Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2018/2019

COURSE NAME	:	POWER SYSTEM PROTECTION TECHNOLOGY
COURSE CODE	:	BNE 43103
PROGRAMME CODE	:	BNE
EXAMINATION DATE	:	JUNE / JULY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

Q1 (a) Briefly explain the terms listed below commonly used in system protection technology.

(i) Protection zones.
(ii) Backup relays.

(2 marks)

(b) A 6-bus power system network is shown in **Figure Q1(b)** and sequence reactance for generators, transformers and lines are tabulated in **Table Q1(b)**. Determine the fault current if the following types of fault happen:

(i) A bolted three phase fault at bus 3.
(ii) Single line to ground fault with Z_f = j0.52 at bus 3.
(iii) Line to line fault with Z_f = j0.66 at bus 3.
(iv) A bolted double line to ground fault at bus 3.

(18 marks)

Q2 (a) Briefly discuss the fundamental operating principles of electromechanical relay with the aid of diagram.

(6 marks)

(b) Briefly compare electromechanical relay and numerical relay. Give **THREE (3)** criteria in your answers.

(3 marks)

(c) Draw the protective zones for the power system shown in **Figure Q2(c)**.

(4 marks)

(d) An overcurrent relay set to operate at 10A is connected to the CT in **Figure Q2(d)** with a 600:5 CT ratio. Estimate the minimum primary fault current that the relay will detect if the burden impedance is 1.704 Ω and 9.704 Ω.

(7 marks)

Q3 (a) For the system shown in **Figure Q3(a)**, directional overcurrent relays are used at breakers B12, B21, B23, B32, B34, and B43. Overcurrent relays are used at B1 and B4. Explain which breakers should be operated to protect against each bus faults.

(4 marks)

(b) **Figure Q3(b)(i)** shows a one-line diagram of a 11 kV, 50 Hz radial system. The data for the system is tabulated in **Table Q3(b)**. Assume that the coordination time interval for the relay is 0.3 second and the voltage is 11 kV (line-to-line) at all buses during normal operation. Also, assume that the breaker operating time is 5 cycles and the CT ratio is 200:5. Determine the current tap settings (TSs) and time-dial settings (TDSs) to protect the system from fault using CO-8 overcurrent relay. The characteristic of the CO-8 relay is shown in **Figure Q3(b)(ii)**.

(14 marks)

(c) State **TWO (2)** types of overcurrent relay setting with simple explanations.

(2 marks)

Q4 (a) Consider the simple system represented by the one-line diagram in **Figure Q4(a)**. The system nominal voltage is 11 kV. The positive Z^1, negative Z^2, and zero Z^0 sequence impedance of the two elements are given in **Table Q4(a)**. Determine the fault impedance seen by relay at bus A for phase-to-ground fault.

(10 marks)

(b) With the aid of one-line diagram, recommend the suitable configuration of differential relays for transformer application and explain the behaviour of the differential protection during internal fault.

(6 marks)

(c) A generator winding is protected by using a percentage differential relay whose characteristic is having a slope of 10%. A ground fault occurred near the terminal end of the generator winding while generator is carrying a load. As a consequence, the currents flowing at each end of the winding are shown in **Figure Q4(c)**. Assuming CT ratios of 500/5 A, determine either the relay will operate to trip the circuit breakers or not.

(4 marks)

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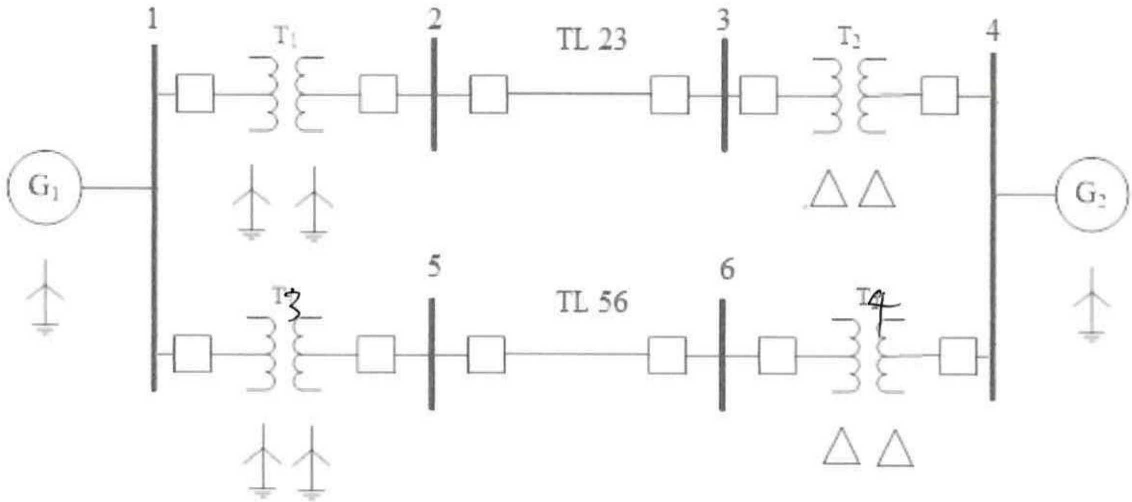

