Province of the
EASTERN CAPE
EDUCATION

NATIONAL SENIOR CERTIFICATE

GRADE 12

SEPTEMBER 2022

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

MARKS: 200

TIME: 3 hours

This question paper consists of 16 pages, including a 2-page formula sheet.

INSTRUCTIONS AND INFORMATION

1. This question paper consists of SEVEN questions.

2. Sketches and diagrams must be large, neat and FULLY LABELLED.

3. Show ALL calculations and round off answer correctly to TWO decimal places.

4. Number the answers correctly according to the numbering system used in this question paper.

5. You may use a non-programmable calculator.

6. Show the units for ALL answers of calculations.

7. A formula sheet is provided at the end of this question paper.

8. Show the units for ALL answers of calculations.

9. Write neatly and legible.

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Various options are given as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question numbers (1.1 to 1.15) in the ANSWER BOOK, for example 1.16 D.

1.1. The purpose of the Occupational Health and Safety Act is to …

A provide for the health and safety of persons at work.
B provide for the health and safety of persons at home.
C prevent wear and tear on machinery.
D prevent workers from using machinery. (1)

1.2 In a parallel RLC circuit …

A $I_L = I_C = I_R$.
B $X_L = X_C = R$.
C $V_L = V_C = V_R$.
D $V_T = I_T = Z_{T.}$ (1)

1.3 The capacitance of a capacitor with a capacitive reactance of 31,83 Ω when connected to a 110 V/50 Hz supply is:

A 10 ɥF
B 100 ɥF
C 100 nF
D 10 nF (1)

1.4 The bandwidth of a series resonant circuit is … affected by its quality factor.

A not
B indirectly
C directly
D negatively (1)

1.5 In a star connected system the line voltage is … the phase voltage.

A equal to
B $\sqrt{3}$ times less than
C $\frac{1}{3}$ of
D $\sqrt{3}$ times more than (1)

1.6 The kWh meter is used to measure the …

A difference in phase between the voltage and the current.
B amount of electrical energy consumed.
C power in a circuit.
D time the power was on in a circuit. (1)

1.7 A delta connected system with a phase current of 25 A will have a line current of:

A 43,3 A
B 14,43 A
C 43,3 V
D 14,43 V (1)

1.8 A step-down transformer …

A increases the voltage with a corresponding decrease in current.
B increases the voltage with a corresponding increase in current.
C decreases the voltage with a corresponding decrease in current.
D decreases the voltage with a corresponding increase in current. (1)

1.9 The coils of a transformer are wound around a soft iron core to …

A make it more flexible.
B decrease the cost of the transformer.
C improve the magnetic coupling and get maximum power transfer.
D allow it to work with a DC supply. (1)

1.10 The following helps avoid cogging and reduces magnetic hum.

A An armature
B A skewed rotor
C The stator
D Cooling fan (1)

1.11 … is the difference between the synchronous speed of the rotating magnetic field and the speed of the rotor.

A Slip
B Efficiency
C Frequency
D Mutual induction (1)

1.12 The rated output power of a three-phase motor with an input power of 11,3 kW and an efficiency of 88,5% is:

A 1 000 W
B 10 000 VA
C 1 kVA
D 10 kW (1)

1.13 An example of an output on a PLC is a …

A switch.
B sensor.
C relay.
D strain gauge. (1)

1.14 The part of a VSD that converts the DC back to AC is the …

A filter.
B inverter.
C converter.
D rectifier. (1)

1.15 The type of braking that occurs when the load on the motor rotates faster than the motor is known as …

A regenerative braking.
B vector braking.
C transistor braking.
D variable frequency braking. (1)

[15]

QUESTION 2: OCCUPATIONAL HEALTH AND SAFETY

2.1 Define *major incident* with reference to the Occupational Health and Safety Act of 1993. (2)

2.2 State ONE cause of unsafe acts in a workshop. (1)

2.3 Describe why the following are unsafe acts or unsafe conditions:

2.3.1 Running in the workshop (2)

2.3.2 Overloading electrical outlets with too many appliances (2)

2.4 Explain how you would conduct a qualitative risk analysis in your workshop at school. (3)

[10]

