higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

9 APRIL 2018

This marking guideline consists of 16 pages.

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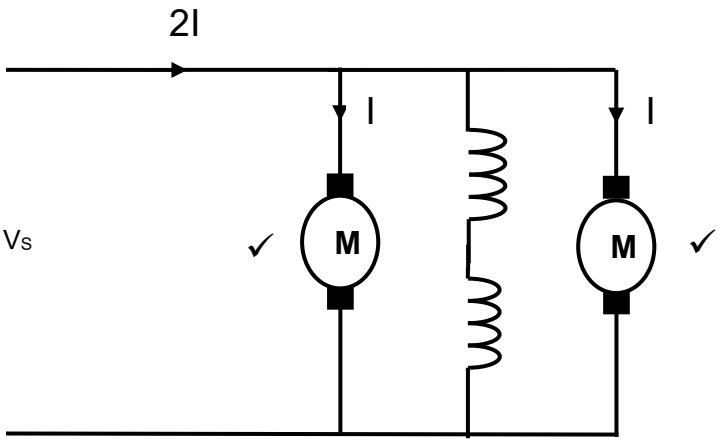
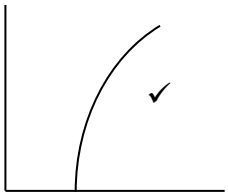
QUESTION 1

1.1 1.1.1

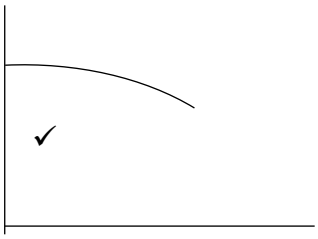


1.1.2 Torque-current characteristics



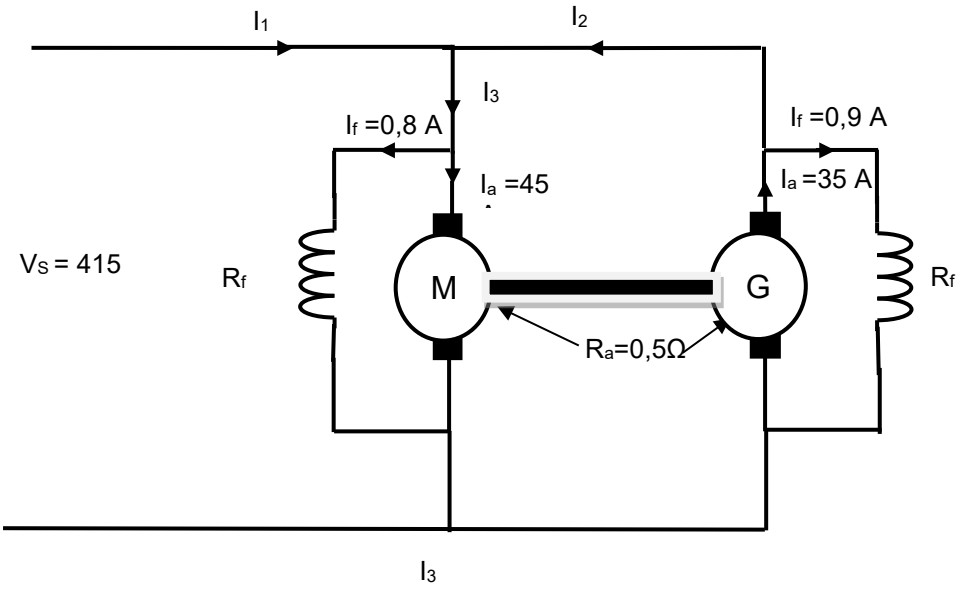
(2)

Speed-current characteristics



(2)

1.2



1.2.1 $I_2 = I_{a(gen)} - I_{f(gen)} = 35 - 0{,}9 = 34{,}1$ A

$I_3 = I_{a(mot)} + I_{f(mot)} = 45 - 0{,}8 = 45{,}8$ A

$I_1 = I_3 - I_2 = 45{,}8 - 34{,}1 = 11{,}7$ A

For a motor	For a generator
Field cu loss $= VI = 415 \times 0{,}8$ $= 332$ W✓	Field cu loss $= VI = 415 \times 0{,}9$ $= 373{,}5$ W✓
Armatur cu loss $= (I_a)^2 . R_a$ $= 45^2 \times 0{,}3$ $= 607{,}5$ W✓	Armatur cu loss $= (I_a)^2 . R_a$ $= 35^2 \times 0{,}05$ $= 367{,}5$ W✓

