ANALYSIS ON INCREASING THE EFFICIENCY OF PHOTOVOLTAIC PANELS BY USING PHASE CHANGE MATERIALS

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ABSTRACT

Photovoltaic technologies ensure the security and diversity of the energy supply without any negative impact on the environment, playing an important role in the production of electricity. At the moment photovoltaic systems oriented to energy performance have a relatively low efficiency, in contrast to the types and technologies of PV, but also the context of their use.

The performance in terms of efficiency and long-term electricity generation depends on the current voltage parameters that differ depending on the temperature of the operating cells Ts.

In the case of optimal operation, respectively at STC considering the global standard radiation G = 1000 W/m2, the operating temperature 25 C and AM = 1.5, the efficiency of the PV panels is maintained near the optimal operation, but under different and real conditions at temperatures and levels. increased radiation the actual power of the PV panel decreases considerably from the nominal operating conditions affecting the electrical efficiency of the PV.

In order to maintain the temperature of the PV cells near the reference temperature, two hybrid systems respectively PV/ PCM can be combined to eliminate the excessive heat behind the PV panel by changing the phases. The study presents the methods of evaluating the contributions of PCM materials on the operation of a PV panels, highlighting a useful methodology that describes the behavior and interaction between the two PV/ PCM systems.

The main advantages are long-term thermal stability, in particular preventing the sudden increase in temperature, low cost of production, low impact on the environment and high efficiency of PV by using a mixed PV / PCM system.

Keywords: Energy efficiency, solar energy, hybrid system, PV/PCM, phase change materials.

INTRODUCTION

In the context of renewable energy sources, solar energy has been dedicated to improving photovoltaic technologies and using a system focused on energy performance, based on

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solar energy. Currently, the solutions of photovoltaic systems have a relatively low efficiency with limited specific conditions.

The concerns regarding the impact on the environment due to the excessive use of fossil fuels make the use of renewable energy sources to be at the forefront of the concerns of all states, regardless of their level of development, given the global energy context, so their use is no longer an alternative form the energy industry through a technological advance that must rapidly reduce carbon emissions with a negative, irreversible impact on the environment.

Given the relevant role of photovoltaic technology in current energy policies, both on a global and European level, a reflection on the innovation process affecting the field of construction is essential. On the way to the implementation of buildings with almost zero energy, the integration of photovoltaic technology into buildings (BIPV) is proving to be very interesting for achieving the energy objectives.

In detail, the use of BIPV modules is constantly improving due to the fact that they can replace almost any conventional building envelope material and can actively contribute to their energy balance. As regards the evaluation of the energy performance of the integrated photovoltaic systems, a complete analysis of the energy performance of the building is required. [1]

This study presents some main innovation trends regarding the increase of the efficiency of PV/ PCM PV panels with an impact on BIPV systems integrated in buildings.

The buildings sector consumed about 30-40% of the total energy produced in developed countries and contributed over 25% to CO2 emissions, especially in the EU, where there are approximately 160 million buildings. [2]

Most being designed and built without taking into account or taking into account passive energy efficiency strategies, as well as integrating SRE (renewable energy sources) to meet active energy demand, in this sense energy can be reduced considerably with efficient solutions. development, to improve significant energy issues. BIPV systems can partially solve the energy requirements in buildings for all types, new residential buildings, industrial buildings, commercial and historical buildings, by introducing PV panels integrated into buildings for the production and storage of electricity.

The annual production volume for all types of solar cells is expected to exceed 100 GW/year by 2020. The future of c-Si solar cells and modules is to break the 25% efficiency barrier. [3]

PHOTOCONVERSION PARAMETERS

In the context of renewable energy sources, solar energy has been dedicated to improving photovoltaic technologies and using a system focused on energy performance, based on solar energy. Currently, the solutions of photovoltaic systems have a relatively low efficiency with limited specific conditions.

The evaluation of a photovoltaic module involves several properties such as, the efficiency of the solar cells and solar radiation, G = 1000 W/m^2, the maximum power Pmax in W, the bandwidth Eg is usually between 1.1 and 1.9 eV, etc. [4] The values reported by solar cell manufacturers are mainly obtained under standard test conditions

(STC) or at operating cell temperature (NOCT). Only a few materials meet these conditions.

Various analyzes of the prototypes or systems applied in the laboratory were performed. In general, the efficiency of the module is low at high temperatures. Many studies are done to solve this fundamental problem, and according to these studies it is shown that the efficiency is increased by the heat absorption behind the PV panels. To create this, such as using air or fluid to create a forced convection, opening alternate inlets between the hot and cold areas of the panel, providing fresh air at the optimum level. In this way, the increase of both the annual energy production and the lifetime of the module can be achieved. Otherwise, the effect due to the increase in temperature has a significant negative effect in order to obtain a higher power and efficiency in the applications of buildings. [2] [5]

The systems for capturing and converting solar energy into electrical and thermal energy, depending on their share in the applications of solar energy whatever the use of the solar source, the installations used must be correlated between the availability of this energy and the load graph of the consumers.

