"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

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IMPACT OF ROTATING MACHINES ON HARMONIC DISTORTION IN POWER DISTRIBUTION SYSTEMS

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Date : 12 MAY 2009

Dedicated to
my beloved parents,
Hamdan Bin Palal and Mariani Binti Mujri,
sisters and brother,
Nur Izua Binti Hamdan and Muhamad Izzuddin Bin Hamdan
for giving a constant source of support and encouragement.

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ABSTRACT

Harmonic cause of distortion of the voltages and current waveforms, which have adverse effects on electrical equipment. Harmonics are one of the major power quality concerns. The estimation of harmonics from nonlinear loads is the first step in a harmonic analysis and this may not be straight forward. Rotating machines are considered sources of harmonics because the windings are embedded in slots which are not perfectly sinusoidally distributed resulting in a distorted mmf. Nonsinusoidal voltage applied to electric machines may cause overheating, pulsating torques or noise. In additional to cross the line applications, adjustable speed drive motors are fed from inverter that can produce significant voltage distortion. In induction motor, they can overheat due to the effects of harmonic currents, depending on their frequency, because of additional rotating magnetic fields in the motor. Harmonic produce harmonic fluxes in motors. The harmonic torques tends to rotate motor at different harmonic synchronous speeds. It can produce high frequency currents in rotor circuits. The data which collect from the site project will be inserting into Visualation Basic, VB. The parameters that will be state are voltage, current, frequency, time and total harmonic distortion. The reading will be collect with the different speed of motor. It causes to show how the speeds of motor produce harmonic distortion. Then it wills using the different type of starter motor there are Direct-On-Line, Auto-Transformer and Star-Delta.

ABSTRAK

Harmonik merupakan punca gangguan terhadap pembentukan gelombang voltan dan arus yang memberi kesan terhadap barangan elektrik. Harmonic adalah salah satu daripada kualiti kuasa yang diambil kira. Had harmonic daripada beban yang tidak linear adalah lang kah yang pertama dalam menganalisis harmonic dan ini tidak secara terus. Putaran mesin merupakan punca harmonik kerana belitan yang tertanam dlm slot tidak sempurna agihan sinusoidal dalam gangguan daya gerak magnet. Voltan yang tidak sinusoidal dalam mesin elektrik akan menyebakan panas yang keterlaluan, denyutan tehadap torq atau gangguan. Tambahan pula untuk merentasi aplikasi, pelaras kelajuan motor merupakan penyalur daripada penyonsang yang menghasilkan isyarat gangguan voltan. Dalam motor induksi, ia boleh mengalami panas keterlaluan wajar dengan kesan terhadap arus harmonik, bergantung pada frekuensi arus dalam litar rotor. Data yang dikumpul daripada tapak projek akan dimasukkan ke dalam perisian Visualation Basic, VB. Parameter yang akan dijelaskan adalah voltan, arus, frekuensi, masa dan jumlah gangguan harmonic. Bacaan yang dikumpulkan dengan mengikut kelajuan yang berbeza. Ini adalah untuk menunjukan bagaimana kelajuan motor menghasilkan gangguan harmonik. Kemudian ia akan menggunakan jenis pemula motor yang berbeza. Ia adalah Direct-On-Line, Auto-Transformer dan Star-Delta.

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V	-	Voltage
ac	-	Alternating Current
dc	-	Direct Current
Ω	-	Ohm
I_i	-	Input Current
Io	-	Output Current
V_{in}	-	Input Voltage
V_o	-	Output Voltage
R_L	-	Load Resistor
Θ	-	Angle
THDV	-	Total Harmonic Distortion of Voltage
THDC	-	Total Harmonic Distortion of Current
mmf	-	Magneto Motive Force
emf	-	Electromotive Force

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CHAPTER 1

INTRODUCTION

1.0 Project Background

The project is based on analysis one of the disturbances in power distribution system. Harmonic is one of the problem manifested in voltage, current or frequency deviations that results in failure or misoperation of customer equipment or the other name called power quality. As we know the harmonic is produce by some device or equipment and nonlinear loads such as power electronic devices, industrial process control, computer system and rotating machines.

This project is focused on the analysis of the impact of rotating machines on harmonic distortion. Rotating machines are considered sources of harmonic distortion because the windings are embedded in slots which can never be exactly sinusoidal. However coil spinning in three-phase machines is used to reduce 5^{th} and 7^{th} harmonics.

