



**higher education
& training**

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

11 July 2022

This marking guideline consists of 12 pages.

QUESTION 1: DC MACHINES

1.1 The current drawn by the motor depends upon:

- The armature circuit resistance (R_a)✓
- The back EMF generated (E)✓

Assume the flux is constant:

When the motor is loaded, the speed (N) decreases, which results in a decrease of the ✓ back EMF (E) and consequently an increase in the current (I).✓

(4)

1.2 **GIVEN:** A shunt-connected motor

$$P = 7,5 \text{ kW}$$

$$V = 230 \text{ V}$$

$$N = 1\,200 \text{ r/min}$$

$$R_{sh} = 180 \text{ ohm}$$

$$R_a = 0,3 \text{ ohm}$$

$$\eta = 86\%$$

$$1.2.1 \quad I_{sh} = \frac{V}{R_{sh}} = \frac{230}{180} = 1,278 \text{ A}$$

No-load conditions:

$$I_{L2} = \frac{P_i}{V} = \frac{600}{230}$$

$$= 2,609 \text{ A}✓$$

$$I_{a2} = I_{L2} - I_{sh} = 2,609 - 1,278$$

$$= 1,331 \text{ A}✓$$

$$E_2 = V - I_{a2} \cdot R_a = 230 - (1,331 \times 0,3)$$

$$= 229,601 \text{ V}✓$$

Full-load conditions:

$$P_i = \frac{P_{out}}{\eta} = \frac{7\,500}{0,86}$$

$$= 8\,720,93 \text{ W}✓$$

$$I_{L1} = \frac{P_i}{V} = \frac{8\,720,93}{230} = 37,917 \text{ A}✓$$

$$I_{a1} = I_{L1} - I_{sh} = 37,917 - 1,278 = 36,639 \text{ A}✓$$

$$E_1 = V - I_{a1} \cdot R_a = 230 - (36,639 \times 0,3) = 219,008 \text{ V}✓$$

$E \propto N \cdot \Phi$ But Φ is constant $\therefore E \propto N$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

$$N_2 = \frac{E_2 \times N_1}{E_1}$$

$$\hat{=} \frac{229,601 \times 1\,200}{219,008}$$

$$\hat{=} 1\,258,042 \text{ r/min} \checkmark$$

(8)

1.2.2 $N_1 = 1\,200 \text{ r/min}$ $\rightarrow$ without R_x
 $N_2 = 1\,000 \text{ r/min}$ $\rightarrow$ with R_x

$E \propto N \cdot \Phi$ But Φ is constant $\therefore E \propto N$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

$$E_2 = \frac{E_1 \times N_2}{N_1} \checkmark$$

$$\hat{=} \frac{219,008 \times 1\,000}{1\,200} \checkmark$$

$$\hat{=} 182,507 \text{ V}$$

$T_2 = T_1 \rightarrow$ Full-load $\therefore T_2/T_1 = 1$

$T \propto I_A \cdot \Phi$ But $\Phi_1 = \Phi_2$ $\therefore T \propto I_A$

$$\frac{T_1}{T_2} = \frac{I_{a2}}{I_{a1}}$$

$$\therefore 1 = \frac{I_{a2}}{I_{a1}}$$

$$I_{a2} = I_{a1}$$

$$\hat{=} 36,639 \text{ A}$$

$$E_2 = V - I_{a2}(R_a + R_x)$$

$$R_x = \frac{V - E_2}{I_{a2}} - R_a$$

$$\hat{=} \frac{230 - 182,507}{36,639} - 0,3 \checkmark$$

$$\hat{=} 0,996 \Omega \checkmark$$

(5)

