

TRIGENERATION SYSTEM BASED ON A SOLAR ENERGY INPUT RANKINE CYCLE

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Abstract. The paper presents an analysis of a trigeneration system, based on a steam-water cycle with stored solar energy input. The system allows to use the recovered heat from condenser for heating during the winter season and for cooling during the summer season. The unit ensures the entire energetically demands of one or several buildings. For this unit the following configuration is considered: solar heater, steam boiler, steam turbine, condenser-thermal accumulator, absorption chiller.

Keywords: trigeneration, solar energy, Rankine cycle, thermal storage.

1. INTRODUCTION

By simultaneous production of three different forms of energy – heating, cooling and power – from the primary energy source, trigeneration provides a great efficiency. Trigeneration converts and distributes up to 90% of the energy contained in the burned fuel into usable energy. Trigeneration provides flexibility and reliability. Prime movers can be steam and gas turbines or reciprocating engines. The using of a trigenerative system allows the obtaining of an energetically independence for a building or a group of buildings.

Efficiency of such system can be increase using solar heat, which is usually stored in molten salts or phase change materials.

The paper presents a small power hybride trigeneration unit, with solar energy input, able to produce 60 kW power, 160 kW heating, 80 kW cooling and 65 kW warm water for domestic or industrial use.

2. THE HYBRIDE SOLAR-RANKINE TRIGENERATION SYSTEM

The water-steam cycle and the input/output amounts of energy are represented in fig.1. The parameters in the main points are given in table 1.

The trigeneration system, whose basic scheme is presented in fig.2, is designed to operate on the basis of a Rankine cycle with solar energy input.

The boiler 1 produce saturated steam using the amount of energy q_{11} from the stored solar energy. The steam boiler 2 overheat the saturated steam at 7 bar and 250°C with energy q_{12} obtained by burning fuel. The overheated steam is sent to the steam turbine 3, which drives the power generator 4. The electrical accumulator 8 has on one hand the role of sustaining the electrical peaks and on the other hand, during the periods of time when the turbine is not operating, provides electricity required by users.

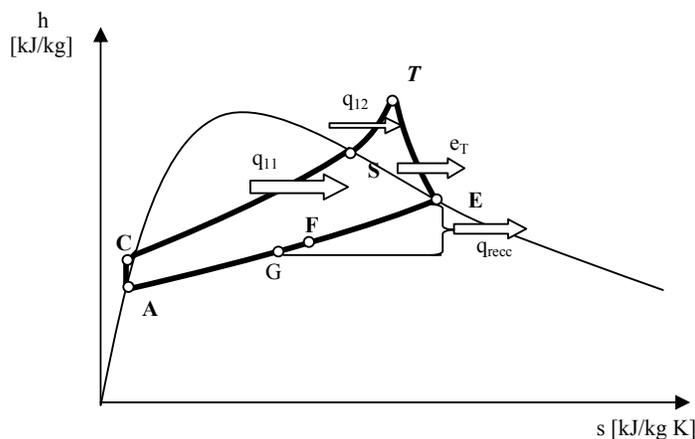


Fig. 1. The water-steam cycle.

The steam that leaves the turbine with parameters 1,1 bar, 110°C is still overheated, but very close by the saturation state. In the condenser 5, which is also a thermal accumulator, the steam is partially condensed. The condensing process is finished in the condenser 6, where the warm water for domestic use produced in heat exchanger 8 is preheated, or/and in the air cooled condenser 7.

Table 1

The parameters of steam and water in the main points of the cycle

	p [bar]	t [°C]	h [kJ/kg]	x
A	1	99,63	418	0
C	7,3	100	420	0
S	7,1	166	2764	1
T	7	250	2954	-
E	1,1	110	2680	$\cong 1$
F	1,01	100	1680	0,55
G	1,01	100	1550	0,50

The water which leaves the condenser-accumulator with 85°C is used for heating or cooling and for preparation of hot domestic water in heat exchanger 9. On winter a part of warm water is used as thermal agent for heating system 10. On

summer, when heating is no more necessary, the heated water is send towards the lithium-bromide absorption cooler 11. This produces chilled water at 5°C for air conditioning. After the heat exchange to the users, the temperature of the water at the entrance in the condenser-accumulator is 65°C.

The steam flowmass is 0,226 kg/s and the warm water flowmas is 0,344 kg/s.

Usually, during the night the electrical energy demand is very low. The steam turboengine can be stopped and the electrical accumulator is used. In this case, the heating demand is covered by the heat that is accumulated in the mass of water from thermal accumulator.

