European Journal of Energy Research
www.ej-energy.org

RESEARCH ARTICLE

The Performance of a Solar Panel with Maximum Power Point Tracking (MPPT) System

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ABSTRACT

Due to the rotation of the earth and its spherical shape, the availability of sunlight at a certain place is not the same. At normal sky conditions at a place, sunlight is minimum in the morning that gradually increases up to 2-3 pm then again tends to a minimum. Usually, solar panels are fixed type and can't absorb the sunlight the whole day properly. In that sense, to increase the efficiency of a solar panel with its necessary accessories has been developed where maximum power point tracking (MPPT) system adopted where the panel can easily move to get the maximum sunlight. The electric charges are then stored in a battery that are being supplied to the electric appliances. The experimental work has been done at the roof-top of the science faculty building of Chittagong University. This experimental study shows that the efficiency of the solar panel starts increasing from morning 9 am with an efficiency of 16.64% and found maximum efficiencies at 12 noon (24.92%); 1 pm (25.94%); and at 2 pm (24.68%) then again starts decreasing with the values of (22.3% and 18.7%) at 3 pm and 4 pm, respectively. It has also been found that the peak value of average efficiency in July is (24.44%). The achieved efficiencies are more than the efficiency of (15.7%) studied in May 2017 with a fixed-type solar panel at the same place.

Keywords: Actuator, efficiency, fill-factor, humidity, intensity, light sensor, open-circuit voltage, short-circuit current and temperature.

Published Online: March 06, 2024

ISSN: 2684-446X

DOI:10.24018/ejenergy.2024.4.1.78

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I. Introduction

Solar converts the sunlight (photons) into electricity. For maximum efficiency, solar cells have been analyzed from different approaches. In 1980, research on Si-solar found an efficiency of 16% [1]. Over the next decade, the theoretical estimation of efficiencies vary from 6% to 44% for amorphous Si-based to multi-junction solar cells; 44.4% for multiple dies assembled into a hybrid package; commercially available multi-crystalline Si-solar cells are around 14-19%; for undoped crystalline 29.4% and by using: Crystalline-Si (25%–29%); GaAs (40%–60%), GaSb (31%–32%)%; InGaAs (30%–32%), InGaP (28%–30%); Ga (20%–22%) but practical efficiencies are more less than that [2]–[7].

The solar cell performance depends on its efficiency, which is based on some meteorological variables such as wind, sunlight, humidity, temperature, pressure, precipitation, and the sky condition at a given time. Solar cells are active when sunlight is available. Due to the rotation of the earth and its spherical shape, the availability of sunlight at a certain place is not the same. At normal sky conditions at a place, sunlight is minimum in the morning that gradually increases up to 2–3 pm, and then again tends to be minimum. Usually, solar panels are fixed type; for that reason, the panel can absorb the sunlight only 3–4 hours a day properly. The rest of the time, the panel absorbs minimum sunlight. If the panel can move with the sunlight, then the number of incident photons absorbed by the panel will be more, and the performance of the panel will be the maximum.

The goal of this study is to increase the efficiency of a solar panel by implementing MPPT system through which the panel can easily move to get the maximum sunlight. A light sensor has been adjusted with the tracker that can indicate the maximum availability of sunlight. The coordination between the sensors and the tracker is done by a software program. The electric charges are then stored in a battery that is supplied to the electric appliances.

II. Present Scenario of Solar Power

A. Current Status of The Solar Power in The World

Nowadays, solar power has become an important resource of energy around the World. Most of the industrialized nations have installed significant solar power into their electrical grids to provide an alternative resource to reduce dependence on expensive imported fuels. The Total production of electricity around the world was about 28,000 TWh in 2020 [8]. By the end of 2020, total photovoltaic capacity in the world reached at least 773.2 GW, and the top installers were China, the United

States, and India [9]. Solar power in Honduras is now sufficient to supply 12.5% of the nation's electrical power, while Italy, Germany, and Greece can produce between 7% and 8% of their respective domestic electricity consumption [10]–[12]. At present, the largest solar power plant in the world in China, with a capacity of 2200 MWAC, was commissioned in 2021; besides that, other large solar power plants are 354 MW in the USA, Solnova Solar Power Station 150 MW in Spain, and the first part of Shams solar power station 100 MW at the United Arab Emirates [8].

