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A FUZZY LOGIC CONTROL BASED MAXIMUM POWER POINT TRACKER FOR A STAND ALONE SOLAR PHOTOVOLTAIC SYSTEM UNDER UNIFORM RADIATION CONDITION

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ABSTRACT

This paper proposes Maximum Power Point Tracking (MPPT) of a photovoltaic system under variable temperature and solar radiation conditions using Fuzzy Logic Algorithm. The cost of electricity from the PV array is more expensive than the electricity from the other non- renewable sources. So, it is necessary to operate the PV system at maximum efficiency by tracking its maximum power point at any weather conditions.

Boost converter increases output voltage of the solar panel and converter output voltage depends upon the duty cycle of the MOSFET present in the boost converter. The change in the duty cycle is done by Fuzzy logic controller by sensing the power output of the solar panel. The results show that the proposed controller is able to track the MPP in a shorter time with less fluctuation. The final result shows that the fuzzy logic controller exhibits a better performance compared to other conventional methods. [1]

1.1 INTRODUCTION

In recent years, the use of photovoltaic (PV) energy has experienced significant progress as an alternative to solve energy problems in places with high solar density, which is due to pollution caused by fossil fuels and the constant decrease of prices of the PV modules. Unfortunately, the energy conversion efficiency of the PV modules is low, which reduces the cost-benefit ratio of PV systems.

The maximum power that a PV module can supply is determined by the product of the current and the voltage at the maximum power point, which depends on the operating temperature and the solar irradiance. The short-circuit current of a PV module is directly proportional to the solar irradiance, decreasing considerably as the irradiation decreases, while the open circuit voltage varies moderately due to changes in irradiation. In contrast, the voltage decreases considerably when the temperature increases, while the short circuit current increases moderately. [2]

Temperature (T), Irradiance (G), have influence on the open circuit voltage (Voc) and short circuit current (I_{sc}) which determine the power generation. The efficiency of a PV plant is affected mainly by three factors: the efficiency of the PV panel (in commercial PV panels it is between 8-15% , the efficiency of the inverter (95-98 %) and the efficiency of the maximum power point tracking (MPPT) algorithm (which is over 98%). Improving the efficiency of the PV panel and the inverter is not easy as it depends on the technology available, it may require better components, which can increase drastically the cost of the installation. Instead, improving the tracking of the maximum power point (MPP) with new control algorithms is easier, not expensive and can be done even in plants which are already in use by updating their control algorithms, which would lead to an immediate increase in PV power generation and consequently a reduction in its price.

1.2 OBJECTIVE

The basic objective would be to study MPPT and successfully implement the MPPT algorithms either in code form or using the Simulink models. Modeling the converter and the solar cell in Simulink and interfacing both with the MPPT algorithm to obtain the maximum power point operation would be of prime importance.

2. MPPT CONTROLLER

2.1 MAXIMUM POWER POINT TRACKING:

Maximum power point tracking is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions. MPPT or Maximum power point tracking is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage).

2.2 WHAT IS MPPT

The maximum power point (MPP) describes the point on a current voltage (I-V) curve at which the solar PV device generates the largest output i.e. where the product of current intensity (I) and voltage (V) is Maximum.

The MPP may change due to external factors such as temperature, light conditions and workmanship of the device.

2.3 MPPT IMPLEMENTATION:

When a load is directly connected to the solar panel, the operating point of the panel will rarely be peak power. The impedance seen by the panel derives the operating point of the solar panel. Thus by varying the impedance seen by panel, the operating point can be moved towards peak power point. Since panels are DC drives, DC-DC converters must be utilized to transform the impedance of one circuit (source) to the order circuit (load). Changing the duty ratio of the DC-DC converter results in the impedance change as seen by panel. At particular impedance the operating point will be at the peak power transfer point. The I-V curve of the panel can vary considerably with variation in atmospheric conditions such as radiance and temperature. Therefore it is not feasible to fix the duty ratio with such dynamically changing operating conditions.

