higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

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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 off all calculations to THREE decimals.
5. Sketches must be large, neat and fully labelled.
6. Use the correct symbols and units.
7. Use only a black or blue pen.
8. Write neatly and legibly.

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QUESTION 1

1.1 A DC series motor is a variable speed motor.

Using suitable formulae, explain why the current drawn by this motor increases when the motor is mechanically loaded. (4)

1.2 A 250 V, DC series motor runs at 1 000 r/min while drawing a current of 40 amperes from the supply. The resistances of the armature and series field are 0,25 ohms and 0,1 ohms respectively. When a 0,2-ohm diverter resistor is connected in parallel with the field coil, the torque is increased by 20% and the field coils are unsaturated.

1.2.1 Draw TWO fully labelled circuit diagrams to show the DC series motor before and after the diverter resistor is connected. (2)

1.2.2 Calculate the speed at which the motor will run after the diverter resistor is connected. (10)

[16]

QUESTION 2

An alternating voltage represented by the expression:

$v = 40 \sin (314t + 25^\circ) + 20 \sin (942t - 30^\circ)$

is applied to a resistor of 180 ohms in parallel with a capacitor of 25 micro-farads.

Determine:

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

2.2 The power factor of the circuit (also state the nature of the power factor) (5)

2.3 The energy dissipated in the circuit in 10 milli-seconds (1)

2.4 Draw a large vector diagram clearly showing the voltages and currents for the fundamental as well as the harmonic component (2)

[16]

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QUESTION 3

3.1 State TWO constant losses occurring in a transformer and state precisely where each occurs. (4)

3.2 A 250 kVA, 3 300/240 V, single-phase transformer produces a maximum efficiency of 92% at 80% of full load.

For a power factor of 0,85 lagging, calculate:

3.2.1 The iron losses (2)

3.2.2 The full-load copper losses (2)

3.2.3 The percentage resistance (4)

3.2.4 The per unit full-load voltage regulation of the transformer when it works at unity power factor (2)

[14]

QUESTION 4

4.1 Explain what is meant by *distribution factor* of a synchronous alternator. (3)

4.2 The following information applies to a three-phase, star-connected alternator:

Open-circuit terminal EMF	3 300 V
Frequency	50 Hz
Speed	1 000 r/min
Number of slots per pole per phase	4
Coil span	150˚
Useful flux per pole	55 milli-webers

Calculate the possible number of conductors per slot. (12)

[15]

QUESTION 5

A 525 V, 6 pole, 50 Hz, three-phase, delta-connected induction motor develops 28 kW when running at a speed of 950 r/min. The rotor iron loss is negligible and the frictional loss in the bearings is 800 watts. For a power factor of 0,8 lagging, calculate:

5.1 The percentage slip at which the motor is operating (3)

5.2 The rotor copper loss (2)

5.3 The power input to the motor if the total losses occurring in the stator amounts to 1 080 watts (3)

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5.4 The current drawn from the supply (2)

5.5 The efficiency of the motor (3)

[13]

QUESTION 6

A large industrial consumer takes 1 MVA at a power factor of 0,75 lagging. To reduce maximum demand, a capacitor bank was installed and the overall power factor was improved to 0,9 lagging.

6.1 Draw a neat, fully labelled vector diagram clearly showing the maximum demand before and after the installation of the capacitor bank (2)

6.2 Determine the size of the capacitor bank (5)

6.3 Determine the cost of the capacitor bank if it sells for R295 per kVAr (2)

6.4 Determine how many months it will take to pay off the capacitor bank using only the savings in maximum demand charges.

Assume that the consumer pays a maximum demand charge of R132 per kVA. (4)

[13]

QUESTION 7

A new development is to be supplied by an existing overhead transmission line. The line is supplied at 145 kV with the power and power factor at the sending end being 20 MW and 0,9 lagging respectively. Each conductor has a resistance of 25 ohms, an inductive reactance of 76 ohms and a capacitive reactance to neutral of 1 750 ohms.

Draw a neat fully labelled nominal T-method diagram for the above data and calculate the following using the nominal T-method:

7.1 The current at the receiving end (8)

7.2 The voltage at the receiving end (3)

7.3 The power in MW available for the development (2)

[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

_
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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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 MOTORS

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

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

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INDUCTION MOTORS

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

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

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

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

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

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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