Total cu losses of motor a $= 322 + 1\,012{,}5 + 373{,}5 + 612{,}5$
$= 2\,320{,}5$ W

Total losses of motor and gen. $= I_1 . V_S = 11{,}7 \times 415$
$= 4\,855{,}5$ W✓

Total iron and friction losses $= 4\,855{,}5 - 2\,320{,}5 = 2\,535$ W

Iron and friction of each machine $= \frac{2\,535}{2}$

$= 1\,267{,}5$ W✓

$$\eta_{motor} = 1 - \frac{P_{out}}{P_{in}} = 1 - \frac{322 + 1\,012{,}5 + 1\,267{,}5}{415 \times 45{,}8}$$

$= 0{,}863$ pu ✓

$$\eta_{gen} = \frac{\text{output}}{\text{output} + \text{losses}} = \frac{415 \times 34{,}1}{(415 \times 34) + (373{,}5 + 367{,}5 + 1\,267{,}5)}$$
$$= 0{,}876 \text{ pu } ✓✓ \quad (9)$$

1.2.2
$$= \sqrt{\frac{I_2}{I_3}} = \sqrt{\frac{34{,}1}{45{,}8}}$$
$$= 0{,}863 \text{ pu } ✓ \quad (1)$$

[14]

QUESTION 2

2.1 Fundamentals

$$X_{C1} = \frac{1}{2.\pi.f.C} = \frac{1}{2 \times \pi \times 50 \times 415 \times 10^{-6}} = \mathbf{7}{,}670\ \Omega$$

$$Z_1 = R - jX_{C1} = 7 - j7{,}67 = 10{,}384 \angle -47{,}615°\ \Omega ✓$$

$$I_{M1} = E_{M1}/Z_1 = 150 \angle 0°/10{,}384 \angle -47{,}615°$$
$$= 14{,}445 \angle 47{,}615°\text{ A } ✓$$

Third harmonic

$$X_{C3} = \frac{X_{C1}}{3} = \frac{7{,}67}{3} = 2{,}557\ \Omega$$

$$Z_3 = R - jX_{C3} = 7 - j2{,}557$$
$$= 7{,}452 \angle -20{,}067°\ \Omega ✓$$

$$I_{M3} = E_{M3}/Z_3 = 75 \angle 30°/7{,}452 \angle -20{,}067°$$
$$= 10.064 \angle 50{,}067°\text{ A} ✓$$

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Fifth harmonic

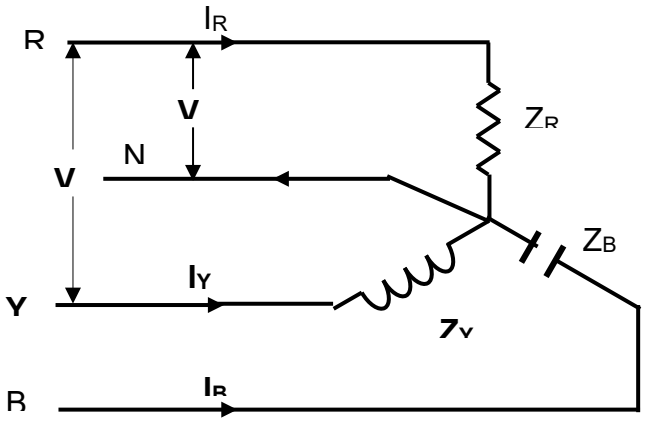
$$X_{C5} = \frac{X_{C1}}{5} = \frac{7,670}{5} = 1,534\,\Omega$$

$$Z_5 = R - jX_{C5} = 7 - j1,534$$
$$= 7,166\angle -12,361°\ \Omega\ ✓$$

$$I_{M5} = E_5/Z_5 = 40\angle 15/7,166\angle -12,361°$$
$$= 5,582\angle 27,361°\ \text{A}\ ✓$$

$$\therefore \text{i} = 14,445\text{Sin}(\omega\text{t} + 47,615°) + 10,064\text{Sin}(3\omega\text{t} + 50,067°)✓$$
$$+ 5,582\text{Sin}(5\omega t + 27,361°)\ \text{A}✓ \qquad (8)$$

