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Maximum PowerPoint Tracking of PV System Based on a SEPIC Converter Using Fuzzy Logic Controller

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ABSTRACT
This paper presents the MPPT (Maximum power point tracking) operation of PV (Photovoltaic) system based on a SEPIC (Single Ended Primary Inverter Converter) converter using fuzzy logic controller. MPPT method such as Incremental conductance base on FLC (Fuzzy Logic Controller) is used to extract maximum output power of the PV system. PV energy is the most essential energy resources since it is pollution free, clean and endless. The FLC proposed scheme is interface with the MPPT to generate the PWM (Pulse Width Modulation) for the SEPIC controller for maximum power point tracking operation.FLChas used Mamdani's method for convergent and divergent of membership function. FLC is used for more efficient performance under the variation in different atmosphere. The fuzzy logic controller with SEPIC for MPPT scheme extract the maximum power point tracking without any change in the voltage at the inverter at different load condition. The behavior of the converter and controller tested in simulation at different operating conditions. Proposed scheme is used for accurately tracking maximum point and also send the smooth, error free signal to the inverter.
Keywords:DC-DC power converters, Fuzzy control, PV (photovoltaic) cells, MPPT (Maximum power Point Tracking)

I. INTRODUCTION

The SEPIC works like a buck boost dc-dc converter, where its output voltage gets varied as per its duty cycle. It's very important to select the proper dc-dc converter which plays vital role for maximum power point tracking operation. There are many factors such as cost, efficiency, flexibility and energy flow which are considered for selection of proper PV converter.

The SEPIC, conventional buck boost and Cuk converter are the once amongst the known converters having an ability to step up and step down the input voltage. So these converters can transfer energy for all irradiation levels. The continuous output current is the second desirable feature which allows converter output parallel connection or conversion to a voltage source with minimum capacitance. The lack of output voltage flexibility is the main reason for buck or boost Converter to be not preferable. For example, the buck and boost converter are not able to charge the battery continuously (in case of PV system battery charger). With MPPT operation as the power voltage curve gets varied with irradiation level and thus the voltage corresponding to the maximum power variation.

To propose dc-dc converter, there reason so many considerable features, like input output energy flow, cost, flexibility and PV array effect. The SEPIC is chosen because output voltage can be higher or lower than the input voltage. Also the input and output voltage are dc isolated. The isolation provided by the series capacitor C, which blocks the D.C. from the supply side to the output side [1]. The voltage multiplier technique and active clamp technique are used to conventional SEPIC converter to increase the voltage gain, reduce the voltage stress of the power switch and diode. There is provision in both the SEPIC and Cuk converter for a choice to have either higher or lower output voltage as compared to the input voltage. Both have contentious input current and better efficiency compared to the buck boost and fly back converter[2]. The literature so far does not have the general opinion on which one of the two converts is better [3]. Now this paper proposes SEPIC converter use due to the Cuk converter's inverted output.

The PV panel yields exponential curve for current and voltage, where the maximum power occurs at the curve's mutual knees [4]. The applied MPPT uses a type of control and logic to look for the knees, which in turn allows the SEPIC converter to extract maximum power from the PV array and the used tracking methods areIC (Incremental Conduction), which provides a new reference signal for controller and extracts the maximum power from PV array.

Fuzzy logic is the simplest intelligent controller to integrate with the system. Because of the FLC's better response than the other conventional controllers, it has drawn significant attention to researches for converter control, motor drives and other process control [5]. Fuzzy controller is capable

to address the imprecision of weather variations that can be reflected by PV arrays. The MPPT algorithm is integrated with FLC in order to take the advantages of fuzzy logic algorithm. Therefore, overall control system will always provide maximum power transfer from the PV array to the inverter side (load), in spite of unpredictable weather conditions.

