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Matlab/Simulink Model of Solar PV Array with Fuzzy Logic Based MPPT for Maximizing PV Array Efficiency

Rashmi N[1] | Hemavathi R[2]

[1]PG Scholar – Control and Instrumentation, Department of Electrical Engineering, University Visvesvaraya College of Engineering (UVCE), Bangalore,
[2]Associate Professor – Control and Instrumentation, Department of Electrical Engineering, University Visvesvaraya College of Engineering (UVCE), Bangalore

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ABSTRACT

The goal of this work is to design and implement a maximum power point using tracker that uses a fuzzy logic control algorithm . in order to succeed in this work , an MPPT system consisting of a PV module, a DC-Dc converter and fuzzy logic controller is designed and simulated in simulink. The efficiency of normal solar PV module is very low , in order to maximize their operating efficiency and to reduce installation cost, maximum power point trackers (MPPT) are coupled with the system. An integrated model of PV module with identified converter is simulated in MATLAB . The simulation results shows that the fuzzy logic controller is able to obtain desired outcomes.

KEYWORDS: - Solar PV, MPPT(Maximum power point tracker), Fuzzy logic controller, DC-Dc boost converter, MATLAB.

1.INTRODUCTION

Solar is an imperative concern among renewable energy due to its noise free, eco friendly and easy maintenance with impressive life span. Solar energy falling on solar photovoltaic (PV) system can precisely disciple into electrical energy. Irradiation and temperature enormously influence the voltage and current which make them nonlinear. The performance of a PV cell largely depends on quality of cell material such as absorption capacity and reflectance of the surface. The operating condition like solar irradiance level, incident angle, temperature and load current plays a big role in dictating the performance of PV array output voltage, current and power delivery. PV systems need to minimize cost, reduce the size and increase the efficiency.

In order to capture the maximum-rated power from a PV module, it is necessary to operate the module at its optimal power point. To do this, a controller called a maximum power point tracker is required. The maximum power point (MPP) is the extraction of power from solar cell under specific circumstances. Load current primarily relies upon radiation, ambient temperature, and cell temperature. Maximum Power Point Tracking (MPPT) is the process to track the maximum power by optimizing the load resistance properly in any environmental condition.

A combined model of the PV module and the selected buck-boost converter is simulated, and the results used to obtain the best design needed to formulate and tune the fuzzy logic control algorithm for tracking the maximum power.

STRUCTURE OF PAPER

The paper is organized as follows: In Section 1, the introduction of the paper is provided along with the structure, important terms, objectives and overall description. In Section 2 we discuss related work. In Section 3 we have the complete information about modeling of solar pv cell. Section 4 shares information about the fuzzy logic controller(FLC), its advantages and disadvantages. Section 5 tells us about the methodology and the process description. Section 6 tells us about the future scope and concludes the paper with acknowledgement and references.

OBJECTIVES

In this paper, the main aim of this work is an approach to extract maximum energy from PV power system . By combining PV module and converter module with fuzzy logic controller. We created complete MPPT module, using it to tune the fuzzy logic controller rules and membership functions.

2.RELATED WORK

Many researchers have implemented various techniques to enhance the efficiency of the solar cell by enhancing the MPPT techniques during last few decades. The P & O of variable step size is proposed by Al-Diab and Sourkounis [2], and the step size is tuned automatically and compared with the conventional method. Ishaque and Salam [3] have contributed a brief literature to the MPPT design by adopting soft computing methods during partial shading. The variable CS MPPT algorithm is validated by comparing with conventional P & O and PSO MPPT algorithm in three distinct case studies and is described in [4]. The efficiency of the partial shading PV module is enhanced up to 32% by using the current of non-shaded module in [5].

In this paper, Fuzzy logic controller based MPPT technique is strived to validate over P & O technique to enhance the power and voltage of the system by contributing gate pulse of DC-DC boost converter. The proposed experiment is executed in MATLAB/SIMULINK environment

3.MODELLING OF SOLAR PV CELL

Through the PV effect, electromagnetic radiation from solar energy can be changed into electricity. When exposed to sunlight, photons with more energy than the semi-conductor's band-gap energy make electron-hole pairs that are proportional to the incident irradiation. A solar cell is essentially a p-n junction set on a thin wafer of semiconductor.

