# VARIABLE SPEED CONTROL OF 3 PHASE INDUCTION MOTOR (DL 1021) USING INVERTER (ABB 550-01-08A8-4)

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*To*

*Muslims*

*May Allah bless us all here and hereafter*

*-Al-fatihah-*

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# ACKNOWLEDGEMENT

In the name of Allah, The Most Gracious, The Most Merciful. Peace be upon the Messenger of Allah, Prophet Muhammad s.a.w, his companions (r.a) and followers until the end of day. Thanks to Allah, with His blessing, this final project is successfully delivered.

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Wassalam

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# ABSTRAK

Projek ini akan memberi fokus kepada membangunkan satu model simulasi mengenai kawalan kelajuan bagi satu penggerak motor induksi 3 fasa melibatkan gabungan kelajuan boleh ubah dan voltan boleh ubah (VVVF). Komponen utama bagi sistem yang dibangunkan ini terdiri daripada sebuah motor induksi 3 fasa (DL 1021) dan sebuah penukar 3 fasa keluaran ABB (ACS 550-01-08A8-4). Merujuk kepada motor induksi 3 fasa yang digunakan, parameter seperti $R_1$, $X_1$, $R_2$, $X_2$ dan $X_m$ ditentukan menggunakan ujian yang dijalankan iaitu ujian litar buka dan ujian litar tutup. Parameter yang lain seperti arus permulaan, daya kilas maksimum dan daya kilas kadaran ditentukan menggunakan gabungan persamaan matematik dan simulasi program MATLAB. Bagi gabungan kelajuan boleh ubah dan voltan boleh ubah (VVVF), penukar ABB akan memainkan peranan utama dalam menentukan aras voltan, aras frekuensi dan aras arus yang akan diterima oleh motor induksi 3 fasa dalam sistem ini. Maka, fokus pada bahagian penukar ABB ini adalah berkenaan dengan pemahaman konsep dan cara memasukkan data-data parameter yang diperlukan ke dalam penukar tersebut. Di akhir projek ini, sebuah manual akan dibangunkan berkenaan gabungan kelajuan boleh ubah dan voltan boleh ubah (VVVF) bagi sistem ini.

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# ABSTRACT

This project will focus on developing a simulation model of variable speed, variable voltage for an induction motor drive. The main component of this system consists of a 3-phase induction motor (DL 1021) and a 3-phase ABB inverter (ACS 550-01-08A8-4). Based on the actual 3-phase induction motor (DL 1021), the parameters such as $R_1$, $X_1$, $R_2$, $X_2$ and $X_m$ is defined using certain tests which are open and short circuit test. Using mathematical equations and MATLAB simulation, others parameter such as starting current, maximum torque and rated torque will also are defined. For variable voltage variable frequency (VVVF), the ABB inverter will play a major role. Inverter section determines the voltage level, frequency level and the current level that a motor receives in order to control the motor speed. So, the inverter section will focus on the concepts study and parameter setting of an ABB inverter. Finally, this project will develop a simple manual of variable speed control system.

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# LIST OF CONTENT


| CHAPTER | TITLE | | PAGE |
|---|---|---|---|
| | SUPERVISOR"S VERIFICATION | | |
| | TITLE PAGE | | i |
| | CONFESSION | | ii |
| | DEDICATION | | iii |
| | ACKNOWLEDGEMENT | | iv |
| | ABSTRAK | | v |
| | ABSTRACT | | vi |
| | LIST OF CONTENT | | vii |
| | LIST OF TABLE | | xi |
| | LIST OF FIGURE | | xii |
| | LIST OF ABBREVIATION | | xv |
| | LIST OF APPENDIX | | xvi |
| I | INTRODUCTION | | |
| | 1.1 | Project Overview | 1 |
| | 1.2 | Project Objectives | 2 |
| | 1.3 | Problem Statements | 3 |
| | 1.4 | Project Scopes | 3 |
| | 1.5 | Expected Results | 4 |
| II | LITERATURE REVIEW | | |
| | 2.1 | Introduction | 5 |
| | 2.2 | Induction Motor Speed Control Methods | 5 |
| | | 2.2.1 Speed Control By Pole Changing | 6 |
| | | 2.2.2 Speed Control By Line Frequency Changing | 6 |


