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A Novel Control Strategy Based Converter Architecture for Distributed Energy Resources

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Abstract

The energy crisis in the present scenario has given more focus on the exploration of new sources of energy, its different methods of implementation for the optimized usage. This paper focuses on the implementation of the double boost converter for the solar application and its detailed description. MPPT controller is introduced for maximum power tracking. Perturb and observe algorithm is used for the MPPT. The verification of the above concept is done by using MAT LAB/SIMULINK software and the computation result is also given. The next section explains the solar panel design, its software implementation and the performance verification. Also propose a novel control strategy for the double boost converter architecture. The proposed control method used is MPPT along with Fuzzy logic controller.

Keywords: Boost converter, double boost converter, solar panel, MPPT controller. P&O algorithm, Fuzzy logic controller.

I. Introduction

DC to DC converters are very important in battery powered electronic devices. Those devices often contain sub circuits, each requiring different voltage levels than that supplied by the battery. Dc to dc converters provides a method of generating multiple controlled voltages from a single battery voltage. For distributed energy resources boost converters are mainly used. There are different types of boost converters are discussed such as bridgeless boost converter and double boost converter. The Bridgeless topology does not have rectifier circuit operated throughout the full cycle and that's the reason for its name [4]. One of the earliest topology in this class which is called the Bridgeless Boost PFC. Bridgeless PFC converter has recently gaining its popularity in giving high efficiency and high performance converter [4]. The bridgeless boost converter provides the output voltage greater than the input voltage. The boost converter is implemented by replacing a pair of MOSFET employing an ac-side boost inductor. Hence the bridgeless boost converter is employed to maximize the power supply efficiency by reducing the number of semiconductor component in the line current path. That is one rectifier is eliminated from the line current path which minimize the conduction losses.

The bridge less boost converter provides slightly higher output voltage than the input voltage where as Double boost converter provides the output voltage which is double the input voltage [8]. Boost converters are mainly used to power factor correction due to its intrinsic characteristics. For high power applications input voltage variations (110 Vrms and 220 Vrms input voltage) the converter performance is very poor [7] .In order to over comes these drawbacks double boost converter is employed. Among them double boost performance is better than the bridge less boost converter. Now we focus about the performance of double boost converter in the solar system.

Renewable energy sources becoming a important resources for power generation due to increase in world's energy demand and scare of resources. Renewable energy sources like photo voltaic are proven to be both clean and economical and do not make any harmful reaction to the environment. Solar systems have become globally accepted as a practical and feasible tool for the power generation. The importance of PV system design and application are more reliable and efficient .The PV module has nonlinear characteristics, so it is necessary to design and simulation of the solar system. Mat lab / Simulink software is used to develop a generalized model for PV cell, module, and PV array etc. The solar cell has 20 to 30 year of life span and no need for maintenance. To improve the efficiency of the solar panel MPPT controllers are used, on which perturb and observe algorithm is employed. The output of the MPPT is a PWM signal (duty cycle as the parameter) which is given to the fuzzy logic controller. The output (duty cycle) of this fuzzy is given to the double boost converter.

II. Characteristics of Solar Panels

Solar panels consist of different PV cells connected in series and parallel in order to achieve desired voltage and current levels. Solar cell is to use a P-type semiconductor materials that have the ability to convert solar irradiation into DC current this is obtained by photo voltaic effect .There are mainly two types of characteristics, they are P-V characteristics and I-V characteristics these are obtained from the equivalent circuit model.

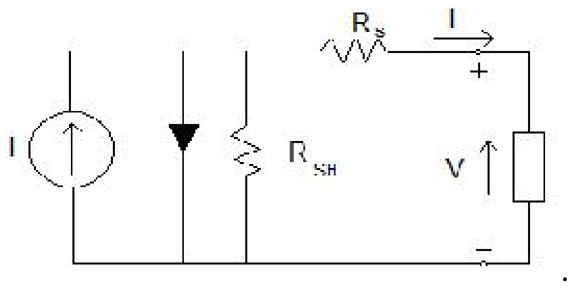

Figure 1: Solar cell circuit model using single diode

The characteristic equation of a photovoltaic array is given by [9].

$$I = I_{LG} - I_{OS}\left\{exp\left[\frac{q}{AKT}(V + IR_s)\right] - 1\right\} - \frac{V+IR_S}{R_{sh}} \quad \ldots(1)$$

Where,

I_{LG} – Current generated by the light (A)

I_{OS} – Reverse saturation current (A)

q- Charge of electron (C)

A-Dimensionless factor

K- Boltz Mann's constant (1.38×10^{-19} J/K)

T- Junction temperature in Kelvin

R_s – Series resistance of the cell (Ω)

R_{sh} – Shunt resistance of the cell (Ω)

From the above characteristic equation we can see that the output voltage of PV panel is nonlinear.