Figure Q1(b)

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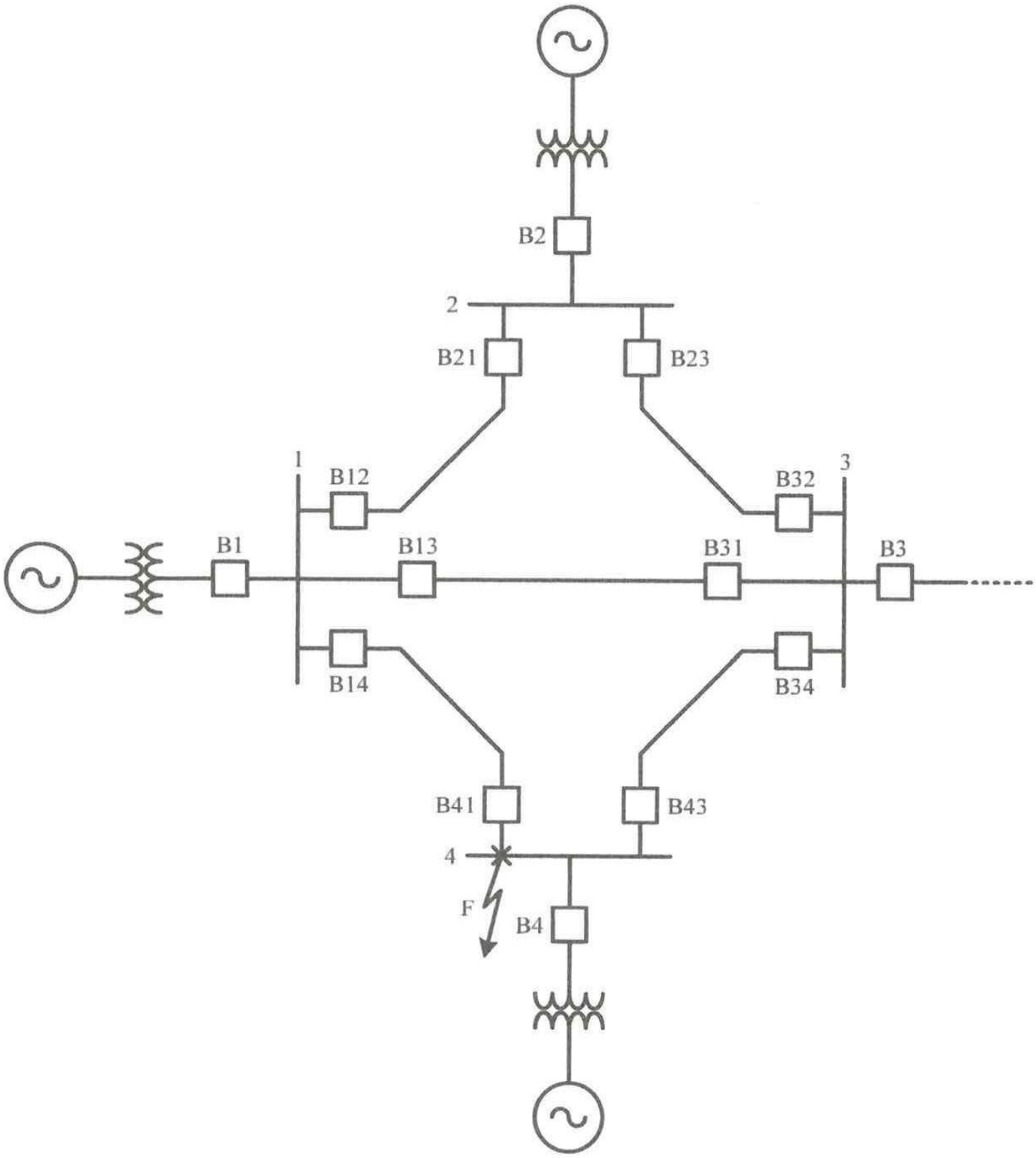

