



basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

**NATIONAL
SENIOR CERTIFICATE**

GRADE 12

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

EXEMPLAR 2018

MARKING GUIDELINES

MARKS: 200

These marking guidelines consist of 11 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.
 - 2.6 Markers should consider that candidates' answers may deviate slightly from the marking guidelines, depending on how and where in the calculation rounding off was used.
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: OCCUPATIONAL HEALTH AND SAFETY (GENERIC)

- 1.1 Workplace is any premises or place where a person performs work ✓ in the course of his employment. ✓ (2)
- 1.2 To cooperate with employer or persons to ensure that any duty given by the employer to the employee shall be performed or compiled in accordance with requirements and procedures. ✓
To take reasonable care of health and safety for himself and other persons who may be affected by his act. ✓ (2)
- 1.3 Dangerous fumes can accumulate ✓ in the workshop that can be inhaled by people making it an unsafe condition. ✓ (2)
- 1.4 To review the effectiveness of health and safety measures. ✓
To identify hazards and potential major incidents at the workplace. ✓ (2)
- 1.5 Quantitative risk analysis is an attempt to numerically ✓ determine the probabilities of various adverse events and the likely extent of the losses if a particular event takes place. ✓ (2)
- [10]**

QUESTION 2: RLC CIRCUITS (GENERIC)

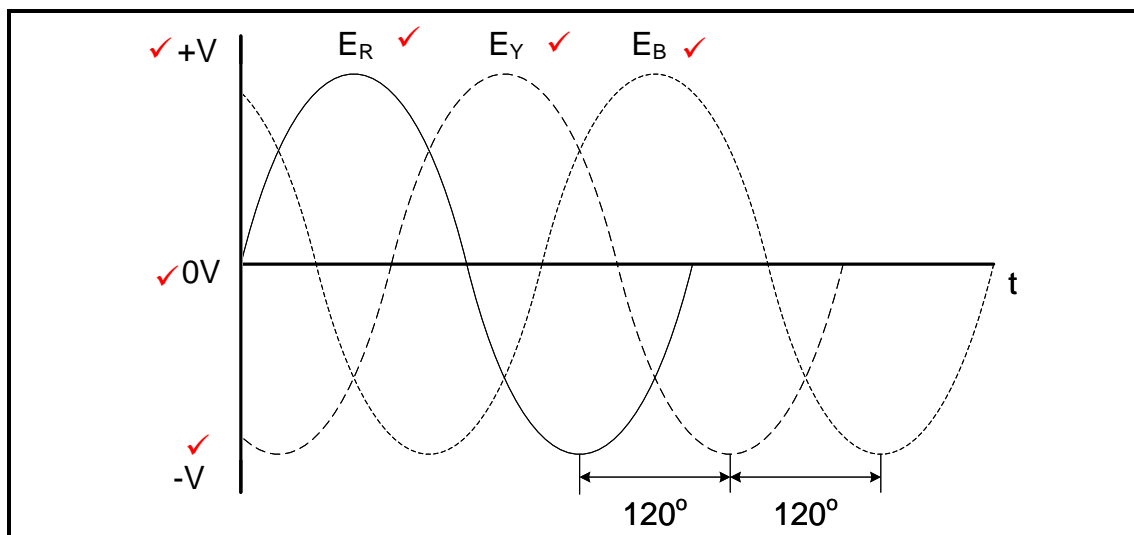
- 2.1 2.1.1 The current and voltage are in phase ✓ and their phase angle is zero ✓ (2)
- 2.1.2 The current and the voltage are out of phase with each other ✓ and the current is leading the voltage by 90° ✓ (2)
- 2.1.3 The current and the voltage are out of phase with each other ✓ and the current is lagging the voltage by 90° ✓ (2)
- 2.2 2.2.1 $X_L = 2 \pi f L$ ✓
 $= 2 \times \pi \times 60 \times 30 \times 10^{-3}$ ✓
 $= 11,31 \Omega$ ✓ (3)
- 2.2.2 $X_C = \frac{1}{2 \pi f C}$ ✓
 $= \frac{1}{2 \times \pi \times 60 \times 150 \times 10^{-6}}$ ✓
 $= 17,68 \Omega$ ✓ (3)
- 2.2.3 $Z = \sqrt{R^2 + (X_C - X_L)^2}$ ✓
 $= \sqrt{12^2 + (17,68 - 11,31)^2}$ ✓
 $= 13,59 \Omega$ ✓ (3)