2.2



$I_R = 15,7\angle 0°$ A

$I_R = 15,7\angle 0°$ A

$I_Y = 39,53\angle -165°$

$I_B = 25,85\angle 206°$

$V_L = 445$ V

$$V_p = V_L/\sqrt{3} = 445/\sqrt{3} = 256,921\ V\ ✓$$

$\text{V}_{\text{RN}} = 256,921\angle 0°\ \text{V}$	$\text{V}_{\text{YN}} = 256,921\angle -120°\ \text{V}$	$V_{BN} = 256,921\angle 120°\ V$

(a) $$Z_{RN} = \frac{V_{RN}}{I_{RN}} = \frac{256,921\angle 0°}{15,7\angle 0°}✓ = 16,364\angle 0°\ \Omega\ ✓$$

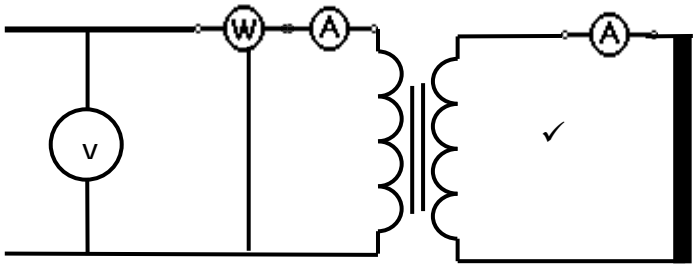
(b) $$Z_{YN} = \frac{V_{YN}}{I_{YN}} = \frac{256,921\angle -120°}{39,53\angle -165°}✓ = 6,499\angle 45°\ \Omega\ ✓$$

(c) $$Z_{BN} = \frac{V_{BN}}{I_{BN}} = \frac{256,921\angle 120°}{25,85\angle 206°}✓ = 9,939\angle -86°\ \Omega\ ✓$$

(7)
[15]

QUESTION 3

3.1



- The secondary is short-circuited through an ammeter.✓
- A low voltage is applied to the primary and adjusted to circulate full-load current in both windings.✓
- The wattmeter reads the full-load copper loss. ✓ (4)

3.2 3.2.1

Method 1	Method 2
$R_{e1} = R_1 + R_2(V_1/V_2)^2$ $= 0,45 + 0,0019(6\,600/415)^2$ $= 0,931\ \Omega$✓	$R_{e2} = R_2 + R_1(V_2/V_1)^2$ $= 0,0019 + 0,45(415/6\,600)^2$ $= 3,679\ m\Omega$✓
$I_1 = S/V_1 = 500\,000/6\,600$ $= 75,758\ A$✓	$I_2 = S/V_2 = 500\,000/415$ $= 1\,204,819\ A$✓
$P_{sc} = (I_1)^2R_{e1} = (75,758)^2 \times 0,931$ $= 5,340\ kW$✓	$P_{sc} = (I_2)^2R_{e2} = (1\,204,819)^2 \times 0,004$ $= 5,340\ kW$✓

$$\eta = \frac{S \cdot Cos\,\theta}{S \cdot Cos\,\theta + P_i + P_{sc}} \times 100\% = \frac{500 \times 0,8}{(500 \times 0,8) + 2,9 + 5,340}$$✓

$$= 97,982\ \%$$✓ (5)

3.2.2

$$= \frac{kSCos\,\theta}{kSCos\,\theta + P_i + k^2P_{sc}} \text{x } 100\%$$

$$= \frac{0,5 \times 500 \times 0,8}{(0,5 \times 500 \times 0,8) + 2,9 + (0,5^2 \times 5,34)} \times 100\ \%$$ ✓

$$= 97,926\ \%$$ ✓

(2)

3.2.3 For η_{max}: $k = \sqrt{P_i/P_{sc}} = \sqrt{2,9/2,583} = 1,060$✓

Method 1

$$\eta_{max} = \frac{kSCos\,\theta}{kSCos\,\theta + P_i + k^2P_{sc}} \times 100\ \%$$
$$= \frac{1,06 \times 500 \times 0,8}{(1,06 \times 500 \times 0,8) + 2,9 + (1,06^2 \times 5,34} \times 100\ \%$$ ✓
$$= 97,944\ \%$$✓

