# POWER ENGINEERING 2 LABORATORY
# SAFE WORKING WITH ELECTRICAL EQUIPMENT

In the Power and Machines Laboratory you may be required to assemble and operate equipment which is connected to 400V, 220V ac, 220V dc, or 110V ac supplies. Every effort has been made to ensure that the equipment and experiments are safe, but we share responsibility for your personal safety. Care and attention must be practised at all times to minimise the possibility of accident.

**Electric Shock**

Electric shock is caused by an electric current passing through the body. A current of only 30mA can cause death, so while 3A-13A fuses will protect equipment, they will not protect you.

Your body will conduct current if there is a potential difference between two parts of you. To prevent electric shock, the first rule is not to come in direct contact with, or touch, any LIVE conductors. Treat all conductors as potentially LIVE and always switch off supplies before working on any part of a circuit or equipment.

- Where supplies are generated in the lab, always switch off and wait for the machine to come to rest before touching any components.

- All supplies at the binnacles are switched and all have indicator lamps. Always check that the switches are open and that the lamps are extinguished, before touching any live components.

It is possible to receive an electric shock as a result of indirect contact with a live conductor, if you touch an unearthed metallic part which has become LIVE.

- Ensure that all conductors are correctly insulated, terminated and shrouded.

- Ensure that all equipment is solidly earthed, so that casings or frames cannot become LIVE.

- As a further precaution do not lean on equipment while working on it. You may unwittingly create a return path in your body through which current would flow if the equipment accidentally became live.

**Injury from Rotating Machines**

- Do not remove guards from machines, or operate machines without guards.

- Do not lean over machines and avoid wearing ties, scarves etc, which can become entangled with the machine. Keep long hair tied back.

- Always wait for machines to come to rest before working on them.

**Working practice and behaviour**

- Bags, coats etc. should be stored near the main door. Avoid wearing jewellery, and watches with metallic wrist straps. Do not sit on chairs or benches near the machines or equipment.

- Lay out equipment neatly. Keep wires as short as possible, but not so short that they are under tension. Use correct colour coding for cables (brown, black, grey and black for three phase and neutral, brown and blue for dc or single phase ac and neutral, and green/yellow for earth).

- Work professionally and responsibly. There will always be a responsible staff member present, and you should consult them if you are uncertain of the safety of your actions.

WE HAVE A GOOD SAFETY RECORD IN THE POWER LABORATORY. PLEASE HELP US TO KEEP IT THAT WAY.

# POWER ENGINEERING 2 LABORATORY
# ASSEMBLY OF A 3 PHASE MOTOR STARTER

## 1. Safety

You will be working with equipment which will be finally connected to a three phase 200 V ac supply. **You should read and obey the preceding general safety instructions.** You should never energise the panel with the front door open. There will be a staff member, and demonstrator on hand all afternoon. If you are in any doubt about a safety issue or require assistance please ask.

## 2. Object

Three phase motors are usually started by the remote closure of a three phase contactor, which may have main contacts at 11,000 V, but where the operator operates a control switch at 24 Vdc. The object of this laboratory is to assemble, test and prove a three-phase switchpanel for a 180 W, 200 V ac cage induction motor. In the process you will gain an appreciation of the techniques, skills and safety procedures involved in the wiring and test of switchgear.

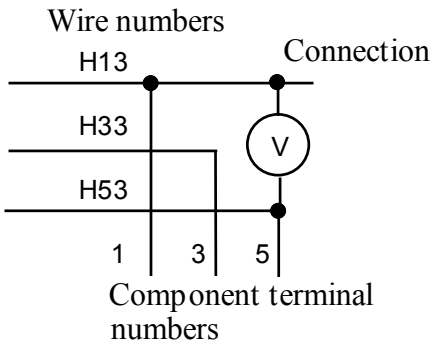
***Note that you will only be able to complete the lab if BEFOREHAND you read these sheets and complete pre-lab the questionnaire at the rear.***

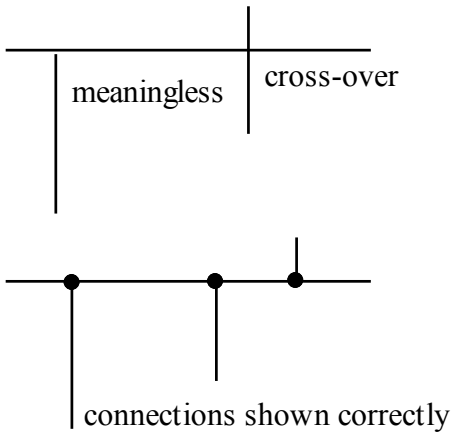
## 3. Skills

There are a number of skills that you will acquire. Even working in pairs you should swap tasks so that you each gain experience of every operation. Over the course of the afternoon you will be assessed on your ability to carry out operations 3.1-3.4, and on the quality of the finished and tested panel. You are provided with one complete set of correctly selected tools which will allow you to work in a safe and professional manner.

