



higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

26 November 2024

This marking guideline consists of 8 pages.

QUESTION 1

1.1 Series-wound motors are suitable for use in:

- Cranes
- Trains
- Trams
- Motor vehicle starters and
- Gate motors

(Any 4 × 1) (4)

1.2

- Lap wound – for low voltage and high current
- Wave wound – for high voltage and low current

(2)

1.3 1.3.1 $E_1 = V - I_a R_a$ (motor)

$$\begin{aligned}
 &= 260 - (60)(0,25) \checkmark \\
 &= 260 - 15 \\
 &= 245 \text{ V} \checkmark
 \end{aligned}$$

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

$$E_2 = 245 \times \frac{900}{1100}$$

$$= 200,45 \text{ V} \checkmark$$

$$\begin{aligned}
 E_2 &= V - I_a(R_a + x) \\
 200,45 &= 260 - 60(0,25 + x) \\
 200,45 &= 260 - 15 - 60x \\
 x &= 0,743 \Omega \checkmark
 \end{aligned}$$

(5)

1.3.2 $T_2/T_1 = 0,5 I_{a2}/I_{a1} \checkmark$

$$I_{a2} = 0,5 I_{a1} = 30 \text{ A} \checkmark$$

$$E_2 = V - I_{a2} R_a = 260 - 30(0,25) = 252,5 \text{ V} \checkmark$$

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

$$N_2 = \frac{E_2}{E_1} \times \frac{N_1}{1} = 252,5 \times \frac{1100}{245} \checkmark = 1133,67 \text{ r/min} \checkmark$$

(5)

1.4 $At/p = (7 - 5,5) \times 1\,800 \checkmark = 2\,700\text{ At/p} \checkmark$

For series winding $= \frac{2700}{343,74} \checkmark = 8 \checkmark$

OR

$At/p = (7 - 5,5) \times 1\,800 = 2\,700\text{ At/p}$

$IL = p/V$

$= 115\,000 / 340$

$= 338,235\text{ A}$

$I_a = 5,5 + 338,235$

$= 343,74\text{ A}$

Turns $= 2\,700 / 343,74$
 $= 8$

(Any 1 × 4) (4)
[20]

QUESTION 2

2.1 $C_1 = 360 \times 10^{-12}\text{ F } (I_{\max})$
 $C_2 = 340 \times 10^{-12}\text{ F } (I_2 = 0,707 I_{\max}) \checkmark$

$X_{C1} = \frac{1}{2\pi f C_1} = \frac{1 \times 10^{-12}}{2\pi \times 75 \times 10^6 \times 360} = 589,76\ \Omega$

$X_{L1} = X_{L2} = 589,76\ \Omega \text{ (resonance)} \checkmark$

$L = \frac{X_L}{2\pi f} = \frac{589,76}{2\pi \times 75 \times 10^6} = 125,087\ \mu\text{H} \checkmark$

$X_{C2} = \frac{1}{2\pi f C_2} = \frac{10^{-12}}{2\pi \times 75 \times 10^6 \times 340} \checkmark = 624,14\ \Omega \checkmark$

Increase in $X_c = 624,14 - 589,76 = 34,38\ \Omega \checkmark$

$(Z_2)^2 = R^2 + (34,38)^2 \checkmark$

$Z_2 = \sqrt{R^2 + (34,38)^2}$

$I_1 = \frac{V}{Z_1} \text{ and } I_2 = 0,707 I_1 \text{ and } Z_1 = R \text{ (resonance)}$

$$\frac{0,707V}{Z_1} = \frac{V}{Z_2}$$

$$\frac{0,707}{R} = \frac{1}{\sqrt{(R^2 + (34,38)^2)}} \checkmark$$

$$(R^2 + (34,38)^2 = 2R^2$$

$$2R^2 - R^2 = (34,38)^2 \checkmark$$

$$R^2 = (34,38)^2$$

$$R = 34,38 \Omega \checkmark$$

(10)