3. FUZZY LOGIC CONTROLLER

The use of fuzzy logic control has become popular over the last decade because it can deal with imprecise inputs, does not need an accurate mathematical model and can handle nonlinearity. Microcontrollers have also helped in the popularization of fuzzy logic control. The Fuzzy Logic tool was introduced in 1965, also by Lotfi Zadeh, and is a mathematical tool for dealing with uncertainty.

Additional benefits of fuzzy logic include its simplicity and its flexibility. Fuzzy logic can handle problems with imprecise and incomplete data, and it can model nonlinear functions of arbitrary complexity.

The fuzzy logic consists of three stages

1. Fuzzification
2. Inference system
3. Defuzzification.

Fuzzification – convert classical data or crisp data into fuzzy data or Membership Functions (MFs)

Fuzzy Inference Process – combine membership functions with the control rules to derive the fuzzy output.

Defuzzification – use different methods to calculate each associated output and put them into a table: the lookup table. Pick up the output from the lookup table based on the current input during an application.

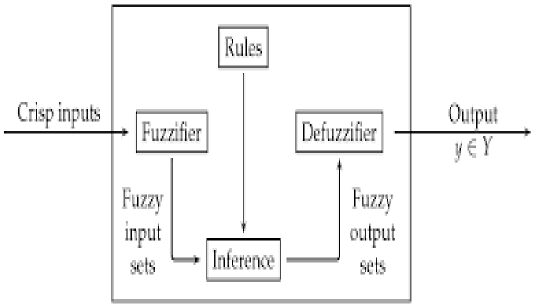


Fig 3.1: Fuzzy logic blocks [2]

3.1 FUZZY INFERENCE SYSTEM:

Fuzzy inference system consists of a Fuzzification interface, a rule base, a database, a decision-making unit, and finally a Defuzzification interface.

RULE BASE: Rule base containing a number of fuzzy IF–THEN rules.

DATA BASE: Database which defines the membership functions of the fuzzy sets used in the fuzzy rules.

DECISION-MAKING:
Decision-making unit which performs the inference operations on the rules.

3.2 FUZZIFICATION:

Fuzzification interface which transforms the crisp inputs into degrees of match with linguistic values.

3.3 DEFUZZIFICATION:

Defuzzification interface which transforms the fuzzy results of the inference into a crisp output.
In this five fuzzy levels are used:

1. NB (Negative Big),
2. NM (Negative Medium),
3. NS (Negative Small),
4. ZERO(Zero),
5. LOW

The values a, b and c are based on the range values of the numerical variable. In some cases the membership functions are chosen less symmetric or even optimized for the application for better accuracy .The inputs of the fuzzy controller are usually an error, E, and the change in the error, Delta E. The error can be chosen by the designer, but usually it is chosen as Delta P/Delta V because it is zero at the MPP.

The output of the fuzzy logic converter is usually a change in the duty ratio of the power converter, ΔD, or a change in the reference voltage of the DC link, ΔV. The rule base, also known as rule base look up table or fuzzy rule algorithm, which associates the fuzzy output to the fuzzy inputs based on the power converter used and on the knowledge of the user. Where the inputs are E and ΔE, and the output is a change in the DC-link voltage, ΔV. For example, if the operating point is far to the right of the MPP, E is NB, and ΔE is zero. Then to reach the MPP the reference voltage should decrease, so ΔV should be NB (Negative) to move the operating point towards the MPP.

3.4 ADVANTAGES:

- Flexible, intuitive knowledge base design.
- Convenient user interface.
- Easy computation.

3.5. DRAWBACKS:

- Manual tuning in large-scale industrial applications. Time-consuming retuning even if applied to a similar plant in other location.
- Many actual implementations are just equivalent to look-up table interpolation schemes.

