THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMMUNICATIONS ENGINEERING

SEMESTER TWO FINAL EXAMINATION (2023)

EE424 – ELECTRICAL POWER SYSTEMS III

FINAL YEAR ELECTRICAL ENGINEERING – POWER (BEEP/4)

TIME ALLOWED: 3 HOURS

INFORMATION FOR STUDENTS:

1. You have **TEN (10) MINUTES** to read the paper.
   You must not begin writing during this time.

2. **Answer all questions.** All answers must be written in the **ANSWER BOOK** supplied.

3. **COMPLETE THE DETAILS REQUIRED ON THE FRONT COVER OF YOUR ANSWER BOOK – DO THIS NOW, & SIGN ON THE SPACE PROVIDED.**

4. Only drawing instruments, calculators and pens are permitted on your desk.
   NO phones allowed.

5. If you are found cheating in the Examination, the penalties specified by the University shall apply.

6. **TURN OFF** all Mobile Phones and place them on the floor under your seat before the start of Examination.

Question 1 **(30 marks)**

For the power system network shown in Figure Q1:

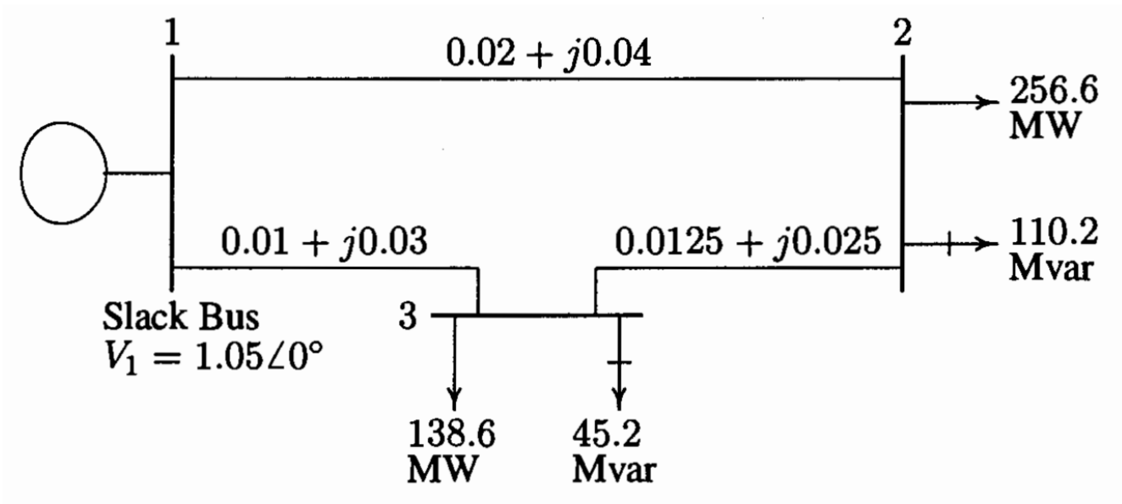


Figure Q1

(a) Convert the line impedance to admittance and redraw the admittance diagram. (Note, all impedances are in per unit on 100 MVA base). ***(5 marks)***

(b) Apply the Gauss-Seidel algorithm to determine the phasor values of the voltage at load Bus 2 and Bus 3 after the First (1^{st}) Iteration. Use initial guess values of voltages on bus 2 and bus 3 to be $V = 1\angle 0°$ ***(5 marks)***

(c) If after the 7^{th} iteration $V_2^{(7)}$ and $V_3^{(7)}$ converge to a solution shown below:

$V_2^{(7)}$ = **0.98400 -j0.0600**
$V_3^{(7)}$ = **1.00 -j0.005**

Find the slack bus Real power (P) and Reactive power (Q). ***(5 marks)***

Question 1 (cont'd)

(d) Find the line currents I_{12}, I_{13}, and I_{23}. ***(6 marks)***

(e) Determine the line power flow by filling in the Table below. ***(9 marks)***

Line Flow	Equation	Results
S_{12}	$V_1 \times I_{12}^*$	
S_{21}	$V_2 \times I_{21}^*$	
S_{13}	$V_1 \times I_{13}^*$	
S_{31}	$V_3 \times I_{31}^*$	
S_{23}	$V_2 \times I_{23}^*$	
S_{32}	$V_3 \times I_{32}^*$	

Question 2 (20 marks)

For the three-bus system in Figure Q2, each generator is represented by an emf behind the transient reactance. All sequence impedances are given in Table Q2. The impedances are expressed in p.u on a common 100 MVA base. Neglecting resistances and shunt capacitances and assuming that all generators are running at their rated voltage and frequency and all emf in phase.

