basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

NOVEMBER 2023

MARKING GUIDELINES

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MARKS: 200

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DEPARTMENT OF BASIC EDUCATION
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APPROVED MARKING GUIDELINE
PUBLIC EXAMINATION

These marking guidelines consist of 15 pages.

INSTRUCTIONS TO THE MARKERS

1. All questions with multiple answers imply that any relevant, acceptable answer should be considered.

2. Calculations:

   2.1 All calculations must show the formulae.

   2.2 Substitution of values must be done correctly.

   2.3 All answers MUST contain the correct unit to be considered..

   2.4 Alternative methods must be considered, provided that the correct answer is obtained.

   2.5 Where an incorrect answer could be carried over to the next step, the first answer will be deemed incorrect. However, should the incorrect answer be carried over correctly, the marker has to re-calculate the values, using the incorrect answer from the first calculation. If correctly used, the candidate should receive the full marks for subsequent calculations.

3. This memorandum is only a guide with model answers. Alternative interpretations must be considered and marked on merit. However, this principle should be applied consistently throughout the marking session at ALL marking centres.

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

1.1	C / D ✓	(1)
1.2	D ✓	(1)
1.3	C ✓	(1)
1.4	C ✓	(1)
1.5	D ✓	(1)
1.6	C ✓	(1)
1.7	B ✓	(1)
1.8	B ✓	(1)
1.9	C ✓	(1)
1.10	C ✓	(1)
1.11	D ✓	(1)
1.12	A ✓	(1)
1.13	C ✓	(1)
1.14	D ✓	(1)
1.15	A ✓	(1)
		[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1
- When any person dies. ✓
- When the health and safety of any person is endangered. ✓
- When a major incident occurs. (2)

NOTE: Only serious injuries are reported to the health and safety inspector.

2.2 Danger means anything that may cause injury to a person ✓ or damage to property. ✓ (2)

2.3 The Emergency Master Switch should be located at a key access point ✓ so that in an emergency, workers could access the switch easily. ✓ (2)

2.4 Charring of tissue. ✓
Difficulty in breathing. ✓
Severe symptoms of shock. (2)
Muscle and bone damage.

2.5 Check whether the person is able to breath. ✓
Send a person to call for medical assistance. ✓
Keep the person lying down.
If unconscious, put the person on his/her side. (recovery position)
Don't move the person in case of neck or spine injuries.
Cover the person to maintain body heat.
Keep a close watch on the person's colour, raising the head or legs to manage the blood flow into the paler areas. (2)

[10]

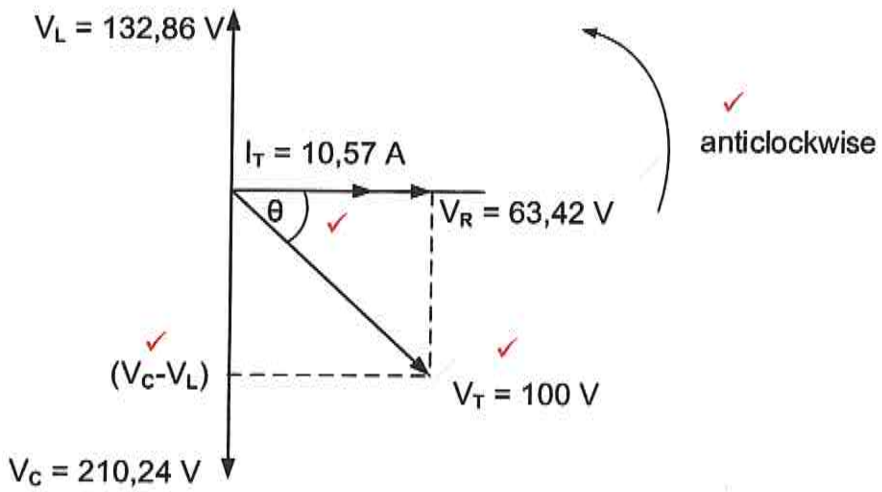
QUESTION 3: RLC CIRCUITS

3.1 Inductive reactance is directly proportional to frequency. ✓ (1)

3.2 The current waveform lags the voltage waveform by 90°. ✓ (1)
(voltage waveform leads the current waveform by 90 degrees)

3.3 3.3.1 The supply current is leading ✓ because Vc is greater than V_L.. ✓ (2)
Alternative motivation:
Because the circuit is more capacitive
The supply current is leading because V_L is smaller than Vc

3.3.2



(4)

