basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

NOVEMBER 2021

MARKING GUIDELINES

MARKS: 200

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. These marking guidelines are 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 QUESTION

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

[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1
- To identify and communicate potential hazards ✓
- To identify potential major incidents ✓ at the workplace to the employer.

OR

- To review the effectiveness of health and safety measures.
- To investigate complaints by employees relating to health and safety at work. (2)

2.2
- Your right to earn a living wage. ✓
- Your right to work for reasonable hours. ✓
- Your right to belong to a trade union. (2)

2.3 An unsafe act is an action committed by a person which may lead to an accident or unsafe condition and/or loss. ✓
An unsafe condition is a work related environmental condition which may lead to or contribute to an accident and/or loss. ✓ (2)

2.4
- High impact, low probability. ✓
- High impact, high probability.
- Low impact, low probability.
- Low impact, high probability.
- Qualitative risk analysis.
- Quantitative risk analysis. (1)

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

2.6
- Use an apron ✓ to protect your clothes from staining.
- Use protective glasses to protect your eyes.
- Use latex gloves to prevent skin irritation.
- Use a mask to reduce the risk of breathing fumes. (1)

[10]

QUESTION 3: RLC CIRCUITS

3.1 Capacitive reactance is the opposition of the capacitor ✓ to alternating current ✓ in an AC circuit. (2)

3.2 There is a 90° phase shift between V_L and I_L ✓ where I_L lags V_L by 90°. (1)

3.3 3.3.1

$$L = \frac{X_L}{2 \times \pi \times f}$$ ✓

$$= \frac{150}{2 \times \pi \times 60}$$ ✓

$$= 0{,}40\ H$$

$$= 400\ mH$$ ✓ (3)

3.3.2

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$ ✓

$$= \sqrt{60^2 + (150 - 120)^2}$$ ✓

$$= 67{,}08\ \Omega$$ ✓ (3)

3.3.3

$$Cos\ \theta = \frac{R}{Z}$$ ✓

$$= \frac{60}{67{,}08}$$ ✓

$$= 0{,}89$$ ✓ (3)

3.3.4
- R = Z ✓
- Phase angle = 0° ✓
- $V_L = V_C$ ✓
- $X_L = X_C$
- I is maximum (3)

3.4 3.4.1 800 Hz ✓ (1)

3.4.2 When the frequency increases from 200 Hz to 1600 Hz, the inductive reactance increases ✓ and the capacitive reactance decreases. ✓ (2)

3.4.3

$$V_L = I_T \times X_L$$ ✓

$$= 0{,}66 \times 10^{-6} \times 750$$ ✓

$$= 495\ \mu V$$ ✓ (3)

3.4.4 $X_C = \frac{1}{2\pi fC}$ ✓

$C = \frac{1}{2\pi fX_C}$

$= \frac{1}{2\pi(600)(1333)}$ ✓

$= 198{,}99 \times 10^{-9}$ F

$= 198{,}99$ nF ✓

(3)

3.5 3.5.1 At resonance Z = R = 20 Ω

$I = \frac{V_T}{Z}$ ✓

$= \frac{220}{20}$ ✓

$= 11$ A ✓

(3)

3.5.2 $V_L = I \times X_L$ ✓

$= 11 \times 50$ ✓

$= 550$ V ✓

(3)

3.5.3 $Q = \frac{X_L}{R}$ ✓

$= \frac{50}{20}$ ✓

$= 2{,}5$ ✓

(3)

NOTE: X_C over R is also accepted

$Q = \frac{V_L}{V_T}$

$= \frac{550}{220}$

$= 2{,}5$

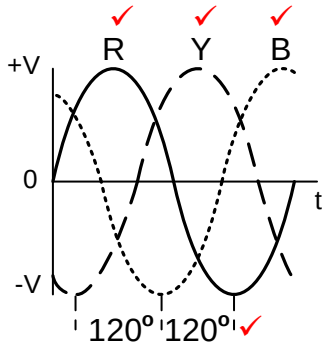
3.5.4 The phase angle would be zero because X_L is equal to X_C ✓ and thus $V_L = V_C$ and out of phase with each other ✓ this would cancel each other, resulting in a power factor of 1.
R=Z
The circuit is at resonance

