POWER QUALITY ANALYSIS OF AN INDUSTRIAL PLANT

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
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CERTIFICATION OF APPROVAL

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Approved:

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TRONOH, PERAK

May 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Muhammad Zaki B Mohd Amir

ABSTRACT

This paper covers the overall view on power quality analysis in the semiconductor industry. The increasing number of power electronic device used especially in the industry has raised the awareness of power quality problem. Normally, this device creates the non-linear loads which will effect to the electrical power system. This paper covers the aspect of power quality disturbance by giving definition, source and the effects of this disturbance to the electrical power system. The objective of this project is to do analysis on power quality monitoring data from one of the semiconductor industry. On-site power quality monitoring data had been done before. Specific equipment had been used to get the actual reading from the plant. By using PQSCADA software, a software that visualizes the graph analysis from each measurement data to determine any power quality disturbance in the electrical power system. The findings will give better insight for the consumer to know the power quality that they have and to predict the future performance of the equipment. The author analysis based on the power quality standard. Based on the result analysis, the author had found power quality disturbances occurring in the system, which is voltage sag and harmonic distortion. These two types of power quality disturbance always occur in the electrical power system. Power quality problem can be solve by add in and installing UPS and harmonic filter for better performance in the electrical system.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Power quality can be defined as the availability of maintaining original sinusoidal voltage waveform [1]. Power quality is a wide issue and big concern from the industry and utility network. Power quality is like electrical property that allows electrical system to function in proper process without major loss of performance.

Recently, there have been changes in the nature of electrical loads. In other word, the characteristics of load have become more complex due to the increased use of power electronic equipment, which results variation from the normal sinusoidal voltage waveform. The electrical equipment has better performance and high efficiency, but it is very sensitive to variation of power supply quality. That is called as power quality disturbance.

Power quality disturbance is generally accepted as any change in the power (voltage, current) waveform that interferes with normal operation of electrical equipment [2].Power quality disturbance are common in industrial because they are using electrical equipment in a large scale. Voltage sags and harmonic distortion is frequently happened in the industry network.

Besides that, power quality disturbance had been concerned because the quality of power can have directed economic on industrial consumers. Industrial customers are now aware of minor disturbance in the power system and admit the contribution of power quality to the electrical power system.For this reason, many utilities could sell electrical energy at different prices to their customers, depending on the quality of the electric power delivery [3].

The importance of power quality should be highlighted because it plays the key role in electrical power system. If good power quality, then any loads connected to it will run satisfactory and efficiently. But, if poor power quality, then loads connected to it will fail or will reduce its lifetime and the efficiency. For the cost maintenance, good power quality will minimize the cost especially the installation running costs compare to the poor power quality.

The power quality aspects can be divided into three like in Table 1:

Table 1: Aspect of Power Quality

Aspects	Power quality
Voltage Stability	i. Under-voltage & Overvoltage ii. Voltage Sag iii. Voltage Swell iv. Flicker
Continuity of Supplying Power	i. Momentary Interruption ii. Temporary Interruption iii. Sustained Interruption
Voltage Waveform	i. Transient ii. Three Phase Voltage Unbalance iii. Harmonic Voltage, Current iv. Notch

The reasons interested in power quality are:

i. Equipment performance
ii. For standardization and performance criteria
iii. Revenue and losses

1.2 Problem Statement

Nowadays manufactures side want faster, more productive, more efficient machinery to increase their productivity. Interestingly, the equipment installed suffers the most from common power disturbance and sometimes become the source of power quality disturbance. Thus, power quality is increasingly important to industrial customers as process operations and facilities depend upon sensitive electronic equipment. The power quality problem effect consumer in production times and cost due to equipment malfunction. Power quality disturbance cover following problem:

i. Harmonics
ii. Voltage Sags
iii. Interruptions
iv. Transient Overvoltage
v. Voltage Swell

This problem would leads to poor power quality. Possible effect of poor power quality includes:

i. Equipment overheating like transformer which will lead lifetime reduction
ii. Unexpected power supply failures
iii. Equipment failure or malfunction
iv. Damage to sensitive equipment

1.3 Objective

The objective of this project is;

i. To analyze power quality monitoring data in the semiconductor industry

ii. To study on the various type of power quality problem

1.4 Scope of Study

The scope of this project consists of research and analysis. The research is important for better understanding on the theory and concept of power quality analysis. In order to achieve the objectives, the scope of work of this study was carried out as following:

i. Study the problem occur in the electrical power system

ii. Study and analyze the power quality monitoring data at the semiconductor industry

iii. Study and familiarize with the power quality analysis, PQSCADA

1.5 Relevance of the Project

The significance of this research is to make aware to people in the important of power quality is. Power quality is very important issue recently because it will cause big loss due to poor power quality. As our country that have a lot number of factory which has high risk electrical equipment that very sensitive to disturbance. Thus, it is very important to know 'how safe' the electrical power system that we have in the industrial.

1.6 Feasibility of the Project

The feasibility of this project is to complete the project within the scope and time frame, while maintaining substance to this project.

During the first semester (FYP I), the scope and task that will be covered are;

i. Research in the most problem occur in electrical power system

For the following semester (FYP II), the scope and task that will be covered are;

i. Analyze power quality monitoring data
ii. Determine possible solution to improve power quality

.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Power Quality

Power quality covers a wide range of issues and many definitions have been made. Power quality can be defined as the availability of maintaining pure voltage sinusoidal waveform. It's mean on how the electrical power system can sustain the power deliver to the load. The closer to the ideal waveform, the better power quality is.

There are standard limit require for voltage and current [2]. The objective to have power quality standard is to protect the equipment from malfunction when voltage and current deviates from its normal waveform. Thus, the purpose to have power quality analysis is to know and determine that the electrical system will function well without major loss of performance. The good quality of power can be described by continuity providing the maximum power output in the electrical power system. There will be power quality disturbance in the system which will affect the original sinusoidal waveform. For instance, a dip in voltage caused by a starting motor can cause the piece of microprocessor-controlled equipment to be shut down or malfunction [3].

Power quality also plays around with the economic issue. In business humanity, time equals to money. The quality of power system will give huge impact to the industrial. For example, the industry will face big losses if the equipment malfunctions. There are many ways and cause for electric power system to have poor power quality.

2.2 Power quality Issues and Its Causes

Research have found that the majority of power quality problems are related to problem in a industry compare to the utility. It was found that 90% of power quality problems are caused from the work site[3]. The cause of power quality disturbance can be as following:

- Overloading
- Load switching
- Non-linear loads
- Poor grouding

Poor power quality will cause several problems. We can categorize power quality problems into transients, long- duration voltage variation, short-duration variations, voltage imbalance and waveform distortion. The causes and effects for the poor power quality will be discussed in Table 2;

Table 2: Causes and effects of poor power quality

Problems	Possible Cause	Effects
Transients	• Lightning, • Switching impulse, • Utility fault clearing	• Loss of data • Possible damage • System halts
Interruption	• Switching • Utility faults • Circuit breakers tripping • Component failure	• Loss of data • Damage shutdown
Voltage Sags	• Startup loads • Faults	• System halts • Loss of data • Equipment shutdown
Voltage Swell	• Load changes • Utility faults	• Nuisance tripping • Equipment damage
Harmonics	• Electrical loads(non-linear loads)	• Transformer heated • System halts

2.2.1 Transient

Transient defined as fast changing in the AC waveform that is look as a sharp discontinuity of the waveform. Transients are difficult to detect because of short duration of time. Transients fall into two-categories which is impulsive and oscillatory.

Impulsive

Impulsive transient defines as a sudden change in the steady state condition of the voltage, current, and indirectional in polarity either positive or negative [4]. It can seen as sudden voltage magnitude increase or decrease to a high or low value in a short amount of time and back to normal after a while.

The sources of impulsive transients come from lightning, poor grounding and the switching of inductive loads [4]. Lightning is normally the main cause for this problem to the electrical system. This problem can lead to the loss of data and physical damage of equipment.

Oscillatory

Oscillatory transient is a sudden change in the steady state of a signal voltage or current and involve the positive and negative value. The oscillatory transient causes the power signal to alternately changes rapidly. Oscillatory transients are the common cause of equipment shutdown and it occur when capacitor switching. These transients can be categorized by their frequency;

i. Low frequency (compenents less than 5 kHz)
ii. Medium frequency (components between 5 kHz and 500 kHz)
iii. High frequency (components between 500 kHz and 5 MHz)

2.2.2 Short Duration Voltage Variation

Voltage sags

Voltage sag is a reduction of AC voltage for a duration of 0.5cycles and 30 cycles and having a typical magnitude in the 0.1 to 0.9 per unit range [4]. Voltgae sags is the most problem that always occur in the system. Sags is caused by system faults and from starting large loads such as start up a large air conditioning unit and starting of large motors inside the industrial [5]. During starting a motor, it can draw high running current and cause voltage drop in the system. Voltage sags will lead to equipment shutdown because don’t receive enough voltage supply to the equipment.

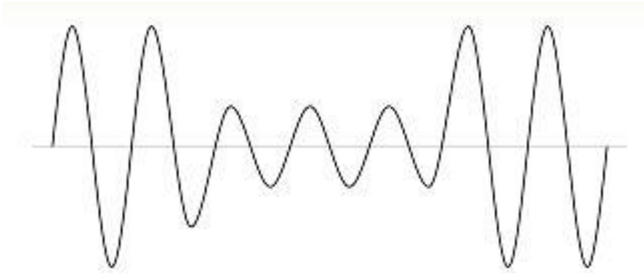


Figure 1: Waveform undergoing sag

Voltage Swell

A swell is the reverse form of a sag which having increase in AC voltage for a duration of 0.5 cycles to 30 cycles with magnitude between 1.1 and 1.8 per unit[4]. Sweels caused by switching off a large load or energizing a large capacitor bank [6]. This problem is not frequently happened but it may affect equipment multifunction and nuisance tripping.

The impacts of this problem can be data errors, flickering of lights and semiconductor damage in electronics [4]. Power line conditioners and UPS systems are common solutions and help to monitor when and how often these events occur.