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| | | | |
|---|---|---|---|
| | | 2.2.3 Speed Control By Line Voltage Changing | 6 |
| | | 2.2.4 Speed Control By Rotor Resistance Changing | 7 |
| | 2.3 | Comparison Between AC And DC Drives | 7 |
| | 2.4 | Speed Control Using VFD | 8 |
| | | 2.4.1 Frequency Adjustment | 9 |
| | | 2.4.2 Voltage And Frequency Patterns | 9 |
| | | 2.4.2.1 General-Purpose Pattern | 10 |
| | | 2.4.2.2 High Starting Torque Pattern | 10 |
| | | 2.4.2.3 Low Starting Torque Pattern | 11 |
| | | 2.4.3 Independently Adjustable Acceleration And Deceleration Ramps | 12 |
| | | 2.4.4 Motor Protection | 12 |
| III | THEORY | | |
| | 3.1 | Introduction | 13 |
| | 3.2 | Induction Motor | 14 |
| | | 3.2.1 Construction Of An Induction Motor | 16 |
| | | 3.2.2 Rotor Rotation | 18 |
| | | 3.2.3 Basic Induction Motor Concepts | 20 |
| | | 3.2.4 Equivalent Circuit Of An Induction Motor | 21 |
| | | 3.2.5 Rotor Circuit Model | 23 |
| | | 3.2.6 Final Equivalent Circuit | 24 |
| | | 3.2.7 Power And Torque In Induction Motor | 26 |
| | | 3.2.8 Induced Torque Equation | 29 |
| | 3.3 | Inverter | 32 |
| | | 3.3.1 Voltage Source Inverter (VSI) | 32 |
| | | 3.3.2 Rectifier, Filter And Inverter | 33 |
| | | 3.3.3 Inverter Control | 34 |
| | | 3.3.3.1 Basic PWM Technique | 34 |
| | | 3.3.3.2 Three Phase Sinusoidal PWM VSI | 37 |


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| | | | |
|---|---|---|---|
| IV | METHODOLOGY | | |
| | 4.1 | Project Phases | 43 |
| | 4.2 | Gantt Chart | 46 |
| | 4.3 | Tests | 47 |
| | | 4.3.1 DC Test | 48 |
| | | 4.3.2 No-load Test | 49 |
| | | 4.3.3 Blocked-rotor Test | 51 |
| | 4.4 | Software | 54 |
| | | 4.4.1 MATLAB Software | 54 |
| | | 4.4.1.1 Compile A Torque-speed Characteristic Curve | 56 |
| | | 4.4.1.2 MATLAB M-file | 59 |
| | | 4.4.2 MATHCAD Software | 61 |
| | | 4.4.3 DRIVE WINDOW LIGHT 2 Software | 64 |
| | | 4.4.3.1 Parameter Browser | 65 |
| | | 4.4.3.2 Drive Status | 66 |
| | | 4.4.3.3 Control Panel | 67 |
| | | 4.4.3.4 Drive Monitoring | 68 |
| | | 4.4.3.5 Monitor Settings | 69 |
| | | 4.4.3.6 Parameter Subset Selection | 71 |
| V | RESULTS AND CALCULATION | | |
| | 5.1 | Introduction | 72 |
| | 5.2 | Results And Calculation Of Induction Motor Test | 73 |
| | | 5.2.1 Test Results | 73 |
| | | 5.2.2 Parameter Calculation | 73 |
| | | 5.2.3 Per-phase Equivalent Circuit | 75 |
| | | 5.2.4 Thevenin Equivalent Circuit | 76 |
| | 5.3 | Results Of MATLAB Simulation | 78 |
| | | 5.3.1 VVVF | 78 |
| | | 5.3.2 VVFF | 81 |


