



**higher education
& training**

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

28 November 2023

This marking guideline consists of 10 pages.

QUESTION 1

- 1.1 Armature reaction is the distortion of the pole flux due to armature flux. (1)

OR

Armature reaction is the distortion of the main field due to the interaction between the two fields (the main field flux and the flux around the armature conductors).

OR

Armature reaction is the distortion of the main magnetic field entering and leaving the armature caused by the magnetic field of the armature.

- 1.2 1.2.1 Demagnetising ampere turns per pole:

$$\begin{aligned}
 &= \frac{IZ}{4cp} \times \frac{4\theta}{360} \\
 &= \frac{120 \times 960}{4 \times 2 \times 3} \times \frac{4 \times 4}{360} \checkmark \\
 &= 4\,800 \times 0,0444 \\
 &= 213,12 \text{ At} \checkmark
 \end{aligned}$$

Cross-magnetising ampere turns per pole:

$$\begin{aligned}
 &= \left(\frac{IZ}{4cp} \right) - \left(\frac{IZ}{4cp} \times \frac{4\theta}{360} \right) \\
 &= \frac{IZ}{4cp} \left(1 - \frac{4\theta}{360} \right) \\
 &= \frac{120 \times 960}{4 \times 2 \times 3} \left(1 - \frac{4 \times 4}{360} \right) \checkmark \\
 &= 4\,800 (1 - 0,0444) \\
 &= 4\,586,88 \text{ At} \checkmark
 \end{aligned}$$

(4)

1.2.2 $I_f = \frac{\text{demag At}}{\text{number of turns}} = \frac{213,12}{1\,100} \checkmark = 0,194 \text{ A} \checkmark$

(2)

1.3 $I_L = \frac{P_{gen}}{V} = \frac{8\,000}{300} = 26,667 \text{ A} \checkmark$

$$\begin{aligned}
 I_a &= I_L + I_{sh} = 26,667 + \frac{V}{R_{sh}} = 26,667 + \frac{300}{300} = 26,667 + 1 \\
 &= 27,667 \text{ A} \checkmark
 \end{aligned}$$

$$\begin{aligned}
 E_{gen} &= V + I_a R_a = 300 + (27,667 \times 0,6) = 300 + 16,6002 \\
 &= 316,6002 \text{ V} \checkmark
 \end{aligned}$$

$$\begin{aligned}
 P_{gen} &= E_{gen} \times I_a = 316,6002 \times 27,667 \\
 &= 8\,759,378 \text{ W} \checkmark
 \end{aligned}$$

$$\begin{aligned}
 P_{input} &= P_{gen} + \text{losses} = 8\,759,378 + 500 \\
 &= 9\,259,378 \text{ W} \checkmark
 \end{aligned}$$

$$\begin{aligned}
 P_{input} &= \frac{2\pi NT}{60} \\
 T &= \frac{P \times 60}{2\pi N} = \frac{9\,259,378 \times 60}{2\pi \times 1\,300}
 \end{aligned}$$

$$= 68,016 \text{ Nm} \checkmark$$

(6)

OR

$$\begin{aligned}
 P_{in} &= P_o + \text{losses} \\
 &= 8\,000 + 500 \\
 &= 8\,500 \text{ W} \checkmark
 \end{aligned}$$

$$I_L = \frac{P_{in}}{V} = \frac{8\,500}{300} = 28,333 \text{ A} \checkmark$$

$$R_{sh} = \frac{V}{R_{sh}} = \frac{300}{300} = 1 \text{ A}$$

$$I_a = I_L + I_{sh} = 28,333 + 1 = 29,333 \text{ A} \checkmark$$

$$E = V + I_a R_a = 300 + (29,333 \times 0,6) = 317,6 \text{ V} \checkmark$$

$$T = \frac{E I_a}{2\pi N} = \frac{317,6 \times 29,333}{2\pi \times 21,667} = 68,042 \text{ Nm} \checkmark \checkmark$$

