MCL 241: ENERGY SYSTEMS AND TECHNOLOGIES

Minor Exam # 2

Date: March 22, 2017

Time: 60 minutes Marks: 35

Instructions:

1. Show all necessary and important steps used to obtain your solution.
2. You are allowed the use of one A4 size paper written in your handwriting and thermodynamic tables only.

PROBLEM 1 (18 marks)

In a gas turbine unit which is measured to produce a power output of 100 MW at the generator, three stages of compression are used with intercooling between stages. The intercooling between stages reduces the fluid temperature to the unit inlet air temperature. The overall compression pressure ratio is 10/1 performed in pressure ratios of 2.5, 2 and 2 for LPC, IPC and HPC, respectively. The air temperature and pressure at the entry to the unit is 20°C and 1 bar, respectively. The HP turbine drives the LP, IP and the HP compressors, while the LP turbine drives the generator. The exhaust from the LP turbine passes through a heat exchanger where heat is transferred to air leaving the HP compressor before being exhausted into the surroundings. There are two combustion chambers, one between the heat exchanger and HPT and the other between HPT and LPT with the gas temperature raised to 650 °C in each. The isentropic efficiencies of compressors and turbines can be taken as 90% each. The following temperature differences in the heat exchanger are measured: (i) between exhaust gases leaving and air entering the heat exchanger is 140 °C; (ii) between air leaving and air entering the heat exchanger is 250 °C. The mechanical efficiency of each shaft can be assumed to be the same and is not known.

a) Draw a neatly labelled schematic of the power generation unit along with a T-s diagram showing the location of all state points. (7)
b) Calculate the thermal ratio of the heat exchanger. (4)
c) Determine the pressure ratio across each turbine. (3)
d) Calculate the mechanical efficiency of the shafts and the overall plant efficiency. (2)
e) Determine the mass flow rate of air required to generate the given power output. (2)

Use $C_p = 1.005$ kJ/kg-K and $\gamma = 1.4$ for air and $C_p = 1.15$ kJ/kg-K and $\gamma = 1.333$ for combustion products.

PROBLEM 2 (17 marks)

A steam power plant using regeneration and producing 100 MW has one each of closed and open feed heater. Superheated steam is supplied from the boiler at 80 bar and expanded to the condenser pressure of 4 kPa in a single turbine. The bleed steam for the closed and open feed heaters is taken at 20 bar and 10 bar, respectively. The bleed steam supplied to the deaerator is dry saturated. The condensed steam from the closed feed heater is throttled and

fed into the open feed heater. Assume ideal expansion process, neglect pump work, and complete condensation of bleed steam in the closed feed heater.

a) Draw a neatly labelled schematic of the plant (showing the exact location of pump(s)) and a T-s diagram showing the location of all state points. (8)

b) Calculate the fraction of boiler steam bled at each stage. (4)

c) Determine the cycle efficiency. (3)

d) Calculate the mass flow rate of steam leaving the boiler. (2)