B. Chronological Progress of Solar Power in Bangladesh

Bangladesh is suffering from severe energy crises because most of the power plants are gas and oil-based. Here solar energy was introduced in 1996, and by this time, it was gaining popularity and contributing power to solving the energy crisis. The Government of Bangladesh is helping, financing, and monitoring the renewable energy sector through Infrastructure Development Company Limited (IDCOL). IDCOL started the solar home system (SHS) program using innovative financial and technology packages in 2003 that initially received credit and grant support from the World Bank. Later, other organizations like GIZ, KFW, ADB, IDB, GPOBA, JICA, USAID, and DFID came forward with additional financial support for the expansion of the SHS Program. At present, 56 Partner Organizations (PO) such as Grameen Shakti, Brac, Rahim Afroze, Bengle Solar, Meghna Power, Desha, and Summit Power are working with IDCOL to expand solar energy programs. Terrief system from the government is available for the consumers [11]. The program supplements the Government's vision of ensuring electricity for all, and up to May 2017, about 4.12 million SHSs have been installed in remote areas where electrification through gird expansion is challenging and costly [11], [12]. Village people, especially in remote areas, benefited from using solar power. Island Sandip of Chittagong district; Char area of Norshingdi, Jamalpur, and Shirajgang district; Rangamati, Khagrachori and Bandorban districts are the model in case of changing the whole electrification scenery by using solar panels. The long-term average sunshine data indicates that the number of bright sunshine hours in the coastal regions of Bangladesh varies from 3 to 11 hours daily [11]. The insulation in Bangladesh varies from 3.8 to 6.4 kWh/m^2/day at an average of 5 kWh/m^2/day, which indicates that there are good prospects for solar thermal and photovoltaic applications in the country [11]. The largest solar power plant in Bangladesh at Mongla, with a capacity of 134.3 MW, was commissioned in 2021 [7]. The government has taken several projects through IDCOL in different districts of Bangladesh, such as Sunamganj (198 MW), Rangamati (8 MW), (Feni-Muhuridam) 200k, Kurigram 30 MW, Chittagong (Rangunia + Mirersharya) 5 MW, Bagerhat 100 MW, Gouripur 73 MW and Teknaf of Cox'sbazar (200 MW) are in final stage of operation to enhance solar energy programs [7].

III. Experimental Procedure and Data Collection

Direct measurement techniques have been considered for data collection. First of all, a Si-solar panel of size (61 cm × 61 cm) has been adjusted on a wheel frame made of iron bar in the open air on the roof-top of the science faculty building to get data directly with its necessary accessories such as Limit switch, two actuators (Left-Right actuator and Up-Down actuator), Light Dependent Resistor (LDR) Sensors, relay switching module, protractor, arduino UNO board (logic board), solar charging controller, voltmeter and Digital Multi-Meter (DMM), luminance meter, thermo-hygrometer, transformer, connecting cables and battery, etc. The LDR sensor indicates the maximum sunlight position, and due to the actuator being adjusted with a wheel frame, the panel can easily move left-right and up-down positions. A software program has been coded to ensure the whole work properly. Through this system a solar panel can easily cover ($45^0 + 180^0 + 45^0 = 270^0$) where a fixed type of solar panel can receive only ($45^0 + 45^0 = 90^0$) during daytime properly. A complete solar panel with a tracker has been set up on the roof-top of the science faculty building of Chittagong University. Several data such as Open-circuit voltage (V_{OC}); Short-circuit current (I_{SC}) are measured manually from the voltmeter and ammeter that are being adjusted with the panel. Luminance meter and hydrometer have been used for the measurement of light intensity, temperature, and humidity, respectively. The storage battery is kept on the second floor and connected by electric cables that are 50 ft away from the panel. All the data have been recorded from 9 am to 4 pm after one hour for five months (June to October). The fill-factor Si-solar cell was fixed at 0.88.

IV. Results and Discussion

With the help of collected data, several graphs are presented to understand the efficiency of solar panels using Equation (1):

$$\eta = \frac{V_{mp}I_{mp}}{P_{in}} = \frac{V_{oc}I_{sc}FF}{P_{in}} \tag{1}$$

where V_{oc}, I_{sc}, FF, P_{in} indicates the open circuit voltage, short circuit current, fill-factor and input power respectively.

The variation of temperature (Fig. 1), of humidity (Fig. 2), of intensity (Fig. 3), of efficiency (Fig. 4), of temperature and efficiency (Fig. 5), of humidity and efficiency (Fig. 6), of intensity and efficiency (Fig. 7) with daytime is shown, respectively.

