HARMONIC ANALYSIS OF DOMESTIC LOAD BY USING FLUKE-43B AT RESIDENTIAL AREA

[*]Kang Chia Yang[1], Hushairi Hj Zen[2,*],Kang Chia Chao[3]
[1]Politeknik Mukah , Sarawak
[2]Faculty of Engineering, University Malaysia, Sarawak
[3]Faculty of Engineering, University Kuala Lumpur,Malaysia Institue of Technology
[*]For correspondence; Tel. + (60) 124359716, E-mail: kangcy87@hotmail.com

ABSTRACT: *Power quality is one of the common and important issue in nowadays especially in the commercial and residential area. It is simply the interaction of electrical power with electrical equipment and is used to describe the degree of consistency of electrical energy expected from generation source to point of use. The term power quality refers to a wide variety of electromagnetic phenomena that characterize the voltage and current at a given time and at a given location on the power system. The effect of poor power quality can be felt where billions of dollars have been wasted every year. One of the common power quality problems such as harmonic distortion may affect the whole electrical environment either industrial area or residential such as office, homes and so on. Many electrical devices are now interconnected to the power network and it can be observed that if the power quality of the network is good, then any loads connected to it will run smoothly and efficiently. On the other hand, if the power quality of the network is bad, then loads connected to it will fail or may cause damage to the equipment's and reduced its lifetime. In this paper, an overview will be given of most common types of single phase nonlinear loads in residential area. A survey was done regarding the usage of the electrical home appliances/domestic loads at randomly selected residential area Taman Li Hua (Phase 1), Mukah, Sarawak. A set of questionnaire was distributed to roughly around 60 families. Analyzation to the different type of loads was done according to the set of questionnaire. The outcome of this research will enable better and novel solutions of poor power quality to the residential area. A list of K-factor table for the different nonlinear loads will also find out.*

Keywords: Power quality, power network, Harmonic Distortion.

1. INTRODUCTION

Nowadays providing an acceptable service is more difficult due to the poor power quality. This is because there has been an increased emphasis and concern for the quality power delivered to factories, commercial establishments and residences. Much of the equipment in use today is susceptible to damage or service interruptions during poor power quality events [1]. Increased competition and limited resources require a partnership between large industrial users and the local utility to address the issue of power disturbances. Power quality problems can be defined as problem that results in failure of customer equipment's, which manifests itself as an economic burden to users, or produces negative impacts on the environment. There has been a proliferation of nonlinear loads in electrical installations due to the great development of electronic equipment. As widely known, everyone using computer whether at home or office has experienced a computer shutdown and reboot, due to power outage which result in loss of working hours. This is caused by the poor power quality on the 240V line. Quality of electricity is very essential for modern industry. Almost all offices and industrial equipment depend on electricity in some form or the other. Heavy industrial equipment's like non-linear variable speed drives powered through power electronic converters may cause power disturbances. Due to this, power quality is becoming a mounting concern in the electric power industry. Electric utility almost supply the end customer with a sinusoidal voltage of fairly constant magnitude and frequency. However there are loads and devices on the system that have nonlinear characteristic which is affected both voltage and current signal and result in harmonic distortion causing poor power quality. Harmonics Distortion occurs when harmonic frequencies are added to the 60 Hertz (60Hz) voltage or current waveform, making the usually smooth wave appear jagged or distorted. Distortion can be caused by solid state devices such as rectifiers, adjustable speed controls, fluorescent lights, and even computers themselves. At high levels, distortion can cause computers to malfunctions and cause motors, transformers, and wires to heat up excessively. Distortion is probably the most complicated and least understood of all power disturbances. Harmonic currents cause overheating of electrical distribution system wiring, transformer overheating and shortened transformer service life.

