higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

2 AUGUST 2018

This marking guideline consists of 12 pages.

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QUESTION 1

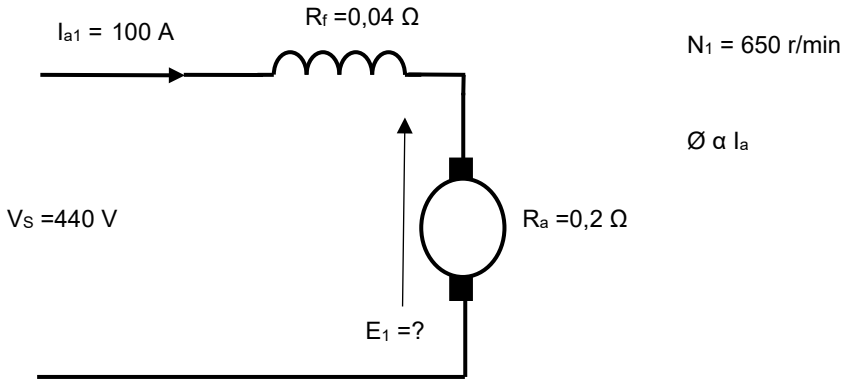
1.1 1.1.1 The speed of a DC motor will be increased with an increase in armature voltage,✓ but not in direct proportion.✓

1.1.2 The speed will be varied inversely proportional to the field current✓ if the poles are unsaturated.✓

(2 × 2) (4)

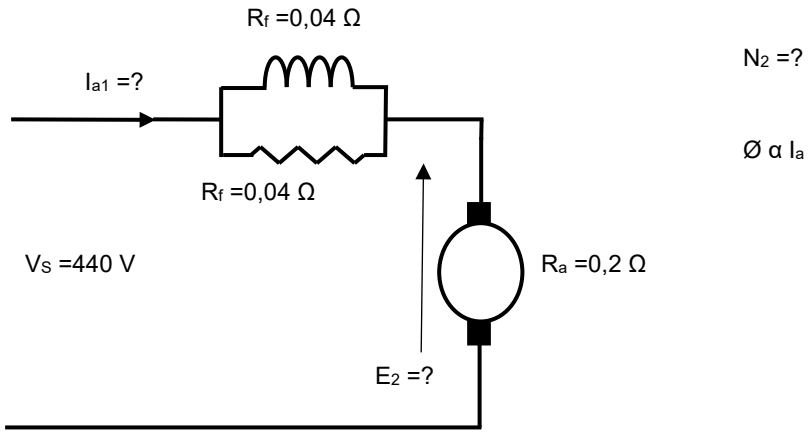
1.2
- Hysteresis loss
- Eddy current loss (2)

1.3 Given: A DC series motor



$$E_1 = V - I_a.(R_f + R_a) = 440 - 100(0{,}04 + 0{,}2) = 416\ V$$✓

Calculating N_2 when $T_2 = 0{,}6T_1$ and a resistor of 0,07 ohms is connected in parallel with the field winding:



Determining I_{a2}:

$T_1 = I_{a1}.\emptyset_1$ and $T_2 \propto I_{a2}.\emptyset_2$

$\therefore \frac{0,07(I_{a2})^2}{0,066} = (I_{a1})^2$ $0,6T_1 \propto {I_{a2}}^2 \times \frac{0,07}{0,11}$

$I_{a2} = \sqrt{\frac{0,066.(I_{a1})^2}{0,07}}$ ✓ $T_1 \propto \frac{0,07{I_{a2}}^2}{0,6 \times 0,11}$

$= \sqrt{\frac{0,066 \times (100)^2}{0,07}} = 97,101$ A✓

$R_{par} = \frac{R.R_f}{R + R_f} = \frac{0,07 \times 0,04}{0,07 + 0,04}$ ✓ $= 0,025\ \Omega$✓