II.   PROPOESED SYSTEM

The main function of the dc-dc converter is to feed the change of voltage level to the inverter. In this paper, the voltage level depends on the maximum power. By changing the duty cycle of the pulse width modulated signal, the controller changes the voltage level, which tracks the reference signal.For getting the supposedly zero error signal, the sinusoidal reference signal is compared with the output signal. And to achieve the maximum power, another reference signal is compared with SEPIC's output. This reference signal is adaptive in nature so it changes its shape as per the weather conditions. The inverter's input should be smooth, but SEPIC MPPT does not produce the smooth signal. But this problem is not so big since the non-smooth signal can be enhanced with the inverter's fuzzy controller and the low pass filter connected to the inverter.Hence, though the input signal is not so smooth, we get maximum power as well as smooth output signal.Fig 1 shows the circuit diagram of the SEPIC dc-dc converter together with MPPT and fuzzy controller.The detailed explanation of the fuzzy controller will be seen in next section.
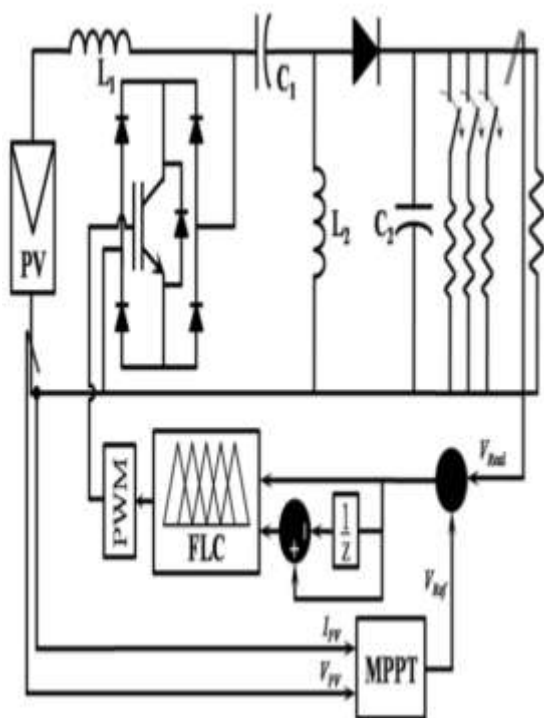
According to the control signal, the PWM changes its duty cycle generating the feedback from the output signal represented in the voltage, current and power to get the reference signal which is unpredictable and adapts itself as per the maximum power point achieved by its duty cycle change.

In Fig. 1, we could have used single switch for SEPIC but due to the dc-dc converter's feature to supply the inverter and to charge the battery, we have use the bi-direction switch.

III.   FLC ALGORITHM

Mamdani's method is used to design the fuzzy controller for both converter and single phase inverter. Fig 2 shows the overall control scheme of the proposed system.Identifying the main control variable and determination of the sets that describe the values of each linguistic variable are the important steps in the design of FLC.The FLC' structure is shown in fig 3.The output voltage error e(n) and the change of this error e'(n) are the input variables of the FLC.The duty cycle d(n) of the pulse width modulation signal (PWM signal) is the FLC output which regulates the output voltage.
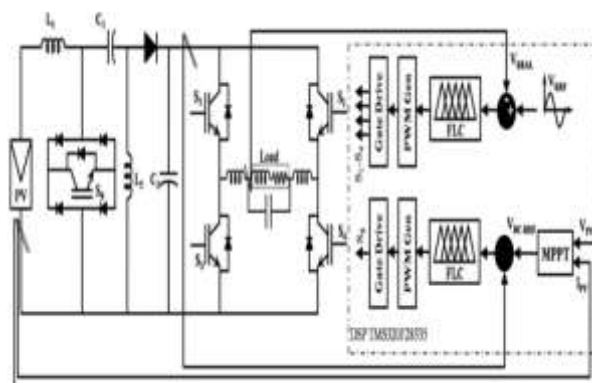

Fig. 2. Overall control scheme for the proposed FLC based MPPT scheme for the SEPIC converter

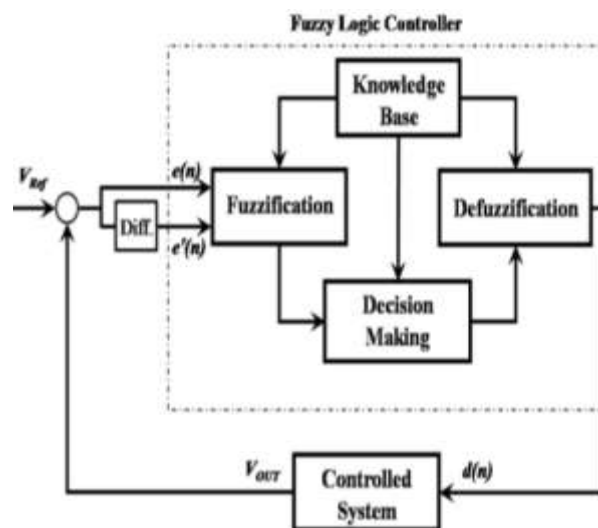Fig. 1. Circuit diagram of the SEPIC converter for FLC based MPPT scheme

