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THD Analysis of Non-Linear Loads

Viveksheel Verma[1], Ved Prakash Verma[2], Harkamaldeep Singh[3]

Lecturer, Electrical Engineering Department, ABVGIE&T Pragatinagar, Shimla, Himachal Pradesh, India[1,2]

Head of Department, Electrical Engineering Department, GGSCMT Kharar, Mohali, Punjab, India[3]

Abstract: The power quality is deteriorating day by day due to the extensive use of power electronic based devices which have non linear relationship between voltage and current. The major domestic and industrial non-linear devices are major source of harmonics in power supply network. The harmonic is measured in various indicators but Total Harmonic Distortion (THD) is one of the popular harmonic indicator. In this paper detailed harmonic analysis is carried out in respect of THD in load current of non linear devices. The THD values of all the non-linear loads are analysed and evaluated in current spectrum with the help of Power Harmonic Analyzer.

Keywords: Harmonic, Non-Linear Load, Total Harmonic Distortion (THD), Power Quality

I. INTRODUCTION

With the invention of power electronic based circuitry, linear devices in domestic as well as industrial sectors are being replaced by modern non linear devices such as computers, Compact Fluorescent lamps, Printers ,Rotary converters etc[1,3]. The excessive use of such loads having non linear behaviour have revealed the various aspects of emerging harmonic pollution in the supply system that are affecting the distribution network and leads poor power quality [4-5]. The energy consumers are ignorant about the harmonic pollution, which can lead to various consequences on energy conservation and economic crisis in near future.
Harmonics are generally referred as the periodic, steady state unwanted frequency which is superimposed on the fundamental frequency [2, 7]. The harmonics are produced by the domestic appliances which exhibit the non linear relationship between current and voltage waveform [9, 11]. These harmonics in the supply system has severe impacts such as malfunctioning of equipments, heating of appliances, voltage sag and swells, corruption of data in computers and interference with telephonic lines.
The analysis of harmonics in domestic sector is quite necessary as it leads to increment in efficiency, saving of economy and proper utilization of appliances. This paper presents the harmonic spectrum obtained from the various domestic and industrial appliances in respect of THD indicator of harmonic [6, 9, 13]. The peak and r.m.s. current values of various appliances are found out along with the THD value. The high value of THD content in the supply system indicates highly distorted wave shapes of current and voltage due to the presence of power electronics based circuit [14, 15].

II. TOTAL HARMONICS DISTORTION

Total Harmonic Distortion (THD) is the most commonly used harmonic indicator in power system network. THD is most dominant factor which is responsible for poor power quality & leading harmonic indicator of power pollution. The THD may be calculated in either voltage or current profile. The THD in voltage and current profiles are calculated by equation (1) and equation (2) respectively.

$$THD_V = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \ldots}}{V_1} \qquad (1)$$

$$THD_I = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1} = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \ldots}}{I_1} \qquad (2)$$

THD is defined as the ratio of the root mean square value of the harmonic component to the root mean square value of fundamental component and is generally expressed in percentage. This indicator is used to find out the variation of a periodic non-sinusoidal waveform with respect to perfect sine wave. THD of an ideal sine wave is zero. Similarly, for individual harmonic distortion of voltage and current at h^{th} order are expressed as V_h/V_1 and I_h/I_1. The THD factor pertaining to the RMS value of the current waveform is given by equation (3).

$$\text{RMS Value} = \sqrt{\sum_{h=1}^{\infty} I_h^2} = I_1\sqrt{1 + THD_I^2} \qquad (3)$$

Variations in the THD factor over a period of time follow a distinct pattern representing non-linear load profile in the system. The THD index is most often used to describe current harmonic distortion.

III. NON-LINEAR LOADS

Non-linear loads are those loads whose impedance changes when the voltage is applied. The change in impedance results in current which will not be sinusoidal. These non sinusoidal currents contain harmonic features that leads to the voltage distortion in the power system equipments connected with it [13]. In this present work some domestic and industrial non-linear loads are consider for THD analysis. The domestic and industrial non-linear loads along with details specification are explained in subsequent sections.

A. *Domestic Loads*

The commonly used domestic devices having non linear characteristics between voltage and current contain harmonics of various orders are taken into consideration for analysis. The list of major non-linear domestic loads is listed in table 1 along with their specification.

