The University Of Sheffield.

`Data Provided: Linear graph paper

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2014-15 (2.0 hours)

EEE301 Power Systems Engineering

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1.

a. What is meant by a synchronous machine "losing synchronisation". Explain why this is undesirable. **(2)**

b. A 200MVA generator is connected to an infinite busbar via a transformer and a pair of identical overhead transmission lines, each having negligible resistance and a reactance of *j*0.2 pu as shown in figure 1.1. The generator voltage is 1.1 pu and the voltage of the infinite busbar is 1.0 pu.

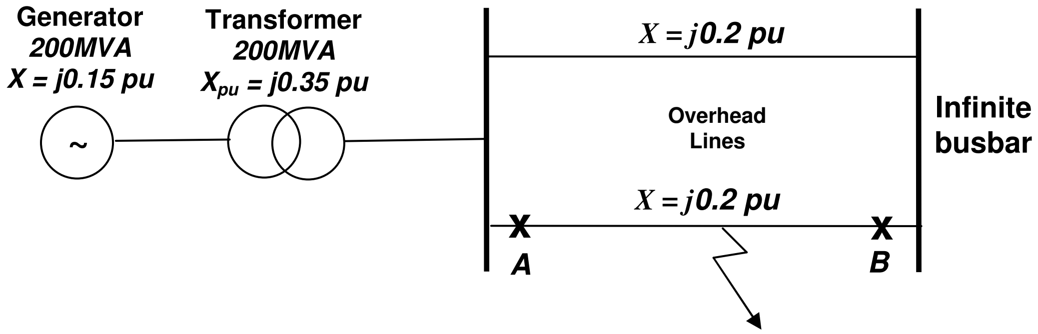

Figure 1.1 Generator and transmission system.

(i) Determine the power-load angle equation for the system. If the generator is delivering 180MW, calculate its load angle. **(3)**

(ii) When a 3-phase short-circuit occurs at the middle of one of the overhead transmission lines, between *A* and *B,* the effective system reactance becomes j1.9pu. Determine the power-load angle equation for the system under fault conditions. **(1)**

(iii) The short-circuit is then cleared by the simultaneous opening of the circuit breakers, *A* and *B* at each end of the faulted line. Determine the new power-load angle equation for the system. **(1)**

(iv) Sketch the power transfer curves for before, during, and after the fault. Mark on the sketch the accelerating area, decelerating area, and the critical load angle. **(3)**

(v) By deriving an analytical expression or otherwise, determine the critical switching angle at which the fault must be cleared in order to ensure system stability. **(5)**

c. If the circuit breakers clear the fault in 0.2s determine if this is sufficient to maintain system stability if the inertia constant of the generator, $M = 2.5 \times 10^{-4}$ pu. Use a time interval, $\Delta t = 0.05$s in conjunction with the swing equation.

(Use may be made of the equation: $\Delta\delta_n = \Delta\delta_{n-1} + \frac{(\Delta t)^2}{M} P_{a(n-1)}$) **(5)**

2.

Figure 2.1 shows the single-line diagram of a power system comprising three 132kV busbars, *Bus 1, Bus2* and *Bus 3*, connected together by overhead transmission lines, *L1* and *L2*. Each busbar is supplied by a generator via a step-up transformer. Generator, *G2,* has its star point earthed through a reactor, X_N, of j0.3Ω, all other star points in the system are solidly earthed. A single phase to earth fault occurs on one end of *L2*, as shown.