Fig. 3. Structure of the proposed FLC

Fig. 4 shows the membership function of the SEPIC side FLC's input and output which is symmetrical with equilateral triangle. Triangular membership function is used in the FLC in order to get easier computation. A five term fuzzy set i.e. (N-II), (N-I), (Z), (P-I) and (P-II) is defined to describe each triangular variable. The output variables of the membership function are nine term fuzzy sets with a classical triangular set i.e. (N4), (N3), (N2), (N1), (Z), (P1), (P2), (P3) and (P4) as shown in fig 4. The control signal is confined between -1 and 1 owing to the PWM carrier wave. Input signal vales are between -100 and 100 due to the error signal caused and the reference signal.
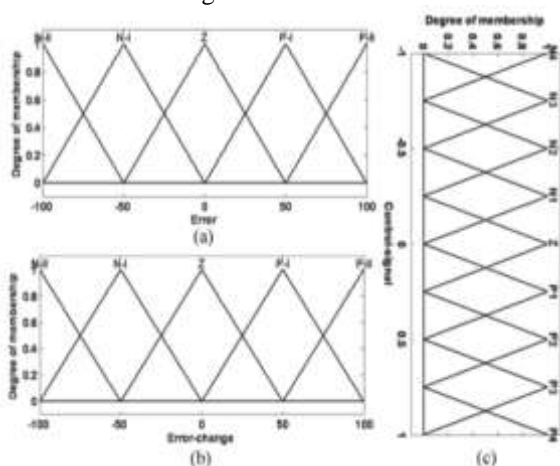

Fig. 4. Symmetrical membership function of the FLC
(a) *e(n),* (b) *e'(n)* and (c) *d(n)*

TABLE I
FUZZY RULE-BASED MATRIX

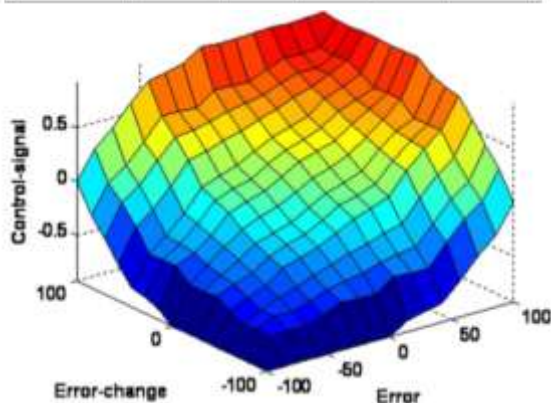| e' \ e	N-II	N-I	Z	P-I	P-II
N-II	N4	N4	N4	N3	Z
N-I	N4	N2	N1	Z	P3
Z	N4	N1	Z	P1	P4
P-I	N3	Z	P1	P2	P4
P-II	Z	P3	P4	P4	P4

Fig.5. Three-dimensional surface corresponding to the membership in Fig.4 and the rule in Table I.

IV. PROPOSED MPPT-BASED SEPIC CONVERTER

The fuzzy controller is applied to the SEPIC converter to mimic the new reference signal coming from the MPPT. The new duty cycle $\delta_{(k)}$ of the SEPIC converter switch was adjusted either by adding or subtracting the previous duty cycle $\delta_{(k-1)}$ with duty cycle's perturbation step size. Equation (1) presents the relation between the present and previous duty cycles, i.e.,

$$\delta_{(k)} = \delta_{(k-1)} \pm \Delta\delta \qquad (1)$$

where $\Delta\delta$is the change in duty cycle, resulting from the change of reference signal. The MPPT control technique is used to gain a new reference voltage for the fuzzy controller witch changes the duty cycle of the PWM signal for the SEPIC converter. The typical solar panel converts about $30\% - 40\%$of the incident solar isolation into electric energy [6]. The MPPT technique is used to improve the efficiency of solar panel. According to the maximum power theorem, the power output of circuit is maximum when the venin impedance of the circuit matches with the load impedance. There are several techniques to track the MPPT, but this paper deals with the incremental conductance.

The incremental conductance method uses information of source voltage and current to find the desired operating point. From PV curve of PV module in Fig. 7, it is clear that slope is zero at maximum point [6] so the formulas are as follows

$$\left(\frac{dP}{dV}\right) mpp = \frac{d(VI)}{dV} \qquad (2)$$

$$0 = I + V\left(\frac{dI}{dV}\right) mpp \qquad (3)$$

$$\left(\frac{dI}{dV}\right) mpp = -\frac{I}{V} \qquad (4)$$

Equation (4) is the condition to achieve the maximum power point, when the variance of the output conductance is equal to the negative of the output conductance, the module will work at maximum power point. The flow chart of the incremental conductance is shown in Fig.6. In this flow chart ,V(k) is the new detection voltage and I(k) is the new detection current, V(k-1) and I(k-1) is previous detection values. When the new value is read in the program, it calculates the previous value compared with the new one, and then determine the voltage differentials is zero or not, according to voltage differentials is zero, the current difference can be determined zero or not. If both of them are zero, it shows that they have the same value of impedance and the value of duty ratio will remain the same as before. If the voltage differential is zero, but the current differential is not zero, it shows that the isolation has changed. When the difference of the current value is greater than zero, duty ratio will