Figure Q2(c)

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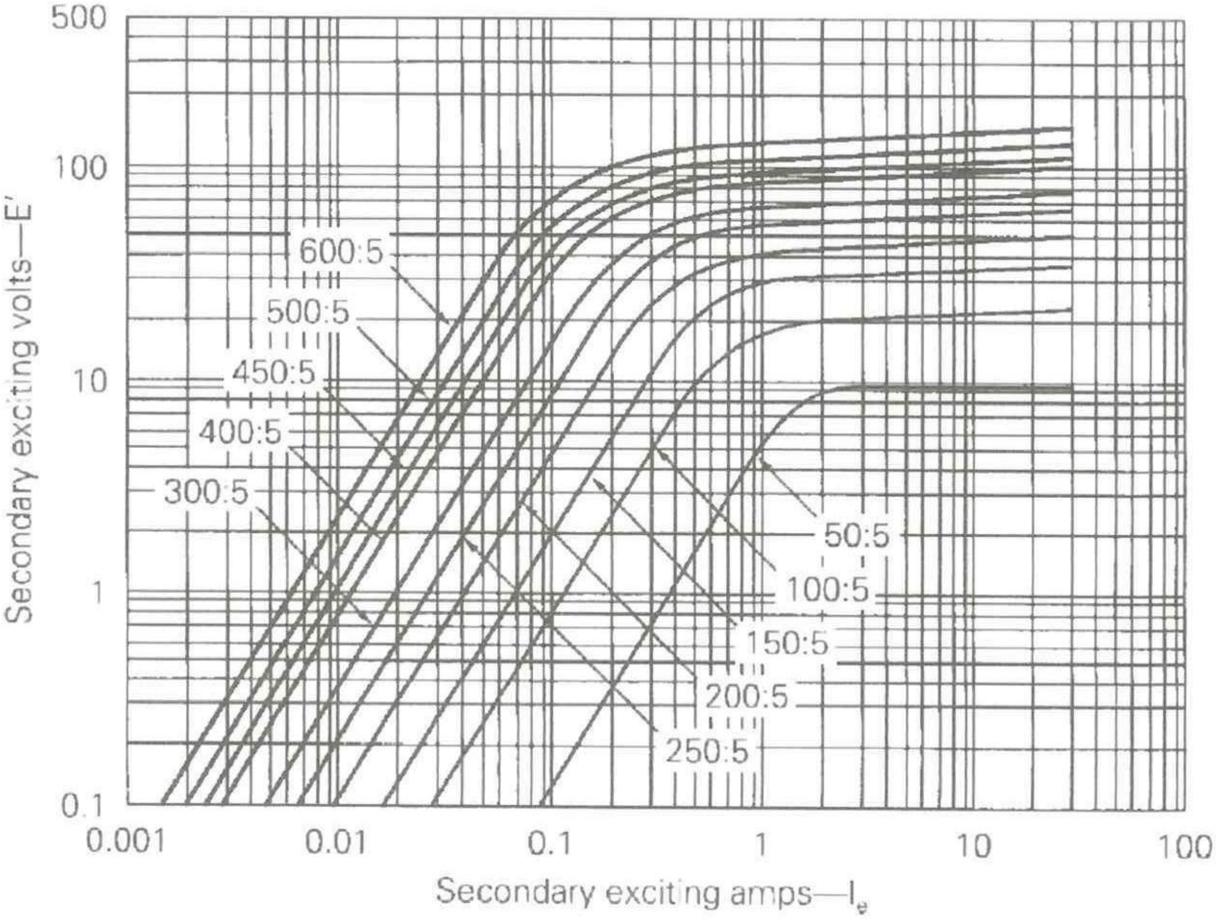

CT ratio	Secondary resistance Ω
50:5	0.061
100:5	0.082
150:5	0.104
200:5	0.125
250:5	0.146
300:5	0.168
400:5	0.211
450:5	0.230
500:5	0.242
600:5	0.296

Figure Q2(d)

