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higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T530(E)(N8)T
NOVEMBER EXAMINATION

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

(8080085)

8 November 2013 (X-Paper)
09:00–12:00

Calculators may be used.

This question paper consists of 6 pages and 2 formula sheets.

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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.

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QUESTION 1

1.1 Sketch a diagram showing the connections of a self-excited generator indicating the supply, armature, field, and measuring instruments for amperes and voltage. (4)

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

1.3 A DC motor with four poles has a wave-connected armature with 1 000 conductors. The brushes are displaced through FIVE angular degrees from the geometrical axis. The armature current is 220 A.

Calculate the following:

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

1.3.2 The additional field current required to neutralize this demagnetization if the field winding has 2 000 turns/pole (2)

1.4 A 450 V, 45 kW, DC motor has to start on full-load and the starting current must not exceed 1,5 times the normal full-load value. If the armature resistance is 0,07 Ω and the starter has 10 elements. Calculate the resistance of the first THREE elements. The full-load efficiency of the motor is 75 %. (8)
[20]

QUESTION 2

2.1 TWO circuits are connected in parallel to a 350 V, 50 Hz supply. The total current taken by the combination is 30 A, at unity power factor. Circuit A consists of a 8,5 Ω resistor and a 185 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)

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2.2 The voltage across a certain circuit element is:
$v(t) = 755 \sin (628\,t + 30°)$ V and the current flowing in this element is:
$i(t) = 8,8 \sin (628\,t + 30°)$ A

Determine the following:

2.2.1 The nature and magnitude of this element (3)

2.2.2 The time period of the waveform (2)

2.3 An impedance of $6 + j18\ \Omega$ is connected in series with TWO impedances in parallel, one of $13 + j18\ \Omega$ and the other of $14 - j13\ \Omega$.
The combination is then connected across a 245 V, AC supply.

Calculate the following:

2.3.1 The total impedance (4)

2.3.2 The total current drawn from the supply (1)

2.3.3 The power factor (2)
[22]

QUESTION 3

3.1 Name TWO conditions for a three-phase system to be balanced. (2)

3.2 A three-phase delta-connected load, each phase of which has an inductive reactance of 55 Ω and a resistance of 34 Ω, is supplied from the secondary of a three-phase star-connected transformer, which has a phase voltage of 270 V.

Calculate the following:

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

3.2.2 The current in each phase of the load (2)

3.2.3 The current in the transformer secondary windings (1)

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

3.3 The ratio of turns of a single-phase transformer is 5 (FIVE). The resistances of the primary and secondary windings are 0,75 and 0,016 Ω respectively and the leakage reactance of these windings are 5,8 Ω and 0,13 Ω respectively.

Calculate the voltage to be applied to the primary to obtain a current of 240 A in the secondary when the secondary terminals are short-circuited. Ignore the magnetizing current. (8)
[18]

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QUESTION 4

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

Calculate their separate readings. (6)

4.2 An overhead, single-phase transmission line delivers 2 400 kW at 36 kV. The power factor is 0, 85 lagging. The total resistance of the line is 22 Ω and the total inductive reactance is 33 Ω.

Determine the following:

4.2.1 The sending line voltage (5)

4.2.2 The per unit regulation (2)

4.2.3 The transmission efficiency (3)

4.3 Calculate the inductance and capacitance per phase of a 28 km, three-phase overhead line having solid copper conductors of diameter 0,8 cm that are spaced on the corners of a triangle having sides of length 120 cm, 160 cm and 220 cm. (6)

[22]

QUESTION 5

5.1 A three-phase slip-ring induction motor gives a reading of 77 V across the slip-rings on open circuit with normal stator voltage applied. The rotor is star-connected and has an standstill impedance of 0,8 + j 6 Ω per phase.

Determine the rotor current when the machine is:

5.1.1 At standstill with the slip-rings joined to a star-connected starter with phase impedance of 7 + j 9 Ω

5.1.2 Running normally with a 5,5% slip

(2 × 3) (6)

5.2 Two similar, three-phase, star-connected alternators are connected in parallel. Each machine has a synchronous reactance of 8,8 Ω per phase and negligible resistance. The machines are adjusted to be in exact phase opposition relative to each other and the excitation of one alternator is adjusted to give an open-circuit voltage of 2 700 V/phase. The circulating current of 50 A.

