



higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NASIENRIGLYN

NASIONALE SERTIFIKAAT

ELEKTROTEGNIEK N6

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Hierdie nasienriglyn bestaan uit 10 bladsye.

VRAAG 1: GS-MASJIENE

1.1 Van: $I_a = \frac{V - E}{R_a}$ ✓ en $E = kN\phi$ ✓,

Wanneer die motor belas is, verhoog die spoed (N), wat daartoe lei dat die EMK (E) ook verhoog, ✓ en dus sal die ankerstroom toeneem. ✓

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1.2

$$R_{t1} = 0,37 + 0,2 = 0,57 \Omega \checkmark$$

$$E_1 = 250 - (55)(0,57) = 218,65 \text{ V} \checkmark$$

$$R_{t2} = 0,2 + \frac{(0,4)(0,37)}{0,4+0,37} = 0,392 \Omega \checkmark$$

$$I_{f2} = \left(\frac{0,4}{0,4 + 0,37} \right) I_{a2} = 0,519 I_{a2} \checkmark$$

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

$$\frac{T_1}{1,3T_1} = \frac{(55)(55)}{I_{a2}(0,519 I_{a2})} \checkmark$$

$$I_{a2} = \sqrt{\frac{(1,3)(55 \times 55)}{0,519}} = 87,046 \text{ A} \checkmark$$

$$I_{f2} = (0,519)(87,046) = 45,177 \text{ A} \checkmark$$

$$E_2 = 250 - (87,046)(0,392) = 215,878 \text{ V} \checkmark$$

$$N_2 = \frac{E_2 N_1 I_{f1}}{E_1 I_{f2}} = \frac{(215,878)(1500)(50)}{(218,65)(45,177)} \checkmark = 1\,639,09 \text{ r/min} \checkmark$$

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VRAAG 2: WS-TEORIE

2.1

FUNDAMENTEEL	DERDE BOFREKWENSIE	TIENDE BOFREKWENSIE
$R_1 = 200 \Omega$ $X_{C1} = \frac{1}{\omega C} = 106,157 \Omega \checkmark$ $Z_A = 200 + j 0 = 200 \angle 0^\circ$ $Z_B = 0 - j 106,157$ $= 106,157 \angle -90^\circ \Omega$ $Z_A + Z_B = 200 - j 106,157$ $= 226,427 \angle -27,959^\circ \Omega$ $Z_1 = \frac{Z_A \times Z_B}{Z_A + Z_B}$ $= \frac{21231,4 \angle -90^\circ}{226,427 \angle -27,959^\circ}$ $= 93,767 \angle -62,041^\circ \Omega \checkmark$	$R_3 = 200 \Omega$ $X_{C3} = \frac{X_{C1}}{3} = 35,386 \Omega \checkmark$ $Z_A = 200 + j 0 = 200 \angle 0^\circ$ $Z_B = 0 - j 35,386$ $= 35,386 \angle -90^\circ$ $Z_A + Z_B = 200 - j 35,386$ $= 203,106 \angle -10,034^\circ$ $Z_3 = \frac{Z_A \times Z_B}{Z_A + Z_B}$ $= \frac{7\,077,2 \angle -90^\circ}{203,106 \angle -10,034^\circ}$ $= 34,845 \angle -79,966^\circ \checkmark$	$R_5 = 200 \Omega$ $X_{C5} = \frac{X_{C1}}{10} = 10,616 \Omega \checkmark$ $Z_A = 200 + j 0 = 200 \angle 0^\circ$ $Z_B = 0 - j 10,616$ $= 10,616 \angle -90^\circ$ $Z_A + Z_B = 200 - j 10,616$ $= 200,282 \angle -3,038^\circ$ $Z_{10} = \frac{Z_A \times Z_B}{Z_A + Z_B}$ $= \frac{2123,2 \angle -90^\circ}{200,282 \angle -3,038^\circ}$ $= 10,601 \angle -86,962^\circ \checkmark$

