higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

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This marking guideline consists of 8 pages.

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√ = ½ mark
✓ = 1 mark

QUESTION 1

1.1
- It is convenient and economical because it requires small power to test a large machine
- Efficiency can be predetermined at any load because constant losses are known (2)

1.2 $V = 250\ V$
$Full\ load\ output\ power = 14\ 920\ W$
$C = Iron\ \&\ friction\ loss = 199\ W$
$R_{sh} = 100\ \Omega$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{100} = 2{,}5A\surd$$

$$Shunt\ field\ Cu\ loss = VI_{sh} = 250 \times 2{,}5 = 625\ W\surd$$

At 80% of rated output:

$\eta = 88\%$
$P_{out} = 0{,}8 \times 14\ 920 = 11\ 936\ W$✓

$$P_{in} = \frac{P_{out}}{\eta} = \frac{11\ 936}{0{,}88} = 13563{,}636W$$✓

$$Total\ losses = P_{in} - P_{out} = 13\ 563{,}636 - 11\ 936 = 1\ 627{,}636W$$✓

$$I = \frac{P_{in}}{V} = \frac{13\ 563{,}636}{250} = 54{,}255A$$✓

$$I_a = I - I_{sh} = 54{,}255 - 2{,}5 = 51{,}755A$$✓

$$Total\ losses = {I_a}^2 R_a + VI_{sh} + C$$

$${I_a}^2 R_a = 1627{,}636 - 625 - 199 = 803{,}636W$$✓

$$R_a = \frac{803{,}636}{51{,}755^2} = 0{,}3\ \Omega$$✓

When $I = 78A$**:**
$I_a = I - I_{sh} = 78 - 2{,}5 = 75{,}5A$✓

${I_a}^2 R_a = 75{,}5^2 \times 0{,}3 = 1\ 710{,}075\ W$✓

$P_{in} = VI = 250 \times 78 = 19\ 500\ W$✓

$$Total\ losses = {I_a}^2 R_a + VI_{sh} + C = 1\ 710{,}075 + 625 + 199 = 2\ 534{,}075\ W$$✓

$$\eta = \frac{P_{in} - Losses}{P_{in}} \times 100\% = \frac{19\ 500 - 2\ 534{,}075}{19\ 500} \times 100 = 87{,}005\%$$✓

(13)
[15]

QUESTION 2

2.1
- Fundamental wave
- Harmonic waves (2)

2.2 2.2.1 Fundamental

$X_{L1} = wL = 314 \times 0{,}05 = 15{,}7\Omega$

$Z_1 = (20 + j15{,}7) = 25{,}426\angle 38{,}132° \ \Omega$✓

3rd harmonic

$X_{L3} = 3wL = 3 \times 314 \times 0{,}05 = 47{,}1\ \Omega$

$Z_3 = (20 + j47{,}1) = 51{,}17\angle 66{,}993° \ \Omega$✓

5th harmonic

$X_{L5} = 5wL = 5 \times 314 \times 0{,}05 = 78{,}5\ \Omega$

$Z_5 = (20 + j78{,}5) = 81{,}008\angle 75{,}706° \ \Omega$✓

$i = \frac{250}{25{,}426}\sin(wt - 38{,}132^0)$ ✓ $+ \frac{50}{51{,}17}\sin(3wt - 6{,}993^0)$√

$+ \frac{20}{81{,}008}\sin(5wt + 74{,}294^0)$ √

$i = 9{,}832\sin(wt - 38{,}132^0)$ ✓ $+ 0{,}977\sin(3wt - 6{,}993^0)$✓

$+ 0{,}247\sin(5wt + 74{,}294^0)$✓ (8)

2.2.2

$I_{rms} = \sqrt{\frac{{I_{m1}}^2 + {I_{m3}}^2 + {I_{m5}}^2}{2}} = \sqrt{\frac{9{,}832^2 + 0{,}977^2 + 0{,}247^2}{2}}$√

$= 6{,}989\ A$✓

$V_{rms} = \sqrt{\frac{{V_{m1}}^2 + {V_{m3}}^2 + {V_{m5}}^2}{2}} = \sqrt{\frac{250^2 + 50^2 + 20^2}{2}}$√$= 180{,}831\ V$✓

$P_T = I^2R = (6{,}989)^2 \times 20 = 976{,}922\ W$✓

$$Power\ factor = \frac{P_T}{VI} = \frac{976{,}922}{180{,}831 \times 6{,}989} = 0{,}773$$✓ (5)

[15]

QUESTION 3

3.1 It is the rise or fall in the secondary voltage✓ when full load is switched off,✓ provided that the primary voltage remains constant✓ (3)

3.2 3.2.1

$$I_1 = \frac{S}{V_1} = \frac{50\,000}{1000} = 50\ A\checkmark$$

$$R_{pu} = \frac{I_1 R_{e1}}{V_1}$$

$$0{,}02 = \frac{50 \times R_{e1}}{1000}$$

$$R_{e1} = 0{,}4\ \Omega\checkmark$$

$$X_{pu} = \frac{I_1 X_{e1}}{V_1}$$

$$0{,}06 = \frac{50 \times X_{e1}}{1000}$$

$$X_{e1} = 1{,}2\ \Omega\checkmark$$ (3)