Determine the fault current during a single-line-ground fault that occurs on phase ***a*** of Bus 2. Assume the fault impedance is zero (0).

<u>Question 2</u> **Cont'd**

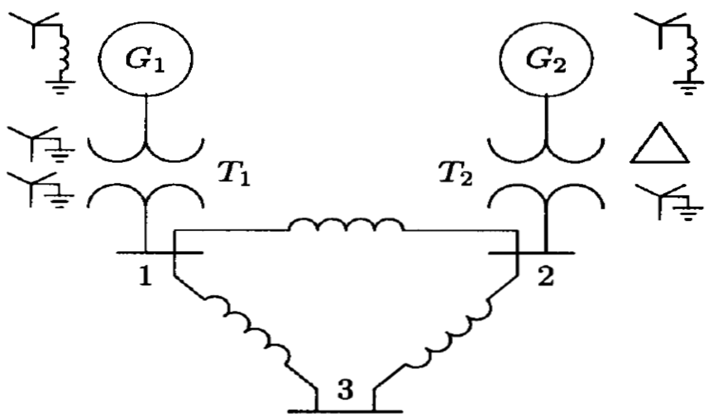


Figure Q2

Table Q2

Item	Base MVA	Voltage Rating	X^1	X^2	X^0
G_1	100	20 kV	0.15	0.15	0.05
G_2	100	20 kV	0.15	0.15	0.05
T_1	100	20/220 kV	0.10	0.10	0.10
T_2	100	20/220 kV	0.10	0.10	0.10
L_{12}	100	220 kV	0.125	0.125	0.30
L_{13}	100	220 kV	0.15	0.15	0.35
L_{23}	100	220 kV	0.25	0.25	0.7125

<u>Question 3</u> **(30 marks)**

Data for a 60-Hz radial system of Figure Q3 are given in Table Q3 (1) and Table Q3 (2).

Three CO-8 relays are required for each breaker per phase, with a 0.3-second coordination time interval. The relays for each breaker are connected such that a fault on any phase will cause all three breakers to open in order to isolate the fault. Assume a 34.5 kV (line-to-line) voltage at all busses during normal operation. The future load growth is included such that the maximum loads over the operating life of the radial system are as indicated in **Table Q3 (1).** Use the CO-8 relay curve attached in the Datasheet.

Select the current tap settings (TSs) and the time-dial settings (TDSs) to protect the system from faults.

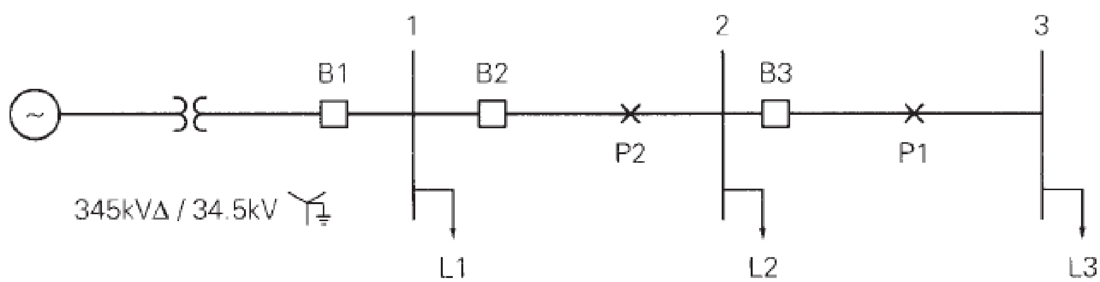


Figure Q3

Table Q3 (1)

	Maximum Load		Symmetrical Fault Current	
Bus	MVA	Lagging p.f.	Maximum A	Minimum A
1	9.0	0.95	5000	3750
2	9.0	0.95	3000	2250
3	9.0	0.95	2000	1500

Question 3 Cont’d

Table Q3 (2)

Breaker	Breaker Operating Time	CT Ratio	Relay
B1	5 cycles	600:5	CO-8
B2	5 cycles	400:5	CO-8
B3	5 cycles	200:5	CO-8

Question 4 (20 marks)

A 60-Hz synchronous generator having inertia constant H= 5 MJ/MVA and a direct axis reactance X_d' =0.3 per unit is connected to an infinite bus through a purely reactive circuit as shown in Figure Q4. The reactances indicated are all to a common base. The generator is delivering real power $\mathbf{P_e = 0.8}$ per unit and $\mathbf{Q = 0.074}$ per unit to the infinite bus at a voltage **V= 1** per unit.