3.3.3

$$V_T = \sqrt{V_R^2 + (V_C - V_L)^2} \quad ✓$$
$$= \sqrt{63{,}42^2 + (210{,}24 - 132{,}86)^2} \quad ✓$$
$$= 100{,}05\ V \quad ✓$$

(3)

3.3.4

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad ✓$$
$$= \frac{1}{2\pi\sqrt{(0{,}02)(80 \times 10^{-6})}} \quad ✓$$
$$= 125{,}82\ Hz \quad ✓$$

(3)

3.4 3.4.1

$$I_T = \sqrt{I_R^{\ 2} + (I_L - I_C)^2} \quad ✓$$
$$= \sqrt{3^3 + (5-5)^2} \quad ✓$$
$$= 3\,A \quad ✓$$

If I_L = Ic the circuit is at resonance

Therefore I_R = I_T

= 3 A

(3)

3.4.2

$$Cos\theta = \frac{I_R}{I_T}$$ ✓

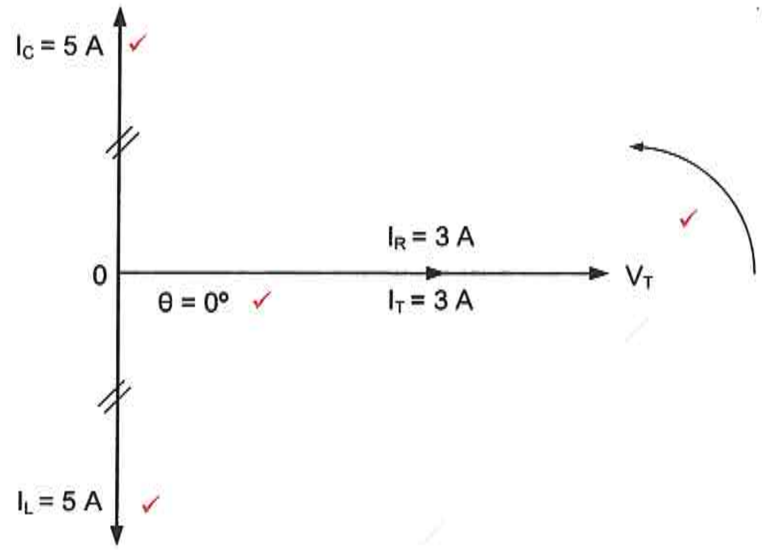
$$\theta = Cos^{-1}\left(\frac{I_R}{I_T}\right)$$

$$= Cos^{-1}\left(\frac{3}{3}\right)$$ ✓

$$= 0^{\circ}$$ ✓

(3)

3.4.3



(4)

3.5 3.5.1

$$Q = \frac{X_C}{Z}$$ ✓ (R = Z at resonance)

$$= \frac{300}{30}$$ ✓

$$= 10$$ ✓

(3)

3.5.2

$$BW = \frac{f_r}{Q}$$ ✓

$$= \frac{4{,}77 \times 10^3}{10}$$ ✓

$$= 477\ Hz$$ ✓

(3)

3.5.3

$$V_L = I_T \times X_L$$ ✓

$$= 1 \times 300$$ ✓ (X_L = X_C at resonance)

$$= 300\ V$$ ✓

(3)

3.5.4 The voltage across the inductor is greater than the supply voltage due to this being a series resonant circuit ✓ and to the voltage magnification ✓ of the Q-factor.

L and C forms a tank/oscillator which amplifies the voltage and supply each other with out of phase energy where the amplification depends on Q.

(2)
[35]

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QUESTION 4: THREE-PHASE AC GENERATION

4.1 4.1.1 Efficiency is the ratio ✓ of the output power to the input power ✓ expressed in percentage. (2)

4.1.2 Power factor correction is the process of reducing the load's phase angle ✓ thereby bringing the power factor closer to 1. ✓ (2)

4.2 An improved power factor reduces the current supplied to a system. ✓
Because of reduced current, thinner supply cables will be required. ✓
Cost of maintenance will be less. (2)

4.3 Power transmission is the large-scale movement of electricity at high voltage ✓ levels from a power station to a substation. ✓ Whereas power distribution is the conversion of high voltage electricity at substations ✓ to lower voltages and distributed for use by domestic and industrial consumers.✓ (4)

4.4 4.4.1

$$I_L = \frac{P}{\sqrt{3}\,V_L Cos\theta}$$ ✓

$$= \frac{5000}{\sqrt{3}(400)(0{,}85)}$$ ✓

$$= 8{,}49\ A$$ ✓

(3)