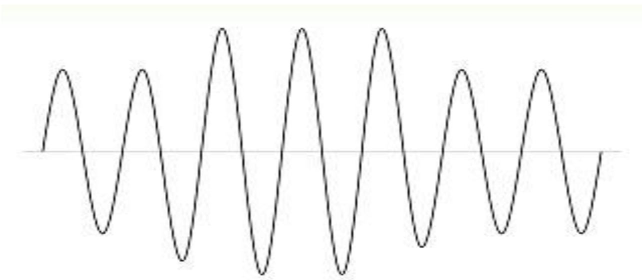


Figure 2: Waveform undergoing swell

Interruption

An interruption is defined as the complete loss of supply voltage or current[4].Some interruptions occur after sag especially when the faults are from the source system. There are three types of interruption and it based on their duration which is instantaneous, momentary, temporary or sustained. The cause of interruption comes from the switching loads, circuit breaker tripping or component failure. This problem may lead to loss data and equipment damage.

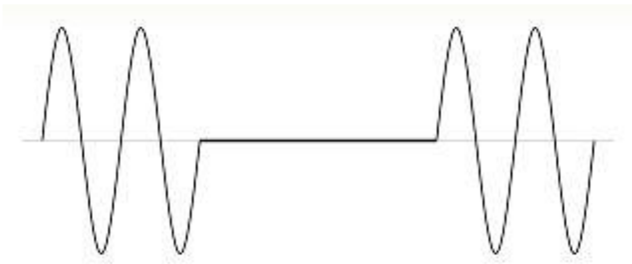


Figure 3: Waveform undergoing interruption

2.2.3 Long Duration Voltage Variation

Long duration voltage can be either over voltages or under voltages. The duration time for this disturbance is lasts longer than one minute. Poor voltage regulation is frequently the source of long duration variants [7].

Overvoltage

Overvoltages refers to an increase in the rms ac voltage to greater than 1.1 per unit for a period longer than one minute. Overvoltage occur because of switching off a large load or energizing of capacitor bank. Overvoltage can produce high current and may cause the unnecessary tripping of downstream circuit breakers, and overheating.

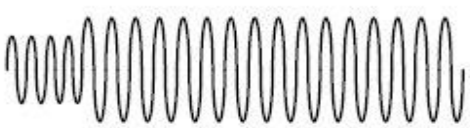


Figure 4: Waveform undergoing overvoltage

Undervoltage

Undervoltages define as decrease in the rms ac voltage to less than 0.9 pu for a period longer than one minute. The cause of undervoltage is switching on large load. Overloaded circuit also lead to undervoltage. Undervoltages can create overheating in motors and lead to the failure of non-linear loads such as computer power supplies. If an undervoltage remains constant, it is a sign for the serious equipment fault.

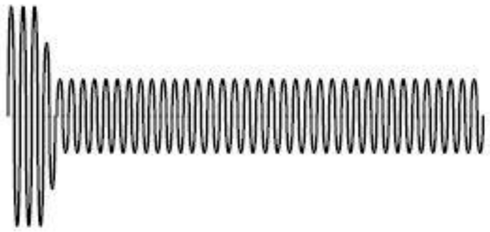


Figure 5: Waveform undergoing under voltage

2.2.4 Waveform Distortion

There are four types of waveform distortion:

i. DC Offset
ii. Harmonics
iii. Nothching
iv. Noise

2.2.4.1 DC Offset

DC offset defines as the presence of a dc voltage or current in a electrical power system. DC offset happen due to geomagnetic disturbance. Overheating and saturation of transformers can be the result of circulating DC currents. Thus, the transformer unable to deliver full power to the load and the abnormal waveform distortion can create other problem in electronic load equipment.

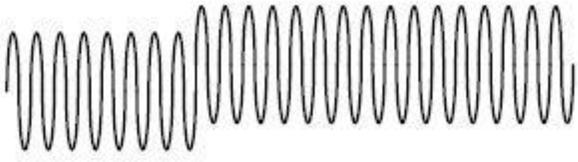


Figure 6: Waveform undergoing DC Offset

2.2.4.2 Harmonic

Fundamental of Harmonic

Harmonics define as sinusoidal voltage or currents having frequencies that integer multiples of the fundamental frequency. Harmonic distortion is the corruption of the fundamental sine wave.

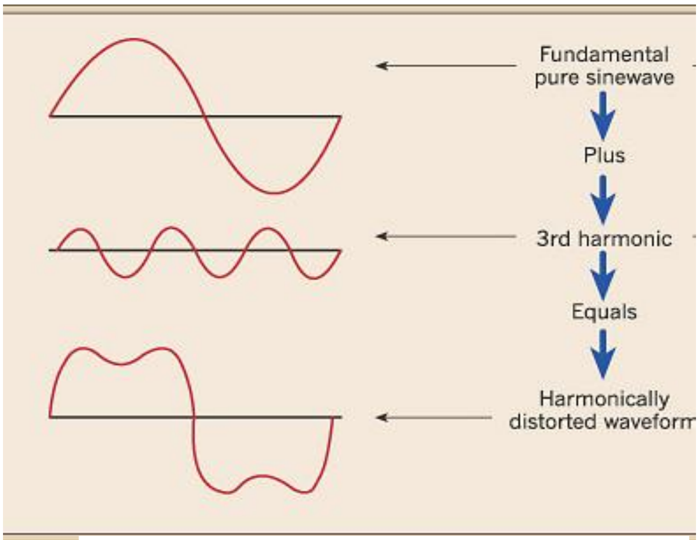


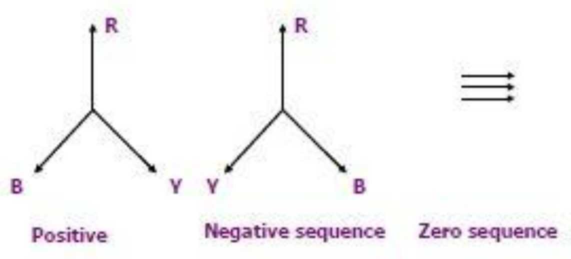
Figure 7: Waveform undergoing Harmonics

Harmonic distortion is continuous and caused by the non-linear load such as computer in the system. This resulting unwanted heating in the electrical system. For example, transformer overheating.

Normally, harmonic analysed up to 40th multiple, but the the earlier harmonic components (3rd, 5th, 7th) are the one give effect on the system. Besides that, non-linear loads normally generates odd harmonics rather than even harmonics. Each odd harmonic associated with the sequence component. Different phase sequence will determine the effect of the harmonic to the system.

Table 3: Harmonic Sequence Component

Harmonic	Sequence Component
1	+
3	0
5	-
7	+



For postive sequence, each phase have same magnitude and displaced by 120 degree from each other. For negative sequence, each phase have same magnitude and displaced by 120 degree from each others. Negative sequence can create a torque in the negative direction of the motor and causing it to decelerate. For zero sequence, gategorize as the worst and refer as triple harmonic. It has same magnitude for three phase but, zero displacement from each other. This resulting the amplitude that is three times of the phase combined causing overheating.

Voltage and Current Harmonic

In non-linear loads, current and voltage waveform is different.This situation create voltage distortion and also excessive current on neutal wire. Harmonic current that produce by the non-linear loads causing distorted current waveforms. Voltage distortion is the result of distorted currents pass through the system impedance.

2.2.4.3 Notching

Notching is a periodic voltage disturbance caused by electronic devices, such as variable speed drives. This problem could be described same as a transient impulse problem, but because the notches are periodic over each ½ cycle, notching is considered as waveform distortion problem. The effects of notching are system halts, data loss, and data transmission problems. UPS and filter are possible solution for notching.

Figure 8: Waveform undergoing notching

2.2.4.4 Noise

Noise is unwanted voltage or current that super imposed on the voltage or current waveform [4]. Noise can be produced by power electronic devices, control circuits, and switching power supplies [8]. Noise will lead to data errors, equipment malfunction, hard disk failure and distorted video displays. There are many different solution to controlling noise. Some methods are:

i. Install noise filters
ii. Cable shielding

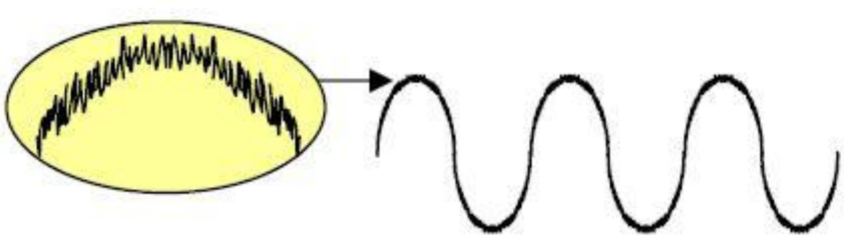


Figure 9: Waveform undergoing noise

2.3 Power Quality Problem Evaluations

Measurement plays an important role to determine the power quality performance. During measurement, record data will show the condition of the system and detect possible causes. Figure 10 show basic steps involved in power quality evaluation;

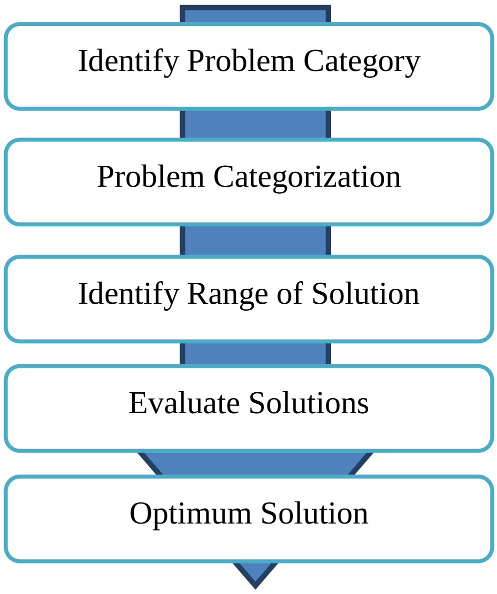


Figure 10: Basic steps in power quality evaluation

2.4 Power Quality Monitoring & Analysis

2.4.1 Objective of Power Quality Monitoring & Analysis

Power quality monitoring is the process of gathering, analyzing and classify measurement data into useful information. The procedure of gathering data usually carried out by continuous measurement of voltage and current for a certain period of time. Several common objective of power quality monitoring:

i. To observe the system performance
ii. To determine the problems occur in the system
iii. To predict future performance of load equipment
iv. To verify that the industry achieves require level for power quality standard

2.4.2 Importance of Power Quality Monitoring & Analysis

The main reason is economic scene. It is because critical loads are harmfully affected by poor power quality. Thus, by having monitoring database, it can provide guideline for future enhancements and system improvement. The information from power quality monitoring system can help to improve the efficiency of operating system and reliability of customer operations. In addition, power quality monitoring allows the industry to know the quality level of power in that area. From there, actions can be taken like taking solution on the fault place for better performance. Thus, time and money can be reduced with early inspection.