Table 1 Major Domestic Non-Liner Loads

Domestic Load	Specification
Compact Fluorescent Lamp (CFL)	200 Watts (10 lamps of 20 Watt each)
Personal Computer	2.5GHz Intel Core i5 Processor with 4GB RAM,Screen of 13.3-inch with Storing Capacity of 256GB
Uninterrupted Power Supply (UPS)	1-φ, 2KVA, 240V±10% V AC, Single phase 50±5% Hz frequency
Printer	HP Laser Jet 1020 plus with laser technology and print speed of 15 ppm.
Mobile Battery Charger	Input: 110V-250 AC, Frequency: 50Hz Capacity: 2600mAH, Output: 5 Volts dc
Photostat Machine	Xerox Ducu Centre SC2020 with memory of 512MB

B. *Industrial Loads*

Due to the extensive use of power electronic based circuitry in industrial sector, majority of industrial loads these days contains harmonics leading to the non sinusoidal behaviour of current and voltage resulting in harmonic distortion. The various industrial loads used for the experimentation purpose along with the technical specification are tabled in table 2

Table 2 Major Industrial Non-Liner Loads

Industrial Load	Specification
Rotary Converter	Voltage, Input: 210V, 230V, 460V, Output: 0-440 V (variable DC) % Regulation: 2-5% at full load & efficiency: >96% at full load
Electrical Furnance	Rated Capacity : 40-400 Tons, Rated Temperature : 1080 C Furnace Transformer Capacity :25-28MVA, 132KV, 50 Hz
Electric Welding Machine	Input power voltage: AC 440V (3-Phase), Rated output voltage: 20-250 V Output current range: 62A, Efficiency: 60% and Power Factor: 85

IV. EXPERIMENTAL SET-UP

An experimental setup is developed to take the reading of current THDs of various domestic and industrial loads with help of PHA 5850 Power Harmonics Analyser. The distorted spectrum of current is obtained with help of analyzer. The view of PHA 5850 Power Harmonic Analyzer and experimental setup along with CFL non-linear load is shown in Fig. 1(a) and Fig. 1(b) respectively.

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Fig. 1(a) PHA 5850 with its Complete Accessories

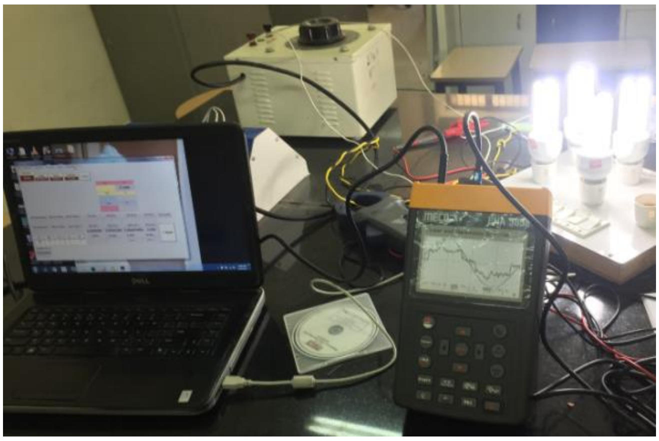

Fig. 1(b) View of Experimental Setup along CFL non-linear load

Further, each recorded current harmonics spectrum of non-linear load is being analysed in detail and calculates other parameters, which are discussed details in next sections.

V. EXPERIMENTAL RESULTS & DISCUSSIONS

The distorted spectrum of each non-linear is obtained with the help of Power Harmonic Analyzer which directly shows the values of THD with respect to order of harmonic. The peak and r.m.s. value of current are also shown in distorted current spectrum as a result of which with the help of peak and r.m.s. values of current peak factor can also be obtained. The %THD value indicates the harmonic distortion in the power supply networks. The harmonic spectrum of various domestic industrial non-linear loads is shown Fig. 2 to Fig.9 respectively.