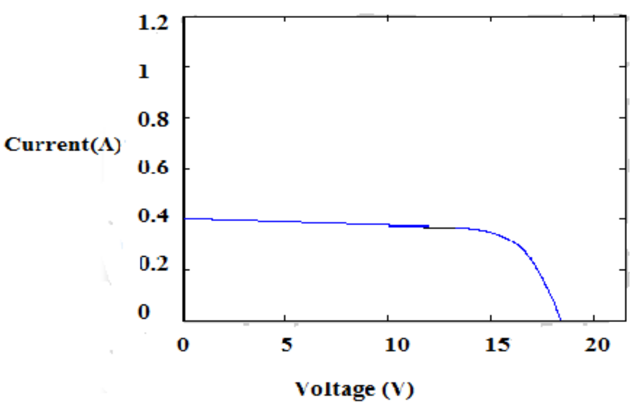

Figure 2: I-V characteristics of PV system

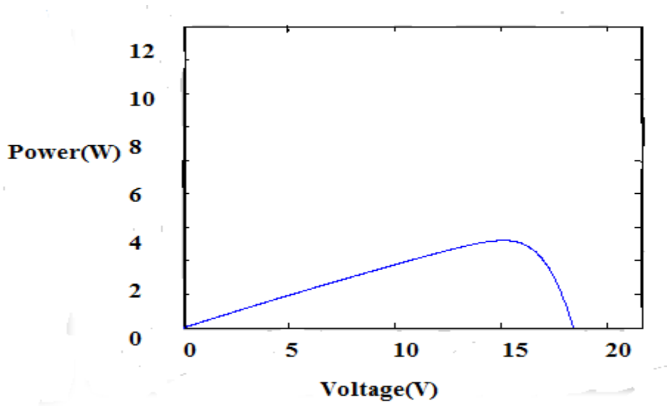

Figure 3: P-V characteristics of PV system

III. MPPT Controller

Photovoltaic system requires maximum power point tracking (MPPT) controller to maximize the output power of the PV array by continuously tracking the maximum power point. The output of the MPPT controller is a PWM signal (duty cycle) which is then given to the fuzzy logic controller then it is given to the double boost converter. Thus the duty cycle of the converter can be controlled. There are different algorithms for this MPPT. Out of them perturb and observe method is commonly used because of easy implementation, and low cost. We can modify this perturb and observe algorithm to simple block to increase the processing speed.

