Harmonics - A power quality problem

A growing power quality concern is harmonics distortion that is caused by the non-linearity of customer loads. This concern has drawn much attention from utilities, manufacturers of equipment and users. Harmonics distorts the waveform shape of voltage & current, and increases the current level, which results in many disturbances. Read on to find out how harmonics affects the power quality and the various ways in which it can be avoided...

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The ideal quality of power supply is characterised by electric power energy with perfect sinusoidal waveform at a constant frequency of specified constant voltage with least amount of interruptions. Harmonics is one of the major factors due to which none of the conditions are fulfilled in practice. 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.

Voltage sags is the most important cause of interruption of industrial processes. Power quality problems encompass a wide range of disturbances such as harmonics distortion, swell transients, interruption, etc. But, voltage sags is a major source of power quality related problems. Poor power quality can affect industrial processes.

Power quality

Power quality problem is defined as any problem manifested in voltage, current or frequency deviations that result in failure or malfunction of customer equipment. Harmonics, voltage flicker, voltage regulation, unbalance, voltage sag, voltage swell, and interruption, usually characterise the quality of electric power. 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 wide use of adjustable AC & DC drives in all industrial applications, analysis of power quality problems is very important.

Ride-through features

Adjustable speed drives are the most sensitive equipment to prevent voltage sags; drives are immediately tripped off when the DC bus voltage drops below the tripping level. There are two parameters involved in ride-through features. One is the DC bus under voltage tripping level. The other is the ride-through time. In some cases, certain ride-through features, by way of changing new parameters of the drive system, are recommended. Some parameters are user programmable, whereas others need changes in hardware in order to ride through the voltage sag. The ride-through features can be achieved in AC drives by changing user-programmable parameters.

Harmonics distortion

A growing power quality concern is harmonics distortion that is caused by the non-linearity of customer loads. This concern has drawn much attention from utilities, manufacturers of equipment, and users. Harmonics distortion is load sensitive; devices that draw non-sinusoidal current from sinusoidal voltage sources cause it. Harmonics current, generated by non-linear loads, interacts with power system impedance to give rise to harmonics voltage distortion. If this distortion exceeds the recommended limit it can cause motor, transformer, and neutral wire heating; computers may exhibit data error or loss of data, and electronic process control may operate out of sequence. Premature failure of power factor correction capacitor is a common problem associated with harmonics distortion.

Harmonics mitigation techniques

The generation of harmonics, whenever an adjustable speed drive is used, is inevitable. The

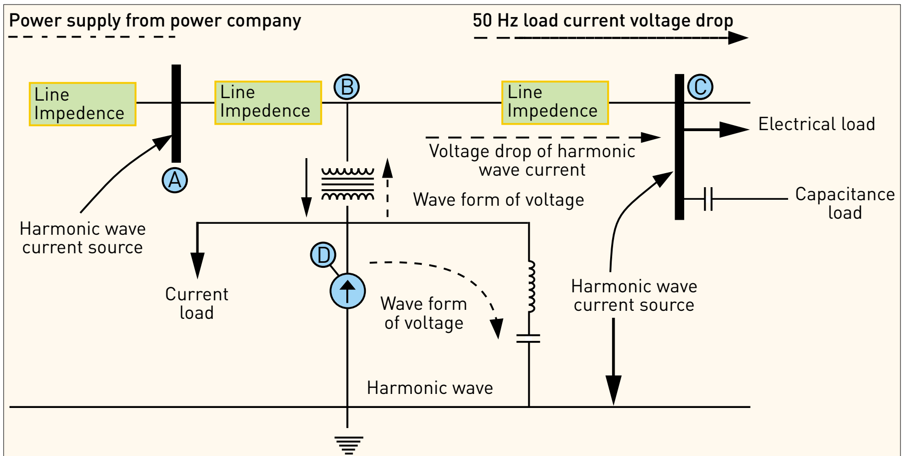

Figure 1: Harmonic wave voltage caused by harmonic wave current

order and magnitude of these harmonics will greatly depend on the drive configuration and system impedance. The various harmonic mitigation techniques available are as follows:

Phase multiplication: Whether the drive is AC or DC, the common means of reducing harmonic generation while in the design process is by phase multiplication or harmonic cancellation. It is effective in reducing low order harmonics as long as the load is balanced.