- 1.4
- Armature reaction
 - Commutation
 - Changes in armature current

(Any 2 × 1) (2)

1.5

$$\begin{aligned}
 E &= V - I_a R_a = 550 - 100(0,4) \\
 &= 550 - 40 \checkmark \\
 &= 510 \text{ V} \checkmark
 \end{aligned}$$

And

$$E = \frac{2p\Phi NZ}{60c} \text{ therefore}$$

$$N = \frac{E60c}{2p\Phi Z} \checkmark = \frac{510 \times 60 \times 2}{2 \times 4 \times 0,07 \times 900} = \frac{61\,200}{504} \checkmark = 121,43 \text{ r/min} \checkmark$$

(5)
[20]

QUESTION 2

- 2.1 2.1.1 $X_C = \frac{1}{2\pi fC}$
- $$= \frac{1}{2 \times 3,142 \times 50 \times 300 \times 10^{-6}} = 10,609 \, \Omega \checkmark$$
- $$Z_A = R_A - jX_C = 15 - j10,609 = 18,373 \angle -35,27^\circ \, \Omega \checkmark$$
- $$I_A = \frac{V_A}{Z_A} = \frac{230 \angle 0^\circ}{18,373 \angle -35,27^\circ} \checkmark = 12,52 \angle 35,27^\circ \, A \checkmark$$
- $$I_B = I_T - I_A = 13 \angle 0^\circ - 12,52 \angle 35,27^\circ$$
- $$= (13 + j0) - (10,22 + j7,229) \checkmark$$
- $$= 2,78 - j7,229$$
- $$= 7,745 \angle -68,97^\circ \, A \checkmark \quad (6)$$
- 2.1.2 Power factor = $\cos 68,97^\circ \checkmark$
- $$= 0,359 \text{ lagging} \checkmark \quad (2)$$
- 2.1.3 $Z_B = \frac{V}{I_B} = \frac{230 \angle 0^\circ}{7,745 \angle -68,97^\circ \, A} = 29,697 \angle 68,97^\circ \, \Omega \checkmark \checkmark \quad (2)$
- 2.1.4 $Z_B = R - jX = 10,657 + j27,7129 \checkmark$
- $$= 27,719 \, \Omega \checkmark \quad (2)$$
- 2.1.5 $\therefore R = 10,657 \, \Omega \quad (1)$
- 2.2 $Z = \frac{L}{CR} = \frac{0,6 \times 10^{-3}}{0,0003 \times 10^{-6} \times 20} = 100 \, 000 \, \Omega = 100 \, k\Omega \checkmark \checkmark \quad (2)$
- 2.3
 - Using capacitor banks in parallel with the supply
 - Using synchronous motors instead of induction motors
 - Using phase advancers(3)
- 2.4
 - The impedance is at its maximum.
 - The resultant current drawn from the supply (I) is at its minimum.
 - The resultant current (I) will be in phase with the voltage (unity power factor).(Any 2 × 1) (2)
- [20]**

QUESTION 3

- 3.1 Useful flux is the flux that links the two windings and has its path through the iron core, while leakage flux is the magnetic flux produced by the primary winding that neither links to the secondary winding nor has its path through the iron core, but instead passes through the winding insulation. (2)

- 3.2 Resistance referred to secondary:

$$\begin{aligned} R_e'' &= R_2 \left(\frac{V_2}{V_1} \right)^2 \\ &= 0,6 + 9 \left(\frac{600}{3\,300} \right)^2 \\ &= 0,6 + 0,2975 \\ &= 0,898 \, \Omega \checkmark \end{aligned}$$

