TERCO

Motor Control

Laboratory Exercises

MOTOR CONTROL

Laboratory Exercises

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Introduction

Electrical Installation is covered by the following courses:

- Lighting Techniques
- Electrical Installation Basic Course
- Electrical Installation Motor Control
- Electrical working environment and safety

Motor Control

Text Book
The Text book gives a wide view over the uses of motor techniques, both in society and in industry. In motor control, power electronics and other control systems are studied in depth. The Text Book shall help to develop the student's basic electrical competence to a more advanced level within the areas where motor techniques are used.

The Text Book can be used for different study objectives and can be complemented according to needs with practice exercises, work projects and/or laboratory exercises.

Practice Exercises
The studies in the Text Book are strengthened with practice exercises for each chapter. Study directions and answers to the exercises are included.

Laboratory Exercises
During the laboratory exercises, studies with motor circuits, also simple and advanced circuits for motor control, are completed.
The equipment is connected using laboratory leads. A suggestion for linking the Text Book and the Laboratory Exercises is shown in the study plan "Different ways to achieve competence in motor control".

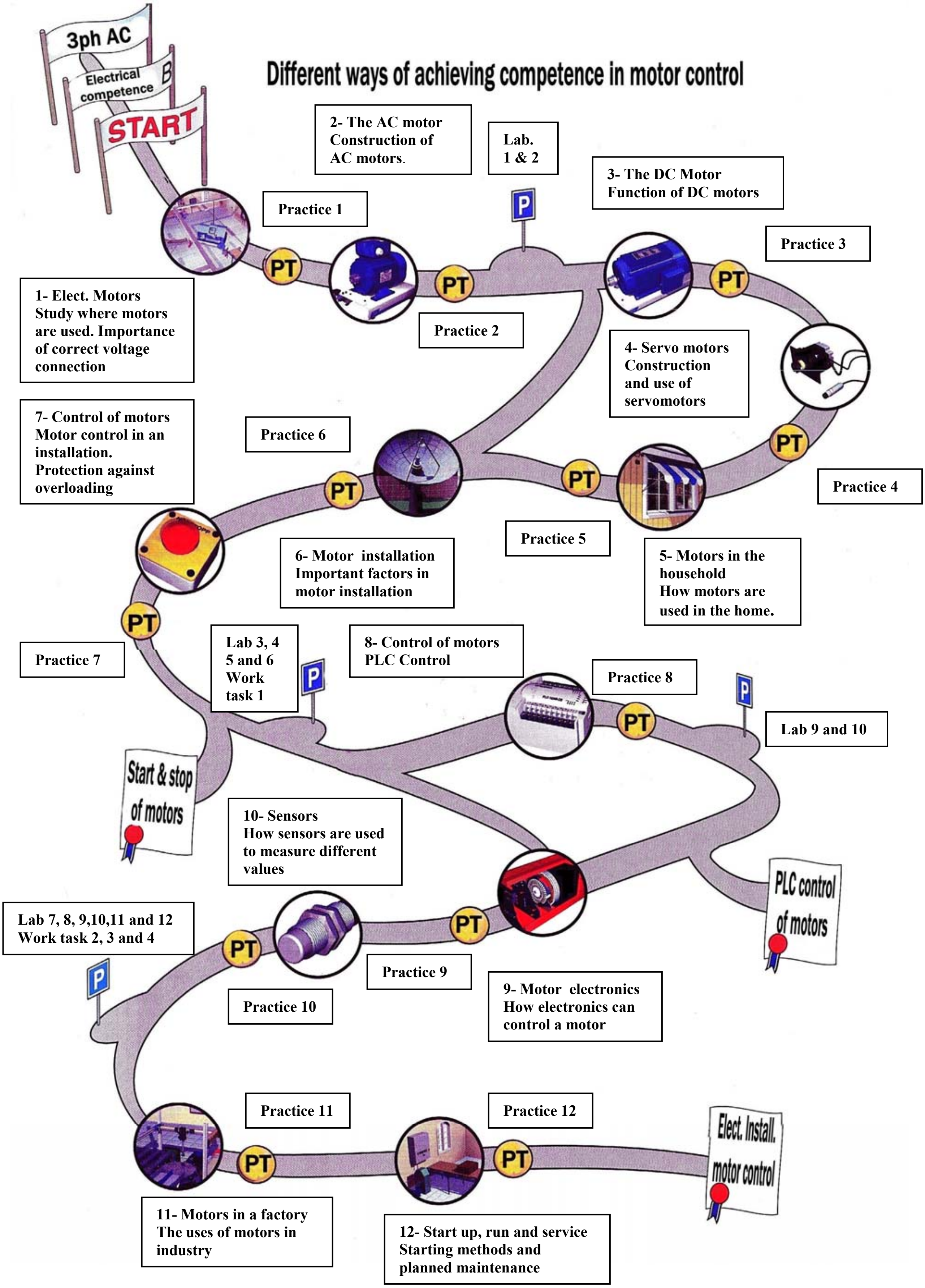
Work Projects
After studying the instructions in the workbook, work projects with installations in a control box with different types of equipment for control of DC or AC motors, are completed. Suggestions for study plans are also given on when the different installations can be completed.

Motor Control in an Electrical Installation
In order to complete the course plan for Electrical Installation, all the Chapters in the Textt Book must be studied. A selection of laboratory exercises and work projects can be made in collaboration with the teacher.

Alternative Objectives
There is also the possibility to have tailor made studies having lower objectives. The studies are planned so that the student can reach a desired level. This is achieved by building up work projects and/or laboratory exercises in the following three blocks:

A) Contactor control
B) PLC control
C) Frequency converter and current rectifier

The order of studies can vary. e.g. A, A+B, A+C, or A+B+C. See "How to achieve competence in motor control" on the following page.



3ph AC
Electrical competence B
START
Different ways of achieving competence in motor control
1- Elect. Motors
Study where motors are used. Importance of correct voltage connection
Practice 1
2- The AC motor
Construction of AC motors.
Practice 2
Lab. 1 & 2
3- The DC Motor
Function of DC motors
Practice 3
4- Servo motors
Construction and use of servomotors
Practice 4
5- Motors in the household
How motors are used in the home.
Practice 5
6- Motor installation
Important factors in motor installation
Practice 6
7- Control of motors
Motor control in an installation.
Protection against overloading
Practice 7
Lab 3, 4 5 and 6 Work task 1
Start & stop of motors
8- Control of motors
PLC Control
Practice 8
Lab 9 and 10
PLC control of motors
10- Sensors
How sensors are used to measure different values
9- Motor electronics
How electronics can control a motor
Practice 9
Practice 10
Lab 7, 8, 9,10,11 and 12
Work task 2, 3 and 4
11- Motors in a factory
The uses of motors in industry
Practice 11
12- Start up, run and service
Starting methods and planned maintenance
Practice 12
Elect. Install. motor control
PT
P

Laboratory Exercises

The Lab Exercises are completed with different types of motor for AC and DC. These can be loaded gradually with a magnetic powder brake.

During the lab exercises studies are made of different control equipment that is used to run and control the motors. A few examples of control equipment are contactors, frequency converters, current rectifiers and PLC. These units are either assembled as a separate unit or as a module card that is fitted to the Base Unit 2000.

Base Unit 2000

The Base Unit is the centre for connecting different equipment. It is supplied by 230V AC and feeds the connected modules. These modules are inserted between two slides to a 64-pole socket.

Base Unit 2000

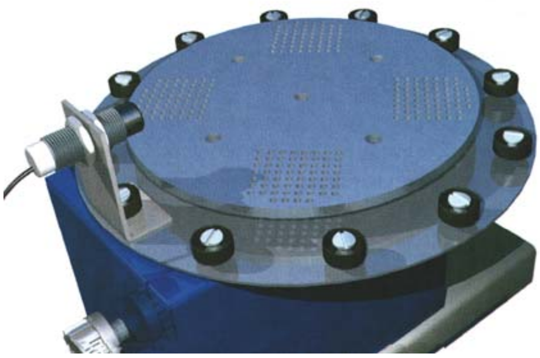
Vs Motor

The Vs motor is a 250W synchronous motor. It is connected to 3phase 400V supply voltage and can be connected in Y or D. (Star or delta). The supply to the Vs motors power circuit is via a 3-phase terminal that is connected to the 3-phase network. It can also be supplied from a frequency converter.

Vs Motor

Circular measuring table

The round measuring table consists of a worm gear having a vertical axle that drives a fixture plate. The worm-gear reduces the speed (rpm) and is driven by an electric motor via a suspended axle supported by ball bearings.
The bracket is fitted with a sensor for detecting different materials.



Round *measuring table with sensor*

Ls Motor

The Ls motor has a power of 250W and has a separately magnetised field winding.
A current rectifier must be used when connecting to 230V AC, single phase.

Ls Motor

Revolution Counter (rpm)

To measure the rotation speed of the motor, a tachometer is attached to the motors axle.

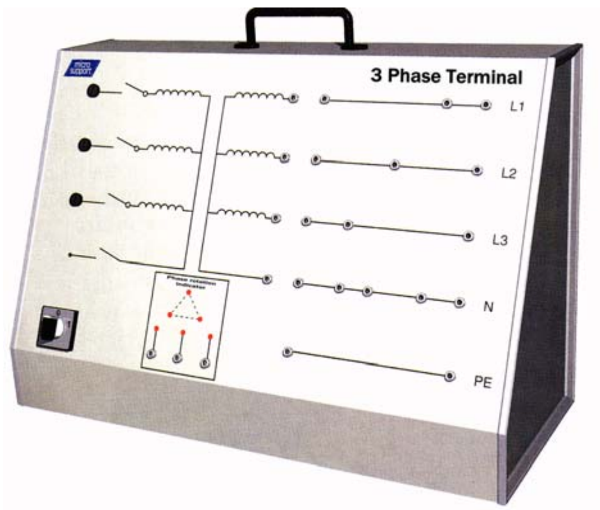
Revolution counter (rpm)

3-Phase Terminal

The connection of the Vs motor to 3-phase is via a 3-Phase Terminal having a 5 pole 16A plug according to standards CEE17. On the terminal there is a control panel for three phases and a neutral. The three phases are fused and fed via an isolating transformer.

The terminal is prepared for current and voltage measurement on all phases. It has also a phase rotation indicator with LEDs showing the rotation.

Connection to the 3-phase terminal is via lab leads, either direct or via the Contactor Module. Only touch protected 4mm lab sockets are used.

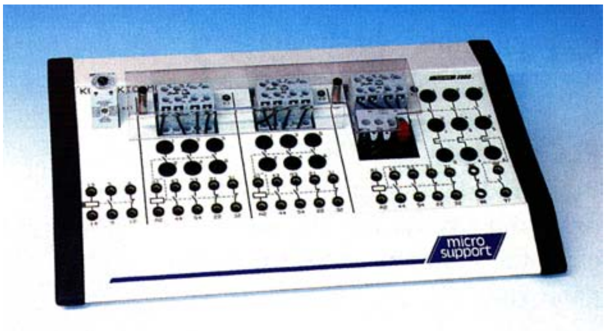


3- phase terminal

Contactor Module

To control the motor a contactor module is used to connect the 3 phases from the 3-phase terminal to the Vs motor.

The contactor module contains 3 mini-contactors. An LED indicates when a contactor is closed. Two of the contactors have additional help contacts and the third has both additional help contact and a thermal overload protection that trips when the current exceeds the set value.

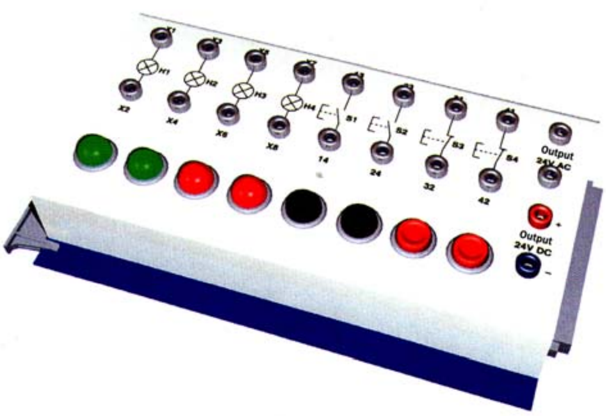


Contactor Module

The help contact is used together with the contacts in the control module when controlling the Vs motor.

Control Module

The Vs motor is started and stopped from this pushbutton control panel. The contactors are marked to show whether they are normally open (**NO)** or normally closed (**NC**). There are two **NO** and two **NC** contacts, two green indicating lamps and two red indicating lamps.



Control Module

For motor control, 24V AC is supplied from the Base Unit to the control module connected. The Base Unit can be loaded up to 50 VA.

Observe that there is also 24V DC on the Control Module, to be used in other courses.

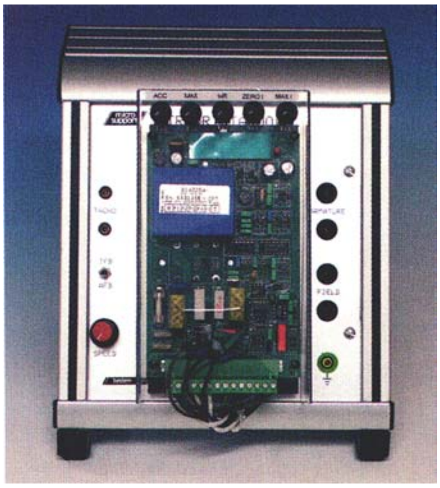
Frequency Converter

To be able to give a soft start and to regulate the speed, a frequency converter is used. This unit can be used for many other functions but in this exercise it is for soft start and stop, speed regulation and study of the overload protection.

Frequency Converter

Current Rectifier Module

The current rectifier is used to drive the DC motor. Different parameters are set such as speed, current limits, acceleration ramp etc.

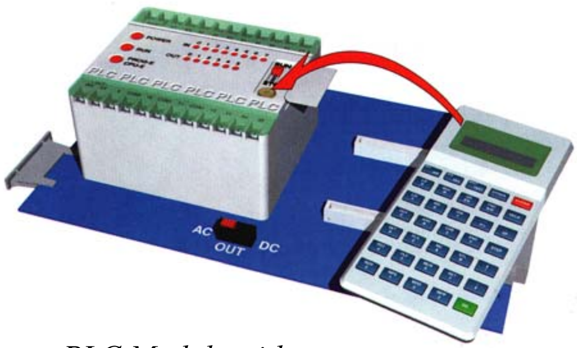


Current Rectifier

PLC Module

The PLC module consists of a PLC system and socket contacts for connection to any selected module card. On the socket module there are a number of switches for simulating faults on the inputs and outputs.

The PLC module is mounted on the Base Unit 2000. To program the PLC a programming unit, connected to the programming port, is used. As an alternative, PC based software for programming, can be used.



PLC Module with Programming Unit

PLC Module with Simulator Module

Simulation Module

With the simulation module connected to the PLC module, the input signals can be changed. The signals from the inputs and outputs are indicated by LED´s on the PLC system.

Socket Module

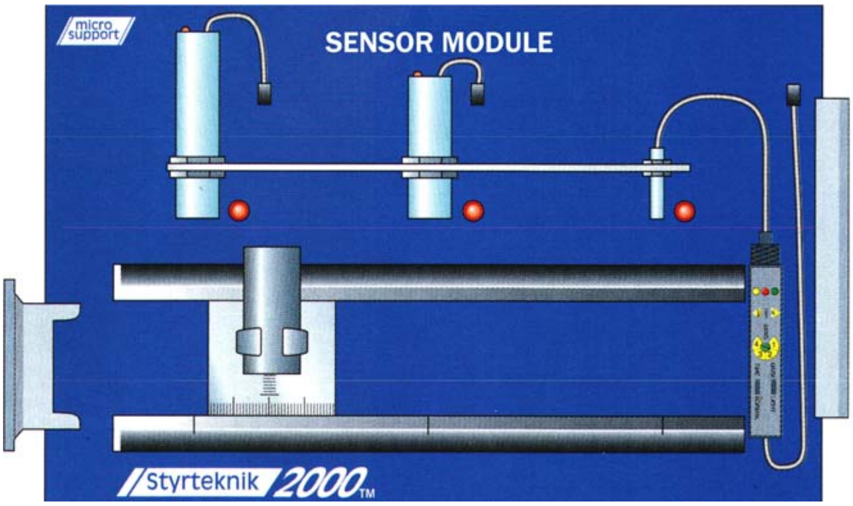
Connection between the PLC and the controlled object is via the socket module. It is pushed into place on the PLC modules contacts. From here all inputs and outputs are via the socket module. Using the lab leads it is then a simple matter to connect the PLC system to the contactor module or any other control object.

On the socket module there are also four switches to give input signals to the PLC system. The switches can be set to **NO** or **NC** positions.

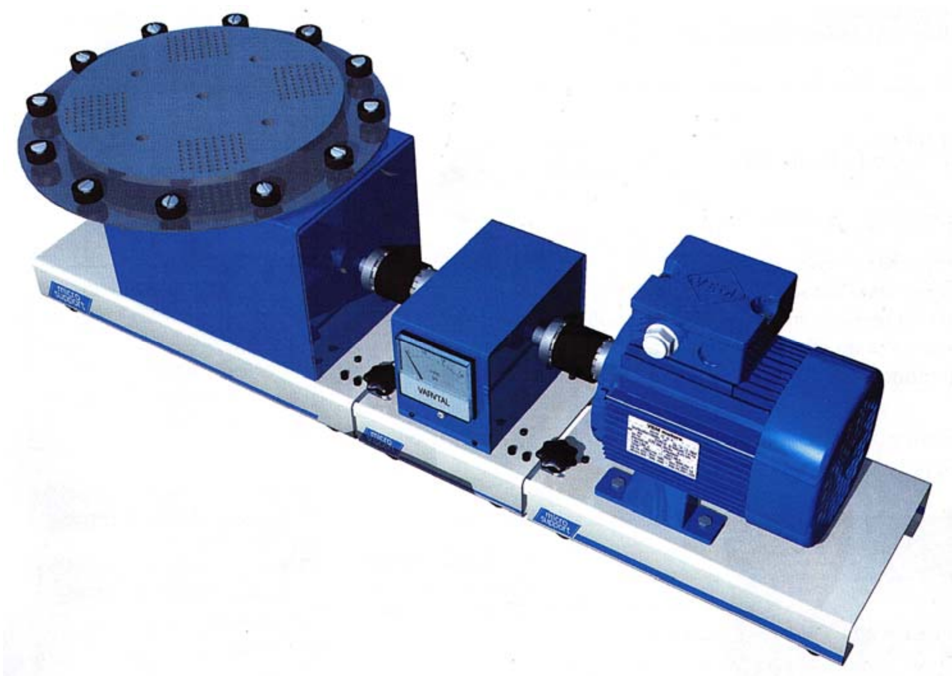
Socket Module

Sensor Module

In the sensor module there are three different types of sensor, inductive, capacitive and optical. The sensors are mounted in a measuring station where the products are pushed in front of the sensors. The distance between the product and the sensor can be set as can the distance after the sensor. By setting the sensitivity of the different sensors the given signal can be adjusted.



Sensor Module



A Vs motor drives the round measuring table via a revolution counter.

1 The Motors Nameplate

Objective: Before connecting up a motor it is important to know the mechanical and electrical data. The mechanical data describes its size, axle diameter and enclosure class. The electrical data describes connections, frequency, power factor, rated current etc. The data found will now be explained.

THE MOTOR DATA

Recommended reading
Motor Control
Chapter 1-Electric motors
Chapter 2 – AC motors
Chapter 3 – DC motors
Chapter 4 – Servo motors

Equipment
Vs motor
Other motors with nameplates

- Place the Vs motor on the workbench so that the nameplate is visible.

1.1 Fill in the data from the nameplate below.

Motor

……………………………………………
……………………………………………
……………………………………………
……………………………………………
……………………………………………
……………………………………………
……………………………………………
……………………………………………

Fig.1.1 Motor nameplate

1.1 What type of motor is described?

……………………………………………………………

1.2 What is the frequency for this motor?

……………………………………………………………

It was shown in the fact book that it is possible to connect a 3-phase motor to different voltages. Depending on the supply voltage, connect the motor either in Y or D (star or delta). Consider the supply voltage and the voltage the motor windings are rated at before connecting.

D With 230V supply voltage connect the motor in delta.

Y With 400V supply voltage connect the motor in star.

The lowest rated voltage has the highest rated current.

The highest rated voltage has the lowest rated current.

1.4 What is the rated voltage of the motor when connected in Y respective D.?

Rated current in delta:..………………………

Rated current in star:…………………………

1.5 What is the stated axle power?

……………………………………………………..

1.6 What is the asynchronous speed of the motor?

………………………………………………….

The speed marked on the nameplate is calculated when the motor is warm and at the correct rated voltage and rated power. i.e. w*hen the motor is loaded.*

The speed given on the nameplate is the asynchronous speed. Using the formula it is possible to calculate the number of poles in the motor also how much slip. Slip is the difference between synchronous and asynchronous speeds. The table shows the motor speed at 50Hz.

p	n_s(rpm)
2	3000
4	1500
6	1000
8	750
10	600
12	500

Formula for motor synchronous speed

$$n_s = 2 \cdot f \cdot 60/p$$

n_s = **synchronous speed**
p = **number of poles**
f = **frequency**

1.7 How many poles has this motor?

……………………………………………………….

1.8 The relative slip **s** can be calculated by comparing $\mathbf{n_s}$ with $\mathbf{n_a}$ = asynchronous speed. What is the percentage slip?

………………………………………………………

1.9 The power factor is given on the nameplate. What is the power factor of this motor?

………………………………………………………………………..

……………………………………………………………………….

1.10 Explain in your own words what power factor means.

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

Motor applications

There are many motors in the home, school, and work and in the community. In the school workshop there may a pillar drill, lathe or similar machine that is driven by an electric motor.

1.11 The first task is to visit the workshop or similar section and make a list of all the motors. Check the nameplates and complete the tables below.

Hand tools 230V	Rated current	Stated axle power	Power factor cos φ	Speed rpm

Machines 230/400V	Rated current Y -connection	Stated axle power	Power factor cos φ	Speed rpm

Machines NC-control 230V/400V	Rated current Y-connection	Stated axle power	Power factor cos φ	Speed rpm

Summary

Many interesting facts can be found by studying the nameplate of an electric motor, especially when it is loaded. It is necessary to study the nameplate before connecting because:

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………...

…………………………………………………………………………………...

2 MOTORS DIRECTION OF ROTATION

Objective: An electric motor can be started and stopped in many different ways. It will be necessary to run the motor in different direction of rotation. These problems will be studied in this chapter.

CONNECTING THE MOTOR

Recommended reading
Motor Control
Chapter 1-Electric motors
Chapter 2 – AC motors
Chapter 7 – Control of motors

Equipment
3-Phase terminal
Vs motor

- Place the Vs motor on the workbench so that the nameplate is visible.

- Connect the motor in star.
  Connect to the 3-phase terminal as shown in figure 2.1 below. i.e. L1-U1, L2-V2, L3-W3.

- Start the motor using the switch on the 3-phase terminal.

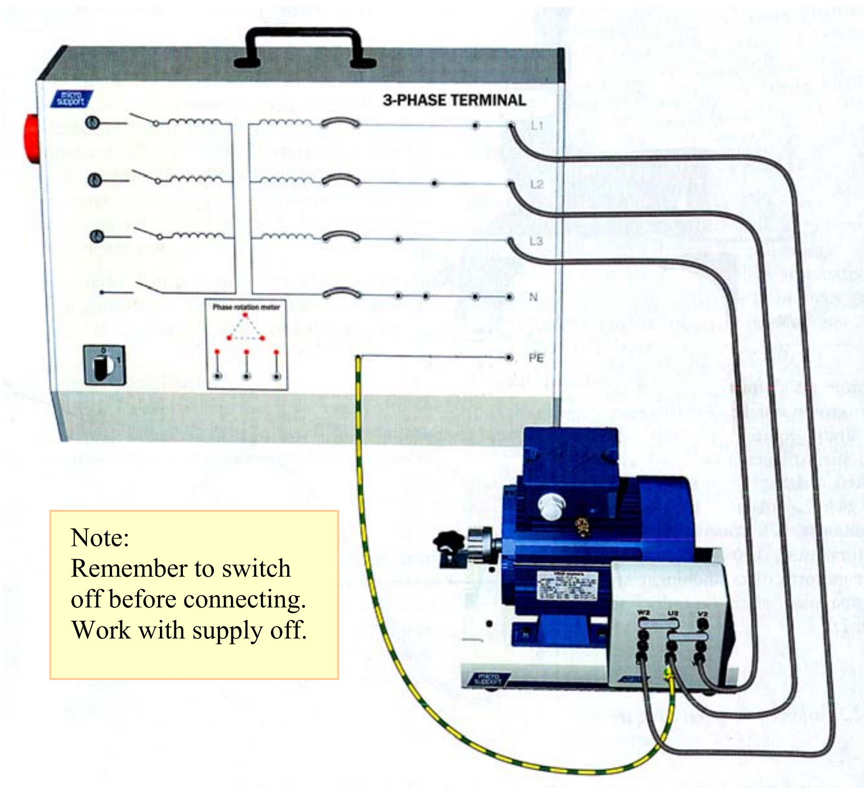
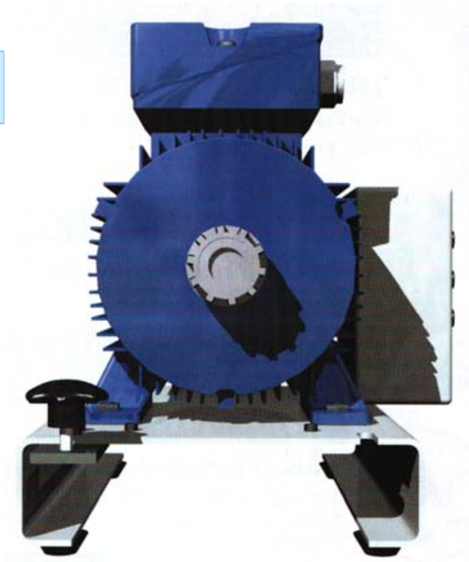


Fig. 2.1 3-Phase terminal with star connected motor.

- Switch off at the 3-phase terminal and study the direction of rotation when the speed is slow enough to see how the axle is turning.

State the direction of rotation seen from the axle end of the motor.

The direction of rotation is always from the axle end.



- Switch off the supply and let the motor stop completely. Change over any two phases, start up the motor and check the direction of rotation.

2.1 Sketch the motors direction of rotation seen from the other end.

By changing over any two phases on an asynchronous motor the direction of rotation will be reversed. The direction of rotation is dependent on the order in which the phases L1, L2 and L3 are connected to the motor windings. The phases have an angle difference of 120 degrees. This means that the motor windings are supplied in rotation. See figure 2.2.