$E_2 = V - I_{a2}(R_{par} + R_a) = 440 - 97,101(0,025 + 0,2)$ ✓

$= 418,152$ V✓

$\frac{N_2.\emptyset_2}{N_1.\emptyset_1} = \frac{E_2}{E_1}$ ✓

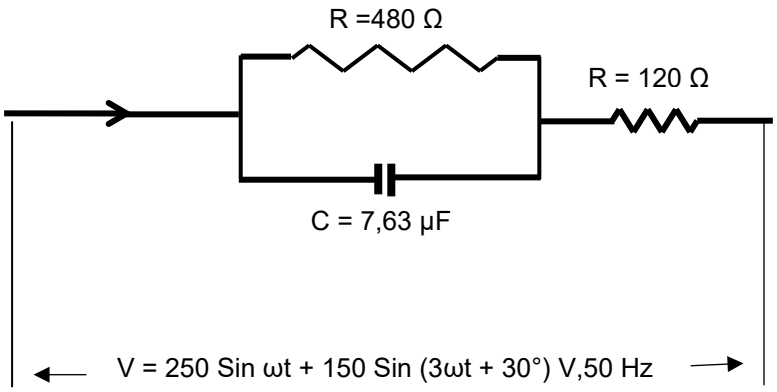
$N_2 = \frac{E_2.N_1.\emptyset_1}{E_1.\emptyset_2} = \frac{418,152 \times 650 \times 100 \times 0,11}{416 \times 97,101 \times 0,07}$ ✓

$= 1\ 057,366$ r/min✓ (9)

[15]

QUESTION 2

Given: A series parallel circuit.



2.1 Calculating an expression for the instantaneous value of the current:

Fundamental:

$$X_{C1} = \frac{1}{2.\pi.f.C} = \frac{1}{2 \times \pi \times 50 \times 7{,}63 \times 10^{-6}} = 417{,}182\ \Omega\checkmark$$

$$Z_{P1} = \frac{R_p.X_C}{R_p + X_{C1}} = \frac{480\angle 0° \times 417{,}182\angle -90°}{480\angle 0° + 417{,}182\angle -90°}\checkmark$$

$$= 223{,}196\angle -90\ \Omega\ \checkmark$$

$$Z_{T1} = R_{ser} + Z_{T1} = 120\angle 0° + 223{,}196\angle -90°\checkmark$$

$$= 253{,}41\angle -61{,}736°\ \Omega\ \checkmark$$

$$I_{M1} = \frac{E_{M1}}{Z_{T3}} = \frac{250\angle 0}{253{,}41\angle -61{,}736°} = 0{,}987\angle 61{,}736\ \text{A}\checkmark$$

Third harmonics:

$$X_{C3} = \frac{X_{C1}}{3} = \frac{417{,}182}{3} = 139{,}061\ \Omega$$

$$Z_{P3} = \frac{R_p.X_{C3}}{R_p + X_{C3}} = \frac{480\angle 0° \times 139{,}061\angle -90°}{480\angle 0° + 139{,}061\angle -90°}\checkmark$$

$$= 133{,}569\angle -73{,}843°\ \Omega\checkmark$$

$$Z_{T3} = R_{ser} + Z_{T3} = 120\angle 0° + 133{,}569\angle -73{,}843°\ \checkmark$$

$$= 202{,}881\angle -39{,}224°\checkmark$$

$$I_{M3} = \frac{E_{M3}}{E_{M3}} = \frac{150\angle 30}{202{,}881\angle -39{,}224°} = 0{,}739\angle 69{,}224\ \text{A}\checkmark$$

$$\text{i} = I_{M1}Sin(314t + \theta_1) + I_{M3}Sin(942t + \theta_3)\checkmark$$

$$= 0{,}987\ Sin(314t + 47{,}027°) + 0{,}739\ Sin(942t - 52{,}806°)\ \text{A}\checkmark \quad (13)$$