2.2 2.2.1 $X_L = 2\pi fL = 2\pi(2,2 \times 10^6 \times 350 \times 10^{-6}) \checkmark$
 $= 4838,1 \Omega \checkmark$

$$f_{res} = \frac{1}{2\pi\sqrt{LC}}$$

$$2,2 \times 10^6 = \frac{1}{2\pi\sqrt{(350 \times 10^{-6} \times C)}} \checkmark$$

$$350 \times 10^{-6} \times C = \frac{1}{(2\pi \times 2,2 \times 10^6)^2} \checkmark$$

$$C = 1,5 \times 10^{-11} = 15 \times 10^{-12} F \checkmark$$

OR

$$X_L = 2\pi fL = 2\pi(2,2 \times 10^6 \times 350 \times 10^{-6})$$

$$= 4838,053 \Omega$$

$$X_L = X_C$$

$$4838,053 = 1 / 2\pi \times 2,2 \times 10^6 C$$

$$C = 14,952 \text{ pf}$$

(Any 1 × 5)

(5)

2.2.2 $Z_p = \frac{L}{CR} = \frac{350 \text{ exp } -6}{15 \text{ exp } -12 \times 30} \checkmark = 777,777 \text{ k}\Omega \checkmark$

(2)

2.2.3 $I_t = \frac{V_t}{Z_t} = \frac{80}{784277,778} = 0,102 \text{ mA}$

$$V_L = I_t \times Z_p = 0,102 \times 1,0^{-3} \times 777777 = 79,336 \text{ V} \checkmark$$

$$I_{coil} = \frac{V_L}{Z_L} = \frac{79,336}{30 + j4838,053} = 16,4 \text{ mA} \checkmark \quad \text{OR } 0,016 \text{ A}$$

$$I_c = 2 \times \pi \times 2,2 \times 10^6 \times 1,5 \times 10^{-11} \times 79,336 = 16,4 \text{ mA} \checkmark \quad \text{OR } 0,016 \text{ A}$$

(3)
[20]

QUESTION 3

3.1 3.1.1 $V_{p1} = \frac{V_L}{\sqrt{3}} = \frac{3\,400}{\sqrt{3}} = 1\,963\text{ V}✓$

$V_{p2} = V_{p1} \times \frac{N_2}{N_1} = 1\,963 \times \frac{60}{510}✓ = 230,9\text{ V secondary line voltage}✓$ (3)

3.1.2 $V_{p1} = 3\,400\text{ V}✓$

$V_{p2} = V_{p1} \times \frac{N_2}{N_1} = 3\,400 \times \frac{60}{510} = 400\text{ V}✓$

$V_{L2} = 400 \times \sqrt{3} = 692,8\text{ V}✓$ (3)

3.2 3.2.1 $R_e = 0,8 + 0,06\left(\frac{450}{130}\right)^2 = 1,52\Omega✓$

$X_e = 1,7 + 0,07\left(\frac{450}{130}\right)^2 = 2,54\Omega✓$

$Z_e = \sqrt{(1,52^2 + 2,54^2)} = 2,96\Omega✓$

OR

$Z_e = R_e + jX_e = 1,52 + j\,2,54 = 2,96\angle 59,102$ (3)

3.2.2 $\cos \phi = 0,9$ and $\sin \phi = 0,436✓$

$I_1(\text{full load}) = \frac{S}{V} = \frac{245\,000}{2650} = 92,45\text{ A}✓$

$V_{\text{reg}}(0,9 \text{ lagging}) = \frac{I_1(R_e \cos \phi + X_e \sin \phi)}{V_1}✓ = \frac{92,5(1,52 \times 0,9 + 2,54 \times 0,436)}{2650} = 0,086\text{ pu}✓$

$V_{\text{no load}} = 2\,650 \times \frac{130}{450} = 765,56\text{ V}✓$

Decrease of V_2 (between no load and full load)

$= 765,56 \times 0,086 = 65,84\text{ V}✓$

$V_{FL} = 765,56 - 65,84 = 699,7\text{ V}✓$

$V_{\text{reg}}(0,9 \text{ leading}) = \frac{I_1(R_e \cos \phi - X_e \sin \phi)}{V_1} = \frac{92,5(1,52 \times 0,9 - 2,54 \times 0,436)}{2\,650} = 0,009\text{ pu}✓$

$V_{\text{no load}} = 2\,650 \times \frac{130}{450} = 765,56\text{ V}✓$

Increase in V_2 (between no load and full load)

$= 765,56 \times 0,009 = 6,89\text{ V}✓$

$V_{FL} = 765,56 + 6,89 = 772,45\text{ V}✓$

(11)
[20]

