Effect of DC-DC Converters on Fuzzy Logic Based MPPT Algorithm for Solar PV Systems

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Abstract- *Solar Photovoltaic Systems is a broad research area now days. There are many techniques and algorithms which are proposed to increase the efficiency of Solar PV Systems. Other than this, to increase the output power at the load, various DC-DC converters are used. In this paper, firstly, a MPPT algorithm based on fuzzy logic is presented. The whole work is carried out in MATLAB/Simulink environment. The output of FLC is used to change the duty cycle of DC-DC converter which is the control parameter. The Power response of Boost Converter and Buck-Boost Converter is presented in this paper. The simulation results show that the proposed system having Buck-Boost Converter effectively increase the power response of the system.*

Keywords- Fuzzy Logic Controller, MPPT, MATLAB/Simulink, DC-DC Boost Converter, .DC-DC Buck-Boost Converter.

I. INTRODUCTION

A great attention has been achieved by the Solar Photovoltaic Systems in research field due to energy crisis and increasing pollution. The main challenge is to increase the efficiency of the solar photovoltaic systems. The other drawback of Solar PV systems is the variation in output voltage with variations in solar radiation and temperature. Several techniques and algorithms have been proposed in this area to overcome the drawbacks of the Solar PV system. PV modules have unique power vs voltage (P-V) characteristics. From the P-V characteristics, PV systems must be operated at a maximum power point (MPP) of specific current and voltage values so as to increase the PV efficiency[2]. For any PV system, the output power can be increased by tracking the MPP of the PV module by using a controller connected to a buck-boost converter. One of such techniques is the use of Fuzzy Logic controllers in Maximum Power Point Tracking of the Solar PV systems. The Maximum power point changes with the variation in the solar radiation and temperature, so FLC is used to force the PV system to operate at the maximum power point[8].

In this paper, a Fuzzy Logic based controller is designed in MATLAB/Simulink environment. The FLC is used in Solar PV system along with a DC-DC Boost and Buck boost converter to increase the efficiency of the Solar PV system. In the Fuzzy Logic Controller the modifications are done in Rule base and membership functions according to the variations in solar radiation and temperature[10][12]. The output of the FLC is the change in the duty cycle of the DC-DC buck boost converter. Then the power response of both the converters is compared[5].

II. MODELING OF PV SYSTEM

The MATLAB/Simulink model of a Solar PV cell is designed by using basic equations. A typical equivalent circuit of solar cell is shown in figure 1.

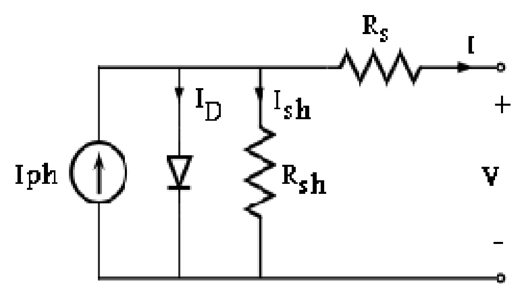

Figure 1: Equivalent circuit of solar cell

It consists of basically a current source, doide, series resistance and shunt resistance. The Solar Module and Arrays are designed by connecting multiple solar cells(36 or 72) in series and several modules in parallel respectively. The solar PV cell developed in MATLAB/Simulink environment is shown in figure 2.

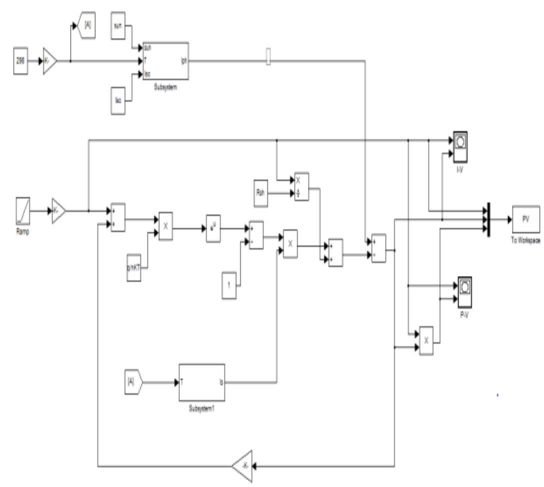

Figure 2: Solar cell model

The PV curves of solar module obtained by varying solar radiation and temperature are shown in figure 3 and 4 respectively.

