Energy assessment of a grid connected photovoltaic thermal (PV/T) liquid cooling system

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Abstract: *Solar energy has a great potential in Albania. The use of hybrid photovoltaic - thermal (PV/T) systems has shown an impressive progress in recent years. PV/T system can produce electricity and thermal energy simultaneously. In this paper, a 200 W PV/T system is introduced using water as cooling fluid, in order to regulate the temperature increase of the photovoltaic panels. The heat is collected via working fluid in a water tank. This study analyses the energy generation of this experimental setup, and aims to provide some accurate information in future developments and implementation of this technology in Albania. Coupling of PV/T system with heat pumps in buildings to meet the energy requirements could be of great interest for Albania's energy consumers*

Keywords*: ENERGY, PHOTOVOLTAIC, THERMAL, EXPERIMENTAL, ON-GRID*

1. Introduction

Solar energy potential in Albania is of great interest, due to its favorable geographic position in the Mediterranean. The new energy crisis the world is facing only confirms the need to exploit the renewable sources and developing new technologies to resolve the problems with heat and electricity supply. Albania is affected by the energy crisis resulting generally in higher fuel and energy prices. On the other hand this is reflected considerably in the economic burden of a typical Albanian household. Thus, exploitation of solar energy is being seen as a very promising opportunity for the Albanian consumers. Photovoltaic panels have shown to be a promising method for the conversion of solar energy into electricity and heat in a sustainable way [2]. Decrease of photovoltaic panel prices in the last decade has helped in promotion of this energy sector. Globally the PV market growth rate is estimated around 35-40 % per year [3]. This trend of PV market is being observed in Albania as well. Photovoltaic thermal system (PV/T) can produce heat and electricity simultaneously. The heat can be collected from a cooling fluid to a water tank for further use to produce hot water, space heating and cooling. Electricity could be stored or distributed to a grid connected system. Diversification of energy sources is a priority of the Albanian National Energy Strategy. Therefore, it requires full efforts of all the interest groups to embrace this approach. This is greatly enforced due to an increase of heat demand in the residential sector. The application of such systems will reduce the country's dependence on hydro resources, firewood, gas and electricity. In addition, PV/T systems result highly useful in terms of:

- the total efficiency per unit area of a PV/T panel is higher than the sum of the efficiencies of individually PV panels and thermal collectors [4].
- the energy payback of a PV/T system would be 2 years, whereas under equal climate conditions it would be 3.4 for PV system and 4.3 for a thermal collector.

However, a disadvantage of PV/T systems is the influence of PV cell temperature on electrical efficiency [5]. The decrease of the PV temperature shows an increase of the efficiency [6], resulting in necessity to cool down the PV panel. In this experimental study carry out in Tirana, water is used as working fluid to cool down the PV panel. The thermal energy extracted from the photovoltaic panel is collected into a water tank. The thermal efficiency of the PV/T panel is expressed as the ratio of thermal energy extracted by the flowing water with total energy reaching the module. In this paper we are focused on the energy production from a 200 W PV/T panel grid connected. The PV/T module is cooled down using water as working fluid. The experimental investigation takes into account the relevant factors of Albanian climate conditions. A special focus is paid to analyze the weather data collected throughout a year, such as air temperature and solar irradiation.

2. Solar energy situation in Albania

Albania's energy sector is highly dependent on hydro resources. Approximately 99.6 % of the electricity generation is based on hydropower. However, this is only one side of the situation. On the average Albania imports annually about 30 % of the total electricity consumption to meet the country's demand. The diversification of the country's electricity sector is critical, as the current system is almost entirely hydro-based and thus susceptible to climatic variations [7]. The National Energy Strategy stresses on diversification of energy sources with the main focus to increase the share of renewable energy, such as wind and especially solar power. Figure 1 shows the total installed photovoltaic capacity in Albania. From the graph we can figure out the prompt increase of the solar power installation in the last two years. This is a promising step to continue this trend in the near future in order to meet the goals set in the National Energy Strategy. These goals are further supported by the Government introduction of the solar Feed-in-Tariffs promote scheme. According to Ministry of Infrastructure and Energy 88 applications for the construction of the solar PV plants up to 2 MW have been accepted. From those 12 PV plants have been already authorized for construction.

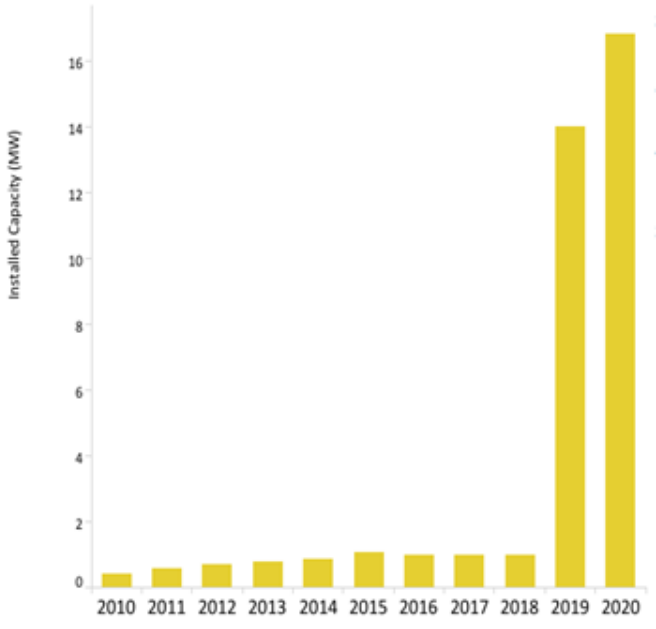

Fig.1 Photovoltaic installed capacity in Albania through the years [8]