2.4.3 Choosing Monitoring Location

The location of power quality monitory depends on the objective of the measurement. For example, if an equipment need to know it performance, monitoring device should place as close as possible to the equipment for better monitoring. Normally, power monitoring is placed at strategic locations such as at main incoming power supply. For power quality monitoring, it must have monitoring device and measurement must be done in a specific way [4, 9]. If a case to monitoring the overall power quality of a facility, then, the monitor should be placed on the secondary of the main service entrance transformer. Then, the monitor will record quality of power supplied to the facility and observe the effect of major loads within the facility.

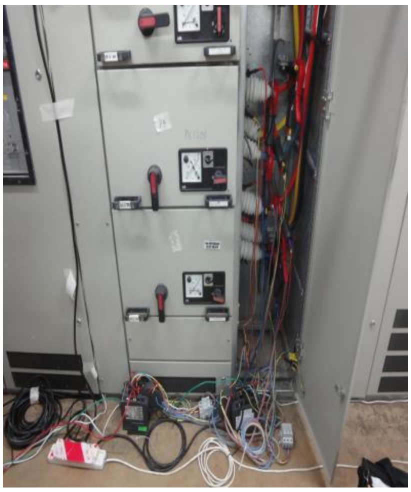


Figure 11: On site connection for power quality

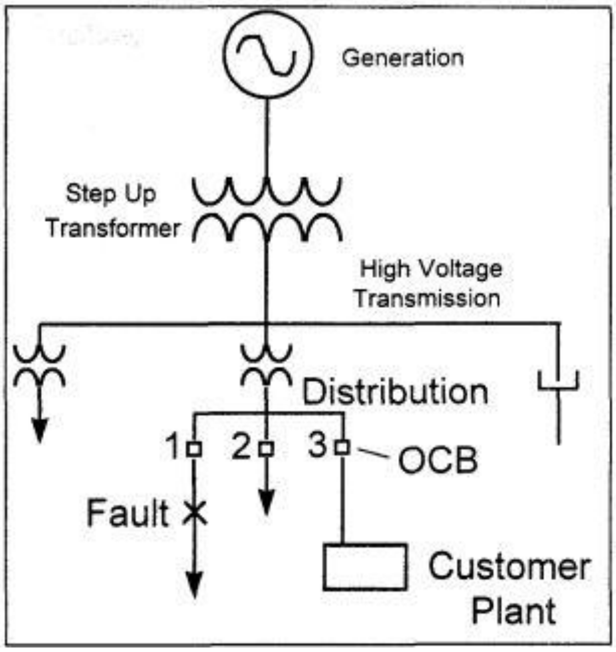


Figure 12: Fault occur at the distribution line

In Figure 12, it show the fault location occur at the distribution line system. Thus, the power quality monitoring device will place at distribution line system.

2.4.4 Assessment of Power Quality Measurement Data

There are two method of power quality data analysis, off-line and on-line analyses [10, 11]. The off-line power quality data analysis is performed off-line at the central processing locations. While for the on-line data analysis is performed within the instrument itself for immediate information.

2.5 Step Approaches for Power Quality Disturbance

2.5.1 Filtering

Harmonics distortion in power distribution systems can be solved using two system namely as passive and active filters.

2.5.1.1 Passive Filter

The passive filtering is the simplest solution to reduce the harmonics distortion. Passive filter consist of inductance, capacitance, resistance and tuned to control harmonics.

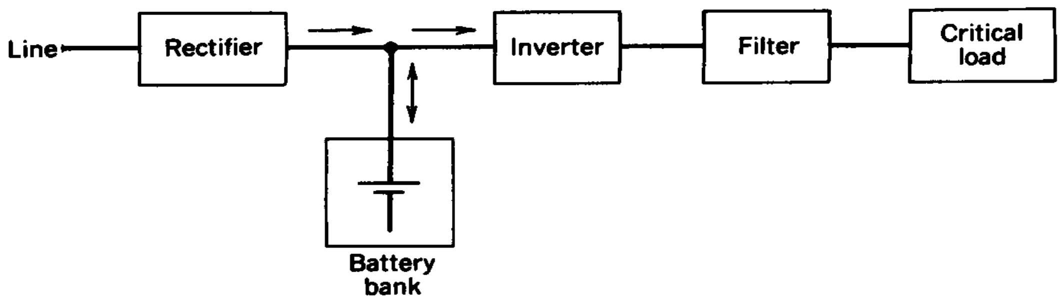
2.5.1.2 Active Filter

The basic principle of active filter is to use power electronic technologies to produce specific currents components that cancel the harmonic currents components caused by the nonlinear load.

2.5.2 Uninterruptible Power Supply (UPS)

UPS is a device that has an alternate source of energy that can provide power when the primary power source is temporarily disabled. It also protects against multiples types of power disturbance.

2.5.2.1 UPS Component



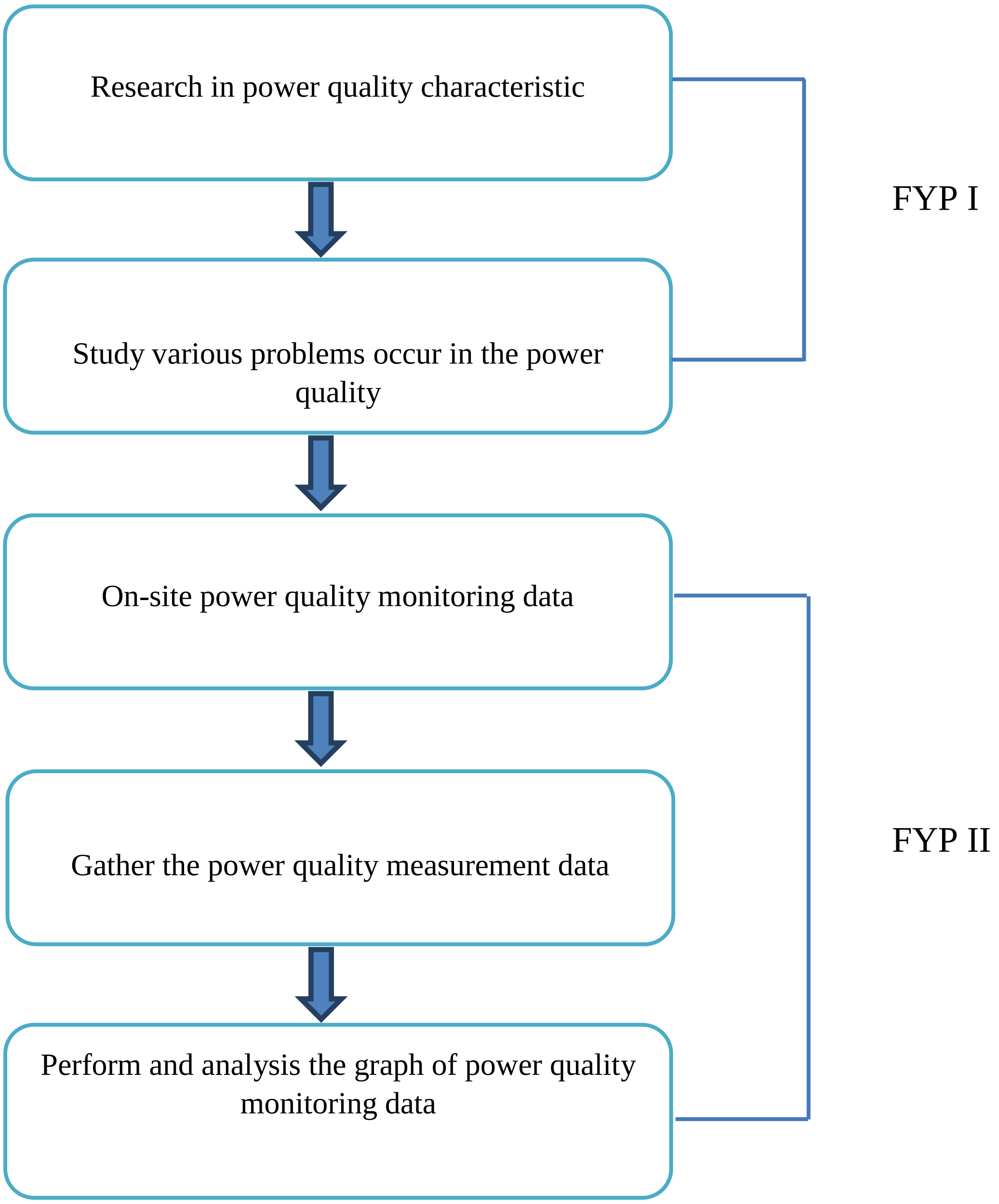
The function of rectifier is to converts AC to DC. Furthermore, it has surge protection device to protect against transient. For battery bank, it looks like a store energy device which protect against interruption. For the inverter, the function is to convert DC to AC. It also has voltage regulator to protect against voltage sags, swell. It also has filter inside it to protect against harmonic, notching and noise.

