Maximum Power Point Tracking of Photovoltaic Panel using Combined ANN and Fuzzy Control Algorithm

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Abstract: A solar panel gives maximum power at a unique operating point. That operating point is called maximum power point (MPP). The maximum power point of the PV panel changes with environmental factors like irradiation, temperature etc. The power output of the solar panel is maximum at a distinct voltage and that voltage varies with the value of irradiation and temperature. To continuously extract the maximum power from the PV panel the load is connected via a boost converter so as to maintain the PV panel voltage equal to the voltage at maximum power point. In this paper a combined artificial neural network and fuzzy logic technique is proposed to track the maximum power point of the PV panel. Artificial neural network is formed for obtaining the maximum power point voltage of the PV panel and fuzzy logic control is used to track the maximum power point Voltage of the PV panel. The result shows a satisfactory maximum power point tracking.

Keywords: Artificial Neural Network, Fuzzy Logic Controller, Maximum Power Point Tracking, Boost Converter

1. INTRODUCTION

The largest source of energy that is available to us is the solar energy. The total solar energy that reaches to the surface of earth is 3.9×10^{24} J annually which is ten thousand times more than the total global energy demand [1]. To harness this potential energy one of the most suitable method is to convert the solar energy into an electrical energy by using the solar photovoltaic panel. Solar energy is a renewable source of energy and it is pollution free.

The meaning of photovoltaic is to generate an electric power from the solar light or the solar photons. Solar photovoltaic panel is a combination of various solar cells connected in series or parallel or both. The efficiency of a commercial photovoltaic panel is around 8-15 % [1]. So it is very much essential of extract the maximum possible solar energy from the PV panel by using the proper control algorithm of maximum power point tracking.

The solar panel has non linear voltage –current characteristics thus MPPT is very much essential. MPPT refers to Maximum power point tracking. The solar panel has one point of voltage at which maximum power can be extracted. The maximum power point voltage is affected by the change in temperature and irradiation. These two conditions vary during the day according to the climatic conditions and also by the presence of clouds. Under all the conditions it is very much necessary to accurately obtain the maximum power point voltage and also to track the maximum power point. There are various algorithms presented in many papers by which maximum power point tracking is possible. Some of the methods to track the maximum power point are perturb and observe method, hill climbing method, incremental conductance method, fuzzy logic control etc. These methods have some problems associated like the complexity in calculations, error, time of response etc.

In this paper fuzzy logic control is done by calculating the maximum power point voltage from the neural network model obtained from the previous work [2]. The neural network model calculates the maximum power point voltage from its input that is temperature and irradiance. Fuzzy logic control is then used to track the maximum power point voltage obtained from the neural network model. The complete modeling and controlling is done in MAT-LAB simulink. The simulation result shows that the proposed algorithm is very much effecting to track the maximum power point voltage.

2. MODELLING OF PV PANEL

A single diode model is used for designing the PV module. In this circuit R_{sh} is the shunt resistance, I is the open circuit current of the solar cell, I_o is the diode saturation current, I_{ph} is the light generated current which depends upon the solar radiation and the cell temperature, I_{sh} is the shunt resistance current, R_{se} is the series resistance, Voc is the open circuit terminal voltage of the cell. The single diode model is shown in fig 1.

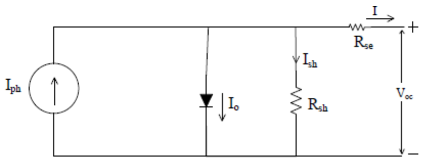

Fig 1 solar cell equivalent circuit

On applying KCL the current equation of the solar cell will be

$$I = I_{ph} - I_o - I_{sh}$$

Here

$$I_{ph} = \left[I_{sc} + K_I \left(T_k - T \right) \right] \times \frac{G}{1000}$$

I_{ph} is the photo current under standard condition with the reference solar radiation of 1000w/m^2 at solar spectrum of 1.5 A and reference solar temperature of solar panel T_k of 25^o c. T is the instantaneous solar panel temperature. K_i is the current temperature coefficient and G is the instantaneous solar irradiation.

The reverse saturation current I_{rs} is expressed as

$$I_{rs} = \frac{I_{sc}}{\left[\exp\left(\frac{q \times V_{oc}}{N_s \times k \times A \times T} \right) - 1 \right]}$$

Here q is the electron charge $\left(1.6 \times 10^{-19} C\right)$, V_{oc} is the solar module open circuit voltage , N_s is the number of cells connected in series, A is the ideality factor and K is the boltzman constant $\left(k = 1.3805 \times 10^{-23} J / K\right)$

The module saturation current I_o is given by

$$I_o = I_{rs} \left[\frac{T}{T_r} \right] \times 3 \times \exp \left[\frac{q \times E_{go}}{A \times K \times \left\{ \left(\frac{1}{T_r} \right) - \left(\frac{1}{T} \right) \right\}} \right]$$

Where E_{go} is the band gap energy of semiconductor here E_{go}=1.1 eV

The module output current is expressed as

$$I_{pv} = N_p \times I_{ph} - N_p \times I_o \left[\exp\left\{ q \times \left(V_{pv} + I_{pv} \times R_{se} \right) \times N_s \times A \times k \times T - 1 \right\} \right]$$

3. BOOST CONVERTER

Boost converter is a DC-DC power converter that steps up voltage while stepping down the current. It comes in a category of switched mode power supply (SMPS) . It contains a power semiconductor switch, a power diode, inductor and capacitor. The circuit diagram of a boost converter is as shown in fig 2.

