ICREN-01/2013 February 16-17, 2013 Constantine, Algeria
First International Conference on Renewable Energies and Nanotechnology impact on Medicine and Ecology

Energetic behavior of hybrid water PV/T collectors integrated in Algerian buildings

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Abstract

The integration of active solar components in the building appears as a key element that reduces energetic and environmental impact of the building sector.
However, the market of solar equipments in Algeria remains to this day relatively modest and their distribution is well constrained.
The aim of our work is to study and estimate the production and performance of hybrid water PV/T collectors and to assess the impact of integrating solar devices on energy and environmental balances of existing building.
The results show the positive influence of the integration of this component in the building on the economic and environmental balance. In addition to the electric production, heat productivity obtained is important, the solar fraction is satisfactory, and the efficiency is high.

Keywords: Performance; hybrid water PV/T collectors; heat Productivity; solar fraction; Efficiency.

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1. Introduction

In Algeria, the building sector is the largest consumer of energy with 70 million tones of oil equivalent i.e. 41% of the national production.
The average annual energy consumption in this sector is now close to 400 kWh of primary energy per m² heated. This energy consumption involves the emission of 120 million tones of CO_2, representing 25% of national emissions.
In this context, the use of electric and thermal solar energy in the building sector is a real issue for the environmental, economic and social problems.
Solar energy produces few wastes and generates low emissions of greenhouse gases blamed for global warming. It has also many advantages in terms of energy security since it is an inexhaustible local source.
Thus, the integration of active solar components in the building appears as a key element that reduces the energetic and environmental impact of the building sector.

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However, the market for solar equipments in Algeria remains to this day relatively modest and their distribution is well constrained.

The aim of our work is to study and estimate the production and performance of hybrid water PV/T collector integrated in a building. This facility provides three functions simultaneously. The supply of domestic hot water, the supply of floor heating circuit at low temperature, and the production of electrical energy.

2. Description of hybrid water PV/T collector

A hybrid PV/T collector has two possible applications: either heating the air [1-3], or heating the water [4-6].

In the context of our study we chose a hybrid water PV/T collector. This system can simultaneously provide the electrical and thermal energy. Photovoltaic panels convert sunlight with an efficiency which depends on the used cell; the remainder of absorbed radiation generates an increase in the cell temperature, which negatively affects the yield (0.5% per degree of the cell temperature).

Thus, the use of a fluid flowing through the absorber bonded just below the photovoltaic cells, recovers this heat. Thus reducing the cell temperature, this leads to an increased yield of the photovoltaic panels [7].

Such a system can be schematized in Figure 1.

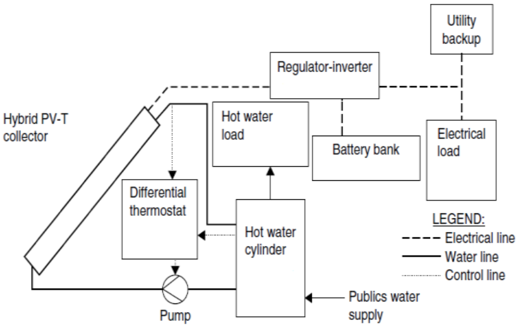

Fig.1. Descriptive scheme of solar hybrid water PV/T collector

3. State of the art of PV/T systems

Researchs on solar collectors are the subject of several works over 25 years [8]. In 2005, a state of the art on the solar PV / T hybrid was developed by Zondag [9-10], based on the report of the European project PV-Catapult [10-11]. Studies were conducted on the geometrical configuration of components and other methods of modeling. Wolf [12] in 1976 analyzed the first hybrid thermal system that includes silicon cells. In 1978 Kern and Russel [13] illustrate the principles water and air solar collectors. In 1982, Hendrie [14] develop a theoretical model of a hybrid PV/T based on correlations related to standard solar collectors. In 1981, Raghuraman [15] presents numerical models to predict the performance of PV/T flat plate water and air solar collectors. Later, in 1985, Cox and Raghuraman [16] developed simulation software to study the performance of hybrid air PV/T, and focusing on the influence of optical properties of glazing on the thermal and electrical efficiencies of these solar components. In 1986, Lalovic et al [17] propose a new type of amorphous a-Si cells transparent as an economic solution for the construction of PV modules [10].

