higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

19 April 2021 (X-paper)
09:00–12:00

Nonprogrammable calculators and drawing instruments may be used.

This question paper consists of 5 pages and a formula sheet of 4 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. Start each question on a new page.
5. Only use a black or blue pen.
6. Write neatly and legibly.

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QUESTION 1: DC MACHINES

1.1 A three-wire DC-system has two operating voltages of 440 V and 220 V.

Show, by means of a neat diagram, how the armatures of two shunt motors are connected to this three-wire system so that the speed of one motor is twice the speed of the other. (4)

1.2 An 8 kW shunt-wound motor takes a current of 20 A from a 450 V mains at full load. The armature has a resistance of 0,3 Ω and the field circuit resistance is 250 Ω.

Calculate:

1.2.1 The combined iron and friction losses (8)

1.2.2 The efficiency at full load (2)

[14]

QUESTION 2: AC CIRCUIT THEORY

2.1 Differentiate between the electrical quantities active power and reactive power. (2)

2.2 A 400 V, unbalanced, three-phase, delta-connected load consists of the phase currents:

I_{RY} = 30 A at a power factor of 0,8 lagging

I_{YB} = 35 A at a power factor of 0,8 leading

I_{BR} = 25 A at unity power factor

Take V_{RY} as phasor reference and R-Y-B as phase rotation.

Calculate the resistance and reactance in each phase of the load. (12)

[14]

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QUESTION 3: TRANSFORMERS

3.1 Explain, with the aid of diagrams, how the efficiency of a single-phase transformer can be calculated from the results obtained from open-circuit and short-circuit tests. (7)

3.2 A 12 kVA transformer has an iron loss of 240 W and a full-load copper loss of 340 W.

Calculate:

3.2.1 The efficiency at 25% of the full load and unity power factor (2)

3.2.2 The efficiency at 75% of full load and 0,8 lagging power factor (2)

3.2.3 The kVA load at which the efficiency will be maximum and the value of this efficiency at a power factor of 0,8 lagging (4)
[15]

QUESTION 4: AC MACHINES – GENERATORS

4.1 Explain, with the aid of a neat diagram, how a short-circuit test is carried out on a three-phase, star-connected alternator. (5)

4.2 A 12 kV, three-phase, 2 MVA, star-connected alternator operates at a power factor of 0,85 lagging and has a synchronous impedance of (6 + j30) Ω.

Calculate:

4.2.1 The open-circuit line voltage to which the machine must be excited to deliver full load (7)

4.2.2 The percentage voltage regulation of the alternator (2)

4.2.3 The load angle at which the machine operates (1)
[15]

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QUESTION 5: AC MACHINES – SYNCHRONOUS MOTORS

5.1 Give TWO uses of synchronous motors. (2)

5.2 A 750 kVA, 3,5 kV, three-phase, star-connected synchronous motor is fully loaded and takes 600 kW at leading power factor. The machine has a percentage impedance of (5 + j60) percent.

Calculate:

5.2.1 The power factor (1)

5.2.2 The resistive and reactive volt drops (6)

5.2.3 The emf to which the machine is excited (4)

5.2.4 The load angle in electrical degrees (1)

[14]

QUESTION 6: AC MACHINES – INDUCTION MOTORS

6.1 Define the term *slip* as it is used in induction motors. (2)

6.2 Name the TWO main parts of an AC motor. (2)

6.3 The input of a six-pole, three-phase, 50 Hz induction motor is 42 kW at a speed of 900 r/min. The stator losses of the motor are 2 kW and the friction and windage losses are 2,5 kW.

Calculate:

6.3.1 The slip (3)

6.3.2 The rotor copper loss (4)

6.3.3 The output of the motor (2)

6.3.4 The full-load efficiency (1)

[14]

QUESTION 7: GENERATION AND SUPPLY OF AC

Use the π method to calculate the voltage, current and power factor at the sending end of a long transmission line. The line delivers 40 MVA at 0,8 power factor lagging and at 132 kV, 50 Hz, three-phase. Each conductor has a resistance of 18 Ω, an inductance of 0,15 H and a capacitance to neutral of 1,2 μf.

HINT: Draw the π-method circuit diagram. **[14]**

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

$\bar{V}$rn =
REFERENCE

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

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

R-Y-B
SEQUENCE

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

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

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 WAVEFORMS

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

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

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

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

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

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

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

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

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

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

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

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

FORMULAE

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

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

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

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

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

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

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

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

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

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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

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

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

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

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

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

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

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