EFFECT OF LIGHTING LOADS ON THE POWER QUALITY

Raghavendra L[1], Sathish K R[2], Parthasarathy L[3]

[1]Associate Prof., Department of Electrical and Electronics Engineering, ATME College of Engineering, Mysuru, Karnataka, India
[2]Assistant Prof., Department of Electrical and Electronics Engineering, ATME College of Engineering, Mysuru, Karnataka, India
[3]Professor and Head, Department of Electrical and Electronics Engineering, ATME College of Engineering, Mysuru, Karnataka, India

***

Abstract - *The increased use of non-linear loads such as lighting technologies has led to power quality variation of distribution networks. In recent times, different lighting technologies are finding their way into the market. As such, it is paramount to evaluate the performance characteristics of these lighting technologies and the possible effects they might have on the power network. In this regard, the current study is a basic step to estimate Individual Harmonic Components (IHD) and Total Harmonic Distortion (THD) of various lighting loads. An experimental setup was developed for this purpose and experiments were conducted for five lighting loads that are commonly used in practice. The waveforms of these loads were recorded, and the Individual Harmonic Components and Total Harmonic Distortion of each load were calculated using the Fast Fourier Transform (FFT). The results obtained were compared with the standard specifications and found to be acceptable in the case of fluorescent and Incandescent lamps whereas a considerable deviation was found for the High-Pressure Sodium Vapour lamp and Compact Florescent lamp. It is also observed that the power factor is improved and the THD is less for a combination of loads in comparison to the lightly load operating individually.*

Key Words: Power Quality, Individual Harmonic Components, Total Harmonic Distortion and Lighting loads.

1. INTRODUCTION

Lighting plays a vital role in regular human activities which may be naturally (sunlight) or artificial (lamps). Artificial lighting has been determined to be one of the components of the electrical system that has an impact on people's quality of life [1]. In order to complete a task comfortably, adequate lighting is essential in work places, classrooms, and offices. As a result, it must be physically acceptable for those who operate in the task area. However, most recent light technologies are categorized as non-linear loads, which may have a negative impact on the surrounding distribution network's power quality. Furthermore, lighting accounts for 21% of total global electrical energy usage [2]. Therefore, utilizing energy efficient lights to reduce electrical energy consumption is widely considered to be one of the most essential options for reducing consumption of electrical energy. Many companies came up to create various lamps in an attempt to give this solution. As a result, various lighting systems have entered the market. As such, it is paramount to evaluate the lighting technology's performance characteristics as well as the potential effects on the power grid.

Although these recent lighting technologies provide numerous advantages, because they are non-linear loads, they have a tendency to produce harmonics. Harmonics in the power system have severe implications for the power system; they increase line losses and cause equipment to overheat, reducing its lifetime. Sub-harmonics may generate flickers, which cause an unpleasant visual impression on the eyes, transformer imbalance and core saturation, and thermal ageing of induction machine. As a result, it is necessary to assess the power system's impact on these latest lamp technologies [3].

Lighting is one such field, where the light sources, such as Fluorescent Tube Light (FTL), Incandescent lamp (GLS), Mercury Vapour Lamp (Hg) and High-Pressure Sodium Vapour lamps (HPSV) are widely used in residential, commercial, industrial applications and street lighting. In HPSV lamps, a 33μF capacitor is commonly utilized to improve ignition and power factor. In recent days, Compact Fluorescent lamps (CFL) are widely being used from the point of consumption. CFL and HPSV behave almost as non-linear loads because they work on the principle of discharge. These discharge lamps contribute for Harmonic Distortion affecting the quality of the power.

The present work experiments were conducted to observe/record waveforms of different lighting loads and the Individual Harmonic Components and Total Harmonic Distortion of each load were calculated using the Fast Fourier Transform.

1.1 INDIVIDUAL AND TOTAL HARMONIC DISTORTION

Individual harmonic distortion (IHD) is the ratio between the root mean square (RMS) value of the individual harmonic and the RMS value of the fundamental.

$IHDn = (In/I_1)*100$ .....(1)

The IHD shows how each harmonic frequency contributes to the total harmonic distortion and describes the net deviation caused by all harmonics. These are both key parameters for solving harmonic issues; information on the composition of individual distortions is required so that any solution may be tailored to the problem.

