Experimental Considerations for Harmonic Characteristics of Office Equipment and Loads

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Abstract- The office equipment is important load components of a distribution power system. The majority of modern loads used in offices are non-linear electronics devices which can generate considerable amount of harmonics. An experimental consideration was given to harmonic characteristics of these equipment and loads by way of automated data acquisition technique using Fluke 435 power quality logger. The logger was programmed to capture essential power system data in a set of harmonic load bank such as compact fluorescent lamps, energy saving lamps (ESL), electric ballast fluorescent lamps (BFL), personal computer (PC) and laptop. The results obtained show a threatened total harmonic distortion of voltage and current for some types of loads that may require an appropriate mitigation measure to be put in place in the incoming supply to an office complex.

Indexed Terms- Compact Fluorescent Lamp, Energy Saving Lamp, Harmonic Power, Quality, Logger

I. INTRODUCTION

Harmonic characteristics of loads connected to low voltage distribution networks is given considerable attentions [1, 2, 3, 4]. Reference [5] acquired harmonic data in the LED and CFL lamps and concluded that the mixture of these lamps from different manufacturers significantly decreases higher harmonic orders. In order to account for time variation and statistical properties of harmonic emission in power installation, measurement of the harmonic variation over time is necessary. The summation of harmonic at the point-of-common coupling is evaluated based upon 95% probability of disturbance levels. This implies that large volume of harmonic data must be acquired over time to come-up with a typical power system harmonic behavior. Excessive harmonic voltage and current distortions have undesirable impacts on power system equipment and apparatus. The Utility and standard organizations have been on the alert to safe-guard the integrity of power supply by enacting and introducing measures to ameliorate the effect of harmonic emission in the grid from the customers' premise. Few of such standards on harmonics are IEEE 519-1992, IEC 61000-3-2, IEC61000-3-4, IEC61000-3-6, [6, 7] and EN51060.14 [7]. The IEEE 519-1992 represents a consensus of guidelines and recommendations for Utility and their customers in controlling harmonic emission from non-linear loads. The IEC 61000-3-2 and IEC 61000-3-4 are set of harmonic limits for installation up to 16A per phase and that larger than 16 per phase respectively. IEC 61000-3-6 defines the limits of harmonic current emission from equipment connected to medium-voltage, high-voltage and extra-high voltage supplies while EN50160 is a European standard that defines specific levels of voltage characteristics which are acquiescence guidelines. Recent research assesses the collective harmonic impact of modern load based upon some load pattern scenario for residential consumers [2]. It was loads based on historic pattern and assumed load curve. In this paper, the harmonic emission level of office loads and equipment was realistically determined with 600W harmonic load banks using the actual switching cycles of the equipment in the laboratory environments. The rest of the paper is arranged with theoretical considerations and experimental set up in section II and III respectively, results and discussion in section IV. Section V is the summary and conclusion. It finally ends with references and short biographies.

II. THEORETICAL CONSIDERATIONS

It becomes imperative to gain more insight into the way harmonic pollution is generated in distribution system. This may be done by way of modeling and simulation in software packages. However, due to idealization in modelling of major components and balanced phase assumption in frequency domain together with time consuming and convergence problems for time domain models, monitoring exercise is a more realistic technique and pragmatic option to quantify and ameliorate the flow of harmonics in grid systems. This section reviews the harmonic distortion limits and new regulations.

A. Harmonic Distortion Limits

Due the distortion in voltages and currents in power network, the RMS value of waveform has been standardized. The equations 1 and 2 give the standardization harmonic level for voltage and current [8] Yazdani-Asrami, et.al, (2010).

$$V_{rms}=\sqrt{\sum_{h=1}^{\infty} {V_h}^2} \quad (1)$$

$$I_{rms}=\sqrt{\sum_{h=1}^{\infty} {I_h}^2} \quad (2)$$

Where V_h and I_h are harmonic rms value of voltage and current.

