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Harmonics: The Distortion in Supplied Waveform – Causes and Remedies

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A B S T R A C T

In Industrial Distribution Power System, the use of electronic devices such as motor drives, rectifiers or converters, power supplies and power electronic devices has been increased tremendously from last decade. In such a systems, switching operations are more in their regular work. It causes distortion in supplied waveform (Harmonics). This increases the Total Harmonic Distortion (THD) of Industrial Distribution Power System which is considered as the main reason for the power quality problems. This paper includes the sources of the harmonics, effects of the harmonics and the recommendations for correction of these problems of power quality resulting from harmonic distortion in the Industrial Distribution Power System.

Introduction

The use of modern power electronic devices has been increasedwhich results in harmonic interference problems in industrial power distribution and transmission systems. Now a days the power electronic devices used in the form of switched mode power supply (Akagi, 1995).

These are found in personal desktop computers, Laptops, Smart televisions, electronic lighting systems, electronic sound systems and adjustable variable speed drives and converters. These devices have so many advantages but they are facing problems of harmonics from source also they are drawing reactive component of current from the supply source. So that, they are producing more non-linear characteristics (Damian, *et al*., 1987; El-Habrouk, *et al.*, 2000).

The currents drawn by these nonlinear loads and power electronic devices have harmonics. Current harmonics are present in these nonlinear loads further results in voltage distortion at the consumer bus and are becoming troublesome problems in AC power lines. The harmonics presence in the power lines results in various problems, like: greater losses in distribution; problems of electromagnetic interference in communication systems; and operation failures of protection devices, electronic

equipment's. These problems result in high costs and lead to a decreasing in productivity and reduction of quality in the products or services. Due to these problems, the quality of the electrical power delivered to the end users is a major concern (James, *et al.*, 1994).

So harmonics are the common problem which occurs in electrical power systems that can cause various problems in distribution system, including inefficient power consumption and equipment damage. The distortion in supplied waveform caused by harmonics has become a major issue for power industries, requires a better knowledge of its causes and remedies. This work objects to provide an ample understanding of harmonics and its effects on power systems. The research which is conducted in this study will be beneficial for power industries and utilities to take preventive measures against harmonics and maintain system efficiency and reliability.

Power quality and its problems

The quality of power supply is the measure of how well the electrical power being supplied matches the requirements of the equipment that is using it. Power quality can be affected by various factors, including voltage fluctuations, presence of harmonics and frequency variations.

Power quality problem is defined as any problem developed in voltage, current or frequency deviations that result in malfunction or failure of customer equipment. Harmonics, voltage flicker, unbalance voltage sag, voltage regulation, voltage swell, and interruption in consistency, usually characterize the quality of electric power. Poor power quality can lead to issues such as equipment failure, downtime, and increased energy costs.

Some of the power quality problems created by the drives are harmonics, notching, etc, being heavily dependent on the supply system configuration, process equipment design, system switching, and protection practices. Due to the greater of adjustable drives in all industrial distribution applications, analysis of power quality issues is very important.

Harmonics and total harmonic distortion

Harmonics are electrical signals that are multiples of the fundamental frequency of the power system. Harmonics is defined as the content of the signal whose frequency is an integer multiple of the system's fundamental frequency. The presence of harmonics distorts the waveform shape of the voltage and current increases the current level, and changes power factor supply, which in turn creates many disturbances. Fig.1 shows the current harmonics and total harmonic distortion and Fig.2 shows the voltage harmonics and total harmonic distortion. This distorted waveform can be expressed as a sum of pure sinusoids. The harmonic number (n) usually specifies a harmonic component, which is the ratio of its frequency to the fundamental frequency.

To measure harmonic distortion, Total Harmonic Distortion (THD) is used. THD is a measure of the harmonic content in a waveform and is expressed as a percentage of the fundamental frequency. Total Harmonic Distortion is used to determine the level of harmonic distortion in an electrical distribution power system and to identify potential problems of power system (Reid and Petrus, 1985).