The square root of the sum of all the squares of IHD is total harmonic distortion. The greater the THD, more the distorted the 50Hz sine wave. Harmonic distortion occurs in current and voltage waveforms. Typically, voltage THD should be less than 5% and current THD should be less than 20% [4].

$THD=\sqrt{(IHD_1^2+ IHD_2^2+ IHD_3^2 \ldots + IHD_{13}^2)}$ .....(2)

While the Total Harmonic Distortion provides no information on the harmonic make-up, it is used to describe the degree of harmonic pollution in the power system.

The various causes of harmonics are, discharge lamps, use of electronic loads, energy conservation devices in both industrial and domestic sectors, adjustable speed drives, solid state power electronic devices, etc,.

2. EXPERIMENTATION

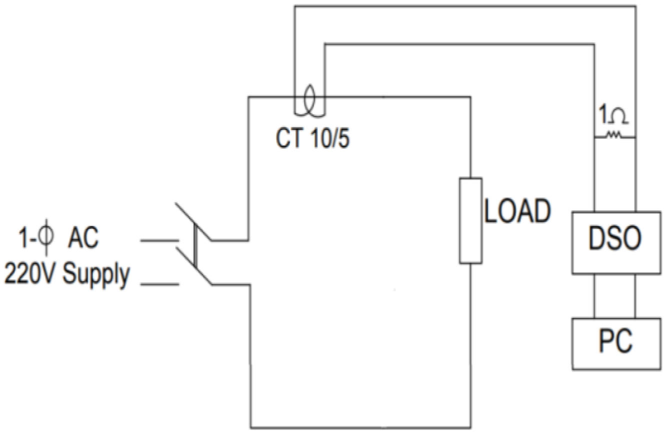

Fig .1 Schematic diagram of experimental set-up

2.1 Experimental setup

Figure.1 illustrates the experimental setup for the present study. It consists of a load manager, a Digital Storage Oscilloscope (DSO), CT (10/5), shunted with a 1Ω non-inductive wire wound resistor and terminals to connect various lighting loads. The output of the DSO is connected to a Personal computer.

2.2 Experimental Procedure

After connecting the lamp across the load terminal, a single-phase supply was given to the circuit. The load manager records the current, voltage, power factor and power. With the help of DSO waveforms were observed and stored. By using ULTRASCOPE software stored waveform was then converted into a data file. The data thus obtained is used in origin software and FFT analysis was performed to obtain different harmonic components.

Table 2.1 gives the various lamp loads used in the present work with their specifications and Experiments were carried out for all of the loads addressed in the study.

Table 2.1 Lighting loads used in the present study

Type of lamp loads	**Rating**
Incandescent bulb	200 W
Fluorescent Tube Light	40 W
Compact Fluorescent Lamp	8 W and 23 W
High Pressure Sodium Vapour lamp employing 33 μF capacitor.	250 W
Mercury Vapour Lamp employing 10 μF and 4 μF capacitor.	125 W

3. RESULTS AND DISCUSSION

In the present work the lighting loads used are GLS, FTL, CFL, Hg and HPSV. Since GLS, CFL and FTL lighting loads are commonly used for residential purpose, Hg and HPSV are lighting loads used in street lighting and in industries. Hence in the present study these individual and combination of lighting loads are considered and the THD of each were calculated.

As a first step, experiment was conducted to find the THD of the input supply and corresponding waveform of FFT analysis are shown in the Fig.2(a) and Fig.2(b) respectively. It can be observed that, the THD of the input harmonic components is about 13.02%, the same input supply was used for all the experiments.

The sample waveforms and respective FFT analysis of the individual and combination of lighting loads considered in the study obtained from the experiments are shown in figures respectively.

