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Effects of Appliances to Voltage, Current, Power Factor and Harmonic Distortion

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ABSTRACT

Power utility always get blame if there are power interruption occurred in residential areas. Many of the residential customers are unaware, that is electrical appliance itself one of the reason that contribute to power quality problem. Effects of appliances also can harm other sensitive equipment as well as electrical distribution system. This paper studies the effects of the appliances to power quality. Appliances that are used in the study are personal computer, fluorescent light, iron, LCD monitor, motor & driver, television, hand drill, laptop and jig saw. Waveform of the phase voltage and current, power components, and distortion of voltage and current for all appliances have been recorded and analyzed using Reliable Power Meter. In this paper concepts of power factor and effects of harmonics are reviewed. Subsequently voltage and current waveform, voltage total harmonic distortion, current total harmonic distortion and power factor are analyzed and discussed.

INTRODUCTION

Power factor is the ratio between the kW and the kVA drawn by an electrical load, where the kW is the true load power and the kVA is the apparent load power [1]. Reactive loads (inductive or capacitive) act on power supply systems to shift the current put of phase with the voltage. The cosine of the resulting angle between the current and voltage is also define as a power factor [1]. It is a measure of how effectively the current is being converted into useful work output and more particularly is a good indicator of the effect of the load current on the efficiency of the supply system. A poor power factor will result in excessive losses along utility company feeder lines, because more current is required to supply a given load with a low power factor than the same load with a power factor close to unity.

A lot of causes that contribute to power system quality problems, could be generated at distribution part, transmission part or at end-user. One cause of power losses in power distribution system is harmonics distortion produced by nonlinear load [2][4]. A nonlinear device is one in which the current is not proportional to the applied voltage [3][4]. Harmonics are sinusoidal voltages or currents having the integer multiples of the frequency at which the supply system is designed to operate [3]. The harmonic currents in a distribution system have the following undesirable effects:

a. Significant effects on the performance of computer power supplies

b. Heating of magnetic devices which can cause premature insulation failure and breakdown

c. Additional losses resulting in higher energy costs

d. Failure of power factor correction capacitors or increased resonance that leads to an even higher order of distortion

e. High frequency fields that can introduce buzz into telephone lines and corrupt data in adjacent data lines

Some waveforms contain large amounts of energy at harmonic frequencies and will effect to power system quality. For non-linear loads, the harmonic currents they draw produce no useful work and therefore are reactive in nature. The power vector relationship becomes 3 dimensional with distortion reactive power, combining with both kVAR and kW to produce the apparent power which the power system must deliver. Power factor remains the ratio of kW to kVA but the kVA now has harmonic components as well. True power factor becomes the combination of displacement power factor and distortion power factor. The result is, power factor becomes low. Distorted currents passing through the linear, series impedance could cause a voltage drop for each harmonic and this will produce voltage harmonics. The amount of voltage distortion depends on the impedance and the current [3]. Harmonic distortion levels are described by the complete harmonic spectrum with magnitudes and phase angles of each individual components. Total harmonic distortion (THD) is commonly used to measure the effective value of harmonic distortion.

METHODOLOGY

The Electrical System Characterization

Reliable power meter was used to recoded voltage, current, power components, and distortion of voltage and current for all appliances. Recording time for every appliance is, 1 hour to accept iron. Recording time for iron is 10 minute. Workshop building at KUKUM was selected to the study purpose of all appliances. The building load is feed by a three phase 50 Hz, 1000KVA transformer. Figure 1 shows a completed single line diagram. The three phase supply voltage was assumed as sinusoidal. It was balanced and a symmetrical load distribution was adopted.

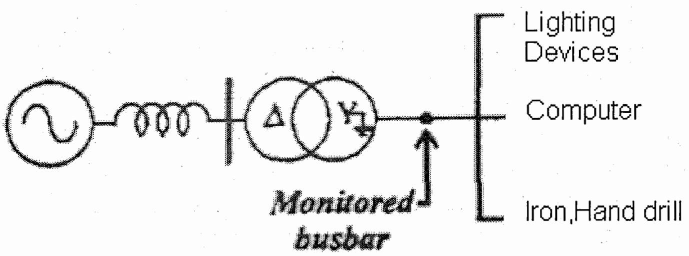

Figure 1: Single line diagram

RESULT AND DISCUSSION

A . Voltage and current Waveform for Personal Computer, Fluorescent Light and Iron

Figure 2, show phase voltage, neutral voltage, phase current and neutral current waveform for personal computer. Maximum voltage for phase voltage is 248.74V and maximum voltage for neutral voltage is 0.7473V. Maximum current for phase current is 0.5235A and maximum current for neutral current is 0.5153A. The personal computer an **Figure 2** is non linear load because voltage and current waveforms are not of the same shape and contain fundamental frequency as well as non fundamental frequencies, so-called harmonics [4].