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| | | | |
|---|---|---|---|
| | | 5.3.3 VFVF | 83 |
| | 5.4 | Results From Drive Window Light 2 | 85 |
| | | 5.4.1 Torque | 85 |
| | | 5.4.2 Speed | 86 |
| | | 5.4.3 Current | 87 |
| | | 5.4.4 Voltage | 88 |
| VI | ANALYSIS AND DISCUSSION | | |
| | 6.1 | Introduction | 89 |
| | 6.2 | VVVF Torque-speed Characteristics | 89 |
| | 6.3 | VVFF Torque-speed Characteristics | 90 |
| | 6.4 | VFVF Torque-speed Characteristics | 90 |
| | 6.5 | Torque Versus Time | 91 |
| | 6.6 | Speed Versus Time | 92 |
| | 6.7 | Current Versus Time | 92 |
| | 6.8 | Voltage Versus Time | 93 |
| VII | CONCLUSION AND SUGGESTION | | |
| | 7.1 | Conclusion | 94 |
| | 7.2 | Suggestion | 95 |
| | REFERENCES | | 96 |
| | APPENDIX | | 97-106 |


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# LIST OF TABLE


| NO | TITLE | PAGE |
|---|---|---|
| 2.1 | Comparison between AC and DC drives | 7 |
| 4.1 | Induction motor‟s parameters | 47 |
| 4.2 | Software and its usage | 54 |
| 4.3 | Voltage and frequency relationship of VVVF | 56 |
| 4.4 | Voltage and frequency relationship of VVFF | 57 |
| 4.5 | Voltage and frequency relationship of VFVF | 58 |
| 4.6 | Icons of the Math Toolbar | 62 |
| 4.7 | Icons of the Control panel Toolbar | 67 |
| 4.8 | Icons of the Drive Monitoring Toolbar | 68 |
| 4.9 | Monitoring Settings | 69 |
| 5.1 | Test results | 73 |
| 5.2 | Induction motor‟s parameters | 75 |
| 5.3 | Thevenin circuit parameters | 77 |
| 5.4 | Torque for different frequency | 85 |
| 5.5 | Speed for different frequency | 86 |
| 5.6 | Current for different frequency | 87 |
| 5.7 | Voltage for different frequency | 88 |


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# LIST OF FIGURE


| NO | TITLE | PAGE |
|---|---|---|
| 1.1 | Variable speed control of a blower system | 2 |
| 2.1 | General purpose pattern | 10 |
| 2.2 | High starting torque pattern | 11 |
| 2.3 | Low starting torque pattern | 12 |
| 3.1 | Induction motor | 14 |
| 3.2 | Stator of an induction motor | 16 |
| 3.3 | Rotor of an induction motor (Squirrel cage type) | 17 |
| 3.4 | Rotor of an induction motor (Wound type) | 17 |
| 3.5 | Rotor rotation (1) | 18 |
| 3.6 | Rotor rotation (2) | 19 |
| 3.7 | Rotor rotation (3) | 19 |
| 3.8 | Transformer model of an induction motor | 22 |
| 3.9 | (a) Rotor circuit model of an induction motor<br>(b) Rotor circuit model with all frequency (slip) effects concentrated in resistor, $R_R$ | 23 |
| 3.10 | The per-phase equivalent circuit of an induction motor | 25 |
| 3.11 | Power flow diagram of an induction motor | 26 |
| 3.12 | Thevenin equivalent voltage | 29 |
| 3.13 | Thevenin equivalent impedance | 30 |
| 3.14 | Simplified equivalent circuit of an induction motor input circuit | 31 |
| 3.15 | Basic Variable Voltage Variable Frequency (VVVF) circuit | 33 |
| 3.16 | Rectifier, Filter and Inverter | 33 |
| 3.17 | Triangular wave (carrier) | 35 |