- 2.2.4 $I_T = \frac{V_S}{Z}$ ✓
 $= \frac{120}{13,59}$ ✓
 $= 8,83 \text{ A}$ ✓ (3)
- 2.2.5 Power factor
 $\text{Cos } \theta = \frac{R}{Z}$ ✓
 $= \frac{12}{13,59}$ ✓
 $= 0,88$ ✓ (3)
- 2.2.6 The phase angle is leading. ✓ (1)
- 2.3 2.3.1 (a) When the frequency of the supply increases, the inductive reactance (X_L) will increase ✓ because the supply frequency is directly proportional ✓ to the inductive reactance. (2)
- (b) When the frequency of the supply increases, the inductive reactance will decrease ✓ because the supply frequency is indirectly proportional ✓ to the capacitive reactance. (2)
- 2.3.2 The resistance of a resistor is not affected by the increase ✓ or decrease of the frequency of the supply voltage. ✓ (2)
- 2.3.3 Z or Impedance ✓ (1)
- 2.4 2.4.1 $F_r = \frac{1}{2\pi\sqrt{LC}}$ ✓
 $= \frac{1}{2\pi\sqrt{30 \times 10^{-3} \times 120 \times 10^{-6}}}$ ✓
 $= 83,88 \text{ Hz}$ ✓ (3)
- 2.4.2 Q – factor = $\frac{X_L}{R}$ ✓
 $X_L = 2 \times \pi \times f \times L$ ✓
 $= 2 \times \pi \times 83,88 \times 30 \times 10^{-3}$ ✓
 $= 15,81 \Omega$ ✓
 $\therefore \text{Q - factor} = \frac{15,81}{10}$ ✓
 $= 1,58$ ✓ (5)
- 2.4.3 $\text{BW} = \frac{F_r}{Q}$ ✓
 $= \frac{83,88 \text{ Hz}}{1,58}$ ✓
 $= 53,09 \text{ Hz}$ ✓ (3)

QUESTION 3: THREE-PHASE AC GENERATION (SPECIFIC)

- 3.1 Three-phase generator of similar frame size has three times the power of a single-phase generator. ✓
 Three-phase power is cheaper to generate than single-phase power. ✓
 Three-phase generator can supply power to three-phase and single-phase load. ✓
 The coil of a three-phase generator can be connected in star to create a neutral point. (3)

3.2



- 3.3 3.3.1 Efficiency is the ratio ✓ of the output power to the input power. ✓ (2)
 3.3.2 Power factor is the ratio ✓ of the real power to the apparent power in the circuit. ✓ (2)
- 3.4 3.4.1 Copper losses ✓ ($I^2 R$) (1)
 3.4.2 By increasing the transmission voltage ✓ thereby decreasing the current ✓ and the power losses will be reduced (2)
- 3.5 3.5.1 Input Power

$$P_{in} = \frac{P_{out}}{\eta}$$
 ✓

$$= \frac{12750 \times 100}{85}$$
 ✓

$$= 15000$$
 ✓

$$= 15 \text{ kW}$$
 (3)
- 3.5.2 Line current

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

$$I_L = \frac{15000}{\sqrt{3} \times 380 \times 0,77}$$
 ✓

$$= 29,60 \text{ A}$$
 ✓ (3)

3.5.3 Phase current

$$I_P = \frac{I_L}{\sqrt{3}} \quad \checkmark$$
$$= \frac{29,60}{\sqrt{3}} \quad \checkmark$$
$$= 17,09 \text{ A} \quad \checkmark$$