QUESTION 3: RLC CIRCUITS

3.1 Refer to FIGURE 3.1 below and answer the questions that follow.

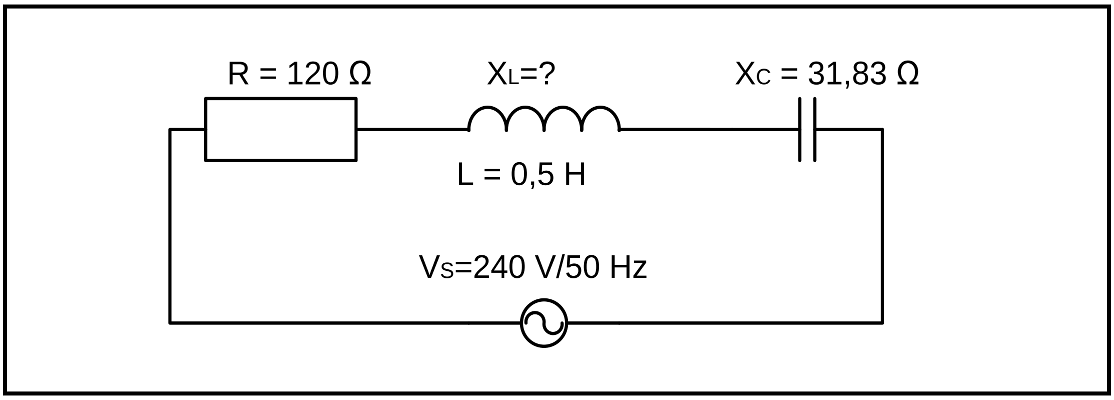


FIGURE 3.1: SERIES RLC CIRCUIT

Given:
R = 120 Ω
L = 0,5 H
X_C = 31,83 Ω
V_S = 240 V
f = 50 Hz

3.1.1 State what would happen to the resistance if the frequency was doubled. (1)

3.1.2 Write down the value of X_L during resonance. (1)

3.1.3 Calculate the:

(a) Inductive reactance of the circuit (3)

(b) Impedance of the circuit (3)

(c) Voltage across the capacitor if a current of 1,38 A is flowing through the circuit (3)

(d) Value of the capacitor required to achieve a capacitive reactance of 42,44 Ω (3)

(e) Current flowing during resonance (3)

