MPPT for PV Array Modeling using Perturb and Observe Algorithm

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Abstract:- Solar energy is an endless, clean, and renewable energy source, yet only a small portion of it is used to directly power human activities. Various types of renewable energy, including the most significant, solar energy, have been addressed. Solar modules are devices that convert sunlight directly into electricity. The maximum power of photovoltaic systems is critical for the system's practical usage. A solar array model was created with the help of MATLAB. The Matlab simulation shows that at different irradiance levels and temperatures. The Matlab simulink photovoltaic array model is evaluated, and the results of the V-P and V-I characteristics verify the validity of the Simulink photovoltaic array model. After simulating the PV array in MATLAB under various irradiance and temperature conditions, we obtained a collection of data. MPPT extracts the maximum amount of electricity from a photovoltaic array. The proposed method utilizes monitoring of maximum power points to approach in the direction of extracting the most powerful solar energy output with little to no oscillation in the output photovoltaic system. The effectiveness of conversion from a photovoltaic method is increased by employing the Cuk Converter and the MPPT algorithm. By altering its duty cycle, the Cuk converter steps up or steps down the photovoltaic voltage level. The MPPT algorithms were created in MATLAB and tested in a simulated environment. Simulation Power System blocks is used to represent the photovoltaic array and Cuk Converter.

Keywords:- Solar; Solar module; PV; MPPT; Cuk Converter; Duty Cycle; MATLAB; P & O Algorithm; Irradiation; Temperature.

I. INTRODUCTION

In nature, energy occurs in several forms, the most significant of which is electrical energy. The current civilization is so reliant on the utilization of electrical energy that it has become an integral part of our everyday life [1]. Energy utilization procedures come in a variety of forms, the most well-known of which are dropping water's raw energy and fuel, oil, and natural gases. Hydroelectric power, sun energy, wind turbines, nuclear reactor energy, natural sources, and some other sources of energy that regenerate on a regular basis are examples of renewable resources [2]. [3] Due to increased energy use, meeting demand is becoming increasingly difficult. Because of the critical state of industrial fuels, sustainable energy is an essential and significant contribution to generating electricity. Photovoltaic cells have among the most efficient topologies for producing electricity. Because it is a non-regulated direct current power source, a PV module does not run at its maximum power level when connected to a load [4]. By employing a cuk converter and performing MPPT, we can extract the most solar power from a PV array under real-world conditions [5]. With the use of MPPT technology, a Cuk converter has been installed to power transmission from the photovoltaic array to the burden [4]. Tracking of MPP is important in tracking maximum power from photovoltaic cells since it extracts the greatest possible power output regardless of irradiance or changes in temperature. As a result, MPPT plays a significant part in efficiency calculations under real-world conditions [2]. MPP tracking is an extremely useful tool in photovoltaic systems applications. Temperature and solar irradiation are the single most significant elements that determine the electrical power delivered by a photovoltaic system. The MPP is the voltage at which a photovoltaic module can output the most electricity (or peak power voltage) [1] [2] [4]. The primary premise of maximum power tracing is to harvest as much power as possible from solar panels and transfer it to the demand using a cuk converter, which scales the voltages increasing or decreasing to the necessary magnitude. Different maximum power point tracking approaches have been employed in the past. However, the Perturbation and Observation method is the most widely used [6]. With rapidly fluctuating irradiance, In addition, the P & O method was already implemented and demonstrated to yield incorrect tracking [5].

II. DEMAND VS GENERATION

[7] As of September 13, 2018, the utility electrical industry in Bangladesh has one power grid with a total capacity of 16,525 MW. There is 20,000 MW of installed capacity (combining solar energy). The power sector in Bangladesh is expanding. Bangladesh recently began development of a 2.4-gigatonne (GW) power plant (Ruppur Nuclear Power Plant), which is anticipated to be operational in 2023. In July 2018, the Bangladesh Power Development Board (BPDB) said that 90% of the country's population has access to power. Bangladesh, on the other hand, has a low per capita energy usage [3].
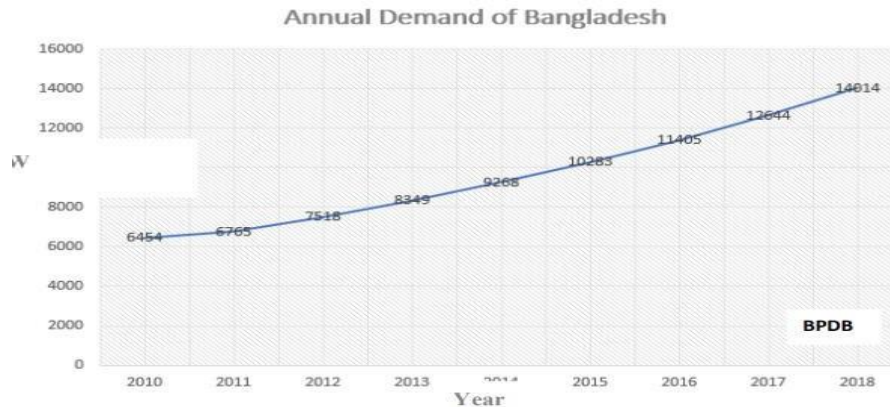
Fig. 1: Annual Demand of Bangladesh

The majority of the nation's gross domestic product is centered on electricity, which is the most important source of energy. Bangladesh seems to have a total installed capacity generating 15,351 MW (including captive energy) and is expected to reach 20,000 MW in 2018 [1].

The yearly demand in 2010 was 6454MW. After 8 years, demand has more than quadrupled to 140154MW. The growth rate is linear and growing at a rate of around 928MW/year [8].

On the other hand, generating capacity is not increasing, although it is more than load demand due to maintenance, and generation capacity is less than the maximum capacity installed. The graph depicts the annual increase in the maximum generation. According to the yearly demand curve, the demand in 2018 was the same as in 2017 [9].

Fig. 2: Growth of the Maximum Generation

The rise in maximum generation each year is seen in Figure 2. According to yearly demand curve, demand in 2018 was 14014 MW, whereas the maximum generation was 11573 MW.

III. RENEWABLE ENERGY

[8, 2] Solar, wind, rain, tidal, surges, and geothermal energy seem to be examples of sustainable energy. Sustainable energy is energy that is pure, limitless, and growing in popularity [2, 3]. They differ from natural gas in terms of variety, quantity, and capacity to be utilized everywhere around the earth; but most significantly, they are renewable. They don't produce carbon dioxide or other pollutants that damage the environment. Their expenses are also falling at a steady pace, although the general price trends for fossil resources, despite the present turbulence, are heading in the other direction [1]. The IEA (the International Energy Agency) estimates that by 2040, worldwide power consumption will have climbed by 70%.

