THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMMUNICATIONS ENGINEERING

SEMESTER TWO FINAL EXAMINATION (2022)

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. There are three (3) questions in this Examination.

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

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

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

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

7. **TURN OFF** all Mobile Phones, Electronic Gadgets 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:

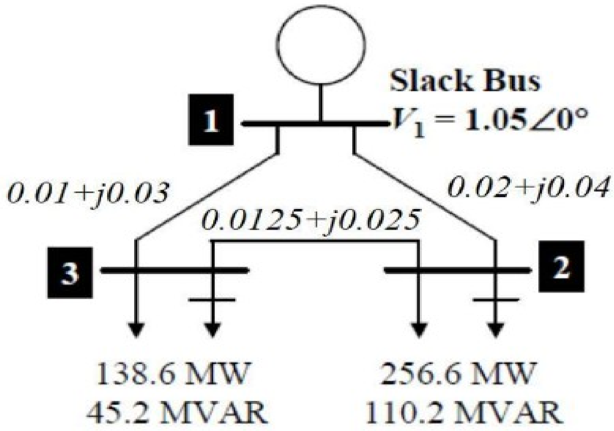


Figure Q1

(a) Convert the line impedance to admittance and redraw the admittance diagram. (Note, all impedances are in p.u on 100 MVA base).

(b) Apply Gauss-Seidel algorithm to determine the phasor values of the voltage at load Bus 2 and Bus 3 after the SECOND (2^{nd}) ITERATION

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

$V_2^{(7)} = 0.9800\text{-}j0.0600$ $V_3^{(7)} = 1.000\text{-}j0.0500$

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

Question 1 **(Cont'd)**

(d) Determine the line flows and line losses, and

(e) Construct a power flow diagram showing the direction of line flow.

Question 2 **(30 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 impedance 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 emfs in phase.

Determine the fault current during a single-line-ground fault which occurs on phase ***a*** of Bus 3. Assume the fault impedance is zero (0).

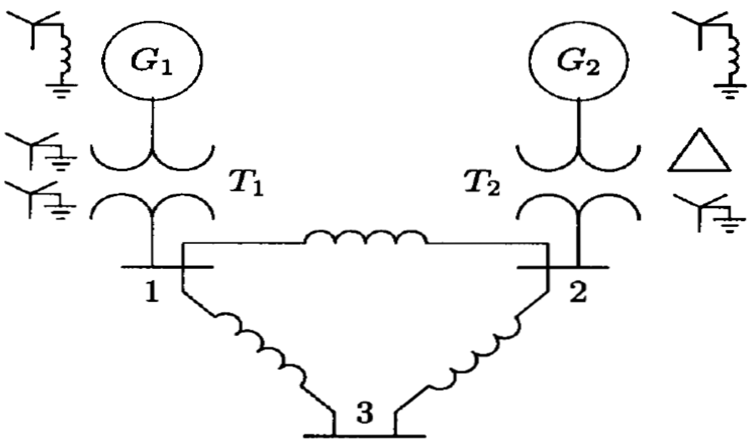


Figure Q2

Question 2 **Cont'd**

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

Question 3 **(40 marks)**

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

Select current tap settings (TSs) and time-dial settings (TDSs) to protect the system from faults. Assume three CO-8 relays 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. Also, future load growth is included such that the maximum loads over the operating life of the radial system are indicated in the Table Q1.

Question 3 **Cont'd**

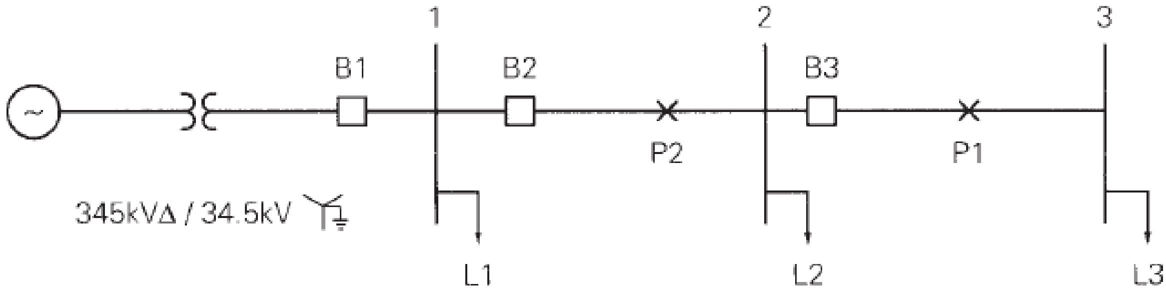


Figure Q3

Table Q3 (1)