(2)
[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 4.1.1 A - Generation ✓
B - Transmission ✓
C - Distribution ✓ (3)

4.1.2



NOTE: The sequence of R,Y,B (V_{L1}, V_{L2}, V_{L3}) must be correct to be awarded full marks
The sequence given in the textbook as B,R,Y will be accepted as correct (4)

4.1.3 The voltage from the Generation process must be stepped up to reduce the current in the transmission lines ✓ and therefore reducing the copper losses (I^2R losses) ✓ in the transmission lines. (2)

4.1.4 Star, ✓ because the end user needs to power both three-phase and single-phase equipment which is only possible with a star connection. ✓ (2)

4.2 4.2.1

$$I_{ph} = \frac{I_L}{\sqrt{3}} \quad ✓$$

$$= \frac{15}{\sqrt{3}} \quad ✓$$

$$= 8{,}66\,A \quad ✓$$

(3)

4.2.2

$$S = \sqrt{3} \times V_L \times I_L \quad ✓$$

$$= \sqrt{3} \times 380 \times 15 \quad ✓$$

$$= 9872{,}69\,VA \quad ✓$$

$$= 9{,}87\,kVA$$

(3)

4.2.3

$$\cos\theta = 0{,}9 \quad ✓$$

$$\theta = \cos^{-1}(0{,}9) \quad ✓$$

$$= 25{,}84^{O} \quad ✓$$

(3)

4.2.4 $Q = \sqrt{3} \times V_L \times I_L \times \sin\theta$ ✓
$= \sqrt{3} \times 380 \times 15 \times \sin(25,84)$ ✓
$= 4303,11 VA_R$ ✓
$= 4,3\ kVA_R$ (3)

4.3 Less current drawn from the supply. ✓
Reduced monthly electricity bill. ✓
Reduced heat generated by equipment that will then last longer.
Less maintenance of equipment. (2)

4.4 4.4.1 The meter shows a lagging power factor. ✓ (1)

4.4.2 The connected load is predominantly inductive. ✓ (1)

4.4.3 By connecting capacitors in parallel with the load. ✓
By using synchronous motors.
By using phase advancers. (1)

4.5 4.5.1 $P_T = P_1 + P_2$ ✓
$= 250 + 460$ ✓
$= 710 W$ ✓ (3)

4.5.2 The phase angle. ✓
Power factor. ✓ (2)

4.5.3 The meters can easily be connected to the lines. ✓
The same connection is used for star or delta connected loads. ✓
It is a more economical method of load measurement. (2)
[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 5.1.1 A - Oil conservator (Oil tank) ✓
B - Bushings (Isolators) ✓ (2)

5.1.2 Oil Natural Air Forced ✓
Oil Forced Air Forced ✓
Oil Natural Air Natural (when the fan is off)
Oil Forced Water Forced (2)

5.1.3 Inverse definite time relay ✓
Instantaneous overcurrent relay ✓
Balanced earth fault relay ✓
Buchholz relay
Restricted earth fault relay
Standby earth fault relay
Directional overcurrent relay (3)

5.1.4
- In a step down transformer the secondary has less windings than the primary. The primary winding is connected to an alternating voltage. ✓
- This sets up an alternating emf in the primary windings and alternating current flows. ✓
- This alternating current creates an alternating magnetic field which links with the secondary winding through the magnetic core. (Faraday's law) ✓
- The alternating magnetic field cuts the secondary winding creating a smaller alternating emf in it. ✓
- Due to the reduced windings, the secondary voltage will be lower than the primary voltage in accordance with the turns ratio and voltage per winding in the primary and secondary windings of the transformer. ✓ (5)