$$i = \frac{60}{93,767} \sin[314t + 25^\circ - (-62,041^\circ)] \checkmark$$

$$+ \frac{30}{34,845} \sin[942t - 30^\circ - (-79,966^\circ)] \checkmark$$

$$+ \frac{10}{10,601} \sin[3140t + 45^\circ - (-86,962^\circ)] \checkmark$$

$$i = 0,6399 \sin[314t + 87,041^\circ] \checkmark + 0,861 \sin[942t + 49,966^\circ] \checkmark$$

$$+ 0,943 \sin[3140t + 131,962^\circ] \checkmark$$

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2.2

$$V_{WGK} = \sqrt{\frac{60^2 + 30^2 + 10^2}{2}} = 47,958 V \checkmark \checkmark$$

$$I_{WGK} = \sqrt{\frac{0,6399^2 + 0,861^2 + 0,943^2}{2}} = 1,01 A \checkmark \checkmark$$

(4)

VRAAG 3: TRANSFORMATORS

3.1 Die koperverlies van 'n transformator hang af van die stroom✓ en die ysterverlies met spanning.✓ Die totale transformatorverlies hang af van die voltampère (VA) en nie die fasehoek tussen die spanning en stroom nie.✓ (3)

3.2 Gegee: 3 300/240 V-eenfasetransformator

$$\%Z = (0,65 + j 6,5) \%$$

$$S = 180 \text{ kVA}$$

$$\text{pf} = 0,8 \text{ nalopend}$$

$$\begin{aligned} 3.2.1 \quad N_1/N_2 &= V_1/V_2 \\ &= 3\,300/240 \\ &= 13,75 \checkmark \end{aligned}$$

$$\text{Windingsverhouding} = 13,75:1 \checkmark \text{ OF } 14:1 \quad (2)$$

$$3.2.2 \quad \cos \theta = 0,8 \text{ en } \sin \theta = 0,6$$

$$\begin{aligned} \% \text{ reëling} &= \%R \cdot \cos \theta + \%X \cdot \sin \theta \\ &= (0,65 \times 0,8) + (6,5 \times 0,6) \checkmark \\ &= 4,42 \% \checkmark \end{aligned} \quad (2)$$

$$\begin{aligned} 3.2.3 \quad V_{2term} &= V - (0,0442 V) \\ &= 240 - (0,0442 \times 240) \checkmark \\ &= 229,392 V \checkmark \end{aligned} \quad (2)$$

3.2.4	Metode 2
Metode 1 $\begin{aligned} P_{SC} &= \%R \cdot S \checkmark \\ &= 0,0065 \times 180\,000 \checkmark \\ &= 1\,170 \text{ W} \checkmark \end{aligned}$	$\begin{aligned} I_2 &= S/V_2 \\ &= 180\,000/240 \\ &= 750 \text{ A} \checkmark \end{aligned}$ $\begin{aligned} \%R &= I_2 R_{e2}/V_2 \\ R_{e2} &= \%R \cdot V_2/I_2 = (0,0065 \times 240)/750 \\ &= 0,00208 \, \Omega \checkmark \end{aligned}$ $\begin{aligned} P_{SC} &= (I_2)^2 \cdot R_{e2} = (750)^2 \times 0,00208 \\ &= 1\,170 \text{ W} \checkmark \end{aligned} \quad (3)$

3.2.5 **Metode 1**

$$\begin{aligned} \%X &= I_2 \cdot X_{e2}/V_2 \\ X_{e2} &= \%X \cdot V_2/I_2 = 0,065 \times 240/750 \\ &= 0,0208 \, \Omega \checkmark \end{aligned}$$

$$\begin{aligned} Z_{e2} &= \sqrt{R_{e2}^2 + X_{e2}^2} = \sqrt{(0,00208)^2 + (0,0208)^2} = 0,0209 \, \Omega \checkmark \\ \cos \theta_e &= R_{e2}/Z_{e2} = 0,00208/0,0209 \\ &= 0,1 \text{ nalopend} \checkmark \end{aligned}$$