Various experimental and theoretical studies have been conducted, for the development of hybrid PV / T collectors [18], [10].

In 1997, Fujisawa and Tani [19], [10] have designed a hybrid solar water PV/T on a university campus in Tokyo, Japan. The in situ experimental study was conducted to compare the monthly energy performance of solar water PV/T; results were confronted with a PV collector and a water thermal solar collector. The glazed hybrid collector produces as much energy as solar thermal collector. The unglazed solar hybrid produces less heat energy but offers the greatest amount of electrical energy [10].

In 2001, Tripanagnostopoulos [18], [10] studied a hybrid solar collector using two types of heat exchange fluids superposed. Three configurations were designed and experimentally analyzed to assess the behavior of each form of heat production (air or water). In 2003, a solar hybrid water PV/T is investigated under dynamic conditions by Chow [19] which performs a model adapted to the transient thermal simulations. This study is based on the work of Bergene and Lovvik [20], [10].

The aim of our work is to study and estimate the production and performance of hybrid PV/T water collectors and to assess the impact of integrating solar devices on energy and environmental balances of existing building.

The solar system chosen for this study is hybrid water PV/T collector. The thermal energy produced is used for sanitary hot water needs, and for the supply of a floor heating system. The auxiliary operates with natural gas.

4. Technical considerations

The building consists of a single floor with a total area of 200 m^2, and a ceiling height of 2.5 m. the temperature of indoor air for the winter season is 20 °C. The floor heating circuit is powered by water at a temperature of 40 °C (to avoid the risk of burn) with a temperature drop of 10 °C.

The needs for daily domestic hot water are 450 l at a temperature of 45°C (to reduce losses of closure). The storage tank is maintained at a temperature of 60°C (elimination of Legionella bacteria).

Simulation is performed for Constantine region; meteorological data are generated by the software METEONORM. Simulation of the operation of the installation is performed by the software TRNsys 16. The characteristics of the hybrid collector PV/T are defined in the TRNSYS library, the total area is 35 m^2.

5. Results and discussion

5.1. Incident and collected Energy

Figure 2 shows the incident power per unit of area on the solar collector; we note that the highest amount is obtained for the months of June, July and August.

Figure 3 shows the power absorbed by the cell and the absorber plate. The amount absorbed by the cell is very important because the cell has very high optical characteristics. Against, the amount converted into electricity is very low compared to that absorbed; this is due to the performance of the cell which is relatively low.

The amount transferred by conduction to the absorber plate is significant, this amount is less, consequently, to that absorbed in the case of a thermal collector flat plate plane.

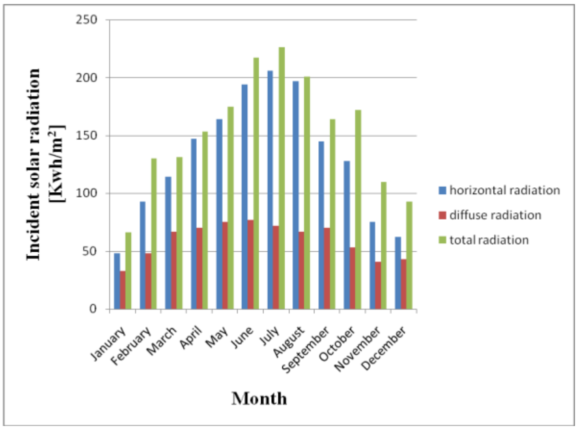

Fig.2. Incident energy on the collector surface

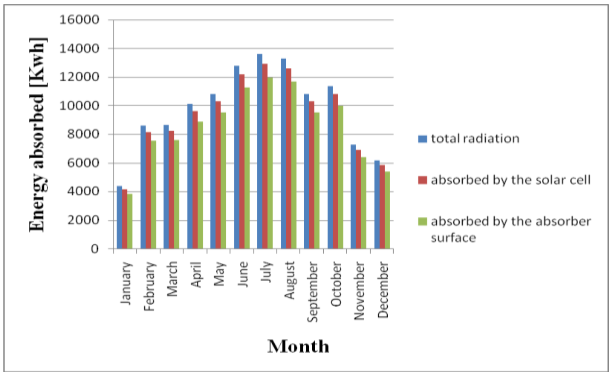

Fig.3. Absorbed energy by collector surface

5.2. Domestic hot water and Heating requirements

Figure 4 reveals easily that requirements for domestic hot water are lower than the heating requirements. High values are observed in the winter period with a slight decrease during the summer. It clearly appears that the heating requirements reaching their maximum values in December and January.