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| | | |
|---|---|---|
| 3.18 | Sine wave (modulating) | 35 |
| 3.19 | Comparison between carrier signal and modulating signal | 36 |
| 3.20 | PWM waveform | 36 |
| 3.21 | 3-phase Sinusoidal PWM Voltage Source Inverter | 37 |
| 3.22 | Repeating sequence | 38 |
| 3.23 | 3 sinusoidal references waves | 39 |
| 3.24 | Comparison between carrier signal and 3 sinusoidal references waves | 39 |
| 3.25 | Comparison between carrier signal and 3 sinusoidal references waves (close up) | 40 |
| 3.26 | PWM waveform for 1st sine wave | 40 |
| 3.27 | PWM waveform for 2nd sine wave | 41 |
| 3.28 | PWM waveform for 3rd sine wave | 41 |
| 3.29 | Output voltage (line to line) | 42 |
| 4.1 | Project phases | 43 |
| 4.2 | Gantt Chart | 46 |
| 4.3 | Per-phase equivalent circuit | 47 |
| 4.4 | Test circuit for DC test | 48 |
| 4.5 | DC test equivalent circuit | 49 |
| 4.6 | Test circuit for No load test | 49 |
| 4.7 | No-load test equivalent circuit | 50 |
| 4.8 | Simplified No-load test equivalent circuit | 51 |
| 4.9 | Test circuit for Blocked-rotor test | 51 |
| 4.10 | Blocked-rotor test equivalent circuit | 52 |
| 4.11 | Simplified Blocked-rotor test equivalent circuit | 52 |
| 4.12 | MATLAB window | 55 |
| 4.13 | M-file window | 55 |
| 4.14 | Voltage versus frequency for VVVF | 56 |
| 4.15 | Voltage versus frequency for VVFF | 57 |
| 4.16 | Voltage versus frequency for VFVF | 58 |
| 4.17 | Example of initializing values needed in the program | 59 |
| 4.18 | Calculate the Thevenin voltage ($V_{TH}$) and impedance ($Z_{TH}$) | 60 |


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| | | |
|---|---|---|
| 4.19 | Torque calculation and torque speed characteristic plot | 60 |
| 4.20 | MATHCAD window | 61 |
| 4.21 | Math Toolbar | 62 |
| 4.22 | Drive Window Light 2 window | 64 |
| 4.23 | Parameter Browser window | 65 |
| 4.24 | Drive Status | 66 |
| 4.25 | Monitoring Settings window | 69 |
| 4.26 | Parameter Subset Selection window | 71 |
| 5.1 | Per-phase equivalent circuit | 76 |
| 5.2 | Thevenin equivalent circuit | 77 |
| 5.3 | VVVF torque-speed characteristic curves | 80 |
| 5.4 | VVFF torque-speed characteristic curves | 82 |
| 5.5 | VFVF torque-speed characteristic curves | 84 |
| 5.6 | Torque versus time | 85 |
| 5.7 | Speed versus time | 86 |
| 5.8 | Current versus time | 87 |
| 5.9 | Voltage versus time | 88 |


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# LIST OF ABBREVIATION

| | |
|---|---|
| AC | - Alternate Current |
| DC | - Direct Current |
| DOL | - Direct On Line |
| EMF | - Electromagnetic Field |
| PSM | - Projek Sarjana Muda |
| PWM | - Pulse-Width Modulated |
| RPM | - Rotation Per Minute |
| TNB | - Tenaga Nasional Berhad |
| UTeM | - Universiti Teknikal Malaysia Melaka |
| VFD | - Variable Frequency Drive |
| VFVF | - Voltage Fix Variable Frequency |
| VSI | - Voltage Source Inverter |
| VVFF | - Variable Voltage Fix Frequency |
| VVVF | - Variable Voltage Variable Frequency |

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# LIST OF APPENDIX


| NO | TITLE | PAGE |
|---|---|---|
| A | Manual of variable speed control of 3-phase induction motor using an ABB inverter | 97-106 |


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# CHAPTER I

# INTRODUCTION

## 1.1 Project Overview

Nowadays, induction motor is used widely in the industrial and domestic sector because of it advantages if compared to Direct Current (DC) motor such as induction motor use Alternate Current (AC) power source to be function which is identical with the power source supplied by the utilities company, Tenaga Nasional Berhad (TNB). It is tough in many applications used and also cheaper. The widely usage of induction motors can be approved because statistic of load shows that merely 70% of load used is contributed by induction load.

