POWER QUALITY ANALYSIS BASED ON HARMONIC DISTORTION LEVEL IN FKEE LAB, UMP

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Specially dedicated, in thankful appreciation, encouragement and understandings to my beloved family and those who contributed for this project

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ABSTRACT

Power quality is defined as any power problem manifested in voltage, current or frequency deviation that results in failure or misoperation of customer equipment. Harmonic is sinusoidal voltage or currents which has frequencies that are integer multiples of the fundamental frequency (frequency at which the supply system is designed to operate, normally 50 or 60 Hz).Firstly the harmonic current and voltage were get at substation board in FKEE lab by using power quality analyzer. After a week, the data transferred to the computer by using FLUKEVIEW software. Then, the data were compared to International Standard which is AS61000.3.6 and IEEE 519 by using Visual Basic (Microsoft Web Developer) to display it. The results show us that all the data were satisfy with the standards. During the study period (between 12 pm until 6 pm) at the lab, there were the peak period of harmonic but from 7 pm to 7 am, the harmonics were lower than before. Its shows us that the usage of the electrical equipment such as computers, lighting, motors were higher during our lab period. So, from the analysis we know when is the peak time of harmonic will occur and the sources of the harmonic. Besides that, we also know about the effect of the harmonic distortion on electrical equipment.

ABSTRAK

Kualiti tenaga adalah ditakrifkan sebagai sebarang masalah kuasa yang dinyatakan dalam voltan, arus atau sisihan frekuensi yang menyebabkan kegagalan operasi peralatan pelanggan. Sinusoidal harmonik bagi voltan atau arus yang mempunyai frekuensi berganda dari frekuensi asas (frekuensi pada sistem bekalan untuk beroperasi, biasanya 50 atau 60 Hz). Kaedah pertama ialah harmonik pada arus dan voltan perlu diambil daripada pencawang di makmal FKEE dengan menggunakan sejenis alat untuk merekod data iaitu power quality analzer. Selepas seminggu, data dipindahkan ke komputer dengan menggunakan perisian FLUKEVIEW. Kemudian, data yang diambil perlu dibandingkan dengan Piawaian Antarabangsa iaitu AS61000.3.6 dan IEEE 519 dengan menggunakan perisian Visual Basic (Microsoft Web Developer), 2005. Keputusan perbandingan menunjukkan bahawa ianya tidak melebihi dari piawaian yang ditetapkan . Semasa jangka masa kajian (antara jam 12 tengah hari sehingga 6 petang) di kawasan makmal, nilai harmonik akan mencapai kemuncak tetapi dari jam 7 petang sehimmga 7 pagi, nilai harmonik akan mengalami penrurnan. Ini menunjukkan bahawa penggunaan peralatan elektrik seperti komputer, lampu, motor adalah lebih tinggi semasa tempoh makmal FKEE beroperasi. Jadi, daripada analisis ini kita dapat menentukan tempoh masa nilai harmonik mencapai kemuncak dan sumber-sumber yang menyebabkan terhasilnya harmonik. Selain itu kita juga dapat mengetaui kesan-kesan yang dihasilkan oleh harmonic pada peralatan-peralatn elektrik pelanggan.

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LIST OF SYMBOLS

THVD	- Total harmonic voltage distortion
N	- Largest harmonic voltage/current order consider
V_i	- Rms value of harmonic voltage component i
V_1	- Rms value of the fundamental voltage component
THID	- Total harmonic current distortion
I_i	- Rms value of harmonic current component i
I_1	- Rms value of the fundamental current component
Isc	- Short circuit current
I_L	- Load current

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The term 'power quality' has become more and more popular in the power industry since the late 1980s, and now both electric utilities and end users of electrical power are beginning to take power quality into account. This is due to the fact that equipment used nowadays is more sensitive to voltage variations and failure to operate can cause massive losses, financially and time. There have been many debates between both utilities and customers on whether which party is the source of the problem but in reality, both sides have a fair share of blame. Nevertheless, power quality disturbances affect the customer side more and this has spurred massive concern thought out the world.

1.2 Objective

The objectives for this project are stated below:

i. To obtain power quality indices and check against International Standard.

ii. To study general causes and effect of power quality problems.

iii. To discuss measurement issues.

iv. To develop GUI using Visual Basic software.

1.3 Scope of the Project

Data has been collected at Substation Board in FKEE lab by using power quality analyzer. The harmonic data that we get will be transferred to the computer by using Flukeview software. After that, harmonic voltage and current has been compared against International Standard which focused on AS 61000.3.6 and IEEE Std 519-1992. Finally, all the comparison data will be display in Visual Basic 2005, (Microsoft Web Developer).

1.4 Literature Review

Another power quality analysis was done by Lee K.J Gordon in Western Power Network which all the data is provided by Western Powers. It’s done in some residential, commercial and industrial areas within the Western Power network were monitored. Disturbances like transients, short duration voltage variations (sags and swells), voltage unbalance and harmonics were monitored. The normal rms voltage and current trends were also investigated. It consisted of data from residential, commercial and industrial areas in between 1999 to 2004. These data was recorded through a data logger placed in these particular sites in order to record the normal trend and also variations in power within that particular area. From the equipment, the data was exported into particular demo software whereby the normal trend and disturbances can be viewed in the form of waveforms. From there, measurements were conducted through the cursors and importance readings were obtained. [1]

Most sites were monitored for about a week although there were some which exceeded to a month. It must be noted that not all sites were being monitored for all types of disturbances. Some sites were monitored for normal voltage and current trends only, whereas others may be monitored for all types of disturbances. The measuring equipment can be configured to monitor the particular trend or disturbances as required. The parameters being monitored depends on the objectives of monitoring the particular area. Most analytical works were conducted through the help of the software. Some of the plots that could be obtained from the software were the rms sag disturbance, rms swell disturbance, impulse disturbance, wave shape disturbance, snapshot waveform, rms strip chart, and harmonic trend. So, three sites were analyzed in term of the harmonic component and the total harmonic distortion. In this section, two residential areas, five commercial areas and 5 industrial areas will be looked into. It must be noted that not all the five commercial and industrial areas covered here are similar to that in the previous section. However, the residential areas remain the same. This is because not all sites are being monitored for all disturbances, and some sites from the previous section do not have harmonic readings. Therefore, additional commercial and industrial sites were monitored for harmonics. [1]

Harmonics for residential areas were checked against AS 61000.3.2 (Class A) for the harmonic currents only as there were no harmonic voltage limits present. Furthermore, this standard does not have any total harmonic distortion limit. Therefore, the IEEE 519 Std. was used to cross check all the total harmonic distortion for residential areas. As for commercial and industrial areas, the current was checked against IEEE 519.Std. as well whereas the voltage was monitored with AS 61000.3.6.Comparison was conducted on odd and even harmonic current and harmonic voltage components. [1]

1.5 Thesis Outline

Chapter 1 discuss about the literature view, objective and scope of the project. Otherwise these chapters discuss more about the application and the goal of power quality analysis.

Chapters 2 discuss more details about the interest in power quality and problems from poor power quality. Beside that, the overview, sources, effects and mitigation of harmonic also discuss on this chapter. The understand concept of power quality analysis is very important before start the project.

In Chapter 3, focuses on methodologies for determine the harmonic data. There is a device to measure the harmonic distortion and the software that will use to display the data. In addition, the flow chart about the main process of analysis will be discussing more details in this chapter. Software Visual Basic 2005 (Microsoft Web Developer) also discuss with details in this chapter.

Chapter 4 discusses on the results obtain of the whole project. The harmonic voltage and current will be comparing against International Standards. All the analysis and result is valuable for future application.

In the last chapter, conclusions for this project have been elaborated with details. The future recommendation required on this project is stated in this chapter for further development.

CHAPTER 2

POWER QUALITY

2.1 Introduction

This chapter will discuss in details about power quality problems, introduction to harmonics, sources and effect of harmonics. Many power quality problems are easily identified once a good description of the problems is obtained. Unfortunately, the tensions caused by power problems often result in vague or overly dramatic descriptions of the problem. When power problems happen, try to note the exact time of the occurrences, its effect on electrical equipment, and any recently installed equipment that could have introduced problems to the system.

2.2 Insight to the term of power quality

Power quality covers a wide range of problems and many definitions have been made. There are definitions from IEEE and IEC which can be considered. From the IEEE dictionary, which originates in IEEE Standard 1100, power quality is defined to as 'The concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment'. As for IEC, the term 'electromagnetic compatibility' is used instead, which is not the same as 'power quality' but there is a strong overlap between the two terms. The definition is given in IEC 61000-1-1 as: 'Electromagnetic compatibility is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment'.

However, there have been many arguments with the use of the term 'power quality' and what it incorporates, but many have come to accept that it has become a very important aspect of power delivery. Since power quality is very much of a customer-driven issue and the customer's point of reference take precedence, one can define power quality as 'Any power problem manifested in voltage, current, or frequency deviations that result in failure or disoperation of customer equipment' (Dugan, McGranaghan & Beaty, 1996).

The dispute has always arisen between the utilities and the customers, both having their own interpretation and both blaming opposite parties as source of problems. The utilities may see power quality as reliability whereas manufacturers of load equipment (customer) may define power quality as the ability to have good characteristics of power supply in order for the equipment to run smoothly. It should not be an issue who the blame should be on but more to analyzing and identifying the problem, and eventually investing in economical means to stamp out the problems.

2.3 Interest in power quality

Ironically, these disturbances or problems have already existed for decades but little was done then to eradicate the problems compared to the present time. Things change as time passes, and many are looking from the perspectives of finance, economy and technology when dealing with electrical supply. As more researches and education are conducted on this issue, more end users are made aware of the problems faced in power quality and many are starting to challenge utility companies to improve the quality of power being delivered. From there, the concern for better power quality is brought up. Nowadays, load equipment is more sensitive to power quality variations than equipment from the past. There are a large number of load devices that contain microprocessor-based control and power electronic devices that are sensitive to many types of disturbances, especially to voltage disturbances. Semi-conductor industries for example, have equipments which will be affected by the slightest change in voltage drop in duration of a few hundred milliseconds, and with that the whole plant may possibly be out of operation for a few hours to allow time for a slow start of the equipments. Furthermore, these sensitive equipments are widely used nowadays, thus causing even more problem in the quality of power. Poor power quality can lead to losses in terms of time and finance. Furthermore, the emphasis on efficiency of the power systems, have lead to the introduction of high-efficiency adjustable-speed motor drives and shunt capacitors for power factor correction (in order to reduce losses). These equipments are also introducing harmonics into the system and this occurrence has impact on system capabilities.

2.4 Problems from poor power quality

There are many problems to consider when talking about poor power quality and a few major ones will be discussed in this section to start off. Some wish to categorize poor power quality into two major types, that is disturbances and steady state variations, whereby disturbances includes transients, sags, swells and interruptions while steady state includes voltage regulation, harmonic and flicker. There are others who categorize power quality problems into transients, short-duration variations, long-duration variations, voltage unbalance, waveform distortion, voltage fluctuations and power frequency variations. For a rough overview, Table 2.0 (FLUKE VR101s User Manual, 1997) shows some of the major problems of power quality, its causes and likely effects.

Table 2.0: Causes and effects of poor power quality

Problem	Causes	Effects
Swells	• Shutdown of heavily loaded equipment • Abrupt power restoration • Utility switching	• Discomfort from flickering lights • Computer damage • Degradation of power protection equipment
Sags	• Abrupt increase in load • Dropouts/outages • Lightning • Outdoor contact with transmission lines • Ground faults • Equipment failures	• Equipment shutdown • Power-down circuitry in power supply operates incorrectly • Computer lock-ups • Diminished speed of disk drives (data error)
Transients	• Switching load on and off • Utility switching • Lightning • Normal computer operations • Fault clearing • Power factor correction capacitors	• Electronic damage (through bypassing protection circuitry) • Insulation breakdown in transformers and motors • Data errors • Data loss
Frequency Variations	• Major load increases • Utility switching	• Incorrect clock timing • Writing errors in

		any electronic wiring devices (magnetic tapes, disk drives)

2.5 Introduction to Harmonics

Harmonics has linear been more of an issue nowadays due to the increased usage of nonlinear-loads which are the cause of harmonics. The non-linear loads here refer to loads which current is not proportional to the applied voltage. Figure 2.0 shows a comparison of linear and non linear load voltage-current characteristic. It must be noted that different non-linear loads will have different slight voltage-current characteristics. Sometimes a slight increase in voltage can cause the current to double.

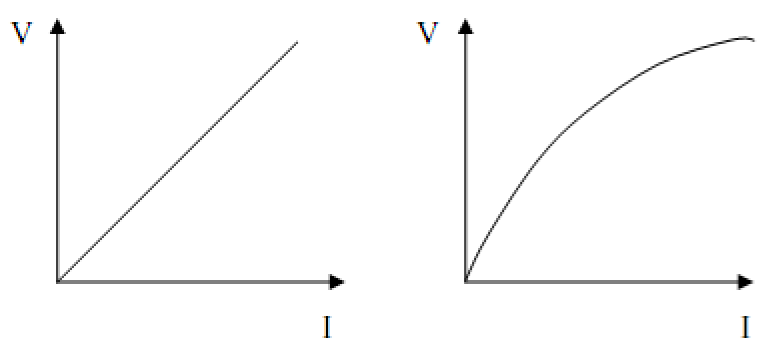


Figure 2.0: Comparison of linear and non-linear VI characteristic

Any periodic, distorted waveform can be expressed as a sum of pure sine waves in which the frequency of each sinusoid is an integer multiple of the fundamental frequency (50Hz for Australia). This multiple is called harmonic of the fundamental. Harmonic are normally analyzed up to the 40^{th} multiple or component but the few odd, earlier harmonic components (3^{rd}, 5^{th}, 7^{th}) are the ones that have significant effect on the system. What differentiate a distorted harmonic waveform and any waveform distortion is that those caused by harmonics are periodic and can be split into harmonics components.

2.6 Voltage and current distortion

Nonlinear loads are the sources of harmonic current causing distorted current waveforms. Voltage distortion is the result of distorted currents passing through the linear, series impedance of the power delivery system. Therefore, it is always the current distortion that results in voltage distortion. Nevertheless, it must be noted that loads have distortion no control over the voltage distortion. The same load in two different locations on the power system will result in two different voltage distortion values.

2.6.1 Even Harmonics

Even harmonics (2^{nd}, 4^{th}, and 6^{th}) are less likely to occur at levels detrimental to electrical systems. This is because non-linear loads normally generate odd harmonics rather than even harmonics. Furthermore, when both the positive and negative half cycles of a waveform are similar in shape, the Fourier series contain only odd harmonics.

2.6.2 Odd Harmonics

Odd harmonics (3^{rd}, 5^{th}, and 7^{th}) are more common in power systems and are the ones which lead to severe consequences if they are not controlled. Each odd harmonic is associated with one of the sequence component (positive, negative or zero). The phase sequence is very important because it determines the effect of the harmonic on the operation of the electrical equipment. Table 2.1 shows the harmonics with their associated phase sequence.

Table 2.1: Harmonics and their corresponding sequence component

Harmonics	Sequence Component
1	Positive
3	Zero
5	Negative
7	Positive
11	Zero
13	Negative
15	Positive
17	Zero
19	Negative
Etc	

Positive sequence harmonics (1st, 7th, 13th, and 19th) consist of three phasors, each equal in magnitude and are displaced from each other by 120 degrees. They have the same phase sequence as phasors representing the nominal current or voltage. The presence of these harmonic can accelerate a motor which may cause them to overwork.

Negative sequence harmonics (5^{th} ,11^{th} ,17^{th}) also consist of three phasors with equal magnitude and are separated from each other by a 120 degree phase displacement. Nevertheless, they have phase sequence opposite to phasors representing the nominal current or voltage. These negative sequence components can create a torque in the negative direction of rotation of the motor causing it to decelerate.

Zero sequence harmonics (3^{rd}, 9^{th} ,15^{th}) are the worst of the lot and are often referred to as triplen harmonics. They consist of three phasors of equal magnitude but have zero phase displacement from each other. Since they are in the same direction, they result in amplitude that is three times any of the phasors when combined in the neutral wire of causing overheating. Furthermore, zero sequence current can also an electrical system drive the magnetic circuit into saturation thus making the particular equipment more non-linear.

2.7 Sources

Common non-linear loads include motor starters, variable speed drives, computers and other electronic devices, electronic lighting, welding supplies and uninterrupted power supplies. The effects of harmonics can be overheating of transformers, cables, motors, generators and capacitors connected to the same power supply with the devices generating the harmonics. Electronic displays and lighting may flicker, circuit breakers can trip, computers may fail and metering can give false readings.

2.7.1 Saturable devices

Saturation devices like transformers, rotating machines and non-linear reactors are common harmonic producing devices. They are also referred to as ferromagnetic devices. These devices produce harmonic because the magnetizing reactance is not linear. Harmonic produced by these devices can be minimized if it operates within the linear regions of the magnetizing characteristic curve. (Jong.J, 1991) Nevertheless, especially for transformers, due to economical reasons, they are operated near the knee point of the curve where significant harmonic is generated since that region is non-linear. The 3^{rd} harmonic is most produced by this type of devices and there is a substantial amount of 5^{th} and 7^{th} harmonic as well.