5.2 The windings are enclosed. ✓
The axis of the shell type can be horizontal or vertical. ✓
The core hides the major part of the windings.
The core has five limbs.
The coils are wound around the central section of the core. (2)

5.3 5.3.1 Delta star ✓ step-down transformer (1)

5.3.2
$$V_{PH2} = \frac{V_{L2}}{\sqrt{3}} \quad ✓$$
$$= \frac{7700}{\sqrt{3}} \quad ✓$$
$$= 4445{,}60 \text{ V} \quad ✓$$
$$= 4{,}45 \text{ kV}$$
(3)

5.3.3 $TR = \frac{V_{PH1}}{V_{PH2}}$ ✓

$= \frac{22000}{4445,60}$ ✓

$= 4,95:1$

$= 5:1$ ✓ (3)

5.3.4 $S = \sqrt{3} \times V_{L2} \times I_{L2}$ ✓

$= \sqrt{3} \times 7700 \times 40$ ✓

$= 533471,65VA$

$= 533,47\ kVA$ ✓ (3)

5.3.5 $\eta = \frac{P_{OUT}}{P_{OUT} + copper\ losses + core\ losses} \times 100$ ✓

$= \frac{450000}{450000 + 1000 + 500} \times 100$ ✓

$= 99,67\ \%$ ✓ (3)

5.3.6 $Cos\theta = \frac{P}{S}$ ✓

$= \frac{450000}{533471,65}$ ✓

$= 0,84$ ✓ (3)

[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 6.1.1 A – Terminal Box (Wiring Cover) ✓
B – Motor frame (Enclosure/Housing/Stator) ✓
C – Rotor ✓ (3)

6.1.2
- Each of the stator windings is connected to a line of the three phase supply in the terminal box. ✓
- Each coil creates a magnetic field at alternate intervals (120°). ✓
- The coils are spaced around the stator in such a way that it creates the impression of a rotating magnetic field to the rotor. ✓

OR

- When a three-phase supply is connected to a three-phase motor stator a rotary magnetic field is established.
- This is achieved by the three phases reaching maximum strength 120° out of phase with each other. (3)

6.1.3 Cranes. ✓
Conveyor belt systems. ✓
Lathes.
Drill presses.
Bench grinders. (2)

6.1.4 Number of pole pairs. ✓
Frequency of the supply. ✓ (2)

6.2 6.2.1 This motor is connected in delta. ✓ (1)

6.2.2 Swop any TWO of the supply lines. ✓ (1)

6.2.3 Disconnect the supply lines from the motor. ✓
Remove the internal connecting plates. ✓ (2)

6.3 6.3.1
$$n_s = \frac{f \times 60}{p} \quad ✓$$
$$= \frac{50 \times 60}{4} \quad ✓$$
$$= 750 \text{ rpm} \quad ✓$$
(3)

6.3.2
$$\text{Slip} = \frac{(n_s - n_r)}{n_s} \times 100 \quad ✓$$
$$= \frac{(750 - 700)}{750} \times 100 \quad ✓$$
$$= 6{,}67\ \% \quad ✓$$
(3)

6.3.3 $P = \sqrt{3} \times V_L \times I_L \times \cos\theta \times \eta$ ✓

$= \sqrt{3} \times 380 \times 6 \times 0,85 \times \frac{90}{100}$ ✓

$= 3021,04\ W$ ✓

$= 3,02\ kW$

(3)

6.4 6.4.1 MC_1N/O_1 ✓ (1)

6.4.2 MC_1N/O_2 is a hold-out contact ensuring that MC_2 ✓ can only be energised if MC_1 is energised. ✓ (2)

6.4.3 If either motor 1 or motor 2 is overloaded ✓ the whole circuit will be isolated. ✓

OR

If any one of the two overload relays are activated by either O/L_1 or O/L_2 it will cut the power to the whole circuit. (2)