CHAPTER 3

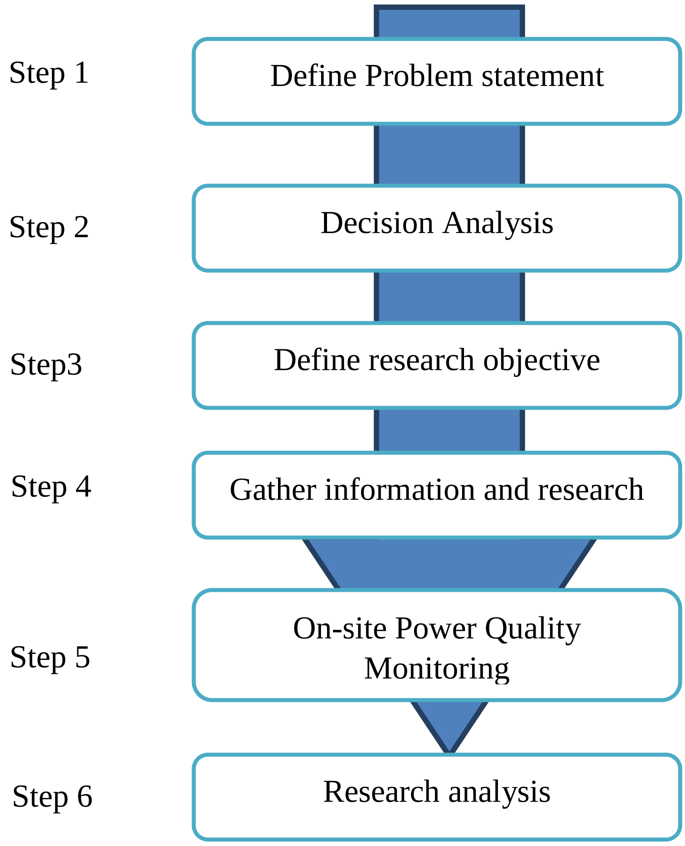
METHODOLOGY

This project will be conducted based on this methodology to meet the objectives. The procedures and stages of the entire project are shown in the flowchart below:

3.1 Research Methodology



3.2 Research Flowchart



Step 1 (Define Problem Statement)

Power quality disturbance is widely occurring in the power system due to increasing of electronic equipment itself. This topic is relevant because many factories have faced this problem and resulting big losses in term of energy and money.

Step 2 (Decision Analysis)

Make decision which location will be the case study for the power quality monitoring.

Step 3 (Define research objective)

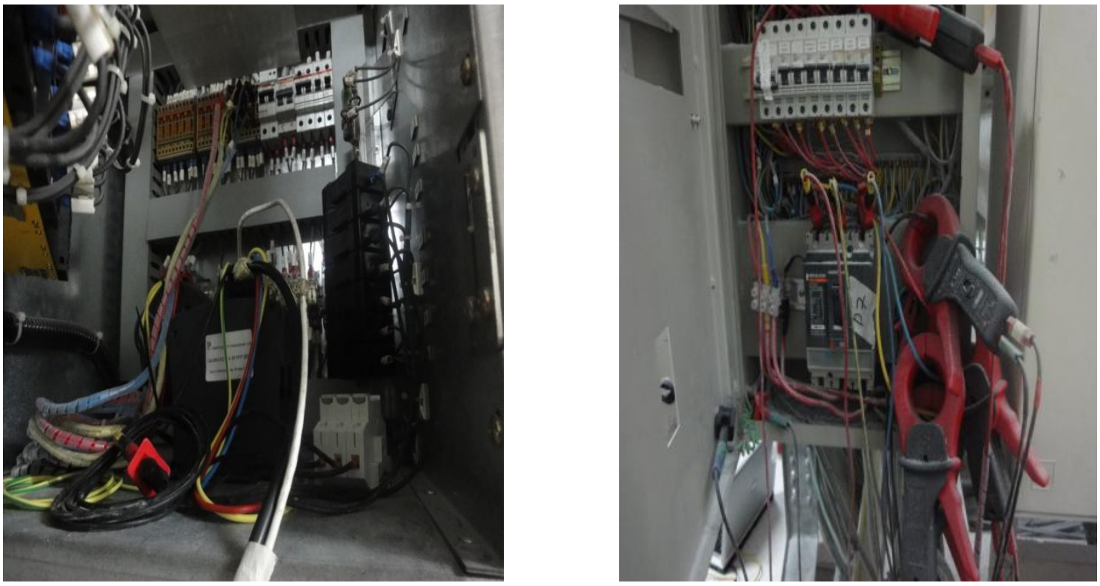
Make sure this project is tolerance with the main objective, to analyze power quality monitoring data.

Step 4(Gather information and research)

Study problem occur in the power quality like the transient, harmonic and others. Besides that, research on the most frequent disturbance occurs in the electrical power system.

Step 5(On-site Power Quality Monitoring)

The monitoring data will be gathering after doing on-site power quality monitoring



(a) (b)

Figure 13: Example of Hardware connection (a) Connection inside the bus bar (b) Current transformer clamp connection

Step 6(Research Analysis)

Analysis will be done based on the power quality standard.

3.3 Project Activities

There are quite number of activities in this project such as;

i. Reading and research material that could expand knowledge on power quality
ii. Do analyze monitoring data based on power quality standard

3.4 Software and Hardware

The research and analysis conducted in this project will be based on the journal, conference paper, Internet sources about the power quality.

For the hardware, the author used G4000 Power Logger. This device can be used to monitor various types of abnormal and variations regarding power quality. The data obtained will be analyzed and possible method to improve the power quality.

G4000 and G4500 Power Logger

This equipment is installed at key measurement points along the grid or electrical network, and data is logged continuously during every cycle of the network at up to 1,024 samples per cycle and stored for more than a year in the internal memory. The data can be gathered periodically via computer using PQSCADA software for detail analysis.

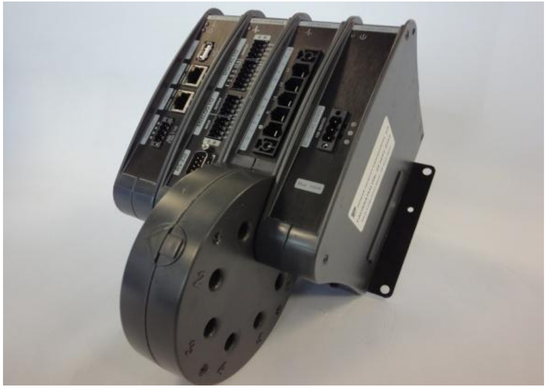


Figure 14: G4000 Power Logger

Figure 15: G4500 Portable Power Logger

For the software, the author will use PQSCADA Analysis Software. Second software is Comprehensive Web server for local and remote real-real time monitoring.

PQSCADA Analysis Software

This is the analysis software enables operator to view, control, analyze and monitor multiple measurement devices simultaneously. For example, the user can select parameter that want to be observed like voltage per phase, harmonic distortion, unbalanced voltage and others. All selected parameter from single or multiple measuring points are presented on one synchronized time line, offering operators a clear and instant graphical view of everything that occurred within the network in a selected timeframe.

Figure 16: PQSCADA Analysis Software

Comprehensive Web Server for Local and Remote Real –Time Monitoring

Web-based applications have many advantages compared to ordinary applications and they offer an easy way for power quality monitoring. Integrated Web server in Power Logger devices allow direct comprehensive real-time monitoring and control of all electrical network parameters. Most operation can be performed via the web server interface besides easy to use. This meant monitoring, managing and analyzing network data can be performed using the web interface.

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3.5 Project Activities and Planning

Details/Week	1	2	3	4	5	6	7	MID SEM BREAK	8	9	10	11	12	13	14
Proposing the topic															
Information gathering															
Extended proposal submission															
Project work preparation															
Gather Monitoring data															
Analysis data															
Familiar with the PQSCADA software															
Proposal Defense															
FYP1Interim draft report submission															
FYP1 Interim report submission															

Process

Table 4: Gantt chart for FYP1

Suggestion Milestone

Details/Week	1	2	3	4	5	6	7	MID SEMBREAK	8	9	10	11	12	13	14
Study each case in Power Quality															
Perform graph based on Analysis Data															
Recommendation of Power Quality															
Pre-EDX															
Submission of Draft Report															
Submission of Dissertation (soft bound)															
Submission of Technical Paper															
Oral Presentation															
Submission of Project Dissertation															

Process

Suggestion Milestone

Table 5: Gantt chart for FYP2

CHAPTER 4
RESULT AND DISCUSSION

This chapter will discuss the result of power quality analysis data that been collected at one of the semiconductor industry. The author has get permission from previous internship company in providing data and used power quality software for the analysis. For the data analysis part, it will explain more on the parameter that influence the performance of the power quality events like voltage and harmonic. Then, will figure out if any power quality disturbance.

4.1 Result

4.1.1 Data Collection

As stated in the methodology, the data collections get from the on-site power quality monitoring. For the location of monitoring, it depends on what location that wants to observe and the period of monitoring is unlimited. Basically, power monitoring equipment is placed at strategic locations such as utility incoming because this incoming will contribute to the rest of downstream applications [12, 13].

The data analyzed in this project consisted of data from power quality monitoring audit at one of the semiconductor industry. The measurement point is at one panel, where the rating for the current and voltage is 200 A, 415 V. The monitoring period is one day and started from 13 December 2011, at 10.55 a.m until 14 December 2011 at 7.30 a.m. The monitoring function is to check any disturbance and abnormal parameter during that period.

During the monitoring period, G4000 Power Logger was used to collect data and monitor various disturbances like transients, voltage sags, voltage swells and harmonics. From the equipment, the data was exported into software whereby the normal trend of disturbance can be viewed in the form of waveforms [14]. From there, measurements ware conducted through the cursors and importance reading were obtained. The result for each parameter will have minimum and maximum value. In this project, the author mainly focuses on voltage and harmonic distortion for power quality analysis.

4.1.1.1 RMS Voltage

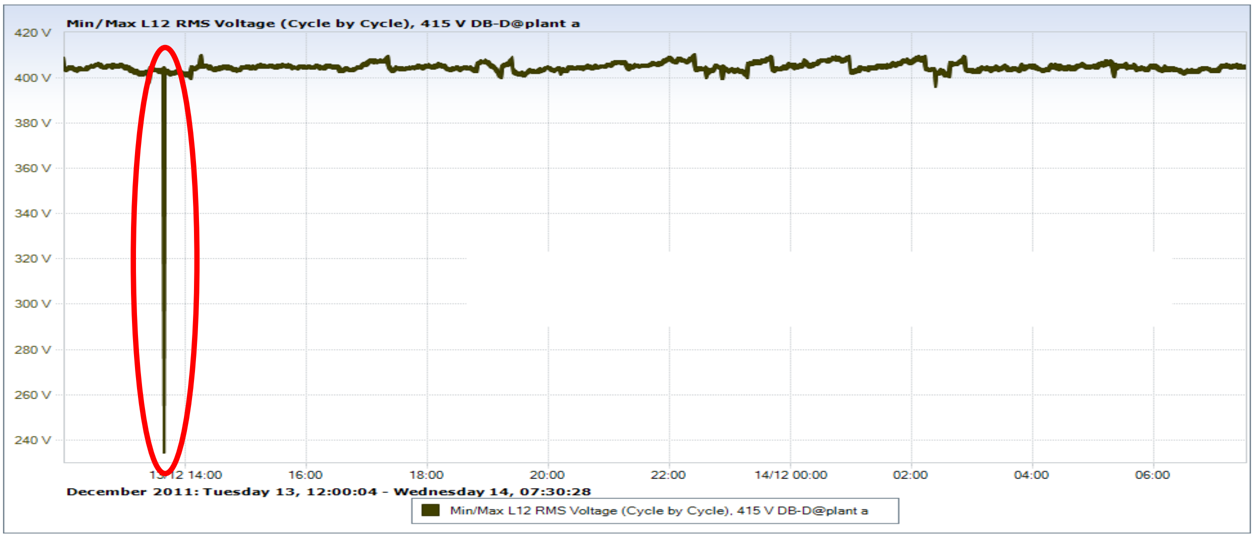
The connection for the voltage is in 3 phases, which is red, yellow and blue. For the voltage connection, it has L12, L23 and L31 connection. Table 5 below show the measurement data for the time power disturbance occur in the system.