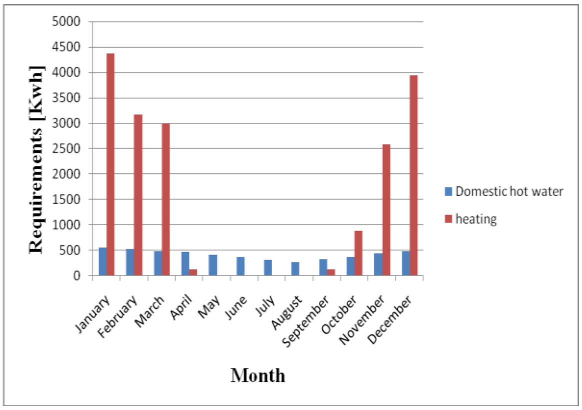

Fig.4. DHW and Heating requirements

5.3. Energy balance

The incident energy, the net requirements and solar gain are shown in Figure 5, which can be noted that the incident energy is much higher than net requirements. While, the auxiliary solar is less than the net requirements in the winter and higher in the summer. This result can be explained by the fact that in the summer heating needs will be void and hot water requirements are lower than the winter one hand, and solar gains are higher in summer than in winter on the other hand. It also appears that the solar gain is low compared to the incident energy. The heat losses in the solar cycle can be in the pipe, and in the two heat exchangers separating the solar cycle and the storage tank on the one hand (the solar cycle is filled with antifreeze to avoid the risk of freezing in the collector field), and between the solar storage tank and booster tank also (to avoid contamination with Legionella bacteria), these losses are estimated at 18%. Another source of losses is the enclosure of the two tanks (solar and auxiliary).

Besides improving the insulation of heat exchangers, pipes and tanks. The technique of low flow rates may be considered. The flow of fluid circulating in the collector is reduced by a factor of 5 to 10, so a flow rate of 7-15 l/(h.m^2) instead of 40 to 70 l/(h.m^2), the application of this technique saves between 18 and 39% depending on the system. This technique coupled with an active stratification tank increases by 8% solar energy collected by solar tank and decrease by 10% the energy supply [21]. This process begins to be applied in solar power systems should be used with caution; however, the low flow rate irrigation provides a heat transfer fluid temperature close to the set temperature, but the temperature of the absorber plate will be higher, which directly affects the temperature of the photovoltaic cell, thus leading to a decrease in photovoltaic panels performance.

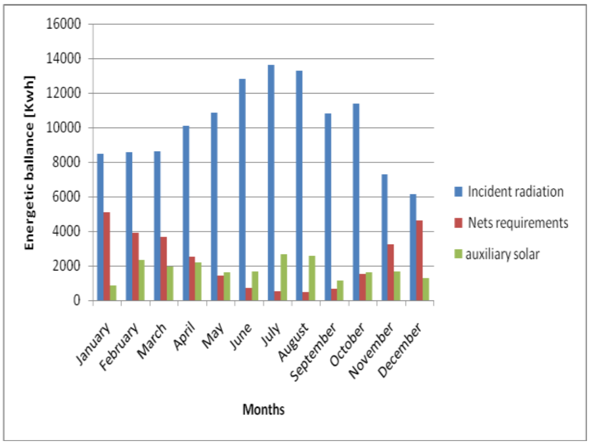

Fig.5. Energy balance of the facility

Figure 6 shows the variation of solar fraction (ratio of useful solar energy recovered and gross requirements) of needs for domestic hot water and heating. We notice that for the case of the domestic hot water, the results are satisfactory in terms of efficiency; the Facility cover between 80 and 100% of domestic hot water needs, the use of auxiliary is greatly reduced. This is due to the fact that the temperature in the collector outlet is close to the set temperature, reducing the use of the auxiliary and limit losses by closure.