2.7.2 Arcing devices

Although as a single device, they do not contribute much to harmonics, arcing devices normally come in large quantities and they constitute a large portion of industrial and commercial loads. Among the common are arc furnaces, arc welders, arc lighting and fluorescent lighting. All arching devices have the same basic configuration – a voltage clamp in series with a reactance that holds the current constant. The voltage will build across the gap until the gases between the gap ionize and become conductive, preventing a further increase in voltage across the gap. The voltage-current characteristic of electric arcs is non-linear. Following arc ignition, the voltage decreases as the arc current increases. This gives the arc the appearance of having a negative resistance for a portion of its operating cycle.(Jong.J, 1991).

2.7.3 Power Electronics

Electronic devices connected directly to the power supply system have an electronic power converter that produce harmonics. In residential areas, loads like microwave oven, televisions, VCRs and personal computers are sources of harmonic thanks to power electronics. As for industrial areas, loads that cause harmonics include variable speed motor drives, high power rectifiers and large thyristor-controlled loads. The electronic power converters in these electronic devices range from a simple bridge rectifier to a complex switching converter. For households, the common converter used the single-phase full wave rectifier. A large number of electronic converters are line commutated like Switch Mode Power Suppliers (SMPS). They contribute to a large 3^{rd} harmonic in the neutral. Three phase converters are normally applied in industrial areas and the six pulse or twelve pulse rectifiers are most commonly encountered in these areas.

2.8 Effects

Harmonics can cause a variety of effects and some of its effects on electrical loads have been discussed in this section. (Pratical Guide to Quality Power, 1997). The effects are likely to show up in the customer's plant before they show on the utility system.

\

2.8.1 Motors

Positive sequence harmonics creates an additional torque on the three phase motor causing it to have a faster forward direction while negative sequence harmonics will try to force motors to turn the opposite direction. The motor will develop a less than expected ability to drive the load, drawing more current and results in overheating.

2.8.2 Transformers

Transformer ratings are based on the heating created by load currents of an undistorted sine wave. When load currents are non-sinusoidal and have a considerable amount of harmonics, they can cause heating than the same number of amount of pure sine waves. This is mainly due to hysteresis and eddy currents. The hysteresis losses are greater for a given rms current at the higher frequency harmonics. As for eddy currents, the losses and increase significantly in the presence of the 5^{th} and 7^{th} harmonics. The losses can be in the order of the square of the order of the harmonic.

2.8.3 Conductors

Harmonic currents cause overheating of conductors and insulating materials as a result of skin effect. At higher frequencies, the center of the conductor carries little or no current. Thus, the effective cross section of the conductor is decreased. This creates or behaves like a smaller conductor with lesser ampacity. Thus, a particular current harmonic causes more conductors heating than the same current at fundamental frequency.

2.8.4 Capacitors

Capacitors have decreasing reactance as the frequency increases. Therefore, capacitors like power factor correction capacitors will appear as a low impedance path for harmonic currents of higher order which lead to blown fuses and bulging capacitor cases.

2.8.5 Over current protection devices

Thermal over current protective devices like fuses are affected by skin effect heating at higher harmonic current levels. Additional heating causes shifts in the time-current characteristics, resulting in nuisance tripping.

2.8.6 Metering

Metering devices are equipped with induction disks that are designed to monitor undistorted fundamental current. Nevertheless, the existence of harmonics may cause the disk to rotate faster or slower than usual. When these metering devices are used for billing, many times the readings are higher.

2.8.7 Electronic equipments

Electronic equipment can malfunction when applied to distorted voltage. The clocking system in them will work faster, causing the equipment being controlled by them to operate incorrectly. Unscheduled activation of off peak hot water system and street lighting are some of the problems due to incorrect clocking systems.

2.8.8 Neutral currents

When zero sequence harmonics, especially the 3^{rd} harmonic, flow into the neutral, they add up, resulting in a neutral current that is three times the phase currents. This causes overheating of the neutral conductor and many times the neutral current has to be sized larger to avoid any faults.

2.9 Summary

Power quality is simply the interaction of electrical power with electrical equipment. If electrical equipment operates correctly and reliably without being damaged or stressed, we would say that the electrical power is of good quality. On the other hand, if the electrical equipment malfunctions, is unreliable, or is damaged during normal usage, we would suspect that the power quality is poor. As a general statement, any deviation from normal of a voltage source (either DC or AC) can be classified as a power quality issue. Power quality issues can be very high-speed events such as voltage impulses / transients, high frequency noise, wave shape faults, voltage swells and sags and total power loss.

CHAPTER 3

POWER QUALITY ANALYSIS METHOD

3.1 Introduction

This chapter presents the methodology of this project. It describes on how the project is organized and the flow of the steps in order to complete this project. The more details about visual basic web developer 2005 will discuss.

3.2 Visual basic web developer 2005

The Visual Web Developer Express is a freeware web development tool that allows developers to evaluate the web development and editing capabilities of the other Visual Studio 2008 editions at no charge. Its main function is to create ASP.NET websites. It has a WYSIWYG interface, drag-and-drop user interface designer; enhanced HTML & code editors; a (limited) database explorer; support for other web technologies (e.g., CSS, JavaScript, XML); and integrated, design-time validation for standards including XHTML 1.0/1.1 and CSS 2.1.VS2005 lacks certain features, such as the Accessibility Checker; the ability to create standalone Class Library Projects (which can be done by the other language-specific Express Editions); the extensibility support necessary to load third-party add-ins, macros and some other features.VS2008 Express Web Developer SP1 supports both class library and Web Application projects, which were not supported in VS2005 Express. It also includes a new integrated HTML designer based on Microsoft Expression Web. However, the functionality to publish the website you develop is not present in this edition.

3.3 Advantages of using Visual basic web developer

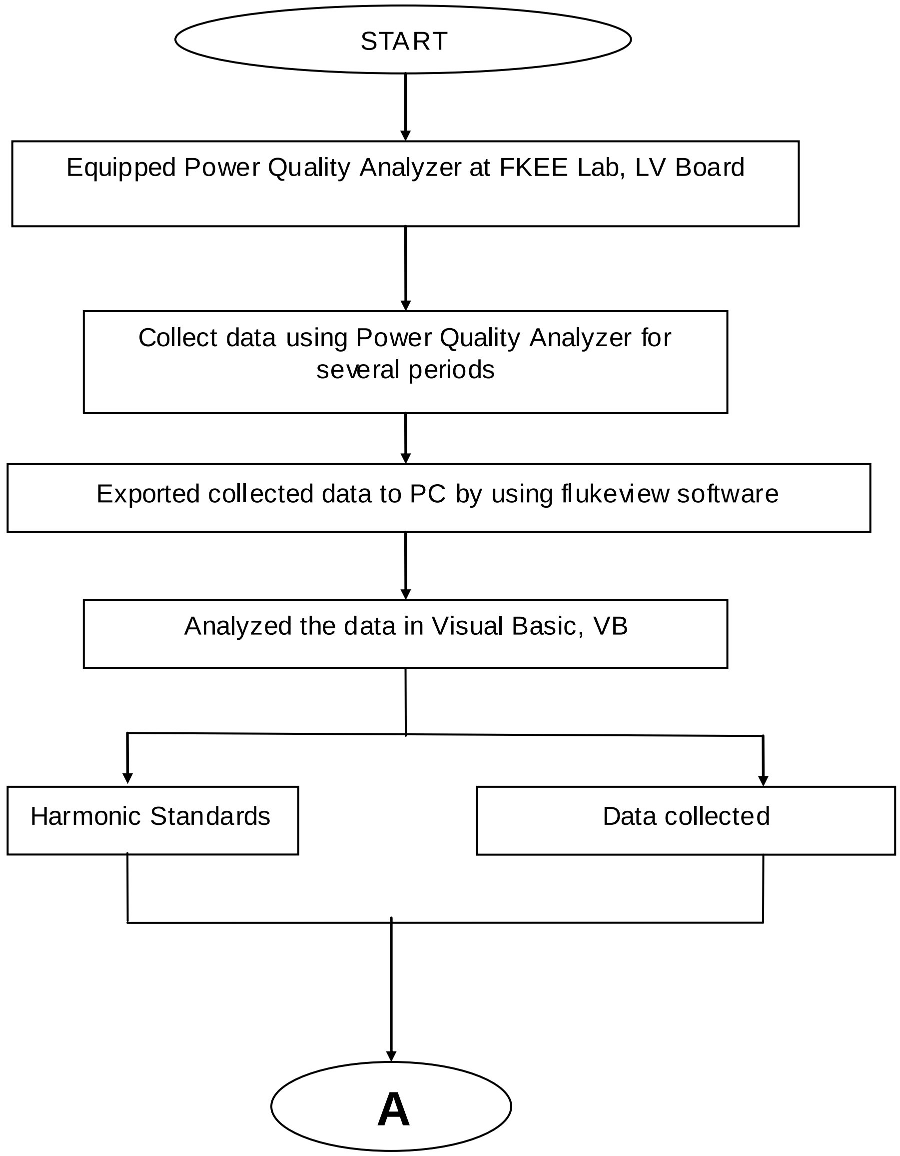
Visual basic web developer has many advantages compare to conventional computer languages for technical problem solving. Among them are the following:

- Tools to Design Web Pages.
  - Use the new Split View pane which shows both the visual designer as well as the corresponding markup.
  - Build CSS enabled pages with the new Manage Styles and CSS Properties windows to easily design, preview, and apply CSS styles to your Web page.
  - Build JavaScript & AJAX-enabled applications with JavaScript IntelliSense, formatting and debugging and built-in support for ASP.NET AJAX
  - Download the free AJAX Control Toolkit which includes over 30 AJAX controls including rounded corners, drop shadows, animation, ratings, slide shows, and more
- Easily Build Data-Driven Web sites
  - Build applications using LINQ (Language Integrated Query) which adds data querying capabilities for SQL Server, XML, and objects to Visual Basic and Visual C#.
  - Use new data controls like the List View control and the LINQ Data Source control to build dynamic Web pages.
- Easily Publish and Share.

- Use the built-in Copy Web Site tools to publish both ASP.NET pages and SQL Server databases to any hoster that supports FTP or FrontPage Server Extensions.

3.4 Flow Chart of the Project

By referring to Figure 3.0, the power quality analyzer has been equipped at a substation board in FKEE lab. Then, it will collect the data in a week. After that, all the data will be transfer to our computer by using FLUKEVIEW software. This software is needed to read the data in power quality analyzer in our computer. After we get the data, analysis will be done to compare either harmonic distortion level in FKEE lab is satisfied with International Standard or not. All the analysis process will be display in Visual Basic to get more view about the harmonic distortion. Then the data will be comparing against International Standard. The standards that will use are IEEE 519 Std. and AS 61000.3.6.If the data is satisfy with the standard, then the analysis process will be end but if not, some suggestion will be done to overcome that problem but in the suggestion process, its contain mitigation and the causes of the harmonic problems. This project is only aim to monitor power quality in FKEE lab which based on harmonic distortion. However, with this general knowledge of the power quality level, one can move on to specifically conduct analysis about how to overcome the harmonic distortion level in FKEE lab.


START
Equipped Power Quality Analyzer at FKEE Lab, LV Board
Collect data using Power Quality Analyzer for several periods
Exported collected data to PC by using flukeview software
Analyzed the data in Visual Basic, VB
Harmonic Standards
Data collected
A

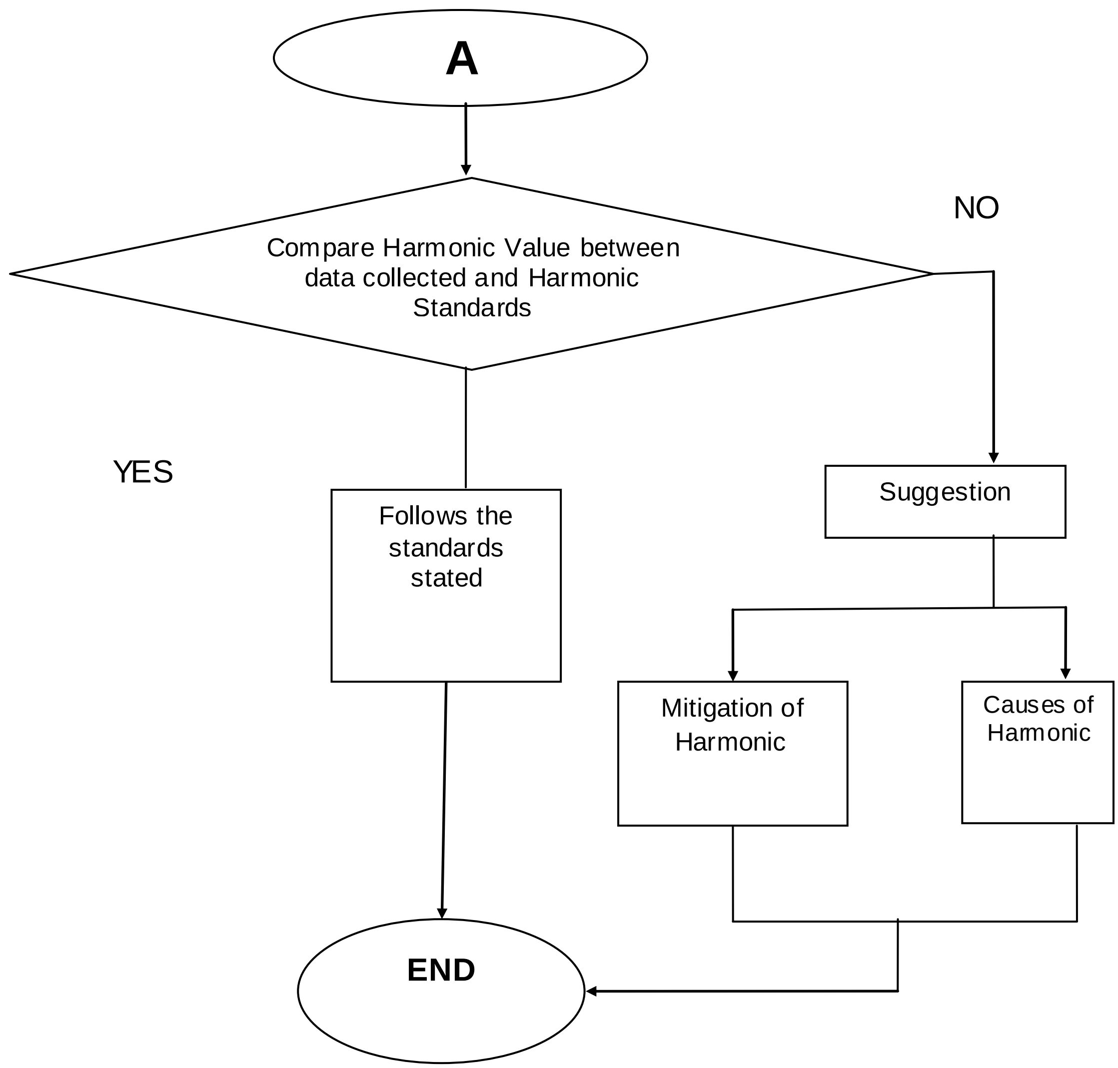


Figure 3.0: Flow chart project

3.5 Total Harmonic Distortion

There are several measures commonly used for indicating the harmonic component of a waveform with a single term or number. The most common means is by calculating the total harmonic distortion (THD), which can be used for both voltages and currents. They are sometimes termed THVD and THID respectively. The total harmonic voltage distortion is expressed as percentage of fundamental.

$$THVD = \sqrt{\frac{\sum_{i=2}^{N} V_i^{\ 2}}{V_1^{\ 2}}} \times 100\% \quad \text{.....................(3.0)}$$

Where **N** = Largest harmonic voltage order considered

V_i = rms value of harmonic voltage component i

V_1 = rms value of the fundamental voltage component

Referring to (3.0), 'N', which is the largest harmonic order to be considered, is normally taken as 40. Similar equation can be applied to calculate the total harmonic distortion of the current as shown by (3.1). The total harmonic current distortion obtained here is expressed as percentage of fundamental. [1]

$$THID = \sqrt{\frac{\sum_{i=2}^{N} I_i^{\ 2}}{I_1^{\ 2}}} \times 100\% \quad \text{.........................(3.1)}$$

Where **N** = largest harmonic current order considered

I_i = rms value of harmonic current component i

I_1 = rms value of the fundamental current component

Nevertheless, many times THID expressed as percentage of fundamental gives a wrong impression of the severity of the harmonic distortion on the waveform. This is because sometimes the fundamental current can drop to a very low value, resulting in a high THID since the reference value is the fundamental current.

Therefore, THD for currents are more appropriately expressed as amperes. This can be shown in (3.2). [1]

$$THID\_in\_amps = \sqrt{\sum_{i=2}^{N} I_i^{\,2}} \quad \text{.....................(3.2)}$$

3.6 Harmonic Standards

The most common international and national standards setting limits on harmonics are described below. There are two standard have been discussed for this type of analysis which are AS61000.3.6 and IEEE 519 - 1992.

3.6.1 AS 61000.3.6 [5]

The harmonics voltage standards for commercial and industrial areas are once governed by AS 2279.2, which is now replaced by AS 61000.3.6. This standard is based on the IEC 61000.3.2 standard entitled 'Assessment of emission limits for distorting loads in MV and HV power systems'. The compatibility level is defined in Table 3.0.