Due mostly to India, China, Africa, the Middle East, and Southeast Asia, its proportion of ultimate energy use increased from 18 to 24 percent during the same time period [3, 8].

IV. RENEWABLE ENERGY IN BANGLADESH

In recent years, the renewable energy sector has seen notable development. [7] Renewable energy sources now provide 404 MW of power. In Bangladesh, solar household systems have been a huge success, and their popularity is expanding in rural regions, especially in off-grid locations [9]. Table 1 displays the development of the renewable energy industry in Bangladesh thus far. Bangladesh has developed a renewable energy development industry so far.

Methods	MW
Solar Home System Installation (3.5 million)	150.00
Rooftop Photovoltaic Installation at Govt./Semi-Govt. offices	3.00
Commercial and retail mall installations	1.00
PVs are installed by the customer during the installation of new power lines	11.00
Wind power plants are being installed	2.00
Biomass power plants are being installed	1.00
Biogas-based power plants are being installed.	5.00
Irrigation with sunlight	1.00
Productions of Hydroelectric Power	230.00
Total	**404.00**

Table 1: displays the development of the renewable energy industry in Bangladesh

The government of Bangladesh had established the purpose of giving energy including all residents around2020, and also assuring a constant and rising source of electricity at a relatively low cost compared. A country's ability to generate enough electricity is essential for long-term social and economic growth. There is no other method to accelerate development but to boost electricity generation by diversifying fuel sources. One of the most significant methods undertaken for the development of renewable energy is really an aspect of the National Energy Program. With 2009's Renewable Energy Policy, the government is committed to facilitating private and public sector investment in renewable energy sources to substitute non-renewable sources of energy and boost the contribution from present sustainable power generation.

V. PV-CELL MODEL

[5] Figure 03 depicts the analogous circuit of a PV cell. It implies that the current generator is a semiconductor, a series resistor, or a load resistor. The total output current of a solar cell is equal to I = Iph –Id-Ish, according to the analogous circuit [1].
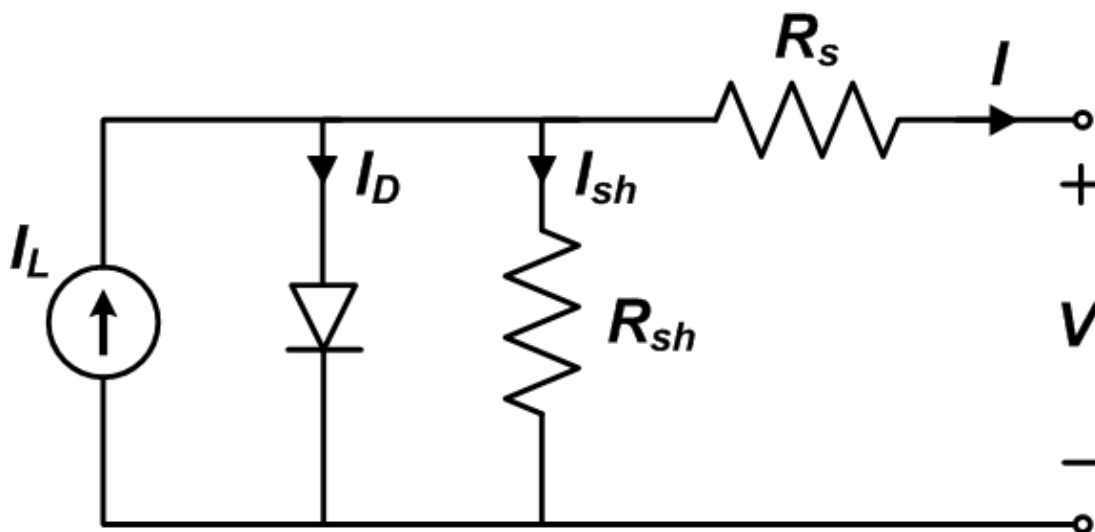

Fig. 3: PV Cell Equivalent Circuit

As a result, [1, 2, 4, 10] denotes the electricity supply to demand.

I=Iph-10 exp [q (V+IRs)/AKT-1]-((V+IRs))/Rsh(I)

In this expression, I_{ph} represents the diode's solar value of current. The electron charge is represented by q, V is the diode's voltage, Boltzmann's constant is represented by K, and the ideality factor of a diode is N, where the series and shunt resistors in the cells are Rs and Rsh, respectively. Consequently, the PV cell's whole physical behavior is influenced by Rs, I_{ph}, I_s, and Rsh on the one hand, and two external characteristics, temperature and solar radiation, for example [11].

The MATLAB model in Figure 4 was created using equation (I). The V-P and V-I curves are constructed for given radiation, temperature, Rs, and Rsh, as illustrated in Figure 05.
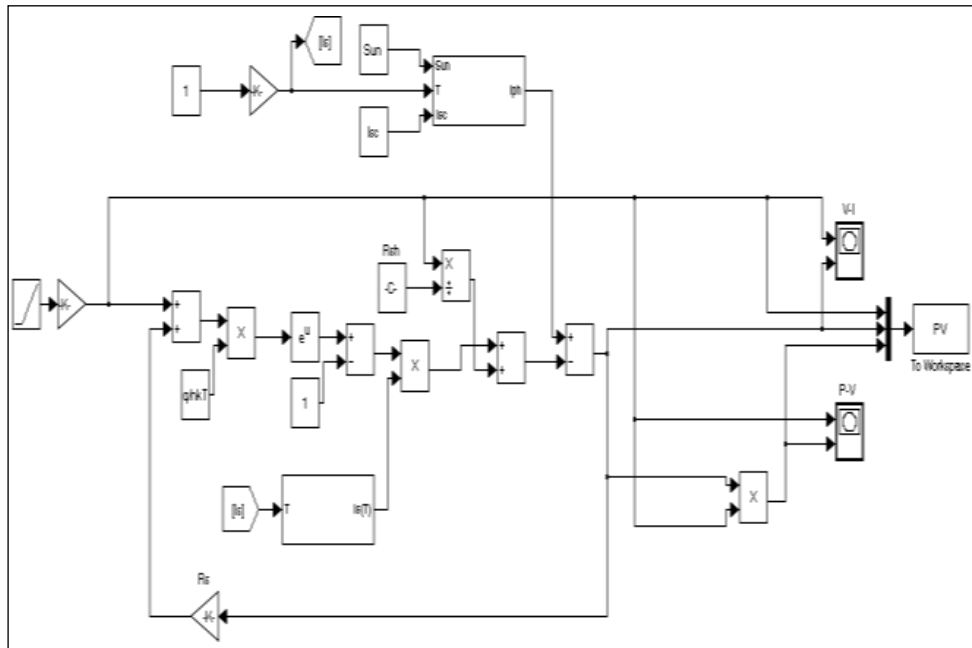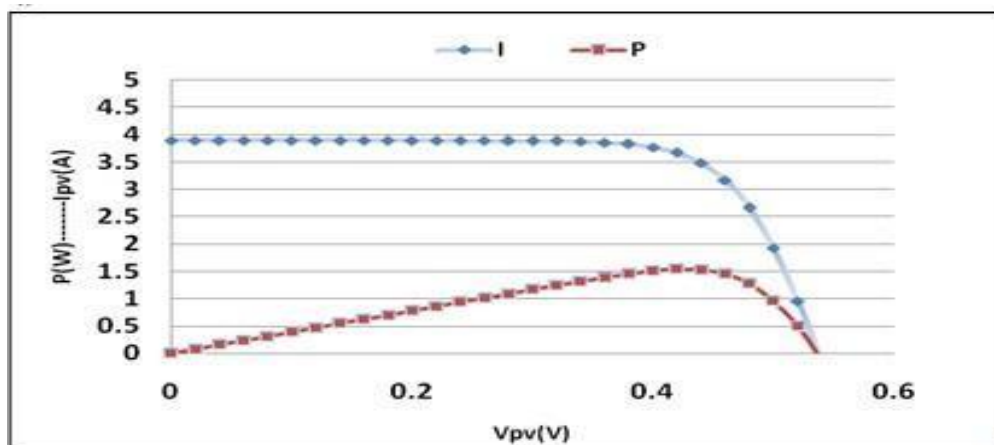
Fig. 4: Matlab Model