In order to achieve this correlation, the installations must include at least three compulsory components, namely the system of solar collectors, energy accumulators and the auxiliary source of energy.

The temperature of the cell increases with the increase of the solar radiation thus the electrical efficiency of the panel is significantly affected by the temperature of the cell, and the increase of the temperature considerably reduces the efficiency of the panel. [6]

Excessive heating must be extracted from PV to maintain the cell temperature near the maximum efficiency temperature (or reference temperature). Figure 1 illustrates the operating principle of PV and the relationship between the efficiency of the panel and the temperature of a photovoltaic panel. The temperature of the cells in the structure of a photovoltaic panel is an important parameter in terms of the long-term performance of a PV system and in terms of electricity generation, so the temperature of the cells of the PV TS depends on several parameters, such as the thermal properties of the materials, used in the encapsulation and configuration of photovoltaic modules, cell type, location mode, specific climatic conditions, ambient temperature, wind speed, solar radiation from the location, so the efficiency of a photovoltaic module depends on the operating temperature of the cells, the higher the temperature great both during the operation of the performance of a module is influenced in terms of efficiency and generation of electricity. The most common models used to predict the temperature of a PV module are (NOCT), nominal operating cell temperature, and (SNL), Sandia National Laboratory temperature prediction. The performance of a solar cell is evaluated by the standard (STC), standard test condition, at the standard solar radiation value of 1000 W/m^2 and (AM), air mass or air mass, of 1.5 considering the reference temperature of 25 °C. [5]

The direct conversion to electricity is affected by the excessive heat from which energy losses result, so the silicon temperatures must be evaluated, and the temperature of the outer surface both influenced by the thermal exchanges in the structure of the solar cell.

Since the actual field conditions cannot be taken into account with a specific accuracy, this temperature can be helpful as a reference regarding the location of a photovoltaic panel, based on the climatic data media taking into account all aspects, but it can be helpful. regarding the verification of the results obtained with the data of the temperature given by (NOCT), nominal operating cell temperature or the nominal operating temperature of the cell, found in the technical specifications of the PV panel manufacturers, generally T NOCT is given between the values of 48- 56 °C, representing the ideal case for standard global solar radiation G = 1000 W/m^2 and a value of air mass (AM) of 1.5, when compared with the cell reference formula:

$$T_c = T_a + \frac{T_{NOCT}}{800} * G \quad (1)$$

Where,

- T_c is the cell temperature;

- T_a is the surrounding environment's temperature;

- T_{NOCT} the NOCT temperature;

- G is the standard global radiation.

It results in a significant temperature difference obtained by a complex numerical model, thus affecting the efficiency of a PV, which is why the performance of a PV system, depends to a large extent on the climate, the angle of solar incidence, the duration of the sun hours, the outside temperature, but also because of the limitations due to the shading, the character of the structure, etc.

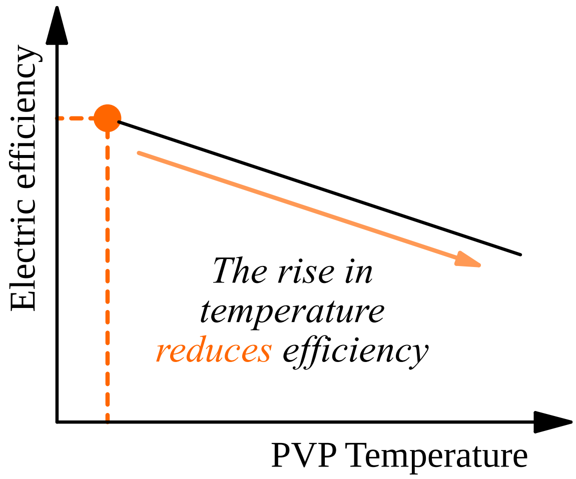

Figure 1. Panel efficiency depending on the temperature.

Of the various definitions, the following correlation is the most widely used to evaluate the efficiency of PV electricity as a function of cell temperature. [7]

$$\eta_{PV} = \eta_{ref}\left[1 - \beta_{PV}\left(T_{PV} - T_{ref}\right)\right] \quad (2)$$

Where, η_{PV} is the efficiency PV, η_{ref} is the reference efficiency, T_{PV} is the PV temperature, T_{ref} is the PV reference temperature.