Table 3.0: Compatibility levels for harmonic voltages (in % of nominal) in LV and MV power systems as stated in AS 61000.3.6

Odd harmonics (non multiple of 3)		Odd harmonics (multiple of 3)		Even harmonics	
Order (n)	Harmonic voltage (%)	Order (n)	Harmonic voltage (%)	Order (n)	Harmonic voltage (%)
5	6	3	5	2	2
7	5	9	1.5	4	1
11	3.5	15	0.3	6	0.5

13	3	21	0.2	8	0.5
17	2	〉21	0.2	10	0.5
19	1.5			12	0.2
23	1.5			〉12	0.2
25	1.5				
〉25	$0.2 + (1.3 \times \frac{25}{n})$				
Total Harmonic Distortion (THD) = 8%					

3.6.2 IEEE 519 – 1992 [6]

As for harmonic current limits for industrial and commercial areas, The IEEE 519-1992 standard entitled ‘IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems’ will be used. This standard specifies the limit of the harmonic current component according to the short circuit ratio (SCR) and the harmonic voltage component according to the voltage level of the system (Table 3.1). Even harmonics are limited to 25% of the odd harmonic limits**.**

Table 3.1: Harmonic current limits as defined in IEEE 519-1992

SCR = $\frac{I_{sc}}{I_L}$	〈11	11〈n〈17	17〈n〈23	23〈n〈35	35〈n	TDD
〈20	4.0	2.0	1.5	0.6	0.3	5.0
20-50	7.0	3.5	2.5	1.0	0.5	8.0
50-100	10.0	4.5	4.0	1.5	0.7	12.0
100-1000	12.0	5.5	5.0	2.0	1.0	15.0

$\rangle$ 1000	15.0	7.0	6.0	2.5	1.4	20.0

$$Short\_Circuit\_Ratio(SCR) = \frac{Maximum\_short\_circuit\_current}{Maximum\_monthly\_demand\_load\_current} = \frac{I_{SC}}{I_L} \quad (3.3)$$

The short circuit ratio can be calculated through (3.3). Isc is the available short circuit current at the point of common coupling. I_L is the maximum demand load current (fundamental frequency component) measured at the PCC. The harmonic voltage limits of this standard are displayed in Table 3.2**.**

Table 3.2: Harmonic Voltage Limits as defined in IEEE 519-1992

Bus Voltage	Maximum Individual Component (%)	Maximum THD (%)
69 kV and below	3.0	5.0
115 kV to 161 kV	1.5	2.5
Above 161 kV	1.0	1.5

3.7 Summary

Basically, by referring to IEC and IEEE standard, the real data have been compared to the standard stated. For the next steps, there are two different standards that will use to compare between voltage-harmonic and current-harmonic. The philosophy of developing harmonic limits in this recommended practice is to limit the harmonic injection from individual customers so that they will not cause unacceptable voltage distortion levels for normal system characteristics and to limit overall harmonic distortion of the system voltage supplied by the utility. This standard is also recognised as American National

Standard and it is widely used in the USA, especially in the municipal public works market.

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 Introduction

This chapter discovered about the result that display and analyzed. So, the data that analyzed and display in Visual Basic satisfy with International Standards. If not, the general causes, mitigation of harmonic will be discussing further to get the solution on improving the power quality in the future.2 cases will consider during analysis:

- Harmonic voltage.
- Harmonic current.

4.2 Case 1: Harmonic voltage

For harmonic voltage, the data will be comparing against AS61000.3.6 standard. The harmonic voltages were measured in a week. This data were got from 4^{th} February until 11^{th} February 2009 starting from 2.00 pm.

4.2.1 Harmonic voltage from power quality analyzer

There are the harmonic data from power quality analyzer that measured in a week. It's display by using FLUKEVIEW software. The data has been display phase by phase which are the red, yellow and blue phase. It's started from 2nd harmonic to 16th harmonic order. Below are the samples of the harmonic value from power quality analyzer:

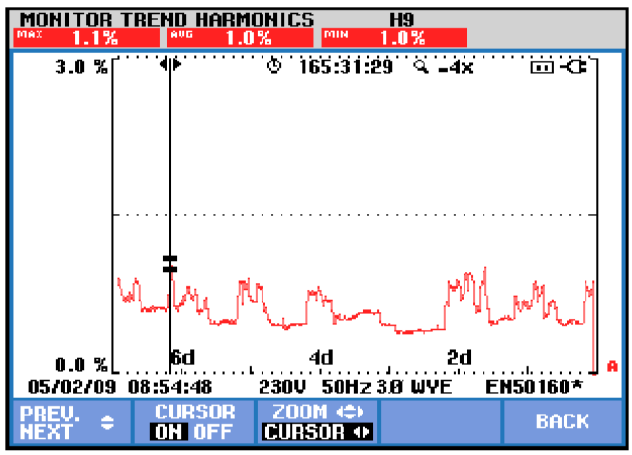


Figure 4.0: Red phase, 9th harmonic order.

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Figure 4.0 show us that harmonic will rise to the peak value when FKEE lab is operated. (usually at day time).At night, the harmonic value will slowly go down and for the other days it will rise up again start from morning to evening. The highest harmonic value for 9th harmonic order is on day 1 which pointed by the cursor.

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4.2.2 Harmonic voltage compared to AS 61000.3.6

This comparing method was run in the Visual Basic Web Developer 2005.The average harmonic components of each phase were used to tabulate an overall three phase average and which was compared to international standards AS 61000.3.6. So there are the results which will appear. All the comparison was done day by day. Figure 4.1 shows the samples of the comparison data for day 1.

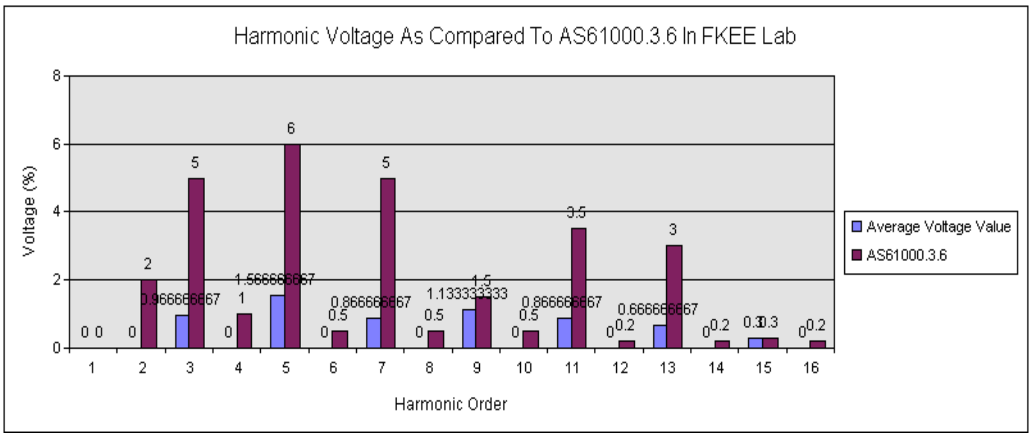


Figure 4.1: Harmonic voltage comparison for day 1

From Figure 4.1, we can see that the highest harmonic order is the 5th harmonic (1.57%)The 2nd highest is the 9th harmonic order (1.13%).Then, followed by the 3rd harmonic (0.97%), 7th harmonic (0.87%), 11th harmonic (0.87%), 13th harmonic (0.67%) and 15th harmonic (0.3%). Therefore, there was only odd harmonics voltage which effected because non-linear load produce odd harmonic. As we know, the highest harmonic is 5th harmonic order. It have phase sequence which opposite to phasors which representing the current or voltage. These negative sequence components can cause the rotating motor to decelerate.

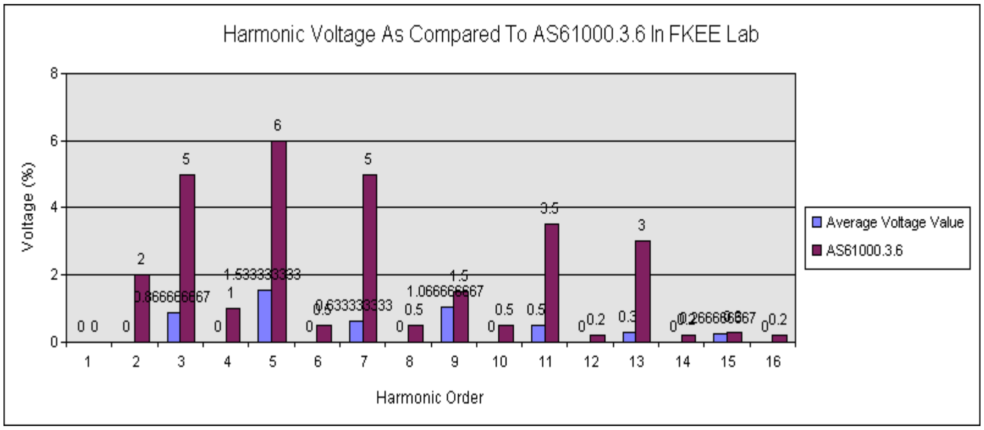


Figure 4.2: Harmonic voltage comparison for day 3

From Figure 4.2, we need to consider the 2nd highest of the harmonic because the highest harmonic is same like day 1. 9th harmonic order is the 2nd highest value because it's produce by zero sequence harmonic. This type of harmonic was produced by computers and VFD's. As we know, in the lab area there are so many computers and VFD's. So, it's not possible why the 9th harmonic order can contribute to the 2nd highest value of the harmonic.

4.3 Case 2: Harmonic current

For harmonic current, the data will be comparing against IEEE 519 standard. The harmonic currents were measured in a week. This data were got from 4th February until 11th February 2009 starting from 2.00 pm.

4.3.1 Harmonic current from power quality analyzer

There are the harmonic data from power quality analyzer that measured in a week. It's display by using FLUKEVIEW software. The data will be display phase by phase which are the red, yellow and blue phase. It's started from 2^{nd} harmonic to 16^{th} harmonic order. Below (Figure 4.3) was the sample of the harmonic current which got from power quality analyzer.

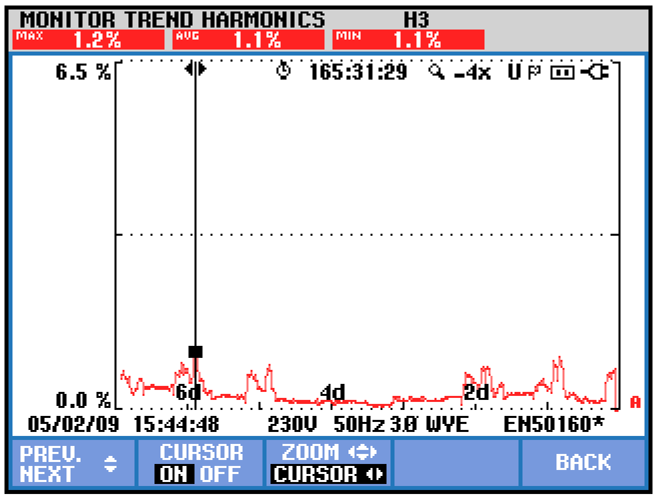


Figure 4.3: Red phase, 3^{rd} harmonic order

From Figure 4.3, we can see that the shape of the harmonic was same as harmonic voltage. Harmonic current only rise up to the peak when the FKEE lab is fully operated. This is happen because all the electronic equipments in the lab are in used. So it gave us the harmonic reading. At night, the lab area is shut down, so the effected of the harmonic value is less than or near to zero. During online operation of the power quality analyzer, we can move the cursor to the point that we need to take reading. So it gave us the value of harmonic, times and dates that harmonic occur.

4.3.2 Harmonic current compared to IEEE 519

The comparison for harmonic current also done in Visual Basic Web Developer 2005 but its compared to the harmonic current standard which is IEEE 519.

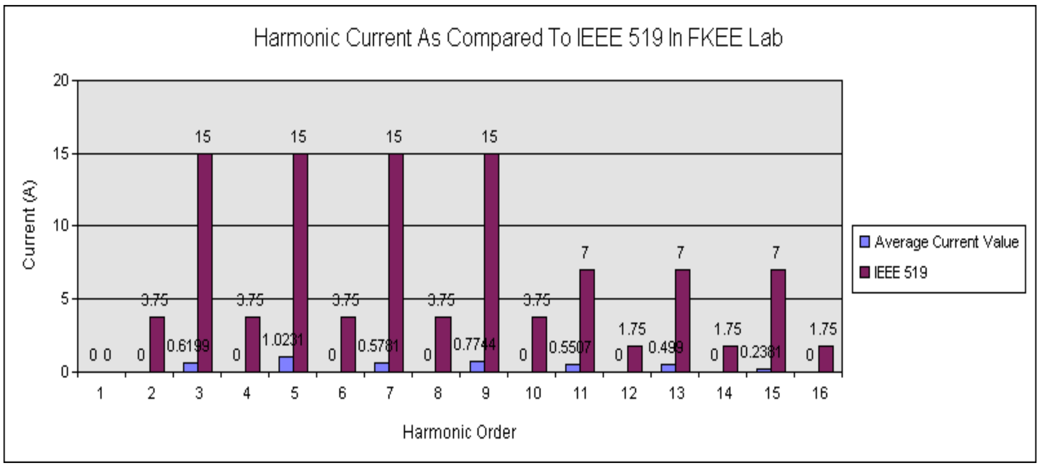


Figure 4.4: Harmonic current comparison for day 1

From Figure 4.4, there was the sample of the harmonic current which was compared. For day 1, the highest harmonic current is on the 5th harmonic (1.02A).The 2nd highest is the 9th harmonic (0.77A).Then followed by the 3rd harmonic (0.62A), 7th harmonic (0.57A), 11th harmonic (0.55A), 13th harmonic (0.49A) and 15th harmonic (0.23A). We need to convert the percentage value of the harmonic current to the actual value because the standard only needed the actual value of the harmonic during comparison. From this graph, we know that the highest harmonic order is 5th harmonic. This happen because in the lab area is full with electronic devices which operate by using 6 pulse converter and transformers.

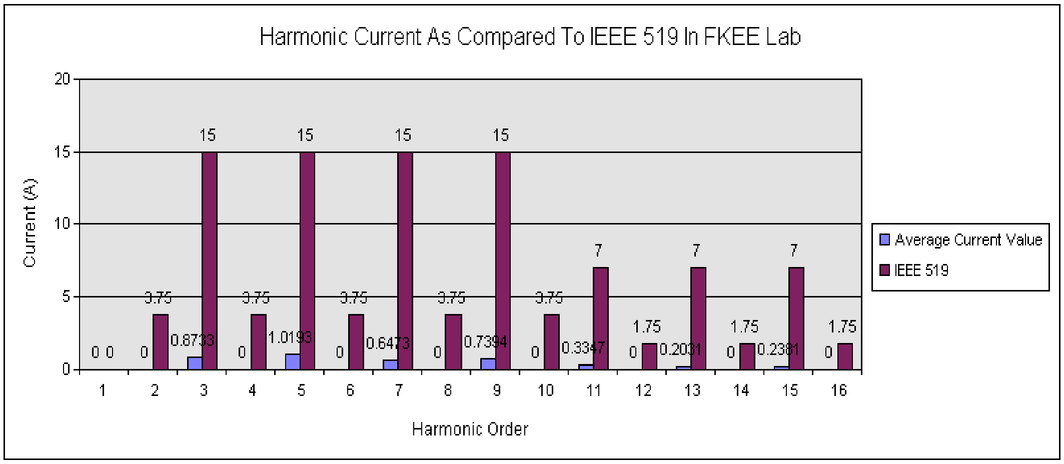


Figure 4.5: Harmonic current comparison for day 2

By referred to Figure 4.5, the highest harmonic order is 5th harmonic. So, it's still the same like day 1 but we need to consider the 2nd highest harmonic which is the 3rd harmonic order. The 3rd harmonic order is the worst and can cause overheating to the neutral wire. Furthermore, it's can cause the particular equipment to be more non – linear. The high usage of the computers was contributed in 3rd harmonic order of distortion.

4.4 Discussion for harmonic current and voltage

From the day by day, there was same result and only a little bit change on the harmonics value. The most effected harmonic voltage and current were on 5th harmonic. Then followed by the other odd harmonic(3rd, 7th, 11th, 13th, and so on). As we know, in the FKEE lab, there are so many electrical equipments which can produce harmonic such as motor, computers, fluorescent lighting, transformer, air-conditioner, and any other power electronic devices. Besides that, only odd harmonic effected because non-linear loads normally generate odd harmonic rather than even harmonics. The 3rd , 9th and 15th harmonic were produced by transformer, rotating machines, electronic/computer, lighting/electronic (fluorescent lighting) while the 5^{th} , 7^{th} ,11^{th} and 13^{th} harmonic were produce by 6-pulse rectifier, 12-pulse rectifier, 18-pulse rectifier, 24-pulse rectifier, electronic/computer, lighting/electronic (fluorescent lighting). As we know, all the comparison were satisfy within the standard stated but we must pay more attention on the highest harmonic value because it will damage the electronic equipments and power system.

4.5 Summary

From the analysis, it can be seen that both the harmonic current and voltage were far from breaching the limits. Therefore, effects from harmonics will not be much of a concern in this area.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

For conclusion, both harmonic voltage and current which compare to International Standard were satisfied within the limit. Comparison between harmonic data against International Standard was done in Visual Basic Web Developer. This analysis shows us that only odd harmonic which effected to electrical component. All the general causes and effect of harmonic have been identified. This situation is very important in open access market in electricity market. This project can be applied to determine whether the harmonic limits are satisfied within the standard or not. This is important because we need to prevent something bad happen to our electronic equipments.