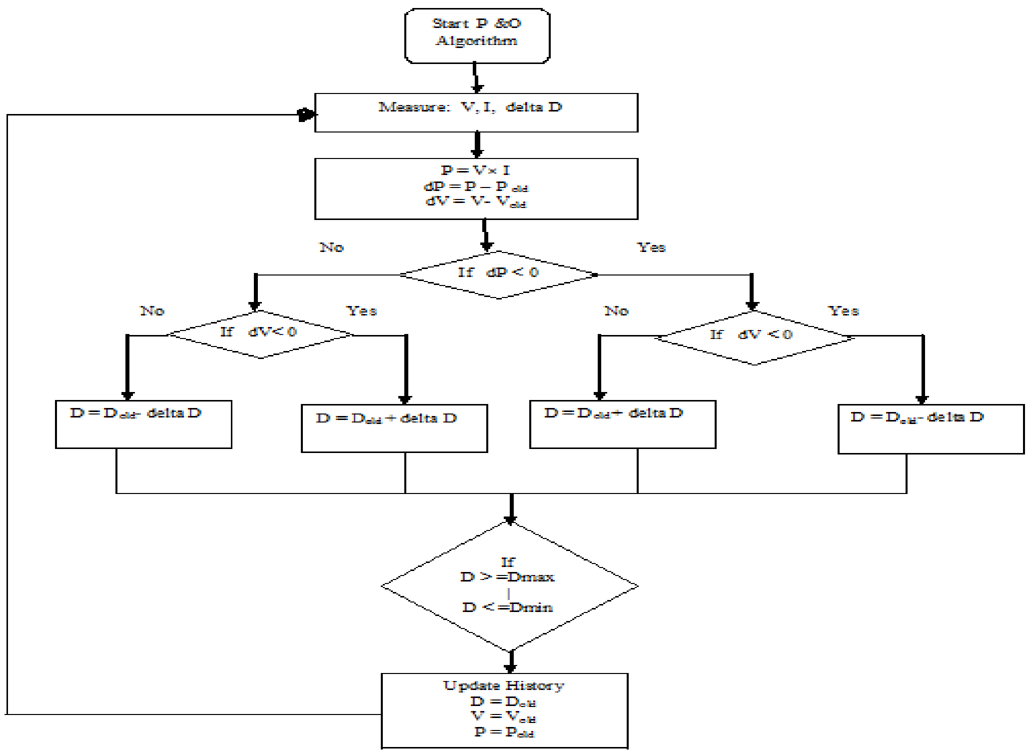

Figure 4: Flow chart for Perturb and observe algorithm (P&O)

IV. Double Boost Converter

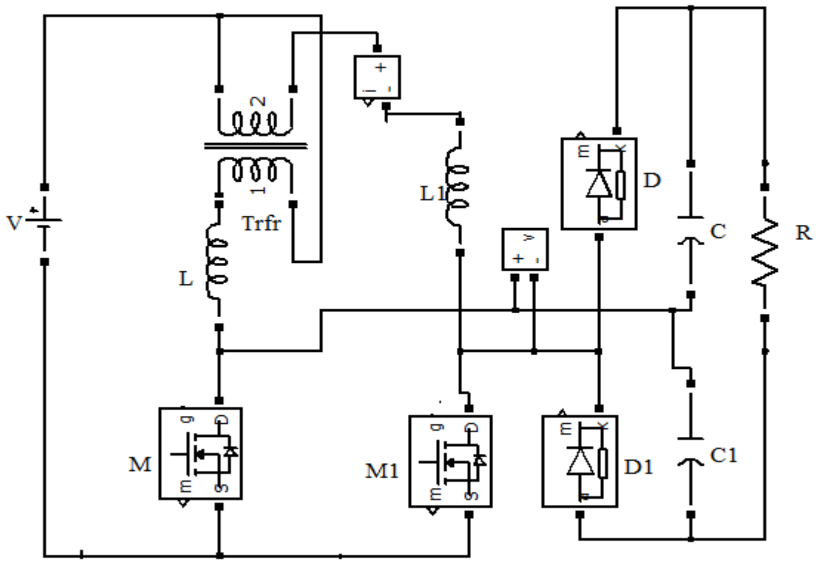

Figure 5: Two inductor model of Double boost Converter

Generally a double boost converter is obtained by split a boost converter into two modules. Where each module is processes half the total output power [7]. Ideally the same drive signal is employed to command the two active switches M and M_1 , they will present exactly the same conduction and commutation times, implying that the output voltage will be distributed equally over the two capacitors C and C_1Double boost converter provides the output voltage which is double the input voltage[8]. The boosting action is mainly done by the two inductors.

V. Fuzzy Logic Controller

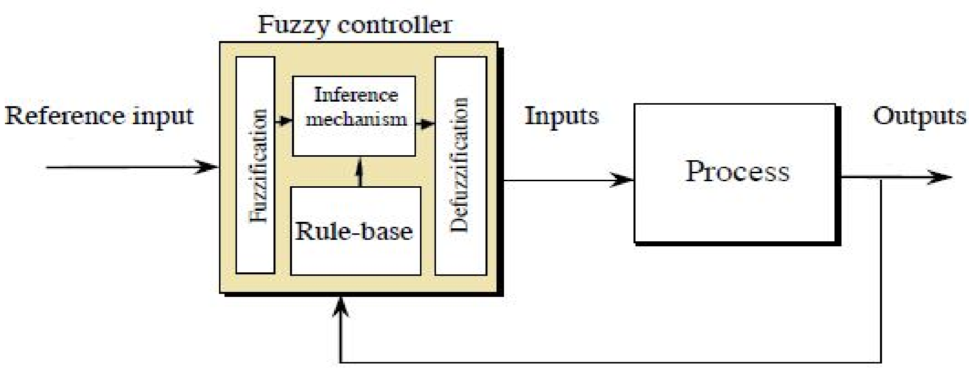

Figure 6: General structure of a fuzzy logic controller on Closed-loop system [10]

Fuzzy logic controller design does not require the knowledge, about the exact model. It is based on the human linguistic concepts .Thus fuzzy logic controller serves as a intelligent controller. It has mainly three steps fuzzification, inference mechanism, and defuzzification. On this proposed controller the input and output are duty cycle.