Metode 2

$$\begin{aligned}\theta_e &= \tan^{-1}(\%X/\%R) \\ &= \tan^{-1}(6,5/0,65) \checkmark \\ &= 84,289^\circ \checkmark\end{aligned}$$

$$\cos \theta_e = \cos 84,289^\circ = 0,1 \text{ nalopend} \checkmark \quad (3)$$

3.2.6

Metode 1

$$\begin{aligned}I_1 &= S/V_1 = 180\,000/3\,300 \\ &= 54,545 \text{ A} \checkmark \\ V_{SC1} &= \frac{P_{SC1}}{\cos \theta_e \cdot I_1} = \frac{1170}{0,1 \times 54,545} \\ &= 214,502 \text{ V} \checkmark\end{aligned}$$

Metode 2

$$\begin{aligned}V_{SC2} &= Z_{e2} \cdot I_2 = 0,0209 \times 750 \\ &= 15,675 \text{ V} \checkmark \\ V_{SC1}/V_{SC2} &= N_1/N_2 \\ V_{SC1} &= \frac{N_1}{N_2} \times V_{SC2} \\ &= \frac{13,75}{1} \times 15,675 = 215,531 \text{ V} \checkmark\end{aligned}$$

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VRAAG 4: WS-MASJIENE

4.1 Die steekfaktor van 'n alternator is die verhouding tussen die werklike EMK verkry en die EMK wat verkry sou word as die spoele volsteek was. $\checkmark$ (2)

4.2 Gegee: Sterverbinde alternator

Getal pole = 10
f = 50 Hz

$E_L = 22\,000 \text{ V}$
Getal gleuwe = 150

4.2.1 Getal gleuwe per pool
= getal gleuwe/getal pole = $150/10 = 15 \checkmark$

$$\gamma = 180^\circ/\text{getal gleuwe per pool} = 180^\circ/15 = 12^\circ \checkmark$$

$$\eta = \text{getal gleuwe/pool/fase} = 15/3 = 5 \checkmark$$

$$\begin{aligned}K_d &= \frac{\sin \frac{\eta \gamma}{2}}{\eta \sin \frac{\gamma}{2}} = \frac{\sin(5 \times 12/2)}{5 \times \sin(12/2)} \checkmark \\ &= \frac{\sin(30^\circ)}{5 \times \sin(6)} = 0,957 \checkmark\end{aligned} \quad (5)$$

4.2.2 Steekfaktor = getal gleuwe/pool = 15
Spoelspan (φ) = $180^\circ \times 3/\text{steekhoogte} = 180^\circ \times 3/15 = 36^\circ \checkmark$
 $K_p = \cos(\varphi/2) = \cos(36/2) = 0,951 \checkmark$ (2)

$$4.2.3 \quad E_p = E_L / \sqrt{3} = 22\,000 / \sqrt{3} \\ = \mathbf{12\,701,706\,V} \checkmark$$

Ook,

$$E_p = 2 \cdot K_f \cdot K_d \cdot K_p \cdot f \cdot \phi \cdot Z_p \\ Z_p = \frac{E_p}{2K_f K_d K_p f \phi} \checkmark \\ = \frac{12\,701,706}{2 \times 1,11 \times 0,957 \times 0,951 \times 50 \times 0,67} \\ = \mathbf{187,66} \text{ sê } 188 \checkmark \quad (3)$$

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VRAAG 5: WS-MASJIENE

- 5.1
- Hul EMK's moet gelyk wees.
 - Hul EMK's moet dieselfde frekwensie hê.
 - Hul EMK's moet gelykfasig wees.
 - Opeenvolgende EMK's moet dieselfde hoekverplasing hê.
- (4)

- 5.2 Gegee: Sterverbinde sinchrone motor
 $S = 250 \text{ kVA}$
 $V_L = 6\,600 \text{ V}$