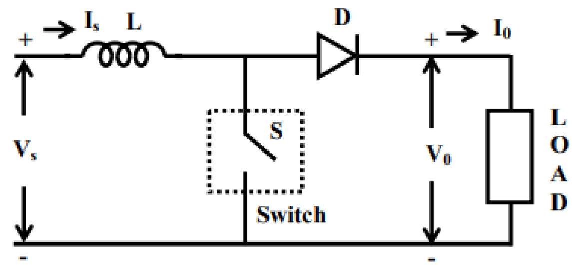

Fig 2 Circuit diagram of boost converter

The output voltage equation of a boost converter is given by

$$V_o = \frac{V_{in}}{1 - D}$$

Where V_o is the output voltage, V_{in} is the input voltage and D is the duty ratio of the boost converter. D is the ratio of ON time T_{on} and the time period T of the switch.

$$D = \frac{T_{on}}{T}$$

On the input side of the boost converter solar panel is connected and at the output side of the boost converter load is connected. Duty cycle D on the boost converter is controlled in such a way so that the input voltage V_{in} becomes equal to the maximum power point voltage such that maximum power can be extracted from the PV panel.

4. FUZZY LOGIC CONTROL

It is a control system that is based on the fuzzy logic principle. Fuzzy logic refers to mathematics that analyses analog value in terms of logic variables that take on continuous values between 0 and 1. Fuzzy logic is widely used in motor control. In fuzzy logic control the control system works as per the human expertise of the system. The fuzzy logic control involves three process namely fuzzification, rule making and defuzzification. In fuzzifcation process the input values are converted into linguistic variables, in rule making rules are made as per the system expertise and in defuzzification the output is obtained from the output linguistic variable.

In the boost converter input voltage decreases with the increase in duty ratio D (V_{in}=Vo*(1-D)). This concept is used in the fuzzy logic control for controlling output voltage of the PV panel.

5. SIMULATION DIAGRAM

The simulation diagram of the proposed model is as shown in fig 3.

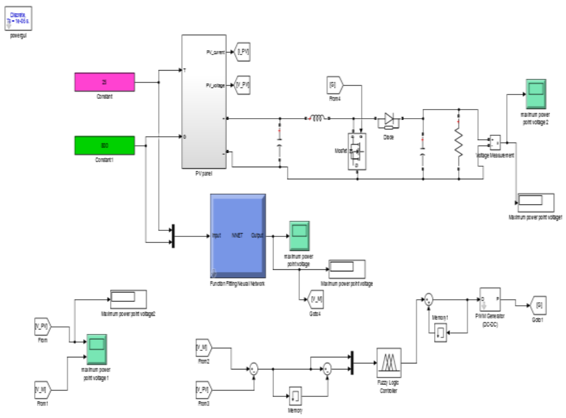

Fig 3 simulation diagram

As seen from the simulation diagram it has a block of solar panel which is connected with an input capacitor. Then it is connected with a boost converter. The boost converter consists of an inductor, an IGBT switch, a diode and output capacitor and a load.

There is also a neural network block which is a neural network model obtained from [2]. The neural network block calculates the maximum power point voltage from its input data that is the PV temperature and the solar Irradiation.

The fuzzy logic block in the simulation diagram is used for controlling of the duty cycle to obtain the desired result.

6. CONTROL ALGORITHM

Fuzzy logic control is used in the research. The neural network block is trained such as to estimate the maximum power point voltage by using the temperature and irradiance data. The PV voltage is also measured. The difference of the maximum power point voltage V_m and the PV voltage V_{pv} is compared and the difference between them is the error. The rate of change of error gives the change in error.

The error (e) and change in error (ce) is given as the input to the fuzzy logic controller. Fuzzification of the input is done. The membership function of the input variable e of the fuzzy controller is as shown in the fig 4.

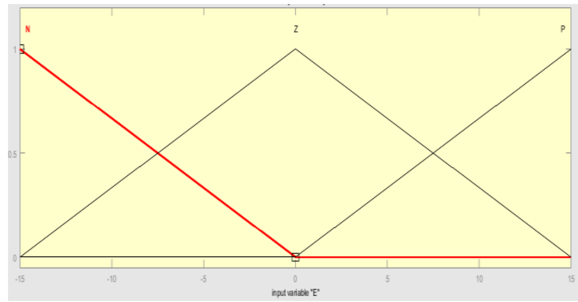

Fig 4 membership function of error

Here n represents negative error, z represents zero error and p represents positive error.