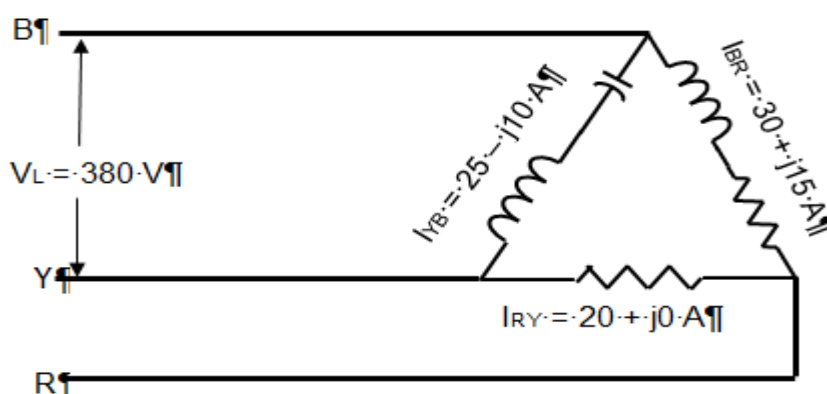
[17]

QUESTION 2: AC CIRCUIT THEORY

- 2.1 A broken or missing neutral in a three-phase circuit has the following effects:
- The phase-to-phase voltage (V_L) will be unaffected;✓ the operation of all balanced three-phase loads will be unaffected.✓
 - The phase-to-neutral voltage (V_P) can vary from 0 V to any value up to the phase-to-phase value;✓ all single-phase loads and three-phase unbalanced loads connected to this supply will experience potential variations.✓
- (Any 1 × 2)

(2)

- 2.2 **Given:** An unbalanced, three-phase, delta-connected load



$$2.2.1 \quad Z_{RY} = \frac{V_{RY}}{I_{RY}}$$

$$= \frac{380 \angle 0^\circ}{20 \angle 0^\circ}$$

$$= 19 \angle 0^\circ \Omega$$

$$Z_{YB} = \frac{V_{YB}}{I_{YB}}$$

$$= \frac{380 \angle -120^\circ}{25 \angle -120^\circ}$$

$$= 15.2 \angle 0^\circ \Omega$$

$$Z_{BR} = \frac{V_{BR}}{I_{BR}} = \frac{380 \angle 120^\circ}{30 \angle 120^\circ}$$

$$= 12.67 \angle 0^\circ \Omega$$

(6)

$$2.2.2 \quad I_R = I_{RY} - I_{BR}$$

$$= 20 \angle 0^\circ - 30 \angle 120^\circ$$

$$= 18.03 \angle -123.69^\circ \text{ A}$$

(6)

$$I_Y = I_{YB} - I_{RY}$$

$$= 25 \angle -120^\circ - 20 \angle 0^\circ$$

$$= 11.18 \angle -63.43^\circ \text{ A}$$

$$I_B = I_{BR} - I_{YB}$$

$$= 30 \angle 120^\circ - 25 \angle -120^\circ$$

PRODUCTION AND QUALITY CONTROL N5
25,495 78,691 ° A

[14]

QUESTION 3: TRANSFORMERS

- 3.1
- Delta – Delta connection
 - Delta – Star connection
 - Star – Delta connection
 - Star – Star connection
- (4)

- 3.2 **GIVEN:** A single-phase transformer
 pf = 1
 S = 250 kVA
 $\eta = 95\%$ at both half-load and full-load
 f = 50 Hz

- 3.2.1 η at half-load:

$$\hookrightarrow \frac{k \cdot S \cdot \cos \theta}{k \cdot S \cdot \cos \theta + P_o + k^2 P_{sc}}$$

$$0,95 = \frac{0,5 \times 250 \times 1}{(0,5 \times 250 \times 1) + P_o + 0,5^2 P_{sc}} = \frac{125}{125 + P_o + 0,5^2 P_{sc}}$$

$$P_o + 0,5^2 P_{sc} = \frac{125}{0,95} - 125 = 6,579 \text{-----} (1)$$

η at full-load:

$$\hookrightarrow \frac{S \cdot \cos \theta}{S \cdot \cos \theta + P_o + P_{sc}}$$

$$0,95 = \frac{250 \times 1}{(250 \times 1) + P_o + P_{sc}}$$

$$\hookrightarrow \frac{250}{250 + P_o + P_{sc}}$$

$$P_o + P_{sc} = \frac{250}{0,95} - 250 = 13,158 \text{-----} (2)$$

$$(2) - (1): \quad P_o + P_{sc} = 13,158$$

$$P_o + 0,5^2 P_{sc} = 6,579$$

$$0,75 P_{sc} = 6,579$$

$$\therefore P_{sc} = \frac{6,579}{0,75}$$

$$\hookrightarrow 8,772 \text{ kW}$$

Substitute P_{sc} in (1) or (2)

$$P_o + 8,772 = 13,158$$

$$P_o = 13,158 - 8,772$$

$$\hookrightarrow 4,386 \text{ kW}$$

(8)