Table 6: Power Monitoring Data for RMS Voltage

Starting Period	L12 RMS Voltage		L23 RMS Voltage		L31 RMS Voltage	
	Min	Max	Min	Max	Min	Max
13/12/2011 13.34 p.m	402.07	404.17	403.24	405.16	402.89	405.18
13/12/2011 13.35 p.m	402.19	403.52	403.28	404.61	402.80	404.37
13/12/2011 13.36 p.m	401.96	404.07	403.08	404.97	402.48	404.50
13/12/2011 13.37 p.m	401.97	403.94	403.08	405.14	402.57	404.63
13/12/2011 13.38 p.m	401.52	403.81	403.13	404.82	402.57	404.49
13/12/2011 13.39 p.m	234.01	404.89	233.45	405.25	403.71	404.71
13/12/2011 13.40 p.m	401.42	403.45	402.88	404.77	402.46	404.38
13/12/2011 13.41 p.m	401.68	403.80	403.12	405.03	402.71	404.58

Based from Table 6, at time 13.39 p.m, the voltage reading at phase 1 and 2 is abnormal which is it goes dip. The limit variation of RMS is 5% from the normal reading. For this system, 5% from 415 V is about 394.25 V and be the minimum value. Base from data, the minimum reading at phase 1 and 2 is below the minimum value. To be clearer, look to the graph analysis for each phase.

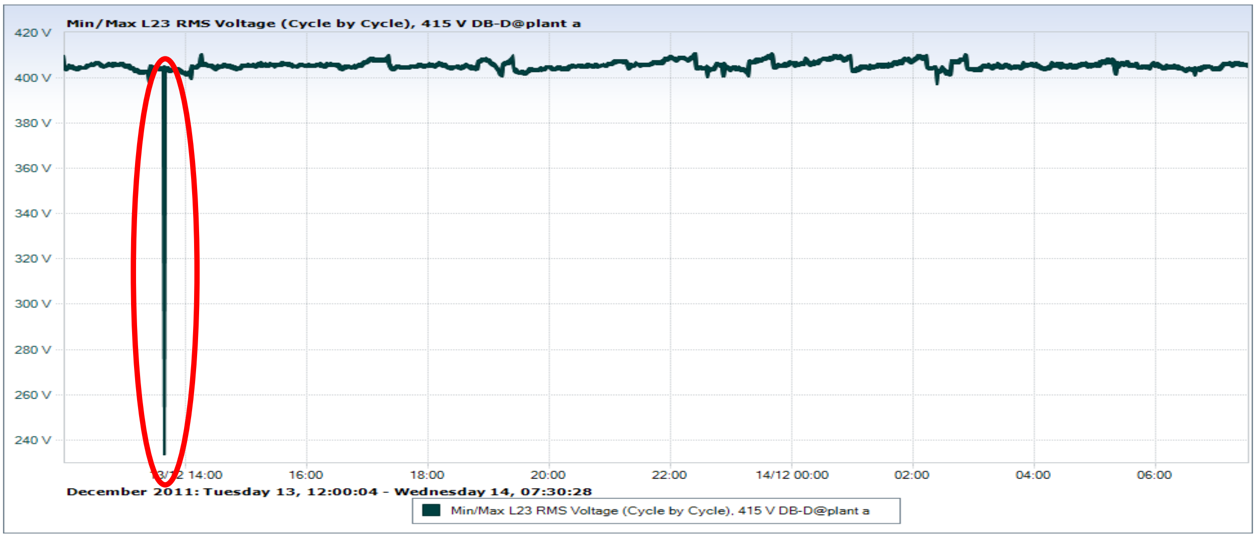
L12 RMS Voltage



Recorded Min RMS Voltage	: 234.01 V	at 01:38:58 PM 13/12/2011
Recorded Max RMS Voltage	: 410.67 V	at 10:23:59 PM 13/12/2011
Average RMS Voltage	: 404.80 V	

For L12 RMS Voltage graph, the reading voltage is typically abnormal because the minimum reading had been recorded at 234.01 V.

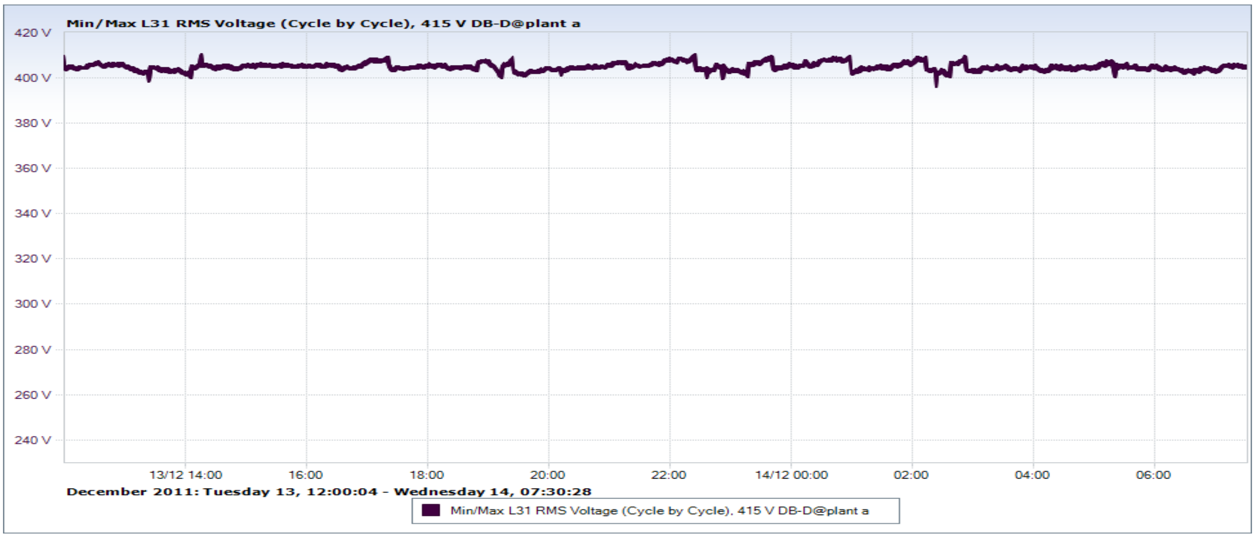
L23 RMS Voltage



Recorded Min RMS Voltage	: 233.45 V	at 01:38:58 PM 13/12/2011
Recorded Max RMS Voltage	: 411.31 V	at 10:23:59 PM 13/12/2011
Average RMS Voltage	: 405.51 V	

For L23 RMS Voltage graph, the reading voltage is typically abnormal because the minimum reading had been recorded at 233.45 V.

L31 RMS Voltage



Recorded Min RMS Voltage	: 395.54 V	at 02:22:59 AM 14/12/2011
Recorded Max RMS Voltage	: 410.80 V	at 10:23:59 PM 13/12/2011
Average RMS Voltage	: 404.92 V	

For L31 RMS Voltage graph, the reading voltage is typically normal because the minimum and maximum is not slightly much difference.

Record Event

Name	Phase	Start Time	End Time	Duration	Deviation
Voltage Dip	2	13/12/2011 13:39:12.275 PM	13/12/2011 13:39:12.845 PM	570ms	98.58 %

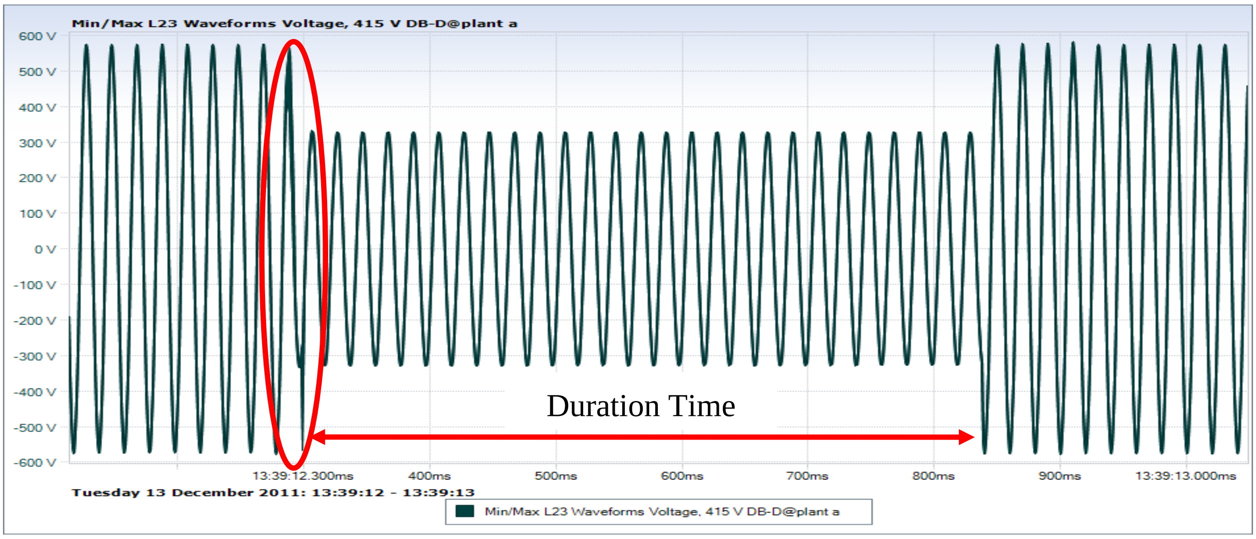


Figure 17: Voltage sag waveform at phase 2

In Figure 17, it noticeably shows that the voltage waveform at phase 2 was goes dip from its standard waveform. This power disturbance is call as Voltage Sags. The time duration for it goes dip is about 570ms which in short duration of time. In Figure 18, it shows the 3 phase waveform where only at phase 3 can maintain the original waveform compare to the waveform at phase 1 and 2.