2.2 Calculating the RMS value of the current and voltage:

(a)
$$I_{RMS} = \sqrt{\frac{{I_{M1}}^2 + {I_{M3}}^2}{2}}$$

$$= \sqrt{\frac{0{,}9878^2 + 0{,}739^2}{2}}\checkmark$$

$$= 0{,}872\ \text{A}\ \checkmark$$

(b)
$$V_{RMS} = \sqrt{\frac{{V_{M1}}^2 + {V_{M3}}^2}{2}}$$
$$= \sqrt{\frac{250^2 + 150^2}{2}} \checkmark$$
$$= 206{,}155 \text{ V} \checkmark$$

(2 + 2) (4)
[17]

QUESTION 3

3.1
- Delta-delta connection
- Delta-star connection
- Star-delta connection
- Star-star connection (4)

3.2 Given: A single-phase transformer

pf = 1
S = 250 kVA
η = 95% at both half-load and full-load
f = 50 Hz

3.2.1 Calculating the iron loss and full-load copper loss:

$$\eta = \frac{\text{k.S.Cos}\,\theta}{k.S.\text{Cos}\,\theta + P_O + k^2 P_{SC}}$$
$$0{,}95 = \frac{0{,}5 \times 250 \times 1}{(0{,}5 \times 250 \times 1) + P_O + 0{,}5^2 P_{SC}} = \frac{125}{125 + P_O + 0{,}5^2 P_{SC}} \checkmark$$
$$P_O + 0{,}5^2 P_{SC} = \frac{125}{0{,}95} - 125 = 6{,}579 - - - - - - - (1) \checkmark$$

η at full-load:

$$\eta = \frac{\text{S.Cos}\,\theta}{\text{S.Cos}\,\theta + \text{P}_\text{O} + \text{P}_\text{SC}}$$
$$0{,}95 = \frac{250 \times 1}{(250 \times 1) + \text{P}_\text{O} + \text{P}_\text{SC}} = \frac{250}{250 + \text{P}_\text{O} + 0{,}5^2\text{P}_\text{SC}} \checkmark$$
$$P_O + P_{SC} = \frac{250}{0{,}95} - 250 = 13{,}158 - - - - - - - (2) \checkmark$$

$(\mathbf{2}) - (\mathbf{1})$: $P_O + P_{SC} = 13{,}158$

$$\mathrm{P_O} + 0{,}5^2\mathrm{P_{SC}} = 6{,}579$$

$$\underline{0{,}75P_{Sc} = 6{,}579}\checkmark$$

$$\therefore P_{SC} = \frac{6{,}579}{0{,}75} = 8{,}772\ \mathrm{kW}\checkmark$$

Substitute P_{SC} in (1) or (2):

$$\mathrm{P_O} + 8{,}772 = 13{,}158$$

$$\mathrm{P_O} = 13{,}158 - 8{,}772 = 4{,}386\ \mathrm{kW}\checkmark$$ (7)

3.2.2 The efficiency at 70% of full-load and 0,8 power factor lagging:

$$\eta = \frac{k.S.\mathrm{Cos}\,\theta}{k.S.\mathrm{Cos}\,\theta + P_O + k^2P_{SC}} \times 100\%$$

$$= \frac{0{,}7 \times 250 \times 1}{(0{,}7 \times 250 \times 1) + 4{,}386 + (0{,}7^2 \times 8{,}772)} \times 100\%\checkmark$$

$$= 90{,}275\%\checkmark$$ (2)

[13]

QUESTION 4

4.1 The distribution factor is the ratio of the actual EMF obtained✓ to the EMF that would be obtained if all the coil sides were concentrated in one slot.✓ (2)

4.2 Given: A three-phase star-connected alternator

S = 850 kVA
V_L = 4 500 V, 50 Hz
R_a = 0,4 ohms
I_{sc} = 175 A
E_L = 1 500 V

4.2.1 Calculating the synchronous reactance:

$$\mathrm{E_p} = \mathrm{E_L}/\sqrt{3} = 1\,500/\sqrt{3} = 866{,}025\ \mathrm{V}\checkmark$$

$$\mathrm{Z_s} = \mathrm{E_p}/\mathrm{I_{sc}} = 866{,}025/175 = 4{,}949\ \Omega\checkmark$$

$$\mathrm{X_s} = \sqrt{{\mathrm{Z_s}}^2 - {\mathrm{R_a}}^2}$$

$$= \sqrt{4{,}949^2 - 0{,}4^2}\checkmark$$

$$= 4{,}933\ \Omega\checkmark$$ (4)

