higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T480(E)(N18)N

NOVEMBER EXAMINATION

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

(8080085)

18 November 2014 (Y-Paper)
13:00–16:00

This question paper consists of 5 pages, and a formula sheet of 2 pages.

ENGINEERING

Copyright reserved

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
ELECTROTECHNICS N5
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers correctly according to the numbering system used in this question paper.
4. Keep subsections of questions together.
5. Write neatly and legibly.

ENGINEERING

Copyright reserved

QUESTION 1

1.1 State TWO characteristics of DC motors. (2)

1.2 1.2.1 Calculate the number of series turns per pole, required on a compound generator, for it to maintain a constant voltage at 630 V, between no-load and full-load of 450 kW. With no series winding, it was found that the shunt current has to be 6 A on no-load and 7, 5 A on full-load, to maintain the voltage constant at 630 V. Number of turns per pole on the shunt winding is 2 400. (5)

1.2.2 If the series coils were wound with 8 turns/pole and had a total resistance of 0, 06 Ω:

Calculate the value of the diverter resistance required to give level-compounding. (5)

1.3 A 30,5 kW, 440 V, eight -pole DC motor has a wave-wound armature with 1 200 conductors , and the commutator has 150 segments. The full-load efficiency is 85 % and the shunt current is 1, 5 A. The brushes are shifted backwards through 1,4 segments from the geometric neutral .

Calculate the demagnetising and cross-magnetising ampere-turns per pole. (8)
[20]

QUESTION 2

2.1 A coil dissipates 1 800 W and draws a current of 20 A when it is connected to a 280 V, 50 Hz alternating current supply. When another coil is connected in parallel with it, the total supply current is 55 A, at a power factor of 0,85.

Calculate the current and power factor when the coils are connected in series across the same supply.

(14)

2.2 A circuit, with a resistance of 8,5 Ω, an inductance of 0,7 H and a variable capacitance in series, is connected across a 180 V, 50 Hz supply.

Calculate:

2.2.1 The capacitance to give resonance. (2)

2.2.2 The voltages across the inductance and the capacitance. (4)
[20]

ENGINEERING

Copyright reserved

QUESTION 3

3.1 A 310 kVA transformer has 660 turns on the primary and 220 turns on the secondary. The primary and secondary resistances are 0,8 Ω and 0,06 Ω and the leakage reactance are 1,7 Ω and 0,07 Ω respectively. The supply voltage is 2 700 V.

Calculate :

3.1.1 The equivalent impedance referred to the primary circuit. (3)

3.1.2 Voltage regulation for power factor of 0,8 lagging, and the secondary terminal voltage on full load. (7)

3.1.3 Voltage regulation for power factor of 0,8 leading and secondary terminal voltage on full load. (4)

3.2 A three phase transformer has 510 turns on the primary and 30 turns on the secondary winding. The supply voltage is 2 600 V.

Calculate the secondary line voltage on no-load when the transformer is connected in:

3.2.1 star – delta (3)

3.2.2 delta – star (3)
[20]

QUESTION 4

4.1 Determine the total resistance, inductance and capacitance of a single-phase, 33 km, overhead line with solid conductors of 1,4 cm diameter and spaced 0, 7 m between centres. Take resistivity of conductor material as 1,7 μ Ω cm and ignore skin effect. (6)

4.2 Calculate the inductance and capacitance per phase, of 35 km of three phase overhead line, having solid copper conductors with a diameter of 1, 5 cm.

When the overhead line is:

4.2.1 spaced 50 cm between adjacent centres in flat regular spacing. (6)

4.2.2 spaced on the corners of a triangle having sides of length 55 cm : 85 cm : 110 cm. (6)

4.3 Calculate the inductance per phase of a 200 km, three phase transmission line, having an equilateral conductor spacing of 10 m and a conductor diameter of 30 mm. (2)
[20]

ENGINEERING

Copyright reserved

QUESTION 5

5.1 A three phase, four-pole, 50 Hz induction motor, with a star-connected rotor, has a rotor resistance of 0.8 Ω per phase and at standstill the reactance is 2,8 Ω. The EMF between the slip-rings is 260 V. Full-load speed is 1 380 r/min.