This work more focused on to construct program with Visual Basic Web Developer software for comparing the data. Programming will construct in Website file. This software is very important to make sure the analysis more systematic and accurate.

5.2 Recommendations

This project can be improved and apply in power system market. We can use this software to determine and comparing the data more efficient. In the future, someone can be determining the harmonic data in different area and by using better power quality analyzer to get more specific result.

5.3 Costing and Commercialization

The overall cost of the whole project is based on the software and computer hardware. Since the software and computer hardware had provided by University Malaysia Pahang, thus, for individual user, this project does not have costing. This project required the understanding of fundamental knowledge about the software and system that going to developed.

Having known the level of power quality in these areas will ease utilities and consumers in identifying the causes of the problems. Furthermore, even more practically, this knowledge will enable them to plan ahead some mitigation means in order to prevent or reduce the adverse effect of power quality problems. With that, losses in terms of time and finance can be reduced remarkably. Finally, this project will be commercialized in power producer industry and as a teaching module which to help the coordinator to explain the problem in the power system network.

REFERENCES

[1] Power Quality and Harmonic Audit of Power Distribution System by Lee K.J. Gordon 12523874.

[2] Power Quality Studies in Distribution Systems Involving Spectral Decomposition by Andrzej Bachry.

[3] Dugan, McGranaghan & Beaty. 1996, ‘Introduction,’ in B.Crawford & M. Smith (eds), Electrical power systems quality, McGraw-Hill, New York pp. 2, 13-28, 45-51).

[4] AS/NZS 61000.3.2:2001, ‘Limits of Harmonic Emissions for equipment with rated current less than or equal to 16A’,Australian Standards, 2001

[5] AS/NZS 61000.3.2:1996, ‘Assessment of emission limits for distorting loads in MV and HV power systems – Basic EMC publication’, Australian Standards, 1996.

[6] IEEE Recommended practices and requirement for harmonic control in electrical power systems, IEEE Standard 519-1992.

[7] Interharmonics in Power Systems by Erich W. Gunther (Electrotek Concepts)

[8] A new approach for voltage harmonic distortion minimization by A.F.Zobaa

[9] A new approach to monitoring electric power quality by P.K.Dash*, S.KPanda, A.C.Liew, B.Mishra, R.K.Jena.

[10] A Power Quality Measure by Dimitris Al.Katsaprakakis, Dimitris G.Christakis, Arthouros Zervos, and Spiros Voutsinas.

[11] Harmonic Analysis for Industrial Customers by Y. H. Yan, C. S. Chen,Member, IEEE, C. S. Moo, and C. T. Hsu.

[12] Indices for Assessing Harmonic Distortion from Power Quality Measurements: Definitions and Benchmark Data by D. Daniel SabinMember, IEEE dsabin@electrotek.com, Daniel L. Brooks Member, IEEE dbrooks@electrotek.com, Ashok Sundaram Member, IEEE asundara@epri.com.

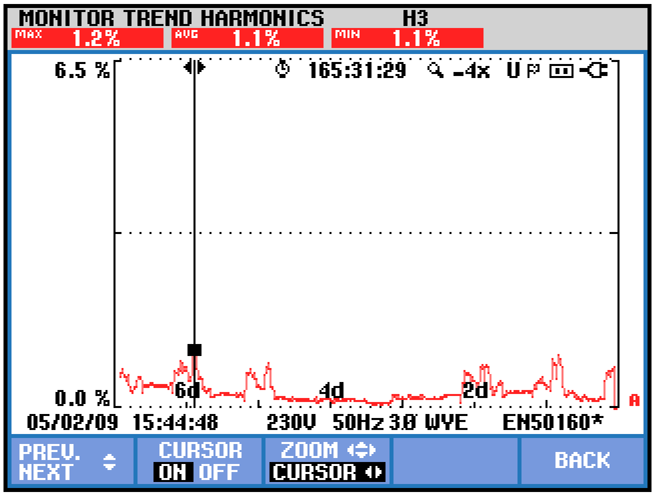
[13] Power Quality in Entertainment Facilities by T.K. Wong.

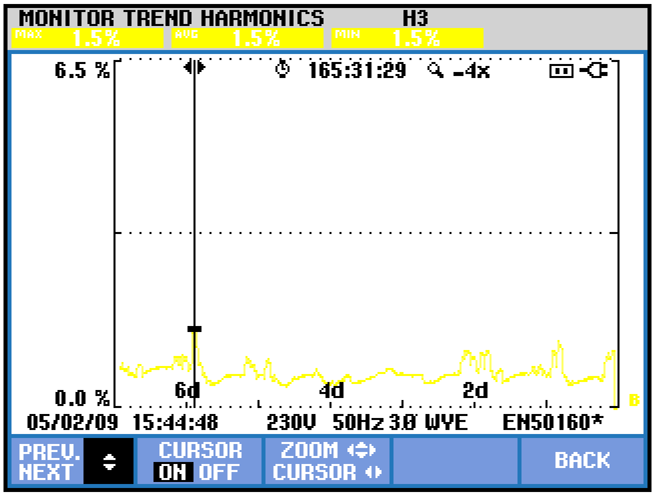
[14] Uncertainties in Compliance with Harmonic Current Distortion Limits in Electric Power Systems by Thomas M. Gruzs, Senior Member, IEEE.

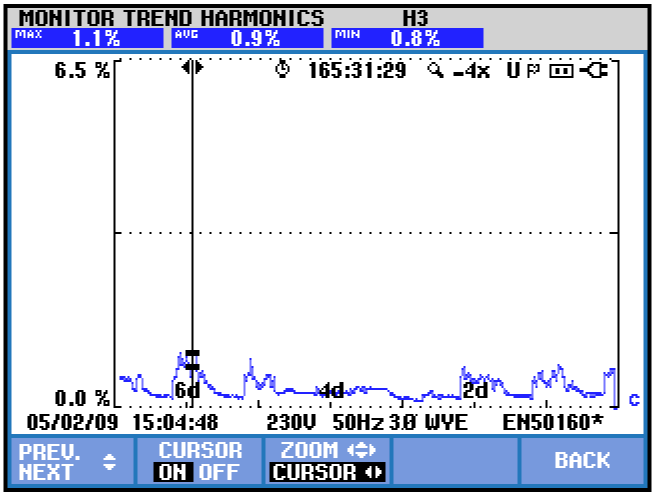
[15] Mitigation of harmonic disturbance at pumped storage power station with static frequency converter by Jung- Chen Chiang, Chi- Jui Wu,And Shih-Shong Yen Department of Electrical Engineering National Taiwan Institute of Technology.

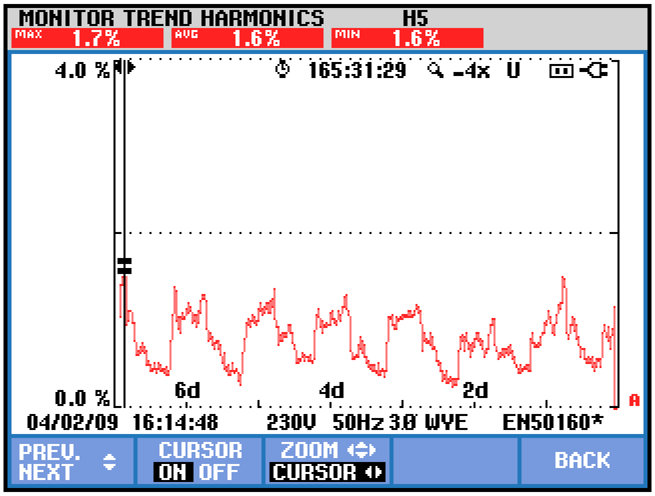
APPENDIX A

Harmonics voltage from power quality analyzer





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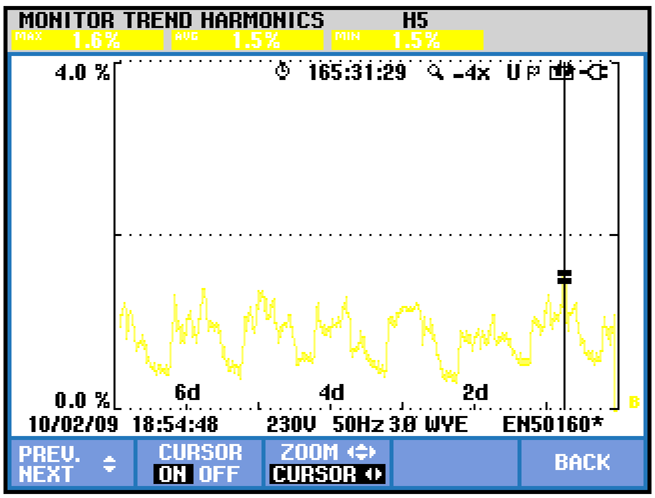
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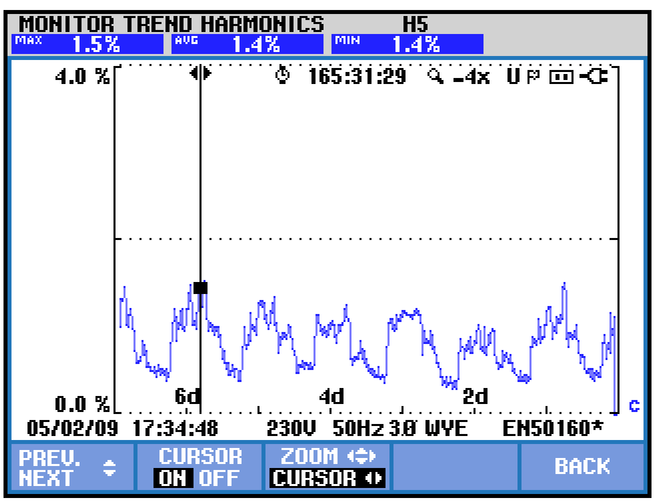
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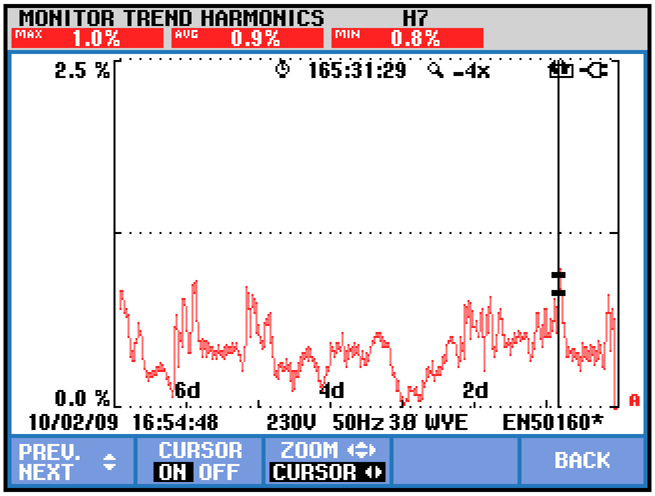
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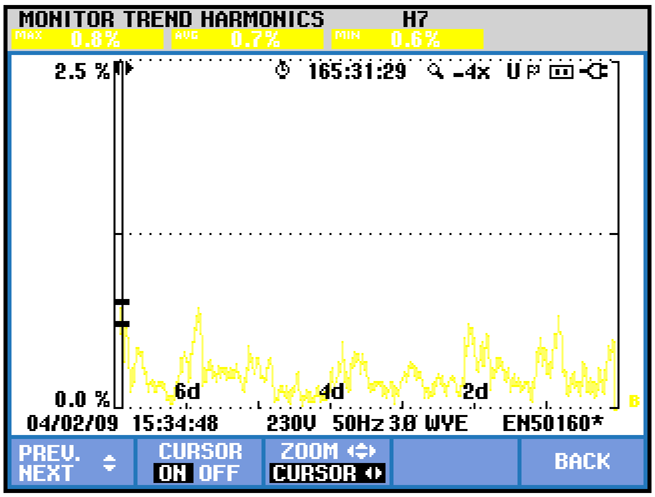
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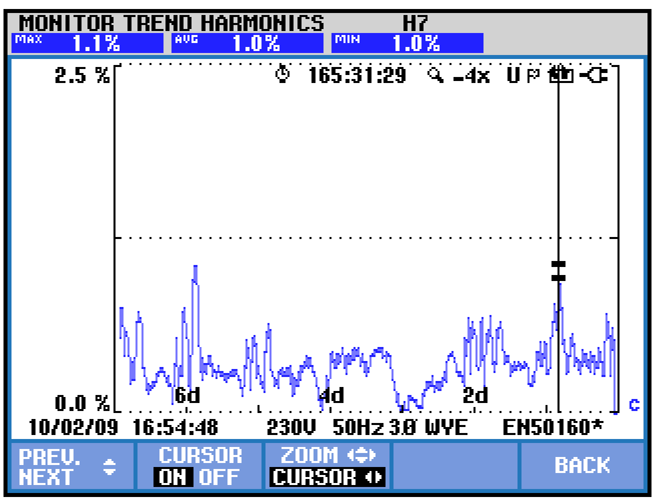
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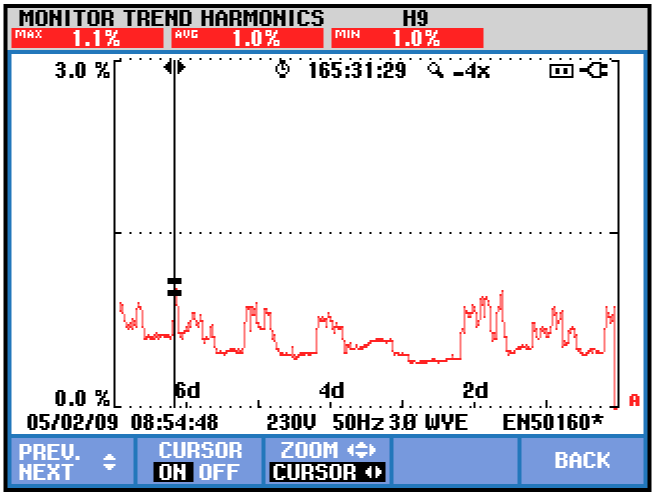
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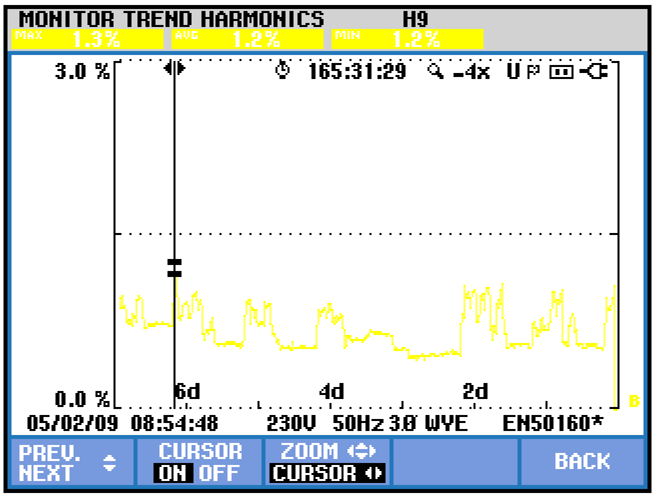
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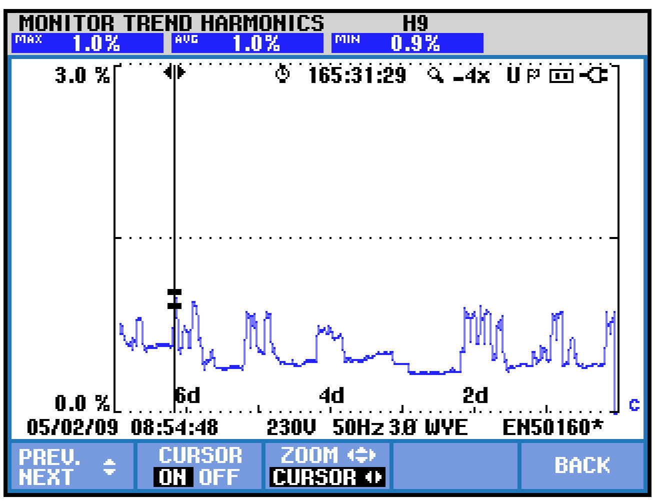
MONITOR TREND HARMONICS H9
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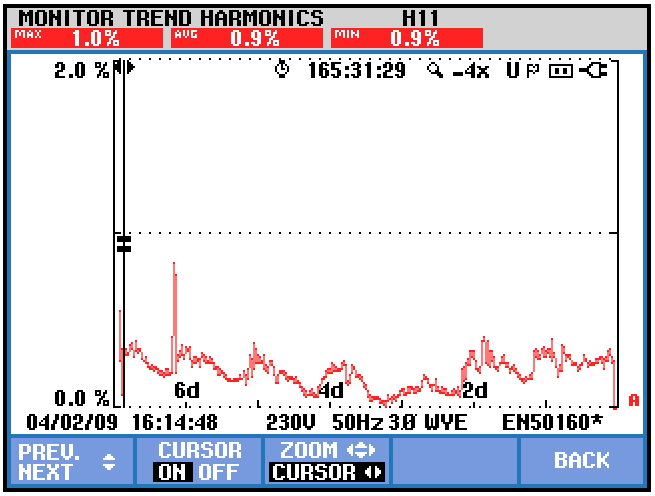
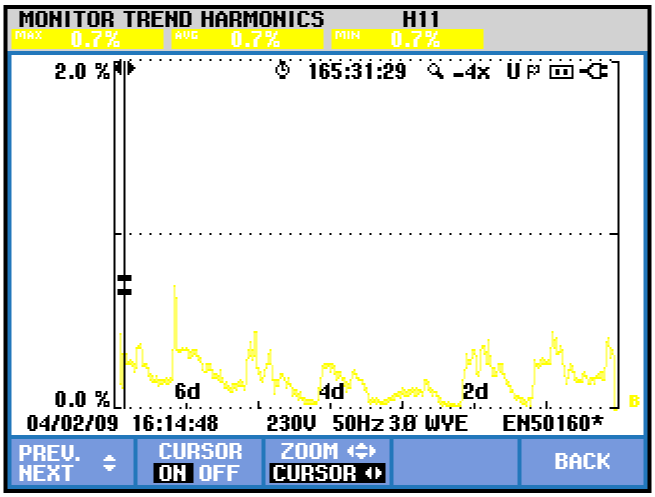
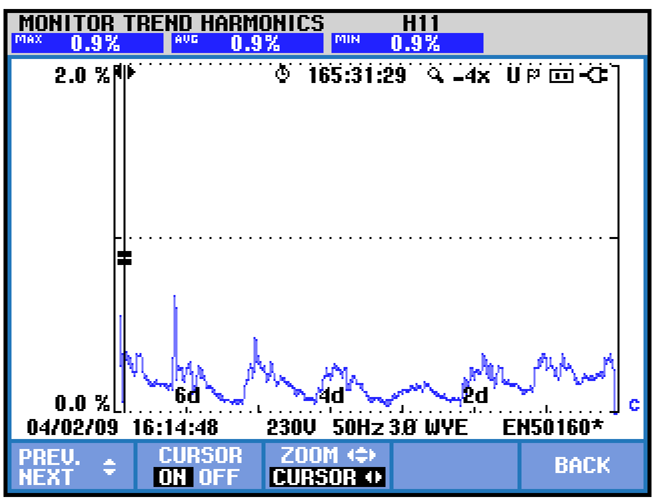
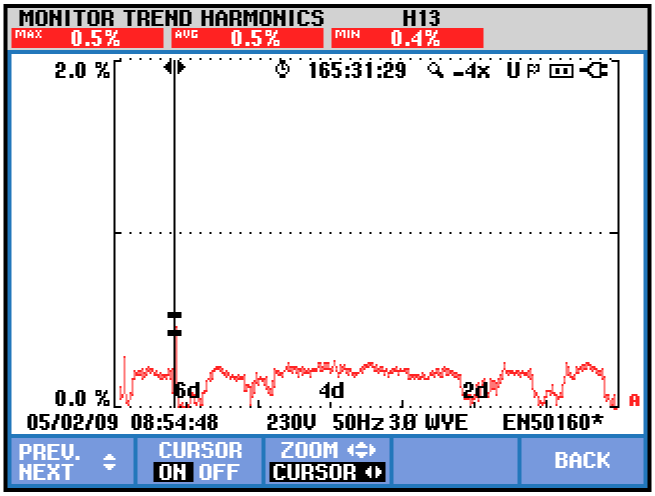
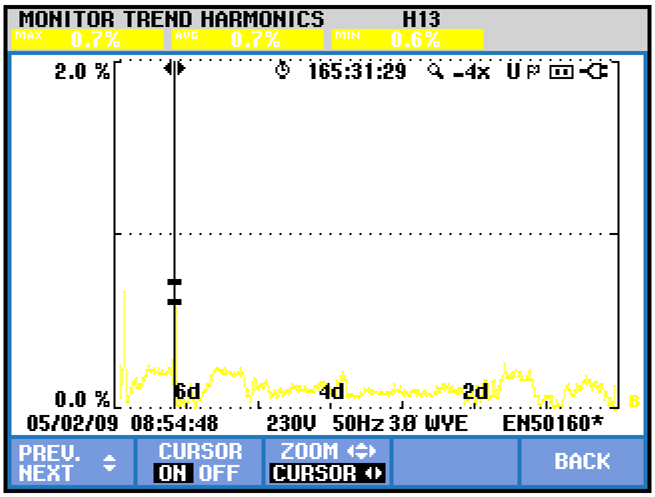
3.0 %
165:31:29
-4x
0.0 %
6d
4d
2d
05/02/09 08:54:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

