



basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

ELECTRICAL TECHNOLOGY: POWER SYSTEMS

EXEMPLAR 2018

MARKS: 200

TIME: 3 hours

This question paper consists of 11 pages and a 2-page formula sheet.

INSTRUCTIONS AND INFORMATION

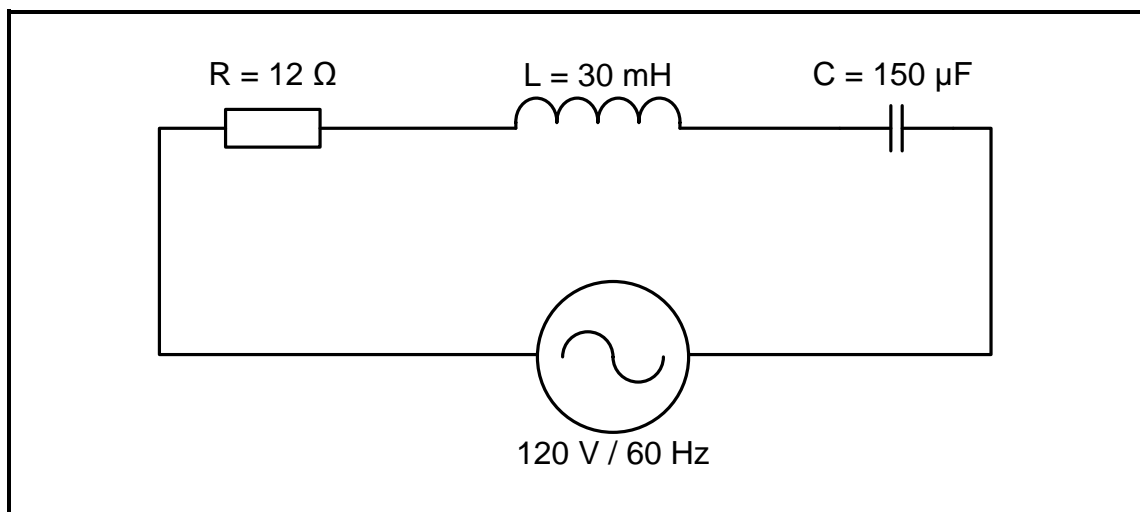
1. This question paper consists of SIX questions.
2. Answer ALL the questions.
3. Sketches and diagrams must be large, neat and fully labelled.
4. Show ALL calculations and round off answers correctly to TWO decimal places.
5. Number the answers correctly according to the numbering system used in this question paper.
6. You may use a non-programmable calculator.
7. Show the units for ALL answers of calculations.
8. A formula sheet is provided at the end of this question paper.
9. Write neatly and legibly.

QUESTION 1: OCCUPATIONAL HEALTH AND SAFETY (GENERIC)

- 1.1 Define the term *workplace* with reference to the Occupational Health and Safety Act, 1993 (Act 85 of 1993) (2)
- 1.2 Name TWO general duties for employees at the workplace. (2)
- 1.3 Explain why 'insufficient ventilation' is an unsafe condition in the workshop. (2)
- 1.4 State TWO functions of a health and safety representative. (2)
- 1.5 Explain *quantitative risk analysis*. (2)

[10]**QUESTION 2: RLC CIRCUITS (GENERIC)**

- 2.1 Explain the phase relationship between current and voltage in the following AC circuits:
- 2.1.1 Resistive circuit (2)
- 2.1.2 Pure capacitive circuit (2)
- 2.1.3 Pure inductive circuit (2)
- 2.2 FIGURE 2.2 below shows an RLC series circuit, which consists of a $12\ \Omega$ resistor, a $30\ \text{mH}$ inductor and a $150\ \mu\text{F}$ capacitor, all connected across a $120\ \text{V}/60\ \text{Hz}$ supply.