A temporary three-phase fault occurs at the sending end at point F. When the fault is cleared, both lines are intact.

Determine the critical clearing angle and the critical clearing time.

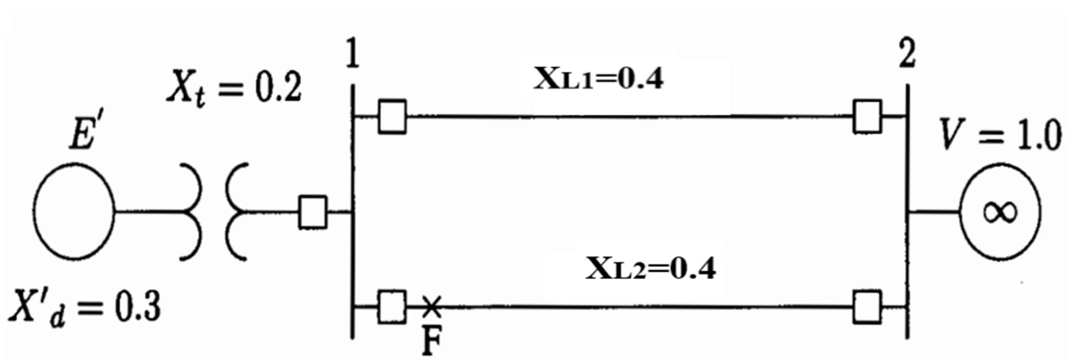
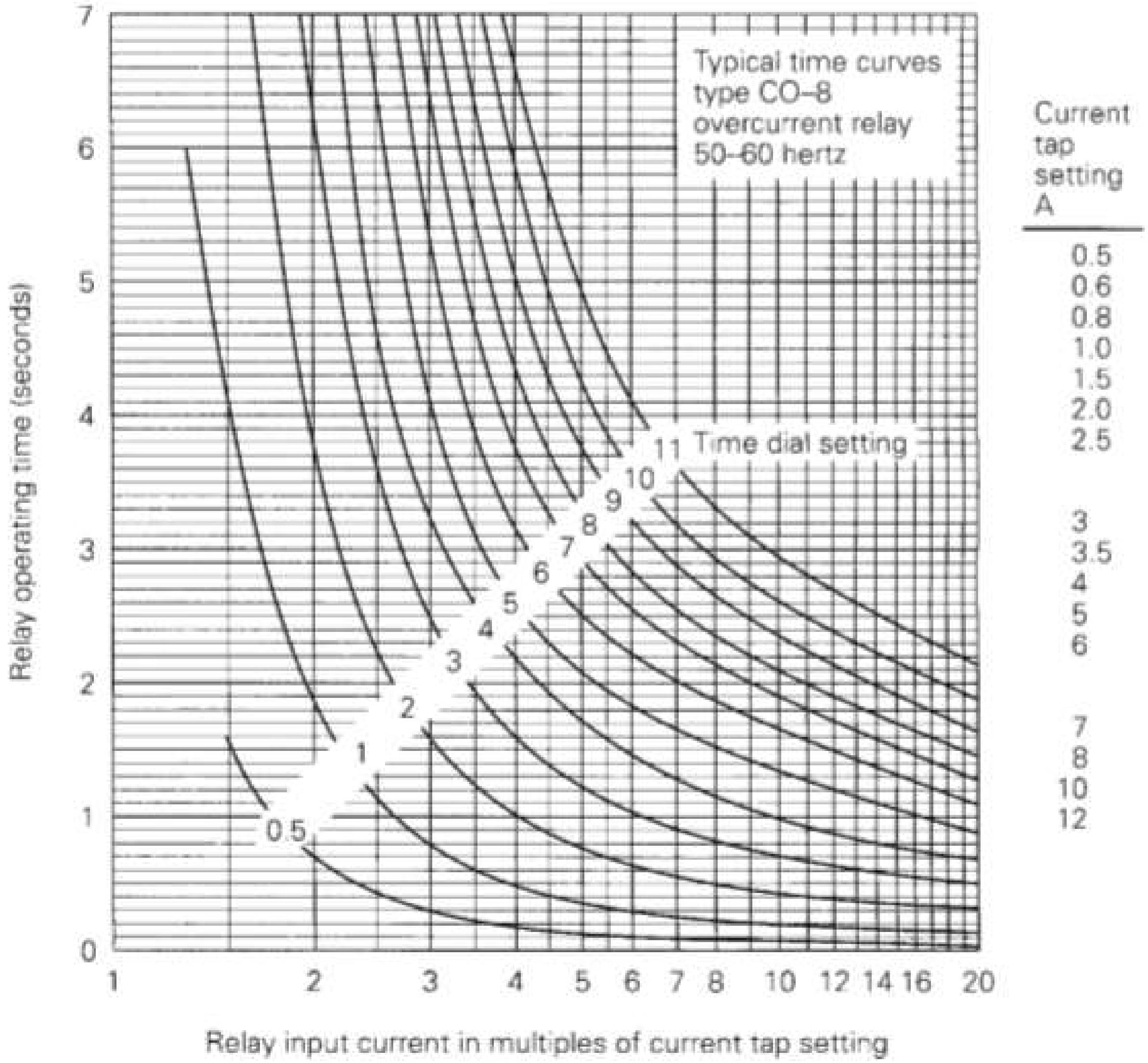


