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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	POWER SYSTEM PROTECTION TECHNOLOGY
COURSE CODE	:	BNE 43103
PROGRAMME CODE	:	BNE
EXAMINATION DATE	:	JULY/AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWERS **ALL** QUESTIONS. 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK**. 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK.

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

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Q1 (a) For each of the following statements, indicate **True (T)** or **False (F)**.

(i) When all the three phases are short circuited, it gives rise to asymmetrical fault current.
(ii) When calculating symmetrical three-phase fault currents, only positive sequence network needs to be considered.
(iii) There are only two types of unbalanced fault which are L-L and L-L-G.
(iv) Transducer, relay and circuit breaker are the main components of protection system.
(v) The two types of current limiting reactor are magnetically shielded type and dry type.
(vi) Current limiting reactors usually used to minimize line to ground fault.
(vii) Symmetrical components are used to analyze symmetrical fault.
(viii) Faulty insulation in a three-core cable is the example of line to line fault.
(ix) A protective zone covers one or at the most two elements of a power system.
(x) A directional power relay which operated when the power in the circuit flows in a particular direction.

(10 marks)

(b) Two generators connected to a common 6.6 kV bus bar and is taken out through a transformer is shown in **Figure 1(b)**. If fault current is limited to four times of the full load current, find the ohmic value of the current limiting feeder reactor if there is a 3-phase fault occurs near the reactor.

(9 marks)

(c) Three 25MVA generators each having a reactance of 0.2 pu are operating in parallel. They feed a transmission line through a 75MVA transformer having a reactance of 0.05pu. Find the fault MVA for a balance fault at the sending end of the line.

(6 marks)

Q2 (a) With the help of a diagrams, draw the zero, positive and negative sequence phasors.

(4 marks)

(b) The one-line diagram of a three-bus power system is shown in **Figure Q2(b)** with two generators connected through two transformers in the system. Each generator is represented by an e.m.f behind the transient reactance. All impedances are expressed in per unit on a common MVA base and tabulated in **Table Q2(b)**. The generators are operating on no load at their rated voltage with their e.m.fs in phase. Determine the following problems:

(i) Symmetrical components values, Z_0, Z_1 and Z_2.

(10 marks)

(ii) Fault current for a three-phase fault with Z_f equal to 0.1pu at bus 3.

(3 marks)

(iii) Fault current for a bolted line-to-line fault at bus 3.

(4 marks)

(iv) Fault current for a single line-to-ground fault with Z_f = 0.63pu at bus 3.

(4 marks)

Q3 (a) Give **FOUR (4)** main points why numerical relay is chosen as protective relay compared to the electromechanical relay.

(4 marks)

(b) Three-zone mho relays are used for transmission line protection of the power system shown in **Figure Q3 (b)**. Positive-sequence line impedances are given in **Table Q3(b)**. Rated voltage for the high-voltage buses is 500 kV. Assume a 1500:5 CT ratio and a 4500:1 VT ratio at B12. One of the protection engineers has done the setting for zone 1, 2 and 3 with the values of $6\angle 80°$, $7.1\angle 85°$, and $8.6\angle 87°$, respectively.

(i) Check whether the setting was appropriate. Do some modification if necessary.

(10 marks)

(ii) Verify that B12 does not trip during emergency loading conditions if maximum current for line 1–2 under emergency loading conditions is 1400 A at 0.90 power factor lagging.

(4 marks)

(c) Draw the protection zones for the system in **Figure Q3(c)**.

(6 marks)

Q4 (a) Overcurrent protective schemes are widely used for the protection of distribution lines. IDMT relay characteristics according to IEC 60255 standards are often being used.

(i) Define the equations for Standard Inverse (SI) and Extremely Inverse (EI) IDMT relay characteristics.

(4 marks)

(ii) If the current plug setting is adjusted to 125% of rated current and the time multiplier setting is adjusted to 0.75 with a CT ratio of 800/5 and the value of fault current is limited to 8 times the relay rated secondary current, determine the relay operating time (ROT) for Standard Inverse (SI) and Extremely Inverse (EI) IDMT relay using the answers in **Q4(a)(i)**.

(6 marks)

(iii) Discuss your answer in **Q4(a)(ii)**.

(2 marks)

(b) Two relays, R_1 and R_2 are connected in two sections to a feeder as shown in **Figure Q4(b)**. Find TMS of R_2 to give time grading margin of 0.5 between the relays and the relay error in each case is 0.1s when a fault at F results in a fault current of 10000 A. Used the Standard Inverse (SI) IDMT relay characteristics for this design.
Relay R1 : CT ratio = 800/5, plug setting = 50%, TMS = 0.3
Relay R2 : CT ratio = 1000/5, plug setting = 75%

(8 marks)

(c) A generator winding can be protected by a percentage differential relay. Based on the **Figure Q4(c)**, explain how percentage differential relay with a slope of 10% able to protect this generator winding from a ground fault occurred near the terminal end of the generator while generator is carrying a load if CT ratio is 400/5.