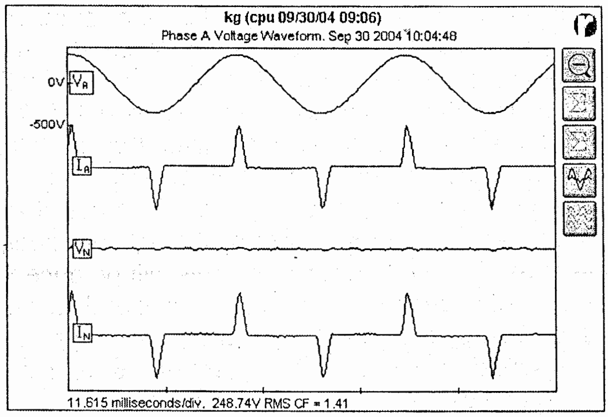

Figure 2: Phase voltage, neutral voltage, phase current and neutral current waveform for personal computer

Figure 3 show phase voltage, neutral voltage, phase current and neutral current waveform for fluorescent light. Maximum voltage for phase voltage is 242.83V and maximum voltage for neutral voltage is 1.6480V. Maximum current for phase current is 0.428A and maximum current for neutral current is 0.471A. **Figure 3** also show, the fluorescent light with a'harmonic's pattern.[4].

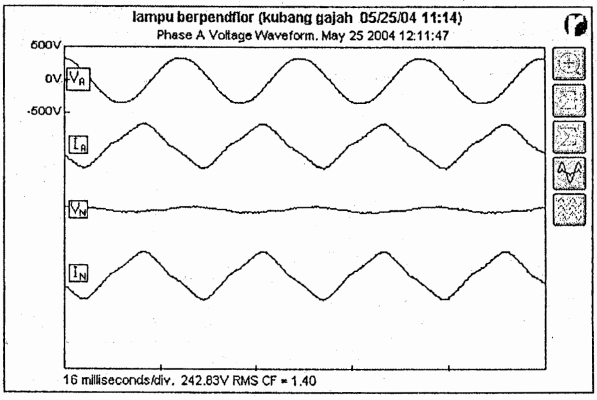

Figure 3: Phase voltage, neutral voltage, phase current and neutral current waveform for fluorescent light.

Figure 4 show phase voltage, neutral voltage, phase current and neutral current waveform for iron. Maximum voltage for phase voltage is 238.44V and maximum voltage for neutral voltage is 5.0347V. Maximum current for phase current is 4.2055A and maximum neutral current is 4.1894A. Figure 4 also show iron is linear load because voltage and current waveforms are of the same shape and contain only fundamental frequency [4].

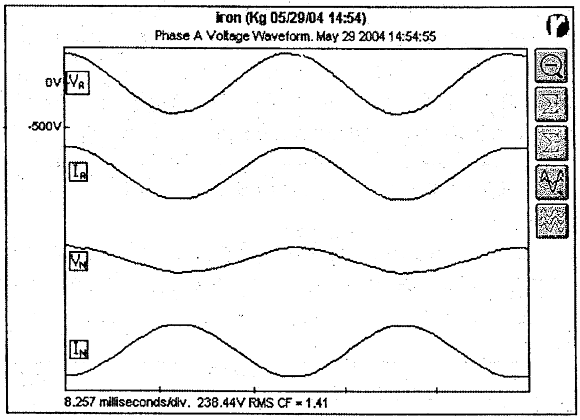

Figure 4: Phase voltage, neutral voltage, phase current and neutral current waveform for iron.

B . Voltage Total Harmonic Distortion (THDv) for Personal Computer, Fluorescent Light and Iron

Figure 5 show voltage total harmonic distortion for personal computer. Minimum voltage total harmonic distortion is 0.6%. Maximum voltage total harmonic distortion is 0.98% and the average is 0.726%.