(3)

3.6 The function of the kWh meter is to measure the amount of electrical energy consumed \checkmark over a certain period. \checkmark

(2)

3.7 $P_T = P_1 + P_2 \quad \checkmark$
 $= 8 + 4 \quad \checkmark$
 $= 12 \text{ kW} \quad \checkmark$

(3)

[30]

QUESTION 4: THREE-PHASE TRANSFORMERS (SPECIFIC)

4.1 Core – type transformer \checkmark
Shell – type transformer \checkmark

(2)

4.2 Constant overloading \checkmark
Insufficient ventilation \checkmark
Transformer oil may be impure due to carbonisation. \checkmark
Transformer oil may be insufficient. \checkmark

(3)

4.3 4.3.1 Hysteresis loss is due to the reversal of magnetisation \checkmark of transformer core whenever it is subjected to the alternating nature of magnetising force \checkmark . Whenever the core is subjected to an alternating magnetic field, the domain present in the material will change their orientation after every half-cycle. The power consumed by the magnetic domains for changing the orientation after every half cycle is called **hysteresis loss**. \checkmark

(3)

4.3.2 When AC voltage is supplied to the primary windings, alternating magnetic flux are created. When this flux links with secondary winding, it induced emf. But some part of this flux linked with the iron core of the transformer result in induced EMF. \checkmark The induced EMF causes small circulating current. \checkmark This current is called eddy current, which is responsible for the dissipation of energy in the form of heat. \checkmark

(3)

4.4 When an alternating voltage is applied across the primary windings, an alternating current will flow, \checkmark creating magnetic field in the magnetic core of the transformer. \checkmark This magnetic field will link with the secondary windings through the magnetic core inducing EMF of the same frequency. \checkmark The induced EMF is responsible for inducing secondary phase current. \checkmark

(4)

- 4.5 4.5.1 Primary phase voltage
 $V_{PH} = V_L$ ✓
 $= 2,2 \text{ kV}$ ✓ (2)
- 4.5.2 Secondary line voltage
 $\frac{V_{ph(s)}}{V_{ph(p)}} = \frac{N_s}{N_p}$ ✓
 $V_{ph(s)} = \frac{1}{5} \times 2200$ ✓
 $= 440 \text{ V}$ ✓
 $V_L = \sqrt{3} V_{PH}$ ✓
 $= \sqrt{3} \times 440$ ✓
 $= 762,08 \text{ V}$ ✓ (6)
- 4.5.3 Active power
 $P = S \times \text{Cos}\theta$ ✓
 $= 12000 \times 0,9$ ✓
 $= 10,800 \text{ W}$ ✓ (3)
- 4.6 4.6.1 Industrial installations ✓
Low-voltage domestic installations ✓ (2)
- 4.6.2 Step-down transformer ✓ because $N_s < N_p$ ✓ or $V_s < V_p$ (2)

[30]

QUESTION 5: THREE-PHASE MOTORS AND STARTERS (SPECIFIC)

- 5.1 Slip is defined as the difference ✓ between the synchronous speed and the rotor speed ✓ and is measured in RPM. (2)
- 5.2 Check the shaft for movement. ✓
Check bearings for smooth rotation. ✓
Check the housing for cracks. (2)
- 5.3 It reduces the magnetic noise, thus keeping the motor quiet during operation. ✓
It avoids cogging. ✓
Increases in effective ratio of transformers between stator and rotor. ✓
Increased slip for a given torque.
Increased rotor resistance, to improve the starting torque.
Increases magnetic coupling between stator and rotor fluxes. (2)