2. PROBLEMS STATEMENTS

The large and increasing spread of electronics in industrial and commercial plants reduce the tolerance of single loads and process to voltage perturbations. Low power quality issue has seriously affected the residential area and resulted in wasted electrical power energy, especially the non-linear characteristics of various offices equipments connected to the power grid which might cause harmonic distortion and electrical disturbances. Some electronic equipment, beyond consuming distorted currents, also requires rigorous parameters of electric energy, meaning that a small disturbance may cause malfunction or even in the most extreme cases, cause serious damage. Non linear equipment such as computer, printer, TV, washing machine, air-conditioner and so on will produce and injecting harmful harmonic current into electrical system, circuit breakers tripping for no apparent reason, computer malfunction, communication failure, conductor failure of heating, electronic equipment shutting down, flickering of fluorescent lights, fuse blowing, motor failures and overheating are some of the effect due to poor power quality which is cause by harmonic distortion. All this phenomena potentially lead to inefficient running of installations, system down time and reduced equipment life and consequently high installation running costs. Due to this, study needs to be carried out to investigate the harmonic distortion causes by non linear load

so that solutions can be designed. It also aims to monitor the probability of harmonic presence from power electronic devices within distribution level.

3. OBJECTIVE

This proposed paper aims to measure one of the power quality phenomena- harmonic distortion base on the surveying of domestic load at residential area by using fluke instrument-FLUKE-43B which is conducted at one Trytonics Sdn. Bhd, Kuching and the impacts they may present to power quality. It mainly focuses on the residential area Taman Li Hua (Phase 1). This residential area is chosen randomly to investigate the waveform of the harmonic distortion. It also attempts to study the K-factor that caused by typical loads. Reliability of supply harmonic current is to be studied by using method of monitoring the result of power waveform. The results of this study will contribute knowledge for researchers to design a more efficient solution to overcome poor power quality, harmonic distortion and other losses such as load imbalance. Other than that, it also contributes to overcome problems such as malfunction of electrical equipment suddenly due to the poor power quality.

4. LITERATURE REVIEW

Harmonic distortion is one of the main factors that contributes to poor power quality and was observed when the sinusoidal voltages or currents have frequencies that are integer multiples of the fundamental frequency being supplied. This distortion is continuous and the most common result is unwanted heating in the electrical system. It is interesting to note that some of the equipment that is sensitive to power quality disturbances usually is equipment that generates harmonics. Equipment such as adjustable speed drives, computer power supplies, UPS equipment and other power electronics create harmonic currents. Harmonic currents generate harmonic voltages as they pass through the system impedance. In addition to power electronics, arcing equipment such as arc furnaces and welders are also major contributors in the harmonic arena [2].

The monitoring of Electric Power Quality is an important tool to detect problems that may be affecting the equipment or the electrical installation. An effective Power Quality Monitoring may also prevent future problems that might cause damage of equipments or premature aging of the installation components like transformers, circuit breakers even the electrical wiring can be affected. Power Quality Monitor prototype was developed at Energy and Power Electronics laboratory of the University of Minho. This prototype is assembled in a strong plastic case with easy to connect plugs for power and sensors and a built-in 14 inch TFT monitor. To allow the Electric Power Quality Monitor to record the consequences of the failure and also the consequences of the return of the electric power, the prototype was equipped with a backup battery, so, it continues working in the occurrence of power outages. The software of the Electric Power Quality Monitor is constituted by several applications and is based in *Lab View*. The developed applications allow the equipment to function like a digital oscilloscope, analyze harmonic contents, detect and record voltage distortions (sags, swells, interruptions, wave shapes), measure energy, power, voltage and current unbalance, power factor, record and watch strip charts and generate reports [3].

Harmonic field measurement is done to verify the degree of severity of harmonic distortion due to domestic non-linear loads in the distribution system [4]. There are number of solid state controlled non-linear equipments are used for domestic application such as electronic fan regulator, personnel computer, printer, etc. These non-linear loads inject harmonic currents in the network thus distorting supply voltage. In carrying out harmonic measurement, six types of domestic application were selected. All the measurements are made at 230 V using Yokogawa make clamp on type Power Analyzer. Harmonic spectrum for each load is plotted showing magnitude of each harmonic frequency that makes up a distorted waveform. The magnitude of each harmonic frequency can be expressed as a percentage of fundamental. Total harmonic distortion is defined from harmonic spectrum as the ratio of the RMS sum of all harmonic frequencies to the RMS value of the fundamental [5].