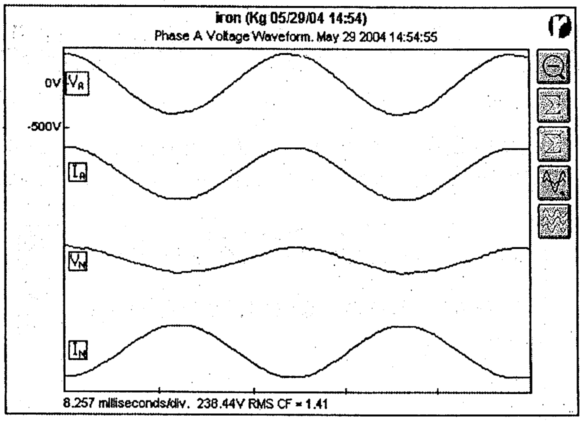

Figure 5: Voltage Total Harmonic Distortion for personal computer

Figure 6, show voltage total harmonic distortion for fluorescent light. Minimum voltage total harmonic distortion is 0.89%. Maximum voltage total harmonic distortion is 76.03% and the average is 1.391%.

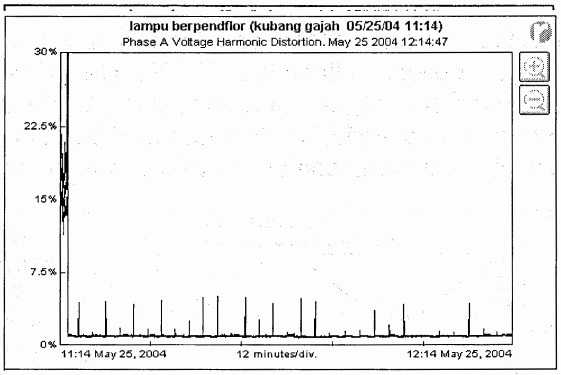

Figure 6: Voltage Total Harmonic Distortion for Fluorescent Light

Figure 7 show voltage total harmonic distortion for iron. Minimum voltage total harmonic distortion is 1.04%. Maximum voltage total harmonic distortion for personal computer is 1.25% and the average is 1.134%.

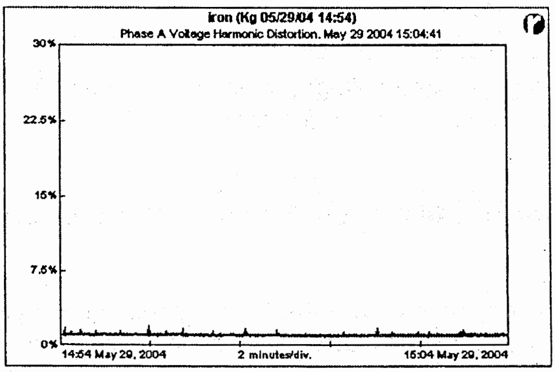

Figure 7: Voltage Total Harmonic Distortion for Iron

C . Current Total Harmonic Distortion (THDi) for Personal Computer, Fluorescent Light and Iron

Figure 8, show current total harmonic distortion for personal computer. Minimum current total harmonic distortion is 164.3%. Maximum current total harmonic distortion is 174.5% and average is 171.5%.

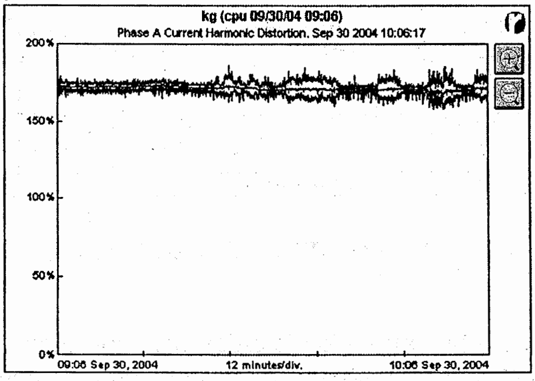

Figure 8: Current Total Harmonic Distortion for Personal Computer

Figure 9 show current total harmonic distortion for fluorescent light. Minimum current total harmonic distortion is 13.1%. Maximum current total harmonic distortion is 13.92% and average is 13.33%.

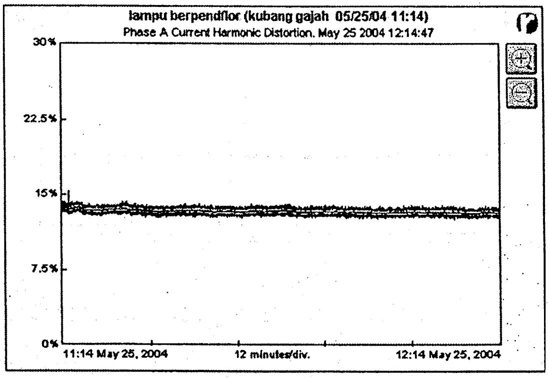

Figure 9: Current Total Harmonic Distortion for Fluorescent Light

Figure 10, show current total harmonic distortion for iron. Minimum current total harmonic distortion is 1.04%. Maximum current total harmonic distortion is 327.6% and average is 177.9%.

