higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

4 December 2023

This marking guideline consists of 9 pages.

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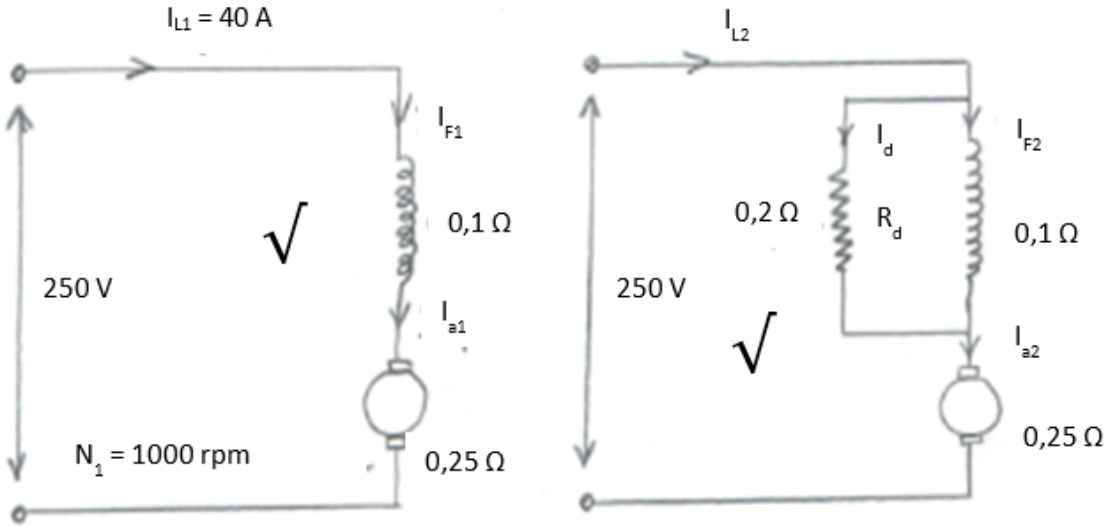
QUESTION 1

1.1 From: $I_a = \frac{V - E}{R_a}$ ✓ and $E = kN\emptyset$ ✓,

When the motor is loaded, the speed (N) decreases, which results in the EMF (E) also decreasing✓ and therefore the armature current will increase.✓ (4)

1.2 1.2.1



(2)

1.2.2 $R_{ac1} = 0,1 + 0,25 = 0,35\ \Omega$✓

$E_1 = 250 - (40)(0,35) = 236$ V✓

$R_{ac2} = 0,25 + \frac{(0,2)(0,1)}{0,2+0,1} = 0,317\ \Omega$✓

$I_{f2} = \left(\frac{0,2}{0,2+0,1}\right) I_{a2} = 0,667\ I_{a2}$✓

$\frac{T_1}{T_2} = \frac{I_{a1} I_{f1}}{I_{a2} I_{f2}}$

$\frac{T_1}{1,2T_1} = \frac{(40)(40)}{I_{a2}(0,667 I_{a2})}$✓

$I_{a2} = \sqrt{\frac{(1,2)(40\times40)}{0,667}} = 53,652\ A$✓

$I_{f2} = (0,667)(53,652) = 35,786$ A✓

$E_2 = 250 - (53,652)(0,317) = 232,992$ V✓

$N_2 = \frac{E_2 N_1 I_{f1}}{E_1 I_{f2}} = \frac{(232,992)(1\,000)(40)}{(236)(35,786)}$✓ $= 1\,103,509\ r/min$✓

(10)
[16]

QUESTION 2

2.1

Fundamental	Third harmonic
$R_1 = 180\ \Omega$	$R_3 = 180\ \Omega$
$X_{c1} = \frac{1}{\omega c} = 127{,}389\ \Omega$ ✓	$X_{c3} = \frac{X_{c1}}{3} = 42{,}463\ \Omega$ ✓
$Z_{R1} = 180 + j\,0$ $= 180 \angle 0^\circ$	$Z_{R3} = 180 + j\,0$ $= 180 \angle 0^\circ$
$Z_{C1} = 0 - j\,127{,}389$ $= 127{,}389 \angle -90^\circ$	$Z_{C3} = 0 - j\,42{,}463$ $= 42{,}463 \angle -90^\circ$
$Z_{R1} + Z_{C1} = 180 - j\,127{,}389$ $= 220{,}517 \angle -35{,}288^\circ$	$Z_{R3} + Z_{C3} = 180 - j\,42{,}463$ $= 184{,}941 \angle -13{,}274^\circ$
$Z_1 = \frac{Z_{R1} \times Z_{C1}}{Z_{R1} + Z_{C1}}$	$Z_3 = \frac{Z_{R3} \times Z_{C3}}{Z_{R3} + Z_{C3}}$
$= \frac{22\,930{,}02 \angle -90^\circ}{220{,}517 \angle -35{,}288^\circ}$	$= \frac{7\,643{,}34 \angle -90^\circ}{184{,}941 \angle -13{,}274^\circ}$
$= 103{,}983 \angle -54{,}712^\circ\ \Omega$ ✓	$= 41{,}329 \angle -76{,}726^\circ\ \Omega$ ✓

