THERMAL REGULATION OF PHOTOVOLTAIC MODULES USING THERMAL ENERGY STORAGE UNITS WITH PCMS

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Abstract *High operating temperatures reduce the performance of commercial polycrystalline silicon photovoltaic (PV) devices by reducing the efficiency of solar to electrical energy conversion in the PV cells. This paper presents the major developments in the construction of a real-scale experimental apparatus to evaluate the efficiency improvement of PV systems by placing a movable thermal energy storage (TES) unit filled with free-form PCMs on the panels' back. In fact, the TES units are intended to control the temperature rise in the PV cells by taking advantage of the thermal regulation potential of PCMs during phase-change. The experimental setup is placed on the flat roof of the ADAI building, located in Coimbra, Portugal. It is composed by four PV modules, separately installed and individually monitored. One of the modules is taken as reference. Different TES units (with several configurations and filled with different PCMs with diverse phase-change temperature ranges) will be added to the other PV modules. The time evolution of the temperature of the PV modules will be compared with each other to measure the effective thermal regulation effect of the TES units. A data acquisition system for current, voltage and power monitoring and recording was developed with a LabVIEW™ program interface in order to compare the efficiency of the different PV/PCM systems throughout the day. A mobile peak power and I-V-curve measurement device for PV modules will be used to measure the short circuit current (I_{SC}) and the open circuit voltage (V_{OC}) of the PV panels. While I_{SC} mostly depends on solar radiation, the V_{OC}-value mainly depends on the temperature of the PV cells. Therefore, the time evolution of the V_{OC}-value will be measured in order to determine the impact of PCMs in the efficiency improvement of the PV modules.*

1. FRAMEWORK

Phase change materials (PCMs) undergo melting/solidification at a nearly constant temperature, becoming very suitable for thermal management and TES applications. As reviewed by Soares *et al.* [1], the incorporation of PCMs in buildings can contribute to: improve thermal performance of buildings' envelope; increase indoor thermal comfort; decrease air-conditioning power needed; reduce heating and cooling demands, fossil fuels consumption and emission of ozone depleting gases; take advantage of renewables, and save money during the operational phase. Previous works have experimentally shown that the containment of PCMs in aluminium capsules with fins is a good technique to simultaneously solve the problem of liquid-leakage and improve the heat transfer to the PCM-bulk [2,3]. These TES units can be included in the design of new TES systems such as bricks and shutters. As proposed by many authors [4-7], they can also be used for the thermal management of PV systems, which can contribute to foster new PV/PCM systems and building-integrated photovoltaics (BIPV).

Polycrystalline silicon PV devices may experience high operating temperatures, which reduces the efficiency of solar to electrical energy conversion in the PV cells. Several strategies have been proposed to mitigate overheating of PV systems and to prevent resulting power loss, including natural or forced air ventilation, hydraulic or refrigerant cooling and the use of PCMs [8,9]. Moreover, as shown in Figure 1, the actual global installed solar PV capacity makes a significant contribution to renewable energy sources, growing at faster rates than wind capacity in the last years. Therefore, the development of technologies that can be used to improve the energy performance of PV systems is seen as an active area of research.

