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Design construction and analysis of solar ridge concentrator photovoltaic (PV) system to improve battery charging performance

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ABSTRACT

A ridge concentrator photovoltaic system for a 10 W multi-crystalline solar panel was designed with the concentration ratios of 1X and 2X. The ray tracing model of ridge concentrator photovoltaic system was carried out using Trace-Pro simulation. The optimum tilt angle for the concentrator PV system throughout the year was computed. The electrical parameters of the 3 panels were analyzed. The effect of temperature on the electrical performance of the panel was also studied. The reduction of voltage due to increasing panel temperature was managed by MPES type Charge controller. Glass reflector with reflectivity 0.95 was chosen as the ridge wall for the concentrator system. The maximum power outputs for the 1X and 2X panel reached were 9 W and 10.5 W with glass reflector. The percentage of power improvement for 1X and 2X concentrations were 22.3% and 45.8% respectively. The 2X concentrated panel connected battery takes lower time to charge compared with normal panel connected battery.

1. Introduction

The cost of solar PV cells is high, primarily due to the material synthesizing processes used in manufacturing of solar cells. This hampers the widespread use of the solar photovoltaic, as an alternative to the non-renewable energy generation, when compared to other renewable energy sources in the modern energy production scenario. One of the attractive way to bring down the cost factor is to concentrate light on solar cells, reducing the required cell area for a given output power (Solanki., 2010; Yupeng et al., 2015; Butler et al., 2011). This concentration can be achieved by using linear Glass mirrors, lenses, holographic and other kind of optical reflectors which are very cheap compared to the solar grade silicon material (Masato and Toshiro, 2005; Chi-Feng et al., 2010; Yun et al., 2014; Maria et al., 2004; Chemisana et al., 2013). However High Concentration Photovoltaic (HCPV) which concentrates sun's energy to 100–1000X are yet not considered to be very cost effective due to various parameters like tracking, optics, cooling, complex design, etc. (Yuan-Hsiang and Tian-Shiang, 2014; Fabienne et al., 2015; Rustu and Ali, 2012; Gabriel., 2012). Hence the usage of low concentrators like V-trough, ridge concentrator is deemed to be more viable. As it employs low concentration it avoids complexities like tracking, high maintenance, etc. (Liu and Tang, 2010; Sangani and Solanki, 2007; Najla et al. 2011). In this study a linear ridge concentrator prototype is designed and analyzed with various concentration ratio and the electrical characteristics are analyzed in relation to the temperature of the system. The study was contacted with one axis North-south tracking mechanism (Mosalam et al., 1995; Libra and Poulek, 2000; Runsheng and Xinyue, 2011; Tao et al., 2011; Farong et al., 2014; Hossein et al., 2009). The additional radiation falling on the solar panel due to Ridge wall will increase the panel power output and temperature. This in turn decreases the efficiency of the panel after certain radiation. So proper heat dissipation from panel is essential for the concentrator system to improve the power output and life of the panel (Ze-Dong et al., 2014; Solanki et al., 2008; Zheng et al., 2011; Steven et al., 2012).For concentrator photovoltaic system, the panel voltage is mostly affected when compared with current (Hui et al., 2015; Eduardo and Fernández, 2015). The working performance and circumstances of high-temperature solar receiver has been greatly improved by minimum trough width. It has a significant influence on the maximum inlet width and the minimum flat reflection mirror width of the system. The receiver being put in the trough improves the heat emission circumstances around the receiver. So the biggest economic benefit can be achieved (Clifford and Brian 2014; Ming et al., 2011).

2. Block diagram of system

In ridge concentrator system the individual panel was connected to battery through MPES charge controller. The reduction of voltage was due to increase in panel temperature. This draw