Fig. 5: I-V and P-V curve

VI. VARIATIONS IN SOLAR RADIATION'S EFFECTS

The aforementioned model has two subsystems: one that calculates the photocurrent of a photovoltaic cell based on solar irradiance and temperature using equations; and the other that calculates the photocurrent of a photovoltaic cell based on [10]. According to equation (ii),

$$I_{ph} = [I_{sc} \ K \ T \ 298 \quad \text{-------------------- (ii)}$$
$$+ \ _i(\ - \ )]\frac{\beta}{1000}$$

The short circuit current temperature coefficient of the cell is Ki=0.0017 A/ ∘C, and solar radiation (W/m2) is β
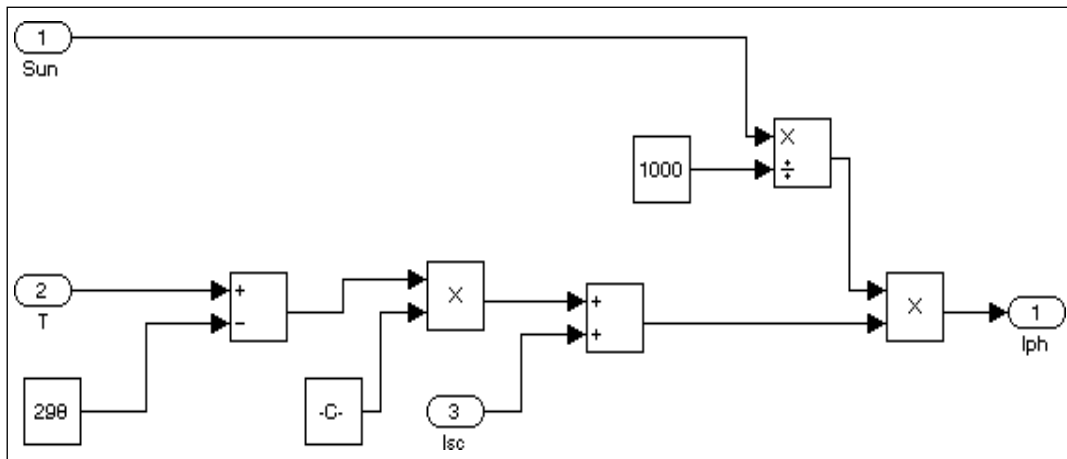
Fig. 6: Subsystem for variable temperature and solar radiation in MATLAB

Figure 07 modifies the incident I-V characteristics radiance curve on PV cells [12]. If the irradiance declines the produced photovoltaic current decreases correspondingly, and moreover, the variation in no-load voltage is minor.

As shown in Figure 8, when the temperature of the PV module rises, the voltage drops, and the generated current remains almost constant [10].

The photovoltaic cell current is highly influenced by solar radiation, as seen in Figures 07 and 8. However w h e n solar energy increased from 400 W/m^2 to 1000 W/m^2, the voltage increased by 50 mV.
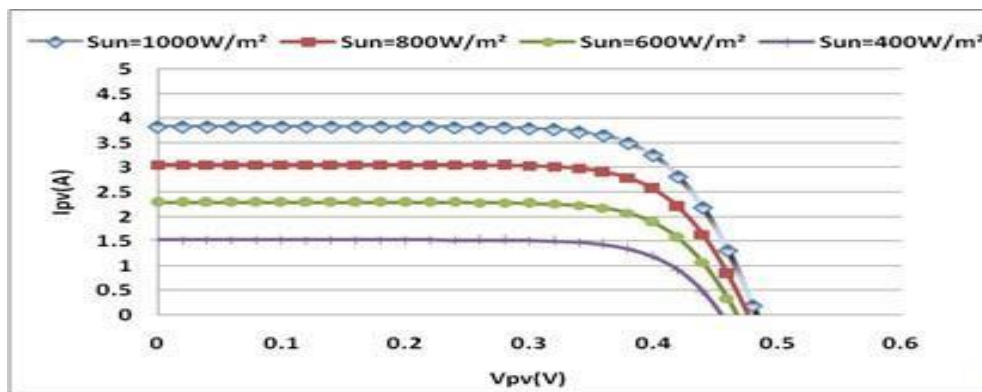
Fig. 7: Curves of I-V for various solar radiations
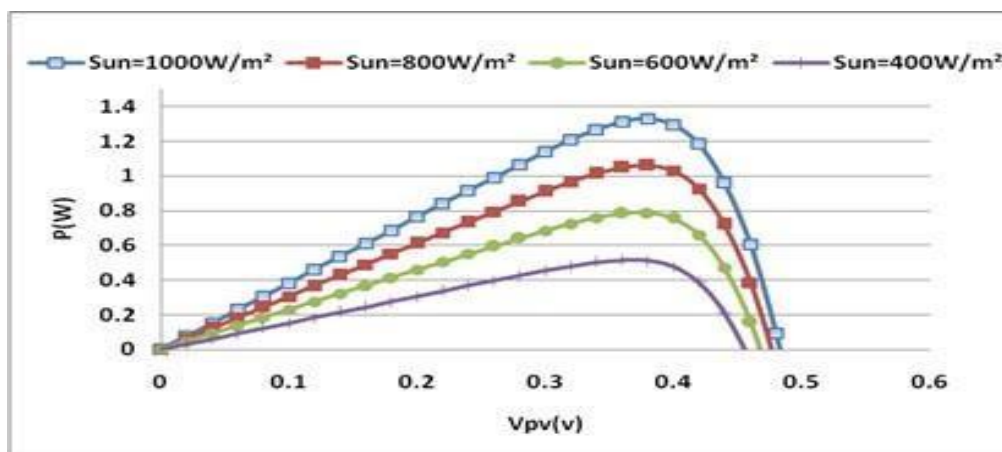
Fig. 8: P-V curves for various levels of solar radiation