There is no single algorithm that can detect the variety of power quality anomalies. Instead, a set of algorithms is need, where each one is responsible for detection of a set of disturbances. The IT group expertise in analog to digital converters (ADCs) testing/characterization and in digital signal processing algorithms will be used in the development of power quality analyzers. The use of ADCs and digital signal processing algorithms will enable the development and implementation of instruments with great versatility which can be easily adapted to the anomalies that degrade power quality [6].

5. RESEARCH METHODOLOGY

This research proposes a study on the power quality phenomena (harmonic distortion) in residential area, Taman Li Hua. It will be carried out in several stages: as below:

Stage 1:

Surveys with residents (around 60 family) in Taman Li Hua (Phase I), record data and information that provided from them. Several customers, selected on the basic of the returned questionnaire have been further contacted by means of personal interview. This allowed to deepen interesting cases, or to check unexpected answer.

Stage 2:

A few types of non-linear load/homes appliances collected from survey will be used to carry out measurement using fluke instruments Fluke-43B. It will be simulated by using suitable parameters on the non-linear loads.

Stage 3:

The measurement results and waveform will be analyzed for a purpose of future improvement and overcome the issue of poor power quality cause by harmonic distortion.

Harmonic Distortion cause by Non Linear Load at Residential Area

The power electronics equipments that produce harmonics in the power system are comes from the daily equipments we use. According to the previous research, there are two main basic categories [7]:

i. Shorts-term – usually the most noticeable and are related to the excessive voltage distortion.

ii. . Long-term – often go undetected and are usually related to increased resistive losses or voltage stresses.

As the use of electronic equipment increases and it makes up a larger portion of the electrical load, many concerns are raised about its impact on the electrical power supply system. Thus, a survey sample was done to the residents at Taman Li Hua (Phase I), Mukah. Around 60 families were randomly chosen to fill out the survey form on type of the loads and daily using equipments. The questionnaire, jointly with some sheets illustrates the scope and the reason of the survey. The details and the purpose of the research have been delivered to the residents at Taman Li Hua (Phase I) in order to adequately fill in the questionnaire. Questionnaire information was included residents information, business nature, daily usage schedule of equipment, and data of the equipment use, type and quantity of load and comment or customer satisfaction of the power quality status for last few years. According to the survey, there is few type of main daily equipment which is classified as non linear loads are most commonly using by residents Taman Li Hua as shown in Table 1.

Table 1: Survey Quantity for types of load from 60 Family

Homes Appliances	Quantity (Per 50 Family)
Monitor/TV	69
Battery Charger	45
CFL Lamp	60
Fan	50
Air-conditioner	40
Printer	29

Analysis to the usage of the domestic load was done and it shows that CFL Lamp, Fan and monitor are the highest domestic load usage at that area. Figure 1 shows the graph analysis for the quantity of the usage on type of domestic load.

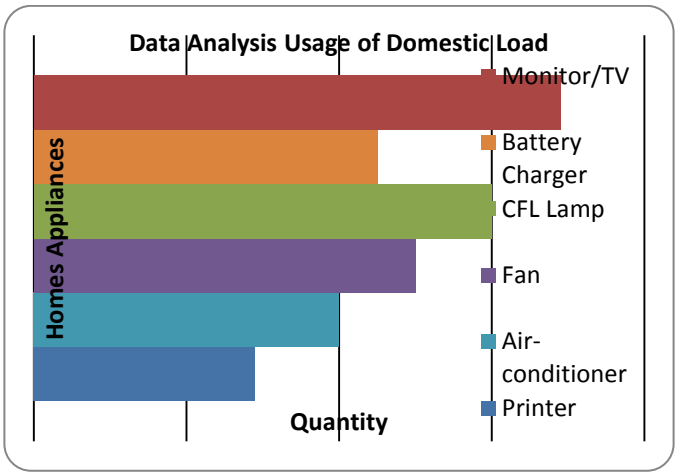

Figure 1: Analysis data on usage of type of domestic load

Individual load ratings were recorded in Table 2 based on the survey result.

Table 2: Load ratings.

