higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T500(**E**)(A7)T
APRIL EXAMINATION

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

(8080085)

7 April 2015 (Y-Paper)
13:00–16:00

Calculators may be used.

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

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 according to the numbering system used in this question paper.
4. Write neatly and legibly.

QUESTION 1

1.1 Briefly explain why the terminal voltage of a DC shunt excited generator drops, as the current supplied by the machine is increased. (2)

1.2 What is the function of the commutating poles and compensating windings in a DC machine? (2)

1.3 An eight pole DC motor has a wave connected armature with 800 conductors. The brushes are displaced through five angular degrees from the geometrical axis. The armature current is 270 A,

Calculate the following:

1.3.1 The demagnetising and cross-magnetising ampere turns per pole. (4)

1.3.2 The additional field current required neutralising this demagnetisation if the field winding has 1600 turns/pole. (2)

1.4 A 535 V shunt motor draws an armature current of 40 A while running at 550 r/min. The armature circuit has a resistance of 0, 5 Ω. If the magnetic flux is decreased by 30 % and the torque developed by the armature increases by 40 %.

Calculate the following :

1.4.1 The armature current. (3)

1.4.2 The speed (7)

[20]

QUESTION 2

2.1 Two circuits are connected in parallel to a 300 V, 50 Hz supply. The total current taken by the combination is 25 A, at unity power factor. Circuit A consists of a 8,8Ω resistor and a 200 μf capacitor connected in series. Circuit B consists of a resistor and an inductive reactance in series.

Calculate for circuit B :

2.1.1 The current (4)

2.1.2 The power factor (2)

2.1.3 The impedance (2)

2.1.4 The reactance (1)

2.1.5 The resistance (1)

2.2 A constant voltage at a frequency of 2,5 MHz is applied across a circuit consisting of an inductor in series with a variable capacitor. When the capacitor is set to 370 pf, the current is at its maximum value. When the capacitance is reduced to 340 pf, the current is 0,707 of its maximum value.

Find the inductance and the resistance of the inductor. (10)

[20]

QUESTION 3

3.1 A three phase delta connected load, each phase of which has an inductive reactance of 75 Ω and a resistance of 50 Ω, is supplied from the secondary of a three phase star connected transformer, which has a phase voltage of 260 V.

Calculate the following:

3.1.1 The potential difference across each phase of the load. (2)

3.1.2 The current in each phase of the load. (2)

3.1.3 The current in the transformer secondary windings. (1)

3.1.4 Total power drawn from the supply and its power factor (3)

3.2 A 15 kVA, 3500/700 volt single-phase transformer, operating at no-load, has resistances and leakage reactance as follows:

Primary winding: Resistance 7,5 Ω, reactance 15 Ω
Secondary winding: Resistance 0,5 Ω, reactance 0,65 Ω

Determine the approximate value of the secondary voltage at full-load, with a power factor of 0,8 (lagging), when the primary supply voltage is 3 500V. (4)

3.3 A three-phase, 500 V, star-connected motor has an output of 100 kW, with an efficiency of 80 % and a power factor of 0,8.

Calculate the following:

3.3.1 The line current (2)

3.3.2 If the motor windings were connected in delta, what would be the correct voltage suitable for a three-phase motor? (2)

3.4 If the phase voltage of a three phase star connected alternator is 360 V, what would the line voltages be when:

3.4.1 The phase is correctly connected. (2)

3.4.2 The connection to the yellow phase is reversed. (2)

[20]

QUESTION 4

4.1 Calculate the inductance and capacitance per phase of a 35 km , three phase overhead line having solid copper conductors of diameter 0,6 cm that are spaced on the corners of a triangle having sides of length 125 cm , 165 cm and 235 cm. (6)

4.2 An overhead, single phase transmission line delivers 2 200 kW at 31 kV. The power factor is 0, 85 lagging. The total resistance of the line is 22 Ω and the total inductive reactance is 30Ω.