Figure 8 shows that a maximum power of 110 W can be reached with 800 W/m² irradiation (red curve), as well as a maximum power of 140 W can be obtained with an irradiance of 1000 W/m² (blue curve). The power generated by the solar array is impacted by changes in irradiance, so this provides a sense of scale.

VII. CELL TEMPERATURE VARIATION:

The temperature-dependent diode reverse saturation current is given as: [13]

$$I(s) = I_s (T/T_{nim})^3 \exp[\{(T/nom)-1\} Eg/NV] ------------------------------------(iii)$$

Tnom denotes the nominal temperature, while Is indicates the diode's reverse saturation current, Eg indicates the semiconductor's band-gap energy, and V represents the thermal voltage.

Equation (**iii**) was used to construct the reverse saturation current subsystem in Figure 9.
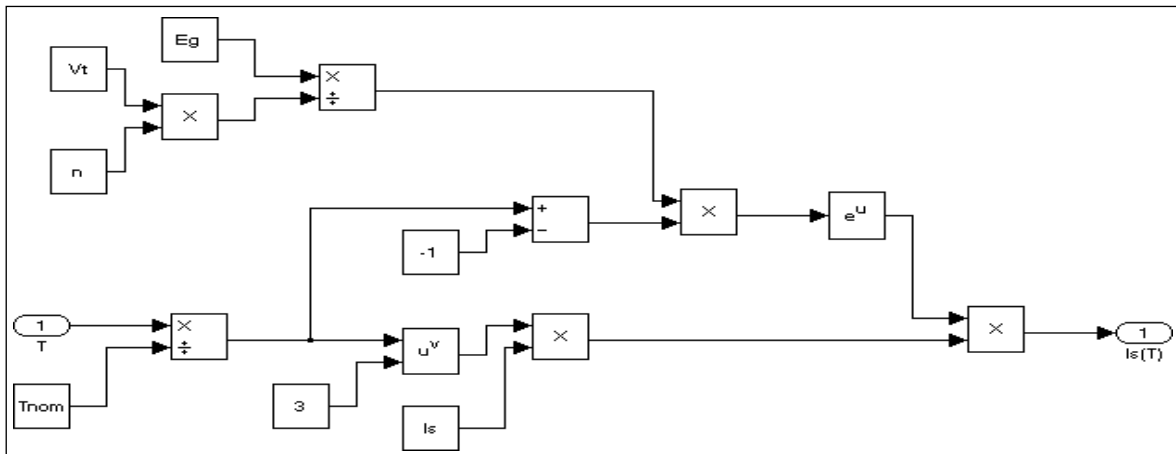

Fig. 9: Subsystem of temperature influence on diode reverse saturation current

The open-circuit voltages (Voc) drop dramatically because as cell temperature increases, but the current in a short circuit rises. Figures 10 and 11 demonstrate this behavior.
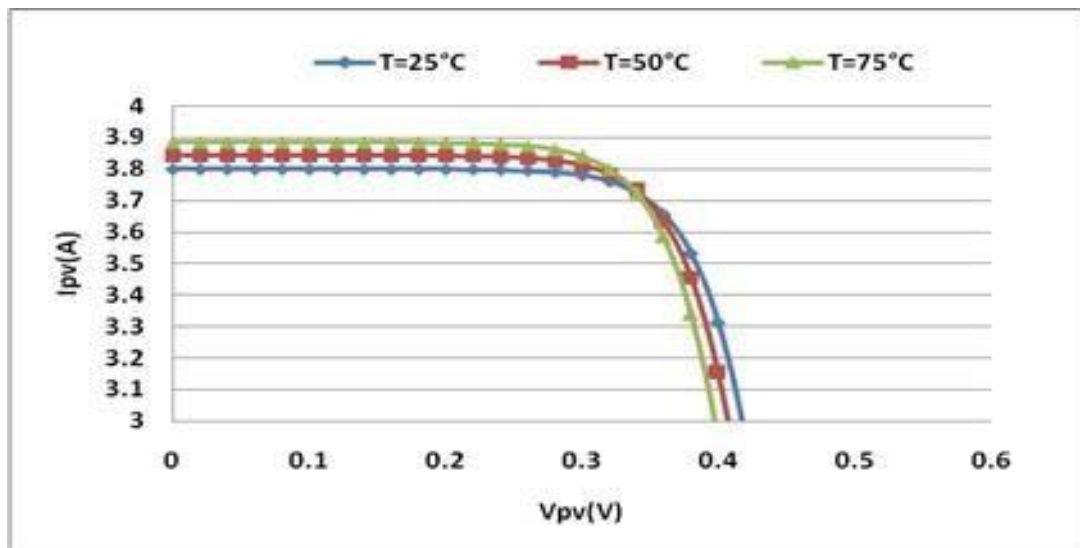