3.2 State the value of the supply current in a parallel RLC circuit during resonance. (1)

3.3 Define the term *bandwidth* of a resonant circuit. (2)

3.4 Mention TWO characteristics of a parallel RLC circuit. (2)

3.5 Refer to FIGURE 3.5 below and answer the questions that follow.

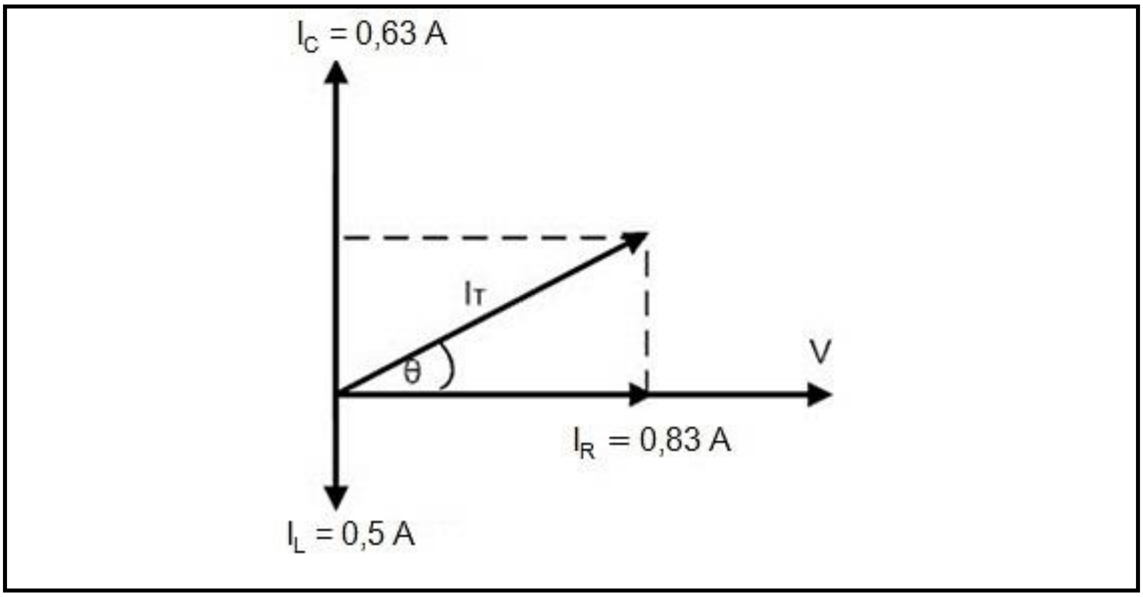


FIGURE 3.5: PARALLEL RLC PHASOR DIAGRAM

Given:
$I_C = 0,63$ A
$I_R = 0,83$ A
$I_L = 0,5$ A

Calculate the:

3.5.1 Total current flowing through the circuit (3)

3.5.2 Voltage if the resistor has a value of 120,487 Ω (3)

3.5.3 Total impedance of the circuit (3)

3.5.4 Phase-angle and state whether the current is leading or lagging the voltage (4)

[35]

