Section A-Research Paper
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Design of Energy-Efficient SM Controller for Photovoltaic System with DC-DC Converter

Dr. Dharmesh J. Pandya
Associate Professor, Department of Electrical Engineering, Atmiya University, Rajkot, Gujarat
Vijaykumar S Biradar
Assistant Professor & HOD, Department of Electrical Engineering, N B NavaleSinhgad College of Engineering, Solapur, Maharashtra
ArpitVarshnry
IILM University, Greater Noida, India
Dr. K. Manimekalai
Assistant Professor, Department of Physics, St. Joseph's Institute of Technology, Chennai, Tamilnadu, India
Mrs. B Neeraja
Lecturer, Department of Electrical and Electronics Engineering, Government Polytechnic Hyderabad, Telangana
Dr. Subash Ranjan Kabat
Associate Professor, Department of Electrical Engineering, Radhakrishna Institute of Technology and Engineering, Bhubaneswar, Khordha

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Abstract

This paper discusses how to utilise MATLAB/SIMULINK to create a Sliding Mode Controller with a Maximum Power Point Tracking (MPPT) Algorithm for solar photovoltaic applications. The author has attempted to showcase a unique project or scheme to apply these strategies to a Single Ended Primary Inductor Converter, a mathematical model is utilised (SEPIC). The method algorithm shown here may be expanded to a wide range of solar converters. The SEPIC converter provides the close loop features. For the proposed Single Ended Primary Inductor Converter, the aforementioned algorithms, namely the sliding mode controller, were examined.

Index Terms--- *solar cell,UPS, maximum point tracking, Sliding Mode Controller, SEPIC Converter*

Introduction

Renewable energy resources are becoming increasingly popular since they provide a major share of energy to structures that use less energy [1]. Solar power systems are becoming more popular among all-renewable energy resources since they give a larger potential to generate electricity [2],[3].

Photovoltaic (PV) arrays are used to power a variety of devices, including household appliances, solar automobiles, and aeroplanes. Because of rapid environmental changes such as increasing or lowering ambient temperature, the output power of a solar panel swings in fractions of seconds [4]. Various ways are being used to improve the efficiency of solar modules, including the most recent concept known as "maximum power point tracking" (MPPT). The MPPT algorithms are used to boost the PV panel's power production.

Maximum power point tracking algorithms are used in the construction of solar panels to collect the best possible power during second-to-second variations in sun light, shade, heat from the sun, and solar PV system attributes. The single ended primary inductor converter (SEPIC) is employed. The converter is used to eliminate the variation caused by the solar panels' output. This converter connects the load to the PV panel [5],[6]. The controller detects the peak power of the PV panel and performs control actions in PV systems, enhancing overall system efficiency.

This study provides a control strategy in which a sliding mode controller with MPPT algorithms is used to monitor peak power from a solar panel, which can then be utilised to power a load through a SEPIC converter.

PROPOSED METHODOLOGY

A PV panel, a SEPIC converter, and a sliding mode controller are used in this power generating method. The PV array converts solar energy into electrical energy. The generated power is transmitted to the SEPIC converter, and the MPPT algorithm supplies the converter with an activating pulse. The MPPT algorithm will operate until the PV panel's maximum power is achieved. As a consequence, the load remains at maximum power. The recommended system block diagram has been demonstrated in Figure 1.

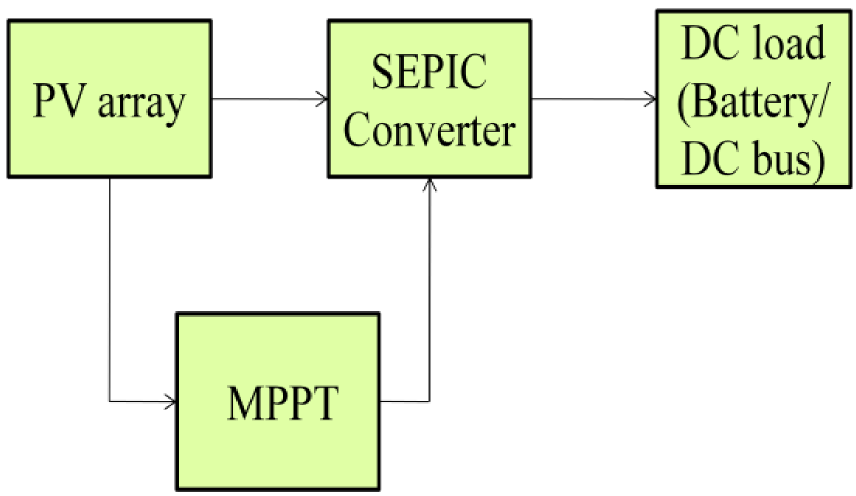


Fig. 1: BasicBlock Diagram of the Proposed Methodology

I. PHOTOVOLTAICMODEL

The photovoltaic array is built using a series/shunt combination of solar cells [7], and the circuit diagram has been formulated and demonstrated as shown in fig.2.