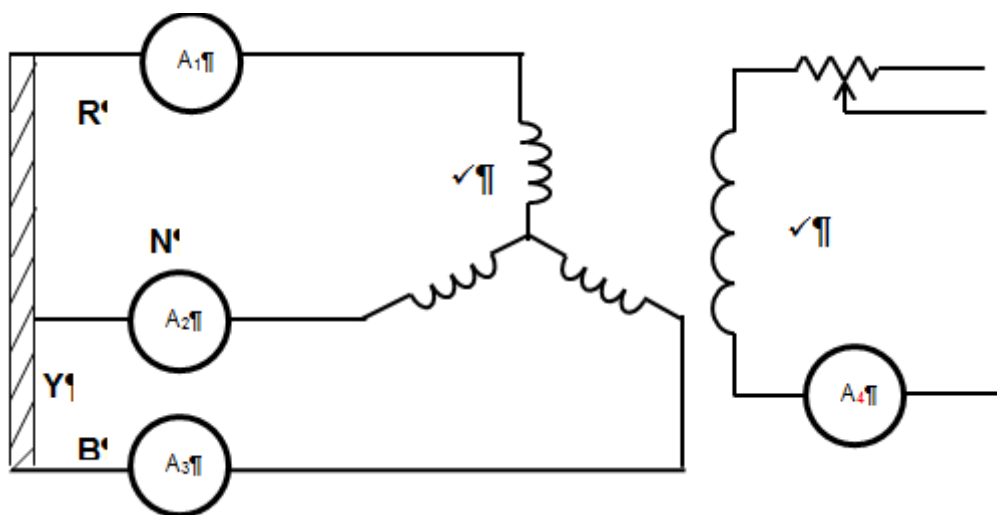
$$3.2.2 \quad \zeta \frac{k \cdot S \cdot \cos \theta}{k \cdot S \cdot \cos \theta + P_o + k^2 P_{sc}} \times 100 \%$$

$$\zeta \frac{0,7 \times 250 \times 0,8}{(0,7 \times 250 \times 0,8) + 4,386 + (0,7^2 \times 8,772)} \times 100 \%$$

$$\zeta 94,159 \% \checkmark$$

(2)
[14]**QUESTION 4: AC MACHINES – ALTERNATORS**

4.1



The short-circuit curve is obtained by short-circuiting the alternator terminals through ammeters ✓ and taking readings of short-circuit current and field current. ✓ The short-circuit current is plotted against the field current and results in a straight line through the origin. ✓

(5)

4.2

GIVEN:

An alternator having the following:

Number of poles = 12

Number of slots = 72

Flux/pole = 0,05 Wb

 $k_f = 1.11$

4.2.1

$$f = \frac{N \cdot p}{60}$$

$$\therefore N = \frac{f \times 60}{p} = \frac{50 \times 60}{6} \checkmark$$

$$\zeta 500 \text{ r/min} \checkmark$$

(2)

$$4.2.2 \quad \text{number of slots/pole} = \frac{72}{12} = 6$$

$$n = \text{Number of slots/pole/phase} = \frac{6}{3} = 2$$

$$\alpha = \frac{180^\circ}{\text{number of slots/pole}} = \frac{180^\circ}{6} = 30^\circ$$

$$kd = \frac{\sin\left(\frac{n\alpha}{2}\right)}{n \cdot \sin\left(\frac{\alpha}{2}\right)} = \frac{\sin\left(\frac{2 \times 30^\circ}{2}\right)}{2 \times \sin\left(\frac{30^\circ}{2}\right)} = 0,966$$

$$Z = \text{Total conductors} \in \text{series per phase} = (72 \times 10) / 3 = 240$$

