Comparative Analysis of MPPT for Solar Power System Implementing Fuzzy Logic and PID Controller

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ABSTRACT

This study and comparison of Maximum power point tracking(MPPT) system using fuzzy logic controller(FLC) and PID controller aims to identify the advantages and appropriate technique to enhance the efficiency of power gain from solar radiations using PV system. MPPT techniques are used to gain maximum outcome from solar energy to obtain higher gain of power and to improve working as well as controlling of system. FLC and PID controllers are used to compare outcomes and fount FLC to be best techniques to control PV system as per this paper's comparison analysis.

Index Terms— Solar Power, MPPT, Fuzzy logic controllers, PID

1. INTRODUCTION

As the power demand in India is increasing from last few years, the requirement of power resources also increased. As well as the conventional resources also decreasing there is need to enhance generation from non- conventional sources. There are many non-conventional sources as solar energy, wind power, bio-fuels, geothermal, tidal energy, hydro power etc. As to generate power from wind requires special area specifications, the simplest and environment friendly and easy to install method is to generate power from solar radiations by installing PV system. But the efficiency of PV system is very less. To increase the efficiency of PV system MPPT techniques are used. Such as Fuzzy logic controllers (FLC), PID, Artificial Neural Network (ANN), perturb and observe, feedback voltage, incremental conductance, Multiagent –System (MAS) etc. in this paper a comparison is done between FLC and PID controller performance.

Total power installed in India is 308834.28 MW (approx.), from which 45916.95 MW is generated from non-renewable sources (NRS), it is 14.86% of whole generation. Power generated from solar energy from this is 8513.23 MW which is again 18.54 % of total NRS up to November 2016[1].

2. PV CELLS EQUIVALENT MODEL AND CHARACTERISTICS

The equivalent models of photovoltaic cells have complex non-linear characteristics, and it depends on light intensity and temperature. Therefore, to obtain maximum power output of PV cell from these effects, firstly, establish the

model, the output voltage, current and light intensity, temperature and other parameters of the function of the type [2].

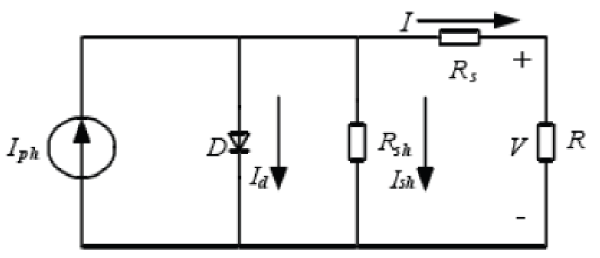

Fig. 1. Equivalent circuit of PV cells

The mathematical model is designed by the equivalent circuit of the photovoltaic cells:

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

$$= I_{ph} - I_o\left\{\exp\left[\frac{q(V+IR_s)}{AKT}\right]-1\right\} - \frac{V+IR_s}{R_{sh}}$$

Which gives

$$I_D = I_o\left\{\exp\left[\frac{q(V+IR_s)}{AKT}\right]-1\right\}$$

Where , I-saturation current (A)

V-Output Voltage (V);

Iph- Light current (A);

Rsh-the equivalent parallel resistance (Ω);

Rs- equivalent series resistance (Ω);

q-electron charge, is 1.6 × 10e-19C;

K-Boltzmann constant (1.38 × 10e-23J / K);

A-the temperature constant;

T-PN junction temperature.

The output characteristics curve of photovoltaic cells will be gain from PV array:

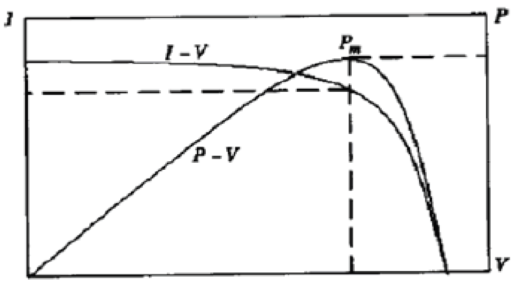

Fig. 2. Output Characteristics of solar array

From the output characteristics curve it is analyzed that P-V characteristics curve peak is the maximum power point at which maximum power can be tracked.[3][4].