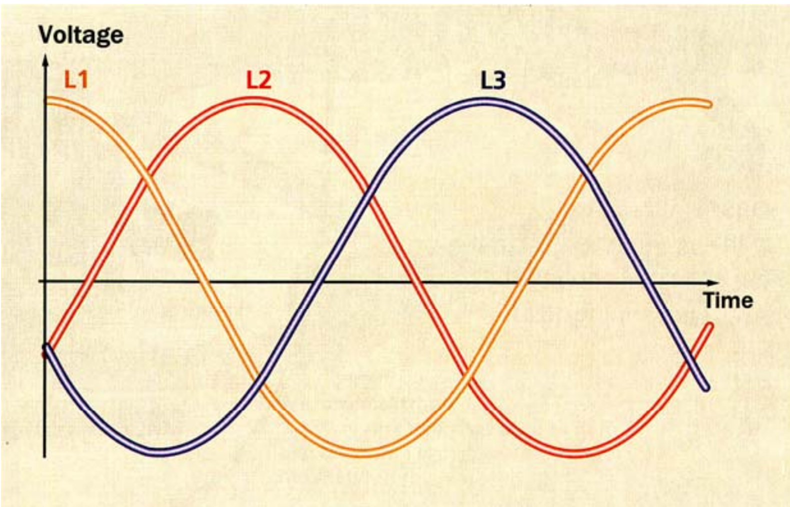


Fig. *2.2 Phase angle*

As the phases come in the order L1, L2 and L3, then according to 2.2 the motor will turn clockwise. If two of the phases are changed then the supply order is changed and the direction of rotation will change to anti-clockwise.

Phase Rotation Meter

A phase rotation meter can be used when the motor is at full speed and it is difficult to see which direction it is turning. This meter gives an optical indication of direction.

A motor that is connected L1-U1, L2-V2 and L3-W3 will rotate clockwise.

- Switch off the supply to the 3-phase terminal.
- Connect the Vs motor and phase rotation meter as shown in figure 2.3.

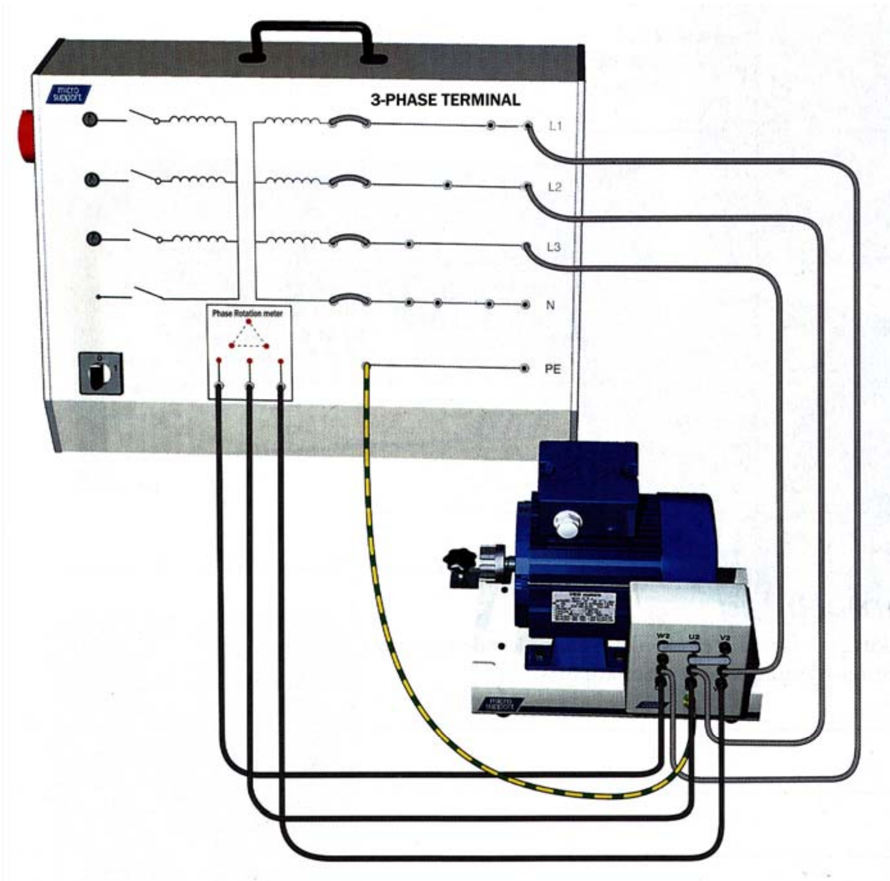


Fig. 2.3 3-Phase terminal with phase rotation meter and Vs motor.

2.3 Switch on the 3-phase terminal and check the phase rotation on the phase rotation meter. Was it correct?

……………………………………………………………………………………

……………………………………………………………………………………

2.4 Check the motor rotation with different phase changes. Leave the phase rotation meter connected and change over the phases as shown in the table below. Mark with rotation arrows the motors direction of rotation.

Note:
Switch off the supply and let the motor stop completely before starting a new connection.

Motor connection	**Direction of rotation**
L1-U1 **L2-V1** **L3-W1**	
L1-U1 **L2-W1** **L3-V1**	
L1-W1 **L2-U1** **L3-V1**	
L1-V1 **L2-U1** **L3-W1**	
L1-V1 **L2-W1** **L3-U1**	
L1-W1 **L2-V2** **L3-U3**	

Summary

By changing any two phases to an asynchronous motor, the motor will change direction of rotation. If the motor is connected ……

…………………………………………………………………

…………………………………………………………………

…………………………………………………………………

…………………………………………………………………

…………………………………………………………………

…………………………………………………………………

3 OVERLOAD PROTECTION

Objective: In this exercise the overload protection on a contactor, will be examined. The construction will also be studied and how it is connected in a motor circuit.

OVERLOAD PROTECTION CONSTRUCTION

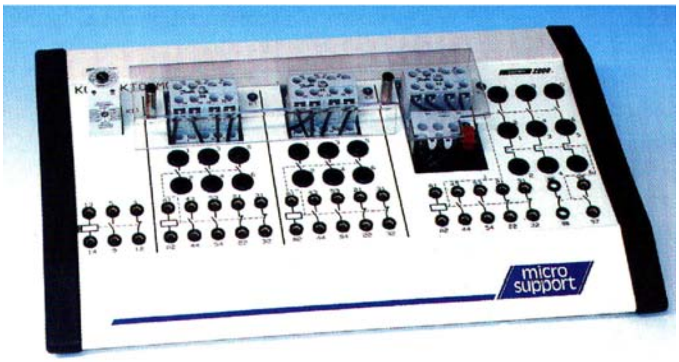
Every motor must be protected against excess current partly by means of short circuit protection and partly by overload protection. The simplest protection from short-circuiting, is a fuse which melts when there is a short circuit. The most common overload protection is by a thermal-switch that opens when the current is too high. An overload senses the combination of current and time if they are higher than the circuit can withstand.

- Place the Vs motor on the workbench so that the nameplate is visible.

- Look for the contactor with the overload protection. It is marked **Q3** at the top right of the contactor module. See figure 3.1

Recommended reading
Motor Control
Chapter 1-Electric motors
Chapter 2 – AC motors
Chapter 7 – Control of motors

Equipment
Base Unit 2000
Contactor Module
Control Module
3-Phase terminal
Vs motor
Universal Instrument



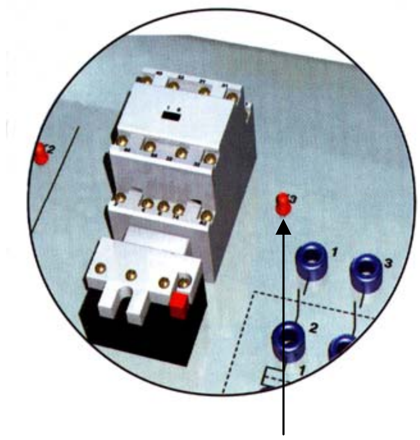


Fig.3.1 Contactor Q3 with overload protection

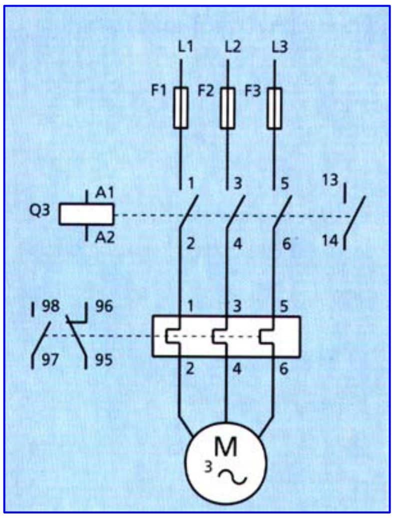


Fig.3.2 Example of the power circuit with contactor and overload protection.

The three fuses are situated on the 3-phase terminal. Contactor **Q3** with overload protection is connected up as shown in figure 3.2. Contacts **95-96** are connected in series with the contactor coil **Q3**. When the overload protection is activated, the normally closed contacts **95-96** open and the contactor coil is de-activated. Contacts **97-98** are used to activate an alarm that indicates when the overload has tripped. This type of overload is often known as contactor controlled overload protection.

3.1 Study the right hand side of the overload. A small activating arm can be set to the current value at which the overload will trip. Write down the highest and lowest values of tripping current.

I_{max} =…………………………… I_{min} =…………………………..

An overload protection, in this case a thermal overload, is usually built up from a bi-metal strip which when heated, bends, opens a pair of contacts and acts as a switch. See figure 3.3.

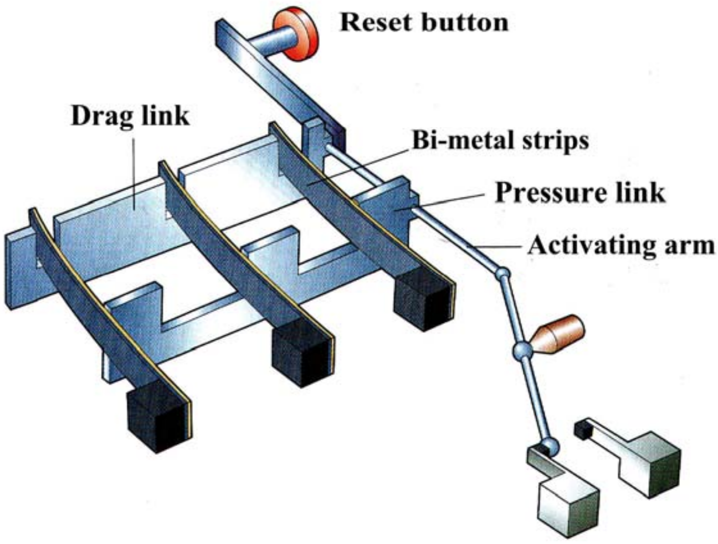


Fig. 3.3 Thermal overload protection.

When the heat increases due to increase of current, the heat in the b-metal strips also increases so that it starts to bend due to the difference in the expansion of the two metals. As they bend they pull the pressure link on the activating arm until the contact is changed from one side to the other. See figure 3.3.

The current can be set using an adjustable arm to the value suitable for the motor circuit. When the overload has been tripped it is necessary to reset by pushing the **RESET** button. This can only be done when the bi-metal has cooled down.

- Study the data sheet for thermal overloads in figure 3.4 and answer the questions.

Thermal overload relays TI 9 for minicontactors CI 4

Range		Max fuse	Single contact change over switch	Code no.
Motor starter A	Y/D – starter A	A		
0.13 – 0.20	–	32	x	047H3040
0.19 – 0.29	–	32	x	047H3041
0.27 – 0.42	–	32	x	047H3042
0.4 – 0.62	–	32	x	047H3043
0.6 – 0.92	–	32	x	047H3044
0.85 – 1.3	–	32	x	047H3045
1.2 – 1.9	–	32	x	047H3046
1.8 – 2.8	3.2 – 4.8	32	x	047H3047
2.7 – 4.2	4.7 – 7.3	32	x	047H3048
4.0 – 6.2	6.9 – 10.7	32	x	047H3049
6.0 – 9.2	10 – 16	32	x	047H3050

Fig. 3.4 Data sheet for thermal overload protection.

3.2 The overload protection is marked **047H3044.** What is the current range for this overload?

……………………………………………………….

3.3 Which two signal contacts are normally open?

………………………………………………………..

3.4 What is the maximum short circuit fuse that can be inserted in the overload circuit?

………………………………………………………...

Overload Protection Tripping Time

From figure 3.5 it is possible to read off the time taken for the overload to trip. On the X-axis in the diagram below, is shown the number of times multiplied by the current, which can pass through the overload protections set value. On the Y-axis is shown the time taken in seconds before the overload trips. Study the diagram and answer the following questions.

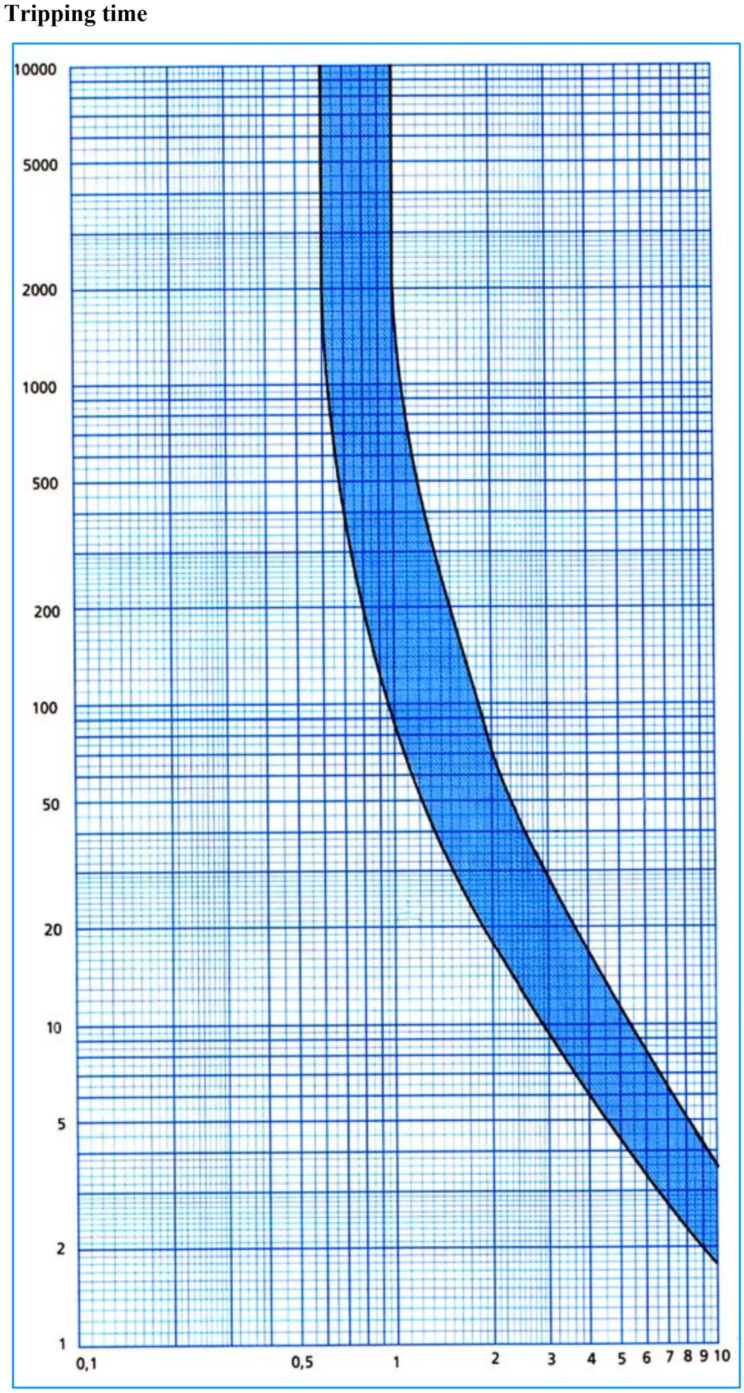


Fig.3.5 Diagram showing current and

3.5 If the current is three times the set current, how long before the overload trips?

……………………………………………………………………

3.6 If the current is the same as the set current, how long will it take for the overload to trip?

………………………………………………………………………..

When setting the overload protection, first check the maximum current the motor takes. This is shown on the nameplate. Then set the overload value using the setting lever to the right.

3.7 What is the maximum current drawn by the motor when connected in star? Check on the nameplate.

I =………………………A

3.8 What should the overload setting be?

I =………………………A

Note:
The setting of the overload protection shall always be the same as the motors maximum current.

Setting the Overload Protection

- Connect the motors power circuit as shown in 3.6.

- Connect the control and contactor module to a control circuit as shown in figure 3.7

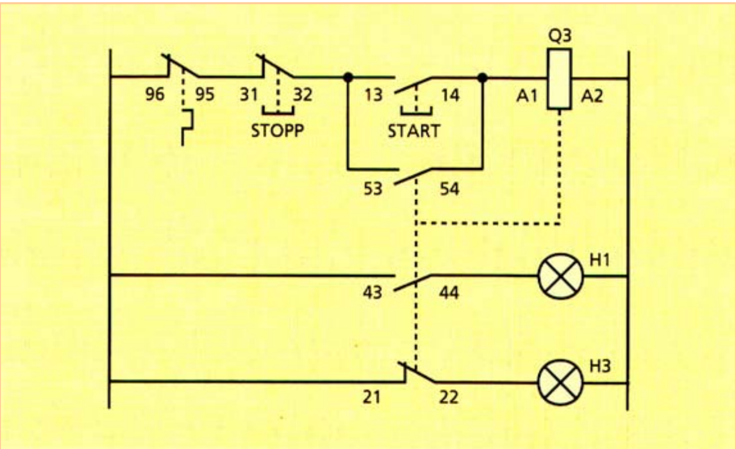


Fig.3.7 Motor control circuit with a hold-in circuit.

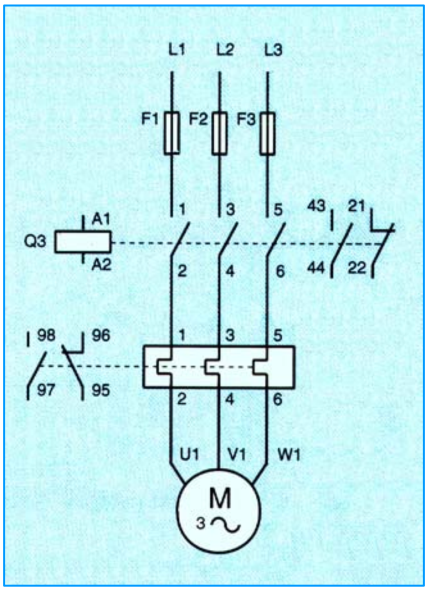


Fig. 3.6 Motor power circuit.

- Switch on the supply to the Base Unit and test the hold-in circuit by pressing the start button **S1** and then the stop button **S3**.
- Set the overload protection as shown in the table below.
- Connect a Universal meter set to **10A AC** and measure the current in one of the phases.
- Switch on the 3-phase terminal.

3.8 Start the motor and measure the phase current and the time it takes to trip. Write up the value in the table below. Divide the measured current by the overloads set current. Write in the value in the table below.

Overload set current	Time before overload trips in seconds	Measured current/set current
0,6 A		/0,6 A =
0,7 A		/0,7 A =
0,8 A		/0,8 A =

3.9 Read from the diagram, between which two values the overload will trip. Write in the values in the table below.

Overload set current	Time before overload trips in seconds
0,6 A	
0,7 A	
0,8 A	

3.10 Did the calculated value agree with the actual value?

……………………………………………………..

3.11 Will the overload trip earlier or later if the current in the motor rises?

………………………………………………………

- Switch off the 3-phase terminal.
- Set the overload according to the value on the motor nameplate.

The setting is now the correct setting for this motor. The value on the nameplate is that value to which the overload must be set.

Loss of a Phase

The next task is to simulate when a motor loses one phase. When one of the phases is lost the current in the other two increases causing the overload to trip.

- Keep the same connections as before with a Universal meter connected to one of the phases.
- Switch on the 3-phase terminal.
- Start the motor by pushing the START button.

3.12 Read the current in one of the phases.

I=……………………………………A

- With a timer, measure how long it takes for the overload to trip.
- Remove one of the phases, not the one the meter is connected to. Start the timer.

3.13 What is the value of the current now?

I =………………………………..A

3.14 How much time did it take for the overload to trip?

……………………………………………seconds

3.15 Did this agree with that in diagram 3.5?

……………………………………………………..

Summary

When installing a motor it must have different types of protection. In this laboratory exercise overload protection of the thermal type was examined. When the current was higher than the set current ..

…………………………………………………………………………….

…………………………………………………………………………….

…………………………………………………………………………….

…………………………………………………………………………….

…………………………………………………………………………….

…………………………………………………………………………….

4 CONTROL OF THE MOTOR

Recommended reading
Motor Control
Chapter 7 – Control of motors
Chapter 12- Starting up, run and service.
Equipment
Base Unit 2000
Contactor Module
Manoeuvre Module
3-Phase terminal
Vs motor

Objective: In this exercise a motor shall be manoeuvred forward, reverse and from two stations.

The first stage is to change the direction of rotation of the motor using a control circuit. Standards give the directions as ***clockwise*** or ***anti-clockwise***. The terms ***forward*** and ***reverse are*** also used.

FORWARD AND REVERSE MANOEUVRES

- Place the equipment on the laboratory bench.

- Study the circuit diagram in figure 4.1.

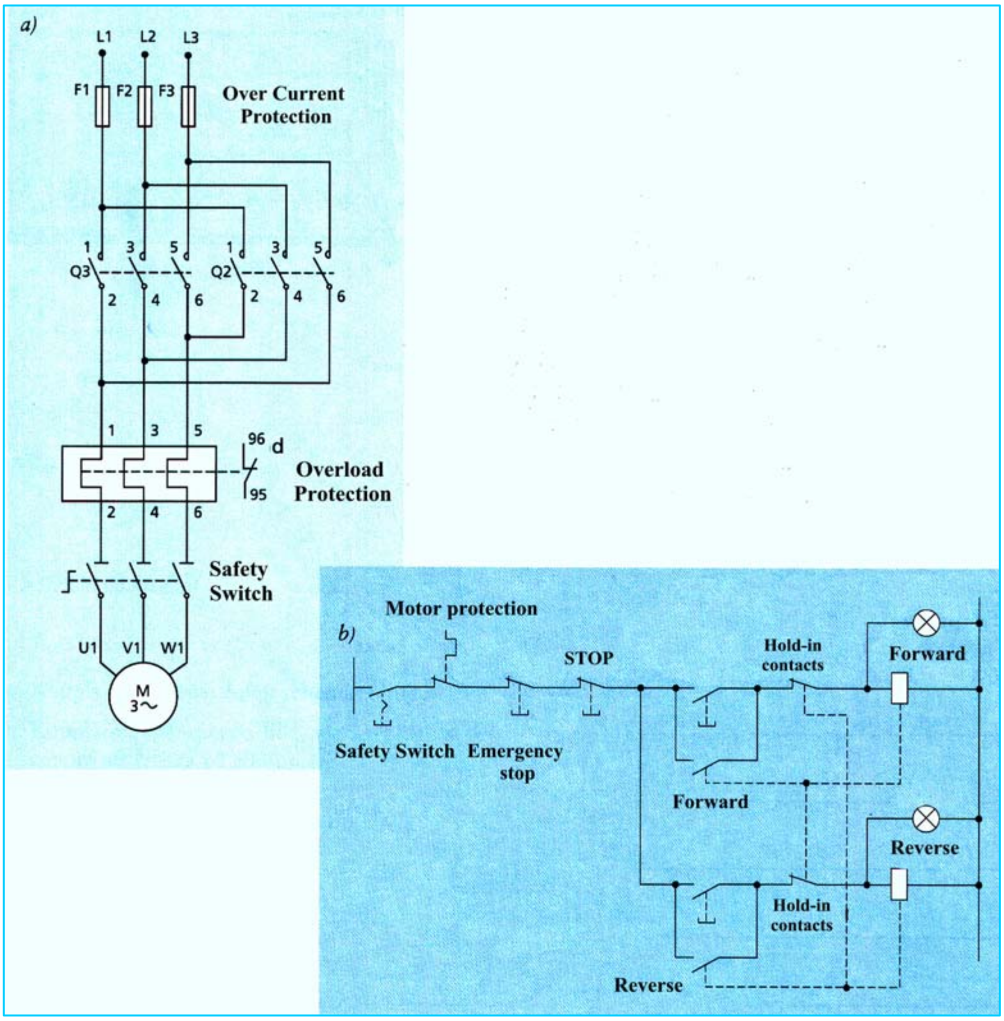


Fig.4.1 Diagram with forward and reverse of motor.
a) Power circuit b) Control circuit.

All contactors, relays and other control equipment that is used to control a motor installation and can possibly create a danger if energised at the same time, shall be interlocked to avoid malfunctioning.

The schematic diagram shows that the forward contactor makes the motor turn clockwise. This is easy to check as contactor **Q3** connects **L1-U1**, **L2-V2** and **L3-W3**. The upper part of the circuit diagram is a hold-in circuit when running the motor anticlockwise. Pressing the **STOP** button stops the motor.

The lower part of the circuit is connected when the motor is run in the anticlockwise direction; the hold-in circuit is broken by contacts **REVERSE.**

If the motor is run clockwise, a lock prevents the possibility of the motor being run in two directions at the same time. If this did happen then there would be a short circuit with a great strain on the motor and the load connected to the shaft. When contactor **Q3** is energised, the hold-in contacts in the lower hold-in circuit, are opened. It is then impossible for contactor **Q2** to be energised.

4.1 Explain in your own words what happens when pushbutton **REVERSE** is pressed to run the motor in anticlockwise direction.

..……………………………………………………………………

……………………………………………………………………..

……………………………………………………………………..

4.2 Which motor winding will be connected to the phases when pushbutton **REVERSE** is pressed and contactor **Q2** is energised? Connect the phase by drawing a line between those marked below.

LI **U1**

L2 **V2**

L3 **W3**

- Switch off the supply to the 3-phase terminal.
- Connect the control circuit as shown in figure 4.1. Number the switches according to the control module and also give the connection number.
- Test the connections ***without having the motor connected***.

4.3 Which contactor was energised when pushbutton **FORWARD** was pressed?

………………………………………………………………………

………………………………………………………………………

4.4 What happens when pushbutton **REVERSE** is pressed?

……………………………………………………………

……………………………………………………………

4.5 Which set of contacts is used to break the hold-in circuit?

……………………………………………………………

- Figure 4.2 below shows a simplified diagram of how the motors power circuit is connected to the 3-phase terminal and contactor module. Connect the power circuit as shown in figure 4.1.

