CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2013/2014

COURSE NAME	:	POWER SYSTEM ANALYSIS & PROTECTION
COURSE CODE	:	BEF43303/BEX44703/BEK4223
PROGRAMME	:	BEV/BEE
EXAMINATION DATE	:	JANUARY 2014
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

Q1 (a) Electric power system can be represented by one-line diagram (OLD). Define OLD and give two (2) advantages of this representation.

(4 marks)

(b) A 30 MVA, 13.8 kV, three-phase generator has a sub-transient reactance of 15%. The generator supplies two motors over a transmission line having transformers at both ends as shown in **Figure Q1(b)**. The motors have rated inputs of 20 MVA and 10 MVA, supplied with 12.5 kV with x" = 20%. The three-phase transformer T1 is rated 35 MVA, 13.2/115 (Δ/Y) kV with leakage reactance of 10%, while the three phase transformer T2 is rated at 30 MVA, 12.5/116 (Y/Δ) kV with leakage reactance of 10%. Series reactance of the transmission line is 80 Ω.

(i) By taking generator rating as base, determine the per-unit (p.u) reactance for T1, T2, transmission line, motor 1 and motor 2

(10 marks)

(iii) Design the impedance diagram for system shown in **Figure Q1(b)**

(3 marks)

(iii) Design the reactance diagram with all reactances in per-unit value obtained in **Q1(b)(i).**

(3 marks)

Q2 (a) Use Gauss Seidal method to find the solution of the following equations:

$$x_1 + x_1 x_2 = 10$$

$$x_1 + x_2 = 6$$

With the initial estimation of $x_1^{(0)} = 1$ and $x_2^{(0)} = 1$. Continue the iteration until $|\Delta x_1^{(k)}|$ and $|\Delta x_2^{(k)}|$ are less than 0.001.

(5 marks)

(b) **Figure Q2(b)** shows the one-line diagram of a simple three-bus power system with generation at bus 1. The magnitude of voltage at bus 1 is adjusted to 1.05 per unit. The schedule loads at buses 2 and 3 are as marked on the diagram. Line impedances are marked in per unit on a 100MVA base and the line charging susceptances are neglected.

(i) Using the Gauss-Seidel method, determine the phasor values of the voltage at the load buses 2 and 3, accurate to 4 decimal places. Perform hand calculation until the second iteration.

(9 marks)

(iii) Calculate the slack bus real and reactive power.

(3 marks)

(iii) Evaluate the line current I_{12} and hence, the line flow S_{12} between busbar 1 and 2.

(3 marks)

Q3 (a) Figure Q3(a) shows the OLD for a three phase system in which a generator supplies a load through a step-up transformer, a transmission line, and a step-down transformer. The transformers are ideal and the turn ratios are line to line values. Evaluate the per unit current if the terminal voltage of the generator is 480 V line to line.

(10 marks)

(b) Referring to the schematic of a power system as shown in **Figure Q3(b)**, as a power system engineer,

(i) Design the zones of protection in which the system should be divided

(4 marks)

(ii) Determine which circuit breakers should open for the fault occuring at point F1 and F2.

(2 marks)

(iii) Identify which breaker provides the primary and secondary protection for the fault occuring at F2

(3 marks)

(iv) Suggest the location of the fault if a single fault has resulted in the operation of breakers B5, B6, B7 and B8.

(1 marks)

Q4 (a) A current transformer (CT) is marked '5P20'. Based on the rating i.e. '5P20', describe the type and accuracy of the CT.

(3 marks)

(b) Give two (2) examples of instrument transformers commonly used for power system protection. Draw a schematic diagram for each transformer to show the circuit connection in power system.

(4 marks)

(c) A CT with a rated current ratio of 200:5 A gives a secondary output current (I_S) of 8.0 A. By using the excitation curve and secondary resistance for multi-ratio CT given in **Figure Q4(c)**,

(i) Calculate the CT primary input (I_P) if the load impedance (Z_B)= 0.5Ω

(5 marks)

(ii) Compute the CT ratio error

(2 marks)

(iii) If an overcurrent relay set to operate at 10 A, is connected to the CT, determine whether the relay will detect a 1.3 kA primary fault current when the load impedance is Z_B = 5Ω. Justify your answer with numerical analysis.

(6 marks)

Q5 (a) A 30 MVA, star-delta transformer is to be protected by a differential protection system. The transformer is supplied from a 132 kV grid. The current ratio of the current transformer on the 132 kV side are 250/5A while those on the 33 kV side are 600/5 A. If the impedance of the transformers is 6%, and a 3-phase fault occurs on the 33 kV side of the transformer outside its zone of protection.