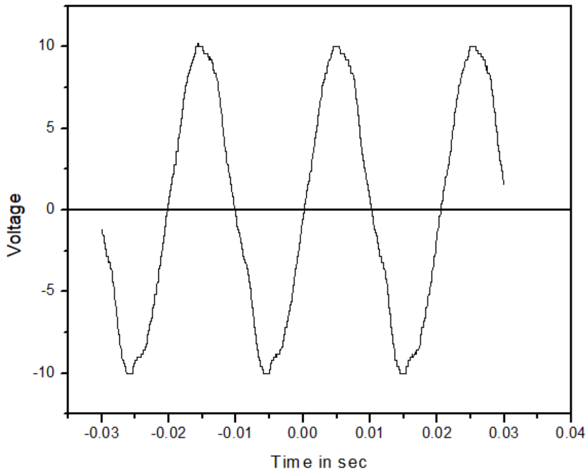

Fig. 2 (a) Wave shape of the input

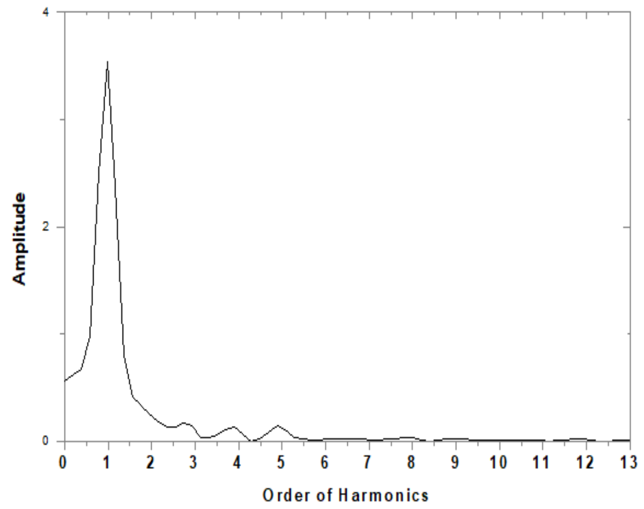

Fig.2 (b) FFT analysis of the input waveform

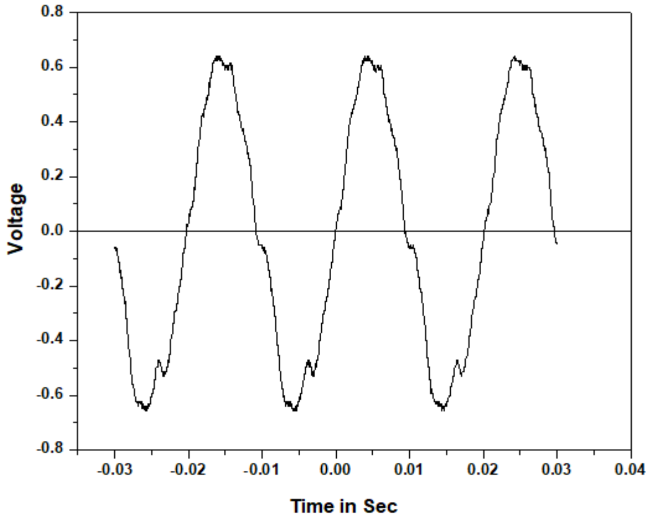

Fig 3 (a) Wave shape of the GLS

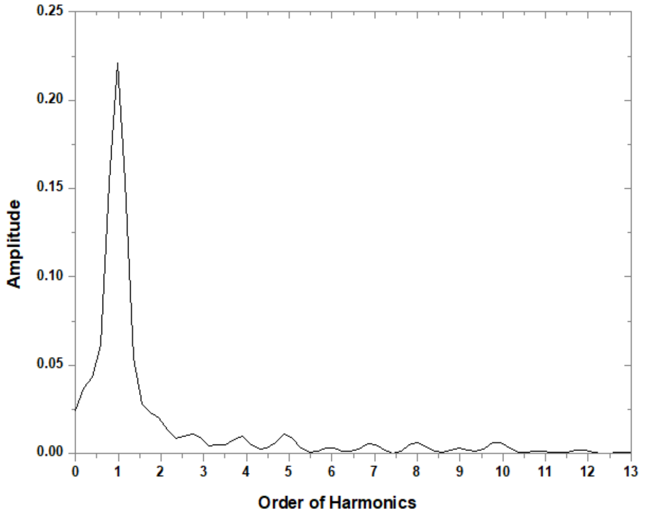

Fig 3 (b) FFT analysis of GLS waveform

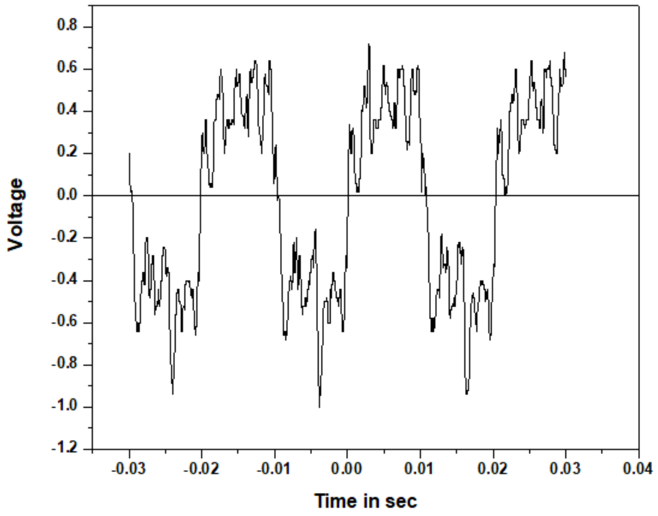

Fig 4(a) Wave shape of the Hg with 10 μF Capacitor

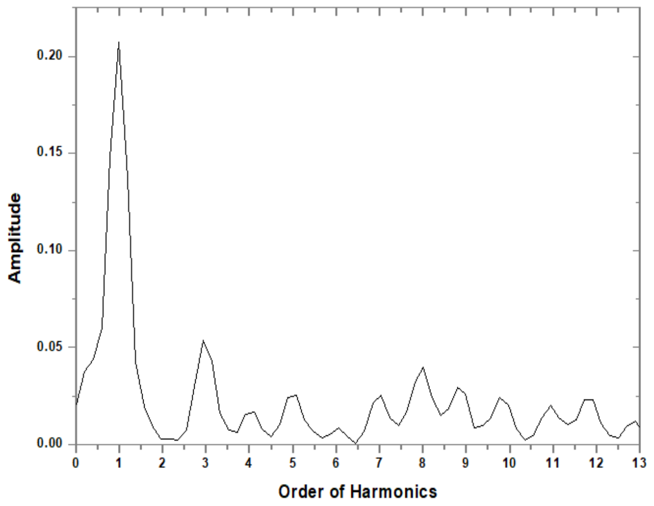

Fig 4 (b) FFT analysis of the Hg with 10 μF Capacitor waveform

