Version MK/3

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 1 May 2014 2 to 3.30

Module 4M18

PRESENT AND FUTURE ENERGY SYSTEMS

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 (a) Fig. 1. is a simplified Sankey diagram, where the losses are carried over to the demand areas, for the UK energy in 2008, taken from a Royal Academy of Engineering Report of 2010. The fossil fuels totalling 198GW(av), from top to bottom of the supply side represent coal, natural gas, oil, and petroleum (in black) respectively. On the demand side there is a distinction made between low grade heat and high grade heat.

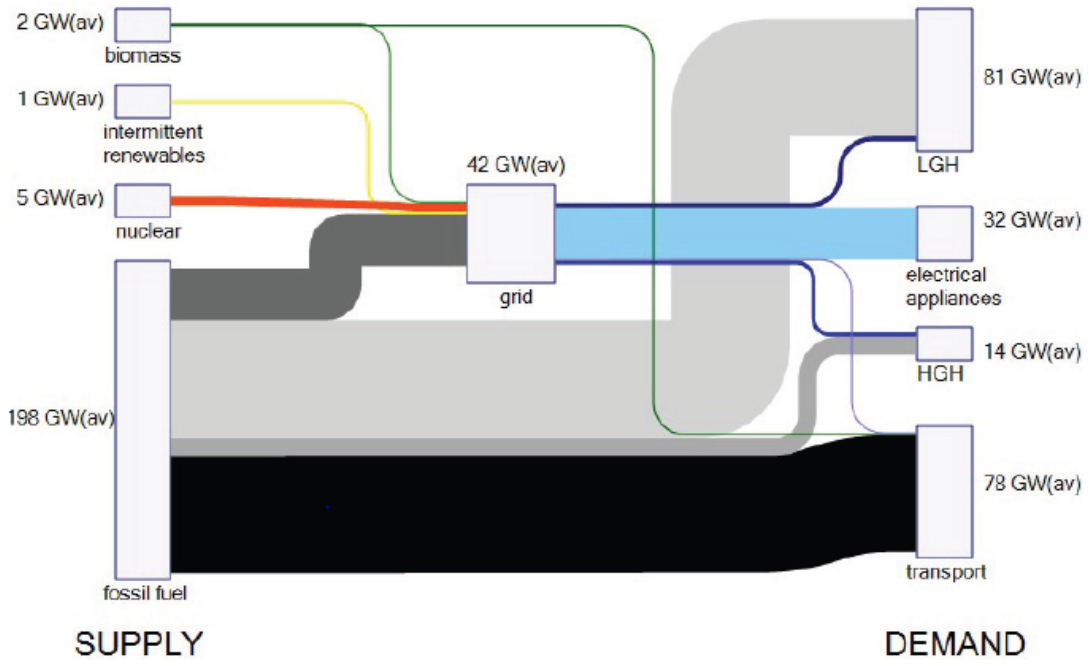

Fig. 1

If the UK were assumed to have met the target of an 80% reduction of carbon dioxide emissions in 2050, how would this diagram have to be modified? Assume that the total UK energy demand remains unchanged. What are the two most serious technical challenges associated with this solution? [50%]

(b) Briefly explain the difference between theoretical, practical, economic and service measures of energy efficiency. For the specific case of petrol fuelled cars give one example for each measure that would make a step change from today's typical cars towards each of the four forms of efficiency and briefly, for each, discuss any challenge you see in implementing it. [50%]

2 (a) What are the three most important modifications to existing domestic buildings to achieve a reduction of energy demand? Describe the extent to which a retrofit of existing buildings, both domestic and non-domestic, might reduce the demand for energy in the UK in 2050. Describe the scale of the national retrofit project for the UK that would be required to reduce energy demand in domestic buildings. [Note that there were 23M homes and 5.5M non-domestic buildings in the UK in 2013 and 87% of the existing building stock will constitute 70% of the 2050 building stock.] [50%]

(b) (i) State two advantages and two disadvantages of a grid system for electricity supply. [10%]