Calculate the following:

4.2.1 The sending line voltage (4)

4.2.2 The per unit regulation (2)

4.2.3 The transmission efficiency (2)

4.3 Each branch of a three-phase star connected load consists of a coil of resistance 5 Ω and reactance 6 Ω. The load is supplied at a line voltage of 400V, 50 Hz. The power supplied to the load measured by the two wattmeter method.

Calculate their separate readings. (6)

[20]

QUESTION 5

5.1 A three-phase star-connected alternator supplies a 650 kW, 3,8 kV delta-connected induction motor, with an efficiency of 85 % and a full-load power factor of 0,8.

Calculate the KVA output of the alternator and the value of the current in the alternator and motor windings. (7)

5.2 A three-phase, 50 Hz induction motor has 4 poles and runs at a speed of 1000 r/min when the total torque developed by the rotor is 170 Nm.

Calculate the following:

5.2.1 The total input power to the rotor (4)

5.2.2 The rotor copper loss in watts (3)

5.3 Determine the number of stator conductors per slot for a three-phase, 50 Hz, alternator, if the winding is star-connected and has to supply a line voltage of 20 kV, when the machine is on an open circuit. The flux per pole is 0, 4 wb. Assume full-pitch coils and the stator to have three slots per pole per phase. The speed is 375 r/ min and the distribution factor is 0,96. (6)

[20]

TOTAL: 100

ELECTROTECHNICS N4

FORMULA SHEET

Any applicable formula may also be used.

1. Principles of electricity

$$E = V + Ir$$

$$V = IR$$

$$R_{se} = R_1 + R_2 + \dots R_n$$

$$R_p = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \dots \frac{1}{R_n}}$$

$$R = \rho \frac{\ell}{a}$$

$$\frac{R_1}{R_2} = \frac{1 + \alpha_o T_1}{1 + \alpha_o T_2}$$

$$R_t = R_\theta \, [1 + \alpha_\theta \, (t - \theta)]$$

$$P = VI = I^2 R = \frac{V^2}{R}$$

$$\Phi = \frac{mmf}{S} = \frac{IN}{S}$$

$$H = \frac{IN}{\ell}$$

$$F = B\ell I$$

$$E = \frac{\Delta\Phi}{\Delta t} . N$$

$$E = B\ell v$$

$$E = \frac{L\Delta I}{\Delta t}$$

$$L = \frac{\Delta\Phi}{\Delta I} . N$$

$$Q = VC$$

$$Q_{se} = Q_t = Q_1 = Q_2 \dots = Q_n$$

$$C_{se} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \dots \frac{1}{C_n}}$$

$$Q_p = Q_1 + Q_2 + \dots Q_n$$

$$C_p = C_1 + C_2 + \dots C_n$$

2. Direct-current machines

$$E = \frac{2Z}{c} . \frac{Np}{60} . \Phi$$

$$c = 2a$$

$$E_{gen} = V + I_a \, R_a$$

$$E_{mot} = V - I_a \, R_a$$

$$R_{start} = \frac{(V - E)}{I_a} - R_a$$

3. Alternating-current machines

$$E_m = 2\pi BANn$$

$$e = E_m \sin \, (2\pi f . \, t \times 57{,}3)^\circ$$

$$E_{ave} = 0{,}637 \; E_m$$

$$E_{rms} = 0{,}707 \; E_m$$

$$T = \frac{1}{f}$$

$$f = \frac{Np}{60}$$

$$\omega = 2\pi f$$

$$Z_L = R + j\omega L$$

$$Z_c = R - j\frac{1}{\omega C}$$

$$pf = \cos\phi = \frac{R}{Z}$$

$$S = VI$$

$$P = V.I\cos\phi = I^2 R$$

$$Q = V.I\sin\phi$$

4. *Transformers*

$$E = 4{,}44\ f\ \Phi_m\ N$$

$$k_t = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

5. *Measuring instruments*

$$R_{SH} = \frac{i_m R_m}{I_{sh}}$$

$$R_{se} = \frac{V}{i_m} - R_m$$

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MARKING GUIDELINE

NATIONAL CERTIFICATE

APRIL EXAMINATION

ELECTROTECHNICS N5

25 MARCH 2013

This marking guideline consists of 8 pages.