VI. Fuzzy Logic Membership Function

The double boost dc-dc converter is a nonlinear function of the duty cycle .Fuzzy controllers does not require an exact mathematical model. Instead, they are designed based on general knowledge of the system. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the duty cycle of double boost converter using Mamdani style fuzzy inference system. Two input variables, duty cycle (D) and delta duty cycle (delta D), which represent the previous value of duty cycle are used in this fuzzy logic system. The single output variable is duty cycle of PWM generated from the fuzzy logic controller.

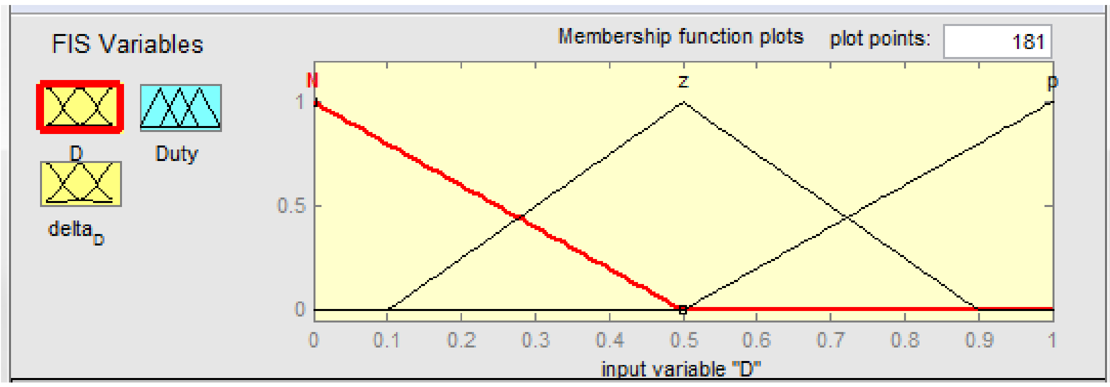

Figure 7: Member ship function plot of input variable ‘D’

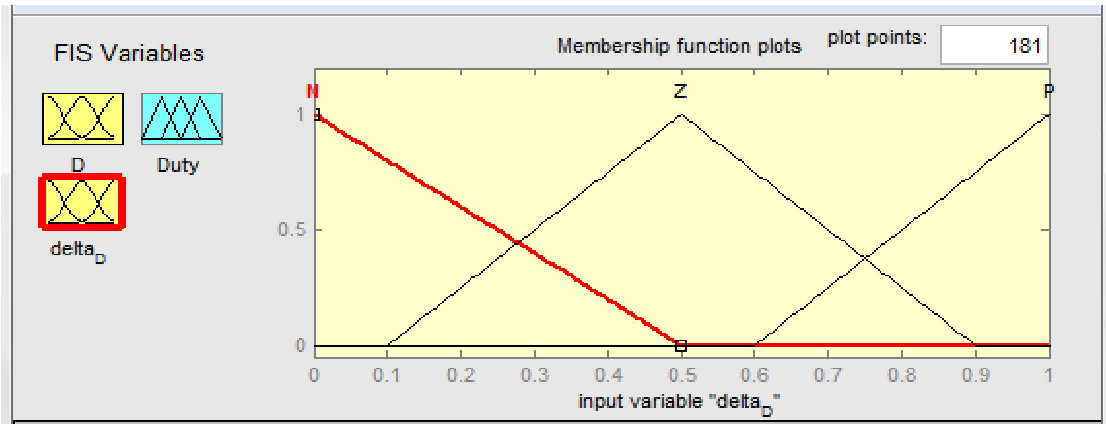

Figure 8: Member ship function plot of input variable ‘deltaD’

