



**higher education
& training**

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE ELECTROTECHNICS N5

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This marking guideline consists of 9 pages.

QUESTION 1

- 1.1
- Fixed poles in the field winding
 - No rotating magnetic flux
 - Great mass due to heavy wound armature
 - $EMF \propto \text{Speed} \propto \text{Flux}$ ($E \propto N \propto \Phi$)
- (Any 2 × 1) (2)
- 1.2 A series motor cannot be started without some mechanical load ✓ because at no-load the field flux is too small to allow the build-up of necessary back EMF which causes the motor to speed up towards infinity until it burns out completely. ✓ (2)
- 1.3 The commutating plane is the area in which commutating poles have influence. (1)
- 1.4
- $$E_1 = V - I_a R_a$$
- $$= 250 - (50)(0,2)$$
- $$= 250 - 10$$
- $$= 240 \text{ V} \checkmark \checkmark$$
- 1.4.1
- $$E = kN\Phi$$
- $$E_1/E_2 = N_2/N_1$$
- $$E_1/240 = \frac{800}{1000} \checkmark \checkmark \checkmark$$
- $$E_2 = 192 \text{ V} \checkmark \checkmark \checkmark$$
- $$E_2 = V - I_a(R_a + x)$$
- $$192 = 250 - 50(0,2 + x) \checkmark \checkmark$$
- $$192 = 250 - 10 - 50x$$
- $$X 0,96 \Omega \checkmark \checkmark \checkmark$$
- (5)
- 1.4.2 When $T_2/T_1 = 0,5$
- $T \propto I_a$ shunt motor
- $$T_2/T_1 = I_{a2}/I_{a1} = 0,5 \checkmark$$
- $$I_{a2} = 0,5 \times I_{a1} = 0,5 \times 50 = 25 \text{ A} \checkmark$$
- $$E_2 = V - I_a R_a$$
- $$= 250 - (25)(0,2) = 245 \text{ V} \checkmark$$
- $$E_1/E_2 = N_2/N_1$$
- $$N_2/1000 = \frac{245}{240} \checkmark$$
- $$N_2 = 1021 \text{ r/min} \checkmark$$
- (5)
- 1.5
- $$P = 450 \text{ kW}$$
- $$V = 380 \text{ V}$$
- $$I = P/V = \frac{450\,000}{380} = 1184 \text{ A}$$
- $$P = 3 \text{ (6 poles)}$$
- $$C = 2p \text{ (lap connected winding)}$$
- $$= 2(3) = 6$$

$$Z = 180$$

$$\theta = 0^\circ$$

Compole $At/p = 1, 3$ armature At/p

$$\begin{aligned}\text{Cross } At/p &= \frac{IZ}{2c2p} \left[1 - \frac{4\theta}{360^\circ} \right] \\ &= \frac{(1184)(180)}{2(6)2(3)} \left[1 - \frac{4(0^\circ)}{360^\circ} \right] \checkmark \\ &= 2961 [1 - 0] \\ &= 2961 \text{ At/p} \checkmark\end{aligned}$$

$$\begin{aligned}\text{Demag } At/p &= \frac{IZ}{2c2p} \left[\frac{4\theta}{360^\circ} \right] \\ &= 0 \text{ At/p, because } \theta = 0^\circ\end{aligned}$$

$$\text{Armature } A/p = 2961 + 0 = 2961 \text{ At/p} \checkmark$$

For compoles:

$$At/p = 1, 3 \times 2961 = 3849 \checkmark$$

$$I_a = \frac{At/p}{t/p}$$

$$1184 = \frac{3849}{t/p}$$

$$t/p = 3, 25 \checkmark$$

(5)
[20]

QUESTION 2

2.1 $V_t = 84, 86 \sin(1000t + 45^\circ)$
 $i_t = 14, 14 \sin(1000t - 45^\circ)$
 Nature: Pure reactance because the current lags by 90° to the voltage $\checkmark$

Magnitude:

$$X_L = \frac{V}{I} = \frac{0,707 \times 84,86}{0,707 \times 14,14} = 6 \Omega \checkmark$$

$$2\pi f = 1000$$

$$f = \frac{1000}{2\pi} = 159 \text{ Hz} \checkmark$$

$$X_L = 2\pi f L \checkmark$$

$$6 = 2\pi(159)L$$

$$L = 0,006 \text{ H} = 6 \text{ mH} \checkmark$$

(5)

2.2 $Z_1 = 2 - j1 = 2,236 \angle 26,6^\circ \Omega$
 $Z_2 = 3 + j5 = 5,83 \angle 59^\circ \Omega$
 $Z_3 = 1 + j2 = 2,236 \angle 63,4^\circ \Omega$