Method 2

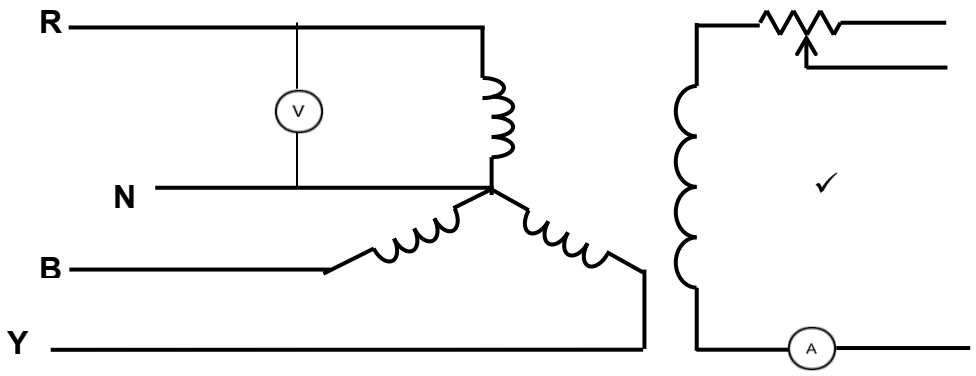
$$\eta_{max} = \frac{kSCos\,\theta}{kSCos\,\theta + 2P_i} \times 100\ \%$$
$$= \frac{1,06 \times 500 \times 0,8}{(1,06 \times 500 \times 0,8) + (2 \times 2,583)} \times 100\ \%$$ ✓
$$= 98,651\ \%$$ ✓

(3)

3.2.4 S = kS = 1,06 × 500 = 530 kW✓ (1)
[15]

QUESTION 4

4.1



The alternator is driven at a normal speed on an open circuit.✓ A series of readings are taken of corresponding values of the field current and the phase emf.✓ The phase emf is then plotted vertically against the field current.✓ (4)

4.2 4.2.1

$$f = \frac{N.p}{60}$$

$$\therefore N = \frac{60.f}{p} = \frac{60 \times 50}{4} \checkmark$$

$$= 750 \text{ r/min} \checkmark \quad (2)$$

4.2.2 $\text{Number of slots per pole} = \text{Number of slots/number of poles}$

$$= 72/8 = 9 \checkmark$$

$$\alpha = 180°/\text{Number of slots per pole} = 180°/9 = 20° \checkmark$$

$$n = \text{Number of slots per pole/Phases} = 9/3 = 3 \checkmark$$

$$Z_p = Z_T/3 = (72 \times 10)/3 = 240 \checkmark\checkmark$$

For full-pitched: $K_p = 1$

$$K_d = \frac{\text{Sin}\left(\frac{n.\alpha}{2}\right)}{n\,\text{Sin}\left(\frac{\alpha}{2}\right)} = \frac{\text{Sin}\left(\frac{3\times 20°}{2}\right)}{3\,\text{Sin}\left(\frac{20°}{2}\right)} = 0,96 \checkmark$$

$$E_p = 2.K_f.K_d.K_p.f.\emptyset.Z_p = 2 \times 1,11 \times 0,96 \times 1 \times 50 \times 0,08 \times 240$$

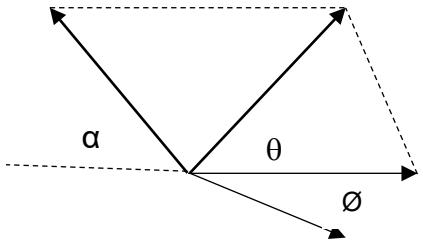
$$= 2\,045,952\ V \checkmark$$

$$E_L = \sqrt{3}.E_P = \sqrt{3} \times 2\,045,952 = 3\,543,693 \text{ V} \checkmark\checkmark \quad (9)$$

[15]

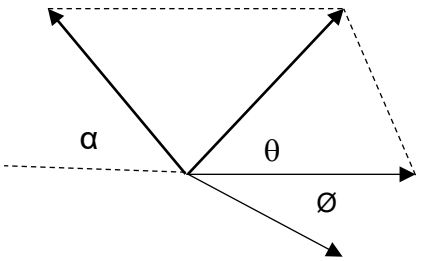
QUESTION 5

5.1



✓

If the load torque increases, angle α also increases, but E remains the same if the excitation is constant.✓



