Palestine Polytechnic University

College of Engineering and Technology
Electrical and Computer Systems Engineering Department

Graduation Project

Design And Build A Treadmill Machine

Project Team

Ali M. Arouri

Mohammad I. Arouri

Supervisor

Dr. Sameer Khader

Hebron-Palestine
June 2011

جامعة بوليتكنك فلسطين
الخليل- فلسطين
كلية الهندسة و التكنولوجيا
دائرة الهندسة الكهربائية و الحاسوب

اسم المشروع

Design And Build A Treadmill Machine

أسماء الطلبة

علي مصطفى العروري   محمد عيسى العروري

بناء على نظام كلية الهندسة و التكنولوجيا و إشراف و متابعة المشرف المباشر على المشروع و موافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى دائرة الهندسة الكهربائية و الحاسوب و ذلك للوفاء لمتطلبات درجة البكالوريوس في الهندسة تخصص الأتمتة الصناعية.

توقيع المشرف

....

توقيع اللجنة الممتحنة

....

توقيع رئيس الدائرة

....

Design And Build A Treadmill Machine

Project Team

Mohammad I. Arouri **Ali M. Arouri**

Supervisor

Dr. Sameer Khader

Graduation Project

Submitted to Electrical and Computer Systems Engineering Department

College of Engineering and Technology

Palestine Polytechnic University

In Partial Fulfillment for the Degree of Bachelor in Industrial Automation Engineering

Palestine Polytechnic University
Hebron-Palestine
May, 2011

Dedication

We dedicate this project to:

Our Beloved Country….

Palestine

Our heroes….

Martyrs and Prisoners

To our Parents

To our Friends

Acknowledgment

Special thanks to our supervisor
Dr .Sameer Khader

Special thanks to our department chairman
Dr. Ramzi Al Qawasmi

Special thanks to the instructors in the department of electrical and computer systems engineering; especially for Dr. Abdel-Kareem DauodAnd Eng. Fayez Abu Ghalyon.

Special thanks to all employees of Palestine Polytechnic University who gave us any kind of help.

Table of Contents

<u>Chapter Three: Conclusion and Recommendation</u>

Appendices

List of Tables

List of Figures

CHAPTER ONE

1.1 Forward

1.2 Project Aim

1.3 Structure of the Machine

1.4 Previous Studies

Abstract

This project describes the design of a Treadmill machine that can be found in widespread applications in health and fitness centers. The design approach concerns with converting a conventional machine (pure mechanical system) into an electromechanical system with the possibility to change the machine velocity . The front panel of the machine illustrates velocity, time, and distance.

The designed model consist of : frequency converter, three-phase motor, control panel, protection circuits, and mechanical body.

The designed model has been simulated using matlab simulink with purpose to observe how the speed, torque behave as the frequency changes. The obtained model presents good results and fulfills the customer needs .

The system has been designed, simulated and practically implemented.

1.1 Forward

Many techniques are adopted for doing sport exercises , now a days companies tried to develop new machines for home sport , one of these machines is **TREADMILL** machine. Treadmill machine is a device used for running, it is offered in many shapes due to the companies providing it.

One of this types is the manual treadmill, it works manually (no motor, no power), this type depends on the person speed , it contains mechanical dampers , the main advantage in this type is that the need for power here is not exist. But here there are several disadvantages : firstly it has no weight measurement device, and it is hard to work on since that the tiered people cant practice running on it because it need more effort for the manual motion.

Here the need for the electrical treadmill appear , the electrical types depends in general on electrical motors , these machines is provided in market but they are very expensive and most of them are not a complete systems that means they haven't a safety system and most of them have no weight measurement .

There are two covers will be covered in this project :

- Electrical .
- Mechanical.

The system will work by 220 v ac , 50 Hz.

1.2 Project aim

The project aims to :

1. Use the new technology in our application which is a frequency converter.
2. To design this system with high efficiency and low cost.

1.3 Structure of the machine

Treadmill machine is a combination of many electrical and mechanical components such as ; ac Induction Motor , conveyor , deck , roller , belt …etc, these component and others are shown on the following figure :

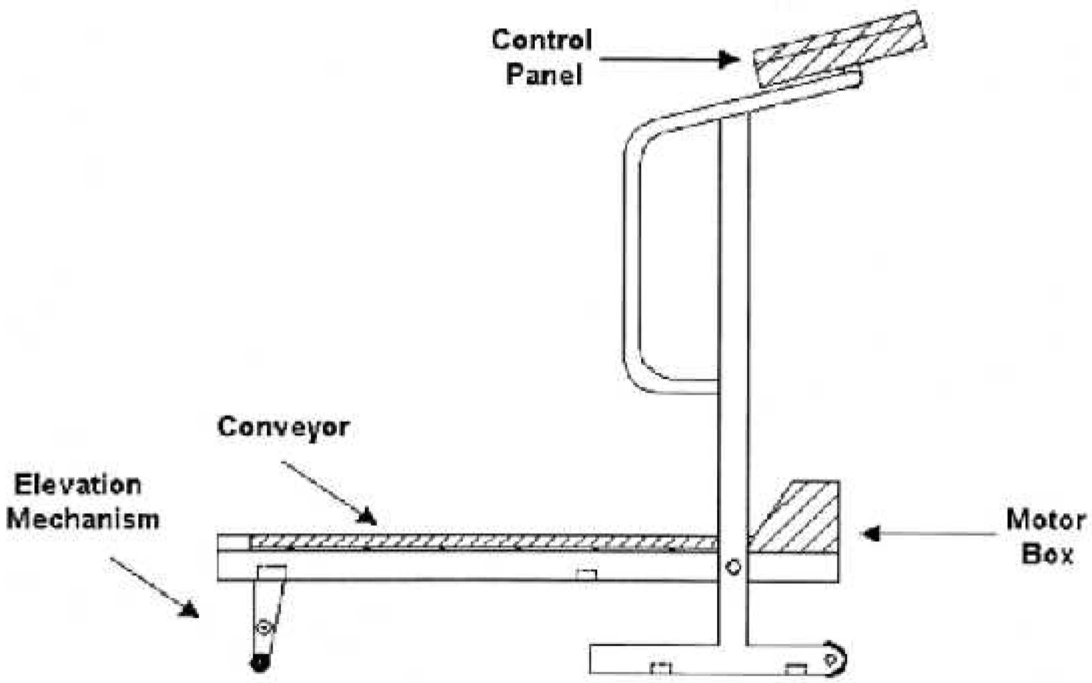


Fig. 1.1 Treadmill Machine Body

1.4 Previous studies

Given the fact that this project is a collection of more than one field , so we must depend on some of previous studies in mechanical design , controlling of IM , protection methods , and some other fields that we discussed in our project , then here abstract for some of these studies :

> One of these studies is a practical and theoretical study that deals with the impulse forces which will appear in the running process on Treadmill machine and how to analyze this force in the dynamic motion equation.
> another study deals about "Exploring Dynamic Similarity in Human Running Using Simulated Reduced Gravity".

The following table contain the final budget of the project , and it contains the main elements with there prices.

Table 1.1

The element type	**Quantity**	**Cost/Qty**	**Price of units**
Induction motor	**1**	**100$**	**100$**
Frequency converter	**1**	**380$**	**380$**
Switches & wires	**-**	**-**	**50$**
Body & mechanical equipment	**-**	**100$**	**100$**
Over load	**1**	**30$**	**30$**
The total cost is 660$			

CHAPTER TWO

2.1 Block Diagram

2.2 Flow Chart

2.3 Main Elements

2.4 Calculations and Analysis

2.5 MATLAB Simulink

2.1 Block Diagram of the system

The mechanism of the system operation is viewed in the block diagram with the main elements . and here are the main blocks :

1- Power supply : which is the electrical source.
2- Main switch : it is on/off switch fixed on the control panel .
3- Protection switch : it is for protection from the high currents , and it is fixed beside the frequency converter on the box.
4- Frequency Converter : it is the controller device and it is explained in chapter two.
5- Three phase induction motor : it is explained in the following chapter too.
6- Speed sensor : it is a magnetic sensor fixed on the pully and it is connected with the control panel.