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Calculate the following:

5.2.1 The open-circuit voltage of the other machine assuming it is less than that of the first machine (6)

5.2.2 The terminal line voltage (2)

5.3 5.3.1 Is a single-phase induction motor self-starting? Give a reason for your answer.

5.3.2 Name TWO methods used for finding the slip of an induction motor.

(2 × 2) (4)
[18]

TOTAL: 100

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ELECTROTECHNICS N5

FORMULA SHEET

Armature ampere-turns/pole $= \frac{1}{2} \cdot \frac{I_a}{C} \cdot \frac{Z}{2P}$

$$E = V \pm I_a R_a$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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FORMULA SHEET (Continued)

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

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

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

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

% Voltage regulation

$$= I_1 \frac{(R_e \cos\phi \pm X_e \sin\phi)}{V_1} \times \frac{100}{1}$$

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

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

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

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

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

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

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

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

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

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

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

% Regulation

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

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MARKING GUIDELINE

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NOVEMBER EXAMINATION

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8 NOVEMBER 2013

This marking guideline consists of 9 pages.

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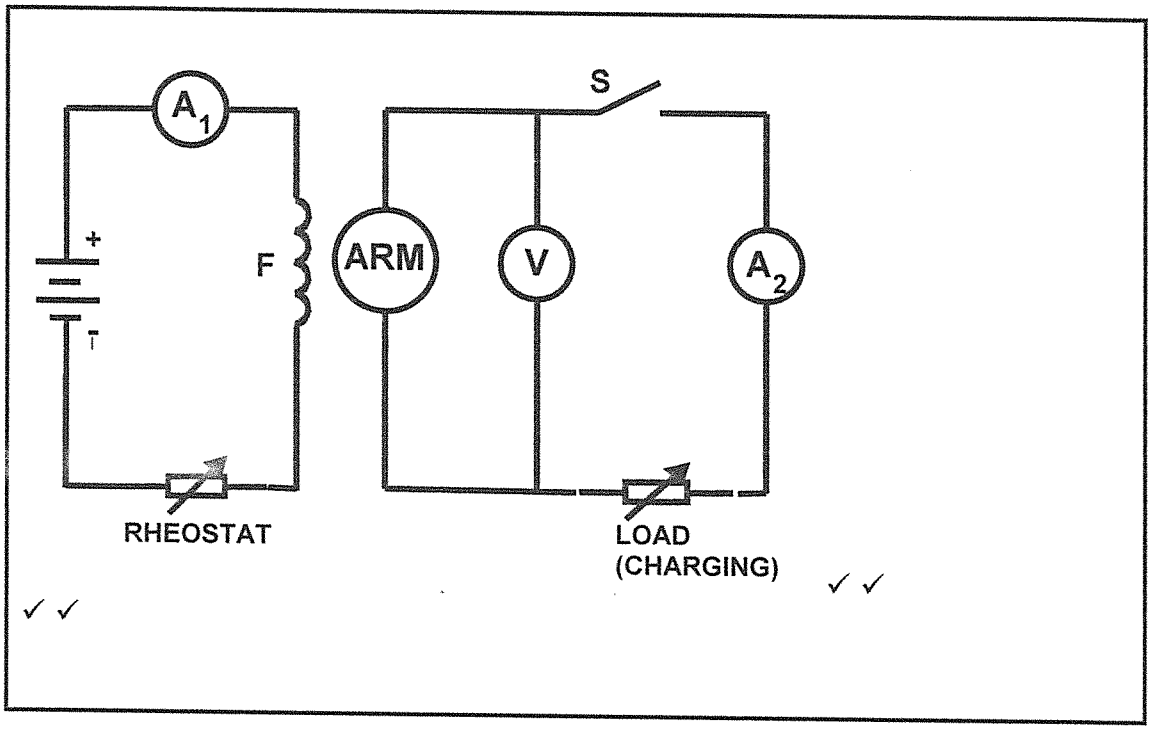
QUESTION 1

1.1



✓ ✓ ✓ ✓

SEPARATELY EXCITED GENERATOR (4)