4.4.2

$$S = \sqrt{3}V_L I_L$$ ✓

$$= \sqrt{3}(400)(8{,}49)$$ ✓

$$= 5882{,}04\ VA$$ ✓

(3)

4.4.3

$$Q = \sqrt{3}V_L I_L Sin\left(Cos^{-1}\frac{P}{S}\right)$$ ✓✓

$$= \sqrt{3}(400)(8{,}49)Sin\left(Cos^{-1}\frac{5000}{5882{,}04}\right)$$ ✓✓

$$= 3098{,}13\ VA_R$$ ✓

$$= 3{,}10\ kVA_R$$

OR

$$\theta = Cos^{-1}\frac{P}{S}$$

$$= Cos^{-1}\left(\frac{5000}{5882{,}04}\right)$$

$$= 31{,}78\,°$$

$$Q = \sqrt{3}V_L I_L Sin(\theta)$$

$$= \sqrt{3}(400)(8{,}49)Sin(31{,}78)$$

$$= 3097{,}83\ VA_R$$

$$= 3{,}10\ kVA_R$$

OR

$$\theta = Cos^{-1}(pf)$$

$$= Cos^{-1}(0{,}85)$$

$$= 31{,}79°$$

$$Q = \sqrt{3}V_L I_L Sin(\theta)$$

$$= \sqrt{3}(400)(8{,}49)Sin(31{,}79)$$

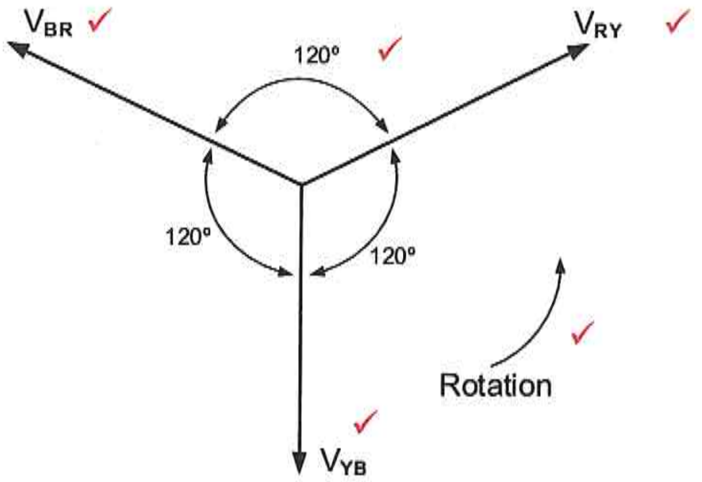
$$= 3098{,}70\ VA_R$$

$$= 3{,}10\ kVA_R$$

(5)

NOTE: This is a higher order calculation; therefore the alternative method would receive 2 marks for calculating θ and 3 marks for calculating the reactive power.

4.4.4



(5)

4.5 4.5.1 Two wattmeter method ✓
Three wattmeter method ✓ (2)

4.5.2 **A** - Line ✓ / L_1
B - Neutral ✓/ Star point (2)

4.5.3 A watt meter measures the power consumed ✓ by an application and a kilowatt-hour meter measures the amount of electrical power consumed ✓ by an application/residence over a certain time period. ✓

NOTE: Kilowatt-hour meter measures electrical energy consumed. (3)

4.6 4.6.1 A reading of 0,9 on a power factor meter indicates that the load is reactive. ✓
The load is inductive.
The load is efficient. (1)

4.6.2 There is a phase angle ✓ of 25,84° between the current and the voltage. (1)
[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 Radiator ✓
Cooling fans ✓
Oil conservator
Water reservoir (tank) (2)

5.2 Copper losses (I^2R losses) ✓ (1)

5.3 Step-up transformer in high voltage supplies. ✓ (1)
NOTE: Step-down transformer is wrong, but will be accepted as this is the answer that is reflected in the prescribed textbook.

5.4 Eddy current losses are reduced by constructing the core out of thin laminations ✓ instead of one solid core. (1)

5.5 Heat is dissipated to reduce the temperature ✓ in the transformer that would cause a continual degradation of its insulation system.✓ (2)

5.6 Oil forced; Water forced (OFWF) ✓ (1)

5.7 A Buchholz relay monitors the gas formation inside the oil of a transformer. ✓ (1)
Sound the alarm when gas is formed inside the oil of a transformer.
Isolate the transformer from the supply when the gas formation exceeds a certain level.
Protect the transformer.

