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Harmonic Analysis to Improve Power Quality

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Abstract- **Presence of nonlinear & power electronic switching devices produce distorted output & harmonics into the system. This paper presents a technique to analyze harmonics using digital series oscilloscope (DSO).In power distribution system further measurements are done by DSO, and the waveforms are analyzed using FFT program. The results of this proposed work is helpful for the investigator to install appropriate compensating device to mitigate the harmonics, in turn improve the power quality. This case study is carried out at AIT chikmagalur. It is done as a starting step towards the improvement of energy efficiency at AIT chikmagalur. And with a overall aim of reducing the electricity bill with complete energy audit of the institution.**

Strategies put forth to reach the above objective; The following strategies were proposed to be implemented to analyze the power quality in EEE department of the institution.

Strategy 1;The power factor has to be measured using the energy meter. Power factor improvement may reduce the voltage drop in lines .This brings the voltages at the socket in the labs closer to the nominal voltage of 230V,& thus power quality improves.

Strategy 2;The harmonics at the power inlet has to be measured by means of a DSO .The DSO waveform is analyzed using FFT to know the percentage harmonic up to the 13th harmonics of 50Hz.Reduction in the harmonics in the inlet of the EEE department may reduce line losses & therefore reduces energy bill to the institution.

I. INTRODUCTION

Power quality is the relative voltage & frequency deviation in the incoming power supplied to the electrical equipment from the customary steady 50Hz sinusoidal waveform of voltage & current. Power quality, as is "a set of electrical boundaries that allows equipment to function in its intended manner without significant loss of performance or life expectancy"[1].

The term is used to describe electric power that drives an electrical load & the load's ability to function properly with the electric power. Without proper power ,an electrical device may malfunction, fail prematurely or not operate at all. There are many ways in which the electric power can be of power quality & many more causes of such poor quality power. Power quality is ultimately a consumer driven issue and the end user's point of reference takes precedence. This paper presents the effect of power quality on the equipment, harmonic distortion in power distribution and increased losses in the distribution system. Till the 3rd quarter of the 20th century, most of the electrical equipments operated on ideal voltage & current waveform. However in the past 25 years there has been an explosion in the use of solid state electronic technology. This new, highly efficient, electronic technology provides improved product quality with increased productivity by the use of smaller & lighter electronic components. Today we are able to produce products at the cost which are considerably lower than the same in the past years, but this new technology requires clean electrical power and is highly sensitive to power distortions.

The utility had to supply the good quality of power supply to the consumer with allowable limits of voltage and frequency variation, voltage harmonics, etc., but today due to the increased gap between supply and the demand and more usage of power electronic equipment, the power quality is being polluted. Power quality issues have become more important in recent years due to the proliferation of microcomputer based system which are sensitive to the power disturbances. Modern electrical equipments imposes stringent demands on voltage stability and power quality. The power has to be free from harmonics and other electrical disturbances. The polluted power supply influence more losses in the system, reduction in the quality of the products and reliability of the power supply. In India, the CBIP report 251 gives in detail the allowable limits of voltage harmonics.

II HARMONICS

Harmonic frequencies are the integral multiple of the fundamental supply, i.e for a fundamental frequency of 50Hz

Third harmonic would be 150Hz & the fifth harmonic would be 250Hz. Harmonic distortion waveform is clearly not a sine wave & that means that normal measurement equipment such as a average reading rms-calibrated multimeter will give inaccurate reading[2].

Types of equipment that generate harmonics

Harmonic load currents are generated by all the non linear loads. These include:

Single phase loads

- Switched mode power supplies(SMPS)
- Electronic fluorescent lightning ballasts
- Small uninterruptible power supplies (UPS) units.

Three phase loads

- Variable speed drives
- Large UPS units

Problems caused by harmonics

- Increased losses .Example: machines will not operate at increased temperature & can be over heated.
- Resonance problems between the inductive and the capacitive parts of the power network.
- Malfunctioning of the control systems since electronic meters, relays etc. are unmatched to the fundamental frequency.
- Overloading of the capacitors leading to malfunctioning and premature aging .
- Interference with telecommunication and computers.
- High currents in neutral conductors.

Standards of electrical power quality

There are many national and international standards of power quality. Two main standards are

1. IEEE standard 1100, "recommended practice for powering grounding sensitive electronic equipment," IEEE standards 1992
2. IEE standard 519-1992, "IEEE recommended practices and requirements for harmonic control in power system," IEEE standards 1992.[3]

The objectives of the current limits are to limit maximum individual frequency voltage harmonic to 3% of the fundamental and the voltage THD to 5% for the systems without the major parallel resonance at one of the injected frequencies.

Achieving low voltage distortion is the principle goal. Measurements for current distortion are to help identify potential voltage distortion problems. This is a important consideration when determining the filter rating requirements & the ability to meet the IEEE 519 harmonic current limits.