- 5.4 When a three-phase supply is connected to the terminal box of a motor, an alternating current will flow in the stator windings, creating rotating stator fields. ✓ These rotating stator fields will cut the metal rod of the squirrel induction motor inducing an EMF in it. ✓ The induced EMF will cause current to flow in the rotor windings, creating the rotor magnetic fields. The rotating stator magnetic fields and rotor magnetic fields relatively react to each other ✓ and a force called torque is developed, which turns the rotor to rotate. (3)
- 5.5 Squirrel-cage induction motors are used in:
Equipment operating at a constant speed
Water pumps ✓
Lathe machines ✓
Drill presses
Bench grinders (2)
- 5.6 5.6.1 (a) Locked-rotor torque ✓ (1)
(b) Breakdown torque ✓ (1)
- 5.6.2 When the slip of the motor is at 100%, no torque will be developed ✓ and the rotor will not turn. ✓ (2)
- 5.7. 5.7.1 Automatic star-delta starter ✓ (1)
- 5.7.2 When the current exceeds the rated value, ✓ the circuit will not be disconnected from the supply ✓ and that would result in the motor being damaged. ✓ (3)
- 5.7.3 (a) The function of the stop button is to disconnect the supply from the circuit ✓ the moment it is pressed. ✓ (2)
(b) The function of MC1 (N/O₁) is to allow current to flow in the circuit ✓ even after the start button is released. ✓ (2)
- 5.7.4 The N/C contact of MC3 is connected in series with the star contact to allow the motor to run in star ✓ when the delta coil is de-energised and to prevent the star coil to be energised when the delta coil is energised. ✓ (2)
- 5.8 5.8.1 The line current drawn from the supply

$$I_L = \frac{P_{IN}}{\sqrt{3} \times V_L \times \text{Cos}\theta} \quad \checkmark$$

$$= \frac{15000}{1.732 \times 380 \times 0,8} \quad \checkmark$$

$$= 28,49 \text{ A} \quad \checkmark$$
 (3)

5.8.2 The apparent power of the motor

$$S = \frac{P}{\cos \theta}$$
$$= \frac{15000}{0,8}$$
$$= 18,750 \text{ kVA}$$

(3)
[40]

QUESTION 6: PROGRAMMABLE LOGIC CONTROLLERS (PLC) (SPECIFIC)

6.1 Ensure that:

The PLC has an earth point. ✓ A separate switch is available to control the power should the need arise. ✓

An anti-surge protection is fitted to protect the PLC from lightning. ✓

Low voltage signal wire and communication cable are not placed next to AC cables to avoid potential difference.

Screws in the connector are not over-tightened to avoid damaging the connector.

Double-check all connections before powering on, as an incorrect wiring could lead to damage to the PLC and physical injury to people. (3)

6.2 TWO types of hardware components of the PLC other than the Central Processing Unit (CPU) are:

PLC input terminals ✓

PLC output terminals ✓ (2)

6.3 Cost ✓

Space ✓

Flexibility ✓

Simplicity (3)

6.4 The interface is connected to the inputs of the CPU to protect the CPU from high input voltages ✓ by converting them to the level compatible with the CPU. ✓ (2)

