Analysis of Sliding Mode Controller for PV Array Fed SEPIC Converter

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Abstract — **This work deals with the application of Maximum Power Point Tracking (MPPT) Algorithm like Sliding mode controller for photovoltaic (PV) applications using MATLAB/SIMULINK. These algorithms are applied to a Single Ended Primary Inductor Converter (SEPIC) using a mathematical model. The proposed methodology algorithm can be expanded to a various class of converters which is capable for photovoltaic applications. The SEPIC converter provides the close loop characteristics. The mentioned algorithms i.e. Sliding mode controller had been analysised for the proposed Single Ended Primary Inductor Converter.**

Index terms—**Photovoltaic (PV), Maximum power point tracking (MPPT), SEPIC converter, Sliding Mode Controller (SMC).**

I. INTRODUCTION

Now a day, Renewable energy resource are becoming popular as they provide major part energy to energy of less consuming building [1]. Between the all renewable energy resource, solar power systems plays a vital role since they gives better opening to generate power and continues to grow in popularity [2],[3].

Photovoltaic (PV) array has variety of applications such as the power house appliances, solar car, and aircrafts. The solar panel output power changes in fraction of seconds due to rapid climatic changes like weather condition rises or reduce in ambient temperature [4].

In the lower efficiency of solar module, various techniques are introduced, the recent idea known as "maximum power point tracking" (MPPT). The MPPT algorithms are used to improve the output power of the PV panel. In the development of solar panels, maximum power point tracking algorithm is the electronic method of electrical load to attain the highest obtainable power, during second to second changes in sun light, shadow, heat from the sun, and solar PV system features. The single ended primary inductor converter (SEPIC converter) is used. The converter is used to avoid the fluctuation that is obtained by the solar panel output. This converter is connected between the load and the PV panel [5],[6]. The controller is used to trace the peak power of PV panel and control action is taken in the PV systems thereby improving efficiency of the overall systems.

This paper proposes a control scheme, how sliding mode controller with MPPT algorithm are used to track peak power obtained from solar panel that can be used to operate the load using SEPIC converter.

II. PROPOSED METHODOLOGY

The proposed system block diagram is shown in fig.1. This strategy of power production contains of PV panel, SEPIC converter, sliding mode controller. The PV array converts the sun light into electrical power. The generated power is fed to the SEPIC converter and the activating pulse to the converter is given by MPPT algorithm. The MPPT algorithm will continue until maximum power obtained from PV panel. Hence the load is sustained to operate at peak power.

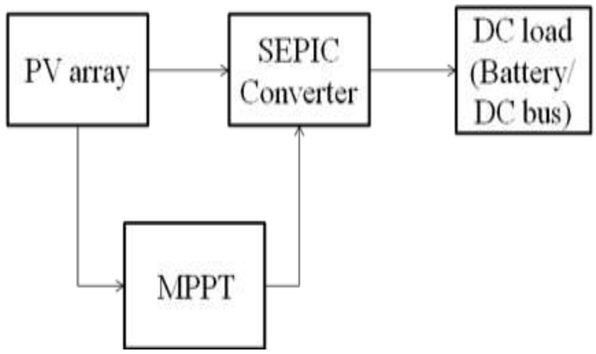

Fig. 1. Block diagram of the proposed methodology

III. PHOTOVOLTAIC MODEL

Photovoltaic array is designed in series/shunt combination of solar cells [7], the circuit representation is shown in fig.2.

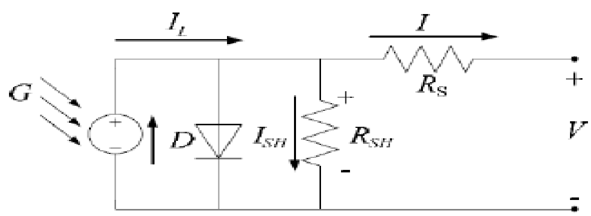

Fig. 2. Simplified circuit of PV panel

The current cell equation is given by,

$$I = I_L - I_D \quad (1)$$

The current diverted through diode is given by,

$$I_D = I_o\left[\exp\left(\frac{V + IR_s}{nkT/q}\right) - 1\right] \quad (2)$$

The current source that delivers short circuit current. The resistance is connected in series and parallel with the current source. The diode is connected parallel with the source that provides the p-n junction. That will provide either voltage or current. The current I_d is produced which is called diode current or dark current.