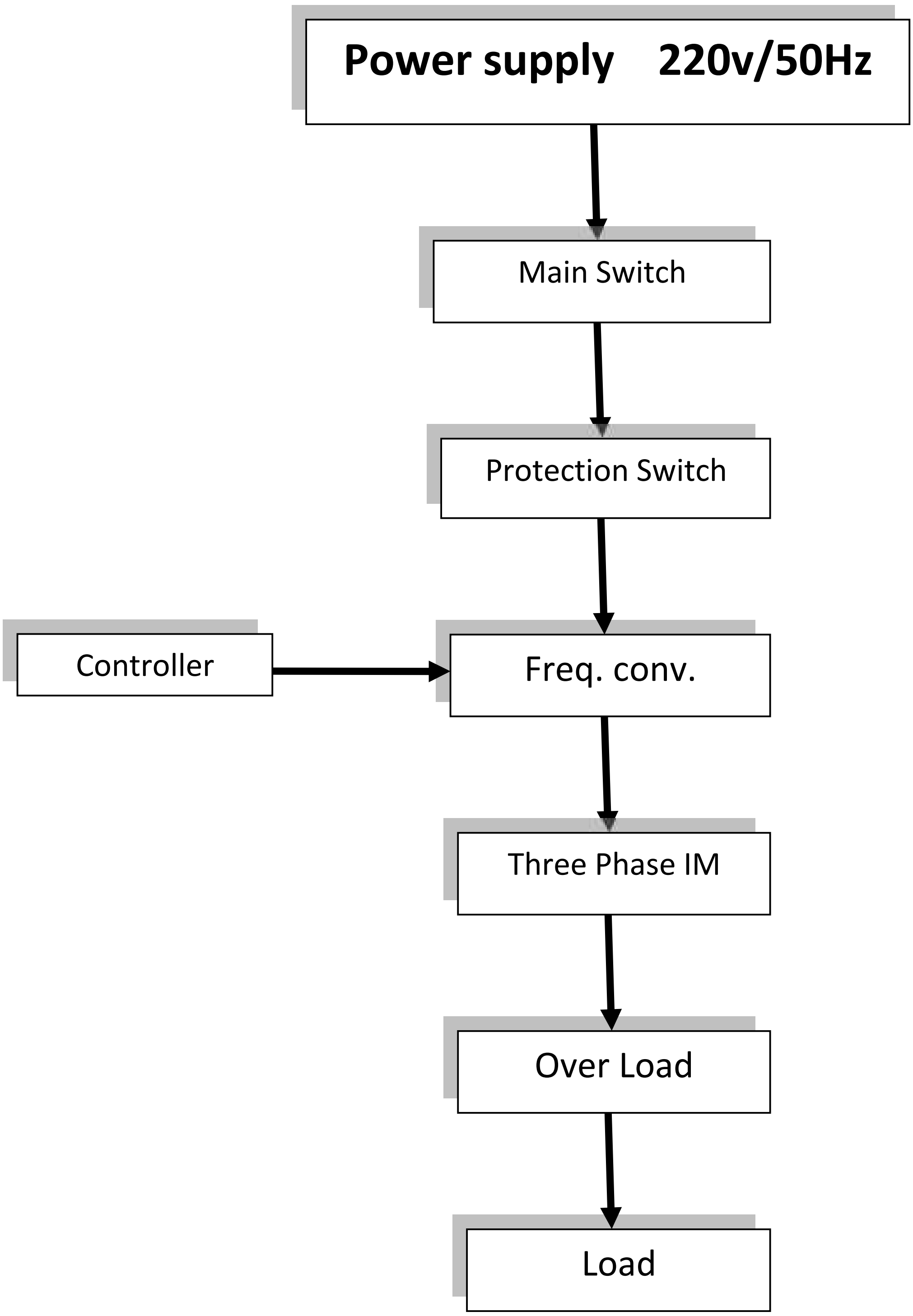


Fig. 2.1 Block Diagram of the System

2.2 Flow Chart of the system

The flow chart in the following page display the behaves of the system , and it is as follows :

After supplying the system with power source set the main switch ON , the protection switch should be ON. If the protection switch on ; the frequency converter will operate , then the frequency converter will operate the motor functionally with the controller.

You can turn OFF the system by switching the main switch OFF.

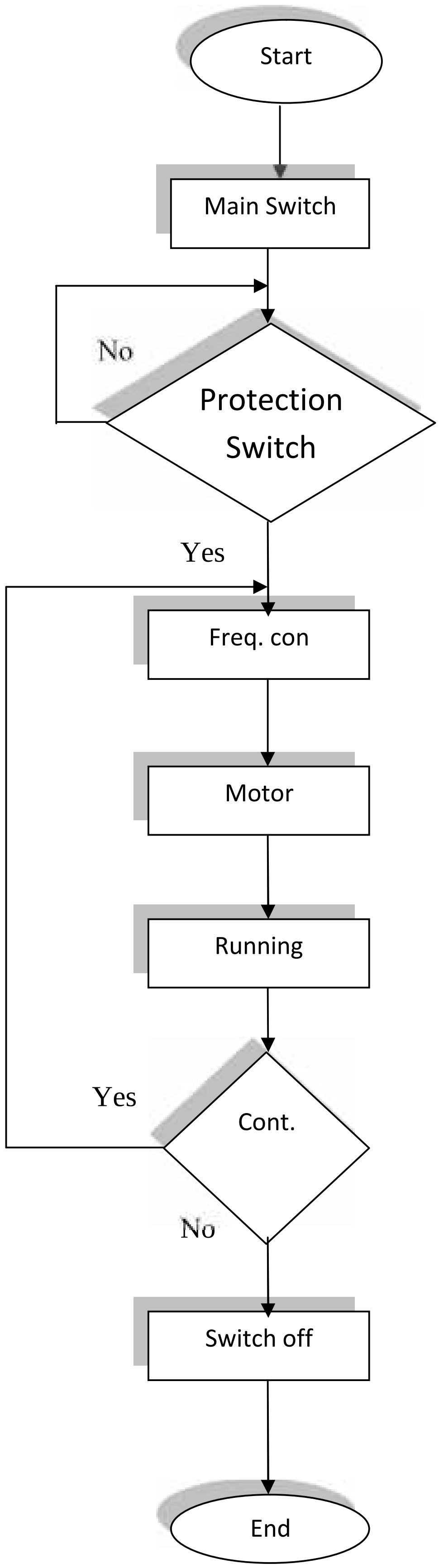

Start
Main Switch
No
Protection Switch
Yes
Freq. con
Motor
Running
Yes
Cont.
No
Switch off
End

Fig. 2.2 Flow Chart of the system

2.3 Main Elements

The main elements of the project are :

- Mechanical body of manual Treadmill machine.
- Three phase induction motor.
- Frequency Converter.
- Belt and Pulley.
- LCD display.
- Switches and wires.

2.3.1 Mechanical Body

The mechanical body we used was for a manual Treadmill machine , so it wasn't ready for electrical design . Because of that we worked on it and Grinded for the belt. And we fixed a new conveyor because the old was damaged. Then we removed some appendices which are not needed. The dimensions of the machine is :

50 * 135 * 120 cm

50cm : the width of the Treadmill

135cm : the tall of the Treadmill

120cm : the high .

The weight of the mechanical body is nearly 35 Kg.

2.3.2 Three Phase Induction Motor

2.3.2.1 Introduction

AC induction motors are the most common motors used in industrial motion control systems, as well as in main powered home appliances. Simple and rugged design, low-cost, low maintenance and direct connection to an AC power source are the main advantages of AC induction motors. Various types of AC induction motors are available in the market. Different motors are suitable for different applications.

Although AC induction motors are easier to design than DC motors, the speed and the torque control in various types of AC induction motors require a greater understanding of the design and the characteristics of these motors.

This application note discusses the basics of an AC induction motor; the different types, their characteristics, the selection criteria for different applications and basic control techniques.

AC motors are used worldwide in many residential, commercial, industrial, and utility applications. Motors transform electrical energy into mechanical energy. An AC motor may be part of a pump or fan, or connected to some other form of mechanical equipment such as a winder, conveyor, or mixer. AC motors are found on a variety of applications from those that require a single motor to applications requiring several motors. Siemens manufactures a wide variety of motors for various applications.

2.3. 2.2 Basic Construction And Operating Principle

Like most motors, an AC induction motor has a fixed outer portion, called the stator and a rotor that spins inside with a carefully engineered air gap between the two.

Virtually all electrical motors use magnetic field rotation to spin their rotors. A three-phase AC induction motor is the only type where the rotating magnetic field is created naturally in the stator because of the nature of the supply. DC motors depend either on mechanical or electronic commutation to create rotating magnetic fields. A single-phase AC induction motor depends on extra electrical components to produce this rotating magnetic field. Two sets of electromagnets are formed inside any motor. In an AC induction motor, one set of electromagnets is formed in the stator because of the AC supply connected to the stator windings. The alternating nature of the supply voltage induces an Electromagnetic Force (EMF) in the rotor (just like the voltage is induced in the transformer secondary) as per Lenz’s law, thus generating another set of electromagnets; hence the name – induction motor. Interaction between the magnetic field of these electromagnets generates twisting force, or torque. As a result, the motor rotates in the direction of the resultant torque.

2.3.2.3 Stator

The stator is made up of several thin laminations of aluminum or cast iron. They are punched and clamped together to form a hollow cylinder (stator core) with slots as shown in Figure. Coils of insulated wires are inserted into these slots. Each grouping of coils, together with the core it surrounds, forms an electromagnet (a pair of poles) on the application of AC supply. The number of poles of an AC induction motor depends on the internal connection of the stator windings. The stator windings are connected directly to the power source. Internally they are connected in such a way, that on applying AC supply, a rotating magnetic field is created.

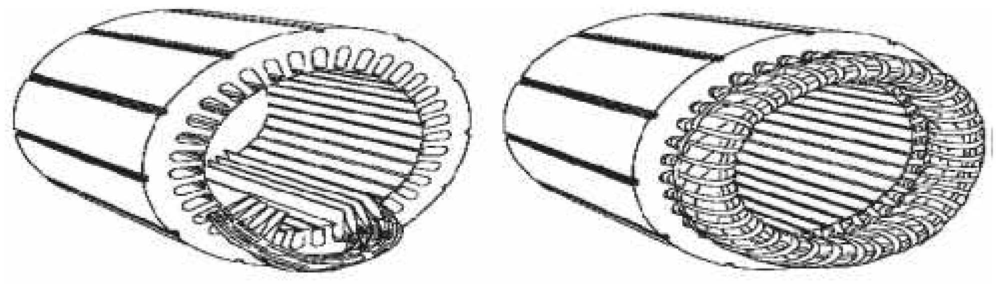


Fig. 2.3 : stator of IM

2.3.2.4 Rotor

The rotor is made up of several thin steel laminations with evenly spaced bars, which are made up of aluminum or copper, along the periphery. In the most popular type of rotor (squirrel cage rotor), these bars are connected at ends mechanically and electrically by the use of rings. Almost 90% of induction motors have squirrel cage rotors. This is because the squirrel cage rotor has a simple and rugged construction. The rotor consists of a cylindrical laminated core with axially placed parallel slots for carrying the conductors. Each slot carries a copper, aluminum, or alloy bar. These rotor bars are permanently short-circuited at both ends by means of the end rings, as shown in Figure 2.4 . This total assembly resembles the look of a squirrel cage, which gives the rotor its name. The rotor slots are not exactly parallel to the shaft. Instead, they are given a skew for two main reasons. The first reason is to make the motor run quietly by reducing magnetic hum and to decrease slot harmonics. The second reason is to help reduce the locking tendency of the rotor. The rotor teeth tend to remain locked under the stator teeth due to direct magnetic attraction between the two. This happens when the number of stator teeth are equal to the number of rotor teeth. The rotor is mounted on the shaft using bearings on each end; one end of the shaft is normally kept longer than the other for driving the load. Some motors may have an accessory shaft on the non-driving end for mounting speed or position sensing devices. Between the stator and the rotor, there exists an air gap, through which due to induction, the energy is transferred from the stator to the rotor. The generated torque forces the rotor and then the load to rotate. Regardless of the type of rotor used, the principle employed for rotation remains the same.