$$i = \frac{40}{103{,}983}\sin[314t + 25^0 - (-54{,}712^0)]\ ✓ + \frac{20}{41{,}329}\sin\left[942t - 30^0 - \left(-76{,}762^0\right)\right]\ ✓$$

$$= 0{,}385\sin(314t + 79{,}712^0)\ ✓ + 0{,}484\sin(942t + 46{,}762^0)\ ✓$$

(8)

2.2

$$V_{RMS} = \sqrt{\frac{40^2 + 20^2}{2}} = 31{,}623\ V\ ✓$$

$$I_{RMS} = \sqrt{\frac{0{,}385^2 + 0{,}484^2}{2}} = 0{,}437\ A\ ✓$$

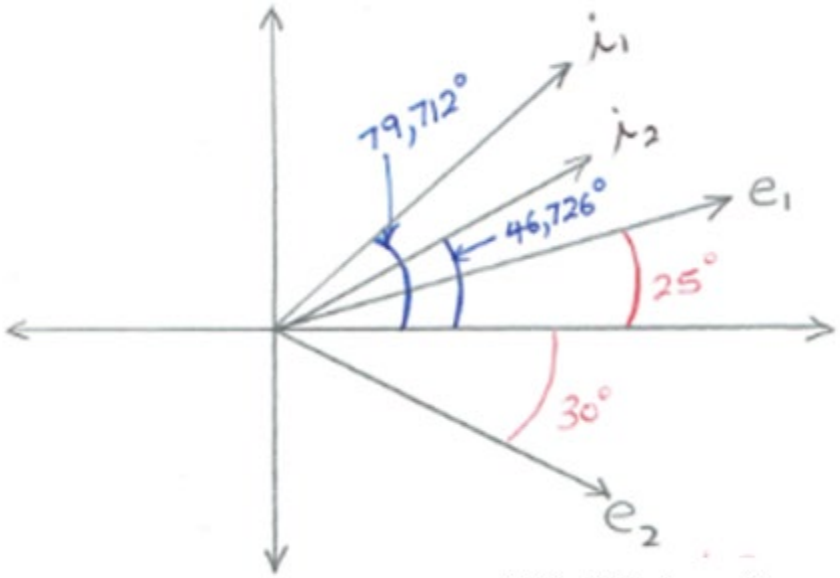
$$P = \frac{40 \times 0{,}385}{2}\cos(54{,}712^0) + \frac{20 \times 0{,}484}{2}\cos(76{,}726^0) = 5{,}559\ W\ ✓$$

$$\cos\theta = \frac{P}{V_{RMS}I_{RMS}} = \frac{5{,}559}{31{,}623 \times 0{,}437}\ ✓ = 0{,}402\ Lagging\ ✓$$

(5)

2.3 Energy = P.t = (5,559)(10× 10^{-3}) = 5,559 mJ (1)

2.4



1 Mark for i_1 and i_2

1 Mark for e_1 and e_2 (2)

[16]

QUESTION 3

3.1
- Eddy current losses✓ in the iron core✓
- Di-electric losses✓ in the insulating material✓
- Hysteresis losses in the iron parts (Any 2 × 2) (4)

3.2 3.2.1

$$\eta_{Max} = \frac{kS\cos\emptyset}{kS\cos\emptyset + 2P_o} \times 100\%$$

$$0{,}92 = \frac{(0{,}8)(250)(0{,}85)}{(0{,}8)(250)(0{,}85) + 2P_o} \checkmark$$

$$= \frac{170}{170+2P_o}$$

$$P_o = 7{,}391 \text{ kW} \checkmark$$ (2)

3.2.2

$$k = \sqrt{\frac{P_o}{P_{sc}}} \Rightarrow P_{sc} = \frac{P_o}{k^2} = \frac{7{,}391}{0{,}8^2} \checkmark = 11{,}548\ kW \checkmark$$ (2)

3.2.3

$$I_1 = \frac{S}{V_1} = \frac{250\,000}{3\,300} = 75{,}758\ A \checkmark$$

$$P_{sc} = I_1^2 R_{e1} \Rightarrow R_{e1} = \frac{11\,548}{75{,}758^2} = 2{,}012\ \Omega \checkmark$$

$$\%\,R = \frac{I_1 R_{e1}}{V_1} \times 100\,\% = \frac{(75{,}758)(2{,}012)}{3\,300} \times 100\,\% \checkmark$$

$$= 4{,}619\,\% \checkmark$$ (4)