4.2.2 Calculating the full-load percentage, voltage regulation at a power factor of 0,8 lagging:

$$I_L = \frac{S}{\sqrt{3}.V_L} = \frac{850 \times 10^3}{\sqrt{3} \times 4\,500} = 109{,}055\ A\checkmark$$

$$V_p = V_L/\sqrt{3} = 4\,500/\sqrt{3} = 2\,598{,}076\ V\checkmark$$

$$I.R_a = 109{,}055 \times 0{,}4 = 43{,}622\ V\checkmark$$

$$IX_s = 109{,}055 \times 4{,}933 = 537{,}968\ V\checkmark$$

Method 1:

$$E = V_p\angle\theta + I.R_a\angle 0° + IX_s\angle 90°$$
$$= 2\,598{,}076\angle 36{,}87° + 43{,}622\angle 0° + 537{,}968\angle 90$$
$$= 2\,983{,}264\angle 44{,}657°\ V\checkmark$$

Method 2:

$$E = \sqrt{(V_p.\cos\theta + I.R_a) + (V_p.\sin\theta + I.X_s)}$$

$$= \sqrt{([2\,598{,}076 \times 0{,}8] + 43{,}622\ \Omega)^2 + ([2\,598{,}076 \times 0{,}6] + 537{,}968)^2}$$
$$= 2\,983{,}264\ V\checkmark$$

Method 3:

$$E = V_p + (I.R_a.\cos\theta) + (IX_{s.}\sin\theta)$$
$$= 2\,598{,}076 + (43{,}622 \times 0{,}8) + (537{,}968 \times 0{,}6)$$
$$= 2955{,}754\ V\checkmark$$

$$\%\ \text{regulation} = \frac{E - V_p}{V_p} \times 100\% = \frac{2\,983{,}264 - 2\,598{,}076}{2\,598{,}076} \times 100\%\ \checkmark$$
$$= 14{,}826\%\checkmark$$

(7)
[13]

QUESTION 5

Give: A three-phase induction motor

Number of poles = 4
f = 50 Hz

R_{rotor} = 0,3 ohms/phase
T_{max} = 186,5 N.m
N_1 = 1 350 r/min

5.1 Calculating the slip at which maximum torque is produce:

$$N_1 = 60.f/p = 60 \times 50/2 = 1\,500 \text{ r/min} \checkmark$$

$$S = \frac{N_1 - N_2}{N_1} \times 100\%$$

$$= \frac{1\,500 - 1\,350}{1\,500} \times 100\%$$

$$= 10\% \checkmark$$ (2)

5.2 Calculating the standstill rotor resistance:

$$R_2 = S.X_O$$

$$\therefore X_O = R_2/S = 0{,}3/0{,}1$$

$$= 3\ \Omega \checkmark$$ (1)

5.3 Calculating the standstill rotor EMF:

$$\text{Rotor input} = 2.\pi.N_1T/60 = 2 \times \pi \times 1\,500 \times 186{,}5/60 = 29\,295{,}351 \text{ W} \checkmark$$

$$\text{Rotor Cu loss} = S.\text{rotor input} = 0{,}1 \times 29\,295{,}351 = 2\,929{,}535 \text{ W} \checkmark$$

$$\text{Rotor Cu loss} = 3.I_2{}^2R_2$$

$$\therefore I_2 = \sqrt{\frac{\text{Rotor Cu loss}}{3.R_2}} = \sqrt{\frac{2\,929{,}535}{3 \times 0{,}3}} = 57{,}053 \text{ A} \checkmark$$

$$Z_2 = \sqrt{R_2{}^2 + (S.X_O)^2} = \sqrt{0{,}3^2 + (0{,}1 \times 3)^2} = 0{,}424\ \Omega \checkmark$$

$$E_2 = I_2.Z_2 = 57{,}053 \times 0{,}424 = 24{,}206 \text{ V} \checkmark$$

$$E_2 = S.E_O$$

$$\therefore E_O = E_2/S = 24{,}206/0{,}1 = 242{,}055 \text{ V} \checkmark$$ (6)