### *3.1 Reading and working from electrical schematics*

The circuit diagram, or electrical schematic, of the switchpanel is attached. You should spend some time at the outset familiarising yourself with the location and function of the components. Note that electrical connections to components are signified by the wire touching the symbol. Where there are a number of phase- or polarity-sensitive connections to a component they are numbered on the drawing to correspond with numbers on the terminals or casing of the component. Connections to more than one component require common wires to be shown connected together, which is signified by a solid black dot. Without the presence of the solid dot wires are deemed electrically separate, even though they may be shown to cross (which may be inevitable) or simply touch (which is bad drawing practice).




### *3.2 Wire numbering*

To ensure consistency of wiring with the electrical schematic each wire is given a number, which may appear at numerous points in the drawing and on connections to many components. The single wire number signifies that many components have connections which are electrically common, at the same voltage. British Standards and Codes of Practice apply to the allocation of wire numbers. AC supplies are prefixed with letter 'H', and numbers are allocated from the convention that:

Brown, Black and Grey (L1, L2 and L3) phase connections have numbers 10-29, 30-49, 50-69 respectively.
Neutral connections are allocated from 70-89
Earth connections are all numbered 90.

***Wires are always numbered one at a time, as they are cut and crimped with slip-on ferrules applied to each end.***

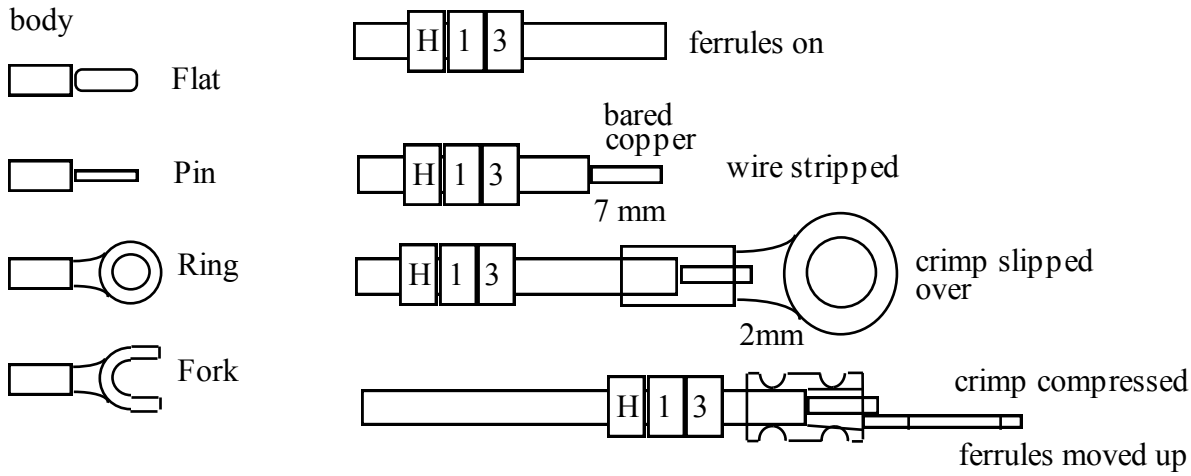
This ensures that a single wire carries identical numbering, since in a large switchpanel it would not always be possible to trace a single wire end-to-end. Ferrules are provided for the wire you will be using and should be slipped over and checked as the wires are made, prior to stripping and crimping the terminals on - as shown below.

*3.3 Wire termination*

Wires are selected to have sufficient cross-sectional area that the resistance of the copper is low enough to minimise heating effect and voltage drop, for the current the wires are required to pass. In this assembly all conductors have csa 1.5 sq mm, which allows each wire to safely carry 16 A. Wires are also selected to safely insulate equipment and persons from the voltage to which the conductors are raised. Within the panel the single layer of pvc insulation will sustain an ac voltage of 450V to earth or 750 V between conductors. The wiring within the panel is generally contained in pvc trunking to provide secondary insulation from the earthed steelwork. Outwith the panel the single-, or three-phase wiring must be double insulated by an outer pvc sheath. If subject to possible mechanical damage the cable would also be armoured and further sheathed. There are examples on display in the laboratory.

