Final Project

Thermodynamics I

Dr. Houshfar

Deadline: 16 January 2023 @ 23:59

System Description

Consider a combined-cycle power plant with two possible waste heat recovery systems as shown in Figure 1.

In the Brayton cycle, air enters the compressor (state 1) and is then compressed to higher pressure (state 2). The compressed air enters the combustion chamber and reacts with natural gas (state 3). The combustion gasses enter the gas turbine and produces electricity and leaves the gas turbine (state 4). An HRSG (heat recovery steam generator) is used to warm the water inside the Rankine cycle. The flue gas leaves HRSG with a lower temperature at state 5.

In the Rankine cycle, water in state 6 enters the HRSG and warm-up and vaporized to reach state 7. Then the steam enters the steam turbine and produces electricity and leaves the turbine at state 8 with a lower temperature and pressure compared to state 7. The condenser is used to cold down and condensate the water to reach state 9. Then by using the pump the water is pressurized to state 6.

Two options are available for the flue gas after HRSG:

A) To enter an NH_3-water or LiBr-water absorption chiller to produce a cooling load.

B) To enter a single-stage flash distillation unit to produce fresh water.

** Options A and B are for extra scores.

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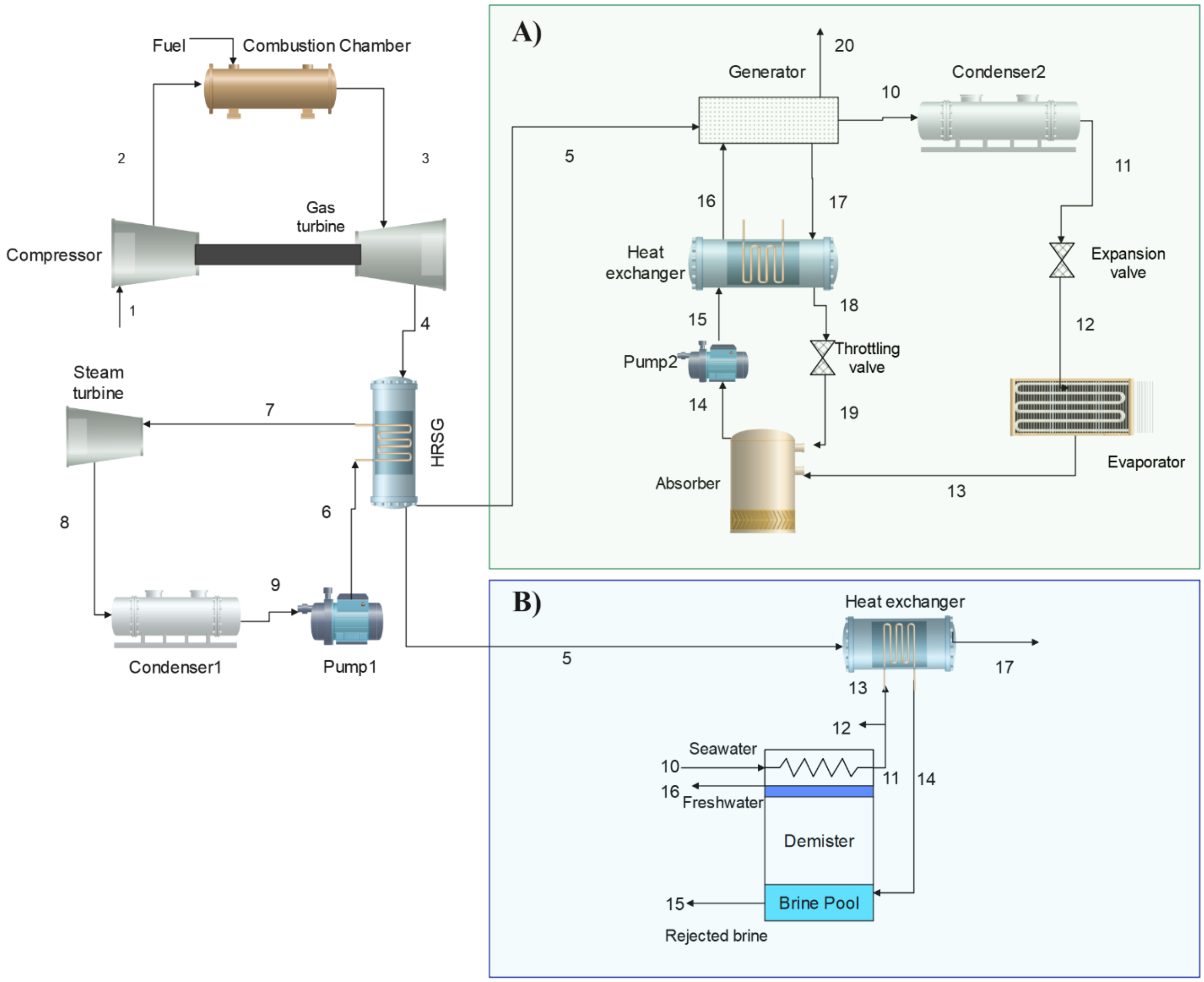

Figure 1. Schematic of the system.