3.2.2 $P_{sc} = {I_1}^2 R_{e1} = 50^2 \times 0{,}4\checkmark = 1\,000\ W\checkmark$ (2)

3.2.3

$$Reg = \frac{I_1(R_{e1}\cos\theta + X_{e1}\sin\theta)}{V_1}$$

$$= \frac{50(0{,}4 \times 0{,}9 + 1{,}2 \times 0{,}436)}{1000}\checkmark$$

$$= 0{,}044\ pu\checkmark$$

$$V_{2(terminal)} = V_2(1 - Reg) = 240(1 - 0{,}044) = 229{,}44\ V\checkmark$$ (3)

3.2.4

$$\eta = \frac{kS\cos\theta}{kS\cos\theta + 2P_0}$$

$$0{,}93 = \frac{0{,}88 \times 50\,000 \times 0{,}9}{0{,}88 \times 50\,000 \times 0{,}9 + 2 \times P_0}\checkmark\checkmark$$

$$P_0 = 1490{,}322\ W\checkmark$$ (3)

[14]

QUESTION 4

4.1
- Their EMFs must be equal
- Their EMFs must have the same frequency
- Their EMFs must be in phase
- Their EMFs must have same angular displacement (Any 3 × 1) (3)

4.2 4.2.1 (a)

$$E_A = \frac{2200}{\sqrt{3}} = 1270{,}171\,V$$

$$E_B = \frac{2000}{\sqrt{3}} = 1154{,}701\,V$$

$$Z_T = Z_A + Z_B$$
$$= (0{,}65 + j3{,}8) + (0{,}65 + j3{,}8) = 1{,}3 + j7{,}6$$
$$= 7{,}71\angle 80{,}293°\ \Omega ✓$$

$$E_R = E_A\angle 0 + E_B\angle 155^0$$
$$= 1270{,}171\angle 0 + 1154{,}701\angle 155^0 ✓$$
$$= 1270{,}171 - 1046{,}515 + j487{,}998 ✓$$
$$= 223{,}656 + j487{,}998$$
$$= 536{,}809\angle 65{,}377^0\ V ✓$$

$$I_c = \frac{E_R}{Z_T} = \frac{536{,}809\angle 65{,}377^0}{7{,}71\angle 80{,}293°} = 69{,}625\angle -14{,}916^0 A ✓$$ (5)

(b) (3)

4.2.2
$$V_p = E_A - 0{,}5E_R$$
$$= 1270{,}171 - 0{,}5(223{,}656 + j487{,}998) ✓$$
$$= 1158{,}343 - j243{,}999$$
$$= 1183{,}763\angle -11{,}895^0\ V ✓$$

$$V_L = \sqrt{3} \times (1183{,}763) = 2050{,}338\,V ✓$$ (2)

[13]

QUESTION 5

5.1 $V_P = \frac{400}{\sqrt{3}} = 230{,}94\ V$

$P_I = \frac{P_O}{\eta} = \frac{40}{0{,}9} = 44{,}444\ kW$✓

$I_P = I_L = \frac{P_I}{\sqrt{3}V_L \cos\theta} = \frac{44{,}444 \times 1000}{\sqrt{3} \times 400 \times 0{,}8} = 80{,}187\ A$✓

$V_P\angle -\theta = 230{,}94\angle -36{,}87^0$
$= (184{,}752 - j138{,}564)\ V$✓

Method 1:

$V_R = I_P R\angle 180^0 = 80{,}187 \times 0{,}1\angle 180^0$
$= 8{,}019\angle 180^0$
$= (-8{,}019)\ V$✓

$V_X = I_P X\angle -90^0 = 80{,}187 \times 1{,}2\angle -90^0$
$= 96{,}224\angle -90^0$
$= (-j96{,}224)\ V$✓

$E_p = V_P\angle -\theta + I_P R\angle 180^0 + I_P X\angle -90^0$
$= 184{,}752 - j138{,}564 - 8{,}019 - j96{,}224$✓
$= 176{,}733 - j234{,}788$
$= 293{,}871\angle -53{,}03^0\ V$✓

Method 2:

$Z = R + jX = 0{,}1 + j1{,}2 = 1{,}204\angle 85{,}236^0\Omega$✓
$I_P Z = 80{,}187 \times 1{,}204\angle 85{,}236^0$
$= 96{,}545\angle 85{,}236^0$
$= 8{,}018 + j96{,}211$✓

$E_p = V_P\angle -\theta - I_P Z$
$= (184{,}752 - j138{,}564) - (8{,}018 + j96{,}21)$ ✓
$= 176{,}734 - j234{,}774$
$= 293{,}86\angle -53{,}028^0\ V$✓ (7)

5.2 $\alpha = 53{,}03^0 - 36{,}87^0 = 16{,}16^0$ Electrical✓
$\alpha = \frac{16{,}16^0}{3}$✓ $= 5{,}387^0$ Mechanical✓ (3)
[10]

