



higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

17 April 2024

This marking guideline consists of 6 pages.

QUESTION 1

1.1 Commutation is the reversal of current caused by the commutator. (1)

1.2

- Armature ampere turns/pole = $\frac{IZ}{4cp} = \frac{820 \times 760}{4 \times (2 \times 3) \times 3} = \frac{623200}{72} = 8655,56 \text{ At}$
- Compole At/pole = $0,7 \times \frac{IZ}{4cp} = 0,7 \times 8655,56 = 6058,89 \text{ At}$
- Turns/pole = $\frac{\text{compole At/p}}{\text{armature current}} = \frac{6058,89}{820} = 7,388 \text{ turns/pole, say } 8 \quad (3 \times 2) \quad (6)$

1.3 1.3.1 $E = V - I_a R_a = 520 - 200(0,35) = 520 - 70 = 450 \text{ V} \quad (2)$

1.3.2 $E = \frac{2p\Phi NZ}{60c}$ thus

$$N = \frac{E60c}{2p\Phi Z} = \frac{450 \times 60 \times 2}{2 \times 3 \times 0,08 \times 1400} = \frac{54000}{672} = 80,36 \text{ r/min} \quad (3)$$

1.4 $E_1 = V - I_{a1} R_a = 500 - 5(0,5) = 500 - 2,5 = 497,5 \text{ V} \checkmark \checkmark$

$E_2 = V - I_{a2} R_a = 500 - 75(0,5) = 500 - 37,5 = 462,5 \text{ V} \checkmark \checkmark$

E_1

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

$$N_2 = \frac{N_1 E_2}{E_1} = \frac{1000 \times 462,5}{497,5} = 929,65 \text{ r/min} \checkmark \checkmark$$

Speed reduction = $N_1 - N_2 = 1000 - 929,65 = 70,35 \text{ r/min} \checkmark \checkmark \quad (8)$
[20]

QUESTION 2

$$2.1 \quad Z_p = \frac{Z_B \times Z_C}{Z_B + Z_C} = \frac{(8 + j3)(10 - j6)}{(8 + j3) + (10 - j6)} = \frac{8,544 \angle 20,556^\circ \times 11,66 \angle -30,96^\circ}{18 - j3} \checkmark \checkmark$$

$$= \frac{99,623 \angle -10,404^\circ}{18,25 \angle -9,46^\circ} = 5,46 \angle -0,944^\circ = (5,459 - j0,08995) \Omega \checkmark \checkmark \checkmark$$

$$Z_T = Z_s + Z_p = (6 + j9) + (5,459 - j0,08995)$$

$$= (6 + 5,459) + j(9 - 0,08995) \checkmark$$

$$= 11,459 + j8,91$$

$$= 14,52 \angle 37,867^\circ \Omega \checkmark$$

$$I_T = \frac{V_T}{Z_T} = \frac{230 \angle 0^\circ}{14,52 \angle 37,867^\circ} = 15,84 \angle -37,867^\circ \text{ A} \checkmark \checkmark$$

Pf $\cos 37,897 = 0,789 \text{ lagging} \checkmark \quad (10)$

2.2

$$f = \frac{1}{2\pi L} \times \sqrt{\frac{L}{C} - R^2} = 1 \text{ MHz}$$

$$1 \times 10^6 = \frac{1}{2 \times 3,142 \times 350 \times 10^{-6}} \times \sqrt{\frac{350 \times 10^{-6}}{C} - 350^2} \checkmark$$

$$= 454,67 \times \sqrt{\frac{350 \times 10^{-6}}{C} - 350^2} \checkmark$$

$$\sqrt{\frac{350 \times 10^{-6}}{C} - 350^2} = \frac{1 \times 10^{-6}}{454,67}$$

$$\frac{350 \times 10^{-6}}{C} - 350^2 = 2199^2 \checkmark$$

$$\frac{350 \times 10^{-6}}{C} = 2199^2 + 350^2$$

$$350 \times 10^{-6} = 4958101 \times C \checkmark$$

$$C = \frac{350 \times 10^{-6}}{4958101} = 7,059 \times 10^{-11} \text{ F}$$

$$= 70,59 \text{ pF} \checkmark$$

(5)

2.3

- It costs the consumer more for the same load.
- Thicker cables have to be used.
- Increased copper losses (I^2R).
- It limits the output of both generators and transformers.
- It reduces the efficiency of the plant (any place where there are machines).