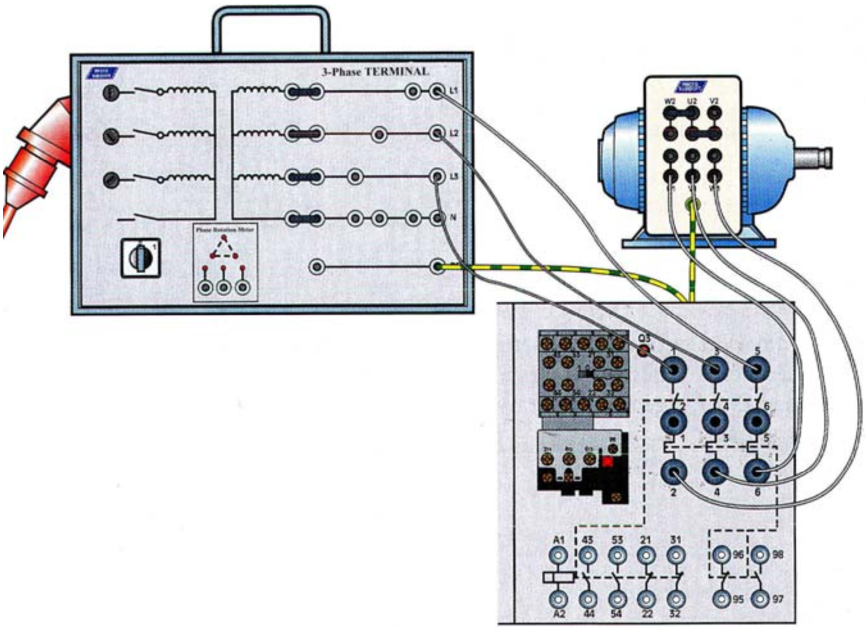
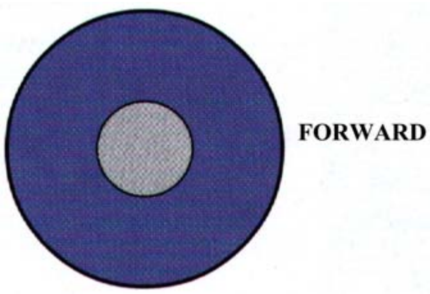


Fig.4.2 Diagram for the connections between the motor and contactor module.

- Connect the control circuit as shown in figure 4.1.

- Switch on the supply to the 3-phase terminal. Start the motor by pressing the pushbutton **FORWARD.**

4.6 Sketch the direction of rotation in the round figure.



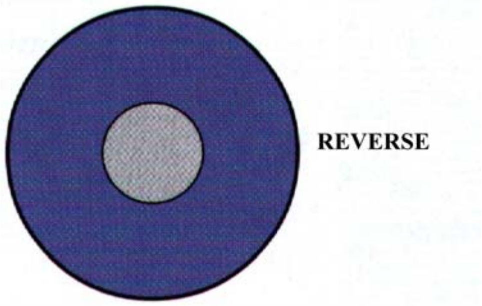
- Stop the motor by pressing the **STOP** button.

- Make sure the motor is completely still.

- Press the pushbutton **REVERSE**.

MAKE SURE THAT THE MOTOR IS COMPLETELY STILL BEFORE PRESSING THE REVERSE BUTTON.

4.7 Sketch the direction of rotation in the figure below.



- Stop the motor by pressing the **STOP** button.

- Make sure the motor is completely still.

The objective of interlocking the hold-in contacts is to prevent contacts Q2 and Q3 from closing at the same time. This would cause a short circuit as the phases are crossed in the power circuit.

TIME CONTROLLED MOTOR

The inclusion of timer control in motor circuits is quite common. It can for example, start or stop a production line after a certain time so that a carton can pass a sensor. Another example is to have a fan rotate 10 minutes of every hour to change the air in a factory. In the next exercise a time-controlled circuit will be connected using a timer relay. The motor shall rotate for 30 seconds after the start button has been pressed.

- Switch off the supply to the Base Unit and 3-phase terminal.

- Complete the control circuit shown in figure 4.3. Add the missing numbers.

- Set the timer relay to **30** seconds using the two control knobs.

- Switch on the supply to the equipment.

- Press pushbutton **S2**.

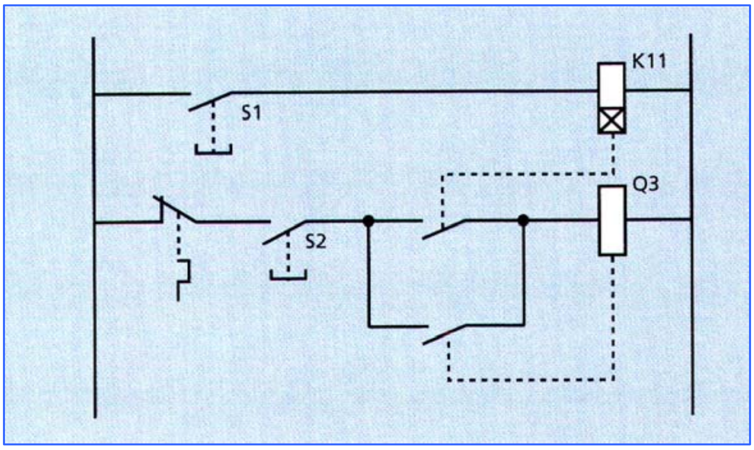


Fig.4.3 Circuit diagram for time control motor protection with hold-in.

4.8 What happened?

……………………………………………………………

……………………………………………………………

4.9 Press pushbutton **S1** and wait 30 seconds, then press **S2**. What happened?

……………………………………………………………

……………………………………………………………

- Change the connections so that the motor starts after a delay of 15 seconds after pressing pushbutton **S1**.

4.10 Sketch the circuit diagram in the space below.

INTERLOCKING with TIMER RELAY

It has been explained earlier why interlocking is necessary in a motor control circuit. Another example of interlocking is when a motor must first be at full speed before a contactor for another task can be energised. Combining an interlock with a timer relay can solve this problem.

- Switch on the supply to the 3-phase terminal.

- Connect the circuit as shown in figure 4.4. Add the missing numbers.

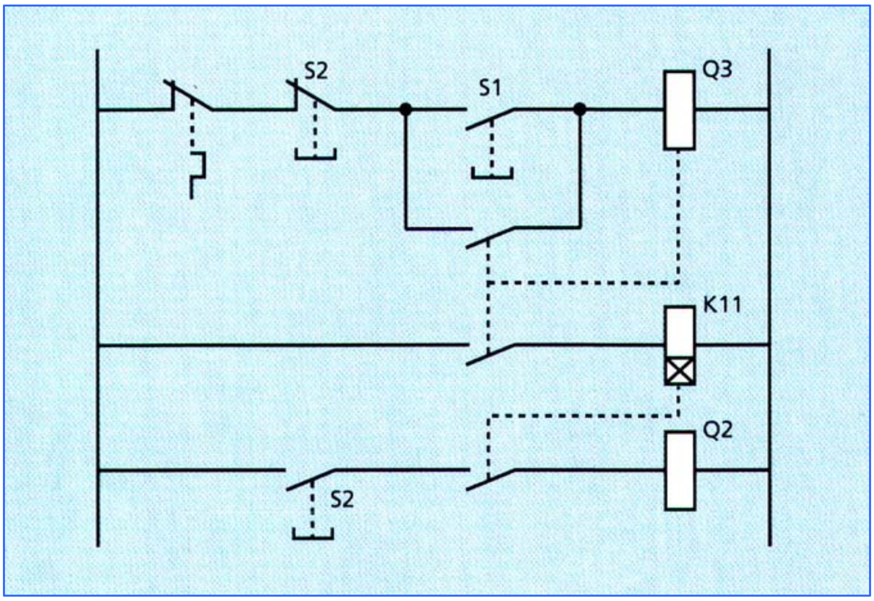


Fig.4.4 Delayed energising of contactor Q2.

- Set the timer relay to **15** seconds.

- Press pushbutton **S2**.

4.11 What happened to the motor?

……………………………………………………………..

……………………………………………………………..

- First press **S1**, wait for **15** seconds and then press **S2**.

4.12 What happened to the motor?

……………………………………………………………..

……………………………………………………………..

4.13 Explain interlocking in the space below.

……………………………………………………………..

……………………………………………………………..

MOTOR CONTROL FROM TWO DIFFERENT PLACES

In some installations it must be possible to start the motor at one station and stop at another. i.e. from two separate control panels.
Before starting to connect this circuit, study figure 4.5.

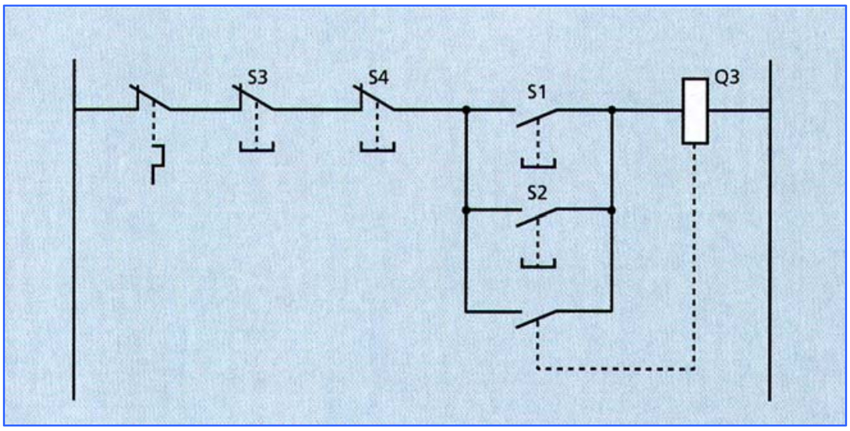


Fig.4.5 Start and stop of a motor from two separate places.

- Switch off the supply to the Base Unit and 3-phase terminal.

- Add the missing numbers in figure 4.5 and connect the circuit.

- Switch on the supply to the Base Unit and 3-phase terminal.

- Check that the motor can be started from two different places. Start the motor by pushing **S1 OR S2**. Stop the motor by pressing **S3 OR S4.**

4.14 Which logic connection has pushbuttons **S1** and **S2**?

……………………………………………………………….

4.15 Which logic connection has pushbuttons **S3** and **S4**?

……………………………………………………………….

SUMMARY

A motors power circuit includes connection of the supply voltage via the contactor to the motor. The control circuit ….

……………………………………………………………….

During the lab exercise it was possible to control a motor with forward/reverse contactors equipped with interlocking. It could be seen that another action could not be stated before certain conditions were met. This means that

……………………………………………………………….

……………………………………………………………….

5 Y/D CONNECTION

Recommended reading
Motor Control
Chapter 7 – Manoeuvre of motors
Chapter 12- Starting up, run and service.

Equipment
Base Unit 2000
Contactor Module
Manoeuvre Module

Objective: In this exercise a control circuit for Y/D connection will be studied.

In earlier exercises the asynchronous motor was started by direct on line starting with the motor connected in Y (star). Now the motor will be started by a method known as Y/D (star-delta) start. This means that the motor first starts up in star and after it reaches speed is switched over to run in delta. By using a Y/D start the start current is reduced to approximately 30% of the value when started directly.

The motor used previously has on its nameplate D/Y 230/400 V. This means that the motor when Y connected should be supplied by 400V. If it were changed to D connection, the winding would be in danger of burning out. The motor needs only 230V when started in delta. For this reason the exercise will be a "dry run", that is, without a motor.

If the motor were marked D/Y 400/690V it would have been possible to connect the motor to the power circuit.

Y/D START without MOTOR

- Study the motors power circuit when Y/D started, as seen in figure 5.1.

In the ***start position*** both of the contactors **Q3** and **Q2** are energised. The incoming phases go through the motor windings and are short circuited at **Q2**. This puts the motor in a star connection when starting.

In the ***run position*** contactor **Q2** opens and contactor **Q1** is energised. Connection is then made between **U1-W2, U2-V1,** and **V2-W1**. In the run position the motor is connected in delta.

Normally an asynchronous motor shall be connected in delta as the mains voltage is 400V, but with a star start the stat current and start torque are lower

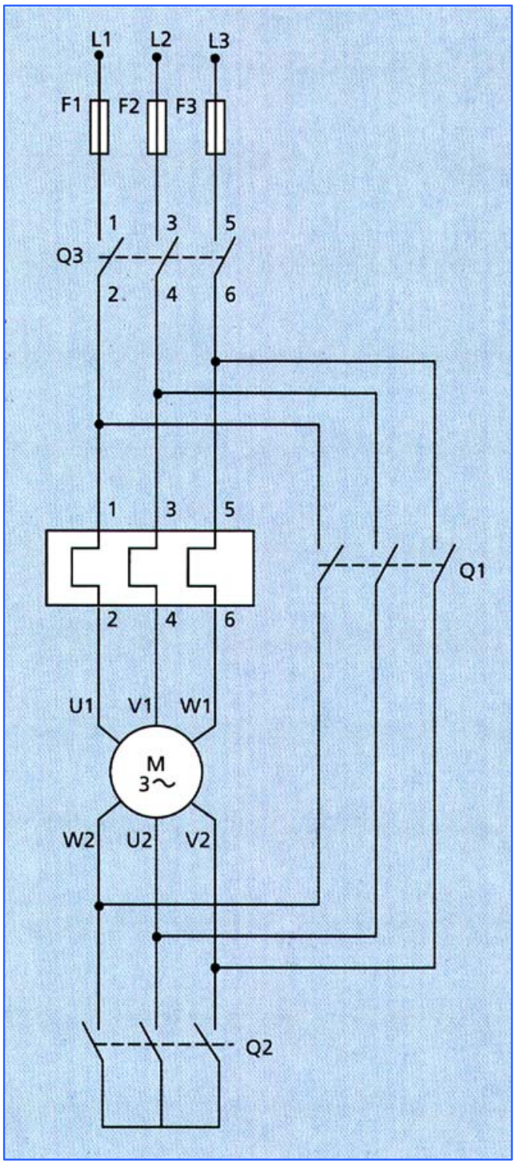


Fig.5.1 Motor power circuit- Y/D start.

Y/D starting will now be simulated using three lamps.
The motors power circuit will not be connected.

- Place the equipment on to the workbench.
- Make sure that the supply is switched off at the Base Unit.
- Connect the motors control circuit as shown in figure 5.2.
  Add the missing numbers.

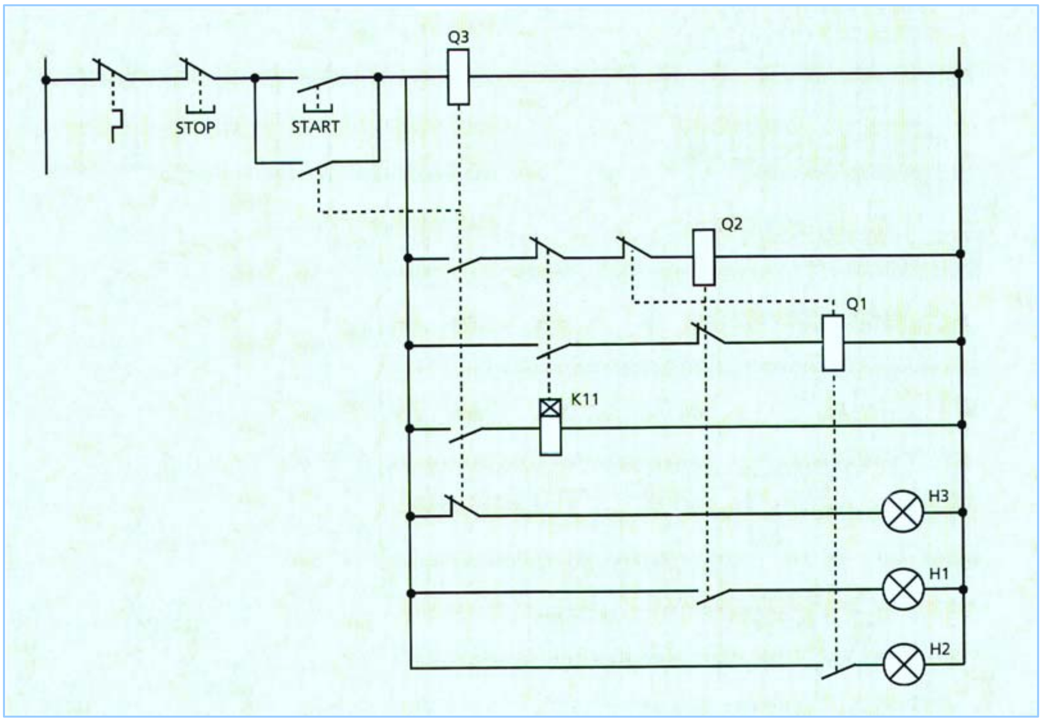


Fig.5.2 Control circuit

5.1 What is the designation for the motor protection?

……………………………………………………..

5.2 What did the lamps indicate? Couple the lamps together with the correct indication.

Lamp H1	**Delta connection**
Lamp H2	**Star connection**
Lamp 2	**Stop**

5.3 Which components are used in the hold-in circuit?

……………………………………………………………………..

……………………………………………………………………..

5.4 Explain the function of star-delta starting.

……………………………………………………………………

……………………………………………………………………

- Set the timer relay **K1** to **10** seconds. This is the delay time for the star connected motor to reach its speed before the motor is switched to run in delta.

- Switch on the supply voltage to the base unit.

- Press the **START** button.

5.5 Wait and study the indicating lamps **H1, H2**, and **H3**.
In which order did the lamps light when the supply voltage is switched on, to the base unit?

H1……………… H2………………..H3………………

-after 5 seconds?

H1……………… H2………………..H3………………

-after 10 seconds?

H1……………… H2………………..H3………………

-after 20 seconds?

H1……………… H2………………..H3………………

-when the stop button is pressed?

H1……………… H2………………..H3………………

Summary

Asynchronous motors are started in Y/D to reduce the start current in the power circuit. In the laboratory exercise, contactors were used for this task. A power circuit contactor with motor protection was used but no motor connected. Two additional contactors were necessary, one for star and one for delta connections.

The most important factors when completing a Y/D start are …..

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………..

6 FAULT FINDING in the CONTROL CIRCUIT

Objective: To be able to complete fault finding in a motor control circuit consisting of switches, contactors and lamps.

FAULT FINDING

A mechanic, operator or technician in a factory workshop where there are many types of production machines must have a good knowledge of motors. This applies to their function, understanding a simple circuit diagram and complete less complicated measurements using a universal instrument. When fault finding in a motor installation it is important to have knowledge about how the equipment functions when it is operational. This can be obtained by:

- Studying the schematic diagram, connections and circuit diagrams.
- Complete a simple measurement when the installation is running.
- Discuss the function of the installation with workmates who are familiar with the installation.

Recommended reading
Electrical Competence A&B
Chapter 6– Motor installation
Chapter 8- Supplying an electrical installation
Motor Control
Chapter 7- Manoeuvring motors
Chapter 12- Installation, starting up, running and service

Equipment
Base Unit 2000
Contactor Module
Manoeuvre Module
3-phase terminal
Vs motor
Universal instrument

Note: When fault finding live (supply on) extra care must be taken. Knowledge of how to take readings live is also necessary. In this exercise the faults will be in the control circuit and not in the power circuit.

Control measurements in the control circuit

A small installation will be made and checked. Three faults will be added and the task is to systematically localise the faults. At the back of the Contactor Module are three switches for setting faults. See figure 6.1. Do **not** set any faults at this time.

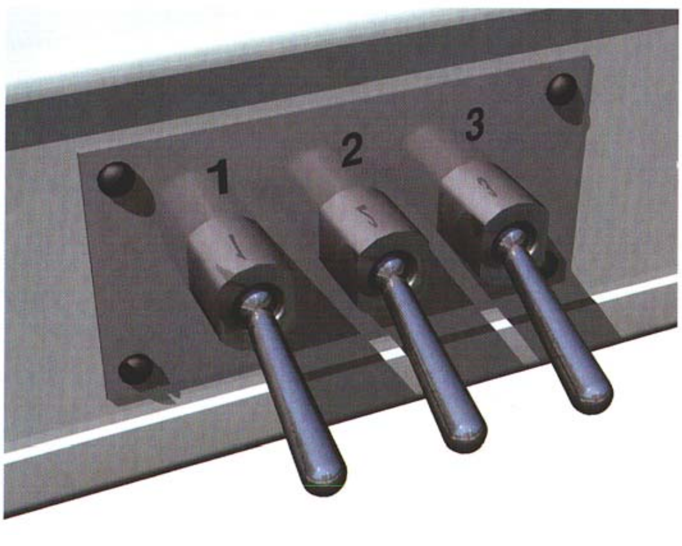


Fig.6.1 Rear view of the Contactor Module showing the fault switches.

- Place the equipment on the workbench. Connect up as shown in figure 6.2.

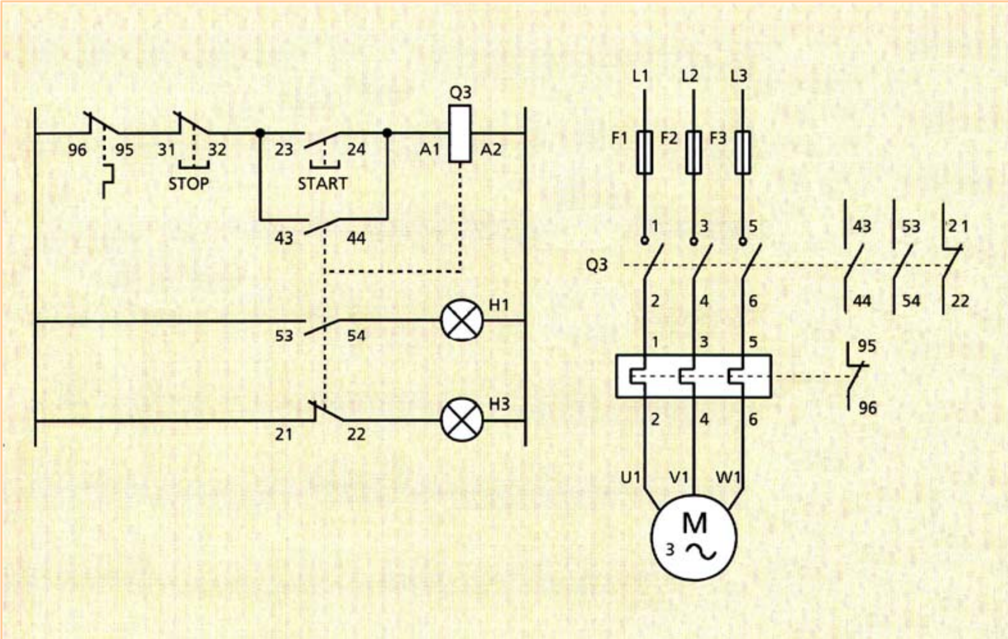


*Fig.6.2 Motor start and stop with indication lamps for **RUN** and **STOP.***

- Switch on the voltage on the base unit and test the function of the circuit by pressing **START** to start the motor and **STOP** to stop it.

6.1 Which lamps were lit during **RUN** and **STOP?**

RUN:…………………..STOP:…………………..

- Stop the motor by pressing **STOP**.

- Start the motor by pressing the mechanical switch at the top of contactor **Q3.**

Note: Be extra careful not to come in contact with live terminals.

By testing the motor in this way it can be seen if there are any faults in the control or power circuits. The next stage is to complete exercises on taking measurements with a universal instrument.

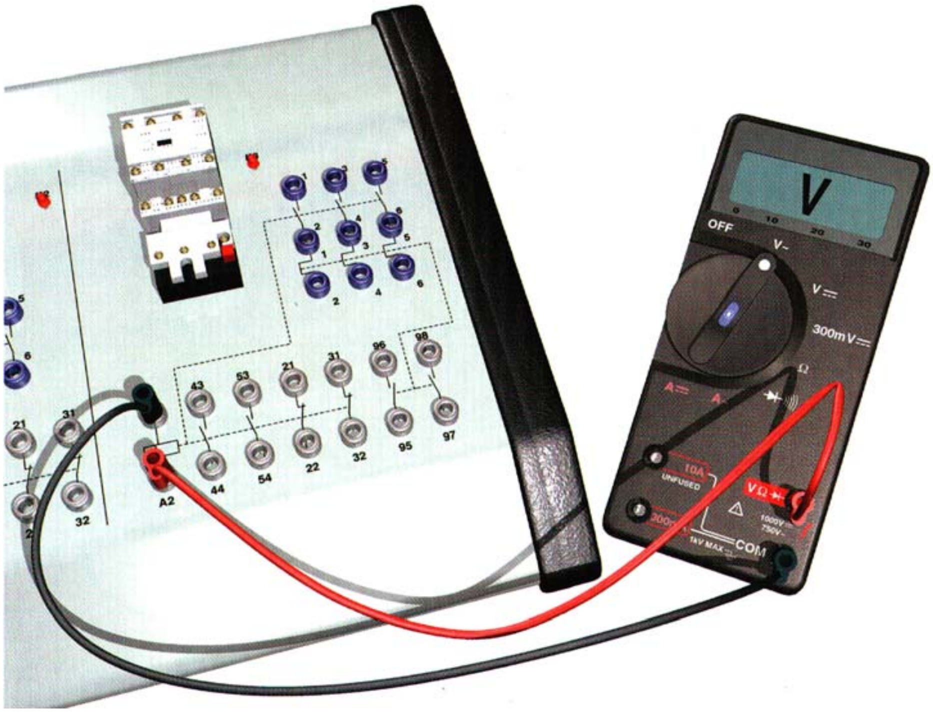


Fig.6.3 Universal instrument connected for measuring voltage.

- Set the universal instrument to AC voltage-min.30V.
- Connect the instrument as shown in Fig. 6.3.
- Press the **START** button and then **STOP**.
- Measure the voltage across the contactor coil when the contactor is energised and when it is open.
- Enter the results in the table below.

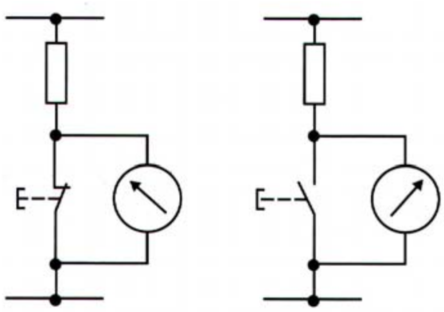


Fig.6.4 Voltage measurement across a switch.

	Contactor Energised	**Contactor open**
$V_{contactor}$		

As can be seen in the table there is a voltage across the contactor when the contactor is open. This reduces to zero when the contactor is energised. This is a usual phenomenon that a “switch” that is open has a voltage across it. On the other hand a closed switch that is a short circuit for the instrument shows no voltage.

Switch off the supply voltage to the base unit.

Fault Finding in the Control Circuit

Note: Connect only one fault at a time.

Fault Nr.1

- Set the fault switch 1 in the UP position. See at the rear of the contactor module.
- Start the base unit.
- Observe any fault that can be seen. e.g. lamps not lit that should be.
- Complete a systematic fault finding with the help of a universal instrument.
- Complete the faultfinding reports. Switch off the base unit.

Inform the teacher when the fault has been located.

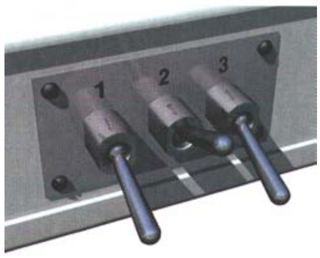
Fault Finding Report

Measuring point	Measuring instrument	Conclusions

Teacher's signature:…………………………………….Date:……………..