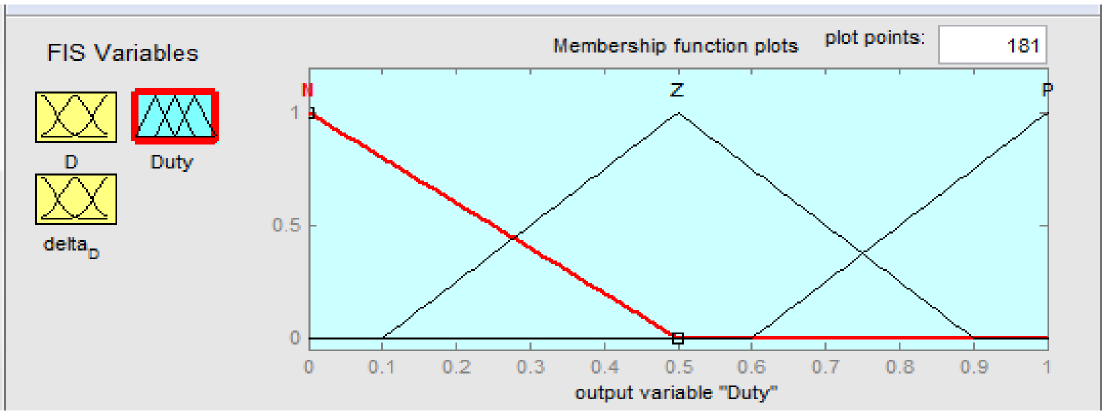

Figure 9: Member ship function plot of output variable 'Duty'

VII. Fuzzy Logic Table Rules

The variable "D" and "delta D" are the inputs to the fuzzy logic controller. These two inputs are divided into three groups; N: negative, Z: zero, P: positive. The fuzzy control rules are represented in table as shown in Table I.