$$E_p = 2 \cdot k_f \cdot k_d \cdot k_p \cdot f \cdot \phi \cdot Z$$

$$\hookrightarrow 2 \times 1,11 \times 0,966 \times 1 \times 50 \times 0,05 \times 240$$

$$\hookrightarrow 1\,286,712 \text{ V}$$

$$E_L = \sqrt{3} \cdot E_p = \sqrt{3} \times 1\,286,712$$

$$\hookrightarrow 2\,228,651 \text{ V}$$

(9)
[16]**QUESTION 5: AC MACHINES – SYNCHRONOUS MOTORS****GIVEN:** A single-phase synchronous motor having the following:

$$V_L = 500 \text{ V}$$

$$R_a = 0,2 \text{ ohm}$$

$$X_s = 3 \text{ ohm}$$

$$P_{\text{out}} = 37,3 \text{ kW}$$

$$\text{pf} = 0,9 \text{ leading}$$

$$\eta = 90\%$$

$$5.1 \quad \hookrightarrow \frac{P_{\text{OUT}}}{P_i}$$

$$\therefore P_i = \frac{P_{\text{out}}}{\square}$$

$$\hookrightarrow \frac{37,3}{0,9}$$

$$\hookrightarrow 41,444 \text{ kW}$$

$$P_i = \sqrt{3} \cdot V_L \cdot I_L \cdot \cos \theta$$

$$\therefore I_L = \frac{P_i}{\sqrt{3} \cdot V_L \cos \theta}$$

$$\hookrightarrow \frac{41,444 \times 10^3}{\sqrt{3} \times 500 \times 0,9}$$

$$\hookrightarrow 53,173 \text{ A}$$

(3)

$$5.2 \quad V_L = \sqrt{3} \times V_p$$

$$V_p = \frac{V_L}{\sqrt{3}} = \frac{500}{\sqrt{3}} = 288,675 \text{ V} \checkmark$$

Method 1

$$\cos \theta = 0,9 \text{ Leading} \quad \therefore \theta = 25,842^\circ \quad I = 53,173 \angle 25,842^\circ \text{ A}$$

$$Z_s = R_a + j X_s = 0,2 + j3$$

$$\hookrightarrow 3,00786,186 \Omega \checkmark$$

$$E_r = I \cdot Z_s = 53,17325,842^\circ \times 3,00786,186^\circ$$

$$\hookrightarrow 159,891112,028^\circ \text{ V} \checkmark$$

$$E_p = E_r - V_p$$

$$\hookrightarrow 159,891112,028^\circ - 288,6750^\circ \checkmark$$

$$\hookrightarrow 378,842156,968^\circ \text{ V} \checkmark$$

$$E_L = \sqrt{3} \cdot E_p$$

$$\hookrightarrow \sqrt{3} \times 378,842$$

$$\hookrightarrow 656,174 \text{ V} \checkmark$$

Method 2

$$I R_a = 53,173 \times 0,2 = 10,635 \text{ V} \checkmark$$

$$I X_s = 53,173 \times 3 = 159,519 \text{ V} \checkmark$$

$$E_p = V_p - \theta + I R_a 180^\circ + I X_s - 90^\circ$$

$$\hookrightarrow 288,675 - 25,842^\circ + 10,635 180^\circ + 159,519 - 90^\circ \checkmark$$

$$\hookrightarrow 378,829 - 48,872^\circ \text{ V} \checkmark$$

$$E_L = \sqrt{3} \cdot E_p$$

$$\hookrightarrow \sqrt{3} \times 378,829$$

$$\hookrightarrow 656,151 \text{ V}$$

(6)
[9]

QUESTION 6: AC MACHINES (INDUCTION MOTORS)**GIVEN:** A three-phase induction motor is star-connected in both the stator and rotor.