If equations (1) and (2) are respectively divided by the fundamental rms values, V_1 and I_1, the indexes internationally accepted are obtained. These are given in equation (3) and (4) and are referred to as total harmonic distortion of voltage and current respectively.

$$THD_v=\frac{\sqrt{\sum_{h=1}^{\infty} {V_h}^2}}{V_1} \quad (3)$$

$$THD_I=\frac{\sqrt{\sum_{h=1}^{\infty} {I_h}^2}}{I_1} \quad (4)$$

B. Malaysian Standard on Harmonic Limits

Out of the existing IEC 61000 standards, the Malaysian technical committee developed its own harmonic limits based on the results of 10 years intensive power quality monitoring exercise in the Peninsular [8]. This document is greatly needed especially during this contemporary period when modern harmonic equipment and loads are extensively used in industrial and commercial facilities. It provides guidelines to the Country’s Utility so that consumers can be supplied with a high quality of power. The Malaysia standard covers compatibility limits for various consumers and system, equipment limits and harmonic measurement protocols. These are given in table I.

TABLE I
Malaysia standard on harmonic limits

Standard No.	Description	Similarity
MS IEC61000-2-2:2005 MS IEC61000-3-6:2001	Customer/ System limits	IEC61000-2-2 IEC61000-3-6
MS IEC61000-3-2:2003 MS 1555:2002 MS IEC61000-3-12:2005	Equipment Limits	IEC61000-3-2 IEC61000-3-4 IEC61000-3-4
MS IEC61000-4-7:2003	Measurement Protocol	IEC61000-4-7

III. EXPERIMENTAL CONSIDERATIONS

The experiment was sep-up as shown in Fig. 1. It comprises of the Fluke 435 is a three-phase power quality analyzer which complies with IEC/EN61010-1-2001 and IEC61000-4-30, 2003 standards and harmonic load banks. The logger has extra memory to logging data using its power log software.

Fig. 1: Experimental Set-up

The specification of the load banks is depicted as shown in table II.

TABLE II
Harmonic Load Bank specification

Equipment Name	Nominal Power P (W)	Number
Compact Fluorescent Lamps (CFL)	18	9
Electronic Fluorescent Lamps	25	5
Magnetic Fluorescent Lamps	30	3
Personal Computer	120	1
Laptop	10	1

During the experiment, the harmonic load banks were controlled one after the other to measure the individual harmonic emission from each load and compared with the harmonic summation of their collective operation. The experiment took one hour under laboratory precautions and guidelines. The switching pattern is provided in table III.

TABLE III
Harmonic Load Bank OPERATIONS

Periods	Time Code	Equipment Connected
9:33am- 9:45am	T_1	PC, Laptop, CFL, MFL, EFL
9:45am-9:50am	T_2	PC, Laptop, CFL, MFL
9:50am-9:55am	T_3	PC, Laptop, MFL
9:55am-10:00am	T_4	PC, Laptop
10:00am-10:05am	T_5	PC Only
10:05am-10:10am	T_6	Laptop Only
10:10am-10:15am	T_7	MFL Only
10:15am-10:20am	T_8	CFL Only
10:20am-10:25am	T_9	EFL Only
10:25am-10:30am	T_{10}	One set of EFL
10:30am-10:35am	T_{11}	One Set of CFL
10:35am-10:40am	T_{12}	One Set of MFL

IV. RESULTS AND DISCUSSIONS

The 3rd harmonic voltage patterns obtained are shown in Figs. 2 to 6.