USING A MIXT PV/PCM SYSTEM

To reduce the temperature and to maintain the temperature of the PV cell near the reference temperature, it is possible to combine: hybrid PV/ thermal systems (natural or forced convection with liquid/ gas environment), heating pipes and PCM phase change materials. At higher solar radiation, PVP/ thermal (PV/T) systems can provide electricity generation and useful heat. PCM can be a simple solution to remove excessive heat by changing phases. The main advantage of the thermal control incorporated by the PCM is that there are no additional components, such as pipes, pumps or fans, and maintenance is not required if the selected PCM has long term thermal stability.

Matter can exist in several distinct forms, called phases, depending on the potential energy of the atomic forces that hold the particles together, the pressure on the substance and the thermal energy of the motion. The phase transition or phase change is used to describe the transitions between the solid, liquid and gaseous states of matter. During a phase transition, certain properties of the environment change are due to temperature, pressure or others. [8, 9]

PCM materials can be defined as materials that can store and release large amounts of energy in the form of heat. Although phase changes can be made between the three phases of the substances (gas, liquid or solid), the most commercially viable condition is that of the liquid state and the solid state. This transformation, from the solid state to the liquid state, is known as the melting-solidification cycle, at a certain temperature range of a selected thermal application. The energy resulting from the phase change or the melting-solidification cycle is absorbed or released as the latent heat of fusion. The heat fluid is absorbed into the material without increasing the temperature. When a PCM material is in the solid phase, it will absorb heat as the outdoor or ambient temperature increases. The PCM temperature will reflect the outside temperature until the PCM melting point is reached. When the outside temperature reaches the melting point of the PCM, it begins to melt, changing from phase, from solid to liquid. During the phase change process, the PCM material will absorb large amounts of heat without nearly any change in temperature. [10]

When a PCM material reaches the melting point, it maintains a constant temperature until all of it melts. During this time the PCM offers a cooling effect.

The time at which the PCM material will provide a cooling effect is determined by the melting enthalpy of the PCM, also called melting heat at latent fusion. The enthalpy varies depending on the PCM material itself, the enthalpy being measured in J / g or kJ / kg. The higher the value, the more PCM will provide a greater cooling effect.

The inverted cycle occurs as the ambient or ambient temperature cools. PCM, now in the liquid phase, can release the heat it absorbs as the outside temperature drops. During this time, the PCM solidifies and provides a heating effect. [11]

In the case (PV/PCM) it is one of the most practical solutions for the thermal management of the panels because the PCM does not require large space on the back of the panels.

The first PV/PCM system was proposed in 1983 by Ames (1983). Almost 20 years after this pioneering invention, research on PV/PCM systems is still in the research phase and there are no clear methods of implementation. A simple diagram for the PV unit incorporated in the PCM is given in Figure 2.

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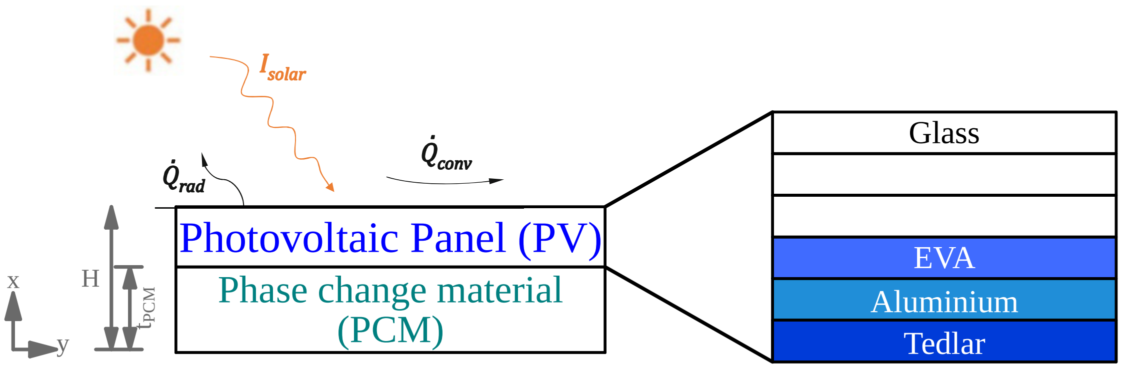

Figure 2. Schematic representation of a PV/PCM Module.

Here a PCM with a thickness of t PCM is located on the back of the panel. During the day, part of the solar radiation is transformed into electricity, and the remaining energy is transformed into heat. During sunny days, a considerable amount of heat is stored in the layers of the panel, and the temperature of the PV cells increases greatly, so the principle of PCM implementation is to store excess heat during the day by melting the PCM, and the stored energy is released during nights by solidifying the PCM. The cyclic characteristic of the PV/PCM must be considered in detail in order to discover the system performance accurately. Partially melting or solidifying PCM may involve investment costs due to excess PCM. In the literature, there are few numerical and experimental works on PV/PCM units that have investigated alternative models to improve system performance. [12]

Hendricks and Van Sark (2011) developed an explicit one-dimensional model to simulate transient thermal conductivity within the PV/PCM system. Two sets of analyzes were performed: constant load and transient load.

