ENERGY SAVER POWER FACTOR CONTROLLER FOR INDUCTION MOTOR

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APRIL 2008

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)"

Signature : .....

Supervisor's name : ALIAS BIN KHAMIS

Date : 30/4/08

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

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ABSTRACT

The purpose of this project is to implement the energy saver power factor controller for alternating current (AC) induction motor. Energy savings for induction motor can be realized with adjustable speed operation. As the speed varies with load, the power consumption characteristic of the motor will also varies.

The control of power consumption to save energy usage is done by using the Variable Frequency Drive (VFD) or its other name, Variable Speed Drive. VFD is a controller that varies the speed of an induction motors. It consists of a rectifier, intermediate direct current (DC) circuit, an inverter, and a controller.

The operating speed of an induction motor which is connected to a VFD is varied by changing the frequency of the motor's supply voltage. Output frequency and voltage is controlled electronically by controlling the voltage pulse width to the motor. These techniques require switching the inverter power devices ON and OFF many times to generate proper RMS voltage level. This action allows continuous process speed control. The power factor of variable frequency drive is discussed.

ABSTRAK

Tujuan projek ini adalah untuk mengaplikasikan penjimat tenaga pengawal faktor kuasa untuk motor aruhan arus ulang alik. Penjimatan tenaga untuk motor jenis ini boleh dilaksanakan dengan kaedah kawalan kelajuan motor. Apabila kelajuan berubah mengikut beban motor, kadar penggunaan tenaga motor juga akan berubah.

Kawalan penggunaan kuasa elektrik untuk menjimatkan tenaga dapat dilakukan dengan menggunakan 'Variable Frequency Drive (VFD)' atau dengan nama lainnya 'Variable Speed Drive'. VFD adalah pengawal yang mengubah kelajuan motor aruhan mengikut keadaan. Ia terdiri daripada pengubah AC-DC, pengubah DC-AC, dan pengawal.

Kelajuan operasi motor aruhan yang menggunakan VFD diubah dengan mengubah frekuensi voltan masukan motor. Frekuansi dan voltan keluaran VFD dikawal secara elektronik dengan mengawal kelebaran denyutan voltan masukan. Teknik ini memerlukan operasi BUKA dan TUTUP berulang kali suis elekronik yang terdapat pada VFD untuk menghasilkan tahap voltan keluaran yang sesuai. Proses ini membolehkan kawalan kelajuan motor aruhan secara berterusan. Faktor kuasa motor dengan menggunakan VFD akan dibincangkan dalam laporan ini.

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CHAPTER 1

INTRODUCTION

Energy saving is important for efficient power consumption and cost savings especially for big industrial company that uses lots of electrical equipment that tends to waste energy in their business. It is their goal to reduce power usage while increasing their production.

Power electrical engineers today have used lots of equipment, devices and methods to control power consumption. The main goal is to reduce power consumption thus reducing electrical bill cost and production cost. Actually, the thing they are doing is to increase their power factor.

In industry, AC induction motor is the workhorse. It is used for many applications. It is also the machine that tends to reduce the plant power factor. Using this kind of machine without any energy saving device will waste power usage and increase electrical bill.

Adjustable speed operations for induction motor are being used in numerous applications such as centrifugal pumps and fans to realize substantial energy savings. The applications are implemented in the basis of kilowatts (kW) savings with long term period payback. The power factor characteristic of a variable frequency drive (VFD) differs from the fixed speed induction motor. It is one of the energy saving method to use the VFD to improve the induction motor power factor.

This thesis report will be discussing about induction motor characteristic and the energy saving power factor correction method through the used of VFD. The main component in preparing this thesis is the analysis of the induction motor and VFD characteristic including the related parameters. These consist of induction motor operations and how it can be operate to reduce power consumption as much as possible. Brief history on induction motor and VFD are also included.

As for conclusion, deep understanding about induction motor construction and its operation can further helps to well save the energy. All the important data obtained in this research analysis is expected to further helps in improving the energy saving method of induction motor.