Albania has outstanding solar irradiation within most of its territory at more than 1 500 kWh/m^2 annually, particularly in the western part of the country. The country has some of Europe's highest number of sunshine hours per year, presenting significant potential for development of solar PV for power generation and solar thermal for heating purposes. On average, the country has 220 sunshine days, or about 2 700 hours of sunshine per year.

Fig. 2 *Photovoltaic power potential in Albania*

According to IRENA studies on the cost-competitive renewable energy potential in South East Europe, Albania's technical potential for the deployment of solar PV is estimated at 2 378 MW, with production of 3 706 GWh annually [9]. Based on a very optimistic energy scenario half of the above capacity is proposed to be installed by 2030.

3. Case study of a PV/T system

A 200 W photovoltaic/thermal panel has been investigated in this study. The device is installed at the terrace of Polytechnic University of Tirana [10]. In Figure 3 is given a clear view of the panel installation and temperature sensor positioning.

Fig.3 *PV/T panel demonstration with temperature sensor installation*

The temperature measurement and monitoring is critical for the PV/T panel since it has a high influence on panel total efficiency. The panel temperatures were measured at four points using temperature sensors connected as presented in the Figure 4.

Fig.4 *View of the PV/T panel process installation devices*

4. Solar irradiation data

The energy production of PV/T system basically depends on the intensity of the solar irradiation. In this study annually climatic data were collected using the meteorological station at Agriculture University of Tirana. The station offers a wide range of weather data. However, the main focus was air temperature data and solar irradiation. In Figure 5 and Figure 6 are shown the air temperature distribution and solar insolation during the year.

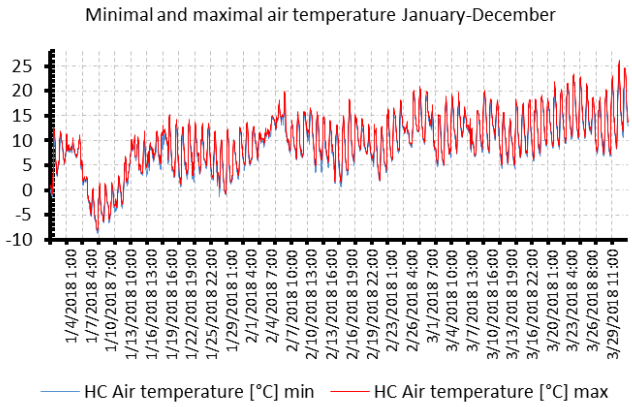

Fig.5 *Ambient temperature variation throughout the year*

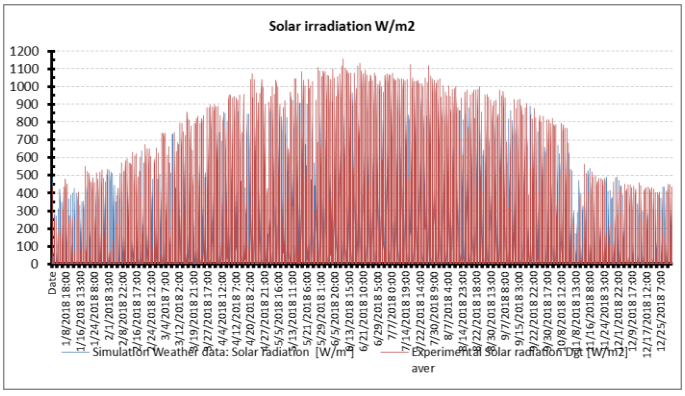

Fig.6 *Experimental and simulated solar irradiation data*

4. Results and Discussions

The 200 W PV/T system is a grid connected panel via a micro inverter. The inverter converts DC power from the solar cell into AC. The output of the PV/T system depends significantly upon air temperature, solar irradiation and wind speed. However, the solar irradiation has the highest influence on the performance of the PV/T

system. Solar irradiation has a significant impact on electrical output. The detailed simulations were run primarily for summer season from June up to September. This period of the year was selected as the solar irradiation increases during this time of the year. The electrical power output of the system for the considered period of the year is presented in Figure 7. The output variation pursues the solar radiation fluctuations.