It takes a lot of experience to become efficient at fault finding. Practice whenever possible.

Fault Nr. 2



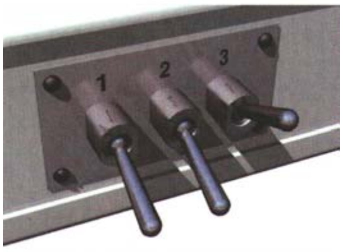
- Reset the fault switch **1.**
- Set the fault switch **2** in the up position.
- Start the base unit and continue fault finding as before.
- Complete the faultfinding report. Switch off the base unit.

Fault Finding Report

Measuring point	Measuring instrument	Conclusions

Teacher's signature: …………………………………………Date:……………..

Fault Nr. 3



- Reset the fault switch **2**.
- Set the fault switch **3** in the up position.
  Start the base unit and continue fault finding as before.
- Complete the faultfinding report. Switch off the base unit.

Fault Finding Report

Measuring point	Measuring instrument	Conclusions

Teacher's signature: ……………………………………………Date:……………..

Summary

During the faultfinding on the motor control circuit it was found that …

………………………………………………………………………..

……………………………………………………………………….

……………………………………………………………………….

……………………………………………………………………….

7 MOTOR CONTROL with FREQUENCY CONVERTER

Objective: In this exercise a frequency converter will be used to control a Vs motor.

FREQUENCY CONVERTER DATA

Frequency converters are being used more and more in industry. e. the speed of asynchronous motors such as pumps, fans and drills. T converter has in many instances replaced the Y/D start.

- Place the frequency converter on the workbench.
- Figure 7.1 shows a typical example of a frequency converter sheet. Study the data for the frequency converter selected.

Recommended reading
Motor Control
Chapter 2- AC motors
Chapter 9- Motor electronics
Chapter 10- Sensors
Chapter 12- Starting up, running and service

Equipment
Base Unit 2000
Manoeuvre Module
Vs motor
Round measuring table
Frequency converter
Magnetic powder brake
Multi-meter
Start /stop pushbuttons

Output data	
Motor power (kW)	0.2 0.4 0.75 1.5
Norm. rated current (A)	1.4 2.5 4.1 7.0
Over current	200% of rated current for 0.5 seconds, 150% under 1 minute
Output voltage	3-phase, 0V to net voltage, programmable
Output frequency (Hz)	0,5 - 120
Regulation principles	Self regulating automatic "Torque Boost"
Modulation method	Sinus formed PWM, soft PWM
Switch frequency (kVA)	
Output Voltage	
Supply voltage	1-ph. 200-240V AC (-15%+10%)
Supply frequency	50/60 Hz +/-5%
Nominal power-in (kVA)	0,9 1,5 2,5 4,4
Setting range	
Frequency set value	Analogue: 0,5V DC, 0-10V DC, 4-20mA Digital: via RS485 or parameter unit
Start signal	Start-forward, start-reverse, hold-in
Reset signal	External resetting after tripping
Programmable speeds	15 speeds can be preset digitally
Other parameters available	Activates via contact
JOG-speed	Activates via tangent board or digitally
Logic	Positive or negative logic, selective
Regulation functions	
Voltage/Frequency conditions	(V/f) Programmable
Acceleration/retardation time	0: 0,1-999 seconds, programmable individually
Current limits	0-200& programmable
Torque boost	Manual within range 0-15% or automatic
Electronic motor protection	Rated current programmable
Slip control	Programmable size and regulation time
Communication RS422/585	ECR has a built in series limit
PID regulator	Process value via 4-20mA, set value via parameter or analogue voltage set value

Fig.7.1 Data sheet for a frequency converter.

Remember that this exercise is only a very small part of all the possibilities and installation open to frequency converters. The instruction manual for the selected frequency converter must always be at hand.

3.12 What is the maximum motor power the frequency converter can withstand?

……………………………………………………………………

3.13 What is the maximum over current the frequency converter can deliver at the output?

……………………………………………………………………

3.14 What is the maximum acceleration time that can be set?

…………………………………………………………………….

Control from the frequency converters front panel

- Place the Vs motor and frequency converter module on the workbench.
- Measure the resistance of the three windings.

U1-U2 =..…………………………ohms

V1-V2 =…………………………..ohms

W1-W2 = …………………………ohms

- Measure the resistance between the phases and motor casing.

Insulation resistance =…………….ohms

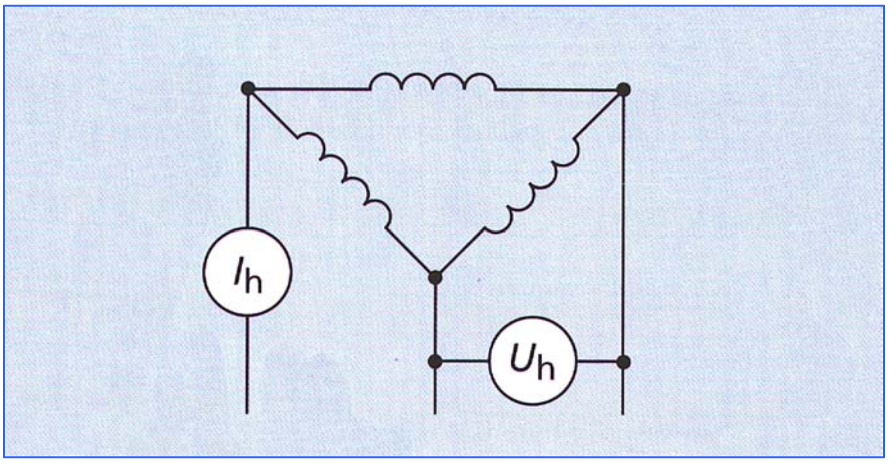
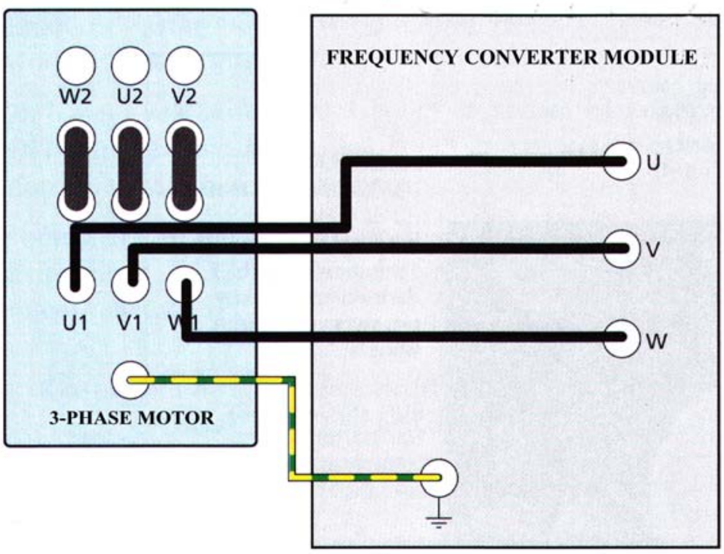


Fig.7.2 The motors three windings in delta. $U_h = U_f$, $I_h = I_f .3$

- Connect the motor in delta using jumpers on the connection box.

Fig. 7.3 Delta connected Vs Motor showing connection box.

- Connect the motor to the frequency converter as shown in figure 7.4. Use only touch safe leads.



Check that U, V, and W on the frequency converter are connected to the correct terminals on the motor, U1, V1 and W1. Check also that the frequency converter and the motor are connected to the earth terminal.

Fig.7.4 Motor and frequency converter inter- connected.

The two sections of the frequency converter are easily distinguished, the frequency converter section and the section for external control.

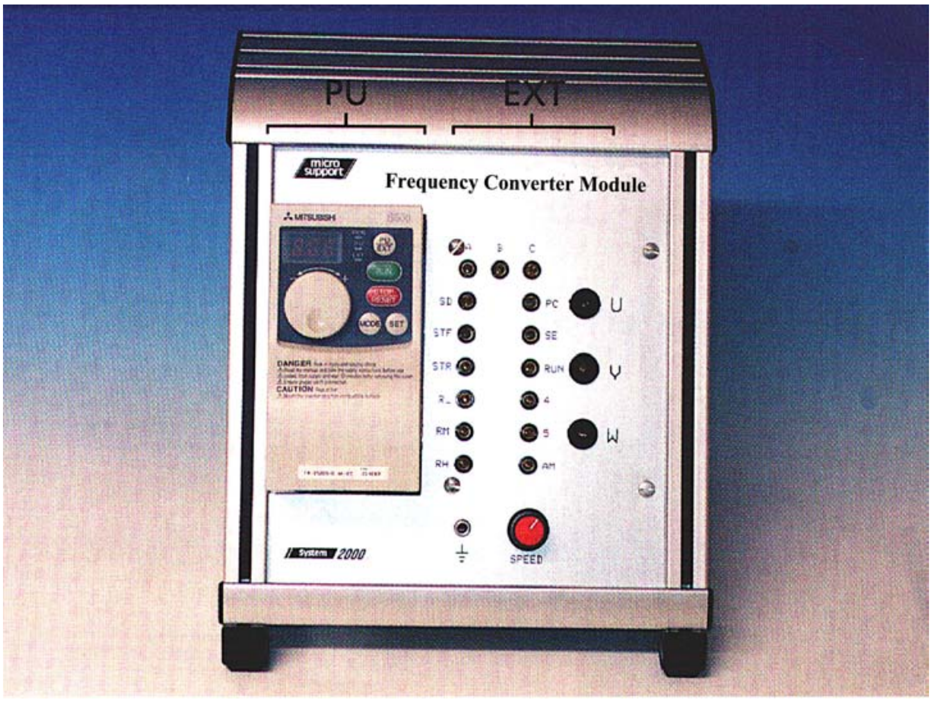


Fig.7.5 The frequency converter module

There is a parameter unit built into the frequency converter. Here it is possible to have different settings for different operation alternatives. Examples of the control knobs function are shown in figure 7.6.

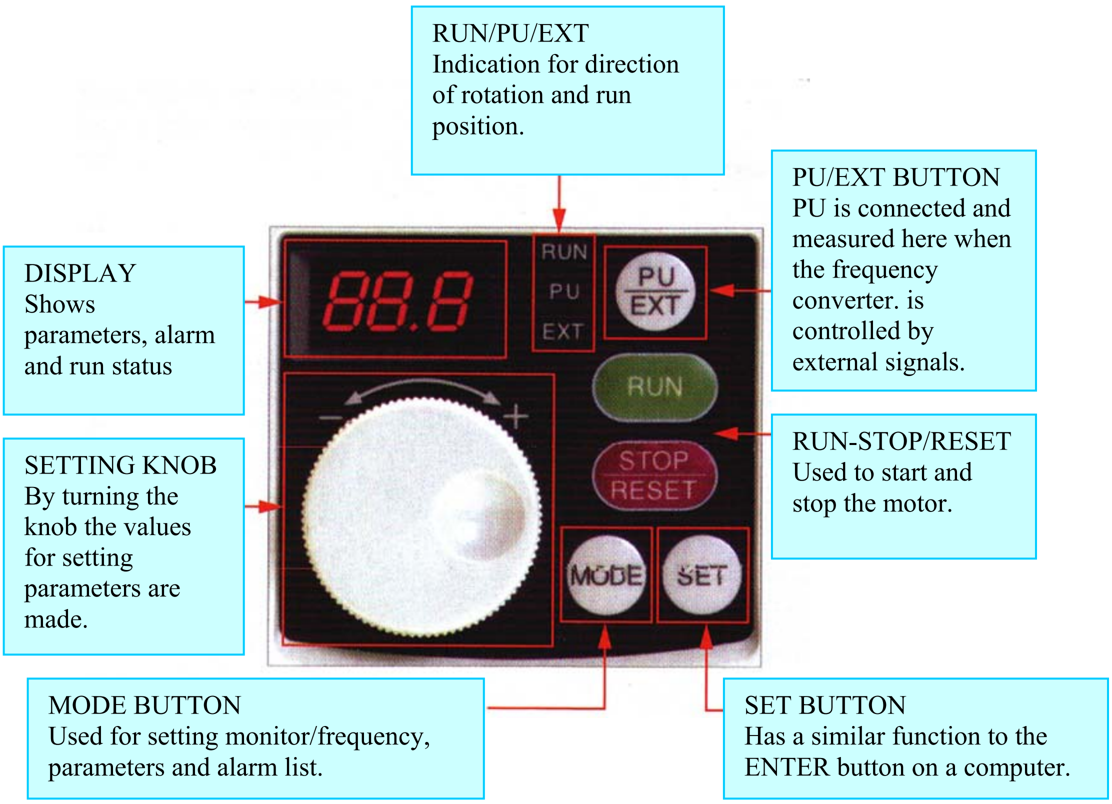


Fig. 7.6 The frequency converters integrated parameter unit.

PARAMETER SETTINGS

Selection of Operational Positions

- Study the schematic diagram figure 7.7 and connect the start-stop pushbuttons for external control as shown in the diagram.
- Check that there is no start signal connected. Connect the frequency converter to the supply.
- Examine the display. Press the **MODE** button and the three modes are displayed.

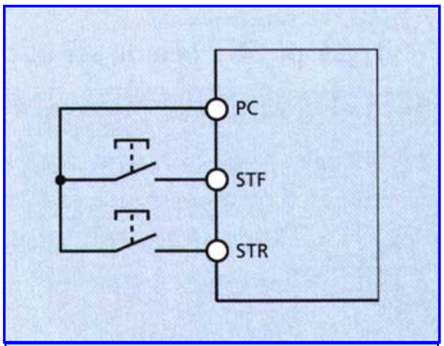


Fig.7.7 The motor is started externally when the PC is connected to STF and stopped by pressing the STOP button. The direction of rotation is changed if the connection is between the PC and STR. Note: If both STF and STR are activated at the same time, the motor will stop.

- Monitor/frequency setting shows **0,0**
- Parameter setting shows **P-0**
- Alarm list shows **E—**

- Press **MODE** until parameter setting is displayed.
- ***Select*** parameter **P79** using the setting knob.
- ***Confirm*** by pressing **SET**. The **RUN** position stored displayed.
- ***Set the run position*** to **0** using the setting knob.
- ***Confirm the setting*** by pressing **SET**. The parameter now been stored and is confirmed when the set values blink alternately. If instead, the next parameter number is shown, this is confirmation that no changes have taken place.
- Before starting the motor make sure that **MODE** is set **Monitor/frequency** setting.
- Run position **0** has now been selected. By pressing butt **PU/EXT**, the start/stop place can be selected. Note: La indication.

Warning: For safety reasons, all parameter changes shall be made in PU position. No start signal to be active on external.

- Check that the motor can be started and stopped at the remote station. Test also if the speed can be altered with potentiometer **SPEED**.

7.4 Check the different run positions for parameter **79** and mark them with an **X** in the below.

Run Position	Start and stop PU EXT	Speed (rpm) EXT
0		
1		
2		
3		
4		

- Complete the exercise by setting the operation position to **0**. Select run position **PU** and check that the **PU** indication lamp, lights up.

Setting the motors rated current

- What is the rated current for the motor when connected in delta?………A
- Press **MODE** until **P-** -is displayed.
- Find parameter **P9** by turning the setting knob.
- Press **SET** and the set value is shown.
- Set the value for the rated current of the motor using the set knob.
- Confirm this value by pressing **SET**. The current value has now been stored and is confirmed when the set values blink alternately. If the next parameter number is shown, this is confirmation that no changes have been made.

Setting the maximum output frequency to the motor

- Read the rated frequency for the motor: ……………………………………
- Press **MODE,** set **P1** to "Maximum output frequency", use setting knob.
- Set the rated frequency for the motor using the set knob.
- Store the setting by pressing **SET**.
- Press **MODE** until **0,0** is displayed.

EXTERNAL MOTOR CONTROL

- Select **EXT** control using button **PU/EXT**.
- Start the motor by connecting the **PC** to **STF** with the start switch. Increase the frequency set value by turning **SPEED**.

7.5 What is shown on the display?

………………………………………………………………………………….

- Reduce the speed to zero. Reset the start switch that connects **PC** to **STF** and activate the switch between **PC** and **STR.**

7.6 What happened to the motor?

…………………………………………………………………………….

7.7 Deduce the acceleration time from zero to maximum speed. Give the time in seconds.

……………………………………………………………………………

7.8 Is the retardation time as long as the acceleration time?

…………………………………………………………

- Stop the motor. The switch between **PC** and **STR** will break the circuit.

- Switch off the supply voltage.

Make it a habit of collecting data from the manufacturers manual for the equipment being used.

With the frequency converter, many parameters can be set. In figure 7.8 below a selection of those parameters are shown. The parameters are set at the factory and between each parameter is a block. This can mean that some parameters can only be altered if other parameters are set to a certain value.

Function	Parameter	Function	Setting range	Factory settings	Note settings	Page reference
Basic Parameters	0	Torque boost,manual torque increase	0–15%	4/5/6% X		6–7
	1	Maximum output frequency	0–120 Hz	50 Hz		6–9
	2	Minimum output frequency	0–120 Hz	0 Hz		6–10
	3	...frequency	0–120 Hz	50 Hz		6–10
	4	1st internal frequency set value (RM)	0–120 Hz	50 Hz		6–12
	5	2nd internal frequency set value (RM)	0–120 Hz	30 Hz		6–12
	6	3rd internal frequency set value (RM)	0–120 Hz	10 Hz		6–13
	7	Acceleration time	0–999 s	5 s		6–14
	8	Retardation time	0–999	5 s		6–14
	9	Thermal overload protection-motor	0–50 s	Rated current X		6–16
	30	Limits to non-basic parameters	0/1	0		6–28
For other non-basic parameters shall parameter P30=1 P77=2						
Parameter for run adjustment	10	DC-Brake (start frequency)	0–120 Hz	3 Hz		6–17
	11	DC-Brake (time)	0–10 s	0,5 s		6–17
	12	DC-Brake (voltage)	0-19% max output voltage	6%		6–17
	13	Start frequency	0–50 Hz	0,5 Hz		6–18
	14	Selection of torque curve	0–3	0		6–19
	15	Jog-frequency	0–120 Hz	5 Hz		6–20
	16	Jog-acceleration/retardation	0–999 s	0,5 s		6–20
	17	Direction fo rotation"RUN" button	0,1	0		6–21

Fig.7.8 Examples of parameters, e.g. function, setting range and factory settings.

7.9 In a forthcoming exercise the motors acceleration time, respective retardation time will be set. Which parameter will be selected?

…………………………………………………………

MOTOR OPERATION

Current consumption of a motor

The next task is to understand how the current changes when an asynchronous motor is loaded.

- Connect an ammeter on one of the motors phases, between the Vs motor and the frequency converter. Select a suitable measuring range.

- Connect the magnetic powder brake to the motors axle. Press together the two couplings and screw up tight with the black knobs.

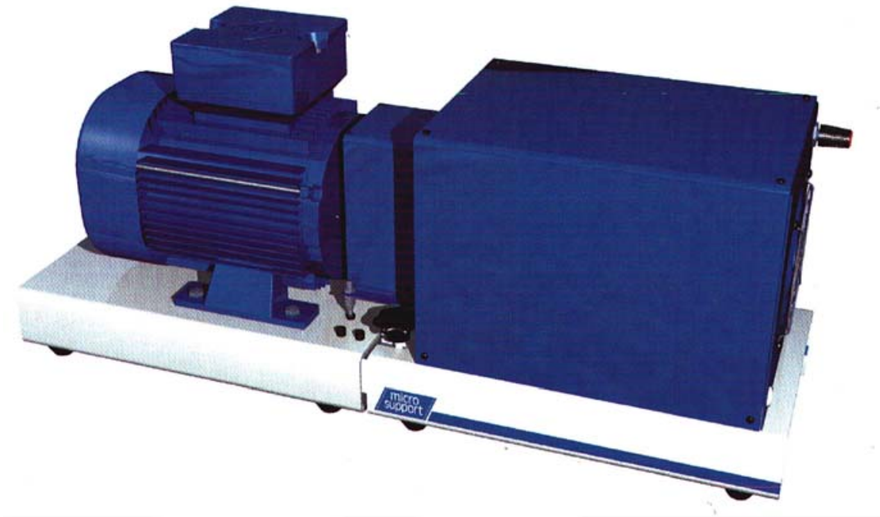


Fig.7.9 Magnetic powder brake coupled to the motor.

- Connect the magnetic powder brake to 230V. The cooling fan should start.

- At the rear of the brake there is a small knob. This is for setting different braking torque. Turn the potentiometer to its maximum position anti-clockwise.

Fig.7.10 Rear view of the magnetic powder brake showing the potentiometer for setting brake torque

- Connect the frequency converter to the mains supply.

- Start the motor from the external panel. Increase the speed by turning the potentiometer marked **SPEED**.

7.10 What is the current when the motor is without load and turning at max speed?

…………………………………………………………………….

- Increase the brake torque by turning the potentiometer at the rear of the brake, slowly in a clockwise direction. Continue until the current taken by the motor has been doubled. At the same time measure the time taken before the motor protection in the frequency converter, takes to trip.

7.11 What happens if the pushbutton **STOP/RESET** is pushed once?

……………………………………………………………………

7.12 Which fault indication is shown on the display? What information is given in the manual about this fault indication?

…………………………………………………………………….

7.13 What action must be taken to be able to restart the motor? Find this information in the manual.

……………………………………………………………………

7.14 What is the current shown on the ammeter when it is loaded to the maximum?

……………………………………………………………………

7.15 How long was the tripping time when the load was increased so that the motor current was double?

……………………………………………………………………

7.16 Did the observations of motor current agree with the theory in the fact book?

……………………………………………………………………

- Turn the potentiometer on the brake, anti-clockwise to the end position and switch off the motor. Disconnect the supply voltage to the brake and frequency converter.

Acceleration and retardation

By changing the parameters **P7** and **P8**, different acceleration and retardation times, can be set. This is very common practice in motor drives. One example is when a water pump must be started and stopped softly and gently. If started at full speed the sudden high water pressure could damage the couplings and pipes. Another example is as an alternative to Y/D start.

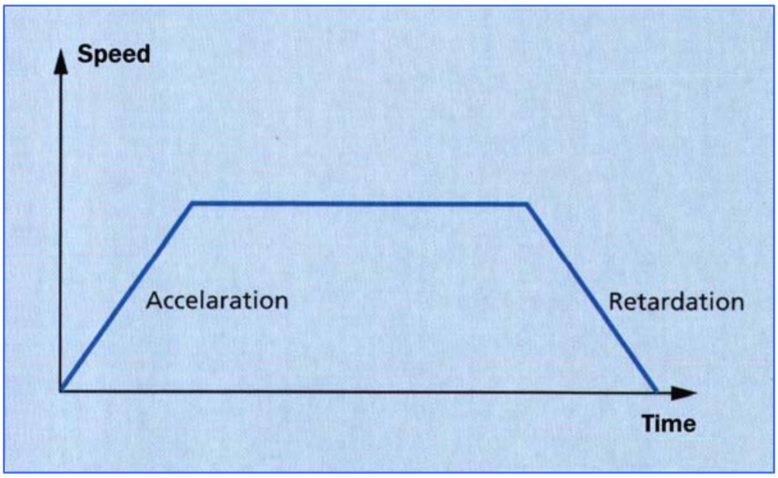


Fig.7.10 Acceleration and retardation time. A steep curve gives a quicker acceleration and retardation.

- Disconnect the brake from the motor axle and replace it with a revolution counter (speed meter). Press the coupling on to the axle and tighten up the black fixing knobs.

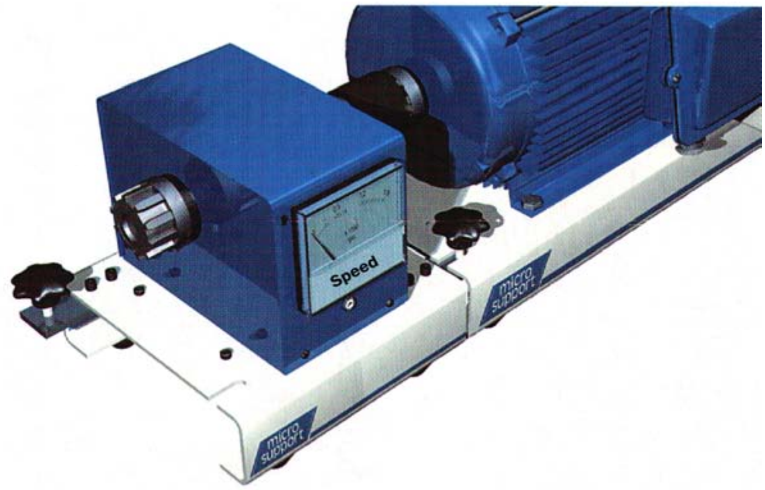


Fig.7.11 Revolution counter connected to the motor.

- Switch on the supply voltage.

- Select **PU**. Parameter **79** mode **1.**

- Select parameter **P7** Acceleration time. Set the time to **10,0** seconds. Confirm by pressing **SET**.

- Set the display in the monitor position by pressing **MODE**.

- Test run the motor by start and stop from **PU**.

7.17 How long was the acceleration time?

……………………………………………………………..

- Set the acceleration time to 15,0 seconds and the retardation time to 10,0 seconds.

- Observe the motors acceleration and retardation times.

7.18 Which buttons were pressed on the front panel to do this setting?

……………………………………………………………..

……………………………………………………………..

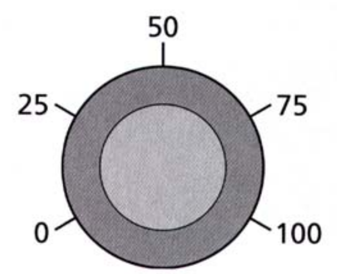
……………………………………………………………..

Speed and direction of rotation of the motor

- Select **EXT** and start the motor. Parameter **79** mode **2**.

7.19 Observe the revolution counter when the motor is running. Take readings at different percentage of the **SPEED** settings.

SPEED %	Revolution counter (rpm)
25%	
50%	
75%	
100%	



7.20 What are the highest and lowest speeds that can be set with potentiometer **SPEED**?

Lowest speed = ………………………………………….rpm

Highest speed = ………………………………………….rpm

- Set the **SPEED** potentiometer to its mid position.

PC = Contact input common terminal
STF = Forward rotation starting terminal
STR = Reverse rotation starting terminal

- Start the motor using the switch that connects **PC** to **STE**.

7.21 Which direction did the motor turn?

……………………………………………………

- Stop the motor.
- Start the motor using the other switch connecting **PC** to **STR**.

7.22 Which direction did the motor turn?

……………………………………………………

- Run the motor forward and then quickly reverse direction.

7.23 What happened?

……………………………………………………

……………………………………………………

7.24 What would have happened if there was no frequency converter and reversing was made direct?

……………………………………………………

……………………………………………………

……………………………………………………

- Disconnect the frequency converter from the supply voltage.

Frequency converters overload protection

- Connect the magnetic powder brake to the other end of the revolution counter. Centralize the axles, press together and tighten up the black knobs.