**FIGURE 2.2: RLC SERIES CIRCUIT**

Given:

$$\begin{aligned} R &= 12\ \Omega \\ L &= 30\ \text{mH} \\ C &= 150\ \mu\text{F} \\ V_s &= 120\ \text{V}/60\ \text{Hz} \\ f &= 50\ \text{Hz} \end{aligned}$$

Calculate the:

- 2.2.1 Inductive reactance (3)
- 2.2.2 Capacitive reactance (3)
- 2.2.3 Impedance (3)
- 2.2.4 Total current (3)
- 2.2.5 Power factor (3)
- 2.2.6 State whether the phase angle is leading or lagging. (1)

2.3 Refer to FIGURE 2.3 and answer the questions that follow.

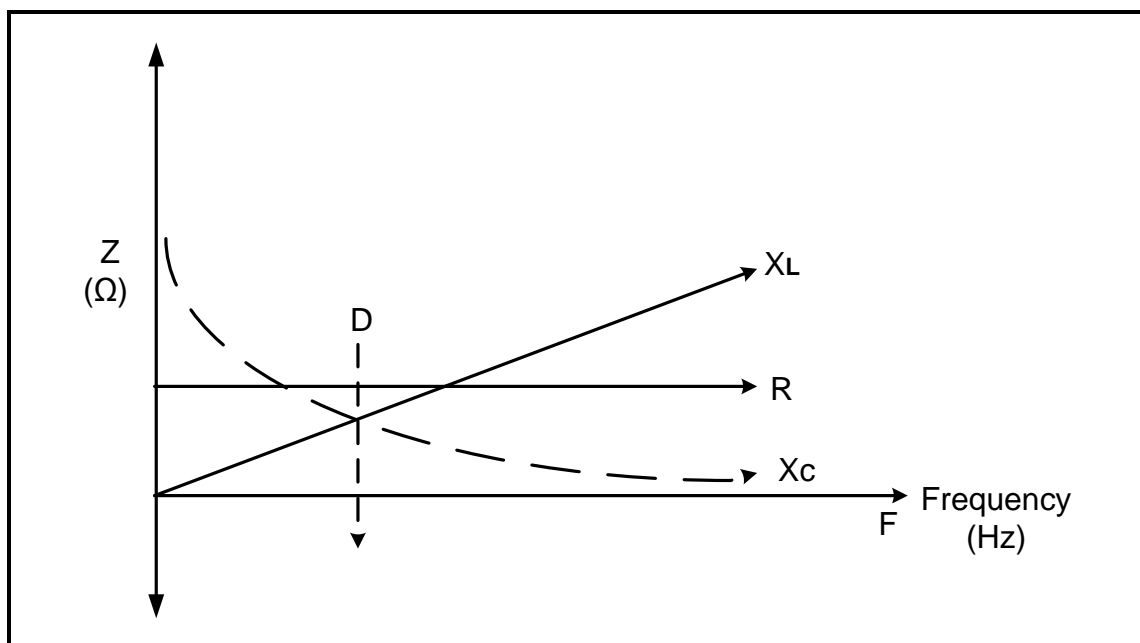


FIGURE 2.3 : FREQUENCY VERSUS IMPEDANCE

- 2.3.1 Describe how an increase in the frequency of the supply voltage will affect the:
- (a) Inductive reactance (2)
- (b) Capacitive reactance (2)
- 2.3.2 Explain why the response of line R is parallel to line F (2)
- 2.3.3 Name the electrical quantity that is equal to R at point D. (1)

- 2.4 An RLC parallel circuit consists of a 30 mH inductor, a 10 Ω resistor and a 120 μ F capacitor connected across a 120 V alternating supply.

Given:

$$\begin{aligned}L &= 30 \text{ mH} \\C &= 120 \mu\text{F} \\R &= 10 \Omega \\V &= 120 \text{ V}\end{aligned}$$

Calculate the:

- 2.4.1 Resonant frequency (3)
- 2.4.2 Q-factor (5)
- 2.4.3 Bandwidth (3)
- [40]**

QUESTION 3: THREE-PHASE AC GENERATION (SPECIFIC)

- 3.1 Name THREE advantages of a three-phase AC generation over a single-phase AC generation. (3)
- 3.2 Draw a fully labelled waveform to represent the generation of a three-phase voltage system. (6)
- 3.3 Explain the following terms:
- 3.3.1 Efficiency (2)
- 3.3.2 Power factor (2)
- 3.4 Refer to the losses occurring during the transmission of electrical power from the power station to the distributing point and answer the following questions:
- 3.4.1 Name the main type of losses occurring in the transmission line. (1)
- 3.4.2 Describe how these losses can be reduced. (2)
- 3.5 A 380 V/50 Hz three-phase AC delta-connected motor has an output power of 12,75 kW and operates at a lagging power factor of 0,77. The efficiency of the motor is 85%.
- Given:
- $V_L = 380 \text{ V}$
 $\eta = 85\%$
 $\theta = 0,77 \text{ lagging}$
 $P_{\text{out}} = 12,75 \text{ kW}$
- Calculate the:
- 3.5.1 Input power (3)
- 3.5.2 Line current (3)
- 3.5.3 Phase current (3)
- 3.6 State the function of a kWh meter. (2)
- 3.7 A two-wattmeter method is used to measure the input power in a balanced three-phase load. If the wattmeter readings are 8 kW and 4 kW respectively, calculate the total input power. (3)

