Birla Institute of Technology and Science Pilani-K K Birla Goa Campus
SECOND SEMESTER 2022-2023
ME F420 Power Plant Engineering
Mid Semester Examination (Closed Book)

DATE: 13/03/2023 **Time: 4:00 PM - 5:30 PM** **Maximum Marks: 60**

Instructions:

- Write all steps while answering the problems.
- All the parts of a question must be answered together at a single place.
- All symbols used in the question paper have their standard meaning.

Q.1. A 30 MW plant capacity has peak demand of 25 MW. It supplies individual loads having maximum demands of 10 MW, 8.5 MW, 5 MW and 4.5 MW. The load factor is 0.45. Estimate the average load, energy supplied during the year, diversity factor and demand factor. **[10 M]**

Q.2. A power station supplies the following loads to the consumers:

Time (hrs)	0 - 6	6 - 10	10 - 12	12 - 16	16 - 20	20 - 22	22 - 24
Load (MW)	30	70	90	60	100	80	60

(a) Draw the load curve and estimate the load factor of the plant. (b) What is the load factor of a standby equipment of 30 MW capacity if it takes up all loads above 70 MW? What is its use factor? Assume peak load = plant capacity for the plant and also for standby equipment. **[10 M]**

Q.3. The incremental fuel costs for two generating units A and B of a power plant are given by the following

$$\frac{dF_A}{dP_A} = 0.06P_A + 11.4 \qquad \frac{dF_B}{dP_B} = 0.07P_B + 10$$

where P is in mega-watts and F is in rupees per hour. Find the economic loading of the two units when the total load to be supplied by the power station is 150 MW. Find the loss in fuel cost per hour if load is equally shared by the two units. **[10 M]**

Q.4. Feedwater from high pressure heater enters the inlet header of the economizer at 600 kg/s and 140 bar, 170^0C. Flue gases flow over the economizer coils at the rate of 1250 kg/s and leave at 450^0C. Flue gas has speed 12 m/s and water leaves the coils at 1.2 m/s. The tubes are 70 mm od and 60 mm id. Overall heat transfer coefficient is 70 W/m^2K. Determine the number of coils and length of one coil. Take C_p of flue gases as 1.12 kJ/kgK. If the vertical pitch of the coil and distance between the two coils is same as 80 mm, and the clearance on the two sides of the duct of width 4.8 m is 5 mm, find the vertical height of the economizer coil and length of the duct. **[30 M]**

ANSWER KEY

Q.1. Energy carries 3 marks, Load factor 3 Marks, Diversity factor 2 Marks, Demand factor 2 Marks.

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Peak Load}}$$

$$0.45 = \frac{\text{Average Load}}{\text{Peak Load } (= 25)}$$

$$\text{Average load} = 11.25 \text{ MW}$$

Energy supplied per year

$$= \text{avearge load} \times 8760 \text{ hrs}$$

$$= 11.25 \times 8760 \text{ MWh}$$

$$= 98550 \text{ MWh per year}$$

Diversity factor

$$= \frac{\text{Sum of individualy connected maximum demand}}{\text{Peak load}}$$

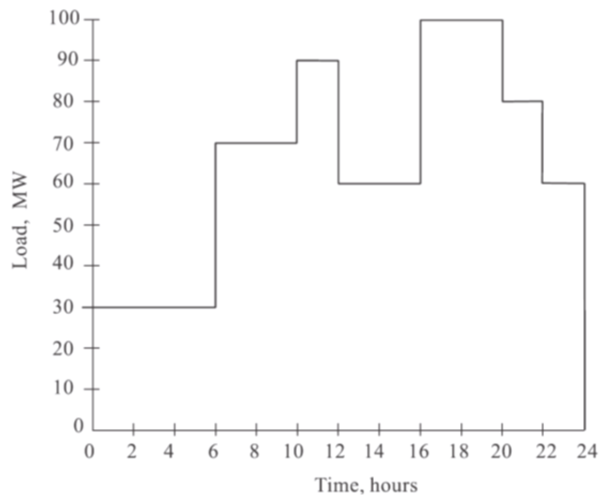
$$= \frac{10+8.5+5+4.5}{25} = 1.12$$

$$\text{Demand factor} = \frac{\text{Maximum demand}}{\text{Total connected load}}$$

$$= \frac{25}{10+8.5+5+4.5} = 0.89$$

Q.2. (a) Load curve 1 Mark, Energy 2 Marks, Average Load 1 Mark and Load factor 1 Mark

(b) Energy 2 Marks, Average load, load factor and use factor carries 1 mark each



(a) Total Load-Hour or Energy generated = area under the load curve

$$= 30\times 6 + 70\times 4 + 90\times 2 + 60\times 4 + 100\times 4 + 80\times 2 + 60\times 2$$

$$= 180 + 280 + 180 + 240 + 400 + 160 + 120$$

= 1560 MWh per day

$$\text{Average load} = \frac{1560\text{ MWh}}{24\text{ h}} = 65\text{ MW}$$

$$\text{Load factor} = \frac{\text{Average Load}}{\text{Peak load}} = \frac{65}{100} = 0.65$$