4. SIMULATION CIRCUITS AND RESULTS

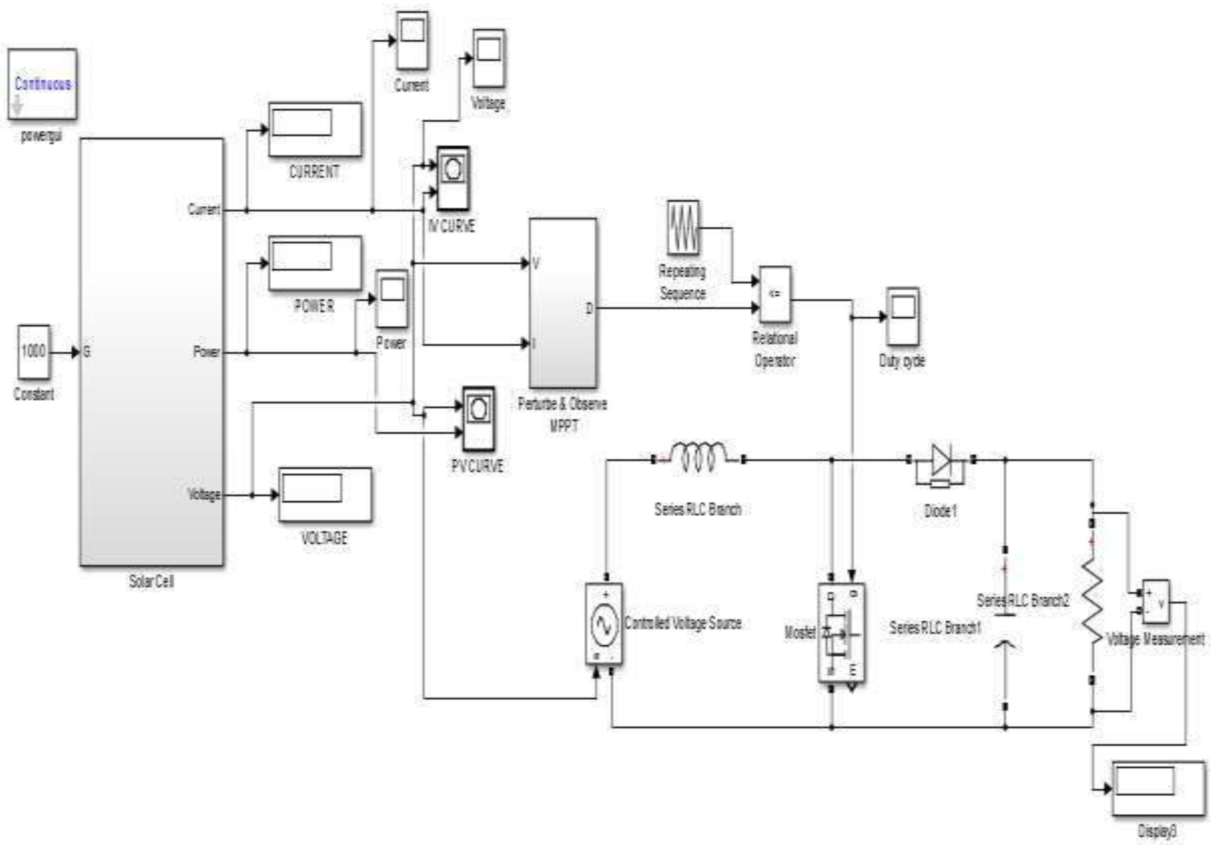


Fig 4.1 PV cell modelling