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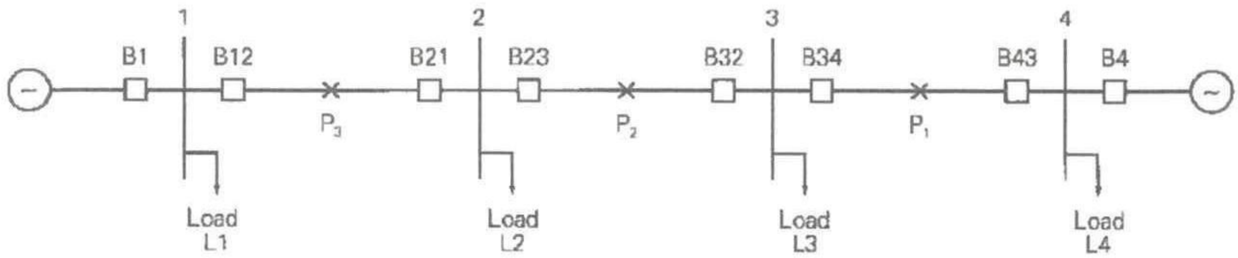

Figure Q3(a)

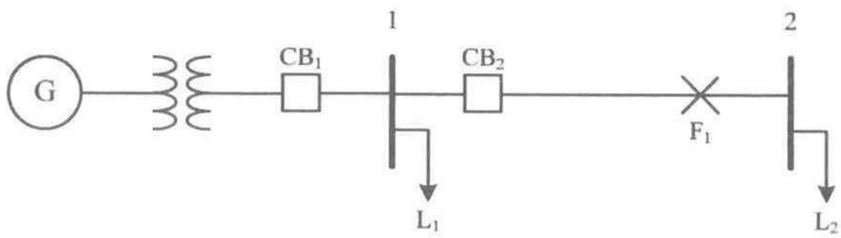

Figure Q3(b)(i)

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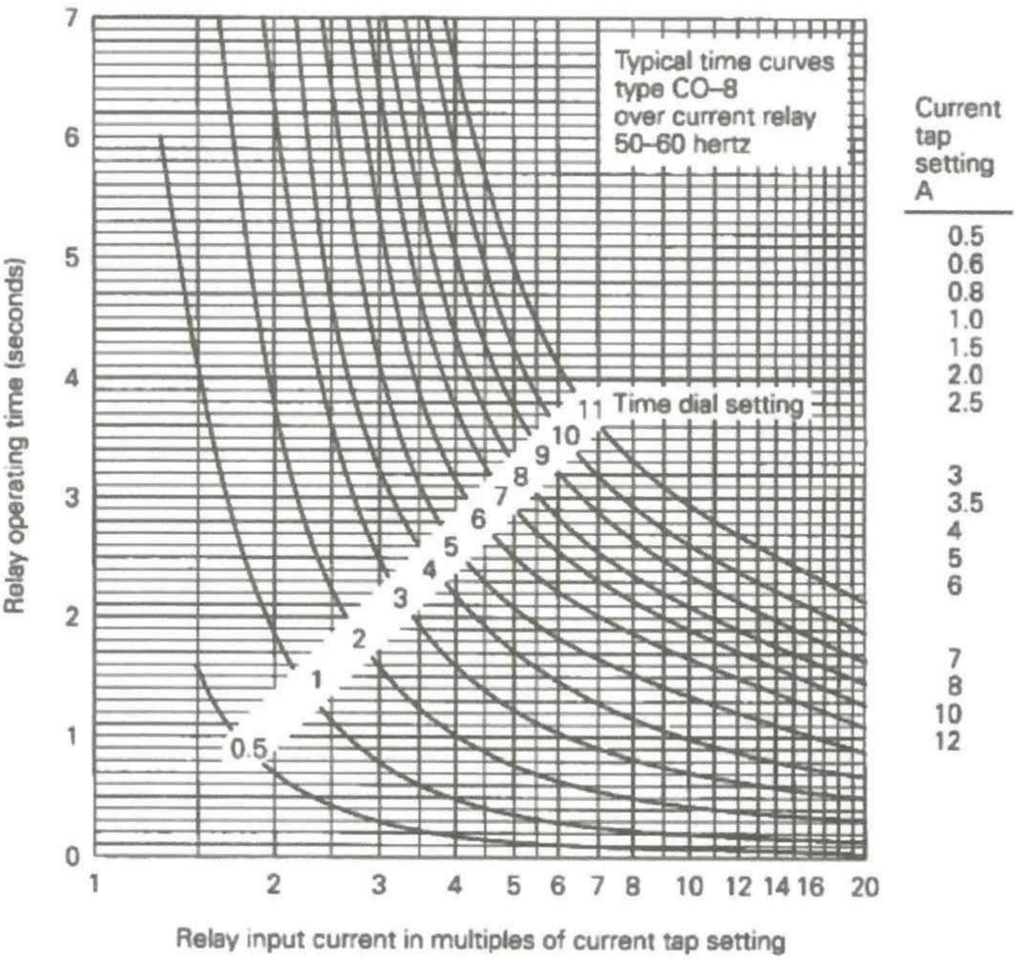