1.1 Problem Statement

Induction motors are the kind of electrical equipment that tends to reduce a plant's power factor. The efficiency of an induction motor will fall at a reduced load. An induction motor takes both active and reactive power from the supply. The rotating torque of the motor is created as an interaction between the active current component and the magnetic field.

The field is produced by the reactive current component. Light load take less active current but, the magnetic field as well as the reactive current stay constant. This means that the power factor of the motor decreases as the load decreases. The current is mainly active at the full load but mainly reactive at the light load. By using the variable speed drive, the benefit of power factor improvement can be realize thus increasing energy saving through speed control. The process control involving the use of induction motor can also be improved.

Traditionally, the induction motor was operated directly from the grid with almost constant shaft speed. With the development of power electronic converter,

induction motor could now be controlled by variable frequency or variable speed drives (VFD). This means that by inserting a converter between the motor and the electrical grid, it is possible to obtain variable speed motor operation. Since the motor applications accounts for a large proportion of electrical energy consumption, VFD would contribute considerably in reducing the energy consumption.

1.2 Project Objectives

The objectives of this project are as follows

a) To study & analyze the energy saver power factor controller for induction motor using variable frequency drive (VFD)
b) To understand the characteristics of an induction motor
c) To understand the operation of VFD
d) To perform simulation on VFD using simulation software packages
e) To analyze the characteristic of Induction motor with VFD
f) To compare the result with the motor without VFD

