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Fuzzy Logic Controller Based Single Buck Boost Converter for Solar PV Cell

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ABSTRACT

This paper deals with solar power production controlled by Fuzzy Logic Controller (FLC) and Single Input Buck-Boost (SIBB) converter. Since the solar energy is continuously varying, according to the irradiation the FLC generates control pulses to switch on the MOSFET device. To analyze the real time feasibility of this method, the system is simulated by using MATLAB/Simulink 2010a. A simulation model of the system is developed with solar Photovoltaic (PV) cell, FLC and SIBB in contradiction of the real world conditions. The results are presented and discussed in this paper.

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1. INTRODUCTION

Solar energy is continuously varying according to the climatic condition. The variation in irradiation affects the solar power produced by the panel. The solar power is considered as predominant resources when compared with others. In this field many researches are carrying on to improve the efficiency of solar power production.

The performance of PV system can be enhanced by power converter with intelligent control techniques to develop the circuit model to improve the efficiency of solar power generation. MPPT algorithm is one powerful suggestion for stand-alone Solar systems to improve the efficiency. The application of Maximum Power Point Tracking in the PV module was developed [1]–[3] to achieve high performance in actual field. Modeling of buck converter using MATLAB is explained in [4]. Researchers are carried out in the solar cell for the understanding of the characteristic features and working scenarios [5]–[7]. The power converter designs for solar PV cells are given in [8]–[11]. The conventional controllers used are insufficient because of changes in operating points during a daily cycle and may no longer be suitable in all operating conditions. The use of intelligence controllers are cited in the most of the papers recently [12]-[14] which has faster transient responses and is more robust than several control method. The method of construction of fuzzy rules and their usage of membership functions are given in [15]-[17].

In this paper, a Fuzzy logic controller along with a single input buck-boost converter is proposed, which can deal with photovoltaic power individually based on their availability at that given instant. In conventional controller, the system or process being controlled is modeled. But in a fuzzy controller, the focus is on the human operator's judgment. Hence fuzzy logic provides a powerful representation and good results for measurements of uncertainties present in this problem. Since, the availability of sun light is continuously varying; the fuzzy logic controller is used to generate the pulses for MOSFET device which is connected with single input buck-boost converter to generate required output.

2. MODELING OF THE SYSTEM

Fig. 1 illustrates block diagram of the solar power generation system. The major circuit elements are PV cell, FLC, MOSFET, single input buck-boost converter, battery and load. The FLC generates the control signal depends on the availability of sun light, to achieve required voltage. The resource available with required power level is connected to the active system to supply the load and the mode of operation preferred will decide by the controller.

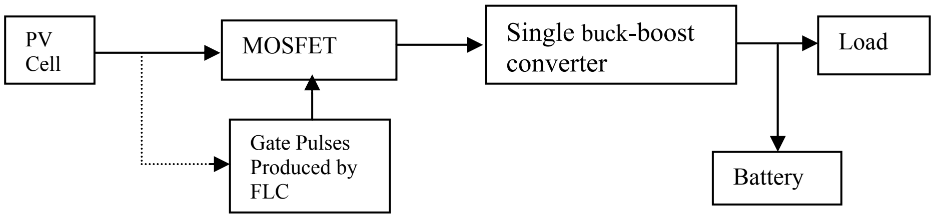

Fig 1. Block diagram of the proposed system

3. PRINCIPLE OPERATION OF THE PROPOSED SYSTEM

A schematic diagram of a single input buck-boost converter is given in Fig. 2. As shown, a buck-boost converter is nothing but cascade connection of the two basic converters: the step-down converter and step-up converter. The main application of such a converter is in regulated dc power supplies, where a negative polarity output may be desired with respect to the common terminal of the input voltage, and the output voltage can be either higher or lower than the input voltage [18]. The control signal generation, for the selection of available energy resource and the regulation of output voltage of the dc-dc converter is controlled by FLC.

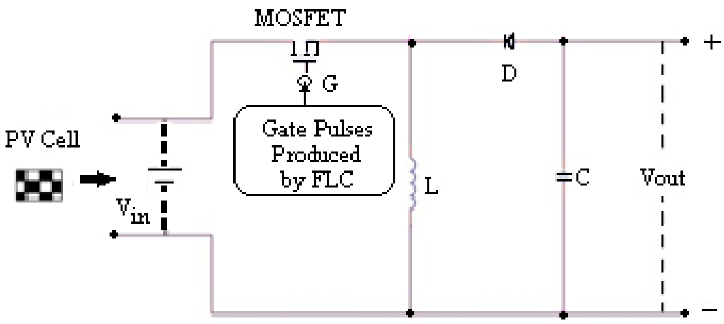

Fig 2. Single input Buck-Boost converter of the proposed system

4. DESIGN OF BUCK BOOST DC-DC CONVERTER

The buck-boost converter circuit parameters of this proposed method is designed as follows. Some of the important circuit parameters are listed as follows:

Input Power	P_{in}	: 50 Watts
PV panel voltage		: 12V
Efficiency	η	: 0.9
Output Power	P_o	: 45 Watts
Output Current	I_o	: 3.75 A
Battery		: 12V
Switching frequency		: 20 kHz
Switching period		$T=1/f=T_{on}+T_{off}$

Regulated output obtained from the dc-dc converter is used to charge the battery and the connected load. The duty cycle D is assumed as 0.5. The minimum value of inductance (L) and capacitance (C)

$$L = R\,[1- D]^2 / 2f \quad (1)$$

$$\Delta V_o/V_o = DT_s / RC \quad (2)$$

Using equations (1) and (2) the minimum values of inductor and capacitor are calculated for the dc-dc converter and expressed below

inductance (L)*L*) : 5mH
capacitance (C) : 15µF

5. DESIGN OF FUZZY LOGIC CONTROLLER

In this paper, the FLC is used to generate the pulses to drive the MOSFET. The PV cell's output voltage (V) and change in output voltage (ΔV) are chosen as an input to the fuzzy logic controller. The control output (u) signal is compared with triangular waveform and generated pulses are used to switch on the MOSFET. The input of FLC PV cell's output voltage (V) and change in output voltage (ΔV) are converted into fuzzy values by fuzzification. The ranges of input and output variables are assigned with linguistic variables. The Gauss membership function is used in this work. The input and output variables are assigned with 5 linguistic variables as follows:

1. The PV cell output voltage (V) is classified into:
   Negative maximum (V_{-vemax}); Negative medium ($V_{□-vemed}$); Zero (V_{zero}); Positive medium ($V_{□+vemed}$); Positive maximum (V_{+vemax})
2. The change in output voltage (ΔV) is classified into:
   Negative maximum (ΔV_{-vemax}); Negative medium (ΔV_{-vemed}); Zero (ΔV_{zero}); Positive medium (ΔV_{+vemed}); Positive maximum (ΔV_{+vemax})
3. The output of fuzzy logic controller u is classified into:
   Negative maximum (u_{-vemax}); Negative medium (u_{-vemed}); Zero (u_{zero}); positive medium (u_{+vemed}); Positive maximum (u_{+vemax}).

The input variable V and ΔV lies within the range of [-0.0188 0.001] and [-0.009.0.0188]. The control output 'u' lies in the range of [0 0.0123]. These input and output ranges are used for designing the FLC, in which each of input and output set is assigned with five linguistic variables and 25 rules are framed in fuzzy inference engine. The rules are given in Fig .3.

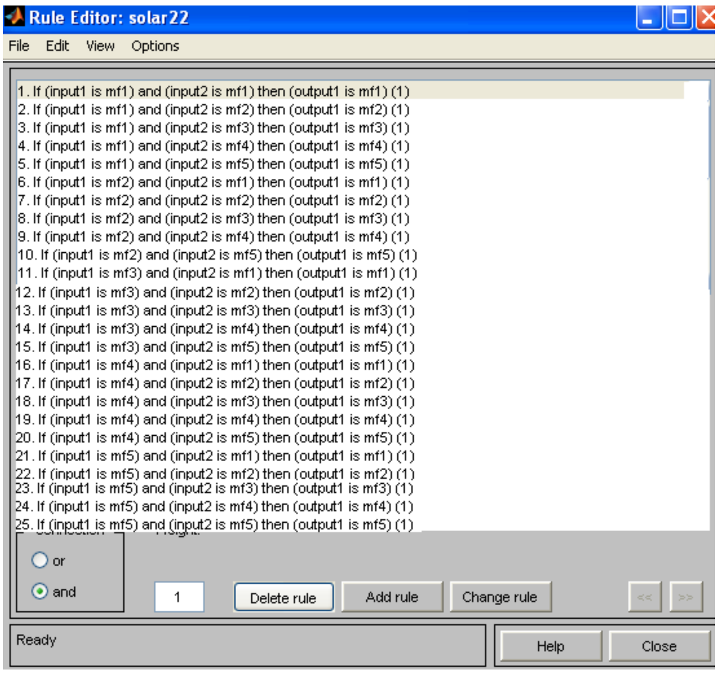

Fig .3 Picture of FLC rule base

In this design, "Center of gravity Method" is used for defuzzification. It should be noted that for various rules (r =1…R) would be in operation for a set of (V, □V), each recommending possibly different fuzzy controller actions. The defuzzified output is obtained by the following expression

$$u = \frac{\sum_{r=1}^{R} \mu_r' H_r}{\sum_{r=1}^{R} H_r} \tag{5}$$

Where μ_r' is the membership value of the linguistic variable recommending the fuzzy controller action and H_r is the precise numerical value corresponding to that fuzzy controller action.