Even though induction motor is widely used, there are many type of load connect to it which is indicate that different kind of load will influence the speed controlling method and the speed needed by the motor. However, the method is suggested after the cost effectiveness and how the induction motor will be use is being considered.

This project basically about controlling the speed of a 3-phase induction motor variably, in this case the DL1021 and the mechanism used to control the speed is by using a 3-phase ABB inverter (ACS 550-01-08A8-4) which is a Low Voltage AC Drives.

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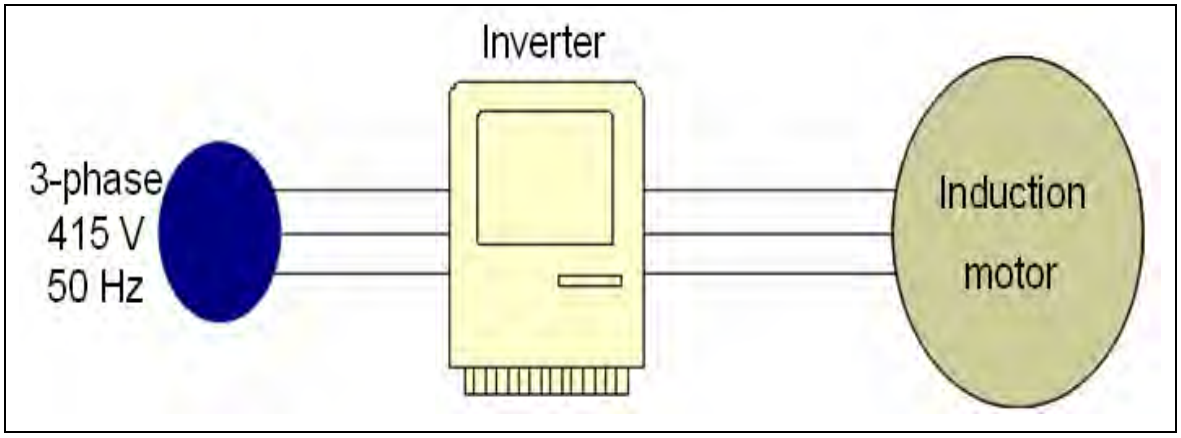


Figure 1.1: Variable speed control of a blower system

## 1.2 Project Objectives

The main objectives of performing this project are:

- To model the per-phase equivalent circuit of a 3-phase induction motor used in this project (DL 1021).
- To simulate the characteristics of the 3-phase induction motor such as starting current, maximum torque and rated torque by using MATLAB or MATHCAD software.
- To study the concept and operation of a 3-phase ABB inverter used in this project (ACS 550-01-08A8-4) and apply it to the speed control system.
- To develop a manual of variable speed control operation

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## 1.3 Problem Statements

Problems which have been known for this project are:

- A high starting current is needed with limited range of speed if using the Direct on Line (DOL) in order to start and controlling the speed of a 3-phase induction motor.
- There is no proper set of experimental instrument in Universiti Teknikal Malaysia Melaka (UTeM) about controlling the speed of a 3-phase induction motor variably using an inverter such as ABB inverter. So, this project will provide a proper and simple experimental manual with a complete education references including simulation and hardware settings of variable voltage variable frequency (VVVF) speed control system.

## 1.4 Project Scope

Project scope is limitation that being considered in order to perform this project. There are:

- This project only considered a 3-phase induction motor (DL 1021) and a Low Voltage AC Drives which is a 3-phase ABB inverter (ACS 550-01-08A8-4).
- Tests that being execute to the 3-phase induction motor are DC test, No-load test and Blocked Rotor test to produce the per-phase equivalent circuit.
- Using MATLAB software in order to simulate the torque-speed characteristics of the 3-phase induction motor.
- The torque-speed characteristic under consideration is only the VVVF.
- Study the ABB inverter manual provided by the manufacturer in terms of concepts, operation and data setting.