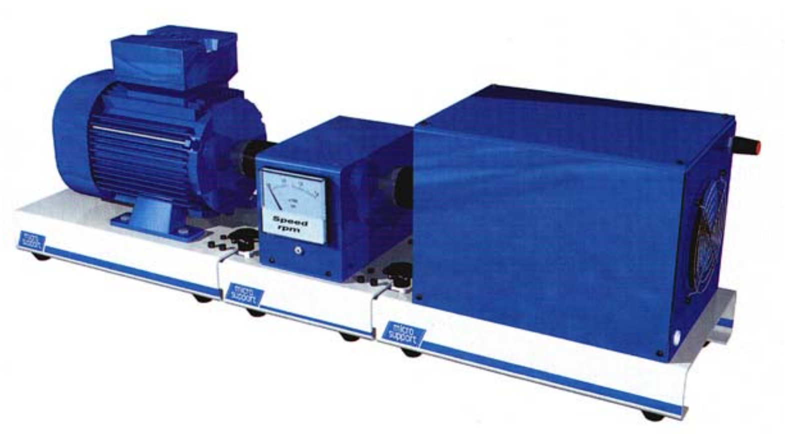


Fig.7.12 Vs motor with revolution counter and magnetic powder brake.

- Connect an ammeter to measure the current between the frequency converter and one of the phases. Set the meter to the correct measuring scale.

- Connect the brake and frequency converter to the supply voltage.

- Check that the setting is **PU**.

- Set the level of overload protection **P9** to **0,1A.**

- Start the motor.

7.25 What happened?

……………………………………………………………….

- Switch the start switch to the stop position. Verify and set the alarm to zero by pressing **STOP/RESET**.

- Start the motor, apply the load and observe the tripping time.

7.26 Complete this exercise twice more directly after each other and observe if the tripping times are the same.

………………………………………………………………

7.27 Set the overload protection to different values and observe the relationship between current/ tripping time.

P9 Overload protection	**Tripping time**
0,1	
0,3	
0,5	
0,7	

- Connect the brake to the supply voltage.

- Start the motor and apply the load to the given current values below. Measure the tripping time for each value.

P9 Overload protection	**Measured current**	**Tripping time**
1,6	**1,7**	
1,6	**1,8**	
1,6	**2,0**	
1,6	**2,4**	

The motors dependency on frequency

- Check that the setting is **PU**.

- Reduce **P1** step by step from the set value of **50Hz** down to **5 Hz** as shown in the table below. Read the values of speed and current when the motor is without load.

Frequency (Hz)	Speed (rpm)	Motor current (Amps)
50		
40		
30		
20		
10		
5		

7.28 What is the relationship between speed and frequency?

…………………………………………………………

…………………………………………………………

7.29 What is the relationship between motor current and frequency?

…………………………………………………………

…………………………………………………………

- Reset **P1** to **50Hz**. Disconnect the brake and frequency converter from the mains supply.

Latch Control

Another method of starting and stopping the motor is to connect the frequency converter with latch control. Only repeated pressing on the **FORWARD** and **REVERSE** buttons is required. Using this connection the frequency converter latches automatically.

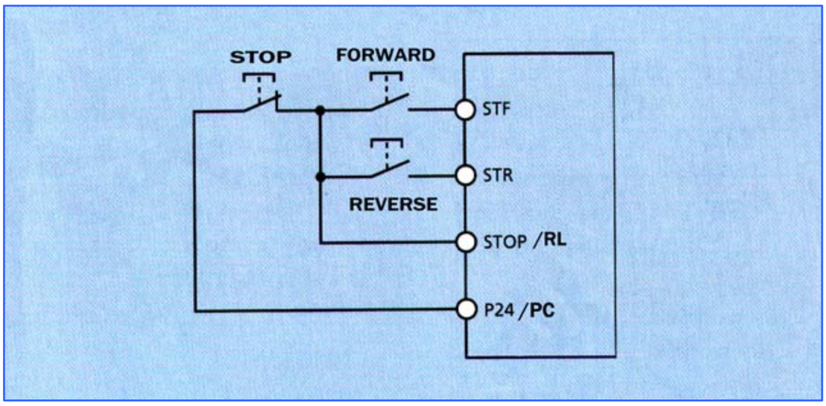


Fig.7.13 Start and stop connections with latching.

- Connect the circuit as shown in figure 7.13. Use the manoeuvre module.
- Connect the frequency converter to the mains supply.
- Select external control and check the function of the circuit.

7.30 How does the circuit function?

…………………………………………………………

…………………………………………………………

…………………………………………………………

- Disconnect the frequency converter from the mains supply.

Motor with speed regulation

Study the frequency converters connection diagram figure 7.14. Compare with the connection diagram on the frequency converter module.

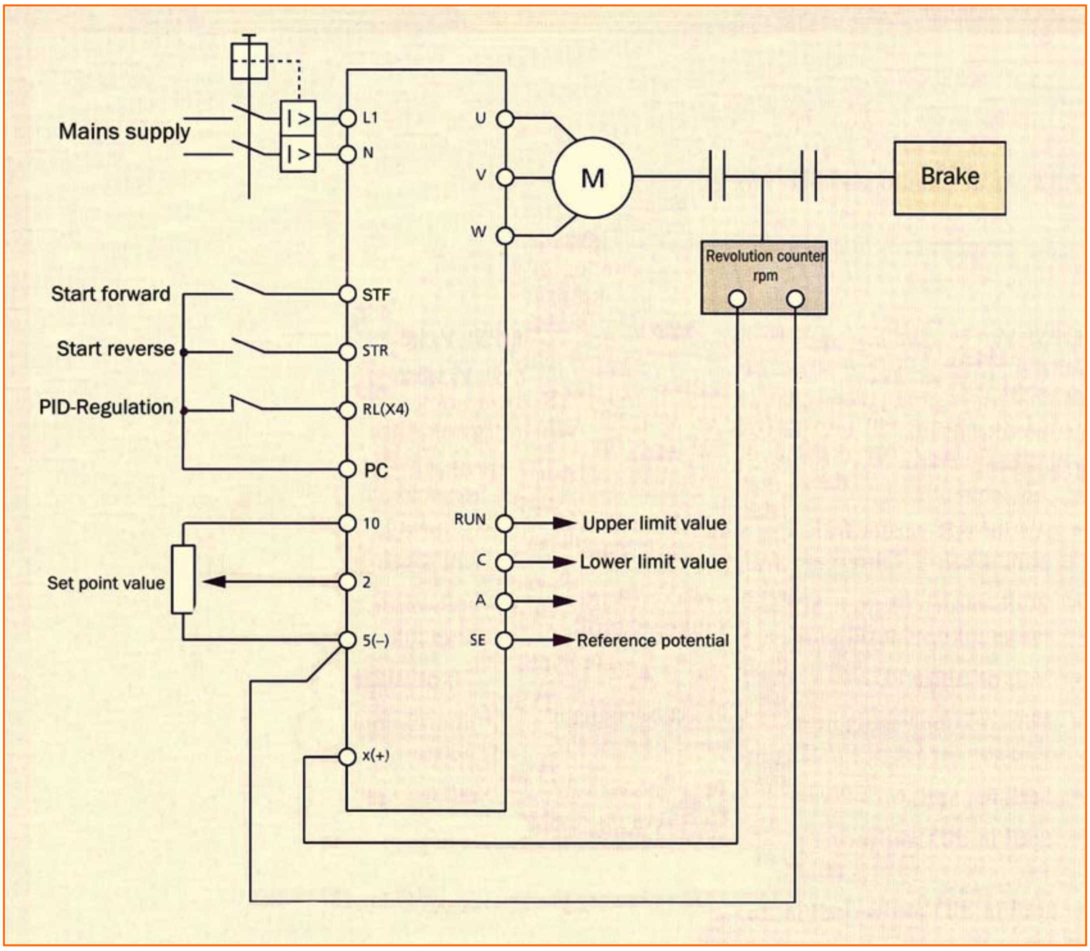


Fig. 7.14 Connection diagram for the frequency converter.

- Connect three switches from the manoeuvre module for **FORWARD**, **REVERSE** and **PID** as shown in Fig. 7.14.

- The equipment used in a revolution counter generates a voltage between 0-10V. It is this value that is measured and displayed on a scale for speed. The next task is to see the relationship between speed and voltage. Connect a voltmeter to the revolution counter. Set the measuring range between **0** and **10V DC.**

- Select **EXT** and start the motor.

7.31 Set different motor speeds using potentiometer **SPEED**.
Read the voltage on the voltmeter and the speed (rpm) when the frequency converter display shows the following:

Display	Revolution counter	Voltmeter
10		
20		
30		
40		
50		

7.32 Is the output voltage linear in relation to the motor speed?

………………………………………………..

Note: The output voltage never reached **10V** at maximum speed. The zero point was = **0V**. According to the diagram the current should be between **4-20 mA**, which this signal differs from. To make observations of the frequency converters regulation it is sufficient with the signal from the revolution counter.

- Connect the process value from the revolution counter via a milliamp meter to plinth **4** and **5**. Observe the polarity.

- The set value (speed knob) on the frequency converter module is already connected to plinth **2-5-10**.

- Select position **PU**.

- To be able to set the regulators parameters, parameter **P30** which is factory set to **0**, must be reset to **P30= 1**.

- Set the regulator P-effect parameter **P89 = 500%.**

- Set the PID activation on the RL input by setting **P60 = 14**.

- Set parameter **P89,** the regulators P-share, to **500**. The regulator is now set with a P-effect and **50%** P-band, the equivalent to an amplification of **2.**

- Select **EXT** and the **SET** value to the mid position. Start the motor and activate the **PID** regulator using the switch that is connected to **RL**. The speed regulation is now installed. Change the set value in small steps and see how the motor answers by changing its speed. Set the speed to **1000 rpm.**

- Connect the brake to the supply voltage and increase the braking torque in small steps.

7.33 How did the regulator react to the changes in load?

…………………………………………………………..

…………………………………………………………..

……………………………………………………………

…………………………………………………………….

7.34 Set a load to a fixed speed and observe the regulation difference at different settings of P89.

P-share %	Speed rpm
100	
300	
500	
700	
900	

- Is the regulation difference as big at each P-effect %?

……………………………………………………………….

……………………………………………………………….

………………………………………………………………

7.35 The difference in regulation is called remainder fault. Why?

………………………………………………………………

………………………………………………………………

………………………………………………………………

- Select **PU** and set the **P-effect** to a value that is an average of the differences if regulation. Connect in the **I-share** of the regulator by setting **P90 = 500s**.

7.36 Select **EXT** and check the time taken for the regulators **I-share** to remove the regulator difference.

………………………………………………………………..

- Select **PU** and connect the regulators **D-effect** by setting **P94 = 1.**

7.37 Select **EXT** and check how the regulator reacts when the load is changed.

………………………………………………………………

………………………………………………………………

………………………………………………………………

7.38 The regulator is now connected with **PID** effect. It is now possible to select how the regulator shall react to a step formed change in load. Seek the optimal answer by setting in values of the P-effect = P89, I-effect = P90 and the D-effect = P94. Limit the number of settings to four for each effect.

Write down the recommended P-, I- and D-effects.

………………………………………………………………

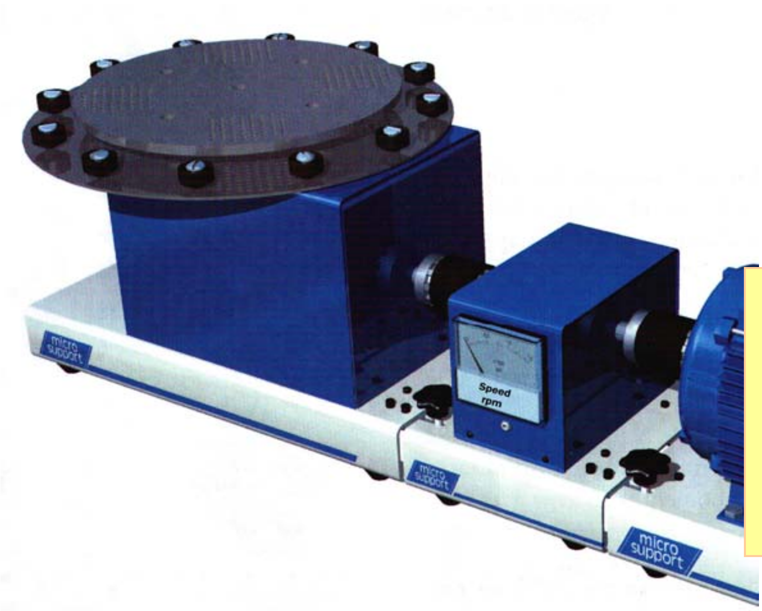
- Stop the motor. Switch off the frequency converter and brake.

Hint! Find from the manual how to reset the frequency converters factory settings. The following points are valid:

- Select PU position.
- Press MODE so that the parameter list is shown.
- Search for "Cir" using the set knob.
- Press SET to show the set value.
- Turn the set knob until value 10 is shown.
- Store this value by pressing SET.
- The display now shows change 10 and Cir.
- Select a new parameter using the set knob. Press SET to see P0.
- The manual will state whether it is possible to select a different number in order to exclude certain parameters from resetting.

CONTROL OF THE ROUND MEASURING TABLE

The motor shall now be coupled to the revolution counter and fixed to the round measuring table. To reduce the strain during start and stop and also set the turning speed of the table, a few of the frequency converters parameters will be use.



WARNING!
When the motor is started the round measuring table will turn with high torque. Check before starting that all safety aspects have been taken to avoid personal damage and damage to equipment.

Fig.7.15 Frequency converter controlled motor driving a revolution counter and round measuring table.

- Disconnect the magnetic powder brake and connect the circular measuring table in its place. Centralise the coupling, press the rubber bushing over the cogs and tighten up the black knobs.

- Turn the motor axle manually and check that the axles are lined up.

- Check that the frequency converter and motor are connected correctly. Check that the **SPEED** is set to the lowest position. Connect the frequency converter to the supply voltage.

- Set parameter **P79** to **2**. That is **EXT** control and setting of speed with the potentiometer on the frequency converter module.

- Check the external control. Start and stop the motor and also reverse direction of rotation.

- To have a soft start and stop, suitable times for acceleration and retardation must be selected. Consideration must also be made when exact positioning is important and when stopping quickly. Select acceleration and retardation to suit the tasks.

P7 Acceleration =…………………………………………………….

P8 Retardation =……………………………………………………..

- Set the time selected and check the time taken using a timer clock.

Selection of Torque Curve

The output voltage characteristics from the frequency converter can be suitable for this task. A constant load torque will be selected here but a quadratic load torque can be selected for tasks with fans and pumps.

- Connect a voltmeter to read the voltage output supply to the motor. Connect an ammeter so that the motor current can be measured. The frequency can be read from the frequency converter.

- Select parameters **P14** and set **P14 = 1**.

- Start the motor and study how the motor functions when the converter is set for quadratic load torque.

- Reset parameter **P14 = 0.**

- Start the motor and study how the motor functions when the converter is set for constant load torque.

7.39 Describe how the motor reacted to the two different settings.

………………………………………………………………………

………………………………………………………………………

Built-in brake

The frequency converter can have an in-built DC-brake that can be operational when the axle is in rotation. It is activated at about 3Hz. Read in the manual how it functions and how much brake torque can be applied.

- Set the brakes setting range.

P10 = ………………………………………………………………………

P11 = ………………………………………………………………………

P12 = ………………………………………………………………………

- Study the reaction between different retardation times and brake effect. Write down the recommended values.

P8 =…………………………………………………………………..

P10 = …………………………………………………………………

P11 = …………………………………………………………………

P12 = …………………………………………………………………

Summary

During the laboratory exercises with the frequency converter different applications of the uses of the frequency converter were studied.

The frequency converter has an in-built overload protection that should be set according to:

…………………………………………………………………………

Manoeuvrings can be selected from:

…………………………………………………………………………

Speed can be set to:

…………………………………………………………………………

Acceleration and retardation times can be set to:

…………………………………………………………………………

State which parameters were used for the different tasks:

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

Give an account on which observations were completed during the laboratory exercises.

…………………………………………………………………………

…………………………………………………………………………

…………………………………………………………………………

8 MOTOR CONTROL with CURRENT RECTIFIER

Objective: Is to study an Is-motor and see how it reacts to different conditions. The motor has separately excited windings and is connected to the AC supply via a current rectifier on which various parameters can be set.

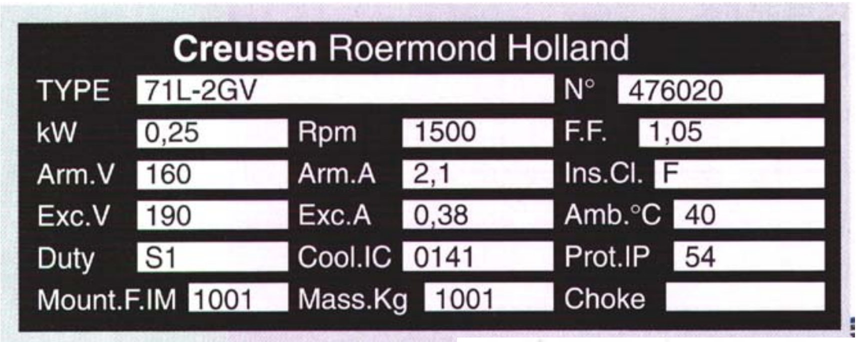
LS-MOTOR DATA

The Ls motor generates a magnetic field either from a field windin permanent magnets built into the stator, replacing the field winding current to the rotor windings is transferred via two carbon brushes commutator.

- Place the Ls motor on the workbench and study the motor da nameplate.

Recommended reading
Motor Control
Chapter 1- Electric motors
Chapter 3- DC motors
Chapter 9- Motor electronics

Equipment
Ls motor
Current rectifier module
Magnetic powder brake
Revolution counter
Universal meter



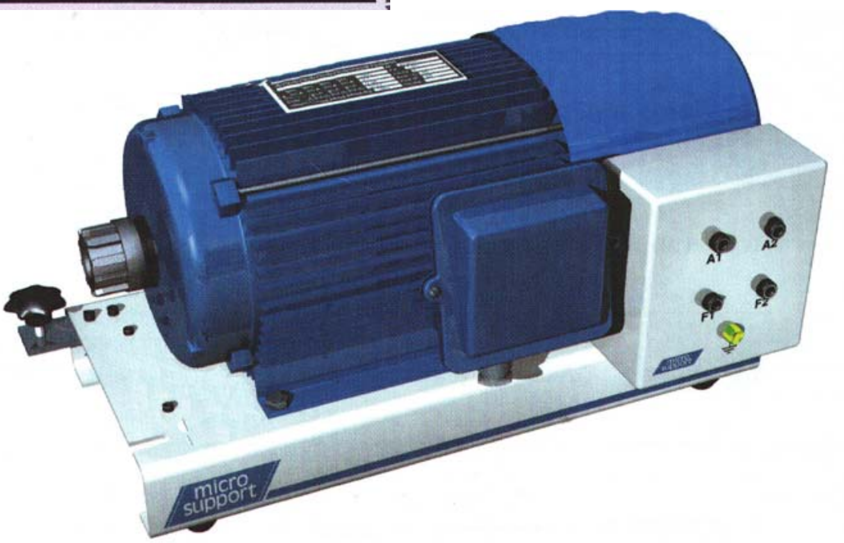


Fig.8.1 Ls motor and data nameplate.

8.1 How heavy is the motor?

………………………..kg

8.2 What is the motor power?

……………………….kW

8.3 What is the running speed of this motor?

……………………….rpm

8.4 What current does this motor take?

……………………….amps

- Remove the cover from the end of the motor.

8.5 What lies behind the plastic protection, between the fan and the stator?

………………………………………………………..

………………………………………………………..

………………………………………………………..

- Replace the plastic protection and fix the cover with the three screws that were removed.

The connection terminals on the Ls motor

- Study the connections of the DC motor in figure 8.2. **F** is for field winding and **A** for armature winding.

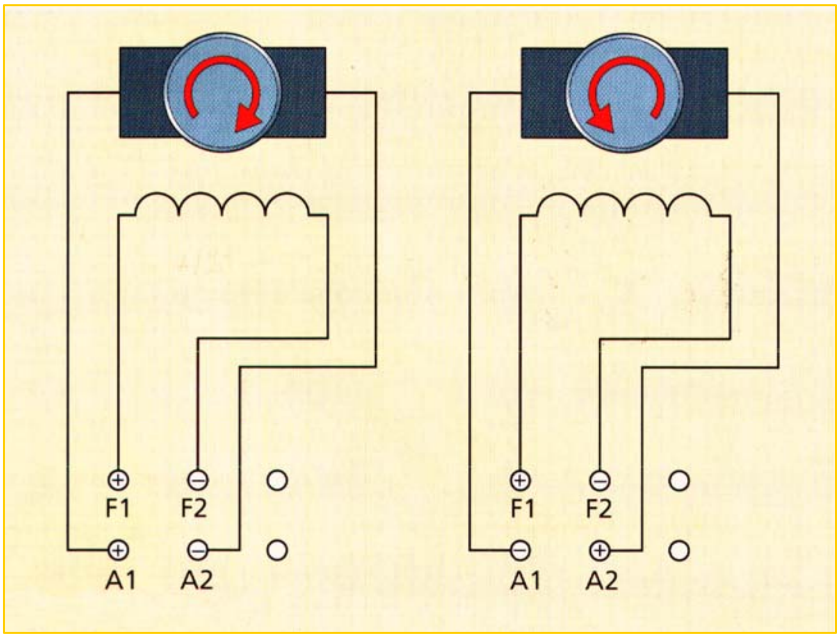


Fig.8.2 Ls motor connection diagram with direction of rotation

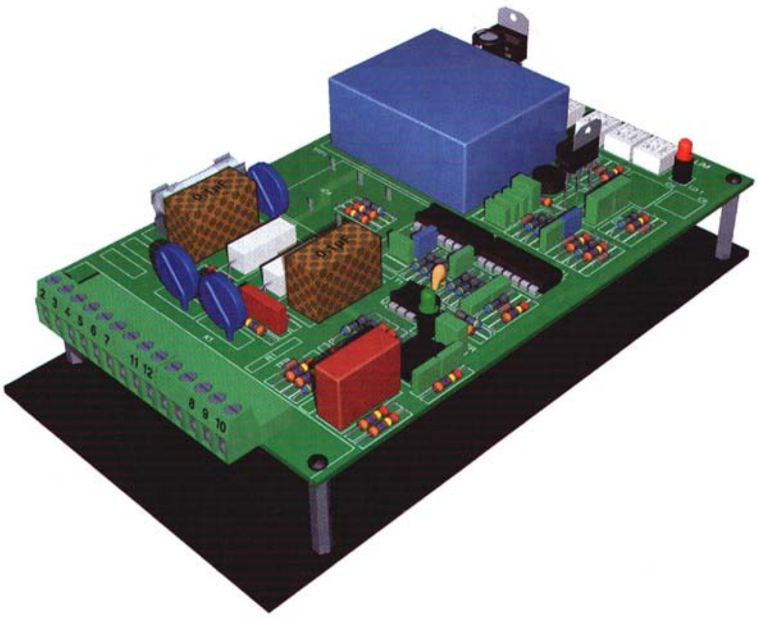
8.6 How must **A** and **F** be connected in the circuit so that the motor will turn clockwise?

F1:………………… A1:…………………

F2: ………………… A2:…………………

Current rectifier control of a DC motor

DC voltage over 100V is seldom used. The most common installation consists of a current rectifier that is connected to 30V AC and the output fed to the Is motor.



The motor torque increases when the magnetic field is stronger.

Fig.8.3 Module with current rectifier GME-1812-AT.

- Study the block diagram and technical data for the current rectifier in figure 8.4.

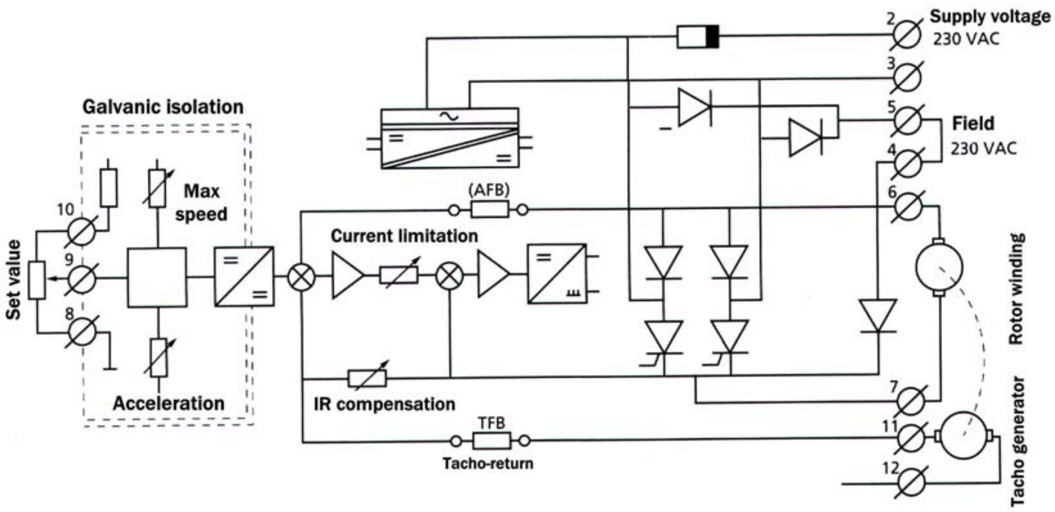


Fig.8.4 Data sheet and block diagram for the current rectifier

Cont. current	**12A**	**Acc.time**	**0,2-5 secs**	**Reg. Effic.**	**1% x max spee**
Current limit	**7-15A**	**Field current**	**1A**	**Return**	**3% x max spee**
Fuses	**Ext. 16A**	**Set value**	**0-10V DC**		
Arm. Winding	**0-180V DC**	**Imp. Input**	**27K ohm**		
Field winding	**200V DC**	**Isol. Spec.**	**1500V DC**	**Linearity**	**Better than 1%**
Supply voltage	**230V +/- 10%**	**Max amb. Temp.**	**+40^0 C**	**Ret. input**	**10-200V DC**
	50/60Hz				

8.7 What is meant by “galvanic isolation”?

……………………………………………………………..

8.8 Between which two pins is the motor armature winding connected?

……………………………………………………………

……………………………………………………………

8.9 Between which two pins is the motor field winding connected?

……………………………………………………………

……………………………………………………………

8.10 What is the maximum output voltage the motor can receive from the current rectifier?

……………………………………………………………

8.11 What is the range of values for setting the acceleration?

Max:……………………………………………………

Min:……………………………………………………

The current rectifiers parameters

- Connect up the Is motor, current rectifier and potentiometer as shown in figure 8.5. Use only touch protected laboratory leads.

  Note! Do not connect to the mains voltage 230V AC until later in the exercise.