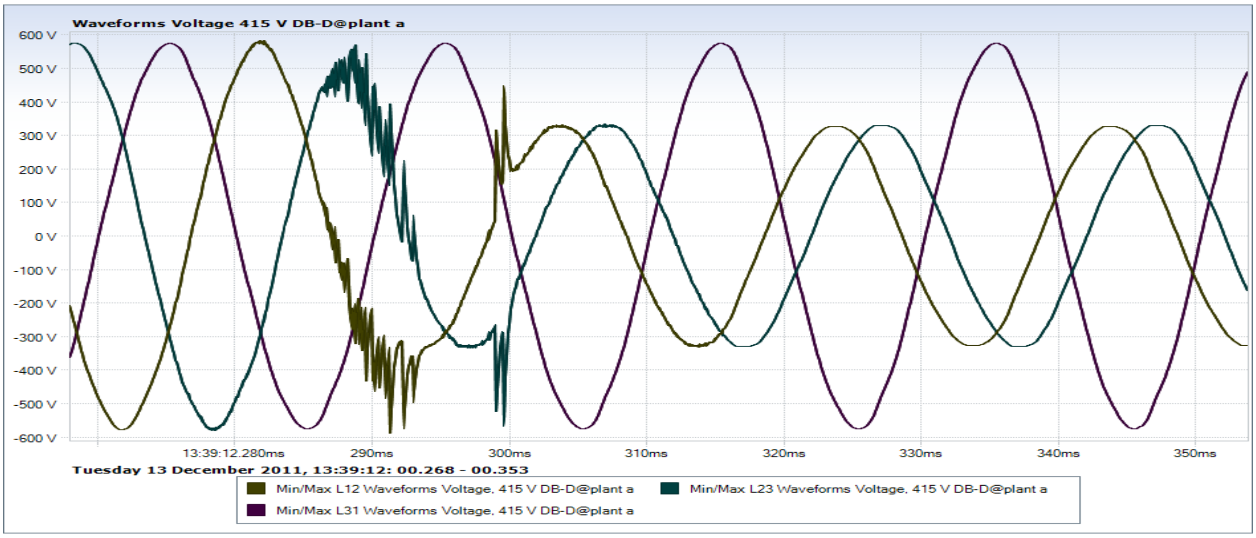


Figure 18: Typical waveform of 3 phase voltage

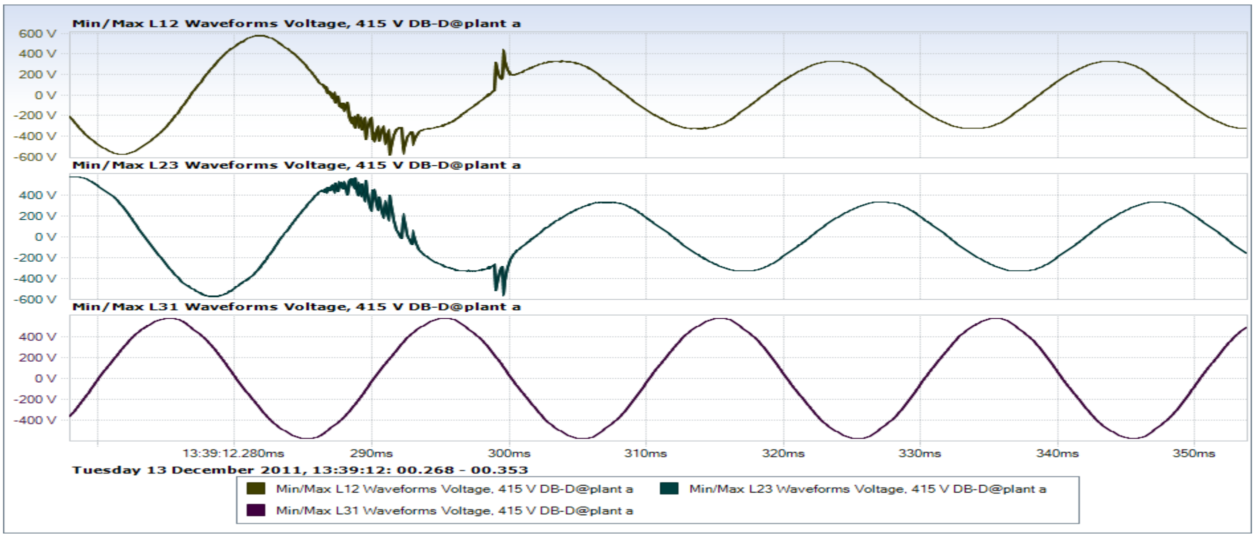


Figure 19: Sinusoidal voltage waveform for each phase

In Figure 19, the graph shows the voltage waveform for each phase. At phase 1 and 2, the voltage waveform is goes dip from its normal sinusoidal waveform and has spike at the waveform. While at phase 3, the normal sinusoidal waveform maintain during the operation.

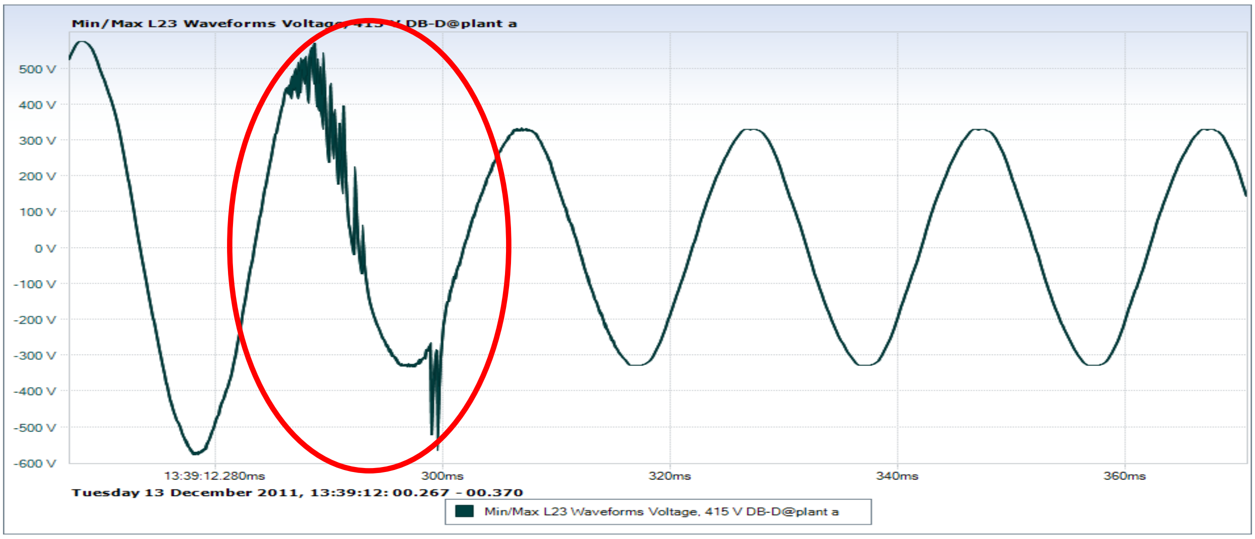


Figure 20: Transient waveform at phase 2

In Figure 20, transient also arise in the waveform because of sudden voltage change from its normal waveform. The voltage spike indicates that it is oscillatory transient type.

Based on the data and graph analysis, at phase 2, there is one time at 13:39:12.275 p.m, the voltage is slightly dip from its normal sinusoidal waveform. The minimum reading for the voltage is 233.45 V and maximum reading is 411.31 V. The cause of the voltage dip is start up the large load during that time. Information from the industry side state that they just install a new large machine at the production site. It might be the cause of this power quality disturbance. Additional monitoring should be done to determine where the source of this power quality disturbance. The time duration it occurs is about 570 ms which is less in 1 second. Even it happen in within less than one second, we need to concern because under voltages can cause component malfunction.

Besides that, a drop in voltage will result in increasing current flowing on the network. The increasing current will cause increase in I^2R losses of the network and increased in energy waste. For instance, 20 % drop in voltage would increase losses in the network by 56 % [15]. Furthermore, drop in efficiency of the equipment where drop in voltage will involve a higher energy use to do the same job. Hence, extra energy is inspired when there is a voltage drop on the network.

4.1.1.2 Harmonic Distortion

Harmonic distortion problem usually occurs in modern electrical networks due to feedback of harmonic currents from nonlinear loads. Harmonic voltage distortion is created due to interaction of such harmonic currents with source impedances. Thus, it can be treated as a form of electrical pollution on the network. Harmonic distortion can be measured by Total Harmonic Distortion (THD) include current and voltage THD [16]. The presence of harmonic distortion has a large impact in increasing energy use to the system.