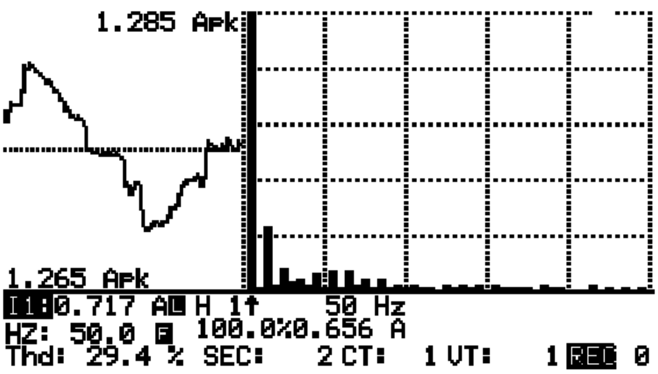

Fig.2 Spectrum of Non-Linear Current through CFL Load

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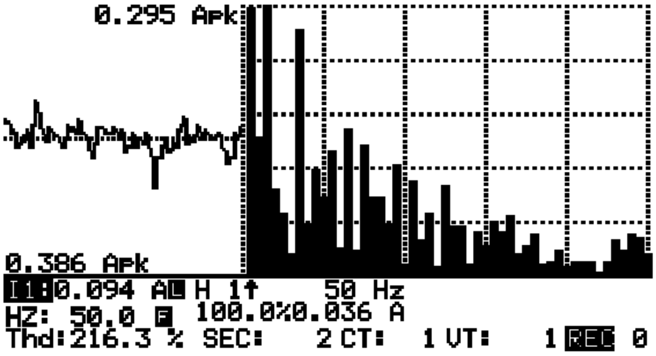