✓

If E retards further, it forces E_r to retard. Angle θ, the impedance angle, remains constant therefore I lags more.✓ (4)

5.2 5.2.1 $V_p = V_L/\sqrt{3} = 2\,500/\sqrt{3} = 1\,443{,}376\ V$✓

$$S = \sqrt{3}.V_L.I_L \ \therefore I_L = \frac{S}{\sqrt{3}.V_L} = \frac{580 \times 10^3}{\sqrt{3} \times 2\,500} = 133{,}945\ A$$✓

Method 1

$\theta = \cos^{-1} 0{,}85 = 31{,}788$✓

$IR = 133{,}945 \times 1{,}5 = 200{,}198\ V$✓

$IX = 133{,}945 \times 4{,}5 = 602{,}753\ V$✓

$$E_p = V_p\angle -\theta + IR\angle 180° + I.X\angle -90°$$
$$= 1\,443{,}376\angle -31{,}788 + 200{,}198\angle 180° + 602{,}753\angle -90°$$
$$= 1\,706{,}482\angle -53{,}013°\ V$$✓

$E_L = \sqrt{3}.E_p = \sqrt{3} \times 1\,706{,}482 = 2\,955{,}714\ V$✓

Method 2

$Z_S = R + jX = 1{,}5 + j4{,}5 = 4{,}743\angle 71{,}565°\ \Omega$✓

$E_r = I_p.Z_S = 133{,}945\angle 31{,}788° \times 4{,}743\angle 71{,}565°$✓

$$= 635{,}301\angle 103{,}353°\ V$$✓

$E_p = E_r - V_p = 635{,}301\angle 103{,}353° - 1\,443{,}376\angle 0°$

$$= 1\,706{,}017\angle 158{,}757°\ V$$✓

$$E_L = \sqrt{3}.E_p = \sqrt{3} \times 1\,706{,}017 = 2\,954{,}908\ V$$✓ (7)