Table I: Table rules for D and delta D

D / Delta D	N	Z	P
N	P	P	P
Z	P	P	P
P	P	P	P

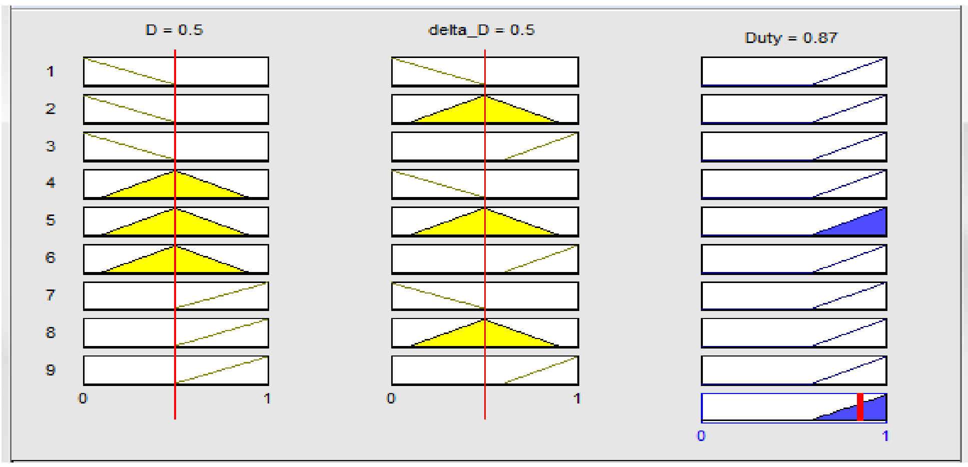

Figure 10 : Fuzzy logic rule viewer

VIII. Results and Discussion

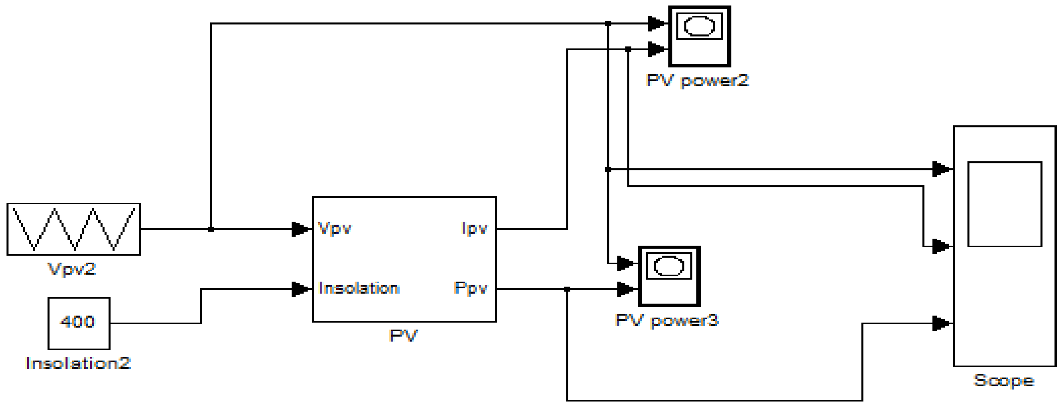

Figure 11: Masked block model of PV system

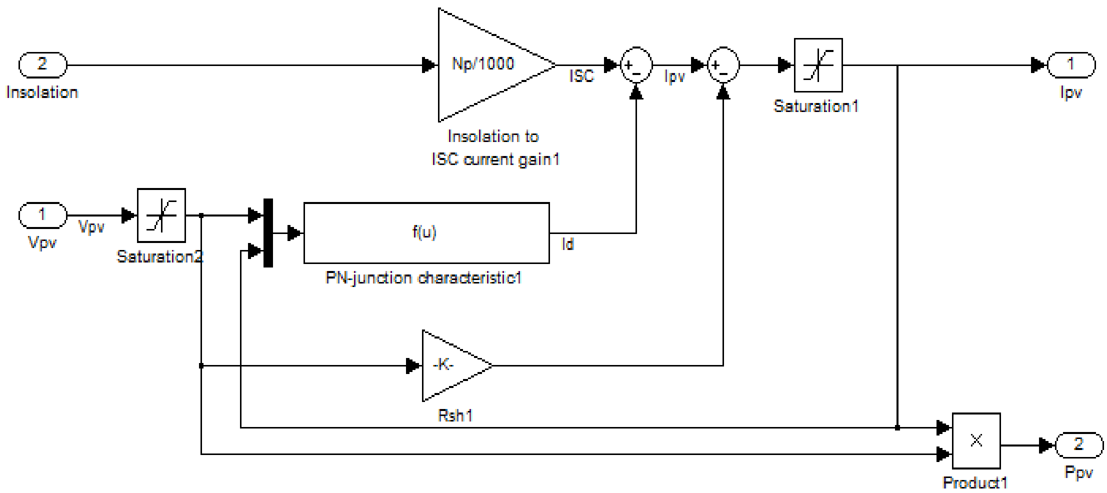

Figure 12: Subsystem of Masked block model of PV system

Masked model of PV system is used for generating the PV system characteristics shown in figure2 and figure3. The PV cell can be modeled from the characteristic equation (1). The sun irradiation is directly proposed to the voltage, which is a time varying one so it can be represented as triangular waveform.

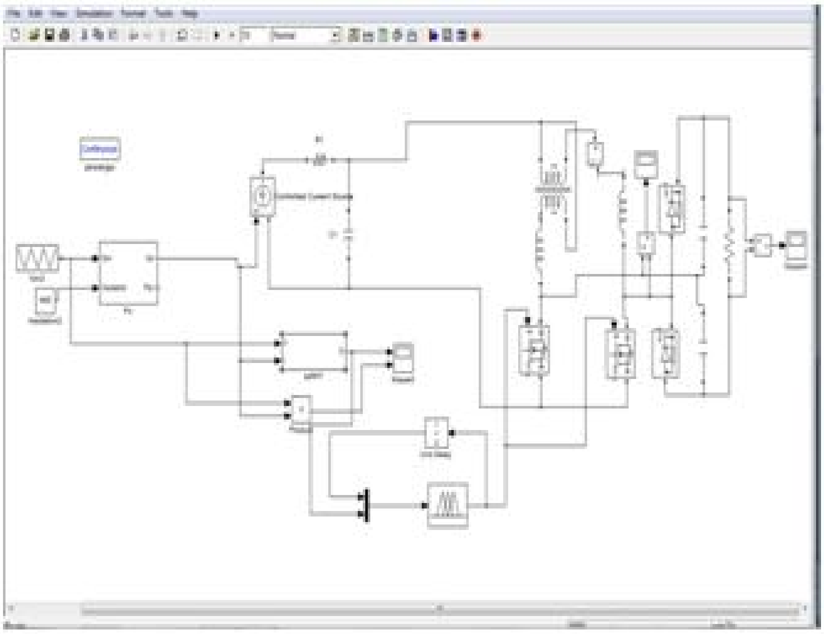

Figure 13: Simulink Model of the proposed Converter Strategy

A single solar cell is modeled and MPPT controller is used to improve its efficiency. Here fuzzy logic controller is used to control the double boost converter. The MPPT controller's perturb and observe algorithm can be made to block model for increasing the processing action, which is shown in figure 14.