Figure Q3(b)(ii)

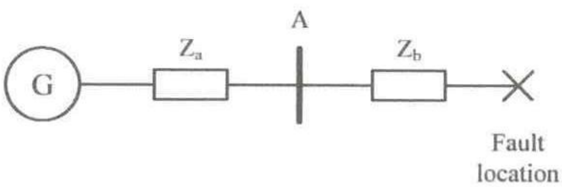

Figure Q4(a)

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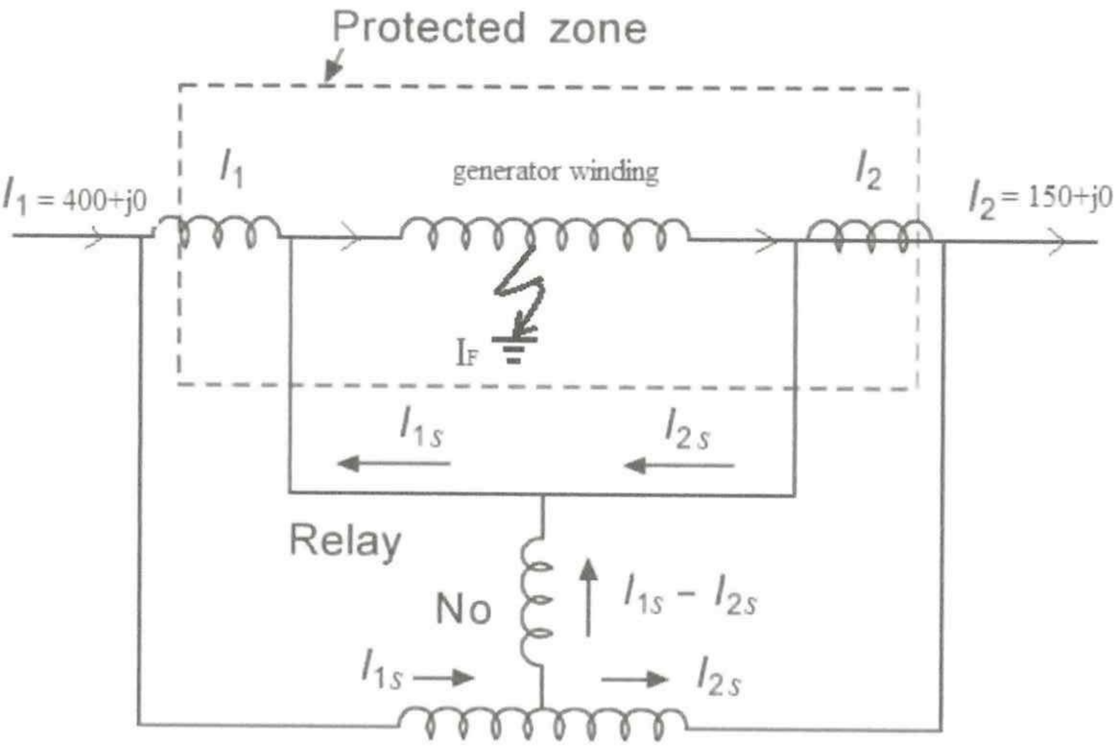

Figure Q4(c)