Fig. 10: *I-V* curves for different cell temperatures

Figure 11 depicts the solar panel's P-V characteristics for 1000 W/m² irradiance and various temperatures, whereas Figure 8 depicts for the photo-voltaic system, the P-V characteristics with various levels of solar irradiance at 25°C depicted in Figure 06.
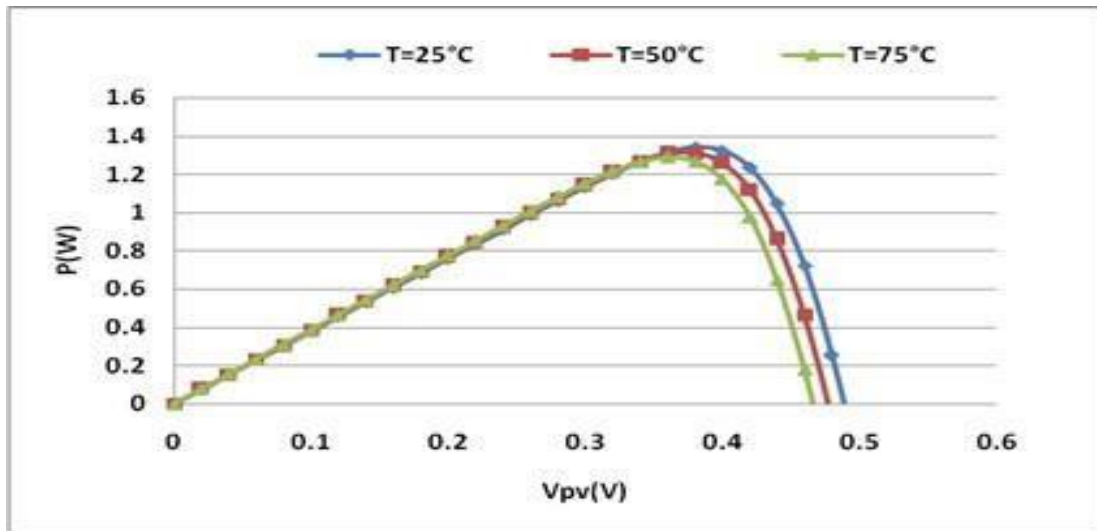
Fig. 11: *P-V* curves for different cell temperature
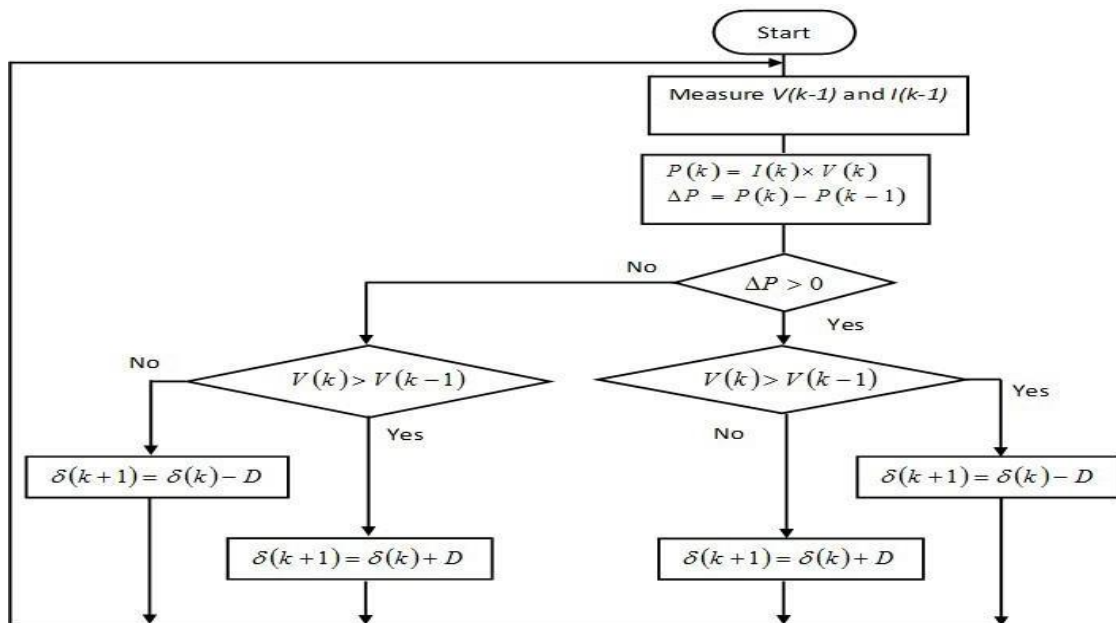
VIII. PROPOSED METHODOLOGY

Fig. 12: Flow chart of the perturb and observe algorithm

The MPPT approaches tackle the challenge of automatically determining the voltage VMPP or current IMPP where a photovoltaic array generates maximum power at a certain temperature and irradiation. The MPPT of the Perturb and Observe method consists of calculating photovoltaic power output and power by sampling both photovoltaic array voltage and current. The tracker operates by varying the maximum power from the solar array on a regular basis [5] [7] [10] [13]. If one perturbation increases (decreases) photovoltaic panels' output power, the next perturbation is created in the same (opposite) direction. The DC chopper's duty cycle is changed, and the procedure is repeated until the maximum power point is attained. In reality, the system revolves around the MPP [14]. The oscillation can be reduced by decreasing the magnitude of the perturbation step. Small step sizes, on the other hand, slow down the MPPT. The PV array's characteristic curves would change depending on the irradiance and cell temperature. Each curve has a peak of maximum power. At this time, the converter receives the maximum voltage [7].
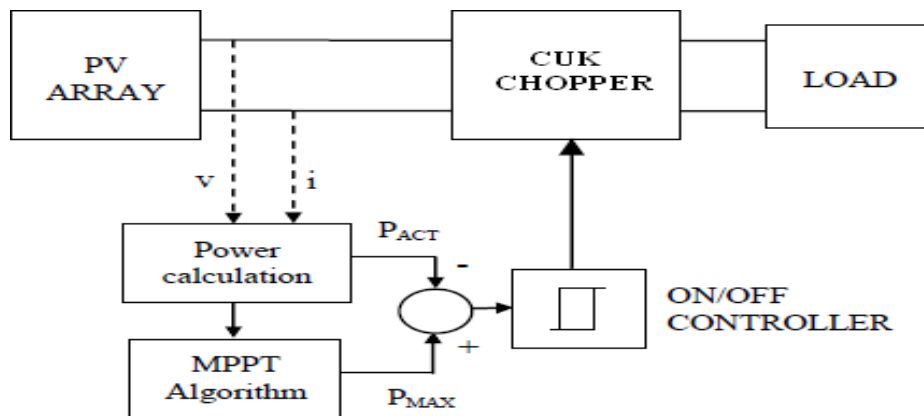
IX. PV SYSTEM MODELING

Fig. 13: Shows a simplified block diagram.

The photovoltaic array's current and voltage input are utilized to compute instantaneous power. The MPP determines the maximum energy, and the duty ratio of the converter is changed correspondingly. The duty ratio is adjusted such that the input power to the converter is almost equivalent to the energy capacity of that same load [14].