6.4.4
- When START 1 is pressed MC_1 will energise. ✓
- This will immediately close contacts MC_1N/O_1 (hold-in) and MC_1N/O_2 (hold-out) and START 1 button can be released. ✓
- Only after MC_1N/O_2 is closed you can press START 2. ✓
- When START 2 is pressed, MC_2 will energise closing contact MC_2N/O_1 so that the start button can be released. ✓
- When the STOP button is pressed, MC_1 will de-energise opening contact MC_1N/O_2 and de-energising MC_2. ✓ (5)

6.4.5 If contact MC_2N/O_1 is faulty and permanently closed, contactor MC_2 will immediately energise ✓ when MC_1 is energised, without pressing START button 2. ✓ (2)

[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLCs)

7.1 7.1.1 Input module ✓
Output module ✓
Power supply (2)

1 7.1.2
- The CPU controls the PLC. ✓
- Performs all calculations. ✓
- It runs the PLC program. ✓
- It processes all the input and output signals. (3)

7.1.3 Transistor ✓
Relay (1)

7.2 'Scan time' is the time ✓ the PLC takes to complete one scan cycle. ✓ (2)

7.3 Software is the machine language ✓ installed on a computer or written into a PLC's control program ✓ that instructs it to interact with its input and output hardware. ✓ (3)

7.4 7.4.1 A sensor is a device that detects a physical condition ✓ and changes its electrical characteristics, such as resistance. ✓ (2)

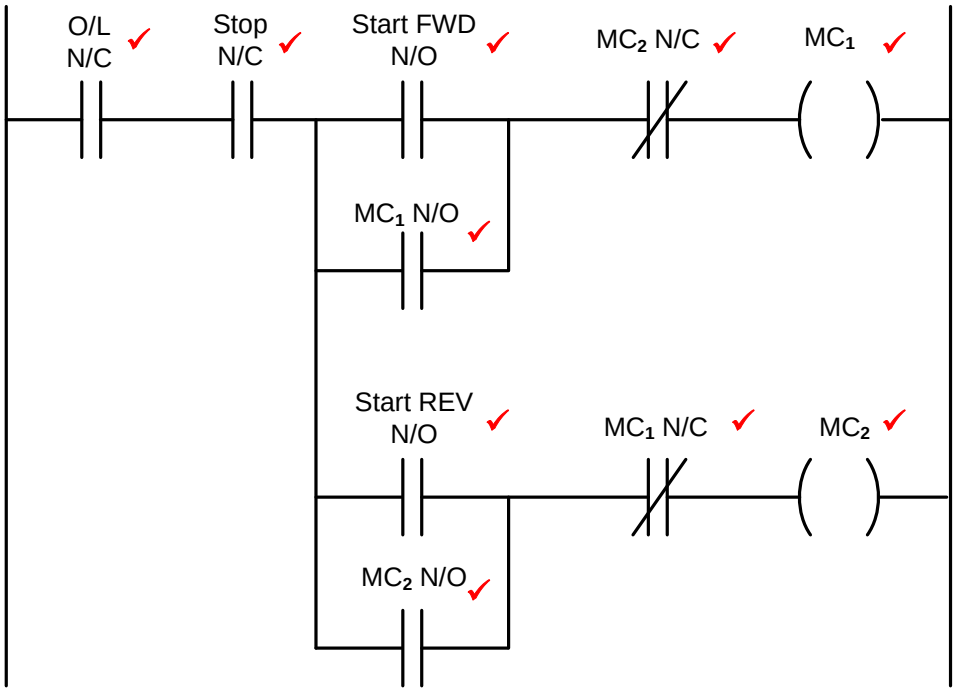
7.4.2 Light sensor. ✓
Level sensor. ✓
Proximity sensor.✓
Temperature sensor. (3)

7.4.3 The overload sensor will continuously ✓ (analogous) change its characteristic resistance ✓ as the load on it is altered or changed. ✓
(Not in a stepped digital format)

OR

When connected to the analogue input on a PLC, parameters can be determined within which the PLC will execute. (3)

