Power systems

First semester 2018-2019 **Name (Print):** _____
Topic 2
14/01/19
Time Limit: 90 Minutes Total: 100 points

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1. Consider the combined cycle power plant shown in Figure 1. This power plant uses natural gas as a fuel and it has two pressure levels at the steam/water circuit. Some information of the properties of water at different pressures is given in Table 1. The following are some additional parameters of the plant:

   - Boiler (flumes chamber) efficiency $\eta_C = 91\%$
   - High pressure steam turbine internal efficiency $\eta_{HP} = 86\%$
   - Low pressure steam turbine internal efficiency $\eta_{LP} = 88\%$
   - Turbines mechanical efficiency $\eta_m = 97\%$
   - Electrical generators efficiency $\eta_g = 98\%$
   - LHV of $38000 kJ/m^3$

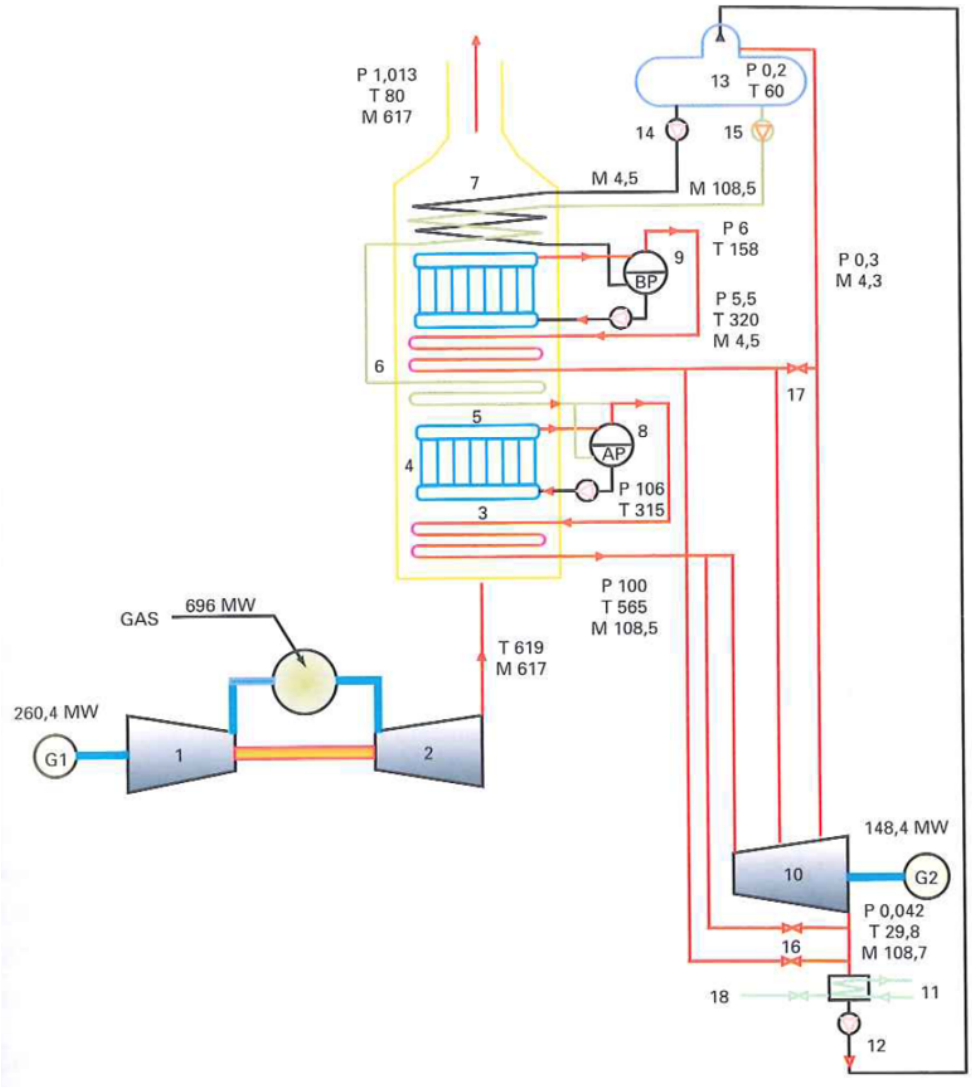

Figure 1: Scheme of the combined cycle power plant. The values shown are in: P(bar), T(C) and M(kg/s)

Table 1: Steam and liquid properties at different pressures

Pressure (bar)	Liquid Enthalpy (kJ/kg)	Steam Enthalpy (kJ/kg)
0.042	124.9	2555.2
0.2	251.4	2608.9
0.3	289.3	2624.6
5.5	655.8	2752.3
100	1408.1	2725.5

Answer the following questions:

(a) (4 points) What is the global efficiency of the power plant?

(b) (5 points) What is the efficiency of the Bryton cycle?

(c) (8 points) What is the efficiency of the water/steam cycle?

(d) (8 points) Draw approximately the T-S diagram. You can draw separately the gas and the water diagrams (consider that valves 16 and 17 are permanently closed).

(e) (5 points) Calculate the power dissipated at the condenser, considering that there are no thermal losses in the circuit.

(f) (5 points) what is the enthalpy at the entrance of the condenser?

(g) (5 points) What is the quality of the water at this point?