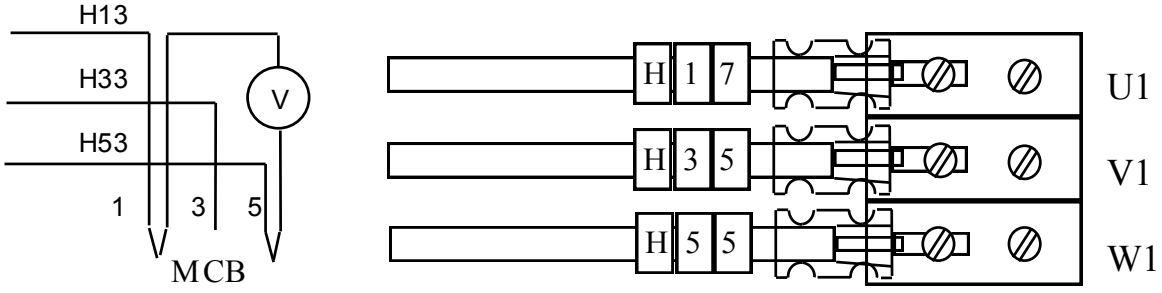
To correctly terminate the wires, the inner (and outer where appropriate) insulation must be removed. This is done with the wire strippers provided, which must be set for the correct copper cross-section - 1.5 sq mm, and also set to remove a consistent length of insulation - 7 mm. A crimp-type terminal is then selected depending on the socket into which the wire will be fitted. The crimp may be flat-, pin- , fork- or ring-type.

The crimp is slipped over the bared copper end of the wire such that 2 mm of wire projects through the body of the crimp, and simultaneously the pvc insulation is seated firmly inside the body of the crimp. This being the case the terminal is crimped with the calibrated tool provided - which is a single shot device only releasing when the crimp is compressed to fully consolidate the wire in the body of the crimp. There should be no bare copper 'above' the body of the crimp and the wire number ferrules should be slipped down to almost touch the body of the crimp, as shown below.




*3.4 Wire fitting*

Wires are always connected together on components, to minimise the number of connections in the assembly. Wires H13 and H53 in the schematic could be looped at the MCB and then to the voltmeter as shown below. The crimped terminals should be fully inserted into the terminal blocks so that the body of the crimp projects into the block, and there is no bare copper or terminal conductor exposed, as shown below. Note that there are Brown, Black, Grey and Blue coloured wires for the phase and neutral connections. Control wiring should be made in grey and earth wiring in green/yellow.



## 4. Components

*Door-mounted*

| Drg ref | Item | Labelled | Rated |
|---|---|---|---|
| SL1 | Brown | | |
| SL2 | Black | Incoming 200 V 3phase supply | 115 V, 3 W |
| SL3 | Grey | | |
| SL4 | White | Contactor CLOSED | 115 V, 3 W |
| SL5 | White | Contactor OPEN | 115 V, 3 W |
| V | Voltmeter | Line voltage | 0-300 V |
| A | Ammeter | Line current | 0-5 A |
| CS | Control switch | Motor supply ON/OFF | |

SL1-3 are phase voltage lamps which are connected across line and neutral conductors. The 200 V ac line voltage of the supply appears as a phase voltage across each lamp of $200/\sqrt{3} = 115$ V.
These lamps are illuminated whenever the panel is connected to the ac supply distributed around the lab, and serve to act as a warning not to open the panel from when the internal components are energised.

SL4&5 are fed from the brown and neutral conductors and indicate when the switched supply is connected to or disconnected from the motor.

V is a voltmeter which is energised from the brown and grey line conductors and displays 200 V when the MCB is closed.

A is a line ammeter in the switched brown phase of the panel. When the contactor FC is closed and the motor is energised this ammeter will display the current taken by the motor.

CS is a control switch which energises the operating coil of contactor FC, rotated clockwise to close the contactor, and anti-clockwise to open the contactor.

***The door-mounted equipment is pre-wired from the door to TB2. You must correctly make and fit the remaining internal wiring in accordance with the schematic.***

*Internally-mounted*

| Drg ref | Item | Labelled | Rated |
|---|---|---|---|
| TB1 | Terminal block | TB1 | |
| TB2 | Terminal block | TB2 | |
| MCB | Miniature circuit breaker | MCB | 6 A |
| FC | Motor contactor | FC | 6 A |

TB1 is a terminal block arranged to receive and pass back out the the three phase and neutral ac supplies and - importantly - connect the system earth through the panel.