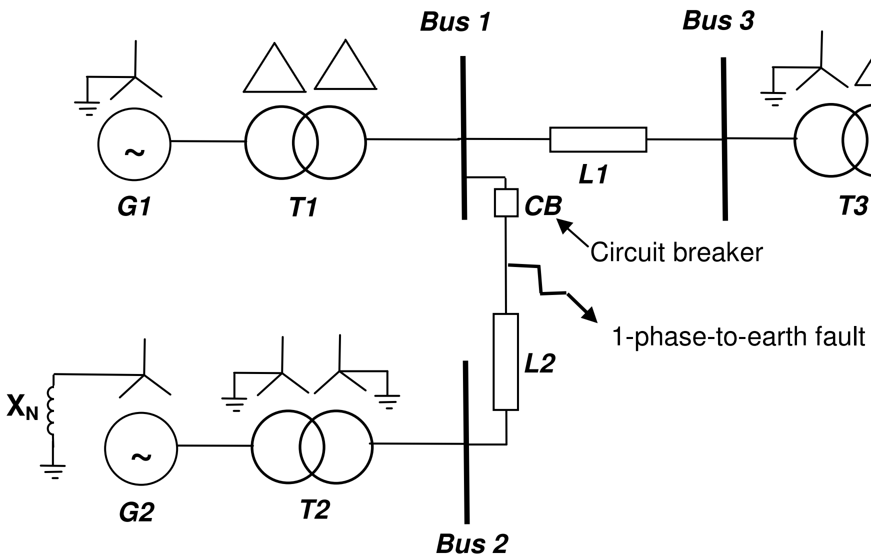

Figure 2.1 Line diagram of power system

	Rating MVA	Voltage kV	X_+	X_-	X_0
G1	100	25	j0.1 pu	j0.1 pu	j0.08 pu
G2	120	25	j0.15 pu	j0.18 pu	j0.14 pu
G3	80	19.5	j0.08 pu	j0.08 pu	j0.06 pu
T1, T2	120	25/132	j0.12 pu	j0.12 pu	j0.12 pu
T3	80	20/132	j0.06 pu	j0.06 pu	j0.06 pu
L1, L2	-	132	j8Ω	j8Ω	j30Ω

a. Calculate all the per-unit reactances of the system using a reference base of 120MVA. **(6)**

b. Draw the positive, negative and zero sequence diagrams for the system and determine Z_+, Z_- and Z_0. **(7)**

c. Determine the total fault current when a single phase-to-earth fault occurs at one end of line, *L2*, as shown in Figure 2.1. **(3)**

d. If each phase of circuit breaker *CB* is set to trip on an over-current of 2500A explain whether circuit breaker *A* is adequately rated for this type of fault. **(4)**

3.

a. Give two examples of the sources of short circuits in power systems and explain why protection is required. **(2)**

b. **(i)** Sketch a diagram showing the main components of an induction relay and explain its operation. **(3)**

(ii) Describe a type of protection relay which may be used to detect faults in an oil-filled transformer and explain its operation. **(3)**

c. **(i)** Explain what is meant by time and current grading in relation to power system protection. **(5)**

(ii) Describe, with the aid of a suitable diagram, how protection may be achieved for a 2 source system using directional relays. **(3)**

d. **(i)** Explain why a current transformer should never be operated without a load. **(2)**

(ii) A 5A current transformer is used to monitor a busbar carrying a maximum current of 15000A. If the reluctance of the core is 3×10^5 H^{-1} and the frequency is 50Hz, estimate the typical emf produced if the load on the secondary winding is accidentally removed. **(2)**

4.

a. Show that, if skin effect is neglected, the component of self-inductance due to the magnetic field within a solid circular conductor is independent of the radius of the conductor. **(5)**

b. Show that the geometric mean radius of the 7-strand conductor shown in figure 4.1, in which the radius of each strand is 1.5mm, is approximately 3.27mm.

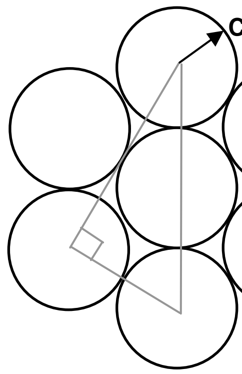

Figure 4.1: 7-strand conductor **(6)**

c. A three phase, 50Hz transmission line has its phases arranged in a flat, horizontal formation. The spacing between phases is 1.4m, and the phases are fully transposed, determine the reactance per kilometre if:

(i) the line has one solid conductor of 4mm radius per phase **(3)**

(ii) the line has a 7-strand conductor, as described in part (**b**), per phase **(1)**

(You may assume the inductance per metre for the fully transposed line is given by:

$$L = 2 \times 10^{-7} \ln\left(\frac{D_g}{R_g}\right) \text{ H/m}$$

where D_g is the geometric mean distance between conductors, and R_g is the geometric mean radius of the conductors).

d. If the transmission line using the stranded conductors (see part **c(ii)** above) is 20km long and supplies a 11kV, 400kW load at 0.8 power factor lagging, calculate the line voltage at the sending end of the line. The resistance of the stranded conductor is 0.25Ω/km. **(4)**

e. Suggest two mechanisms by which the voltage at the receiving end of the line could be regulated. **(1)**

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