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Extracting Maximum Power from PV Model using Fuzzy Logic Technique

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Abstract− ***Electricity has become an inseparable part of our daily lives, its domain approach is boundless. Due to continuous use of energy resources (both renewable and non- renewable), it is our priority to conserve our resources. What is extracting power through PV cell? Solar energy is inexhaustible and can be extracted to electrical energy which eases the high consumption of non renewable resources. How to maximize the solar energy? Maximum energy can be obtained by some external aid in the form of MPPT. Why do we incorporate different techniques in a MPPT? To control the maintenance of operating point of PV array at its maximum peak Optimization of renewable energy has drastically increased over the past few decades and now capable of conservation at a higher level. Solar energy is prime example of renewable source. Not more than 50% solar irradiance is converted to solar energy without any external aid (MPPT). These techniques are mentioned in the literature work below and the respective algorithms as well.***

Keywords: MPPT, Fuzzy , Photo Voltaic

I. INTRODUCTION

Without any ambiguity, it can be asserted that energy is the basis of our life. According to first law of thermodynamics, energy can neither be created nor be destroyed. This fact supports the genesis of renewable resources. Since, we are exhausting earth's natural resources on a daily basis , the regular requirement of electrical energy is increasing, various measures should be incorporated keeping in mind the economical as well as environmental factors to meet the basic need of electricity of increasing population . Due to continuous increase in greenhouse gases, a common scientific consensus came under a suggestion of reducing these emissions more than 25 percent by 2020 and more than 80 percent by 2050. Renewable energy has its sources in the form natural resources such as sunlight, rain, tidal energy, wind and geothermal heat. These resources are renewable and can be naturally replenished. Conversion of solar energy into electricity not only improves generation of electricity but also reduces pollution due to fossil fuels.

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With the advancement in Power Electronics field, the efficiency of the PV system can be increased along with Maximum Power Point Tracking Controller.
The output power of solar panel depends on solar irradiance, load impedance and the temperature. The solar irradiance and temperature are dynamic.
Hence an algorithm which dynamically computes the operating point of the solar panel is required. There are various MPPT algorithms such as Perturb and Observe, Neural Network, Fuzzy Logic, Incremental Capacitance etc.

II. PHOTOVOLTAIC CELLS

A solid state semiconductor when exposed to solar irradiance generates electricity is known as PV cell and a group of such cells is a PV module.
A Solar panel absorbs the sun rays falling at different angles on the panel and converts it into electricity, a solar inverter is required to produce AC power from PV output, The working system should have proper mounting chamber, insulated cable system and other required electrical accessories .
A solar tracking system improves the overall performance which is required to acquire the maximum sunlight exposure to attain maximum efficiency and include an integrated battery solution[3].
The prime defiance while working on PV power generation and MPPT techniques is to withstand the PV array characteristics.
The PV characteristics varies with the change in irradiance level and temperature. PV array provides different results due to the difference in availability of irradiance level, this maybe because of clouds and bad weather conditions or even trees.
There are various types of photovoltaic systems.

- Grid Connected PV systems
- Standalone PV systems
- PV Hybrid Systems

Inverter used in Grid Connected PV system and Standalone PV systems uses multilevel and these systems require boost converter for the extraction of maximum power.[3-4] .
Main application includes water motor pumps, ventilating fans and solar water heating pump systems [3-4].

III. MPPT

MPPT refers to maximum power point tracking. This control technique is used mainly to extract electrically the

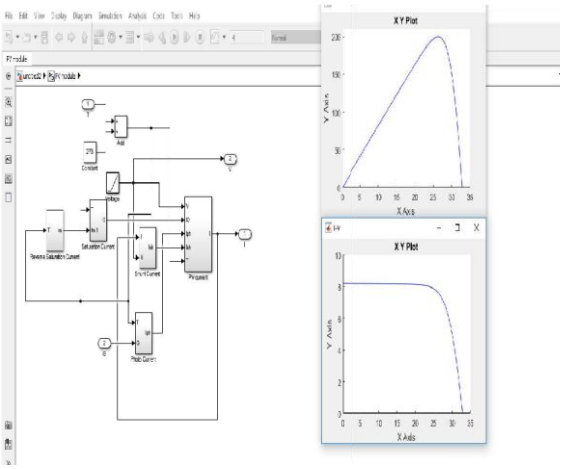


Fig. 1 Matlab model of PV module

maximum power that a PV module can output, with respective solar irradiance and temperature by Maximum Power Point Tracking Controller at particular instant of time. Several techniques of MPPT control are available to improve the efficiency and the section below deals each technique in brief.