QUESTION 1

1.1 It is the reversal of current ✓ when the commutator brush short-circuits the two commutator segments to which the armature coil is connected, ✓ (2)

1.2 Armature reaction is the distortion of the main field flux ✓ due to the interaction between the two fields. ✓ (main field flux and flux around the armature conductors) (2)

1.3 $E = V - Ia\,Ra$

$= 500 - 61(0,2)$ ✓

$= 469,5$ ✓

Wave c = 2

$Z = 72 \times 10$

$= 720$ conductors ✓

$$E = \frac{2\,z\,Np\Phi}{c \times 60}$$

$$469,5 = \frac{2 \times 720}{2} \times \frac{N \times 3}{60} \times 50 \times 10^{-3} \quad ✓$$

$$N = \frac{469,5 \times 60 \times 10^{3}}{720 \times 3 \times 50} \quad ✓$$

$= 260,8$ r/min ✓ (6)

1.4 $V = 500$ V Pout $= 40$ kW $N_2 = 0,8\,N_1$ Ia= 100A $T_2 = 0,8\,T_1$
$Ra = 0,35$ $Rx = ?$

$$\frac{T_1}{T_2} = \frac{Ia_1\Phi_1}{Ia_2\Phi_2} \qquad \Phi_1 = \Phi_2$$

$$\frac{T_1}{0,8T} = \frac{100}{Ia_2} \quad ✓$$

$Ia_1 = 100 \text{ x } \Phi \text{ x } 0,8$

$= 80$ A ✓

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

$$\frac{465}{E_2} = \frac{N_1}{0,8\ N_1}$$

$E_2 = 465 \text{ X } 0,8$

$= 372$ V ✓

$E_1 = V - Ia\ Ra$

$= 500 - 100 \times 0{,}35$
$= 465\ V$ ✓

$E_2 = V - Ia\ R$
$= 500 - 80R$
$R = 1{,}6\ V$ ✓

$Rx = R - Ra$ (6)
$= 1{,}6 - 0{,}35$
$= 1{,}25\ \Omega$ ✓

1.5 1.5.1 $V = 650\ V$ $P = 55\ kW$ $N = 1\ 800\ rpm$ Eff. = 85 %

$Ra = 0{,}3$ $If = 3A$ $Ia\ Rb = 2{,}5\ V$

Input to motor = Output/η

= 55 000/0,8

= 68,75 kW ✓

Input = V x IL

$\therefore$ IL = 68 750/650

= 105,77 A ✓ (2)

1.5.2 =Ia = IL – ISH

= 105,77 – 3

= 102,77 A ✓

$E = V - (Ia\ Ra + Ia\ Rb)$

$= 650 - [(102{,}77 \times 0{,}3) + (2{,}5)]$

$= 616{,}67\ V$ ✓

$E\ Ia = 2\pi\ NT/60$

$= 60 \times E \times Ia / 2\pi N$

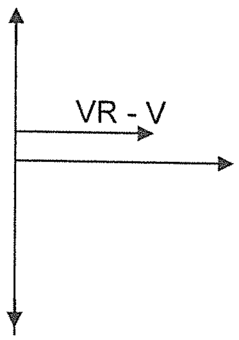
$= 60 \times 616{,}67 \times 102{,}77/2\ \pi \times 1\ 800$ ✓

Shaft torque (FL) = 336,22 N.m ✓ (4)

[22]

QUESTION 2

2.1 Phasor diagram for series circuit at resonance



(3)

2.2 2.2.1

$i_1 = (0 + 10.1)/2 = 5,05$ A
$i_2 = (10,1 + 22,4)/2 = 16,25$ ✓
$i_3 = (22.4 + 30)/2 = 26,2$
$i_4 = (30 + 27)/2 = 28,5$ ✓
$i_5 = (27 + 22.4)/2 = 24,7$
$i_6 = (22.4 + 0)/2 = 11,2$ ✓

