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The Improved MPPT Controller For Photovoltaic System Under Partial Shading Condition

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Abstract: **The performance of a photovoltaic (PV) array is affected by temperature, solar insolation, shading and array configuration. The PV system exhibits a non-linear I-V characteristic and its unique maximum power point on the P-V curve varies with insolation and temperature. Often the PV array gets shadowed, completely or partially, by passing clouds, neighbouring buildings and trees. This situation is of particular interest in case of large PV installations such as those used in a distributed power generation scheme and residential PV systems. Under partially shaded conditions, the P-V characteristic becomes more complex with multiple peaks. Conventional Maximum Power Point Tracking (MPPT) techniques fail to reach global peak power point and tend to stay in local peak power point which significantly reduces the efficiency of the PV system. This paper mainly focuses on extracting the maximum power from PV array under partially shaded conditions by executing improved hill climbing algorithm to identify the global maximum power point (GMPP).**

Keywords: **PV; GMPP; MPPT; P&O; INC;**

INTRODUCTION

In 21st century energy crises, drag every researchers concentration towards the renewable energies, renewable energy is a source of clean and green energy. Among all renewable energies photovoltaic (PV) and wind are considered to be good sources of energy. Many researches are going on in the area of PV system, big challenge in this area is to track maximum power point (MPP) in the dynamic atmospheric conditions and shading condition because MPP varies with change in temperature and insolation.

To track maximum power point, technique use called maximum power point tracking technique (MPPT).In literature we found many MPPT tracking techniques in which main concentration is towards the fast tracking of MPP and operate PV system in global maximum power point.

Perturb and observer (P&O) and incremental conductance (INC), these two methods are frequently found in literature because of its easy implementation and effective tracking. In this thesis we described about INC. Boost converter is used as intermediate converter to perform switching and regulated output. In many literatures it has proved that boost converter has more advantages over the buck converter.

To understand PV system easily, it is operated under the constant load condition and avoids battery. Battery is used to store extra power from PV system. Partial shading is problem which interrupts PV system to operate in global MPP and system efficiency reduces because of this. Effect of partial shading in I-V and P-V curves also explained in this thesis. Analog implementation of MPPT makes system's transient response faster and it is cheaper, this also discussed with results.

The system under consideration

PV system under constant temperature and irradiation

As shown in Figure 1.1 system consist of a PV module, DC-DC boost converter, MPPT with constant resistive load. Boost converter consist of two switches S1 and S2, an inductor L, two capacitors C1 and C2 and load resistance R. Switches are operate by control logic, develop by MPPT. Matlab coding is use to make MPPT, its purpose is to track maximum power so that PV module utilizes maximum.

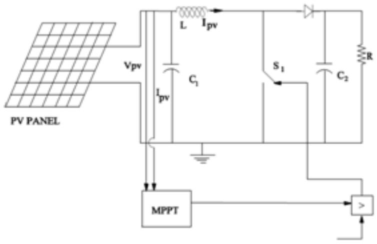


Figure 1.1: PV module with boost converter.

PV system under constant temperature and varying irradiation

Dynamic atmospheric condition affects the output of PV panel, so output of boost converter also, our purpose is to track maximum power deliver by the module in any atmospheric conditions. Our MPPT should be robust enough to track MPP. System discussed in previous section is for constant atmospheric condition, same system consider again but for different irradiations and constant temperature.

PV system under varying temperature and constant irradiation

Temperature is inversely proportional to the voltage, so as the temperature increases voltage decreases, it affects the output power.

RELATED WORK

T. Esram*et.al.* [2] discussed and compared different MPPT techniques available in literature and explained about nineteen MPPT methods. The author has given summary of these MPPT techniques and their implementation methods which serve as a useful guide in choosing the right MPPT method for specific PV systems. Shading is a big problem in the photovoltaic system W. Xiao *et.al.* [3] discussed the topologies used for photovoltaic power systems to optimize the operation of MPPT. The author proposed an individual power interface for each photovoltaic module and recommended a structure suitable for the photovoltaic features and MPPT to minimize the performance reduction caused by non-ideal conditions.