6. SIMULATION RESULTS

The adaptability of this proposed method is studied by simulating the circuit model against the different possible real world situations using MATLAB/Simulink 2010a. The simulation diagram is shown in Fig .4. The solar irradiation is given to photo voltaic cell. The solar photovoltaic cell generates voltage based on the solar irradiation.

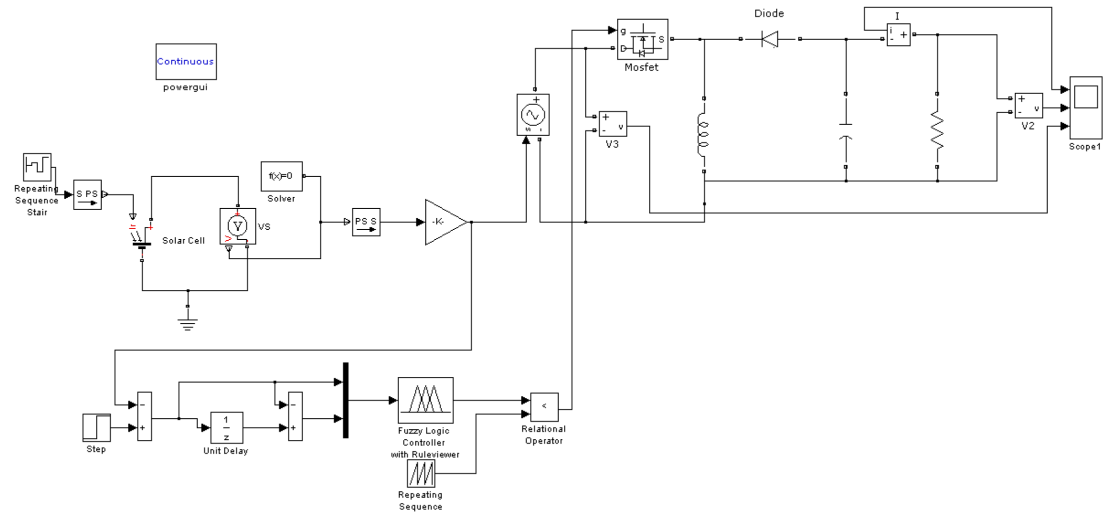

Fig .4 Simulink model

The solar irradiation is continuously changing because of weather and cloud. In this paper, the variation is chosen as shown in Fig .5. The voltage (V) from solar cell is given as one of the input to FLC and the change in voltage (ΔV) is given as another input to FLC. The FLC output is compared with ramp signal to produce gate pulses. The width of the gate pulses is used to decide the duty cycle (d) of the MOSFET. The FLC output, ramp signal and trigger pulse generated are given in Fig 6.a, 6.b and 6.c.