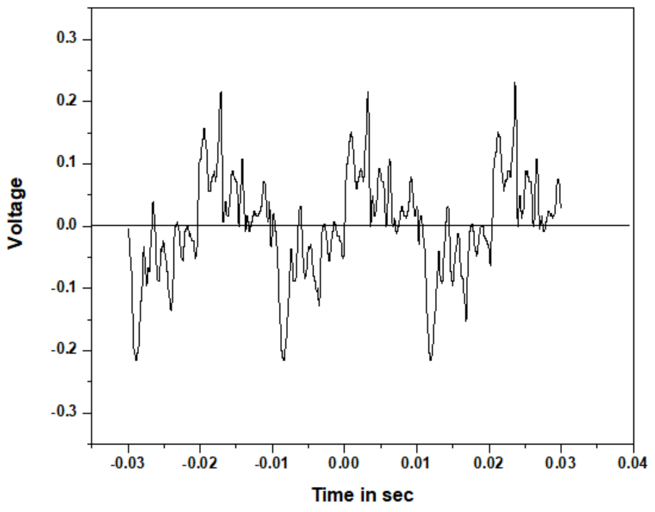

Fig 5 (a) Wave shape of the HPSV with 33 μF Capacitor

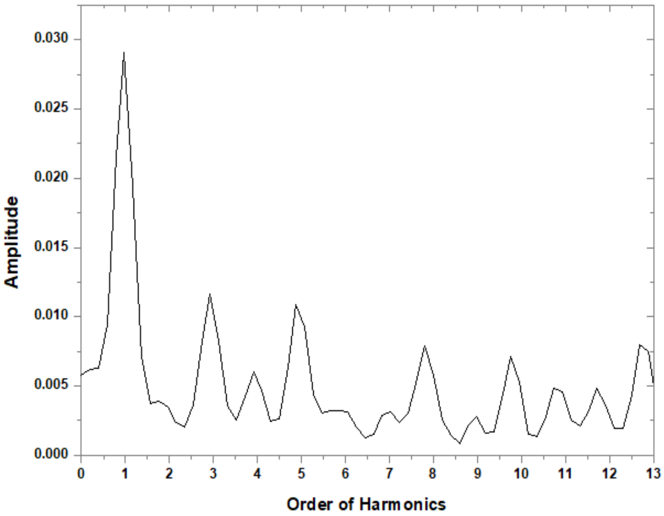

Fig 5 (b) FFT analysis of the HPSV with 33 μF Capacitor waveform

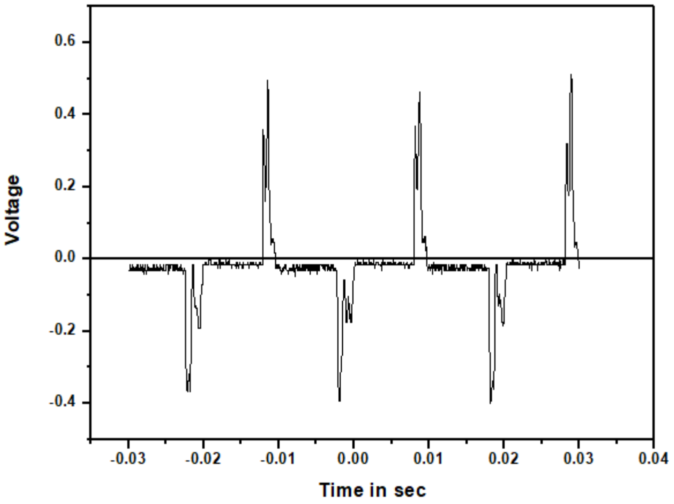

Fig 6 (a) Wave shape of the CFL_23W

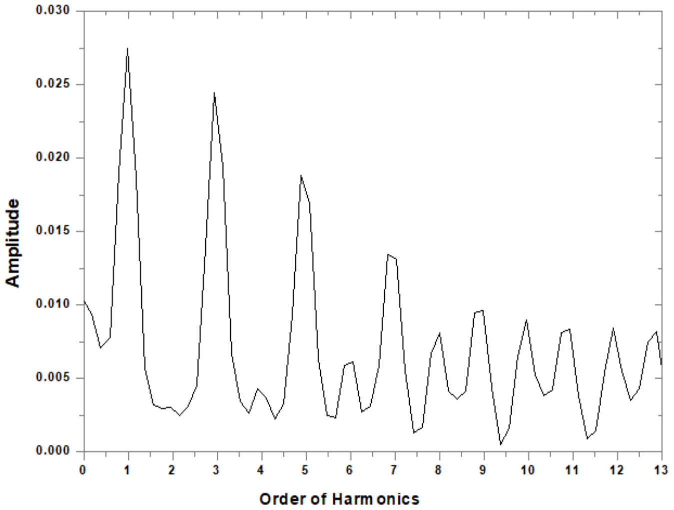

Fig 6 (b) FFT analysis of the CFL_23W waveform

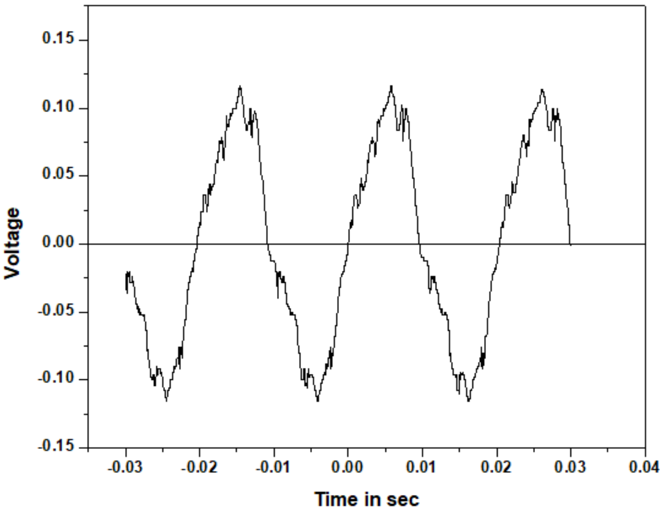

Fig 7 (a) Wave shape of the Hg _4 μF and FTL

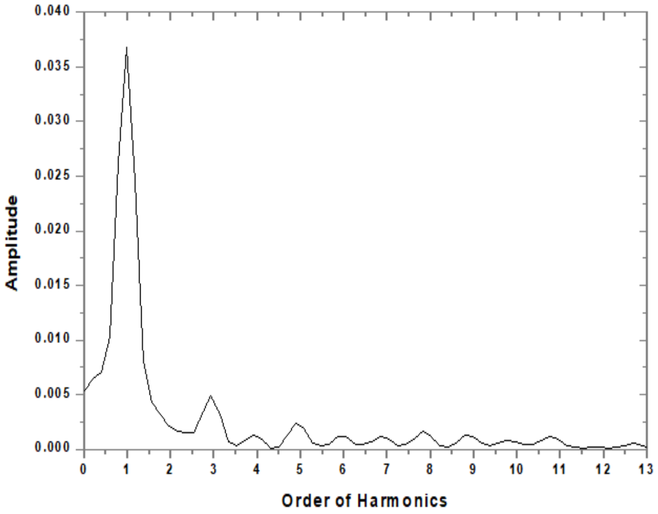