M. Chen *et.al.* [12] proposed an accurate, intuitive, and comprehensive electrical model to capture the entire dynamic characteristics of a battery, from nonlinear open-circuit voltage, current, temperature, cycle number, and storage time-dependent capacity to transient response. I.-S. Kim *et.al.* [13] proposed a sliding mode controller for the single-phase grid connected photovoltaic system. The sliding mode controller has been constructed based on a time-varying sliding surface to control the inductor current and solar array power simultaneously. R. Gules *et.al.* [14] analysed, designed and implemented a parallel connected MPPT system for a stand- alone photovoltaic power generation.

A. Safari *et.al.* [11] discussed incremental conductance (INC) method and practical implementation of this method. H. Patel *et.al.* [15**]** have discussed about specifically partial shading condition and extensive study about the partial shading condition has been done by the author. They made a generalisedprogramme for PV array simulation.

W. Xiao and W. G. Dunford, "A modified adaptive hill climbing MPPT method for photovoltaic power systems," in Proc. Power Electron. Spec. Conf. (PESC'04), vol. 3, Jun. 2004, pp. 1957–1963: Maximum power point tracking (MPPT) must usually be integrated with photovoltaic (PV) power systems so that the photovoltaic arrays are able to deliver maximum available power. In this paper, a modified adaptive hill climbing (MAHC) MPPT method is introduced. It can be treated as an extension of the traditional hill climbing algorithm. The simulation and experimental results show that the proposed MPPT control can avoid tracking deviation and result in improved performance in both dynamic response and steady-state.

N. Femia, G. Petrone, G. Spagnuolo, and M. Vitelli, "Optimization of perturb and observe maximum power point tracking method," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 963–973, Jul. 2005: Maximum power point tracking (MPPT) techniques are used in photovoltaic (PV) systems to maximize the PV array output power by tracking continuously the maximum power point (MPP) which depends on panels temperature and on irradiance conditions. The issue of MPPT has been addressed in different ways in the literature but, especially for low-cost implementations, the perturb and observe (P&O) maximum power point tracking algorithm is the most commonly used method due to its ease of implementation. A drawback of P&O is that, at steady state, the operating point oscillates around the MPP giving rise to the waste of some amount of available energy; moreover, it is well known that the P&O algorithm can be confused during those time intervals characterized by rapidly changing atmospheric conditions. In this paper it is shown that, in order to limit the negative effects associated to the above drawbacks, the P&O MPPT parameters must be customized to the dynamic behavior of the specific converter adopted. A theoretical analysis allowing the optimal choice of such parameters is also carried out. Results of experimental measurements are in agreement with the predictions of theoretical analysis.

CLASSIFICATIONS OF SOLAR PHOTOVOLTAIC SYSTEM

3.1 Introduction solar PV system

PV system is design to give the electric supply to load and load can be ac type or dc type. Supply can be needed in day time or evening time or both time. PV system can give supply only in day time for night hours we needed supply for that we have batteries, where power can store and utilize [13].

3.1.1Types of PV system

Stand-alone PV system

Depending on the type of load, cost, resources availability and requirements of the load stand-alone system divided into several categories, which are describe below

a) Unregulated standalone system with DC load

Usually this type of system is for low power applications. A PV system is directly connected to the load without any MPPT controller, night hours it will not provide any supply because of the absence of the battery.

Figure 3.1: Unregulated standalone system with DC load

b) Regulated standalone system with DC load

Figure 3.2: Regulated standalone system with DC load

It is similar to unregulated standalone system with DC load but basic difference between this and previous one that this system requires a MPPT technique. Usually system with MPPT should have one battery otherwise extra power will be waste.

c) Regulated standalone system with battery and DC load

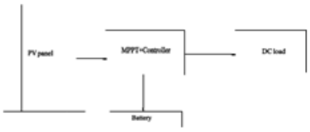


Figure 3.3: Regulated standalone system with battery and DC load

Most common configuration PV array, battery, MPPT and DC load. Battery use to store the extra power of PV system, this will increase the cost of PV system. A charge controller is must for this type of system because battery life is less compare to PV module, extra charging deep discharging can reduce the life of battery [1,2].

d) Regulated standalone system with battery, AC and DC loads

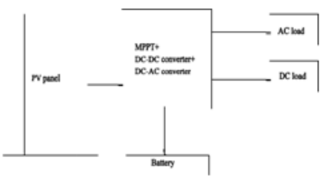


Figure 3.4: Regulated standalone system with battery, AC and DC loads

This system is similar to previous one but here AC load can also draw the power from PV system and inverter (DC to AC converter) is require, it will increase the cost.

