higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

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NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

9 April 2018 (X-Paper)
09:00–12:00

Calculators may be used.

This question paper consists of 6 pages and a formula sheet of 5 pages.

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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 according to the numbering system used in this question paper.
4. Write neatly and legibly.

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QUESTION 1

1.1 1.1.1 Make a neat sketch of a pair of identical shunt motors mechanically coupled to the same load and connected in parallel. (2)

1.1.2 Draw the speed and torque characteristics against the armature current of the shunt motors described above. (2)

1.2 The following results were obtained in a Hopkinson test on two shunt machines:

Supply voltage	415 V
Generator armature current	35 A
Motor armature current	45 A
Motor field current	0,8 A
Generator field current	0,9 A
Armature resistance of each machine	0,5 Ω

Calculate the efficiency of the machine acting as a generator, assuming each of the following:

1.2.1 Equal iron and friction losses (9)

1.2.2 Equal efficiency (1)

[14]

QUESTION 2

2.1 An EMF represented by $e = 150\sin(\omega t) + 75\sin(3\omega t + 30°) + 40\sin(5\omega t + 15°)$ V is applied to a series circuit having a resistance of 7 Ω and a capacitance of 415 µF. The fundamental frequency is 50 Hz.

Calculate the expression for the instantaneous value of the current. (8)

2.2 Given below are three line currents of an unbalanced four-wire, three-phase star-connected.

$$I_R = 15,7\angle 0° \text{ A}$$

$$I_Y = 39,53\angle -165° \text{ A}$$

$$I_B = 25,85\angle 206° \text{ A}$$

The line voltage is 445 V.

Use V_{RN} as phasor reference and R-Y-B as phase rotation and calculate the load impedances of Z_{RN}, Z_{YN} and Z_{BN}. (7)

[15]

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QUESTION 3

3.1 Explain, with the aid of a neat diagram, how the short-circuit test is conducted on a single-phase transformer. (4)

3.2 A 500 kVA, single-phase transformer has an iron loss of 2,9 kW. The following data is also supplied:

	Primary	**Secondary**
Voltages	6 600 V	415 V
Winding resistance	450 mΩ	1,9 mΩ

Calculate each of the following for a load power factor of 0,8 lagging:

3.2.1 Full-load efficiency (5)

3.2.2 Efficiency at half-load (2)

3.2.3 Maximum efficiency (3)

3.2.4 Output at maximum efficiency (1)

[15]

QUESTION 4

4.1 Explain, with the aid of a neat diagram, how the open-circuit test is conducted on a three-phase star-connected alternator. (4)

4.2 The armature of an 8-pole alternator with a flux of 0,08 Wb per pole has 72 slots.

Calculate each of the following:

4.2.1 The alternator speed if the frequency is 50 Hz (2)

4.2.2 The terminal EMF if the alternator is wound with a three-phase, star-connected, full-pitched winding having 10 conductors per slot (9)

[15]

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QUESTION 5

5.1 Explain, with the aid of phasor diagrams, what happens when the load torque of a synchronous motor is increased. (4)

5.2 A 580 kVA, 2 500 V 8-pole three-phase star-connected synchronous motor has a resistance of 1,5 Ω per phase and a synchronous reactance per phase of 4,5 Ω operating at a power factor of 0,85 leading.

Calculate each of the following using the data above:

5.2.1 Generated EMF (7)

5.2.2 Load angle in electrical and mechanical degrees (2)

[13]

QUESTION 6

The following are the results of a test on a 20 kW, 380 V, 50 Hz, three-phase, star-connected induction motor. The terminal-to-terminal resistance of the star-connected stator is 0,4 Ω.

No-load test	380 V	15 A	2 468 W
Locked-rotor test	190 V	60 A	5 923 W

6.1 Draw, to scale 1 cm = 5 A, a circle diagram using the information above. (10)

6.2 Use the circle diagram in QUESTION 6.1 to determine each of the following:

6.2.1 Efficiency at full-load

6.2.2 Line current at full-load

6.2.3 Power factor at full-load

6.2.4 Input power at full-load

6.2.5 Rotor copper loss at standstill

(5 × 1) (5)

[15]

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QUESTION 7

7.1 Give TWO reasons why consumers install power-factor improvement equipment. (2 × 2) (4)

7.2 A three-phase induction motor taking 250 kW at 0,8 power factor lagging is in parallel with a three-phase synchronous motor taking 300 kVA at 0,9 power factor leading. The supply voltage is 3,2 kV.

7.2.1 Calculate the line current and the power factor of the total load. (5)

7.2.2 The synchronous motor is disconnected and a capacitor bank is connected across the load while the power factor of the combination changes to 0,9 lagging.

Calculate the kVA rating of the capacitor bank. (4)

[13]

TOTAL: 100

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FORMULA SHEET

DC MACHINES

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

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

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

SPEED CONTROL

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

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

TESTING
DIRECT METHOD

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

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 EFFICIENCIES THE SAME

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

IRON LOSS

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

$$= C$$

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

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

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AC LOADS
STAR SYSTEMS

$\bar{}$
Vrn = VERWYSING
REFERENCE

R-Y-B VOLGORDE
SEQUENCE

$$\bar{I}_R = \frac{V\ o°}{Z_{RN}\ \phi_1}$$

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

$$\bar{I}_B = \frac{V\ |120°}{Z_{BN}\ \phi_3}$$

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

BALANCED CIRCUIT

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

DELTA-SYSTEMS

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

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

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

THREE-WIRE SYSTEMS

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

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

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

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

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

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

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

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COMPLEX WAVE FORMS

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

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

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

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

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

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

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

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

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

TRANSFORMERS

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

Any value of load
at k of full-load

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

MAXIMUM EFFICIENCY

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

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

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FORMULAE

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

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

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

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

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

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

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

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

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

AC MACHINES
ALTERNATORS

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

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

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

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

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

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

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

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

SYNCHRONOUS MOTOR

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

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

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INDUCTION MOTOR

$$\frac{Eo}{V_1} = \frac{Zr}{Z_s} \qquad E_2 = SEo$$

$$X_2 = SXo \qquad I_2 = \frac{E_2}{Z_2}$$

$$Z_2 = \sqrt{R_2^2 + (SXo)^2} \qquad Io = \frac{Eo}{Zo}$$

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

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

MAXIMUM EFFICIENCY

$$R_2 = SXo$$

Rotor copper loss = S rotor input

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

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

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

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