Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2014-15 (2.0 hours)

EEE341 Electrical Power Systems

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 three-phase, star-connected load is supplied via a balanced 6.6kV, three-phase, 3-wire supply, of phase sequence ABC. The three-phase load consists of three single-phase loads of (25 + j60) Ω, (15 + j20) Ω and (40 – j25) Ω, connected between phases *A, B, C* and the load star point respectively, as shown in Figure 1.1.

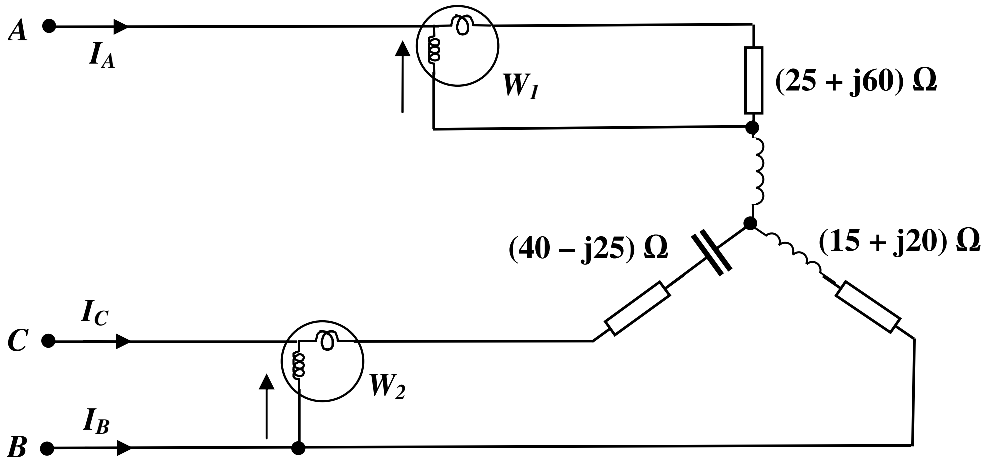

Figure 1.1

a. Using the star to delta transformation, or otherwise:

(i) calculate the current in each phase of the load **(7)**

(ii) hence calculate the voltage across each phase of the load **(2)**

b. Two wattmeters, W_1 and W_2 are to be used to measure the input power to the load. However, during installation the wattmeters were incorrectly connected as shown in Figure 1.1:

(i) sketch the phasor diagram for the system showing the three line and phase voltages of the supply, the voltages across the wattmeter voltage measuring coils, the three line currents and their relevant angles. **(4)**

(ii) hence, calculate the readings on the two wattmeters. Comment on the relevance of the readings on W_1 and W_2. **(3)**

c. **(i)** Describe how W_1 may be reconnected to correctly measure the power in the unbalanced load and calculate the new reading for W_1. **(2)**

(ii) Verify that the sum of the power readings on the two wattmeters measures the true power dissipated in the unbalanced three-phase load. **(1)**

(iii) If the star point of the load was connected to the neutral point of the supply would the sum of the power readings on the two wattmeters still measure the true power? (Assume the neutral conductor has zero impedance and that the Wattmeters are correctly connected). **(1)**

2.

a. Briefly explain and illustrate the operation of the Arc Chute and Blow-out Coil types of plain air break circuit breakers. **(3)**

b. Describe what in general is meant by the per-unit value of any quantity. How is this general definition usually applied in 3-phase systems? **(2)**

c. Figure 2.1 shows a line diagram of a three-phase network in which it is proposed to link the 66kV busbar ***B*** to the 132kV system at ***A*** via an overhead line and a 100 MVA transformer (*T3*) as shown.

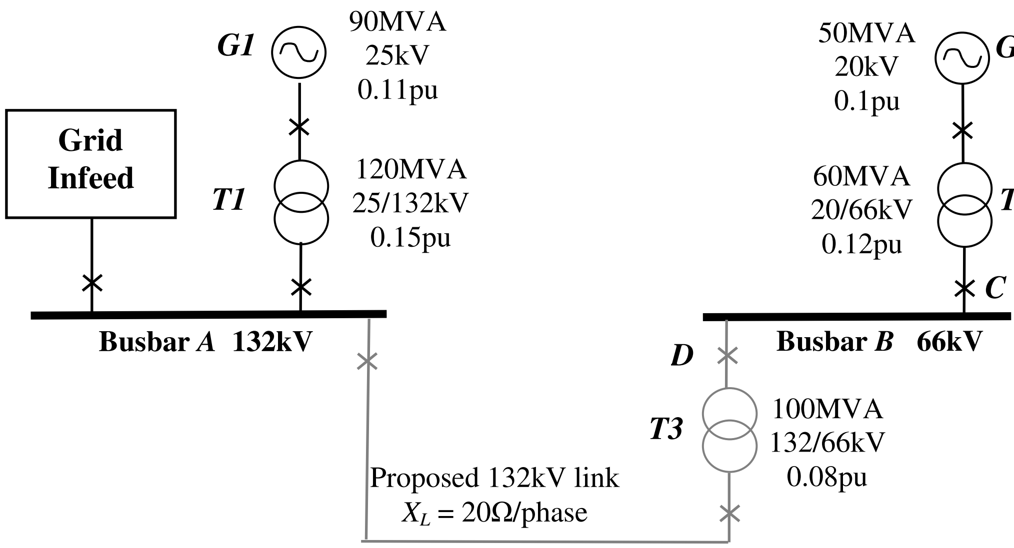

Figure 2.1

(i) Calculate the fault level at busbar *B* before the 132 kV system is linked in. **(3)**

