Province of the
EASTERN CAPE
EDUCATION

NATIONAL
SENIOR CERTIFICATE

GRADE 12

SEPTEMBER 2020

ELECTRICAL TECHNOLOGY: POWER SYSTEMS
MARKING GUIDELINE

MARKS: 200

This marking guideline consists of 12 pages.

INSTRUCTIONS TO 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.

   2.6 Markers should consider that candidates' answers may deviate slightly from the marking a guideline depending on how and where in the calculation rounding off was used.

3. These marking guidelines are only a guide with model answers.

4. 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: OCCUPATIONAL HEALTH AND SAFETY

1.1 Accident means an incident arising out of and in the course of an employee's employment and resulting in a personal injury, illness ✓ or the death of the employee. ✓ (2)

1.2
- Take reasonable care for the health and safety of him/herself and of other persons who may be affected by his or her action. ✓
- Cooperate with the employer or persons to enable any duties given by the requirements and procedures. ✓
- Carry out any lawful order given to him, and obey the health and safety rules and procedures laid down by his employer or by anyone authorised there by his employer, in the interest of health or safety.
- If any situation which is unsafe or unhealthy comes to his/her attention, as soon as practical report this to his/her employer, or a healthy and safety representative who should report it to the employer. (Any 2) (2)

1.3
- Horseplay ✓
- Running in the workshop ✓
- Throwing things
- Leaving bags, stools or material in the walkway
- Spilling a liquid or oil without cleaning.
- Any relevant answer. (Any 2) (2)

1.4 Third degree burn: where all layers of skin have been burned, causing permanent skin damage ✓ affecting fat, muscle and even bone. ✓ (2)

1.5
- To review the effectiveness of health and safety measures. ✓
- To identify hazards and potential major incidents at the workplace. ✓ (2)

[10]

QUESTION 2: RLC CIRCUIT

2.1 2.1.1 The current and the voltage are out of phase with each other ✓ and the current is leading the voltage by 90°. ✓ (2)

2.1.2 The current and the voltage are out of phase with each other ✓ and the current is lagging the voltage by 90°. ✓ (2)

2.1.3 The current and voltage are in phase ✓ and their phase angle is zero. ✓ (2)

2.2 2.2.1 $XL = 2\pi FL$ ✓

$= 2\pi \times 60 \times 44 \times 10^{-3}$ ✓

$= 16,587\ \Omega$ ✓ (3)

2.2.2 $Xc = \frac{1}{2\pi FC}$ ✓

$Xc = \frac{1}{2\pi \times 60 \times 120}$ ✓

$Xc = 22,105\ \Omega$ ✓ (3)

2.2.3 $Z = \sqrt{R^2 + (XL - Xc)^2}$ ✓

$= \sqrt{25^2 + (22,105 - 16,58)^2}$ ✓

$Z = 25,6\ \Omega$ ✓ (3)

2.2.4 $IT = \frac{VT}{ZT}$ ✓

$= \frac{120}{25,6}$ ✓

$= 4,69\ A$ ✓ (3)

2.3 The capacitive reactance will decrease ✓ because the capacitive reactance is inversely proportional ✓ to frequency. ✓ (3)

2.4 2.4.1 $IT = \sqrt{IR^2 + (IL - IC)^2}$ ✓

$= \sqrt{6^2 + (5 - 4)^2}$ ✓

$= 6,08\ A$ ✓ (3)

2.4.2 $COS\theta = \frac{IR}{Iz}$ ✓

$\theta = Cos^{-1} \frac{6}{6,08}$ ✓

$= 9,305°$ ✓ (3)

2.4.3 $XL = \frac{VT}{IL}$ ✓

$XL = \frac{240}{5}$ ✓

$XL = 48\ \Omega$ ✓ (3)

2.4.4 $Xc = \frac{VT}{IC}$ ✓

$XC = \frac{240}{4}$ ✓

$= 60\ \Omega$ ✓ (3)