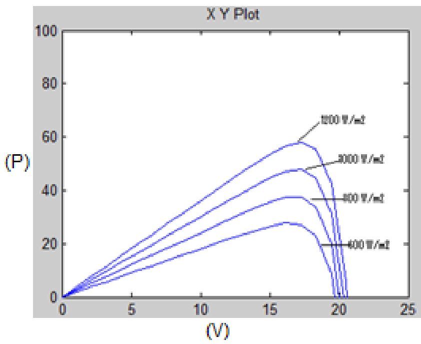

Figure 3: PV curves with Soalr radiation variation

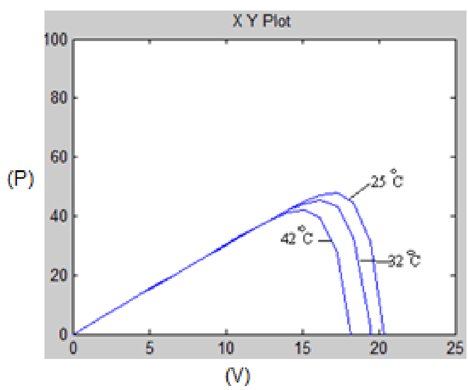

Figure 4: PV curves with temperature variation

III. FUZZY LOGIC CONTROLLER

The Fuzzy logic controller uses the fuzzy logics to make the decisions and to control the output of the controller. The main components in fuzzy logic based MPPT controller are fuzzification, rule-base, inference and defuzzification as shown in figure 5.

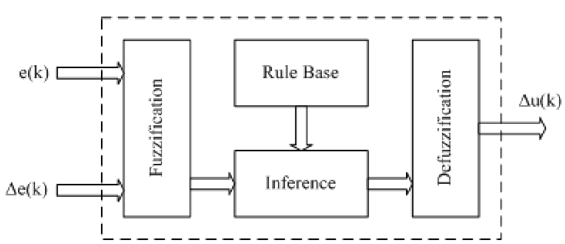

Figure 5: Fuzzy Logic basic block diagram

There are two inputs to the controller – error e(k) and change in error Δe(k). The Fuzzification block converts the crisp inputs to fuzzy inputs. The rules are formed in rule base and are applied in inference block. The defuzzification converts the fuzzy output to the crisp output. The fuzzy inference is carried out by using Mamdani's method, and the defuzzification uses the centre of gravity to compute the output of this FLC which is the change in duty cycle of Boost and Buck-Boost Converters.

IV. DC-DC CONVERTERS

In this paper, Boost converter and Buck-Boost Converter is used.

A. DC-DC Boost Converter

A boost converter (step-up converter) is a DC to DC power converter with an output voltage is greater than its input voltage. It is a class of witched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. The boost converter is used to regulate a chosen level of the solar photovoltaic module output voltage and to keep the system at the maximum possible power from solar panels at all times.

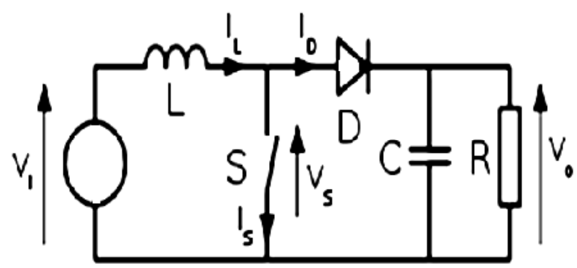

Figure 6: Boost Converter

B. DC-DC Buck-Boost Converter

The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. Figure 7 shows the simple diagram of a Buck-Boost Converter.

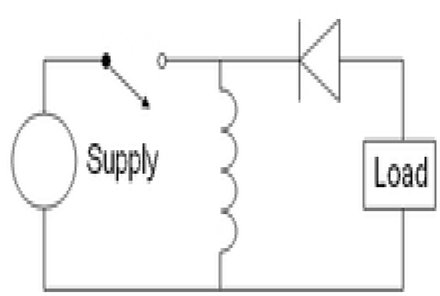

Figure 7: Buck-Boost Converter

Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, from an output voltage much larger (in absolute magnitude) than the input voltage, down to almost zero.

V. METHODOLOGY

The fuzzy logic controller used in the system has two inputs. The error is the change in the power with respect to the change in the voltage. The equations for error and change in error is given by

$$E(k) = \frac{P_{ph}(k) - P_{ph}(k-1)}{V_{ph}(k) - V_{ph}(k-1)} \quad (1)$$

$$CE(k) = E(k) - E(k-1) \quad (2)$$

The output of the controller is ΔD, change in the duty cycle of the DC-DC Buck boost converter and Boost Converter.