(5 marks)

- END OF QUESTIONS -

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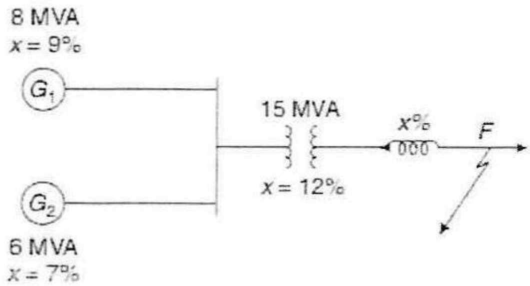

Figure Q1 (b)

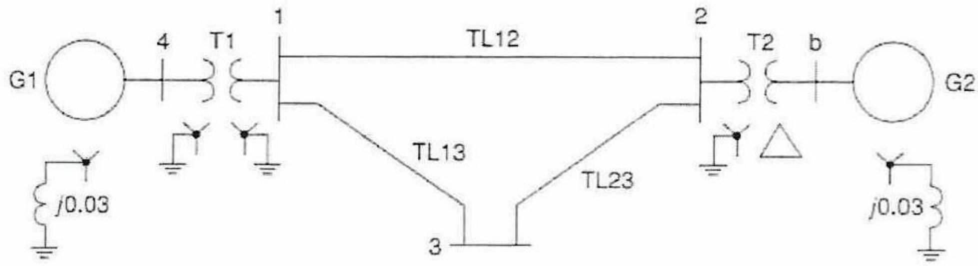

Figure Q2 (b)

Table Q2 (b)

Devices	$X_1(pu)$	$X_2(pu)$	$X_0(pu)$
Generator (G1)	0.15	0.15	0.05
Generator (G2)	0.15	0.15	0.05
Transformer (T1)	0.1	0.1	0.1
Transformer (T2)	0.1	0.1	0.1
Transmission line (TL12)	0.125	0.125	0.3
Transmission line (TL13)	0.125	0.125	0.35
Transmission line (TL23)	0.125	0.125	0.7125

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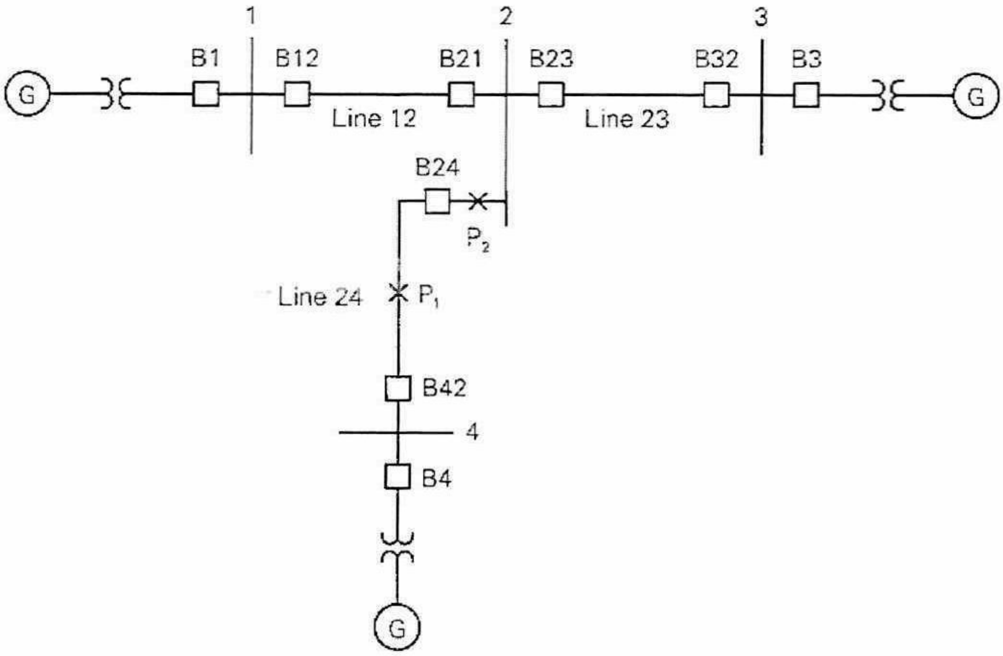

Figure Q3 (b)