Similarly the membership functions of change in error and output is shown in fig 5 and fig 6

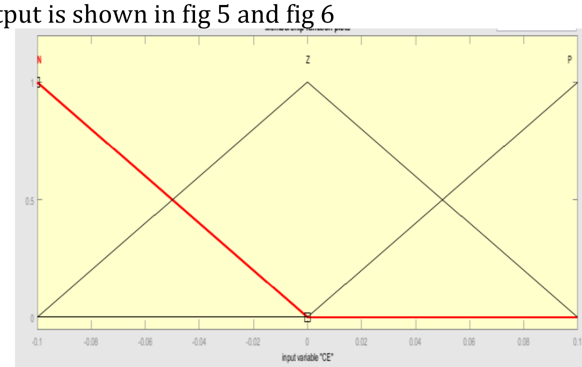

Fig 5 membership function of change in error

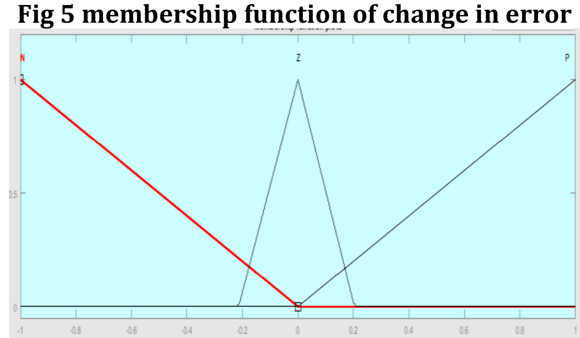

Fig 6 membership function of output

7. RESULT

The simulation diagram in modeled and the model is simulated in MATLAB simulink to obtain the result. The simulation is performed on two value of irradiation one for irradiation value of 1000 w/m² and another for value 800 w/m². Fig 7 shows the tracking of maximum power point voltage by the PV voltage for irradiance of 1000 w/m² and fig 8 shows variation of PV power for irradiance of 1000 w/m².

Fig 9 shows the tracking of maximum power point voltage by the PV voltage for irradiance of 800 w/m² and fig 10 shows variation of PV power for irradiance of 800 w/m².

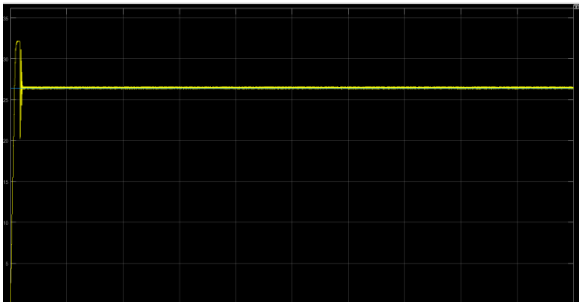

Fig 7 variation of PV voltage with time for G=1000 w/m²

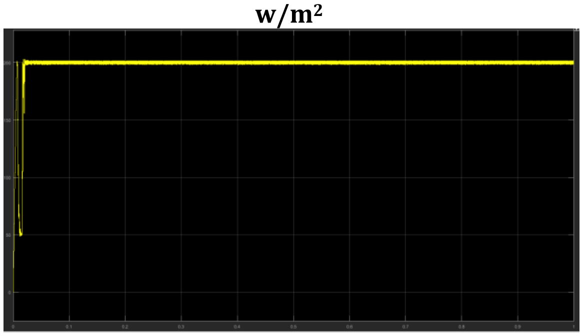

fig 8 variation of PV power with time at G=1000 w/m²

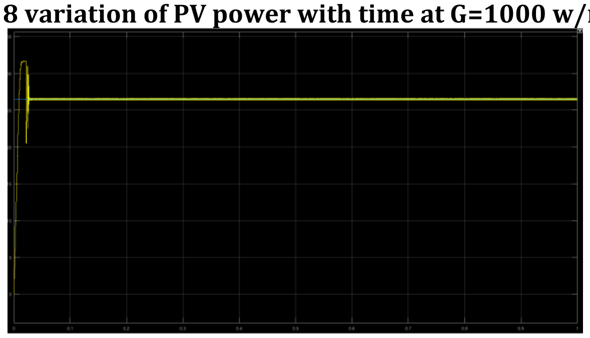

Fig 9 variation of PV voltage with time for G=800 w/m²

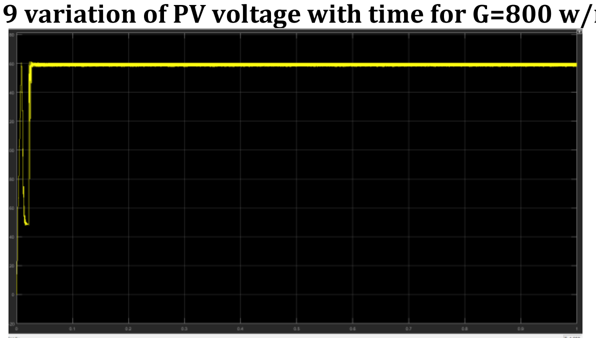

fig 10 variation of PV power with time at G=800 w/m²

8. CONCLUSION

From the result it is very much clear that the proposed algorithm proves to be very simple in tracking the maximum power point of the PV panel. By using the proposed control strategy the PV voltage rapidly tracks the maximum power point voltage and thus the response time is very less. Also the accuracy of the proposed method is also very satisfactory. The control structure works very well in both the conditions of irradiance.

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