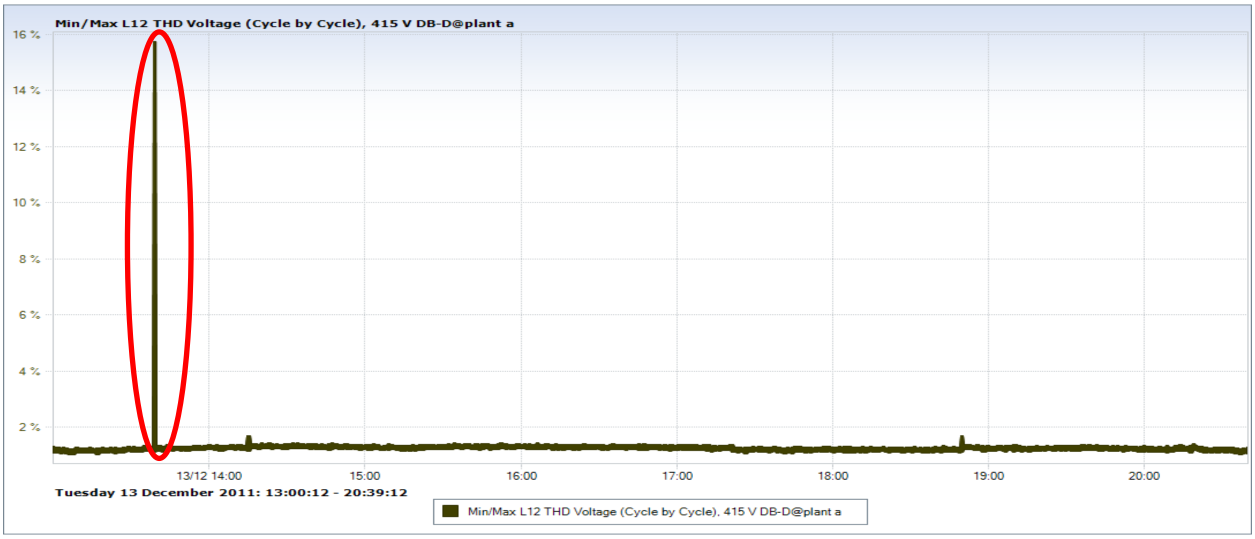
Total Harmonic Voltage Distortion

Table 7: THD Voltage Data

Starting Period	L12 THD Voltage		L23 THD Voltage		L31 THD Voltage	
	Min	Max	Min	Max	Min	Max
13/12/2011 13.35 p.m	1.20	1.41	1.51	1.66	1.19	1.36
13/12/2011 13.36 p.m	1.24	1.42	1.51	1.64	1.18	1.31
13/12/2011 13.37 p.m	1.24	1.44	1.50	1.66	1.17	1.36
13/12/2011 13,38 p.m	1.24	1.44	1.50	1.66	1.17	1.36
13/12/2011 13.39 p.m	1.24	15.77	1.52	15.23	1.20	1.37
13/12/2011 13.40 p.m	1.25	1.44	1.55	1.71	1.17	1.35

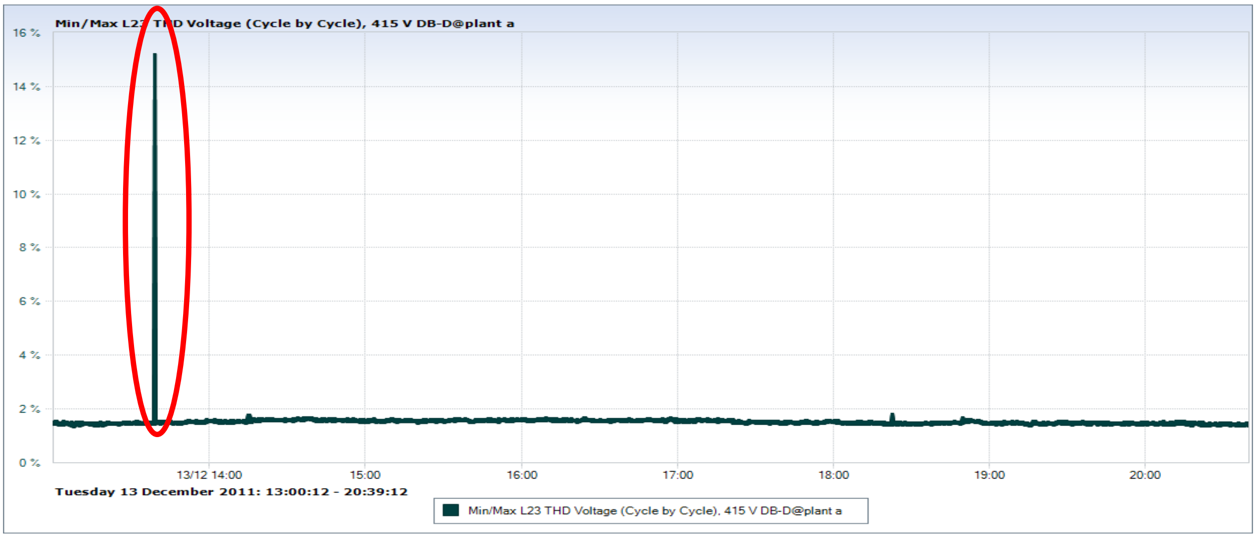
Harmonic distortion can be measured by Total Harmonic Distortion (THVD). Table 7 shows the percentage reading for THD Voltage. Based from the table, at time 13.39 p.m, the maximum reading for total harmonic voltage reading at phase 1 and 2 is over the standard limit. Based on IEEE 519 standard for voltage distortion, the maximum THD for 415V system is 5%. To be clearer, the graph analysis for each phase following;

L12 THVD



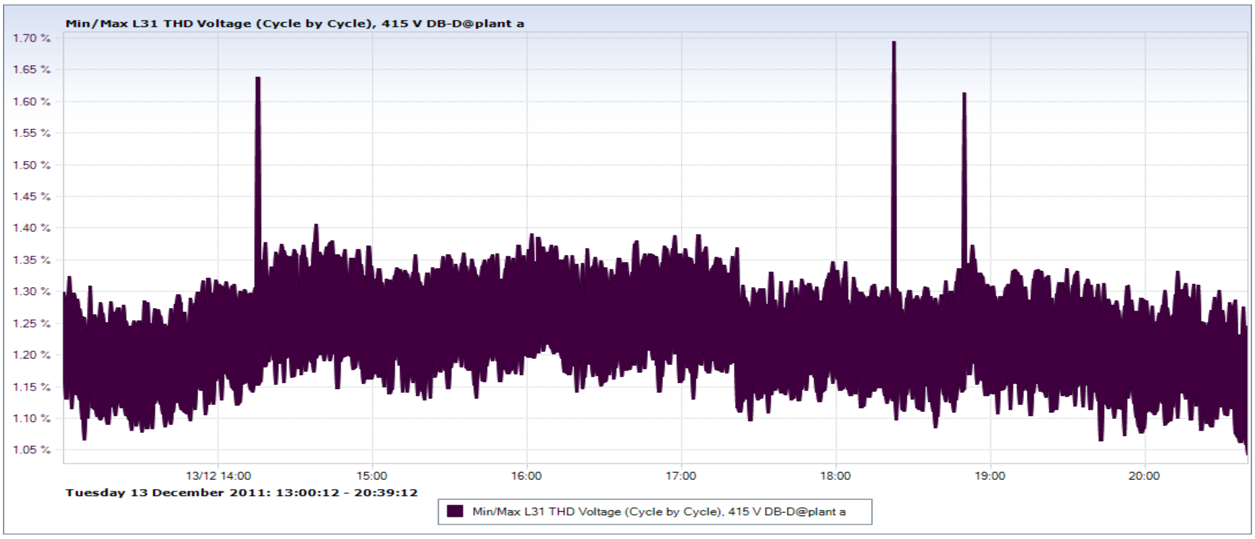
Recorded Min THVD	: 0.81%	at 03:23:35 AM 14/12/2011
Recorded Max THVD	: 15.77 %	at 01:39:29 PM 13/12/2011
Average THVD	: 1.13 %	

L23 THVD



Recorded Min THVD	: 1.20 %	at 11:38:54 AM 13/12/2011
Recorded Max THVD	: 15.24 %	at 01:39:29 PM 13/12/2011
Average THVD	: 1.43 %	

L31 THVD



Recorded Min THVD	: 0.98 %	at 03:33:57 AM 13/12/2011
Recorded Max THVD	: 2.53 %	at 09:52:26 PM 13/12/2011
Average THVD	: 1.18 %	

Based from the graph analysis, at phase 1 and 2, the maximum THVD is over limit by the IEEE 519 standard, which is 5%. The time happen is tolerance with the time when voltage dips in the system.

Harmonic Voltage

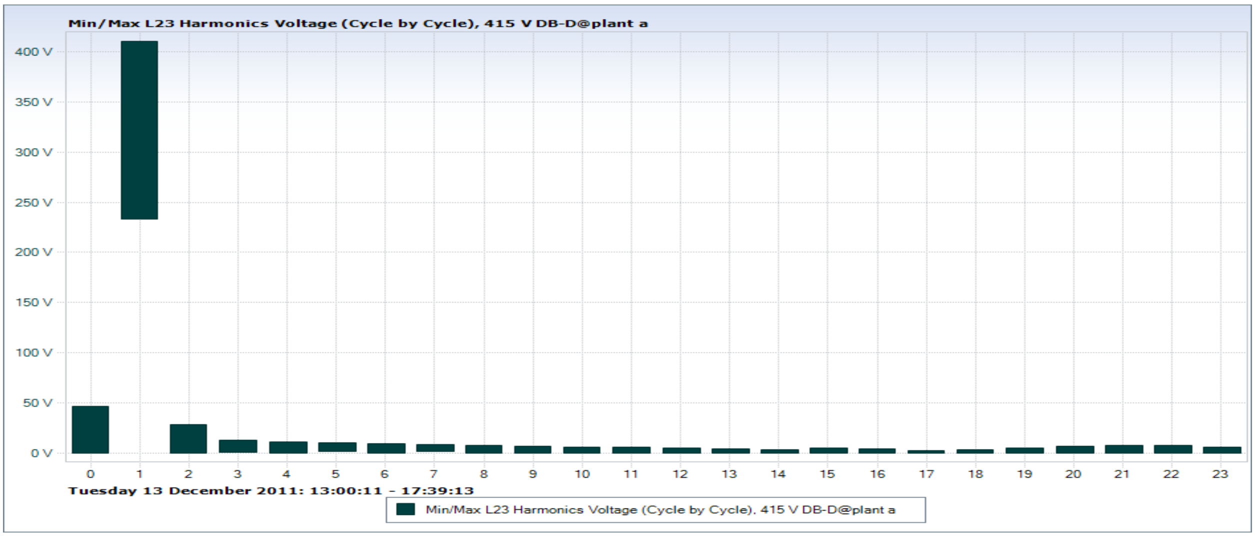


Table 8: Harmonic order for voltage

Harmonic Order	Voltage(V)	Percentage (vs Fundamental)	Standard IEEE 519 1992 (%)
1	410.6307		
3	12.75647	**3.10**	1.00
5	10.4353	**2.54**	1.00
7	8.398231	**2.04**	1.00
9	7.2081	**1.76**	1.00

Non-linear load basically will produce odd harmonic in the power system. Table 8 shows the odd harmonic order for the voltage. The odd harmonic normally will give effect to the system. For the third order harmonic which is triple harmonic, with zero sequence, is the worst. It consists of three phases with same magnitude but zero displacement from each other. Thus, three phases will have same direction and resulting three time the amplitude and when combined in neutral wire, it cause overheating. IEEE standard for the harmonic parameter is about 1%. But, based in the table, the odd harmonic percentage is over the standard.