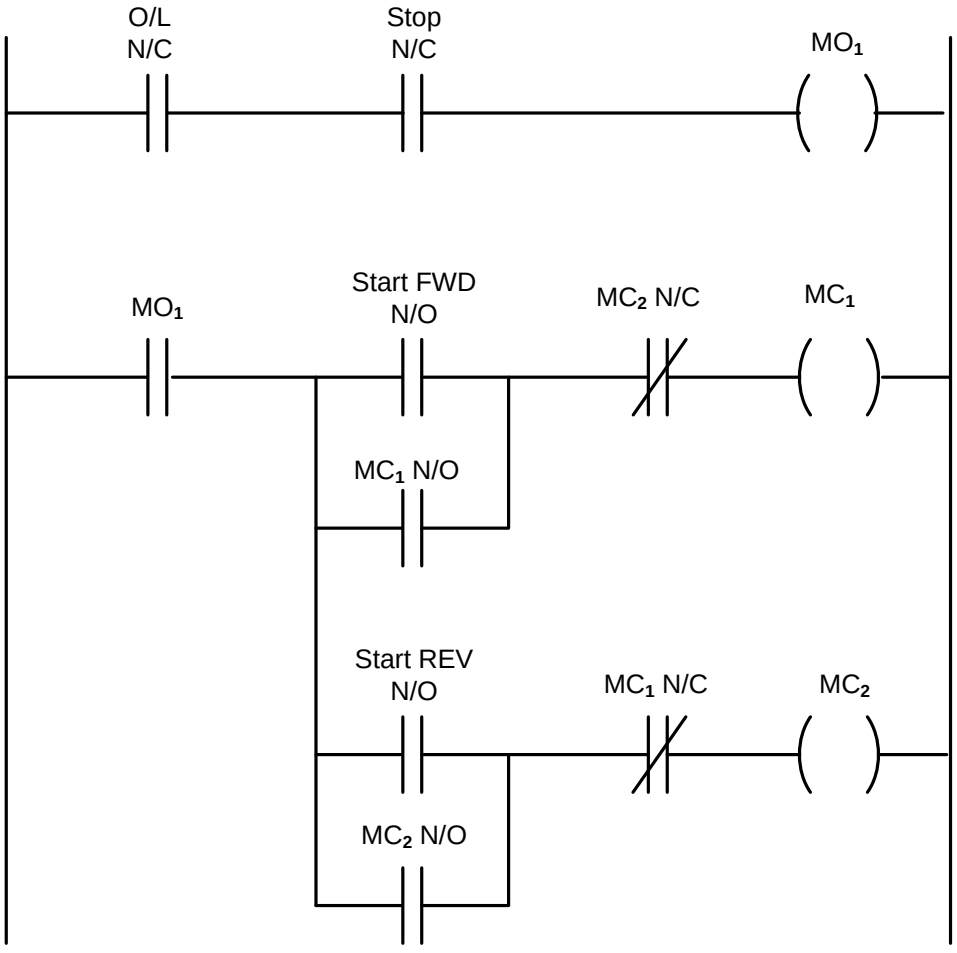
7.5



NOTE: O/L and Stop must both be in the same condition (either open or closed)

(10)

OR



7.6 7.6.1 DC-to-AC Inverter. ✓ (1)

7.6.2 Insulated Gate Bipolar Transistor (IGBT) ✓
Metal Oxide Semi-Conductor Field Effect Transistor (MOSFET) (1)

7.6.3 Improves energy usage. ✓
Reduces motor wear. ✓
Achieves variable motor speed control. (2)

7.6.4 Vector drives use a mathematical model of the drive-in software. By measuring the current vectors ✓ in relation to the applied voltage.✓ They are able to maintain a constant field at all frequencies ✓ below the line frequency. (3)

7.7 When the momentum of a load drives the motor, the motor changes into a generator ✓ converting the mechanical energy into electrical energy ✓ and in the process slowing the acceleration of the load. ✓ (3)

7.8 Braking Resistor. ✓ (1)
[40]

TOTAL: 200