EFFECT OF TEMPERATURE ON THE PHOTOVOLTAIC CHARACTERISTICS OF POLYCRYSTALLINE SILICON SOLAR CELLS AT HAMBANTOTA SOLAR POWER PLANT

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ABSTRACT

As a renewable energy source, solar power is becoming one of the most important promising energy sources in the modern era. In past two decades, many researches on operational principle of photovoltaic (PV) devices and their power generation efficiencies have greatly increased over the world. And also, there is an enormous trend towards the field of solar energies in Sri Lanka as well. Manufactures in this particular field under standard test condition predict the temperature coefficient of power generation efficiency designated by γ is approximately - 0.41% per Celsius. But as usual, it changes under realistic environmental conditions. Quantitatively finding the influence of temperature on the power generation efficiency of polycrystalline silicon solar cells by the sensor monitoring system under realistic environment conditions is the main aim of this research study. Accordingly, the temperature and the total output power of the polycrystalline silicon solar cells were simultaneously measured to analyse the effect of temperature on the photovoltaic characteristics of solar cells under these circumstances. The temperature coefficient of power generation efficiency γ with +0.04% per Celsius has been observed for these solar devices at Hambantota Solar Power Plant.

Keywords: Silicon solar cell; PV module; Temperature coefficient.

1. INTRODUCTION

Solar energy is an abundant resource with simply conversion into electrical energy, naturally replenished and no harm to environment. Photovoltaic (PV) solar cell is a device used to convert solar radiation into electrical energy using semiconductor materials. With the utilization of modern technology, it has been achieved to be fabricated a low cost and high efficient device. And further, it requires little maintenance attention. As such, PV power generation is a promising technology for generating renewable energy from solar irradiation. There are many types of PV solar cells. Polycrystalline silicon, mono-crystalline silicon, thin film and amorphous are some of commercially available common types of PV cells. The crystalline silicon solar cell is one of the first to be developed and it is still the most widely used type [1-2].

Hambantota solar power station is the first commercial scale solar plant in Sri Lanka which is connected to the grid with a capacity of 1.2 MW. It is consisting two separate parts. Average daily electricity generation has been estimated to be 6,200 kWh, which will result in 2,268,000 kWh annual generation. This electricity annual generation will be sufficient to the amount of electricity consumed by more than 2,000 rural homes or 1,000 average Sri Lankan homes in a year. Silicon poly crystalline solar cells have been used to generate electricity in the Hambantota Solar Power Station.

The operation of the PV solar cell is mainly depending on the sunlight irradiated upon it. When the sunlight expose to the surface of the PV cell, some of the photons are absorbed and release electrons from the solar cell that are used to produce an electric current. Sunlight is the main source of energy used to generate electricity and thermal heat on the other hand is not required to produce electricity in PV systems. But the operating temperature plays a key role in the photovoltaic conversion process. When the PV cell is illuminated, less than 20% of solar irradiance is transformed to electric power [3]. Much of the remaining balance of unused energy is converted to thermal heat, which leads to an increase temperature in the PV cell. It leads to decrease cell performance due to increased internal carrier recombination rates, caused by increased carrier concentrations. Theoretically, the output power of a crystalline solar cell decreases 0.4% when the temperature increases by 1 ^{0}C [4-5].

The effect of temperature on the power of solar panel is measured by its thermal coefficient, expressed as % K^{-1} or % $°C^{-1}$. Manufactures in this particular field under standard test condition predict the temperature coefficient of power generation is - 0.41% $°C^{-1}$.Our aim of this research study is quantitatively finding the influence of temperature on the power generation efficiency of polycrystalline silicon solar cells at Hambantota solar power station by the sensor monitoring system under realistic environment conditions.

2. EXPERIMENTAL DETAILS

In this work, poly-Si solar cells of 4783.48 m^2 area were used and the measurements were performed employing solar cells which are connected to the national grid through the three DC to AC inverters. The total output power was measured by using standard power meter. The experiment was carried out at real environmental condition. Global horizontal irradiance was measured by pyrometer. Six temperature sensors were used to measure the panel temperature. All these measurements were processed and recorded by Nippon (CK – 4100) data logger within one minute time interval.