$$V_L = 380 \text{ V}$$

$$p = 2$$

$$f = 50 \text{ Hz}$$

$$Z = (0,2 + j1) \text{ ohm per phase}$$

$$\text{rotational loss} = 200 \text{ W}$$

$$S = 5\%$$

$$\text{Stator-rotor turns ratio} = 2:1$$

$$\text{Stator loss} = 400 \text{ W}$$

$$6.1 \quad f = \frac{N_1 \cdot P}{60}; N_1 = \frac{60 \cdot f}{P} = \frac{60 \times 50}{2} = 1500 \text{ r/min}$$

$$N_2 = N_1 - (S \cdot N_1)$$

$$= 1500 - (0,05 \times 1500)$$

$$= 1425 \text{ r/min} \checkmark$$

$$V_p = \frac{V_L}{\sqrt{3}} = \frac{380}{\sqrt{3}} = 219,393 \text{ V}$$

$$\frac{V_p}{E_o} = \frac{N_1}{N_2}$$

$$\therefore E_o = V_p \times \frac{N_2}{N_1}$$

$$= 219,393 \times \frac{1}{2}$$

$$= 109,697 \text{ V}$$

$$I_2 = \frac{S \cdot E_o}{\sqrt{R_2^2 + \dots}}$$

$$= \frac{0,05 \times 109,697}{\sqrt{0,2^2 + (0,05 \times 1)^2}}$$

$$= 26,605 \text{ A}$$

Let P_r = rotor copper loss

$$P_r = 3 \cdot I_2^2 R$$

$$= 3 \times 26,605^2 \times 0,2 = 424,696 \text{ W}$$

$$P_r = \frac{2 \cdot \pi \cdot (N_1 - N_2) \cdot T}{60}$$

$$\therefore T = \frac{60 \times P_r}{2 \times \pi \times (N_1 - N_2)}$$

$$= \frac{60 \times 424,696}{2 \times \pi \times (1500 - 1425)}$$

$$= 54,074 \text{ Nm}$$

Method 1:

$$\begin{aligned} \text{Rotor output} &= \frac{2 \cdot \pi \cdot N_2 \cdot T}{60} \\ &= \frac{2 \times \pi \times 1\,425 \times 54,074}{60} \\ &= 8,069 \text{ kW} \end{aligned}$$

Method 2:

$$\begin{aligned} P_r &= \frac{S}{1-S} \times P_{OUT} \\ &= \frac{P_r \times (1-S)}{S} \\ &= \frac{424,696 \times (1-0,05)}{0,05} \\ &= 8,069 \text{ kW} \end{aligned} \quad (7)$$

$$\begin{aligned} 6.2 \quad \text{Stator copper loss} &= \text{Rotor copper loss} \\ &= 424,696 \text{ W} \end{aligned}$$

$$\begin{aligned} \text{Total losses} &= \text{Stator copper loss} + \text{Stator iron loss} + \text{Rotor copper loss} + \\ &\quad \text{Rotational loss} \\ &= 424,696 + 400 + 424,696 + 200 \\ &= 1,449 \text{ kW} \end{aligned}$$

$$\begin{aligned} &= \frac{P_{out}}{P_i} \times 100 \% \\ &= \frac{P_{out}}{P_{out} + \text{Total losses}} \times 100 \% \\ &= \frac{8,069}{8,069 + 1,449} \times 100 \% \\ &= 84,776 \% \end{aligned} \quad (3)$$

[10]

QUESTION 7: GENERATION AND SUPPLY OF AC

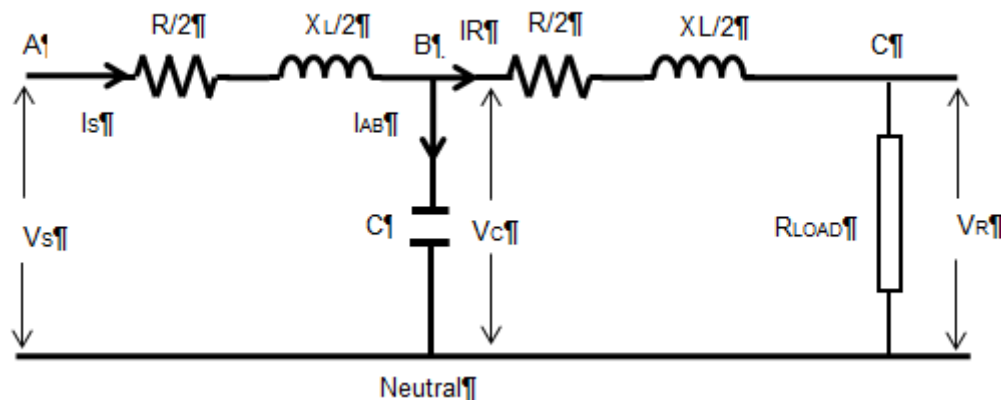
- 7.1 Voltage regulation is defined as the rise and fall in the receiving-end voltage ✓ when full load is switched off, ✓ provided that the sending-end voltage remains constant. ✓