In the rule base, there are 5 membership functions of error and change in error each, whereas, the output which is the change in duty cycle, also has 5 membership functions. There are 17 rules in the rule base. The rules are formed as shown in Table 1.

Table 1: Rule Base

CE / E	NB	NM	ZE	PM	PB
NB	-	-	NB	NB	NB
NM	-	-	NM	NM	NM
ZE	NM	ZE	ZE	ZE	PM
PM	PM	PM	PM	-	-
PB	PB	PB	PB	-	-

The membership functions for Error, Change in Error and the Output Variable are shown in Figure 8, 9 and 10 respectively.

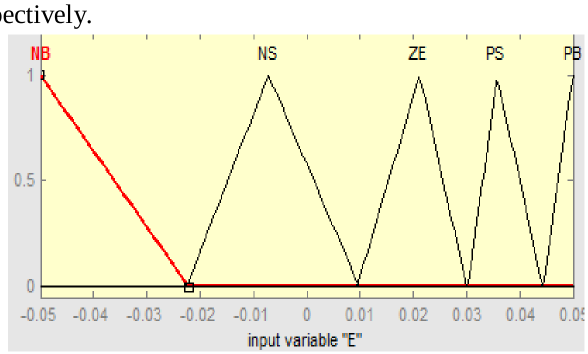

Figure 8: Membership functions of Error Signal

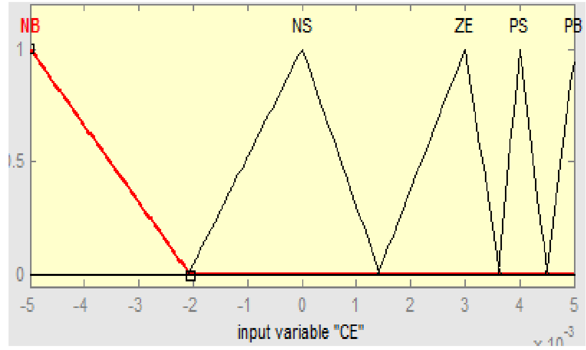

Figure 9: Membership functions of Change in Error

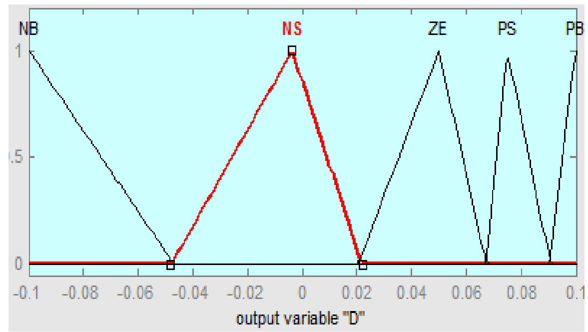

Figure 10: Membership functions of Output variable

A. Simulink Models

The Simulink model of the proposed system with Boost Converter is shown in figure 11.

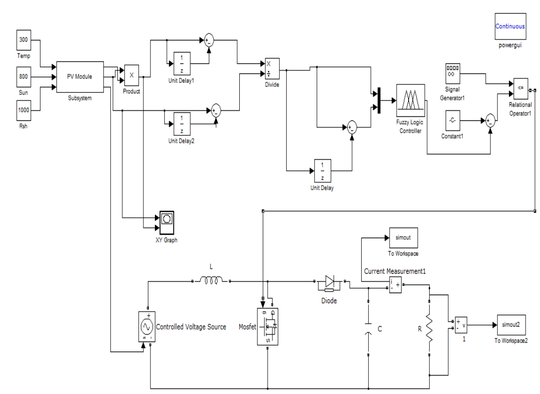

Figure 11: FLC Based System with Boost Converter

The Simulink model of the proposed system with Buck-Boost Converter is shown in figure 12.