increase, when the difference of the current value is less than zero, duty ratio will decrease. If the voltage differential is not zero determine it weather satisfy the eq.(4) or not, when eq.(4) is satisfied, the slope of power curve will be zero that means the system is operating at MPP, if the variance of conductance is greater than negative conductance value, it means the slope of power curve is positive and the duty ratio is to be increased, otherwise it should be decreased [7].

The motive is to automatically find the voltage V_{mpp} or current I_{mpp} at which a PV module should operate to obtain the maximum power output P_{mpp} under given temperature and irradiance.
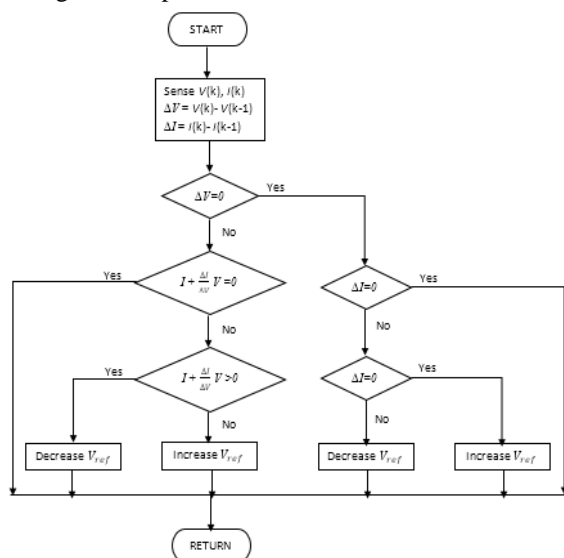

Fig.6. Flow chart of Incremental Conductance method

The MPPT converters were done using MATLAB/Simulink. Solar panel module given in the simulink is used in the second simulation. SimPower toolbox has been used to build the SEPIC circuit.
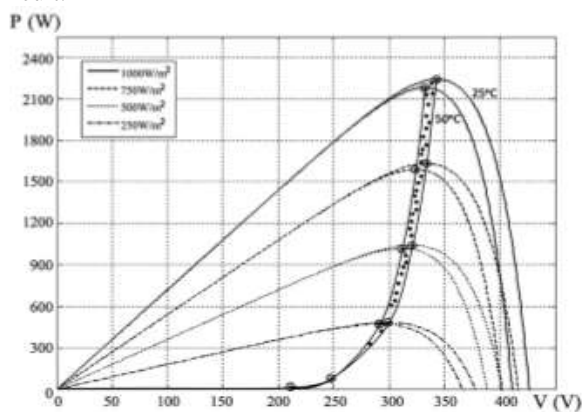

Fig. 7. Power-voltage (P-V) relation for the prescribed PV array.

V. SIMULATION RESULTS

The practical implementation of the proposed SEPIC fuzzy controller for the single phase inverter has been verified by applying the simulation on the MATLAB/Simulink. The output voltage and current signals of PV panel are shown in fig.8. and fig.9.respectively.Voltage of PV panel is 35V and current is around 9A.The output voltage and current signals of the proposed FLC based MPPT at constant load condition are shown in Fig.10.It is noticeable that the signals were not smooth; on the contrary, they carried a component of the maximum power between voltage and current. The voltage range changed from 250v to 350v.
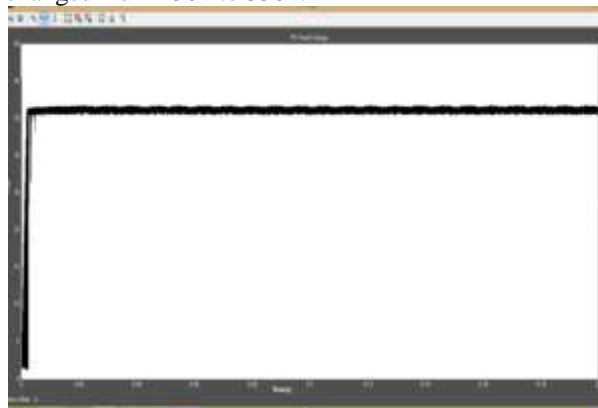

Fig.8. Output voltage signal of PV panel.