5.8 5.8.1

$$I_{L1} = \frac{S}{\sqrt{3}V_L} \quad ✓$$

$$= \frac{100\ 000}{\sqrt{3}(11\ 000)} \quad ✓$$

$$= 5{,}25\ A \quad ✓$$

(3)

5.8.2

$$\frac{N_1}{N_2} = \frac{V_{PH1}}{V_{PH2}} \quad ✓$$

$$V_{PH2} = \frac{V_{PH1} \times N_2}{N_1}$$

$$= \frac{11\ 000 \times 1}{48} \quad ✓$$

$$= 229{,}17\ V \quad ✓$$

(3)

5.8.3

$$P = S \times Cos\theta \quad ✓$$

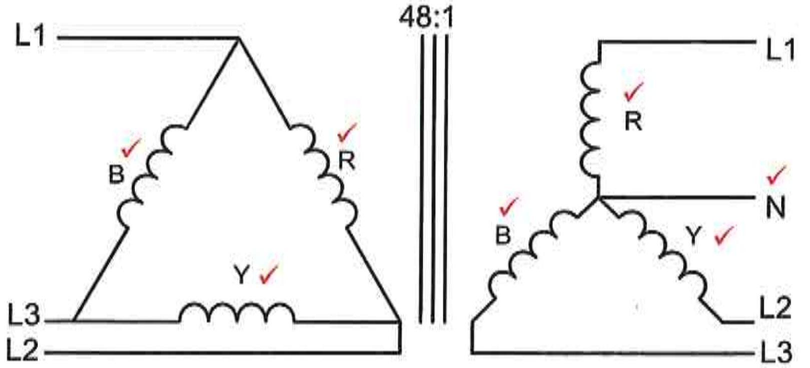
$$= 100\ 000 \times 0{,}9 \quad ✓$$

$$= 90\ 000\ W \quad ✓$$

$$= 90\ kW$$

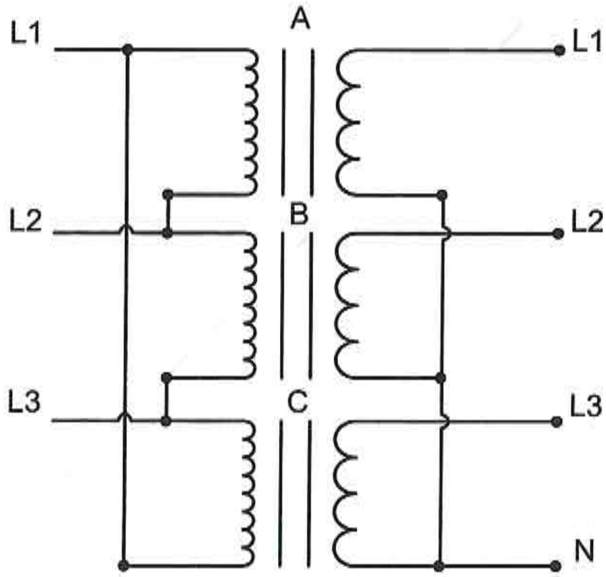
(3)

5.8 5.8.4



NOTE: If the learner omits the labelling of the coils, but the supply lines are correctly labelled, marks will be awarded accordingly.

OR



NOTE: 1 mark for each correctly labelled primary coil.
1 mark for each correctly labelled secondary coil and neutral (7)

5.8.5 Step-down transformer, ✓ because the winding ratio is 48:1.✓ (2)

5.9 The primary power is equal to the secondary power in a transformer, ✓ therefore when the voltage is stepped down, the current will step-up ✓ with the same ratio ✓ to maintain the power in the transformer. (3)

[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 Stator windings ✓
Terminal box ✓
Stator core (2)

6.2 6.2.1 The supply voltage is 400 V. ✓ (1)

6.2.2 85 % ✓ (1)

6.2.3
$$n_s = \frac{60 \times f}{p}$$ ✓
$$= \frac{60 \times 50}{2}$$ ✓
$$= 1500\ r/min$$ ✓ (3)

6.2.4
$$slip = n_s - n_r$$ ✓
$$= 1500 - 1250$$ ✓
$$= 250\ r/min$$ ✓ (3)

6.3
- When a three-phase supply is connected to the motor, current starts flowing in the stator windings creating an electromagnetic field around the stator coils. ✓
- This electromagnetic field cuts the rotor bars inducing an emf inside them which in turn creates their own magnetic field. ✓
- The rotor magnetic field interacts with the stator magnetic field✓ (strengthening it on the one side and weakening it on the other side) causing the rotor to rotate ✓ and in the process transferring electrical power from the supply to mechanical power on the shaft through electromagnetic induction. (4)