5.4 Calculating the starting torque:

Method 1:

$$n_1 = N_1/60 = 1\,500/60 = 25 \text{ r/sec} ✓$$

$$T_{start} = \frac{3.S.{E_O}^2.R_2}{2.\pi.n_1.\left({R_2}^2 + [S.X_O]^2\right)} = \frac{3 \times 1 \times 242{,}055^2 \times 0{,}3}{2 \times \pi \times 25 \times (0{,}3^2 + [1 \times 3]^2)}$$

$$= 36{,}931 \text{ N.m} ✓$$

Method 2:

$$\frac{T_{max}}{T_{start}} = \frac{S_1.R_2}{{R_2}^2 + (S_1.X_O)^2} \times \frac{{R_1}^2 + (S_2.X_O)^2}{S_2.R_2}$$

$$\frac{186{,}5}{T_{start}} = \frac{0{,}1 \times 0{,}3}{0{,}3^2 + (0{,}1 \times 3)^2} \div \frac{1 \times 0{,}3}{0{,}3^2 + (1 \times 3)^2} = 5{,}05 ✓$$

$$T_{start} = \frac{186{,}5}{5{,}05} = 36{,}931 \text{ N.m} ✓$$

(2)
[11]

QUESTION 6

6.1 The rotating flux of a three-phase induction motor can be reversed by interchanging the connection between two supply conductors. (1)

6.2 Given: 3θ induction motor with a star-connected rotor
f = 50 Hz

Number of pole = 4
E_o = 300 V
Z_o = (0,18 + j1,2) ohm

6.2.1 Calculating the torque developed at a full-load slip of 5%:

$$E_{O_P} = E_O/\sqrt{3} = 300/\sqrt{3} = 173{,}205 \text{ V} ✓$$

$$Z_2 = \sqrt{(R_2)^2 + (S.X_O)^2} = \sqrt{0{,}18^2 + (005 \times 1{,}2)^2} = 0{,}19\ \Omega ✓$$

$$I_2 = \frac{S.E_{OP}}{Z_2} = \frac{0{,}05 \times 173{,}205}{0{,}19} = 45{,}644 \text{ A} ✓$$

$$\text{Rotor Cu. loss} = 3.{I_2}^2.R_2 = 3 \times (45{,}644)^2 \times 0{,}18 = 1\,124{,}999 \text{ W} ✓$$

$$\text{Rotor input} = \frac{\text{Rotor Cu loss}}{\text{S}}$$

$$= \frac{1\ 124{,}999}{0{,}05} = 22\ 499{,}979\ \text{W}\checkmark$$

$$\text{N}_1 = 60.\text{f/p} = 60 \times 50/2 = 1\ 500\ \text{r/min}\checkmark$$

$$\text{Rotor input} = \frac{2.\pi.N_1.T}{60}$$

$$\therefore T = \frac{60 \times \text{rotor input}}{2 \times \pi \times N_1}$$

$$= \frac{60 \times 22\ 499{,}979}{2 \times \pi \times 1\ 500}\checkmark$$

$$= 143{,}239\ \text{Nm}\checkmark$$

(8)

6.2.2 Calculating the full-load power output if the friction and windage losses are 900 W:

$$N_2 = N_1 - S.N_1 = 1\ 500 - (0{,}05 \times 1\ 500) = 1\ 425\ \text{r/min}\checkmark$$

$$\text{Gross rotor input} = \frac{2.\pi.\text{N}_2.\text{T}}{60} = \frac{2 \times \pi \times 1\ 425 \times 143{,}239}{60}$$

$$= 21\ 374{,}933\ \text{W}\checkmark$$

$$\text{Power output} = \text{gross rotor output} + \text{friction and windage losses}$$

$$= 21\ 374{,}933 + 900$$

$$= 22\ 274{,}933\ \text{W}\checkmark$$

(3)