2.2.1 Refer to FIGURE 1 on Addendum A (attached). (Nothing attached) (2)

$$\begin{aligned}
 2.2.2 \quad Z_1 + Z_2 &= 5 + j4 = 6,4 \angle 38,7^\circ \Omega \checkmark \checkmark \\
 Z_p &= (Z_1 \times Z_2) / (Z_1 + Z_2) = \frac{13,04 \angle 85,6^\circ}{6,4 \angle 38,7^\circ} \checkmark = 2,04 \angle 46,9^\circ \Omega \checkmark \checkmark \checkmark \\
 V_p &= V_1 = I_1 Z_1 = 10(2,236) \checkmark = 22,36 \text{ V} \checkmark \checkmark \checkmark \\
 I_2 &= (V_p / Z_2) = \frac{22,36}{5,83} = 3,835 \text{ A} \checkmark \checkmark \\
 I_3 &= I_1 + I_2 = 10 + 3,835 = 13,835 \text{ A} \\
 V_3 &= I_3 \times Z_3 = 13,835(2,236) = 30,93 \text{ V} \checkmark \checkmark \checkmark \checkmark \\
 V_T &= V_p + V_3 = 22,36 + 30,93 = 53 \text{ V} \checkmark \checkmark \\
 Z_4 &= 3 + j4 = 5 \angle 53,13^\circ \Omega \checkmark \checkmark \\
 I_4 &= \frac{V}{Z} = \frac{53}{5} = 10,6 \text{ A} \checkmark \checkmark \\
 I_T &= I_1 + I_2 + I_4 \\
 &= 10 + 3,835 + 10,6 \checkmark \checkmark \\
 &= 24 \text{ A} \checkmark \checkmark
 \end{aligned}$$

(13)
[20]**QUESTION 3**

$$\begin{aligned}
 3.1 \quad V_L &= 415 \text{ V} \\
 V_L &= \sqrt{3} V_P \\
 V_P &= V_L / \sqrt{3} = \frac{415}{\sqrt{3}} = 239,6 \text{ V} \checkmark \checkmark \\
 I_P &= I_L \\
 X_L &= 2\pi f L = 2\pi (50)(0,02) = 6,283 \Omega \checkmark \checkmark \\
 X_C &= \frac{1}{2\pi f C} = \frac{1000000}{2\pi (50)(31,8)} = 100,1 \Omega \checkmark \checkmark \\
 Z_1 &= R + jX_L = 10 + j6,283 = 11,81 \angle 32,81^\circ \Omega \\
 Z_2 &= R - jX_C = 10 - j100,1 = 100,1 \angle -90^\circ \Omega \\
 Z_1 + Z_2 &= 10 - j93,817 = 94,348 \angle -83,9^\circ \Omega \\
 Z_T &= (Z_1 \times Z_2) / (Z_1 + Z_2) = \frac{1182,18 \angle -57,9^\circ}{94,35 \angle -83,9^\circ} = 12,53 \angle 26^\circ \Omega \checkmark \checkmark \\
 I_P &= V_P / Z_P = \frac{239,6}{12,53} = 19,122 \text{ A} \checkmark \checkmark \\
 I_L &= I_P = 19,122 \text{ A} \dots\dots\dots (\text{Star-connected})
 \end{aligned}$$

(5)

$$\begin{aligned}
 3.2 \quad &\text{Single phase transformer load-sharing} \\
 &33 \text{ kV} / 3,3 \text{ kV} \\
 &\text{Two transformers: 500 kVA and 1000 kVA} \\
 &S_T = 1200 \text{ kVA} \\
 &\cos \phi = 0,8 \text{ lag} \\
 &\phi = 36,87^\circ \\
 Z_1 &= \frac{1000}{500} (1,5 + j6) = 3 + j12 = 12,37 \angle 76^\circ \Omega \checkmark \checkmark \\
 Z_2 &= 1 + j6,2 = 6,28 \angle 80,8^\circ \Omega \\
 Z_1 + Z_2 &= 4 + j18,2 = 18,63 \angle 77,6^\circ \Omega \checkmark \checkmark \\
 S_1 &= S_T \times (Z_2 / (Z_1 + Z_2)) = \frac{1200 \angle -36,87^\circ \times 6,28 \angle 80,8^\circ}{18,63 \angle 77,6^\circ} \checkmark \checkmark \\
 &= 404 \angle -34^\circ \text{ kVA} \checkmark \checkmark \\
 &= 404 \text{ kVA with power factor of 0,82 lagging} \checkmark \checkmark
 \end{aligned}$$

$$S_2 = S_T \times (Z_1 / (Z_1 + Z_2)) = \frac{1200 \angle -36,87^\circ \times 12,37 \angle 76^\circ}{18,63 \angle 77,6^\circ} \checkmark \checkmark$$

$$= 796 \angle -39^\circ \text{ kVA}$$

$$= 796 \text{ kVA with power factor} = 0,77 \text{ lagging} \checkmark \checkmark \quad (7)$$