Harmonic Current

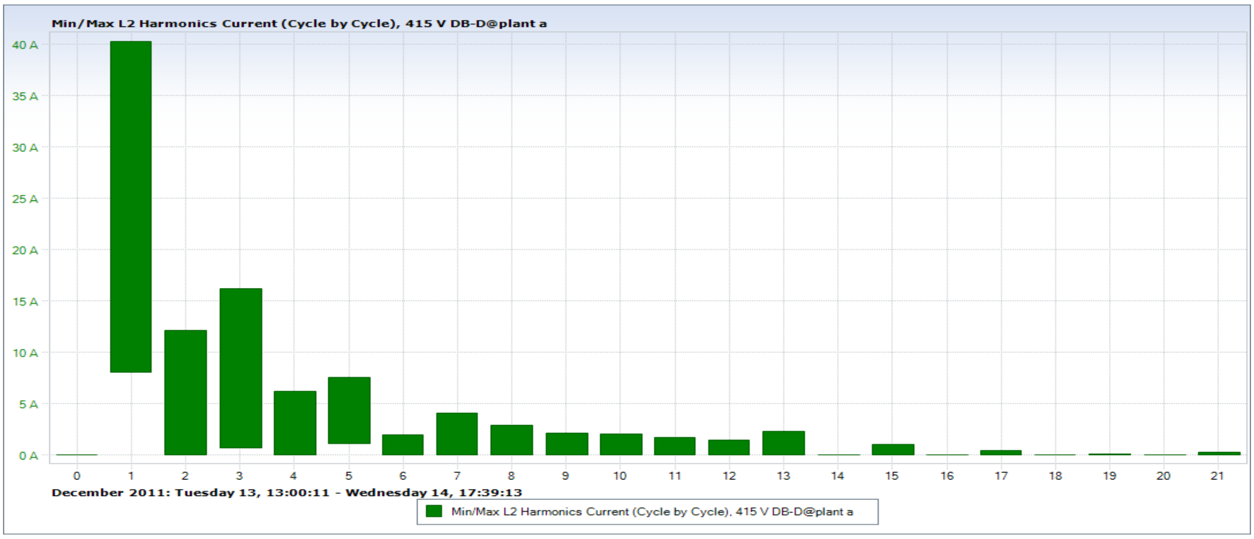


Table 9: Harmonic order for current

Harmonic Order	Current(I)	Percentage (vs Fundamental)	Standard IEEE 519 1992 (%)
1	40.303		
3	16.196	**40.19**	3.00
5	7.540	**18.71**	3.00
7	4.112	**10.20**	3.00

Table 9 shows the odd harmonic order for the current. Harmonic current will result voltage distortion. It is because voltage distortion is created due to interface of harmonic currents with source impedance [16]. Harmonic current provide power that cannot be used.

Table 10: Summary Data for Power Quality Analysis

Location	Description	Phase	Min	Max	Average
Case Study Plant	RMS Voltage (V)	A	234.01	410.67	404.80
		B	233.45	411.31	405.51
		C	395.54	410.80	404.89
	THD Voltage (%)	A	1.24	15.77	1.13
		B	1.52	15.23	1.43
		C	1.20	1.37	1.18

4.2 Discussion

Based on Table 10, at phase 2, there is one time at 13:39:12.275 p.m, power quality disturbances occurring in the system. It is voltage sags and harmonic distortion. The variation limit of RMS voltage is 5% from its normal value [17]. For the voltage sags, it can be categorized when the percentage voltage drop is 60% from its normal reading [17]. In this case, 60% from the 415 V systems is about 249V. From the Table 10, the minimum reading for the voltage is 233.45 V which can be conclude that the system had face voltage sags during the operation.

For harmonic distortion, based on IEE 519 standard for voltage distortion, the maximum THD for 415V systems is 5% [18]. But, based on Table 10, the maximum reading is about 15.23 % which is over the standard limit. Thus, harmonic distortions occurring in the system. The existence of harmonics in the grid is harmful because it will cause further power losses and malfunctions of the components [19].

4.2.1 Solution for Power Quality Disturbance

For this research, voltage dip and harmonic was occurred in the case study location. For voltage dip, there are several solutions to reduce the impact of voltage sags to the operation:

i. Adding Uninterruptible Power Supply (UPS) to deliver sensitive control equipment.

ii. Use soft starter for the large load such as large motor to avoid voltage dips and current high during motor starting.

For harmonic distortion, it can be solve by using harmonic filter [20]. The main function of the harmonic filter is to reduce neutral currents and also reduce total harmonic distortion. It has 2 types which are active filter and passive filter.

Active filter

It uses power electronic to remove the harmonic distortions produced by the non-linear loads. It mostly used for low-voltage networks.

i. The series filter connected series with AC distribution network. It functions to offset harmonic distortions produced by the load.
ii. The parallel filter connected parallel with AC distribution network. It function offset harmonic distortions produced by the load.

Passive Filter

It is build using an array of capacitor, inductor and resistor.

i. The series filter placed in series with the load, inductor and capacitor are in parallel and function as current rejector.
ii. The parallel filter placed parallel with the load, inductor and capacitor are in series and function as current acceptor.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The widespread of power electronic device has raised the awareness of power quality issue. The main reason for monitoring and analyzing data is to observe the abnormal parameter when the faults occur. Power quality problem are classified based on waveform problem which include transient, voltage sags and harmonic distortion.

From the research that has been done, harmonic distortion and voltage sag are the most common problem in the electrical power system. In some case, poor quality can be tolerated, however in most of the cases they need to be eliminated or reduced in order to ensure a smooth operation.

The impact due to the poor power quality is the equipment will malfunction thus interrupt the production side resulting in loss of revenue. Besides that, power quality problem will reduce the overall operating efficiency of electrical networks, increase in cost maintenance and also result in increased power supply demand and unnecessary wastage of energy.

Economical solutions such as harmonic filter are available to mitigate the effects of power quality disturbances. To summarize, this project is very reasonable to study because the increasing number of non-linear loads equipment in recent year which will create power quality disturbance in the power delivery output.

5.2 Recommendation

In future, it is recommended to carry out this study in other industry to determine the most power disturbances in a different environment.

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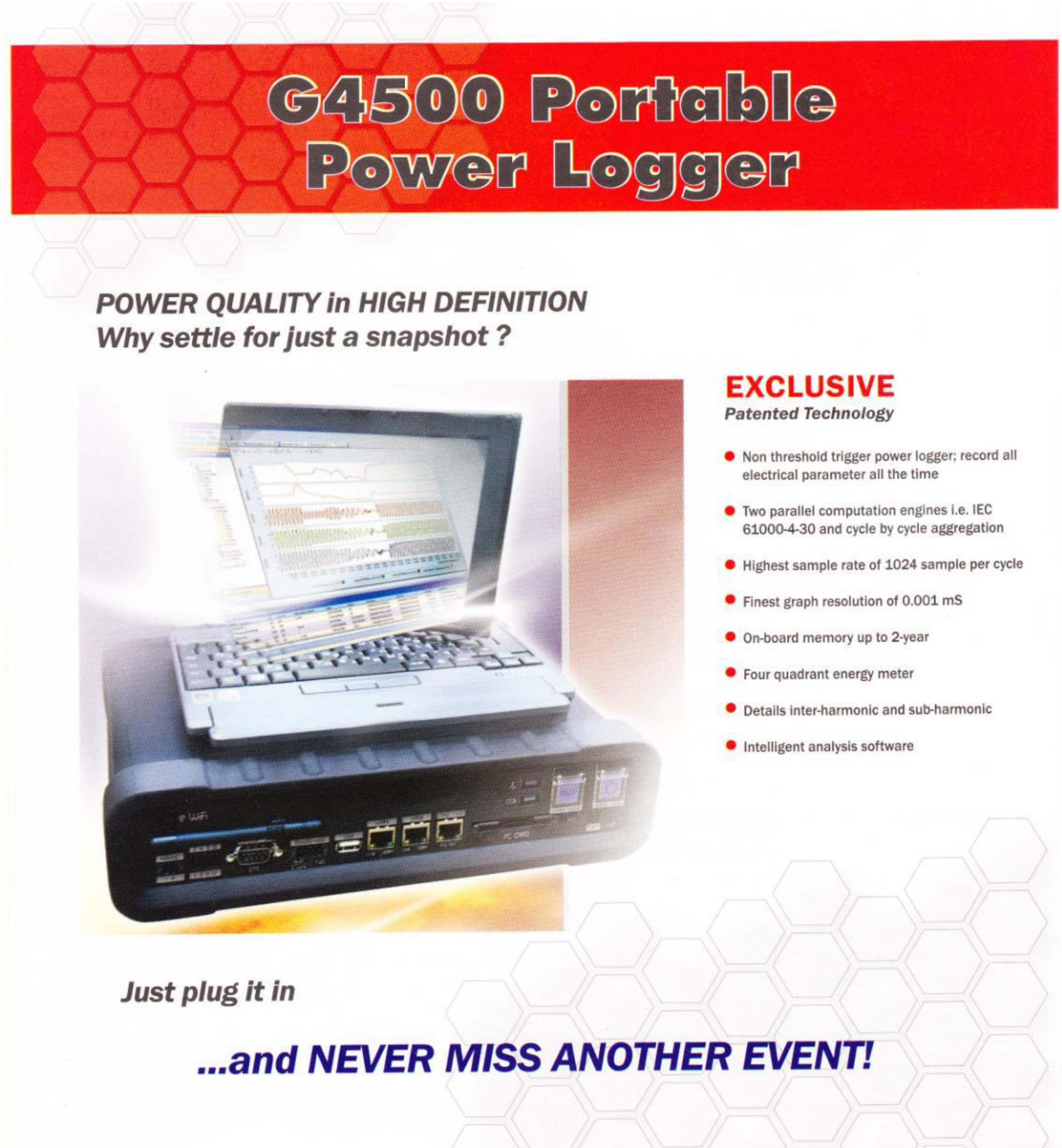
APPENDIX



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