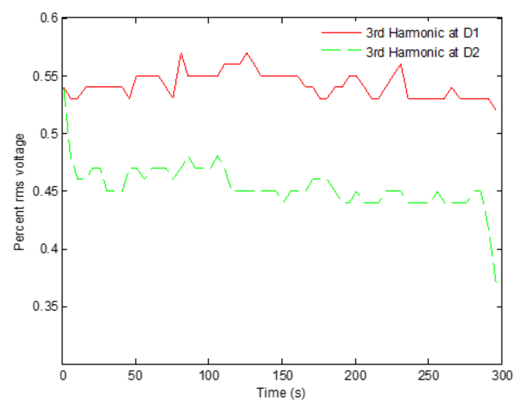

Fig. 2: Comparison of Harmonic pattern at Periods D_1 and D_2

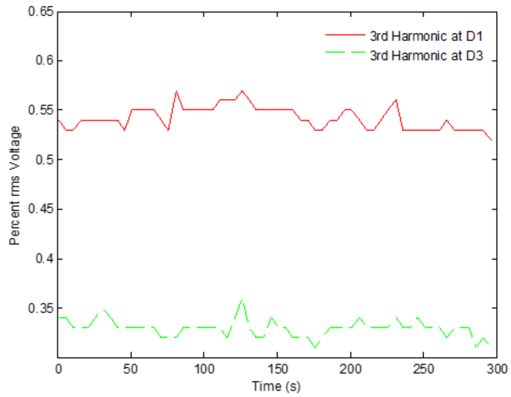

Fig. 3: Comparison of Harmonic pattern at Periods D_1 and D_3

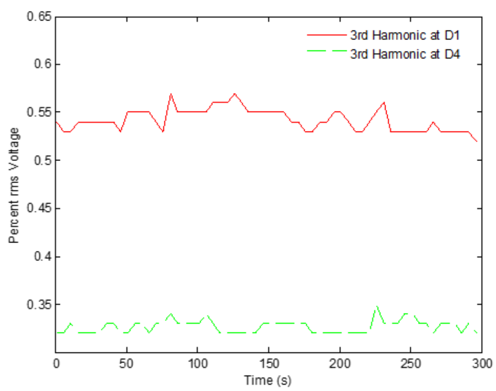

Fig. 4: Comparison of Harmonic pattern at Periods D_1 and D_4

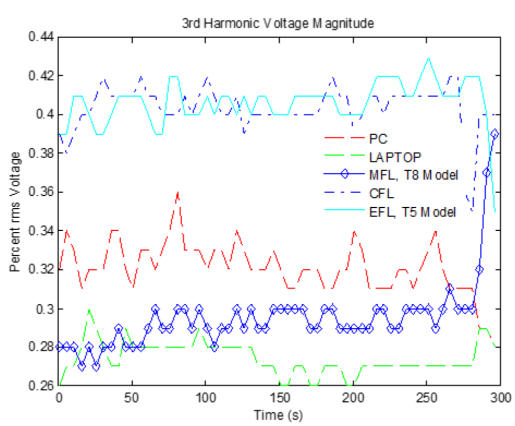

Fig. 5: Comparison of Individual Harmonic patterns

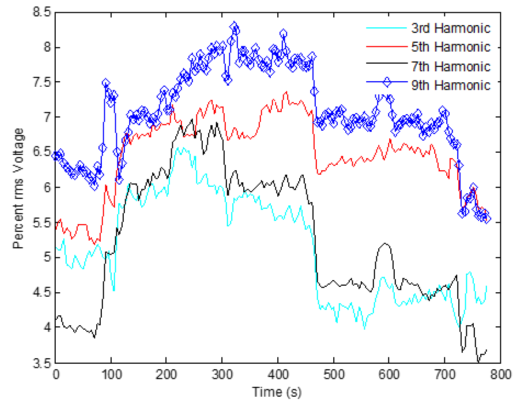

Fig. 6: Comparison of Dominant Harmonic Components with all Loads Connected

TABLE IV
Comparison of Total harmonic distortions

Time Code	THD_v Simulated (%)	THD_v Experimental (%)
T_1	1.0375	1.06
T_2	1.0195	1.04
T_3	0.9976	1.02
T_4	0.9476	0.98
T_5	0.9624	0.99
T_6	0.9740	1.02
T_7	0.9101	0.94
T_8	0.9133	0.93
T_9	0.9420	0.97