Domestic Load	Load Ratings
Monitor/LCD	200 W
Battery Charger	12V, 3A
CFL Lamp	20 Watt
Fan	75 Watt
Air-conditioner	1hp,746 Watt
Printer	848 Watt

All the devices from Table 2 can cause nearby equipment, such as sensitive computer controls or digital clocks, to malfunction. It is also possible for these devices to cause voltage distortion or trigger a resonance with the utility's or neighbor's power system equipment, and thus cause more widespread problems. Due to this a laboratory experimentations were conduct at Tytronics Sdn. Bhd, Kuching to find out the harmonic waveforms. Harmonic current for each load is also recorded and THDs are calculated for analyzing the effect of harmonics introduced by these loads.

Figure 2: Fluke-43B that are using to simulate harmonic distortion

Each of the loads was connected with the instrument to see the waveform of the harmonic distortion. The expected outcome is to shows successfully the harmonic current and K-Factor of the load.

5. SIMULATION OF THE DOMESTIC LOAD

1) Monitor/TV

The characteristic behavior of non-linear loads is that they draw a distorted current waveform even though the supply voltage is sinusoidal. The current distortion, for each device, changes due to the consumption of active power, background voltage distortion and changes in the source impedance. One of the examples of nonlinear loads-monitor which are rich in harmonics and generally produced a pulse waveform. From

Figure 3, K-factor shows that 34.35 with THDI nearly 91.6% which are classified quite high in producing harmonic. THD value and % of harmonic founded in this supply current are crossing the limit as compare to IEC 61000-3-2 Standard and IEEE 519- 1992 Standard [8].

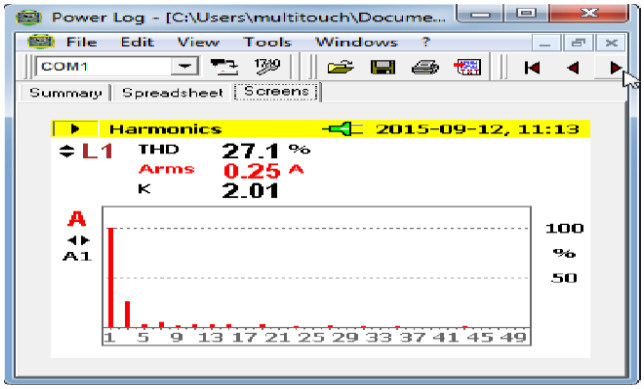

Figure 3: THD and K-Factor analysis for monitor.

2) Battery Charger

Battery charger becomes one of the important equipments nowadays. It provides convenient to the end user while there is out of electricity.

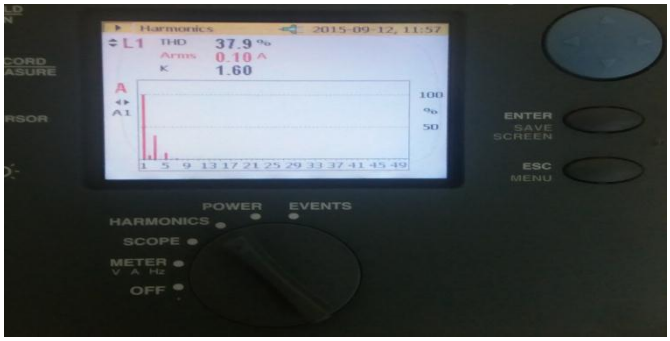

Figure 4: THD and K-Factor analysis for battery charger.

Figure 4 shows that THD value for battery charger is 37.9% and the K-Factor 1.6.

3) Compact Fluorescents Light (CFL)

Electronic lighting ballast and compact fluorescents light (CFL) have become popular in the recent years due to their improve efficiency. Fluorescent lamp behaves as negative dynamic resistance that is required for the ballast to limit the current. The measurement was conduct between compact fluorescent light using fluke instruments. Figure 7 shows that the outcome of the measurement.

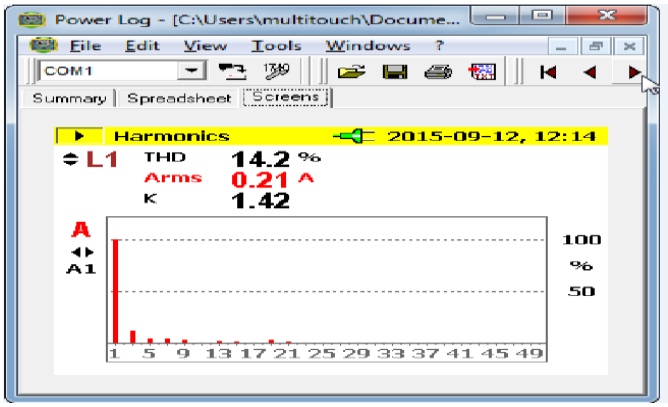

Figure 5: THD and K-Factor analysis for CFL

The outcome shows that total harmonic distortion for CFL is 14.2% and showing a K-factor 1.42.