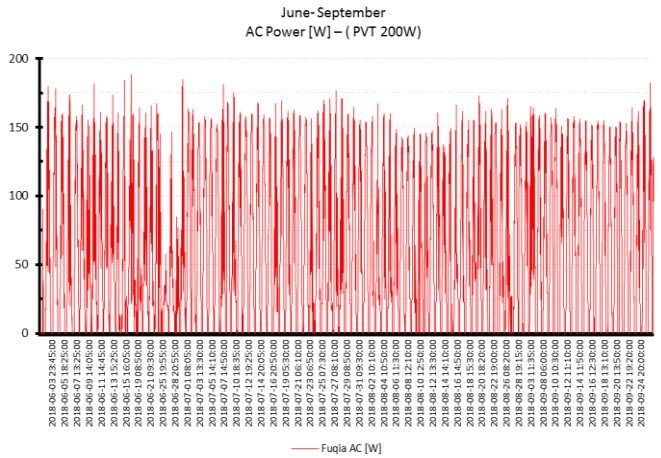

Fig.7 *AC Power output from PV/T panel during June- September*

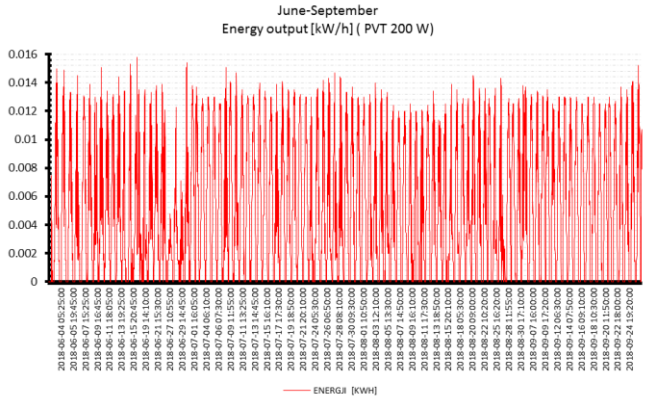

Fig.8 *Energy production of the PV/T panel during June-September*

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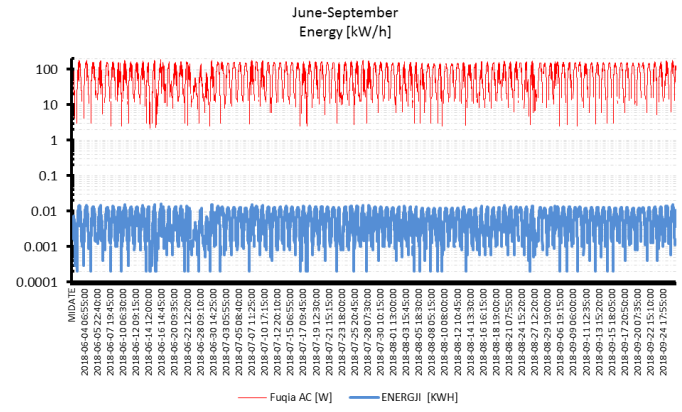

Fig.9 *Power and energy production during the period of experiment*

Total energy generation from the PV/T system is illustrated in Figure 8 and Figure 9. In Figure 9 the energy production is shown with blue color whereas power is presented in red color. Thermal energy production for the observed equals to 665 kWh. On the other hand the electrical energy production of the system accounts to 237 kWh for the time period. Overall electrical energy production is summarized in Figure 9. The results extracted from the experimental investigation in the selected time period show the importance of hybrid PV/T system use especially in climatic conditions comparable with Albania. Simultaneous production of thermal and electrical energy for a typical consumer could increase its energy consumption and further reduce the dependence on other energy sources.

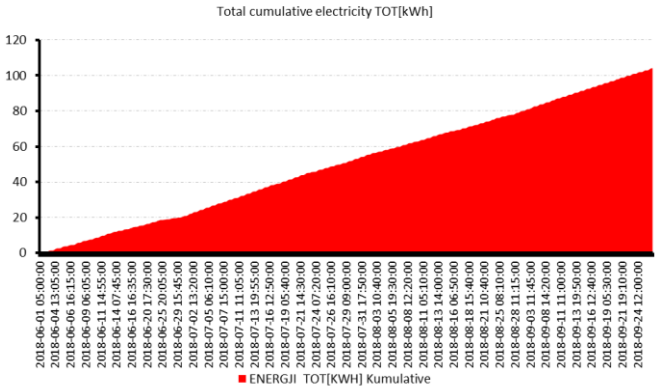

Fig.10 *Cumulative electricity generation*

4. Conclusions

Albania has an outstanding solar energy potential. The country enjoys 220 days of sunshine annually with approximately 2700 hours per year. Photovoltaic plant investments have been increased considerably in the last two years. This is supported by the FiT schemes applied recently by the government. However, the capacity installation remains below the technical potential. A photovoltaic thermal panel was analyzed in this study. Water flows in the panel in order to decrease the temperature which has an influence on energy efficiency. Climatic data have been collected experimentally at the meteorological station placed in Tirana. Energy production of the PV/T system was investigated for the time period June-September of the year. From the analysis results the annual thermal energy production of the PV/T it was found to be 665 kWh. The electricity generation by the PV/T system results about 237 kWh. Thermal energy and electricity production rate will show the way to further discussion on coupling PV/T system with heat pumps in building. The use of PV/T systems in buildings in integration with heat pumps will be the focus of another study in the near future.

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