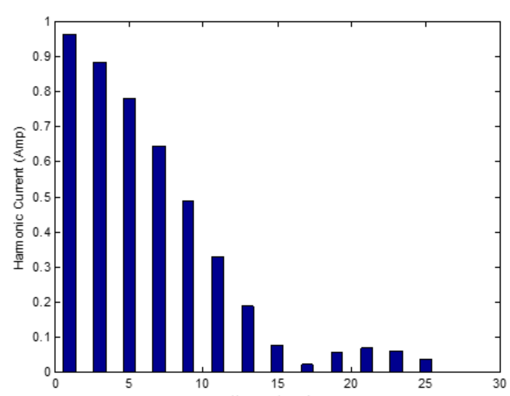

Fig. 8: Harmonic Spectrum of PC

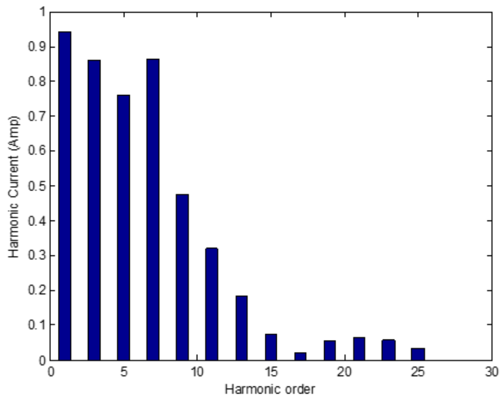

Fig. 9: Harmonic Spectrum of Laptop

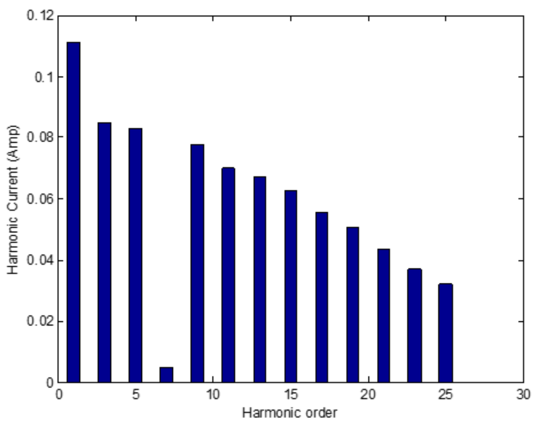

Fig. 10: Harmonic Spectrum of BFL

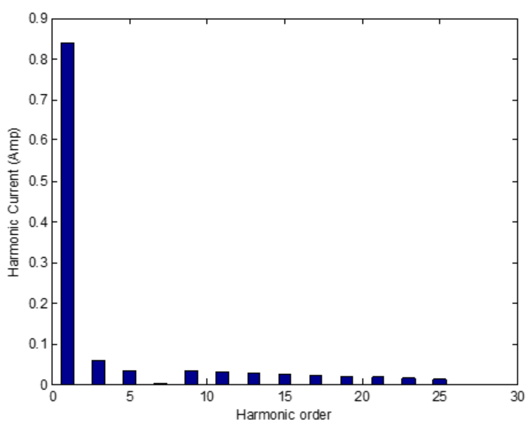

Fig. 11: Harmonic Spectrum of ESL

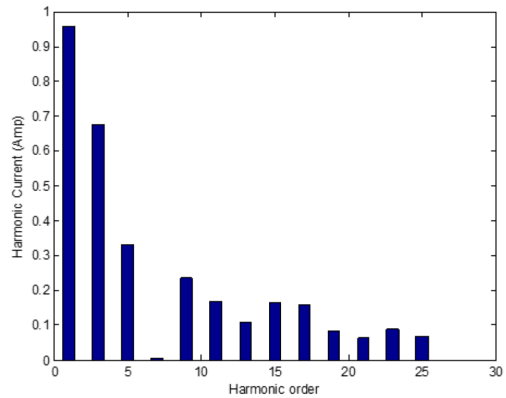

Fig. 12: Harmonic Spectrum of BFL

Figures 2 to 6 show the dominant harmonic voltage characteristics. For illustrative purpose, figures 2 to 4 compare the 3rd harmonic voltage obtained during the time code T_1 with T_2, T_3 and T_4 when one device was taken out of the supply one after the other. The range of voltage distortion of the time code T_1 was 0.52 to 0.57, T_2 between 0.53 and 0.57, time T_3 between 0.44 and 0.56 and T_4 was 0.30-0.45. In Fig. 5, the 3rd harmonic of the individual device was compared. The CFL showed the highest distortion value. The 3rd and 5th harmonics are the most paramount harmonic components as shown in Fig. 6. Figure 8 to 12 depict the harmonic spectral of PC, Laptop, BFL, ESL and BFL respectively. Cumulatively, BFL displayed the most threatened harmonic current spectrum and CFL show the best harmonic characteristics.

SUMMARY AND CONCLUSION

The harmonic characteristics of typical equipment and loads use in distribution network especially in offices are studied. This provides more insight into the way harmonics are generated in an office complex. This may go a long way to assist the manufacturers to make further improvement in design of such devices. It may equally give Utility and standard organizations better understanding of harmonic emission from office equipment and loads with the global objectives of purifying the power supply from the pandemonium of harmonics.

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