higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T550**(E)**(A2)T

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

2 August 2018 (X-Paper)
09:00–12:00

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. Start each question on a NEW page.
5. Keep subsections of questions together.
6. Round ALL calculations off to THREE decimal places.
7. Use the correct symbols and units.
8. Use a pen to write, but ALL drawings/sketches/diagrams must be done in pencil only.
9. Write neatly and legibly.

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QUESTION 1

1.1 Explain how to vary the speed of a DC motor in relation to each of the following:

1.1.1 Armature voltage

1.1.2 Field current

(2 × 2) (4)

1.2 Name TWO types of iron loss. (2)

1.3 A 500 V, DC, series motor takes 100 A from the supply when running at 700 r/min. The armature resistance is 0,15 Ω and the field resistance is 0,05 Ω.

Calculate the speed of the motor when a resistor of 0,134 Ω is connected in parallel with the field winding while the torque is 75% of its full-load value. Assume the flux to be proportional to the field current. (9)

[15]

QUESTION 2

A 7,63 µF capacitor is connected in parallel with a resistor of 480 Ω and this combination is connected in series with a resistor of 120 Ω. An EMF of $E = 250\sin(\omega t) + 150\sin(3\omega t + 30^\circ)$ V is connected across the circuit. The fundamental frequency is 50 Hz.

Determine:

2.1 An expression for the instantaneous value of the current (13)

2.2 The RMS value of the current and voltage (2 + 2) (4)

[17]

QUESTION 3

3.1 Name FOUR of the most common three-phase transformer connections. (4)

3.2 A 250 kVA, single-phase, 50 Hz transformer working at a unity power factor has an efficiency of 95% at both half-load and full-load.

Calculate:

3.2.1 The iron loss and full-load copper loss (7)

3.2.2 The efficiency at 70% of full-load and 0,8 power factor lagging (2)

[13]

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QUESTION 4

4.1 Explain the term *distribution factor of an alternator*. (2)

4.2 An 850 kVA, 4 500 V, 50 Hz, three-phase star-connected alternator has armature resistance of 0,4 Ω per phase. A certain field current produces a short-circuit current of 175 A and an open-circuit terminal EMF of 1 500 V.

Calculate:

4.2.1 The synchronous reactance (4)

4.2.2 The full-load percentage voltage regulation at a power factor of 0,8 lagging (7)

[13]

QUESTION 5

A four-pole, 50 Hz, three-phase induction motor has a rotor resistance of 0,3 Ω per phase and develops a maximum torque of 186,5 Nm at a speed of 1 350 r/min.

Calculate:

5.1 The slip at which maximum torque is produced (2)

5.2 The standstill rotor resistance (1)

5.3 The standstill rotor EMF (6)

5.4 The starting torque

HINT: $T_{start} = \dfrac{3 \times S \times E_0 \times R_2}{2 \times \pi \times \eta_1 \left(R_2^2 + \left[S \times X_0\right]^2\right)}$ (2)

[11]

QUESTION 6

6.1 Name ONE way in which the rotating flux of a three-phase induction motor may be reversed. (1)

6.2 The standstill EMF of a three-phase, 50 Hz, four-pole induction motor with a star-connected rotor is 300 V between the slip rings. The standstill rotor impedance is $(0{,}18 + j1{,}2)\ \Omega$ per phase.

Calculate:

6.2.1 The torque developed at a full-load slip of 5% (8)

6.2.2 The full-load power output if the friction and windage losses are 900 W (3)

6.2.3 The speed at maximum torque (2)

[14]

QUESTION 7

A three-phase, short-transmission line, 40 km in length, supplies a load of 3 600 kW at a power factor of 0,8 lagging. The impedance (line-to-neutral) per km of each conductor is $(0{,}6 + j0{,}7)\ \Omega$.

7.1 If the line voltage at the receiving end is 11 kV, determine:

7.1.1 The voltage at the sending end (9)

7.1.2 The efficiency of the transmission (3)

7.1.3 The percentage regulation of the line (2)

7.2 Draw a vector diagram to illustrate the answer. (3)

[17]

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 iron loss

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

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

$$= C$$

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

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

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AC loads

Star systems

$\bar{V}$rn = reference

R-Y-B 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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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

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

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

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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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