The machines which used in this project are induction motor (3-phase). The induction will use different starter or connection. There are star-delta, auto-transformer and direct-on-line. So from this three types of motor control we get the analysis of harmonic distortion and also their impact.

The data needed while doing this analysis is voltage harmonic, current harmonic, frequency and total harmonic distortion. All the data are collected from Power Quality Analyzer (PQA). Then the data will insert into Visual Basic 2005 (VB) to show the analysis.

1.2 The Objectives

1) To analyze harmonic in power distribution
2) To study about impact of rotating machine.
3) To specified harmonic distortion with different type of machines

1.3 The Scope Of The Project

1. This project will analyze the impact of rotating machine on harmonic distortion in power distribution system.

2. To measure total harmonic distortion in power distribution system using AC motor as a load

3. The machine which used is induction motor three phase.

4. This project will use VB to show the data and the analysis

1.4 Literature review

In power distribution system, the loads are producing harmonic distortion are:

1) Electronic lighting ballasts
2) Adjustable speed drives
3) Electric welding equipment
4) Solid state rectifiers
5) Industrial process controls
6) Uninterruptible Power Supplies (UPS)systems
7) Saturated transformers
8) Computer system

Rotating machines are considered sources of harmonics because the windings are embedded in slots which are not perfectly sinusoidally distributed resulting in a
distorted mmf.

Harmonic distortion is distortion where the waveform is non-sinusoidal but periodic with a period equal to the period of the power system frequency (50 or 60Hz). Most of the literature on waveform distortion only considers this harmonic distortion, which is an acceptable approximation in many cases. However most power quality studies consider more or less exceptional situations, so that we cannot limit ourselves to harmonic distortion only.

The presence of a dc component can be seen as a special case of harmonic distortion, but is often treated separately due to difference in measurement techniques and consequences.

Interharmonic distortion is mathematically the same as harmonic distortion. The difference with harmonic distortion is that the period is a multiple of the period of the power system frequency. For example, a 50 Hz signal with a 180 Hz interharmonic component has a period of 100 ms (5 cycles of 50 Hz, 18 cycles of 180 Hz). Mathematically, a frequency component at an irrational multiple of the power system frequency would lead to a non-periodic signal, but that case does not need to be considered in practice.

Subharmonic components are components with a frequency less than the power system frequency. They can be considered as interharmonic distortion, but are often treated separately because their consequences are different from those of higher frequency components.

The power system is not a static entity but it changes all the time, so that strictly applying the above definitions would imply that everything is noise. To distinguish between the different types of distortion is indeed not always possible. A way of distinguishing would be by taking the spectrum of the signal over a reasonable number of cycles, e.g. 50 cycles (1 s). Harmonics and interharmonics show up as sharp lines in the spectrum whereas noise is seen as a continuous spectrum. Light flicker cannot be observed directly from the spectrum, although the presence of frequency components within 10 Hz of the fundamental component is a good indication. For the analysis of light flicker, the flickermeter algorithm has been developed.

1.5 Thesis Outline

This thesis contains 6 chapter which is every chapter have its own purpose. After viewing the entire chapter in this thesis hopefully viewer can understand the whole system design for this project.

Chapter 1 describe on the background of the project, objectives, scope of the project and the literature review that referred to in the analysis of harmonic distortion and rotating machines.

Chapter 2 is focused to the theory of the harmonic distortion where it described about characteristics, standard harmonic limitation, mitigation and quantify the harmonic.

Chapter 3 only focused about the load which use in this project, motor control. This chapter focused how the connection work and effect on harmonic.

Chapter 4 explains how rotating machines give an impact on level of voltage, flow of current and harmonic distortion.

Chapter 5 presents the data and result that have been got from the analysis. The result of this project also is accompanied by the discussions for each problem statements.

Lastly is chapter 6, in this chapter the conclusion have been made for the project from the whole aspect and there are also recommendations of reduce harmonic distortion

CHAPTER 2

HARMONIC DISTORTION

2.1 Introduction

Harmonic distortion is a term describes the condition that occurs when waveform is changed from the original shape by addition of harmonic frequency. Harmonics cause distortion of the voltage and current waveforms, which have adverse effects on electrical equipment. Harmonic are one of the major power quality concerns. The estimation of harmonics from nonlinear loads is the first stepin a harmonic analysis and this may not be straightforward. There is an interaction between the harmonic producing equipment, which can have varied topologies and the electrical system. Over the course of recent years, much attention have been established for permissible harmonic current and voltage distortion.