While, for the case of heating, the solar fraction has lower values compared to those of domestic hot water. This difference reflects the fact that the irrigation from booster tank is done with a temperature of 60°C, while the heating circuit is supplied with water at a temperature of 40°C (to avoid the risk of burns). This difference of 20°C leads to considerable losses of closure, thus reducing the solar fraction on the one hand, leading to a higher flow rate required to power the heating cycle (high needs compared to the needs of domestic hot water) on the other hand.

If heating circuit is supplied directly from the tank, the influence on the stratification will be harmful, the consumption of the auxiliary increase significantly leading to a decrease in performance of the facility. The use of closure is necessary to reduce the flow mitigated from the tank.

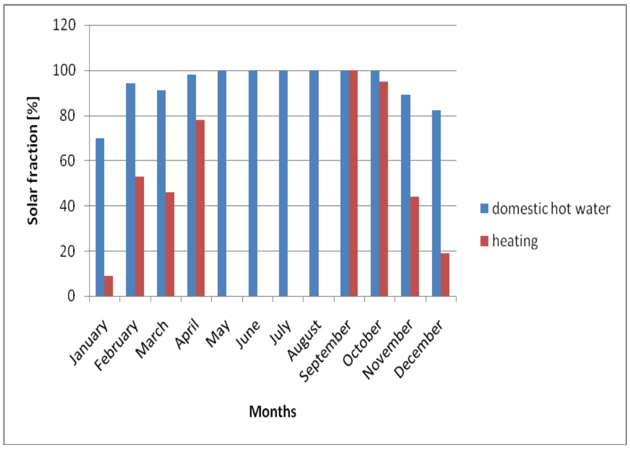

Fig.6. Solar fraction of the solar collector

5.4. System efficiency

Figure 7 illustrate the productivity of the solar collector (ratio of useful solar energy and collector surface). For collective solar installations, the production of facility range between 500 and 600 KWh. m 2.an-1.for our case the value of the productivity is 460 KWh. m 2.an-1. It should be noted that the useful energy recovered by the heat transfer fluid is less in the case of a hybrid collector than in a flat plate collector, from which this difference. This value is close to the range, making this plant productive. This value can be increased by reducing the collector area, which is not possible in our case, since the needs are high.

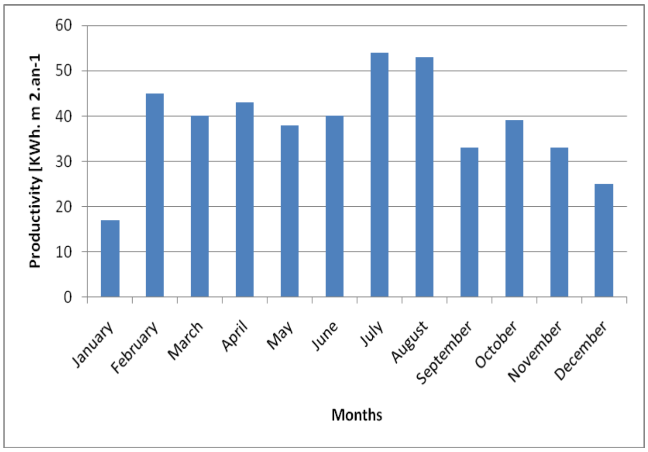

Fig.7. Productivity of the solar collector

Figure 8 shows the system efficiency. Experimentally this parameter is generally less than 30%. In our case the values of the efficiency range from 20 to 35%. Losses in the solar cycle are the main cause of the decrease in the value of efficiency.