The quantity of warm water stored in the thermal accumulator must be able to cover the heating demand for a longer period of time. The thermal comfort is maintained at a minimum 40-50°C temperature of water in the radiators. In order to establish the mass water, it was done the calculus of this non-stationary heat exchange process. The optimum mass of water from the accumulator is 12.000 kg. For this quantity of water the cooling time from 85°C to 45°C is 4 hours. After restarting of steam turboengine the temperature of water from accumulator comes back to 85°C in 1,3 hours.

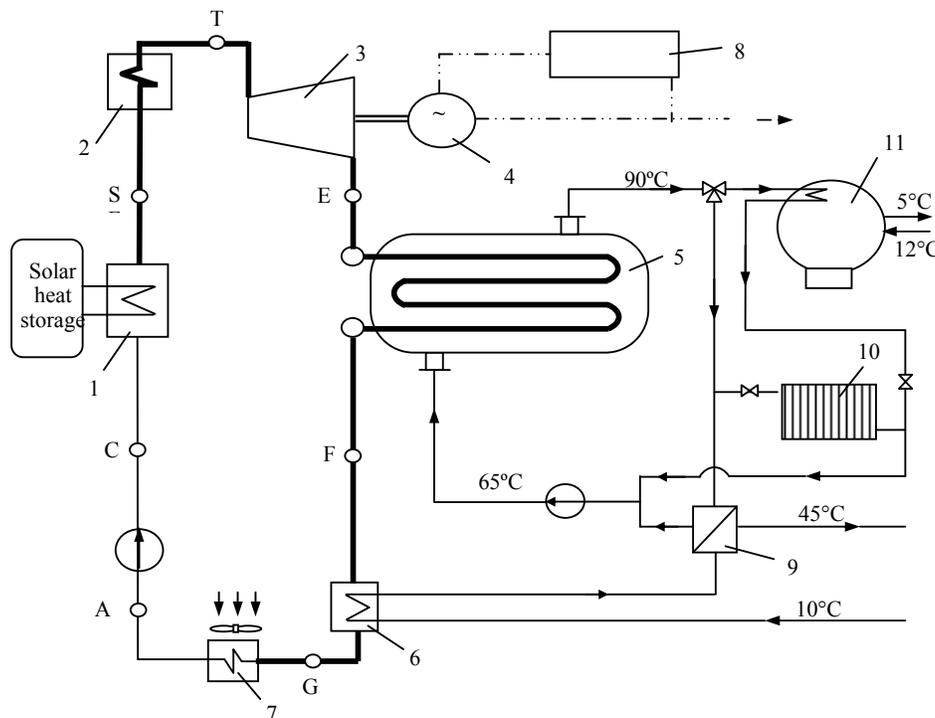


Fig. 2. The trigeneration system:

1 – saturated steam boiler 2. overheated steam boiler; 3 – steam turbine; 4 – power generator; 5 – condenser-thermal accumulator; 6 – water cooling condenser; 7 – air cooling condenser; 8 – electrical accumulator; 9 – heat exchanger for domestic hot water; 10 – heating system; 11 – absorption chiller.

3. THE CALCULUS OF THE THERMAL EFFICIENCY

The thermal efficiency of the trigeneration unit is:

$$\eta_t = \frac{e_t + q_{rec}}{q_{11} + q_{12}} \quad (1)$$

where: e_t is the energy produced by the turbine, for 1 kg steam [kJ/kg]; q_{rec} – the thermal energy recovered from the latent condensing heat of 1 kg steam [kJ/kg]; q_{11} – the heat from solar energy storage, for 1 kg steam [kJ/kg]; q_{12} – the heat quantity introduced by burning fuel, for 1 kg steam [kJ/kg].

These quantities of energy are also represented in Figure 1.

Using the notations from Figure 1, the relation (1) becomes:

$$\eta_t = \frac{(h_T - h_E) + (h_E - h_G) + q_{tac}}{h_T - h_A} = \frac{h_T - h_G + q_{tac}}{h_T - h_A} \quad (2)$$

where h is the enthalpy for every specific point and q_{tac} is the heat delivered by thermal accumulator during the night.

The values for thermal efficiency are 0,81 in the winter and 0,68 in the summer.

4. CONCLUSIONS

A high efficiency of small trigenerative installations can be achieved only for a great demand of heat. The report between the electrical power and thermal power is usually 1/4-1/5.

The values of efficiency are smaller in summer because the heat quantity necessary for air conditioning is smaller than the heat quantity necessary for heating in winter.

If the legislation allows, it can be achieved the connection with electrical grid for selling or buying energy.

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