1.2
- Commutating poles improve commutation. ✓
- Compensating windings minimise armature reaction. ✓ (2)

1.3 1.3.1 p = 2 c = 2 (wave) Z = 1 000 mech deg. = 5° and
Elect deg = p x 5 = 10°
Ia = 220 A Field winding = 2 000 t/p

Demag At/p = 0.5 x Ia/c x Z/2p x 4θ/360
= 0,5 x 220/2 x 1 000/4 x (4 x 10/360)✓
= 1 528 At/p ✓

Cross-mag At/p = 0,5 x 220/2 x 1 000/4 x [1 – (4 x 10/360)] ✓

= 12 222 At ✓ (4)

1.3.2 MMF = N I
I = 1 528/2 000 ✓
= 0,76 A ✓ (2)

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1.4 P = 45 kW V = 450 V Ra = 0,07 ohm m = 10 η = 75 %

$\% \eta$ = Output/Input $\times$ 100%

P = 45 000/0,75
= 60 kW ✓

P = V x I_2
I_2 = P/V
= $\frac{60\,000}{450}$
= 133,33 A ✓

Max starting current

I_1 = 1,5 I_2
= 1,5 x 133,33 A
= 200 A ✓

$R1 = \frac{V}{I_1}$ = 450/200

= 2,25 Ω ✓

$k = \sqrt[n]{R_1 \div R_M}$

$= \sqrt[10]{2,25 \div 0,07}$
= 1,41 ✓

$r_1 = R1 \frac{(k - 1)}{k}$

$= 2,25 \frac{(1,41 - 1)}{1,41} = 0,65\ \Omega$ ✓

$r_2 = r1/k$

= 0,65 / 1,41

= 0,461 Ω ✓

$r_3 = r_2 / k$

= 0,461/1,41

= 0,327 Ω ✓ (8)

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QUESTION 2

2.1 2.1.1 ZA = R – j X c

= 8,5 – j (1/2π f c)
= 8,5 – j (1/2 π 50 x 185 x 10-6)
= 8,5 – j17,21
= 19,19 ∠ - 63,72✓

IA = V/ZA
= 350 ∠0/19,19 ∠- 63,72
= 18,24 < 63,72 ✓

I B = IT – IA
= 22 < j 0 – 18,24 ∠ 63,72
= 22 + j 0 – (8,08 + j16,35)✓
= 13,92 – j16,35
= 21,47 ∠– 49,59 ✓ (4)

2.1.2 Cos ϕ = Cos 49,59✓

pf = 0,648 Lagging ✓ (2)

2.1.3 ZB = VB/IB

= 350 ∠ 0/21,47 ∠ - 49,59 ✓

ZB = 16,3 ∠49,59 ✓ (10,57 + i 12,41) (2)

2.1.4 XL = 12,41 Ω (from ZB = 10,57 + j 12,41) ✓ (1)

2.1.5 R = 10,57 Ω (from ZB = 10,57 + j 12,41✓ (1)

2.2 2.2.1 V = 755 sin (628 t + 30°)
I = 8,8 sin (628 t + 30°)
Vrms = 0,707 x Vmax
= 0,707 x 755
= 533,79 V
Irms = 0,707 x Imax
= 0,707 x 8,8
= 6,22 A ✓

R = V/I
= 755 ∠30 / 8,8 ∠30
= 85,8

PURE RESISTANCE

Nature:
It is a pure resistance because the current is in phase with the voltage. ✓

Magnitude:
R = V/I = 533,79/6,22 = 85,8 ohms✓ (3)

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2.2.2 Time period (t) of the wave sin 628 t + 30° = sin 2πft + 30°

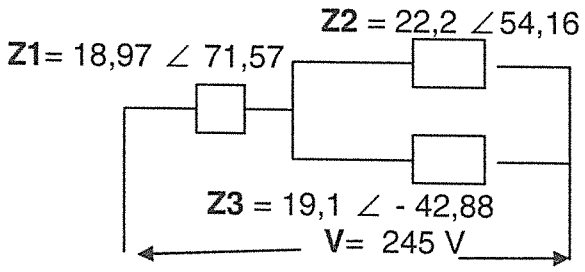
$2\pi f = 628$

$f = 628/ 2\pi$ ✓

$= 99,95$ Hz/second

= 10 ms/cycle ✓ (2)