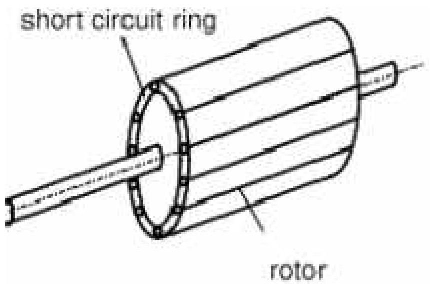


Fig. 2.4 Rotor of squirrel cage IM

2.3.2.5 Advantages of squirrel cage motors

Uncomplicated, rugged construction. For the user this means low initial cost and high reliability. Good efficiency coupled with low maintenance costs resulting in low overall operating costs.

Squirrel cage motors are asynchronous induction machines whose speed depends upon applied frequency, pole pair number, and load torque. At a positive slip, the squirrel cage machine will act as a motor - at a negative slip, as a generator. To reverse the machine's direction of rotation, the phase sequence to the motor must be changed. Assuming similar conditions, the phase current drawn by a squirrel cage motor will depend only on the slip.

2.3.2.6 Torque

The physical size of a motor is not purely dependent on the kW rating. A 15 kW 6 pole motor, for instance is far larger than a 15 kw 2 pole machine.

If there were a single factor which determined the frame size of a motor it would be the torque. Torque is the rotational equivalent of linear force and for any rotating machine, if the power and speed are known, then the torque is given by the formula:

Torque = $P \times 9550$ Newton Metres $\div \# \, of \, poles$ P : in Kw

When a motor is driving the load at full speed, the torque developed by the motor will always equal the torque required by the load to keep it running at that speed. The more accurate the motor selection, the closer this torque value will approach the rated full load torque (F.L.T.) of the motor.

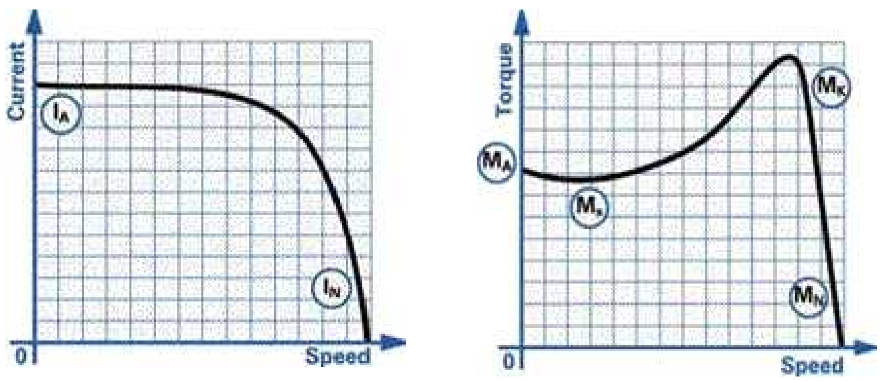


Fig. 2.5 Motor Chars.

During the starting cycle (or Run Up Time), however , the torque developed by the motor at any given instant must always exceed the torque required by the load at that particular speed, otherwise the load will not continue to accelerate and the motor will stall.

At any given speed during run up, the difference between the motor torque and the load torque is known as the Accelerating Torque and, taken over the complete curve of torque against speed from zero to 100% speed, it is this accelerating torque - together with the load Moment of Inertia - which determines the run up time.

The above curve is typical for a squirrel cage motor. The initial point is known as the starting torque or locked rotor torque (L.R.T.) , the minimum point is known as the Pull Up torque (P.U.T.) and the maximum point known as the Pull Out Torque (P.O.T.) .

2.3.3 Gears With Rotational and Translational Motion

The motors generally drive a load (machine) through some transmission system while motor always rotate the load may rotate or may undergo a translational motion load maybe different from that of motor, others may go through at translational motion it is , however , convenient to represent the motor load system by an equivalent rotational system .

The chars. Used in the Gear equations :

J : polar moment of inertia of motor-load system reversed to the motor shaft , Kilogram.m^2

ω_m : instantaneous angular velocity of motor shaft , rad/sec .

T : instantaneous value of developed motor torque , Nm .

TL : instantaneous value of load (resisting) torque , reserved to motor shaft , Nm .

$Jeq = Jm + Jg + J\omega.a^2 + m.(v/\omega m)^2$

$TL = TLm + (T\omega.a)/\eta + m.g(a.r)/(\eta g+\eta m)$

Table 2.1 Gear Types

Gear type	Transmission ratio	η
Worm gear	60	0.5….0.8
Pulley gear	8	0.94….0.97
Chain Gear	6	0.97….0.98
Friction gear	6	0.95….0.98

2.3.4 Frequency Converter

2.3.4.1 Introduction

Initially the main reason for using frequency conversion technology was for speed control, however to consider the needs of power control, today's frequency converters in addition to being used for speed control are also used for energy conservation purposes. Frequency conversion control technology is already being applied in many application areas, in home appliances such as fridges, washing machines, air-conditioners in addition to driving industrial motorized equipment etc. Frequency converters when used in electric motor control, are used to both control the frequency and voltage. The Holtek HT46R14 MCU device is used here in an example to show how frequency conversion is used for electrical motor control. An actual circuit is supplied for the users consultation.

2.3.4.2 Frequency Converter Principles

The normal household power supply or industrial power supply voltage and frequency is well defined and not open to change. The device, which takes this fixed voltage and frequency AC power and converts it into a variable voltage or variable frequency AC supply, is known as a Frequency Converter. In order to generate a variable voltage and frequency, the system must first rectify the AC input power source into DC after which the DC will be reconverted back into AC using the converter. The device, which converts the DC back into AC, and which can be controlled in both voltage and frequency, is known as the frequency converter. The frequency converter′s output is a simulated sine wave whose main purpose is to control the speed of an asynchronous induction motor.

Because of the characteristics of electric motors, most frequency converters must supply a Voltage/Frequency means of control. When the frequency is changed the voltage must change with it, When the frequency is reduced the voltage must reduce as well. If the frequency is reduced but the voltage does not change, the electric motor can easily overheat and burn out. This is especially true for very low frequencies. Therefore the frequency converter must be able to produce both voltage and frequency changes. In addition, most frequency converters also provide an acceleration and deceleration function, for use in emergency increase or decrease applications and for slow increase and decrease speed applications.

Most frequency converter′s application area is for three phase AC induction motors. The next figure shows a simple open-loop three phase output frequency converter block diagram. Most frequency converters supply single phase or three phase AC outputs. After bridge rectifying and filtering, the DC power is provided to the power drive circuits. The SMPS will convert the high voltage DC to the required isolated DC voltages and supply it to the protection circuits, drive converter interface circuits and the control circuits. The control circuits will provide the necessary control signals to drive the power circuits to control the motor’s rotational speed and voltage. The frequency converter needs to provide protection circuitry for over-voltage, over-current, low-voltage, etc. which are used to protect the converter from adverse conditions. The driver converter frequency converter interface is an MCU control circuit and is an interface to the power drive circuit and provides voltage isolation. The usual way of providing isolation is with IC opto-couplers.

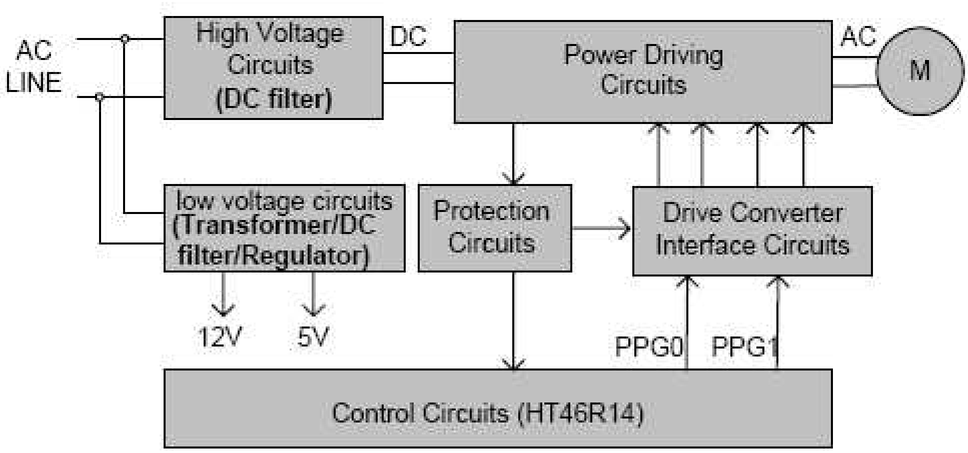


Figure 2.6 frequency converter circuit

The main function is to provide driving signals for a single phase AC induction motor. The important circuits include high voltage circuits, low voltage circuits, power driving circuits, drive converter interface circuits, protection circuits, control circuits etc.