(3)

- 7.2 **GIVEN:** A 3-phase transmission line

$$\begin{aligned} P &= 50 \text{ MW;} \\ V_L &= 132 \text{ kV;} \\ f &= 50 \text{ Hz} \\ \text{pf} &= 0,8 \text{ lagging} \end{aligned}$$

$$\begin{aligned} C &= 0,75 \text{ } \mu\text{F} \\ R &= 12,4 \text{ } \Omega \\ L &= 0,15 \text{ H} \end{aligned}$$



$$7.2.1 \quad \frac{R}{2} = \frac{12,4}{2} = 6,2 \Omega$$

$$\frac{X_L}{2} = 2 \cdot \pi \cdot f \cdot \frac{L}{2} = 2 \times \pi \times 50 \times \frac{0,15}{2} = 23,562 \Omega$$

$$Z_{BC} = \frac{R}{2} + \frac{jX_L}{2} = 6,2 + j23,562 = 24,36475,258 \Omega$$

$$V_R = \frac{V_L}{\sqrt{3}} = \frac{132 \times 10^3}{\sqrt{3}} = 76210,235 \text{ V} \checkmark$$

$$I_R = \frac{P}{\sqrt{3} \cdot V_L \cdot \cos \theta} = \frac{50 \times 10^6}{\sqrt{3} \times 132 \times 10^3 \times 0,8} = 273,367 - 36,87^\circ \text{ A}$$

$$V_{BC} = I_R \cdot Z_{BC} = 273,367 - 36,87^\circ \times 24,36475,258^\circ$$

$$= 6660,31438,388^\circ \text{ V}$$

$$V_{BN} = V_{BC} + V_R = 6660,31438,388^\circ + 76210,2360^\circ$$

$$= 81535,7142,908^\circ \text{ V} \checkmark$$

$$X_C = \frac{1}{2 \pi f C}$$

$$= \frac{1}{2 \times \pi \times 50 \times 0,75 \times 10^{-6}}$$

$$= 4244,132 \Omega$$

$$Z_{BN} = 0 - jX_C$$

$$\hookrightarrow 0 - j4\,244,132$$

$$\hookrightarrow 4\,244,132 - 90^\circ \Omega$$

$$I_{BN} = \frac{V_{BN}}{Z_{BN}}$$

$$\hookrightarrow \frac{81\,535,7142,908^\circ}{4\,244,132 - 90}$$

$$\hookrightarrow 19,211\,92,908^\circ \text{ A}$$

$$I_S = I_{BN} + I_R = 19,211\,92,908 + 273,367 - 36,87$$

$$\hookrightarrow 261,493 - 33,633^\circ \text{ A}$$

(12)

7.2.2 $V_{AB} = I_S \cdot Z_{AB}$

$$\hookrightarrow 261,493 - 33,633^\circ \times 24,364\,75,258^\circ$$

$$\hookrightarrow 6\,371,015\,41,625^\circ$$

$$V_S = V_{AB} + V_{BN}$$

$$\hookrightarrow 6\,371,015\,41,625^\circ + 81\,535,7142,908^\circ$$

$$\hookrightarrow 86\,598,3995,545^\circ \text{ V}$$

$$V_L = \sqrt{3} \cdot V_S = \sqrt{3} \times 86\,598,399$$

$$\hookrightarrow 149,993 \text{ kV}$$

(3)

7.2.3 $\text{Power factor} = \cos(5,545^\circ + 33,633^\circ)$

$$\hookrightarrow \cos(39,178) \hookrightarrow 0,775 \text{ Lagging}$$

(2)

[20]**TOTAL: 100**