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higher education & training

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Higher Education and Training
REPUBLIC OF SOUTH AFRICA

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NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

11 November (X-Paper)
09:00 – 12:00

Calculators may be used.

This question paper consists of 5 pages and a 5-page formula sheet.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
ELECTROTECHNICS N6
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers correctly according to the numbering system used in this question paper.
4. Start each question on a NEW page.
5. Keep subsections of questions together.
6. ROUND OFF ALL calculations to THREE decimal places.
7. Use the correct symbols and units.
8. Write neatly and legibly.

PTO

QUESTION 1

1.1 Explain, with the aid of a neat diagram, the operation of a Ward-Leonard control system, controlling the speed and direction of a large DC shunt motor. (7)

1.2 When running on no-load, a 220 V DC shunt motor draws a line current of 5 A and runs at 1 000 r/min. The armature and shunt field resistances are 0,5 ohms and 110 ohms respectively. The motor draws a line current of 45 A when running on full-load.

Calculate the following:

1.2.1 The full-load motor output (11)
1.2.2 The full-load efficiency (2)
[20]

QUESTION 2

2.1 The three line currents of an unbalanced, four-wire, three-phase, star-connected load is:

$I_R = 12{,}7\ \angle 0°$ A
$I_Y = 35{,}93\angle -165°$ A
$I_B = 20{,}88\ \angle 201°$A

The line voltage is 440 V. Take V_{RN} as phasor reference and R-Y-B as phase rotation.

Calculate the load impedances Z_{RN}, Z_{YN} and Z_{BN}. (7)

2.2 The current flowing in a circuit is represented by:

$i = 5 \sin \omega t + 0{,}5 \sin 3\omega t$ amperes and the voltage by:

$v = 200 \sin (\omega t + \frac{\pi}{6}) + 20 \sin (3\omega t + \frac{\pi}{3})$ volts.

Calculate the following:

2.2.1 The total power supplied (3)
2.2.2 The RMS value of the voltage and current (4)
2.2.3 The power factor (2)
[16]

QUESTION 3

3.1 Explain, with the aid of a neat diagram, how an open-circuit test is carried out on a single-phase transformer. (5)

3.2 A 125 kVA, 2 000/400 V, single-phase transformer has a primary resistance of 0,17 ohms and a secondary resistance of 0,0083 ohms. The iron loss is 1,3 kW.

Calculate the following:

3.2.1 The equivalent resistance referred to the secondary (2)

3.2.2 The full-load efficiency at 0,8 power factor lagging (4)

3.2.3 The maximum efficiency at 0,8 power factor lagging (3)

3.2.4 The percentage voltage regulation at full-load and at unity power factor (2)

HINT: $R_{E2} = R_2 + R1\left(\frac{V_2}{V_1}\right)^2$

[16]

QUESTION 4

4.1 Define *regulation of an alternator.* (3)

4.2 A 12 MVA, 11 000 V, 50 Hz, three-phase, star-connected alternator is driven at 300 r/min. There are 360 slots in the stator containing SIX conductors per slot. The coil pitch is $\frac{5}{6}$ of the pole pitch and the open-circuit EMF is 11 000 V.

Calculate the flux per pole if the form factor is 1,2. (12)

[15]

QUESTION 5

5.1 Explain, with the aid of phasor diagrams, how a synchronous motor can be made to have a leading power factor. (6)

5.2 A 700 kVA, 2 200 V, three-phase, star-connected synchronous motor is fully loaded and takes 550 kW at a leading power factor. The machine has a percentage impedance of (5 + j50) percent.

Calculate the following:

5.2.1 The power factor (1)
5.2.2 The resistive and reactive volt drops (3)

5.2.3	The EMF to which the machine is excited	(4)
5.2.4	The load angle in electrical degrees	(1)
		[15]

QUESTION 6

A 415 V, 6-pole, 50 Hz, three-phase induction motor has a rotor resistance of 0,15 ohms per phase and a rotor reactance of 0,7 ohms per phase at standstill. The rotor is star-connected and at standstill the EMF between slip-rings is 238 V.

Calculate the following:

6.1	The gross torque at a full-load slip of 5%	(8)
6.2	The full-load output if the friction and windage losses are 500 W	(2)
		[10]

QUESTION 7

7.1 What are the effects of a low power factor? (2)

7.2 The voltage supply to a consumer is 400 V, 50 Hz, three-phase. The consumer has a lighting load of 2 kW at unity power factor and a 30 kW induction motor operating at a power factor of 0,8 lagging. The efficiency of the induction motor is 85%.