X. MATLAB MODELING AND EXPERIMENTAL RESULTS

The Photovoltaic System and V-P V-I blocks contain embedding blocks that include a mathematical description of the photovoltaic array [13]. These blocks are required to compute the MPPT's maximum power approach as well as to show the characteristic curves depending on various irradiance levels. Likewise, things can be done for varying temperatures in the environment.
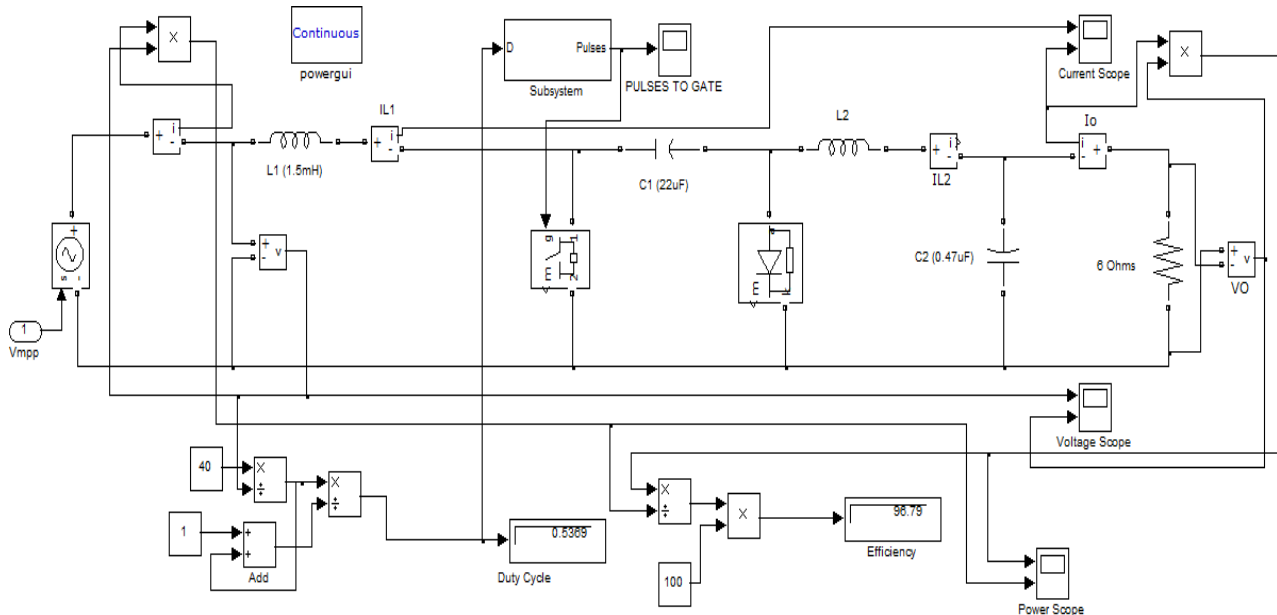

Fig. 14: Cuk converter with an 8-ohm fixed load

In this system, the Cuk Converter is employed [13]. It offers certain advantages and the over buck-boost converter. It is similar to the buck-boost converter and may increase or decrease the output voltage. In this instance, the capacitance serves as a major battery bank. It helps to assure continuous current flow, while the inductor on the load side lowers output current ripple. The duty ratio is modified based on the voltage input, which is the voltage at the highest power, to allow the maximum power transmission from the input source to the load [2] [10] [7].

A. *The following are the findings with varying levels of irradiance. The levels of irradiance shift at regular intervals while the temperature remains constant.*
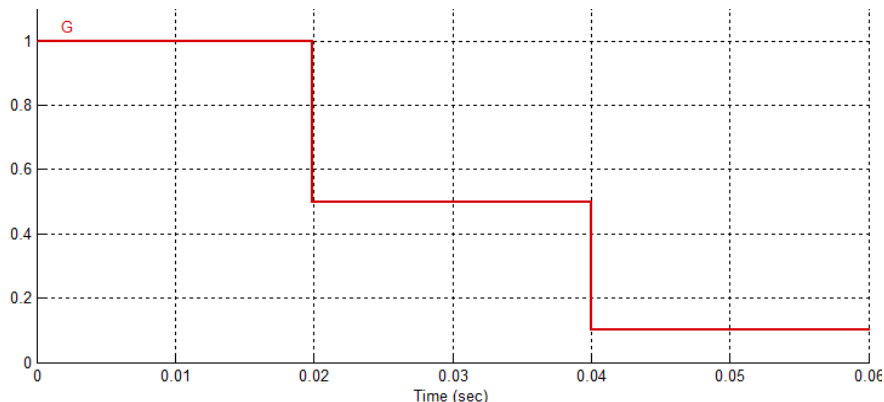

Fig. 15: Changing the irradiance levels of the photovoltaic array while maintaining the ambient temperature
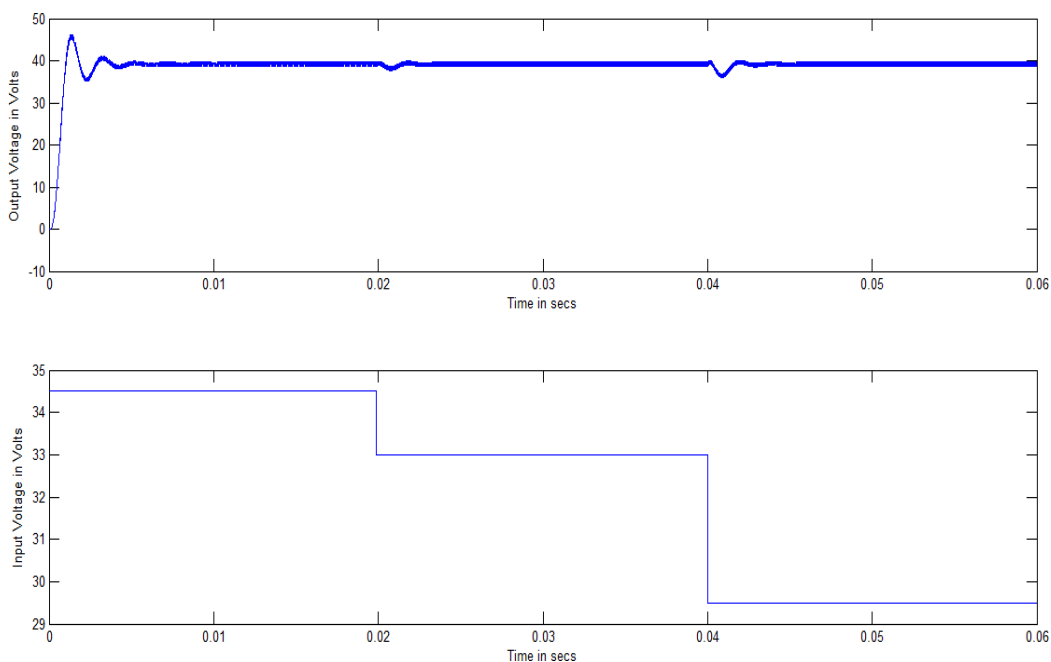