4) Fan

In residential loads, fan becomes one of the daily usage equipment. There is at least one fan in very family from the survey. Figure 8 shows that there is a simple fan was measurement using fluke to see the harmonic distortion

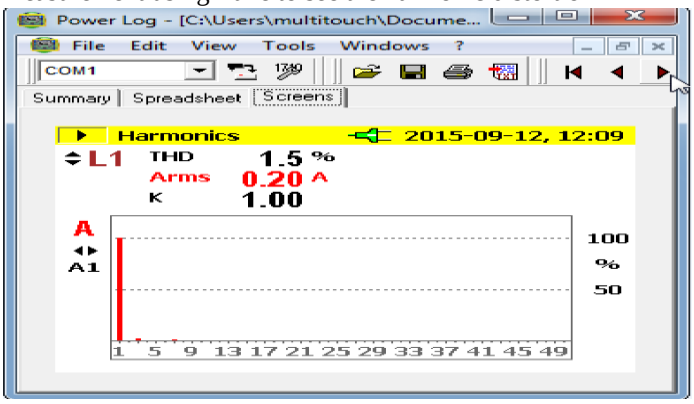

Figure 6: Harmonic Distortion Measurement for Fan

Figure 6 shows that measurement analysis for fan which is THD for fan shows that 1.5% and K-Factor is 1.

5) Air-Conditioner

The invention of the air conditioner has had a profound impact on our lives. In today world, air conditioning is a must. **Air conditioning** is the process of altering the properties of air (primarily temperature and humidity) to more comfortable conditions, typically with the aim of distributing the conditioned air to an occupied space such as a building or a vehicle to improve thermal comfort and indoor air quality. From the survey, it shows that almost 40 out of 60 families were having at least one units of air conditioner in their house.

Figure 7 shows that the harmonics distortion for the air conditioner.

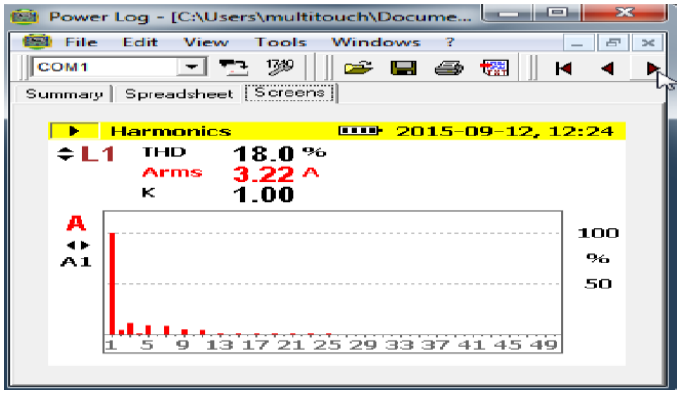

Figure 7: THD and K-Factor of Air-Conditioner.

6) Printer

These days neither company nor housing has a printer. Printers have become an important part of the office automation needs that are a requirement of every office. Printers are an absolute necessity for people that have lots of admin work that needs to be done each month. From printing documents and quotations to printing important documents such as pay slips and contracts, companies use their printers daily and furthermore they cannot afford to have set backs due to broken printers or unreliable machines that work the one minute but won't work the next. The same things happen at residential area when people get works done in their homes. Survey shows that 29 out of 60 families were having a unit of printer at their homes.

Figure 8 shows that the measurement of the harmonic distortion for printer.

