higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

NOVEMBER EXAMINATION

ELECTROTECHNICS N6

28 November 2016

This marking guideline consists of 8 pages.

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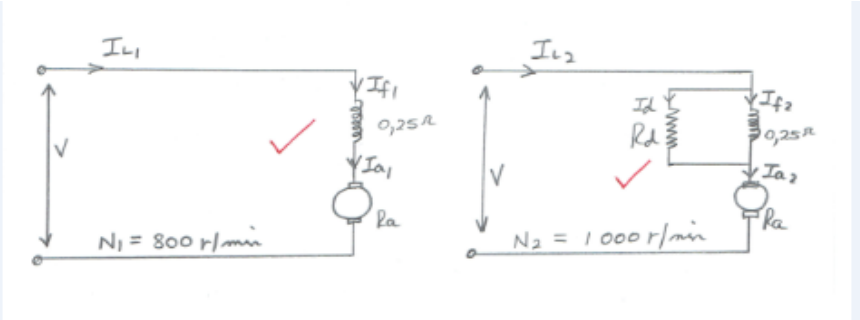
QUESTION 1

1.1 1.1.1 Decrease the shunt field current by inserting a resistor in series with the shunt field. (2)

1.1.2 Decrease the voltage across the armature by inserting a resistor in series with the armature. (2)

1.2



(2)

$I_{L1} = I_{f1} = I_{a1} = I_{L2} = I_{a2} \neq I_{f2}$ ✓

$I_{f2} = \left(\frac{x}{x + 0,25}\right) I_{a2}$ ---------- (1) ✓

$E_1 = V - I_{a1}R_{ac1}$ $E_2 = V - I_{a2}R_{ac2}$

But resistive volt-drop $I_aR_a = 0$

$E_1 = V$ $E_2 = V$ $\therefore E_1 = E_2$ ✓

$\frac{E_1}{E_2} = \frac{N_1I_{f1}}{N_2I_{f2}}$ $\therefore I_{f2} = \frac{N_1I_{f1}}{N_2} = \frac{(800)(I_{f1})}{1\,000} = 0,8\ I_{f1}$ ---------- (2) ✓

Substitute (2) into (1)

$0,8\ I_{f1} = \left(\frac{x}{x+0,25}\right) I_{a2}$ But $I_{a2} = I_{f1}$ ✓

$0,8\ (x + 0,25) = x$ ✓

$0,8x + 0,2 = x$

$\therefore x = 1\ \Omega$ ✓ (7)

[13]

QUESTION 2

2.1 $V_P = \frac{380}{\sqrt{3}} = 219{,}393\ V$ ✓

$R - N : I = 20\ A \ \cos\emptyset_R = 0{,}6\ lagging \ \therefore \ \emptyset_R = 53{,}13°$

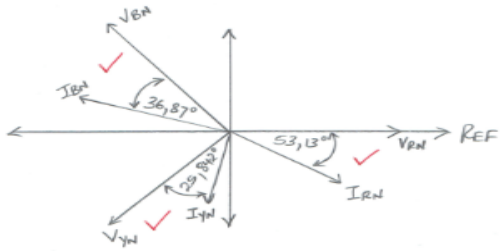
$Y - N : P = 4{,}95\ kW \ \cos\emptyset_Y = 0{,}9\ leading \ \therefore \ \emptyset_Y = 25{,}842°$

$I = \frac{4\,950}{(219{,}393)(0{,}9)} = 25{,}069\ A$ ✓

$B - N : S = 3{,}8\ kVA \ \cos\emptyset_B = 0{,}8\ leading \ \therefore \ \emptyset_B = 36{,}87°$

$I = \frac{3\,800}{(219{,}393)} = 17{,}321\ A$ ✓

Using V_{RN} as reference and a phase sequence of $R - Y - B$



(7)

