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THE OPEN UNIVERSITY OF SRI LANKA
BACHELOR OF TECHNOLOGY
ECX5332 –POWER SYSTEMS II
FINAL EXAMINATION 2013/2014

Duration: Three hours

Date: 05th August 2014 Time: 0930-1230 hrs.

This paper contains of seven **(07)** questions. Answer any **five (5)**. All questions carry equal marks.

Graph papers and log-log papers will be available on your request

Q1.

I. Briefly define the following terms associated with power system stability:
   a) Steady state stability
   b) Transient stability

II. The kinetic energy stored in a rotor of a 50 MVA, six pole, 60 Hz synchronous machine is 200 MJ. The mechanical input to the machine is 25 MW at a developed electrical power of 22.5 MW. Calculate the acceleration of the rotor.

III. A Synchronous generator has an internal voltage behind the transient reactance of 1.2 p.u. and is connected to an infinite bus operating at a voltage of 1.0 p.u. through transmission lines. The effective reactance of the transmission lines is 0.3 p.u. A three phase short circuit fault occurs somewhere in a line. Subsequently, circuit breakers operated and the reactance between the generator and bus becomes 0.4 p.u. Assuming power input to the generator is 1.0 p.u.
   a) Draw the Power angle curves for pre-fault, during fault and post fault condition.
   b) Determine the critical clearing angle.

Q2.

Per-phase, per-unit length parameters of a 800 kV, 400 km, 50 Hz, three-phase long transmission line are $Y = j3.2 \times 10^{-6}$ S/km and series impedance $Z=(0.1+j0.5)\ \Omega$/km. The line supplies 2000 MW load at unity power factor. Calculate;

I. Characteristic impedance, attenuation constant and phase constant
II. The sending end voltage and current
III. The voltage regulation
of the transmission line

Hint

$$\cosh(\alpha+j\beta) = \cosh\alpha \cos\beta + j \sinh\alpha \sin\beta$$
$$\sinh(\alpha+j\beta) = \sinh\alpha \cos\beta + j \cosh\alpha \sin\beta$$

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Q3.

I. A 75 MVA 66/230 kV Δ/Y power transformer needs to be protected using a differential protection. 800/5 A current transformers (CTs) are used at 66 kV side (no load current and the inrush current effect can be neglected)
   a) How would you connect the CTs on the primary and secondary sides of the transformer
   b) Select suitable current transformer for the HV side of the transformer (available CT are 1000/5, 800/5, 600/5, 400/5 A)

II. A transmission line with two sections are shown in Figure Q3 is to be protected by using three impedance relays located at "A" providing three zone distance protection. The CT and PT ratios used to energized relays were 200/1 A and 132 kV/110 V. determine the impedance setting of the three relays and draw their characteristics on a R-X diagram

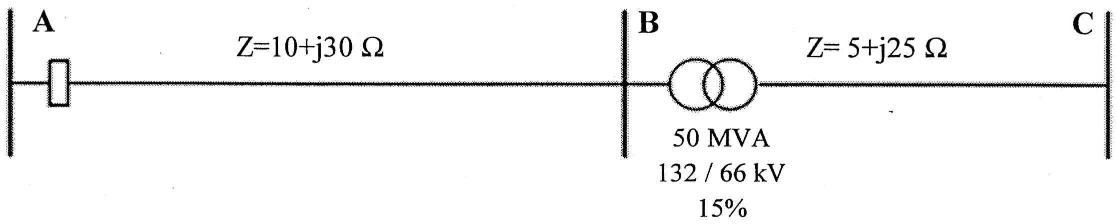

Figure Q3

Q4

A 33 kV radial distribution system is shown in figure Q4 (loads indicated are the maximum values at respective locations). Induction cup type over current relays are installed for protection purposes controlling the circuit at locations A,C and E. The system equivalent has an impedance Z_1=Z_2=30% on 100 MVA under minimum generation conditions and 10 % of 100 MVA under maximum generation conditions. Each transmission line (L_1, L_2, L_3) has a positive sequence impedance of 15% on 100 MVA. The overcurrent relays have pick-up settings adjustable by taps at 0.5, 0.75, 1.25, 1.5, 1.75 and 2 A, and a continuously adjustable time-multiplier adjustable from 0.1 to 1.0 The operating time at any PSM is proportional to the time-multiplier. With the time multiplier set 1.0, the time-current characteristic of the relay on any pick-up setting is as follows:

PSM	1.5	2	5	10	20
Time (s)	18	10	4.3	3.0	2.2

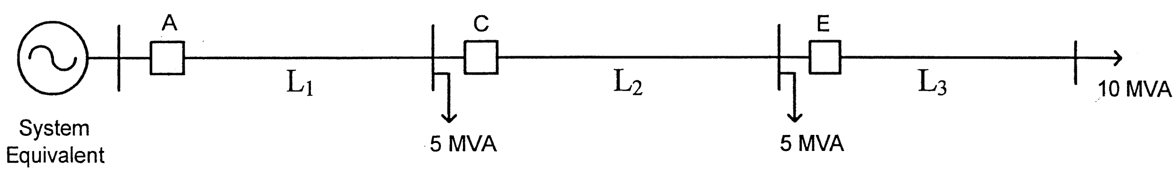

Figure Q4

With respect to the overcurrent relays at A,C and E,

I. Determine the pick-up settings of the relays for the protection against phase faults.
II. If relay at E have the Time Leaver set at 0.1, determine suitable time multiplier settings (TMS) of the relay C to provide back-up protection.