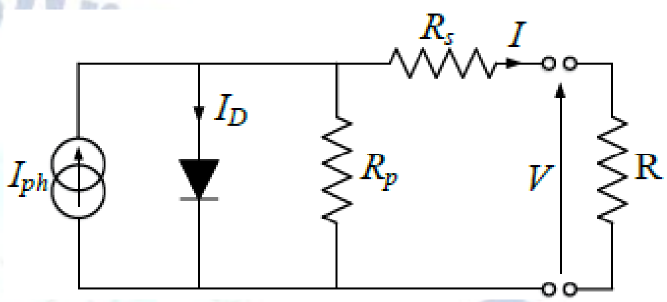


Figure3. PV cell modeled as diode circuit

As shown, the current source, Iph, represents the cell photocurrent, Rsh represents the cell's intrinsic shunt resistances, while Rs represents the cell's series resistances. Typically, the Rsh value is significant, whereas the Rs value is slight, so they can be left out in order to simplify the analysis. PV cells in groupings are called PV modules, and these groupings can be further interconnected in a parallel-series configuration to form PV arrays.

The photovoltaic panel can be mathematically modeled Module photo current

Iph = [Iscr+Ki (T-298)]*λ/1000

Module Reverse Saturation current

Irs = Iscr / [exp (q.Voc/Ns.k.A.T)]

Here, we can see that the module's saturation current Is varies according to cell temperature, given as:

Is =Irs*[T/Tr] 3 exp [q*Ego {(1/Tr)-(1/T)}]

The PV module current is thus

Ipv =Np* Iph -Np*Is [exp {(q*Vpv+Ipv*Rs)/NsAkT}]

Where Vpv =Voc, Np=1, Ns=36 .

Now replacing by km in equation

W(S)/Va(S) = (1/km)/(1+Stem+S²TaTem)

As Ta<<Tem

Hence the equation can be written as

w(S)/Va(S) = (1/km)/(1+5Tem)(1+STa)

3.1MPPT CONTROL TECHNIQUES

The MPPT modifies the output voltage and current of the PV module and determines the operating point that will give the maximum power. The function of the MPPT is to compensate for the varying current-voltage characteristics of the solar cell.

The MPPT must be able to accurately track the constantly varying operating point where the maximum power is delivered to increase the efficiency of the PV module.

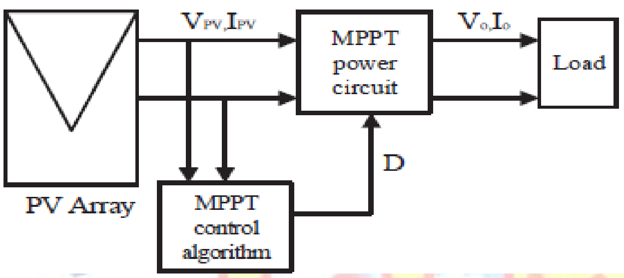


Figure4. Block diagram of MPPT control

3.2DC-DC BOOST CONVERTER

The basic purpose of design of boost converter is to boost the output voltage of the dc system. The output of the converter is enormously influenced by the switching frequency (gate pulse). Figure 4 represents the boost converter and the output of the converter may be characterized in equation.

The average output and input voltage and current values for an optimized boost converter are as follows:

Vo = Vg / (1-D)

Io = Ig (1 – D)

The input side's load resistance *R'* is expressed as:

R' = R (1– D)2

The load seen by source can only be decreased by varying *D* as 0 < D < 1. As such, a boost converter's tracker would only be able to extract maximum power when the PV module's maximum power point current *Imp* is higher than the original load.

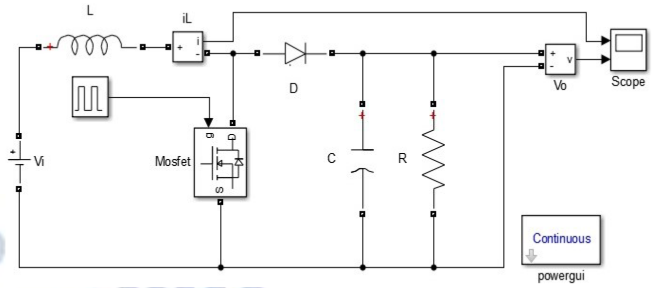


Figure5. Boost converter

Table1. Boost converter parameters

Model Components	**Parameters**
Inductance, L	1 μH
Capacitance, C	4000 μF
Load, R	24 Ω
DC voltage, Vdc	30 V ms
Switching frequency	50 Hz

4. FUZZY LOGIC CONTROLLER

Fuzzy logic functions by designating and enacting rules that combine an expert's inputs with the wanted outputs. There are usually four main determining factors of fuzzy logic: fuzzy sets, membership functions, linguistic variables and fuzzy rules. These four factors are explained in detail below and Figure 1-4 shows the main structure of a fuzzy logic system.

Fuzzification

Fuzzification is a process whereby clearly delineated values are made fuzzy. To accomplish fuzzification, the linguistic variables and terms to be utilized must first be defined. Numerical values are not used in this process; rather, words and/or phrases from a natural language comprise both the input and output variables. In this system, temperature (T) is the linguistic variable that designates the room's temperature, which can be described (qualified) in general linguistic terms as "hot" or "cold". Then, in order to translate the "crisp" (i.e., non-fuzzy) input data to fuzzy linguistic terms, we can apply membership functions, as explained below.