[30]

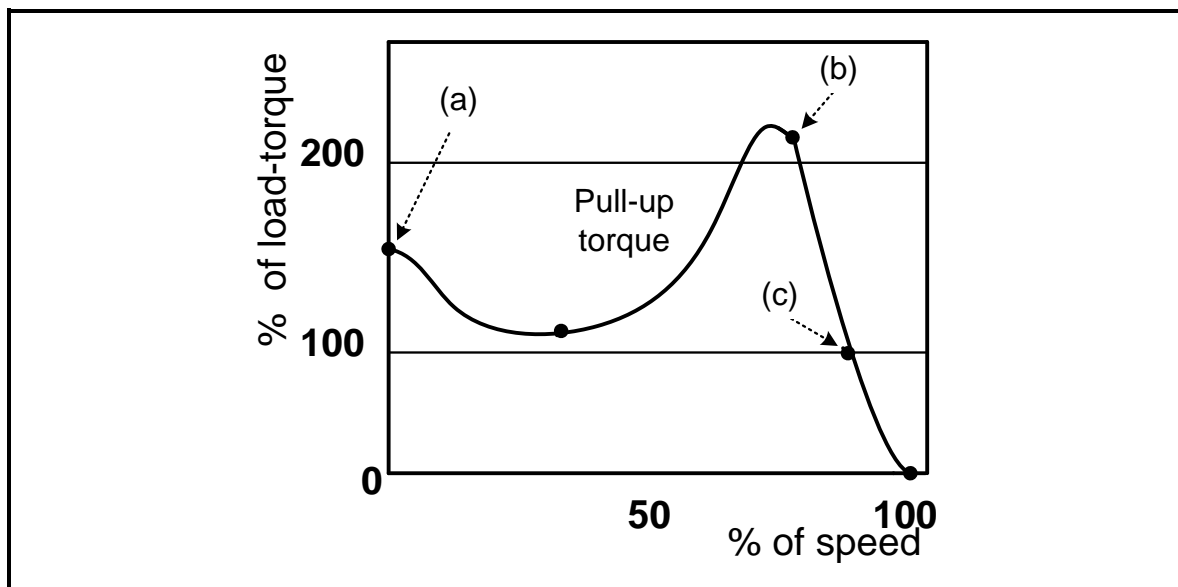
QUESTION 4: THREE-PHASE TRANSFORMERS (SPECIFIC)

- 4.1 Name TWO construction types of transformers. (2)
- 4.2 State THREE factors that may contribute to the excessive heating of transformers. (3)
- 4.3 Explain how the following losses occur in the transformers:
- 4.3.1 Hysteresis losses (3)
- 4.3.2 Eddy current losses in a transformer (3)
- 4.4 Describe how the phase current is induced in the secondary winding of the transformer. (4)
- 4.5 A 12 kVA three-phase transformer is connected in delta-star and has a turns ratio of 5 : 1. The primary line voltage is 2,2 kV.
- Given:
- S = 12 kVA
TR = 5 : 1
 V_L = 2,3 kV
pf = 0,9 lagging
- Calculate the:
- 4.5.1 Primary phase voltage (2)
- 4.5.2 Secondary line voltage (6)
- 4.5.3 Active power if the transformer has a lagging power factor of 0,9 (3)
- 4.6 Refer to QUESTION 4.5 and answer the questions that follow.
- 4.6.1 Name TWO applications of this type of transformer. (2)
- 4.6.2 State, with reason, whether the transformer is a step-down transformer or a step-up transformer. (2)

[30]

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

- 5.1 Define the term *slip* with reference to a three-phase AC squirrel-cage induction motor. (2)
- 5.2 State TWO mechanical inspections that must be conducted after installation and before commissioning. (2)
- 5.3 Give TWO reasons why the rotor of the squirrel-cage induction motor is skewed. (2)
- 5.4 Explain how the torque is developed in a squirrel-cage induction motor. (3)
- 5.5 State TWO applications of a squirrel-cage induction motor. (2)
- 5.6 Refer to FIGURE 5.6 below and answer the questions that follow.

