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Article

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Performance analysis of a solar–hydrogen driven multigeneration system

S. Erzen[a], E. Açıkkalp[a,*], A. Hepbasli[b]

[a] Department of Mechanical Engineering, Engineering Faculty, Bilecik S.E. University, 11230 Bilecik, Turkey
[b] Department of Energy Systems Engineering, Faculty of Engineering, Yasar University, 35100 Bornova, Izmir, Turkey

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Abstract

Environmental concerns have gained great attention in the last decades, especially the global warming caused by usage of fossil fuels mostly. Renewable energy sources are the most reasonable way to decreasing the fossil fuel usage as a primary source and to preventing its environmental effects. In this regard, renewable source multigeneration systems seem to be an alternative. In this paper, a solar driven multigeneration system consisting of PV/T panels, a hydrogen fueled diesel engine generator, an electrolyzer, a hydrogen compressor, a hydrogen storage tank, batteries, an air cooled chiller, a hydrogen combustor, a water storage tank, and a control systems is considered. The simulation of this system is performed through TRNSYS 18. Outputs from the proposed system are heating, cooling, electricity and hydrogen. The performance analysis is done for Izmir, which is the third biggest city in Turkey by population while the obtained results are evaluated over a period of one year.

Peer-review under responsibility of the scientific committee of the 6th International Conference on Energy and Environment Research, ICEER 2019.

Keywords: Air cooling chiller; Hydrogen; Multigeneration; Solar energy

1. Introduction

Energy demand of the world is increasing day by day. Unfortunately, main energy resource is fossil fuels that release emissions causing the global warming and various environmental problems. Environmental concerns have gained attention, such as the global warming. In addition to this, one of the most important problems is the exhausting fossil fuels. Using renewable energy more effectively may be a solution for overcoming the energy demand and environmental problems. Renewable energy based multigeneration systems can provide power, heating, cooling, hydrogen production, etc, forming the one or multiple renewable energy sources. These kinds of systems have increased for the last decade because of the opportunity to use energy sources more efficiently and environmental friendly. In this regard, renewable energy based multigeneration systems would be an alternative.

* Corresponding author.
E-mail address: emin.acikkalp@bilecik.edu.tr (E. Açıkkalp).

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In this study, a solar energy–hydrogen driven multi-generational application is taken into account. Some similar studies done are given in Refs. [1–4]. The considered system is composed of PV/T panels, a storage tanks, a hydrogen combustor, a diesel generator, an air cooled chiller, an alkaline electrolyzer, a hydrogen gas tank, batteries, and a hydrogen compressor as main components. TRNSYS 2018 is used for simulation studies, for which the city of Izmir, Turkey is chosen. The performance analysis of the system is conducted and evaluated.

2. System description and simulation

The simulation was made for one year while the primary energy is solar energy and hydrogen. PV/T panels produce electricity and hot water. This electricity is stored in batteries and used in electrolyzer to produce hydrogen gas. Hydrogen is sent to a storage where a control system keeps at a certain pressure. Hot water produced by the PV/T is sent to the water store tank. The water stored in this tank is employed for meeting the hot water demand (heating and domestic usage). The water at the exit of the tank is taken at 50 °C minimum via a control system. The auxiliary heat energy is obtained from the hydrogen combustor. The combusted hydrogen is a portion of the hydrogen produced in the system. The electricity demand, the power required by the air cooled chiller and the power consumed at the hydrogen compressor are met by the generator fueled by hydrogen. Finally, this system produces electricity, heating, cooling and hydrogen by solar energy. A schematic of the system and types of components used in the simulation can be seen in Fig. 1. Some parameters used in the simulation can be listed as follows:

– The total area of the PV/T panels is 1500 m^2
– The water flow rate is 500 kg/h
– The minimum temperature of the water at the tank exit is 50 °C
– The efficiency of hydrogen combustor is 0.9
– The chilled water mass flow rate is 500 kg/h
– The maximum hydrogen pressure in the tank is 500 bar