3.3 30 kVA transformer: 6000/230 V

$$R_1 = 12 \Omega$$

$$R_2 = 0,018 \Omega$$

$$X_e = 26 \Omega$$

$$\cos \phi = 0,8 \text{ lag}$$

$$R_e = R_1 + R_2(N_1/N_2)^2 = 12 + 0,018 \left(\frac{6000}{220} \right)^2 \checkmark \checkmark$$

$$= 12 + 12,249 = 24,25 \Omega \checkmark \checkmark$$

$$I_{FL} = \frac{P}{V} = \frac{30000}{6000} = 5 \text{ A} \checkmark \checkmark$$

$$\text{Regulation} = I_1(R_e \cos \phi + X_e \sin \phi) / V_1$$

$$= 5[(24,25)(0,8) + (26)(0,6)] / 6000 \checkmark \checkmark$$

$$= 0,02917 \text{ per unit} \quad (5)$$

$$= 2,917 \% \checkmark \checkmark$$

3.4

- The same voltage ratio
- The same per unit or percentage impedance
- The same polarity
- The same phase sequence and zero relative phase displacement

(Any 3 × 1) (3)
[20]

QUESTION 4

4.1 $P_T = P_2 + P_1 = 820 + (-480) = 340 \text{ W} \checkmark$

$$\tan \phi = \sqrt{3}(P_2 - P_1) / (P_2 + P_1) = \frac{\sqrt{3}(1300)}{340} = 6,623 \checkmark$$

$$\phi = 81,41^\circ$$

$$\cos \phi = 0,1493$$

For three phase:

$$P_T = \sqrt{3} V_L I_L \cos \phi$$

$$340 = \sqrt{3}(120) I_L (0,1493) \checkmark$$

$$I_L = 10,956 \text{ A}$$

$$I_p = I_L / \sqrt{3} = \frac{10,956}{\sqrt{3}} = 6,326 \text{ A} \checkmark$$

$$Z_p = V_p / I_p = \frac{120}{6,326} = 18,97 \Omega \checkmark \quad (5)$$

4.2 $P = 20 \text{ kW}$ Output power of the motor

$$\text{Efficiency} = 90\% = 0,9$$

$$\cos \phi = 0,45 \text{ and } \phi = 63,25^\circ \checkmark \checkmark$$

$$P_{in} = \frac{20}{0,9} = 22,222 \text{ kW}$$

$$\therefore P_1 + P_2 = 22222 \text{ W} \checkmark$$

$$\tan \phi = \tan 63,25^\circ = 1,9845$$

$$\tan \phi = \sqrt{3}(P_2 - P_1)/(P_1 + P_2)$$

$$1,9845 = \sqrt{3}(P_2 - P_1)/(22222)$$

$$(P_2 - P_1) = 25461 \text{ W} \checkmark \checkmark$$

Equation 1 + Equation 2:

$$2P_2 = 47683$$

$$P_2 = 23842 \text{ W}$$

Substitute P_2 into Equation 1

$$P_1 + 23842 = 22222$$

$$P_1 = -1620 \text{ W}$$

$$W_1 = P_1 = -1620 \text{ W} \checkmark \checkmark$$

$$W_2 = P_2 = 23842 \text{ W} \checkmark \checkmark$$

(5)

4.3 Transmission line (three phase)

$$S = 2500 \text{ kVA}$$

$$V_R = 11 \text{ kV}$$

$$\cos \phi = 0,8$$

$$I_L = \frac{S}{\sqrt{3}V} = \frac{2500}{\sqrt{3}(11)} = 131,2159 \text{ A} \checkmark$$

$$\begin{aligned} \text{Volt-drop} &= IR \cos \phi + IX \sin \phi \\ &= I[R \cos \phi + X \sin \phi] \checkmark \\ &= 131,22[(3)(0,8) + (6)(0,6)] \\ &= 787 \text{ V (phase value)} \checkmark \\ &= 1363 \text{ V (line value)} \checkmark \end{aligned}$$

$$V_s = V_R + \text{Volt-drop}$$

$$= 11 \text{ kV} + 1,363 \text{ kV} = 12,363 \text{ kV} \checkmark$$

OR

$$V_s = V_R \angle 36.87^\circ + IR \angle 0^\circ + IX \angle 90^\circ$$

$$V_s = \frac{11000}{\sqrt{3}} \angle 36.87^\circ + (131.22 \times 3) \angle 0^\circ + (131.22 \times 6) \angle 90^\circ \checkmark$$

$$= 6350.853 \angle 36.87^\circ + (393.647 + j0) + (0 + j787.295) \checkmark$$

$$= (5080.676 + j3810.521) + (393.647 + j787.295) \checkmark$$

$$= 5474.322 + j4597.816 = 7148.994 \angle 40.026^\circ \checkmark$$

$$V_{s(\text{Line})} = (\sqrt{3} \times 7148.994) = 12382.421 \text{ V} = 12.382 \text{ kV}$$

$$\text{Regulation} = 0.1256 = 12.56\% \checkmark \checkmark$$

$$\begin{aligned} 4.3.1 \quad \text{Regulation} &= (V_s - V_R)/V_R = \frac{1,363}{11} = 0,1239 \text{ pu} \checkmark \checkmark \checkmark \checkmark \\ &= 12,39\% \end{aligned}$$