$I_{RN} = 20 \angle -53{,}13° = 12 - j\,16$ ✓

$I_{YN} = 25{,}069 \angle -94{,}158° = -1{,}818 - j\,25{,}003$ ✓

$I_{BN} = 17{,}321 \angle 156{,}87° = -15{,}929 + j\,6{,}804$ ✓

$I_N = I_{RN} + I_{YN} + I_{BN} = -5{,}747 - j\,34{,}199 = 34{,}679 \angle -99{,}539°$ ✓ (3)

2.2 $e = 220\sin(314t + 20°) + 60\sin(942t - 30°)$

Fundamental	Third Harmonic
$X_{L1} = (314)(20 \times 10^{-3}) = 6{,}28\ \Omega$ ✓	$X_{L3} = 3 \times X_{L1} = 18{,}84\ \Omega$ ✓
$X_{C1} = \frac{1}{(314)(C)}$	$X_{C3} = \frac{X_{C1}}{3}$
$X_{C1} = 3 \times (18{,}84) = 56{,}52\ \Omega$ ✓	For Resonance : $X_{L3} = X_{C3}$
$\therefore \ C = \frac{1}{(314)(56{,}52)} = 56{,}347\ \mu F$ ✓	

(4)

Alternate solution: $X_{L3} = (942)(20 \times 10^{-3}) = 18{,}84\ \Omega = X_{C3}$ ✓✓

$X_{C3} = \frac{1}{(942)(C)} \quad \therefore \ C = 56{,}347\ \mu F$ ✓✓

[14]

QUESTION 3

3.1 All constant losses are voltage dependent, all variable losses are current dependent and since none of the losses are phase angle dependent, all transformers are rated in kVA. (3)

3.2 3.2.1 $\eta = \frac{kS\cos\emptyset}{kS\cos\emptyset + P_o + k^2P_{sc}} \times 100\%$

$0{,}95 = \frac{(1)(200)(0{,}9)}{(1)(200)(0{,}9) + P_o + (1)^2P_{sc}}$ ---------- (1) ✓

$0{,}95 = \frac{(0{,}5)(200)(0{,}9)}{(0{,}5)(200)(0{,}9) + P_o + (0{,}5)^2P_{sc}}$ ---------- (2) But (1) = (2) ✓

$\frac{180}{180 + P_o + P_{sc}} = \frac{90}{90 + P_o + 0{,}25\,P_{sc}}$ ✓

$(180)(90 + P_o + 0{,}25P_{sc}) = (90)(180 + P_o + P_{sc})$

$180 + 2P_o + 0{,}5P_{sc} = 180 + P_o + P_{sc}$ ✓

$\therefore \quad P_o = 0{,}5P_{sc}$ substitute into (1)

$0{,}95 = \frac{(1)(200)(0{,}9)}{(1)(200)(0{,}9) + 0{,}5\,P_{sc} + (1)^2P_{sc}}$ ---------- (1) ✓

$180 + 1{,}5P_{sc} = \frac{180}{0{,}95}$

$\therefore P_{sc} = 6{,}316\,kW \quad and \quad P_o = 0{,}5\,P_{sc} = 3{,}158\,kW$ ✓✓ (7)

3.2.2 For η_{max} $k = \sqrt{\frac{P_o}{P_{sc}}} = \sqrt{\frac{0{,}5\,P_{sc}}{P_{sc}}} = 0{,}707$ ✓

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

$= \frac{(0{,}707)(200)(0{,}9)}{(0{,}707)(200)(0{,}9) + 2\,(3{,}158)}\ x\ 100\%$ ✓

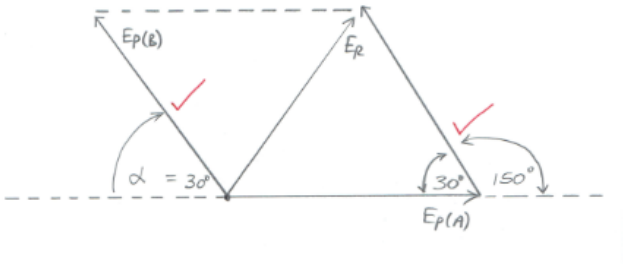
$= 95{,}272\ \%$ ✓ (4)