QUESTION 4: THREE-PHASE AC GENERATION

4.1 Briefly describe how a three-phase AC system is generated. (2)

4.2 Refer to FIGURE 4.2. below and answer the questions that follow.

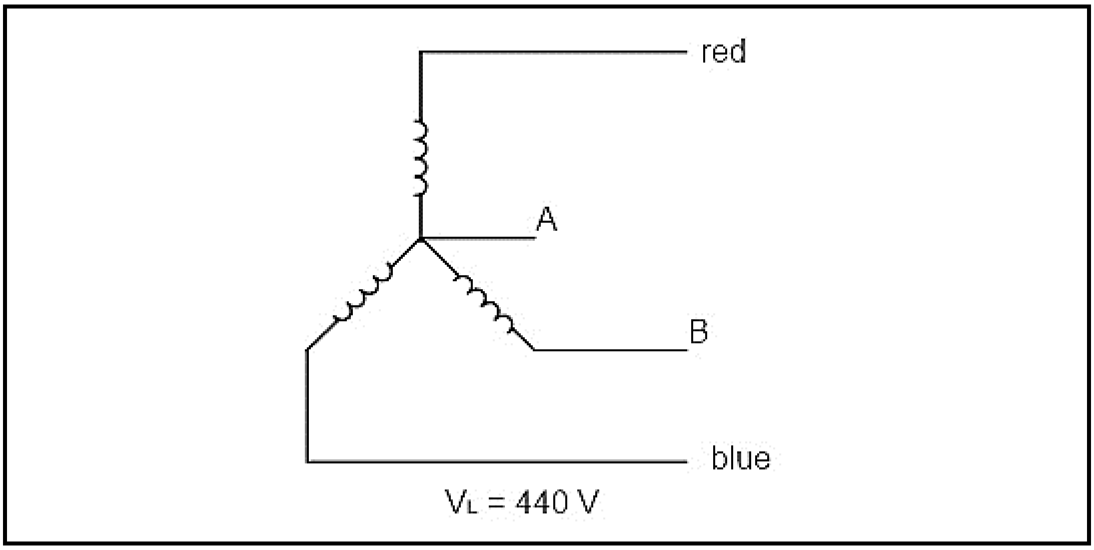


FIGURE 4.2

4.2.1 Identify the system shown in FIGURE 4.2. (1)

4.2.2 Label the lines **A** and **B** as shown in the diagram. (2)

4.2.3 Explain how the neutral is created in this system. (1)

4.2.4 Determine the phase value of the system. (3)

4.3 Answer the following questions with reference to power factor of a system.

4.3.1 Define *power factor* of a system. (2)

4.3.2 State the relationship between the current level and the power factor of a system. (1)

4.4 A three-phase system draws 4,5 A at 380 V and delivers 6,5 A at 220 V. Determine the efficiency of the system.

Given:
V_{in} = 380 V
I_{in} = 4,5 A
V_{out} = 220 V
I_{out} = 6,5 A (3)

4.5 A delta-connected three-phase system draws a line current of 27 A when connected to a supply of 380 V. The power factor meter shows a reading of 0,89 lagging.

Given:
$I_L = 27$ A
$V_L = 380$ V
$\cos\theta = 0{,}89$

Calculate the:

4.5.1 Phase voltage (2)

4.5.2 Phase-angle (3)

4.5.3 Apparent power (3)

4.5.4 Real power (3)

4.6 The three-wattmeter method was used to calculate the total power in a three-phase system. W_1 and W_2 gave readings of 12 kW and 7 500 W respectively. Determine the reading of W_3 if the total power measured was 28,75 kW.

Given:
$W_1 = 12$ kW
$W_2 = 7\,500$ W
$P_{TOT} = 28{,}75$ kW (3)

4.7 A power factor meter shows an inductive or lagging power factor of 0,7. Explain how this reading disadvantages the commercial consumer. (3)

4.8 The following readings were obtained using the two-wattmeter method.

Given:
$W_1 = 16{,}6$ kW
$W_2 = 5{,}5$ kW

Calculate the power factor of the system. (3)

[35]

QUESTION 5: THREE-PHASE TRANSFORMERS

5.1 Name TWO losses that occur in transformers. (2)

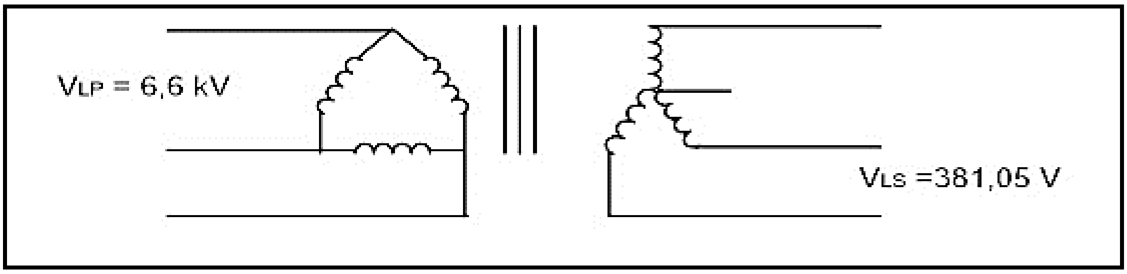
5.2 State the function of the Bucholtz relay when placed in the oil conservancy tank of a transformer. (3)

5.3 Match the configuration in COLUMN A with the application in COLUMN B. Write only the letter (A–D) next to the question numbers (5.3.1 to 5.3.4).

COLUMN A CONFUGURATION	COLUMN B APPLICATION
5.3.1 Star-delta	A Interior wiring of premises
5.3.2 Delta-star	B Step down transformer in high voltage supply lines
5.3.3 Star-star	C Heavy industries where a high-power transfer is essential
5.3.4 Delta-delta	D Step down transformer in distribution systems

(4 x 1) (4)

5.4 Refer to FIGURE 5.4 below and determine the turns ratio of the transformer.



(6)

FIGURE 5.4: THREE-PHASE TRANSFORMER

5.5 A three-phase delta-star connected transformer delivers an output power of 500 kW at a power factor of 0,9. The primary line voltage is 33 kV with a primary line current of 9,72 A. The secondary line voltage is 11 kV.