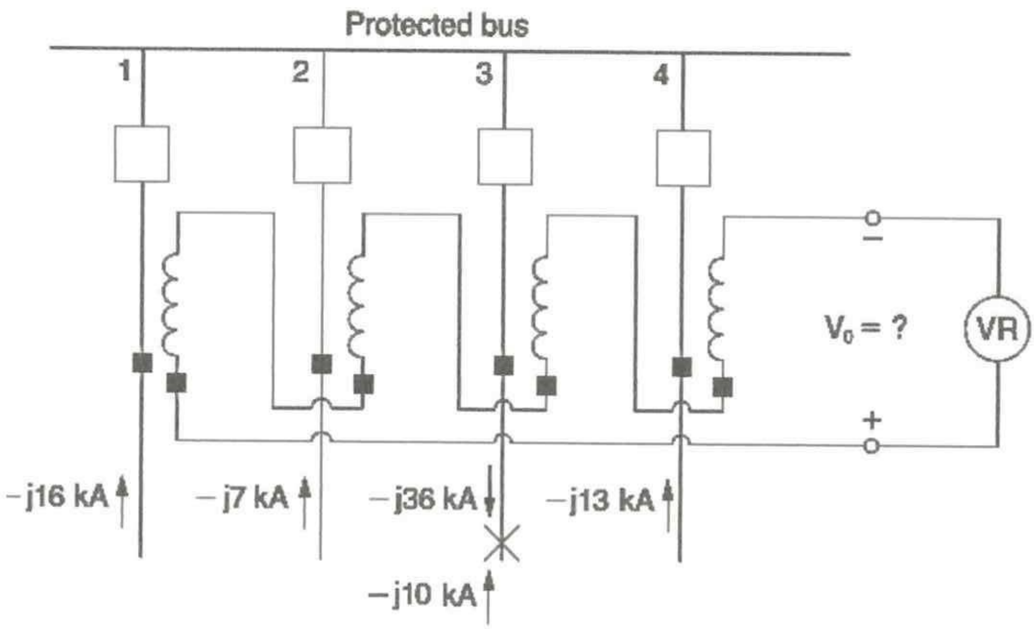

Figure Q5(d)

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Table Q1(b)

Device	X_1 (pu)	X_2 (pu)	X_0 (pu)
G_1	0.2	0.14	0.06
G_2	0.2	0.14	0.06
T_1	0.2	0.2	0.2
T_2	0.3	0.3	0.3
T_3	0.25	0.25	0.25
T_4	0.35	0.35	0.35
T_{L23}	0.15	0.15	0.3
T_{L56}	0.22	0.22	0.5

Table Q3(b)

Bus	S (MVA)	Power Factor	Maximum fault current (A)
1	3.0	0.90	2000
2	4.5	0.90	1680

Table Q4(a)

Impedance	Z_a	Z_b
Positive sequence	0+j6	3+j27
Negative sequence	0+j6	3+j27
Zero sequence	0+j10	9+j60

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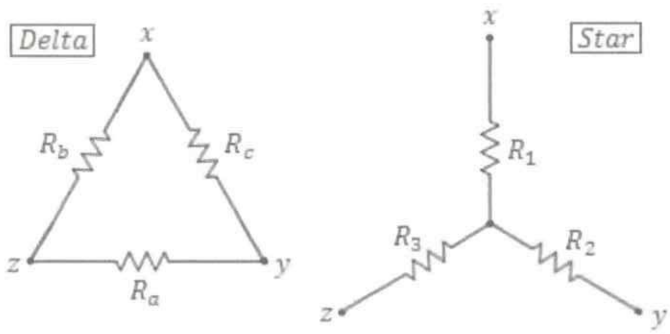
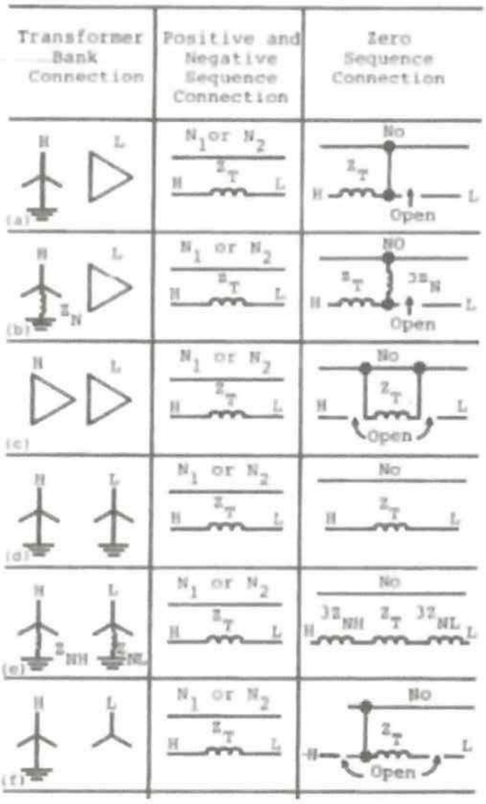
Appendix



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

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

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



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Appendix

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 $I_a^0 = -\frac{E_a - Z^1 I_a^1}{Z^0+3Z_f}$ $\quad I_a^2 = -\frac{E_a - Z^1 I_a^1}{Z^2}$ $I_a^1 = \frac{E_a}{Z^1 + \frac{Z^2(Z^0+3Z_f)}{Z^2+Z^0+3Z_f}}$ $I_f = I_b + I_c = 3I_a^0$	CT performance: $E' = (Z' + Z_B)I'$ $I = n(I' + I_e)$