Passive filters: Improved power factor reduces high frequency harmonics. Large tuning reactors are not used as instability may occur due to parallel resonance with the source impedance. Performance depends upon source impedance; it cannot be measured accurately and can vary with system changes. Hence, passive filters are not appropriate for cycloconverters.

Active filters: With improved power factor, the output current can be controlled. Active filters provide stable operation against AC source impedance variation, and fast response irrespective of the order and magnitude of harmonics. These filters are appropriate for cycloconverters. The initial and running costs are usually higher than passive filters. The injection may flow into other system components.

Harmonics injection: Harmonics injection takes care of uncharacteristic harmonics. System impedance is not a part of the design criteria as it may give rise to low order harmonics.

Harmonics mitigation techniques with PWM: Harmonics can be reduced to less than one per cent of the fundamental with the help of PWM; it is programmable to eliminate specific harmonics. In addition to the above techniques, harmonics can be reduced by a number of circuit techniques.

Harmonics waveform

Electricity is produced and delivered in its fundamental form as a 50 cycles/sec (Hz) sine wave in India. Harmonics are multiples of the 50 Hz waves. For eg, the second harmonic is at 100 Hz, the third is at 150 Hz, etc. As harmonics are superimposed on the fundamental waveform, frequency of the electricity does not follow a smooth sine. Most electrical equipment are designed to handle smooth frequencies. Hence, distortions created by harmonics can cause a variety of problems.

Sources of harmonics

More use of solid-state power converters for industrial furnaces for mini steel and non-ferrous metal plants, use of thyristors for locomotives, especially for railways due to the massive electrification programme, and extensive use of single-phase electronic loads in domestic sectors are causes of harmonics generation. Rapid use of energy conservation devices such as electronic chokes for tube lights, electronic energy controllers for the motors, and electronic fan regulators, etc, in both domestic as well as the industrial sectors, also inject harmonics substantially.

The operation of the transformers closer to the saturation region of magnetisation characteristic, non-sinusoidal air gap flux in synchronous machines, magnetisation current of saturated reactors are some of the causes of harmonics generation that are related to electrical equipment. Capacitors used in transmission systems do not generate harmonics. However, they may cause resonance near a harmonic frequency, which in turn induces a large current and voltage. Thus, the widespread use of shunt capacitors to improve power factor and stability, influence harmonics levels significantly. The major causes of generation of harmonics are related to the supply system converters and tractions.

Effects of harmonics on equipment:

There are two major categories of harmonics effects on equipment:

a) Heating effects in power handling equipment such as motors, capacitors, and transformers that most often reduce the equipment's operating life
b) Disruption of operation that includes, for the most part, electronically controlled equipment

Harmonic current amplification

Application of power factor improvement capacitor in presence of static power converters can result in another problem, especially if the resonant frequency is close to one of the characteristic harmonics. Exciting the natural frequency of the parallel combination of the capacitor and system inductance will result in amplified harmonic currents. Amplified currents may cause overheating of equipment protective devices.

Parallel resonance created with the use of capacitors in the presence of harmonics can result in overloading or equipment damage. This problem can be avoided by shifting the resonant frequency, derating the equipment, and applying harmonic filters.

Measuring harmonics wave current:

While talking about harmonic waves the emphasis is always on harmonics wave voltage. The resonance is very simple, because the easiest way of observing power quality is to observe it with an oscillator. The waveform observed with an oscillator is the voltage waveform, but very few people can see the waveform of current. As a result, many people assume harmonics wave voltage to be the troublemaker causing many obstacles. In fact, the troublemaker resulting in an unusual change in voltage waveform is the harmonics wave current. Therefore, if you are affected by harmonics or have been unable to cope with the control standards required by power/utilities companies, you should know the measure of the harmonics wave contained in waveform of current or percentage value within the power system. Nevertheless, measuring the current is not very easy unless detection element serials are included in the circuit.