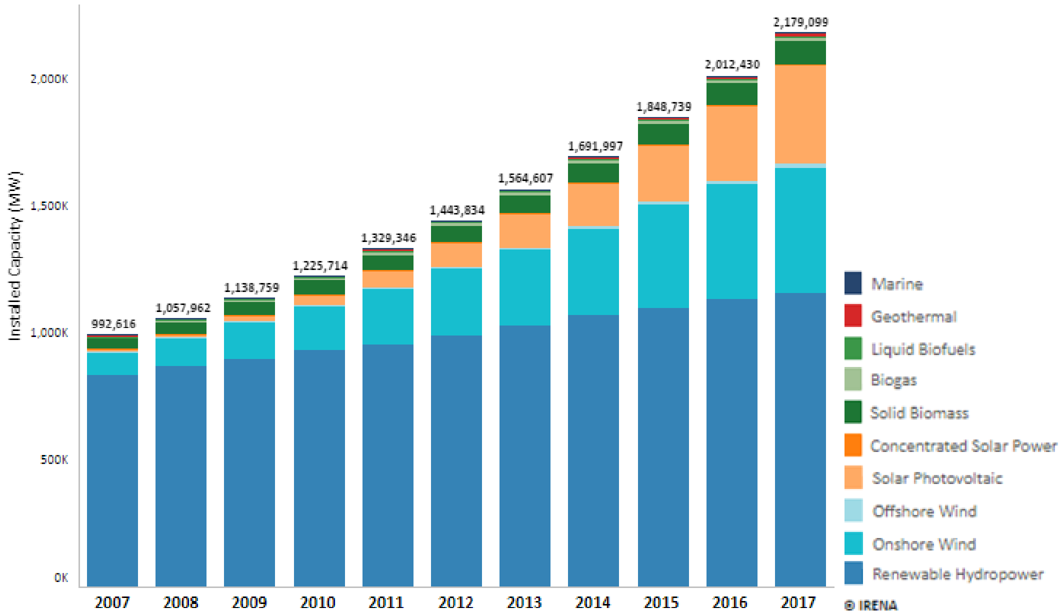

Figure 1. Worldwide renewable energy installed capacity trends [10].

This work aims to develop a real-scale experimental apparatus (*i*) to evaluate the efficiency improvement of PV/PCM systems incorporating TES units filled with free-form PCMs; (*ii*) to carry out an experimental parametric study to evaluate the influence of different configurations of the TES unit (horizontal and vertical oriented cavities) and the impact of different phase-change temperature ranges of the PCM – the PCMs RT22HC, RT25HC and RT28HC from RUBITHERM® will be used; and (*iii*) to provide reliable experimental results for numerical validation purposes.

2. METHODOLOGY

Figure 2 shows a sketch of the experimental setup developed (with the main equipments and instruments used) to evaluate the behaviour of a set of four Risen RSM60-6-250P PV modules under various test conditions. The PV modules are separately installed and individually monitored. One of the modules shall be taken as reference for every experiments. Different TES units made of aluminium and with several configurations will be filled with different free-form PCMs (Figure 3). The term "free-form" means that the metallic unit is the only way of containment in order to avoid liquid leakage. The organic PCMs RT22HC, RT25HC and RT28HC from RUBITHERM® will be used. The respective melting-peak temperature of these PCMs is 22ºC, 25ºC and 28ºC. Since these materials show a volume expansion of about 12.5% during phase-change, a small air space was left on the top of each cavity. The time evolution of the temperature of the PV modules will be compared with each other to measure the effective thermal regulation effect of the TES units. The current, voltage and power of each PV module will also be recorded during the experiments. The monitoring and data acquisition system is composed by a LabVIEW™ developed program; the PicoLog® data acquisition program; seven Pico® USB TC-08 thermocouple data loggers; 126 thermocouples (K-type) properly calibrated; 12 flexible heat flux sensors; a pyranometer to measure the solar irradiance; and a Davis Instruments Vantage Pro2™ weather station for measuring the weather conditions. The electrical setup has four voltage dividers and four 0.05Ω resistors for the acquisition of voltage and current data, respectively; and four DC/AC microinverter. A PVPM2540C mobile peak power and a *I*-*V*-curve measurement device for PV modules will be used to measure the I_{SC} and the V_{OC} values of the PV panels. Firstly, these values will be measured during a characteristic day, and prior to integrating the TES units on the panels' backs, to assure consistency in the panels. Afterwards, the time evolution of these values during a characteristic day will be measured in order to determine the impact of the TES units (thermal regulation effect) in the efficiency improvement of the PV modules.