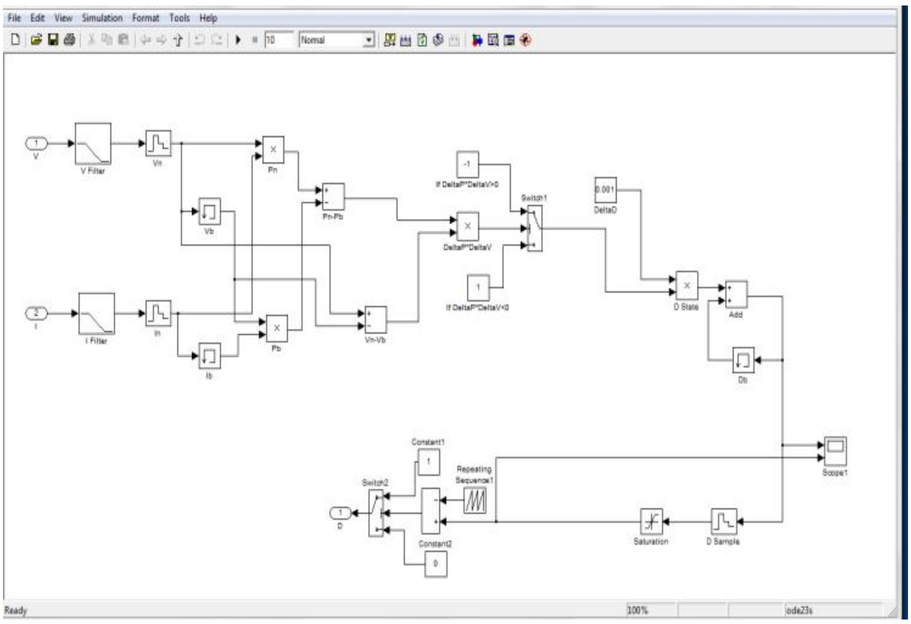

Figure 14: Subsystem for MPPT Controller

The duty cycle obtained from the MPPT controller is nearly 50% only.

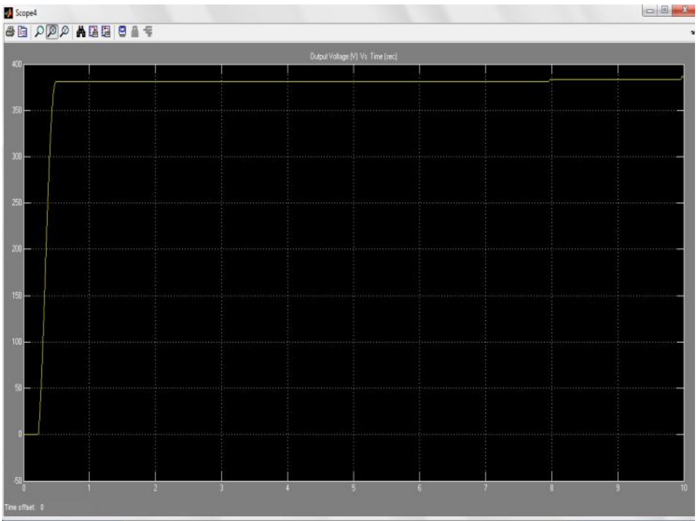

Figure 15: Output wave form for the proposed Converter Strategy

The output voltage obtain from the solar panel is nearly 20V dc. Also MPPT controller improves the solar panel efficiency. The boosting action is done by double boost converter and the fuzzy logic controller control the duty cycle of the double boost converter there by its voltage can also control. Then we get the output voltage from the converter is 380V that is nearly 400V. By providing this fuzzy controller along with the MPPT controller, we get the duty cycle near unity, stable output waveform, and controlled output voltage.