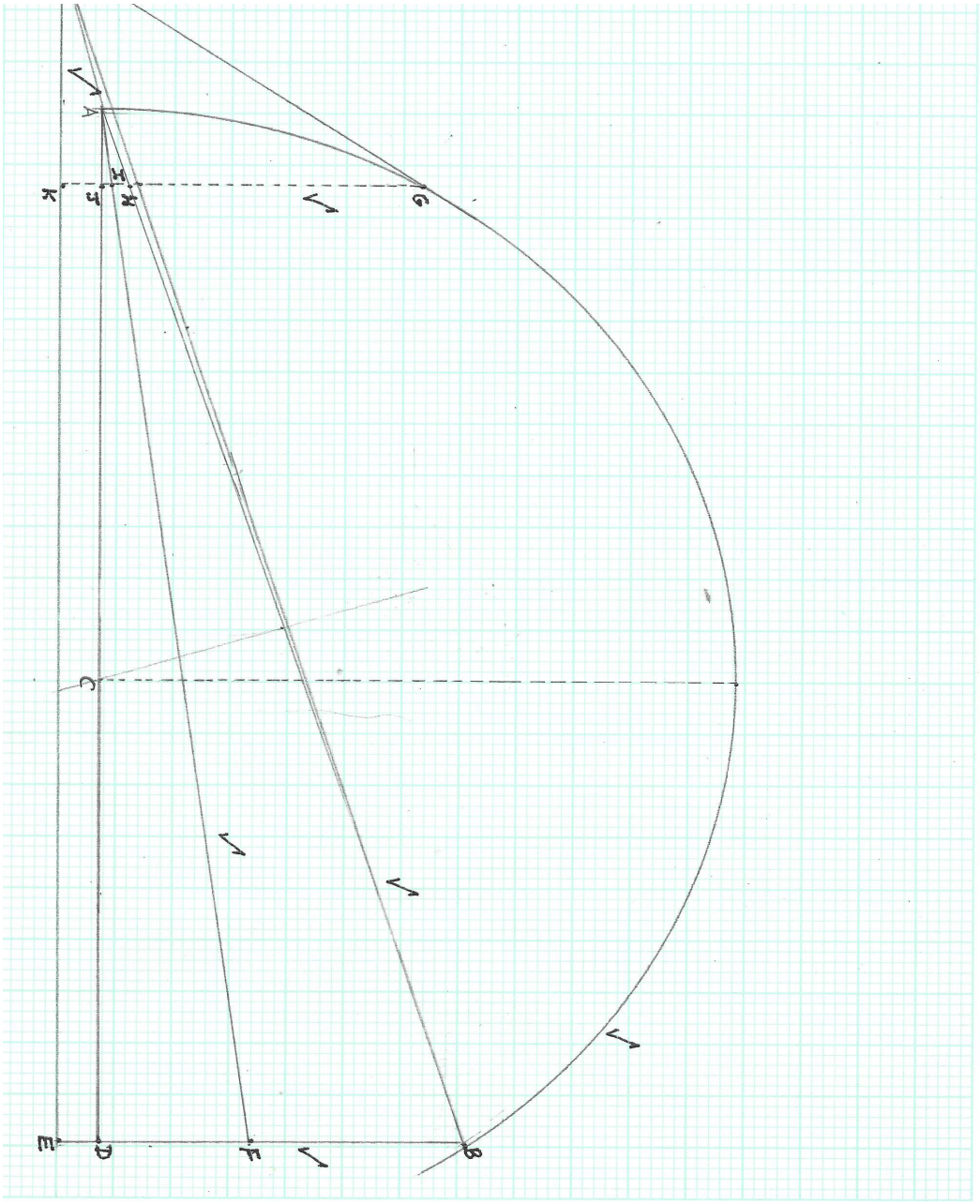
5.2.2

Method 1	Method 2
$\alpha = 53{,}013° - 31{,}788$ $= \mathbf{21{,}225}°$ (Electrical)✓	$\alpha = 180° - 158{,}757$ $= \mathbf{21{,}243}°$ (Electrical)✓
$\alpha = 21{,}225/2$ $= \mathbf{10{,}613}°$ (Mechanical)✓	$\alpha = 21{,}243/2$ $= 10{,}622°$ (Mechanical)✓

(2)
[13]

QUESTION 6

6.1



(3)

$$\theta_{NL} = Cos^{-1}\left(\frac{P}{\sqrt{3}.V_L.I_L}\right) = Cos^{-1}\left(\frac{5\ 923}{\sqrt{3} \times 190 \times 60}\right) \checkmark$$
$$= 75{,}524° \checkmark$$

$$\theta_{SC} = Cos^{-1}\left(\frac{P}{\sqrt{3}.V_L.I_L}\right) = Cos^{-1}\left(\frac{2\ 468}{\sqrt{3} \times 380 \times 15}\right) \checkmark$$
$$= 72{,}544° \checkmark$$

Stator resistance per phase = 0,4/2 = 0,2 Ω✓

$$I_{SC} = \text{Test current} \times \frac{\text{rated voltage}}{\text{test voltage}} = 60 \times \frac{380}{190} = 120 \text{ A}✓$$

FD on the circle diagram = stator copper losses at standstill

$$FD = \frac{3.I_{SC}{}^2.R_S}{\sqrt{3}.V_L.\text{Scale}} = \frac{3 \times 120^2 \times 0{,}08}{\sqrt{3} \times 380 \times 5} = 2{,}625 \text{ cm}✓$$

Scale: 1cm = 5 A I_{NL} = 15/5 = 3 cm I_{SC} = 120/5 = 24 cm (7)

6.2 6.2.1 $\eta = P_{out}/P_{in} \times 100\%$
$= GH/GK \times 100\% = 6{,}15/7{,}6 \times 100\% = 80{,}921\%$ ✓

6.2.2 $I = \text{Distance} \times \text{Scale} = OG \times 5 = 9{,}3 \times 5 = 46{,}5\ A$✓

6.2.3 $\text{Power factor} = \text{Cos } 35 = 0{,}819 \text{ lagging}$ ✓

6.2.4 $P_{in} = \sqrt{3}.V_L.\text{Distance(GK)}.\text{Scale} = \sqrt{3} \times 380 \times 7{,}6 \times 5$
$= 25{,}011 \text{ kW}$✓