Fig.3 Spectrum of Non-Linear Current of Photostat Machine

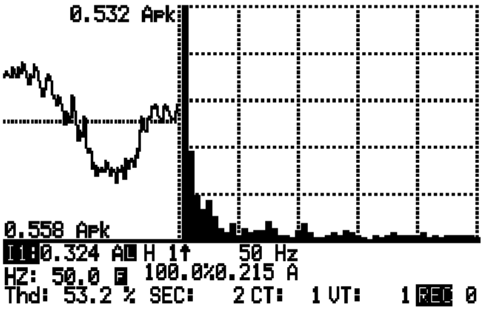

Fig.4 Spectrum of Non-Linear Current through PC

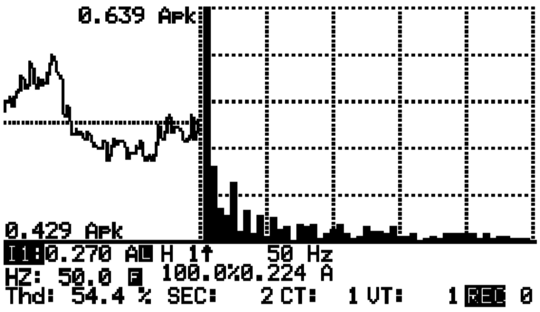

Fig.5 Spectrum of Non-Linear Current through Mobile Charger

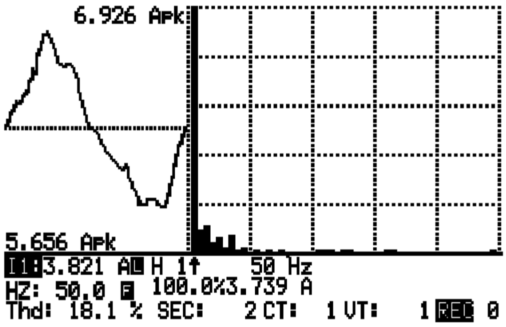

Fig.6 Spectrum of Non-Linear Current through UPS

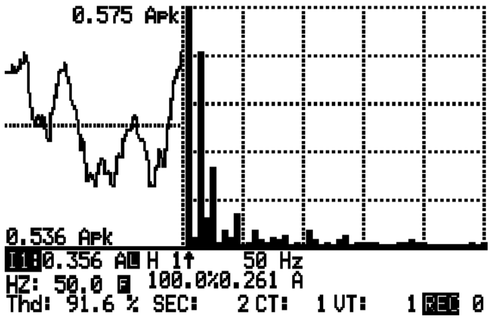

Fig.7 Spectrum of Non-Linear Current through Rotary Converter

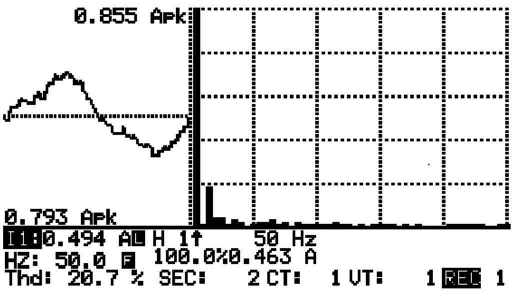

Fig.8 Spectrum of Non-Linear Current of Welding Machine

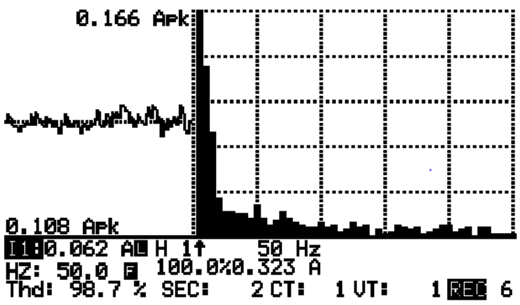

Fig.9 Spectrum of Non-Linear Current of Electrical Furnance

Form above Fig.2 to Fig.9, we can calculate peak value, r.m.s. value, Peak factor, THD and order of pronounced harmonics of current of every non-linear load. The table 3 shows the THD and pronounced order of harmonic of every non-linear load.

Table 3 THD & Pronounced Order of Harmonic of Non-Linear Load

Load	I_{Peak} (A)	$I_{r.m.s}$ (A)	Peak Factor= $\frac{I_{Peak}}{I_{rms}}$	THD (%)	Pronounced Harmonics Order
CFL Load	1.285	0.717	1.79	29.4	3rd
Photostat Machine	0.295	0.094	3.14	216.3	3rd & 7th
Personal Computer	0.532	0.324	1.64	53.2	2nd &3rd
Printer	0.639	0.270	2.36	54.4	2nd & 5th
Mobile Charger	0.187	0.071	2.63	126.4	3rd , 5th &7th
UPS	6.926	3.821	1.81	18.1	2nd &3rd
Rotary Converter	0.575	0.356	1.61	91.6	3rd,5th,7th
Welding Machine	0.855	0.494	1.73	20.7	3rd
Electrical Furnance	0.166	0.062	2.67	98.7	2nd&3rd

VI. CONCLUSION

In this paper harmonics injected by some commonly used nonlinear loads are studied with help of Power Harmonics Analyzer. This article was intended to identify the harmonics introduced in the power system network due to various nonlinear domestic and industrial loads. This paper also helps to identify the levels of order of harmonic currents present in such non-linear loads. It is observed that significant distortion in the current exists due to the use of these non-linear loads and other electronic equipments in domestic and industrial sectors too. Increasing use of these equipments may result in serious problems in near future. The current distortion differs widely from one section to the next. Significant distortion in the current is recorded at customer end with high percentage of 2nd, 3rd, 5th & 7th harmonic content in power supply network. In lieu of measurement of harmonics from various devices and their detailed analysis, it is concluded that there is an urgent need to educate consumer about the harmonic pollution and also energy providing companies must adopt appropriate policies to reduce such harmonics in the supply networks.

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BIOGRAPHY

Viveksheel Verma is presently working as Lecturer in Electrical Engineering Department at Atal Bihari Vajpayee Govt. Institute of Engineering & Technology, Pragatinagar, Shimla (HP)-India. He has teaching experience of 6 years. He did his B. Tech degree in Electrical & Electronics Engineering from Punjab Technical University Jalandhar and pursuing his Master Degree in Electrical Engineering from PTU Jalandhar.

Ved Prakash Verma is presently working as Lecturer in Electrical Engineering Department at Atal Bihari Vajpayee Govt. Institute of Engineering & Technology, Pragatinagar, Shimla (HP) India. He has teaching experience of 09 years. He did his B. Tech degree in Electrical Engineering from Punjab Technical University Jalandhar and Master of Engineering in Electrical (Instrumentation & Control) Engineering from NITTTR, Chandigarh under Panjab University. He has authored two books and has published eight research papers in international Journals and conferences.

Harkamaldeep Singh is presently working as Head of Department in Electrical Engineering Department at GGSCMT Kharar Mohali (PB), India. He has teaching experience of 15 years. He did his B. Tech degree in Electrical Engineering from NIT Calicut (Kerela) and Master of Engineering in Electrical Engineering from Giani Zail Singh College of Engineering And Technology Bathinda Punjab India. He is pursuing PhD from PTU Jalandhar. He has published 20 research papers in international and national conferences.