6.2.3 Calculating the speed at maximum torque:

$$\text{S} = R_2/X_O = 0{,}18/1{,}2 = 0{,}15\checkmark$$

$$N_2 = N_1 - S.N_1 = 1\ 500 - (0{,}15 \times 1\ 500) = 1\ 275\ \text{r/min}\checkmark$$ (2)

[14]

QUESTION 7

Given: A 3-phase, short-transmission line 5 km long

Z = (0,6 + j0,7) Ω/km P = 3 600 kW
V_R = 11 kV pf = 0,8 lagging

7.1 7.1.1 $P = \sqrt{3}.V_L.I_L.\cos\theta$

$$\therefore\ I_L = \frac{P}{\sqrt{3}.V_L.\cos\theta}$$

$$= \frac{36\,000 \times 10^3}{\sqrt{3} \times 11\,000 \times 0{,}8}$$

$$= 236{,}189 \text{ A} \checkmark$$

$$V_p = V_L/\sqrt{3} = 11\,000/\sqrt{3}$$

$$= 6\,350{,}853 \text{ V} \checkmark$$

$$R_{T(LINE)} = 5 \times 0{,}6 = 3\ \Omega \checkmark$$

$$\text{I.R} = 236{,}189 \times 3 = 708{,}567 \text{ V} \checkmark$$

$$X_{T(LINE)} = 5 \times 0{,}7 = 3{,}5\ \Omega \checkmark$$

$$\text{I.X} = 236{,}189 \times 3{,}5 = 826{,}662 \text{ V} \checkmark$$

$$V_S = V_R + I.R + IX$$

$$= 6\,350{,}853\angle 36{,}87° + 708{,}567\angle 0° + 826{,}662\angle 90° \checkmark$$

$$= 7\,634{,}806\angle 29{,}94 \text{ V} \checkmark$$

$$V_L = \sqrt{3}.V_S = \sqrt{3} \times 7\,634{,}806$$

$$= 13\,223{,}872 \checkmark \quad (9)$$

7.1.2 $\text{Losses} = 3.I^2.R = 3 \times 236{,}189^2 \times 3$

$$= 502\,067{,}194 \text{ W} \checkmark$$

$$\eta = \frac{\text{output}}{\text{output} + \text{losses}} \times 100\%$$

$$= \frac{3\,600}{3\,600 + 502{,}067} \times 100\% \checkmark$$

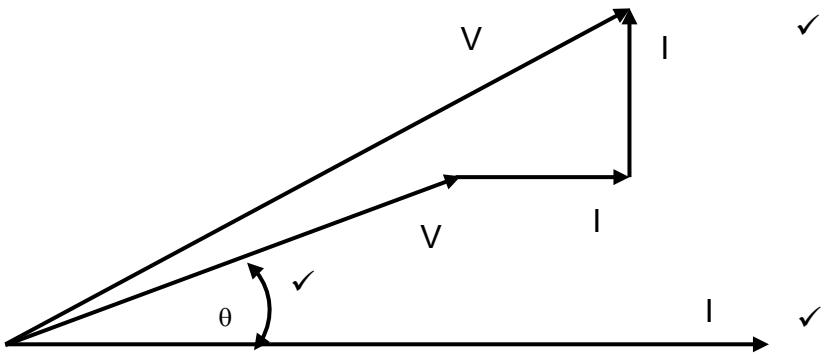
$$= 87{,}761\ \% \checkmark \quad (3)$$

7.1.3 $$\% \text{ regulation} = \frac{V_S - V_R}{V_R} \times 100\%$$

$$= \frac{7\,634{,}806 - 6\,350{,}853}{6\,350{,}853} \times 100\% \checkmark$$

$$= 20{,}217\% \checkmark$$ (2)

7.2



(3)
[17]

TOTAL: 100

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