QUESTION 4

$$4.1 \quad I_L = \frac{P}{\sqrt{3} V_L \cos \phi} = \frac{820000}{\sqrt{3} \times 33000 \times 0,8} \checkmark = 17,93 \text{ A} \checkmark$$

$$\begin{aligned} V_s &= V_r \angle 0^\circ + I R \angle 0^\circ + I X \angle 90^\circ = 19\,052,56 \angle 36,87^\circ \\ &17,93 \times 40 \angle 0^\circ + 17,93 \times 70 \angle 90^\circ \\ &= 19\,052,56 \angle 36,87^\circ + 717,2 \angle 0^\circ + 1\,255,1 \angle 90^\circ \checkmark \\ &= (15\,242 + j\,11\,431,56) + (717,2 + j\,0) + (0 + j\,1255,1) \checkmark \\ &= 1\,559,2 + j\,12\,686,1 \\ &= 20\,387 \angle 38,48^\circ \text{ V} \checkmark \end{aligned}$$

$$V_L = V_p \times \sqrt{3} = 20\,387 \times \sqrt{3} = 35\,311,32 \text{ V} \checkmark$$

$$\% \text{Reg} = \frac{V_s - V_r}{V_r} \times 100\% = \frac{20387 - 19052,56}{19052,56} \times 100\% \checkmark = 7\% = 0,007 \text{ pu} \checkmark$$

OR

$$\begin{aligned} V_{\text{drop}} &= I R + j I X \\ &= 17,933 (40 + j70) \checkmark \\ &= 717,32 + j1255,31 \\ &= 1\,445,805 \angle 60,255^\circ \end{aligned}$$

$$\begin{aligned} V_s &= V_r (\cos \phi + j \sin \phi) + V_{\text{drop}} \\ &= 19\,052,559 (0,8 + j0,6) + 717,32 + j1255,31 \checkmark \\ &= 15\,959,367 + j\,12\,686,845 \checkmark \\ &= 20\,387,678 \angle 38,483^\circ \text{ V} \checkmark \end{aligned}$$

(8)

$$4.2 \quad \tan \phi = \frac{\sqrt{3}(W_2 - W_1)}{(W_2 + W_1)} = \frac{\sqrt{3}(1\,200 - 650)}{(1\,200 + 650)} = \sqrt{3} \frac{550}{1\,850} = 0,515 \checkmark$$

$$\phi = 27,25^\circ \checkmark$$

$$P_f = \cos 27,25 = 0,89 \checkmark$$

$$I_L = \frac{P_t}{\sqrt{3} V_L \cos \phi} = \frac{1\,850}{\sqrt{3}(150)(0,89)} = 8 \text{ A} \checkmark$$

OR

$$I_p = \frac{W_t}{3 V_p \cos \phi} = \frac{1\,850}{3 \times 150 \times 0,89} = 4,62 \text{ A} \checkmark$$

$$I_p = \frac{I_L}{\sqrt{3}} = \frac{8}{\sqrt{3}} = 4,62 \text{ A} \checkmark$$

$$Z = \frac{V}{I} = \frac{150}{4,62} = 32,47 \, \Omega \checkmark$$

(6)

$$4.3 \quad P_t = W_2 + W_1 = 920 + 295 = 1\,215 \text{ W} \checkmark$$

$$\tan \phi = \frac{\sqrt{3}(W_2 - W_1)}{W_2 + W_1} = \frac{\sqrt{3}(920 - 295)}{(920 + 295)} \checkmark = \sqrt{3} \frac{625}{1215} = 0,891 \checkmark$$

$$\phi = 41,7^\circ$$

$$\cos \phi = 0,747 \checkmark$$

- 4.4 Voltage regulation is the rise or fall in the receiving end voltage of transmission lines when full load is switched off, ✓ provided that the sending end voltage remains constant. ✓

(2)
[20]

QUESTION 5

5.1 5.1.1 $N_s = \frac{60f}{p} \checkmark = \frac{60(50)}{2} \checkmark = 1\,500 \text{ r/min} \checkmark$

OR

$N_s = f/p = 50/2 = 25 \text{ r/s} \quad (\text{Any } 1 \times 3) \quad (3)$

5.1.2 $N_r = N_s - sN_s = 1500 \checkmark - (0,075) \times 1\,500 \checkmark = 1\,387,5 \text{ r/min} \checkmark$

