**Assignment -3: Power Plant Engineering**

**Submit only Problem No. 2,3,6,9,12 (Due date 25 Oct 2017)**

1. A steam power station uses the following cycle:
   Steam at boiler outlet: 150 bar, 550 °C. reheat at 40 bar to 550 °C. Condenser at 0.1 bar. Assuming ideal processes find (a) the quality at turbine exhaust, (b) the cycle efficiency, and (c) the steam rate.
2. An ideal steam power plant operates between 165 bar, 550 °C and 0.07 bar. It has five feedwater heaters, all optimally placed. Find the optimum pressure at which the heaters operate. Draw a neat *T-s* diagram.
3. A steam power plant operates on the reheat Rankine cycle. Steam enters the high-pressure turbine at 12.5 MPa and 550°C at a rate of 7.7 kg/s and leaves at 2 MPa. Steam is then reheated at constant pressure to 450°C before it expands in the low-pressure turbine. The isentropic efficiencies of the turbine and the pump are 85 percent and 90 percent, respectively. Steam leaves the condenser as a saturated liquid. If the moisture content of the steam at the exit of the turbine is not to exceed 5 percent, determine (a) the condenser pressure, (b) the net power output, and (c) the thermal efficiency.
4. A steam power plant operates on an ideal regenerative Rankine cycle with two open feedwater heaters. Steam enters the turbine at 10 MPa and 600°C and exhausts to the condenser at 5 kPa. Steam is extracted from the turbine at 0.6 and 0.2 MPa. Water leaves both feedwater heaters as a saturated liquid. The mass flow rate of steam through the boiler is 22 kg/s. Show the cycle on a T-s diagram, and deter- mine (a) the net power output of the power plant and (b) the thermal efficiency of the cycle.
5. Steam is generated in the boiler of a cogeneration plant at 10 MPa and 450°C at a steady rate of 5 kg/s. In normal operation, steam expands in a turbine to a pressure of 0.5 MPa and is then routed to the process heater, where it supplies the process heat. Steam leaves the process heater as a saturated liquid and is pumped to the boiler pressure. In this mode, no steam passes through the condenser, which operates at 20 kPa. (a) Determine the power produced and the rate at which process heat is supplied in this mode. (b) Determine the power produced and the rate of process heat supplied if only 60 percent of the steam is routed to the process heater and the remainder is expanded to the condenser pressure.
6. The gas-turbine portion of a combined gas–steam power plant has a pressure ratio of 16. Air enters the compressor at 300 K at a rate of 14 kg/s and is heated to 1500 K in the combustion chamber. The combustion gases leaving the gas turbine are used to heat the steam to 400°C at 10 MPa in a heat exchanger. The combustion gases leave the heat exchanger at 420 K. The steam leaving the turbine is condensed at 15 kPa. Assuming all the compression and expansion processes to be isentropic, determine (a) the mass flow rate of the steam, (b) the net power output, and (c) the thermal efficiency of the combined cycle. For air, assume constant specific heats at room temperature.
7. A steam power plant operates on an ideal reheat–regenerative Rankine cycle with one reheater and two feedwater heaters, one open and one closed. Steam enters the high-pressure turbine at 15 MPa and 600°C and the low pressure turbine at 1 MPa and 500°C. The condenser pressure is 5 kPa. Steam is extracted from the turbine at 0.6 MPa for the closed feedwater heater and at 0.2 MPa for the open feedwater heater. In the closed feedwater heater, the feedwater is heated to the condensation temperature of the extracted steam. The extracted steam leaves the closed feedwater heater as a saturated liquid, which is subsequently throttled to the open feedwater heater. Show the cycle on a T-s diagram with respect to saturation lines. Determine (a) the fraction of steam extracted from the turbine for the open feedwater heater, (b) the thermal efficiency of the cycle, and (c) the net power output for a mass flow rate of 42 kg/s through the boiler.

8. A cyclic steam power plant is to be designed for a steam temperature at turbine inlet of 360 °C and an exhaust pressure of 0.08 bar. After isentropic expansion of steam in the turbine, the moisture content at the turbine exhaust is not to exceed 15%. Determine the maximum allowable steam pressure at the turbine inlet, and calculate the Rankine cycle efficiency for these steam conditions. Estimate also the mean temperature of heat addition.
9. A steam power plant with inlet steam to the h.p. turbine at 90 bar and 500 °C, and condensation at 40 °C produces 500 MW. It has one stage of reheat optimally placed which raises the steam temperature back to 500 °C. One closed feedwater heater with drains cascaded back to the condenser receives bled steam at the reheat pressure, and the remaining steam is reheated and then expanded in the l.p. turbine. The h.p. and l.p. turbines have isentropic efficiencies of 92% and 90% respectively. The isentropic efficiency of pump is 75%. Calculate (a) the mass flow rate of steam at turbine inlet in kg/s, (b) the cycle efficiency, and (c) the cycle work ratio. Use TTD = -1.6 °C.
10. Steam at 150 bar, 550 °C is expanded in an h.p. turbine to 20 bar when it is reheated to 500 °C and expanded in i.p. and l.p. turbines to condenser pressure of 0.075 bar. There are five feedwater heaters, one extraction from h.p. turbine at 50 bar, 3 from i.p. turbine at 10 bar, 5 bar and 3 bar, and one from l.p. turbine at 1.5 bar. The middle heater is the deaerator and all others are closed heaters. Assuming ideal conditions, determine (a) the cycle efficiency, (b) the feedwater temperature at inlet to the steam generator, (c) the steam rate, (d) the heat rate, (e) the quality of steam at turbine exhaust, and (f) the power output if the steam flow rate is 300 t/h. Take TTD = 0 for all the heaters.
11. An ideal Rankine cycle operates at 70 bar, 540°C. It has one closed feedwater heater with drain cascaded backward placed at 7 bar. The condenser pressure is 0.07 bar. Use TTD=3°C. The heater has a drain cooler resulting in drain cooler temperature difference of 5°C. Repeat the problem for one closed-type feedwater heater with drain pumped forward. Assume, TTD=5°C.
12. Test data from a boiler are as follows:
    Coal analysis (by mass): C 82%, H 6%, O 2%, moisture 4% and ash 6%.
    Calculate the stoichiometric air-fuel ratio. The actual air supllied is 18 kg/kg fuel. Given that 90% of the carbon and all the hydrogen are completely burnt, calculate the volumetric analysis of the dry products. Remaining 10% carbon gets converted to CO. Find the adiabatic flame temperature assuming the reactants enter at 25°C.
13. A forced draught fan supplies air at 12 m/s against a draught of 20 mm of water across the fuel bed. Estimate the power required to run the fan if 2000 kg/hr of coal is consumed and 16 kg of air is supplied per kg of coal burned. The temperature of the flue gas and the ambient air may be taken as 600 K and 300 K respectively. If the forced draught fan is replaced by an induced draught fan, what will be the power required to drive the fan?