3. FUZZY LOGIC CONTROLLER

The process of fuzzy logic controller is shown in fig.3. FLC is used to track maximum power point from V-I peak points using fuzzy rules with most efficiently and rapidly, with accuracy of maximum tracking.[3-5].

Fuzzy logic control generally consists of three processes:

A) Fuzzification

B) Fuzzy rule matrix & inference engine and

C) Defuzzification.

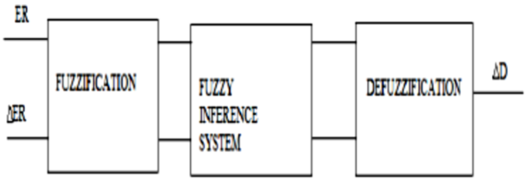

Figure-3: configuration of fuzzy controller for MPPT

A. Fuzzification

The Fuzzification comprises the process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function is used to associate a grade to each linguistic term. In this paper FLC MPPT method has two input variables, P(PV power) and B(Battery power) and output variable L. The two input variables are described by:

$$P(m) = \frac{P(m) - P(m-1)}{I(m) - I(m-1)}$$

$$B(m) = E(m) - E(m-1)$$

Where, *P(m)* and *B(m)* are the power and battery of the PV module, respectively. At MPP, *B(m)* is zero. These input and output variables are expressed in terms of five linguistic variables or labels, such as **Negative Medium (NM), Negative Small *(NS)*, Zero *(ZE)*, Positive Small *(PS)*, Positive Medium *(PM)*,** The input and output membership functions are shown in fig-4,fig.5 and fig-6 respectively[13-15].

B. Fuzzy Rule Algorithm

In this work 25 fuzzy control rules are used as shown in Table I .Fuzzy rules are designed based on the zero error condition at the steady state of the MPP.

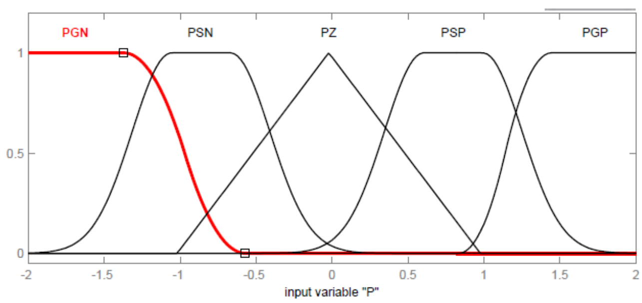

Fig-4: Input membership function (error ER and change error ΔER) of fuzzy logic controller

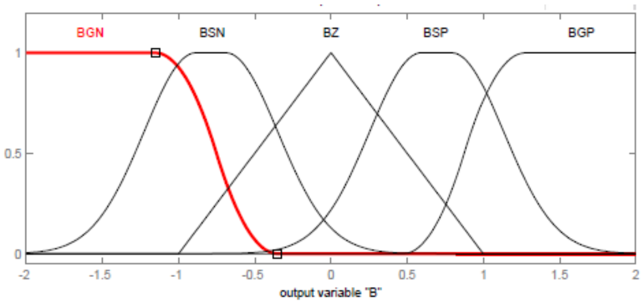

Fig-5: Output membership function (Δd) of fuzzy logic controller

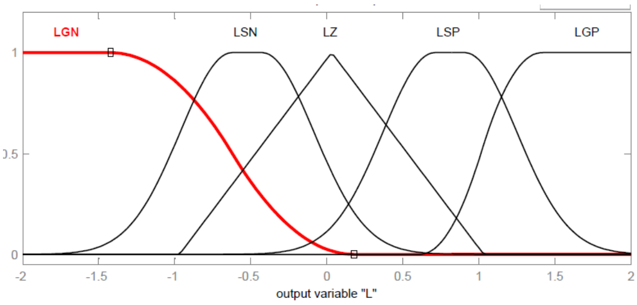

Fig-6: Output membership function (Δd) of fuzzy logic controller

Table-I Fuzzy Rule Base Table

B\P	GBN	BSN	BZ	BSP	BGP
PGN	LGN	LGN	LGN	LSN	LZ
PSN	LGN	LGN	LSN	LZ	LSP
PZ	LGN	LSN	LZ	LSP	LSP
PSP	LSN	LZ	LSP	LGP	LGP
PGP	LZ	LSP	LSP	LGP	LGP