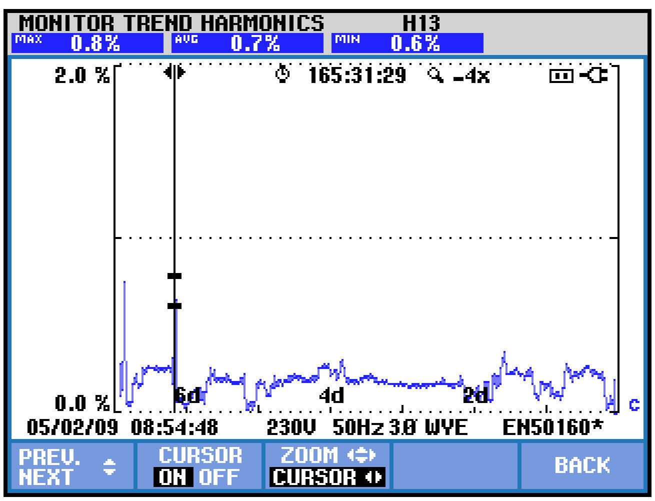

MONITOR TREND HARMONICS H11
MAX 1.0%
AVG 0.9%
MIN 0.9%
2.0 %
165:31:29
-4x
0.0 %
6d
4d
2d
A
04/02/09 16:14:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

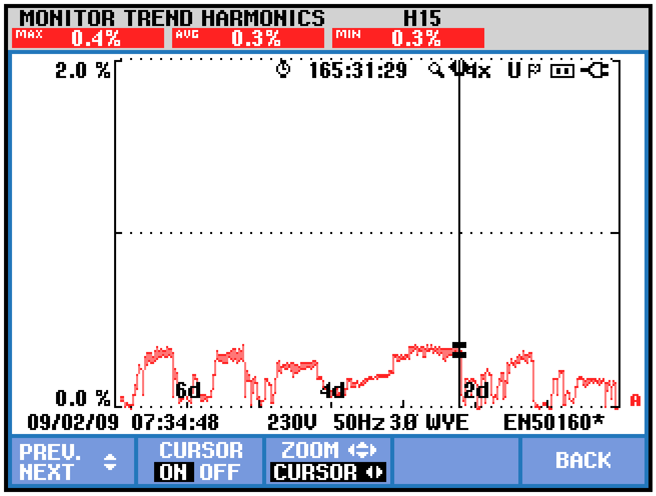

MONITOR TREND HARMONICS H11
MAX 0.7%
AVG 0.7%
MIN 0.7%
2.0 %
165:31:29
-4x
0.0 %
6d
4d
2d
B
04/02/09 16:14:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

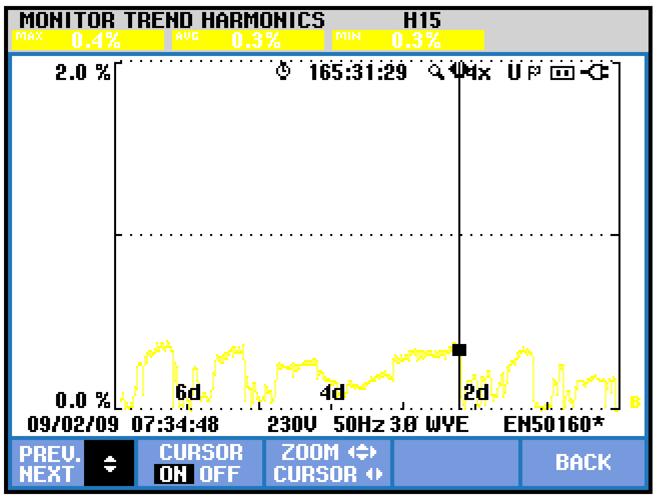

MONITOR TREND HARMONICS H11
MAX 0.9%
AVG 0.9%
MIN 0.9%
2.0 %
165:31:29
-4x
0.0 %
6d
4d
2d
C
04/02/09 16:14:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

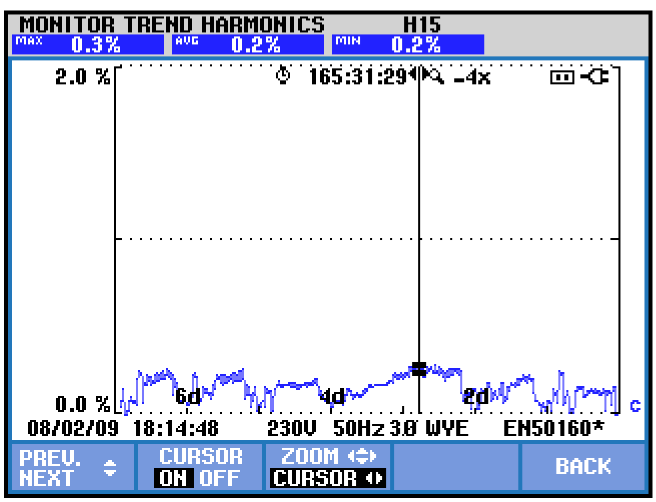

MONITOR TREND HARMONICS H13
MAX 0.5% AVG 0.5% MIN 0.4%
2.0 %
165:31:29
-4x
0.0 %
6d 4d 2d
05/02/09 08:54:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK


MONITOR TREND HARMONICS H13
MAX 0.7% AVG 0.7% MIN 0.6%
2.0 %
165:31:29
-4x
0.0 %
6d 4d 2d
05/02/09 08:54:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK


MONITOR TREND HARMONICS H13
MAX 0.8% AVG 0.7% MIN 0.6%
2.0 %
165:31:29
-4x
0.0 %
6d 4d 2d
05/02/09 08:54:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

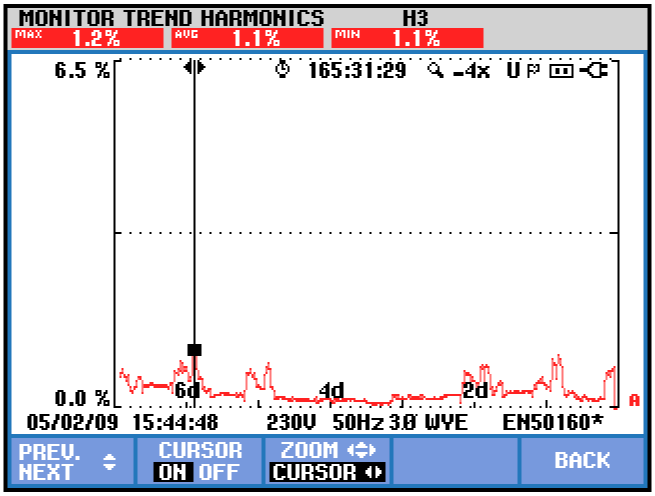

MONITOR TREND HARMONICS H15
MAX 0.4%
AVG 0.3%
MIN 0.3%
2.0 %
165:31:29
4x
0.0 %
6d
4d
2d
A
09/02/09 07:34:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

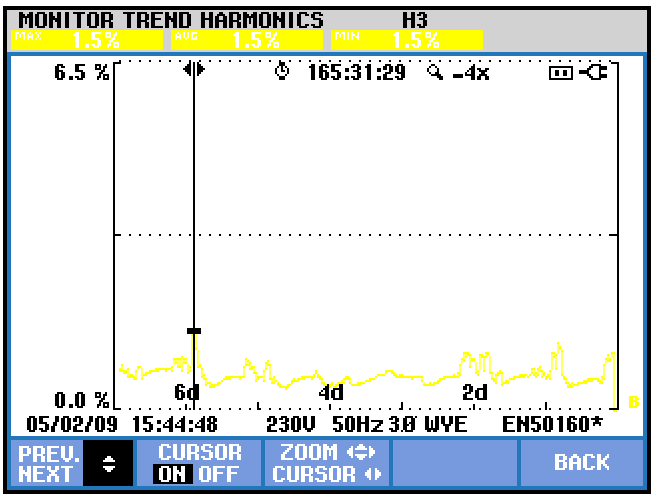

MONITOR TREND HARMONICS H15
MAX 0.4%
AVG 0.3%
MIN 0.3%
2.0 %
165:31:29
4x
0.0 %
6d
4d
2d
B
09/02/09 07:34:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

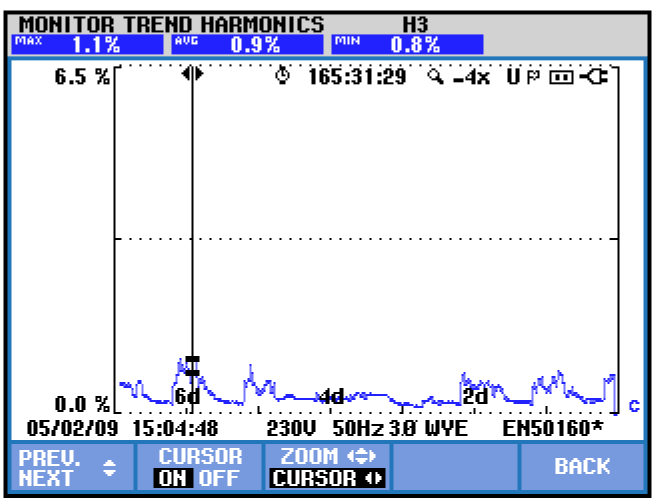

MONITOR TREND HARMONICS H15
MAX 0.3%
AVG 0.2%
MIN 0.2%
2.0 %
165:31:29
-4x
0.0 %
6d
4d
2d
C
08/02/09 18:14:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

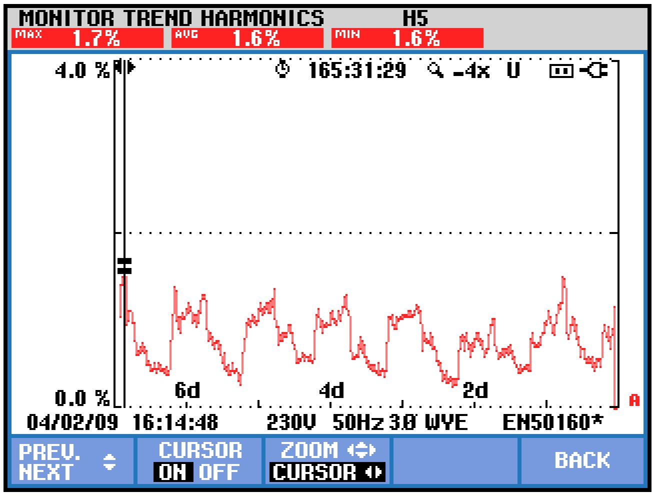
APPENDIX B

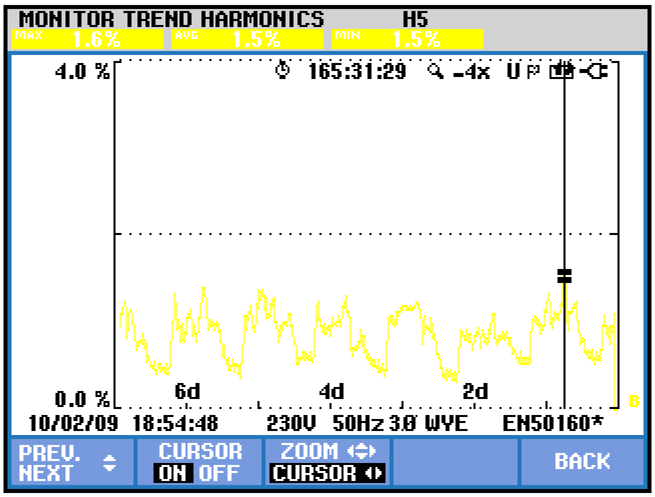
Harmonics current from power quality analyzer