FS1-3 are fuses contained in TB1 rated to blow if the current exceeds 10 A. This ensures that wiring errors or component failure in the panel can not result in a sustained fault current in excess of 10 A

TB2 is not shown in the schematic, but connections through it are signified ☑

MCB is a miniature circuit breaker which is used to isolate the equipment inside the panel.
If the current through the MCB just exceeds 6 A the MCB will trip in a short period of time.
If the current greatly exceeds 6 A, the MCB will trip instantaneously.

FC/5 is a contactor which is operated electrically, by the rotation of switch CS which energises the operating coil of FC. When the coil is energised the main contacts FC1-3 close simultaneously. In addition FC-4 closes to illuminate SL4 and signify that the motor has been energised and should be running. Simultaneously FC-5 (which is normally closed) opens to extinguish the lamp that signifies the motor supply is off.

*External*

| Drg ref | Item | Labelled | Rated |
|---|---|---|---|
| Motor | Motor | | 200 V, 180 W |

The motor is a delta-connected three phase cage induction machine. We cannot readily load the motor up but for the purposes of this assembly the motor is just treated as a demanding three phase load.

## 5. Assembly

First check that the incoming and outgoing three phase cables are disconnected from the panel. Stages of the assembly process are:

- Identify on the schematic the leads off the door terminated in TB2, and mark these on the drawing in one colour.
- Cut, ferrule, strip, crimp and fit the remaining connections one at a time, marking these on the schematic individually as they are done. Allow suficient slack on the connecting wires that they may be loosely looped in the trunking provided.
- Close up the internal trunking

## 6. Test

There is a hold-point between assembly and test, and prior to running the induction motor. Prior to connecting the switchpanel to the ac supply you will be required to test and prove to a supervisor that it is correctly assembled and safe to energise. First check that all internal connections are made and are sound, and then insert the Brown, Black and Grey Phase fuses FS1,2, &3.

***You will be issued with a test sheet on the day you attend the lab.***

- Earth integrity and continuity of conductors
  Using the yellow multimeter measure and prove the resistance of the earth connection into/out of the panel.
  Record this in the test sheet.
  Hint: prove the meter's ability to measure a short circuit before and after the test.

  Using the multimeter, prove continuity around the panel at all like wire numbers.
  Record this in the test sheet.