2.5 2.5.1 $FR = \frac{1}{2\pi\sqrt{LC}}$ ✓

$FR = \frac{1}{2\pi\sqrt{0{,}2\times0{,}05^{-6}}}$ ✓

$FR = 1\ 591{,}5\ Hz$ ✓ (3)

2.5.2 $XL = 2\pi FL$ ✓
$XL = 2\pi \times 1\ 591{,}5 \times 0{,}2$
$XL = 1\ 999{,}938\ \Omega$ ✓

$Q = \frac{XL}{R}$ ✓

$Q = \frac{1999{,}938}{10}$

$Q = 200$ ✓ (4)

2.5.3 $BW = \frac{Fr}{Q}$ ✓

$BW = \frac{1591{,}5}{200}$ ✓

$= 7{,}958$ Hz ✓ (3)

2.6 2.6.1 $Q = \frac{Fr}{BW}$ ✓

$Q = \frac{95\times10^6}{200\times10^3}$ ✓

Q $= 475$ Hz ✓ (3)

2.6.2 $Xc = \frac{1}{2\pi FC}$ ✓

$Xc = \frac{1}{2\pi\times95\times10^6\times2{,}5\times10^6}$

$Xc = 22{,}105\ \Omega$ ✓ (2)

2.6.3 $R = \frac{XL}{Q}$ ✓

$R = \frac{670}{475}$

$= 1{,}4466\ \Omega$ ✓ (2)

[50]

QUESTION 3: THREE-PHASE AC GENERATION

3.1

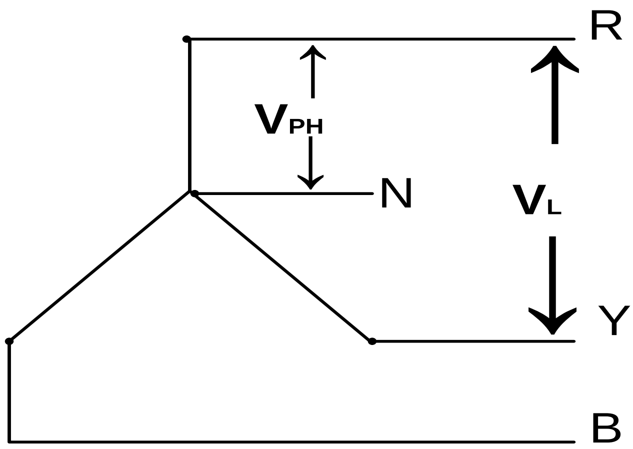


Diagram correctly drawn ✓
V_{PH} ✓
V_L ✓
Phasors labelled correctly ✓ (4)

3.2. 3.2.1 It is a device that measures the amount of electrical energy consumed ✓ over a certain time. ✓ (2)

3.2.2 A device that measures the power consumed by an application. ✓ (1)

3.3
- Cannot be distributed economically over long distances. ✓
- Not suitable for heavy duty applications requiring large amounts of power. ✓
- Uses larger currents and hence thicker cables.
- For an equivalent application it is not as economical as three-phase. (2)

3.4. 3.4.1 The current coils of the two wattmeters are connected in series to the red and blue phases.✓
The voltage coils of the two wattmeters are connected to each ✓ other and to the yellow phase✓ (3)

3.4.2 $P_T = W_1 + W_2$ ✓

$= 5\ 000 + 7\ 500$ ✓

$= 12\ 500\ \text{W} = 12{,}5\ \text{kW}$ ✓ (3)

3.4.3 $\tan\theta = \sqrt{3}\left(\frac{P_1 - P_2}{P_1 + P_2}\right)$ ✓

$= \sqrt{3}\left(\frac{5\ 000 - 7500}{5\ 000 + 7\ 500}\right)$ ✓

$= -0{,}35$ ✓

$\theta = \tan^{-1}(-0{,}35)$

$= -19{,}29°$ ✓

Power factor $= \cos(-19{,}29)$

$= 0{,}94$ ✓ (5)

3.5 3.5.1 $V_{PH} = \frac{V_L}{\sqrt{3}}$ ✓

$= \frac{380}{\sqrt{3}}$ ✓

$= 219{,}39 \text{ V}$ ✓ (3)