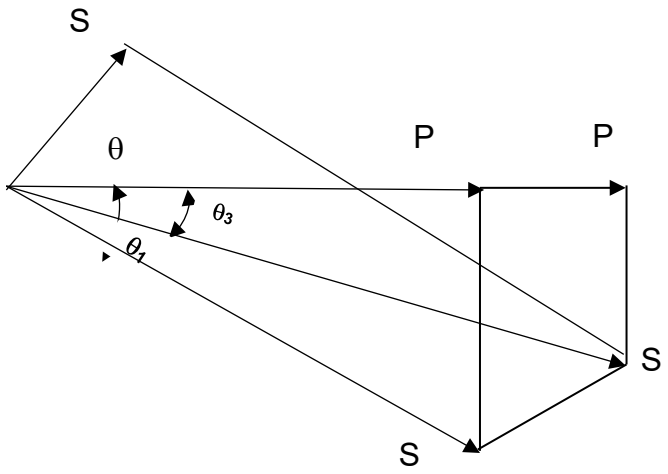
6.2.5 $P_{in} = \sqrt{3}.V_L.\text{Distance(GK)}.\text{Scale} = \sqrt{3} \times 380 \times 3{,}75 \times 5$
$= 12{,}341 \text{ kW}$✓

(5 × 1) (5)
[15]

QUESTION 7

7.1
- At a poor power factor, the kVA demand is high and Eskom charges per kVA.✓ At an improved power factor, the kVA and the charges are reduced.✓
- At a poor power factor, the current is high and as the drop in the line and cable volt depends on the current,✓ the consumer voltage decreases.✓ (4)

7.2 7.2.1 Method 1



$$S_1 = \frac{P}{\cos\theta} = \frac{250}{0{,}8} = 312{,}5\angle -36{,}87 \text{ kVA}\checkmark$$

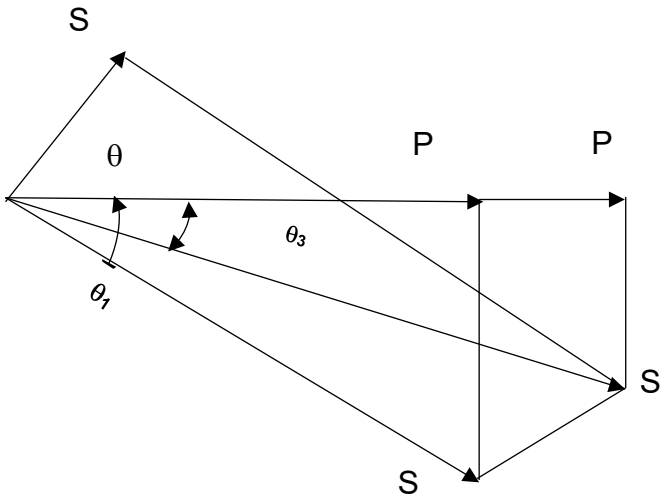
$$S_2 = 300\angle 25{,}842 \text{ kVA}$$

$$S_3 = S_1 + S_2$$
$$= 312{,}5\angle -36{,}87 + 300\angle 25{,}842\checkmark$$
$$= 523{,}085\angle -6{,}265 \text{ kVA}\checkmark$$

$$S_3 = \sqrt{3}.V_L.I_{L3} \ \therefore \ I_{L3} = \frac{S_3}{\sqrt{3} \times V_L} = \frac{523{,}085 \times 10^3}{\sqrt{3} \times 3\,200} = 94{,}371 \text{ A}\checkmark$$

$$\text{Power factor} = \text{Cos}\,6{,}265 = 0{,}994 \text{ lagging}\checkmark$$

Method 2



$$I_{L1} = \frac{P}{\sqrt{3}.V_L.\times \text{Cos}\,\theta} = \frac{250\,000}{\sqrt{3} \times 3\,200 \times 0{,}8}$$
$$= 56{,}382\angle -36{,}87° \text{ A}\checkmark$$

$S_2 = \sqrt{3}.V_L I_{L2}$

$$I_{L2} = \frac{S_2}{\sqrt{3}.V_L} = \frac{300 \times 10^3}{\sqrt{3} \times 3\,200}$$