Fig 7 (b) FFT analysis of the Hg _4 μF and FTL waveform

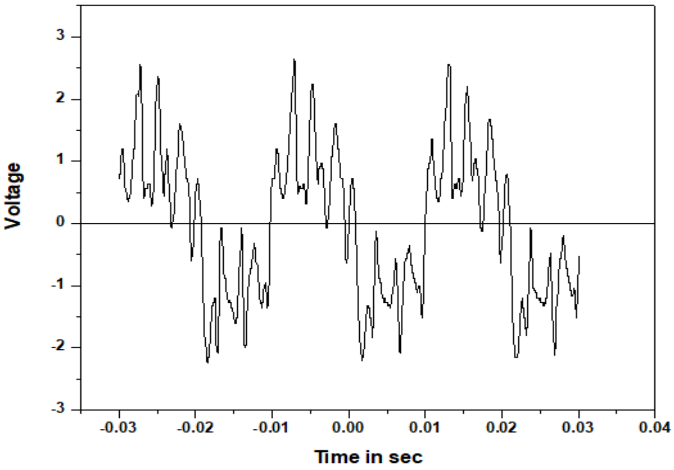

Fig 8 (a) Wave shape of the HPSV_33 μF and Hg _10 μF

Table 3.1 Experimental Readings Recorded and THD values

SL. No.	Loads	Voltage in Volts	Current in Amperes	Power Factor	Power in Watts	%THD
1	Input Power	230	0.8	……	….	13.02
2	GLS_200 W	232	0.79	0.9	167	14.79
3	CFL _8 W	230	0.09	0.40	8	79.42
4	CFL_23 W	239	0.23	0.49	25	104
5	FTL_40 W	232	0.37	0.64	54	14.96
6	Hg _4 µF	231	0.84	0.67	130	30.83
7	Hg _10 µF	234	0.64	0.83	124	79.41
8	HPSV_33 µF	233	1.77	0.73	301	74.29
9	FTL and CFL_8 W	242	0.4	0.67	65	35.85
10	FTL and CFL_23 W	238	0.49	0.70	81	54.33
11	Hg _4 µF and FTL	236	1.24	0.64	187	24.62
12	Hg _10 µF and CFL_23 W	234	0.75	0.83	145	63.09
13	HPSV_33 µF and Hg_10 µF	233	2.24	0.80	413	116.47
14	FTL and HPSV_33 µF	234	1.86	0.80	348	59.46
15	HPSV_33 µF and Hg_4 µF	232	2.29	0.77	411	83.55
16	FTL, Hg_10 µF and CFL_23 W	238	1.05	0.82	204	62.96
17	FTL, Hg_10 µF and HPSV_33 µF	233	2.44	0.82	466	64.67