6.4 6.4.1 **A** - Breakdown torque ✓/ Maximum torque/Peak torque
B - Rated Speed / Full load torque ✓ (2)

6.4.2 By increasing the load beyond the full load value, the speed of the motor will decrease ✓ causing an increase in torque. ✓ (2)

6.4.3 The motor will stall when the load is increased beyond the breakdown point **A**. ✓ (1)

6.5 6.5.1 Contacts **A** and **B** are interlocking contacts ✓ preventing MC_1 and MC_2 from being energised at the same time. (1)

6.5.2 The function of MC_2N/O is to keep the current flowing to MC_2REV ✓ even after the reverse start button is released.✓ (2)

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6.5.3 If MC_1N/O becomes faulty and permanently closed, MC_1 will be permanently energised ✓ without the need to press Start FWD. MC_1 will de-energize only when the stop button is pressed and held in, ✓ and as soon as the stop button is released, MC_1 will energize again. Because of interlocking contacts **A** and **B**, MC_2 will never be energised. ✓ (3)

6.6 6.6.1

$$I_{PH} = \frac{I_L}{\sqrt{3}} \quad ✓$$
$$= \frac{8{,}59}{\sqrt{3}} \quad ✓$$
$$= 4{,}96\ A \quad ✓$$
(3)

6.6.2

$$Cos\theta = \frac{P}{S} \quad ✓$$
$$= \frac{P}{\sqrt{3}V_L I_L} \quad ✓$$
$$= \frac{5\ 000}{\sqrt{3}(400)(8{,}59)} \quad ✓$$
$$= 0{,}84 \quad ✓$$

OR

$$S = \sqrt{3}V_L I_L$$
$$= \sqrt{3}(400)(8{,}59)$$
$$= 5951{,}32\ VA$$
$$Cos\theta = \frac{P}{S}$$
$$= \frac{5\ 000}{5951{,}32}$$
$$= 0{,}84$$

$$P = \sqrt{3}V_L I_L Cos\theta$$
$$Cos\theta = \frac{P}{\sqrt{3}V_L I_L}$$
$$= \frac{5000}{\sqrt{3}(400)(8{,}59)}$$
$$= 0{,}84$$
(4)

6.6.3

$$P_{OUT} = \sqrt{3}V_L I_L Cos\theta\eta \quad ✓$$
$$= \sqrt{3}(400)(8{,}59)(0{,}84)\left(\frac{90}{100}\right) \quad ✓$$
$$= 4499{,}20\ W$$
$$= 4{,}50\ kW \quad ✓$$
(3)

OR

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100$$
$$90 = \frac{P_{OUT}}{5000} \times 100$$
$$P_{OUT} = 4{,}5\ kW$$

[35]

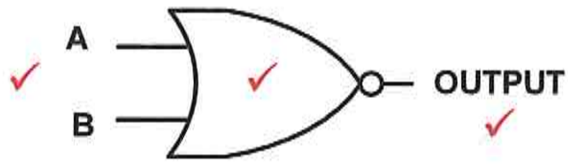
QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

7.1 7.1.1
- PLC systems requires less relays and switching devices. ✓
- When adding another function to the circuit, a PLC program is modified rather than making extra space for relays or timers.✓ (2)

7.1.2 In process control, changes can be made to the software if hardware requirements change ✓ without the need for switchboard and hardware changes/replacements.✓ (2)

7.2 7.2.1 NOR gate ✓ (1)

7.2.2



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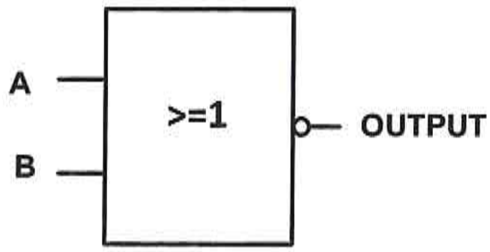


(3)

7.2.3 W = 1 ✓
X = 0 ✓ (2)

7.3 7.3.1 Capacitive proximity sensor✓ (1)