Reactance referred to secondary:

$$\begin{aligned} X_{e''} &= X_2 + X_1 \left(\frac{V_2}{V_1} \right)^2 \\ &= 0,9 + 16 \left(\frac{600}{3\,300} \right)^2 \\ &= 0,9 + 0,529 \\ &= 1,429 \, \Omega \checkmark \end{aligned}$$

$$\begin{aligned} I_{2FL} &= \frac{S}{V_2} \\ &= \frac{15 \times 10^3}{600} \checkmark \\ &= 25 \, A \checkmark \end{aligned}$$

$$\begin{aligned} \bar{z}_e'' &= R_e'' + jX_e'' \\ &= 0,898 + j1,429 \checkmark \\ &= 1,688 \angle 57,85^\circ \, \Omega \checkmark \end{aligned}$$

$$\begin{aligned} V_2 &= V_2 - I_2 \cos(\phi_e - \phi_2) \\ &= 600 - 25 \times 1,688 \cos(57,85^\circ - 36,87^\circ) \checkmark \\ &= 600 - 39,40 \\ &= 560,6 \, V \checkmark \end{aligned}$$

OR

(8)

$$\begin{aligned}\text{Reg} &= \frac{I_2(Re \cos\phi + Xe \sin\phi)}{V_2} \\ &= \frac{25(0,898 \times 0,8 + 1,429 \times 0,6)}{600} \\ &= 0,0657 \text{ pu}\end{aligned}$$

$$\begin{aligned}V_2 &= 600 - (600 \times 0,0657) \\ &= 560,58 \text{ V}\end{aligned}$$

3.3 Taking the 1 400-kVA transformer as the base:

$$\begin{aligned}R'_a &= \frac{T_a}{T_b} (R_a) \\ &= \frac{1\,400}{1\,000} (2\%) \\ &= 2,8\% \checkmark\end{aligned}$$

$$\begin{aligned}X'_a &= \frac{T_a}{T_b} (X_a) \\ &= \frac{1\,400}{1\,000} (6\%) \\ &= 8,4\% \checkmark\end{aligned}$$

$$\begin{aligned}\bar{Z}_{series} &= \bar{Z}_a + \bar{Z}_b \\ &= (2,8 + j8,4) + (3 + j7) \\ &= (5,8 + j15,4) \\ &= 16,46 \angle 69,36^\circ \% \checkmark\end{aligned}$$

$$\begin{aligned}\bar{S}_a &= \bar{S}_t \left(\frac{\bar{Z}_B}{\bar{Z}_A + \bar{Z}_B} \right) \\ &= 2\,000 \angle -31,79^\circ \left(\frac{3 + j7}{16,46 \angle 69,36^\circ} \right) \\ &= 2\,000 \angle -31,79^\circ \left(\frac{7,616 \angle 66,80^\circ}{16,46 \angle 69,36^\circ} \right) \checkmark \\ &= \left(\frac{1\,5232 \angle 35,01^\circ}{16,46 \angle 69,36^\circ} \right) \checkmark \\ &= 925 \angle -34,35^\circ \text{ kVA (below the 1 000-kVA rating)} \checkmark\end{aligned}$$

$$\begin{aligned}\bar{S}_b &= \bar{S}_r \left(\frac{\bar{Z}_a}{\bar{Z}_A + \bar{Z}_B} \right) \\ &= 2\,000 \angle -31,79^\circ \left(\frac{2,8 + j8,4}{16,46 \angle 69,36^\circ} \right) \\ &= 2\,000 \angle -31,79^\circ \left(\frac{8,85 \angle 71,57^\circ}{16,46 \angle 69,36^\circ} \right) \checkmark \\ &= \left(\frac{17\,700 \angle 39,78^\circ}{16,46 \angle 69,36^\circ} \right) \\ &= 1\,075,33 \angle -29,58^\circ \text{ kVA (below the 1 400-kVA rating)} \checkmark\end{aligned}$$

(8)