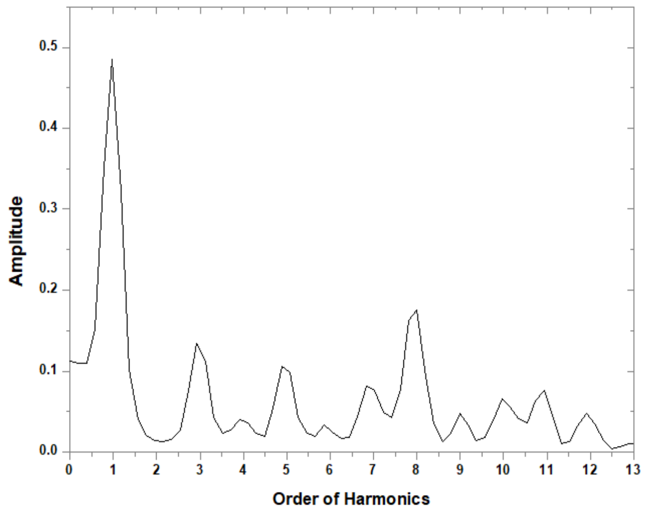

Fig 8 (b) FFT analysis of the HPSV_33 µF and Hg _10 µF waveform

As discussed earlier, in most of the applications different lighting loads are used. From the waveforms and respective FFT analysis of combination of loads shows that, combination of FTL and Hg_4µF gives a minimum THD of 24.62% and combination of HPSV_33 µF and Hg_10 µF gives a highest THD of about 116.47% among the combination.

It is also noted that, the power factor in case of combination of loads is above 0.64 in all the cases as compared to individual loads. The wave shape for each lamp load depends on the input wave shape.

It is found that the Total Harmonic Distortion ranges from about 13.02 % to 116.47 %. The power factor in the case of a combination of loads is better in comparison to the lightly load operating individually. The THD in the case of a combination of loads is less in comparison to the lightly load operating individually.

4. CONCLUSIONS

The main goal of this study was to calculate the Total Harmonic Distortion of individual and combination of lighting loads. The following conclusions are drawn from the experimental results:

1. Manufacturers should address the harmonics generated by CFLs to extend the life of CFLs and reduce THD, hence improving Power Quality.

2. Low THD is achieved by GLS and FTL, with GLS having the lowest and CFL 23 W having the highest THD among the loads studied in this work.

3. Individual harmonic components estimated in the case of CFL_8 W do not meet IEEE 519 requirements, i.e., the 3rd and 5th harmonic components are much higher than the percentage of fundamental component (i.e. 3rd harmonic component is less than 5 percent and 5th harmonic component is less than 2.5 percent of the fundamental).

4. The power factor is better and THD is less in the case of a combination of loads in comparison to the lightly load operating individually.

5. REFERENCES

[1] A. S. O. Ogunjuyigbe, T. R. Ayodele, V.E Idika "Effect of Lamp Technologies on the Power Quality of Electrical Distribution Network" 2017 IEEE PES-IAS Power Africa, pp: 159-163.

[2] Kalle Ruuth, Antti Hilden, Jenni Rekola "The impact of led lighting systems to the power quality and recommendations for installation methods to achieve the expected energy efficiency" 25th International Conference on Electricity Distribution, CIRED 2019.

[3] Lukasz Michalec, Michal Jasinski "Impact of Harmonic Currents of Nonlinear Loads on Power Quality of a Low Voltage Network: Review and Case Study" Energies 2021, 14, 3665. https://doi.org/10.3390/en14123665.

[4] 519-1992 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.

AUTHORS

Raghavendra L
Associate Professor
Department of EEE
ATME College of Engineering, Mysuru, Karnataka.

Dr. Sathish K R
Assistant Professor
Department of EEE
ATME College of Engineering, Mysuru, Karnataka.

Dr. Parthasarathy L
Professor and Head
Department of EEE
ATME College of Engineering, Mysuru, Karnataka.