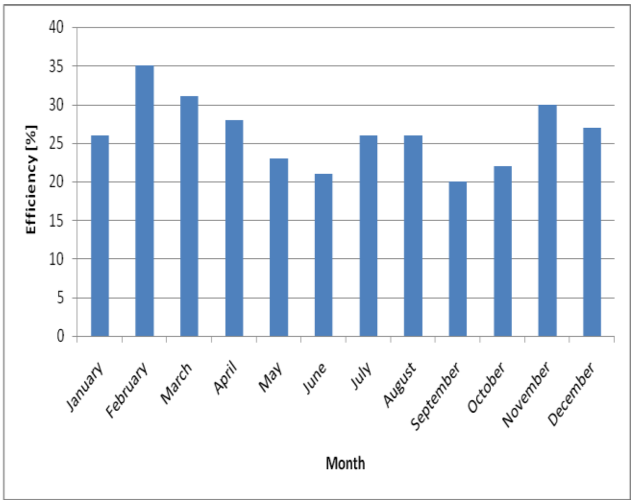

Fig.8. Efficiency of the solar part (without auxiliary)

Figure 9 shows the rate of economy to achieve with this installation. Values vary between 28 and 98%. The highest values are recorded in the summer because the heating requirements are zero.

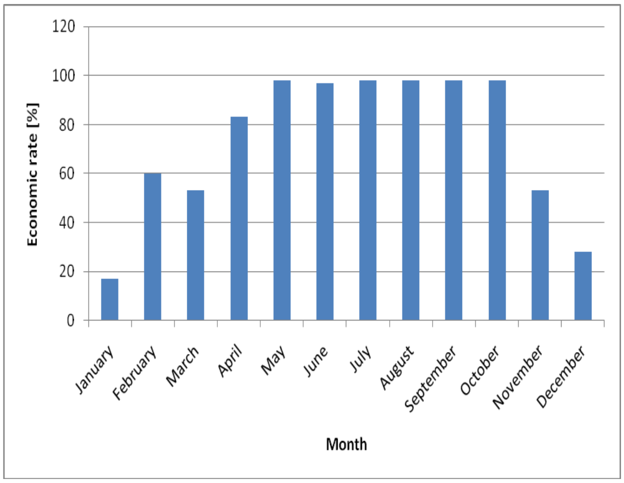

Fig.9. Economy rate achieved

5.5. Environmental balance

Figure 10 shows the amount of CO_2 to avoid by this facility for each month. This quantity depends essentially on the auxiliary used. For our case the auxiliary work with natural gas, so we count 0.28 kg per kWh (natural gas is less polluting). The highest values are recorded in the winter period when the use of auxiliary is larger since the loads are high.

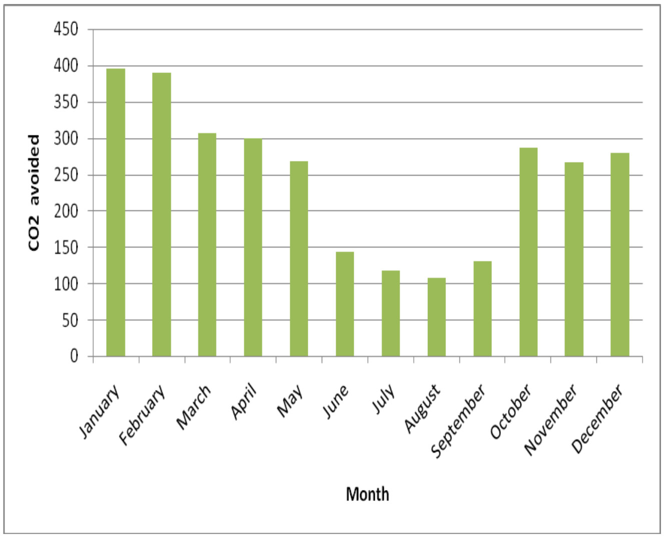

Fig.10. Environmental balance of the installation

6. Conclusion

The main objective of this work is to study and estimate the production and performance of hybrid water PV/T solar collector, and to assess the impact of the integration of solar devices on the energetic and environmental balances of existing buildings.

The results show clearly the importance of using these facilities for covering the energy needs of buildings. Our interest is focused only on thermal performance of this facility, regardless of electrical performance.

These results led us to a number of observations:

- The solar contribution is small compared to the incident energy; this is due to various losses in the solar circuit.
- The solar contribution covers the needs in the summer period characterized by the absence of heating loads, but using the auxiliary in the winter months is required.
- This installation has very high solar fractions of hot water. While for heating, the solar fraction is modest due to the closures losses.
- Productivity and efficiency of this system are high compared with ordinary solar systems.
- The economy rate achieved is very high, also the amount of CO2 emissions avoided is important.

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