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Modeling Information

a) Both EES and MATLAB can be used for coding.

b) For simplicity, LHV of natural gas can be used for modeling the combustion chamber and the C_p of states 3, 4, and 5 can be considered about 1.07 times air C_p (note that, this method is only acceptable for a class project at the bachelor's level). Moreover, to obtain more accurate results you can use any relation available in the literature such as:

$$C_p = 0.991 + \frac{6.997T}{10^5} + \frac{2.712T^2}{10^7} - \frac{1.2244T^3}{10^{10}}$$

c) The data for modeling is available in Table 1. Other parameters must be set by a rational value.

Table 1. Modeling parameters

Parameters	Value
Ambient temperature (K)	298.15
Ambient pressure (kPa)	101.325
Inlet air mass flow rate (kg/s)	50
Brayton pressure ratio	12
Isentropic efficiency of compressor	0.88
Isentropic efficiency of gas turbine	0.9
Gas turbine inlet temperature (GTIT) (K)	1300
HRSG pinch point (K)	5
Isentropic efficiency of steam turbine	0.92
Rankine higher pressure (kPa)	1000
Rankine lower pressure (kPa)	80

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Objectives of the Project

a) Modeling the system and finding the main results of the system (energy efficiency of the overall system, and total net power production).

b) Report the mass flow rate, specific enthalpy, and specific entropy values of each state (see Figure 2).

c) Find the effects of GTIT, isentropic efficiency of the compressor, and isentropic efficiency of the gas turbine on the energy efficiency of the overall system, and total net power production.

Extra Points

a) Modeling schemes A or B.

b) Modeling the combustion process.

c) Exergy analysis of the system which includes the exergy of each state, exergy efficiency, and the exergy destruction rate of each component.

d) Economic analyses of the system.

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Report Tips

a) If the report is in English, use Times New Roman with a font size of 12, and if in Persian, use B-Nazanin with a font size of 14. The figures and tables caption font is recommended to be one order smaller than the size of the body of the report.

b) Each figure and table must have captions and be mentioned in the report.

c) The report must consist of an introduction, system description, modeling, results and discussion, conclusion, and reference.

d) Introduction section: a brief description of electricity production, cooling production, and freshwater production. If applicable, a brief literature review. At the end of the introduction section, the objectives of the project must be included.

e) System description section: similar to what has been done on the first page of the project. It is recommended to draw the system figure again.

f) Modeling section: the complete modeling includes equations and adjusted values for each parameter (see Figure 3).

g) Results and discussion section: is the most important part. The main results and objectives of the project must be discussed. The results of any figure that is used must be discussed with reasons.

h) Conclusion section: a brief description of what has been done, and mention the main outcomes of the project. If it is possible, give some opinions for future works.

i) Reference section: include references that are used in the report.

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Supplementary Figures

state	P (kPa)	T(^oC)	h (kJ/kg)	s (kJ/kg.K)	$\dot{m}$(kg/s)	ex (kJ/kg)	Working fluid
1	101.3	25	298.4	6.86	30.11	0	Air
2	1267	374.5	658	6.929	30.11	339	Air
3	1267	945.1	1301	7.637	30.11	770.9	Air
4	101.3	412.6	698.6	7.716	30.11	144.9	Air
5	101.3	262.6	540.5	7.456	30.11	64.3	Air
6	1000	93.57	392.7	1.233	1.722	29.61	Water
7	1000	350	3157	7.301	1.722	985.2	Water
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 2. Sample table for reporting each state.

System components	Exergy balances equations
Compressor	$\dot{m}_1 ex_1 + \dot{W}_{com} = \dot{m}_2 ex_2 + \dot{E}x_{D,com}$
Solar receiver	$\dot{m}_2 ex_2 + \dot{Q}_{rec}\left(1 - \frac{T_0}{T_{rec}}\right) = \dot{m}_3 ex_3 + \dot{E}x_{D,rec}$
Turbine-I	$\dot{m}_3 ex_3 = \dot{m}_4 ex_4 + \dot{W}_{T-I} + \dot{E}x_{D,T-I}$

Figure 3. Sample modeling table that can be used for equations.