(i) Sketch circuit diagram to represent and summarize the above problem. Label with appropriate technical data and indicate the fault location

(3 marks)

(ii) Determine the primary current I_P and secondary current I_S for the 30 MVA transformers at the CTs' output. Ignore the impedance of the cables

(4 marks)

(iii) Determine the average restraint current I_r and operating current I_o in the relay

(3 marks)

(iv) The bias characteristic of the relay is $y = mx + c$ where y is the operating current, x is the average restraint current and m is slope. Draw the characteristic curve of this relay on a graph paper, if the percentage bias setting is set to 25 % and relay setting current, I_{set} = 15 A

(3 marks)

(v) On the characteristic curve, clearly indicate the operating point of the relay due to this fault. Determine whether the relay will operate and state your reason

(3 marks)

(b) Briefly describe the principle operation of Induction Disc Relays.

(4 marks)

- END OF QUESTIONS –

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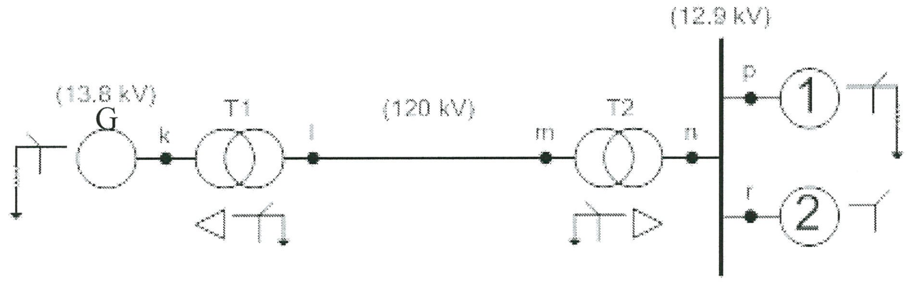

FIGURE Q1(b)

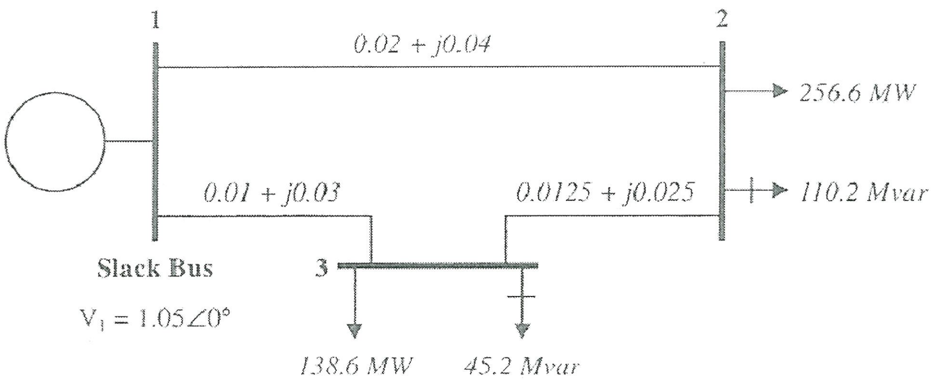

FIGURE Q2(b)

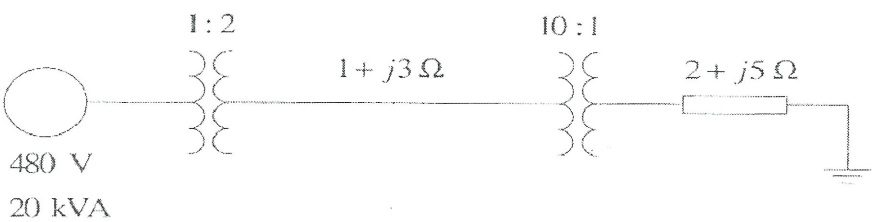

FIGURE Q3(a)