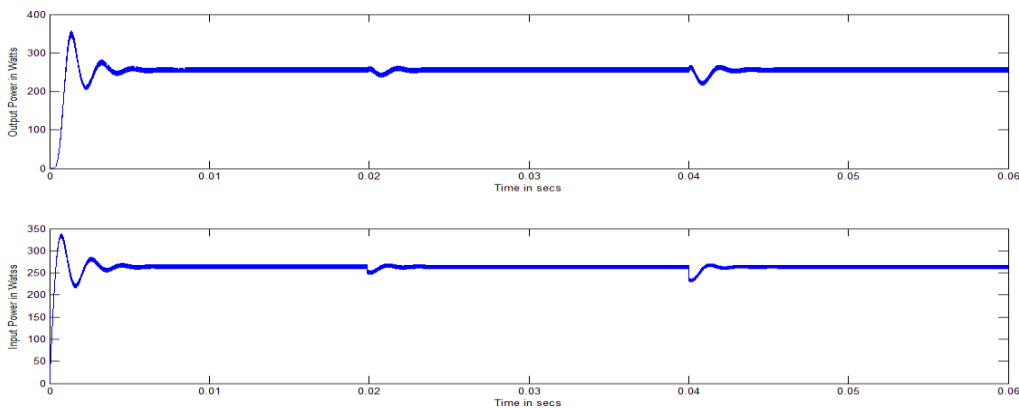Fig. 16: Changes in output and input voltages

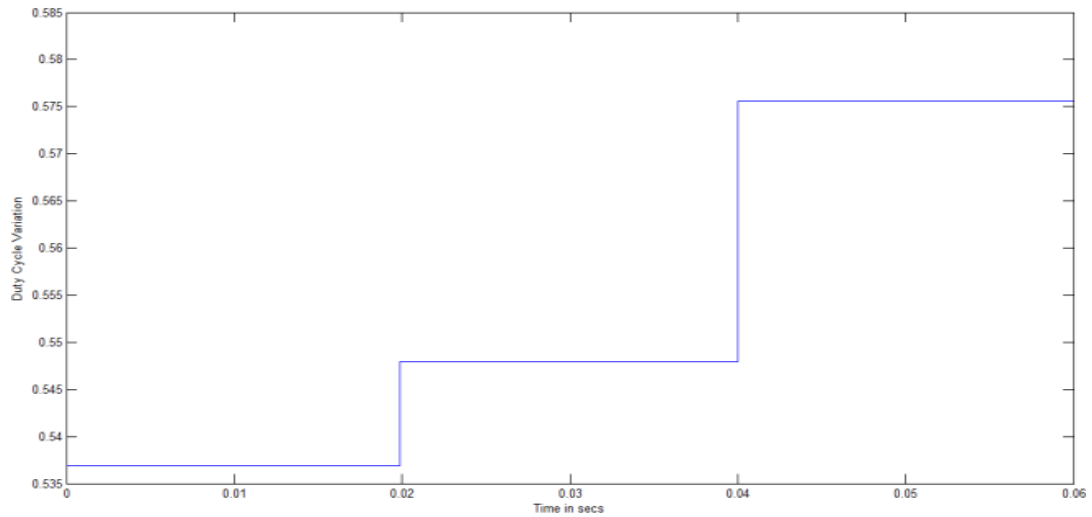Fig. 17: Variation in input power and output power

Fig. 18: Duty Cycle Fluctuation

B. The results are as follows, with ambient temperature variations. The ambient temperature varies at regular intervals while the irradiance remains constant.
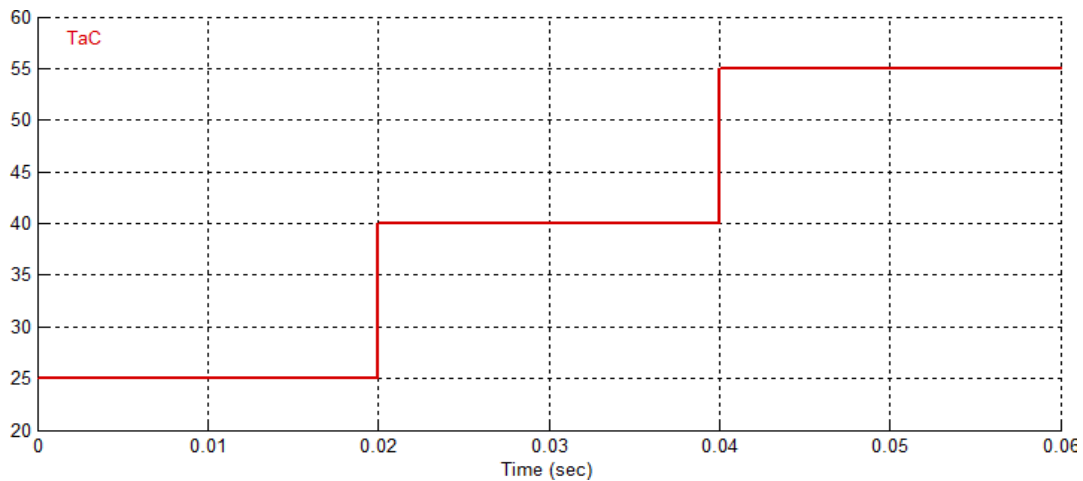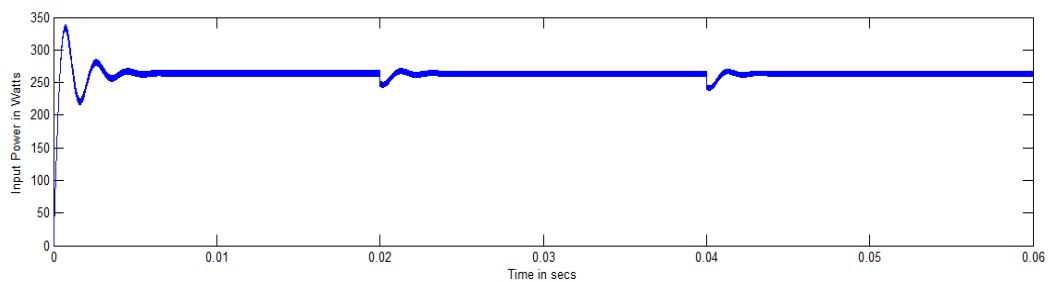