$I\ Ave = i_1 + i_2 + i_3 + i_4 + i_5 + i_6 / n$

$= \dfrac{5,05 + 16,25 + 26,2 + 28,5 + 24,7 + 11,2}{6}$ ✓✓

$= 111,9/6$

$= 18,65$ A ✓ (6)

2.2.2

$IRMS = \sqrt{I_1^2 + I_2^2 + I_3^2 + I_4^2 + I_5^2 + I_6^2 \div n}$

$= \sqrt{2523,79/6}$ ✓

$= 20,5$ A ✓ (2)

2.3 2.3.1

$X_C = \frac{1}{2\pi f c}$

$= \frac{1}{2\pi \times 50 \times 75 \times 10^{-6}}$

$= 42,44\ \Omega$ ✓

$X_L = 2\pi f L$
$= 2\pi \times 50 \times 0,0191$
$= 6\ \Omega$

$I_A = \frac{VT}{ZA} = \frac{120}{10 + j6} = \frac{120 \angle 0}{11,6 \angle 30,9} = 10,29 \angle -30,9$ ✓

$I_B = \frac{VT}{ZB} = \frac{120}{5 - j\,42,44} = \frac{120 \angle 0}{42,734 \angle -83,3} = 2,8 \angle 83,3$ ✓ (3)

2.3.2 $IT = I_1 + I_2 = 10,29 \angle(-30,9) + 2,8 \angle 83,3$ A
$= 8,83 - j\,5,28 + 0,326 + 2,78$
$= 9,156 - j\,2,499$
$= 9,49 \angle -15,26$ ✓ ✓

Pf = cos (15,26) lagging
= 0,964 lagging ✓

$P = VI \cos \Phi$
$= 120 \times 9,49 \times 0,964$
$= 1\ 097,8$ W ✓ (4)

[18]

QUESTION 3

3.1 3.1.1 Iron losses will increase with an increase of frequency.✓ (1)

3.1.2 By laminating the iron core✓ (1)

3.1.3
- Making the transformer window long and narrow ✓
- Arranging the primary & secondary windings concentricall ✓
- Sandwiching the primary and secondary windings ✓
- Using shell-type construction ✓ (Any 3 × 1) (3)

3.2 They must have: .

- Same voltage ratio ✓
- Same per unit impedance ✓
- Same polarity ✓
- Same phase sequence ✓
- Zero relative phase-displacement ✓ (Any 4 × 1) (4)

3.3 Single-phase transformer 12 kVA

$V1/V2 = 250/500 = N1/N2$
$R1 = 8{,}5\ \Omega$ $R2 = 0{,}5\ \Omega$ $X1 = 15\ \Omega$ $X2 = 0{,}9\ \Omega$ $V1 = 2\ 500$ V $\cos\phi = 0{,}85$

$I_1 = VA/V_1$
$= 12\ 000/2\ 500$
$= 4{,}8$ A ✓
$Re = R1 + R2\ N/N2)^2$
$= 8{,}5 + 0{,}5(5)^2$
$= 8{,}5 + 12{,}5$
$= 21$ ✓

$Xe = X1 + X2\ (N1/N2)^2$
$= 15 + 0{,}9\ (5)^2$
$= 15 + 22{,}5$
$= 37{,}5\ \Omega$ ✓

$Ze = \sqrt{(Re)^2 + (Xe)^2}$

$= \sqrt{(21)^2 + (37{,}5)^2}$

$= 42{,}98\ \Omega$ ✓

OR

$Ze = Re + j\,Xe$

$= 21 + j\,37{,}5$

$= 42{,}98 \angle 60{,}75$

Reg. $= I_1\,(Re \cos\phi + Xe \sin\phi) / V_1$

$= 4{,}8\ [(21)(0{,}85) + (37{,}5)(0{,}527)]/2\ 500$
$= 4{,}8\ [17{,}85 + 19{,}76]/2\ 500$
$= 0{,}072$ per unit ✓

Full V2 = No Load V2 – Change
$= (500) - (N/L\ V2 \times reg)$
$= 500 - (500 \times 0{,}072)$
$= 500 - 36$
$= 464$ V✓ (6)