3.1.2 Grid interactive PV system

Grid connected PV system is a system when grid is connected to PV system .In this type of system consist PV array and inverter. Figure 2.5 shows grid connected PV system. Grid connected system deals with AC. Grid connected system deals with very high power applications, so is tough to store this much of power in battery [13].

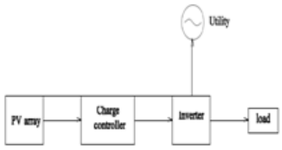


Figure 3.5: Grid interactive PV system

PROPOSED GMPP

4.1 MPPT:

PV system's efficiency depends on MPPT [2].MPPT is the most important in PV system; efficient tracking is the key issue. Many literature we found who has taken care of irradiation and temperature changes because these are key factors of shifting of MPP, in chapter 3 we already have described about the effect of temperature and irradiation on the parameters of current equation, roughly we can say temperature is inversely proportional and irradiation directly proportional to output power. In partial shading condition we have multiple local maxima and one global maxima and it's tough to track the global maxima through one MPPT, without using it in distributed manner. Fast tracking of MPPT is also a big problem.

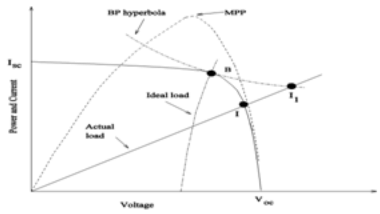


Figure 4.1: The concept of load-mismatch and MPP tracking

Figure 4.1 Maximum power hyperbola BP intersects I-V curve at point B, load mismatch can cause PV array to operate in sub-optimal point. Actual load line intersects I-V curve in I, ideal load curve in B [4].

4.2 Partial shading

Partial shading occurs in PV system or cell because of dirt, neighbor building, aging effect of module etc. Shaded cell gives less power output and it's tough to consider the shading of each and every cell analysis will become tougher, so considering the effect of shading in module, we simulated.

We have considered two modules one is shaded and one is full illuminated, and check the how out P-V and I-V curve affected. Figure 1.2 shows partial shading phenomena. When one cell is shaded, cell become reverse bias, breakdown voltage can occur in this situation, which can cause serious damage in the cell, so anti parallel diode connected in series to bypass the current. Figure 7.2 and figure 7.4 shows how P-V and I-V curve will look like in this case.

Why we need to simulate PV array in partial shading condition because P-V curve had multiple local peak and a global peak, so MPPT should be good enough to track this global peak. So in partial shading condition I-V and P-V curve will give essential information for designing MPPT.

4.2.1 Modeling of partial shading phenomena in PV system

We can code or give a modeling approach to check partial shading effect in P-V and I-V curves, modeling is little bit easy. Modeling approach of PV system having following advantages

- Helps researchers to predict the effect of irradiation and temperature change in P-V and I- V curves.
- Different configuration can be check with its efficiency of PV system
- Different configuration can be check with different MPPT approach.

Two module output in shading condition:

Two module is simulated in shading condition one is getting 1000 W/m2 and other one is getting 100 W/m2.Figure 7.2 and Figure 7.4 clearly shows how the I-V curve and P-V curve change respectively in partial shading condition.