QUESTION 6

6.1 $N_s = \frac{60f}{p} = \frac{60\times50}{3} = 1000\ r/min$✓

$\%S = \frac{N_s - N}{N_s} = \frac{1000 - 930}{1000} \times 100 = 7\%$✓ (2)

6.2 $P_{cu(rotor)} = P_{Out(rotor)}\left(\frac{S}{1-S}\right)$

$= 15\left(\frac{0,07}{1-0,07}\right)$✓

$= 1,129\ kW$✓ (2)

6.3 **Method 1:**

$P_{Output(stator)} = P_{Input(rotor)} = \frac{P_{cu(rotor)}}{S} = \frac{1,129}{0,07} = 16,129\ kW$✓

$P_{Input} = P_{Output(stator)} + P_{Stator\ losses}$
$= 16,129 + 0,8$
$= 16,929\ kW$✓

Method 2:

$P_{Input} = P_{Out(rotor)} + P_{cu(rotor)} + P_{Iron(rotor)} + P_{Losses(stator)}$
$= 15 + 1,129 + 0,8$✓
$= 16,929\ kW$✓ (2)

6.4 $I_L = \frac{P_{Input}}{\sqrt{3}V_L \cos\theta}$

$= \frac{16,929 \times 1000}{\sqrt{3} \times 400 \times 0,7}$✓

$= 34,907\ A$✓ (2)

6.5 $P_{Output} = P_{Out(rotor)} - Friction\ \&\ windage\ losses = 15 - 0,5 = 14,5\ kW$✓

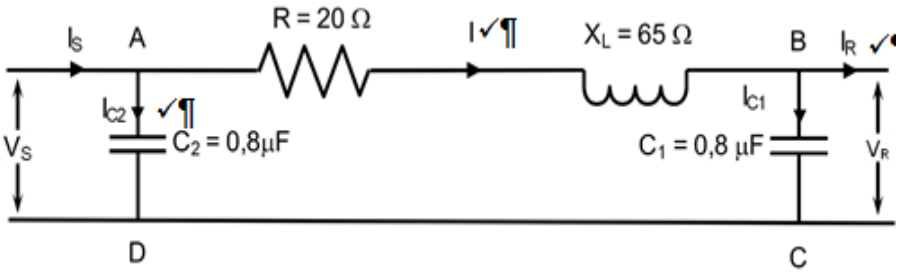
$\eta = \frac{P_{Output}}{P_{Input}} \times 100\% = \frac{14,5}{16,929} \times 100$✓ $= 85,652\%$✓ (3)

[11]

QUESTION 7

7.1
- True power
- Apparent power
- Reactive power (3)

7.2.1



(3)

7.2.2 (a) Use V_R as reference : $V_R = 76\,210{,}236\angle 0^\circ$ ✓

$$I_R = \frac{30 \times 10^6}{\sqrt{3}(132\,000)(0{,}8)} = 164{,}02\angle -36{,}87^\circ$$
$$= 131{,}216 - j\,98{,}412$$ ✓

$$Z_{AB} = 20 + j65 = 68{,}007\angle 72{,}897^0\Omega$$ ✓

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(50)(0{,}8 \times 10^{-6})} = 3\,978{,}874\,\Omega$$ ✓

$$Z_{AD} = Z_{BC} = -j3\,978{,}874 = 3\,978{,}874\angle -90^0$$ ✓

$$I_{C1} = \frac{V_R}{Z_{BC}} = 19{,}154\angle 90^\circ = 0 + j\,19{,}154$$ ✓

$$I = I_{c1} + I_R = 131{,}216 - j79{,}258 = 153{,}295\angle -31{,}133^0$$ ✓

$$V_{AB} = IZ_{AB}$$
$$= (153{,}295\angle -31{,}133^0)(68{,}007\angle 72{,}897^0)$$ ✓
$$= 10\,425{,}133\angle 41{,}764^0$$
$$= 7\,776{,}051 + \text{j}\,6\,943{,}805$$ ✓

$$V_S = V_R + V_{AB} = 83\,986{,}287 + \text{j}\,6\,943{,}805 =$$
$$84\,272{,}848\angle 4{,}726^0\ \text{V}$$ ✓
$$\therefore V_S = \sqrt{3}(84\,272{,}848) = 145{,}965\ \text{kV}$$ ✓ (11)

(b) $I_{C2} = \frac{V_S}{Z_{AD}} = 21{,}18\angle 94{,}726^\circ = -1{,}745 + j\,21{,}108$ ✓

$$I_S = I + I_{C2}$$ ✓
$$= 129{,}471 - \text{j}\,58{,}15$$
$$= 141{,}93\angle -24{,}187^\circ\ \text{A}$$ ✓ (3)

(c) $\cos\emptyset_s = \cos(4{,}726^\circ + 24{,}187^\circ)$ ✓ $= 0{,}875\ lagging$ ✓ (2)

[22]

TOTAL: 100

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