2.3.4.3 High Voltage Circuits

The main parts here are a bridge rectifier and filter, to power the main power high voltage DC circuits.

2.3.4.4 Low Voltage Circuits

The AC first passes through a transformer to reduce the voltage and then a bridge rectifier, filter and regulator to provide two voltage levels, 12V and 5V, which are provided to the driver interface circuits, protection circuits and the MCU controller circuits.

2.3.4.5 Power Driving Circuits

The Power Driving Circuits are composed of power switches which are used to drive the load. Such applications usually utilize IGBTs or Power Mosfets. This circuit uses four IRF840 Power Mosfet transistors, to form a bridge driver circuit, which is used to drive a single phase AC induction motor load.

2.3.4.6 Driver Converter Interface Circuit

The driver converter interface circuits sits between the MCU controller circuit and the power driver circuits. It provides voltage interface conversion, supplies Dead Time protection and Shut Down function protection etc. The present circuit uses two IR2109 devices as a driver converter interface.

2.3.4.7 Protection Circuits

In the present example the protection circuits are for over-current protection and will protect the system from overload situations. The designer may wish to add further protection such as circuits for over-voltage, low-voltage etc. This circuit′s output is connected to the SD pin of the IR2109 device and the MCU INT pin. Should a situation of over-current present itself, then the protection circuit’s output pin will go from high to low which will shut-down the IR2109 and generate an MCU interrupt. The MCU will then return to its reset condition and stop outputting information.

2.3.4.8 Controller Circuits

The controller circuit uses the Holtek HT46R14 MCU device′s PPG function as the central part of the system. The MCU controller circuit provides the following functions:

• Uses a VR for speed control, uses an ADC to monitor the desired speed

• Uses the PFD to control the 32kHz carrier wave output, uses the PPG to control the PWM duty cycle signal

• Controls the frequency output to have a range between 10Hz and 120Hz

• Provides a two stage V/F control for increased deceleration function

• Over-current stop motor protect function

• Display over-current and rotation status

• Start and stop switch functions

Fig. 2.7 frequency converter photo

This is the frequency converter that we used in our project , more information's are in appendix A .

2.4 Calculations and analyses

Load Data

M : the maximum weight of the user = 100 Kg.

V : the maximum speed of the conveyor = 6.3 m/s.

Machine Data

R1 : the radius of the motor pulley 4 cm so r1 = 4 cm.

R2 : the radius of the pulley of the conveyor 8 cm so r2 = 8 cm.

a = r1/r2 = 1/2 = 0.5.

L : the length of the conveyor = 108 cm.

W : the width of the conveyor = 35 cm.

For the conveyor

Ɵ = elevation angle (15°)

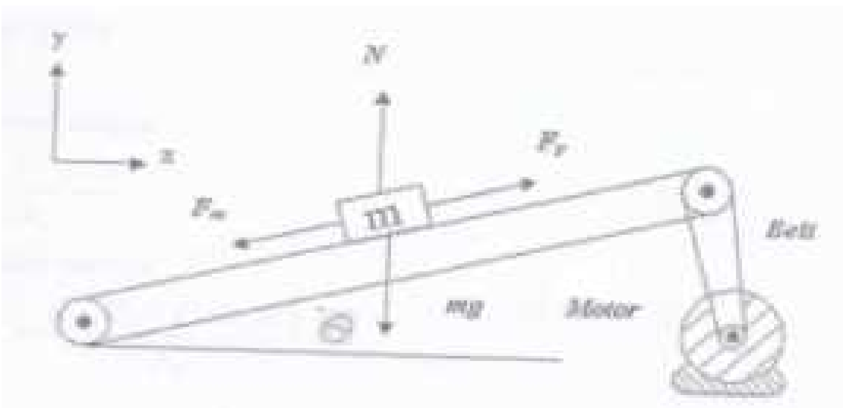


Fig. 2.8 free body diagram

$$\sum F_x = m_{eq} * x'' = -F_m - F_{ex}\cos\Theta + \mu_f * N + F_p \quad (2.1)$$

Where :

$$\cos\Theta = N/F_{ex} \quad (2.2)$$

$N = F_{ex}\cos\Theta$

$$F_{ex} = Mg_{static} + F_d \quad (2.3)$$

N : Normal Force.

Θ : Elevation Angle.

F_{ex} : Total force that effect on deck.

Then :

$$N = Mg\sin\Theta \quad (2.4)$$

$$F_{pully\ friction} = N_{pully}\ \mu_{pully} \quad (2.5)$$

⇒ Synchronous speed :

$$n_s = 120*f/p \quad (2.6)$$

$= 120*50/4 = 1500$ rpm

⇒ $n = 1450$ rpm standard rpm

⇒ $\omega_s = 4*\pi*f/p$ (2.7)

$= 4*3.14*50/4 = 157$ rad/s

⇒ $\omega = 2*\pi*n/60$ (2.8)

$= 2*3.14*1450/60 = 151$ rad/s

⇒ $T = F\ D$ (2.9)

$= Mg\sin\Theta\ D$

$= 100*9.81*0.08*0.258$

$= 20.25$ Nm

⇒ $P_{out} = T*\omega$ (2.10)

$= 20.25*75.5$

$= 1528.71W$

The standerd is 1492 w = 2HP

⇒ $F = (M_{person} + M_{conveyor})*g \sin\Theta$ (2.11)

=1000 N , Mconveyor (neglected)

After gear

⇒ T =9.93 * 2=19.86 N.m

Gear ratio K=1/a =2

ω=151/2 =75.5 rad/s

⇒ $P_{in} = \sqrt{3} * V_L * I_L * \cos\Theta$ (2.12)

$= \sqrt{3} * 220 * 4.9 * .86 = 1605.7$ W

⇒ $\eta = (P_{out}/P_{in})*100\%$ (2.13)

= (1492 /1605.7) * 100%

= 92.92%

But the actual efficiency of the motor is 86% , the difference because of that we neglected the mechanical losses.

$\eta_{total} = \eta_{motor} * \eta_{gear} * \eta_{converter}$

= 86%*95%*98% = 80%

⇒ V at max n = r*ω (2.14)

at 50Hz

gear ratio= 0.5

$\omega = (4*\pi*f/p)*0.5$

$= (4*\pi*50/4)*0.5$

=78.54 rd/s

V=r*ω

=0.08*75.5

= 6.3 m/

Table 2.2 : The values of the speed .

F(Hz)	V(m/s)
5	0.63
10	1.26
15	1.88
20	2.51
25	3.14
30	3.77
35	4.4
40	5.03
45	5.65
50	6.3

So as it looks in the following figure the speed increase by increasing the frequency.

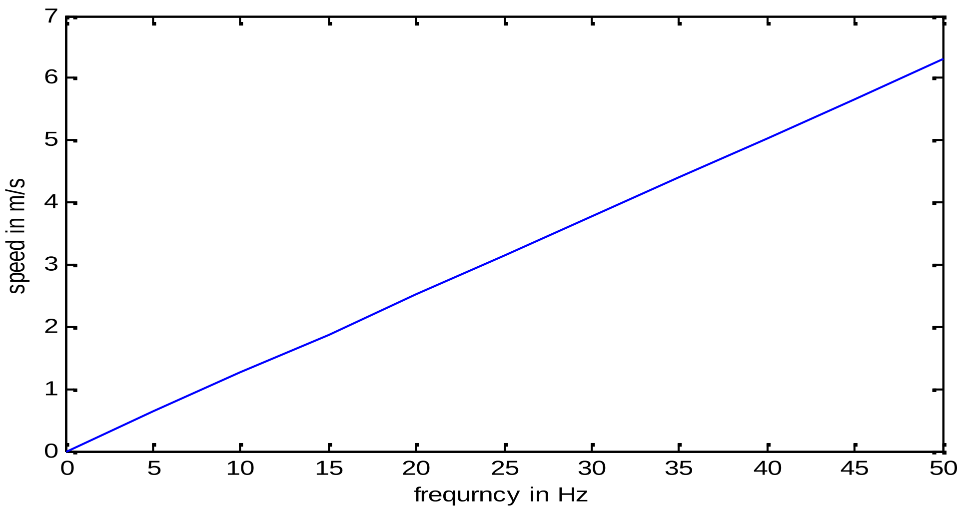


Fig. 2.9 speed – frequency relationship

So the speed start from zero at zero hertz untill it reach the maximum value at maximum frequency which is 50Hz.