Given:
$V_{lp} = 33$ kV
$I_{lp} = 9{,}72$ A
$\cos\theta = 0{,}9$
$V_{ls} = 11$ kV

Calculate the:

5.5.1 Secondary phase voltage (3)

5.5.2 Apparent power (3)

5.5.3 Secondary line current (3)

5.5.4 Primary phase current (3)

5.6.5 Efficiency if the losses amount to 1 800 W. (3)
[30]

QUESTION 6: THREE-PHASE MOTORS AND STARTERS

6.1 State THREE advantages of using squirrel cage rotors when compared to wound rotors in induction motors. (3)

6.2 Name TWO applications of induction motors in engineering workshops. (2)

6.3 The table below represents the results of two electrical tests performed on a three-phase motor. Study the table below and answer the questions that follow.

TEST	RESULT	TEST	RESULT	TEST	RESULT
U_1–U_2	42 Ω	U_1–E	∞	U_2–E	∞
V_1–V_2	∞	V_1–E	∞	V_2–E	0 Ω
W_1–W_2	42 Ω	W_1–E	∞	W_2–E	∞

FIGURE 6.3

6.3.1 Name the TWO tests that were performed. (2)

6.3.2 Explain, giving reasons, whether the motor is suitable for installation in the industry. (3)

6.4 Refer to FIGURE 6.4 below and answer the questions that follow.

Voltage	380 V	Full load speed	3 000 rpm
Phase	3	$\cos\theta$	0,8
Current	24 A	Kw	10
Frequency	50 Hz	Model no.	12 341 A