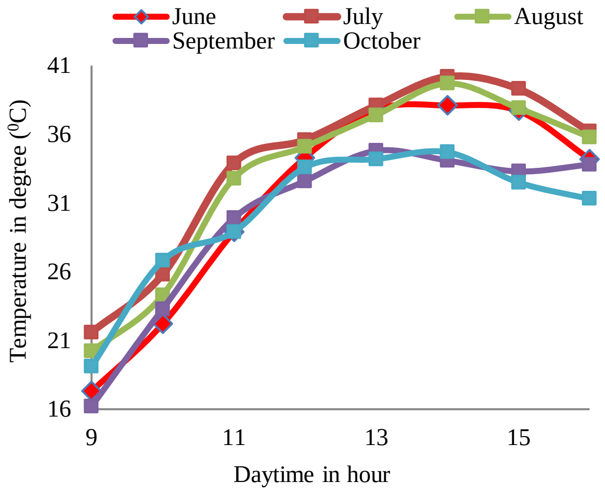

Fig. 1. Graphical representation of the daytime versus temperature.

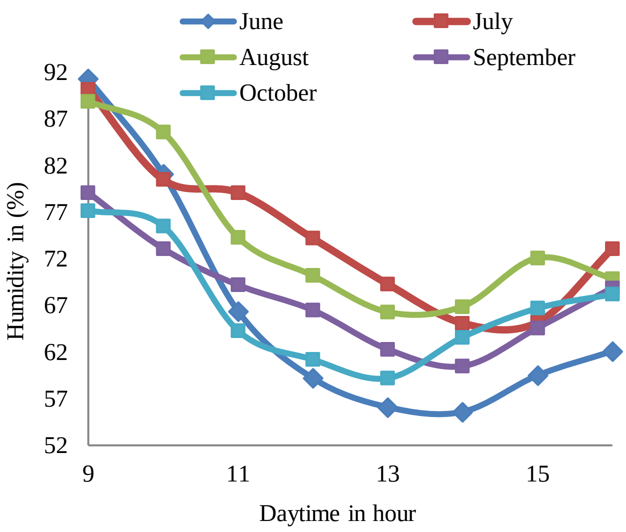

Fig. 2. Graphical representation of the daytime versus humidity.

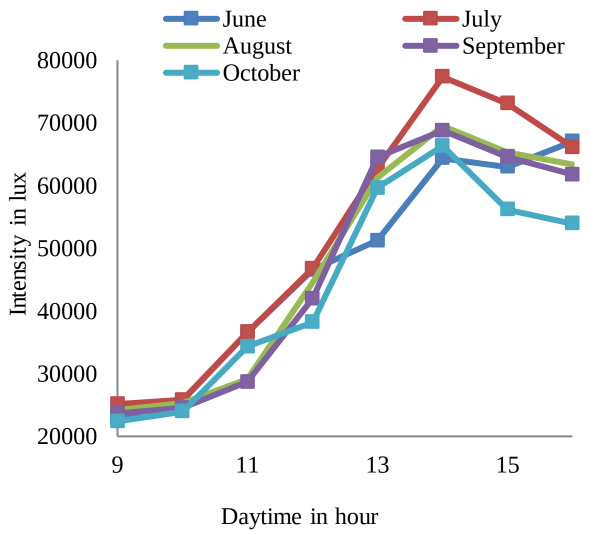

Fig. 3. Graphical representation of the daytime versus intensity.

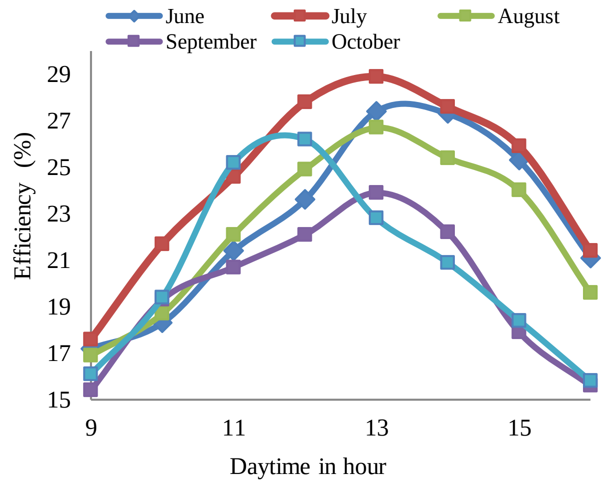

Fig. 4. Graphical representation of the daytime versus efficiency.