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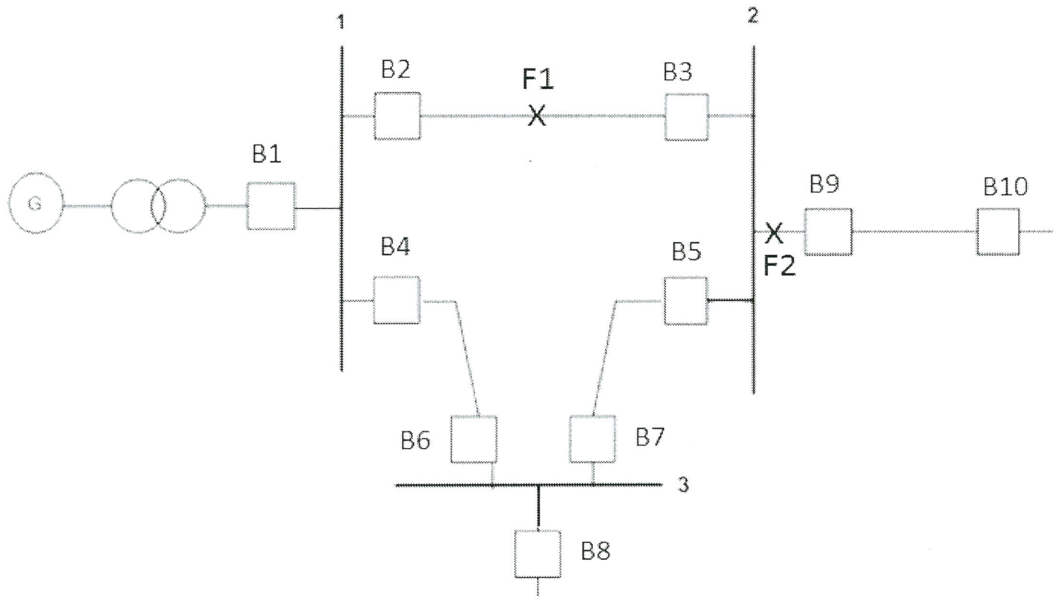
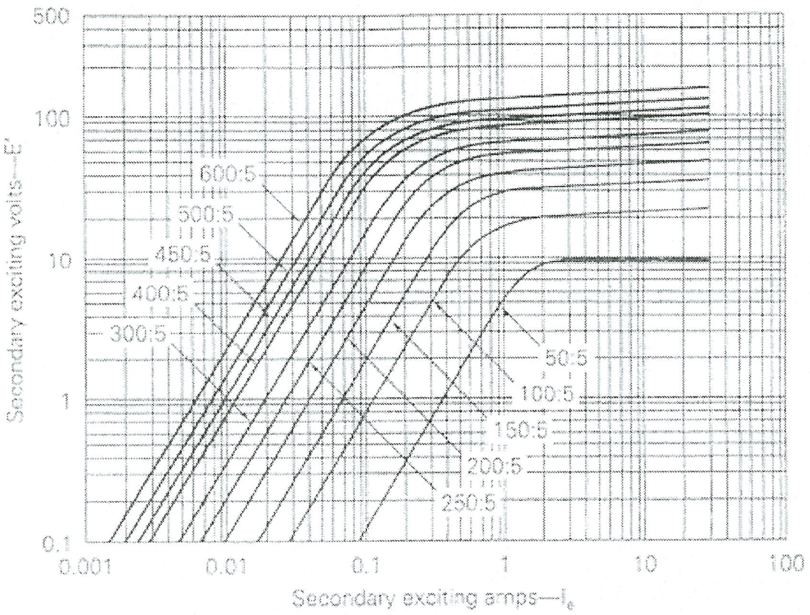


FIGURE Q3(b)



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 Q4(c)

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Formula:

Conversion of a given base per-unit impedance on a new base:

$$Z_{new(pu)} = Z_{old(pu)}\left(\frac{kV_{base(old)}}{kV_{base(new)}}\right)^2\left(\frac{MVA_{base(new)}}{MVA_{base(old)}}\right)$$

Nominal T model:

$$V_S = 1 + \frac{YZ}{2}V_R + Z + \frac{Z^2Y}{4}I_R$$

$$I_S = YV_R + 1 + \frac{ZY}{2}I_R$$

Gauss Seidal power system analysis:

$$Q_i^{(k+1)} = -\operatorname{Im} g\left\{V_i^{*(k)}\left[V_i^{(k)}\sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j^{(k)}\right]\right\} \qquad j \neq i$$

$$V_i^{(k+1)} = \frac{\dfrac{P_i^{sch} - jQ_i^{sch}}{V_i^{*(k)}} + \sum_{j=1}^{n} y_{ij}V_j^{(k)}}{\sum_{j=0}^{n} y_{ij}} \qquad j \neq i$$

$$I_{ij} = yi_j\left(V_i - V_j\right) \text{ and } I_{ji} = -I_{ij}$$

$$S_{ij} = V_i I_{ij}^* \text{ and } S_{ji} = V_j I_{ji}^*$$

$$S_{Lij} = S_{ij} + S_{ji}$$