Fig. 2.10 Built Treadmill Machine

2.5 MATLAB Simulink

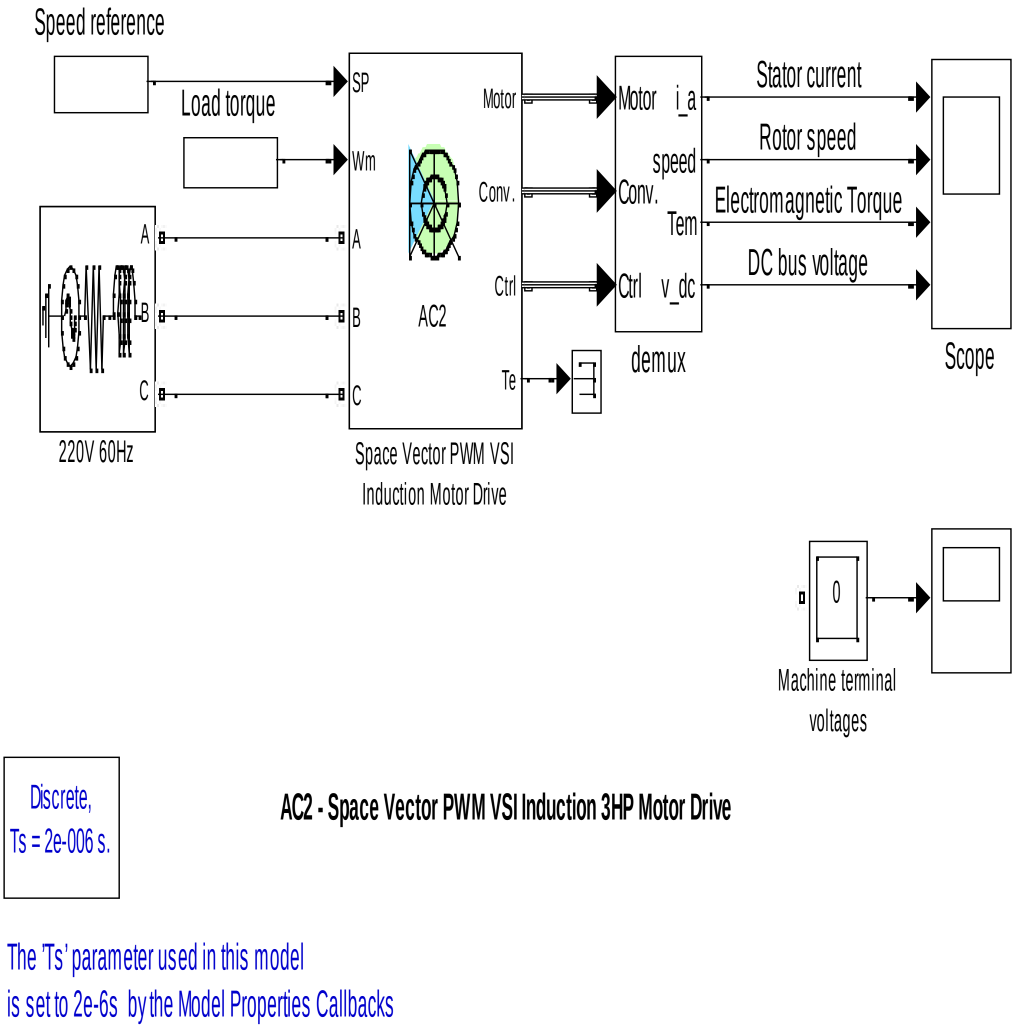


Fig. 2.11 Motor drive circuit

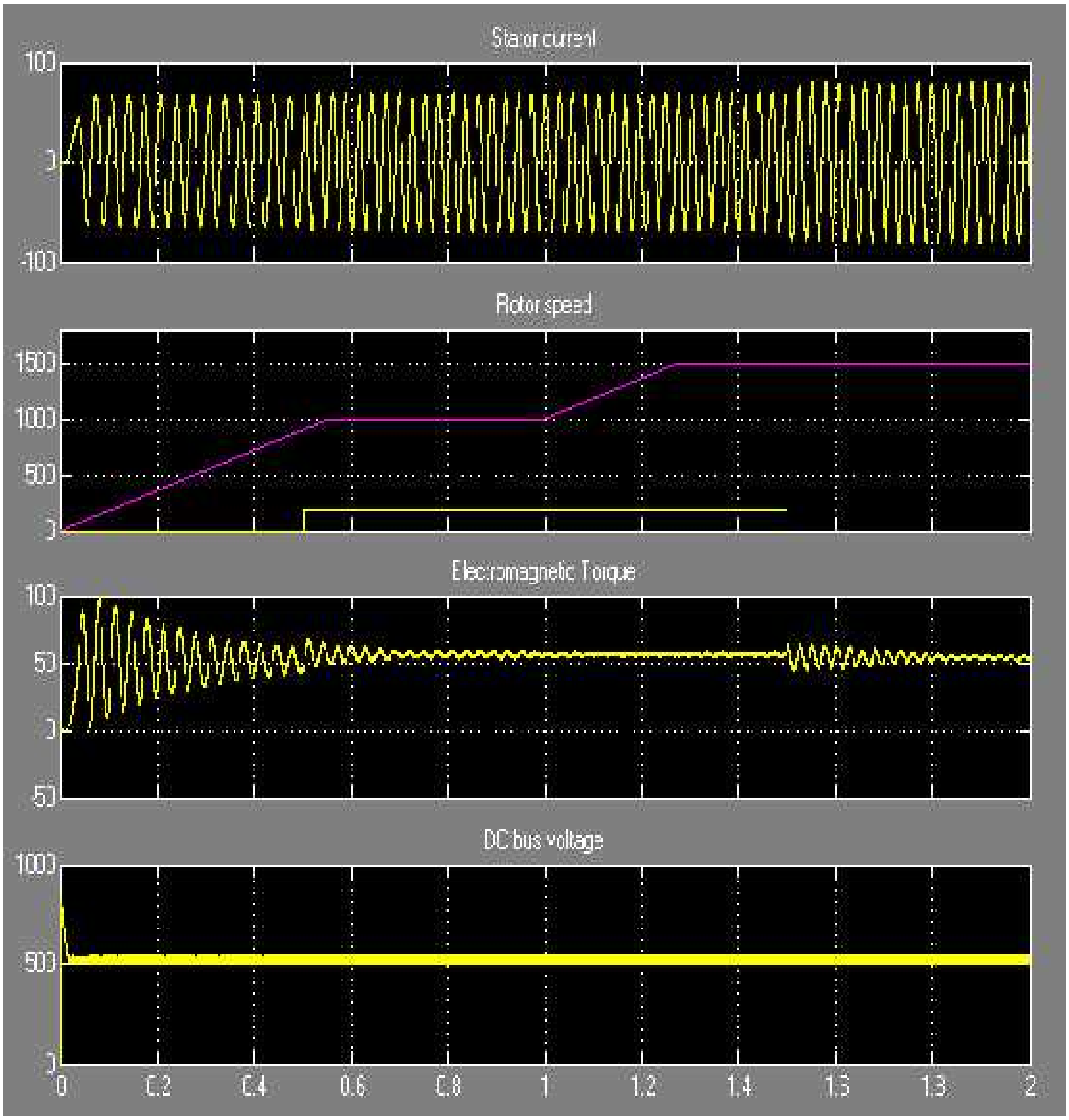


Fig. 2.12 Motor Simulation.

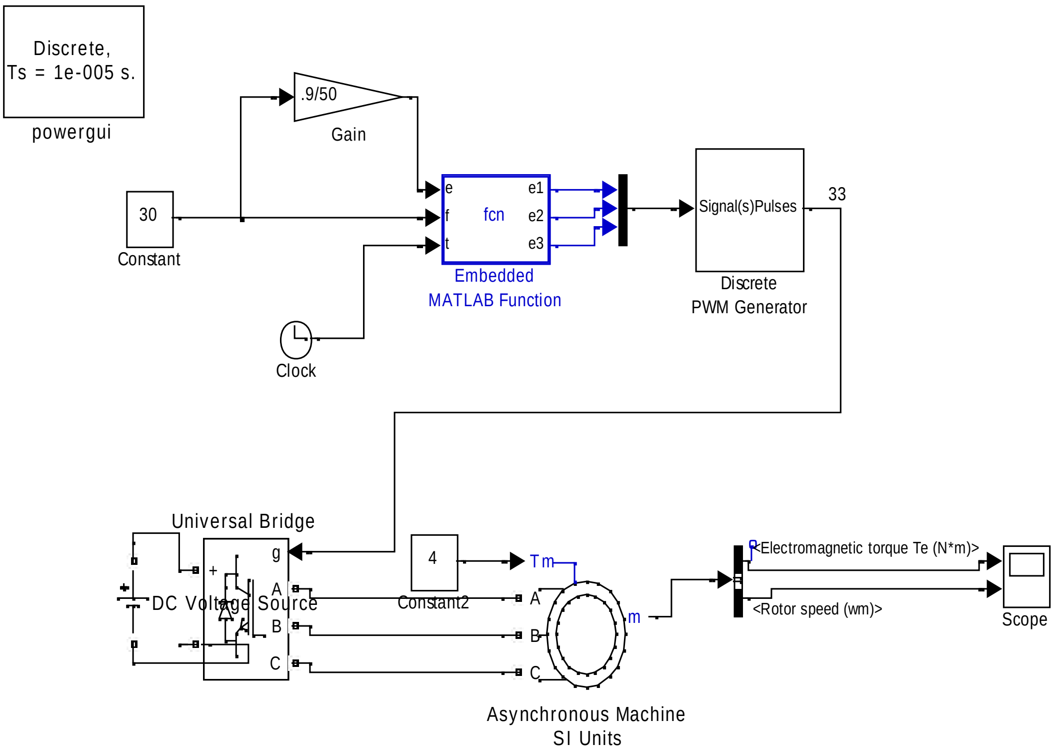


Fig. 2.13 Embedded function circuit

Note : The function code listed in appendix C.

CHAPTER THREE

3.1 Conclusion

3.2 Recommendation

3.1 Conclusion

Treadmill machines are widely used in home domestic sport and fitness centers. Therefore working over enhancement the machine behavior , in term of speed regulation.

The design procedure in converting classical Treadmill machine to electromechanical Treadmill machine, the speed can be regulated upon costumer request.