Where the symbol are given as follows,

I_o – Reverse saturation current, A

n – Diode ideality factor

T – Absolute temperature

e – Electron charge (1.602*10-19 C)

q – Elementary charge

k – Boltzmann constant (1.38*10-23 J/K)

I_D – Diode current, A

I_L – Photo generated current, A

R_s – Series resistance of cell

IV. PROPOSED CONVERTER

While choosing an MPPT algorithm, the important thing is to select and design a very good converter, which is operated as the major part of MPPT. The switching mode supply DC-DC converter efficiency is mostly used. The high efficiency is obtained by using switching mode power supply [8].

Among the entire converters available, single ended primary inductor converter (SEPIC) is a DC-DC converter which is most efficient and popularly used. It can be work in all modes such as continuous, discontinuous, or boundary condition mode. The duty cycle of the SEPIC converter is controlled by the control transistor [9]. SEPIC converter has low ripple and no pulsating. It improves the tracking efficiency of the solar PV array. SEPIC's are useful in battery voltage that can vary the regulator's calculated output. A SEPIC converter consists of a coupling capacitor, C_1 and output capacitor, C_2, coupled inductors L_1 and L_2 and diode as shown in fig. 3.

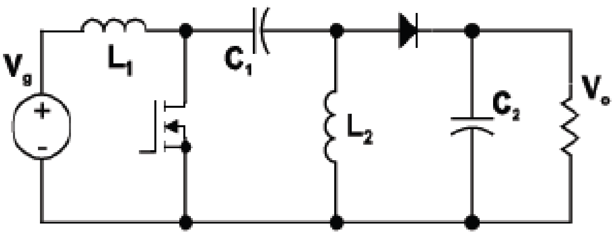

Fig. 3. SEPIC converter circuit diagram

Fig. 4 shows the converter when switch is on. The input voltage source is obtained by charging the inductor L_1 at this time. The energy is drawn from the inductor L_2 through the capacitor C_1, and the output capacitor is obtained by the load current. The load capacitor does not supply energy at that time. The polarity of the Inductor current and capacitor voltage are also decided.

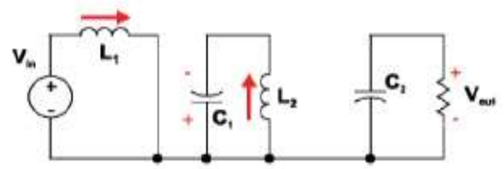

Fig. 4 SEPIC converter when switched ON

Fig. 5 shows the converter when the switch is off, the current given to load system is obtained by charging the capacitor C_l by inductor L_1. The load will be connected to the inductor L_2 at that time. This operation is done when the output capacitor will capture a current pulse, basically noisier than a buck converter. The SEPIC converter is most efficient and it will track maximum efficiency in solar array.

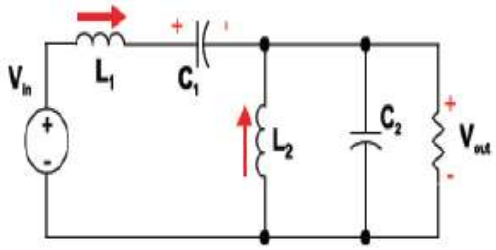

Fig. 5 SEPIC converter when switched OFF

The duty cycle is formulae by,

$$Dmin = \frac{Vout + Vd}{Vin(max) + Vout + Vd} \quad (3)$$

$$Dmax = \frac{Vout + Vd}{Vin(min) + Vout + Vd} \quad (4)$$

V. SLIDING MODE CONTROLLER

The sliding mode control is a non linear control method that has the dynamics of a non linear system that force the system to slide along a cross-section of system normal behavior. The motion of the system as it slides along the boundaries called sliding mode [10],[11]. The design of sliding mode depends on choice of surface, establishment of invariance condition, determination of control law. The advantages of sliding mode controller are fast dynamic, high stability, high tracking efficiency, simple implementation and low cost.