OR

$0,075 = 25 - N_r/N_s$

$1,875 = 25 - n_r$

$N_r = 23,125 \text{ r/s} \quad (\text{Any } 1 \times 3) \quad (3)$

5.1.3 $F_r = s \cdot f$
 $= 0,075 \times 50 \checkmark$
 $= 3,75 \text{ Hz} \checkmark$

(2)

5.2 5.2.1 $Z = 0,8 + j\,9,5$
 $E_A = E_B = 2100 \text{ V}$
 $E_Z = jE_A - (E_B \sin \phi - j E_B \cos \phi) \checkmark$
 $= j\,2\,100 - (2\,100 \sin 40^\circ - j\,2\,100 \cos 40^\circ) \checkmark$
 $= j\,2\,100 - (1\,349,853 + j\,1\,608,693) \checkmark$
 $= -1\,349,853 + j\,491,307 \checkmark$
 $= 1\,436,484 \angle 160^\circ \text{ V} \checkmark$

$I = \frac{E_Z}{2X_s} = \frac{1436,484 \angle 160}{2(9,534)} \checkmark = 75,335 \angle 74,14^\circ \text{ V} \checkmark$

OR

$E_R = E_a \angle 0 + E_B \angle 180 - \phi$
 $= 2\,100 \angle 0 + 2\,100 \angle 180 - 40$
 $= 2\,100 \angle 0 + 2\,100 \angle 140$
 $= 1\,436,485 \angle 70^\circ \text{ V}$
 $= 491,306 + j\,1349,854 \text{ V}$

$I_c = E_R / 2Z$
 $= 1\,436,485 \angle 70 / 19,067 \angle 85,186$
 $= 75,343 \angle -15,186 \text{ A}$

OR

$$\begin{aligned} Z_t &= Z_1 + Z_2 \\ &= 1,6 + j19 \\ &= 19,067 \angle 85,186 \end{aligned}$$

$$\begin{aligned} E_s &= E_a + E_b \\ &= 2\,100 \angle 90 + 2\,100 \angle -130 \\ &= -1\,350 + j\,491,3 \\ &= 1\,436,6 \angle 160 \end{aligned}$$

$$\begin{aligned} I_s &= E_s / Z_t \\ &= 1\,436,6 \angle 160 / 19,067 \angle 85,186 \\ &= 75,345 \angle 74,814 \text{ A} \end{aligned}$$

(Any 1 × 6) (6)

5.2.2 $V = E_a \cos\left(\frac{\theta}{2}\right) = 2\,100 \cos 20^\circ \checkmark = 1\,973,35 \text{ V} \checkmark$

OR

$$\begin{aligned} T_V &= E_a \angle 0 - \frac{1}{2} E_R \\ &= 2\,100 \angle 0 - 1\,436,485 \angle 70 / 2 \\ &= 2\,100 \angle 0 - 718,243 \angle 70 \\ &= 1\,973,354 \angle -20 \text{ V} \checkmark \end{aligned}$$

OR

$$\begin{aligned} V_p &= E_a + E_b / 2 \\ &= 2\,100 \angle 90 + 2\,100 \angle 50 / 2 \\ &= 1\,349,85 + j\,3\,708,69 / 2 \\ &= 3\,946,7 \angle 70 / 2 \\ &= 1\,973,35 \angle 70 \end{aligned}$$

(Any 1 × 2) (2)

5.2.3 $P = VI = 1973,35 \times 75,335 \checkmark = 148,662 \text{ kW} \checkmark$

OR

$$\begin{aligned} P &= VI \cos \theta &= \cos(\theta_{Ic} - \theta_{Tv}) \\ &= 1\,973,354 \times 75,343 \times 0,996 &= \cos(-15,186 - (-20)) \\ &= 148,154 \text{ kW} &= 0,996 \end{aligned}$$

OR

$$\begin{aligned} P &= VI \cos \theta \\ &= 1\,973,35 \times 75,345 \times \cos(74,814 - 70) \\ &= 148,158 \text{ Kw} \end{aligned}$$

(Any 1 × 2) (2)

5.3 Slip is the difference between the synchronous speed of the magnetic field ✓
and the actual speed of the rotor in an induction motor. ✓ (1 × 2) (2)

[20]

TOTAL: