Design of A P&O Based Fuzzy Logic Controller for Maximum Power Point Tracking of a Standalone Solar PV System under Partial Shading Condition

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***Abstract*- The MPPT controllers are used in photovoltaic system to make full utilization of PV array output power. The output power of a photovoltaic module depends on the solar irradiance and the operating temperature, therefore it is necessary to apply maximum power point tracking controllers (MPPT) to obtain the maximum power of a PV system regardless of variation in climatic conditions. The traditional solution for MPPT controllers is the perturbation and observation (P&O) algorithm, which presents oscillations around the operating point. This work provides a theoretical study of the P&O maximum power point tracking technique, using fuzzy logic controller applied to the standalone PV system. With conventional P&O algorithm it is impossible to satisfy both performance and good accuracy under irradiance and temperature changing. To get rid of these limitations, P&O based fuzzy logic controller is used. The output of the MPPT controller is given to a PWM modulator, the output of PWM modulator is given to the DC-DC boost converter to generate maximum power from the PV system. The detailed modeling is then simulated step by step using MATLAB/Simulink software due to its frequent use and its effectiveness**

I. INTRODUCTION

In recent years, the use of photovoltaic (PV) energy has experienced significant progress as an alternative to solve energy problem in places with high solar density, which is due to pollution caused by fossil fuels and the constant decrease of prices of the PV module. Unfortunately, the energy conversion efficiency of the PV module 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 change in irradiation. In contrast, the voltage decreases considerably when the temperature increases, while the short circuit current increases moderately.

In summary, increase in solar irradiation produces increase in the short-circuit current, while increase in temperature decrease the open circuit voltage, which affects the output power of the PV module. This variability of the output power means that in the absence f a coupling device between the PV module and the load, the system does not operate at the maximum power point (MPP).

According to the previous context, the use of maximum power point controllers is currently increasing. These devices are responsible for regulating the charge of the batteries, controlling the point at which the PV module produces the greatest amount of energy possible, regardless of variations in climatic conditions. Taking into account the above, different researches have been carried out using traditional algorithms for the modeling and implementation of MPPT controllers. Also, algorithms based on artificial intelligence techniques such as fuzzy-logic and neutral networks have been used. The effectiveness of these control techniques was demonstrated in order to achieve a fast and stable response for real power control and power system applications. The use of MPPT controllers in PV system has the following advantage:

- They yield more power, depending on weather and temperature.
- They allow the connection of PV modules in series to increase the voltage of the system,

which reduces the wiring gauge and adds flexibility.

- They offer a cost saving in the transmission wire needed for the installation of the PV system.

OBJECTIVE

The main objective of this work is the design, modeling and simulation of a P&O based fuzzy logic MPPT controller and a DC-DC converter for a standalone solar PV system.

II. 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). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

III. 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.

In order to ensure maximum power output (Pmax) of a solar PV device in view of these external factors, maximum power output trackers (MPPT) may be operated to regulate the resistance of the device.

IV. 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.

V. PERTURB AND OBSERVE METHOD

The most commonly used MPPT algorithm is P&O method. This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle. In this algorithm a slight perturbation is introduce to the system. This perturbation causes the power of solar module various. If the power increases due to perturbation then the perturbation is continued in the same direction. After the peak power is reached the power at MPP is zero and the next instant decreases and hence after the perturbation reverses as shown in fig. below.

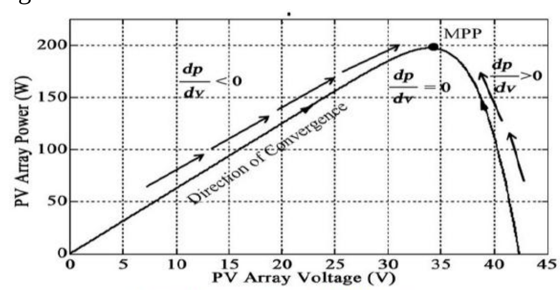
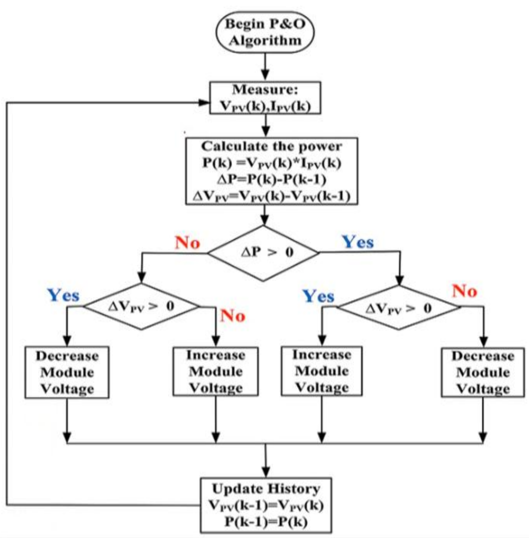


Figure 15: P and O based MPPT technique.