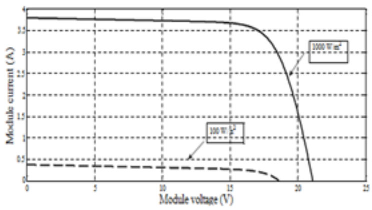


Figure 4.2 Module IV curves

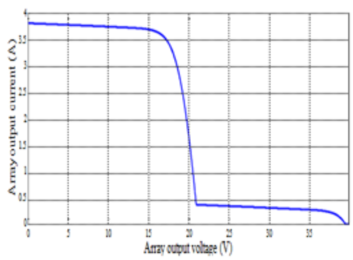


Figure 4.3 :Array IV curve

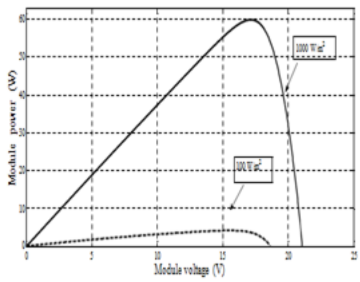


Figure 4.4: Module PV curves

FLC MPPT TECHNIQUE:

Fuzzy logic controller (FLC) is a nonlinear control method. Hence, it can be easily applied for nonlinear characteristics of PV system to track maximum power point [35]. Principle of fuzzy logic control was developed in 1965 by [36]. The basic advantage of FLC is that it can operate at uncertainty conditions like weather change and load variations. Moreover, it does not depend upon the exact model of the system. Its control strategies depend upon the measured data base and expert knowledge of the system. In addition to the merits, FLC based MPPT has good accuracy in terms of tracking and better robustness as compared to hill climbing techniques [37].

The fuzzy logic controller (FLC) based MPPT method comprises of following components:

- Fuzzification interface, where predefined fuzzy subsets determine the input crisp values.
- Fuzzy rule base, which provides the set of "*if then*" statements to define the controller behaviour.
- Inference engine, which processes output from input set of fuzzy values using the fuzzy rule base.
- Defuzzification interface, where crisp values of output fuzzy set is obtained.

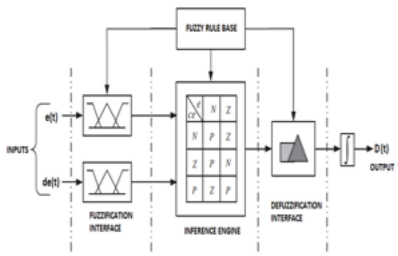


Fig 4.5 Basic Structure of FLC based MPPT

GLOBAL MPPT ALGORITHM

The global MPPT methods implemented so far fail to reach the global MPP when global MPP occurs in between two local MPPs as shown in fig.5. Therefore, the proposed algorithm has been developed such that it tracks global MPP under any operating condition under two stages.

(i) Global search with a large step size, Δd

(ii) Local search with a small step size, Δd in the region of global MPP

The proposed MPPT algorithm is based on the hill climbing method. The improved hill climbing algorithm sweeps the majority of the entire P-V curve with a large step size in duty cycle, Δd in the search space set between the Dstart and Dend so that no maximum power point is missed during the entire search. During the search started from Dstart, whenever the sign of difference in power, ΔP(k)=P(k) – P(k-1) , changes from positive to negative, it indicates that there exist a maximum power point in the region corresponding to the duty cycle D(k-1) and D(k). Therefore, corresponding duty cycle that represents the starting point of the region D(k-1) and corresponding power P(k-1) are stored. Then the search is continued until the duty cycle D is equal to Dend. During the rest of the search also, Duty cycles D and corresponding powers P with respect to other maximum power points are also stored in a similar manner. Once the global search is over, then global MPP is identified from the stored values of all the maximum power points just by comparing the powers P of each duty cycle, D. since the step size Δd used for the global search is sufficiently large enough, time taken to finish the entire global search is reduced. The global maximum power point identified by the global search will not transfer the actual maximum power available under the given weather conditions because global MPP identified by the global search is near to the actual global MPP. Therefore to reach the exact global MPP, local search is started now with starting duty cycle as D(k-1) with small step size in duty cycle, Δd. once the exact global MPP is reached, there will be a two step oscillation around the global MPP. Since the step size Δd is very small, the magnitude of oscillation around the global MPP is reduced so that the efficiency of the PV system is increased. According to this algorithm, global search is repeated every five minutes as weather conditions may have changed.