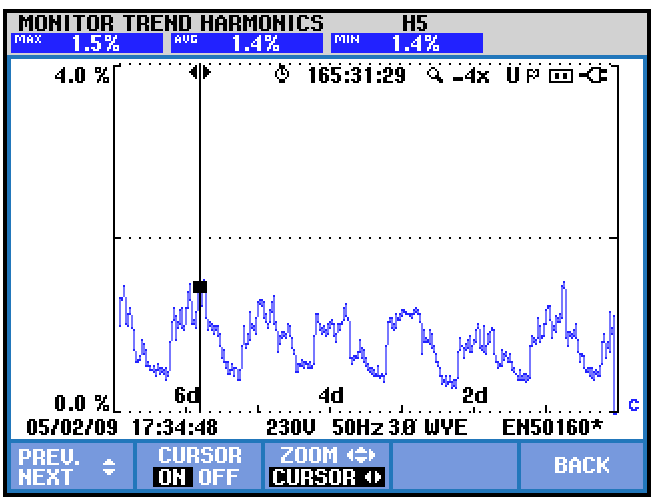


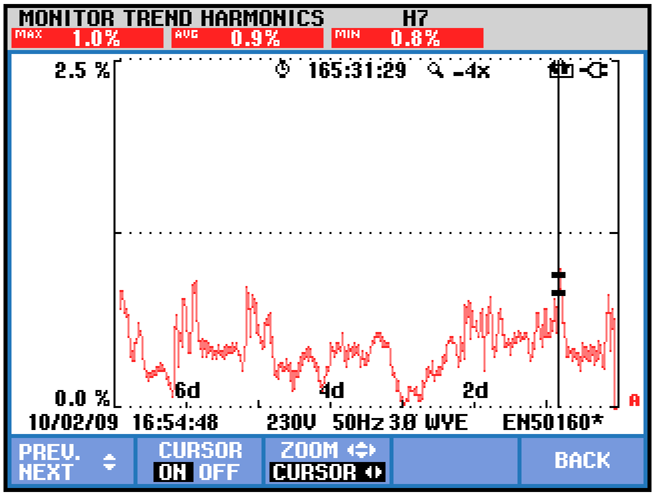


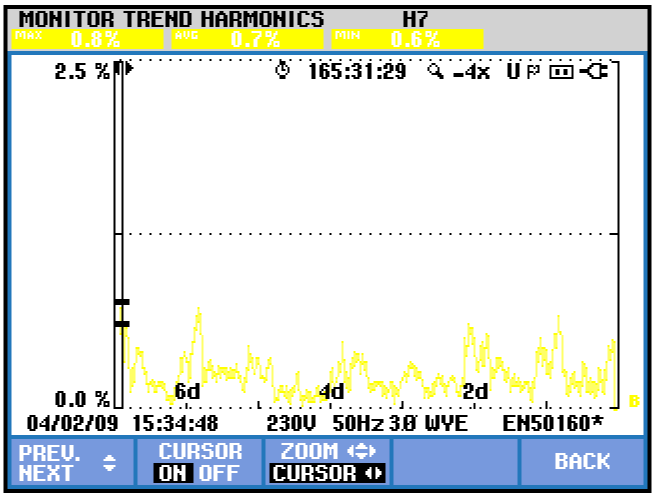


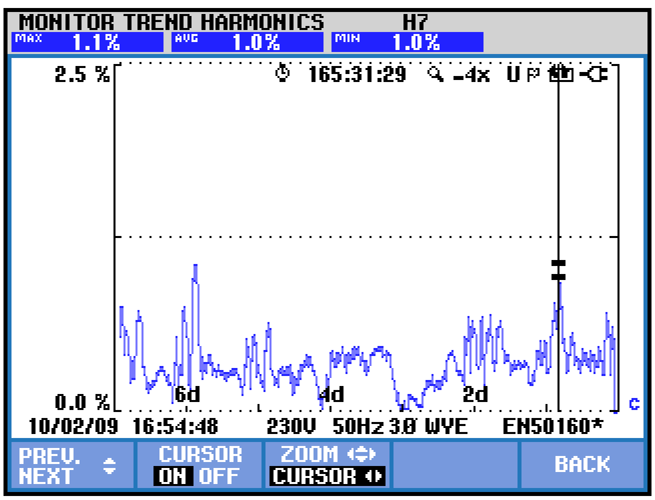

MONITOR TREND HARMONICS H5
MAX 1.7% AVG 1.6% MIN 1.6%
4.0 %
165:31:29 -4x U
0.0 %
6d 4d 2d
04/02/09 16:14:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

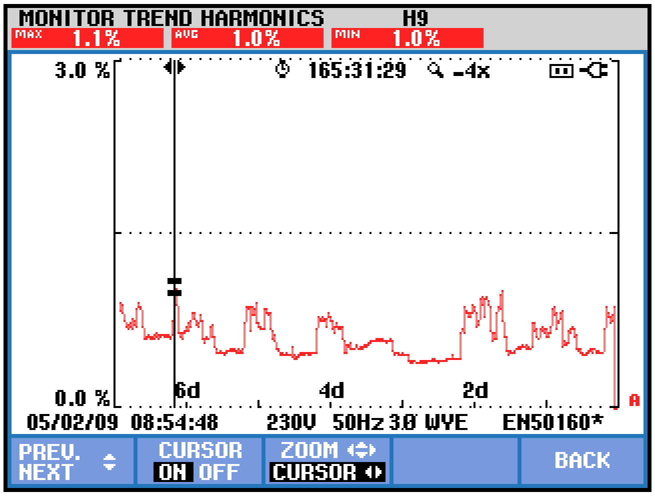

MONITOR TREND HARMONICS H5
MAX 1.6% AVG 1.5% MIN 1.5%
4.0 %
165:31:29 -4x U
0.0 %
6d 4d 2d
10/02/09 18:54:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

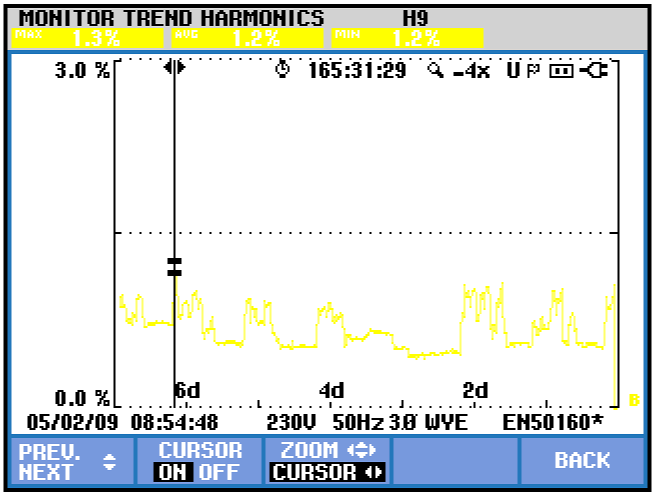

MONITOR TREND HARMONICS H5
MAX 1.5% AVG 1.4% MIN 1.4%
4.0 %
165:31:29 -4x U
0.0 %
6d 4d 2d
05/02/09 17:34:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

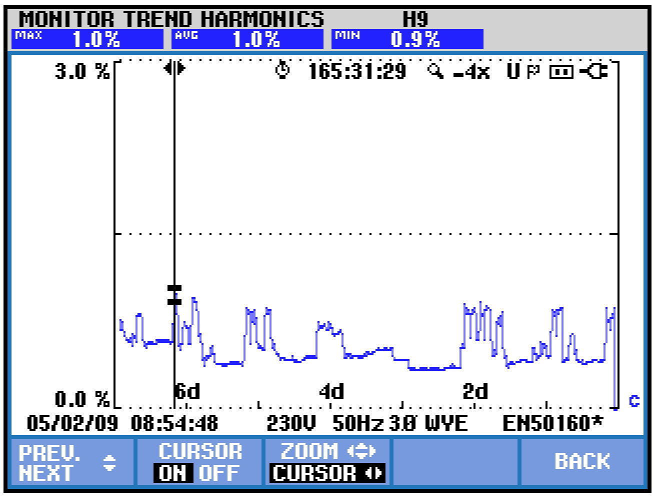

MONITOR TREND HARMONICS H7
MAX 1.0% AVG 0.9% MIN 0.8%
2.5 %
165:31:29 -4x
0.0 %
6d 4d 2d
10/02/09 16:54:48 230V 50Hz 3.0 WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

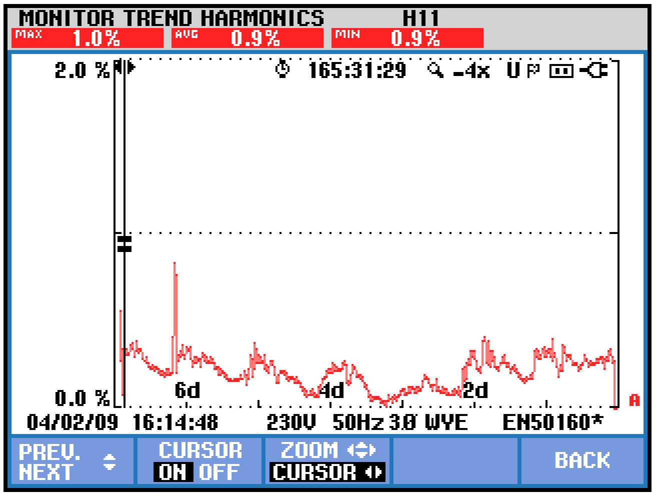

MONITOR TREND HARMONICS H7
MAX 0.8% AVG 0.7% MIN 0.6%
2.5 %
165:31:29 -4x
0.0 %
6d 4d 2d
04/02/09 15:34:48 230V 50Hz 3.0 WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

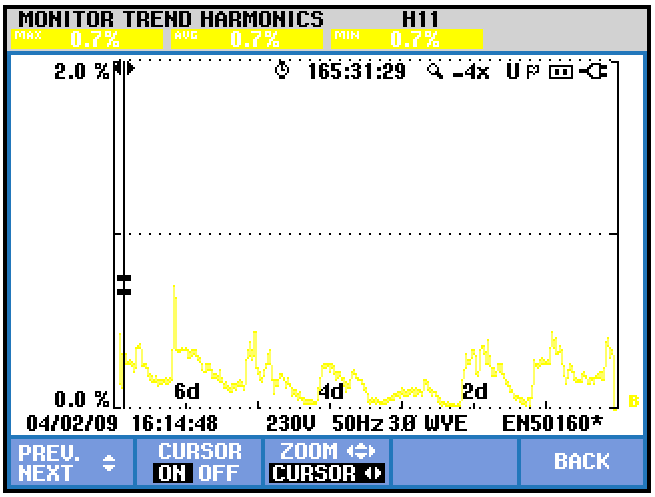

MONITOR TREND HARMONICS H7
MAX 1.1% AVG 1.0% MIN 1.0%
2.5 %
165:31:29 -4x
0.0 %
6d 4d 2d
10/02/09 16:54:48 230V 50Hz 3.0 WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

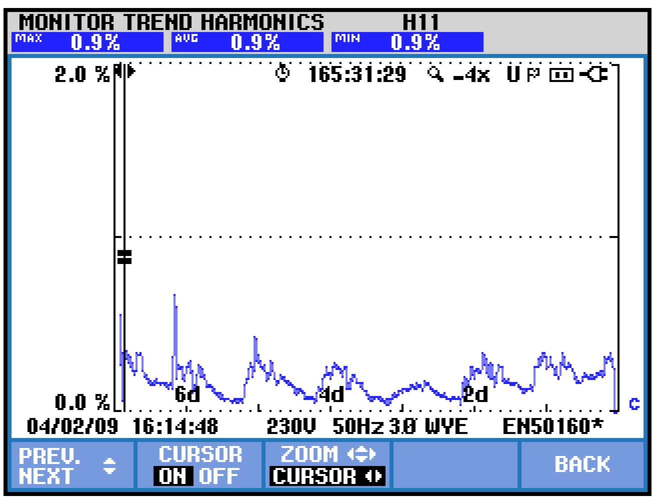

MONITOR TREND HARMONICS H9
MAX 1.1% AVG 1.0% MIN 1.0%
3.0 %
165:31:29 -4x
0.0 %
6d 4d 2d
A
05/02/09 08:54:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

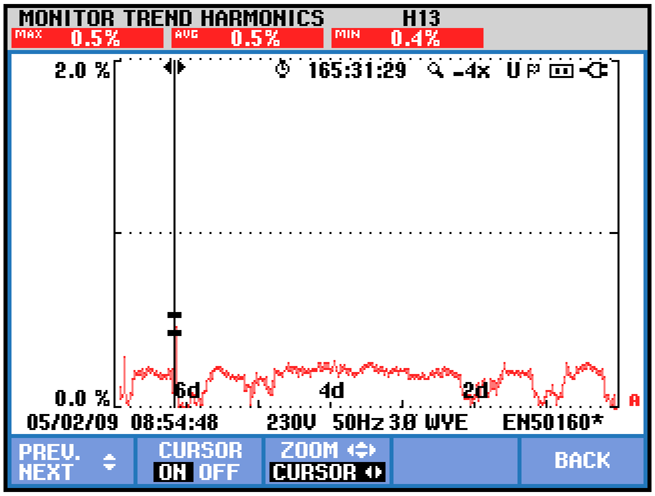

MONITOR TREND HARMONICS H9
MAX 1.3% AVG 1.2% MIN 1.2%
3.0 %
165:31:29 -4x
0.0 %
6d 4d 2d
B
05/02/09 08:54:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

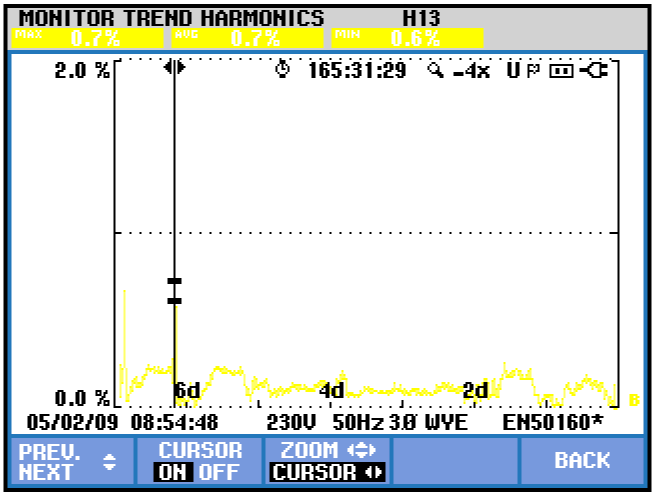

MONITOR TREND HARMONICS H9
MAX 1.0% AVG 1.0% MIN 0.9%
3.0 %
165:31:29 -4x
0.0 %
6d 4d 2d
C
05/02/09 08:54:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

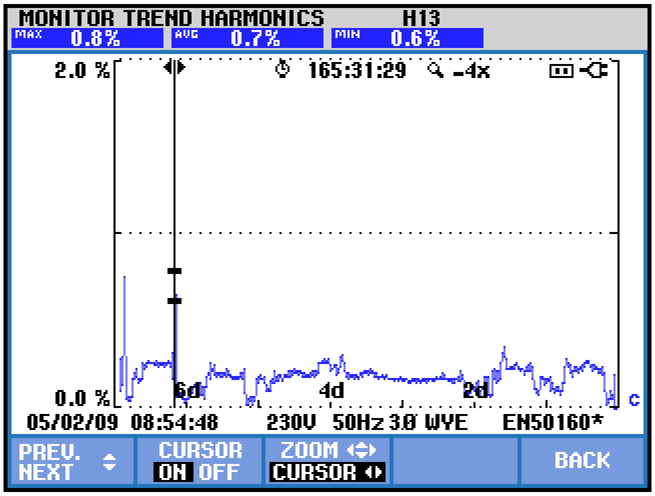

MONITOR TREND HARMONICS H11
MAX 1.0% AVG 0.9% MIN 0.9%
2.0 %
165:31:29 -4x
6d 4d 2d
0.0 %
A
04/02/09 16:14:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

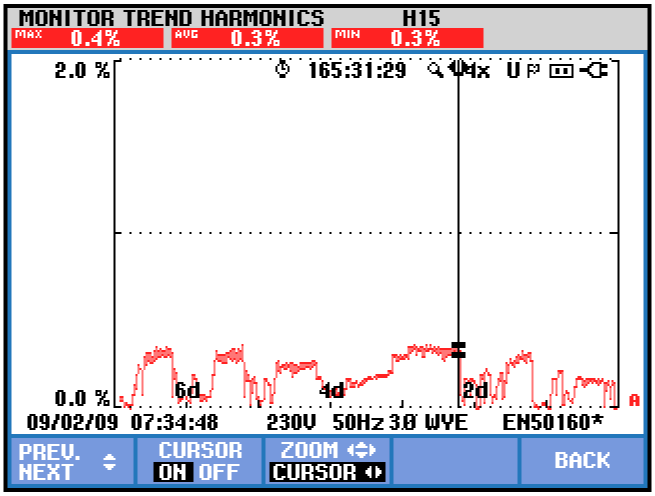

MONITOR TREND HARMONICS H11
MAX 0.7% AVG 0.7% MIN 0.7%
2.0 %
165:31:29 -4x
6d 4d 2d
0.0 %
B
04/02/09 16:14:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

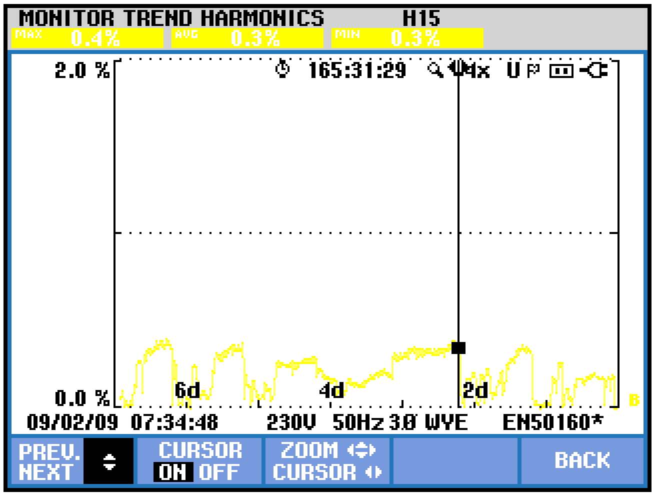

MONITOR TREND HARMONICS H11
MAX 0.9% AVG 0.9% MIN 0.9%
2.0 %
165:31:29 -4x
6d 4d 2d
0.0 %
C
04/02/09 16:14:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