The controlled FLC PWM signal can achieve two advantages to the inverter; first ,it produce smooth error- free sine wave, and second, it achieves a smooth transition for the current signal and constant transition for the voltage signal.

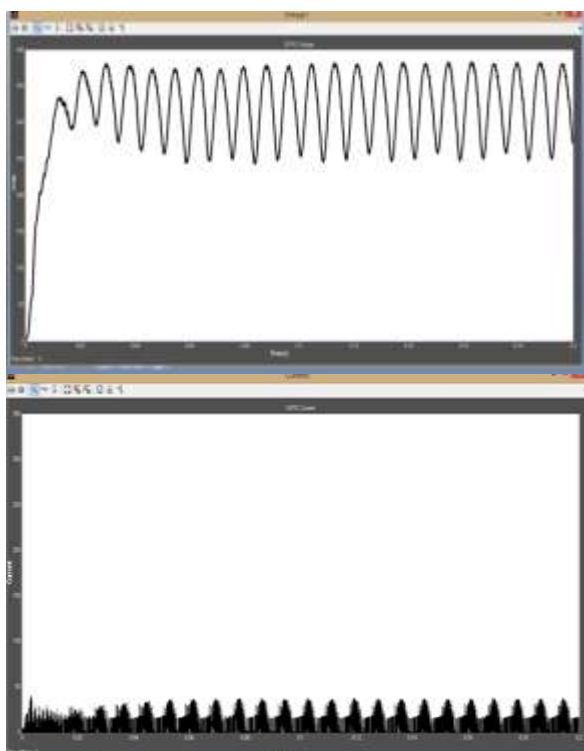Fig.9. Output current signal of PV panel

Fig.10. Output voltage (top) and current (bottom) waveforms of the SEPIC converter with the proposed FLC based MPPT scheme

In Fig.11.It is noticeable that PV panel power is getting at 330w and the maximum output power is around 3400w of the SEPIC converter under different irradiance condition and at a temperature 60ºC.In Fig.12. Shows the inverter's voltage and current signal.
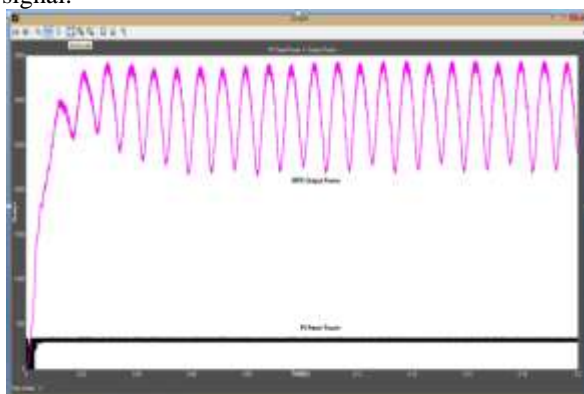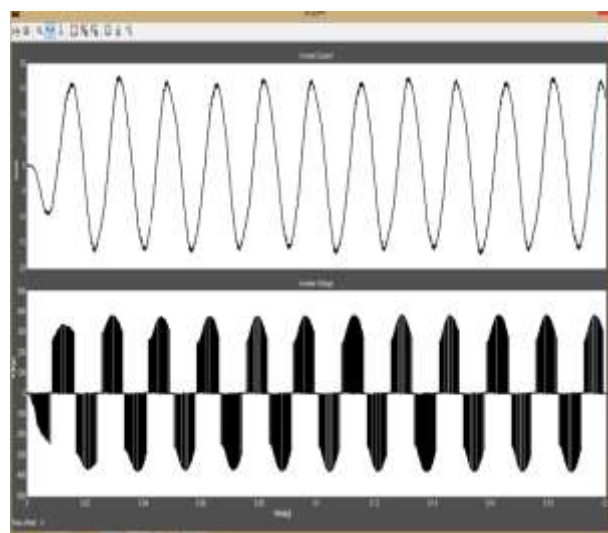

Fig.11. PV Panel power and Output power of SEPIC converter.

Time(s)

Fig.12. Inverter Current and Voltage for proposed FLC based SEPICconverter.

VI.   CONCLUSION

This paper has presented an FLC based MPPT scheme for SEPIC converter and inverter system for PV power application. A standalone solar PV energy generation system with SEPIC dc-dc converter has been designed and the performance analysis of the system has been presented under variation in solar radiation with the device current and voltage. It has been found that the performance of the proposed controller is better than that of the conventional based converters. It is highly possible to use the proposed FLC based MPPT scheme for the SEPIC converter for the implementation of the real time PV converter under variable load conditions.

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