3.5.2 $P = \sqrt{3}V_L I_L \cos\theta$

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

$= \frac{25000}{\sqrt{3}\times 380\times 0{,}8}$ ✓

$= 47{,}48\text{A}$ ✓ (3)

3.5.3 $Q = \sqrt{3}V_L I_L \sin\theta$ ✓ $\theta = \cos^{-1} 0{,}8$

$= \sqrt{3} \times 380 \times 47{,}48 \times \sin(\cos^{-1} 0{,}8)$ ✓

$= 18\ 750{,}21 \text{ VA}_r = 18{,}75 \text{ kVA}_r$ ✓ (3)

3.6 Delta is a three-phase, three wire supply and dwellings need a neutral point ✓ to supply a single-phase voltage of 220 V. ✓ (2)

3.7 A low power factor causes lagging currents. ✓ This causes a higher current flow for a given load. ✓ As the line current increases, the voltage drop in the conductor increases, ✓ which may result in a lower voltage at the equipment. ✓ (4)

3.8.1 Electricity is generated in power stations by converting natural gases, coal, fossil fuel, nuclear fuel and water action into electrical energy. ✓
Basic fuels heat steam to drive turbines which drive huge generators. ✓ (2)

3.8.2 The generate electricity is stepped up to a high voltage and then fed to a national grid. ✓
From the national grid it is transmitted with overhead power lines to different power stations. ✓ (2)

3.8.3
- Commercial buildings ✓
- Dwellings
- Industries
- Government buildings
- Any other relevant answer (1)

[40]

QUESTION 4: THREE-PHASE TRANSFORMERS

4.1 Core-type ✓
Shell-type ✓ (2)

4.2 The mineral oil insulates ✓ and cools the windings. ✓ (2)

4.3
- Inverse definite minimum time relay ✓
- Instantaneous overcurrent relay ✓
- Balanced earth fault relay
- Buchholtz relay (Any 2) (2)

4.4
- Oil Natural, Air Natural ✓
- Oil Natural. Air Forced ✓
- Oil forced, Air Forced
- Oil Forced, Water Forced (Any 2) (2)

4.5 Mutual induction ✓ (1)

4.6. 4.6.1

$$S = \sqrt{3}V_{LS}I_{LS}$$

$$I_{LS} = \frac{S}{\sqrt{3}V_{LS}} \quad ✓$$

$$= \frac{20\ 000}{\sqrt{3} \times 500} \quad ✓$$

$$= 23{,}09\ A \quad ✓$$

(3)

4.6.2

$$V_{LP} = V_{PHP} = 6\ 000\ V$$

$$V_{PHS} = \frac{V_{LS}}{\sqrt{3}} \quad ✓$$

$$= \frac{500}{\sqrt{3}} \quad ✓$$

$$= 288{,}68\ V \quad ✓$$

$$T.\,Ratio = \frac{V_{PHP}}{V_{PHS}} \quad ✓$$

$$= \frac{6000}{288{,}68} \quad ✓$$

$$= 20{,}78 : 1 \quad ✓$$

(6)

4.6.3

$$P_{INPUT} = S\cos\theta$$
$$= 20\ 000 \times 0{,}88$$
$$= 17\ 600\ W = 17{,}6\ kW$$

OR

$$P_{INPUT} = \sqrt{3}V_L I_L \cos\theta \quad ✓$$
$$= \sqrt{3} \times 500 \times 23{,}09 \times 0{,}88 \quad ✓$$
$$= 17596{,}94\ W = 17{,}6\ kW \quad ✓$$

(3)

4.6.4

$$\eta = \frac{P_{INPUT} - P_{LOSSES}}{P_{INPUT}} \times 100 \quad ✓$$

$$= \frac{20\ 000 - 160}{20\ 000} \times 100 \quad ✓$$

$$= 99{,}2\% \quad ✓$$

(3)

4.7 Transformers have no moving parts ✓ as a result fewer losses develop, ✓ and it delivers a better power output. ✓ Transformers have a more efficient design. (3)