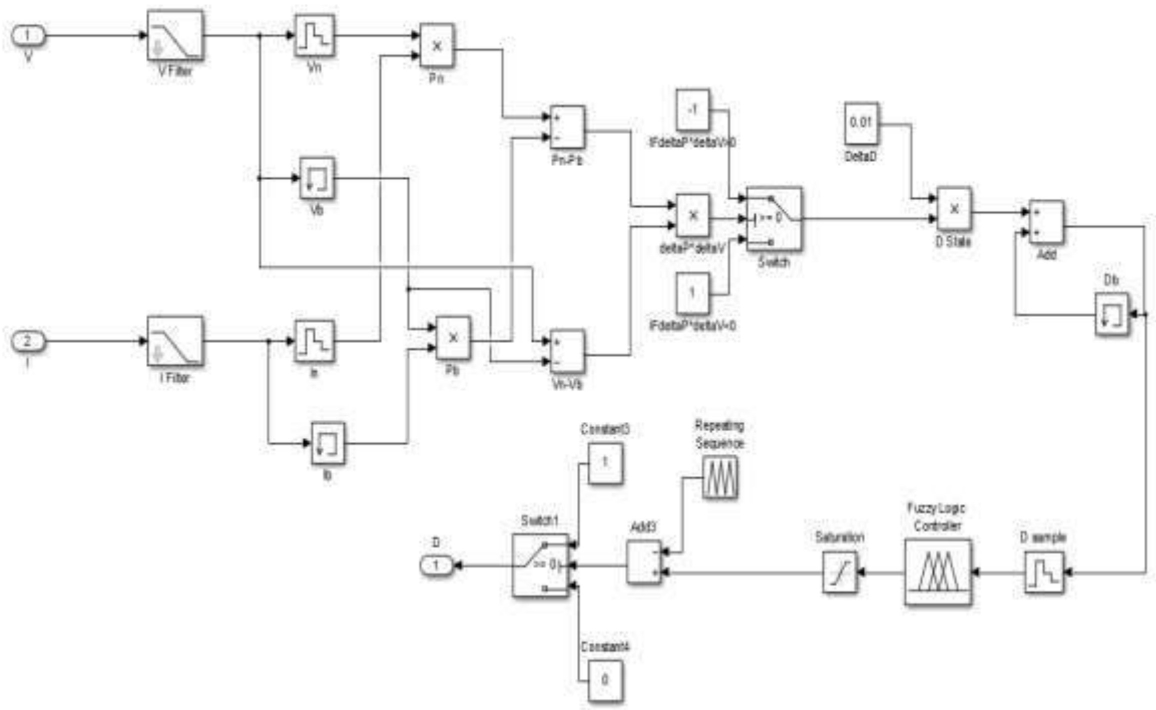


Fig 4.2 MPPT circuit

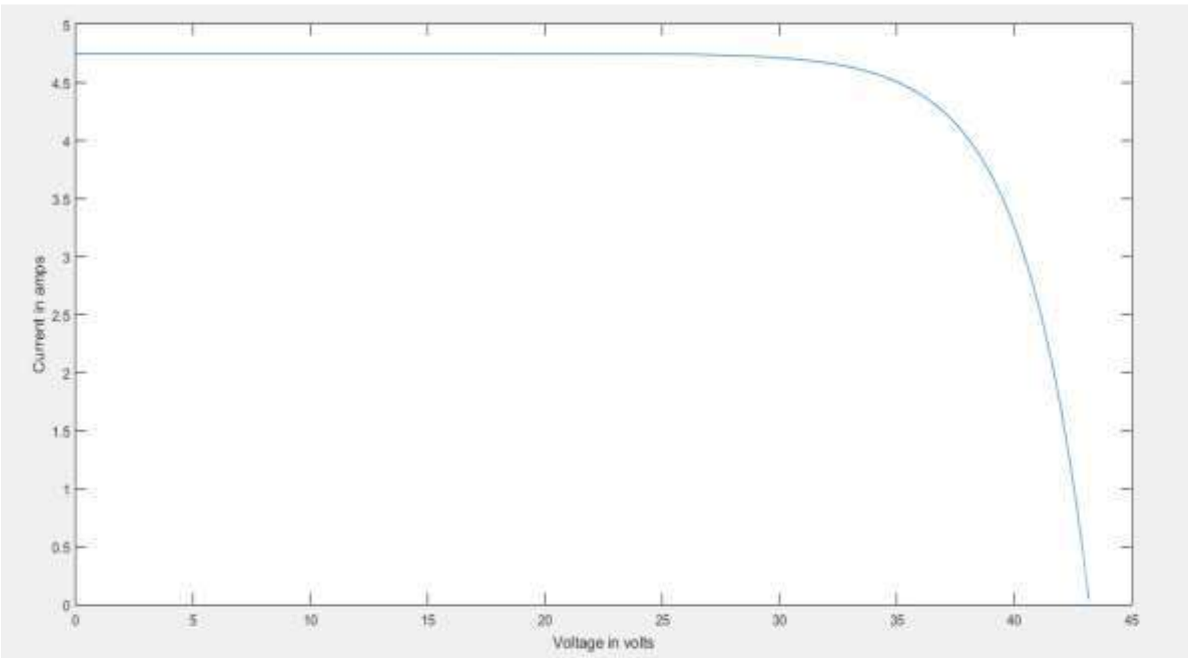


Fig 4.3: Current