type filter is also employed to limit the harmonic and inter harmonic components in the power system. They can attenuate a wide range of harmonics produced by industrial furnace and cycloconverter.

IV. MatLab Simulation

The simulation is designed with matlab with a DC input voltage of 230V and a non liner load is connected across the output side. Scopes and multimeter is connected at different level to observe the response at each point.

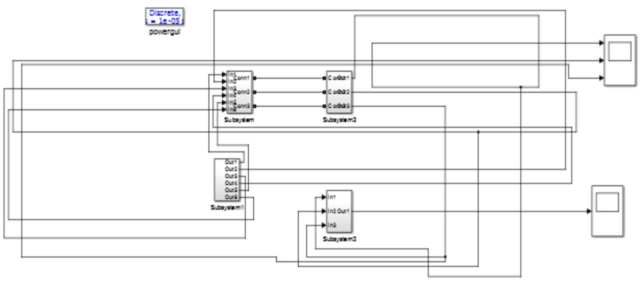

Fig: 9 Simulation diagram

Figure 9 shows the simulation diagram where masking is done to avoid the complexity of the circuit.

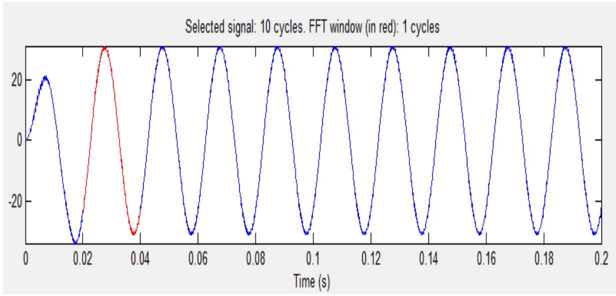

Fig: 10 Available signals

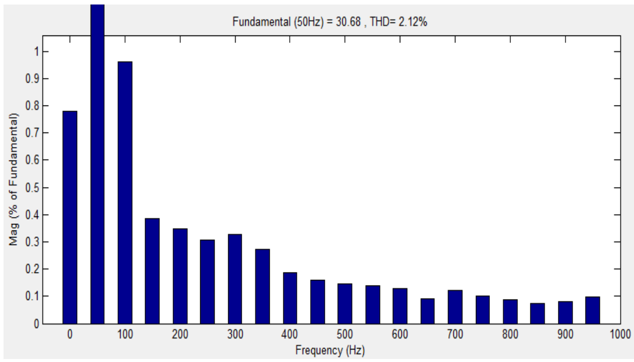

Fig: 11 Harmonics Distortion

Figure 11 shows the net harmonics present in the system. from the figure one can easily guess the 3rd,5th and 7th harmonics are more prominent than other harmonics present in the system. These harmonics can be eliminated from the system by the use of suitable filters such as passive shunt type filter.

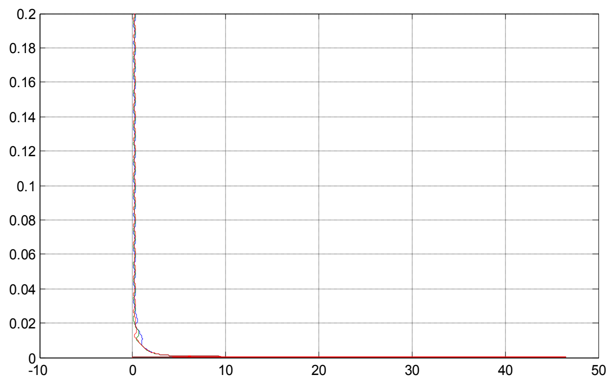

Fig: 12 THD

Fig: 12 shows the scope view of harmonics present in the system

ISSN: 2278 – 7798

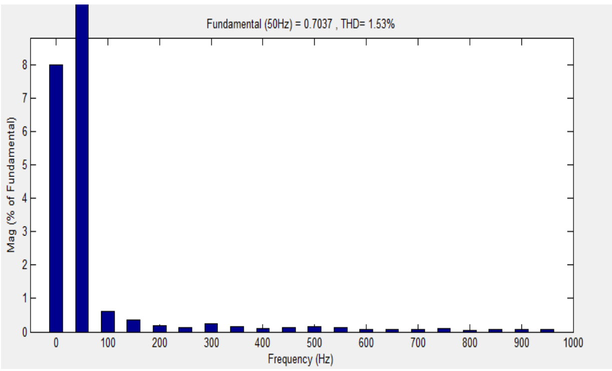

Fig: 13 Total harmonic distortion after the use of filter

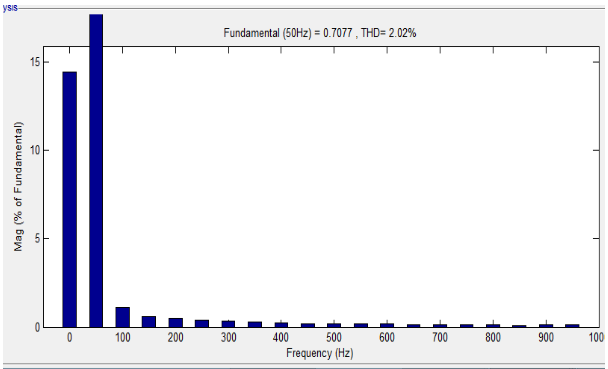

Fig: 14 Total harmonic distortion after allowing the zeroth component

Fig 13 and Fig 14 shows the harmonic reduction in the wave form after the use of filter i.e. a phase shifting transformer and allowing the zeroth harmonic component in the system.

V. Conclusion

Since harmonic effect in the transmission system is due to the use of vast power electronic equipments especially due to SMPS, the transmission line must be designed to handle such distorted current. Suitable filter design can eliminate the harmonics however they suffer from resonance effect. This can be eliminated with an active filter. In order to reduce the inter harmonic problem more sophisticated C type filter can also be employed.

VI. Reference

[1]. Najwa Mahamad, C. M. Hadzer and Syafrudin Masri," Application of LC Filter in Harmonics Reduction", National Power & Energy Conference (PECoo) 2004 Proceedings, Kuala **Lumpur,**pp 268-271.

[2]. Hui Jin, Yang Honggeng," A New Harmonics/Inter-harmonics Detection Approach based on Leakage Estimation" , 2010 China International Conference on Electricity Distribution.

[3]. Ahsan H. Chowdhury, W. Mack Grady, Ewald F. Fuchs," An Investigation of the Harmonic Characteristics of Transformer Excitation Current Under Nonsinusoidal Supply Voltage", IEEE Transactions on Power Delivery, Vol. 14, No. 2, April 1999,pp 450-458.

[4]. Mansoor, W. M. Grady, R. S. Thallam, M. T. Doyle, *S.* D. Krein, M. J. Samotyj," Effect of Supply Voltage Harmonics on the Input Current of Single-phase Diode Bridge Rectifier Loads", IEEE Transactions on Power Delivery, Vol. 10, No. 3, July 1995,pp 1416-1420.

ISSN: 2278 – 7798