Harmonics emission can have varied amplitudes and frequencies. The most common harmonics in power systems are sinusoidal components of a periodic waveform that have frequencies which can be resolved into some multiples of the fundamental frequency. Power systems also have harmonics that are noninteger multiples of the fundamental frequency and have a periodic waveforms.

2.1.1 Definition of harmonic distortion

Harmonic:

Harmonic are sinusoidal voltages or current having frequencies that are integer multiples of the fundamental frequencies

Distortion:

Qualitative term indicating the deviation of a periodic wave from its ideal waveform characteristics.

2.1.2 Characteristics

A frequency is harmonic if it is an integral multiple of fundamental frequency otherwise it may be interharmonic. The fundamental is the first harmonic. The second harmonic is two times the frequency of fundamental; the third harmonic is three times the fundamental and so on.

A distorted waveforms \having a Fourier series with fundamental frequency equal to power system frequency and a periodic steady state exists. This is the most common case in harmonic studies.

A distorted waveform also having submultiples of power system frequency and a periodic steady state exists. Certain types of pulsed loads and integral cycle controllers produce these types of waveforms.

The waveform is a periodic but perhaps almost periodic. A trigonometric series expansion may still exist. Example is arching devices.

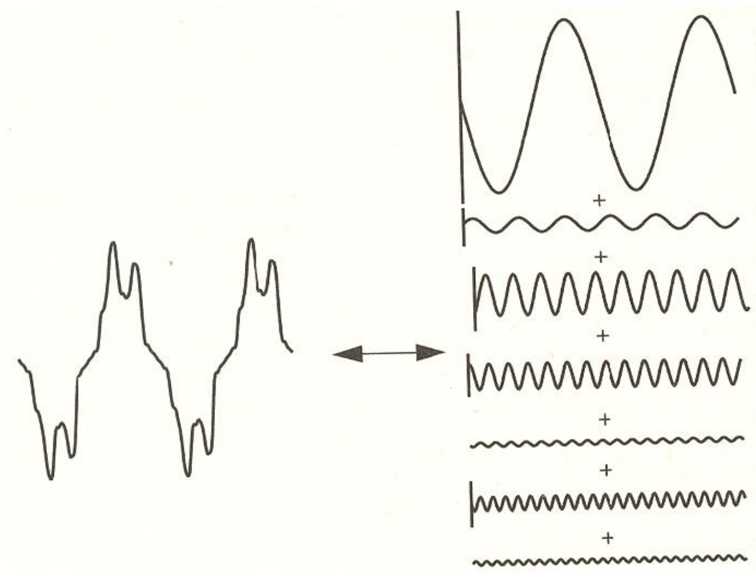

Figure 2.1: Harmonic generation

2.2 Load Producing Harmonic

The generation of harmonics in power system occurs from two distinct types of loads:

1. Linear time-invariant loads are characterized so that an application of a sinusoidal voltage results in a sinusoidal flow of current. These loads display a constant steady state impedance during the applied sinusoidal voltage. If the voltage is increased, the current is also increase in direct proportion. Tooth ripples and slotting may produced forward and reverse rotating harmonics. Magnetic circuit can saturate and generate harmonics. As an example, saturation in transformer on abnormally high voltage produces harmonic, as the relationships between magnetic flux density B and the magnetic field intensity H in the transformer core is not linear. Under normal operating conditions these effects are small. Synchronous generators in power system produce sinusoidal voltageand the loads draw nearly sinusoidal currents. The harmonic pollution produced due to these load types for applied sinusoidal voltages is small.

2. The second category of loads is described as nonlinear. In a nonlinear device the application of sinusoidal voltage does not result in a sinusoidal flow of current. These loads do not exhibit a constants impedance during the entire cycle of applied sinusoidal voltage. Nonlinearity is the same as the frequency dependence of impedance such as the impedance of a reactor change in proportion to applied frequency but it is linear at each applied frequency. On the other hand, nonlinear loads draw a current that may even be discontinuous or flow in pulses for a part of the sinusoidal voltages cycle.

The loads producing harmonic distortion are:

1. Electronic lighting ballasts
2. Adjustable speed drives
3. Electric welding equipment
4. Solid state rectifiers
5. Industrial process controls
6. Uninterruptible Power Supplies (UPS)systems
7. Saturated transformers
8. Computer system
9. Cycloconverter
10. Switching mode power supply
11. HVDC transmission
12. Battery charging and fuel cells
13. Wind and solar power generation
14. Slip recovery schemes of induction motor
15. Electric traction