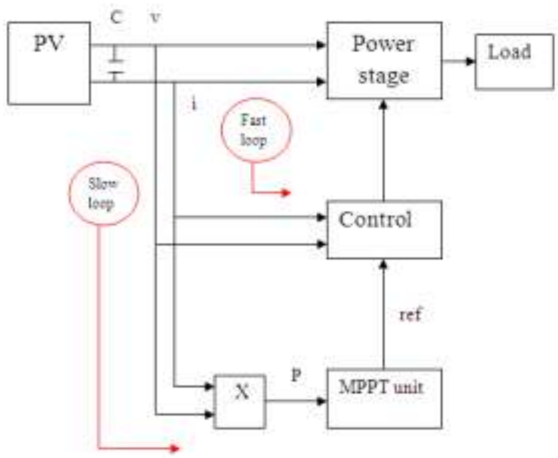

Fig. 6 MPPT with dual loop

Fig. 6 shows the dual loop concept with MPPT. The control is the SM controller that represents the actual value and the MPPT unit that represent the reference value. In fast loop, the voltage and current is given to the SM control then to the power stage. In slow loop, the voltage and current is given to the reference MPPT and then to SM controller to power stage. Then it is given to the load.

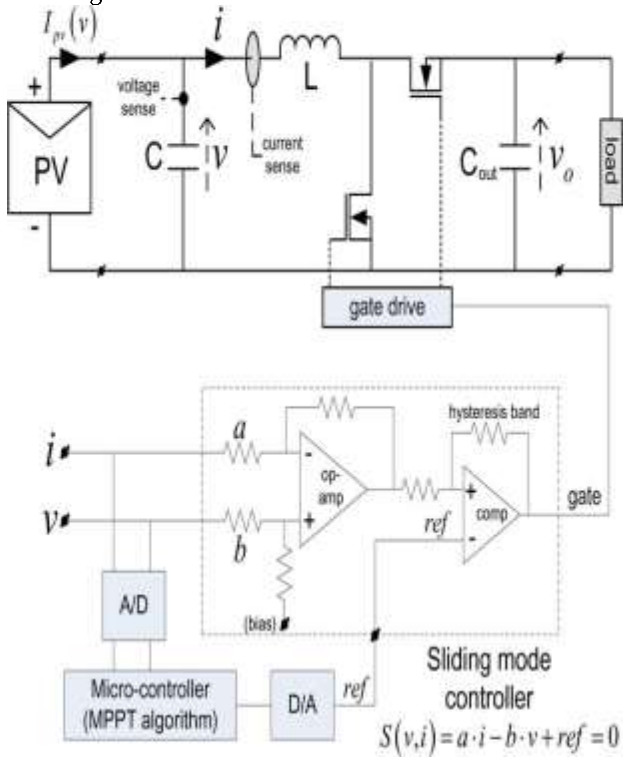

Fig. 7 MPPT implementation based sliding mode

Fig. 7 shows the MPPT implementation based sliding mode. The PV voltage and current is given to the operational amplifier, then given to the comparator. This is the sliding mode controller. Again the PV voltage and current is given to A/D converter. The converter will convert the analog into digital and given to MPPT algorithm. The MPPT algorithm is given to D/A converter. This end is given to the comparator. Now the comparator will compare the two signals and given to the gate drive of SEPIC converter[12].