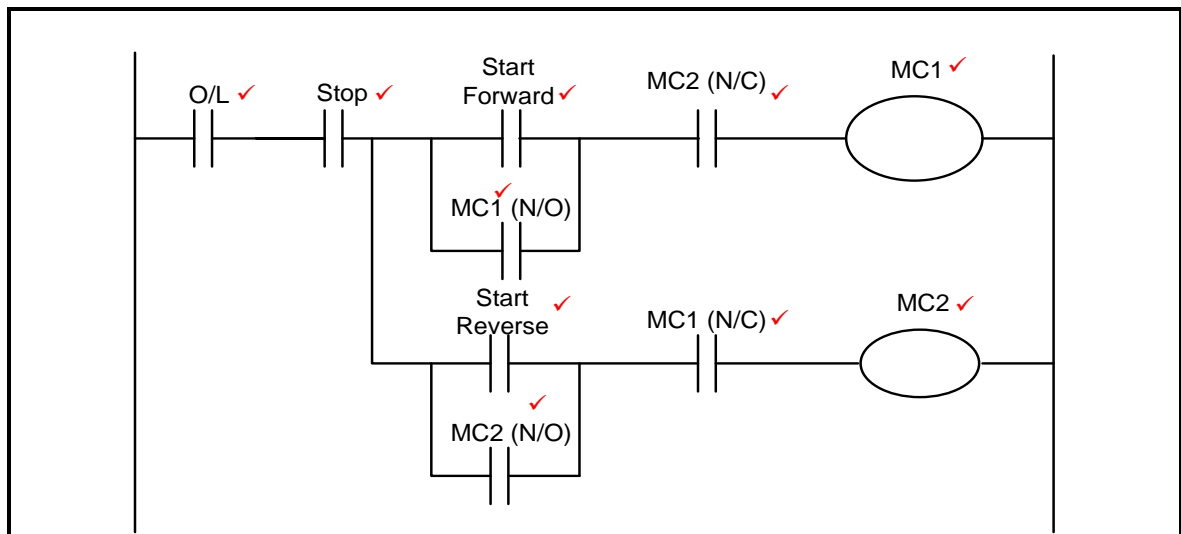
6.5 6.5.1 The input scan sequentially scan all its input terminals ✓ to see if either their input conditions are ON/OFF ✓ and read each condition into the input memory ✓ (3)

6.5.2 After the PLC reads the ON/OFF conditions of every input in the input memory, it will start to execute ✓ every instruction in the program in a sequentially order. ✓ The execution result ON/OFF of every output coil will be stored in order into the memory. ✓ (3)

6.5.3 Output scan activates each output according to the conditions of the output stored in its memory ✓ to turn the appropriate load devices as per the conditions of the output. ✓ (2)

- 6.6 6.6.1 Analogue inputs are variables with multiple states ✓ that can vary between 0 to 1 within a certain bandwidth or range, ✓ while (4)
- Digital inputs are variables with only two states ✓ that are either 1 or 0 of a binary number, ON or OFF of a switch. ✓
- 6.6.2 TWO examples of a digital inputs are:
 Push button ✓ and
 Limit switch ✓ (2)
- 6.6.3 Applications of the inductive proximity sensor is to:
 Detect the presence of a metal object and state whether they are ferrous or non-ferrous ✓
 Detect the absence of a part in an object ✓
 Count and position an object ✓ (3)
- 6.7 A marker or a flag function is used in the PLC to connect the end of a rung ✓ to the beginning of the next rung ✓ of a PLC program.
OR
 A marker or a flag function is used in the PLC to transfer digital information to another part of the program. (2)

6.8



(10)

FIGURE 6.8: LADDER LOGIC DIAGRAM

- 6.9 VSD is applied in:
Water pumping system ✓
Exhaust air system ✓
Extracting dust ✓
Heating system for air and liquid
Variable air volume air conditioning system (3)
- 6.10 THREE methods in which the speed of the motor can be controlled with the exception of Pulse Width Modulation are:
V/Hz drive control ✓
Vector drive control ✓
Direct torque control ✓ (3)
- 6.11 The Pulse Width Modulation consists of three pairs of switches. ✓ For every pair of switch, one pair controls the positive part of the output voltage ✓ while the other switch controls the negative part of the output voltage. ✓ The two switches conduct first in one direction and after a predetermined time, they conducts in the opposite direction resulting in a train of positive and negative pulses. ✓ (4)
- 6.12 6.12.1 Diode bridge rectifier convert AC supply ✓ voltage to a DC voltage ✓ (2)
- 6.12.2 Filtering circuit smooth the AC ripple ✓ to ensure pure DC ✓ voltage on the rail ✓ (3)
- 6.12.3 The DC voltage is then inverted back into an AC voltage ✓ but at a different frequency ✓ by switching the insulated gate bipolar transistor ON and OFF ✓ (3)
- 6.13 Regenerative braking is a form of braking in motor driven loads ✓ in which the loss of kinetic energy from braking is stored ✓ and then fed back later to provide power ✓ to the motor. (3)

[60]**TOTAL: 200**