**FIGURE 5.6: CHARACTERISTIC CURVE OF SPEED VS TORQUE**

- 5.6.1 Identify the torque developed at the following points: (1)
- (a) (1)
- (b) (1)
- 5.6.2 Explain why the torque developed at (c) is zero (2)

- 5.7 FIGURE 5.7 below shows a control circuit. Study the diagram and answer the questions that follow.

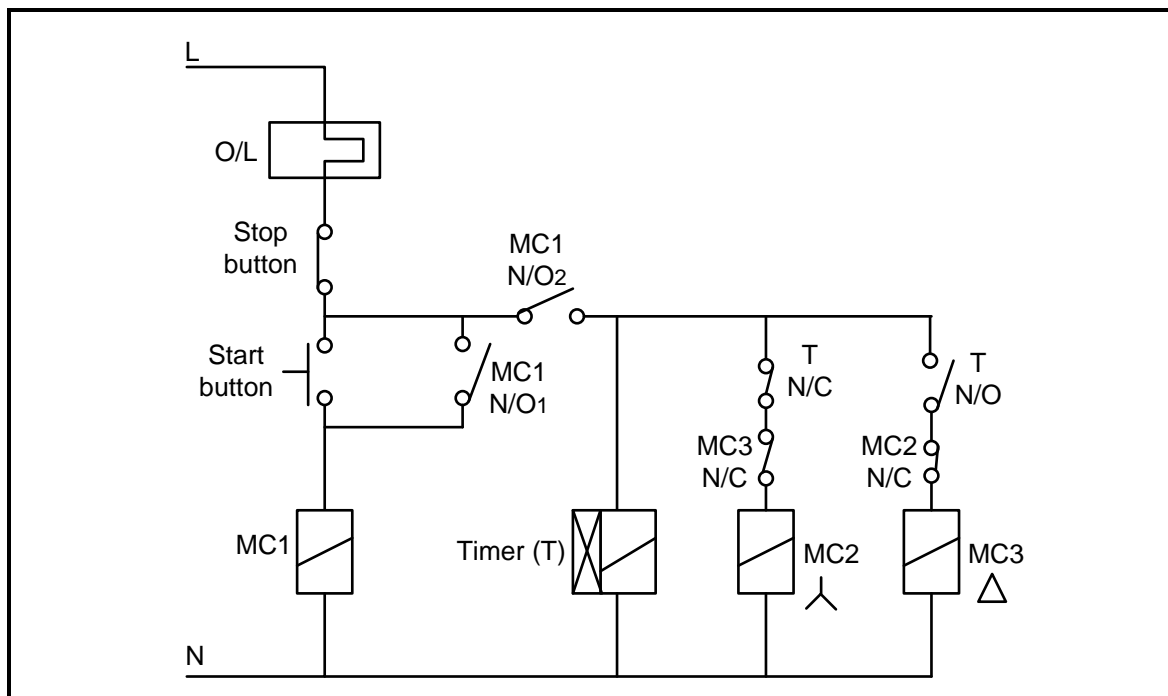


FIGURE 5.7: CONTROL CIRCUIT

- 5.7.1 Identify the control circuit diagram in FIGURE 5.7. (1)
- 5.7.2 Describe what will happen to the motor if the normally closed contact of the overload is permanently closed due to a fault. (2)
- 5.7.3 Describe the function of the following components as used in the circuits: (2)
- (a) Stop button (2)
- (b) MC1 (N/O₁) (2)
- 5.7.4 State why the N/C contact of MC3 is connected in series with a star contactor. (2)
- 5.8 A three-phase 15 kW induction motor is connected in delta to a 380 V/50 Hz supply. The motor has a lagging power factor of 0,9.
- Given:
- $P = 15 \text{ kW}$
- $f = 50 \text{ Hz}$
- $\text{Cos } \varnothing = 0,8 \text{ lagging}$
- $V_L = 380 \text{ V}$
- Calculate the:
- 5.8.1 Line current drawn from the supply (3)
- 5.8.2 Apparent power of the motor (3)