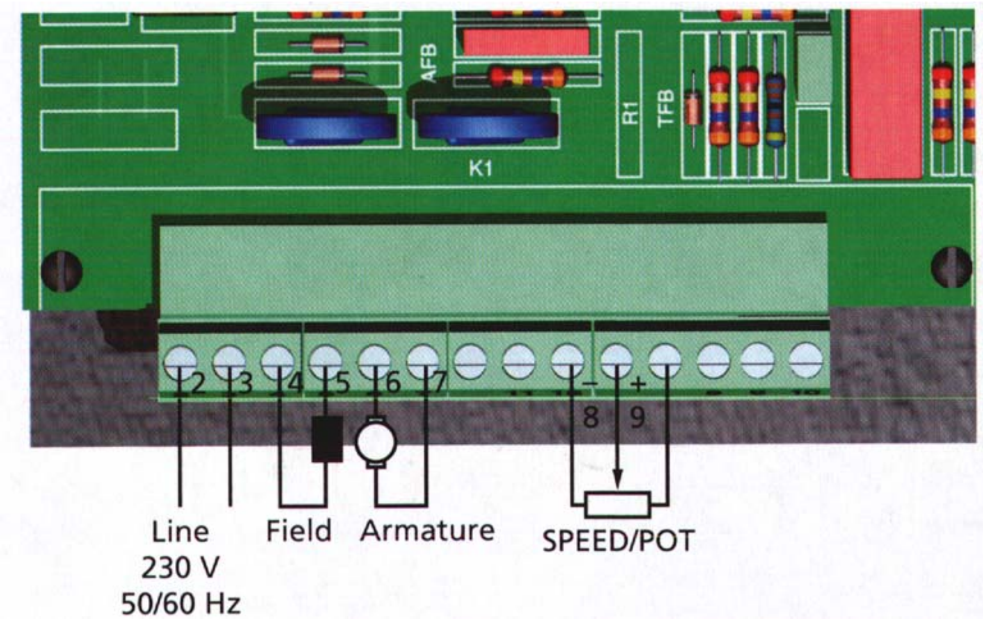


Fig .8.5 Connections for the Is motor.

- There are 5 potentiometers on one side of the current rectifier card. They are marked ACC, MAX, I*R, and MAXI.

Speed Potentiometer (speed adjustment)
This is used for setting stepless motor speed.

Armature
The armature winding is connected to A1 and A2. Changing the two poles can change the direction of rotation. See Fig.8.2

Field
The field winding is connected to F1 and F2. Changing the two poles can change the direction of rotation. See Fig.8.2

ACC (P1)
Is used for setting the acceleration time between 0,2 - 5,0 seconds.

MAX (P2)
Is used for setting the maximum speed. Independent of the SPEED potentiometer setting.

I*R
This potentiometer will not be used as it is only used if an AFB resistor is installed.

ZERO 1 (P4)
This is for setting the lower current limit to the motor. The light diode LIM will light up if the current limit is exceeded.

MAX I (P5)
This is for setting the upper current limit to the motor. The light diode LIM will light up if the current limit is exceeded.
LIM (Light diode)
This is the LED that will light up when the limits are exceeded. The current limit is set using potentiometers P4 and P5.

Notes

Setting the speed

- Before start and stop it is important to reduce the speed with the speed potentiometer "**SPEED POT**".

- Connect the mains supply, 230V AC to the current rectifier.

- Set the speed potentiometer "**SPEED POT**" to the mid position.

8.12 Is it possible to control the motor speed with speed potentiometer **ACC**?

…………………………………………………………………….

- Alter potentiometer **ACC** so that the motor has an acceleration of **0** to max rpm in **3** seconds.

- Connect the revolution counter (speed meter) as shown in figure 8.6.

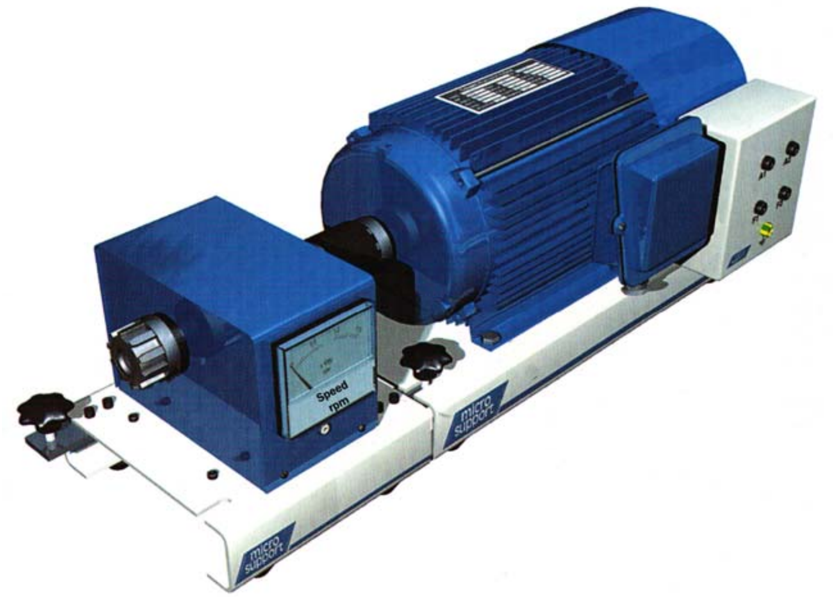


Fig.8.6 Revolution counter connected to the Is motor.

- Investigate how to vary the motor speed using the speed potentiometer.

8.13 What is the fastest speed that can be set for this motor?

……………………………………………………………

- Change the direction of rotation of the Is motor.

8.14 How was this done?

…………………………………………………………….

…………………………………………………………….

Current Indication

- Connect the magnetic powder brake on the other side of the tachometer. Set the braking torque to **MIN** using the potentiometer at the back of the brake.
- Set the potentiometer **IMAX** to a position where the light diode **LIM** does not light up.
- Start the motor and brake very carefully.

8.15 When did the light diode **LIM** light up?

………………………………………………………………..

To protect the motor against excessive current, an extra fuse is fitted in the motors terminal box.

Summary

In this laboratory exercise a current rectifier was connected between the supply voltage and the DC motor. The following parameters could be set and observed:

…………………………………………………………………

…………………………………………………………………

…………………………………………………………………

With the current rectifier the following parameters could also be set:

…………………………………………………………………

…………………………………………………………………

…………………………………………………………………

The DC motor field was built up by:

…………………………………………………………………

…………………………………………………………………

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9 MOTOR CONTROL with PLC

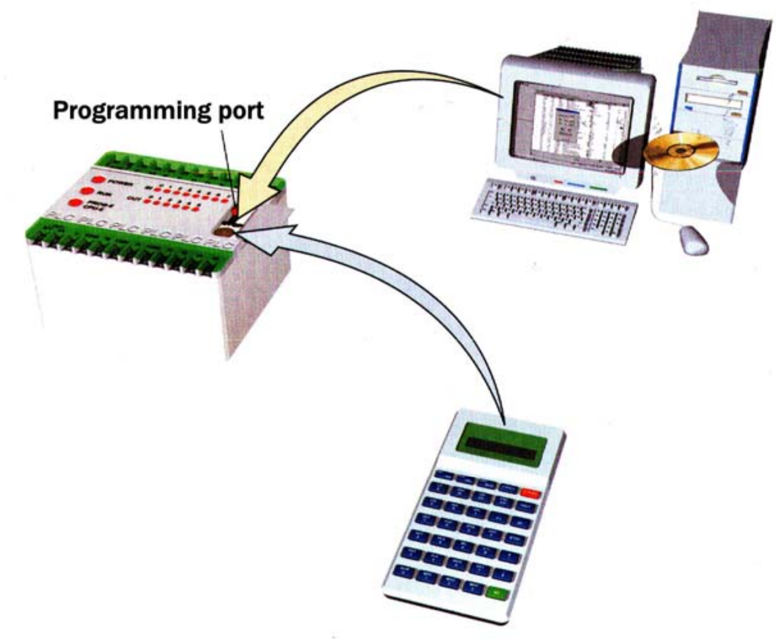
Objective: The objective in this exercise is to be able to connect a PLC to control a motor and to program the PLC to run the motor.

PLC-MOTOR CONTROL

The PLC is a small mini computer for industrial use. It has all the necessary functions collected in one capsule. Inputs to the PLC come from different sensors or switches. Output signals are via contactors, pneumatic valves, etc. Before the PLC can carry out the required control it must first be fed with instructions in the form of a program. The sequence of writing a program is similar to building control with switches or logic elements. With the PLC it is easier and more flexible when it is necessary to add or change a program.

The PLC module

Figure 9.1 below shows a PLC module and a hand held programming unit. Alternatively a computer with a suitable program can be used. The LED indication lamps on the top of the module show whether the programming is correct or whether a fault has occurred.



Recommended reading
Motor Control
Chapter 8- Control of motors

Equipment
Base Unit 2000
PLC module
Programming unit or
PC based software
Vs motor
Socket module
Contactor module
3-phase terminal

Fig.9.1 PLC module with programming aids.

9.1 What is the first PLC instruction that must always be used when writing a programme? What is the last instruction to finish off a programme?

………………………………………………………………………

………………………………………………………………………

9.2 Complete the table with the equivalent in a Mitsubishi PLC system.

The word Mitsubishi means "three diamonds" in Japanese.

Logic operator	Instructions in Mitsubishis PLC system
AND	
OR	
NOT	
RESET	

This exercise is written for the Mitsubishi PLC system – MELSEC FXO. If the exercises are to be completed with Siemens SIMATIC or other PLC system then the symbols used in those systems must be understood. Whichever system is used, continue by following the instructions.

- Place the Base unit, PLC module, socket module, and programming unit on the workbench.

- Check that the base unit is switched off.

- Assemble the PLC module and socket module on the base unit as shown in figure 9.2.

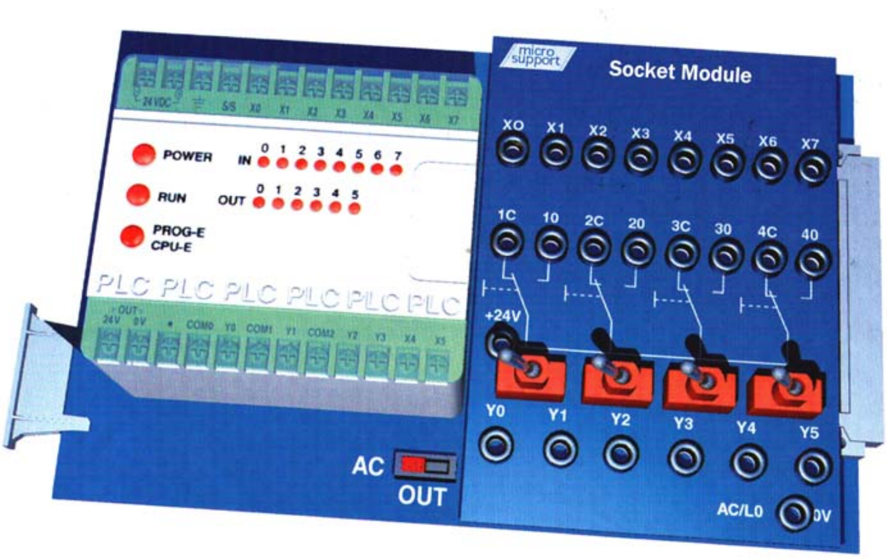


Fig. 9.2 *PLC module with socket module.*

- Switch on the supply voltage to the base unit.

Socket module

The socket module is used to communicate with the PLC. There are four switches on the socket module. They are used are change over contacts, in the right hand position they are normally open (**NO**) and in the left position normally closed (**NC**). The switches are marked **1C, 2C** etc for normally closed contacts and **1O, 2O** etc for normally open contacts. “**24V DC** is connected to the switches and are used as signal 1.
At the top of the socket module there are eight PLC inputs **X0-X7**. To set a **1** signal at input **X1** connect a jumper or lab lead between e.g. **1O** and **X1** and put the switch in the right hand position.

- Connect a jumper between **1O** and **X1**.

- Set the switch to the right hand position.

9.3 Which input is lit on the PLC?

……………………………………………………………………

- Switch off the supply to the base unit.

On the lower part of the socket module there are six outputs, **Y0-Y5**. Using a change–over switch on the PLC module, it is possible to select DC or AC voltage for the output signals. When using relays or contactors having AC coils, AC voltage must be selected. See figure 9.3.

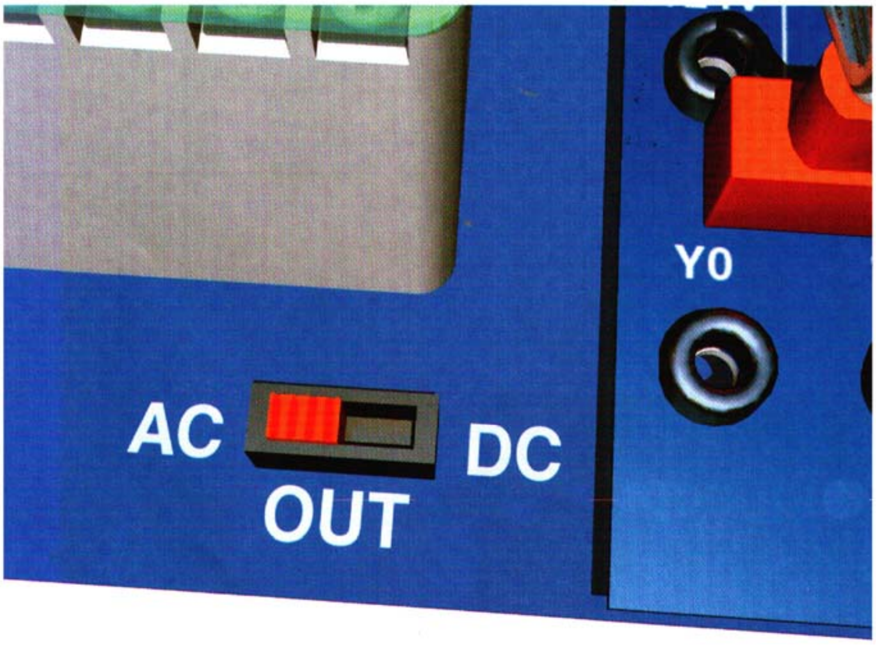


Fig.9.3 The PLC module switch for selecting AC or DC voltage.

- Set the voltage selector switch to **AC** voltage.

Programming with the PLC

The instructions that follow are for programming with the programming unit. The first stage is to learn how to talk to the PLC so that it understands what is required. After each row the GO button at the bottom right, must be pressed. This is similar to ENTER on a PC. The first task is to install a program into the PLC and then check its function.

- Connect the programming unit with the special cable to the programming port on the PLC.
- Check that the RUN-STOP switch is on the STOP position. This switch is situated under a small cover near the programming unit's connection.
- Switch on the supply voltage to the base unit. The following display is now shown on the programming unit.

Fig.9.4 Display after the programming unit is connected.

- Press the **W** (WRITE) button, top left. A **W** should now be seen on the display.
- Write in the following programme. Finish each row with **GO**.

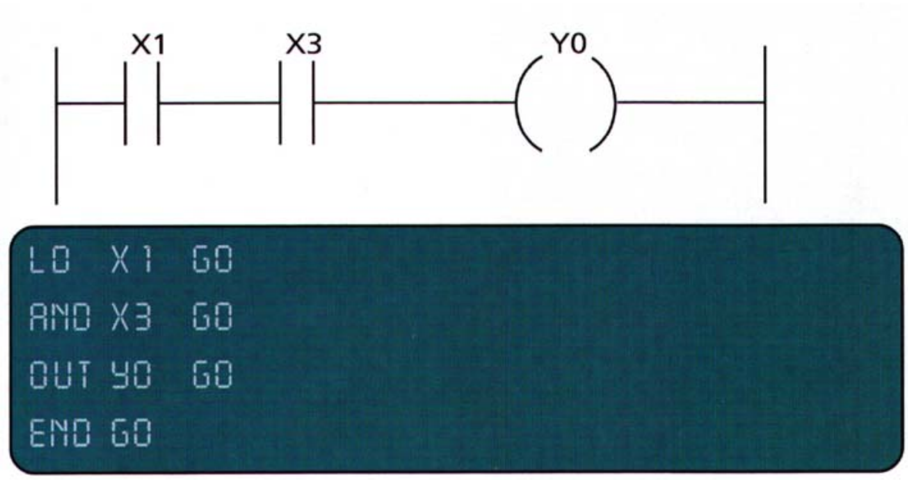


Fig 9.5 Ladder scheme with instruction list.

- Connect a jumper between **1O** and **X1** and a jumper between **2O** and **X2** on the socket module.
- Set the **RUN-STOP** switch to the **RUN** position.

9.4 Check the programme by setting the switches on the socket module to different positions according to the truth table below. Complete the table.

X1	X2	Y0
0	0	
0	1	
1	0	
1	1	

Change over contact positions
Right = 1:a
Left = 0:a

The PLC is now functioning as a logic **AND**. In make output Y0 active both switches 1 **AND** 2 must be pressed. The next stage is to connect a contactor to the output to simulate a printing press.

At this stage it is necessary to have both hands on the pushbuttons for the machine to function.

- Switch off the supply voltage to the base unit.

The PLC will store the programme in a memory inside the PLC. The programme will still be stored after the unit is switched off.

- Place the contactor module to the right of the base unit.
- Connect the PLC and contactor module as shown in figure 9.6.
- Switch on the supply voltage to the base unit.
- Check that the PLC is set to the RUN position.
- Test the programme by setting the two, change- over switches to the right hand position.

Connect

Socket module	Contactor module
0V	A2
Y0	A1

Fig .9.6 Connections between the PLC, socket module and contactor module.

9.5 What happened when both switches were in the right hand position?

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………..

- Switch off the PLC by setting the small switch to **OFF**.

- Leave the contactor connected to the socket module.

- When programming the instructions must be translated to a language that the PLC understands. In this course the ladder scheme and instruction list, will be used.

9.6 Write an instruction list for the ladder scheme in figure 9.7.

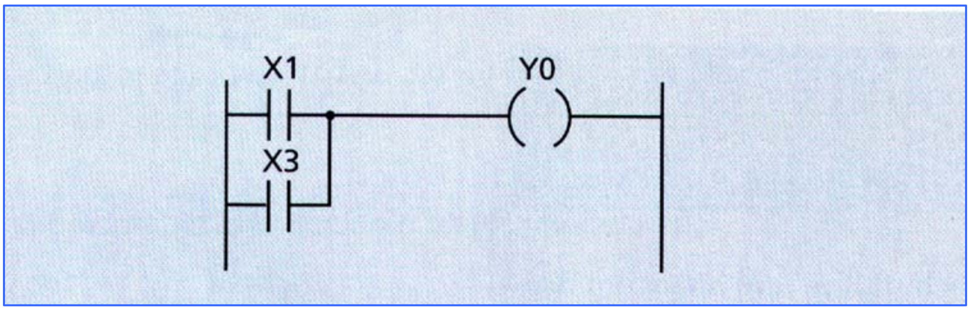


Fig. 9.7 Ladder scheme

- Load in the programme.

- Set the RUN-STOP switch to the RUN position.

- Check the programme by following the PLC systems indications and create a truth table.

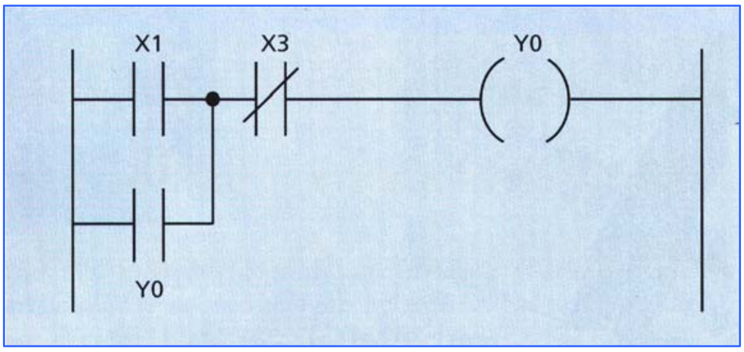
X1	X2	Y0
1	0	
2	1	
3	0	
1	1	

9.7 Which type of logic function has been created?

……………………………………………

Programming a hold-in circuit

When starting a motor it is necessary to have a hold-in circuit so that the motor will continue to run when the start button has been released. The stop button breaks the hold-in circuit and the motor stops. Study the ladder scheme and truth table in figure 9.8.



X1	X2	Y0
2	0	
4	1	
5	0	
1	1	

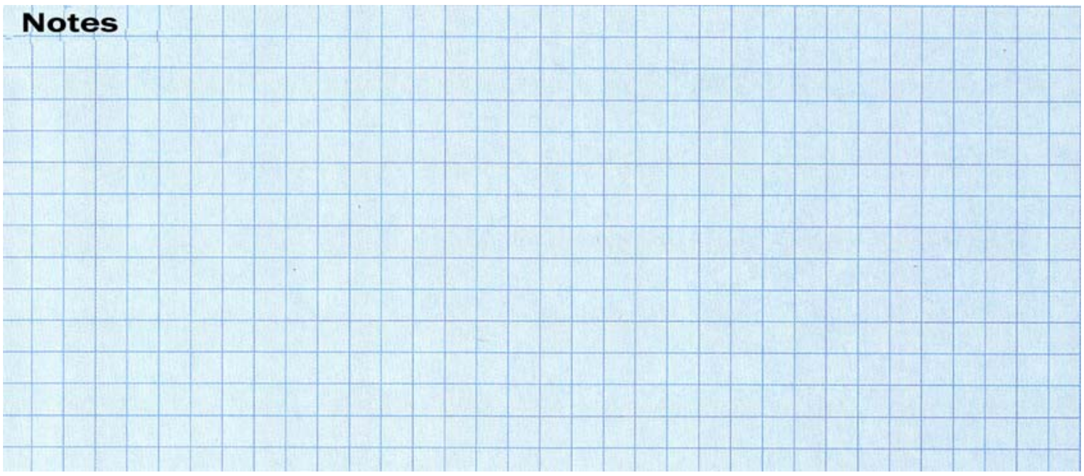
Fig.9.8 Ladder scheme and truth table.

The ladder scheme shows an example of how it can be used as a hold-in circuit. When start button **X1** is pressed the coil **Y0** is energised and contacts **Y0** are closed. **Y0** and **X1** are in parallel so now **X1** can be released and the coil remains energised via contacts **Y0**. By pressing **X3** (stop button) the hold-in circuit is broken and the motor stops.

- Remove the jumper on the socket module and the lab leads between the output of the socket module and the contactor module.
- To remove the whole programme memory from the PLC, press:

  RD → WR → NOP → A → GO → GO

- Write the instruction list for a hold-in circuit in the space below.



- Load the programme into the PLC.
- Connect the circuit as shown in figure 9.9 using the socket module and the contactor module.

Connect	
Socket module	Contactor module
0V	A2
Y0	A1

Fig. 9.9 Connections for the socket module and contactor module

Remember that the switch on the PLC module shall be in the AC position.

- Set the **RUN-STOP** switch on the PLC to **RUN**.
- Test the hold-in circuit by pressing the **START** button and then the **STOP** button.
- Keep the connections between the socket and contactor modules.

9.8 How did the programmed hold-in circuit function?

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

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………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

In this exercise it was seen how it is possible to programme a hold-in circuit with only a few rows of instruction. This opens new possibilities. E.g. Connections can be made in the PLC so that a normally open contact can be made a normally closed contact. Study the basic instructions in figure 9.10.

Instruction	Explanation
LD (LoaD)	Start a branch with normally open contacts
LDI (LoaD Inverse)	Start a branch with normally closed contacts
OUT	End of a branch. Transfer of status to the output. Memory cell
AND	Series connection with normally open contacts
ANI (ANd Inverse)	Series connection with normally closed contacts
OR	Parallel connection with normally open contacts
ORI (OR Inverse)	Parallel connection with normally closed contacts
END	End of programme

Fig. 9.10 PLC. Basic in

The next section to be examined is the memory function with time delay and counter functions.

Memory Function

Compare the ladder scheme with the instruction list for the memory function in figure 9.11.

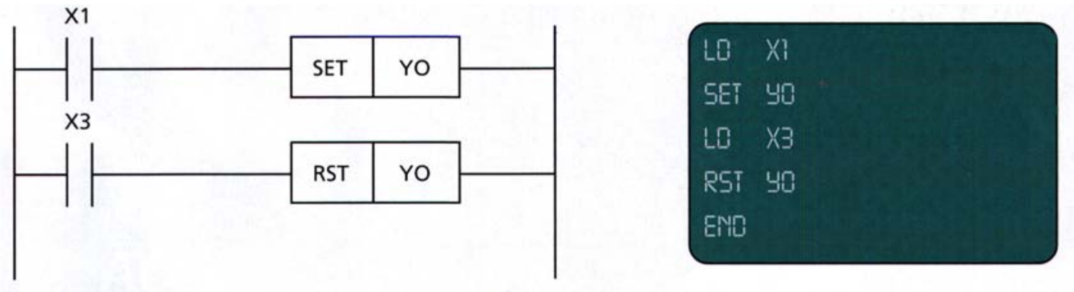

Fig. 9.11 Ladder scheme and instruction list for the memory function.

- Feed in the programme according to the instructions list and check the function by setting the changeover contacts on the socket module or the pushbuttons used. Observe how the contactors are set to give a signal.

A simplified hold-in circuit has been created where a memory cell was set to give a signal for **X1** and then “zeroed” by giving a signal **X3**.

9.9 What happens if an **X1**and an **X3** signal is given at the same time?

……………………………………………………………….

………………………………………………………………

Time function

Compare the ladder scheme with the instruction list for the time function in figure 9.12.

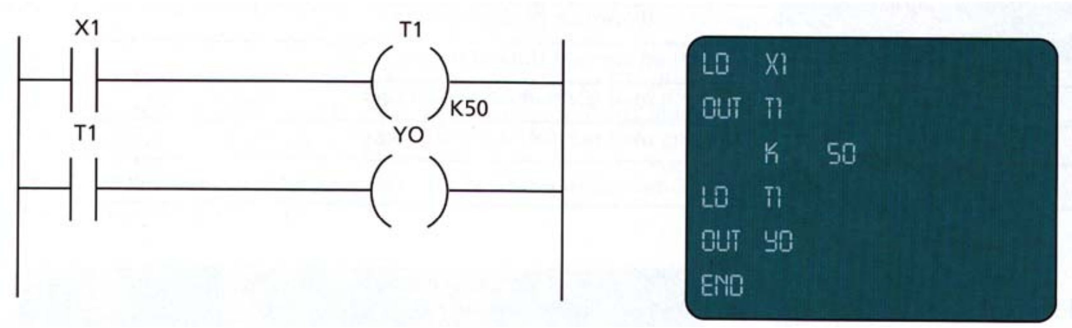

Fig. 9.12

Ladder scheme and instruction list for the time function.

- Feed in the programme according to the instruction list and control the function by setting the changeover contacts on the socket module. The signal must be kept during this time. If the signal is removed then the time function will be zeroed.

  K 50 means that the delay time before the time function affects **Y0** is **5** seconds.