VI. SIMULATION RESULT

The proposed system consists of the PV circuit model, SEPIC converter, MPPT algorithm and it is designed using MATLAB as shown in fig. 8. The PV panel output power is determined by the electrical circuit model of solar array. The PV array that provides voltage and current is given to the converter and controller simultaneously. The SEPIC converter will adjust the duty cycle directly. The simulink diagram is shown in fig.8

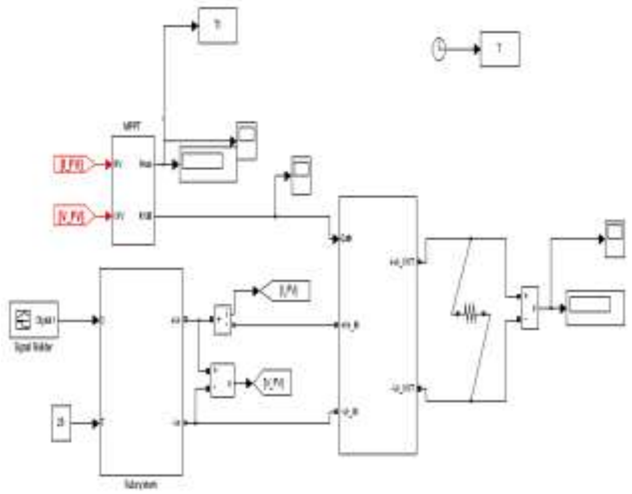

Fig. 8 Simulink daigram for the proposed system

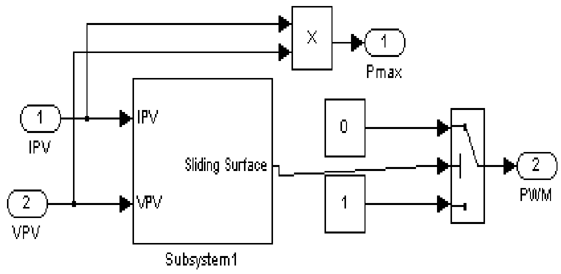

Fig. 9 Simulation for the SM Controller algorithm

The voltage and current from PV panel is given to the sliding surface. The product of voltage and currrent is obtained by maximum power. The output from the sliding surface is given to the gate drive of SEPIC converter.

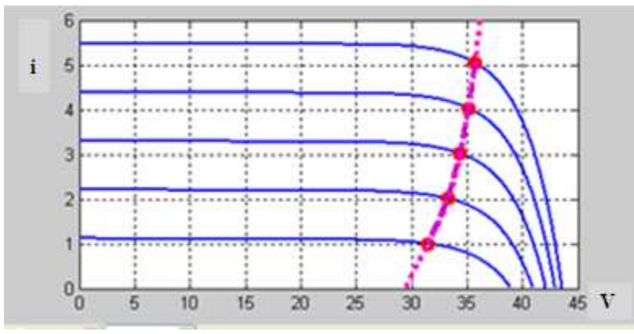

Fig.10 PV characteristics under different irradiation, and the optimal switching surface

The PV characteristics under different irradiation and the optimal switching surface graph are shown in fig 6.10. The maximum power point in the graph matches with cubic equation. This can be done by using MATLAB/SIMULINK. The equation is shown $Y=0.02499x^3-2.346x^2+73.82x-778.1$ By using this, the sliding surface is designed. The sliding surface block is shown in fig 6.11