Fig 1: Yokogawa DL1520 digital oscilloscope

Experimental setup for machines lab

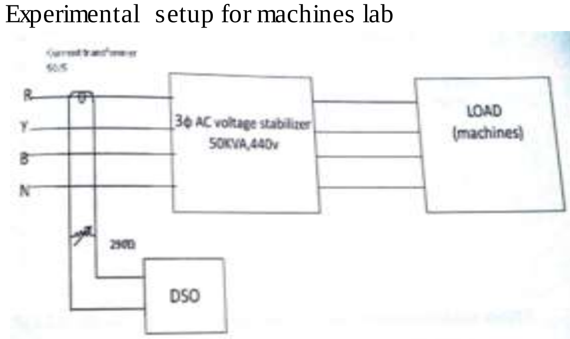


Fig.2.Schematic block diagram for measurement of RMS & FFT current waveforms at the stabilizer input in the machine

III METHODOLOGY

The paper deals with the study of the voltage and the current harmonic distortion produced in the computer and machines laboratory of the EEE department using Yokogawa DL1520 digital oscilloscope as in fig.1 and the setup is designed as in fig.2.Any periodic waveform may be shown to be composed of the superposition of a direct component with a fundamental pure sine wave component, together known as harmonics at frequencies which are integral multiples of fundamental. A non sinusoidal wave is often referred to as a complex wave and is mathematically expressed as

v=

$V_0 + V_1\sin(\omega t+\emptyset_1) +$
$V_2 \sin(2\omega t+\emptyset_2)+\ldots\ldots V_n \sin(n\omega t+\emptyset_n)$

Where V is the instantaneous value at any time instant t

V_0 is the direct or mean value .

V_1 is the maximum value of the fundamental component

V_3 is the maximum value of the second harmonic component.

V_n is the maximum value of the nth harmonic component.

The distortion relating to a particular harmonic component in a waveform may be expressed as the relative magnitude of RMS harmonic voltage of the order n to the RMS amplitude of the fundamental.

The total harmonic distortion (THD) factor is the ratio of RMS value of all the harmonic components together to the RMS amplitude of the fundamental.

$$\text{THD factor}=\frac{V_{2(rms)}^2+V_{3(rms)}^2+\cdots\ldots\ldots+V_{n(rms)}^{0.5}}{V_{1(rms)}}$$

$$=\frac{(V_{(rms)}^2-V_{1(rms)}^2)^{0.5}}{V_{1(rms)}}$$

IV RESULTS

Voltage Harmonics

Voltage harmonics are generated by nonlinear loads. With linear loads and sinusoidal voltage supply, all the waveforms are sinusoidal. output results measurement of RMS & FFT current waveforms at the stabilizer input in the machine as in fig.3 with the calculations. The amount of voltage harmonics depend upon the amount of harmonic currents being drawn by the load & the source impedance ,which includes all the wiring and transformers back to the source of the electricity . According to Ohm's law, voltage is equal to current multiplied by impedances.

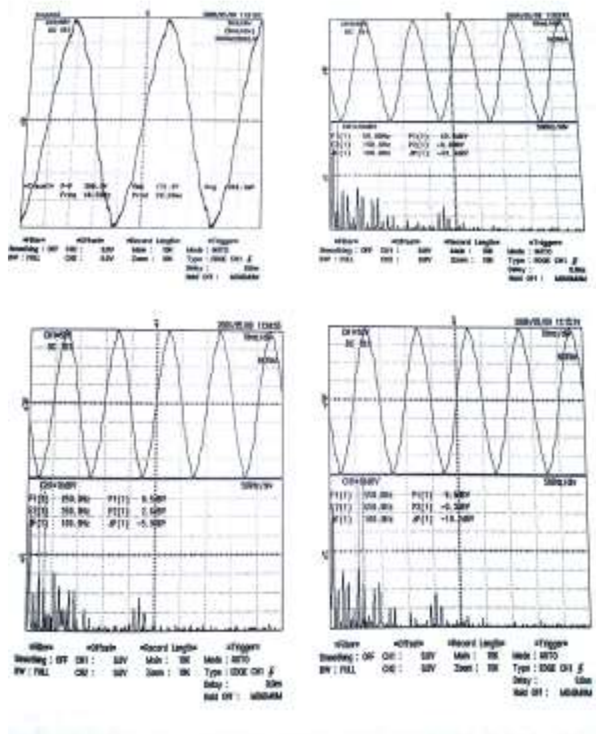


Fig.3:output results measurement of RMS & FFT current waveforms at the stabilizer input in the machine

Calculations

Total voltage harmonic distortion of line

Total RMS value of line to neutral voltage (V)=130.5volts

Voltage in Decibel for 50Hz=42.1dB

To convert voltage from dB to volts

dB=20logV_1

42.1=20logV_1

$V_1 = 10^{\frac{42.1}{20}}$

V_1=127.3volts

UPS in the computer lab	Phase current in the computer lab	THD (on loading)
Input	Phase current	138.38%
Output	Phase current	163.04%