Calculate

5.1.1 the fractional slip (3)

5.1.2 the EMF induced in each phase of the rotor (2)

5.1.3 the rotor reactance per phase (1)

5.1.4 the rotor current and power factor (if rings are short –circuited) (3)

5.1.5 the rotor frequency (1)

5.2 With reference to induction motors, what is meant by the term *slip*?

Explain why slip is necessary for an induction motor to operate. (4)

5.3 A three-phase, 50 Hz, eight pole induction motor has a slip of 0,05 per unit, when the output is 45 kW. The frictional loss is 375 W.

Calculate:

5.3.1 Rotor speed (2)

5.3.2 Rotor copper loss (4)
[20]

TOTAL: 100

ENGINEERING

Copyright reserved

FORMULA SHEET

Armature ampere-turns/pole
Ankerampèrewindings/pool

$$= \frac{1}{2} \cdot \frac{I_a}{C} \cdot \frac{Z}{2P}$$

$$E = V \pm I_a R_a$$

$$E = \frac{2pNZ\Phi}{60c}$$

$$T = 0{,}318 \frac{I_a}{c} ZP\Phi$$

$$k = n\sqrt{\frac{R_1}{r_m}}$$

$$r_1 = R_1\left[\frac{k-1}{k}\right]$$

$$r_1 = R_s \frac{1-y}{1-y^m}$$

$$R_1 = bR_1\ (k-1) \times \frac{1-b^n}{1-b} + r_m$$

$$y = \frac{I_2}{I_1}$$

$$r_1 = bR_1\ (k-1)$$

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

$$\frac{T_1}{T_2} = \frac{K\Phi_1 I_{a1}}{K\Phi_2 I_{a2}}$$

$$I_{ave/gem} = \frac{i_1 + i_2 + i_3 + \ldots i_n}{n}$$

$$I_{rms/wgk} = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 + \ldots + i_n^2}{n}}$$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$f = \frac{1}{2\pi L}\sqrt{\frac{L}{C} - R^2}$$

ENGINEERING

Copyright reserved

$$P = \sqrt{3} I_L V_L \cos\phi$$

$$P_1 = V_L I_L \cos(30 - \phi)$$

$$P_2 = V_L I_L \cos(30 + \phi)$$

$$\tan\phi = \frac{\sqrt{3}\,(P_2 - P_1)}{(P_2 + P_1)}$$

% Voltage regulation
% Spanningsreëling

$$= I_1 \frac{(R_e \cos\phi \pm X_e \sin\phi)}{v_1} \times \frac{100}{1}$$

$$Z_e = \sqrt{R_e^2 + X_e^2}$$

$$\%Z_e = \frac{I\,Z_e}{V} \times \frac{100}{1}$$

$$S_1 = S \frac{Z_2}{Z_1 + Z_2}$$

$$E = 2{,}222\ k_d k_p\ Z\Phi f$$

$$I_r = \frac{E_r}{Z_r}$$

$$E_o = V_p \frac{Z_r}{Z_s}$$

$$\cos\phi_r = \frac{R}{Z_r}$$

$$s = \frac{2\pi T(n_s - n_r)}{2\pi T\ n_s}$$

$$L = 0{,}05 + 0{,}2\ Lin \frac{d}{r}$$

$$C = \frac{1}{36 Lin \frac{d - r}{r}}$$

$$C = \frac{1}{18 Lin \frac{de}{r}}$$

% Regulation
% Regulering

$$= \frac{V_s - V_R}{V_R} \times \frac{100}{1}$$

ENGINEERING

Copyright reserved

ENGINEERING

Copyright reserved

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

NOVEMBER EXAMINATION

ELECTROTECHNICS N5

18 NOVEMBER 2014

This memorandum consists of 9 pages.