4.8 A transformer has no moving parts for induction to take place. ✓ Unlike DC-current, the AC-current produces an alternating flux which expands and collapses ✓ to produce the movement of the magnetic field that is required for induction. ✓ (3)

[30]

QUESTION 5: THREE-PHASE MOTORS AND STARTERS

5.1 Slip is the difference between the rotor speed ✓ and the rotating magnetic field of the stator. ✓ (2)

5.2
- To reduce magnetic humming ✓
- To avoid cogging ✓
- Increase in effective ratio of transformation between stator and rotor
- Increase slip for a given torque (Any 2) (2)

5.3. 5.3.1 To ensure that the insulation of the windings is not damaged ✓ and touching the frame of the motor. ✓ (2)

5.3.2 Reading must be at least 1 MΩ ✓ (1)

5.4 To reduce the starting voltage of the motor windings ✓ (1)

5.5. 5.5.1 Three-phase forward reverse starter ✓ (1)

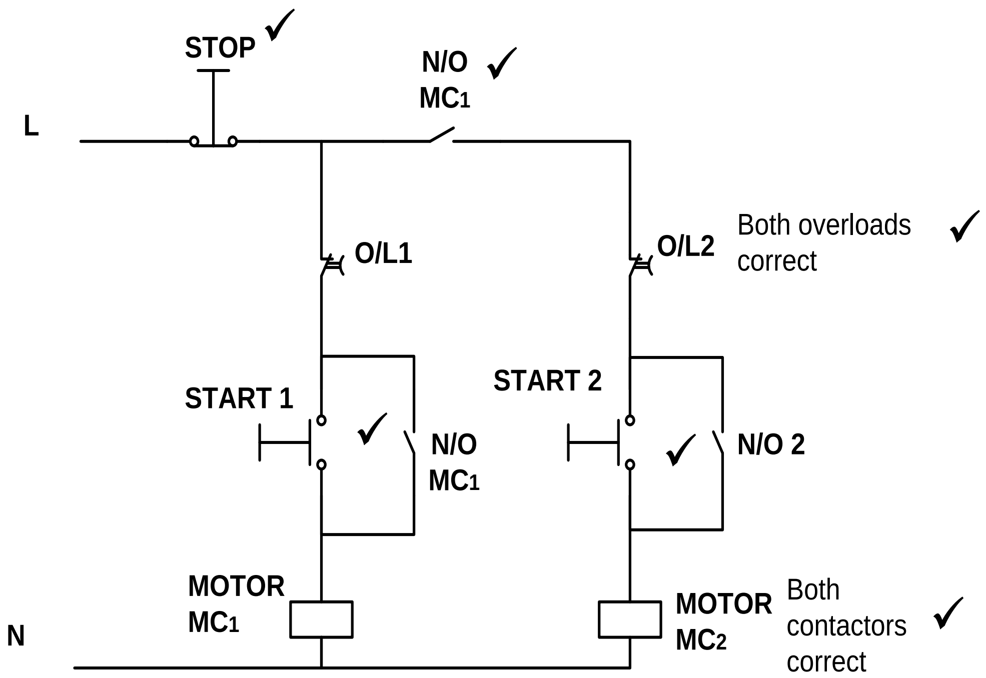
5.5.2 They are electrical interlocking contacts ✓ that prevent both contactors being energised at the same time. ✓ (2)

5.5.3 The forward contactor is energised. ✓ The N/O F contactor closes, keeping the forward contactor energised after the start forward button is released. ✓ At the same time the N/C F opens thus preventing the reverse contactor from being energised ✓ until the stop button is pressed. ✓ (4)

5.5.4 To automatically disconnect the motor from the supply ✓ in the event of excessive currents flowing. ✓ (2)

5.5.5 When the circuit is energised the reverse contactor would be energised ✓ and the motor would run in reverse. ✓ When the stop button is pressed the motor would run in reverse as soon as the stop button is released. ✓ The motor will not be able to run in the forward direction. ✓ (4)

5.6



(6)