A. **Perturb & Observe**

Fig. 2 shows flowchart for the Perturb & Observe technique. The aim of P&O MPPT technique is to maintain oscillating power output around the MPP with or without maximum renewable source input. When there is increase in exhausted array power, the operating point show deviation in favor of MPPT conditions this aids the working voltage to operate in the same direction. If there is decrease in exhausted PV array power, the operating point show deviation opposite from the MPPT conditions, this overturned the direction of the working voltage now [10–12]. P&O MPPT method also posses some disadvantage in the form of wastage of energy when operated at steady state. There is increase in energy wastage due to oscillations of the operating point near MPPT region. In power converter the duty ratio perturbation is a part of Hill climbing technique which is shown in Fig. 3. When a power converter is connected to PV array, the perturbation of PV array current by power converter takes place and consequently the PV array voltage is also perturbed. Hill climbing and P&O methods envisage the same fundamental result but are way different in their approach.

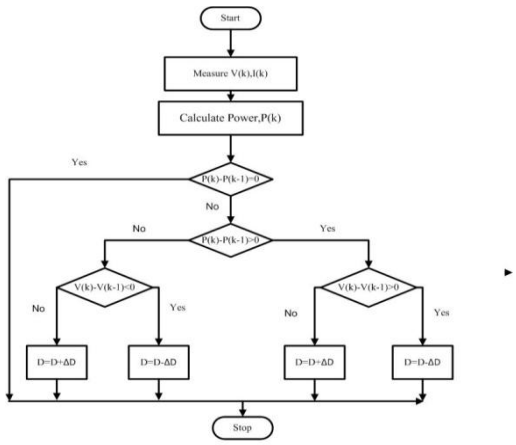


Fig. 2 Perturb & Observe Technique

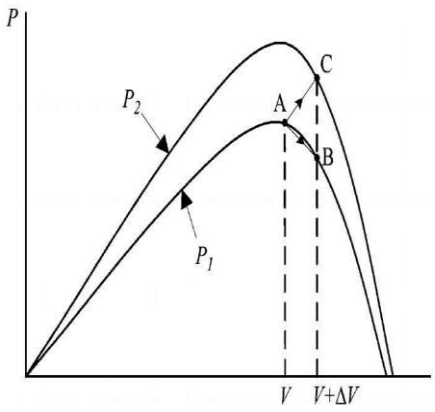


Fig. 3 Hill Climbing Concept

B. **Incremental Capacitance**

Fig. 4 shows the Incremental Capacitance Technique. The incremental conductance [14], [1]–[2] method describes the nature of slope, i.e. when is it zero, or positive with respect to MPP or negative with the same. Zero, positive, and negative conditions are as follows - dP /dV > 0, increase conductance dP /dV = 0, optimum conductance