Calculate the following:

7.2.1	The total kVA of the load	(5)
7.2.2	The power factor of the load	(1)
		[8]

TOTAL: 100

ELECTROTECHNICS N6

GS-MASJIENE	*DC MACHINES*

$$E = V - Ia\,Ra$$

$$\frac{E_1}{E_2} = \frac{N_1\,\Phi_1}{N_2\,\Phi_2}$$

$$\frac{T_1}{T_2} = \frac{I_1\,\Phi_1}{I_2\,\Phi_2}$$

SPOEDBEHEER — ***SPEED CONTROL***

$$E = V - Ia\left(\frac{R\,Rse}{R + Rse} + Ra\right)$$

$$E = V - Ia\,Ra - Ise\,Rse$$

TOETSING DIREKTE METODE — ***TESTING DIRECT METHOD***

$$\eta = \frac{2\pi Nr\,(W - S)}{60\,IV}$$

SWINBURNE-METODE — ***SWINBURNE METHOD***

$$\eta_{motor} = \frac{IV - (Ia^2 Ra + Ia_o\,V + Is\,V)}{IV}$$

$$\eta_{generator} = \frac{IV}{IV + Ia^2\,Ra + Ia_o\,V + Is\,V}$$

HOPKINSON-RENDEMENTE DIESELFDE — ***HOPKINSON EFFICIENCIES THE SAME***

$$\eta = \sqrt{\frac{I_1}{I_1 + I_2}}$$

YSTER-VERLIES — ***IRON LOSS***

$$= I_2\,V - \left\{(I_1 + I_3)^2\,Ra + (I_1 + I_2 - I_4)^2\,Ra + (I_3 + I_4)\,V\right\}$$

$$= C$$

$$\eta_{generator} = \frac{I_1 V}{I_1 V + (I_1 + I_3)^2\,Ra + I_3\,V + \frac{C}{2}}$$

$$\eta_{motor} = \frac{(I_1 + I_2)\,V - \left\{(I_1 + I_2 - I_4)^2\,Ra + I_4\,V + \frac{C}{2}\right\}}{(I_1 + I_2)\,V}$$

WS-BELASTING STERSTELSELS / **AC LOADS STAR SYSTEMS**

$$\overline{I}_R = \frac{V\,\underline{|0°}}{Z_{RN}\,\underline{|\phi_1}}$$

$\overline{V}rn$ = VERWYSING / REFERENCE

$$\overline{I}_y = \frac{V\,\underline{|-120°}}{Z_{YN}\,\underline{|\phi_2}}$$

R-Y-B VOLGORDE / SEQUENCE

$$\overline{I}_B = \frac{V\,\underline{|120°}}{Z_{BN}\,\underline{|\phi_3}}$$

$$\overline{I}_N = \overline{I}_R + \overline{I}_B + \overline{I}_Y$$

GEBALANSEERDE KRING / **BALANCED CIRCUIT**

$$\overline{I}n = 0$$

DELTASTELSELS / **DELTA-SYSTEMS**

$$\overline{I}_{RY} = \frac{\overline{V}_{RY}}{\overline{Z}_{RY}} \quad \overline{I}_R = \overline{I}_{RY} - \overline{I}_{BR}$$

$$\overline{I}_{YB} = \frac{\overline{V}_{YB}}{\overline{Z}_{YB}} \quad \overline{I}_Y = \overline{I}_{YB} - \overline{I}_{RY}$$

$$\overline{I}_{BR} = \frac{\overline{V}_{BR}}{\overline{Z}_{BR}} \quad \overline{I}_B = \overline{I}_{BR} - \overline{I}_{YB}$$

DRIEDRAAD-STELSELS / **THREE-WIRE SYSTEMS**

$$V_{sn} = \frac{\frac{\overline{V}_{an}}{\overline{Z}_1} + \frac{\overline{V}_{bn}}{\overline{Z}_2} + \frac{\overline{V}_{cn}}{\overline{Z}_3}}{\frac{1}{\overline{Z}_1} + \frac{1}{\overline{Z}_2} + \frac{1}{\overline{Z}_3}}$$

$$\overline{V}_{aN} = \overline{V}_{aS} + \overline{V}_{sN}$$

$$\overline{V}_{bN} = \overline{V}_{bS} + \overline{V}_{sN}$$

$$\overline{V}_{cN} = \overline{V}_{cS} + \overline{V}_{sN}$$

$$\overline{I}_a = \frac{\overline{V}_{aS}}{\overline{Z}_1}$$

$$\overline{I}_B = \frac{\overline{V}_{bS}}{\overline{Z}_2}$$

$$\overline{I}_C = \frac{\overline{V}_{cS}}{\overline{Z}_3}$$

PTO

KOMPLEKSE GOLFVORMS / **COMPLEX WAVE FORMS**

$$e_1 = E_m \; Sin\, \omega t$$

$$e_2 = K_2 \; E_m \; Sin\, 2\, \omega t$$

$$e_3 = K_3 \; E_m \; Sin\, 3\, \omega t$$

$$e = E_m \; (Sin\, \omega t + k_2 \; Sin\, 2\, \omega t + k_3 \; Sin\, 3\, \omega t)$$