(5)

[20]

QUESTION 3

3.1

Building up the core of the transformer with laminations reduces eddy currents.

(2)

3.2

$$3.2.1 \quad \frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$$V_2 = \frac{V_1 \times N_1}{N_2} = \frac{220 \times 1}{25} = 8,8 \text{ V} \checkmark \checkmark \checkmark$$

(3)

$$3.2.2 \quad \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

$$I_1 = I_2 \times \frac{N_2}{N_1} = 10 \times \frac{1}{25} = 0,4 \text{ A} \checkmark \checkmark \checkmark$$

Or

$$\frac{V_1}{V_2} = \frac{I_2}{I_1}$$

$$\frac{220}{8,8} = \frac{10}{I_1} \quad I_1 = 0,4 \text{ A} \checkmark \checkmark \checkmark$$

(3)

- 3.3
- Making the transformer's window long and narrow
 - Arranging the primary and secondary windings concentrically
 - Using a shell-type construction
 - Sandwiching the primary and secondary windings
- (4)

3.4 $R_e = R_2 + R_1 \left(\frac{V_2}{V_1} \right)^2 = 0,2 + 1,3 \left(\frac{250}{2200} \right)^2 = 0,2 + 1,3(0,1126) = 0,2168 \Omega \checkmark \checkmark$

$$X_e = X_2 + X_1 \left(\frac{V_2}{V_1} \right)^2 = 0,4 + 4,6 \left(\frac{250}{2200} \right)^2 = 0,4 + 0,06 = 0,46 \Omega \checkmark \checkmark$$

$$I_2 = \frac{S}{V_2} = \frac{30 \times 10^3}{250} = 120 \text{ A} \checkmark$$

$$Z_e = R_e + jX_e = 0,2168 + j0,46 = 0,509 \angle 64,77^\circ \Omega \checkmark$$

$$\begin{aligned} V_2 &= V_2 - I_2 Z_e \cos(\phi_e - \phi_2) = 250 - 120 \times 0,509 \times \cos(64,77^\circ - 36,87^\circ) \checkmark \\ &= 250 - 53,98 \\ &= 196,02 \text{ V} \checkmark \end{aligned}$$

Or

$$I_p = \frac{S}{V_p} = \frac{30\,000}{2\,200} = 13.636 \text{ A} \checkmark$$

$$\begin{aligned} \text{Reg} &= \frac{I_p [R_{e1} \cos \phi + X_{e1} \sin \phi]}{V_p} \\ &= \frac{13.636 [16.785 \times 0.8 + 35.576 \times 0.6]}{2200} \checkmark \checkmark \checkmark \\ &= 0.216 \checkmark \end{aligned}$$

$$\begin{aligned} V_2 &= V_2 - (V_2 \times \text{Reg}) \checkmark \\ &= 250 - (250 \times 0.216) \checkmark \\ &= 196 \text{ V} \checkmark \end{aligned}$$

(8)
[20]

QUESTION 4

4.1 $V_{ph} = E_{rms}$

$$E_{rms} = \frac{2,22 \Phi N_p Z K_p K_d}{60} \checkmark$$

$$Z = \frac{E_{rms}}{2,22 \Phi N_p K_p K_d} = \frac{2\,400}{2,22 \times 0,04 \times 50 \times 0,86 \times 0,96} = 654,72 = 655 \text{ conductors/phase} \checkmark \checkmark$$

$$p = \frac{f \times 60}{N} = \frac{3\,000}{600} = 5 \text{ pairs} = 10 \text{ poles} \checkmark \checkmark \checkmark$$

$$\begin{aligned} \text{Slots} &= \text{poles} \times \text{slots per pole} \\ &= 10 \times 4 \\ &= 40 \checkmark \end{aligned}$$

$$\text{Conductors per slot} = \frac{655}{40} = 16,375 = 17 \checkmark$$

4.2

$$\begin{aligned}
 E_z &= E_a + E_b \\
 &= 2200\angle 90^\circ + 2250\angle -130^\circ \\
 &= (0 + j2200) + (-1446,27 - j1723,6) \checkmark \\
 &= -1446,27 + j476,4 \\
 &= 1522,7\angle 161,77^\circ \text{ V} \checkmark
 \end{aligned}
 \tag{4}$$