Copyright reserved

QUESTION 1

1.1
- Fixed poles in the field winding.
- No rotating magnetic flux.
- Great mass due to heavy wound armature. (Any 2 x 1) (2)

1.2.1 Ampere turns required on no load = 6 x 2400 = 14400 ✓

Ampere turns required on full load = 7,5 x 2400 = 18000 ✓
Ampere turns required on series field on full load = 18000 - 14400

= 3600 ✓

Full load line current IL = P/V

$= \frac{450 \times 10^3}{630}$

= 714,29 A ✓

Constant field current If = 6A
Ia = IL + If
= 720,29 A ✓

Turns required on series field $= \frac{3600}{720,29}$

= 5 ✓ (6)

1.2.2 With series winding of 8 t/p and resistance of 0,06Ω

Ampere turns required = 3600
With 6 turns , series field current If = 3600/8
= 450 A ✓
Current through diverter Rx = 720,29 – 450

= 270 A ✓

Voltage across diverter = voltage across series field

(Ix) (Rx) = If (series) x R (series)
Rx = $\frac{450 \times 0,06}{264.29}$ ✓

= 0,102 Ω ✓ (4)

Copyright reserved

1.3 $Pi = \frac{30500}{0,85}$

$= 35882,35\ W$ ✓

$I_L = \frac{35882,35}{440}$ ✓

$= 81,55\ A$

$I_a = 81,55 - 1,5$

$= 80,05\ A$ ✓

Total At/p = $I_a Z / 4 p c$

$= \frac{80,05 \times 1200}{4 \times 4 \times 2}$

$= 3001,88$ ✓

$\theta = \frac{360°}{\text{segments}} \times \text{shift} \times p$

$= 360/150 \times 1,4 \times 4$

$= 13,44$ ✓

Demag At/p = $At/p \times \frac{4\theta}{360}$

$= 3001,88 \times \frac{4 \times 13,44}{360}$ ✓

$= 448,28$ ✓

Cross- mag At/p = At/p - Demag At/p

$= 3001,88 - 448,28$

$= 2553,6$ ✓ (8)

[20]

QUESTION 2

2.1

$P = I V \cos \phi$

$1800 = 20 \times 280 \cos \phi$

$\cos \phi = 0,321$ lagging ✓

$P = I^2 R$

$R = P/I^2 = 1800/ 20^2 = 4,5\ \Omega$ ✓

$\text{Cos } \phi = R/Z$

$Z_1 = R/\cos\phi$

$= 4,5 / 0,321 = 14\ \Omega$

$Z1 = 14 < 71,28$ ✓

OR

$Z1 = V/I = \frac{280 < 0}{20 < -71,28}$

$= 14 < 71,28$

$= 4,49 + j\ 13,26$

PARALLEL

$I_1 = 20 < -71,28 = 6,41 - j\ 18,94$

$IT = 55 < - 31,79 = 46,75 - j\ 29$ ✓

$I_2 = IT - I_1$ ✓

$= (46,75 - j\ 29) - (6,41 - j\ 18,94)$

$= 46,75 - j\ 29 - 6,41 + j\ 18,94$ ✓

$= 40,34 - j\ 10,06$

$= 41,58 < -14$ A ✓

$Z2 = V/I_2 = \frac{280 < 0}{41,58 < -14}$ ✓

$= 6,73 < 14$ ✓

$= 6,53 + J\ 1,63\ \Omega$

SERIES

$ZT = Z1 + Z2$ ✓

$= 4,49 + j\ 13,26 + 6,53 + J\ 1,63$

$= 11,02 + j\ 14,89$

$= 18,52 < 53,5\ \Omega$ ✓

$I = V/ZT = \frac{280 < 0}{18,52 < 53,5}$ ✓

$= 15,12 < - 53,5$ A

$\cos \phi = \cos 53,5 = 0,595$ lagging ✓

$I = 15,12$ A ✓ (14)