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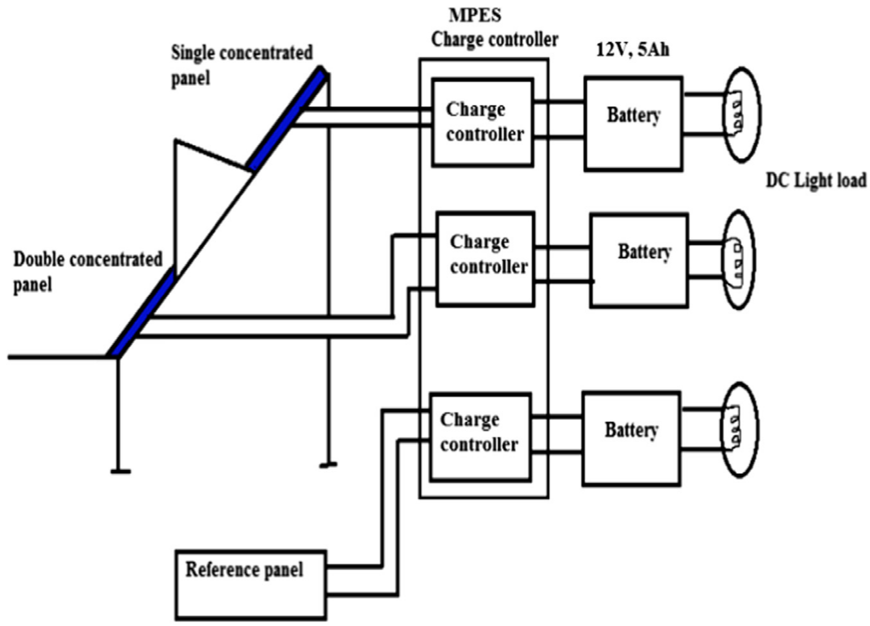

Fig. 1. Block diagram of ridge concentrator system with MPES charge controller.

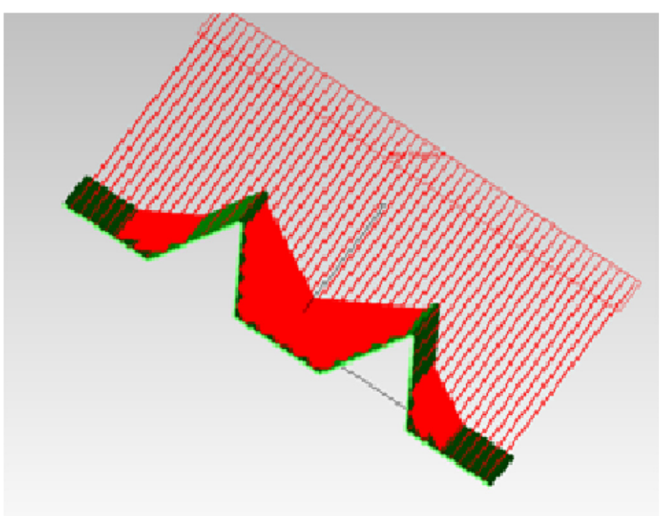

Fig. 2. Ray tracing model for ridge concentrator system.

back was overcome by the Maximum Power Extraction System type charge controller (MPES) Fig. 1. The conventional charge controller acts like a preventer for the battery whereas in this type of charge controller additional voltage booster is incorporated within the circuit. So whenever the voltage was decreased it will boost the voltage and then send it to the charge controller. If we have voltage above the 12 V it will directly charge the battery through the charge controller this separation was carried out by the DPDT relay mechanism.

3. Ray tracing model

For the simulation the reflector and panel are assumed as perfect reflector and absorber. Source was considered as lambertian source and this thus defined as grid source. Angular

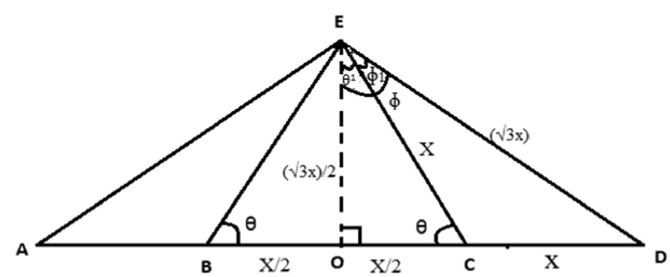

Fig. 3. Mathematical model for ridge concentrator system. OE – Height of the reflector from axis, OC – Length of reflector, CD – length of panel, DE- length of reflected ray, θ=Trough angle.

distribution was taken to be uniform and solar half angle was not considered. The wave length is considered for global radiation and was optimized as 0.5461 μm. The refractive index is assumed as one. The ray tracing pattern was shown in Fig. 2.

4. Mathematical modeling for trough angle

Height of the reflector to be mounted (OE) with respect to axis shown in Fig. 3

$$\Delta OCE,\ \ OE = \frac{X\sqrt{3}}{2}$$

For trough angle (θ), $\sin\ \theta = \frac{\left[\frac{X\sqrt{3}}{2}\right]}{X}$

Δ ODE, $(DE)^2 = (OC + CD)^2 + (OE)^2$

So the length of the reflected ray $= X\sqrt{3}$

$$\cos\ \varphi = \frac{\left[\frac{X\sqrt{3}}{2}\right]}{X\sqrt{3}}$$

Reflected angle $\phi_1 = \phi - \theta_1$