Q5.

An area of an interconnected power system has two fossil fuel units operating on economic dispatch. The variable operating costs of these units are given by;

$$C_1 = 10\,P_1 + 8\times 10^{-3}\,P_1^2\ \$/hr \qquad 100 \le P_1 \ll 600\ \ MW$$

$$C_2 = 8\,P_2 + 9\times 10^{-3}\,P_2^2\ \$/hr \qquad 400 \le P_2 \ll 1000\ \ MW$$

Where P_1 and P_2 are in megawatts

Determine the power output of each unit, the incremental fuel cost and the total operating cost (C_T), assuming continuous running of two generators under most economical division of load between the two units at the demands of:

a) 600 MW
b) 1100 MW
c) 1400 MW

Neglect the transmission losses

Q6.

I. A power system consisting of N buses has G number of PV busses. Explain and determine the sizes of sub matrixes of the Jacobian matrix.
II. A three bus system shown in figure Q6 has line data as given in Table Q6. Determine the bus voltages at the end of one iterations by using **Decoupled method**

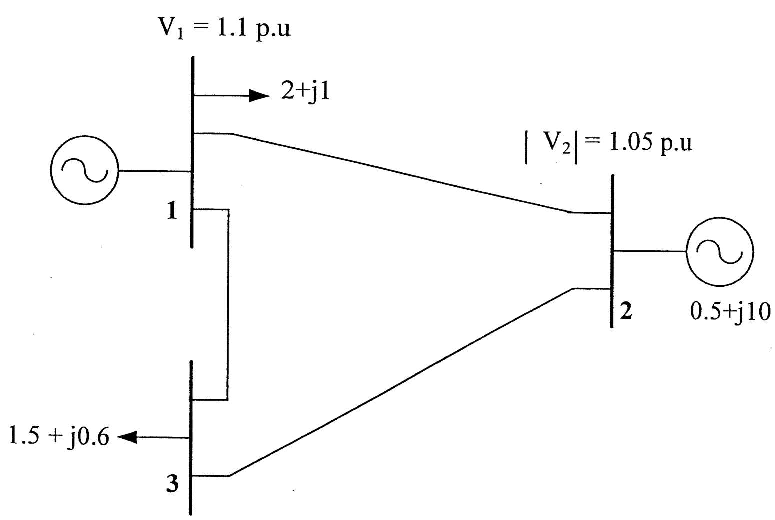

Figure Q6

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Line	Series impedance (p.u.)	Total shunt admittance (p.u.)
1 - 2	j 0.25	-
1 - 3	j 0.5	j 0.5
2 - 3	j 0.5	j 0.5

Table Q6

Q7.

I. A two bus system shown in Figure Q7 has element data of its bus admittance matrix as, $Y_{11}=Y_{22}$ = (0.278 - j1.576) p.u. and $Y_{21}=Y_{12}$ = (-0.33+j 1.871) p.u. Determine the voltage at BUS 2 after 2 iterations using of Gauss Siedal method.

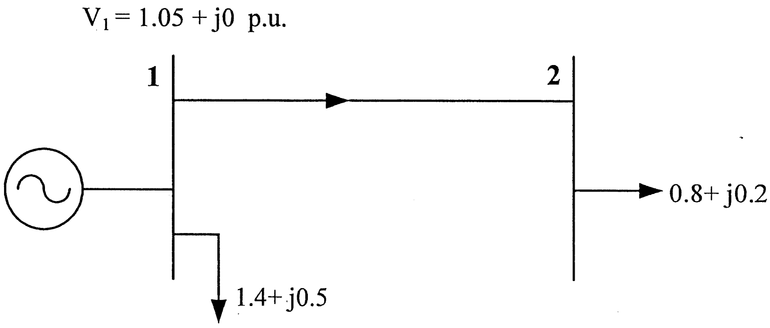

Figure Q7

II. A power system is supplied by two generators. The incremental cost of each generator is given by Rs per MWh.

$$\frac{dF_1}{dP_1} = 0.01\ P_1 + 20 \quad \text{and} \quad \frac{dF_2}{dP_2} = 0.015\ P_2 + 22.5$$

If this system running under optimal scheduling with $P_1 = P_2 = 150$ MW and $\frac{dP_L}{dP_2} = 0.3$ calculate the plant penalty factors and the value of $\frac{dP_L}{dP_1}$