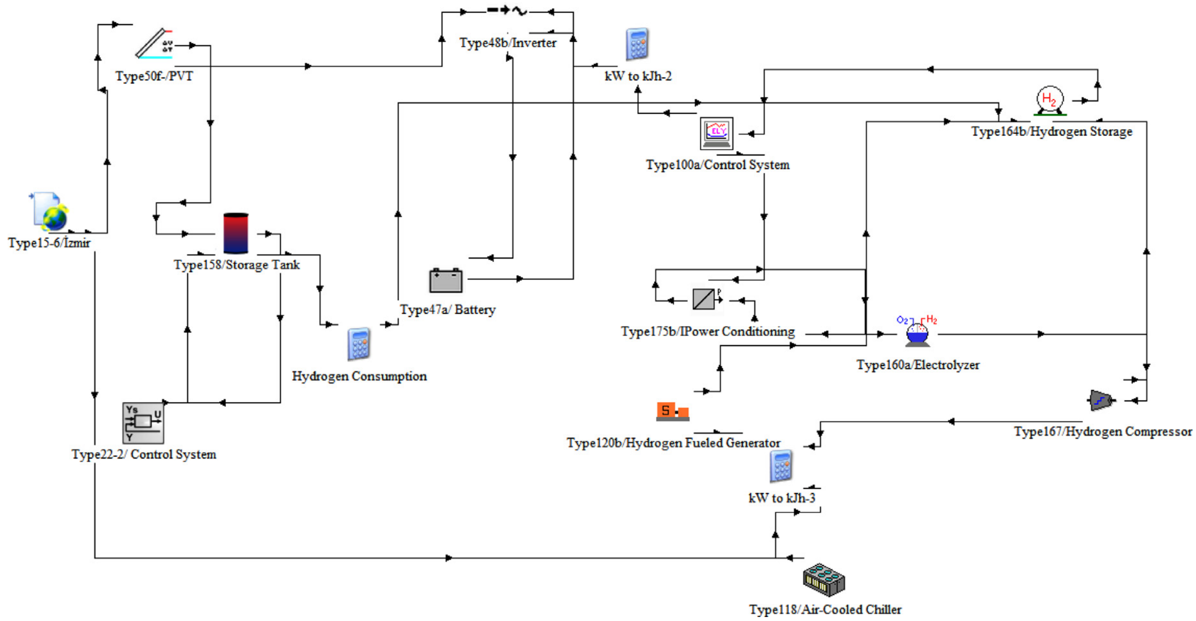

Fig. 1. Schematic of the multigeneration system.

3. Simulation results

In this section, the results of the simulation are presented and shown in Figs. 2–9. Variation of the power at the battery is depicted in Fig. 2. In this figure, the positive values represent the charge status of the battery while the negative values are power from the battery. The results show that the power used from the battery increases at the

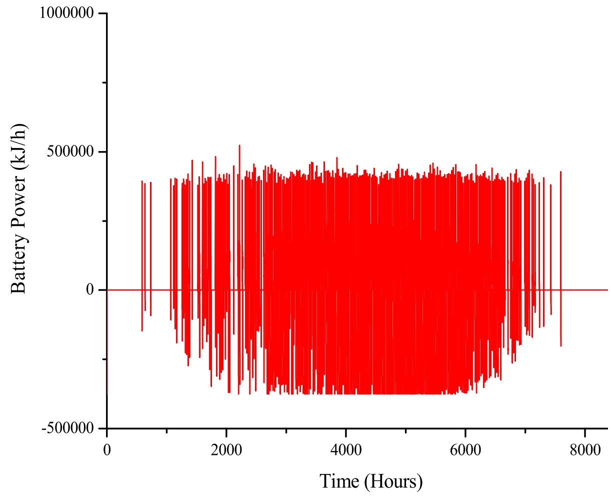

Fig. 2. Variation of the battery power.