2.3 2.3.1



Z1 = 6 + j18 = 18,97 ∠ 71,57°

Z2 = 13 + j18 = 22,2 ∠54,16°

Z3 = 14 – j13 = 19,1 ∠ - 42,88°

ZP = Z2 x Z3/Z2 + Z3

= 22,2 ∠ 54,16 x 19,1 ∠ - 42,88/(13 + j18)+ (14 – j13) ✓

= 424,02 ∠ 11,28/27,46 ∠10,49 ✓

. = 15,44 ∠ 0,79✓ (15,44 + j 0,21)

ZT = Z1 + ZP = 6 + j18 + 15,44 + j 0,21

= 21,44 + j18,21

= 28,13 ∠40,34 ✓

IT = VT/ZT = 245∠ 0°/28,13 ∠ 40,34°

= 8,71 ∠ - 40,34°✓ (4)

2.3.2 $\cos\phi = \cos(-40,34°)$ ✓ (1)

2.3.3 pf = 0,76 lag ✓ (2)

[22]

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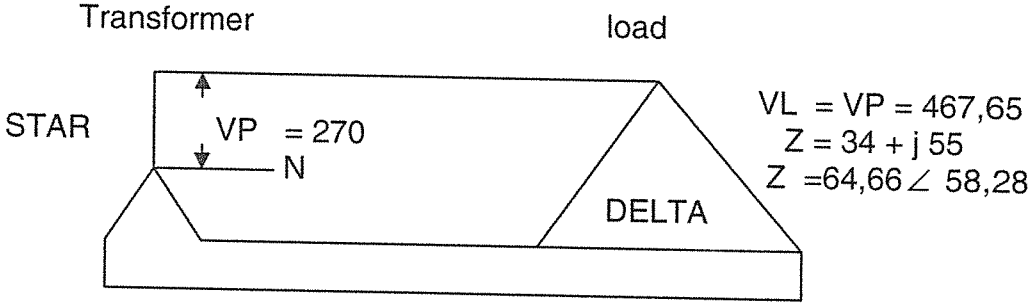
QUESTION 3

3.1
- The load must be balanced. ✓✓
- The neutral current must be zero.
- The currents in phases must be the same.

(Any 2 × 1) (2)

3.2



3.2.1 $VL = \sqrt{3}\ VP = \sqrt{3} \times 270 = 467,65\ V$ ✓ = VP = 467,65 ✓ (2)

3.2.2 IP(load) = VP/ZP
= 467,65∠ 0°/64,66∠ 58,28° ✓
= 7,23 ∠ -58,28° ✓ (2)

3.2.3 $IL = \sqrt{3} \times 7,23 = 12,52\ A$ ✓ (1)

3.2.4 $P = \sqrt{3}\ IL\ VL \cos\phi$
$= \sqrt{3} \times 12,52 \times 467,65 \times 0,526$ ✓
= 5,33 kW✓

$\cos\phi = \cos 58,28°$

pf = 0,526 ✓ (3)

3.3 $N_1/N_2 = 5/1$ R1 = 0,75 R2 = 0,016 X1 = 5,8 X2 = 0,13 $I_2 = 240$ A

$N_1/N_2 = I_2/I_1$
$I_1 = I_2 \times N_2/N_1$ ✓
= 240 x 1/5
= 48 A✓

Refer values to primary side:

Re = R1 + R2 (N1/N2) ²✓
= 0,75 + 0,016 (5) ²
= 1,15 ohms ✓

Xe = X1 + X2 (N1/N2) ² ✓
= 5,8 + 0,13 (5) ²
= 9,05 Ω ✓

Ze = Re + j Xe
= 1,15 + j9,05 ✓
= 9,12∠82,8°✓

V1 = I x Ze
= 48 x 9,12∠ 82,8°✓
= 437,76 V✓ (10)

[18]

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QUESTION 4

4.1 $Z = 5,5 + j\,6,5 = 8,51 \angle 49,76°$ VL = 400 V $\phi = 49,76°$ lag

$Vp = 400/\sqrt{3}$
$= 230,9$ V ✓
$IP = VP/ZP$
$= 230,9 \angle 0°/8,51 \angle 49,76°$
$= 27,03 \angle -49,76°$ ✓