Measuring harmonics wave voltage

Owing to a change in the load current value, including 60 Hz base frequency and harmonics wave current of each level, one should check whether the voltage is normal before imposing a load. Customarily, the voltage waveform determines the power quality.

Harmonics wave voltage and current

As shown by the full-line arrow in Figure 2, load relates to power supply from the power company, and a 60 Hz load current comes from the power system. The load current will keep on causing drops in voltage. If it is a general load, voltage will drop by getting closer to the end of feed line, if it is a capacitance load current, then voltage rises. The waveform of current is a 60 Hz sine wave; hence, the waveform of voltage also remains a 60 Hz sine wave.

Harmonics wave current flows out of a non-linear load and some SCR non-linear loads obtain 60 Hz sine wave current from the power supplying company, and then harmonics wave current is delivered to the power system.

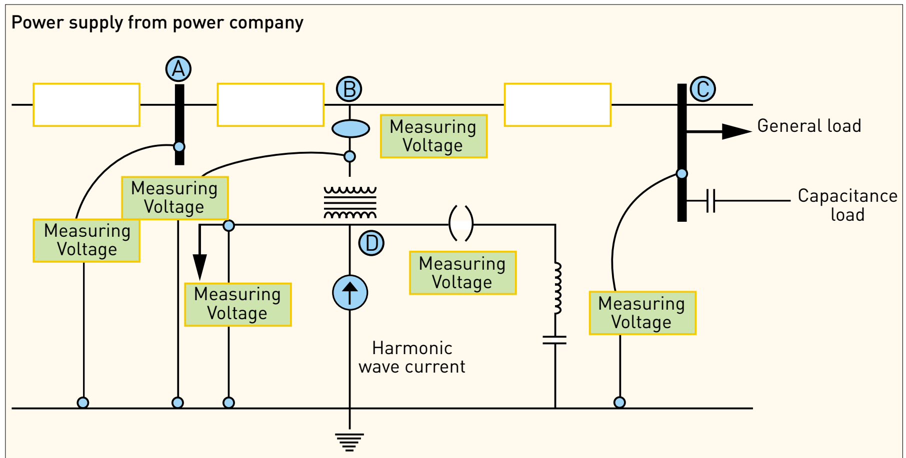

Figure 2: Measuring points of harmonic wave

As shown by the dotted-line arrow in Figure 1, voltage drop due to harmonic wave current takes place in the power system. Voltage at point A is a voltage drop due to 60 Hz load current as a result of voltage reduction in power system. Voltage at point B is the same. Voltage drop at point C is due to a 60 Hz load current and harmonics wave current as a result voltage reduction in the power system. Therefore, such a waveform is an unusual change rather than the 60 Hz sine wave form. The increase in voltage at point D is due to an unusual voltage waveform to the harmonics wave current.

On observing Figure 1, one realises that each point, as shown in Figure 2, is required for measuring the harmonics wave current and voltage form. As it is based on different objectives of analysis, the measuring points are different. This figure serves reference purposes only.

In order to ensure quality performance of various power system devices it is necessary to understand the problems deeply and incorporate more remedial measures.

While providing solutions to power quality problems, cost plays a major role. Hence, it is always necessary to find cost effective solutions to resolve power quality issues, and minimise equipment downtime and loss of production. This objective can be achieved by not only taking some minor precautions but also by measuring and monitoring the devices regularly. The disturbances due to power quality problems can be easily monitored using handy and quality instruments. The clamp-on power, leakage & harmonics analyser (model 5850) manufactured by Meco Instruments is one such instrument. Meco has also introduced an analyser (model PHT 4545), which is a state-of-the-art versatile instrument using micro controller technology and having various functions. It would be ideal for an inspector to carry out periodic visits, vigilance checks, surveys, raids, and audits at the industrial and consumers end.

The objectives of 'solution for harmonics in power' are very good, but the road ahead is very long and rough. It needs full cooperation from manufacturers and the users of power as well as the central and the state governments.

Note: Some of the details, examples or case studies taken from articles like IEEMA journal (a article by Prof B E Kushare, Dr A A Ghatol, A K Mathur & K Ravikumar) as well as from journals and magazines are issued herewith for the awareness & knowledge of readers.

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