Getal pole = 8
 $\% Z = (5 + j45) \%$
 $\text{pf} = 0,8 \text{ nalopend}$

$$5.2.1 \quad V_L = \sqrt{3} \cdot V_p \\ V_p = \frac{V_L}{\sqrt{3}} = \frac{6\,600}{\sqrt{3}} = \mathbf{3\,810,512\,V}$$

$$\%R = \frac{I_p \cdot R}{V_p} \\ I_p \cdot R = \frac{\%R}{100\%} \times V_p = \frac{5}{100} \times 3\,810,512 = \mathbf{190,525\,6\,V} \checkmark \checkmark \\ \%X = \frac{I_p \cdot X_s}{V_p} \\ I_p \cdot X_s = \frac{\%X}{100\%} \times V_p = \frac{45}{100} \times 3\,810,512 = \mathbf{1\,714,73\,V} \checkmark \checkmark \quad (4)$$

$$5.2.2 \quad S = \sqrt{3} \cdot V_L \cdot I_L$$

$$I_L = \frac{S}{\sqrt{3} \cdot V_L} = \frac{250 \times 10^3}{\sqrt{3} \times 3300} = 21,869 \text{ A} \checkmark$$

Metode 1:

$$I_L = 21,869 \angle 36,87^\circ \text{ A} \checkmark$$

$$E_p = V_p \angle -\theta + I_p \cdot R_a \angle 180^\circ + I_p \cdot X_s \angle -90^\circ$$

$$= 3810,512 \angle -36,87^\circ + 190,5256 \angle 180^\circ + 1714,73 \angle -90^\circ \checkmark$$

$$= 2857,88 - j4001,043$$

$$= 4916,745 \angle -54,465^\circ \text{ V} \checkmark$$

$$E_L = \sqrt{3} \cdot E_p = \sqrt{3} \times 4916,745 = 8516,052 \text{ V} \checkmark$$

Metode 2:

$$Z_s = R + jX_s = 8,712 + j78,409 = 78,892 \angle 83,66^\circ \Omega$$

$$E_r = I_p \cdot Z_s = 21,869 \angle 36,87^\circ \times 78,892 \angle 83,66^\circ$$

$$= 1725,289 \angle 120,53^\circ \text{ V} \checkmark$$

$$E_p = E_r - V_p = 1725,289 \angle 120,53^\circ - 3810,512 \angle 0^\circ \checkmark$$

$$= 4916,901 \angle 162,408^\circ \text{ V} \checkmark$$

$$E_L = \sqrt{3} \cdot E_p = \sqrt{3} \times 4916,901 = 8516,322 \text{ V} \checkmark \quad (5)$$

$$5.2.3 \quad \alpha = 54,465^\circ - 36,87 = 17,595^\circ \text{ elektries} \checkmark$$

OF

$$180^\circ - 162,408^\circ = 17,592^\circ$$

$$\alpha = 17,595/3 = 5,865^\circ \text{ meganies} \checkmark \quad (2)$$

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VRAAG 6: OPWEKKING EN TOEVOER VAN WS-KRAG

- 6.1
- Direk-op-die-lyn-aansitting
 - Ster-delta-aansitting
 - Outotransformator-aansitting
 - Sleeping-aansitting
- (Enige 3 × 1) (3)

6.2 Gegee: Twee sterverbinde alternators wat parallel werk

$$P_1 = 60 \text{ kW teen arbeidsfaktor van een}$$

$$S_3 = 415 \text{ kVA teen } 0,8 \text{ pf nalopend}$$

$$P_2 = 380 \text{ kW teen } 0,9 \text{ pf nalopend}$$

$$I_{\text{masjien1}} = 150 \text{ A teen } 0,8 \text{ pf nalopend}$$

$$V_L = 3,3 \text{ kV}$$

6.2.1 Metode 1

Vir die 60 kW-las: $S_1 = P_1 / \cos \theta = 60 / 1 = 60 \angle 0^\circ \text{ kVA} \checkmark$