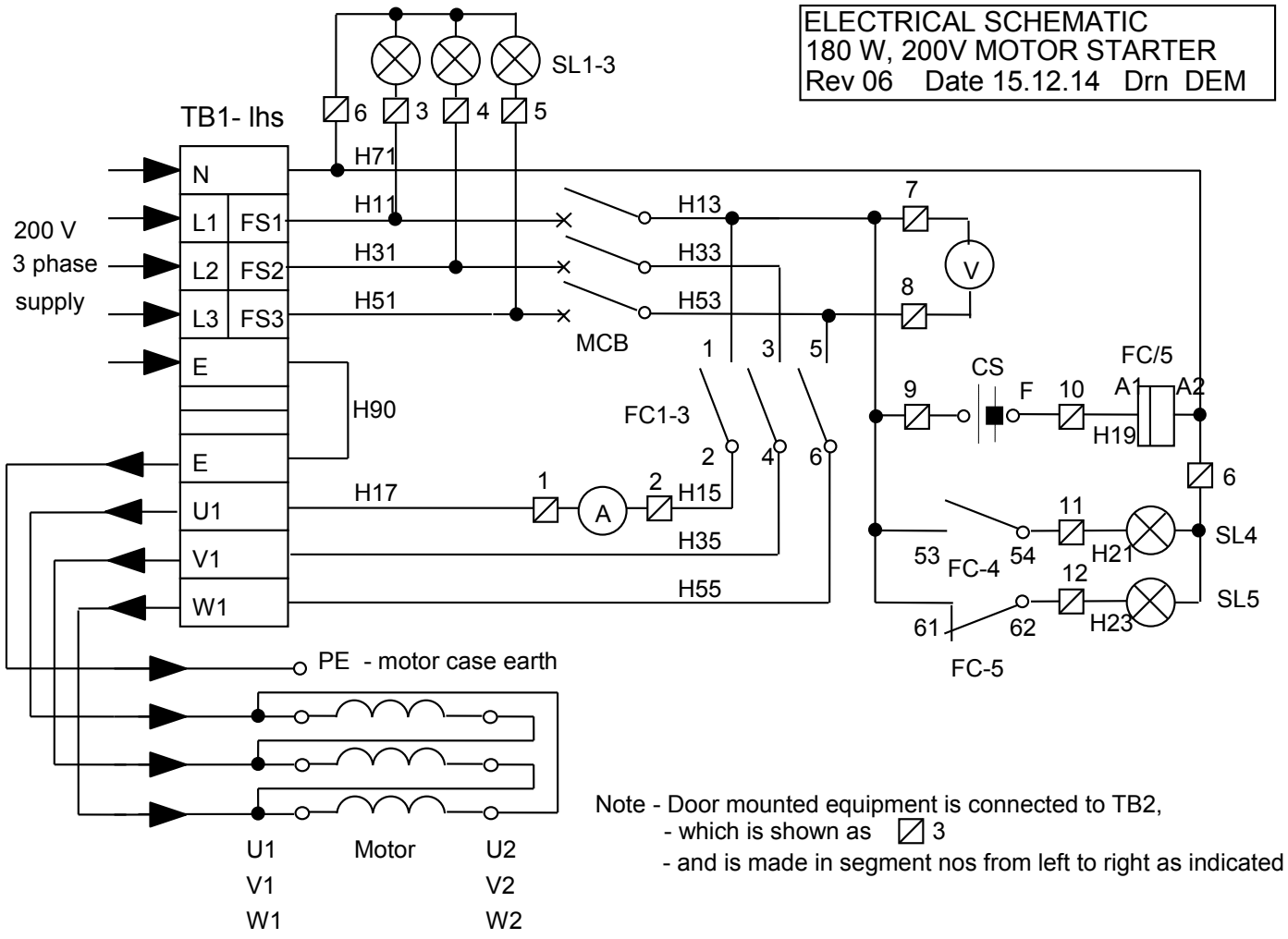
- Insulation resistance
  ***Open the connecting links at TB2 to isolate the door-mounted equipment*** Close MCB
  **Ask the supervisor** to demonstrate the Metrohm insulation tester, and measure and prove the insulation resistance of the panel wiring by applying 500 V between the terminals listed in the test sheet. There is one only test plug to enable this.
  Record the insulation resistance in the test sheet.
  ***Close the connecting links at TB2 to reconnect the door-mounted equipment*** Open MCB

- Functional tests **with the door closed, and the supervisor present**
  Replace fuses FS1-3 and connect the incoming three phase supply
  check that SL1-3 have illuminated
  check that SL4 is extinguished and SL5 is illuminated
  Close the MCB and check the voltmeter display
  Rotate switch CS to the F position and
  check that SL5 is extinguished and SL4 is illuminated
  Rotate switch CS to the O position and
  check that SL4 is extinguished and SL5 is illuminated

- Phase rotation - **with the door open and the supervisor present**
  Close contactor FC and using the 'Martindale' Voltage Tester
  check the presence of a three phase supply at the output terminals U1, V1 and W1
  Using the 'Martindale' Phase Rotation Tester
  check the phase rotation of the supply at terminals L1, L2 and L3
  check the phase rotation of the supply at terminals U1, V1 and W1
  compare and confirm phase rotation is preserved.
  Open contactor FC and check the absence of a three phase supply at the output terminals U1, V1, W1

- Motor Test
  Open the contactor FC, disconnect the incoming ac supply, and connect the induction motor.
  Reconnect the incoming ac supply, and close the contactor FC.
  check and record the direction of rotation of the motor.
  Measure and record the start and no-load current of the motor.
  Open the contactor FC, disconnect the incoming ac supply, and disconnect the induction motor.

When you have completed assembly and test you should disconnect from the three phase supply and prove isolation before dis-assembling the panel.


ELECTRICAL SCHEMATIC
180 W, 200V MOTOR STARTER
Rev 06 Date 15.12.14 Drn DEM
SL1-3
TB1- lhs
6
3
4
5
H71
N
H11
L1
FS1
200 V
3 phase
supply
H31
L2
FS2
H51
L3
FS3
MCB
H13
H33
H53
1
3
5
7
V
8
E
H90
FC1-3
CS
FC/5
9
F
10
A1
A2
H19
E
2
4
6
6
H17
1
A
2
H15
U1
H35
11
SL4
53
FC-4
54
H21
V1
12
SL5
H55
61
62
H23
W1
FC-5
PE - motor case earth
U1
Motor
U2
V1
V2
W1
W2
Note - Door mounted equipment is connected to TB2,
- which is shown as 3
- and is made in segment nos from left to right as indicated