When the stable condition is arrived the algorithm oscillates around the peak power point. In order to maintain the power variation small the perturbation size is remain very small. The technique is advanced in such a style that it sets a reference voltage of the module corresponding to the peak voltage of the module. It is observed some power loss due to this perturbation also fails to track the maximum power under fast changing atmospheric conditions. But remain this technique is very popular and simple.

Perturbation & Observation Flowchart:

The perturbation and observation method is a practical method that offers very easy feedback and there are a number of parameters that are measured. The perturbation and observation theory works by perturbing the array of a PV system in periodic time and then comparing it with the output power of previous perturbs. When the perturbation that caused the increase or decrease in the power of the array is ascertained, the succeeding perturbation is prepared in a similar or in an opposite direction. In this manner, the peak point of the power tracker incessantly looks for the peak point of the power condition. Fig. below shows the flowchart of P&O algorithm.



VI. FUZZY LOGIC CONTROLLER

Fuzzy logic system works on the principle of assigning a particular output depending on the probability of the state of input. Fuzzy logic was developed in 1965 by Lotfi Zadeh at the University of California, as a way to perform computer processors based on the natural values rather the binary values. With, fuzzy logic the control output is smooth, despite of wide range of input variations. Fuzzy logic can control nonlinear systems that would be difficult or impossible to model mathematically.

The traditional P&O algorithm can't satisfy both performance requirement of fast dynamic response and good accuracy during steady state at the same time. So, we propose a P&O method with fuzzy controller and apply it to the standalone PV system. This method can greatly improve the dynamic performance of the PV output power.

Fuzzy Logic Controller method has been used for tracking the maximum power of PV system since it has the advantages such as it is relatively simple to design. The main elements of FLC system are shown in fig. below. It mainly consists of four sections i.e., Fuzzification, Interference engine, Defuzzification and Rule-base.

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: It defines the membership functions of the fuzzy sets used in the fuzzy rules.

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

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

DEFUZZIFICATION: Defuzzification interface which transforms the fuzzy results of the inference into a crisp output.

ADVANTAGES:

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

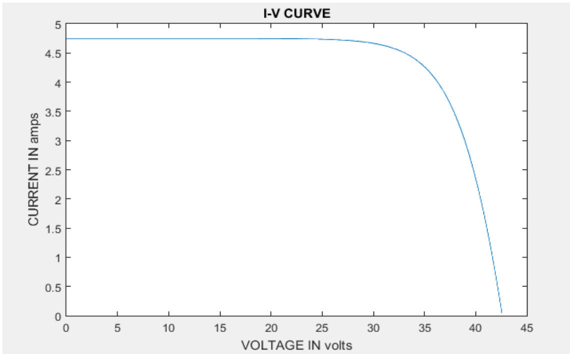
DRAWBACKS:

- 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.

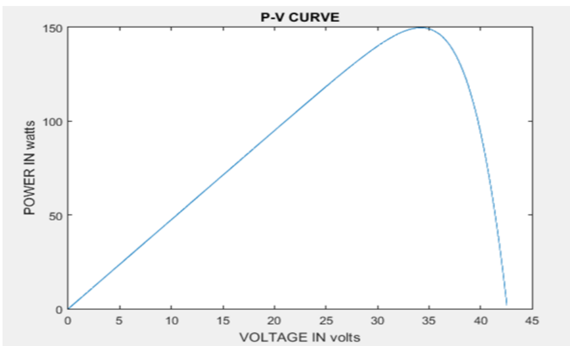
VII. SIMULATION RESULTS

CHARECTARSSTICS OF SOLAR PV PANEL UNDER UNIFORM CONDITION

- CURRENT vs. VOLTAGE

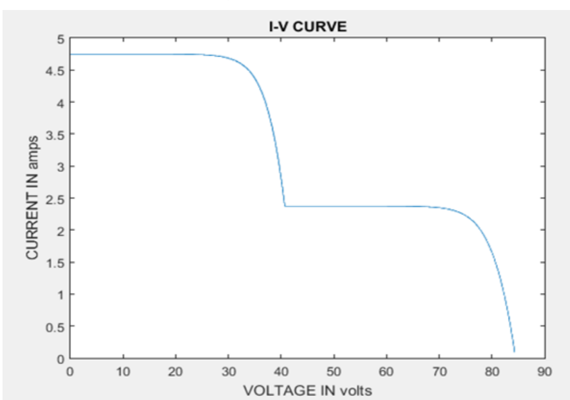


- POWER vs. VOLTAGE CURVE:

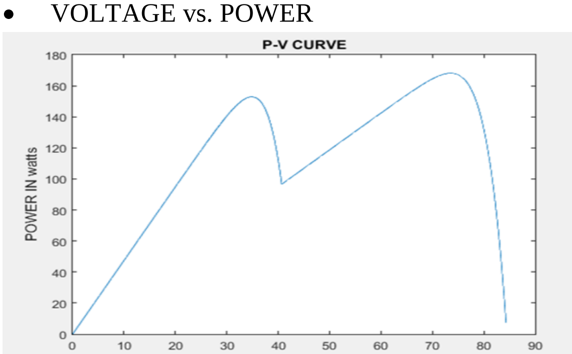


CHARACTERISTS OF SOLAR PANEL UNDER PARTIAL SHADING CONDITION

- CURRENT vs. VOLTAGE



- VOLTAGE vs. POWER



- POWER vs. TIME

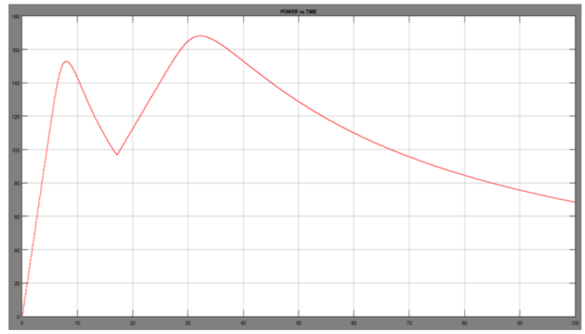


Fig. Time on x-axis and Power (w) on y-axis

- VOLTAGE vs. TIME

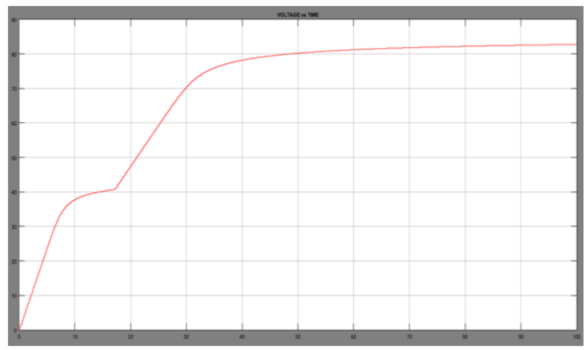


Fig. Time on x-axis & voltage (v) on y-axis

- CURRENT vs. TIME

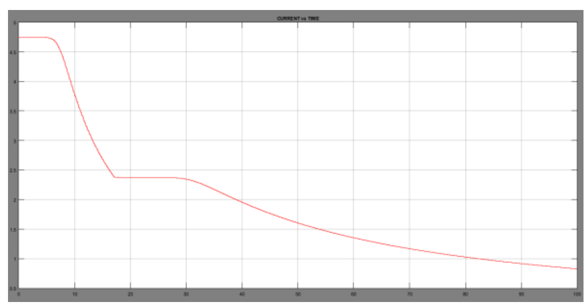
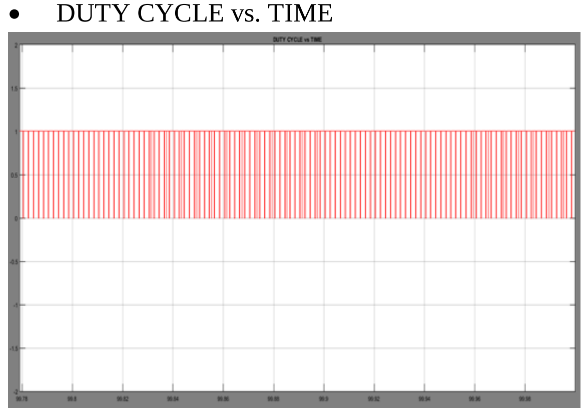


Fig. Time on x-axis & current (A) on y-axis

- DUTY CYCLE vs. TIME



RESULTS OF PV MODULE AT DIFFERENT IRRADIATION

PARAMETERS	1000 W/m^2	800 W/m^2	500 W/m^2
Short-circuit current (I_{sc}) amps	4.75	3.8	2.375
Voltage at P_{max} (V_{mpp}) volts	40.4	39.37	36.16
Current at P_{max} (I_{mpp}) amps	4.29	3.47	2.16
Maximum power point (watts)	149.6	118.5	74.13
Load voltage (V_0) volts	379.4	369.1	338.8
Load power (P_0) watts	464.2	439.5	370.2

VIII. CONCLUSION AND FUTURE SCOPE

It is observed that perturb and observe method suffers from loss of tracking because of changing atmospheric conditions and steady state oscillations near maximum power point (MPP).

We found that P&O based fuzzy logic controller decreases the output time, oscillations and the effect of change in irradiation. The P&O based fuzzy logic controller decreases the number of steps required to reach MPP.

As future work, this work can be extended by using search algorithms such as Particle Swarm Optimization, Cuckoo search algorithm, Flower Pollination algorithm, Grey Wolf Optimization etc.

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