$\text{THD}=\frac{(130.5^2-127.3^2)^{0.5}}{127.3}$=0.22=22%

Machine lab	Phase current in the machine lab	THD (on loading IM)
Input	Phase current	23.74%
Output	Phase current	80%

Table 1: THD measured at the stabilizer output in machines lab

Three phase voltages	THD (without load)	THD(on no load)	THD(on loading)

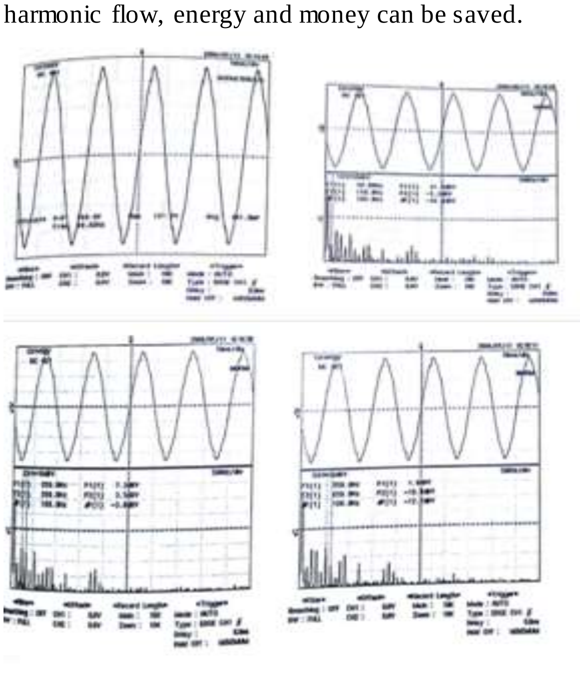
Line to line	11.5%	17.56%	7.87%
Line to neutral	9.49%	16%	22%

Table 2: THD measured at the stabilizer input in machines lab

Three phase voltages	THD (without load)	THD(on no load)	THD(on loading)
Line to line	10.3%	4.2%	15.73%
Line to neutral	3.7%	5.4%	14.1%
Neutral to ground	118.1%	171%	144%

Current Harmonics

It is important to distinguish current harmonics from voltage harmonics. Output results measurement of RMS & FFT current waveforms in the machines lab are as in fig.4.Current harmonics are created by diode, thyristor & IGBT rectifier loads (VSD, UPS, computers, controlled lighting equipment) and are a result of a non-sinusoidal current waveform drawn from the paper line. Current harmonics will affect only equipment in serial to the diode rectifier load. This means that the wires to the diode rectifier load have to be bigger and the switching gear has to be oversized. Most drives today already have built in harmonic mitigation in the form of DC or AC coils in front of the drive. This ensures that wires and serial equipment are not affected. Harmonic current flow generates heat in all parts of the distribution system, which wastes energy .By getting rid of the current harmonic flow, energy and money can be saved.



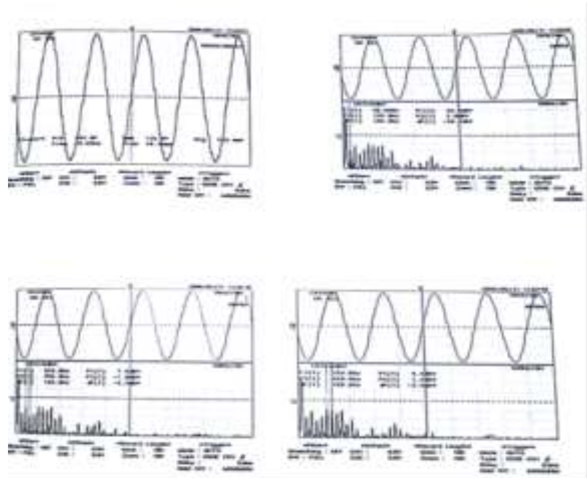


Fig.4:output results measurement of RMS & FFT current waveforms in the machines lab

V.CONCLUSION

Among the several power quality quantities harmonics is selected to analyze power quality .Virtually all modern and electronic equipment contain a SMPS or involves some form of power control and so is a non linear load. Linear loads are comparatively rare, undimmed filament bulbs and uncontrolled heaters being the only examples. The real impact on harmonic pollution produced by electronic equipment such as PC's. As the quantity of installed equipment rises, it is likely that harmonic pollution will continue to increase. This is a risk to business that needs to be managed by investment in good design practice, the right electrical equipment & good maintenance. Compatibility problems always have two solutions in this case either clean up the power or make the equipment stronger.

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About the author

Rumana Ali graduated Bachelor of engineering Electrical & Electronics Engineering in 2009, & Masters of engineering Electrical & Electronics Engineering in 2012.Presently working as assistant professor in Mangalore Institute of technology, Mangalore India. Area of interest power system, power electronics