Or

$$\begin{aligned}
 E_R &= E_A\angle 0 + E_B\angle 180 - \phi \\
 E_R &= 2200\angle 0^\circ + 2250\angle 140^\circ \checkmark \\
 &= 476.401 + j1446.272 \\
 &= 1522.71\angle 71.768^\circ \text{ V} \checkmark
 \end{aligned}$$

$$I_c = \frac{E_z}{Z_T} = \frac{1522,7\angle 161,77^\circ}{20\angle 90^\circ} = 76,135\angle 71,77^\circ \text{ A} \checkmark \checkmark$$

4.3

$$N_s = \frac{f \times 60}{p} = \frac{50 \times 60}{5} = 600 \text{ r/min} \checkmark \checkmark$$

$$\begin{aligned}
 N_R &= N_s - (s \times N_s) = 600 - (0.06 \times 600) \checkmark \\
 &= 564 \text{ r/min} \checkmark
 \end{aligned}
 \tag{4}$$

4.4

- Their EMFs must be the same
- Their EMFs must have the same frequency
- Their EMFs must be in phase
- Their EMFs must have the same angular displacement

(4)
[20]

QUESTION 5

5.1

$$a = \frac{\pi d^2}{4} = \frac{(3,142 \times 19 \times 10^{-3})^2}{4} = 283,57 \times 10^{-6} \text{ m}^2 \checkmark$$

$$R = \frac{\rho l}{a} = \frac{0,0173 \times 10^{-6} \times 15000}{283,57 \times 10^{-6}} = 0,915 \Omega \checkmark$$

$$\begin{aligned}
 L &= 0,05 + 0,2 \ln\left(\frac{d}{r}\right) \text{ mH/km} \\
 &= [0,05 + 0,2 \ln\left(\frac{1100}{9,5}\right)] \times 15 \checkmark \\
 &= 15 \text{ mH} \checkmark
 \end{aligned}$$

$$\begin{aligned}
 C &= \frac{1}{18 \ln\left(\frac{d}{r}\right)} \mu\text{f/km} \\
 &= \left(\frac{1}{18 \ln\left(\frac{1100}{9,5}\right)} \mu\text{f}\right) \times 15 \checkmark \\
 &= 0.176 \mu\text{f} \checkmark
 \end{aligned}
 \tag{6}$$

$$5.2 \quad P_{\text{loss}} = \% \text{loss} \times P_r = 12\% \times 3,5 = 420 \text{ kW} \checkmark \checkmark$$

$$I_r = \frac{P_r}{\sqrt{3} V_r \cos \phi} = \frac{3500000}{\sqrt{3} \times 11000 \times 0,85} = 216,120 \text{ A} \checkmark \checkmark$$

$$P_{\text{loss}} = 3 I^2 R$$

$$R = \frac{P_{\text{loss}}}{3 I^2} = \frac{420\,000}{(216,120)(216,120) \times 3} = 2,997 \, \Omega / \text{phase} \checkmark \checkmark \quad (6)$$

$$5.3 \quad 5.3.1 \quad \text{Total Power} = W_1 + W_2 = 15 + (-5) = 10 \text{ kW} \quad (2)$$

$$5.3.2 \quad \tan \phi = \frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)} = \frac{\sqrt{3}(15 - (-5))}{(15 + (-5))} = \frac{\sqrt{3}(20)}{10} = 3,464 \checkmark \checkmark$$

$$\phi = \tan^{-1}(3,464)$$

$$= 73,397^\circ \checkmark$$

$$\text{And } \cos \phi = 0,2774 \checkmark \quad (4)$$

$$5.3.3 \quad I_L = \frac{P_{\text{input}}}{\sqrt{3} V_L \cos \phi} = \frac{10 \times 10^3}{\sqrt{3} \times 400 \times 0,2774} = 52 \text{ A} \checkmark \checkmark \quad (2)$$

[20]

TOTAL: 100