[30]

QUESTION 6: PROGRAMMABLE LOGIC CONTROLLERS (SPECIFIC)

- 6.1 State THREE safety precautions to be observed when connecting external cables to a PLC. (3)
- 6.2 Name TWO types of hardware components of the PLC other than the central processing unit (CPU). (2)
- 6.3 State THREE advantages of the PLC over the hardwired system. (3)
- 6.4 State why an interface is connected at the inputs of the CPU. (2)
- 6.5 Explain the programmed scan cycle under the following headings:
- 6.5.1 Input scan (3)
 - 6.5.2 Process scan (3)
 - 6.5.3 Output scan (2)
- 6.6 Refer to analogue and digital input as used in the PLC and answer the following questions:
- 6.6.1 Explain the difference between an *analogue input* and a *digital input* (4)
 - 6.6.2 Give TWO examples of the digital inputs. (2)
 - 6.6.3 State THREE applications of the inductive proximity sensor as an analogue input. (3)
- 6.7 State when a maker/flag function is used in the PLC. (2)
- 6.8 Refer to FIGURE 6.8 on the next page and draw the PLC ladder logic diagram that would execute the same function.

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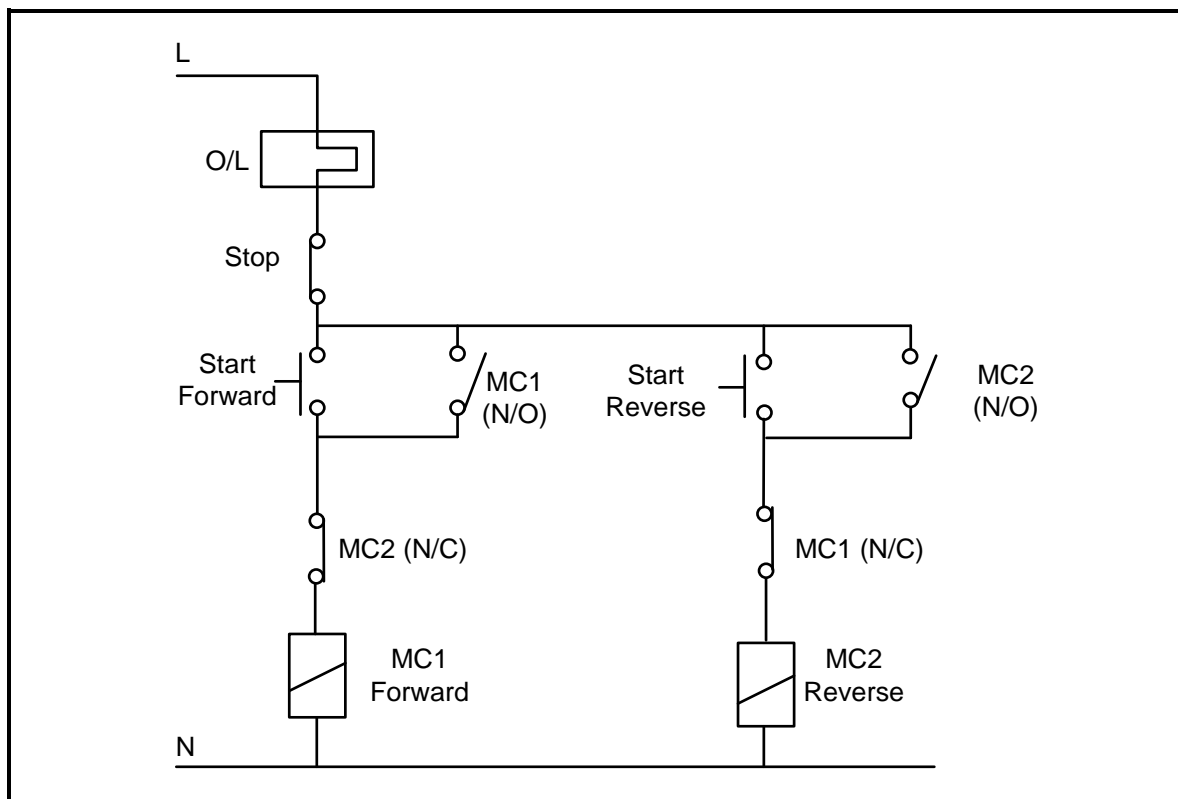