OR

$$\begin{aligned}
 Z_a &= (0,02 + j0,06) \frac{1\,400}{1\,000} \\
 &= 0,028 + j0,084 \\
 &= 0,089 \angle 71,57^\circ \Omega
 \end{aligned}$$

$$\begin{aligned}
 Z_b &= 0,03 + j0,07 \\
 &= 0,076 \angle 66,801^\circ \Omega
 \end{aligned}$$

$$\begin{aligned}
 Z_a + Z_b &= 0,058 + j0,154 \\
 &= 0,165 \angle 69,362^\circ \Omega
 \end{aligned}$$

$$\begin{aligned}
 S_1 &= S_T \angle \phi \times \frac{Z_b}{Z_a + Z_b} \\
 &= 2\,000 \angle -31,79^\circ \times \frac{0,076 \angle 66,801}{0,165 \angle 69,362} \\
 &= 922 \angle -34,351^\circ \text{ kVA}
 \end{aligned}$$

$$\begin{aligned}
 \text{Pf} &= \cos \phi \\
 &= \cos 34,351 \\
 &= 0,826 \text{ lagging}
 \end{aligned}$$

$$\begin{aligned}
 S_2 &= S_T \angle \phi \times \frac{Z_a}{Z_a + Z_b} \\
 &= 2\,000 \angle -31,79^\circ \times \frac{0,089 \angle 71,57}{0,165 \angle 69,362} \\
 &= 1078 \angle -29,582^\circ \text{ kVA}
 \end{aligned}$$

$$\begin{aligned}
 \text{Pf} &= \cos \phi \\
 &= \cos 29,582 \\
 &= 0,869 \text{ lagging}
 \end{aligned}$$

- 3.4
- Hysteresis loss is proportional to AC frequency (f) and magnetic flux density (B). Hysteresis loss $\propto B \cdot f$.
 - Eddy current loss is proportional to the square of flux density, the square of frequency and the square of thickness of laminations. Eddy current loss $\propto B^2 \cdot f^2 \cdot t^2$; therefore, the higher the frequency, the higher the iron core losses.

(2)
[20]

QUESTION 4

4.1 It is the ratio between the voltage (EMF) that is induced by distributing the conductors in different slots to the voltage that would have been induced if all the conductors were concentrated in one slot. (2)

4.2 $E_{rms} = 2,22\Phi f Z k_p k_d$

$$Z = \frac{E_{rms}}{2,22\Phi f k_p k_d} = \frac{E_{rms}}{2,22 \times 0,04 \times 50 \times 1 \times 0,96} = \frac{19\,053}{4,2624} = 4\,470\,\Omega \checkmark \checkmark$$

$$P = \frac{f \times 60}{N} = \text{three pairs} = \text{six poles} \checkmark \checkmark$$

$$\text{Conductors per pole} = \frac{4\,470}{6} = 745 \checkmark$$

$$\text{Conductors per pole per phase} = \frac{745}{3} = 248,33, \text{ say } 249 \checkmark \checkmark$$

$$\text{Conductors per slot per pole per phase} = \frac{249}{3} = 83 \checkmark \quad (8)$$

4.3 $N_s = \frac{f \times 60}{p} = \frac{50 \times 60}{2} = 1\,500 \text{ r/min} \checkmark \checkmark$

$$\begin{aligned} N_R &= N_s - (s \times N_s) \\ &= 1\,500 - (0,04 \times 1\,500) \\ &= 1\,400 \text{ r/min} \checkmark \checkmark \end{aligned} \quad (4)$$

$$\begin{aligned} 4.4.1 \quad \text{Stator output} &= \text{stator input} \times \eta \\ &= 430 \times 0,88 \\ &= 378,4 \text{ kW} \checkmark \checkmark \end{aligned}$$

$$\begin{aligned} 4.4.2 \quad P_{dev} &= \text{stator input} - \text{stator Cu losses} - \text{rotor losses} \\ &= 430 - (12\% \times 430) - 13 \\ &= 365,4 \text{ kW} \checkmark \checkmark \end{aligned}$$

$$\begin{aligned} 4.4.3 \quad \text{Rotor input} &= \frac{2\pi N_s T}{60} \\ T &= \frac{\text{rotor input} \times 60}{2\pi N_s} \\ &= \frac{365,4 \times 10^3 \times 60}{2 \times 3,142 \times 1\,000} \checkmark \\ &= 3\,488,86 \text{ Nm} \checkmark \end{aligned}$$