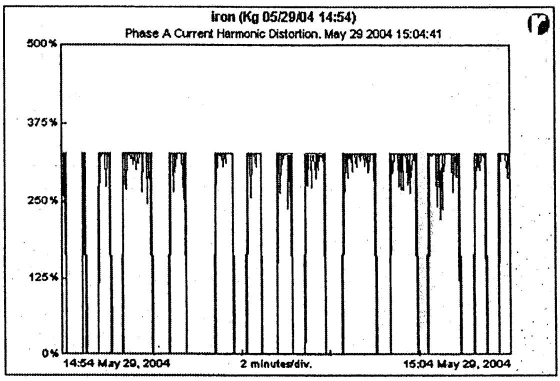

Figure 10: Current Total Harmonic Distortion for Iron

D . Power Factor for Personal Computer, Fluorescent Light and Iron

Figure 11, show power factor summary for personal computer. Minimum power factor is 0.467 leading. Maximum power factor is 0.529 leading and average power factor is 0.499 leading.

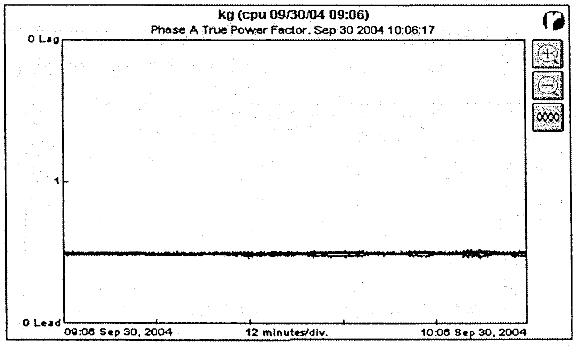

Figure 11: Power Factor Summary for Personal Computer

Figure 12, show power factor summaries for fluorescent light. Minimum power factor is 0.009 leading. Maximum power factor is 0.586 lagging and average power factor is 0.473 leading.

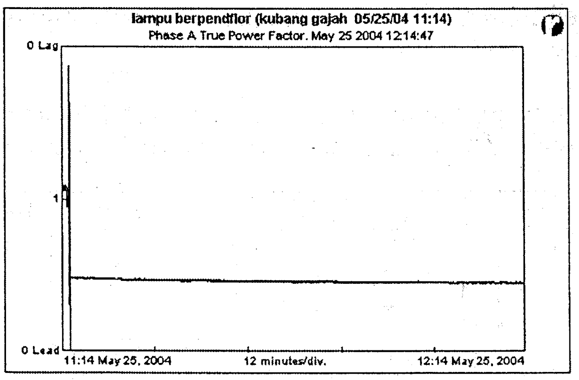

Figure 12: Power Factor Summary for Fluorescent Light

Figure 13, show power factor summaries for iron. Minimum power factor is 0.00. Maximum power factor is 0.00 and average power factor is 0.767 leading.

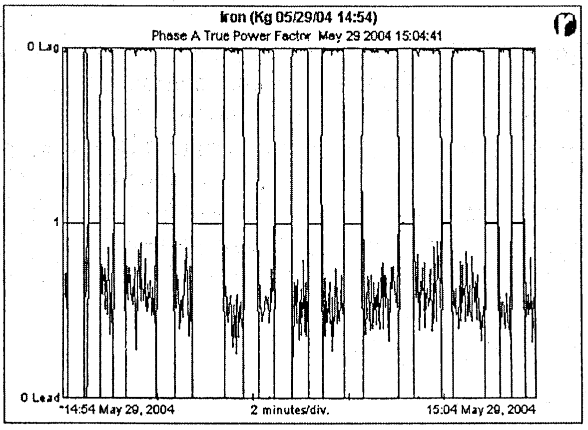

Figure 13: Power Factor Summary for Iron

Table 1: Voltage, Current, Power and Power Factor measurement for all appliance.

Equipment	V(V)	I(A)	P(W)	P.F
PC	246.1	579.1mA	74.74	0.5
Fluorescent light	239.1	426.9mA	47.87	0.47
Jig saw	243.9	731.6mA	86.18	0.53
LCD Monitor	246.8	140.6mA	16.93	0.46
Motor & Driver	234.2	241.1mA	65.95	0.58
Television	244.1	486.8mA	66.58	0.55
Hand drill	248.3	385.9mA	86.45	0.54
Laptop	243.8	246.9mA	57.28	0.49
Iron	241.7	1.910A	453.7	0.77

Table 1, is a summary of average value for voltage, current, power and power factor. Among the appliances, iron is the equipment that uses a lot of energy compared to other equipments, followed by jig saw and the less is LCD monitor. iron. Power factor for iron is the best. Power factor for iron is 0.77.