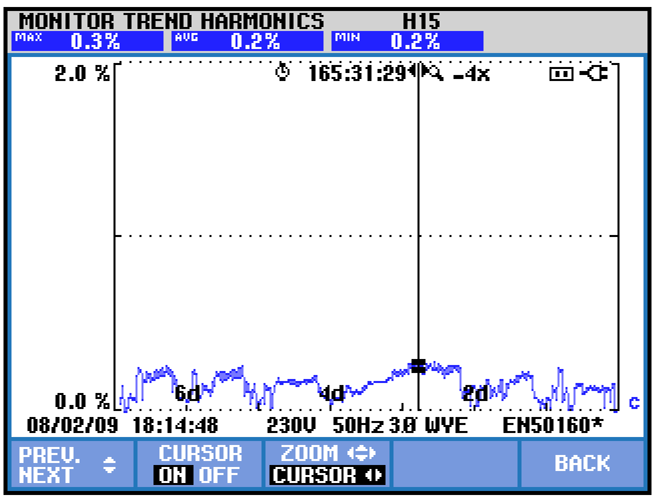

MONITOR TREND HARMONICS H13
MAX 0.5%
AVG 0.5%
MIN 0.4%
2.0 %
165:31:29
-4x
0.0 %
6d
4d
2d
A
05/02/09 08:54:48
230V 50Hz 3Ø WYE
EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK


MONITOR TREND HARMONICS H13
MAX 0.7%
AVG 0.7%
MIN 0.6%
2.0 %
165:31:29
-4x
0.0 %
6d
4d
2d
B
05/02/09 08:54:48
230V 50Hz 3Ø WYE
EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK


MONITOR TREND HARMONICS H13
MAX 0.8%
AVG 0.7%
MIN 0.6%
2.0 %
165:31:29
-4x
0.0 %
6d
4d
2d
C
05/02/09 08:54:48
230V 50Hz 3Ø WYE
EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

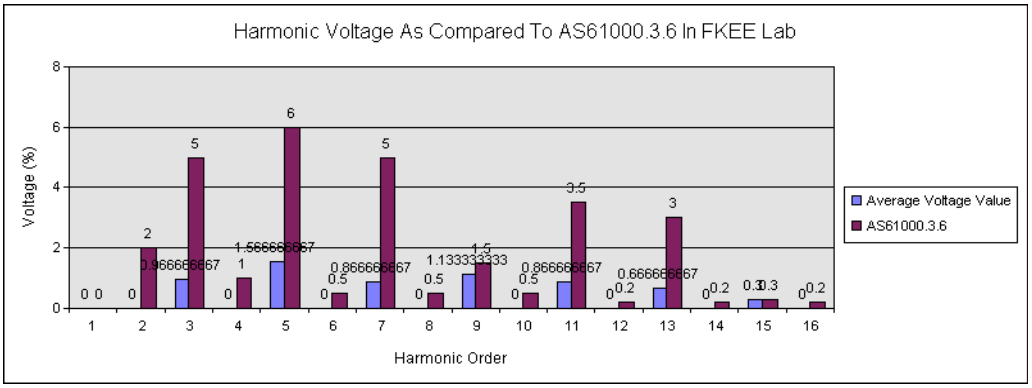

MONITOR TREND HARMONICS H15
MAX 0.4% AVG 0.3% MIN 0.3%
2.0 %
165:31:29
4x
0.0 %
6d
4d
2d
09/02/09 07:34:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

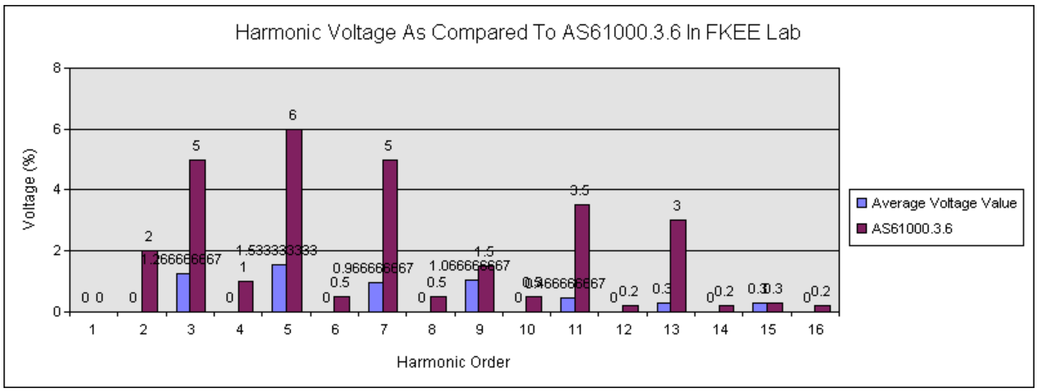

MONITOR TREND HARMONICS H15
MAX 0.4% AVG 0.3% MIN 0.3%
2.0 %
165:31:29
4x
0.0 %
6d
4d
2d
09/02/09 07:34:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

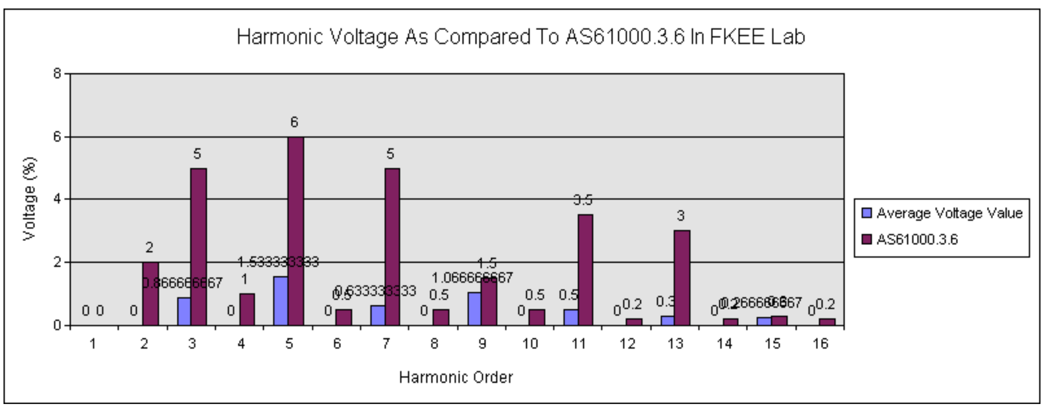

MONITOR TREND HARMONICS H15
MAX 0.3% AVG 0.2% MIN 0.2%
2.0 %
165:31:29
-4x
0.0 %
6d
4d
2d
08/02/09 18:14:48 230V 50Hz 3Ø WYE EN50160*
PREV. NEXT
CURSOR ON OFF
ZOOM CURSOR
BACK

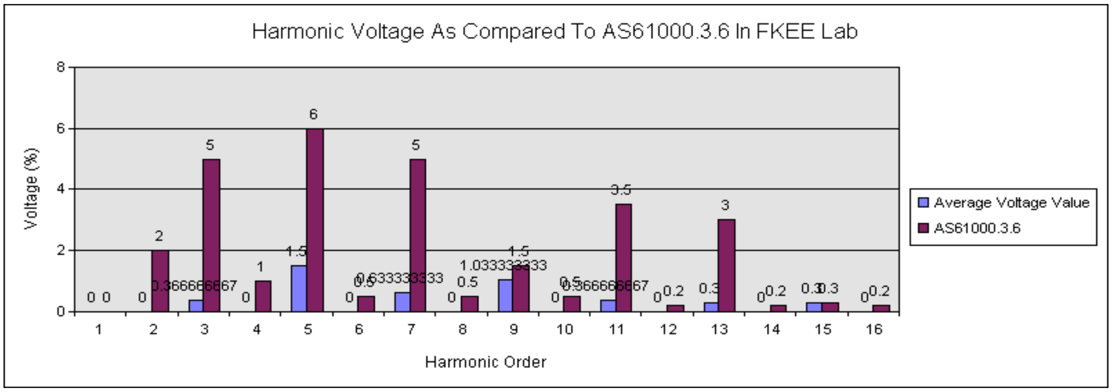
APPENDIX C

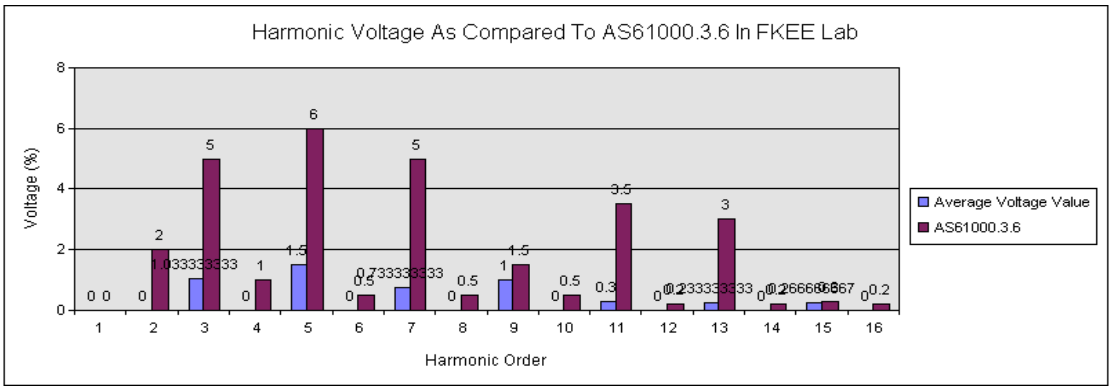
Comparison for harmonics voltage in a week by using Visual Basic Web Developer

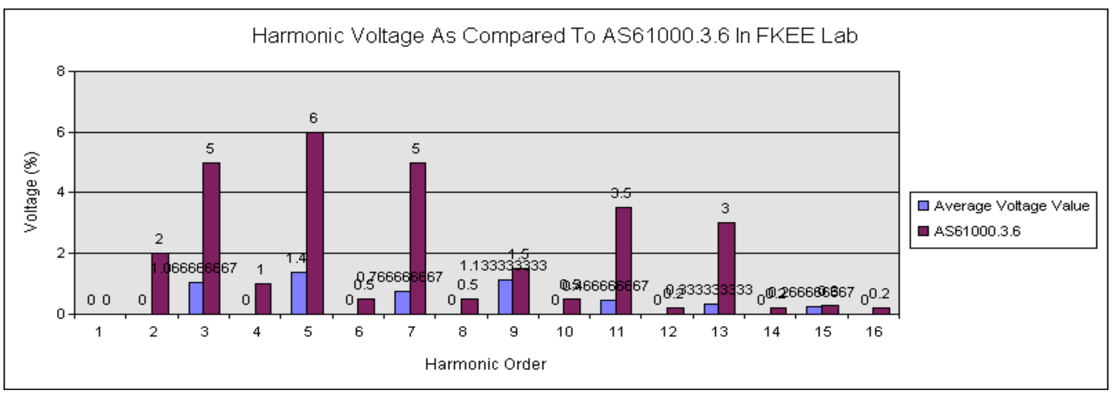






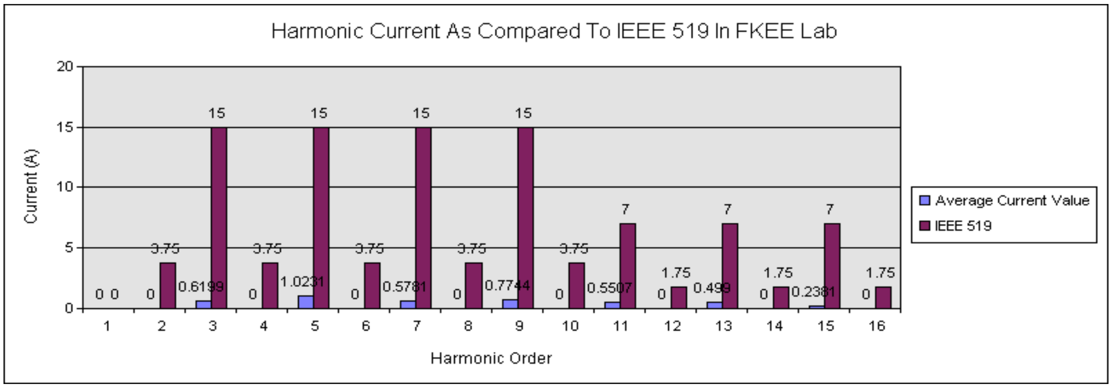

Harmonic Voltage As Compared To AS61000.3.6 In FKEE Lab
Voltage (%)
0
2
4
6
8
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Harmonic Order
Average Voltage Value
AS61000.3.6

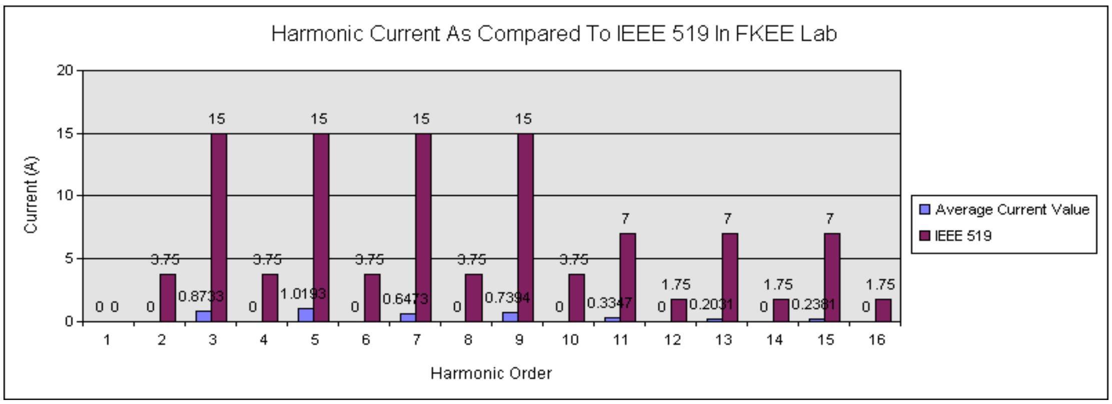

Harmonic Voltage As Compared To AS61000.3.6 In FKEE Lab
Voltage (%)
0
2
4
6
8
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Harmonic Order
Average Voltage Value
AS61000.3.6

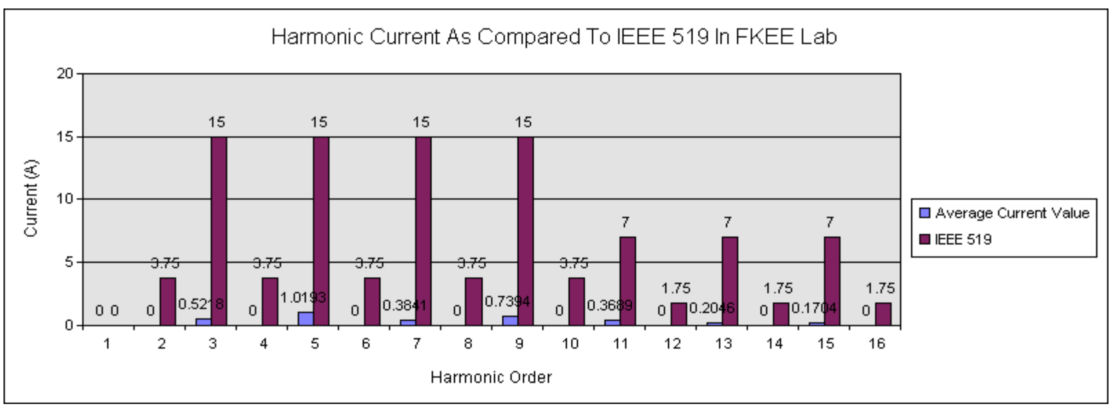

Harmonic Voltage As Compared To AS61000.3.6 In FKEE Lab
Voltage (%)
0
2
4
6
8
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Harmonic Order
Average Voltage Value
AS61000.3.6

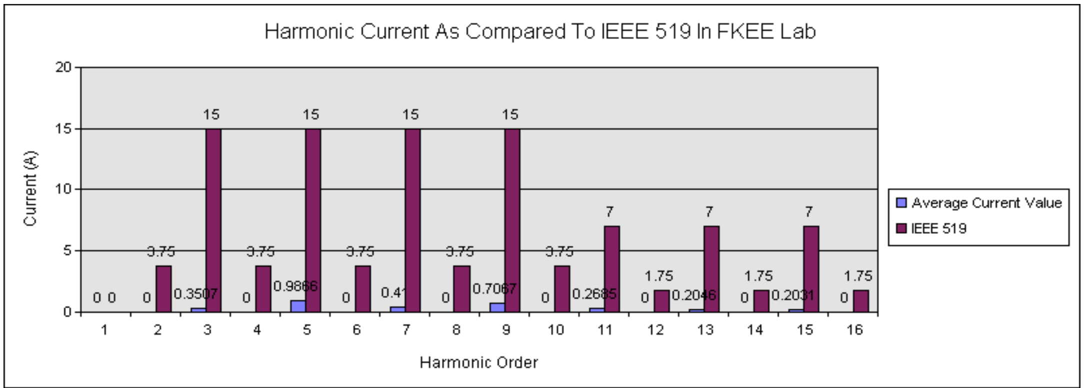
APPENDIX D

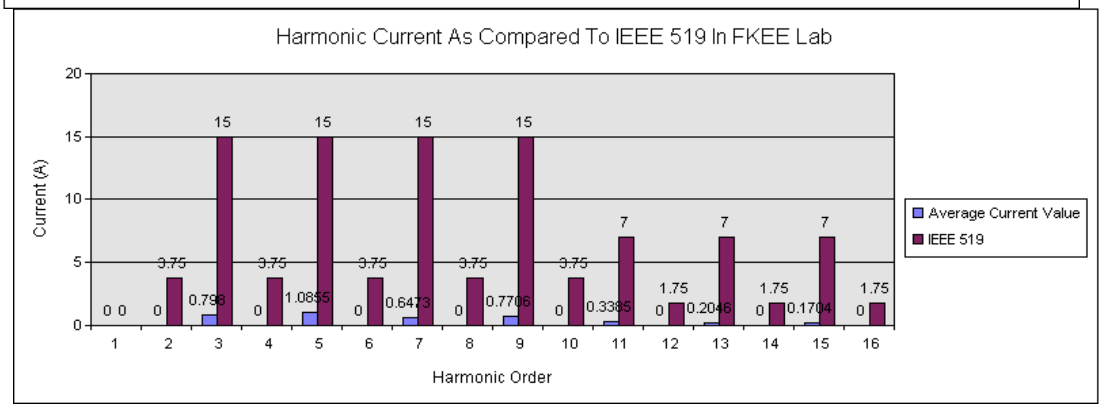
Comparison for harmonics current in a week by using Visual Basic Web Developer