3.4 3.4.1 Three-phase star-connected motor VL = 660 V P out = 85 kW $\eta = 0{,}9$
$\cos\phi = 0{,}8$

P in $= 85/0{,}9$
$= 94{,}444$ kW ✓
$P = \sqrt{3}\ I_L V_L \cos\phi$
$94444 = \sqrt{3}\ I_L\,(660)(0{,}8)$ ✓

$I_L = 103{,}27$ A✓ (3)

3.4.2 FOR DELTA CONNECTED MOTOR WINDING:

IL = $\sqrt{3}$ IP = $\sqrt{3}$ × 103,27 = 178,87 A ✓

P = $\sqrt{3}$ IL VL COS ϕ

94 444 = $\sqrt{3}$ x 178,87 × V × 0,8

VL = 381,05 V ✓ (2)

[20]

QUESTION 4

4.1
- Frequencies must be the same. ✓
- The voltages of the alternator and busbar must be the same in magnitude and phase. ✓
- The phase sequence of the busbar voltage and alternator must be the same. ✓ (3)

4.2 Sudden changes of load on synchronous motors✓ sometimes set up oscillations that are superimposed upon the normal rotation, ✓ resulting in periodic variations in speed of very low frequency✓ . (3)

4.3 The ratio of the total EMF of a coil ✓ which is distributed over a number of slots✓ to the EMF that would be obtained if all the conductors of the coil side were concentrated in one slot ✓is called the distribution factor.

4.4 P1 = 17,5

P2 = 17,5 Cos ϕ =0,8 (36,87°)

Total Power = P1 + P2 = 35 kW ✓

Tan ϕ = √3 (P2 – P1)/P2 +P1

Tan 36,87 ° / √ 3 = P2 – P1/P2 + P1 ✓

0,75 / √ 3 = P2 – P1/P2 + P1

P2 – P1 = 0,433 (P2 + P1) ✓

= 0,433 (35) ✓

= 15,16 kW ✓

Per Meter = 7,58 KW ✓

Readings: P1 = 17,5 – 7,58

= 9,92 ✓

P2 = 17,5 + 7,58

= 25,08 KW ✓ (8)

4.5 4.5.1 V = 370 Vf = 50Hz W1 = 2,5 W2 = 1,8

Tan ϕ = $\sqrt{3}$ (W1 –W2)/W1+W2

= √3 (2,5 – 1,8)/(2,5 +1,8) ✓

= 0,281 ✓

∴ ϕ = 15,7°

∴ Cos ϕ = Cos 15,7°= 0,96 ✓ (3)

4.5.2 IL = PT/√3 VL COS ϕ
= $(4,3 \times 10^3)/\sqrt{3} \times 370 \times 0,96$ ✓
= 6,99 A ✓ (2)

[22]

QUESTION 5

5.1 5.1.1 p = 8/2 = 4 f = 50 Hz

Synchronous speed : Ns
f = Ns p/60 ✓

Ns = f × 60/4
= 50 × 60/4 ✓
= 750 r/min ✓ (3)

5.1.2 Nr = Ns – s Ns✓
= 750 – (0,08 × 750)✓
= 690 r/min✓ (3)

5.1.3 fr = p (Ns – Nr)/60 ✓
= 4 (750 – 250)/60
= 33,33 Hz ✓ (2)

5.2 5.2.1 Z = 0,8 + j 10,5
EA = EB = 2 300 V ✓
EZ = j EA – (EB Sin ϕ + j EB Cos ϕ) ✓
= j 2 300 – (2 300 Sin 40 ° + j2 300 Cos 40 °)
= j 2 300 – (1 478,41 + j 1 761,9)✓
= -1 478,41 + j 538,01
= 1 573,26∠ 160° ✓
I = EZ/2XS ✓
= 1 573,26/2 (10,53)
= 74,7 A ✓ (6)

5.2.2 V = EA COS ϕ /2 ✓
= 2 300 COS 20
= 2 161,29 V ✓ (2)

5.2.3 P = V I ✓
= 2 161,29 x 74,7
= 161 448,36 kW ✓

(2)
[18]

TOTAL: 100