C. Defuzzification

This is the final process of the fuzzy controller, where the fuzzy control subset must be converted to the crisp(user understand) value. As mentioned earlier the output of the fuzzy controller is the required load power,

Fig-4 to fig fig.6 shows the configuration of fuzzy controller, which consists of input-output variables, Fuzzification, fuzzy Inference rule and Defuzzyfication [17-24].

4. MODELLING

The system is designed with solar PV power generation and battery system. 1KW PV system is connected to a DC load of 750 W, two batteries are connected with PV system of 300 Ah each.

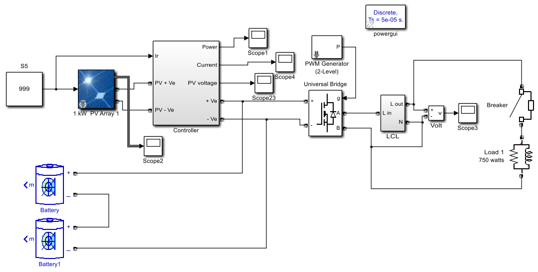

Fig 7. Solar PV model with fuzzy MPPT controller.

Analysis of PV system power with fuzzy logic MPPT controller, voltage and current and load voltage is done and compared with simple PID controller outputs.

5. RESULTS

Outcome analysis is shown in following figures with output of solar PV system power, current, voltage and load voltage of Fuzzy logic controller and PID controller.

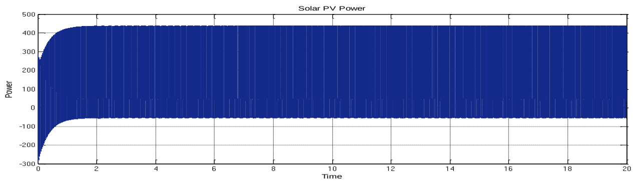

Fig 8. Solar PV system power with fuzzy MPPT controller

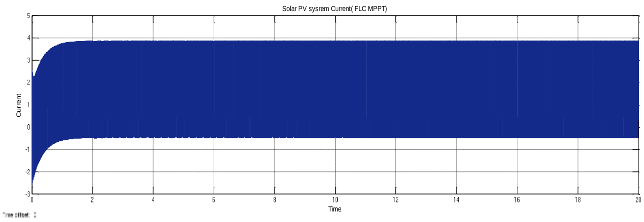

Fig 9. Solar PV system (FLC MPPT) Current

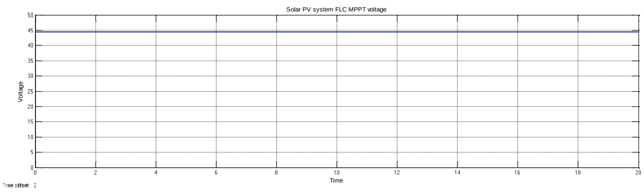

Fig 10. Solar PV system (FLC MPPT) Voltage

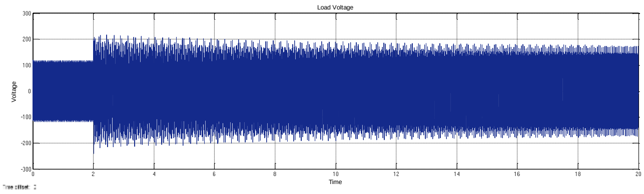

Fig 11. System load voltage(FLC MPPT)

