MAE 110A Fall 2013 Design Problem

Due: Friday December 6

Background

The Inland Empire power station in Riverside County with 2 units of GE 107H 400MW combined-cycle systems (H class) can generate enough electricity to supply nearly 600,000 households while reducing future carbon dioxide emissions by more than 146,000t (148 million kilogrammes) per year over a typical CCGT (Combined Cycle Gas Turbine) plant. The H class represents GE's latest gas turbine technology and the Inland Empire Energy Center is the first US plant to use them.

Problem Description

For this problem, you will prepare a preliminary design for a Rankine Vapor Power Cycle with reheat as part of a *Combined Gas Turbine-Vapor Power Cycle*. Data from the GE 107H will be used to define operating conditions for the gas turbine. Energy from the gas turbine system is transfered to the vapor power cycle through a Heat Recovery Steam Generator (HRSG). Some operating conditions for the vapor power cycle are given. You will select or determine the rest.

Gas turbine system *(GE 7H Gas turbine standard rating condition from Reference 3)*:

- Air standard analysis, internally reversible, steady state processes
- Compressor: inlet $\mathrm{P}_1 = 100$kPa, $\mathrm{T}_1 = 300$K; Pressure ratio (see reference);
- Gas turbine: inlet temperature T_3 (reference); Air flow rate $\dot{m}_{\mathrm{g}}$ (reference)
- Heat recovery steam generator (HRSG): Adiabatic, constant pressure $P_4 = P_5 = 100$kPa, exit temperature $T_5 = 400$K;

Vapor power cycle:

- Rankine (steam) power cycle with irreversibilities and reheat
- Steam Turbine: isentropic efficiency $\eta_{\mathrm{t}} = 80\%$; inlet pressure $\mathrm{P}_6 = \mathrm{P}_7$, temperature T_7 and Reheat pressure($\mathrm{P}_a = \mathrm{P}_b$), temperature T_b , selected by the Designer; maximum pressure $P = 20$MPa and maximum temperature $T = 500^{\mathrm{o}}$C due to material limit. The exit of the steam turbine should have quality $0.9 < x_8 < 1$.
- Condenser inlet pressure $\mathrm{P}_8 = 8$kPa, Water enters the pump as saturated liquid at $\mathrm{P}_9 = 8$kPa. The pump isentropic effciency is $\eta_{\mathrm{p}} = 75\%$

Steps

1. Read section 9.9 in text and References. Learn basic aspects of the Gas Turbine-based Combined Cycle.
2. Review sections 9.5-9.6 on gas turbine modeling. For gas turbine GE 7H, look up required data from Ref. 3.
3. For vapor power cycle, select inlet pressures and temperatures of steam turbines. Resulting operating conditions must meet restrictions given above. Determine the net power output obtained and combined cycle thermal efficiency.
4. Perform and present complete analysis of combined cycle. Include the following:
   a. Operating temperatures and pressures for all defined states within the system; Prepare summary table and include corresponding enthalpy values; Draw $T - s$ diagram;
   b. All energy transfer rates; Prepare summary table listing components;
   c. Thermal efficiency η of combined-cycle;
   d. Comment on the results.

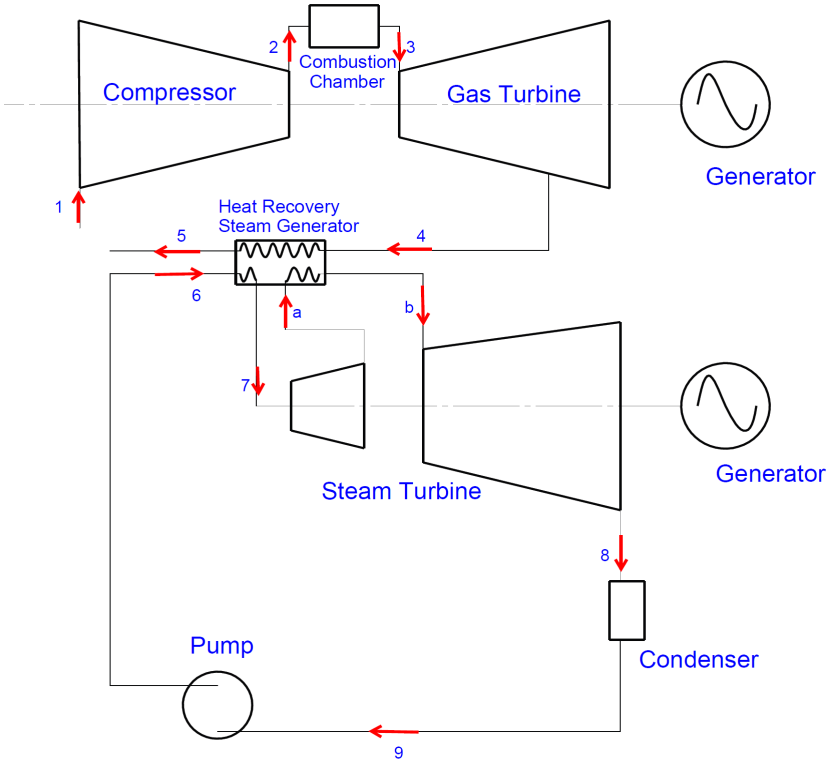

Figure 1: Combined gas turbine-vapor power cycle with reheat process a-b

Reference

1. Inland Empire Energy Center
   www.energy.ca.gov/sitingcases/inlandempire/
2. Inland Empire CCGT Power Station, United States of America
   www.power-technology.com/projects/inland/
3. Power Systems for the 21st Century H Gas Turbine Combined-Cycles