3.2.4 P/u regulation = $\frac{I_1[R_{e1}\cos\emptyset + X_{e1}\sin\emptyset]}{V_1} = \frac{75{,}758[(2{,}012)(1)+0]}{3\,300}$ ✓ $= 0{,}046$ ✓ (2)

[14]

QUESTION 4

4.1 It is the ratio✓ of the actual EMF obtained✓ to the EMF that would be obtained if all the conductors were concentrated in one slot only.✓ (3)

4.2 $E_P = \frac{3\,300}{\sqrt{3}} = 1\,905{,}256$ V ✓

$f = \frac{Np}{60}$ $p = \frac{(60)(50)}{1\,000} = 3$ $\therefore\ 6\ poles$✓

Total slots = (4)(6 poles)(3 phases) = 72 ✓

$\varphi = 180° - 150° = 30°$ ✓

$k_p = \cos\frac{\varphi}{2} = \cos\frac{30°}{2} = 0{,}966$ ✓

$\gamma = \frac{180°}{4\times3} = 15°$ ✓

$k_d = \frac{\sin\frac{\eta\gamma}{2}}{\eta\sin\frac{\gamma}{2}} = \frac{\sin\frac{(4)(15°)}{2}}{4\sin\frac{15°}{2}} = 0{,}958$✓

$E_p = 4f\emptyset T_p k_f k_p k_d$

$T_p = \frac{1\,905{,}256}{(4)(50)(55\times10^{-3})(1{,}11)(0{,}966)(0{,}958)}$ ✓ $= 168{,}615$✓

$Z_p = 168{,}615 \times 2 = 337{,}23$✓

$Z_T = 337{,}23 \times 3 = 1\,011{,}69$✓

$\therefore\ Conductors\ per\ slot = \frac{1\,011{,}69}{72} = 14{,}051$ $say\ 14$✓ (12)

[15]

QUESTION 5

5.1 $N_s = \frac{60\,f}{p} = 1\,000\,r/min$✓

$\%\,S = \frac{N_s - N}{N_s} \times 100\,\%$ ✓$= 5\,\%$✓ (3)

5.2 Power developed = Rotor output = 28 kW

Rotor copper loss = $Rotor\ output\ \left(\frac{S}{1-S}\right)$

$= 28\ \left(\frac{0,05}{1-0,05}\right)$✓

= 1,474 kW✓ (2)

5.3 Power input = Rotor output + Rotor copper loss + Rotor iron loss + Total stator loss

= (28) + (1,474) + (0) + (1,08)✓✓

= 30,554 kW✓ (3)

5.4 $P_i = \sqrt{3}\,V_L I_L \cos\emptyset$

$I_L = \frac{30,554 \times 10^3}{(\sqrt{3})(525)(0,8)}$ ✓ = 42 A✓ (2)

5.5 Power output = Rotor output – frictional loss

= 28 – 0,8✓

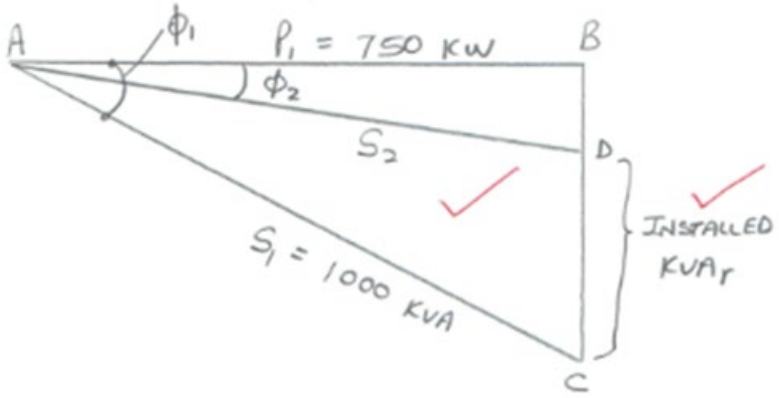
= 27,2 kW✓

$\eta = \frac{P_o}{P_i} \times 100\,\% = 89,023\,\%$✓ (3)

[13]

QUESTION 6

6.1



(2)

6.2 From triangle ABC:

$\tan(41{,}41^\circ) = \frac{\overline{BC}}{750}$✓

$\overline{BC} = 661{,}447\ kVAr$✓

From triangle ABD:

$\tan(25{,}842^\circ) = \frac{\overline{BD}}{750}$✓

$\overline{BD} = 363{,}243\ kVAr$✓

Installed kVAr = $\overline{BC} - \overline{BD} = 298{,}204\ kVAr$✓ (5)

6.3 Cost of capacitor bank = (298,204)(295✓) = R87 970✓ (2)

6.4 kVA charge before installation of capacitor bank = (1 000) (132) =R132 000✓

kVA after installation = $\overline{AD} = \sqrt{750^2 + 363{,}243^2}$ = 833,334 kVA✓

kVA charge after installation of capacitor bank = (833,334) (132) = R110 000

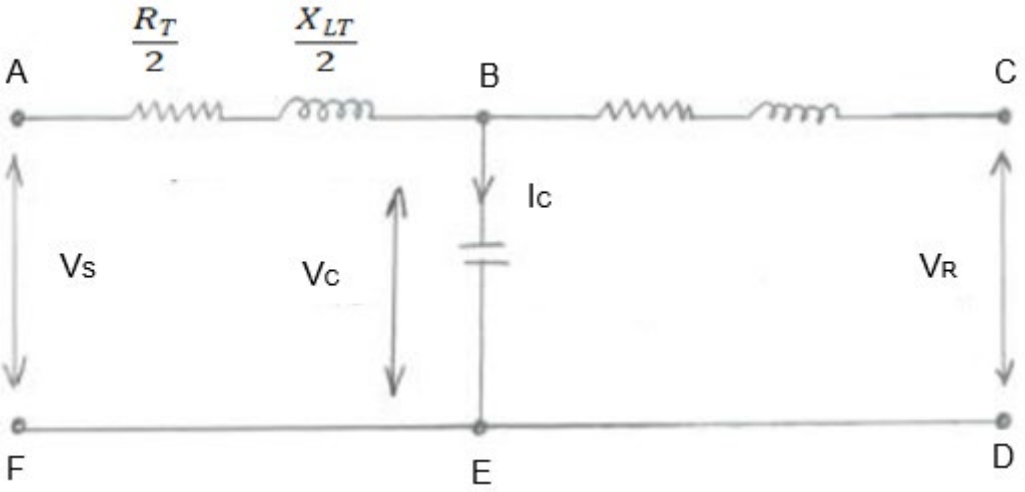
Monthly savings in kVA charge = R132 000 – R 110 000 = R22 000✓

Number of months = $\frac{87\ 970}{22\ 000}$ = 4 ✓ (4)

[13]

QUESTION 7

7.1



$V_S = \frac{145\,000}{\sqrt{3}} = 83\,715{,}79 \angle 0°$ ✓

$\cos \emptyset_S = 0{,}9\ lagging \quad \therefore \emptyset_S = -25{,}842°$

$P_S = \sqrt{3}\, V_L I_L \cos \emptyset$

$I_S = \frac{20\times10^6}{\sqrt{3}\,(145\times10^3)(0{,}9)} = 88{,}483 \angle -25{,}842°$ A✓

$= 79{,}635 - j\ 38{,}569$

$Z_{AB} = Z_{BC} = 12{,}5 + j\ 38 = 40{,}003 \angle 71{,}792°$ ✓

$Z_{BE} = 0 - j\ 1\,750 = 1\,750 \angle -90°$ ✓

$V_{AB} = I_S Z_{AB} = 3\,539{,}585 \angle 45{,}95°$ V✓

$= 2\,461{,}023 + j\ 2\,544{,}018$

$V_C = V_S - V_{AB} = 81\,254{,}766 - j\ 2\,544{,}018$

$= 81\,294{,}582 \angle -1{,}793°$ V✓

$I_C = \frac{V_C}{Z_{BE}} = 46{,}454 \angle 88{,}207°$ A✓

$= 1{,}453 + j\ 46{,}431$

$I_R = I_S - I_C = 78{,}182 - j\ 85$

$= 115{,}488 \angle -47{,}393°$ A✓ (8)

7.2 $V_{BC} = I_R Z_{BC} = 4\,619{,}866 \angle 24{,}399°$ ✓

$= 4\,207{,}27 + j\ 1\,908{,}414$

$V_R = V_C - V_{BC} = 77\,047{,}496 - j\ 4\,452{,}432$

$= 77\,176{,}038 \angle -3{,}307°$ ✓

$\therefore V_R = \sqrt{3}(77\,176{,}038) = 133{,}673\ kV$ ✓ (3)

7.3 $P_R = \sqrt{3}\, V_L I_R \cos \emptyset_R$
$= \sqrt{3}\,(133\,673)(115{,}488)[\cos(47{,}393° - 3{,}307°)]$✓
$= 19{,}206$ MW✓ (2)
[13]

TOTAL: 100

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