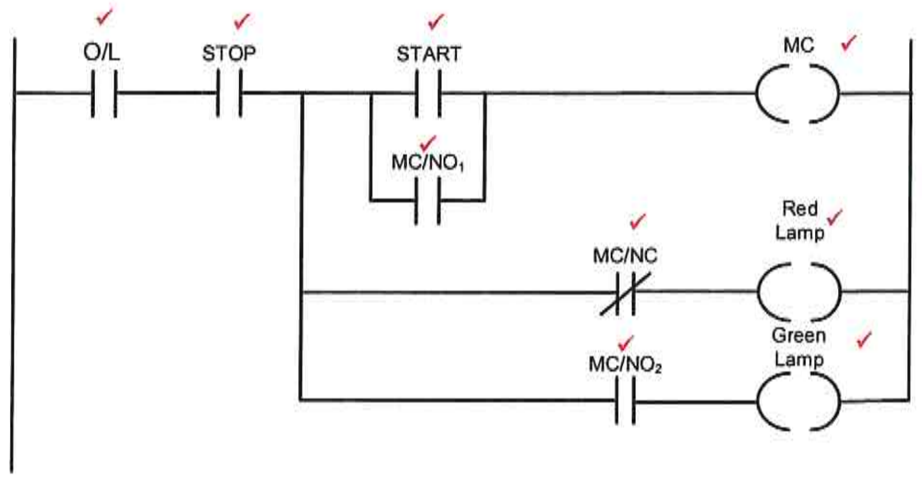
7.3.2 A light sensor can be used as a safety feature ✓ to prevent the door from closing whenever there is an interruption in the beam of light. ✓
A light sensor can be used as a safety feature to enable the garage door to open as soon as the presence of the object is detected. (2)

7.3.3 A temperature sensor is built into the drill bit. ✓ When the temperature reaches a dangerous level ✓ that could lead to the drill bit breaking, the sensor sends a signal to the operator to stop drilling. ✓ (3)

7.4 7.4.1 The function of the timer is to provide a delay ✓ in the logic sequence of a PLC's ladder logic program. ✓ (2)

7.4.2 PLC output ports operate with single phase power and have the ability to drive the coil of a contactor ✓ which uses its auxiliary contacts✓ to control high current three-phase loads. (2)

7.5 7.5.1



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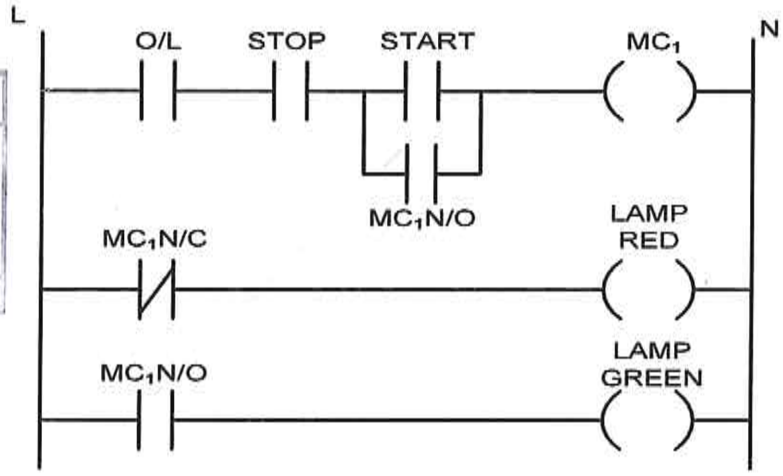

NOTE: It will also be accepted if both the O/L and STOP symbols are closed. NB, both O/L and STOP must be the same state. (9)

7.5.2 The 'Red Lamp' will be OFF ✓
The 'Green Lamp' will be ON ✓ (2)

7.5.3 The function of the MC (contactor coil) is to close ✓ and open ✓ the contacts the moment it is energised. (i.e. MC/NO₁ and MC/NO₂ will close and MC/NC will open) (2)

7.6 7.6.1 Pulse width modulation. ✓ (1)

7.6.2 The installation of the system should be done by a qualified, experienced technician. ✓
Avoid using long cable runaways to reduce losses.✓
An energy efficient motor should be considered.
Harmonics should be kept to a minimum.
Consider the installation safety instructions (2)

7.6.3

- When a three-phase AC is applied to the input unit, the diode bridge rectifying ✓ circuit convert AC to DC.
- DC with ripple voltages are smoothed ✓ by filter capacitors.
- DC voltages are then inverted back by Insulated Gate Bipolar Transistor (IGBT) into AC voltage ✓ and variable frequency through switching circuits that results in variable speed control. ✓

NOTE: The following response will be awarded 2 marks.
When a three-phase or single-phase supply is connected to a VSD, its circuitry will increase or decrease the frequency of the output AC power signal supplied to the motor. (4)

[40]

TOTAL: 200