Capacity factor and Load Factor will be same

because in this problem Peak Load = Plant Capacity

(b) If the load above 70 MW is supplied by a stand by unit of **30** MW capacity, the energy generated by it

$= 20\times 2 + \underline{30}\times 4 + 10\times 2 + \underline{0}\times 16$

$= 40 + 120 + 20 + 0 = 180$ MWh

Average Load = Total MWh /(Total hrs = Operating hrs + Non-operating hours)

Average load = 180/(2 + 4 + 2 +16) = 180/(24)= 7.5 MW

Load factor = 7.5/30 = 0.25 =CAPACITY FACTOR

Use Factor = 180 MWh / (30 × 8) = 0.75

Q.3. Getting Correct value of PA and PB for economic loading carries 2.5 Makrs each. For equal sharing load, CA and CB carries 2 Marks each and their difference carries 1 Mark.

- PA+ PB = 150 MW……(i)

For economic loading $\frac{dF_A}{dP_A} = \frac{dF_B}{dP_B}$

Hence, 0.06PA+11.14 = 0.07 PB+10……(ii)

Solving (i) and (ii), PA = 70 MW, PB = 80 MW

- If load will be shared equally means PA=PB=75 MW,

Then increase in cost for unit A = CA

$$\int_{70}^{75} (0.06\, P_A + 11.4) dP_A = Rs.78.75\, per\ hour$$

Increase in cost for unit B will be

$$\int_{80}^{75} (0.07\, P_B + 10) dP_B = -Rs.77.12\ per\ hour$$

This shows that in case of unit B there is decrease in cost.

Hence NET increase in cost due to departure from economic distribution

– = 78.75 - 77.12 = Rs. 1.63 per hour.

Q.4. **Detailed calculations on the interpolation carries 9 marks for 100 bar, 150 bar and 140 bar pressure. Correct value of Tg1, Area Ao, number of coils, length of each coil, number of turns in each coil, vertical height of the coil, and length of the duct carries 3 marks each.**

Sol → At 140 bar for saturated liquid water

$h_f = 1571.08$ kJ/kg
$v_f = 0.001611$ m³/kg
$T_{sat.} = 336.75°C$
} table B.1.2

At 140 bar, 170°C Water, Compressed State

Using table B.1.4

100 bar, 160°C, h = 681.07 kJ/kg
180°C, h = 767.83 kJ/kg

∴ 100 bar, 170°C, h = 724.45 kJ/kg

150 bar, 160°C, h = 684.07 kJ/kg
180°C, h = 770.48 kJ/kg

∴ 150 bar, 170°C, h = 727.275 kJ/kg

∴ 140 bar, 170°C, h = 726.71 kJ/kg = $h_{170°C}$

Rate of heat transfer in the economiser

$$Q = w_s (h_f - h_{170°C}) = w_g C_{p_{gas}} (T_{g_1} - T_{g_2}) \quad \text{— (I)}$$

Also, $Q = U_o A_o \Delta T_{lm}$ — (II)

Using (I), $T_{g1} = 787.75°C$

Using II, $A_o = \dfrac{Q}{U_o \Delta T_{lm}} = \dfrac{w_s (h_f - h_{170°C})}{U_o \times (785.75 - 336.75)}$

Using II, $A_o = \dfrac{600\,(1571.08 - 726.71)}{70 \times \dfrac{451 - 280}{\ln\left(\frac{451}{280}\right)}}$

$\therefore A_o = 20.1751 \times 10^3\ m^2$

For Numbers of coils, $w_s = n \left(\dfrac{\pi d_i^2}{4}\right)(V_{w\,exit})(\rho_{f\,exit})$

$\therefore n = 285$ coils

$\therefore A_o = n \pi d_o l = 20.175 \times 10^3 \ m^2$

$\therefore l = \dfrac{20.175 \times 10^3}{285 \times \pi \times 0.070}$

$l = 321.9 \ m$

Number of turns in one coil,

$n_t = \dfrac{l}{\text{width} - 2 \times \text{clearance}} - 1$

$= \dfrac{321.9}{4.8 - 2 \times 0.005} - 1$

$= 67.2 - 1$

$n_t = 67 \text{ turns}$

Vertical Height of economiser coils, h

$h = n_t \times (\text{vertical pitch}) + 2 \times (\text{outer Radius})$

$\text{height} = 67 \times 0.08 + 0.07$

$\therefore h = 5.43 \ m$

Length of duct = ((n-1) × horizontal pitch) + 2 (outer radius) + 2 × clearance

Length of duct = 22.80 m