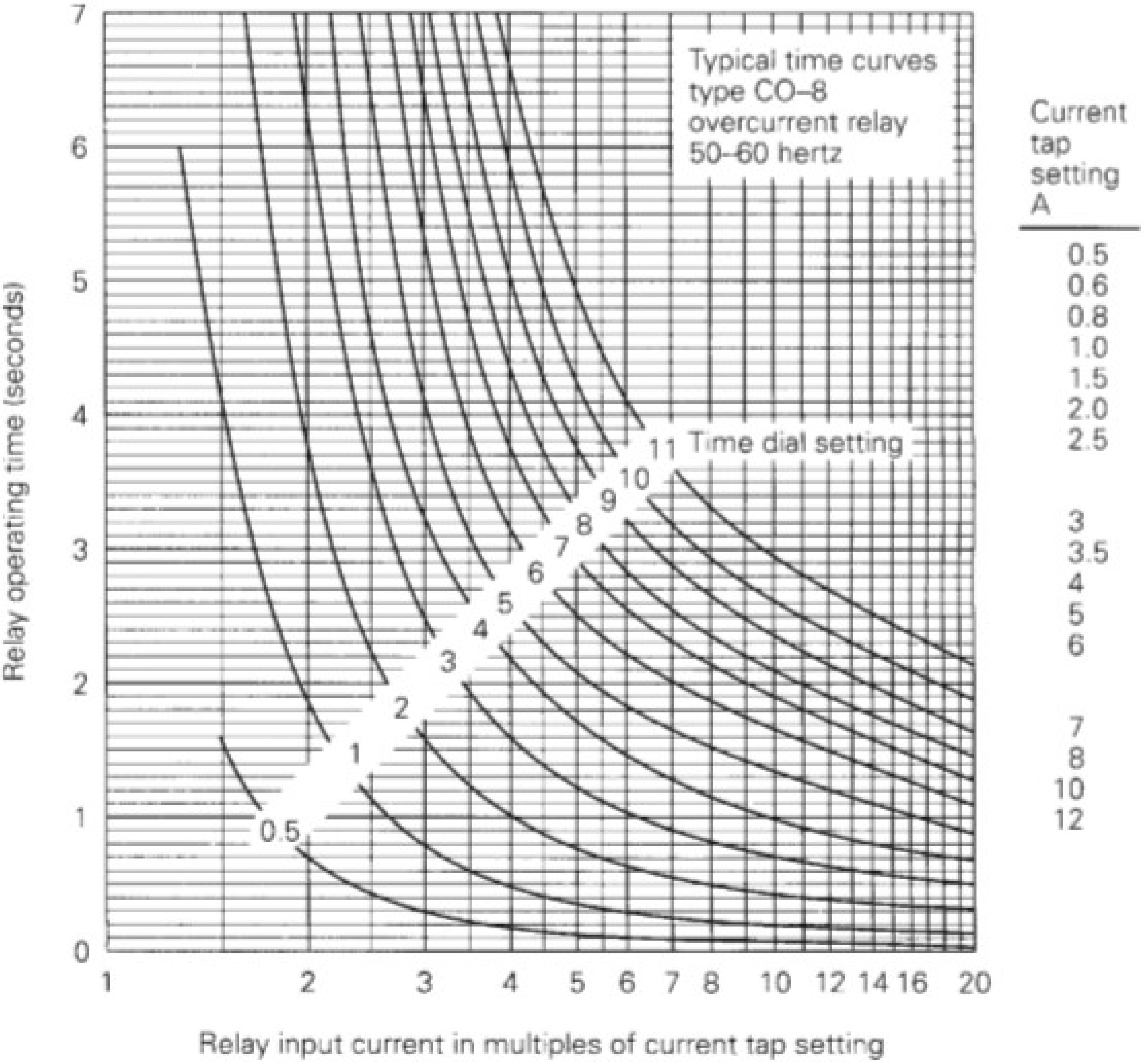
Bus	Maximum Load MVA	Maximum Load Lagging p.f.	Symmetrical Fault Current Maximum A	Symmetrical Fault Current Minimum A
1	9.0	0.95	5000	3750
2	9.0	0.95	3000	2250
3	9.0	0.95	2000	1500

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

Note: CO-8 relay curve is attached.

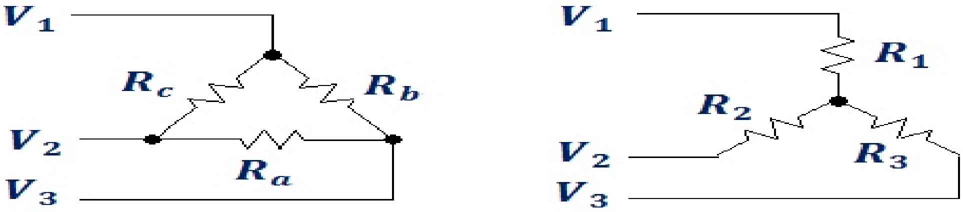
****END OF EXAM QUESTIONS****



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
11
10
9
8
7
6
5
4
3
2
1
0.5
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

Data Sheet

Delta to Star (Δ to Y) Resistance Conversion Formula

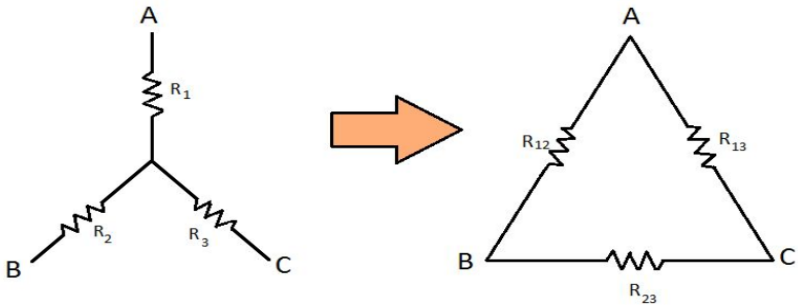


$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

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

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

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

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

¿

I_a

I_b

I_c

righ

[ ]=1 1 1

$1 a^2 a$

¿ $1 a a^2$

righ

I^1

I^2

I^0

righ

[ ][ ]

¿

where

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

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

$$a^3 = 1 + j0$$