Vir die 380 kW-las: $S_2 = P_2 / \cos \theta = 380 / 0,9 = 422,222 \angle -25,842^\circ \text{ kVA} \checkmark$

Vir die 415 kVA-las: $S_3 = 415 \angle -36,87^\circ \text{ kVA} \checkmark$

Vir die 90 kW-las: $S_4 = P_4 / \cos \theta = 90 / 0,8 = 112,5 \angle 36,87^\circ \text{ kVA} \checkmark$

$$S_T = S_1 + S_2 + S_3 + S_4$$

$$= 60 \angle 0^\circ + 422,222 \angle -25,842^\circ + 415 \angle -36,87^\circ + 112,5 \angle 36,87^\circ \checkmark$$

$$= 936,301 \angle -22,980^\circ \text{ kVA} \checkmark$$

$$S_A = \sqrt{3} \cdot V_A \cdot I_A = \sqrt{3} \times 3300 \times 150 = 857,365 \angle -36,87^\circ \text{ kVA} \checkmark$$

$$S_B = S_T - S_A = 936,301 \angle -22,980^\circ - 857,365 \angle -36,87^\circ =$$

$$230,604 \angle 40,211^\circ \text{ kVA} \checkmark$$

$$\therefore IB = \frac{230,604}{\sqrt{3} \times 3300} = 40,345 \text{ A} \checkmark$$

Metode 2

Vir die 60 kW-las: $I_{L1} = P_1 / \sqrt{3} \cdot V_L = 60 / \sqrt{3} \times 3300 \times 1$
 $= 10,497 \angle 0^\circ \text{ A} \checkmark$

Vir die 380 kW-las: $I_{L2} = P_2 / \sqrt{3} \cdot V_L = 380 / \sqrt{3} \times 3300 \times 0,9$
 $= 73,87 \angle -25,842^\circ \text{ A} \checkmark$

Vir die 415 kVA-las: $I_{L3} = S_3 / \sqrt{3} \cdot V_L = 415 / \sqrt{3} \times 3300$
 $= 72,606 \angle -36,87^\circ \text{ A} \checkmark$

Vir die 90 kW-las: $I_{L4} = P_4 / \sqrt{3} \cdot V_L = 90 / \sqrt{3} \times 3300 \times 0,8$
 $= 19,682 \angle 36,87^\circ \text{ A} \checkmark$

$$I_T = I_1 + I_2 + I_3 + I_4$$

$$= 10,497 \angle 0^\circ + 73,87 \angle -25,842^\circ + 72,606 \angle -36,87^\circ + 19,682 \angle 36,87^\circ \checkmark$$

$$= 163,810 \angle -22,980^\circ \text{ A} \checkmark$$

Vir masjien 1: $I_A = 220 \angle -36,87^\circ \checkmark$

Vir masjien 2: $I_T = I_{a1} + I_{a2}$

$$\therefore I_B = I_T - I_A$$

$$= 163,810 \angle -22,980^\circ \text{ A} - 220 \angle -36,87^\circ \checkmark$$