$IL = IP = 27,03 \angle -49,76°$

$P2 + P1 = \sqrt{3}\ VL\ IL \cos\phi$
$= \sqrt{3} \times 400 \times 27,03 \cos 49,76$
$= 12,097$ kW ✓
$\tan\phi = \sqrt{3}\ (P2 - P1)/P2 + P1$
$P2 - P1 = \tan 49,76° \times 12,097/\sqrt{3}$
$= 8,25$ kW ✓
$2\,P1 = 3,85$
$P1 = 1,92$ kW ✓
$P2 = 12,097 - 1,92$
$= 10,18$ kW✓ (6)

4.2 4.2.1 R = 22 ohms; X = 33 ohms
P =2 400 kW; Vr = 36 kV ; $\cos\phi = 0,85 = 31,79$

$I = P/V \cos\phi$
$= 2\,400\,000/36\,000 \times 0,85$✓
$= 78,43$ A ✓

$Vs = V \angle \phi + IR + IX \angle 90$ ✓

$= 36\,000 \angle 31,79 + 78,43 \times 22 + 78,43 \times 33 \angle 90$
$= 30\,599,45 + j\,18\,965,07 + 1\,725,46 + j2\,588,19$ ✓
$= 32\,324,91 + j\,21\,553,26$
$= 38\,851,55 \angle 33,69$ kV✓ (5)

4.2.2 $Reg = Vs - Vr/Vr$
$= 38\,851,55 - 36\,000/36\,000$ ✓
$= 0,079$✓ (2)

4.2.3 $\eta = Po/Po + Losses$ ✓
$\eta = \dfrac{2\,400\text{ kW}/2\,400\text{ kW} + (78,43)^2 \times 22}{1\,000}$ ✓
$= 94,66\ \%$ ✓ (3)

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4.3 d1 = 120 x 10^{-2} m dia. = 0,8 cm
d2 =160 x 10^{-2} m r = 0,4 x 10^{-2}m
d3 = 220 x 10^{-2}

km = 28

de $= \sqrt[3]{1.2 X 1,6 X 2.2}$ ✓

= 1,62 m ✓

L = km [0,05 + 0,2 $\log_e$ (de/r)] mH

= 28 [0,05 + 0,2 $\log_e$ (1,62/0,004)] mH✓

= 35,02 mH ✓

C = 28 [1/18 $\log_e$ (1,62 / 0,004)] ✓

= 0,259µf ✓ (6)
[22]

QUESTION 5

5.1 5.1.1 VL = 77 V Zo = 0,8 + j6

Eo = 77/$\sqrt{3}$
= 44,46 V ✓
Zo = (0,8 + j 6) + (7 +j 9)
= 7,8 + j15
= 16,9 ∠ 62,53 ✓
Io = Eo/Zo
= 44,46/16,9
= 2,63 A ✓ (3)

5.1.2 S = 5,5 % = 0,055

E2 = s Eo
= 0,055 x 44,46
= 2,45
X2 = s Xo
= 0,055 x 6
= 0,33 ✓
Z2 = $\sqrt{R^2 + X}^2$
= $\sqrt{(0,8)^2 + (0,33)^2}$
= 0,87 ✓
I_2 = E2/Z2
= 2,45/0,87
= 2,82 A ✓ (3)

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5.2 5.2.1 X = 8,8 Ω
EA = 2 700 V/PH
IR = 50A ✓

IR = ER/2X ✓
ER = IR x (2X)
= 50 x (2x 8,8) ✓
= 880 V ✓
ER = EA + EB
EB = EA – ER ✓
= 2 700 – 880
= 1 820 V ✓ (6)

5.2.2 Terminal Voltage = EA – 0.5 ER ✓
= 2 700 – (0,5 x 880)
= 2 260 V✓ (2)

5.3 5.3.1 NO ✓ - There is NO rotating magnetic flux in single phase. ✓ (2)

5.3.2
- measurement ✓
- calculation ✓ (2)

[18]

TOTAL: 100

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