Harmonics producing appliances

Harmonic distortion in waveform is caused by nonlinear deices connected to the power system. There are many types of load that can produce harmonics. Some examples of common sources of power system harmonics some of which may not cause serious problems are:

LCD bulbs and lights

Electric welding devices

Variable frequency motor drives

Computer and laptops

Different types of Battery chargers
Television power supplies.

Distribution Transformer saturation

Magneto Motive Force distributions in induction motors

Inverters

Converters and Rectifiers

Faults in protection system and control circuits.

Effects of harmonics

Voltage distortion

Harmonics can cause voltage distortion, leading to equipment malfunctions and failure. Voltage distortion can also affect the accuracy of measurement equipment, such as meters and sensors.

Overheating

Harmonics can cause overheating in electrical equipment, such as motors and transformers. The non-sinusoidal current waveforms caused by harmonics increase the current flow and generate additional heat, leading to premature failure of the equipment.

Increased maintenance costs

The effects of harmonic distortion can lead to increased maintenance costs due to the premature failure of equipment and the need for more frequent repairs.

Resonance

Harmonics can cause resonance in electrical systems, leading to increased voltage levels and equipment failures.

Noise interference

Harmonics can cause noise interference in communication systems and other sensitive electronic equipment, leading to reduced performance and reliability.

Harmonic smitigation

There are following methods to mitigate the harmonics and THD:

Passive Filters

These filters are mainly contains combination of inductor and capacitor. There are series and shunt types of passive filters. Mostly the shunt passive filter is used to trap the harmonic current to correct the power factor of the load and properly filter the harmonics of the load. Shunt filters are usually more practical to use than series filters.

Figure 3(a) shows a simple example of a single frequency tuned filter having a very high admittance at its tuned frequency. Figure 3(b) shows a system with multiple filters tuned to different frequencies.

Active filters

Active filters use electronic circuits to cancel out the harmonic currents. Active filters are more efficient in mitigating harmonic distortion than passive filters, as they can detect and correct harmonic distortions in real-time. An active power filter compensates for harmonics and corrects the power factor by supplying the harmonic currents drawn by non-linear loads. Generally, the active filter is connected in parallel with the harmonic-inducing load. A general block diagram showing this scheme is given in Figure. A typical active filter includes a power electronic converter with either a capacitor or inductor acting as an energy storage element and a controller for determining the desired reference signal and generating the converter gating pulse patterns.