FIGURE 6.4: NAMEPLATE OF MOTOR

6.4.1 State whether the motor is suitable for South African commercial consumers. (1)

6.4.2 Calculate the input power of the motor. (3)

6.4.3 Determine the efficiency of the motor. (3)

6.4.4 Calculate the synchronous speed if the slip is 4%. (3)

6.5 Refer to the control circuit in FIGURE 6.5 and answer the questions that follow.

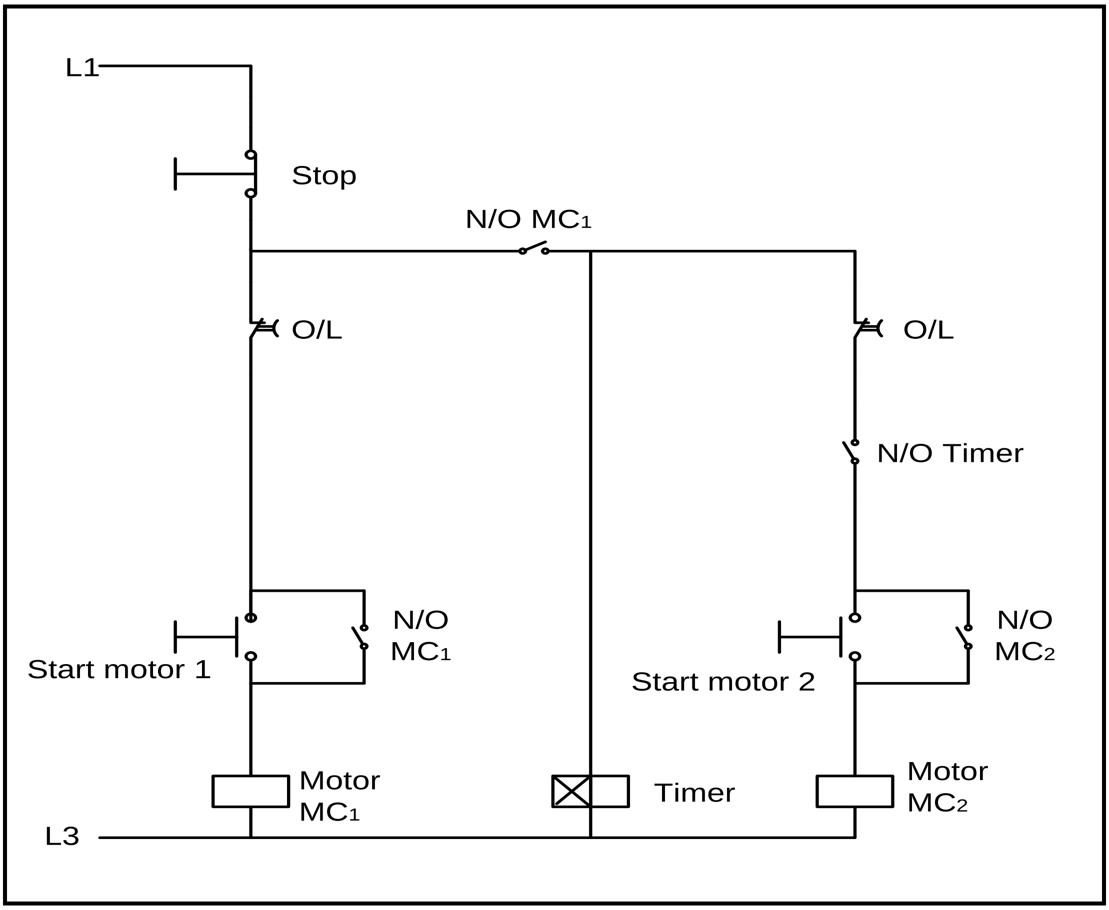


FIGURE 6.5: SEQUENCE MOTOR CONTROL STARTER WITH TIMER

6.5.1 State the function of the timer in the circuit. (1)

6.5.2 Write down the rated voltage of the contactor coils in the circuit. (1)

6.5.3 Explain what would happen if N/O MC_2 was faulty and remained open. (2)

6.5.4 Describe the sequence of operation of the starter. (4)

6.6 Explain the purpose of the star and delta contactors in an automatic star delta starter. (4)

6.7 A star connected three-phase motor has a rated power of 6 kW at a power factor of 0,78. The supply voltage was measured at 380 V.

Given:
$P_{OUT} = 6$ kW
$V_L = 380$ V
$\cos\theta = 0{,}78$

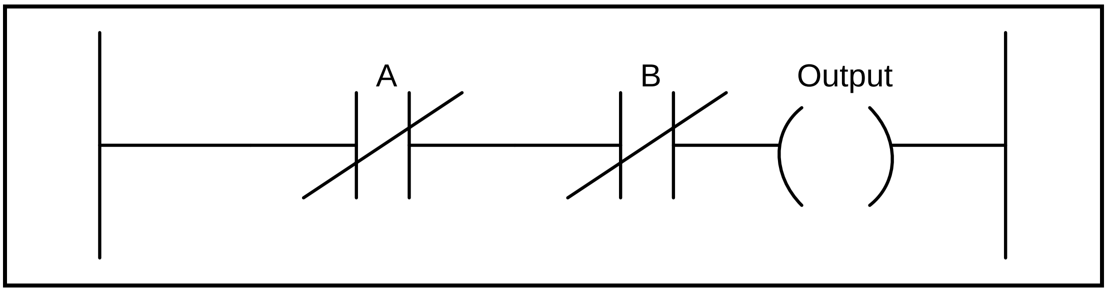
Calculate the line current of the motor. (3)

[35]

QUESTION 7: PROGRAMMABLE LOGIC CONTROLLERS (PLC's)

7.1 Name the THREE sequential scan processes of a PLC. (3)

7.2 Refer to the ladder diagram below and answer the questions that follow.



7.2.1 Draw the logic gate symbol represented above. (3)

7.2.2 Complete the truth table below by writing the correct output state in place of the given letter.

A	B	output
0	0	1
0	1	a
1	0	b
1	1	0

(2)

