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HARMONIC IN LOW VOLTAGE THREE PHASE FOUR WIRE IN ELECTRICAL DISTRIBUTION SYSTEM

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"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references"

Signature : ....
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Date : 22/11/2005

For my beloved parents En Salim and Pn Norizan thank you for giving me support to finish my study

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ABSTRACT

This project presents the harmonics research in low voltage three-phase four-wire in electrical distribution system. There are two major categories of harmonic effects on equipment. The first is overheating in power handling equipment such as transformers, capacitors and motors, which could reduce the equipment's operating life. The second category is disruption of operation for electronic controlled equipment such as PC's, PLC's and other electronic equipment. The work has been done through analysis of the results of measurements from different monitoring programs.

ABSTRAK

Kajian ini bertujuan untuk mengkaji tentang harmonik pada wayar neutral pada voltan rendah tiga fasa empat dawai yang biasa digunakan pada sistem pengagihan. Terdapat dua kategori utama yang disebabkan oleh harmonik iaitu kesan pelampauan haba pada peralatan seperti transformer, kapasitor dan motor, yang mana boleh menyebabkan jangka hayat peralatan itu tidak lama atau dalam erti kata lain boleh menyebabkan peralatan mudah rosak. Kesan kedua adalah boleh menyebabkan gangguan operasi pada peralatan elektronik seperti komputer, PLC, dan lain-lain peralatan elektronik. Kajian ini dilakukan dengan cara menganalisis keputusan daripada pengukuran daripada pelbagai pemantauan program.

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LITERATURE REVIEW

1.1 Background of the Project

Loads in low voltage distribution systems are mostly single-phase rectifiers, which are included in electronic equipment such as radio, television, etc. Three-phase loads that use three-phase rectifiers in distribution systems include adjustable motors, uninterruptible power supply systems, battery charger, etc. The rectifier units have been known to draw a non-linear current (harmonics) when connected to the supply mains.

Without any harmonic cancellations, non-linear loads may cause an excessive distortion in the phase current. The neutral current of this system may reach more than 100% of phase current magnitude resulting in thermal overloading of the neutral wire [1]. This is due to the vector sum of the triple-n harmonic currents from each phase. Excessive harmonic current in the line and in the neutral may cause serious malfunction of the protection equipment, interference to computers and reduce transformer efficiency [4]. However, harmonic cancellation may occur due to the counter-phase of single and three-phase harmonics [7].

This project presents the harmonics research in low voltage three-phase four-wire in electrical distribution system. All the work will be done through analysis of the results of measurements from different monitoring programs

1.2 Problem Statement

Nowadays, many problems can arise from harmonic currents in a power system. Some problems are easy to detect; others exist and persist because harmonics are not suspected. Higher RMS current and voltage in the system are caused by harmonic currents, which can result in any of the problems listed below:

i. Failed Power Factor Correction Capacitors
ii. Blown Fuses
iii. Misfiring of AC and DC Drives
iv. Overheated Transformers
v. Tripped Circuit Breakers
vi. Overheated Conductors
vii. Voltage Distortion
viii. High Neutral Currents
ix. High Neutral to Ground Voltages
x. Increased System Losses (heat)
xi. Rotating and Electronic Equipment Failures
xii. Capacitors Bank Overload and Failures
xiii. Reduced Power Factor

1.3 The Mitigation of Harmonic Problems

There are some method can be used to mitigate the harmonics. These include:

1. Correcting harmonics

If an Uninterruptible Power Supply (UPS) is used in conjunction with the equipment, then in some cases the UPS can correct or eliminate the harmonics. Some single phase UPS eliminates neutral current entirely. If a power factor correcting UPS is used to power clusters of Personal Computers (PCs), the harmonics problem cannot pass upstream to the building wiring or power transformers. This approach has the advantage that it can be retrofit to an existing building, and used with existing loads. It also corrects both the wiring and the transformers issue. For the other types of load, such as large industrial motor drives which are not covered by the harmonic regulations, specialized products are available that can absorb harmonics near the source.

2. Over sizing neutral wire

In modern facilities the neutral wire should always be specified to be the same capacity as the power wiring (or larger). This is in contrast the electrical codes which may permit under sizing the neutral wire

3. K-rated transformers

Modern office facilities with high densities of PCs should always be specified to include transformers with "K" rating of at least 9. These transformers have been specially designed to withstand harmonic currents. For datacenters, a "K" rating of 9 would be sufficient to ensure harmonic carrying capability for the fraction of the datacenter consisting of old legacy loads, PC loads, or lighting loads.