VS Voltage curve of solar panel

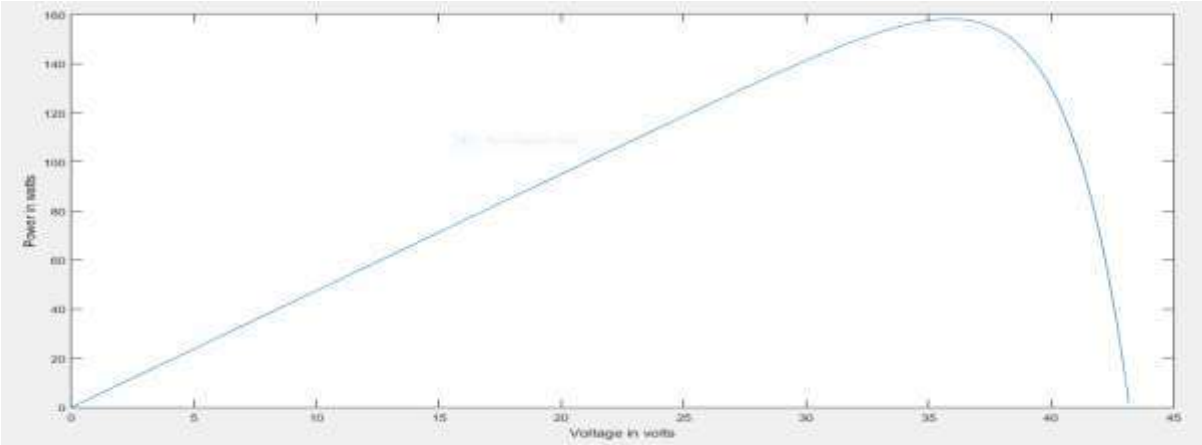
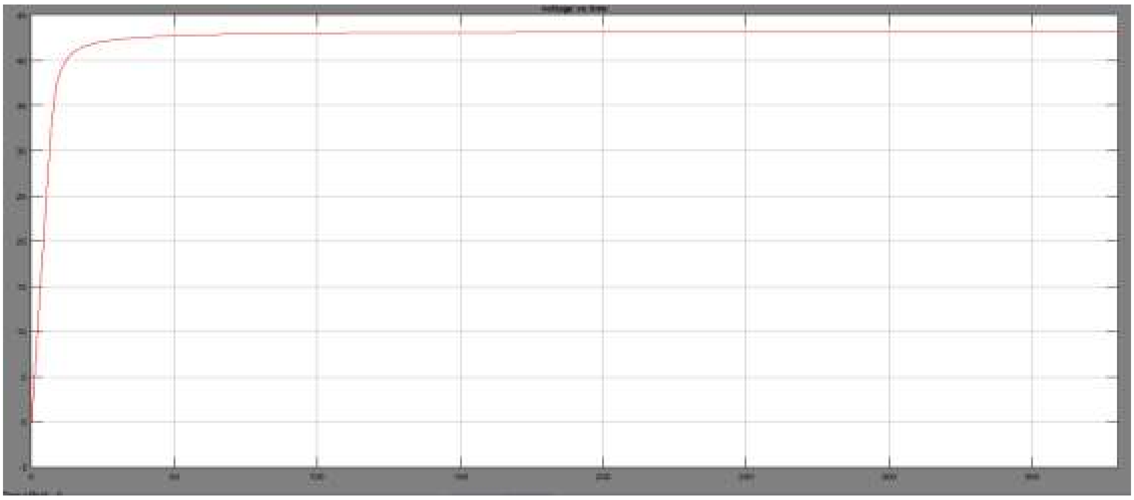