7.3 Describe in detail what *markers* or *flags are.* (4)

7.4 Draw a labelled block diagram of a typical pulse width modulation (PWM) variable frequency drive (VFD). (7)

7.5 Explain how the first two parts of a variable speed drive (VSD) achieve their functions. (4)

7.6 State ONE basic application of a VSD. (1)

7.7 Explain the difference between *a switch* and *a sensor* when used as input devices. (2)

7.8 Refer to FIGURE 7.8 and answer the questions that follow.

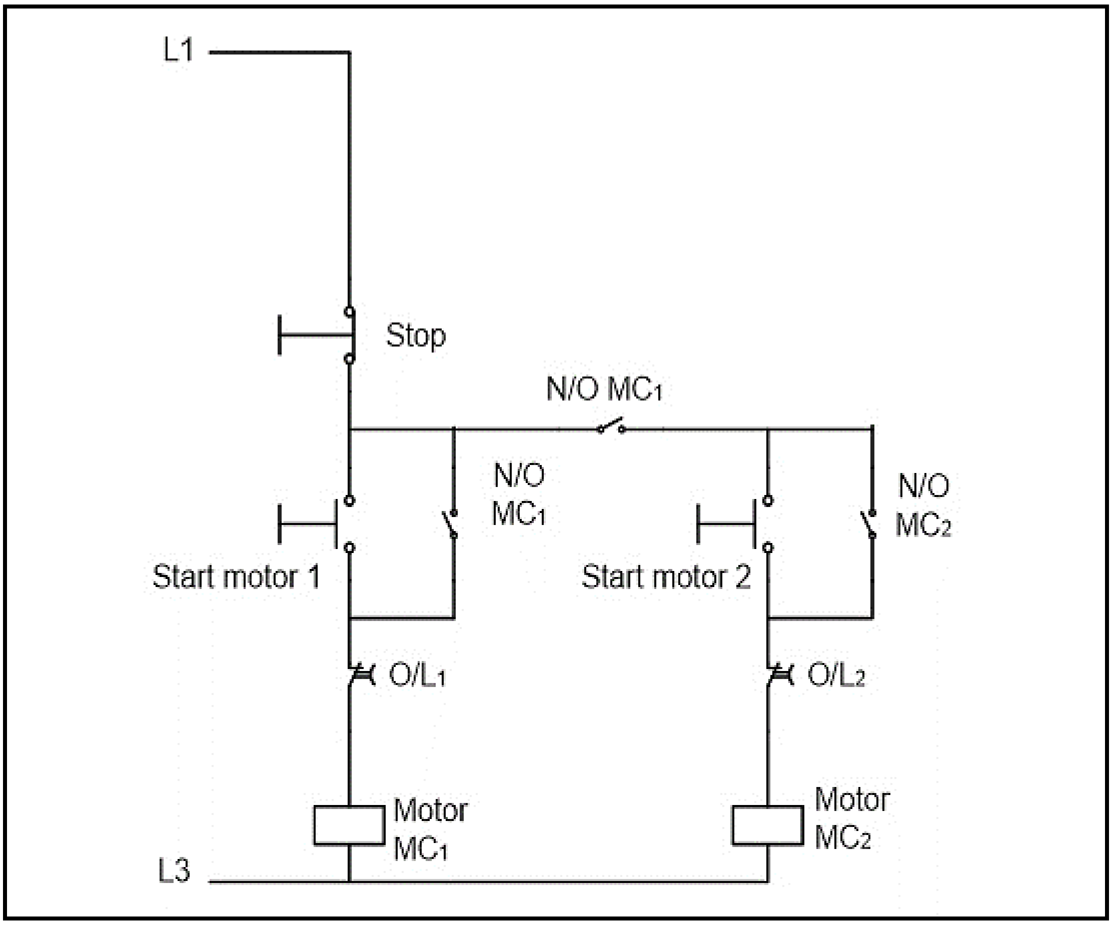


FIGURE 7.8: MANUAL SEQUENCE STARTER WITHOUT TIMER

7.8.1 Draw the PLC ladder logic diagram that will execute the same function in a PLC system. (11)

7.8.2 Explain why the two overloads are connected in series with the contactor coils. (2)

7.8.3 Describe the purpose of the N/O MC_1 contact that is connected in series with the start motor 2 pushbutton. (1)
[40]

