

PERFORMANCE CHARACTERISTICS OF INVERTER DRIVEN SYNCHRONOUS MOTOR

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JUDUL: **PERFORMANCE CHARACTERISTICS OF INVERTER
DRIVEN SYNCHRONOUS MOTOR**

SESI PENGAJIAN: 2008/2009

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**PERFORMANCE CHARACTERISTICS OF INVERTER DRIVEN
SYNCHRONOUS MOTOR**

MAHYUZIE BIN JENAL


A thesis submitted

**In fulfillment of the requirements for the award of the
Degree of Master of Electrical Engineering**

**Faculty of Electrical and Electronic Engineering
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MAY 2009

I declare that this report on “Performance Characteristics of Inverter Driven Synchronous Motor” is the result of my own project except for works which have been cited in the references. The report has not been accepted any degree and not concurrently submitted in candidature of any other degree.

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Date : MAY 2009

*For my dearest wife Nazalina,
My beloved sons M.Luqman Al-Hakim and M.Uwais Afiq,
My beloved daughters Nuraniqah Humaira and Nurqamarina Husna.*

ACKNOWLEDGEMENT

Alhamdulillah, all praise to Allah, the Most Beneficent and the Most Merciful, who has taught what I knew not. It is by the grace of the Almighty Allah that this project work has been completed successfully.

A deepest appreciation is dedicated to Prof Madya Dr Zainal Alam Bin Haron for his extraordinary patience and his enduring optimism. I really admire his knowledge, intelligence and patience. I do appreciate his dedicated guidance, suggestion, critical comments and warm support which have given me the opportunity to develop my research skills. I am blessed and honored to be his student.

Special thank and appreciation goes to all my lecturer friends especially Mr Suhaimi Saiman and Mr Md Zarafi Ahmad, technicians Mr Shamsudin Muslim and Mr Omar Salleh and others whose name could not be mentioned here one by one. Your encouragement, help and concern is greatly appreciated.

My warmest thanks go to my family for their ongoing encouragement and support.

Finally, I wish to thank everyone who has helped in one way or another towards the successful implementation of this project.

ABSTRACT

Three phase synchronous motor has a wide range of applications. Its constant-speed operation (even under load variation and voltage fluctuation) and high efficiency make it most suitable for constant-speed, continuous-running drives such as motor-generator sets, air compressors, centrifugal pumps, blowers, crushers and many types of continuous-processing mills. However, this motor is not a self-started type. There are many methods implemented in order to bring up the motor's speed to the required limit. One of the approaches is by using variable-frequency supply starter that is used in this project work. Realizing the importance of motor performance information in practice, this project aimed to carry out the standard motor tests and observe the characteristics. Two main methods are applied in this particular system where one of them is by running up the synchronous motor conventionally. "Prime mover" is coupled to the motor and drives it to the desired speed before supplying electrical sources. The other method is by using variable-frequency (inverter) supply connected to the synchronous motor and run the motor accordingly. A number of experiments are set up either with and without the inverter to analyze and compare their performance characteristics. The results are reported and discussed in this work.

ABSTRAK

Motor segerak tiga fasa memiliki aplikasi penggunaan yang sangat meluas. Operasi kelajuan yang tetapnya (walau pun beroperasi dibawah nilai beban yang pelbagai dan ketidakstabilan voltan) dan kecekapan yang tinggi membuatnya adalah yang paling sesuai bagi pemacu dari jenis kelajuan-tetap dan memerlukan operasi yang berterusan seperti set motor-penjana, pam empar, peniup, mesin penghancur dan lain-lain kategori industri yang berkaitan. Walaubagaimanapun, motor ini bukanlah dari jenis yang boleh digerakkan dengan hanya memberikan bekalan elektrik. Terdapat banyak kaedah yang digunakan untuk menggerak motor daripada keadaan rehat kepada tahap kelajuan yang dikehendaki. Salah satu daripadanya adalah dengan menggunakan bekalan pemula pembolehkan frekuensi yang juga telah digunakan didalam kerja ini. Atas kesedaran akan kepentingan motor segerak, tesis ini bermatlamat untuk melaksanakan beberapa ujikaji dan pemerhatian keatas karektor prestasinya. Dua kaedah telah digunapakai didalam sistem ini diman salah satu daripadanya adalah memacu motor secara konvensional. "Penggerak utama" disambung kepada motor dan memacunya kepada kelajuan yang dikehendaki sebelum sumber elektrik dibekalkan. Satu lagi kaedah adalah dengan menyambungkan bekalan pembolehkan frekuensi (penyongsang) kepada motor segerak dan memacunya. Beberapa set ujikaji dijalankan sama ada menggunakan penyongsang atau tidak telah dijalankan untuk menganalisis dan membandingkan karektor prestasi motor tersebut. Hasilnya telah diapor dan dibincangkan didalam kerja ini.