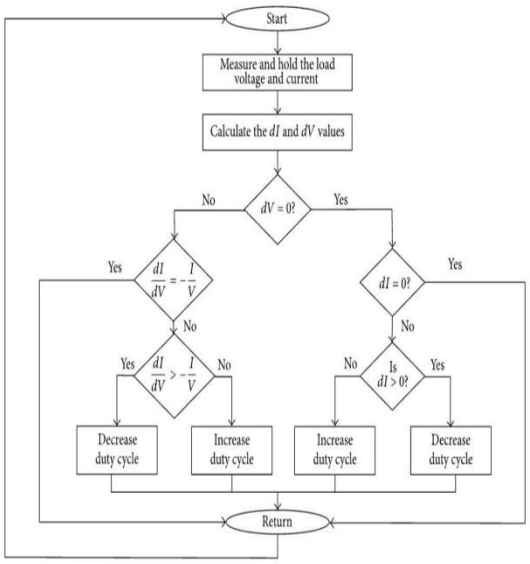


Fig. 4 Incremental Capacitance Technique

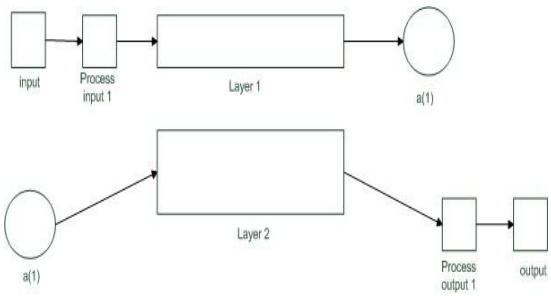


Fig. 5 Two layer Artificial Neural Network

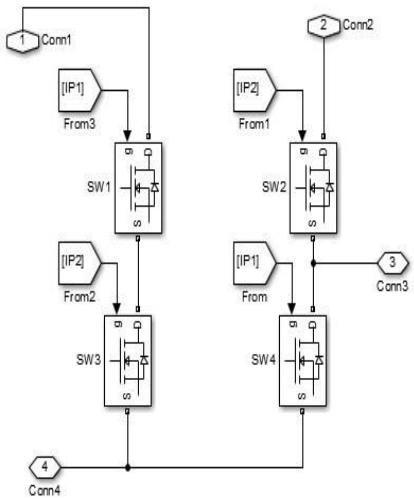
C. Artificial Neural Network

A cascade neural network technique is the one that predicts the PV array voltage at which the maximum power is attainable. They develop a non-linear relationship between the input and output with a hidden layer that functions with preferences like neurons of our brain. The hidden layer in the model is generally a two layer neural network as shown in Fig. 5.The input of layer 1 comprises of a set of 10 neutrons. The output of layer 1 is the input for layer 2 with another set of 10 neurons that assigns weightage to the values and generates a pure linear transfer function.

System dP /dV < 0, decrease conductance.

H-Bridge Inverter System −The H-bridge inverter is a single phase inverter which consists of 4 MOSFET switches (SW1, SW2, SW3 and SW4) as shown in Fig. 6. DC source is inverted to AC by operating two switches simultaneously.

In this method the MPP is obtained by comparing the instantaneous conductance (I/V) with the incremental conductance (ΔI/ΔV). The MPPT tracking can also be seen in the flowchart. PV array is operated forcefully at reference voltage V_{ref}. At the MPPT, V_{mpp} becomes equals to V_{ref}. PV array maintains the constant operation when MP point is reached, unless and until ΔI shows some serious deviation. This could be due to change in MPP as per atmospheric conditions. This algorithm increases or decreases V_{ref} to calculate the new MPP



The 4 sets of switching signals can be classified into two groups – The MOSFETs SW1 & SW4 form the first group while MOSFETs SW2 & SW3 form the second[14].

D. Fuzzy Logic

The system itself is an arrangement of DC-DC Buck-boost converter with a photovoltaic solar module. Under variable solar irradiation and photovoltaic temperature, the system can be studied and used as an alternative to P&O and INC. After various researches and comparisons and on the basis of adequate parameters such as: efficiency of tracking and response to control input, it is observed that the proposed method is able to reduce losses and ultimately increase system efficiency. So this technique is implemented and substituted in place of conventional methods. When the point of operation is far from MPP, this leads to bigger perturbation shift and relatively smaller shifts, near to MPP. The Fuzzy Logic controller holds the plus point of operating smoothly under highly non-linear system and its parameters can be studied under precise Matlab Simulink model.

Three stages are defined to study the process of fuzzy logic-

- Fuzzification
- Inference
- Defuzzification

The initial step is fuzzification which involves a crisp input, this crisp input can be a change in the voltage reading and combination of these values can be compared and combined together with the stored membership function, this produces an intermediate function known as fuzzy inputs. First of all each input is processed individually by a membership function. In fuzzification with the help of membership function, a real time input is processed to produce fuzzy input values. After the first step the second step involves control action that should be incorporated against the given set of input values by deducing Inference which are calculated using lingual rules. Each type of control action results as Inference from fuzzy output. The last step in FLC involves the isolation of a crisp value which determines the probable value of an output variable in the vast field of the output fuzzy sets. The Fuzzy output values are obtained by processing input by their respective membership function. The defuzzification technique which is most popular is called COG (Center of Gravity).