[14]

QUESTION 4

4.1 The pitch factor is the ratio of the actual emf obtained to the emf that would be obtained if all the coils were full-pitched. (3)

4.2 4.2.1



(2)

$Z_A = Z_B = 0{,}15 + j4\ \Omega/\text{phase}$

$E_{P(A)} = E_{P(B)} = \frac{3\,300}{\sqrt{3}} = 1\,905{,}256\,V$ ✓

$E_R = E_{P(A)} \angle 0° + E_{P(B)} \angle 150°$ ✓

= 1 905,256 ∟ 0° + 1 905,256 ∟ 150°

= (1 905,256 + j 0) + (— 1 650 + j 952,628)

= 255,256 + j 952,628

= 986,233 ∟ 75° V ✓

$Z_T = Z_A + Z_B = 0{,}3 + j\,8 = 8{,}006 \angle 87{,}852°$ ✓

$I_c = \frac{E_R}{Z_T} = 123{,}187 \angle -12{,}852°\ A$ ✓ (5)

4.2.2 $V_P = E_A - 0{,}5\,E_R$ ✓

= (1 905,256 + j 0) — (127,628 + j 476,314)

= 1 777,628 — j 476,314

= 1 840,336 ∟ -15° ✓

$\therefore\ V_L = \sqrt{3}\,V_P = 3\,187{,}555\,V$ ✓ (3)

4.2.3 $P = 3\,V_P\,I_c\,\cos\emptyset$

$= (3)(1\,840{,}336)(123{,}187)\cos(15° - 12{,}852°)$ ✓

$= 679{,}639\,kW$ ✓

Alternate Solution

$P = \sqrt{3}\,V_L I_C \cos\emptyset$

$= \sqrt{3}(3\,187{,}555)(123{,}187)\cos(15^{\circ} — 12{,}852^{\circ})$

= 679,638 kW (2)
[15]

QUESTION 5

5.1 By interchanging any two phases (2)

5.2 5.2.1

$N_S = \frac{60f}{p} = \frac{(60)(50)}{2}$ = 1 500 r/min ✓

$S = \frac{N_S - N}{N_S} = \frac{1\,500 - 1\,400}{1\,500} = 0{,}067$ ✓

$E_2 = E_1 \times \frac{N_2}{N_1} = (380) \times \frac{1}{3} = 126{,}667\,V$ ✓

$E_R = SE_2 = (0{,}067)(126{,}667) = 8{,}487\,V$

$X_R = SX_2 = (0{,}067)(0{,}9) = 0{,}06\,\Omega$

$Z_R = 0{,}15 + j\,0{,}06 = 0{,}162 \angle 21{,}801°$✓

$I_R = \frac{E_R}{Z_R} = \frac{8{,}487\angle 0^{\circ}}{0{,}162\angle 21{,}801^{\circ}} = 52{,}389 \angle -21{,}801^{\circ}$ A ✓

$Rotor\ copper\ losses = 3(I_R)^2 R = (3)(52{,}389)^2(0{,}15) =$
$1\,235{,}073\,W$ ✓

$Rotor\ input = \frac{Rotor\ copper\ loss}{S} = \frac{1\,235{,}073}{0{,}067} = 18{,}434\,kW$ ✓

$T = \frac{60\,Rotor\ input}{2\pi N_S} = \frac{(60)(18\,434)}{(2\pi)(1\,500)} = 117{,}354\,Nm$ ✓ (8)

5.2.2 $For\ maximum\ torque\ :\ R_2 = S_m X_2 \therefore S_m = \frac{R_2}{X_2} = \frac{0{,}15}{0{,}9} = 0{,}167$ ✓

$$T_m = \frac{T_1[(R_2)^2 + (S_1 . X_2)^2]S_m}{2S_1(R_2)^2}$$

$$= \frac{117{,}354[(0{,}15)^2 + (0{,}067\times 0{,}9)^2](0{,}617)}{(2)(0{,}067)(0{,}15)^2}$$ ✓✓

$$= \frac{117{,}354\ (4{,}365\times 10^{-3})}{3{,}015\times 10^{-3}}$$

$$= 169{,}901\ Nm$$ ✓ (4)