$= 54{,}127\angle 25{,}842\ \text{A}$✓

$I_{L3} = I_{L1} + I_{L2}$

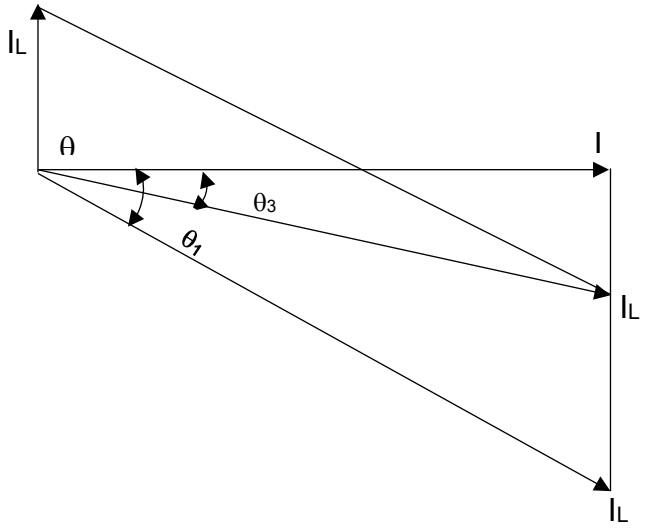
$= 56{,}382\angle -36{,}87° + 54{,}127\angle 25{,}842°$✓

$= 94{,}377\angle -6{,}226°\ \text{A}$✓

Power factor $= \text{Cos}\ 6{,}226 = 0{,}994$ ✓ (5)

7.2.2 Before the installation of the capacitor bank:

Method 1



$\text{Cos}\ \theta_1 = 0{,}8$ lagging $\quad \therefore \theta_1 = 36{,}887°$

$\text{Cos}\ \theta_3 = 0{,}9$ leading $\quad \therefore \theta_3 = 25{,}842°$

$P = \sqrt{3}.V_1.I_{L1}.\text{Cos}\ \theta_1$

$$I_{L1} = \frac{P}{\sqrt{3}.V_L.C\ \text{os}\ \theta_1} = \frac{250\,000}{\sqrt{3} \times 3\,200 \times 0{,}8}$$

$= 56{,}382\ \text{A}$✓

$\text{Cos}\ \theta_1 = I_W / I_{L1}$

$\therefore I_W = I_{L1}.\text{Cos}\ \theta_1$

$= 56{,}382 \times 0{,}8 = 45{,}105\ \text{A}$✓

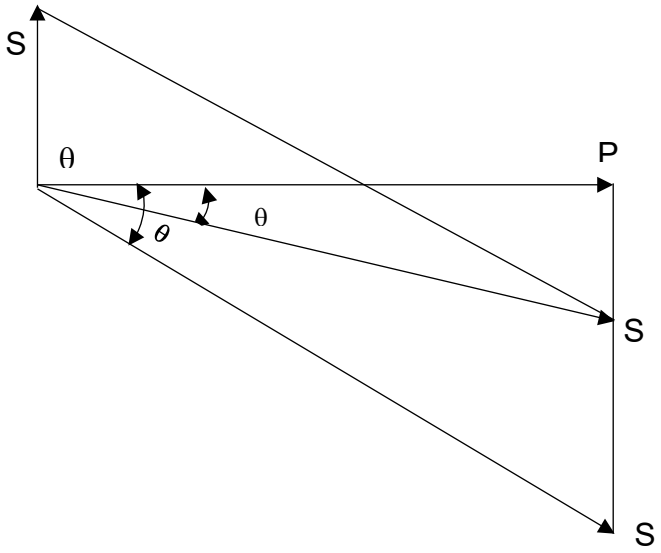
$I_{L2} = I_W(\text{Tan}\ \theta_1 - \text{Tan}\ \theta_3)$

$= 45{,}105(\tan 36{,}87° - \tan 25{,}842°)$

$= 11{,}944\ \text{A}$✓

$S = \sqrt{3}.V_L.I_{L2}$
$= \sqrt{3} \times 3\,200 \times 11{,}984$
$= 66{,}42$ kVA✓

Method 2



$S_1 = 312{,}5\angle -36{,}87$ kVA✓

After the installation of the capacitor bank:

$\text{Cos}\,\theta_3 = P_1/S_3$
$\therefore S_3 = P_1/\text{Cos}\,\theta_1 = 250\,000/0{,}9$
$= 277{,}778$ kVA ✓

$S_3 = S_1 + S_2$
$\therefore S_2 = S_3 - S_1$
$= 277{,}778\angle -25{,}842° - 312{,}5\angle -36{,}87°$✓
$= 66{,}42\angle 90°$ kVA✓ (4)
[13]

TOTAL: 100

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