Membership Functions

The membership function is a way to express graphically the participation level of individual inputs.

It allocates a value to the inputs that can also serve as functional overlaps between the inputs. In so doing, the membership function strongly influences the output response. A critical determining factor of the membership function is configuration or, as it is usually termed, “shape”. The various potential shapes include Gaussian, triangular, trapezoidal, generalized bell and sigmoidal. A triangular membership function comprises straight line segments and is thus easy and practical to apply under fuzzy control. However, the Gaussian membership function approach is better suited when smooth and continuous output is desired.

Inference engine

Inference is a process whereby novel information is derived via existing information. In fuzzy logic control systems, inference refers to a process whereby the final result is derived by combining the outcomes of each rule in terms of fuzzy values. There are several different methods that can be followed to obtain inference, the most popular of which are Mamdani and Takagi-Sugeno- Kang. The Mamdani approach was developed by Ebrahim H. Mamdani as a means to modifying the behavior of a steam engine and boiler in 1975. Mamdani’s (1975) control method derives from Lofti Zadeh’s (1973) paper describing fuzzy algorithms for complex systems and decision processes. In Zadeh’s (1973) method, the minimum operation Rc is applied as a fuzzy implication, while the max-min operator is applied to obtain the composition.

For instance, let us assume that the following form comprises a designated rule base. Hence:

IF input x = A

AND input y = B

THEN output z = C

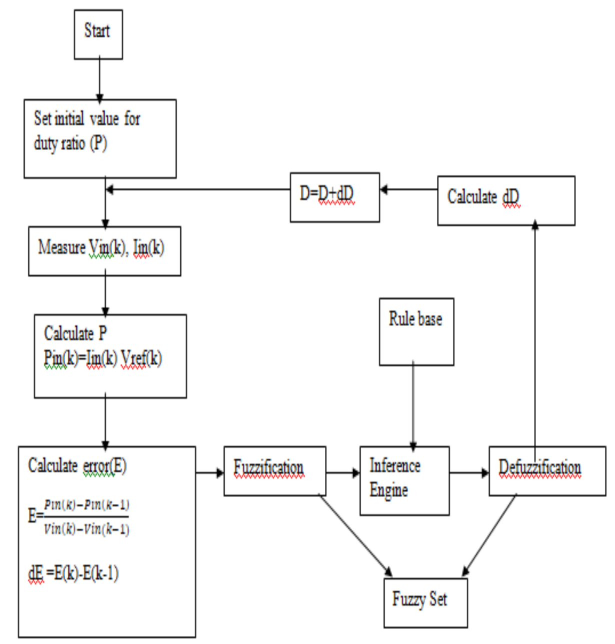
Rule base

A rule-based system best described by ‘If-Then’ designations . These rules generally include fuzzy logic quantification made by an expert on how to attain optimal control. So, for instance, if a fuzzy rule asserts that if x is A, then y must be B if A and B are values designated by fuzzy sets stipulating a range of X and Y, respectively. In this rule, the “If” portion is deemed the antecedent or premise, while the “Then” portion is referred to as the conditional consequent or conclusion. Ultimately, a fuzzy rule is, at its core, an If-Then rule that features both conditions and a conclusion.

Defuzzification

The process of defuzzification is a means to change the fuzzy output of the inference engine to a clearly defined (crisp) output by applying membership functions such as those utilized by the fuzzifier. A defuzzification interface that changes the outcomes of the inference mechanism into useable inputs that will ‘feed’ the process and move it forward.

Flowchart



The above flowchart which shows the representation of fuzzy logic applied to the MPPT based solar system. In which first is a start and second is a duty ratio , where k stands for discrete system which is not continuous , (k-1) is previous value , E is an error and dE is change in error in 5th block of flowchart. And then this error block is given to fuzzy logic system and consequently output will be given to change in duty ratio and this into boost converter.

5. METHODOLOGY

The Simulink model of PV module with Fuzzy logic based MPPT controller is portrayed in Figure . The proposed isolated solar system is portrayed , basically consisting of PV array, DC-DC Boost converter and MPPT controller. MPPT controller regulates gate pulse of boost converter by conceding the voltage and current of the PV module. The regulated pulse of the converter enhances the efficiency of the solar system.