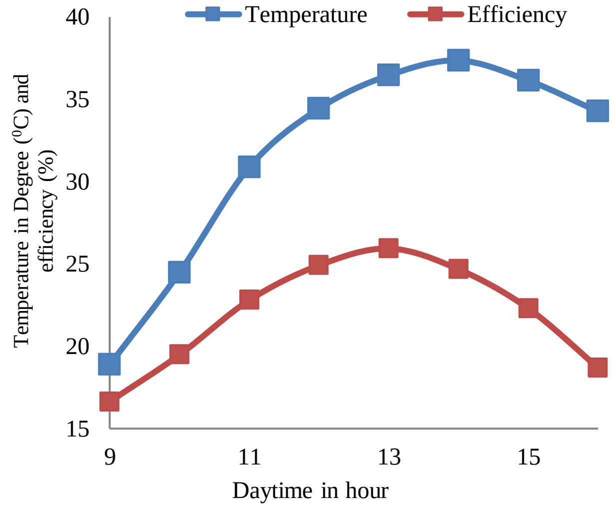

Fig. 5. Graphical representation of the daytime versus temperature and efficiency.

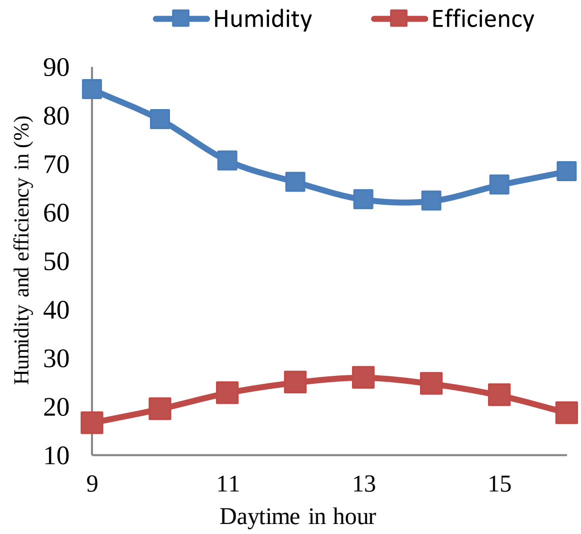

Fig. 6. Graphical representation of the daytime versus humidity and efficiency.

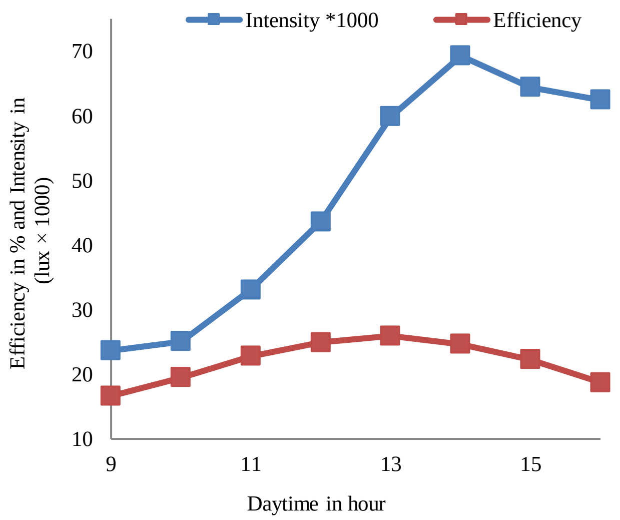

Fig. 7. Graphical representation of the daytime versus temperature and efficiency.

Figs. 1–7 indicates that the efficiency mostly depends on the light intensity and temperature and slightly depends on humidity. The efficiency of a solar panel increases with increasing light intensity and temperature but decreases with the increase in humidity. From Fig. 7, it is clear that at 9 am, the average value of efficiency found (16.64%) reached the peak at 12 noon (24.92%), at 1 pm (25.94%), and at 2 pm (24.68%) then again starts decreasing with the values of 3 pm (22.3%) and 4 pm (18.7%). This variation is due to the spherical shape of the earth and its rotation. Under normal sky conditions, the temperature and light intensity start increasing in the morning, and at noon, they are at their maximum, then again tend to be at a minimum, but when humidity increases, the efficiency decreases on average.

V. Conclusion

It has been found that the average efficiency in June (22.70%) started increasing, reaching (24.44%) during July, then again decreased in August (22.29%), September (19.64%), and October (19.06%). It is because in June–July, the temperature and intensity are high during the summer season in this area, but at that time, due to rainy and cloudy weather, the humidity suddenly increases, and the efficiency is not up to that level.

Acknowledgement

I am deeply indebted to the Planning and Development Division, University of Chittagong, for giving me funds to conduct this project. Special thanks to Tahmina Meena and Ayesha Siddaqua for their continuous cooperation.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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