Table 2: Voltage THD and Voltage Harmonics Components

Equipment	VH1 (Vrms)	VH2 (%)	VH3 (%)	VH4 (%)	VH5 (%)	VH6 (%)	VH7 (%)	THDv (%)
CPU	246.19	0.07	0.105	0.035	0.25	0.04	0.22	0.723
Fluorescent Light	239.2	0.25	0.22	0.04	0.83	0.04	0.32	1.39
Jigsaw	244.12	0.35	0.28	0.11	0.67	0.07	0.53	1.06
LCD monitor	246.88	0.14	0.38	0.03	0.59	0.03	0.59	1.40
Motor&Driver	243.34	0.28	0.25	0.07	0.85	0.04	0.53	1.17
Television	244.21	0.28	0.21	0.07	0.85	0.04	0.57	1.35
Hand drill	248.44	0.10	0.21	0.07	0.90	0.04	0.56	1.17
Laptop	243.86	0.21	0.25	0.07	0.81	0.04	0.53	1.13
Iron	241.79	0.29	0.18	0.07	0.86	0.04	0.57	1.13

Table 2, show voltage THD and voltage harmonic component for the appliances. Voltage THD for all of the appliances surveyed was between 0.723% and 1.40%. This meets the 5.0% voltage THD limit for end user load recommended by IEEE 519 [8]. From this figure we can say that all the appliances above did not effect the voltage of the distribution system even though most of the equipments are nonlinear load and having high current THD, refer to Table 2. LCD monitor have the highest voltage distortion among the appliances and personal computer have less voltage distortion. From the above table, 3rd, 5th and 7th harmonics are contributing to voltage distortion.

Table3:Current THD and Current Harmonics Components

Equipment	IH1 (Irms)	IH2 (%)	IH3 (%)	IH4 (%)	IH5 (%)	IH6 (%)	IH7 (%)	THDi (%)
CPU	0.37	2.22	94.27	2.23	85.64	1.66	73.76	171.6
Fluorescent Light	0.43	1.16	13.26	0	1.16	0	1.16	13.33
Jigsaw	0.43	80.47	53.65	31.77	18.35	11.06	7.29	173.7
LCD monitor	0.10	5.10	63.27	5.1	58.16	5.1	47.96	110.7
Motor&Driver	0.1	29.81	94.23	29.81	89.42	29.81	84.62	221.3
Television	0.28	11.27	90.55	9.46	77.09	7.64	62.18	149.0
Hand drill	0.35	5.97	22.16	2.94	4.55	1.42	1.42	226.4
Laptop	0.24	8.64	23.46	4.12	10.70	2.06	4.12	32.05
Iron	1.90	0.26	0.26	0	0.84	0	0.53	177.9

Table 3 show current THD and current harmonics components for appliances. From **Table 3**, most of the appliances have current THD more than 100% except Fluorescent light (13.33%) and Laptop (32.05%). High THD current waveform does not necessarily pose a problem to the electrical system or other nearby connected load. The RMS magnitude and the distribution of the harmonic spectrum are more important indicators for determining and electrical systems susceptibility to harmonics [5].

From **Table 2** and **Table 3** all distortion occurred due to odd harmonics especially 3rd harmonic. This means that odd harmonic producing the most distortion compared to even harmonic [6][7]. Even though even harmonic exist in the system, the percentage of the component is too small and can be ignored, but this condition cannot be applied for all appliances.

CONCLUSION

The term harmonics is becoming very common in power system, small, medium or large. As the use of power electronic devices are growing, so the need to understand the effects of harmonic and the application of mitigation methods are very important. Fortunately, harmonics in a strict sense are not transient phenomena. Their presence can be easily measured and identified. In some cases they should be minimized or eliminated. A clear understanding of the theory behind power system harmonics is a prime important. It is important to make sure the end user or appliances not generate any current and voltage distortion or harmonic that can harm to power supply system.

This paper discussed and analyzed effects of appliances to voltage, current, power factor and harmonic distortion. Total voltage harmonic distortion for all appliances surveyed was between 1.06% and 1.40%. This meet 5.0% total voltage harmonic distortion limit for end user load recommended by IEEE 519 [8]. Total current harmonic distortion for all appliances surveyed was between 13.33% and 221.3%.

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