4. Specifying equipment that does not create harmonics

In the case of networking equipment, the problem is solved because of the International Electro technical Commission (IEC), regulations. In the case of PCs, it is more difficult since a large amount of the harmonic contribution comes from the monitor. One approach is to use PCs and monitors with lower power draw overall, such as the use of Liquid Crystal Display (LCD) monitors or laptop PCs. This avoids both building wiring and transformer problems

1.4 Objectives

The objectives for the project are;

1. For identifying and monitoring harmonic in 3-phase 4-wire in electric distribution system.
2. Power quality monitoring and measurement.
3. Most of the works focused on the distribution system.

CHAPTER 2

HARMONIC SCHEMES

Power line harmonics is just one of the many power quality issues that arise with public utilities. Effectively, current harmonics represent a distortion of the normal sine wave provided by the utility.

Nowadays, more electronic equipment in the workplace raises the likelihood of potential interactions with the electric distribution system and requires a more sophisticated approach to preventing these interactions.

Common power quality concerns, including voltage sags, swells, and surges, have led to the increased used of additional facility equipment, such as uninterruptible sources and battery-supported systems, to increase electrical reliability.

In addition, signal interactions in sensitive equipment can be difficult to trace. Energy managers can engage in a number of practices that will improve overall power quality in a facility and reduce the interactions due to harmonic currents in the load devices.

2.1 Introduction of Harmonic

Harmonic happen when a product such as a Silicone Controlled Rectifier (SCR) switched load or a switching power supply distorts the current, harmonics at multiples of the power line frequency are generated. Two significant consequences arise as a result of harmonic generation.

First, because of finite impedances of power lines, voltage variations are generated that other equipment on the line must tolerate. Second, when generated in a three-phase system, harmonics may cause overheating of neutral lines.

Power line harmonics are generated when a load draws a non-linear current from a sinusoidal voltage. The harmonic component is an element of a Fourier series which can be used to define any periodic wave shape. The harmonic order or number is the integral number defined by the ratio of the frequency of the harmonic to the fundamental frequency (e.g., 180 Hz is the third harmonic of 60 Hz; n = 180/60 (see at Figure 2.1)). At Malaysia, we used fundamental frequency at 50 Hz.