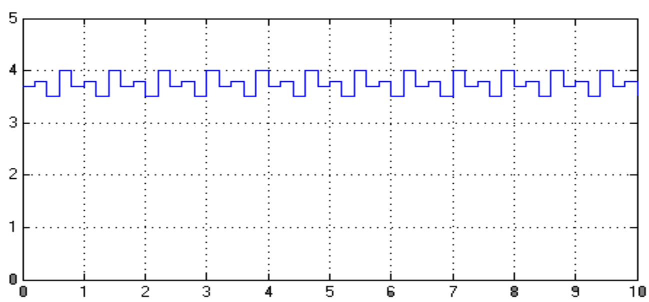

Fig .5 Solar irradiation –input

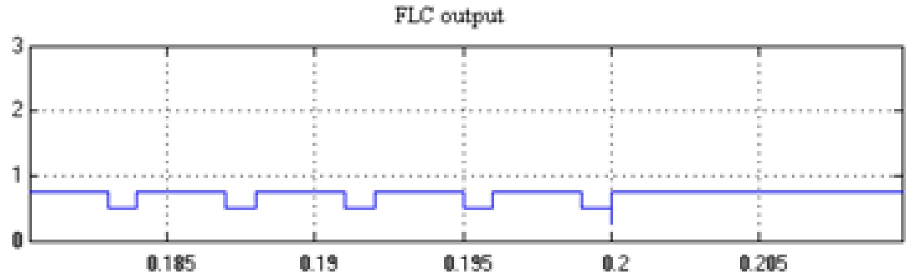

Fig .6.a

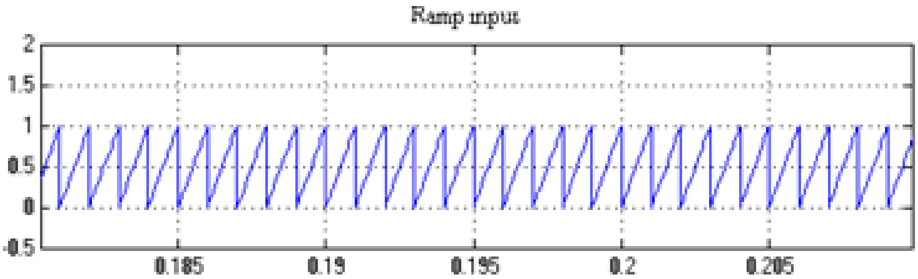

Fig . 6.b

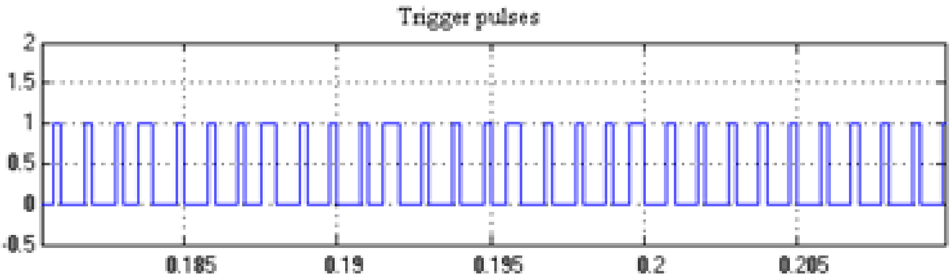

Fig .6.c

The input waveform of buck boost converter is shown in Fig. 7.a. The focused waveform is obtained in between 0.18 sec to 0.22 sec is shown in Fig .7.b for clear observation. From the Fig .7.b and Fig 5, it is observed that the input variation in solar irradiation is reflected in the output of solar PV cell.

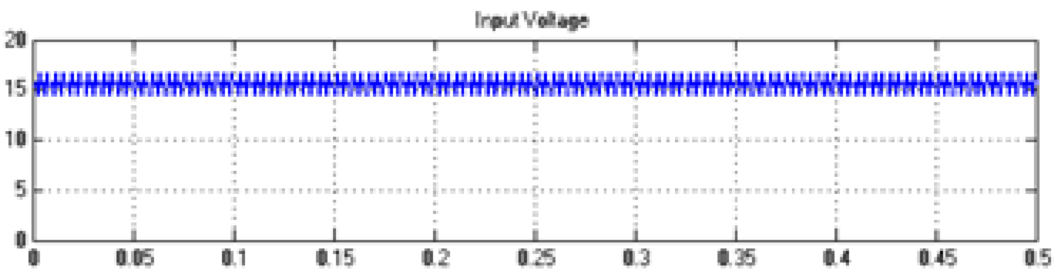

Fig .7.a

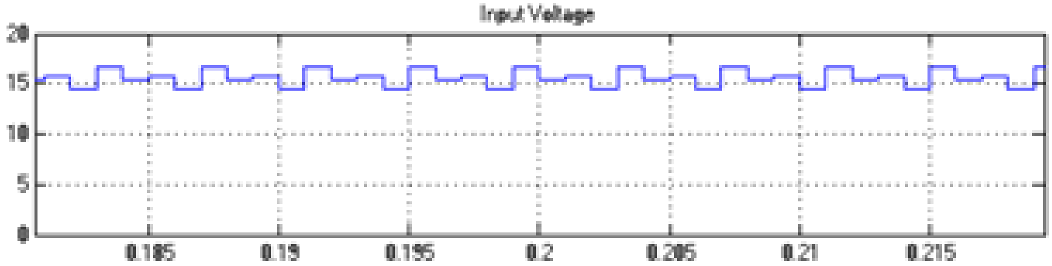

Fig .7.b

The trigger pulses are driving the MOSFET. When power MOSFET is switched ON, the current will flow through the inductance. Hence inductor L stores energy during the T_{on} period. When the power MOSFET is switched OFF, the inductor current tends to decrease and as a result, the polarity of the emf induced in L is reversed. Thus the inductance energy discharges in the load. The output voltage waveform across load is shown in Fig .8.a and 8.b. The focused waveform is obtained in between 0.18 sec to 0.22 sec is shown in Fig .8.b for clear observation. The output current waveform across load is shown in Fig .9.a and 9.b. The focused waveform is obtained in between 0.18 sec to 0.22 sec is shown in Fig .9.b for clear observation.