Table Q3(b)

line	Positive sequence impedance Ω
1-2	6+j60
2-3	4+j40
2-4	5+j50

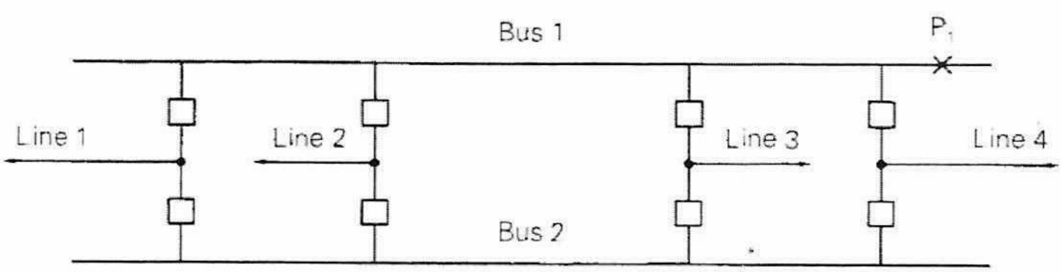

Figure Q3 (c)

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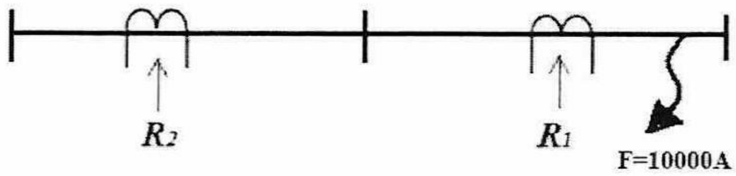

Figure Q4 (b)

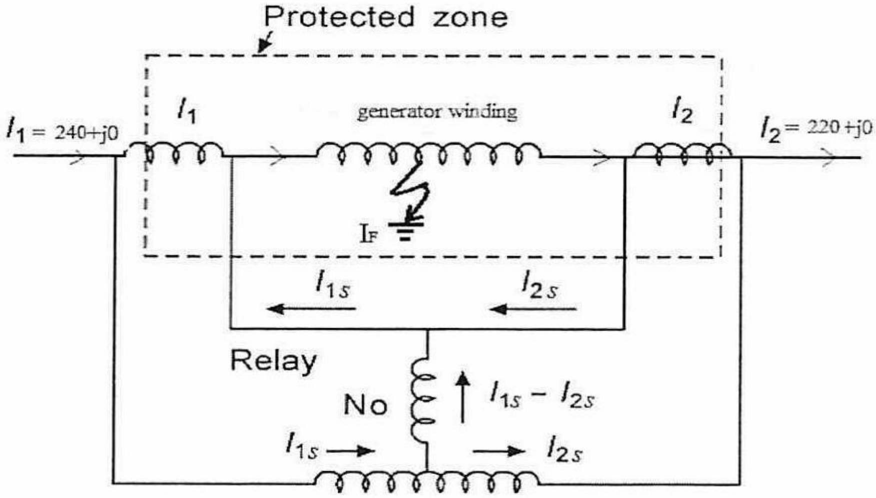

Figure Q4 (c)

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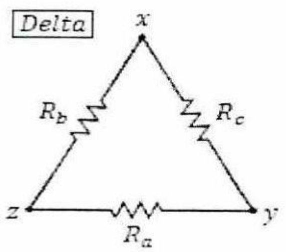
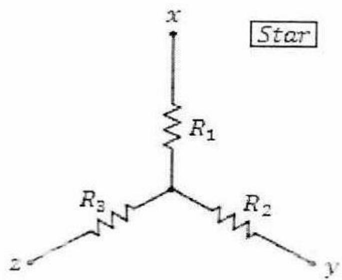
Appendix





$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} \qquad R_1 = \frac{R_bR_c}{R_a + R_b + R_c}$$

$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} \qquad R_2 = \frac{R_aR_c}{R_a + R_b + R_c}$$

$$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} \qquad R_3 = \frac{R_aR_b}{R_a + R_b + R_c}$$

Quantity in per-unit $= \frac{\text{Actual quantity}}{\text{Base value of quantity}}$	I_{base}: $Z_B = \frac{V_B/\sqrt{3}}{I_B}$
$Z_{pu}^{new} = Z_{pu}^{old}\frac{S_B^{new}}{S_B^{old}}\left(\frac{V_B^{old}}{V_B^{new}}\right)^2$	Z_{base}: $I_B = \frac{S_B}{\sqrt{3}V_B}$
Single-line-to-ground fault: $I_a = 3I_a^0 = \frac{3E_a}{Z^0+Z^1+Z^2+3Z_f}$	Line-to-line fault $I_b = -I_c = (a^2 - a)I_a^1$ OR $I_b = -j\sqrt{3}\,I_a^1$
Double-line-to-ground fault $I_a^0 = -\frac{E_a - Z^1I_a^1}{Z^0+3Z_f}$ $I_a^2 = -\frac{E_a - Z^1I_a^1}{Z^2}$ $I_a^1 = \frac{E_a}{Z^1+\frac{Z^2(Z^0+3Z_f)}{Z^2+Z^0+3Z_f}}$ $I_f = I_b + I_c = 3I_a^0$	CT performance: $E' = (Z' + Z_B)I'$ $I = n(I' + I_e)$