Many advantages has been verified in this project , some of them are : simplicity , long live , low maintenance , and high efficiency.

The speed regulation verified by frequency converter. The implemented model and tasks design presents acceptable solution with needs for further enhancement.

3.2 Recommendations

1. One of the most important recommendations is that to make this machine multy function by controlling the slope angle, it is possible by fixing a piston and decreasing the angle from 15 degree to zero degree.

2. Another important recommendation is To support the machine with weight sensors circuit to be function with the drive system to increase and decrease the speed according to the user weight.

References

[1] George McPherson , Robert D.Laramore , 1984 , "An Introduction to Electrical Machine and Transformer" , Second Edition , Canada.

[2] James T. Humphries , 1988, "Motors and Control" , Second Edition , 43216, Columbus , Ohio , USA.

[4] Robert H. Creamer , 1983 , " Machine Design " , Third Edition , USA.

[5] www.ieee.com

[6] Electrical Drive Machine Book.

[7] Gk Dubey . Fundamentals of Electrical Drive.

[8] Y.H. Chang and others

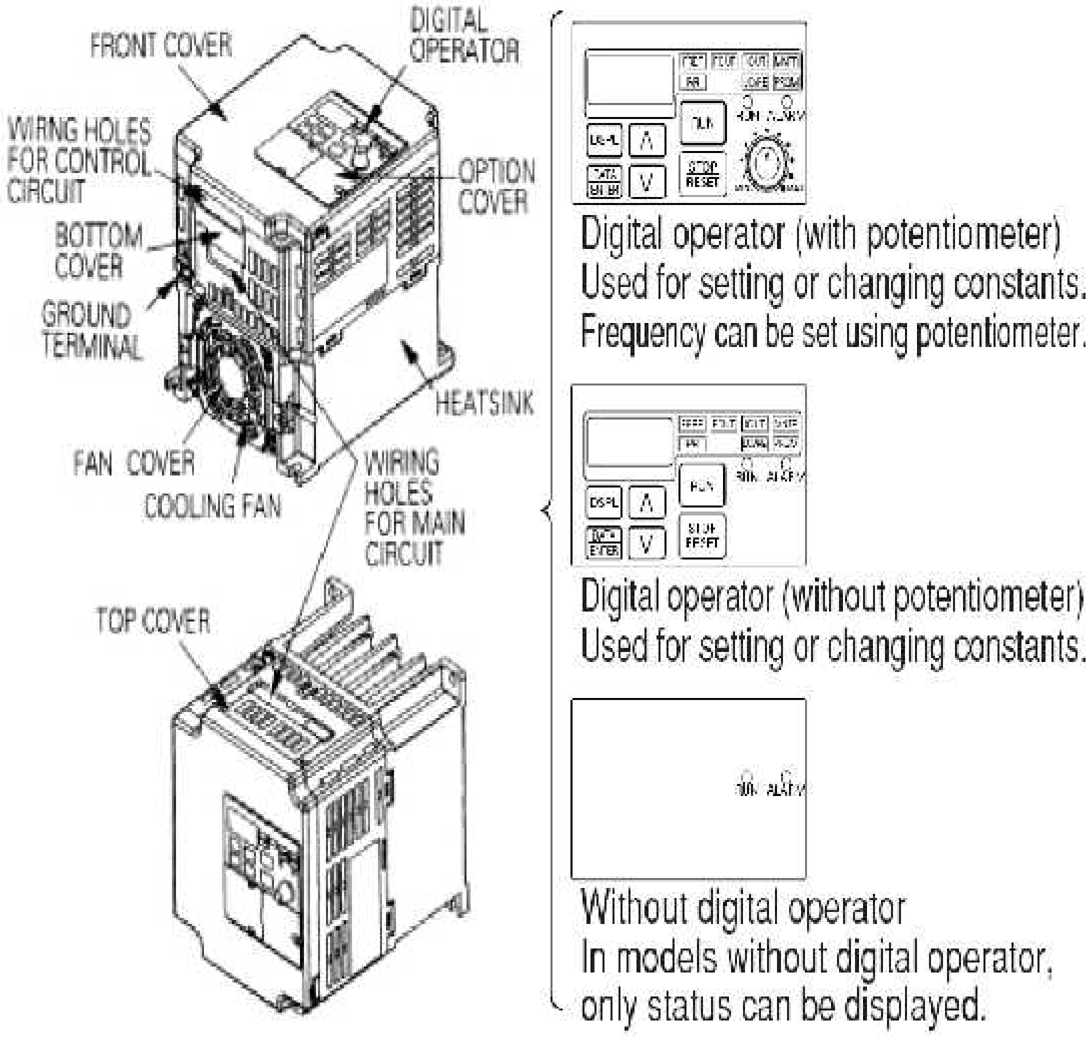
[9] J.M. Donelan and R. Kram

[10]Jibril , Abu Awwad and Itieh

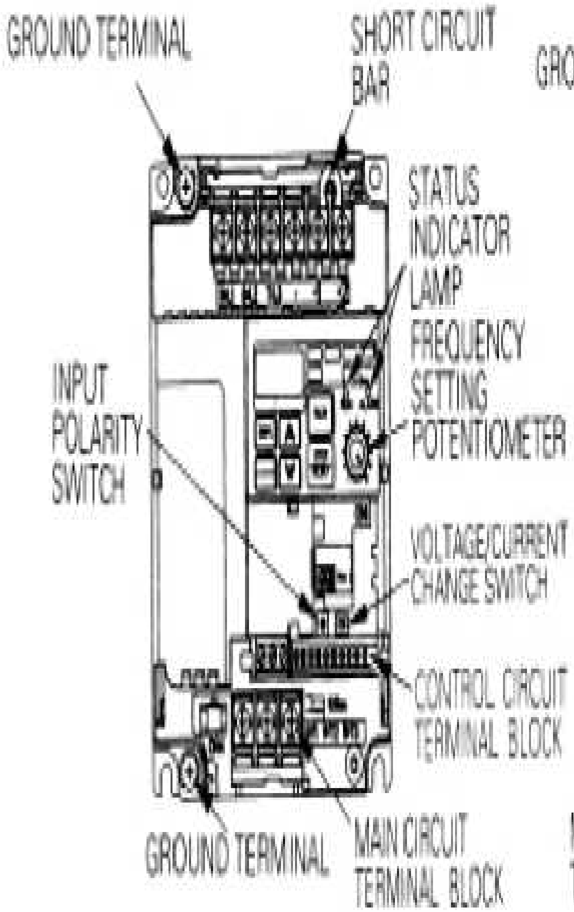
Appendix A

Datasheets

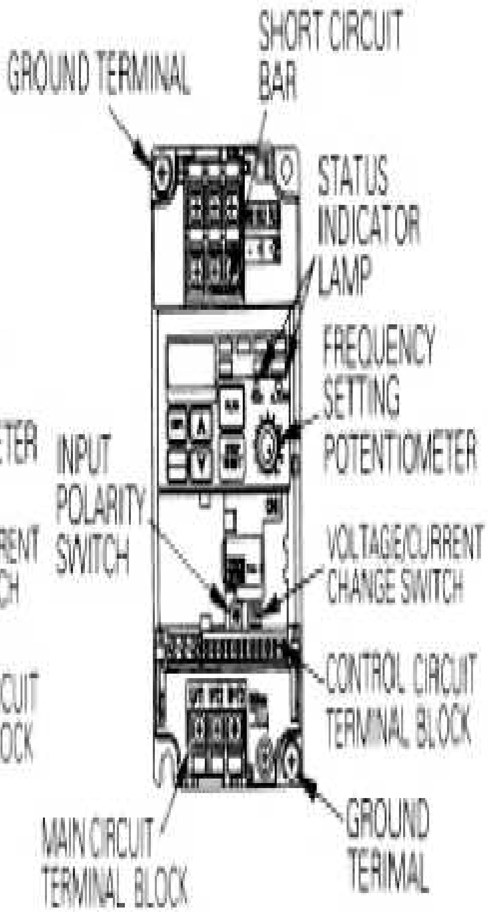
Frequency Converter Datasheet



Opening the covers



CIMR-J7**21P5, 22P2, 23P7
B0P7, B1P5
40P2, 40P4, 40P7, 41P5
42P2, 43P0, 43P7



CIMR-J7**20P1, 20P2, 20P4, 20P7,
B0P1, B0P2, B0P4

■ Wiring Instructions

(1) Always connect the power supply (for main circuit inputs) and power input terminals R/L1, S/L2, and T/L3 (R/L1, S/L2 for single-phase) via a molded-case circuit breaker (MCCB) or a fuse. Never connect them to terminals U/T1,V/T2,W/T3, -, +1, or +2. The inverter may be damaged.

Refer to page 108 for Recommended Peripheral Devices. For single-phase inverters, always use terminal R/L1 or S/L2. Never connect to terminal T/L3.

Inverter Power Connection Terminals

200V 3-phase Input Power Supply Specification Product: CIMR-J7□□2□□□	200V Single Input Power Supply Specification Product CIMR-J7□□B□□□	400V 3-phase Input Power Supply Specification Product CIMR-J7□□4□□□
Connect to R/L1, S/L2, T/L3	Connect to R/L1, S/L2	Connect to R/L1, S/L2, T/L3

(2) If the wiring distance between inverter and motor is long, reduce the inverter carrier frequency. For details, refer to "Reducing motor noise or leakage current (n46)" on page 57.

(3) Control wiring must be less than 50m in length and separate from the power wiring. Use twisted-pair shielded wire when inputting the frequency signal externally.

(4) Tighten the screws on the main circuit and control circuit terminals.

(5) Do not connect or disconnect wiring, or perform signal check white the power supply is turned ON.