(3 × 2) (6)
[20]

QUESTION 5

$$5.1 \quad a = \frac{\pi d^2}{4} = \frac{3,142 \times (19 \times 10^{-3})^2}{4} = 283,57 \times 10^{-6} \text{ m}^2 \checkmark$$

$$R = \frac{\rho l}{a} = \frac{0,0173 \times 10^{-6} \times 15\,000}{283,57 \times 10^{-6}} = 0,915 \, \Omega \text{ per conductor} \checkmark \checkmark$$

$$R_t = 0,915 \times 2 = 1,83 \, \Omega \text{ for the route} \checkmark$$

$$\begin{aligned} L &= 0,1 + 0,4 \ln\left(\frac{d_e}{r}\right) \text{ mH/km} \\ &= 0,1 + 0,4 \ln\left(\frac{1\,000}{9,5}\right) \times 1 \checkmark \\ &= 1,9626 \times 15 \\ &= 29,44 \text{ mH} \checkmark \end{aligned}$$

$$\begin{aligned} C &= \frac{1}{36 \text{ Lin} \frac{d-r}{r}} \, \mu\text{f/km} \\ &= \left(\frac{1}{36 \text{ Lin} \left(\frac{1-0,0095}{0,0095} \right)} \right) \times 15 \\ &= 0,089 \, \mu\text{f} \checkmark \checkmark \end{aligned}$$

(8)

$$5.2 \quad P_{\text{in}} = \frac{P_o}{\eta} = \frac{70}{0,9} = 77,8 \text{ kW} \checkmark \checkmark$$

$$\begin{aligned} \cos \phi &= 0,85 \\ \phi &= \cos^{-1}(0,85) \checkmark \\ &= 31,79^\circ \checkmark \end{aligned}$$

$$P_{\text{in}} = W_1 + W_2 = 77,8 \text{ kW} \dots\dots\dots (1) \checkmark$$

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

$$\tan 31,79 = \sqrt{3} \left(\frac{W_1 - W_2}{77,8} \right) \checkmark$$

$$0,6198 = \sqrt{3} \left(\frac{W_1 - W_2}{77,8} \right) \checkmark$$

$$\frac{0,6198}{\sqrt{3}} = \left(\frac{W_1 - W_2}{77,8} \right) \checkmark$$

$$27,84 = W_1 - W_2 \dots\dots\dots (2)$$

$$2W_2 = 77,8 - 27,84 \checkmark$$

$$W_2 = 24,98 \text{ kW} \checkmark$$

And

$$W_1 = 77,8 - 24,98$$

$$W_1 = 52,82 \text{ kW} \checkmark$$

OR

$$\begin{aligned}
 P_{\text{in}} &= \frac{P_o}{\eta} \\
 &= \frac{70}{0,98} \\
 &= 71,778 \text{ kW}
 \end{aligned}$$

$$\begin{aligned}
 I_L &= \frac{P_{\text{in}}}{\sqrt{3}VL \cos \phi} \\
 &= \frac{71,778 \times 10^3}{\sqrt{3} \times 500 \times 0,85} \\
 &= 105,659
 \end{aligned}$$

$$\begin{aligned}
 \cos \phi &= 0,85 \\
 \phi &= \cos^{-1} 0,85 \\
 &= 31,79^\circ \checkmark
 \end{aligned}$$

$$\begin{aligned}
 W_1 &= VLIL \cos(30 + \phi) \\
 &= 500 \times 105,659 \cos(30 + 31,79^\circ) \\
 &= 24,973 \text{ kW}
 \end{aligned}$$

$$\begin{aligned}
 W_2 &= VLIL \cos(30 - \phi) \\
 &= 500 \times 105,659 \cos(30 - 31,79^\circ) \\
 &= 52,804 \text{ kW}
 \end{aligned}$$

(12)
[20]

TOTAL: 100