(ii) If the Grid Infeed can feed 300 MVA into a symmetrical fault at busbar A calculate the new fault level at *B* when the 132kV link is connected. Hence calculate the rms fault current through circuit breakers *C* and *D* for a fault on busbar *B*. **(7)**

(iii) For the fault at busbar *B* described in part **(ii)** above, calculate the rms phase current which flows in generator *G1*. (Assume *G1* is star-connected). **(2)**

(iv) If the new fault level at busbar *B* has to be limited to 500MVA calculate the required per-unit series reactance which must be inserted in the 132kV line linking busbars *A* and *B*. **(3)**

3.

a. **(i)** Draw the equivalent circuit of a three-phase synchronous machine and explain the physical significance of the various voltages, currents and impedances. **(3)**

(ii) Describe what tests would be used to characterise a synchronous machine and obtain the parameters for the equivalent circuit. **(3)**

(iii) Write down the circuit equation for the machine acting as a **<u>motor</u>** and use this to derive phasor diagrams for operation at leading, lagging and unity power-factor. (You can assume the machine is connected to an infinite busbar system). **(4)**

b. A star-connected three-phase **<u>generator</u>** is connected to a 50kV (line voltage) infinite busbar system and has a synchronous reactance of 8Ω per phase and negligible armature resistance.

(i) Calculate the excitation voltage required for operation at 8MVA and 0.75 power-factor lagging. What is the percentage regulation for this condition? **(3)**

(ii) The excitation is kept constant at the value calculated in part **b(i)** and the mechanical input power increased until the generator operates at unity power factor. Calculate the new input power and the load angle. **(3)**

(iii) If the power input to the generator is kept at the same level as part **b(i)**, calculate the output phase current and power-factor if the excitation is decreased to a value which would give a 12% lower open-circuit voltage. **(4)**

4.

a. What conditions would be preferred when operating transformers in parallel, and explain the consequences of deviations from these ideal conditions. **(3)**

b. Explain, with the aid of suitable circuit and voltage phasor diagrams, what the designations Dy11 and Dy1 indicate on a transformer nameplate. **(4)**

c. The existing electrical supply to an industrial company is taken via an 8MVA, 66:11kV, 3-phase transformer, *T1*, which has a per-unit impedance of $(0.03 + j\ 0.06)$. The company adds a new assembly line which increases the maximum demand from 8MVA to 10MVA at a power-factor of 0.7 lagging. As a short-term solution, the supply authority arranges for a second supply to the company to be taken via a 4MVA, 66:11kV transformer, *T2*, having a per-unit impedance of $(0.05 + j\ 0.15)$, and connected in parallel with the existing 8MVA transformer, as shown in Figure 4.1.

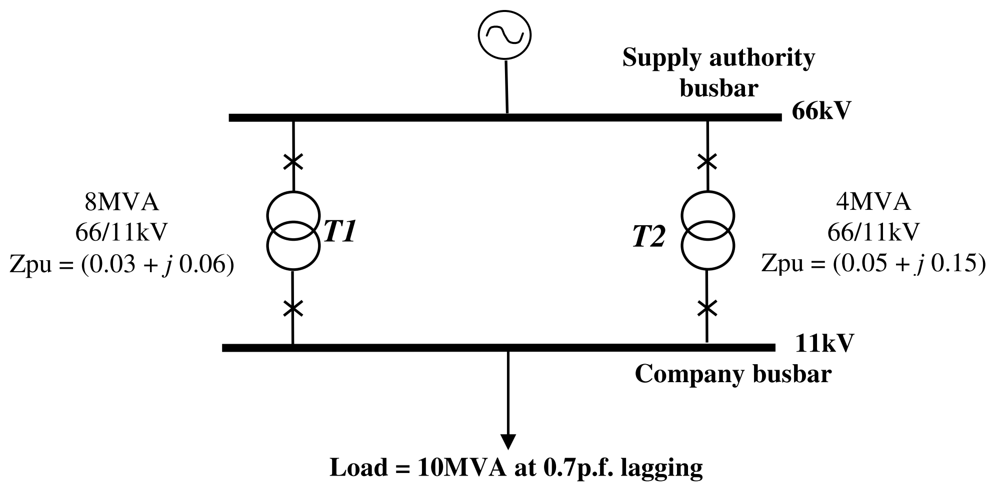

Figure 4.1

(i) Calculate the load and power-factor of each transformer when they are operating in parallel and supplying the demand of 10MVA at 0.7 p.f. lagging. **(5)**

(ii) Comment on the suitability of this solution in terms of transformer load share. **(1)**

d. An in-line reactor is connected in series with one of the transformers in Figure 4.1 to apportion the transformer loadings relative to their respective MVA ratings.

(i) Explain where you would connect the in-line reactor and calculate its per-unit impedance and MVA rating. **(3)**

(ii) Calculate the new loadings taking into account the reactor, to give evidence that the reactor has achieved load sharing. **(2)**

e. To meet future production needs it is proposed to add a 4MVA synchronous motor, operating at 0.8 p.f. leading, in addition to the existing 10MVA load in Figure 4.1. Calculate the new overall demand of the factory and decide whether the two transformers (including the in-line reactor) could still cope without being overloaded. **(2)**

KM / AG