FIGURE 6.8: CONTROL CIRCUIT

(10)

- 6.9 State THREE basic applications of the variable speed drive (VSD). (3)
- 6.10 Name THREE methods in which the speed of the motor can be controlled with the exception of pulse width modulation. (3)
- 6.11 Describe how the pulse width modulation as a method of varying the speed of the motor achieves its function. (4)
- 6.12 Describe how the VSD controls the speed of motors under the following subcircuits:
- 6.12.1 Diode bridge rectifier (2)
 - 6.12.2 Filtering circuit (3)
 - 6.12.3 Inverting circuit (3)
- 6.13 Describe the concept of *regenerative braking*. (3)

[60]

TOTAL: 200

FORMULA SHEET	
THREE-PHASE AC GENERATION	RLC CIRCUIT
<p>STAR $V_L = \sqrt{3} V_{PH}$ and $V_{PH} = I_{PH} \times Z_{PH}$ $I_L = I_{PH}$</p> <p>DELTA $V_L = V_{PH}$ and $I_L = \sqrt{3} \times I_{PH}$ $V_{PH} = I_{PH} \times Z_{PH}$</p> <p>POWER $S(P_{app}) = \sqrt{3} \times V_L \times I_L$ $Q(P_R) = \sqrt{3} \times V_L \times I_L \times \sin \theta$ $\cos \theta = \frac{P}{S}$ $P = \sqrt{3} \times V \times I_L \times \cos \theta$</p> <p>TWO-WATTMETER METHOD $P = P_1 + P_2$</p>	$X_L = 2\pi fL \quad \text{and} \quad X_C = \frac{1}{2\pi fC}$ $F_o = \frac{1}{2\pi\sqrt{LC}}$ <p>SERIES $I_T = I_R = I_C = I_L$ $Z = \sqrt{R^2 + (X_L - X_C)^2}$ $V_L = I X_L$ and $V_C = I X_C$ $V_T = I Z$ and $V_T = \sqrt{V_R^2 + (V_L - V_C)^2}$ $I_T = \frac{V_T}{Z}$ $\cos \theta = \frac{R}{Z}$ $\cos \theta = \frac{V_R}{V_T}$ $\cos \theta = \frac{V_R}{V_T}$ $Q = \frac{X_L}{Z} = \frac{X_C}{Z} = \frac{V_L}{V_s} = \frac{V_C}{V_s} = \frac{1}{R} \sqrt{L/C}$</p>
<p style="text-align: center;">THREE-PHASE TRANSFORMERS</p> <p>STAR $V_L = \sqrt{3} V_{PH}$ and $I_L = I_{PH}$</p> <p>DELTA $I_L = \sqrt{3} I_{PH}$ and $V_L = V_{PH}$</p> <p>POWER $S(P_{app}) = \sqrt{3} \times V_L \times I_L$ $Q(P_R) = \sqrt{3} \times V_L \times I_L \times \sin \theta$ $\cos \theta = \frac{P}{S}$</p>	<p>PARALLEL $V_T = V_R = V_C = V_L$ $I_R = \frac{V_R}{R}$ and $I_C = \frac{V_C}{X_C}$ $I_L = \frac{V_L}{X_L}$ $I_T = \sqrt{I_R^2 + (I_L - I_C)^2}$ $\cos \theta = \frac{I_R}{I_T}$ $Q = \frac{X_L}{Z} = \frac{X_C}{Z} = \frac{V_L}{V_s} = \frac{V_C}{V_s} = \frac{1}{R} \sqrt{L/C}$</p>

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

$$S(P_{app}) = \sqrt{3} \times V_L \times I_L$$

$$\frac{V_{ph(p)}}{V_{ph(s)}} = \frac{N_p}{N_s} = \frac{I_{ph(s)}}{I_{ph(p)}}$$

THREE-PHASE MOTORS AND STARTERS

STAR

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

DELTA

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

POWER

$$S(P_{app}) = \sqrt{3} \times V_L \times I_L$$

$$Q(P_R) = \sqrt{3} \times V_L \times I_L \times \sin \theta$$

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

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

$$\text{Efficiency } (\eta) = \frac{P_{in} - \text{losses}}{P_{in}}$$

MOTOR SPEED

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

$$\text{Slip} = \frac{n_s - n_r}{n_s}$$