(7)

4.3.2 $\text{Losses} = 3I^2R$ (W cancelled)
 $= 3(131,2159)^2(3)✓$
 $= 154,959 \text{ kW}$
 $= \frac{154,959}{0,8} = 193,7 \text{ kVA}✓$
 $\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Output}}{\text{Output} + \text{Losses}} = \frac{2500}{(2500 + 193,7)} = 0,928 \text{ pu}$
 $= 92,8 \%✓$

(3)
[20]**QUESTION 5**

5.1 When the load varies on the alternator, its terminal voltage will also vary because of the change in power-factor✓ and the internal volt-drop inside the machine due to its impedance.✓ (2)

5.2 • Their EMFs must be equal
 • Their EMFs must have the same frequency
 • Their EMFs must be in phase
 • Successive EMFs (in poly-phase machines) must have the same angular displacement, i.e. 120° or three-phase machines (Any 3×1) (3)

5.3 Slip-ring induction motor, star-connected

$$E_o = \frac{55}{\sqrt{3}} = 31,754 \text{ V}$$

$$R_o = 0,7 \Omega$$

$$X_o = 5 \Omega$$

$$\text{Rotor} = 0,7 + j5$$

$$R_{st} = 4 \Omega$$

$$X_{st} = 3 \Omega$$

$$\text{Starter} = 4 + j3$$

5.3.1 At starting (stand-still)

$$Z_o = \sqrt{[(0,7 + 4)^2 + (5 + 3)^2]} \\ = 9,278 \Omega✓$$

$$I_o = E_o/Z_o = \frac{31,754}{9,278} = 3,423 \text{ A}✓✓ \quad (3)$$

5.3.2 With $s = 5\% = 0,005$

$$E_2 = sE_o = (0,05)(31,75) = 1,5877$$

$$Z_2 = \sqrt{[(R_2)^2 + (sX_o)^2]} \\ = \sqrt{[(0,7)^2 + (0,05 \times 5)^2]} \\ = 0,7433 \Omega✓$$

$$I_2 = E_2/Z_2 = \frac{1,5877}{0,7433} = 2,136 \text{ A}✓ \quad (2)$$

5.4 Alternator (three phase)

$$E_L = 15 \text{ kV}$$

$$E_o = \frac{15000}{\sqrt{3}} = 8660 \text{ V per phase} \checkmark$$

$$\Phi = 0,15 \text{ Wb}$$

$$K_p = 1$$

3 slots per pole per phase

$$N = 250$$

$$K_d = 0,96$$

$$E_o = 2,22k_d k_p \Phi f Z_{\text{phase}}$$

$$8660 = 2,22(0,96)(1)(0,15)(50)Z_{\text{phase}} \checkmark$$

$$Z_{\text{phase}} = 541,81 \text{ and}$$

$$Z_T = 3(541,81)$$

$$= 1625 \checkmark$$

$$f = \frac{np}{60}$$

$$50 = \frac{250 \times p}{60}$$

$$p = 12 \text{ (pole pairs)}$$

$$p = 24 \text{ poles} \checkmark$$

$$3 = \frac{\text{slots}}{\text{poles} \times \text{phases}} = \frac{\text{slots}}{24 \times 3}$$

$$\text{Slots} = 3 \times 24 \times 3 = 216$$

$$\text{Conductors per slot} = \frac{Z_T}{\text{slots}} = \frac{1625}{216} = 7,523 \text{ say } 8 \checkmark$$

(5)

5.5 Alternators in parallel (three-phase star connection)

$$X_s = 7,5 \Omega$$

$$5.5.1 \quad I_p = E_z / 2X_s$$

$$64 = E_z / 2(7,5) \checkmark \checkmark$$

$$E_z = 960 \text{ V} \checkmark \checkmark$$

$$E_a = E_b - E_z$$

$$= 3800 - 960 = 2840 \checkmark \checkmark$$

(3)

$$5.5.2 \quad E_p = (E_b + E_a) / 2$$

$$= (3800 + 2840) / 2 \checkmark \checkmark$$

$$= 3320 \text{ V}$$

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

$$= \sqrt{3} (3320)$$

$$= 5750 \text{ V} \checkmark \checkmark$$

(2)

[20]**TOTAL: 100**