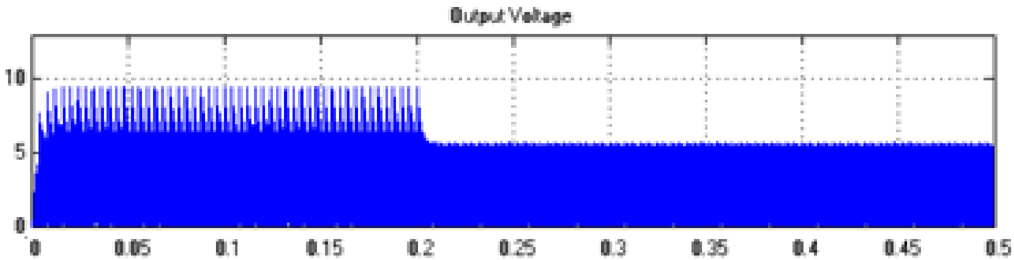

Fig .8.a

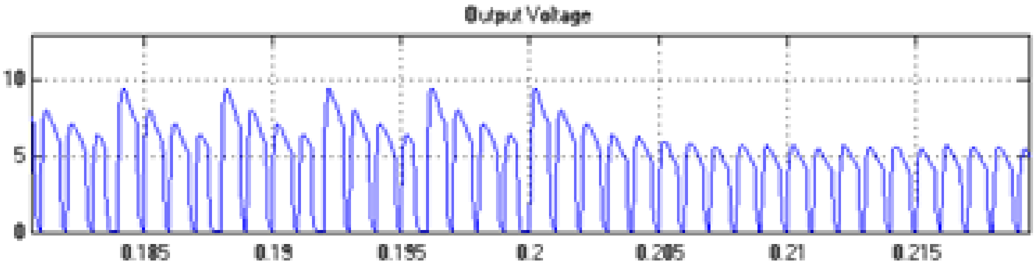

Fig .8.b

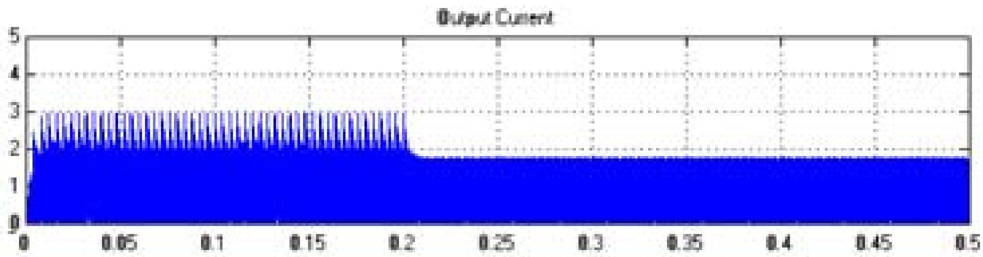

Fig .9.a

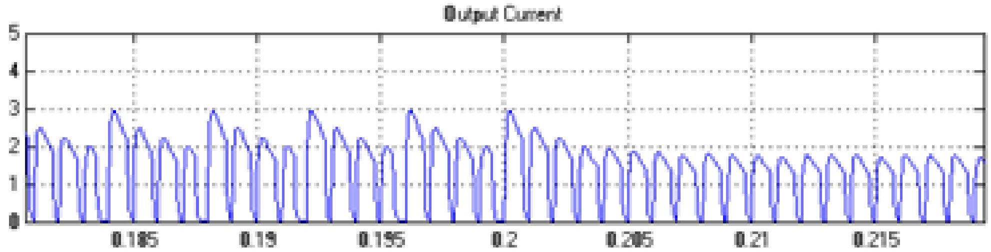

Fig .9.b

To analyze the performance of single buck boost converter, the step pulse is given as an input through the summation block to the FLC as shown in simulink model in Fig .4. From Fig .8 and Fig .9, it is observed that up to 0.2 sec the converter is in boost mode and after 0.2 sec, it is buck mode of operation.

7. CONCLUSION

This paper presented an idea of solar PV system controlled by FLC with single input buck boost converter. The simulation model of the proposed system is developed and the results obtained under different conditions are discussed and presented in this paper. The variation in solar irradiation is compensated by FLC and single buck boost converter and the output voltage remains same irrespective of solar irradiation. The results proves that the validation and real time feasibility of the proposed new model. For the research purpose only single PV cell is considered in this study. There is a possibility to control the entire solar power plant using solar PV cells with the same method.

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