FLC is arguably developed and implemented to extract the maximum power (MP) under time varying weather and temperature conditions from the PV module. By using this method MPP (Maximum Power Point) oscillations are reduced at a faster rate as compared with the other general MPPT methods. The basic input to fuzzy logic controller is ΔP (change in the power level of the PV module) and ΔV (change in the voltage level of the PV module). The output U obtained from FLC technique is the modulation signal. This signal is now applied to the PWM modulator. Switching pulses are produced by this process. During fuzzification, the membership functions processes numerical input variables to convert into linguistic variables. Generally five fuzzy levels NS (negative small), NB (negative big), ZE (zero), PS (positive small), PB (positive big) are used for all

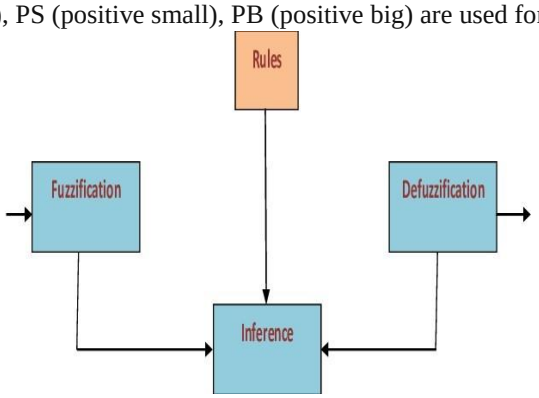


Fig. 7 Fuzzy logic technique

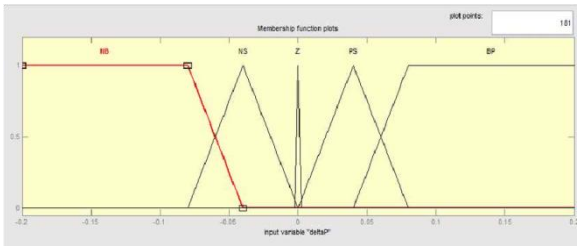


Fig. 8 The Membership function of the input variable (ΔP)

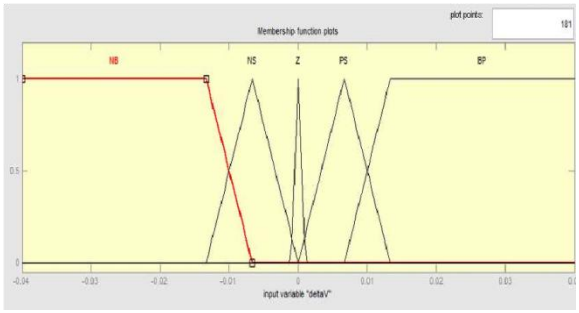


Fig. 9 The Membership function of the input variable (ΔV)

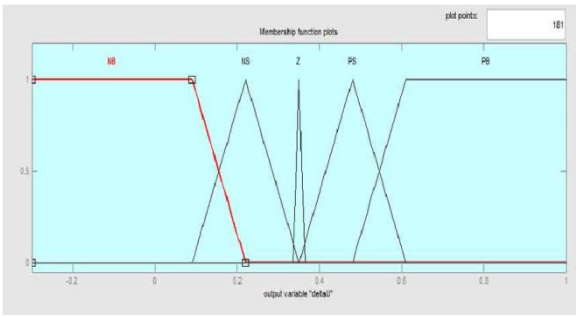


Fig. 10 The Membership function of the input variable (ΔU).

the inputs and outputs variables. Fig. 8-10 shows the plot of different membership function and their output.

Table I Comparison of different technique

Control Technique	PV Array Dependent	True MPPT	Analog/ Digital
Perturb & Observe	No	Yes	Both
Incremental Capacitance	No	Yes	Digital
Neural Network	Yes	Yes	Digital
Fuzzy logic	Yes	Yes	Digital

IV. CONCLUSION

The most basic and progressive step that can be taken in the field of energy conservation using PV module is with the installation of panel at rooftops. This step can be modified with proper technique and maximum power can be derived. The MPPT techniques developed are compared on the basis of type of control strategy, the number of control variables involved, circuit complexity and their applications. After careful investigation most suitable MPPT technique is selected for grid tied or standalone mode of operations.

Perturbation, Observation and Incremental Conductance control techniques are the most fundamental and widely used MPPT techniques since long. They are used by many researches, but they also possess a drawback of their own which is now capitalized by the introduction of new techniques The drawbacks include low utilization efficiency and slow tracking. These drawbacks can be overcome by using fuzzy and neural network techniques. Fuzzy logic provides infinite possibilities between a set of membership function. After thorough study of membership function it could be seen for any instance where the solar irradiance is lower , maximum power is obtained Under the Various DC-DC converters are used along with Battery Energy Storage Systems (BESS) depending upon the requirement. These battery storage systems provide maximum energy to be stored from solar PV panel.

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