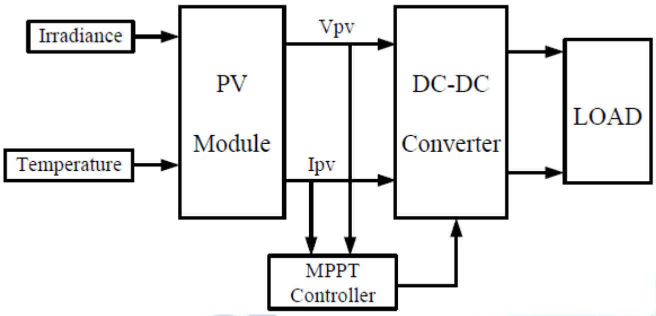


Figure2. Block diagram of solar system

Process Description

The following diagram makes it easier to understand how we proceed.

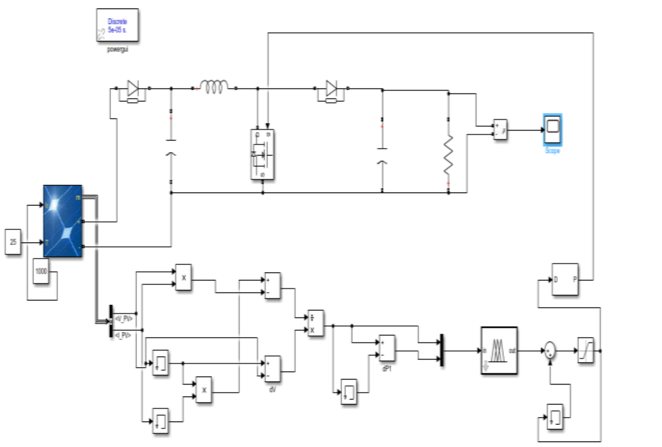
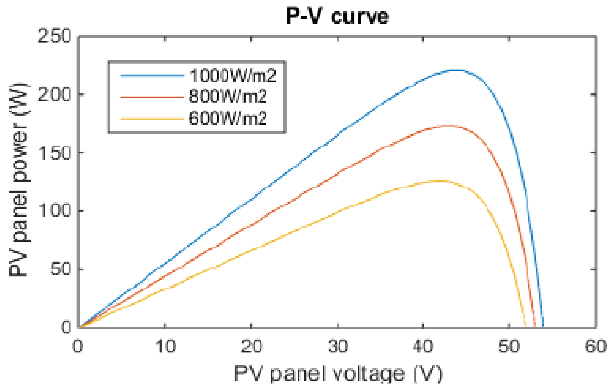


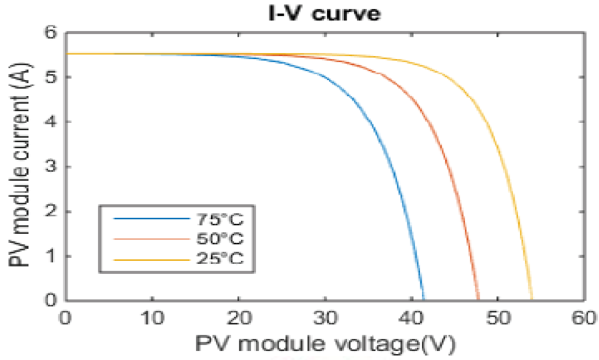
Figure4. Simulink model of Fuzzy logic based solar system

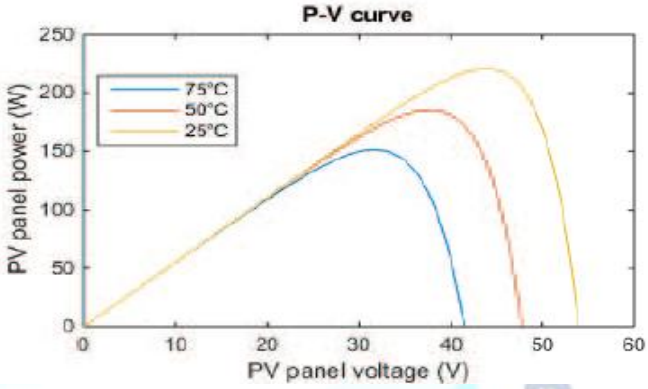
6.SIMULATION RESULTS

The I-V and P-V characteristics are illustrated in Figure. The settling time, rise time, delay time and oscillation of output responses (power, voltage and current) of PV module with fuzzy logic based MPPT controller are lower than the P & O based MPPT technique. Overshoot evaluated by considering the difference between steady state maximum power and maximum power. Implementation of proposed MPPT technique enhances the responses of PV module remarkably. Finally, fuzzy logic based MPPT technique is validated as a better technique over P & O based MPPT technique to enhance the efficiency of the PV module.

Results are as follows.







7. FUTURE SCOPE AND CONCLUSION

In this paper, From the speed response of the system for a fuzzy pid controller as shown in simulation results , it is clear that settling time and overshoot for bldc motor controlled by fuzzy pid controller is much lesser than that of conventional pid controller and also the simulation results shows that both the transitory performance and steady performance are better than that of conventional pid.

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