9.10 Change the programme so that time delay is **10** seconds. Which value of **K** must be set?

K = ……………………………………………………………

Notes

Counter Function

A counter function can be used in production lines where for example 10 packets of ice cream must be laid into a carton before the transport conveyer starts to move the carton to the next stage. A sensor gives a signal for each packet of ice cream to the PLC. These signals are counted until the programmed number has passed.

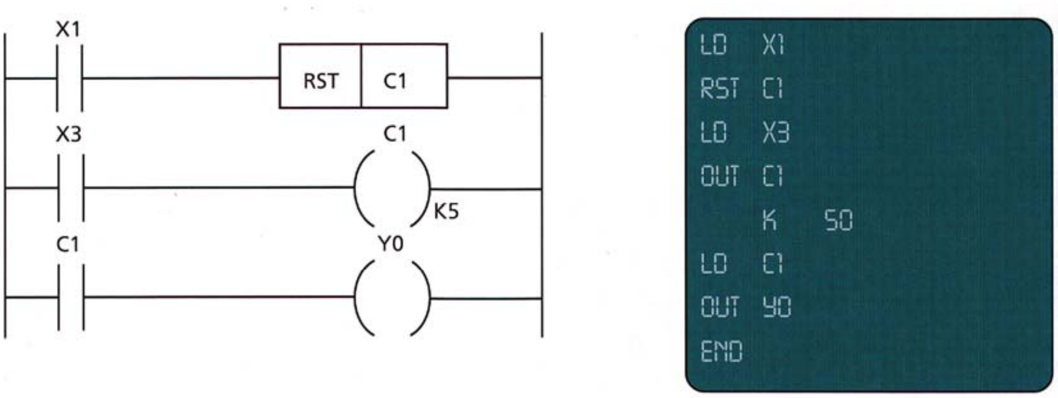

Fig.9.13 Ladder scheme and instruction list for the counter function.

- Feed in the programme according to the instruction list and test the function by zero setting the counter with one of the changeover contacts.
- Activate the changeover contacts **5** times to simulate five packets of ice cream.

9.11 How many pulses were required before the counter gave a **1-** signal?

……………………………………………………………………………………..

9.12 What changes are necessary to the instruction list so that the counter shall count to **12**?

…………………………………………………………

…………………………………………………………

Instruction	Explanation
Memory function	**M0-M511, M800- M8255**
Set to M+ nr	**1 setting of memory cell**
RST reset M+ nr	**zero-setting of memory cell**
Time function	**T0-T62**
OUT T+ nr	**Switch on, 100ms T0-T31 10ms T32-T55**
OUT T+ nr	**Switch off, 100ms T0-T55**
Counter function	
OUT c+ nr	**Counter, C0-C31**

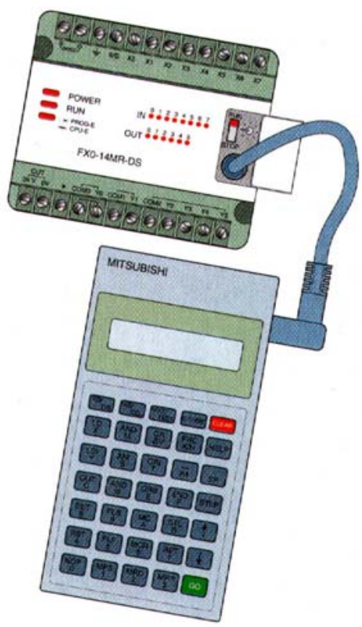

Fig.9.14 Summary of the basic instructions for the PLC

Programming motor operation

The motor should remain connected to the contactor module and to the PLC. The motor shall now be controlled by means of the switches on the socket module and a programme in the PLC.

- Place the 3-phase terminal, contactor module and Vs motor on to the workbench.
- Make sure that the voltage is switched off to all the components.
- Connect the motors power circuit as shown in figures 9.15 and 9.16.

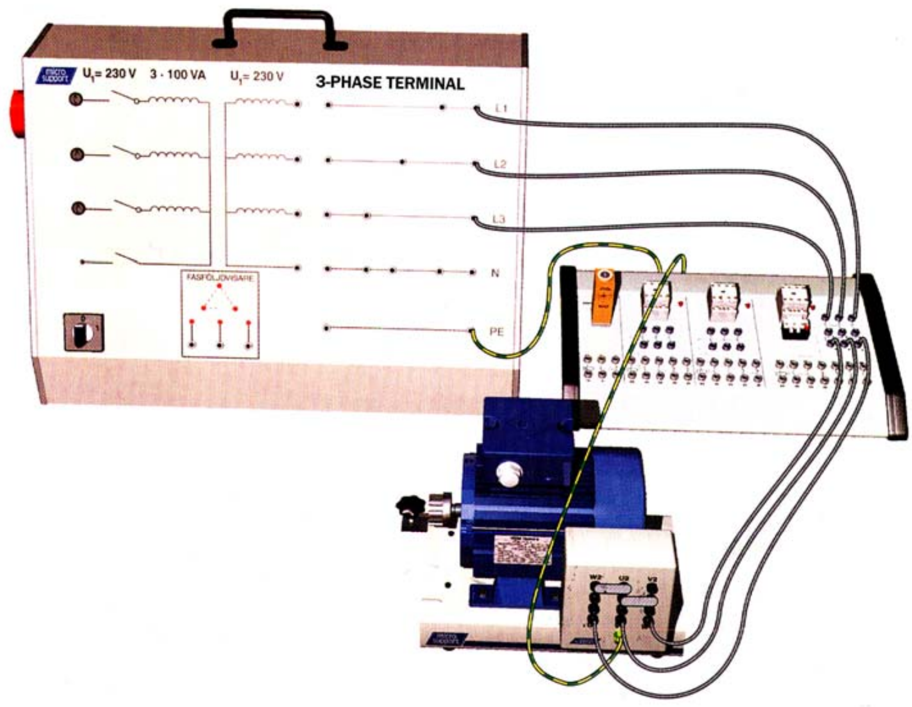

Fig.9.15 The motors power circuit. Connect from the 3-phase terminal via contactor module to the Vs motor.

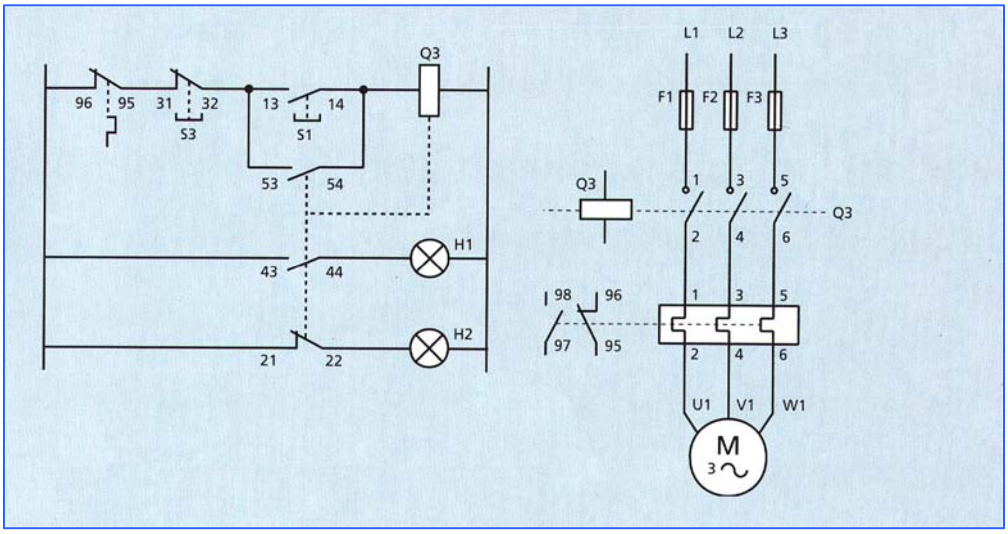

Fig.9.16 Control circuit for the motor and power circuit.

- Study the circuit diagram for the motors control circuit as shown in figure 9.16. The connection is a memory function. See page 74.

The next stage, before programming, is to decide which outputs will be used and what title they will have. This is done in an I/O list, which, in this case, consists of two inputs and three outputs.

- The table shows a completed I/O list for inputs and outputs.

Inputs

I/O	Title	Comments
X1	S1	START button
X2	S2	STOP button

Outputs

I/O	Title	Comments
Y0	Q3	Motor power contactor
Y1	H1	Lamp display START
Y2	H3	Lamp display STOP

When the I/O list is completed, a ladder scheme for the memory function must be drawn. See figure 9.19.

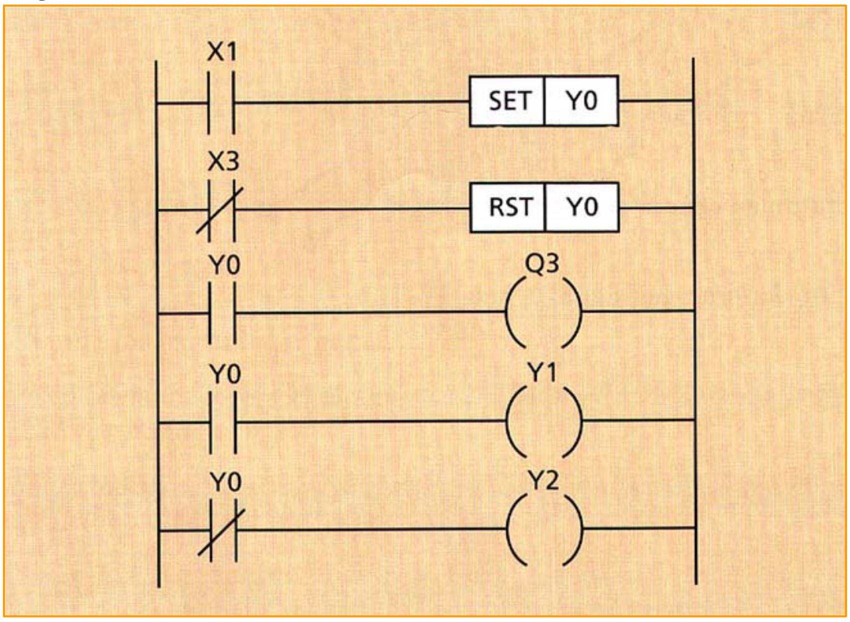

Fig.9.17 Ladder scheme for the motor control circuit.

9.13 Write an instruction list for the control circuit on the following page.

From the ladder scheme it is quite easy to write an instruction list for the programme. Write an instruction list for a hold-in circuit according to the ladder scheme in figure 9.17.

1 ………………………………………………………………

2 ………………………………………………………………

3 ………………………………………………………………

4 ………………………………………………………………

5 ………………………………………………………………

6 ………………………………………………………………

7 ………………………………………………………………

8 ………………………………………………………………

9 ………………………………………………………………

10 ……………………………………………………………..

- Copy the programme into the PLC. Switch on the supply voltage to the 3-phase terminal.
- Try to start the motor from the socket module by changing the position of **START**.
- Reset the **START** button so that it does not give a **1** signal continuously.
- Stop the motor by pressing **STOP**.

Notes

Starting a conveyer belt with time-controlled stop

A transport conveyer for packing ginger biscuits shall be programmed.
See figure 9.18.

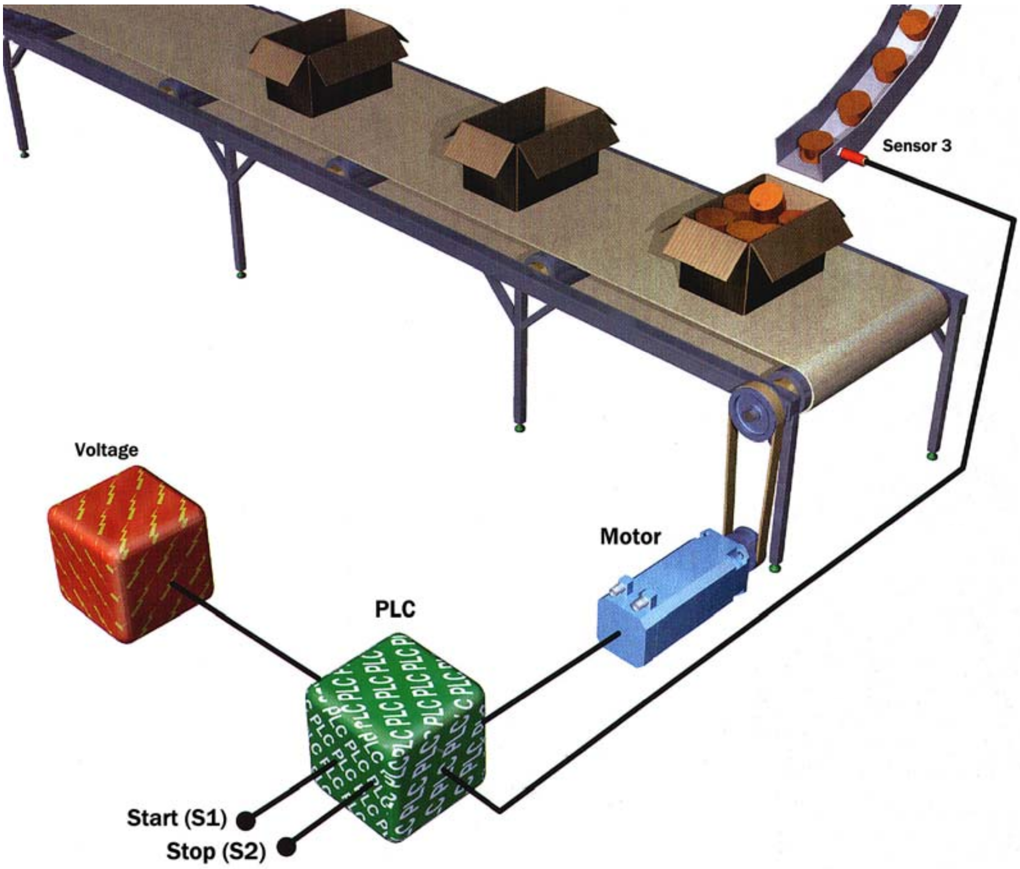

Fig.9.18 Conveyer belt with cartons filled with ginger biscuits.

The following conditions are valid:

- The ginger biscuits are filled from a large container to a carton on he conveyer belt.
- The cartons can hold **20** biscuits and a sensor signals one at a time to the PLC.
- When **20** biscuits have passed the sensor the PLC shall stop the supply of biscuits and start the conveyer belt.
- The conveyer belt shall continue forward for **10** seconds and then stop.
- The start arm for forward feeding simultaneously places a new carton on to the conveyer.
- The carton is then filled etc etc.
- The whole procedure is started with the **START** button and stopped by the **STOP** button.

- Keep the same connections for the 3-phase terminal, motor and contactor module as shown in figure 9.15.

Start by writing an instruction list.

Inputs

I/O	Title	Comments
X1	S1	START button
X2	S2	STOP button
X5	S3	Sensor counting biscuits

Outputs

I/O	Title	Comments
Y0	Q3	Motor power contactor
Y1	H1	Lamp indicating START
Y2	H3	Lamp indicating STOP

A switch on the socket module can be used to simulate sensor **S3**. For indication of **START** and **STOP** the lamps on the manoeuvre module can be used.

9.14 Create a ladder scheme for this task.

Ladder scheme

9.15 Create an instruction list for this task.

Instruction list

- Write the programme in the PLC. Switch on the supply voltage to the 3-phase terminal and base unit. Start the installation.

Summary

In the laboratory exercises the following knowledge was gained:

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10 FAULT FINDING on the PLC

Objective: The objective in this exercise is to be able to complete methodical fault finding on a PLC that is connected to a control system for motors.

PROGRAMMING A CONTROL SYSTEM

To be competent at fault finding it is necessary to practice as much as possible. Analyse every fault and remember the symptoms of the fault. Like a doctor it is important to know the effects on the patient before applying any medicine.

- Place the base unit, PLC module and socket module on the workbench.

- Remove the socket module from the PLC module.

There is a small DIP switch on the PLC, see figure 10.1.

Recommended reading
Motor Control
Chapter 12- Starting, operation and service.

Equipment
Base Unit 2000
PLC module
Programming unit or
PC based software
Socket module
Contactor module
Universal instrument

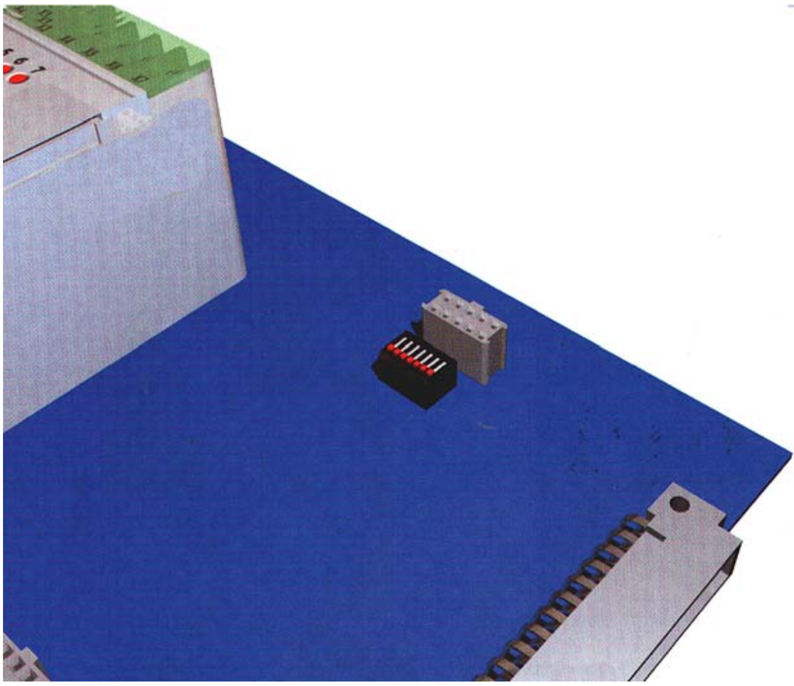


Fig.10.1 DIP switch on the PLC module

DIP stands for ”Dual In Package”. The DIP-switch has two positions.

The DIP-switches on the PLC module are used for simulating faults in the in- and outputs. The faults that can arise in the control system are often signal faults. It can be a missing signal from a sensor, or a break in the output signal from the PLC. Four faults will be simulated and then located by methodical fault finding.

- Check that the base unit is switched off.

- Check that the fault switches are in the no fault position.

- Mount he socket module on the PLC module.

Study the I/O list below.

Inputs

I/O	Title	Comments
X1	S1	START button
X2	S2	STOP button

Outputs

I/O	Title	Comments
Y0	Q3	Motor power contactor
Y1	H1	Lamp indicating START
Y2	H3	Lamp indicating STOP

- Connect up a control circuit as shown in figure 10.2.

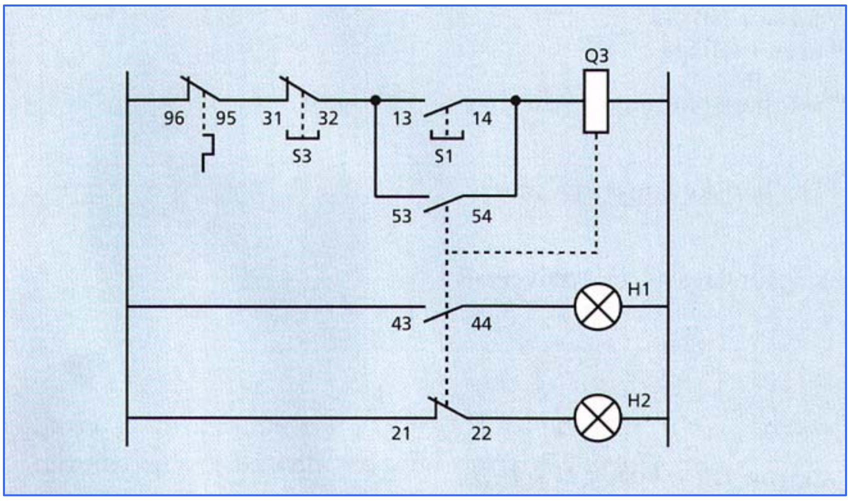


Fig.10.2 Connections are made via the PLC systems socket module and contactor module.

Note! Check that the fault switches on the contactor module are in the fault free position.

- Write the programme shown on the right into the PLC.

- Set the RUN-STOP switch to the RUN position and test the programme using the switches S1 and S3 on the socket modu

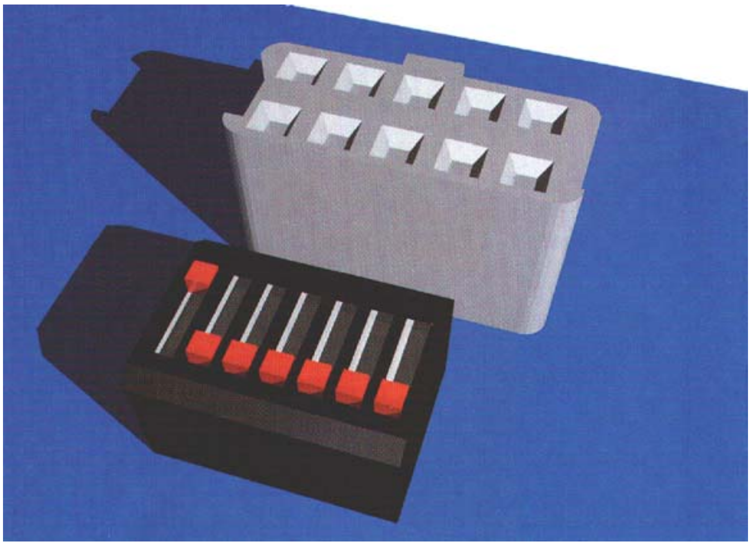
```
LD    X1
SET   Y0
LDI   X3
RST   Y0
LD    Y0
OUT   Y1
LDI   Y0
OUT   Y2
END
```

10.1 What happened?

……………………………………………………………

……………………………………………………………

Fault nr. 1



- Switch off the supply to the base unit and remove the socket module from the PLC module.
- Set the top left switch to the fault position.
- Replace the socket module and switch on the supply to the base unit.
- Observe the fault symptoms that can be seen. e.g. lamps not indicating.
- Carry out methodical faultfinding using a universal instrument.
- Enter the results in the fault report.

Fault finding report

Measuring point	Measuring instrument	Conclusions

Teacher's signature:……………………………… Date:………………………..

Fault nr. 2

Fault finding report:

Measuring point	Measuring instrument	Conclusions

Teacher's signature:……………………………… Date:………………………..

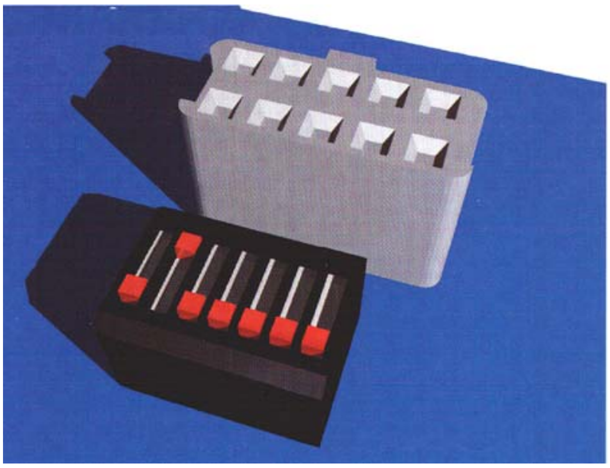
Fault nr. 3

Fault finding report:

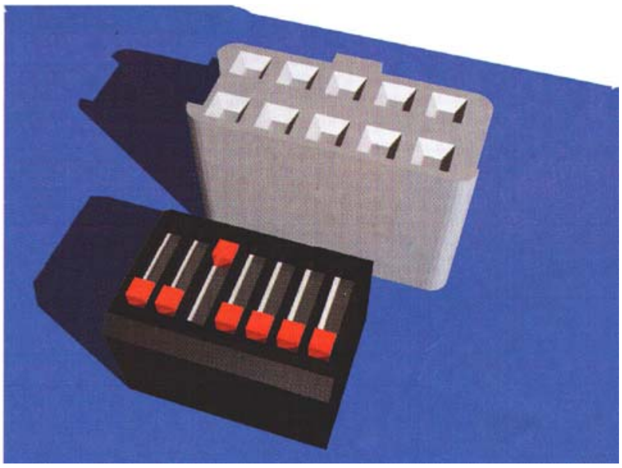
Measuring point	Measuring instrument	Conclusions

Teacher's signature:……………………………… Date: ………………………..

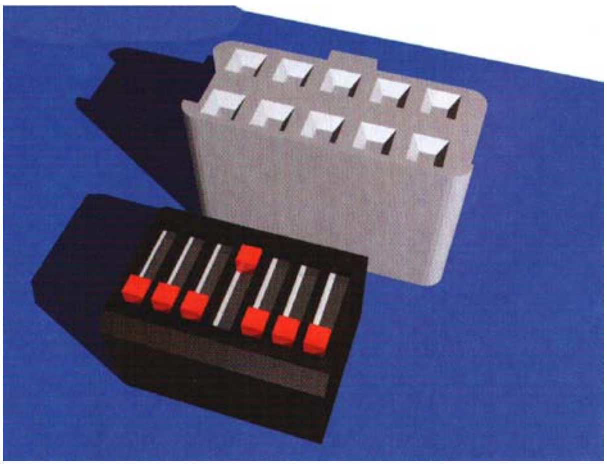
Fault nr. 2



Fault nr. 3



Fault nr. 4



Fault finding report

Measuring point	Measuring instrument	Conclusions

Teacher's signature:……………………………… Date:………………………..

Summary

The following faults were located in the PLC system……

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11 SENSORS

Objective: The objective in this exercise is to study the difference between a capacitive, inductive and an optical sensor and how they are used in practice.

A sensor is a measuring tool that converts a measured signal to an electrical or optical signal. This can be a speed meter in a car, light meter in a camera or a bathroom scale for measuring weight. In many industrial situations sensors are used to detect different types of material.

- Assemble the sensor module on to the base unit as shown 11.1.

Recommended reading
Motor Control
Chapter 12- Starting, operation and service.

Equipment
Base Unit 2000
Sensor module
Contactor module

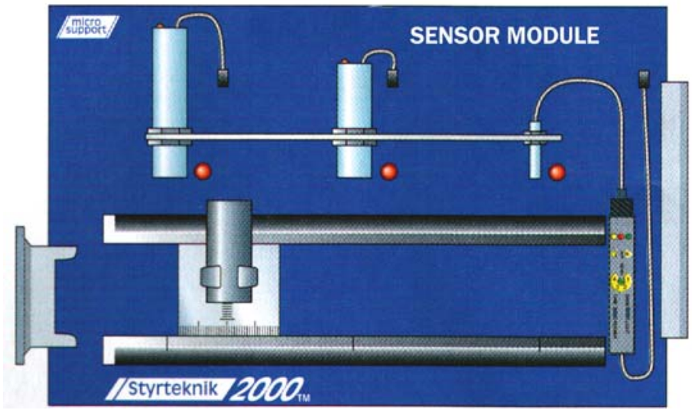


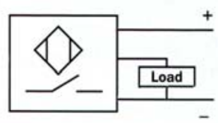
Fig.11.1 The sensor module

On the right hand side of the sensor module is an optical sensor, in the middle an inductive and to the left a capacitive sensor. On the sensor module there is also a sliding plate on which different materials can be fixed. Before completing the next task, the data sheet for the different sensors will be examined.