Copyright reserved

2.2 2.2.1 $2\pi f L = 1 / 2\pi f C$

$C = 1 / (2 \times \pi \times 50)^2 \times 0,7$ ✓
$= 14,47\ \mu F$ ✓ (2)

2.2.2 $I = V / R$
$= 180 / 8,5$
$= 21,18\ A$ ✓

$V_L = 2 \times \pi \times 50 \times 0,7 \times 21,18$ ✓

$= 4657,73\ V$ ✓

$VC = VL = 4657,73\ V$ ✓ (4)
[20]

QUESTION 3

3.1.1 $Re = 0,8 + 0,06\ (660/220)^2$

$= 1,34\ \Omega$ ✓

$Xe = 1,7 + 0,07\ (660/220)^2$

$= 2,33\ \Omega$ ✓

$Ze = \sqrt{(1,34)^2 + (2,33)^2}$

$= 2,69\Omega$ ✓ (3)

3.1.2 $\cos \phi_2 = 0,8 \quad \sin \phi_2 = 0,6$ ✓

$I_{1\ (FULL\ LOAD)} = \frac{VA}{V} = \frac{310000}{2700} = 114,81\ A$ ✓

$V\ reg.(\ Pf.\ 0,8\ lagging) = \frac{I_1 (Re \cos \phi_2 + Xe \sin \phi_2)}{V_1}$

$= \frac{114,81 (1,34 \times 0,8 + 2,33 \times 0,6)}{2700}$ ✓

$= 0,105\ p.u.$ ✓

V_2 (no load) $= 2700 \times 220/660 = 900\ V$ ✓

Decrease of V_2 (bet. no load and full load)

$= 900 \times 0,105 = 94,5\ V$ ✓

V_2 (full load) $= 900 - 94,5 = 805,5\ V$ ✓ (7)

Copyright reserved

3.1.3 V reg.(Pf. 0,8 leading) $= \frac{V1}{V2} I1 (Re \cos \phi 2 - Xe \sin \phi 2)$

$= 114,81(1,34 \times 0,8 - 2,33 \times 0,6)$ ✓
2700

$= 0, 0139$ p.u. ✓

Increase of V 2 (bet. no load and full load)

$= 900 \times 0,0139 = 12,51$ V ✓

V 2 (full load) $= 900 + 12,51 = 912,51$ V ✓ (4)

3.2 3.2.1 Vph 1 $= VL / \sqrt{3}$
$= 2600 / 1,732 = 1501,11$ V ✓

Vph 2 = Vph 1 x N2/N1

$= 1501,11 \times 30 / 510$ ✓

$= 88,3$ V ✓

= secondary line voltage (3)

3.2.2 Vph 1 = 2600

Vph 2 = 2600 x N2/N1 = 2600 X 30/510
= 152,94 V ✓

VL 2 = 252 V x $\sqrt{3}$ ✓
= 264,9 V ✓ (3)
[20]

QUESTION 4

4.1 Loop resistance $= \frac{\rho l}{a}$

$= \frac{1,7 \times 66 \times 10^5}{10^6 \times \pi \times 0,7^2}$ ✓

$= 7,29\Omega$ ✓

Loop inductance $= 66 [0,05 + 0,2 \log e \, d/r]$ mH ✓

$= 66 [0,05 + 0,2 \log e (70/0,7)]$ mH
$= 64,01$ mH ✓

Total capacitance $= \frac{33}{36 \log e (\frac{d}{r} - r)}$ ✓

$= \frac{33}{36 \log e (\frac{70}{0,7} - 0,7)}$

$= 0,2165 \, \mu F$ ✓ (6)