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## 1.5 Expected Results

The final results which are being expected are:

- An operational and stable variable speed control system of VVVF of 3-phase induction motor system is developed.
- A proper, simple experimental manual and a complete education references including simulation and hardware settings of VVVF will be produce.
- The manual produced can be used as a short term syllabus for the future usage in a related field such as Electric Machine subject.

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# CHAPTER II

# LITERATURE REVIEW

## 2.1 Introduction

Literature review is conducted in order to achieve project objectives. The main chapter under consideration is about controlling the speed of 3-phase induction motor variably using an AC drive.

## 2.2 Induction motor speed control methods

In point of fact, speed controlling application is not suitable for an induction motor because the normal operating range of typical induction motor is confined to be less than 5% slip, and the speed variation over that range is more or less directly proportional to the load on the shaft of the motor [1]. This is because induction motor efficiency will be low if slip is high due to larger rotor copper losses. However, before a modern solid-state drive is introduce, 2 major techniques in controlling speed of an induction motor are used:

1. Vary the synchronous speed (stator and rotor magnetic speed) by changing electrical frequency and changing number of poles on the machine.
2. Vary the slip by varying the rotor resistance or varying the terminal voltage of the motor.

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### 2.2.1 Speed control by pole changing

Scheme for pole changing are method of consequent poles and multiple stator windings. The method of consequent poles can be done via changing numbers of poles in the stator windings of an induction motor by a factor of 2:1 through simple changes in coil connection. Using this method, a winding with two stator magnetic poles will has four magnetic poles which are twice as before. However, this method disadvantage is that ratio 2:1 is an obligation. In order to conquer the inconvenience ratio of 2:1, multiple stator windings can be employed. Regrettably, this choice adds the expense of the motor and can only be energize a set at a time.

### 2.2.2 Speed control by line frequency changing

As we know, the rate of rotation of magnetic field is directly proportional to electrical frequency. So, when frequency is varying, the speed can be adjusted either above or below the base speed. Due to safety issue, it is vital to maintain certain voltage and torque limits by reduce the terminal voltage when running below the base speed called *derating I*f it is not done, the steel in the core of the induction motor will saturate and excessive magnetization currents will flow in the machine [1]. Next, maintain the rated voltage supply to the stator when running above the base speed to protect the winding insulation of the motor.

### 2.2.3 Speed control by line voltage changing

Induction motor torque is proportional to the square of applied voltage. By using this varying the line method, the speed can only be controlled over a limited range after taken into consideration the load torque-speed characteristic.

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### 2.2.4 Speed control by rotor resistance changing

Torque-speed curve of a wound rotor induction motor can be change by inserting extra resistance into the rotor circuit. Because of efficiency reduced if using this method, it is normally applied for only short periods.

## 2.3 Comparison between AC and DC drives.

There are 2 types of drives in the market, AC drive and DC drive. This project will be using an AC drive rather than a DC drive because of its advantages. Comparison between AC drive and DC drive are stated below:

Table 2.1: Comparison between AC and DC drives

| AC drive | DC drive |
|---|---|
| They use conventional, low cost, 3-phase AC induction motors for most applications | DC drives are less complex with a single power conversion from AC to DC. |
| AC motors are smaller, lighter, more commonly available, and less expensive than DC motors. | DC drives are normally less expensive for most horsepower ratings. |
| Whenever the operating environment is wet, corrosive or explosive and special motor enclosures are required. Special AC motor enclosure types are more readily. Available at lower prices. | DC motors have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose. |
| Multiple motors in a system must operate simultaneously at a common frequency / speed. | Cooling blowers and inlet air flanges provide cooling air for a wide speed range at constant torque. |

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