higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

25 November 2022 (X-paper)
09:00–12:00

Drawing instruments and nonprogrammable calculators may be used.

This question paper consists of 5 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. Round all calculations off to THREE decimal places.
5. Use the correct symbols and units.
6. Start each section on a new page.
7. Use only blue or black ink.
8. Write neatly and legibly.

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QUESTION 1

1.1 State TWO advantages of Swinburne's test. (2)

1.2 A 250 V, 14,92 kW DC shunt motor has constant iron and friction losses of 199 W, and the motor has an efficiency of 88% when delivering 80% of its rated output. The resistance of the shunt field is 100 Ω.

Calculate the efficiency of the motor when it draws a current of 78 A from the mains. (13)
[15]

QUESTION 2

2.1 Name the TWO types of sinusoidal waves that, when summed together, constitute a complex wave. (2)

2.2 A voltage $v = 250\sin(\omega t) + 50\sin(3\omega t + 60^0) + 20\sin(5\omega t + 150^0)$ is applied to a series circuit of resistance 20 Ω and inductance 0,05 H.

Take ω = 314 rad/s. and determine:

2.2.1 An expression for the instantaneous value of current (8)

2.2.2 The power factor of the circuit (5)
[15]

QUESTION 3

3.1 Define voltage regulation of a transformer. (3)

3.2 The percentage impedance of a 50 kVA, 1 000/240 V, single-phase transformer is (2+j6)%.

Calculate for a power factor of 0,9 lagging:

3.2.1 The equivalent resistance and reactance referred to the primary side. (3)

3.2.2 The full-load copper losses. (2)

3.2.3 The secondary terminal voltage at full load. (3)

3.2.4 The iron loss if the transformer produces maximum efficiency of 93% at 88% of full load. (3)
[14]

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QUESTION 4

4.1 State THREE factors that must be satisfied before two alternators may be connected in parallel. (3)

4.2 Two similar three-phase, star-connected alternators operate in parallel to supply a common load.

Each machine has a synchronous impedance of 0,65 + j3,8 ohms per phase. The machines are excited so as to give open-circuit voltages of 2,2 kV and 2 kV respectively. The machines have a phase displacement of 25° (electrical) relative to each other.

4.2.1 Calculate the following:

(a) The current that circulates between the two machines (5)
(b) The terminal voltage of the machines (3)

4.2.2 Draw a vector diagram clearly showing the phase voltages and the load angle. (2)
[13]

QUESTION 5

A 40 kW, 400 V, 6-pole, three-phase, star-connected, 50 Hz synchronous motor has a resistance of 0,1 Ω per phase and a synchronous reactance per phase of 1,2 Ω. If the motor operates at a full-load efficiency of 90% with a power factor of 0,8 leading.

Calculate the following:

5.1 Generated EMF (7)

5.2 Load angle in electrical and mechanical degrees (3)
[10]

QUESTION 6

A 400 V, 6 pole, 50 Hz, three-phase, delta-connected induction motor develops 15 kW when running at a speed of 930 r/min. The rotor iron loss is negligible and the frictional loss in the bearings is 0,5 kW. For a power factor of 0,7 lagging, calculate:

6.1 The percentage slip at which the motor is operating (2)

6.2 The rotor copper loss (2)

6.3 The power input to the motor if the total losses occurring in the stator amount to 800 watts (2)

6.4 The current drawn from the supply (2)

6.5 The efficiency of the motor (3)
[11]

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QUESTION 7

7.1 Name THREE types of power associated with an AC circuit. (3)

7.2 An overhead transmission line delivers a three-phase load of 30 MW at 132 kV, 50 Hz and a power factor of 0,8 lagging. Each conductor has a resistance of 20 ohms, an inductive reactance of 65 ohms, and a total capacitance to neutral of 1,6 micro-farad.

7.2.1 Draw a neat, fully labelled circuit diagram of the transmission line, based on the nominal π method. (3)

7.2.2 Calculate, using the nominal π method:

(a) The sending end voltage (11)
(b) The sending end current (3)
(c) The sending end power factor (2)
[22]

TOTAL: 100

ELECTROTECHNICS N6

FORMULA SHEET

Any applicable formula may also be used.

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

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Vrn = VERWYSING
REFERENCE

R-Y-B VOLGORDE
SEQUENCE

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

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

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

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

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 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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FORMULES

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

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

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

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

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

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

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

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

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

AC MACHINES
ALTERNATORS

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

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

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

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

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

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

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

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

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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