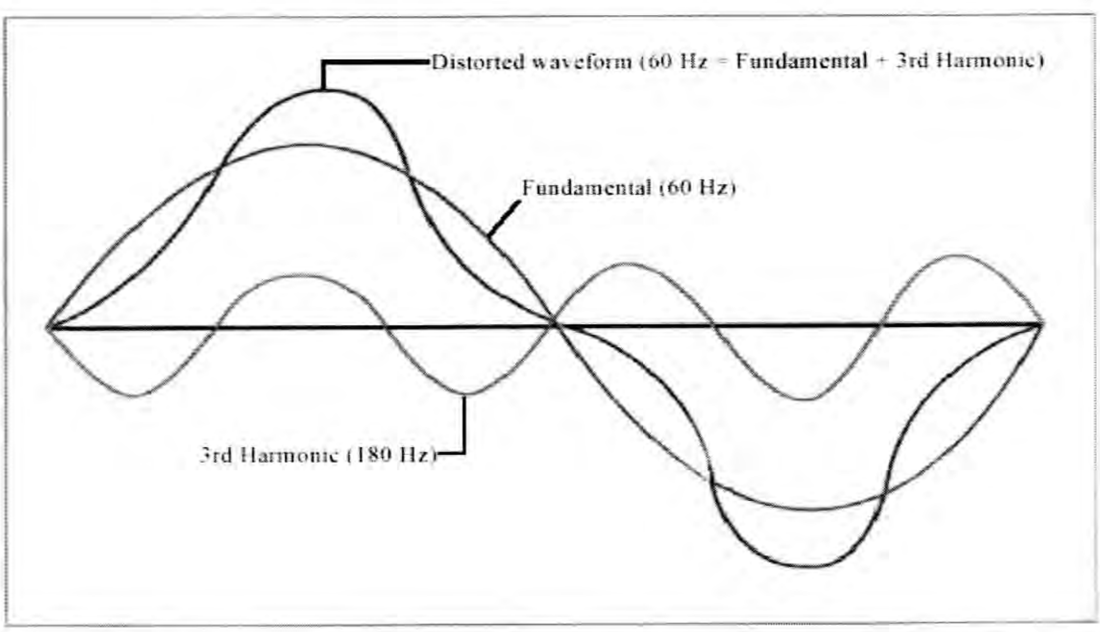

Figure 2.1: Distorted waveform composed of fundamental and 3rd harmonic

A second harmonic is therefore two times the fundamental frequency of the supply line volt current. If the supply voltage had been generated by an ideal source (zero impedance), the current distortion would have little effect on the supply voltage sine wave graph. However, because a power system has finite impedance, the current distortion caused by a nonlinear load creates a corresponding voltage distortion in the supply lines.

This voltage distortion can subsequently disrupt operation of other sensitive equipment connected to the same line. Voltage distortion can also cause motors operating on the line to overheat. Because neutral lines are not fused or protected by circuit breakers, overheating of neutral conductors in a three-phase line can be a significant safety hazard. Such damaging occurrences are usually attributable to the use of single-phase loads attached to three-phase or single-phase wiring systems. Excessive neutral current is caused by the existence of "triplen" harmonics, which add in series in the neutral line. The triplen harmonic will be discussed in other chapter.

2.2 Harmonic Loads and Their Effect

Harmonics are multiples of the fundamentals frequency of an electrical power system. If, for example, the fundamental frequency is 50 Hz, then the 5^{th} harmonic is five times that frequency, or 250 Hz. Likewise, the 7^{th} harmonics is seven times the fundamental of 350 Hz, and so on for the higher order harmonics.

The harmonics can be discussed in terms of current or voltage. A 5^{th} harmonic current is simply a current flowing at 250 Hz on a 50 Hz system. The 5^{th} harmonic current flowing through the systems impedance creates a 5^{th} harmonic voltage. Total Harmonic Distortion (THD) expresses the amount of harmonics. The following is the formula for calculating the THD for current:

$$THDcurrent = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \cdots + I_n^2}}{I_1} \qquad (2.1)$$

When harmonic currents flow in a power system, they are known as poor "power quality" or "dirty power". Other causes of poor power quality include transients such as voltage spikes, surges, sags, and ringing. Because they repeat every cycle, harmonics are regarded as a steady state cause of poor power quality.

The effect of the harmonics includes:

1. Overheating in power handling equipment such as transformers, capacitors and motors; which will reduce the operating life of the equipment.

2. The disruption of operation for electronics equipment such as PCs, PLCs, televisions, light fixture ballasts, and other electronics equipment.

2.3 Harmonic Producing Equipment

There is much equipment that can produce the harmonics. The equipment is listed below [8].

i. Copy machines
ii. Electric typewriters
iii. Light fixture ballasts
iv. Personal computers
v. Televisions
vi. Recorders
vii. Video tapes players
viii. Computers systems
ix. Computer terminals
x. Audio visual equipment

xi. Laboratory testing equipment
xii. Silicone Controlled Rectifier drives for elevators
xiii. Silicone Controlled Rectifier drives for motors
xiv. Uninterruptible Power Supply systems

2.4 Problems of Harmonic in the Building

Harmonic can caused many problems that related in the building. The problems are [8]:

i. Line voltage distortion
ii. Overheating and damage the panel boards' feeder
iii. Overheating and damage the neutral conductors
iv. Nuisance tripping of circuit breakers
v. Higher common mode voltage
vi. Overheating and premature failure of distribution

2.5 How Harmonics Produced?

CHAPTER 3

MEASURING THE HARMONIC CURRENT AND THE RESULT

3.1 Introduction

Harmonic measurements are an important part of the overall investigation for a number of reasons. Most importantly, the measurements must be used to characterize the level of harmonic generation for the existing nonlinear loads. Voltage and current harmonic levels are measured at multiple sites to accomplish this.

It is important to accurately document system conditions at the time of the measurements so that the results can be used to verify analytical results. The specific objective of the measurements including determine the harmonic current at the neutral wire. This is done by performing current measurements at a variety of non linear loads.

For this part, Data Logger is used to measure the harmonic current at the non linear load. The personal computers and electronic ballast were chosen as the non linear loads for the harmonic measurement.