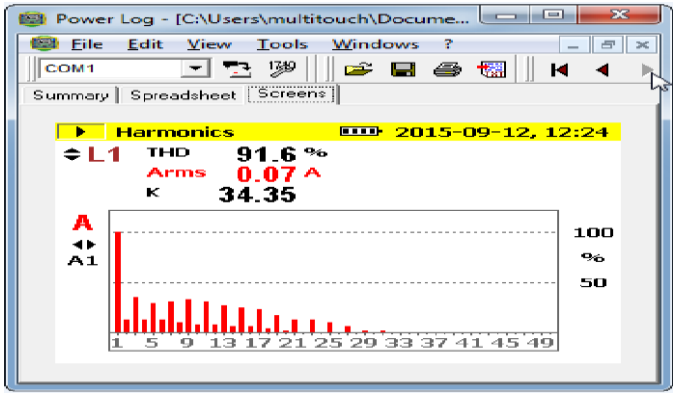

Figure 8: Harmonic measurement for Printer

6. RESULT AND ANALYSIS

From the measurement through the typical domestic loads on the residential area Taman Li Hua (Phase I), it was found that printer has shows that the higher harmonic distortion throughout the survey. There is 29 out of 60 family using printers which is causing total harmonic distortion of 91.6% and 34.35 of K-Factor. According to the ANSI/IEEE, a K-Factor of 1.0 indicates linear loads (no harmonics content). Printer shows that it has a very high harmonic content due to the large value of K-Factor. The higher the K-factor the greater the harmonic heating effect. Table 3 shows that the summarize result of the measurement analysis of domestic load/home appliances in residential area Taman Li Hua (Phase I).

Table 3: Measurement result for the domestic load/homes appliances.

Domestic Load	Total Harmonic Distortion (THD)	K-Factor
Monitor	27.10%	2.01
Battery Charger	37.90%	1.6
CFL Lamp	14.20%	1.42
Fan	1.50%	1.0
Aircond	18.00%	1.0
Printer	91.6%	34.35

From Table 3, it shows that Fan has the lower THD value among the loads which is only 1.50% and a K-factor of 1.0. Conclusion can be make that most of the harmonic distortion neither industrial or residential area was caused by part of the printer as it has the highest THD and monitor was the equipment where there is a must for all the user in nowadays.

7. CONCLUSION

Customer-oriented surveys are a proper tool to assess present problems and attitudes on PQ in different segments of end-use, and to investigate several specific aspects regarding PQ like, for example, the effects on equipment operation and productive processes continuity, component damages, PQ related costs. The papers performed in residential area and mainly focus on the harmonic issues which are mostly cause by home appliances. Although there are some of the homes appliances are not included but for future recommendation, a more details including the Power Quality event happens will be included in the survey form. The result of the study will also assist in the future study and develop in the power system network. Another survey was conduct at Taman Ching Ching for the purpose of the comparison on the domestic load. Therefore more works should be carrying out in this area so that to improve power quality problems-harmonic distortion.

REFERENCES

[1] K. Johnson & R. Zavadil, "Assessing the Impacts of Nonlinear Loads on Power Quality in Commercial Buildings—An Overview," *Conference Record of the 1991 IEEE Industry Applications Society Annual Meeting*, September 28–October 4, 1991, pp. 1863–1869.

[2] M. Negnevitsky, J. Milanovic & M. Green, 1997, *Survey of Power Quality in Tasmania*, Dept. of Electr. Eng. &Computer. Sci., Tasmania Univ., Hobart, Tas

[3] John F. Hibbard, *Understanding and Correcting Harmonic Distortion*, PCIM Power Quality '92 Conference and Exhibition, September, 1992.

[4] Renato Alves, Pedro Neves, D. Gonçalves, J. G. Pinto, José Batista, João L. Afonso *Electric Power Quality Monitoring Results in Different Facilities*

[5] M. S. Lalli & I. P. S. Paul, Field *Measurement of Power Quality in Steel Rolling Mills*, Centre Power Research Institute (CPRI), Banglore. Pp.279-282

[6] J D. C. Bhonsle, R. B. Kelkar, *Harmonics Pollution Survey and Simulation of Passive Filter Using Matlab*

[7] Siti Saleha Binti Abas, "Simulation of Harmonic Currents and Voltages Due to Power Electronic Equipments" May 2006

[8] G. S. Wojichowski, C. D. P. Crovato, & R. C. Leborgne. 2012 *Proposal of a Power Quality Analyzer for the new Brazilian Distribution Procedures (PRODIST)*