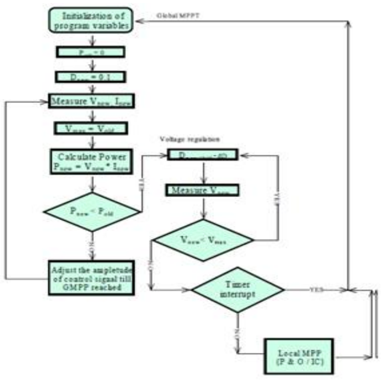
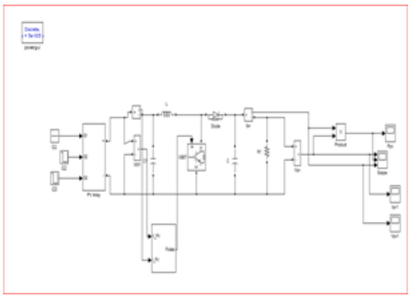


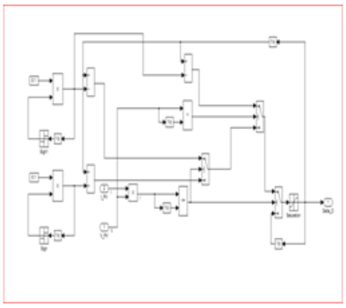
Fig 4.6. Flow chart of GMPPT Algorithm

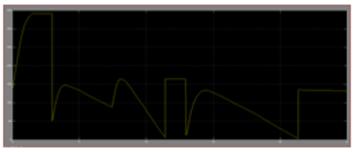
SIMULATION RESULTS

Main Diagram

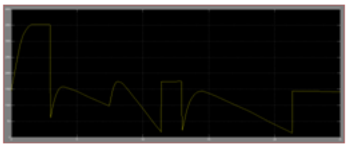


Global MPPT

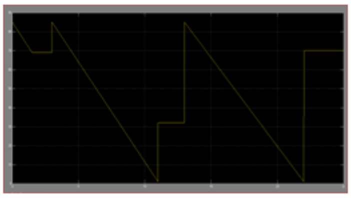




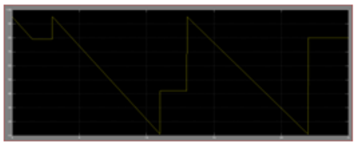
LMPPT (PV value without FUZZY)



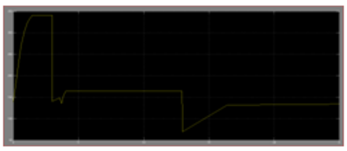
LMPPT (PV value with FUZZY)



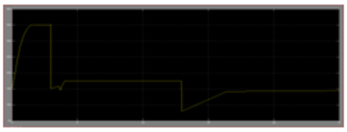
LMPPT (Voltage value without FUZZY)



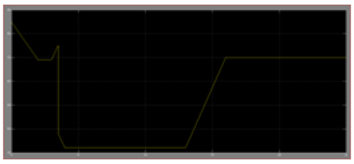
LMPPT (Voltage value with FUZZY)



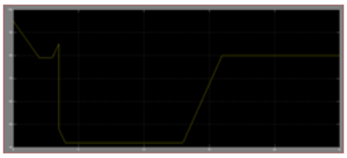
GMPPT (PV value without FUZZY)



GMPPT (PV value with FUZZY)



GMPPT (Voltage value without FUZZY)



GMPPT (Voltage value with FUZZY)

CONCLUSION

In this project a fuzzy logic based MPPT technique is suggested and to justify its better performance the results are compared with two other proved techniques. All the techniques are implemented on a grid connected PV system as shown in the simulation model to study their individual efficiency and response for tracking the maximum power point under various partial shading conditions. The proposed fuzzy logic based MPPT controller has been proved to be better MPPT technique as compare to Global MPPT techniques in terms of efficiency and tracking ability and harmonic reduction.It has better speed of response towards the PV system even without the knowledge of the actual model and the optimal operating point does not oscillate around the MPP.

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