INITIAL FIELD TESTING OF CONCENTRATING SOLAR PHOTOVOLTAIC (CSPV) THERMAL HYBRID SOLAR ENERGY GENERATOR UTILIZING LARGE APERTURE PARABOLIC TROUGH AND SPECTRUM SELECTIVE MIRRORS

Jonathan R. Raush
Ph.D. Candidate

Faculty Advisor: Dr. Shengmin Guo

ABSTRACT

Initial field testing has been completed of a test unit of the MH Solar Concentrating Solar Photovoltaic (CSPV) system. The CSPV unit is a retrofit system for use with a parabolic trough type concentrating solar power (CSP) thermal solar collector which redirects a portion of the incident solar radiation spectrum to a PV module while allowing normal operation of the thermal system to continue. The system was tested at the UL Lafayette Solar Energy Laboratory utilizing the existing Large Aperture Trough (LAT) test field. The dichroic cold mirror reflected solar radiation of between 500 and 1000 nm to vertical multi junction (VMJ) silicon PV cells which provided high efficiency operation under a concentration ratio of 30. The testing produced a PV module efficiency of 30% across the portion of the spectrum which was redirected, while the thermal efficiency was reduced by only about 9 percentage points, resulting in an overall efficiency increase of the power plant. The total power output of the power plant could therefore be increased through utilization of the hybrid configuration.

For solar energy technologies to reach full market penetration, continued improvements must be made in order to lower the levelized cost of electricity (LCOE) of primary solar energy technologies, including both photovoltaics (PV) and concentrating solar thermal power (CSP). According to the U.S. Department of Energy SunShot Initiative, which proposes a goal of $0.06/kWh LCOE for solar energy technologies by the year 2020, a market share of 14% of total U.S. electric production could be reached by 2030 [1]. In an effort to improve overall plant efficiency to drive down LCOE, significant interest in hybrid solar collector systems has been generated. Differing techniques for hybrid systems have been investigated which combine PV and photo-thermal (PT) energy conversion in parallel by incorporating spectral beam splitting technologies [2]. PT energy conversion processes tend to convert solar radiation to thermal energy at efficiencies relatively constant over the solar spectrum. Beam-splitting allows the portion of the spectrum that is most advantageous for the PV cell, which is wavelength dependent, to be directed to the cell, while the remaining spectrum can proceed to a thermal receiver for conversion to thermal energy, as in Figure 1 [3].

Recent testing has been completed of a CSPV solar energy generator at the UL Lafayette Solar Technology Applied Research and Testing (START) Center, on an operating solar thermal power plant. The CSPV module was installed on a 7.3 aperture trough oriented in a North-South configuration, while tracking from East to West. The thermal receiver was the Schott PTR70, 70 mm heat collection element (HCE) tube. Figures 2 and 3 depict the installation of the test unit and the START Center. The parabolic trough CSPV system produces thermal energy by way of traditional concentrating solar power through the existing heat collection element (HCE) tubes, while producing electricity directly from a concentrating PV system operating in parallel. This is accomplished by splitting the solar radiation beam by way of a dichroic “cold mirror”, filtering out the spectrum of wavelengths (500-1000 nm) that are most efficiently converted to electricity by the silicon PV cells and redirecting the radiation onto the PV module, while leaving the remaining ultraviolet and infrared light to pass to the existing thermal receiver of the parabolic trough (Figure 4). A depiction of the cold mirror operation in Figure 4 demonstrates the beam splitting. This type of hybrid system, utilizing a single axis linear concentrator, a solar radiation beam splitter, and linear thermal receiver has been proposed previously [5]. However, the current system applies a VMJ solar cell which
makes it uniquely suitable for this application. The VMJ cell is produced by stacking and bonding together a large number of P-N diffused silicon wafers, which are then cut vertically into thin VMJ solar cells in series allowing high voltage operation. Also, VMJ solar cell’s performance is reduced by only 3% for every 10°C operation above its standard test conditions [6]. This performance loss is not as dramatic as conventional silicon solar cells, which can lose 5% in performance for every 10°C temperature rise [4].

The VMJ cells were placed linearly in parallel with the HCE tube and with rotatable mirrors installed to either supply all of the incident solar radiation to the HCE tube while stowed, or to provide a selected spectrum of radiation to the cells while deployed. The solar cells are passively cooled by use of a heat sink to ambient temperature.

Test results of the CSPV system are depicted in Figure 8. The combination of the CPV performance data and the thermal performance data show an overall increase in system efficiency from the base thermal only case. Based on this first test unit, an overall system solar-to-electric efficiency improvement from 21.7 percent to 22.5 percent was achieved. Future refinements to the prototype design are expected to further improve the efficiency.

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REFERENCES