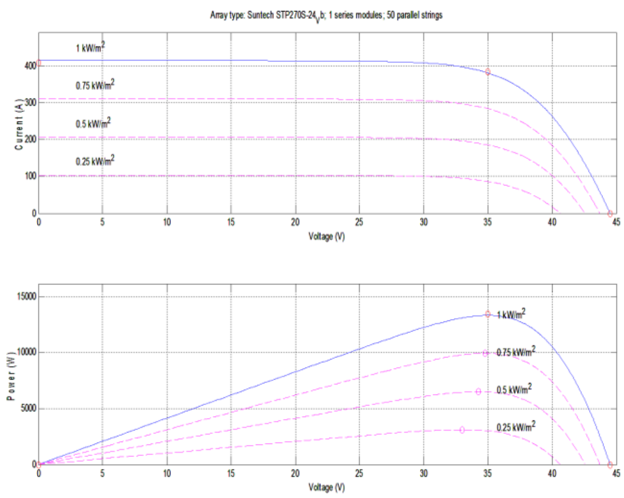

Fig 12. I-V and P-V characteristics of PV array

Figure 12 shows the I-V and P-V characteristics of PV array at rating of 1KW.

The results form solar PV system with fuzzy logic controller is then compared with simple PID controller to analyses the outcome from FLC and identify the difference in FLC and PID controllers.

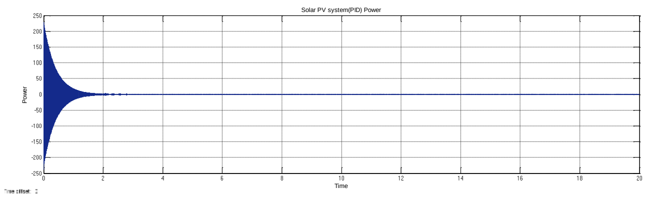

Fig 13. Solar PV system power with PID MPPT controller

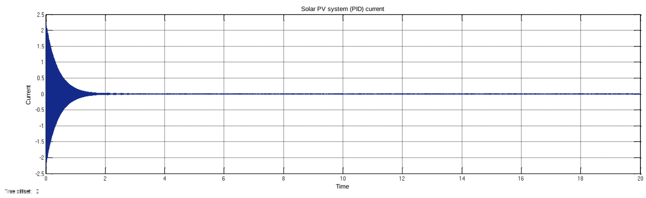

Fig 14. Solar PV system (PID MPPT) Current

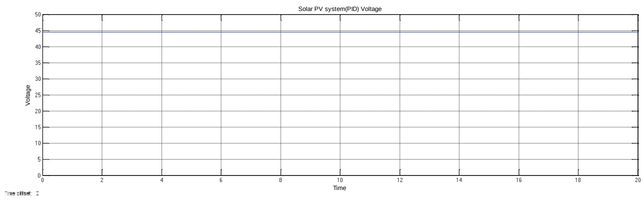

Fig 15. Solar PV system (PID MPPT) Voltage

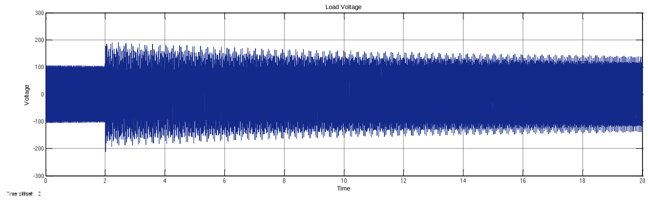

Fig 16. System load voltage(PID MPPT)

As shown in figure 8 to Figure 16 the output waveforms, this shows the effectiveness and advantages of using FLC on place of PID controller as the output power and voltage are improved in case of FLC.

6. CONCLUSION

In this paper a comparative analysis is done in between fuzzy logic controller and normal PID controller by implementing on 1KW solar PV system with DC load and battery connected system. The simulation is done in MATLAB shown the output waveform of the controllers' power, current, voltage and load voltage. The results shows that the output from FLC are more accurate and improved as power increases and voltage and current are in stable condition and variation in load voltage decreases. The advantage of using FLC is to maintain the stability of system and accuracy of system improves. PID controller is not able to achieve the efficiency at maximum power tracking.

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