$$P = \frac{E_m^2 1 + E_m^2 2 + E_m^2 3 + ... + E_m^2 N}{2R}$$

$$P = \left(I_m^2 1 + I_m^2 2 + I_m^2 3 + ... + I_m^2 N\right) R$$

$$I = \sqrt{\frac{I_m^2 1 + I_m^2 2 + ... + I_m^2 N}{2}}$$

$$E = \sqrt{\frac{E_m^2 1 + E_m^2 2 + ... + E_m^2 N}{2}}$$

$$Cos\, \phi = \frac{I^2 \; R}{E\; I} = \frac{\frac{E^2}{R}}{E\; I}$$

TRANSFORMATORS / **TRANSFORMERS**

$$\eta = \frac{S \; Cos\, \phi}{S \; Cos\, \phi + Po + Psc}$$

Enige waarde van belasting by k van vollas / *Any value of load at k of full-load*

$$\eta = \frac{k \; S \; Cos\, \phi}{k \; S \; Cos\, \phi + Po + k^2 \; Psc}$$

MAKSIMUM RENDEMENT / **MAXIMUM EFFICIENCY**

$$K = \sqrt{\frac{Po}{Psc}}$$

$$\eta = \frac{k \; S \; Cos\, \phi}{k \; S \; Cos\, \phi + Po + k^2 \; Psc}$$

FORMULES **FORMULAE**

$$\% R = \frac{I\,Re}{V}$$

$$\% X = \frac{I\,Xe}{V}$$

$$\% Z_e = \% R_e + j\,\% X_e$$

$$V_{SC} = I\,Z_e$$

$$P_{SC} = I^2\,R_e$$

$$Cos\,\phi_e = \frac{P_{SC}}{I_1\,V_{SC}}$$

$$Reg = \frac{V_{SC}\,Cos\,(\phi_e \pm \phi_2)}{V}$$

$$Reg = \frac{I\,Z\,Cos\,(\phi_e \pm \phi_2)}{V}$$

$$Reg = \frac{I\,(Re\,Cos\,\phi_2 \pm Xe\,Sin\,\phi_2)}{V}$$

WS-MASJIENE / ALTERNATORS **AC MACHINES / ALTERNATORS**

$$n = \frac{f}{p}$$

$$Kd = \frac{Sin\,\frac{n\alpha}{2}}{n\,Sin\,\frac{\alpha}{2}}$$

$$Kp = Cos\,\frac{\psi}{2}$$

$$E = 2\,Kf\,Kd\,Kp\,f\,\Phi\,Z$$

$$E = \sqrt{(V\,Cos\,\phi + IR)^2 + (V\,Sin\,\phi \pm IX)^2}$$

$$E = V + IR\,Cos\,\phi \pm IX\,Sin\phi$$

$$\overline{E} = E\,\underline{|\phi} + IR\,\underline{|o} + Ix\,\underline{|90}$$

$$Reg = \frac{E - V}{V}$$

SINCHRONE MOTOR **SYNCHRONOUS MOTOR**

$$\overline{V} + \overline{E} = \overline{E}_R \qquad \overline{E}_R = \overline{IZ}$$

$$\overline{E} = V\,\underline{|-\phi} + IR\,\underline{|180^\circ} + IX\,\underline{|-90^\circ}$$

INDUKSIEMOTOR / ***INDUCTION MOTOR***

$$\frac{Eo}{V_1} = \frac{Zr}{Z_s}$$

$$E_2 = SEo$$

$$X_2 = SXo$$

$$I_2 = \frac{E_2}{Z_2}$$

$$Z_2 = \sqrt{R_2^2 + (SXo)^2}$$

$$Io = \frac{Eo}{Zo}$$

$$Zo = \sqrt{R_2^2 + Xo^2}$$

$$I_2 = \frac{SEo}{\sqrt{R_2^2 + (SXo)^2}}$$

$$Io = \frac{Eo}{\sqrt{R_2^2 + Xo^2}}$$

MAKSIMUM RENDEMENT / ***MAXIMUM EFFICIENCY***

$$R_2 = SXo$$

Rotorkoperverlies = S rotorinset
Rotor copper loss = S rotor input

$$S = \frac{N_1 - N_2}{N_1}$$

$$P = \sqrt{3}\, V_L\, I_L \, Cos\, \phi$$

$$KVA = \sqrt{3}\, V_L\, I_L$$