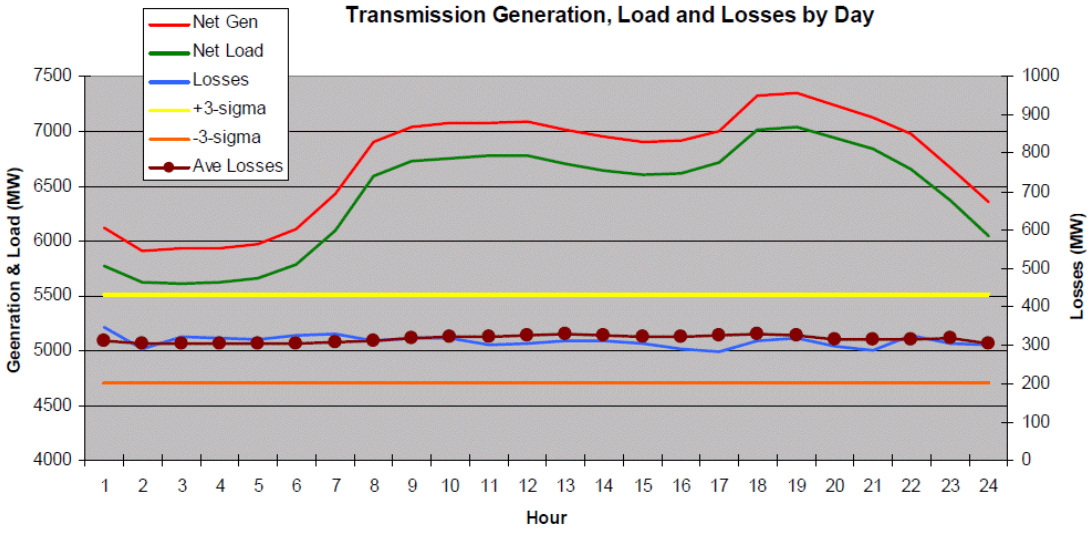

Fig. 2

(ii) The day load curve for a region of Canada is shown in Fig. 2. Discuss carefully the shape of the day load curve in Fig. 2 and the use of the day load curve in system planning. [20%]

(iii) Consider the losses curves shown in Fig. 2, and their three sigma boundaries. Do these curves have the shape you would expect for the given load curve? Suggest how the losses are incurred in this system and compare them with losses you might expect for London. [20%]

3 (a) A large petrochemical plant is connected to a weak grid using three high voltage lines. The plant also has a Combustion Gas Turbine (CGT) used for bulk power generation. There is a circuit breaker (CB) between the plant and the grid. A simplified one line diagram is shown in Fig. 3. The power flow in the line is given by

$$P = (V_A V_B / X_L) \sin(\delta_A - \delta_B)$$

where X_L is the reactance of the line, V_A and V_B are the node voltages and δ_A and δ_B are their respective phase angles.

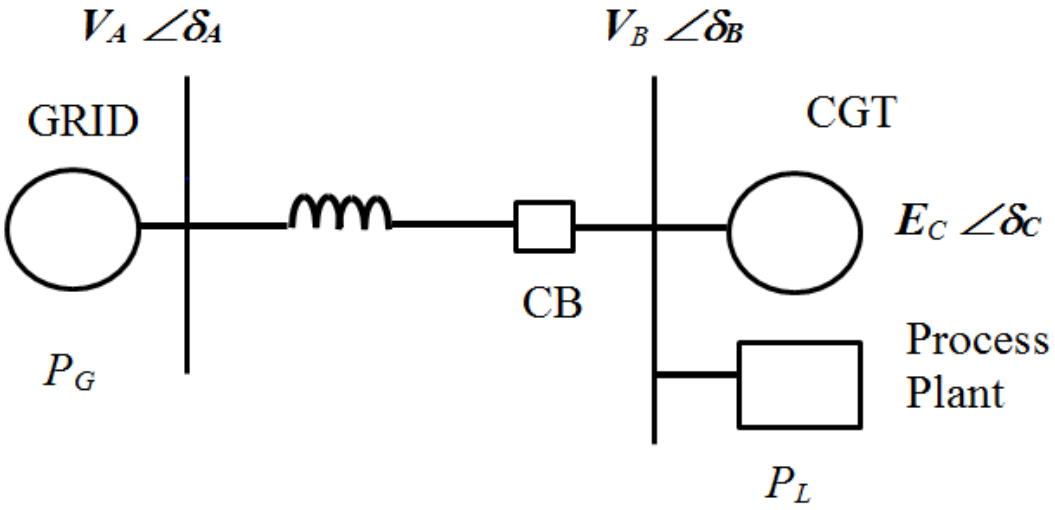

Fig. 3

(i) Make a list of grid disturbances which may cause the circuit breaker CB to open. [15%]

(ii) The CGT generator is a conventional generator which has some synchronous reactance, with a load angle δ_C, and an excitation voltage E_C. Sketch the equal area diagram for δ_C on the opening of CB in the case where $|P_G| = |P_L|/2$ before the fault, and stability is not lost. Assume that E_C remains of constant magnitude during the fault. Mark clearly on your diagram the particular equal areas. [20%]

(iii) By considering your diagram, list the main specifications for CGT and its protection system as proportions of P_L. [15%]

(cont.

(b) (i) Discuss the importance of frequency control in power systems. [10%]

(ii) Explain how a local disturbance in one part of a power system can propagate throughout the network. [20%]

(iii) Explain what is meant by the "Economic Dispatch Problem". Discuss connections and differences with frequency control schemes that occur at a faster timescale. [20%]

4 (a) Make a table of features of reciprocating engines and gas turbines for electricity production from natural gas. Describe briefly one such application where reciprocating engines are preferred. [50%]

(b) With reference to suitable thermodynamic principles, explain why a power station with an amine scrubbing unit which captures the CO_2 from the flue gases, has a lower efficiency than a standard coal fired power station? Whilst calculations are not required, you should illustrate your answer with any important equations or sketches. [50%]

END OF PAPER

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