Fig 4.4: Power VS Voltage curve of solar panel

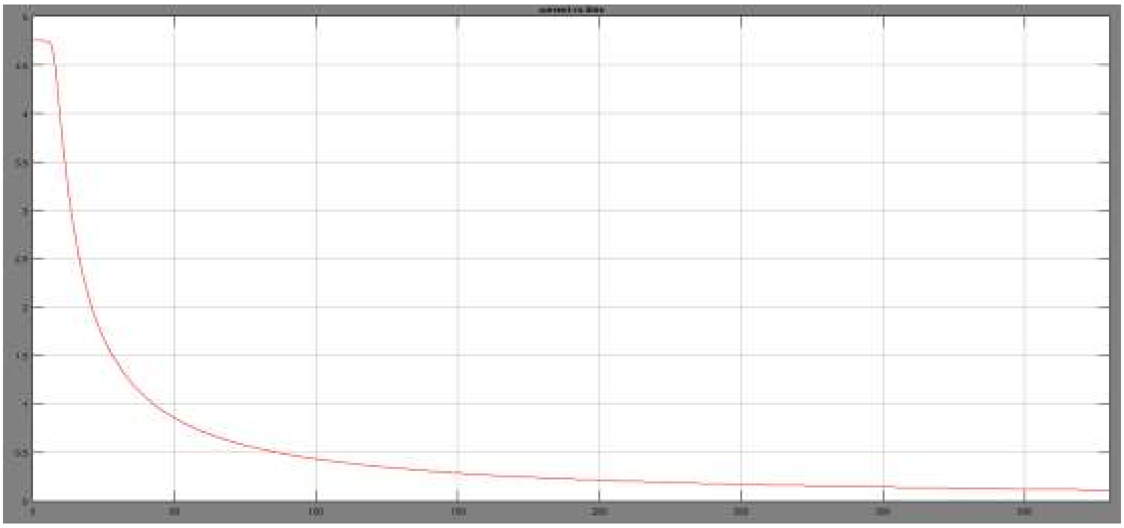
Voltage in volts



Time in sec

Fig 4.5: Voltage VS Time

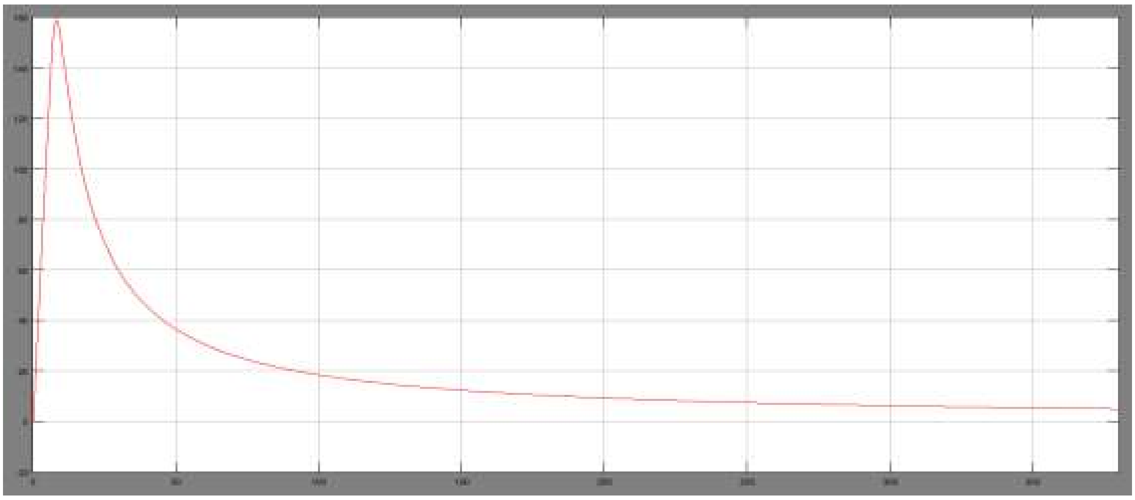
Current in amps



Time in sec

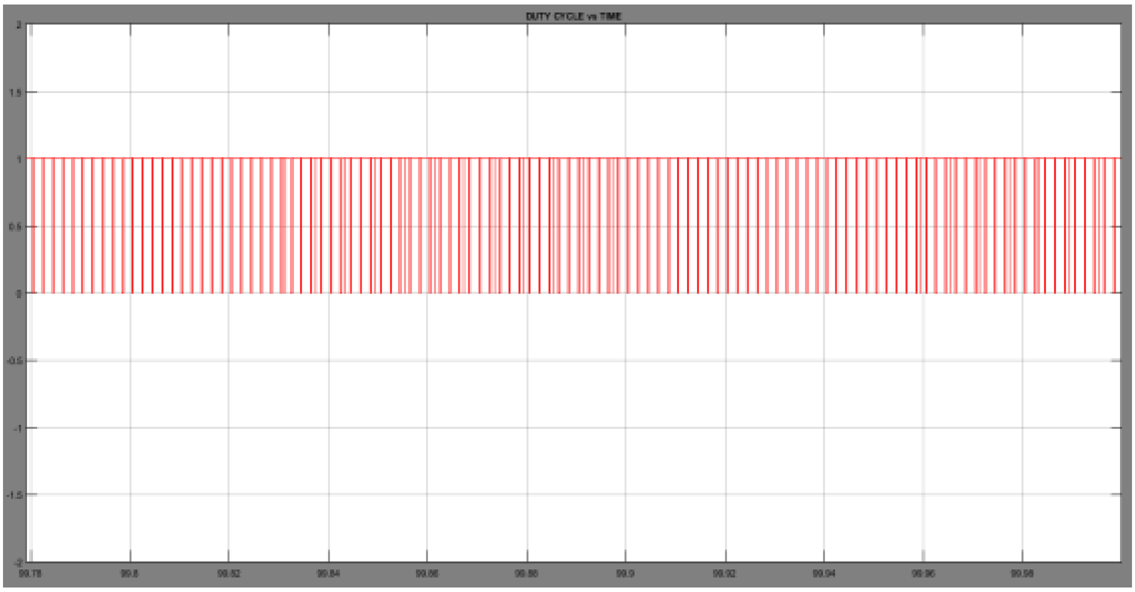
Fig 4.6: Current VS Time

Power in watts



Time in sec

Fig 4.7: Power VS Time



Time in sec

Fig 4.8: Duty Cycle VS Time

5. TEST RESULTS

PARAMETERS	1000 W/M²	800 W/M²	500 W/M²
Short-circuit current (I_{sc}) amps	4.75	3.8	2.375
Voltage at P_{max} (V_{mpp}) volts	36.02	35.7	32.58
Current at P_{max} (I_{mpp}) amps	4.403	3.5	2.279
Maximum Power point (watts)	158.9	124.9	74.25
Load voltage (V_0) volts	362.8	326.7	315
Load power (P_0) watts	384.56	344.34	320.04

6. CONCLUSION

Perturb & Observe method suffers from loss of tracking because of changing atmospheric conditions and steady state oscillations near maximum power point (MPP). P&O based fuzzy logic controller decrease the output time, oscillations and the effects of changing irradiations. The fuzzy logic controller decreases the number of steps required to reach maximum power point.

This work can be extended by using controllers based on search algorithms such as particle swarm optimization, cuckoo search, moth flame optimization algorithm etc….

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