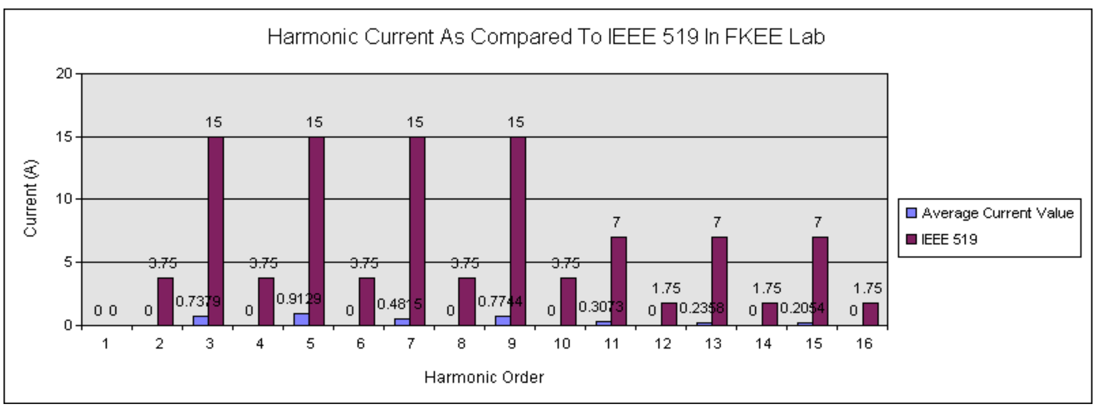







Harmonic Current As Compared To IEEE 519 In FKEE Lab
Current (A)
Harmonic Order
Average Current Value
IEEE 519
0 0 0 3.75 0.3507 15 0 3.75 0.9866 15 0 3.75 0.41 15 0 3.75 0.7067 15 0 3.75 0.2685 7 0 1.75 0.2046 7 0 1.75 0.2031 7 0 1.75


Harmonic Current As Compared To IEEE 519 In FKEE Lab
Current (A)
Harmonic Order
Average Current Value
IEEE 519
0 0 0 3.75 0.798 15 0 3.75 1.0855 15 0 3.75 0.6473 15 0 3.75 0.7706 15 0 3.75 0.3385 7 0 1.75 0.2046 7 0 1.75 0.1704 7 0 1.75


Harmonic Current As Compared To IEEE 519 In FKEE Lab
Current (A)
Harmonic Order
Average Current Value
IEEE 519
0 0 0 3.75 0.7379 15 0 3.75 0.9129 15 0 3.75 0.4815 15 0 3.75 0.7744 15 0 3.75 0.3073 7 0 1.75 0.2358 7 0 1.75 0.2054 7 0 1.75

APPENDIX E

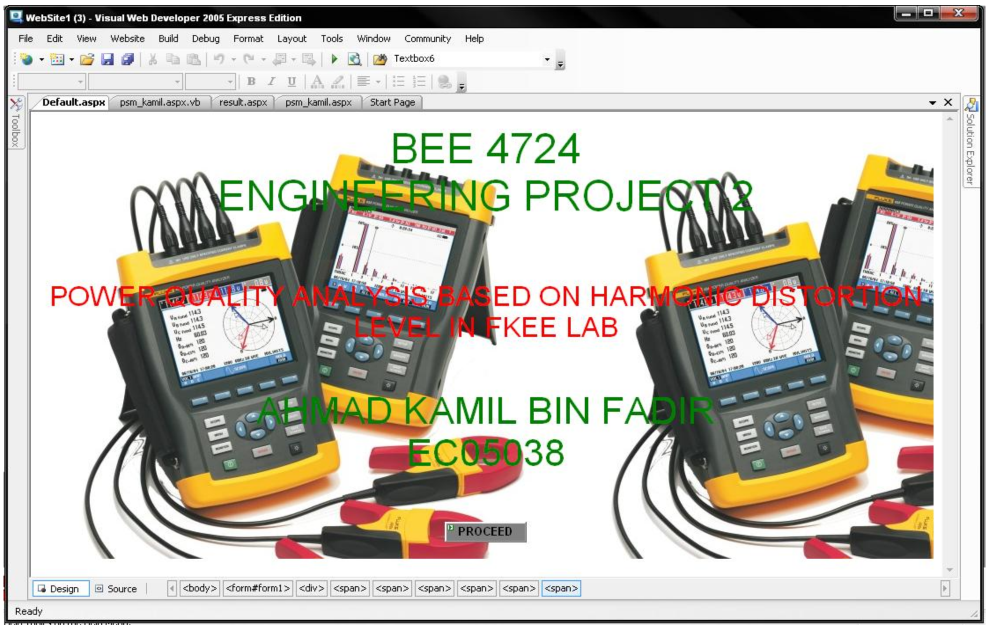
Power Quality Analyzer which equipped at substation board

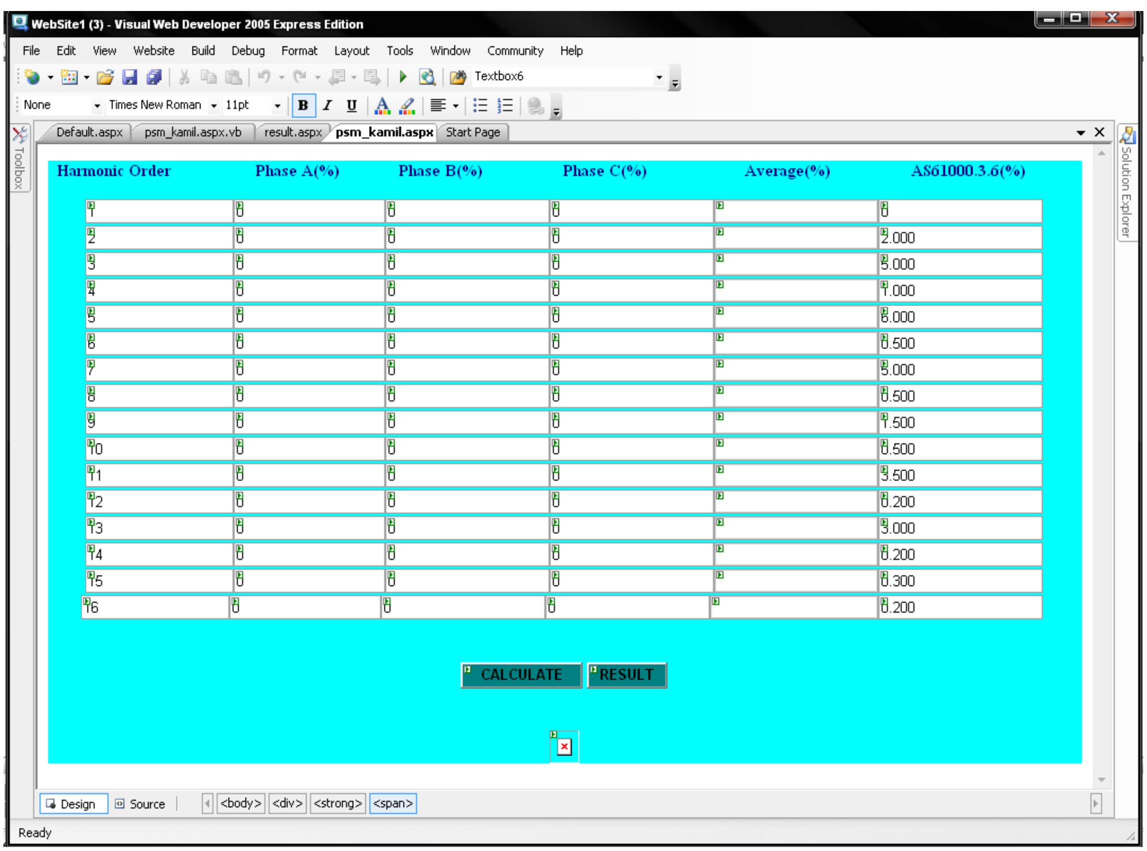

05/01/2007


05/01/2007

APPENDIX F

Main menu for Visual Basic Web Developer





APPENDIX G

Coding to run the Visual Basic software

```
Imports OWC10
Partial Class psm_kamil
   Inherits System.Web.UI.Page
 Protected Sub Button1_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles Button1.Click
      Dim noOfHarmonic As Integer = 16
      Dim phaseA(noOfHarmonic) As Double
      Dim phaseB(noOfHarmonic) As Double
      Dim phaseC(noOfHarmonic) As Double
      Dim average(noOfHarmonic) As Double
      Dim constant(noOfHarmonic) As Double
      phaseA(0) = TextBox2.Text
      phaseB(0) = TextBox3.Text
      phaseC(0) = TextBox4.Text
      phaseA(1) = TextBox8.Text
      phaseB(1) = TextBox9.Text
      phaseC(1) = TextBox10.Text
      phaseA(2) = TextBox14.Text
      phaseB(2) = TextBox15.Text
      phaseC(2) = TextBox16.Text
      phaseA(3) = TextBox20.Text
      phaseB(3) = TextBox21.Text
      phaseC(3) = TextBox22.Text
      phaseA(4) = TextBox26.Text
      phaseB(4) = TextBox27.Text
```

```
      phaseC(4) = TextBox28.Text
      phaseA(5) = TextBox32.Text
      phaseB(5) = TextBox33.Text
      phaseC(5) = TextBox34.Text
      phaseA(6) = TextBox38.Text
      phaseB(6) = TextBox39.Text
      phaseC(6) = TextBox40.Text
      phaseA(7) = TextBox44.Text
      phaseB(7) = TextBox45.Text
      phaseC(7) = TextBox46.Text
      phaseA(8) = TextBox50.Text
      phaseB(8) = TextBox51.Text
      phaseC(8) = TextBox52.Text
      phaseA(9) = TextBox56.Text
      phaseB(9) = TextBox57.Text
      phaseC(9) = TextBox58.Text
      phaseA(10) = TextBox62.Text
      phaseB(10) = TextBox63.Text
      phaseC(10) = TextBox64.Text
      phaseA(11) = TextBox68.Text
      phaseB(11) = TextBox69.Text
      phaseC(11) = TextBox70.Text
      phaseA(12) = TextBox74.Text
      phaseB(12) = TextBox75.Text
```

```
    phaseC(12) = TextBox76.Text
    phaseA(13) = TextBox80.Text
    phaseB(13) = TextBox81.Text
    phaseC(13) = TextBox82.Text
    phaseA(14) = TextBox86.Text
    phaseB(14) = TextBox87.Text
    phaseC(14) = TextBox88.Text
    phaseA(15) = TextBox92.Text
    phaseB(15) = TextBox93.Text
    phaseC(15) = TextBox94.Text
    For i As Integer = 0 To noOfHarmonic - 1
        average(i) = (phaseA(i) + phaseB(i) + phaseC(i)) / 3
    Next
    TextBox5.Text = Math.Round(average(0), 1)
    TextBox11.Text = Math.Round(average(1), 1)
    TextBox17.Text = Math.Round(average(2), 1)
    TextBox23.Text = Math.Round(average(3), 1)
    TextBox29.Text = Math.Round(average(4), 1)
    TextBox35.Text = Math.Round(average(5), 1)
    TextBox41.Text = Math.Round(average(6), 1)
    TextBox47.Text = Math.Round(average(7), 1)
    TextBox53.Text = Math.Round(average(8), 1)
    TextBox59.Text = Math.Round(average(9), 1)
    TextBox65.Text = Math.Round(average(10), 1)
```

```
    TextBox71.Text = Math.Round(average(11), 1)
    TextBox77.Text = Math.Round(average(12), 1)
    TextBox83.Text = Math.Round(average(13), 1)
    TextBox89.Text = Math.Round(average(14), 1)
    TextBox95.Text = Math.Round(average(15), 1)
    constant(0) = TextBox6.Text
    constant(1) = TextBox12.Text
    constant(2) = TextBox18.Text
    constant(3) = TextBox24.Text
    constant(4) = TextBox30.Text
    constant(5) = TextBox36.Text
    constant(6) = TextBox42.Text
    constant(7) = TextBox48.Text
    constant(8) = TextBox54.Text
    constant(9) = TextBox60.Text
    constant(10) = TextBox66.Text
    constant(11) = TextBox72.Text
    constant(12) = TextBox78.Text
    constant(13) = TextBox84.Text
    constant(14) = TextBox90.Text
    constant(15) = TextBox96.Text
    chart2(average, constant, noOfHarmonic) 'function utk lukis graf
    Image1.Visible = True
End Sub
```

```
Sub chart2(ByVal average() As Double, ByVal constant() As Double, ByVal noOfHarmonic As Integer)
    '       Dim intWeek() As Integer = {30, 31, 32, 33, 34}
    'initial declaration for variable on the graph
    Dim average_string As String = ""
    Dim constant_string As String = ""
    Dim noOfHarmonic_string As String = ""
    'for loop utk gabung semua variable2 menjadi 1 string panjang sbb utk lukis graf, dia hanya bleh baca string
    For i As Integer = 0 To noOfHarmonic - 1
        average_string += average(i) & ", "
        constant_string += constant(i) & ", "
        noOfHarmonic_string += i + 1 & ", "
    Next
    'Substring-untuk buang "koma(,)" di ujung string
    average_string = average_string.Substring(0, average_string.Length - 2)
    constant_string = constant_string.Substring(0, constant_string.Length - 2)
    noOfHarmonic_string = noOfHarmonic_string.Substring(0, noOfHarmonic_string.Length - 2)
    'declaration/initialization of obcject for OWC10 class
    Dim oChartSpace As New OWC10.ChartSpaceClass
    With oChartSpace
        .Charts.Add(0) '
        .Charts(0).Type = ChartChartTypeEnum.chChartTypeColumnClustered
        .Charts(0).HasTitle = True
        .Charts(0).HasLegend = True
        .Charts(0).Title.Caption = "Harmonic Voltage As Compared To AS61000.3.6 In FKEE Lab"
```

```
        .Charts(0).Axes(0).HasTitle = True
        .Charts(0).Axes(0).Title.Caption = "Harmonic Order"
        .Charts(0).Axes(0).Title.Font.Size = 9
        .Charts(0).Axes(1).HasTitle = True
        .Charts(0).Axes(1).Title.Caption = "Voltage (%)"
        .Charts(0).Axes(1).Title.Font.Size = 9
    End With
    oChartSpace.Charts(0).SeriesCollection.Add()
    oChartSpace.Charts(0).SeriesCollection(0).Caption = "Average Voltage Value"
    oChartSpace.Charts(0).SeriesCollection(0).DataLabelsCollection.Add()
    oChartSpace.Charts(0).SeriesCollection(0).DataLabelsCollection(0).HasValue = True
    oChartSpace.Charts(0).SeriesCollection(0).SetData(OWC10.ChartDimensionsEnum.chDimCategories,
OWC10.ChartSpecialDataSourcesEnum.chDataLiteral, noOfHarmonic_string)
    'oChartSpace.Charts(0).SeriesCollection(0).SetData(OWC10.ChartDimensionsEnum.chDimCategories,
OWC10.ChartSpecialDataSourcesEnum.chDataLiteral, app)
    oChartSpace.Charts(0).SeriesCollection(0).SetData(OWC10.ChartDimensionsEnum.chDimValues,
OWC10.ChartSpecialDataSourcesEnum.chDataLiteral, average_string)
    oChartSpace.Charts(0).SeriesCollection.Add()
    oChartSpace.Charts(0).SeriesCollection(1).Caption = "AS61000.3.6"
    oChartSpace.Charts(0).SeriesCollection(1).DataLabelsCollection.Add()
    oChartSpace.Charts(0).SeriesCollection(1).DataLabelsCollection(0).HasValue = True
    oChartSpace.Charts(0).SeriesCollection(1).SetData(OWC10.ChartDimensionsEnum.chDimValues,
OWC10.ChartSpecialDataSourcesEnum.chDataLiteral, constant_string)
    Dim picname As String = System.DateTime.Now.Ticks.ToString()
```

```
Untitled - Notepad
File  Edit  Format  View  Help

        Dim picname As String = System.DateTime.Now.Ticks.ToString()
        Dim strFullPathAndName As String = Server.MapPath(picname & ".gif")
        oChartSpace.ExportPicture(strFullPathAndName, "gif", 800, 300)
        Image1.ImageUrl = "~/" & picname & ".gif"
        'Session("img") = String.Format("{0}.gif", picname)
    End Sub
    Protected Sub Button2_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles Button2.Click
        Response.Redirect("result.aspx")
    End Sub
    Protected Sub Page_Load(ByVal sender As Object, ByVal e As System.EventArgs) Handles Me.Load
    End Sub
    Protected Sub TextBox1_TextChanged(ByVal sender As Object, ByVal e As System.EventArgs)
    End Sub
End Class
```