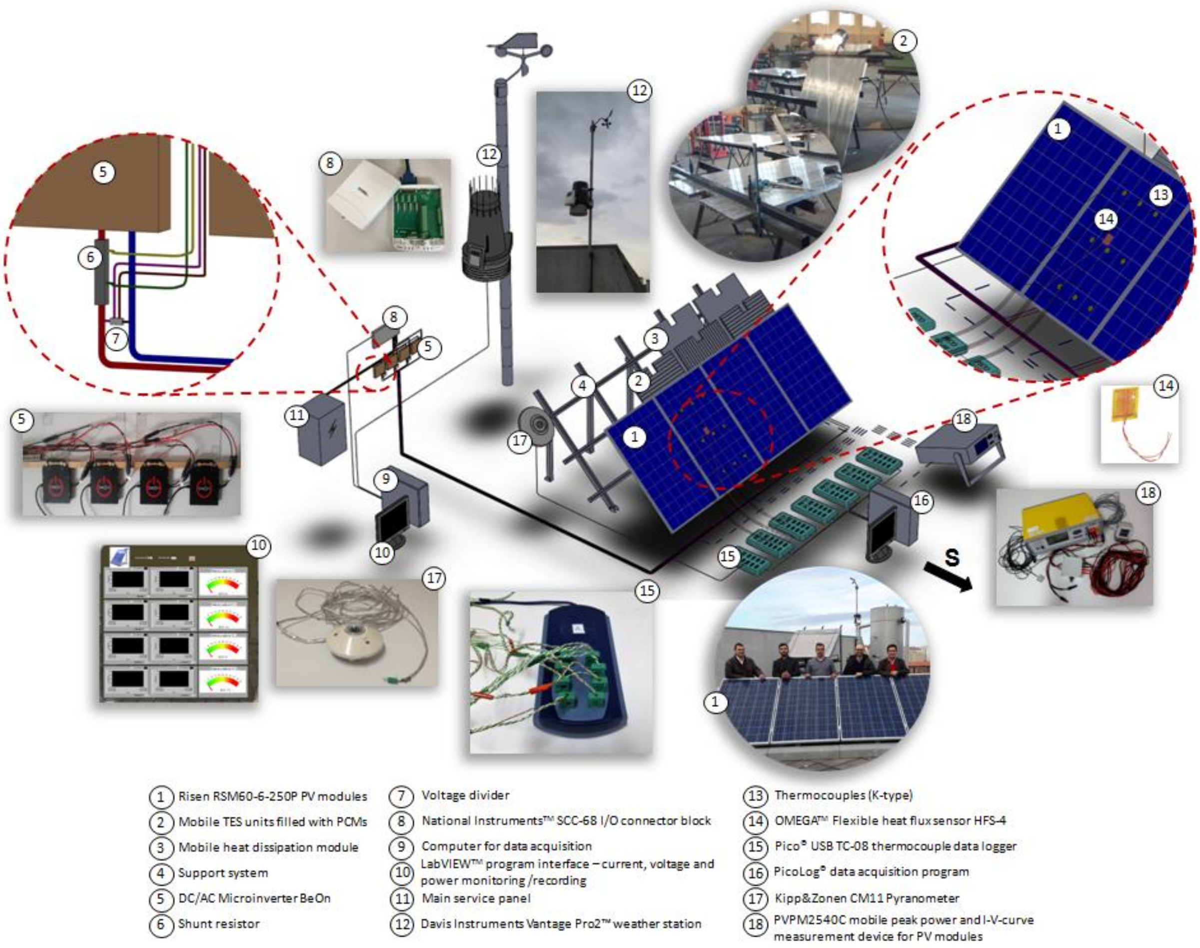

Figure 2. Sketch of the experimental setup with the main equipments/instruments used.

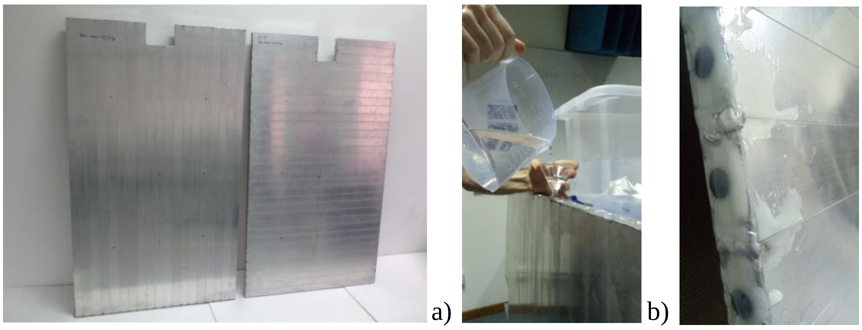

Figure 3. a) Aluminium units with vertical and horizontal cavities; b) filling the cavities with the liquid PCM; c) the cavities are sealed with rubber caps and epoxy glue to prevent leakage of liquid material.

3. PRELIMINARY RESULTS

The experimental apparatus is presently assembled and ready for the execution of experiments during the Summer of 2018.

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