Fig.1 Current Harmonics and THD

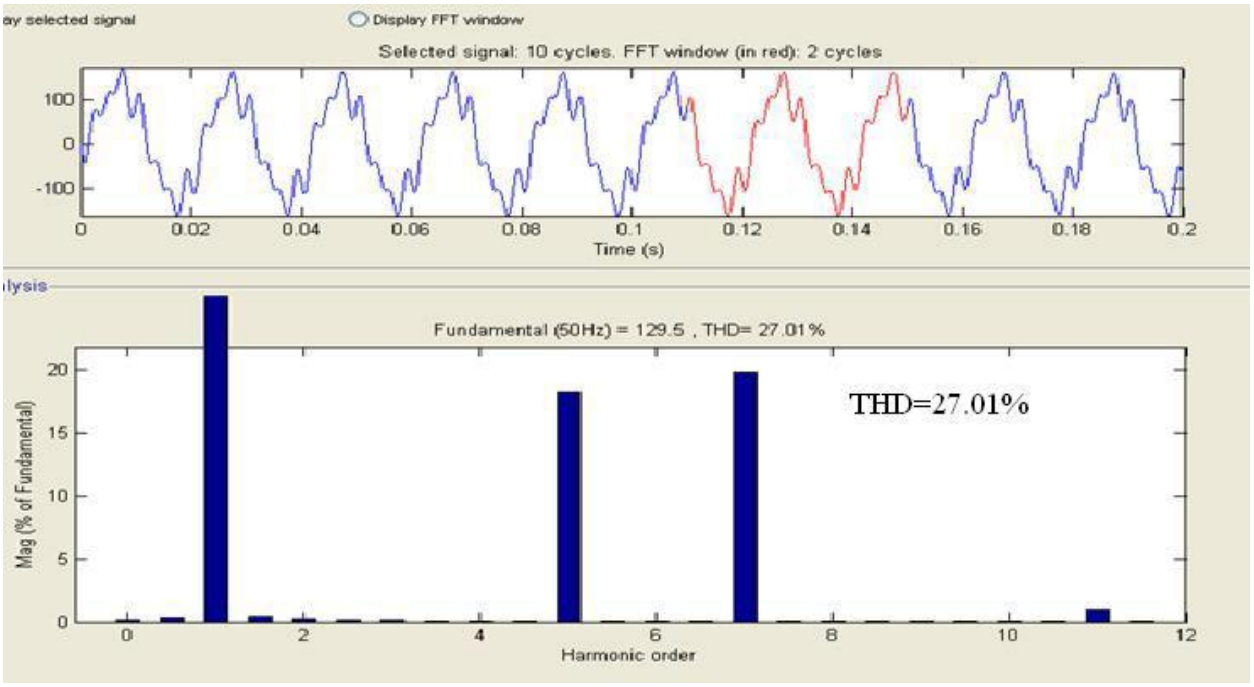


Fig.2 Voltage Harmonics and THD

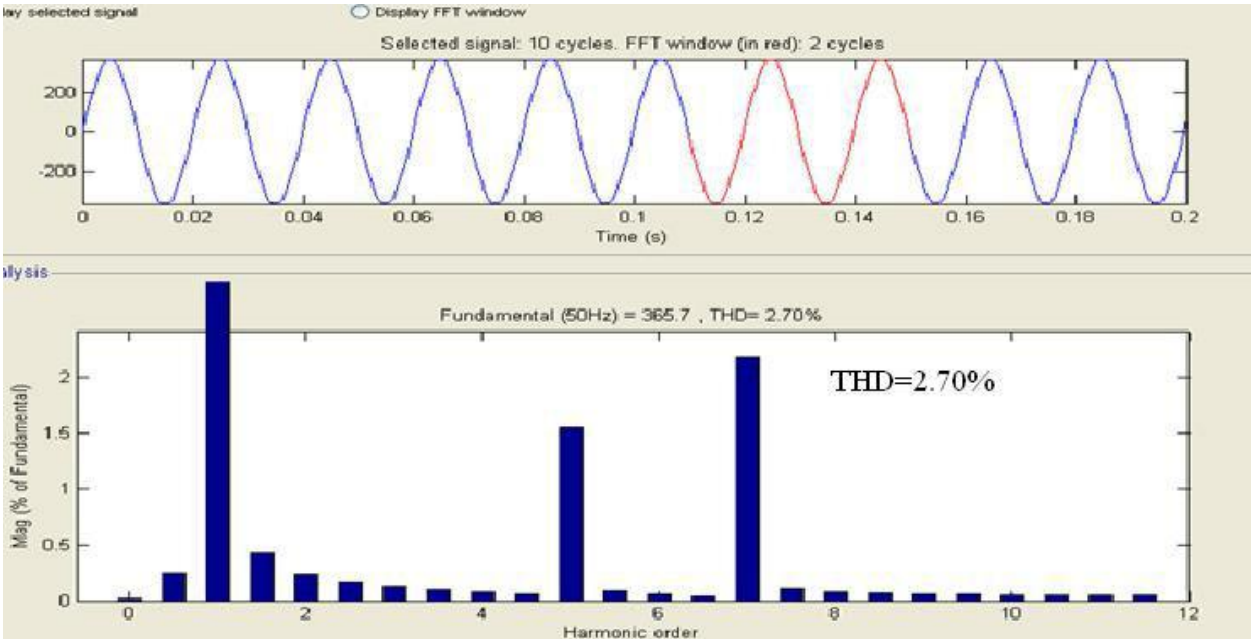


Fig.3 Passive Filters

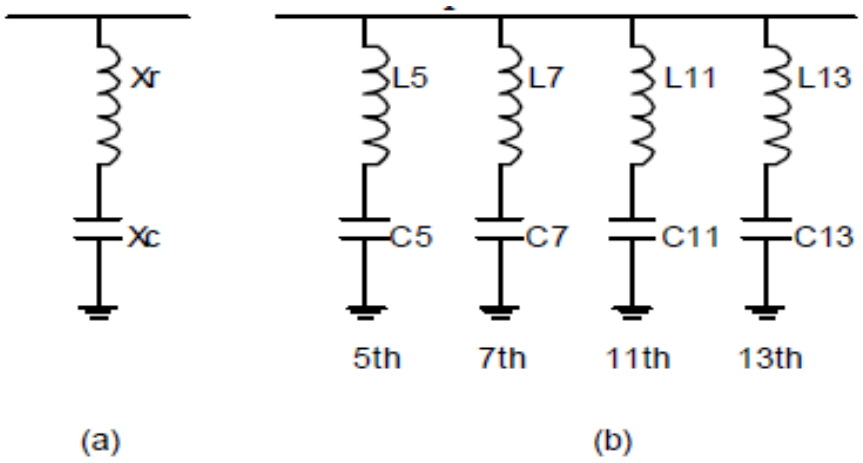


Fig.4 Active Filter

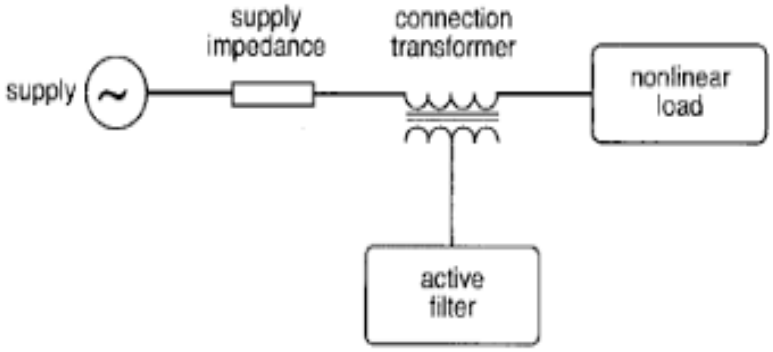
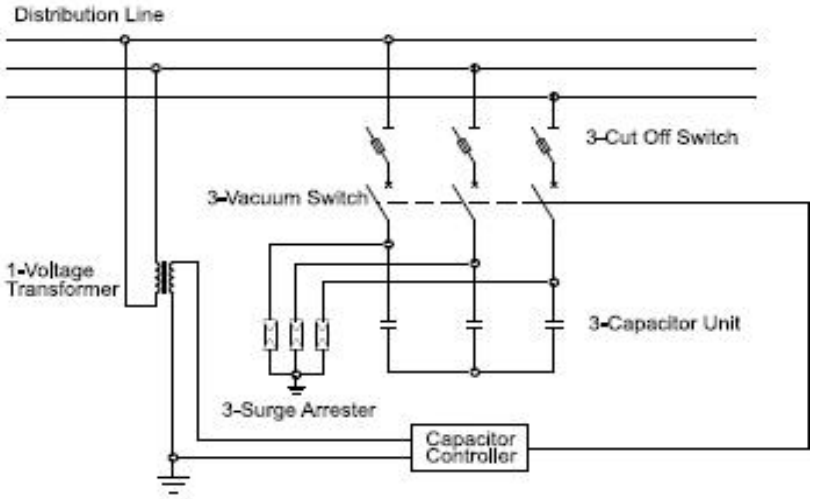


Fig.5 Capacitor banks



Capacitor Banks

The installation of capacitor banks can help reduce harmonic distortion, as they help to improve the power factor of the electrical system, reducing the reactive power and the harmonic currents.

VFDs and Soft Starters

The use of Variable Frequency Drives (VFDs) and Soft Starters can help reduce harmonics generated by motors, as they regulate the speed and starting torque of the motor, thereby reducing the amount of harmonic current drawn.

Phase Shifting Transformers

Phase shifting transformers are used to create phase shifts between the primary and secondary windings, which can help to reduce the level of harmonics. Due to the nonlinear load the harmonics in the distribution power system has been increased which leads to malfunctions in protection system, control circuits and damages costly equipments of the consumers. So it is important to understand the causes of harmonics, their effects on the system, and the available remedies to minimize their impact. So it is required to mitigate the harmonics and its distortion with proper planning and design using proper harmonic mitigating technique.

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