3. RESULTS AND DISCUSSION

Generally solar cells are sensitive to temperature. Rising in the temperature increases the kinetic energy of electrons in the material. Thus, lower energy gap is required to excite electrons from valence band to conduction band. In the bonding model of a semiconductor band gap as well, it has been explained that the reduction of the bond energy reduces the band gap [6-7]. As such, when temperature increases, the band gap of the semiconductor reduces resulting with lowering photo voltage. Simultaneously, the lower band gap allows more incident energy to be absorbed because a greater percentage of the incident light has enough energy to raise electrons from valance bands into conduction band enhancing photocurrent. The contribution to the conversion efficiency of the solar cell due to the increase in the photocurrent is proportionately lower than to the decrease in the photo voltage for a given temperature rise. Hence the conversion efficiency of the cell is reduced [8-10].

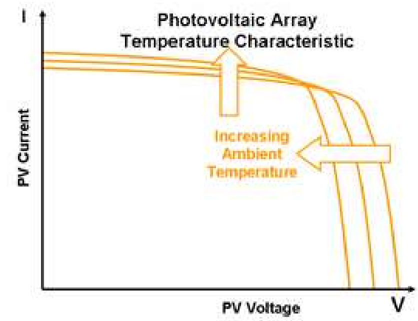

Fig.1. current voltage variation with temperature.

To find the performances of the photovoltaic module in the field, it is generally used the conversion efficiency. The solar energy conversion process into electrical energy is the conversion efficiency of the solar cell while it is defined as the ratio of electrical energy on incident solar energy. It is given by

$$\eta = \frac{W_e}{W_s}$$

Where, W_s and W_e are the incident solar energy and the generated electric energy converted by the cell, respectively [11].

The data of incident solar energy is measured by Pyranometer sensor. This sensor is used to measure the global solar radiation intensity and confirms to the second class which is regulated in ISO 9060. In the same time, total power output of the power plant was measured by standard power meter. Then, it was calculated the output energy per unit area.

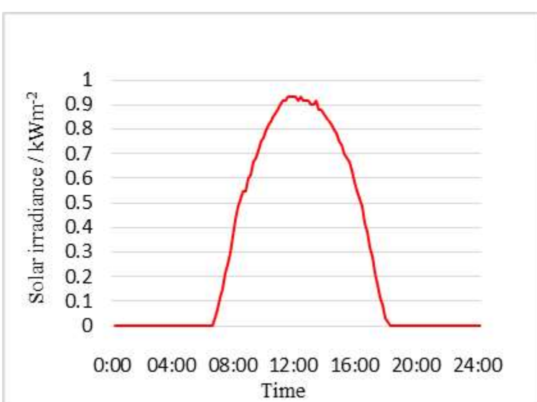

Fig.2. daily variation of solar irradiance.

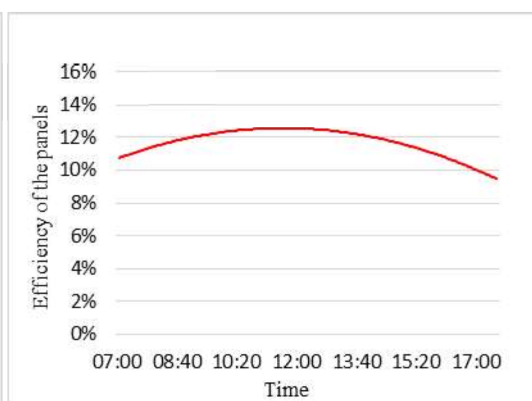

Fig. 3 daily variation of panel efficiency.

The conversion efficiency at the standard test conditions provided by Manufacture is 13.7%. Fig.2 shows that the incident solar energy variations from time to time. According to Fig.3, it is found that the conversion efficiency in real environment at Hambantota Solar Power Plant is 11.9%.

Module temperatures were measured by T – type thermocouple sensors. This sensor is made by connecting two different kinds of metal wire at the end. Tiny voltage (thermo electromotive force) was produced by the temperature difference across these ends. It is used as temperature signal. This sensor is fixed by the attached insulating tape and aluminium tape at the backside of the solar panel. It was covered the sensitive element by the insulate tape first and put the aluminium tape on it at the solar panel. It was fixed the cable sheath part not to move by the aluminium tape at 3 or 4 places. There were six temperature sensors which have been fixed in six places in the plant. Average module temperature of each sensor was used to analysis. The data logging equipment process the signal from each sensor (Thermo couples, solar radiation sensor, and Output power) to the meteorological data and storage data were at every 1 minute.