5.2.3 $S_m = \frac{N_S - N}{N_S}$ ✓

$\therefore N = 1\,500 - (0{,}167)(1\,500) = 1\,249{,}5\ r/min$ ✓ (2)
[16]

QUESTION 6

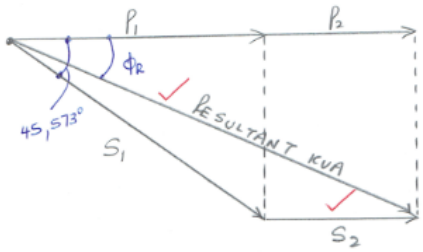
6.1
- Use a capacitor bank in parallel with the supply.
- Use an over-excited synchronous motor.
- Ensure that large induction motors do not run lightly loaded. (Any 2 × 1) (2)

6.2 6.2.1 $P_1 = \frac{12}{0{,}8} = 15\ kW$ ✓

$\cos \emptyset_1 = 0{,}7\ lagging \therefore \emptyset_1 = 45{,}573°$

$S_1 = \frac{P_1}{\cos \emptyset_1} = 21{,}429\ kVA$ ✓

$P_2 = 8\ kW \quad and \quad S_2 = 8\ kVA \quad \cos \emptyset_2 = 1 \quad \therefore \emptyset_2 = 0°$



(2)

Resultant kVA = 21,429∟—45,573° + 8 ∟0° ✓

= (15 — j 15,303) + (8 + j0)

= 23 — j 15,303

= 27,626∟—33,638° kVA ✓

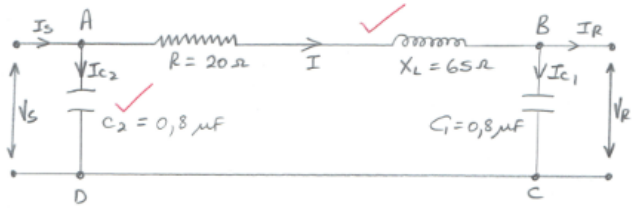
Maximum demand charge = (140)(27,626) = R3 867,64 ✓✓

(6)

6.2.2 $\cos \emptyset_R = \cos 33{,}638° = 0{,}833\ lagging$✓✓ (2)
[12]

QUESTION 7

7.1



(2)

Use V_R as reference : V_R = 76 210,236 ∟0° ✓

$I_R = \frac{30\times10^6}{\sqrt{3}(132\,000)(0{,}8)} = 164{,}02 \angle -36{,}87° = 131{,}216 - j\,98{,}412$ ✓

Z_{AB} = 20 + j 65 = 68,007 ∟72,897° ✓

$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi(50)(0{,}8\times10^{-6})} = 3\,978{,}874\ \Omega$ ✓

Z_{AD} = Z_{BC} = 0 — j 3 978,874 = 3 978,874 ∟—90° ✓

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

$I = I_{C1} + I_R$ = 131,216 — j 79,258 = 153,295 ∟—31,133° A ✓

V_{AB} = I . Z_{AB} = 10 425,133 ∟41,764° = 7 776,051 + j 6 943,805✓

V_S = V_R + V_{AB} = 83 986,287 + j 6 943,805 = 84 272,848 ∟4,726° V✓

∴ V_S = $\sqrt{3}$ (84 272,848) = 145,965 kV ✓ (10)

7.2 $I_{C2} = \frac{V_S}{Z_{AD}} = 21{,}18 \angle 94{,}726° = -1{,}745 + j\,21{,}108$ ✓

$\therefore\ I_S = I + I_{C2}$

= 129,471 —j 58,15

= 141,93 ∟—24,187° A ✓ (2)

7.3 $\cos \emptyset_s = \cos(4{,}726° + 24{,}187°) = 0{,}875\ lagging$✓✓ (2)
[16]

TOTAL: 100

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