STARTING AND SPEED CONTROL OF 2-PHASE INDUCTION MOTOR (SPLIT-PHASE INDUCTION MOTOR)

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May 2006

"Saya akui bahawa saya telah membaca karya ini dan pada pandangan saya karya ini adalah memadai dari skop dan kualiti untuk tujuan penganugerahan ijazah Sarjana Muda Kejuruteraan Elektrik (Kuasa Industri)."

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"Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya jelaskan sumbernya."

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Nama : Adrian Tham Tuck Man

Tarikh : 03 | 05 | 2006

To my dearest parents

For their continuous love, motivation, support and encouragement

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ABSTRACT

In the terms of cost for operation and maintenance, industries and commercial buildings, single phase induction motor are known to have the edge out of other types of motor which makes it much more preferable. In relation to this, a variety of variable speed drives have been applied to vary the speed of these induction machines. For this project, speed variation is being obtained by applying simple inverter topologies to vary the voltage applied to the single-phase induction motor using a pulse width modulation. The control is done by a voltage source PWM inverter which uses low power MOSFETs as low power transistors and because of the inverter design's low-cost topologies it could easily satisfy the market demand. The low power MOSFETs is configured in a H-brige which allows unipolar switching process. On the other hand, an IC gate drive (IR2184) would be applied to drive or switch the low power MOSFET's which content in the H-bridge circuit from off to on stage and vice versa. Utilization of the driver would generally provide a better form of alternative to the conventional speed control method whereby it eliminates mechanical wears due to frictions and so forth, costly expenses of components and mechanical parts and reduces bulky form factor (device sizing).

ABSTRAK

Dari segi faktor pengoperasian dan penyelenggaraan, sama ada dalam sektor perindustrian ataupun untuk bangunan-bangunan komersial, motor aruhan fasa tunggal mempunyai kelebihan yang nyata sekiranya dibandingkan dengan jenis-jenis motor yang lain. Selaras dengan itu, pelbagai jenis aplikasi litar pemandu kawalan halaju telah digunakan bagi mengawal kelajuan motor aruhan fasa tunggal sejak kebelakangan ini. Bagi projek ini, teknik kawalan halaju putaran motor yang dicadangkan adalah dengan menggunakan konsep litar penukar bagi mengawal voltan masukan motor aruhan fasa tunggal dengan menggunakan PWM ("pulse width modulation"). Kawalan dilakukan dengan membekalkan voltan masukan ke atas penukar PWM yang mempunyai empat MOSFET berkuasa rendah. Selain itu, kelebihan litar penukar dari segi faktor kos pula meningkatkan kemampuannya untuk memenuhi permintaan dan keperluan industri. MOSFET berkuasa rendah ini akan dipasang dalam bentuk H-bridge bagi membenarkan proses pensuisan satu polar. Di samping itu, pemandu get litar bersepadu akan digunakan bagi mengawal MOSFET berkuasa rendah yang terkandung dalam litar H-bridge tersebut. Perlaksanaan litar pemandu kawalan halaju ini akan menggantikan kaedah-kaedah kawalan halaju yang konvensional malah akan mengurangkan kepincangan jenis mekanikal akibat daripada daya geseran dan sebagainya, mengurangkan kos dari segi penggunaan komponen-komponen dan bahagian-bahagian mekanikal yang mahal dan akhir sekali bagi menggantikan litar-litar pemandu kawalan halaju motor yang bersaiz besar.

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LIST OF ABBREVIATIONS

AC	Alternating Current
DC	Direct Current
EMF	Electromagnetic Field
IC	Integrated Circuit
IEEE	Institute of Electrical and Electronics Engineer
IGBT	Insulated Gate Bipolar Transistor
MOSFET	Metal Oxide Silicon Field Effect Transistor
Op-amp	Operational Amplifier
PAM	Pole Amplitude Modulation
PIC	Programmable Interrupt Control
PWM	Pulse Width Modulation
SPIM	Single Phase Induction Motor

CHAPTER 1

INTRODUCTION

1.1 Introduction

For this project, the two-phase induction motor is actually a single-phase induction motor. However it is often referred as the two-phase when discussed about the three-phase system. In the three-phase system, the single-phase induction motor is connected with only two-phase (or two lines of three lines; main and auxiliary). That is why it is called the two-phase induction motor *[1]*.