2. Consider a Pressurized water reactor working at nominal conditions with the control rods slightly inserted in the reactor (20 out of 270 steps).

(a) (4 points) What is the reactivity of the reactor at this moment?

(a) _____

(b) (6 points) While chatting in the control room one operator sits on the console and inserts the control rods 50 additional steps. Orientatively, draw in Figure 2 the possible evolution of the reactivity in the reactor. In a couple of lines explain what happens.

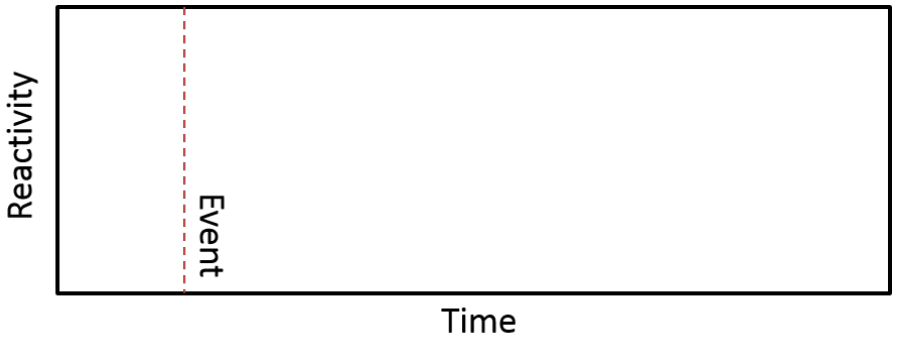

Figure 2: Draw the evolution of the power

3. (10 points) Determine the average electrical power generated by a nuclear power plant during a cycle in which the average fuel burnup was 16400 MWd / tU, the overall efficiency of the power plant was 34.0%, the cycle duration was 400 days and the total mass of uranium 79 tones. Answer below!

3. _____

4. Consider a remote island with a population of 400000 people. the power system is composed of 25 wind turbines, 1 million solar photo-voltaic panels, a concentrating solar thermal plant (CSP) and a combined cycle power plant (CCPP). The characteristics of each system are as follows:

   - The wind turbines are a GAMESA R-132 model and have the power curve shwon in Figure 3
   - The photo-voltaic panels are a Siemens design with a peak power of 110 W and a useful surface of $0.82m^2$.
   - The CSP plant has a solar field collecting area of $10^6 m^2$, the efficiency of the solar field considering the optical plus the thermal losses is in average (62%). The fluid circulating through the solar field is molten salt (cp is 2.319 kJ/kg/K). The temperatures of the hot and cold tank are 665 and 563 K. The efficiency of the rankine cycle is 38%. The maximum and minimum power at which the CSP plant can work are 150 and 100 MW.
   - The CCPP has a nominal power of 150 MW.

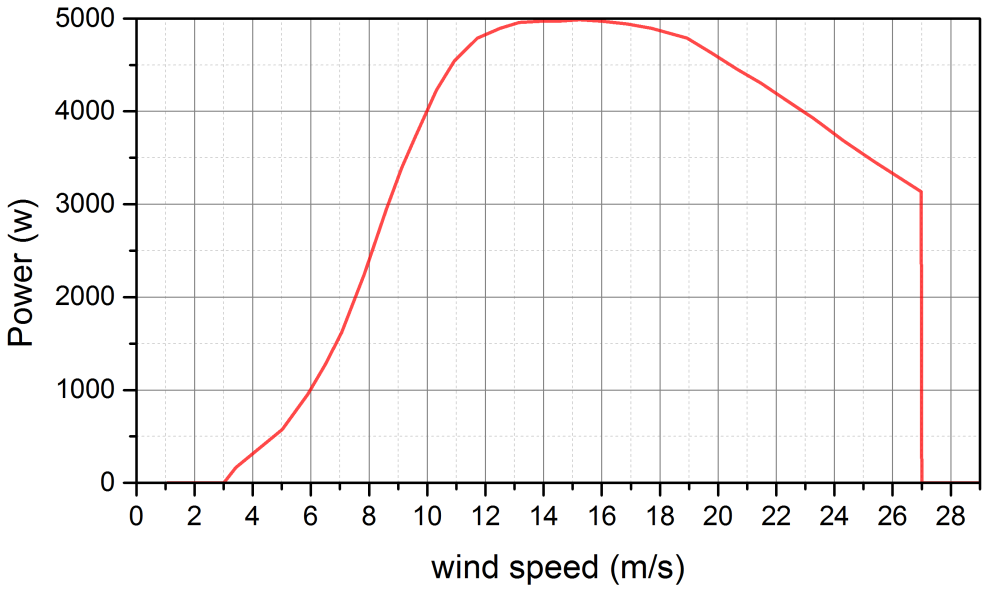

Figure 3: Power curve of the GAMESA R-132 Wind turbine

During the last hour, the wind at the wind farm was blowing at 22 m/s and the sun radiation at the solar stations was $733 W/m^2$. The demand per capita was 0.69 kWh.

(a) (25 points) Calculate the power produced by each technology in order to satisfy the demand. Keep in mind that the objective is to minimize fuel consumption and CO_2 emmissions (separate clearly each calculation and explain the logic of your decisions)

(b) (15 points) Provide the variation of the hot tank fluid in the CSP plant in kilograms.