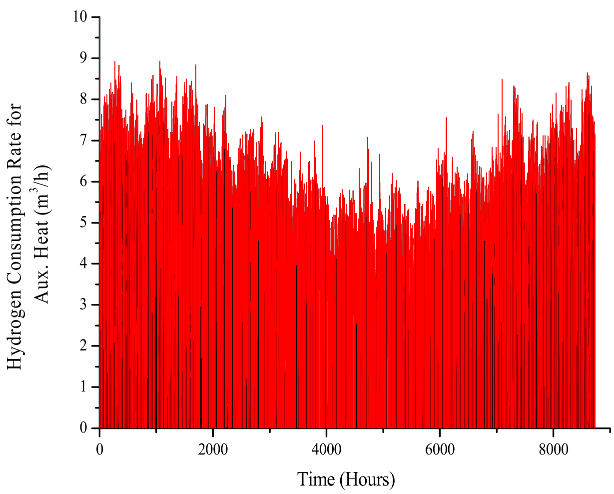

Fig. 3. Variation of the hydrogen consumption rate for aux. heat.

summer times because of operation of chiller. The hydrogen consumption rate for meeting the auxiliary heat can be seen in Fig. 3.

The auxiliary heat is required to keep the temperature of the water exit at the tank as 50 °C. The hydrogen consumption rate decreases at the summer times naturally and nearly reaches 9 m^3/h maximum while the average consumption rate is nearly 7 m^3/h. Fig. 4 indicates the tank exit temperature, which is minimum as 50 °C and regulated by a control system. One can see that the maximum temperature reaches nearly 130 °C at the summer times. The excess heat can be stored by means of the phase change material. Fig. 5 shows variation of the net power output (electricity). The net electricity production decreases at the summer time because the cooling load rises at that time, the volume of the hydrogen increases and consequently the compressor power increases, too. The average net power is about 1063000–1064000 kJ/h. As seen in Fig. 6, variation of the auxiliary heat is similar to that of the hydrogen consumption rate. Naturally, the auxiliary heat is minimum at the summer times. In the winter, the auxiliary heat reaches 1100000 kJ/h and the average rate is about 800 MJ/h. Variation of the COP values is depicted in Fig. 7. For the COP, the time period is considered from April to October because the set temperature is defined as 30 °C and this temperature is reached at these months. According to the results, the minimum COP values are

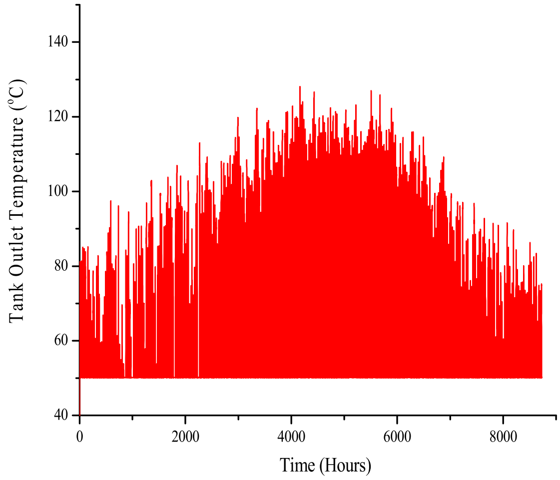

Fig. 4. Variation of tank outlet temperature.

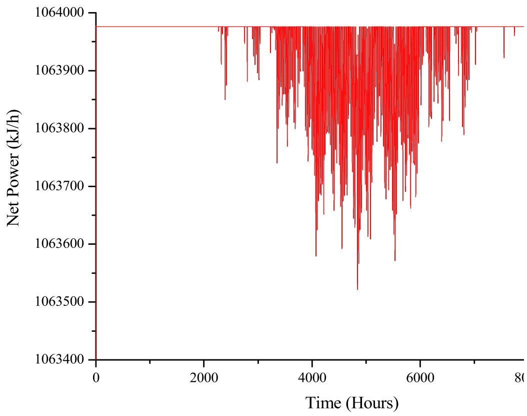

Fig. 5. Variation of the net power.