5.7 $V_L = V_{PH} = 380\ VN$

$P_{INPUT} = \sqrt{3}V_L I_L \cos\theta$ ✓

$= \sqrt{3} \times 380 \times 25 \times 0{,}866$ ✓

$= 14\ 249{,}58\ W = 14{,}25\ kW$ ✓ (3)

5.8 The velocity of the rotating magnetic field ✓ in the stator windings. ✓ (2)

5.9 $Slip = \frac{n_s - n_r}{n_s} \times 100$ ✓

$= \frac{1\ 200\ - 1\ 140}{1\ 200} \times 100$ ✓

$= 5\%$ ✓ (3)

5.10
- Supply voltage ✓
- Frequency ✓
- Speed ✓
- Rated current
- Output power
- Power factor (Any 2) (3)

5.11 No, ✓ the rated frequency and voltage are not suitable for South Africa which uses 380 V / 50 Hz. ✓ (2)

[40]

QUESTION 6: PROGRAMMABLE LOGIC CONTROLLERS

6.1 6.1.1 D ✓ (1)

6.1.2 C ✓ (1)

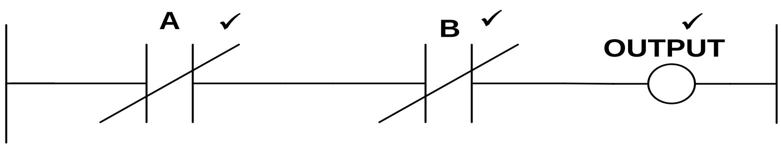
6.1.3 A ✓ (1)

6.1.4 E ✓ (1)

6.1.5 B ✓ (1)

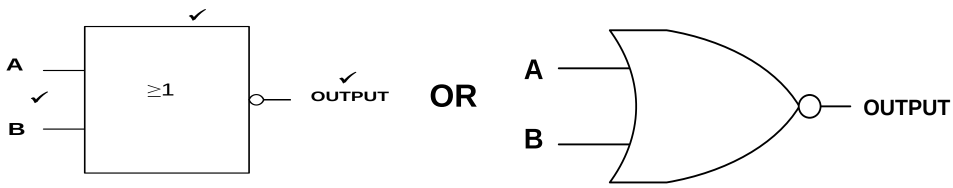
6.2 Software is installed to provide data and instructions to a computer or PLC's control program, ✓ to allow it to interact with its input hardware, ✓ to achieve a desired output. ✓ (3)

6.3 6.3.1



(3)

6.3.2



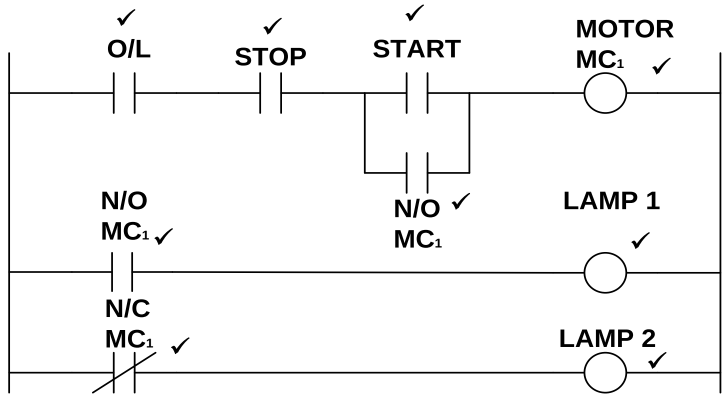
(3)

6.4 It is a semiconductor device that uses light ✓ to transfer an electrical signal between circuits or elements of a circuit ✓ while keeping them electrically isolated from each other. ✓ (3)

6.5
- Safety or security devices (light beams as a switch for garage door) ✓
- Control the brightness of screens of electronic devices (TV's, computers, phones). ✓
- Switches lights on automatically. (Any 2) (2)

6.6 The timer is used to provide an 'ON' or an 'OFF' delay ✓ in the operation of a PLC's logic program. ✓ (2)

6.7



(9)

[30]

TOTAL: 200