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LIST OF SYMBOLS/ ABBREVIATIONS**Symbols:**

| | | |
|----------------|---|-------------------------|
| μ | - | Micro (10^6) |
| Ω | - | Ohm |
| f | - | Frequency (<i>Hz</i>) |
| π | - | Pi (180) |
| ϕ | - | Flux |
| ω | - | Omega |
| φ | - | Phase displacement |
| δ | - | Torque angle |
| η | - | Efficiency |
| s | - | Slip |
| S | - | Apparent Power |
| R _a | - | Armature Resistor |
| T | - | Torque |
| n | - | Speed |
| m | - | mili (10^{-3}) |
| M | - | Mega (10^6) |
| I | - | Current |
| X _s | - | Synchronous Reactance |
| p | - | Pole |
| P | - | Power |
| A | - | Ampere |
| E | - | Generated Voltage |
| V | - | Voltage |
| t | - | Time |
| Z | - | Impedance |

Abbreviations:

| | | |
|----------|---|--|
| AC (a.c) | - | Alternating Current |
| DC (d.c) | - | Direct Current |
| e.m.f | - | Electric Magnetic Force |
| m.m.f | - | Magnetomotive force |
| LN | - | Lucas Nulle |
| KV | - | Kilo-Volt |
| IEEE | - | Electrical and Electronic Engineer |
| FKEE | - | Fakulti Kejuruteraan Elektrik & Elektronik |
| UTHM | - | Universiti Tun Hussein Onn Malaysia |
| VSI | - | Voltage Source Inverter |
| CSI | - | Current Source Inverter |
| VVVVF | - | Variable Voltage Variable Frequency |
| BJT | - | Bipolar Junction Transistor |
| TTL | - | Transistor-transistor Logic |
| MOS | - | Metal Oxide Semiconductor |
| CMOS | - | Complementary Metal Oxide Semiconductor |
| SCR | - | Silicon Controlled Rectifier |
| IGBT | - | Insulated Gate Bipolar Transistor |
| PWM | - | Pulse Width Modulation |
| THD | - | Total Harmonic Distortion |
| sync | - | Synchronous |
| ACC | - | Acceleration |
| DEC | - | Deceleration |

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CHAPTER II

LITERATURE REVIEW

This chapter will review past literature and discuss about operating characteristics of synchronous motor. The elements of speed control will be briefly discussed as well as the application for three phase synchronous motor. Finally, all the reviewed literature will be summarized.

2.1 Synchronous Motor

Synchronous means *to occur at regular or fixed intervals*. An AC Synchronous Motor is an electrical motor that rotates at a fixed speed, regardless of any increase or decrease in load. The motor will keep its fixed speed regardless of the torque required up until it reaches its stall torque rating. If the load becomes greater than the motor's stall torque, the AC Synchronous Motor will not slow down until it reaches a point at which it will stall and stop turning. The AC Synchronous motor is an effective way to obtain a fixed speed at a very low motor system cost [10]. No expensive driver or amplifier is

necessary. Most synchronous motors are used where precise timing and constant speed are required.

AC Synchronous Motors range in size from sub-fractional horsepower to over 10,000 horsepower. Smaller synchronous motors can be found in household devices such as clocks, timers, fans and cassette players, and as stepper motors in computer disk drives and printers. Larger synchronous motors are used in process industries and drive equipment such as compressors. Large synchronous motors most commonly employ a three-phase system. The smaller AC Synchronous Motors commonly use a single-phase system. The three-phase AC Synchronous Motor is the focus of this study.

Basically, according to the shape of the field, synchronous motor may be classified as cylindrical-rotor (non-salient pole) motor (Figure 2.1) and salient-pole machines (Figure 2.2).

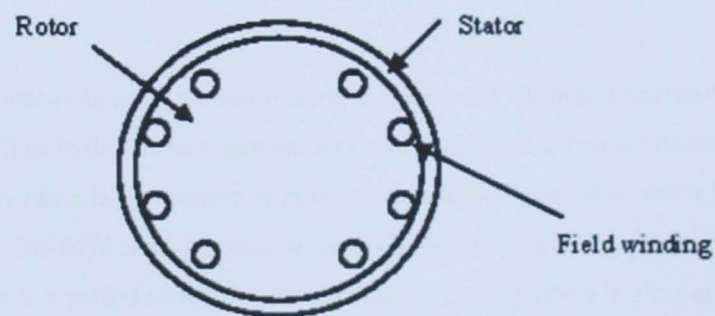


Figure 2.1: Basic construction of cylindrical-rotor synchronous motor type