DIRECT SUNLIGHT FACILITY FOR TESTING AND RESEARCH IN HCPV

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1. Introduction

The research activity aimed at optimizing the performances of HCPV modules requires to perform a wide variety of measurements, characterizations, and ageing tests of individual components and assembled systems. Such activities can largely benefit from the availability of the real sunlight inside a laboratory. In the framework of the FAE "Fotovoltaico ad Alta Efficienza" (FAE) project (PO FESR Sicilia 2007/2013 4.1.1.1)[1], we have set-up a low cost heliostat that provides a large size beam for testing both refractive and reflective concentrators, cells, as well as different materials and components for HCPV applications. Beside the heliostat, the set-up testing facility is equipped with: an optical bench for mounting and aligning the CPV module components; an electronic bench to characterize the I-V curves of high efficiency multi-junction cells operated at high sunlight concentration; a system to characterize heat-sinks performances; a system to circulate a fluid in the heat-sink at controlled temperature and flow-rate; a system to thermally cycle PV cells at fast rate; and a climatic chamber with large test volume (≈ 500 liters) to test fully assembled CPV modules.

2. Work Description

The heliostat, aimed to provide a large size (> 60 cm diameter) sunbeam, consists of a commercially available Sun-mirror device modified by the addition of a large format high flatness extra clear glass mirror (with very low content of iron), coated with silver on the back side. The mirror has a high reflectivity over the full solar spectrum including ultraviolet, visible and infrared bands. The system is arranged to test both refractive (e.g. Fresnell lenses) and reflective optics. The adopted configuration, constrained by the available laboratory space and building location, has been optimized to operate efficiently mainly in the a.m. hours with a beam flux up to 90% of the direct sunlight.. In order to properly characterize the efficiency of CPV modules based on multi-junction cells it is crucial to know the flux and spectral distribution of the test beam. For these purposes, the beam flux in the laboratory is continuously monitored by the use of a pyroheliometer, which allows to normalize the small flux change in between two subsequent tracking corrections occurring approximately every 60 s. The spectral distribution is characterized by use of high band-pass optical filters with edges at 630 nm and 900 nm that are very close to the band gaps of InGaP and InGaAs, respectively. By use of a test parabolic reflecting mirrors, we have been able to perform measurement with > 2000 suns. A critical parameter in the operation of CPV modules is the temperature of the cell which has to dissipate a large fraction of the concentrated power towards an efficient heat-sink. We have set-up a testing equipment to characterize the performance of heat-sinks as a function of heat power, inlet fluid temperature, flow-rate, and pressure drop. Cells are operated under sun concentration with a circulating fluid at controlled temperature and flow-rate. The use of this equipment allows to evaluate hybrid systems which recover part of the thermal energy dissipated onto the heat-sink. The CPV testing facility is also equipped with an electronic load used to analyze I-V curves, controlled by a computer which is also interfaced with PT100 thermometers mounted on the cell and the heat-sink, as well as with the pyroheliometer. An I-V curve can be acquired in 10 ms, with a maximum measured current of 60 A. Finally, a climatic chamber Angelantoni model HYGROS - 50 with a test volume of 800mm × 700mm × 892mm, has been refurbished and its control interface upgraded to perform environmental tests on fully assembled CPV modules. In order to test ageing of cells due to differential thermal expansion coefficients of the various components (e.g. substrate, multi-junction semiconductors, electrodes, encapsulants, frustum, etc) a dedicated equipment has been built to run a large number of fast thermal cycles in the range 0÷150 °C. A fluid with high boiling point is stored in two separate cold and hot reservoirs. By use of remotely controlled fluid pumps and electro-valves, the cold and hot fluid is alternatingly circulated inside a copper test plate hosting up to 8 cells. The test plate is switched between the cold and hot temperatures at a maximum rate of one cycle per minute to allow the cells to reach thermal equilibrium each time.

References

[1] FAE: A CPV-CHP SYSTEM AT CONCENTRATION 2000 TO PRODUCE ELECTRIC POWER AND HEAT presented in this conference CPV-10.