The current cell equation is been presented by,

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

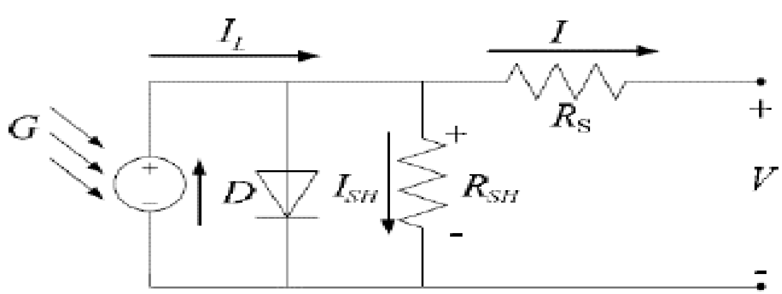


Fig. 2: Shortened Circuit of photovoltaic Panel The current is diverted through diode and is given by,

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

The source of current that provides short-circuit current. The resistance is linked to the current source in series and parallel. The diode is linked in parallel with the source, which creates the p-n junction. This will either produce voltage or current. The current Id is generated, which is known as diode current or dark current.

Where the symbol is 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

Proposed Novel Converter

The main element of MPPT, the converter, must be chosen and created with great care when choosing an MPPT algorithm. The most popular type of DC-DC converter is one with a switching mode supply. High efficiency is attained by using a switching mode power supply [8].The most effective and popular DC-DC converter available is the single ended primary inductor converter (SEPIC). It can function in all modes, including boundary condition, discontinuous, and continuous. The control modifies the SEPIC converter's duty cycle current. At that point, the load capacitor is not supplying energy. Inductor current and capacitor voltage polarity are also determined.

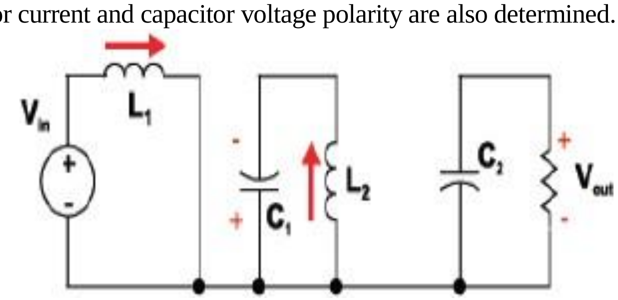
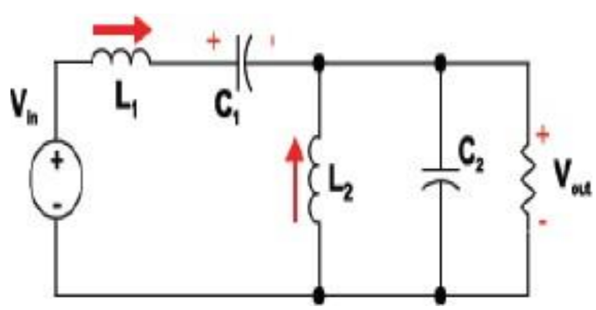


Fig. 4: SEPIC Converter when Switched ON

When the switch is depressed, the current supplied to the load system is measured by charging the capacitor Cl via inductor L1. The load will then be connected to the inductor L2. When the output capacitor captures a current pulse,



which is generally noisier than a buck converter, this action is performed. The SEPIC converter is the most efficient and will maximise solar array efficiency.

Fig. 5: SEPIC Converter when Switched OFF The duty cycle is formulae by,

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semiconductor [9]. There is no pulsing or significant ripple in the SEPIC converter. It increases the tracking effectiveness of the solar PV array. Variations in battery voltage that have an impact on the regulator's computed output can be mitigated by SEPICs. As shown in Fig. 1, a SEPIC converter consists of a diode, linked inductors L1 and L2, a coupling capacitor, C1, an output capacitor, C2, and a coupling capacitor.