CAPACITIVE SENSORS

A capacitive sensor functions when the capacitive effect is changed by increasing/decreasing the distance between the capacitor plates or by changing the dielectrics between the plates.

- Study the data sheet for the capacitive sensor as shown in figure 11.2.



Housing size			12 x 1
Sensitivity distance Sn			0 – 4 mm
Installation			No internal building
Indication			LED
Casing material			Plast (PA6,6)
Electrical connection			Cable 2m
Voltage 3 core	NPN	Closing	650,7319, 001, CNT12NS004K1
		Breaking	650,7119001, CNT12NO004KLP2
Electrical data	Supply voltage		10 – 36 V
	Max current		200 mA
	Frequency		25 Hz

Fig.*11.2 Data sheet for a capacitive sensor.*

11.1 What is the supply voltage to the sensor?

……………………………………………………………..

……………………………………………………………..

11.2 What is the max distance at which the sensor can react?

……………………………………………………………

11.3 At the rear of the sensor is a small light emitting diode – LED – that indicates if the sensor has detected something. What is the colour of this LED?

……………………………………………………………

Inductive sensor

The inductive sensor consists of an inductor that is placed behind the sensors sensing surface. When a metallic object comes near the sensor the induced magnetic field is disturbed giving an output signal.

- Study the data sheet for the inductive sensor. See figure 11.3.

Data	DC
Voltage distance	2 mm
Supply voltage	12 – 24 V
Max current	200 mA
Internal consumption	2,5 mA/24 V
Voltage drop	ca 1 V
Hysterisis	ca 10 %
Repetitiveness	5 %
Reaction time	≤ 50 ms

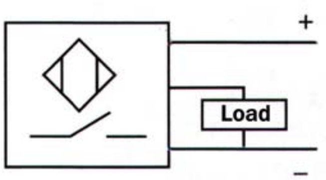


Fig.11.3 Data sheet for an inductive sensor.

11.4 What is the supply voltage to the sensor?

………………………………………….

11.5 What is the max distance at which the sensor can react?

………………………………………….

11.6 What is the sensors reaction time?

…………………………………………………………………

11.7 At the rear of the sensor is a small light emitting diode – LED – that indicates if the sensor has detected something. What is the colour of this LED?

…………………………………………………………………

Optical sensor – Fibre photocell

From the optical sensor a light ray is sent from a lamp, light diode or laser. The ray is reflected off the detected material and is bounced back to a light sensitive component inside the optical sensor.

- Study the data sheet for the optical sensor. See figure 11.4.

Model description

Model	Fig
Light source	Green LED (590 nm)
Power supply	12 – 24 V, DC ± 10 % ripple 10 %(Max)
Current consumption	35 mA (Max)
Operating mode	Light ON, Dark-ON selectable
Offdelay timer	50 msec
Output mode	Open collector NPN output
Ratin	Sink current 30 V DC 100 mA (Max) Short circuit protection built up
Output mode	Open collector NPN output
Ratin	Sink current 30 V DC 100 mA (Max)
...teresis	10 % (Max) (Reflection Typ)
Response time	500 μ sec (Max)
Indicator	Signal light. RedLED Tolerance light UP: Green LED LOW: Yellow LED
Sensitivity adjust	4 turns adjustment with indicator
Encloser	P40

Appearance of fibre end	
Order number	FR8EBC
Length of fibre leads	2 meter
Material in the fibres	Plast, polymetacrylat, PMMA
Material in the fibre cover	Plast, polyetelen
Temperature range	–30°C till + 70°C
Bending radius	–20R
Other info	**Can be cut at the back edge**
Sn = sensitivity distance (mm)	3

Fig. 11.4 Data sheet for an optical sensor.

11.8 What type of light source does the sensor have?

……………………………………………………………

11.9 What is the voltage to the sensor?

……………………………………………………………

11.10 What is the sensitivity distance has a sensor with fibre leads?

……………………………………………………………..

11.11 What is the smallest object that can be detected by a sensor with fibre leads?

……………………………………………………………..

- Switch on the supply voltage to the base unit.

The sensitivity of the sensor can be set as shown in the table.

LED on the fibre photo cell	
Green	**Accept signal**
Red	**Unsure signal**
Yellow	**Not accepted signal**

The best setting for sensitivity is when the green LED and the red LED light at the same time.

- Check that the light-dark setting is set on **LIGHT**. This should be done when it is installed so that the surrounding light can affect the sensor.

- Set the switch for time delay to the **NORMAL** position.

- Set the sensitivity as follows:

1. Place an object in the tool holder on the sensor module.

2. Turn the 4-revolution potentiometer carefully anticlockwise until a point where the sensitivity is adjusted in relation to bright reflected light.

3. Read the indication for sensitivity.
The sensitivity setting with a measured object: ……………

4 Remove the measured object from the too holder.

5 Complete the same setting with the reflection from the background.

6 Read the indication for sensitivity.
Sensitivity without the measured object:…………………

7 Set the ideal sensitivity, as a middle value.
Ideal sensitivity setting value:……………………………..

THE SENSOR MODULE

In this exercise different materials will be detected using different types of sensor.

- Assemble the sensor module on to the base unit.
- Switch on the supply voltage to the base unit.
- Place the materials set with the round rods, on the workbench.
- Secure the aluminium rod in the fixture.
- Place sledge in front of the capacitive sensor, far left on the sensor module.
- Push the round rod forward towards the sensor.
- Measure the distance the sensor gave an indication. Use the mm scale.
- Write up the distances in the table below.

Mark in the table with an X If there is no indication.
Carry out tests with all the rods and sensors. Fill in the values in the table below.

Round rod	**Capacitive sensor**	**Inductive sensor**	**Optical sensor**
Aluminium			
White plastic			
Black plastic			
Glass			

11.12 What material can be detected with the optical sensor?

……………………………………………………………..

11.13 Which of the sensors functioned best when it was dirty.

……………………………………………………………..

Summary

In these laboratory exercises three different types of sensor were studied. The capacitive……….

…………………………………………………………………

…………………………………………………………………

…………………………………………………………………

…………………………………………………………………

12 CONTROL of the ROUND MEASURING TABLE

Objective: Using a PLC it is possible to control a Vs motor with a frequency converter. This gives a very flexible system that is easy to programme and can be used for many types of electric motor control.

With a frequency converter controlled Vs motor and a PLC system there are many possibilities for safe and optimal operation of the round measuring table.

ROUND MEASURING TABLE

Imagine the fixture plate on the round measuring table as a factory production line. Together with sensors and ejection tools the products are sorted out. A Vs motor drives the round measuring table.

The next task is to construct an installation where the motor has soft start in both directions. The movement speed and braking must also be adjustable.

To solve this problem a frequency converter must be installed in the motor power circuit. Soft start and braking can be combined with stepless speed control.

A PLC can also be installed in the control circuit. A fixed programme for speed, position, direction and time, can control the time and actions of the circular measurement table.

The laboratory exercise stats with a few simple instructions, step by step. These instructions will be gradually reduced until the student can solve the problem without help. Consult the manual if help is required.

Recommended reading
Motor Control
Chapter 8- Control of motors
Chapter 9- Motor electronics
Chapter 10- Sensors
Chapter 12- Starting up, running and service

Equipment
Vs motor
Revolution counter
Round measuring table
Frequency converter
Base Unit 2000
PLC module
Programming unit
Manoeuvre Module
Universal meter

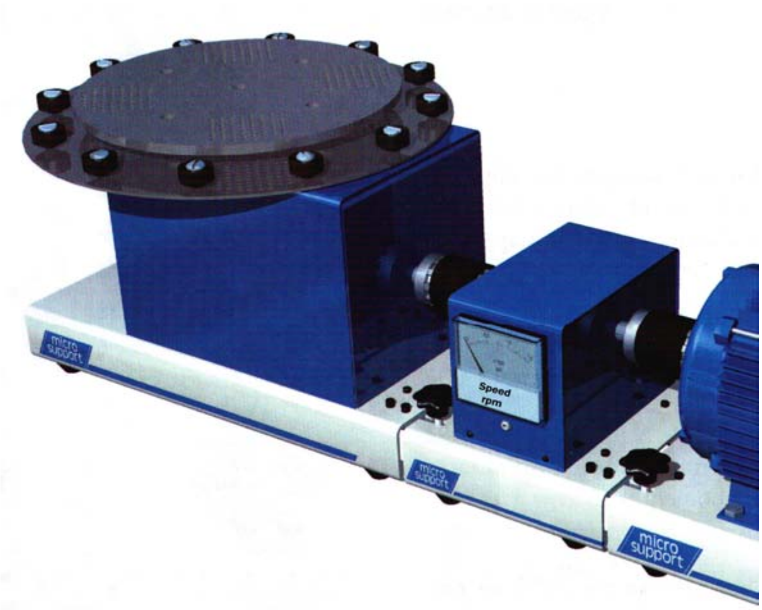


Fig.12.1 The round measuring table connected to the revolution counter and 3-phase motor.

Equipment

- Place the round measuring table, revolution counter, 3-phase motor, base unit with PLC module and socket module, manoeuvre module and frequency converter on the workbench.
- Line up the shafts of the measuring table, revolution counter and motor and push the rubber bushes into place over the cogs.
- Fix the bottom plates against each other and tighten the black knobs.
- Turn the motor axle to check that they are lined up correctly.

Connecting the power

- Place the frequency converter, motor and lab leads on the workbench.
- Connect the motor in delta. From the motor connect to the frequency converters 3-phase output and earth.
- Connect the frequency converter to the 1-phase supply voltage.

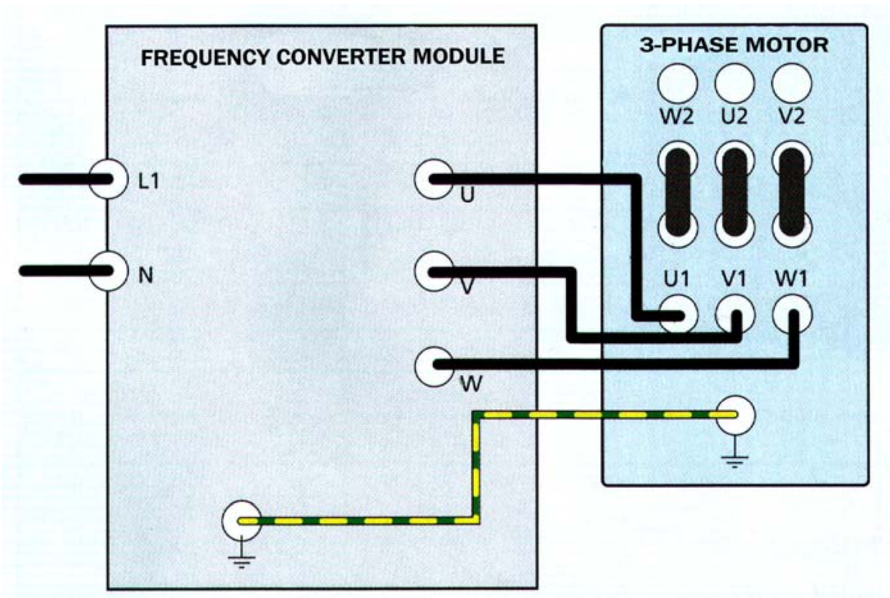


Fig.12.2 Frequency converter connected to 1-phase supply and 3-phase motor.

When the motor starts up the round measuring table will rotate with strong force. Check before starting that all safety precautions have been made against personal damage and damage to the equipment.

Start and stop from the PU unit

Inside the frequency converter there is a parameter unit. This is used for reading the operational status, fault indications and for setting the parameters. The motor can also be operated direct from the parameter unit. See the instructions for the parameter unit in laboratory exercise 7 and figure 7.6, or read the makers manual.

- Switch on the voltage to the frequency converter.

- Set the frequency converter to the **PU** position and reset all the parameters to the factory settings according the makers manual.

- Set the following:

- Electronic overload protection **P9** according to the rated current of the motor.
- Maximum output frequency **P1** according to the rated frequency of the motor.
- Operation position **P79** to position **0**. From here the operation can be selected from **PU** or EXT.

Fig.12.3 The frequency converters parameter unit.

- Check that operation is in the **PU** position.

- Set to a low speed with potentiometer **SPEED** in the frequency converter module.

- Start the motor by pressing the **START** button.

- Stop the motor by pressing the **STOP** button.

Setting the speed

- Read the display on the frequency converter when measuring the speed of the motor. (Frequency)

- Place three pucks made of different materials on the round measuring table.

- Increase the speed of the measuring table until it is such that the pucks slide off the table. Try with different positions on the table and pucks of different weight.

Puck 1) Material………………………..Frequency……………….

Puck 2) Material………………………..Frequency……………….

Puck 3) Material………………………..Frequency………………

Fig.12.4 Motor driving the revolution counter and round measuring table.

- Maximum and safe speed (frequency) …………………………………… ……………………………………

12.1
Set the following parameters according to selection.

- Highest output frequency P1 =…………………………...

- Acceleration time P7 =…………………………….…..

- Retardation time =……………………..……………….

- DC Brake P 10 = …………………………………………

- DC brake P12 =…………………………………………..

- Torque curve P14 =……………………………………….

12.2 Write up the times taken for:

Acceleration =…………………………………………….

Retardation =……………………………………………..

Connecting the control circuit

- Place the PLC module and Base unit on he workbench. Study the PLC system instructions. Check how many inputs and outputs.

  Inputs:………………………………………………….

  Outputs:…………………………………………………

  Study the following I/O list. Make ant necessary changes.

Input	Signal	Comments
X0		START turn right
X1		START turn left
X2		STOP button
Output		Comments
Y0		Motor START turn right
Y1		Motor START turn left
Y2		Motor STOP button

- Connect the control circuit between the manoeuvre module, PLC module and frequency converter as shown in 12.5.

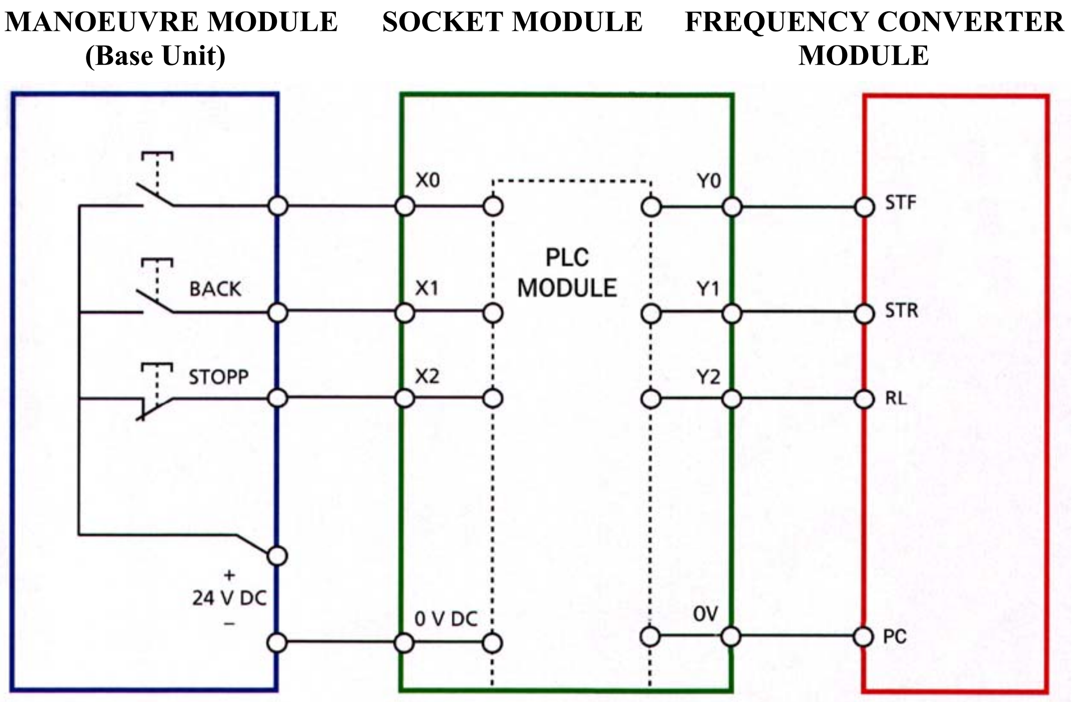


Fig.12.5 Circuit diagram for connection of the PLC with control circuit to the frequency converter.

External start and stop

- Connect the programming equipment to the programming port on the PLC.
- Erase all information from the flash memory in the PLC.
- Write in the programme according to 12.6, to the PLC.

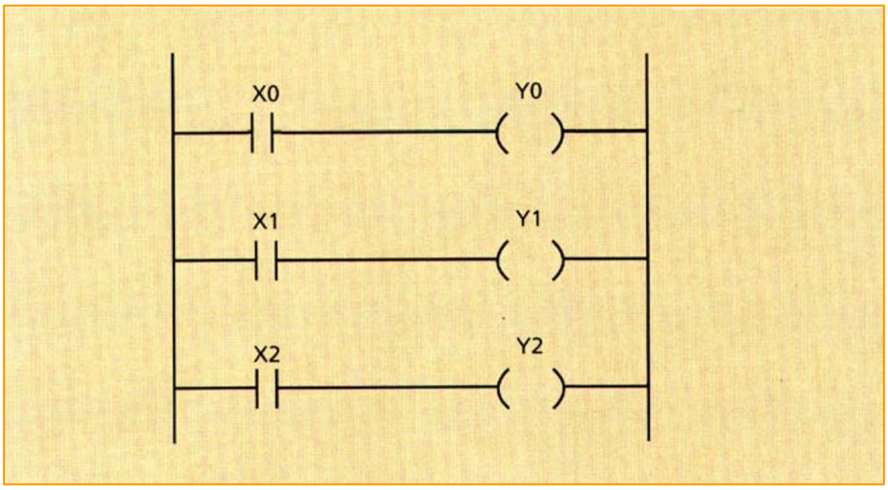


Fig.12.6 Ladder scheme and instruction list for time control of a Vs motor.

- Set the frequency converter in the operational position **EXT** mode and the PLC in position **RUN**.
- Check that the motor can be started in both directions and also stopped at the external station.
- Check that the speed can be set with the potentiometer on the frequency converter.

12.3 How did the **FORWARD, REVERSE** and **STOP** connections, function?

………………………………………………………………………………..

………………………………………………………………………………..

12.4 What are the purposes of the **RUN-STOP** switches?

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

- Stop the motor and set the **RUN-STOP** switch to the **STOP** position.

Control with time function

In a production line it is often necessary to have time delays between stages.
A simple example is that a start in the forward direction must be delayed for a certain time after the start signal has been given.

Change the programme so that the motor starts in a forward direction with a delay of five seconds. See 12.7. Make changes as necessary.

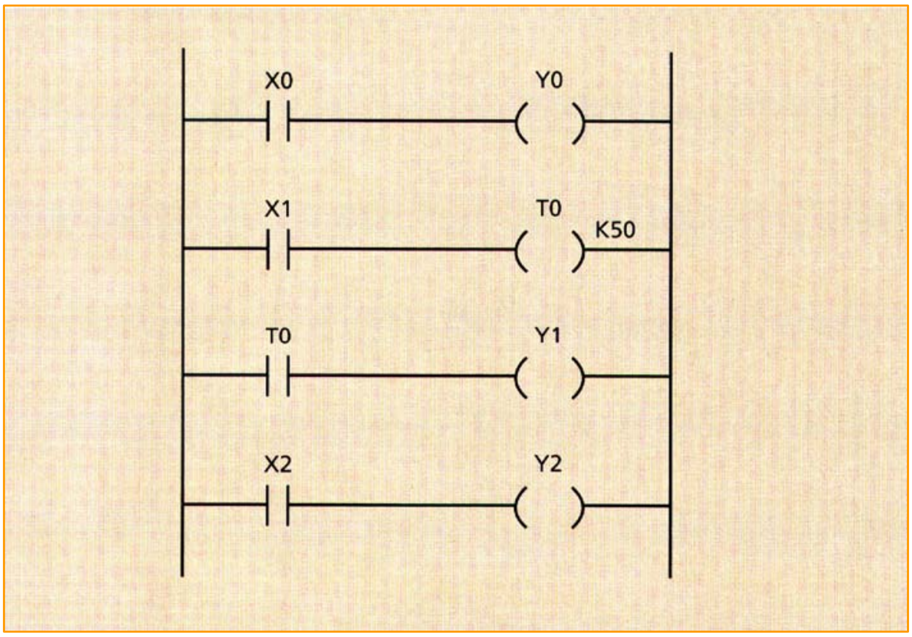


Fig.12.7 Ladder schema with time delayed start in the forward direction.

- Start the motor and test to see if the circuit functions as planned.

12.5 What changes were made to the programme?

……………………………………………………………………

- Stop the motor and set the **RUN-STOP** switch to the **STOP** position.

Control by counter function

A typical example of counter control is with the circular measurement table. The table is controlled by the PLC to select pucks of different materials. The installation shall be started and stopped as before but will be complemented with the following:

In order that the table need not be moving continuously there is store that collects the pucks. When twenty pucks have been collected in the store the motor will start moving the table. It will then stop when all the pucks have passed the last of the three positions.

To start the motor a sensor is mounted beside the store. The sensor detects when the pucks are pushed one by one into the store. A counter function in the PLC adds up the correct number of these signals and when it reaches twenty it gives a start signal. There is also a timer function in the PLC that is used to determine how much time is needed between pucks for all to be detected. The table stops after the set time.

- Decide what type of material the pucks are made of and select the types of sensor to use.
- Add sensor X3 to the I/O list.
- Mount the sensor on the circular measuring table bracket.

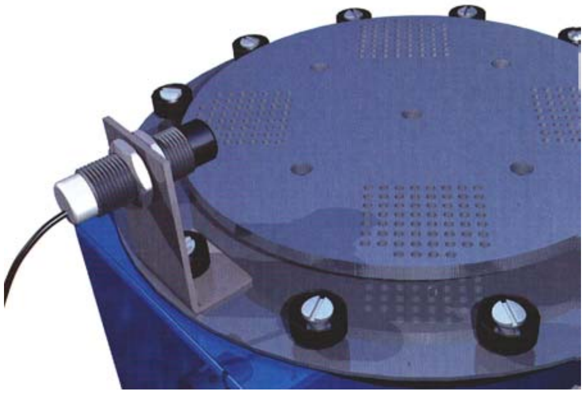


Fig.12.8 The sensor fixed to the bracket .

- Connect the sensor to the PLC +24V and 0V. The sensor output to X3.
- Erase the flash memory in the PLC.
- Consider the programme in 12.9. Make changes as necessary.

Note! Instruction **M8002** is only for the first cycle of the PLC. This means that the counter **C0** is zeroed when the PLC is set to the **RUN** position **OR** when **Y1** becomes **1**.

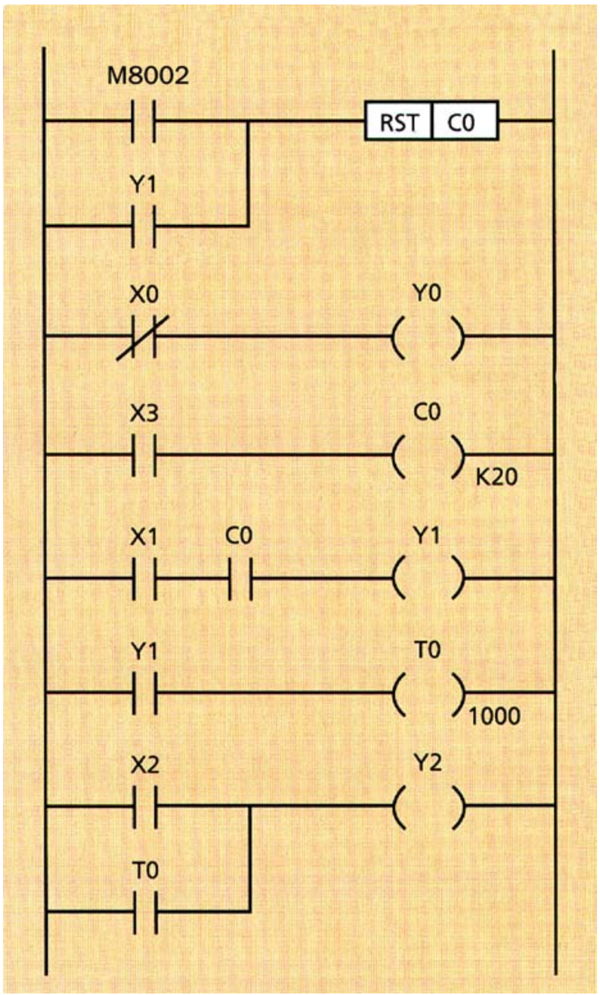


Fig. 12.9 Counter function in a PLC controlled motor installation.

- Set the **RUN-STOP** switch to the **RUN** position.
- Check that the motor can start and stop with the switches on the manoeuvre module.
- Start the motor by letting **20** pucks pass sensor **X3**.

12.7 What would happen if **M8002** were not included in the programme?

…………………………………………………………………………….

…………………………………………………………………………….

…………………………………………………………………………….

12.5 Write a new PLC programme for the following procedure. The programme can be revised so that the motor drives the measuring table in the reverse direction when the sensor has been activated five times. Create a ladder scheme and instruction list for this task.

After consultation with the teacher select one of the following tasks:

Task 1
The sensor shall start and stop the measuring table

The installation shall start and stop and also emergency stop with the switches on the manoeuvre module.

The round measuring table shall be ready waiting for the first object to be laid on the table.

- If the object is metallic then the table will turn in the reverse direction.
- If the object is non-metallic then the table will turn in the forward direction. Irrespective of direction of rotation the table will stop when a certain position is reached.

- Select the type of sensor to be used.
- Select the position where the detection shall take place.
- Install the sensors required.
- Create an I/O list.
- Write a programme, ladder scheme and instruction list for the task.
- Copy in the programme to the PLC.
- Complete a control run of the installation.
- Optimize the parameter settings.

Collect the results and report to the teacher.

Task 2
The sensor selects by stopping the table

The installation shall start and stop and also emergency stop with the switches on the manoeuvre module.

To complete the selection the table must stop at different positions depending on the material of which it is made. Objects containing metal must stop at a position marked “Metal”. For those objects containing no metal the table must stop at the position marked “Non metal”.

- Select the different stop positions.
- Select suitable sensors for the task.
- Create an I/O list.
- Mount the sensors on the round measuring tables fixed plate.
- Connect the sensors to the PLC.
- Write a programme, ladder scheme and instruction list for the task.
- Copy in the programme to the PLC.
- Complete a control run of the installation.
- Optimize the parameter settings.

Collect the results and report to the teacher.