TOTAL: 200

FORMULA SHEET

RLC-CIRCUITS

$X_L = 2\pi fL$ and $X_C = \frac{1}{2\pi fC}$

$f_r = \frac{1}{2\pi\sqrt{LC}}$ and $I = \frac{V}{R}$

$P = VI\cos\theta$

SERIES

$I_T = I_R = I_L = I_C$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$V_L = I \times X_L$ and $V_C = I \times X_C$

$V_T = IZ$ and $V_T = \sqrt{{V_R}^2 + (V_L - V_C)^2}$

$\cos\theta = \frac{R}{Z}$ and $\cos\theta = \frac{V_R}{V_T}$

$Q = \frac{X_L}{Z} = \frac{X_C}{Z} = \frac{V_L}{V_S} = \frac{V_C}{V_S} = \frac{1}{R}\sqrt{\frac{L}{C}}$

PARALLEL

$V_S = V_R = V_L = V_C$

$I_R = \frac{V_R}{R}$

$I_L = \frac{V_L}{X_L}$ and $I_C = \frac{V_C}{X_C}$

$I_T = \sqrt{{I_R}^2 + (I_L - I_C)^2}$

$Z = \frac{V}{I_T}$

$\cos\theta = \frac{I_R}{I_T}$

$Q = \frac{X_L}{Z} = \frac{X_C}{Z} = \frac{V_L}{V_S} = \frac{V_C}{V_S} = \frac{1}{R}\sqrt{\frac{L}{C}}$

THREE-PHASE AC GENERATION

STAR

$V_L = \sqrt{3} \times V_{PH}$ and $V_{PH} = I_{PH} \times Z_{PH}$

$I_L = I_{PH}$

DELTA

$V_L = V_{PH}$ and $V_{PH} = I_{PH} \times Z_{PH}$

$I_L = \sqrt{3} \times I_{PH}$

POWER

$S = \sqrt{3}V_L I_L$

$Q = \sqrt{3}V_L I_L \sin\theta$

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

$P = S\cos\theta$

$\cos\theta = \frac{P}{S}$

$\eta = \frac{output}{input} \times 100\%$

TWO-WATTMETER METHOD

$P_T = W_1 + W_2$

$\tan\theta = \sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)$

THREE-WATTMETER METHOD

$P_T = W_1 + W_2 + W_3$

FORMULA SHEET

THREE-PHASE TRANSFORMERS

STAR

$V_L = \sqrt{3} \times V_{PH}$ and $I_L = I_{PH}$

DELTA

$V_L = V_{PH}$ and $I_L = \sqrt{3} \times I_{PH}$

POWER

$S = \sqrt{3} V_L I_L$

$Q = \sqrt{3} V_L I_L \sin\theta$

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

$P = S \cos\theta$

$\cos\theta = \frac{P}{S}$

$\eta = \frac{P_{output}}{P_{output} + losses} \times 100\%$

$\mathrm{T.\,Ratio} = \frac{V_{PHP}}{V_{PHS}} = \frac{N_P}{N_S} = \frac{I_{PHS}}{I_{PHP}}$

THREE-PHASE MOTORS AND STARTERS

STAR

$V_L = \sqrt{3} \times V_{PH}$ and $I_L = I_{PH}$

DELTA

$V_L = V_{PH}$ and $I_L = \sqrt{3} \times I_{PH}$

POWER

$S = \sqrt{3} V_L I_L$

$Q = \sqrt{3} V_L I_L \sin\theta$

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

$P = S \cos\theta$

$\cos\theta = \frac{P}{S}$

$\eta = \frac{P_{output}}{P_{input}} \times 100\%$

MOTOR SPEED

$n_s = \frac{60 \times f}{p}$

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

$S = N_S - N_R$