Copyright reserved

4.2 4.2.1

$de = \sqrt[3]{d \times d \times 2d}$

$= \sqrt[3]{50 \times 50 \times 100}$ cm ✓

$= 63 \times 10^{-2}$ m ✓

$L = Km [0,05 + 0,2 \log e (de/r)]$

$= 35 [0,05 + 0,2 \log e (0,63 / 0,75 \times 10^{-2})]$ ✓

$= 32,76$ mH per phase ✓

$C = Km [1/ 18 \log e (de/r)$

$C = 35 [1/ 18 \log e (0,63 / 0,75 \times 10^{-2})]$ ✓

$= 0,44 \mu F$ ✓ (6)

4.2.2 $de = \sqrt[3]{d1 \times d2 \times d3}$

$= \sqrt[3]{55 \times 85 \times 110}$ ✓

$= 80,12 \times 10^{-2}$ m ✓

$L = Km [0,05 + 0,2 \log e (de/r)]$

$= 35 [0,05 + 0,2 \log e \frac{(80,12 \times 10^{-2})}{0,75 \times 10^{-2}}]$ ✓

$= 34,45$ mH per phase ✓

$C = Km [1/ 18 \log e (de/r)]$

$= 35[1/ 18 \log e \frac{(80,12 \times 10^{-2})}{0,75 \times 10^{-2}}]$ ✓

$= 0,416 \mu F$ per phase ✓ (6)

Copyright reserved

4.3

Km = 200 3 ph. d = 10m r = 15 x 10^{-3} m

L = Km [0,05 + 0,2 log e (d/r)] mH

= 200 [0,05 + 0,2 log e (10 / 15 x 10^{-3})] mH ✓

= 270,01 mH ✓ (2)

[20]

QUESTION 5

5.1 5.1.1 Syn. speed = f/p = 50/2 = 25 r/s ✓

S = $\frac{\text{Syn. speed - Actual speed}}{\text{Syn. Speed}}$ ✓

= $\frac{25 - 23}{25}$

= 0,08 ✓ (3)

5.1.2 E2 = 260 / √3 = 150,11 V ✓

SE2 = 0,08 X 150,11
= 12,01 V ✓ (2)

5.1.3 SX2 = 0,08 X 2,8
= 0,228 Ω ✓ (1)

5.1.4 I rotor = $\frac{SE2}{Zr}$

Z r = 0,8 + j 0,228

= 0,83 < 15,91 ✓

I r = $\frac{12,01 < 0}{0,83 < 15,91}$

= 14,47 < - 15,91 ✓

cos ϕ = 0,96 lagging ✓ (3)

5.1.5 Rotor frequency = Sf
= 0,08 x 50
= 4 Hz ✓ (1)

Copyright reserved

5.2 The difference between the synchronous speed (Ns) ✓ and the actual speed (N) of the rotor is known as slip. ✓
For an induction motor to develop torque, EMF and current must be induced in the rotor. ✓
This will only occur when there is a relative speed difference between the rotating magnetic field and the rotor (i.e. The motor has to have a slip) ✓
Hence an induction motor must have slip to develop torque . (4)

5.3 5.3.1 $f1 = \frac{n1\ p}{60}$

$50 = \frac{n1 \times 4}{60}$

$n1 = 750$ r/min ✓

$n2 = n1 - s\,n1$

$= 750 - 0{,}05\,(750)$

$= 712{,}5$ r / min ✓ (2)

5.3.2 Gross $P = \frac{2\pi \times n_2 \times T}{60}$

$45375 = \frac{2\pi \times 712{,}5 \times T}{60}$ ✓

$T = 608{,}14$ Nm ✓

Rotor input $= \frac{2\pi \times n_1 \times T}{60}$

$= \frac{2\pi \times 750 \times 608{,}14}{60}$

$= 47763{,}2$ W ✓

Rotor cu. Loss = s x rotor input

$= 0{,}05 \times 47763{,}2$

$= 2388{,}16$ W ✓ (4)
[20]

TOTAL: 100

Copyright reserved