The single-phase induction machine is known to be the most frequently used motor for refrigerators, washing machines, clocks, drills, compressors, pumps, and so on. In fact these single-phase induction machines are widely in many light duties applications for either commercial or domestic purposes where three-phase power supplies are not readily available in homes or remote areas.

Regardless that the single-phase induction motor may be inferior to the poly-phase (three-phase) induction motor due to its zero starting torque, higher torque harmony and bigger frame size, they are still used for small ratings. For this reason, the operation of these motors over a range of speeds as varied (variable speed) is necessary. Before this, the control of rotational speed for these motors are limited and normally only relies on inefficient and complicated mechanical and electrical techniques. Thus, these limited techniques requires expensive external parts and they are quite troublesome whereby mechanical switches for example are expose to mechanical wears which will affect the drives performance.

However, advancement in technology nowadays have widened the scope of variable speed drives whereby it enables the rapid employment of practical power electronic topologies. Regarding to this, inverter-fed motors are more reliable and have gained a lot of interest plus they also provide a promising way of energy saving. Thus, they are a more economical solution to the conventional variable speed drives.

1.2 Problem statement

Ever since the single-phase induction machine have been frequently and widely used among motor applications for everyday appliances such as refrigerators, washing machines, clocks, drills, compressors, pumps, and so on, it has overwhelmingly overcome problems that occurred from the fact that three-phase power supplies are still not readily available in certain homes or remote areas.

Besides that, the control of rotational speed for these motors are currently limited and normally only relies on inefficient and complicated mechanical and electrical techniques. These limited techniques requires expensive external parts and they are quite troublesome since it is known that mechanical switches for example are normally exposed to mechanical wears due to frictions and so forth which will eventually affect the drives performance.

On economical aspects, studies and research have been widely done on variable speed drives throughout the engineering societies in search for a reliable yet low cost topology which could be implemented in homes and the industries.

1.3 Project objective

The project title requires the design and development of a power electronic driver which is connected between the single-phase 50Hz mains and the two-phase motor through simulation and hardware implementation. The power electronic driver should be able to allow variable speed control of the motor by designing an H-bridge inverter circuit to vary the voltage applied to the single-phase induction motor using pulse width modulation (PWM).

1.4 Scope

The project requires designing and developing of a power electronic driver which includes simulation and also hardware design. Deliverables of the project would be a complete power electronic driver that meets the requirement of the project objective as listed in the previous sub-chapter. To allow variable speed control, an inverter is design to vary the voltage applied the single-phase induction motor using a pulse width modulation (PWM) In terms of limited cost, the inverter switch is suggested to be controlled by an analog controller because

i. It is costly
ii. The time frame associated with the project is limited (2 semesters) and the project would be out of the time frame if a microcontroller design is included

The constraint of the project is on the technical reference and implementation knowledge. Where the knowledge obtained through past lectures is insufficient especially on implementing the circuit design from simulation to hardware configuration. For this project, performance concern of the power electronic driver will not be included.

1.5 Project significant

The benefit that could be obtained from this project is that it allows speed variation for an induction motor of lower specification at places where the poly-phase induction motor of high specification aren't applicable or the three-phase power supply are unavailable from the utility whether for commercial or domestic use. Besides that, it also provides an alternative to the expensive and complicated conventional methods of speed control of the single-phase induction motor by replacing it with a simple power electronic drive which is in fact much more economical. At the same time, it eliminates disadvantages imposed by the conventional speed drives for example mechanical switches that are exposed to mechanical wears which would adversely affects the motor reliability. In terms on device sizing, it will eventually eliminate the use of bulky and large form factor types of variable speed drives. Basically, a great number of applications would also benefit from a single-phase induction motor driven from an adjustable speed controller.