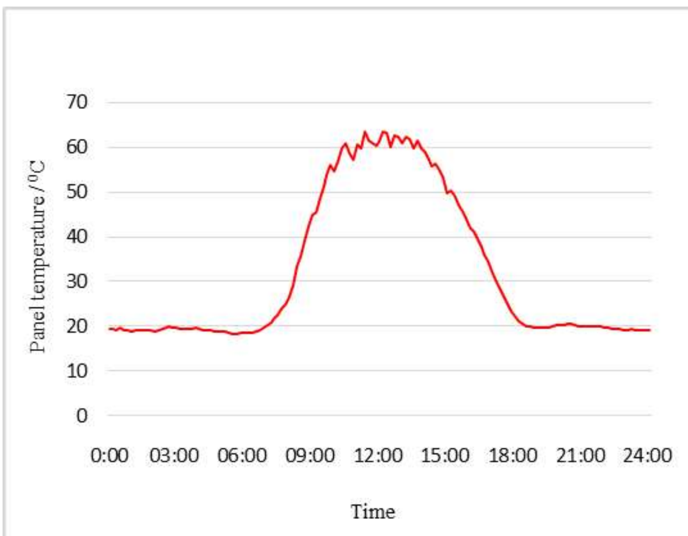

Fig.4. daily variation of panel temperature.

There are many factors affect to the PV module temperature. In ambient temperature, local wind speed, precipitations and solar radiation are some of them. The system/type of panel installation also effect on the temperature of panels. When solar panels are installed on a small height from ground, then it increases temperature than panels that are fixed more height to the ground because air flow go through the panels in the higher level allowing to cooling effect on the panel.

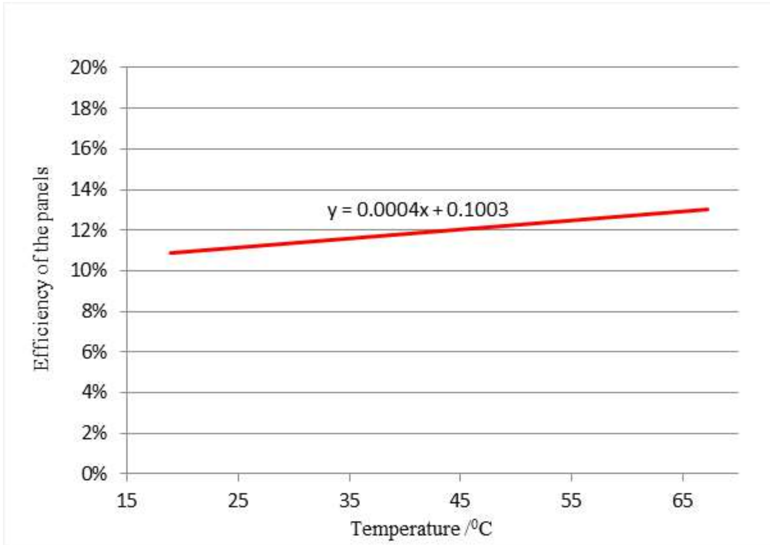

Fig.5. variation of efficiency with panel temperature.

Fig.5 shows the variation of the efficiency with panel temperature. It can be seen that the conversion efficiency of the module is not constant and varies in a real environmental conditions, according to the incident irradiance and temperature. According to Fig.5 graph, 0.04% of efficiency has increased when the temperature increasing a Celsius. Manufacture has provided temperature coefficient under standard test condition as -0.41% per Celsius. But as usual, depending on the incident solar irradiance and other parameters of cell, it is not a constant value. The inverter converts direct current (DC) into alternate current (AC), so energy produced by solar panels has been connected to the inverter. Then that electrical energy is given to national grid via step up transformer. This process is not 100% efficient. Further there may be a small voltage drop between the solar panel stream and the inverter. However, it has been considered only final out put power of the power plant.

4. CONCLUSION

The conversion efficiency of the solar cells at the standard test conditions provided by Manufacture is 13.7%. In this research study, it is found that under real environmental condition, it is 11.9%. They have provided temperature coefficient under standard test condition as -0.41% per Celsius. Contradictory to above result, the temperature coefficient of power generation efficiency γ with +0.04% per Celsius has been observed for these solar devices at Hambantota Solar Power Plant.

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