$$= 40,345 \angle 40,211^\circ \text{ A} \checkmark$$

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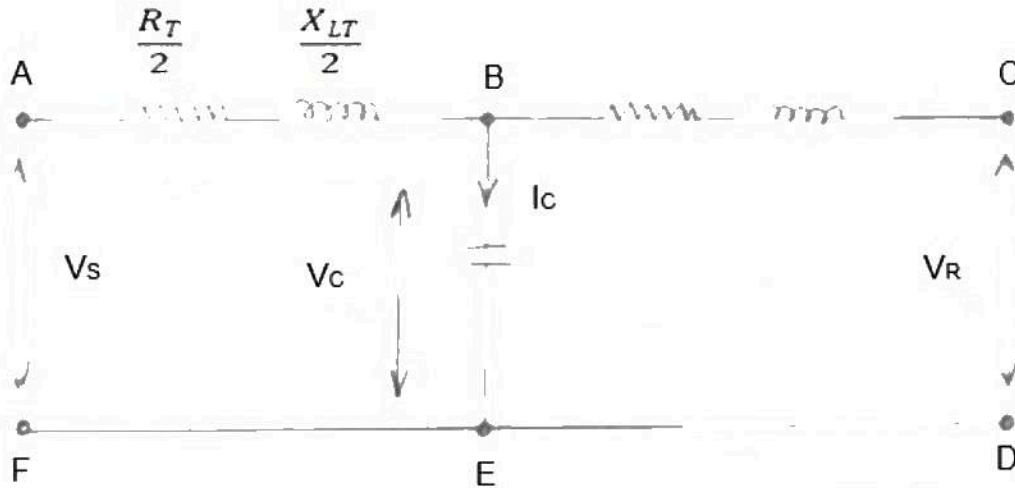
6.2.2 Arbeidsfaktor $\cos 40,211^\circ = 0,764$ voorlopend $\checkmark$

(1)

6.2.3 $P_2 = \sqrt{3} \cdot V_L \cdot I_{y2} \cdot \cos \theta_2 = \sqrt{3} \times 3300 \times 40,345 \times 0,764$
 $= 176,180 \text{ kW} \checkmark$

(1)

6.3



$$V_{R/ph} = \frac{133\,000}{\sqrt{3}} = 76\,787,586 \angle 0^\circ \text{ V} \checkmark$$

$$\cos \phi = \frac{\text{ware vermoë}}{\text{skynvermoë}} = \frac{24 \times 10^6}{30 \times 10^6} = 0,8 \quad \therefore \phi = -36,87^\circ \checkmark$$

$$S_R = \sqrt{3} V_L I_L$$

$$I_R = \frac{30 \times 10^6}{\sqrt{3} (133 \times 10^3)} = 130,229 \angle -36,87^\circ \text{ A} \checkmark$$

$$Z_{AB} = Z_{BC} = 16 + j40 = 43,081 \angle 68,199^\circ \checkmark$$

$$X_C = \frac{1}{2\pi \times 50 \times 2 \times 10^{-6}} = 1\,591,549 \, \Omega$$

$$Z_{BE} = 0 - j1\,591,549 = 1\,591,549 \angle -90^\circ \checkmark$$

$$V_{BC} = I_R Z_{BC} = 130,229 \angle -36,87^\circ \times 43,081 \angle 68,199^\circ \\ = 5\,610,396 \angle 31,329^\circ \text{ V} \checkmark$$

$$V_C = V_{ph/R} + V_{BC} = 76\,787,586 \angle 0^\circ + 5\,610,396 \angle 31,329^\circ \\ = 81\,632,101 \angle 2,048^\circ \text{ V} \checkmark$$

$$I_C = \frac{V_C}{Z_{BE}} = \frac{81\,632,101 \angle 2,048^\circ}{1\,591,549 \angle -90^\circ} = 51,291 \angle 92,291^\circ \text{ A} \checkmark$$

$$I_S = I_R + I_C = 130,229 \angle -36,87^\circ + 51,291 \angle 92,291^\circ \\ = 105,613 \angle -14,749^\circ \text{ A} \checkmark$$

$$\begin{aligned} V_{AB} &= I_S Z_{AB} = 105,613 \angle -14,749^\circ \times 43,081 \angle 68,199^\circ \\ &= 4\,549,914 \angle 53,45^\circ \text{ V} \checkmark \end{aligned}$$

$$\begin{aligned} V_{S/PH} &= V_C + V_{AB} = 81\,632,101 \angle 2,048^\circ + 4\,549,914 \angle 53,45^\circ \\ &= 84\,545,39 \angle 4,459^\circ \checkmark \end{aligned}$$

$$\therefore V_S = \sqrt{3}(84\,545,39) = 146,437 \text{ kV} \checkmark$$

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TOTAAL:

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