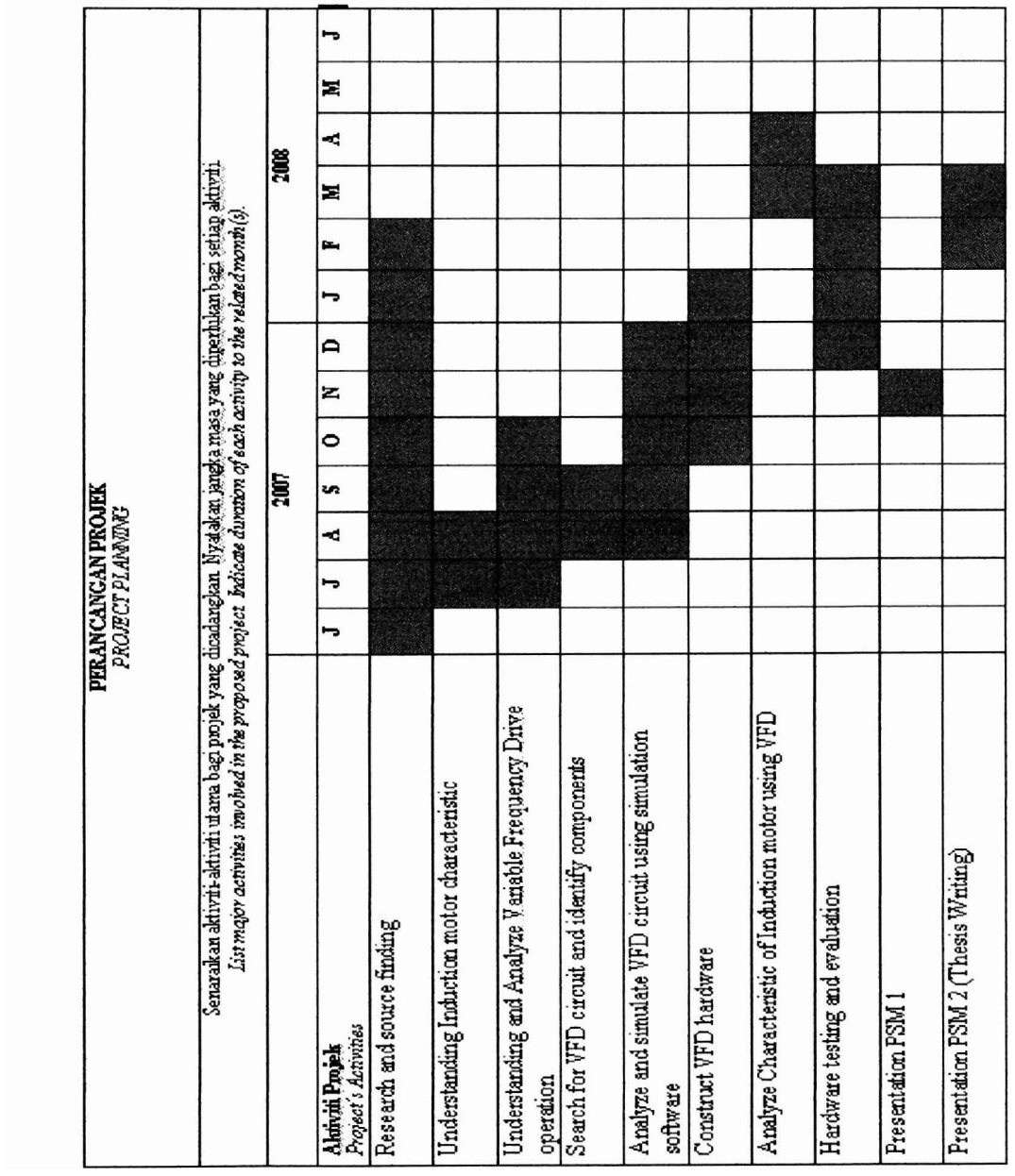
1.3 Project Scopes

This project covers the knowledge management of the previously studied Electrical Machine course which has been taken in the previous semester. The operation of induction motor and information on how it can save energy via speed control are studied. The main things to be done are to learn the VFD which consists of a rectifier, filter, inverter and controller.

The information of energy saving VFD is obtained through readings of books and journals and also internet resources. The electronic circuit of the drive (controller) is analyzed and simulates to obtained performance characteristics before proceeding to the hardware construction part.

This report will discuss about all the research that has been done including the basic theoretical part of the project in study. The basic theory of power factor, the basic characteristics of induction motor and introduction to VFD are included in the literature review. The expected future results of the project and comparisons of power factor performance of induction motor with and without VFD are also studied.

1.4 Project Planning



PERANCANGAN PROJEK *PROJECT PLANNING*																		
Senaraikan aktiviti-aktiviti utama bagi projek yang dicadangkan. Nyatakan jangka masa yang diperlukan bagi setiap aktiviti *List major activities involved in the proposed project. Indicate duration of each activity to the related month(s).*																		
		2007											2008					
Aktiviti Projek *Project's Activities*	J	J	A	S	O	N	D	J	F	M	A	M	J					
Research and source finding																		
Understanding Induction motor characteristic																		
Understanding and Analyze Variable Frequency Drive operation																		
Search for VFD circuit and identify components																		
Analyze and simulate VFD circuit using simulation software																		
Construct VFD hardware																		
Analyze Characteristic of Induction motor using VFD																		
Hardware testing and evaluation																		
Presentation PSM 1																		
Presentation PSM 2 (Thesis Writing)																		

Table 1 Project planning chart

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review is done by using references from books and online journal from IEEE and numerous author using web resources to further understand the research being performed. There are also references taken from the previously studied subject lecture note used in the preparation of this report.

2.2 Introduction to Power Factor

Power factor is the ratio of true power or watts (kW) to the apparent power or volt amperes (kVA). They are identical only when the current and voltage are in phase. Then the power factor will be 1.0. Power factor is a measure of how effective the current is converted into useful work output.

All current will cause loss in the supply and distribution system. A poor power factor can be the result of phase different between current and voltage at the load terminals or it can be due to harmonic distorted current waveform. The power in an alternating current (AC) circuit is seldom equal to the direct product of volts and amperes.