The results for the steady state of the solar charge are given in figure 3. Here RT-27 (melting temperature of 27 °C) is used as PCM. For a PV without PCM, the stationary cell temperature can reach 82 °C and 71 °C below 1000 W/m^2 and 750 W/m^2 respectively. The implementation of PCM in the back of the PV prevents the sudden increase of the temperature.

For the configuration that includes PCM, the change in cell temperature over time has three stages: the sensitive heating of the solid PCM, the phase change and the sensitive heating of the liquid PCM. In the first stage of heating, the curves overlap for PV / PCM. When the system temperature reaches the PCM melting point, the excess heat is stored in the PCM, and the PV temperature remains constant. For G = 750 W/m^2, it takes more than 2500s of seconds to get the full PCM melt.

Beyond this point, the PV temperature rises gradually and reaches the temperature at steady state. For a radiation greater than G = 1000 W/m^2 the complete melting time is less than 2000 s. PCM can maintain the PV temperature close to the reference temperature of a PV for longer periods of time. Lowering the PV temperature improves the electrical efficiency of a PV. [13, 14]

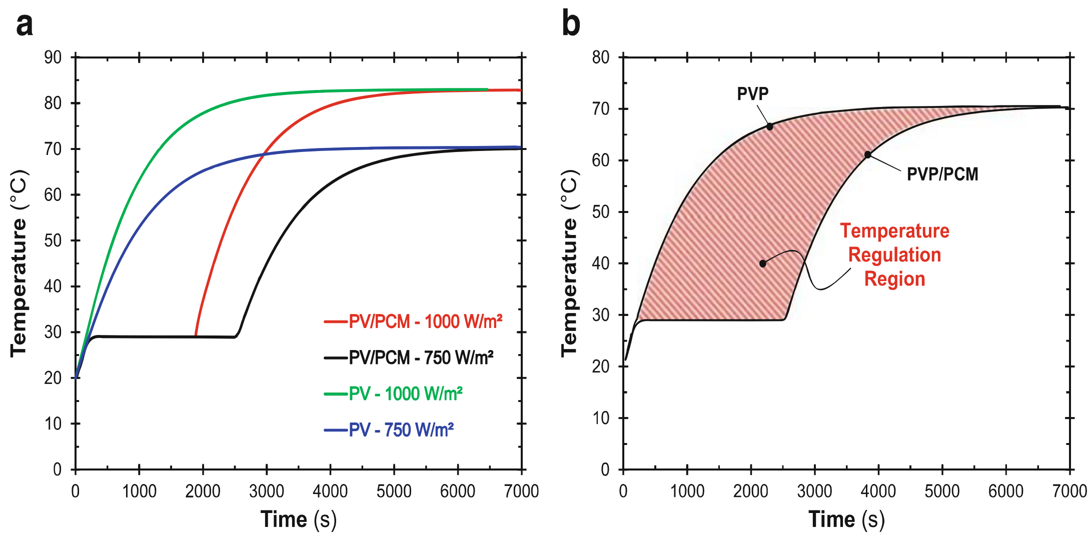

Figure 3. The variations in time for PVP and PVP / PCM units. (a) PCM influence, (b) Thermal region relation.

CONCLUSIONS

The buildings sector currently consumes between 30% and 40% of the total energy produced in the developed countries while contributing over 35% of the total carbon emissions, most of them being built without taking into account passive strategies as well as the integration of renewable energy resources RRE. Given that the technology of solar energy is constantly increasing, adapting continuously to existing solutions is necessary.

Photovoltaic technologies are considered to be growing rapidly, as compared to other renewable sources, as a result of numerous studies on this topic. As part of these studies, integrated photovoltaic energy systems play an important role in the production of electricity. BIPV systems depend directly on electricity generation, linking factors, temperature analysis and localization variables. These are important aspects to study the performance of the system, the selection of photovoltaic technology for the success of any PV energy project. New photovoltaic technologies are available, but not all are used for commercial PV use.

All the obstacles that are still not technical, so it is only a matter of time until the new technologies will be the next generation of electricity and will turn from a concept into a product itself.

Research on opportunities for future systems has been investigated in this article, and the progress of PV/PCM development is still at an early stage, but its impact on new materials and solutions for improving panel efficiency is significant.

The low cost of production, the low impact on the environment and the high efficiency are considered key factors for the implementation in new systems of generation, generation and storage of energy by using PV/PCM.

The PV/PCM heat storage performance needs to be further improved by improving the heat transfer inside the PCM cavity to make PV/PCM models more feasible.

In the literature there are shortcomings regarding the use of macro, micro or nano additives within PCM. The purpose is to provide new concepts about different technologies that use solar energy in interaction with solid structures of buildings using PV technologies.

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