(6) For 400V class inverters, make sure to ground the supply neutral to conform to CE requirements.

(7) Only basic insulation to meet the requirements of protection class 1 and overvoltage category II is provided with control circuit terminals. Additional insulation may be necessary in the end product to conform to CE requirements.

(8) A closed-loop connector should be used when wiring to the main circuit terminal.

(9) Voltage drop should be considered when determining wire size.

Voltage drop can be calculated using the following equation:

Phase-to phase voltage drop (V)

$= \sqrt{3} \times$ wire resistance (Ω/km) $\times$ wiring distance (m) $\times$ current (A) $\times 10^{-3}$

Select a wire size so that voltage drop will be less than 2% of the normal rated voltage.

■ Wire and Terminal Screw Sizes

1. Control Circuit

Model	Terminal Symbol	Screw	Tightening Torque N•m	Wire: Applicable size mm²	Wire: Applicable size AWG	Wire: Recommended size mm²	Wire: Recommended size AWG	Type
Common to all models	MA, MB, MC	M3	0.5 to 0.6	twisted wire 0.5 to 1.25 single 0.5 to 1.25	20 to 16 20 to 16	0.75	18	Shielded wire or equivalent
	S1 to S5,SC,FS, FR,FC,AM,AC	M2	0.22 to 0.25	twisted wire 0.5 to 0.75 single 0.5 to 1.25	20 to 18 20 to 16	0.75	18	

2. Main Circuit
200V Class 3-phase Input Series

Model	Terminal Symbol	Screw	Tightening Torque N•m	Wire: Applicable size mm²	Wire: Applicable size AWG	Wire: Recommended size mm²	Wire: Recommended size AWG	Type
CIMR-J7*A 20P1	R/L1,S/L2,T/L3, −,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	0.75 to 2	18 to 14	2	14	600V vinyl-sheathed wire or equivalent
CIMR-J7*A 20P2	R/L1,S/L2,T/L3, −,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	0.75 to 2	18 to 14	2	14	
CIMR-J7*A 20P4	R/L1,S/L2,T/L3, −,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	0.75 to 2	18 to 14	2	14	
CIMR-J7*A 20P7	R/L1,S/L2,T/L3, −,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	0.75 to 2	18 to 14	2	14	
CIMR-J7*A 21P5	R/L1,S/L2,T/L3, −,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	2 to 5.5	14 to 10	2	14	
CIMR-J7*A 22P2	R/L1,S/L2,T/L3, −,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	2 to 5.5	14 to 10	3.5	12	
CIMR-J7*A 23P7	R/L1,S/L2,T/L3, −,+1,+2, U/T1,V/T2,W/T3 ⏚	M4	1.2 to 1.5	2 to 5.5	14 to 10	5.5	10	

Note : The wire size is set for copper wires at 75°C.

200V Class Single-phase Input Series

Model	Terminal Symbol	Screw	Tightening Torque N·m (lb·in)	Wire: Applicable size mm²	Wire: Applicable size AWG	Wire: Recommended size mm²	Wire: Recommended size AWG	Type
CIMR-J7*A B0P1	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	0.75 to 2	18 to 14	2	14	600V vinyl-sheathed wire or equivalent
CIMR-J7*A B0P2	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	0.75 to 2	18 to 14	2	14	
CIMR-J7*A B0P4	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	0.75 to 2	18 to 14	2	14	
CIMR-J7*A B0P7	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	2 to 5.5	14 to 10	3.5 2	12 14	
CIMR-J7*A B1P5	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	2 to 5.5	14 to 10	5.5 2	10 14	

Note : 1. The wire size is set for copper wires at 75°C.
2. Three-phase input is also available for single-phase input series.

400V Class 3-phase Input Series

Model	Terminal Symbol	Screw	Tightening Torque N·m (lb·in)	Wire: Applicable size mm²	Wire: Applicable size AWG	Wire: Recommended size mm²	Wire: Recommended size AWG	Type
CIMR-J7*A 40P2	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	2 to 5.5	14 to 10	2	14	600V vinyl-sheathed wire or equivalent
CIMR-J7*A 40P4	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	2 to 5.5	14 to 10	2	14	
CIMR-J7*A 40P7	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	2 to 5.5	14 to 10	2	14	
CIMR-J7*A 41P5	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M3.5	0.8 to 1.0	2 to 5.5	14 to 10	2	14	
CIMR-J7*A 42P2	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M4	1.2 to 1.5	2 to 5.5	14 to 10	2	14	
CIMR-J7*A 43P0	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M4	1.2 to 1.5	2 to 5.5	14 to 10	2 3.5	14 12	
CIMR-J7*A 43P7	R/L1,S/L2,T/L3, –,+1,+2, U/T1,V/T2,W/T3 ⏚	M4	1.2 to 1.5	2 to 5.5	14 to 10	2 3.5	14 12	

Note : The wire size is set for copper wires at 75°C.

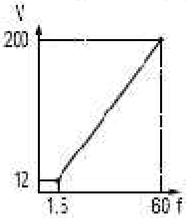
• Typical setting of V/f pattern

Set the V/f pattern according to the application as described below. For 400V class, the voltage values (n10, n13, and n15) should be doubled. When running at a frequency exceeding 50Hz/60Hz, change the maximum output frequency (n09).

Note: Be sure to set the maximum output frequency according to the motor characteristics.

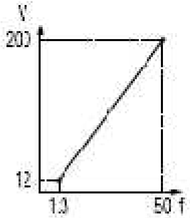
(1) For general-purpose applications

Motor Specification : 60Hz
(Factory setting)



Constant	Setting
n09	60.0
n10	200
n11	60.0
n12	1.5
n13	12
n14	1.5
n15	12

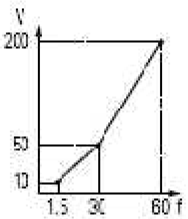
Motor Specification : 50Hz



Constant	Setting
n09	50.0
n10	200
n11	50.0
n12	1.3
n13	12
n14	1.3
n15	12

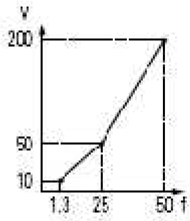
(2) For fans/pumps

Motor Specification : 60Hz



Constant	Setting
n09	60.0
n10	200
n11	60.0
n12	30.0
n13	50
n14	1.5
n15	10

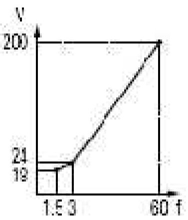
Motor Specification : 50Hz



Constant	Setting
n09	50.0
n10	200
n11	50.0
n12	25.0
n13	50.0
n14	1.3
n15	10

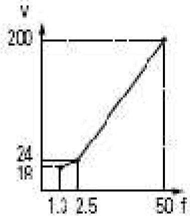
(3) For applications requiring high starting torque

Motor Specification : 60Hz



Constant	Setting
n09	60.0
n10	200
n11	60.0
n12	3.0
n13	24
n14	1.5
n15	18

Motor Specification : 50Hz



Constant	Setting
n09	50.0
n10	200
n11	50.0
n12	2.5
n13	24
n14	1.3
n15	18

Increasing voltage of V/f pattern increases motor torque, but an excessive increase may cause motor overexcitation, motor overheat or vibration.

■ Selecting Frequency Reference

Frequency reference can be selected by the following methods.

○ Setting by operator

Select REMOTE or LOCAL mode in avance. For the method for selecting the mode, refer to page 40.

LOCAL mode

Select command method by constant n07.

n07=0 : Enables the setting by potentiometer on digital operator (initial setting).
Factory setting of the model with digital operator (without potentiometer) is n07=1.

=1 : Enables the digital setting by digital operator, setting value is stored in constant n21 (frequency reference 1).

- Digital setting by digital operator

Input frequency while FREF is lit (press ENTER after setting the numeric value).

Frequency reference setting is effective when 1 (initial setting : 0) is set to constant n08 instead of pressing ENTER key.

n08=0 : Enables frequency reference setting by ENTER key.

=1 : Disable frequency reference setting by ENTER key.

REMOTE mode

Select command method by constant n03.

n03=0 : Enables frequency reference setting by potentiometer on digital operator (initial setting).
Initial setting of the model with digital operator (without potentiometer) is n03=1.

=1 : Frequency reference 1 effective. (constant n21)

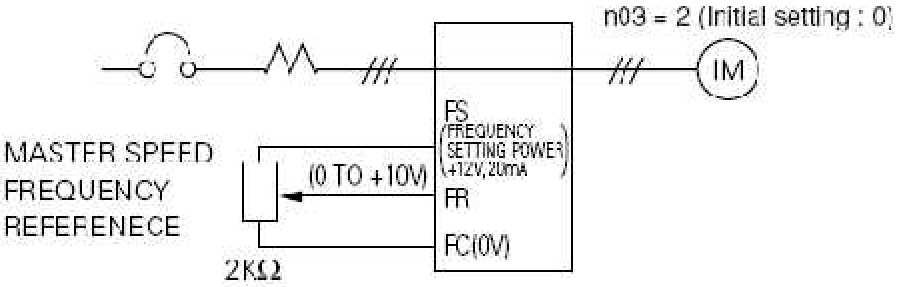
=2 : Voltage reference (0 to 10V) (See the figure below)

=3 : Current reference (4 to 20mA) (Refer to page 67)

=4 : Current reference (0 to 20mA) (Refer to page 67)

=6 : Communication (Refer to page 74)

Example of frequency reference by voltage signal



■ Selecting Stopping Method

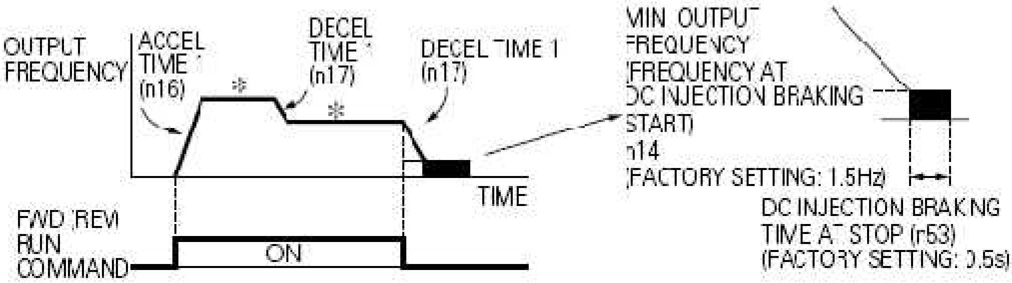
Selecting stopping method (n04)

Selects the stopping method suitable for application.