Fig. 20: Changes in output and input voltages
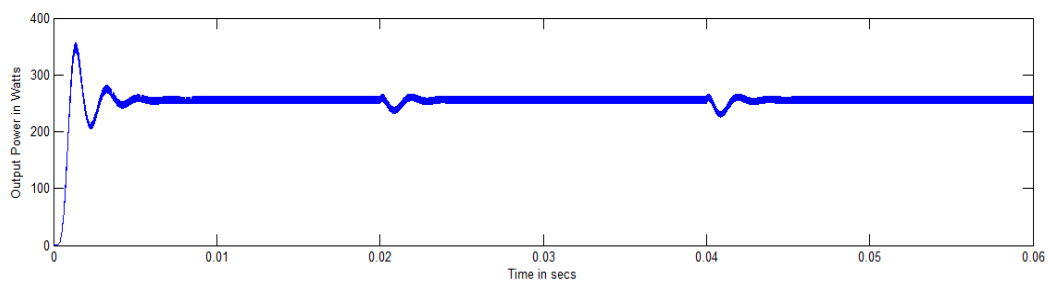

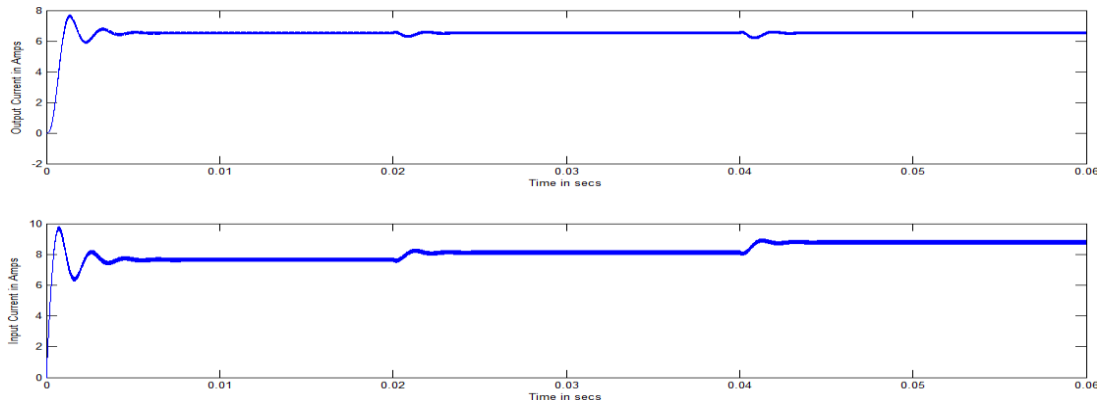Fig. 21: Changes in output and input power
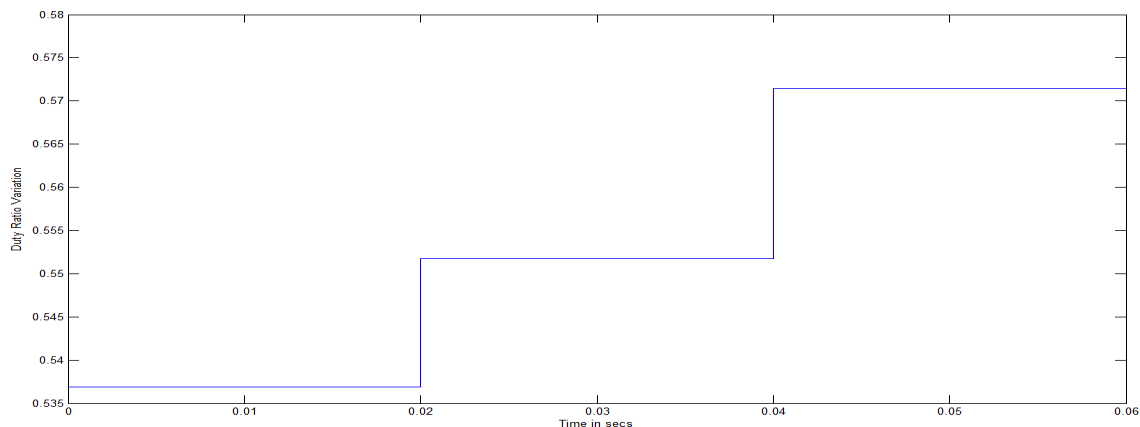
Fig. 22: Changes in inputs and output current

Fig. 23: Duty Cycle Fluctuation

The experimental findings indicate that the duty ratio fluctuates in such a way that the output voltage across the load remains constant. Some loads are voltage sensitive, so a constant voltage output is required.

XI. DISCUSSION

The suggested model is set up in MATLAB software when a photovoltaic module's output properties are analyzed and examined. The perturbation and observation algorithms are mostly used to determine the photovoltaic array's peak power-point. [14] To attain this maximum power point, a Cuk converter is utilized, which aids in stepping up or stepping down the array voltage to the maximum operating point voltage. The capacitor serves as the primary storage element in this case. It contributes to continuous current flow, while the inductor on the load side lowers ripple in the output current. As a result of the MPPT algorithm and the cuk converter, the solar array operates regardless of sunlight irradiation. In addition, we may construct an inverter circuit that transforms DC power into AC power. With the aid of an inverter, it can be connected to the grid. In solar PV applications, in addition to maximum power point tracking methods, the DC-DC conversion step is extremely significant.

This research examines the cuk converter in-depth, including its dynamics [2]. The design equations and modeling for a cuk converter connected to a photovoltaic system were provided. In MATLAB's SIMSCAPE package, the cuk converter is examined. In MATLAB's SIMSCAPE package, the cuk converter is examined. The findings demonstrate that the current input of the cuk converter is continuously, with tolerable changes in inductance voltages and current output. The results show that the developed converter may be used with any MPPT approach and provides the maximum power at a duty cycle of 65.06%. This study also includes a tiny signal analysis of a cuk converter, which is particularly useful for stability analysis [12].

XII. CONCLUSION

A mathematical model of the solar array has been created. The MPPT technique's programs attain the maximum PowerPoint. It has been demonstrated that at the specific irradiance levels, the maximum power supplied by the photovoltaic array is supplied to the load. If the temperature changes, the process is repeated. It is a straightforward MPPT configuration that results in a very efficient system. Finally, non-traditional energy sources will be used to supplant conventional energy sources soon, and the sun's energy, which is the most renewable source of energy, is used here.

This study demonstrates a potential model for making observations in terms of various influencing factors. This paper explains how to use MATLAB® to create modern photovoltaic cells for photovoltaic arrays and a model based on experimental data. Solar cells were made with the photovoltaic block, and the electricity generated using a photovoltaic array was impacted by changes in irradiance.

Modeling was being used to validate the implemented model. The data implies that the suggested approach is capable of modeling solar system activity.

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