In direct current (DC) electrical circuit, power is a measure of the delivery rate of energy and expressed as the product of volts and amps. But in AC power system, AC currents may flow into and back out of the load without delivering energy. This current which is called the reactive current gives rise to apparent power ($Volt \times Amp$) which is larger than the actual power consumed. The difference between the apparent power and the true power gives rise to the power factor. Therefore the actual power in an AC system is the VA rating multiplied by the power factor.

The higher the percentage of reactive power (kVAR) results in the lower ratio of kW to kVA thus resulting in lower power factor. The relationship of kW, kVAR, and kVA is illustrated by the power triangle shown in figure 2.1.

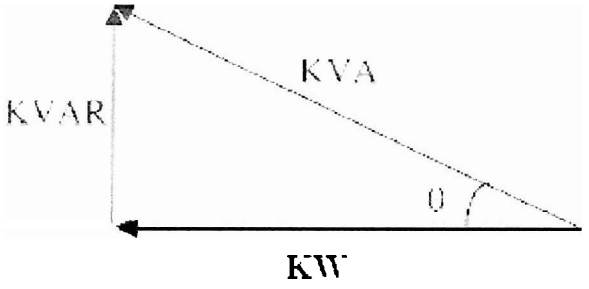


Figure 2.1: Power triangle

From the figure 2.1, the mathematical equations for the power factor is as followed

$$\text{power factor} = \frac{kW}{kVA} = \cos\theta \qquad (2.0)$$

Since power factor is defined as the ratio of true power to the apparent power, we see that low power factor results when the true power is small in relation to apparent power. Low power factor causes an increase in required apparent power. So, a facility with low power factor causes the utility to have to increase its generation and transmission capability in order to handle this extra demand. This would occur when the reactive power is large and the main cause of large reactive power is the inductive load.

Inductive load which are the source of reactive power includes the transformer, induction motor, and others.

Power factor improvement (unity power factor) is the goal of power electrical engineer. The benefits of improving power factor include:

a) Lower utility fees by reducing peak kW billing demand and eliminating the power factor penalty
b) Increased system capacity and reduces system losses in power system
c) Increased voltage level in electrical power system

2.3 Induction Motor

Induction motor is widely used in the industrial. It is the workhorse of the industrial. This fact is proved when 70% of industrial power consumption came from this kind of motor.

Brief history of induction motor can be understood by knowing the history of Nikola Tesla. He is one of the pioneers that invent the usage of field forces toward the operation of electrical motor. In 1882, he discovered the principle of magnetic field rotation. He later performs further research on the principle and manages to design a unique two-phase induction motor on the year of 1883. His invention has attracted many of intellectual at that time to further the researches which contribute a lot in today electric motor technology.

Tesla discovery of rotational magnetic field principle has opened a new sheet of motoring design when the new era of industrial revolution started in the year of 1888. This is proved through the ability and power of industry to improve the efficiency of electrical generation, transmission and distribution in a more far distance. Before Tesla contributed his thinking, motor operation are simply based on linear movement across

conductors on static magnetic field. In his research, he proposed that commutator which is normally used as conductors can be removed and replaced with other device that operates toward rotational magnetic field.

Later in 1889, Tesla's invention has been recognize and patented by the United State. His invention had become famous where the induction motor at that time being called electromagnetic alternating current motor.

Induction motor is one of the alternating current types of motors and has an endearing characteristic that it can be run by direct connection to a three phase power source. This type of motor is called induction because the rotor voltage which produced rotor current and rotor magnetic field is induced in the rotor windings. It is a singly fed motor which does not require commutator or brushes. An induction motor is like a rotating transformer where the source is only connected to the primary winding and the secondary winding receives energy through induction while it rotates. This means that there is no mechanical contact between the stator and the rotor.

Because of this induced rotor voltage, no DC field current is required to run the motor. The behavior of the motor depends on rotor voltage and current which relates to speed.

There are many advantages of induction motor compared to other types of motors. The advantages include:

i) High efficiency

   Induction motor can operate with high efficiency level. However, the motor ability to run efficiently depends on motor's rated parameters. Ratio of work must be suitable with the motor's rated power ratings.