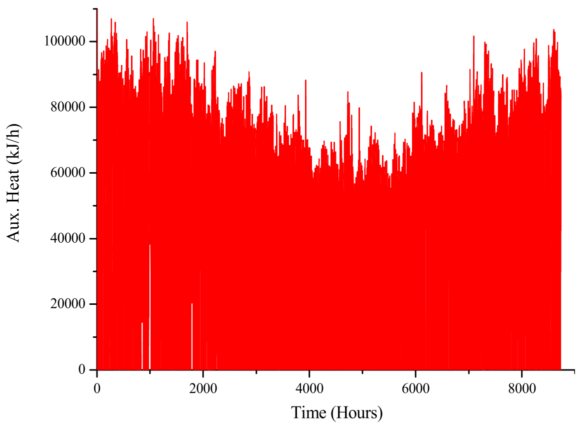

Fig. 6. Variation of the aux. heat.

obtained at the summer times because the cooling load increases at these times. The minimum COP value reaches nearly 7.7, ranging from 7.7 to 10.8. Variation of the hydrogen production rate is illustrated in Fig. 8. The yearly

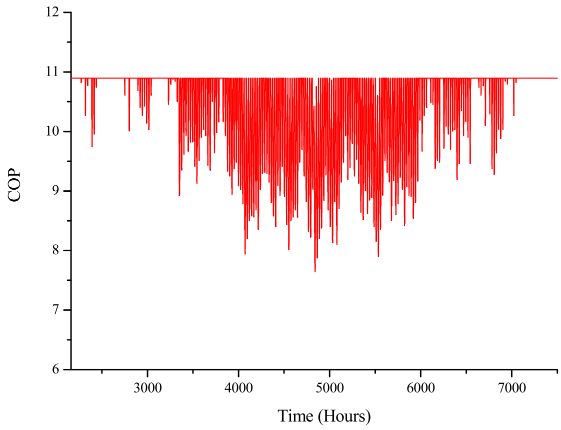

Fig. 7. Variation of COP.

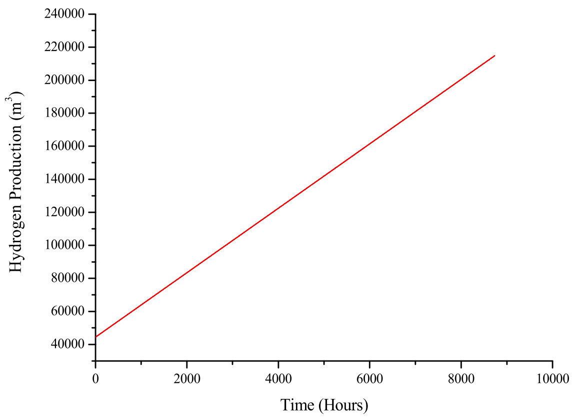

Fig. 8. Variation of the hydrogen produced.

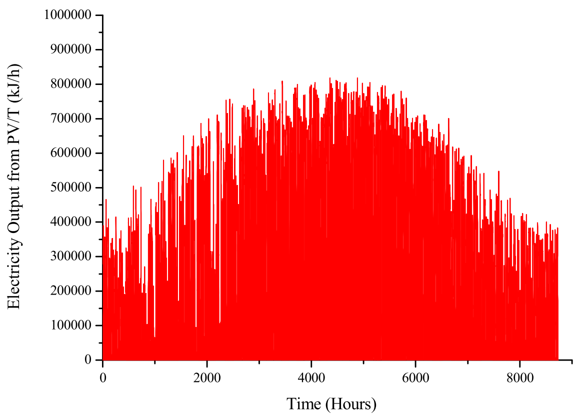

Fig. 9. Electricity output form PV/T panels.

hydrogen production rate reaches 210000 N m^3. Finally, the electricity provided by the PV/T panels can be seen in Fig. 9 where the electricity rate reaches 80000 kJ/h as maximum at the summer times naturally.

4. Conclusions

In this study, a solar fueled multigeneration system was analyzed by TRNSYS 18 over a period of one year. The simulation was performed for the city of Izmir, Turkey. The considered multigeneration system was used to produce heating, cooling, electricity and hydrogen simultaneously from the solar energy. According to the results, 210000 N m^3 hydrogen, 1063000 kJ/h electricity, hot water between 50–130 °C, and 6.67 °C chilled water could be obtained. For a future study, performing the exergetic and economic analyses are recommended.

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