Figure Q4

****END OF EXAM QUESTIONS****

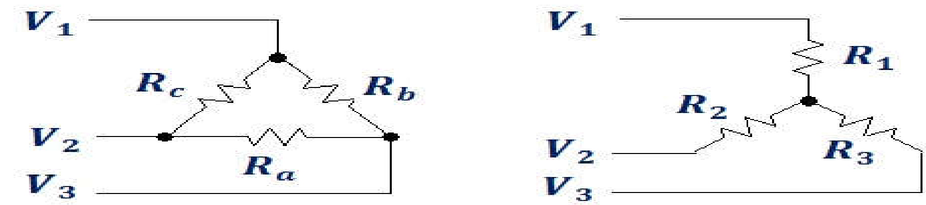
Datasheet



Typical time curves
type CO-8
overcurrent relay
50-60 hertz
Current tap setting A
0.5
0.6
0.8
1.0
1.5
2.0
2.5
3
3.5
4
5
6
7
8
10
12
Time dial setting
0.5 1 2 3 4 5 6 7 8 9 10 11
Relay operating time (seconds)
0 1 2 3 4 5 6 7
1 2 3 4 5 6 7 8 10 12 14 16 20
Relay input current in multiples of current tap setting

Datasheet Cont'd

Delta to Star (Δ to Y) Resistance Conversion Formula

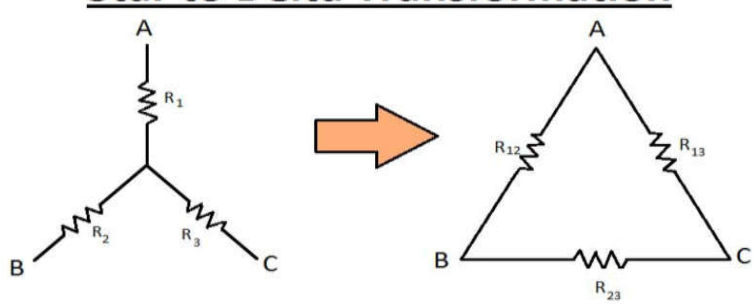


$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_a R_c}{R_a + R_b + R_c}$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$

Star to Delta Transformation



$$R_3 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_A}$$

$$R_1 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_B}$$

$$R_2 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_C}$$

Data sheet Cont'd

$$I^0 = I^1 = I^2 = \frac{V(0)}{Z^1 + Z^2 + Z^0 + 3Z_f}$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \times \begin{bmatrix} I^1 \\ I^2 \\ I^0 \end{bmatrix}$$

where

$$a = -0.5 + j0.866$$

$$a^2 = -0.5 - j0.866$$

$$a^3 = 1 + j0$$