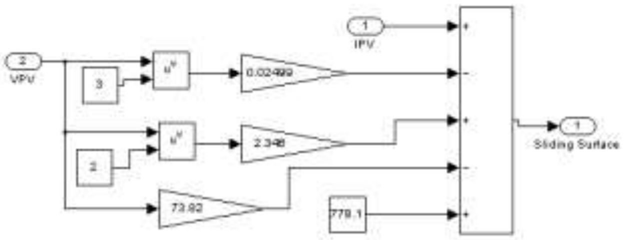

Fig.11 Simulink diagram for the Sliding surface

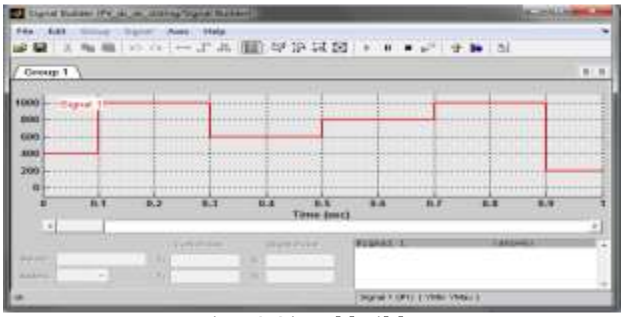

Fig. 12 Signal builder

The signal builder is designed by various irradiation level. The sliding mode will search for maximum power from PV panel. It will select maximum of five maximum point, then it will select the maximum power among the five maximum power. So that maximum power will allow to match the algebric equation i.e., linear equation, cbic equation. In this work it matches for cubic equation.

(i) MPPT output and output power for T=25°C and different irradiation level.

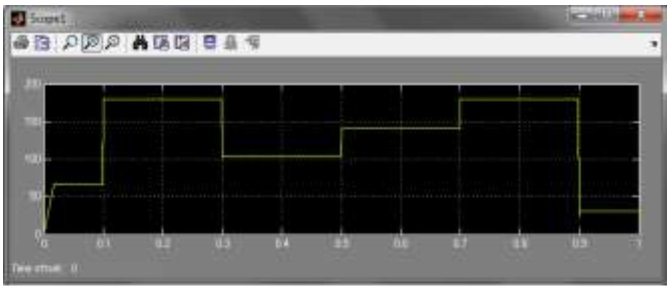

Fig. 13 MPPT output for T=25°C

The above figure shows the MPPT output. If the temperature is reduced means, power will start to increase. Here T=25º so power starts to increase. If the irradiation increase means, the output power will increase.

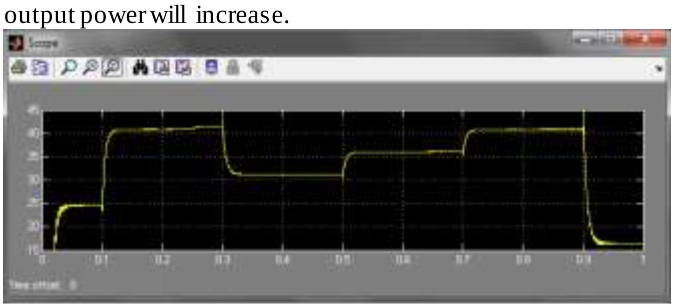

Fig. 14 Output power for T=25°C

(ii) MPPT output and output power for T=70°C and different irradiation level.

Fig. 15 MPPT output for T=70°C

The above figure shows the MPPT output. If the temperature is reduced means, power will start to increase. Here T=70º so power starts to decrease. If the irradiation increase means, the output power will increase. The output is taken for different temperature level.

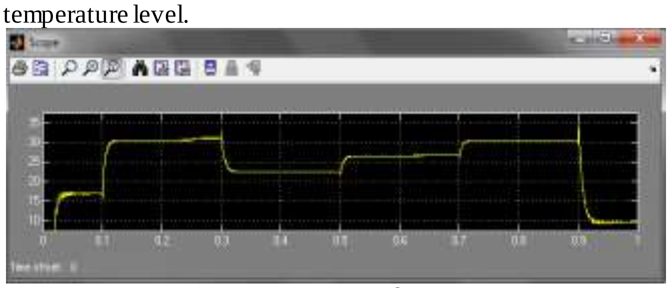

Fig. 16 Output power for T=70°C

VII. CONCLUSION

This project presented the application of Maximum Power Point Tracking (MPPT) like Sliding Mode Controller Algorithms for photovoltaic (PV) applications using MATLAB/SIMLINK. The SM Control algorithm is applied to a Single Ended Primary Inductor Converter (SEPIC) using a mathematical model. The Sliding Mode Controller algorithm was designed by various temperature and irradiation for the proposed Single Ended Primary Inductor Converter.

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