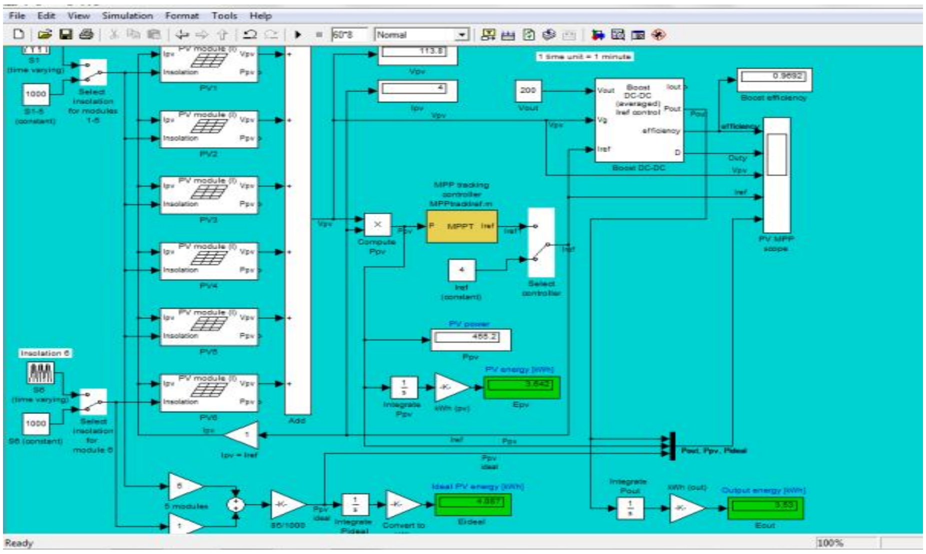

Figure 16: Simulink model of the PV modules with the MPPT controller and the proposed Converter

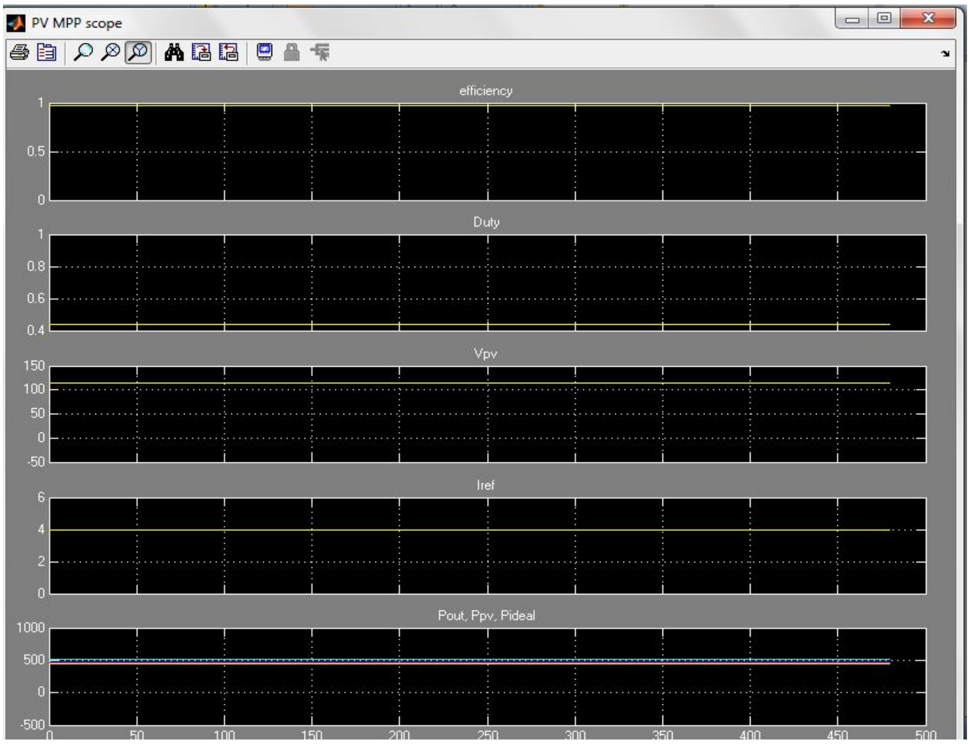

Figure 17: Output wave forms of PV modules with the MPPT controller and Proposed Converter

The output power obtained from the PV modules is about 455 W, the ideal power from the module is 500 W and power output obtained from the converter is nearly 430W. Thus the maximum energy harvesting is obtained by using this MPPT controller and proposed converter. Here the duty cycle nearly 50% only thus for making the duty cycle near unity fuzzy controller is also included and thus make system more stable, figure 13.

IX. Conclusion

Thus from the proposed converter and control strategy, we can get maximum energy harvesting, reducing the switching losses and improve the efficiency of the system. Also from this we can conclude that, this double boost converter can be use in distributed energy resources like solar system instead of boost converter. Here it is clear from the Simulation result, the output voltage obtained from the solar panel is just a 20V so it cannot be used for any application such as driving a dc motor drive. So the necessity of double boost converter is arises for boosting the voltage.. Also from the result we can see the difference between, without the fuzzy logic and with the fuzzy logic controller. That is MPPT controller alone can control the double boost converter but the result is not more stable.

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