1.6 Expected result

The expected result of the project is a power electronic driver (hardware) that meets the requirement of the project objectives listed for the project title. Besides that, the power electronic driver would provide a more economical alternative to the conventional drivers and at the same time capable of reducing starting current in the process and which contribute to power saving. However, performance concerns of the power electronic drive is not included for the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to complete this project, literature review and project methodology plays an important role during the early phase of the project development.The description of literature review is the process of searching, collecting, analyzing, comparing and to summarize a conclusion from all the material that have been read and study. The result later will be come in handy as a supportive reference for the project title. It is also a result of the compilation of a series of material from all kind of sources. The sources can be from all kinds of reading materials which include books, journals, technical reports, project/research papers and etc. For this project, the materials have been used are reference books, thesies ,project/research papers, and technical reports from the library, internet and organizational journals such as of IEEE. The details of the literature study and the project methodology is under the two sections below. All the reference that been use are approved by international bodies.

2.2 Facts and findings

This subtopic below describes in general about the project papers studied and also information on the related field of the project title.

2.2.1 Comparison of Variable Speed Drives of Single-Phase Induction Motors

Different possibilities of employing a single-phase induction motor in a variable speed drive are surveyed in this paper by Frede Blaabjerg, Florin Lungeanu, Kenneth Skaug, and Andreas Aupke from the Institute of Energy Technology of Aalborg University *[7]*. The paper states that the motor features prove to depend mostly on the elimination or keeping the running capacitor in series with the auxiliary winding, as well on the chosen voltage-frequency profile (in open-loop control). In fact that the market requirement for low-cost topologies affects the drive performance, and since that a capacitor-less motor appears to be the best solution, it still however requires higher voltage for the auxiliary winding. The permanent split-capacitor motor offers a good compromise if the V/Hz dependency is in accordance with the maximum efficiency or the minimum pulsating torque optimization criteria.

Besides that, inverter topologies suitable for low-cost, single-phase induction motor drive systems are analyzed and tested, both in simulations and experiments. It is concluded that the elimination of the running capacitor provides an advantage only if the stator asymmetry is smaller or inexistent, as is the case of the symmetrical motor. Therefore, by keeping the running capacitor in series with auxiliary winding and compensating for the increasing of its reactance at low speeds, may lead to a competitive solution in application areas with no tough demands for high performance, such as pumps and fans.

In conclusion, it states that there is not only one solution for the Single-Phase Induction Motor (SPIM). Despite that by eliminating the running capacitor will perform well only at low speed, increasing the speed limit being correlated with an increase in the drives cost and complexity. Consequently if the price aspect is less important than the performance of the drives then the capacitor-less solution should be chosen for driving the motor. However by keeping the running capacitor in the circuit provides an attractive solution since it does not require an increased output voltage capability for the drive which reflects in the dc link voltage level. Requirement of a supplementary inverter in considered reasonable and reduced ripple current through the dc capacitor is another advantage for the three-phase supply with or without the running capacitor in action.

By referring to the studies done on this paper it will make it much more comprehensive at the early stages of the project where the most suitable variable speed drive could be determined from the various selection of variable speed drives and since the project paper proposed requires the implementation of a supplementary component (capacitor) for motor starting, it states an idea on what to expect at the end of the project if the supplementary component is not eliminated from the auxiliary winding.

2.2.2 Torque and Slip Behavior of Single-Phase Induction Motors Driven from Variable frequency Supplies

E. Randolph Collins, Jr. of the Department of Electrical and Computer Engineering of Clemson University examines the operation of a single-phase induction motor when operated from a variable frequency power supply *[8]*. The motivation for this study is that it will show that the single-phase induction motor behaves quite differently than the three-phase induction motor at low frequencies and the ever-improving power semiconductor and microprocessor technology now make very dedicated, low power single-phase drive economically feasible. An adjustable-frequency drives have not been widely used with single-phase induction motors. However computations in this paper shows that, unlike the three-phase induction motor, the single-phase induction motor's slip is not constant with changes in frequency at a constant load torque. A constant volts-per-hertz law is found to provide nearly rated torque over a portion of the upper speed range, but the maximum available torque decays rapidly below about 50% of the base frequency.

Besides that, the behavior of the single-phase induction motor under variable-frequency operation is studied, providing insights to possible scalar control laws for optimizing performance at all speeds. Several possible open-loop control strategies are examined using computer simulations on a 0.5-hp single-phase induction motor. Experimental results show excellent agreement with the analysis and simulation. These experiments provide proof that an adjustable-frequency power supply can be used for speed control of the single-phase induction motor if the motor's unique operating characteristics are accounted for.

In conclusion, the paper proves that the single-phase induction motor can be