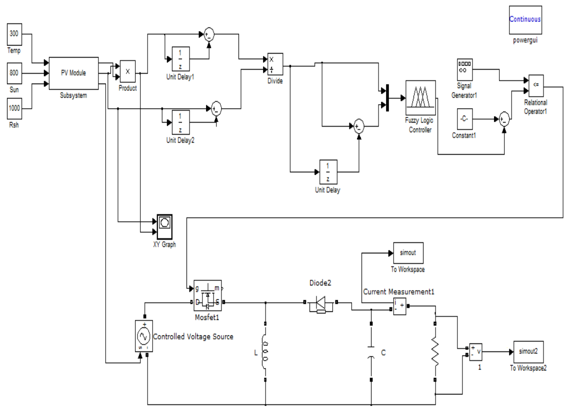

Figure 12: FLC Based System with Buck-Boost Converter

B. Converters Configuration

The values for Boost Converter are calculated from following given equations:

$V_0 = V_s/(1-D)$

$L = V_{in}*(V_0-V_{in})/(\Delta I_L*F*V_0)$

$C = I_0*D/(F*\Delta V_0)$

F = 20 KHz

The values for Boost Converter are calculated from following given equations:

$$L = \frac{D(1-D)^2R}{2F}$$

$$C = \frac{D}{R\frac{\Delta V_0}{V_0}F}$$

VI. SIMULATION RESULTS

The Simulation is done in MATLAB/Simulink Environment. The results of Output Power with Boost and Buck-Boost Converters is shown in figure 13 and 14 respectively.

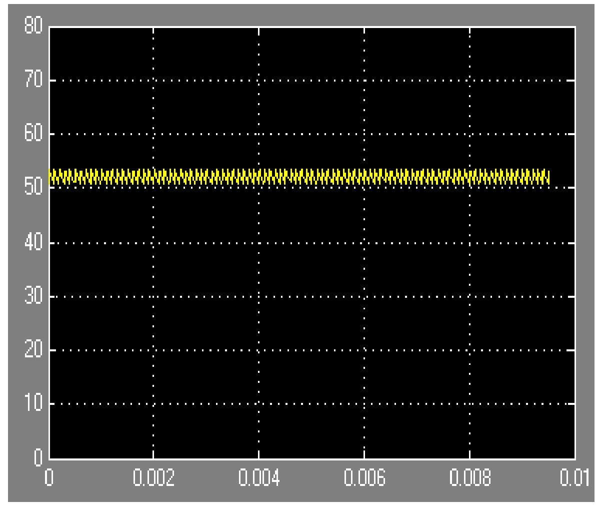

Figure 13: Boost Converter Output

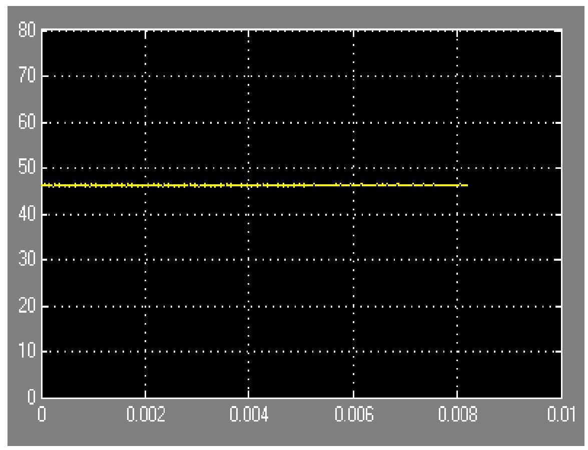

Figure 14: Buck-Boost Converter Output

The Gate Pulse given to MOSFET is shown in figure 15.

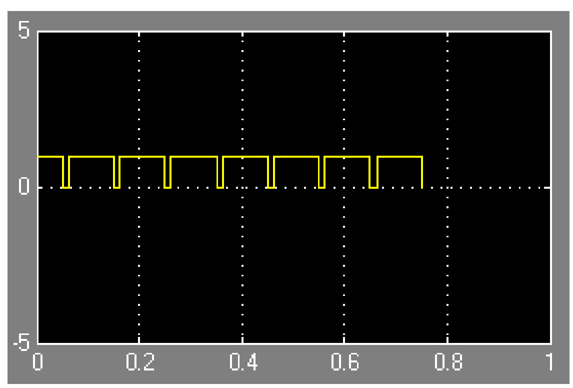

Figure 15: Gate Pulse to MOSFET

VII. CONCLUSION

The proposed model was simulated in MATLAB/Simulink environment. The PV Module system was first simulated by varying solar radiation and then by varying temperature. Then the PV Module is integrated with

Fuzzy Logic Controller. The power from the two DC-DC converters is then obtained and plotted. The results showed that there is slight amount of increase in the output power from the Boost converter but at the same time the fluctuations are more. On the other hand, the output power resulted from Buck-Boost converter has lesser fluctuations than Boost converter and hence a better response.

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