Setting	Description
0	Deceleration to stop
1	Coast to stop

• Deceleration to stop

Example when accel/decel time 1 is selected



* When frequency reference is changed during running.

Upon termination of the FWD (REV) run command, the motor decelerates at the decel rate determined by the time set to deceleration time 1 (n17) and DC injection braking is applied immediately before stop. DC injection braking is also applied when the motor decelerates by setting frequency reference lower than min. output frequency (n14) with FWD (or REV) run command ON. If the decel time is short or the load inertia is large, overvoltage (OV) fault may occur at deceleration. In this case, increase the decel time.

■ Building Interface Circuits with External Devices

Using input signals

Multi-function input terminal S2 to S5 functions can be changed when necessary by setting constants n36 to n39 respectively. The same value cannot be set to different constant settings.

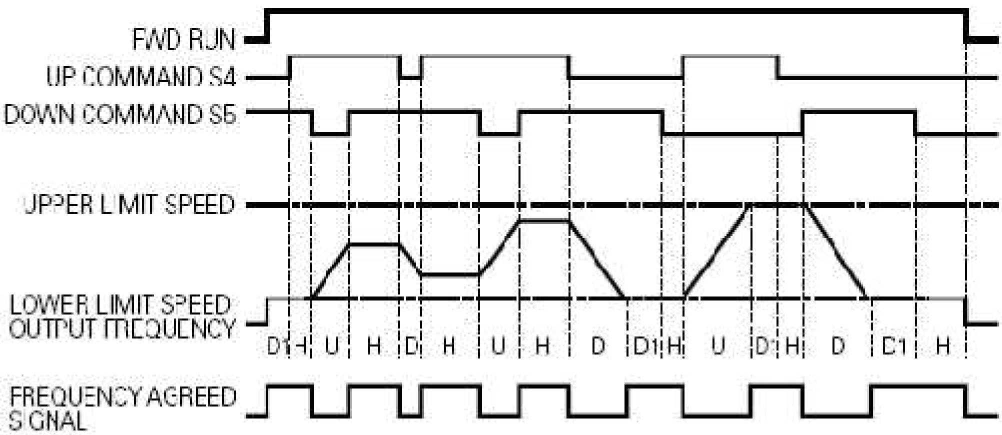
Setting	Name	Description	Ref.
0	FWD/REV run command (3-wire sequence selection)	Setting enabled only for n37	63
2	Reverse run (2-wire sequence selection)		41
3	External fault (NO contact input)	Inverter stops by external fault signal input. Digital operator display is "EF□*."	-
4	External fault (NC contact input)		-
5	Fault reset	Resets the fault. Fault reset not effective with the run signal ON.	43
6	Multi-step speed reference 1		43
7	Multi-step speed reference 2		43
8	Multi-step speed reference 3		43
10	JOG command		44
11	Accel/decel time select		47
12	External baseblock (NO contact input)	Motor coast to a stop by this signal input. Digital operator display is "bb"	-
13	External baseblock (NC contact input)		-
14	Search command from maximum frequency	Speed search reference signal	54
15	Search command from set frequency		54
16	Accel/decel hold command		55
17	LOCAL/REMOTE selection		40
18	Communication/ control circuit terminal selection		65
19	Emergency stop fault (NO contact input)	Inverter stops by emergency stop signal input according to stopping method selection (n04). When frequency coasting to a stop (n04 is set to 1) method is selected, inverter coasts to a stop according to decel time setting 2 (n19). Digital operator display is STP. (lit at fault, blinking at alarm)	-
20	Emergency stop alarm (NO contact input)		-
21	Emergency stop fault (NC contact input)		-
22	Emergency stop alarm (NC contact input)		-
34	UP/DOWN command	Setting enabled only for n39 (terminal S5)	63
35	Self-test	Setting enabled only for n39 (terminal S5)	-

* Numbers 2 to 5 is displayed in □ corresponding to the terminal numbers S1 to S5 respectively.

Initial setting

No.	Terminal	Initial Setting	Function
n36	S2	2	Reverse run (2-wire sequence selection)
n37	S3	5	Fault reset
n38	S4	3	External fault (NO contact output)
n39	S5	6	Multi-step speed reference 1

Time Chart at UP/DOWN Command Input



U = UP (accelerating) status
D = DOWN (decelerating) status
H = HOLD (constant speed) status
U1 = UP status, clamping at upper limit speed
D1 = DOWN status, clamping at lower limit speed

Notes :

1. When UP/DOWN command is selected, the upper limit speed is set regardless of frequency reference.

   Upper limit speed = Max. output frequency (n09)
   × Frequency reference upper limit (n30)/100%
2. Lower limit value is either min. output frequency (n14) or Max. output frequency (n09) × frequency reference lower limit (n31)/100% (whichever is larger.).
3. When the FWD (REV) run command is input, operation starts at the lower limit speed without an UP/DOWN command.
4. If the jog command is input while running by the UP/DOWN command, the jog command has priority.
5. Multi-step speed reference 1 to 3 is not effective when UP/DOWN command is selected. Multi-step speed reference is effective during running in hold status.
6. When "1" is set for HOLD output frequency memory selection (n62), output frequency can be recorded during HOLD.

Setting	Description
0	Output frequency is not recorded during HOLD.
1	When HOLD status is continued for 5 seconds or longer, the output frequency during HOLD is recorded and the inverter restarts at the recorded frequency.

General information
Product information

List of abbreviations

η	[%]	Mechanical efficiency,
cos φ		Power factor,
f_N	[Hz]	Rated frequency,
I_A	[A]	Starting current,
$I_{N,\Delta}$	[A]	Rated current, Triangle
$I_{N,Y}$	[A]	Rated current, Star
m	[kg]	Mass
M_A	[Nm]	Starting torque,
M_K	[Nm]	Stalling torque,
M_N	[Nm]	Rated torque,
n_N	[r/min]	Rated speed,
P_N	[kW]	Rated power,
$U_{N,\Delta}$	[V]	Rated voltage, Triangle
$U_{N,Y}$	[V]	Rated voltage, Star

EN 50347	Three-phase asynchronous motors for general use with standardised dimensions and outputs

Three-phase AC motors
Rated data

Rated frequency 50 Hz

4-pole motors

	P_N	n_N	M_N	M_A	M_K	$I_{N,\Delta}$	$I_{N,Y}$	I_A / I_N	$U_{N,\Delta}$	$U_{N,Y}$	cos φ	η	m
	[kW]	[r/min]	[Nm]	[Nm]	[Nm]	[A]	[A]		[V]	[V]		[%]	[kg]
MDERAXX056-12V1	0.060	1330	0.43	0.50	0.66	0.47	0.27	4.00	230	400	0.65	50	3.20
MDERAXX056-22V1	0.090		0.65	1.17	1.30	0.62	0.36				0.73		3.40
MDERAXX063-12V1	0.12	1340	0.86	1.35	1.72	0.79	0.41	4.40			0.72	57	4.00
MDERAXX063-32V1	0.18		1.25	2.10	2.56	1.06	0.61				0.73	58	4.50
MDERAXX071-12V1	0.25	1345	1.77	3.72	3.89	1.30	0.75	5.20			0.74	65	5.20
MDERAXX071-32V1	0.37	1340	2.64	5.54	5.91	1.84	1.06				0.75	67	6.70
MDERAXX071-42V1	0.55	1390	3.78	8.32	9.45	2.58	1.49	5.30				71	9.20
MDERAXX080-12V1													8.90
MDERAXX080-32V1	0.75	1380	5.19	11.9	13.0	3.38	1.93				0.76	73	9.60
MDERAXX090-12V1	1.10	1390	7.55	17.4	19.4	4.69	2.71	6.00			0.77	76	12.5
MDERAXX090-32V1	1.50		10.3	23.7	25.8	6.13	3.54				0.78	79	15.0
MDERAXX100-12V1	2.20	1415	14.8	34.0	37.0	8.26	4.78	7.00			0.82	81	19.2
MDERAXX100-32V1	3.00		20.2	46.5	50.5	11.1	6.39					83	23.0
MDERAXX112-32V1	4.00	1430	26.7	61.4	66.6	8.26			400		0.83	84	29.0
MDERAXX132-12V1	5.50	1445	36.3	83.5	90.8	11.2						86	43.5
MDERAXX132-32V1	7.50		49.6	114	124	14.8					0.84	87	53.5

Appendix B

Embedded Function Code

```
function [e1,e2,e3] = fcn(e,f,t)

e1=e*sin(2*pi*f*t);

e2=e*sin(2*pi*f*t-2*pi/3);

e3=e*sin(2*pi*f*t-4*pi/3);
```