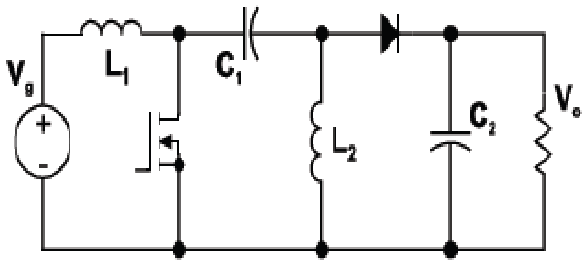


Fig. 3: SEPIC Converter Circuit Diagram

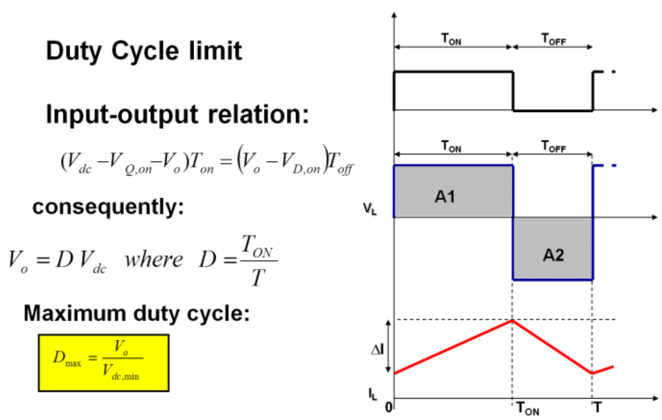


Figure 4 depicts the converter with the switch activated. The input voltage source is obtained at this point by charging the inductor L1. The energy is extracted from the inductor L2 via the capacitor C1, and the output capacitor is obtained by the load.

SLIDING MODECONTROLLER

The system is forced to slide along a cross-section of its typical behaviour via the sliding mode control, a nonlinear control technique with nonlinear system dynamics. Sliding mode refers to the system's motion as it slides along the limits. [10]-[11]. The surface selected, the invariance requirement created, and the control rule defined all influence the design of a sliding mode. The benefits of a sliding mode controller are quick dynamic response, high stability, high tracking efficiency, ease of installation, and cheap cost.

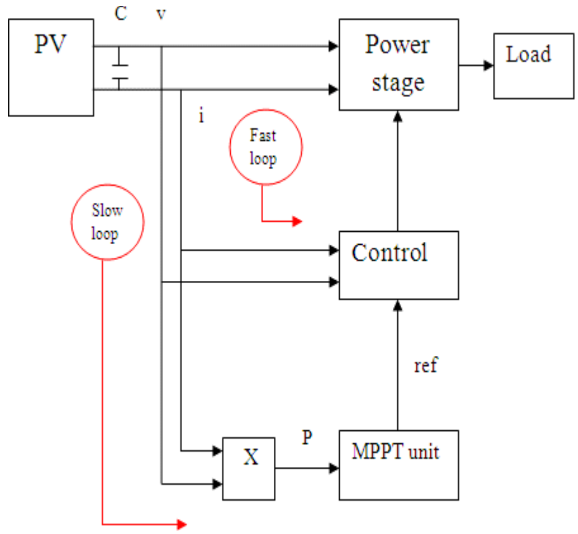


Fig. 6: MPPT with Dual Loop

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. The voltage and current are supplied to the SM control and then to the power stage in the fast loop. In slow loop, the voltage and current are given to the reference MPPT and then to SM controller to power stage. Then it is given to the load.

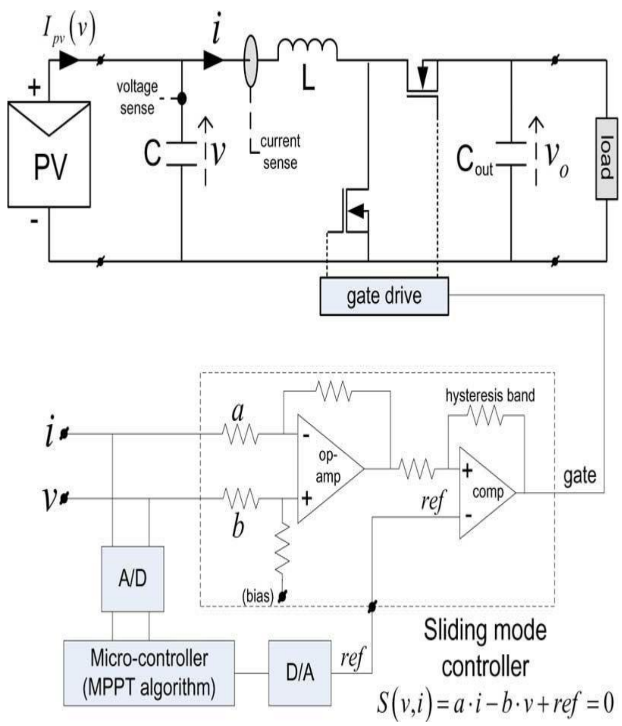
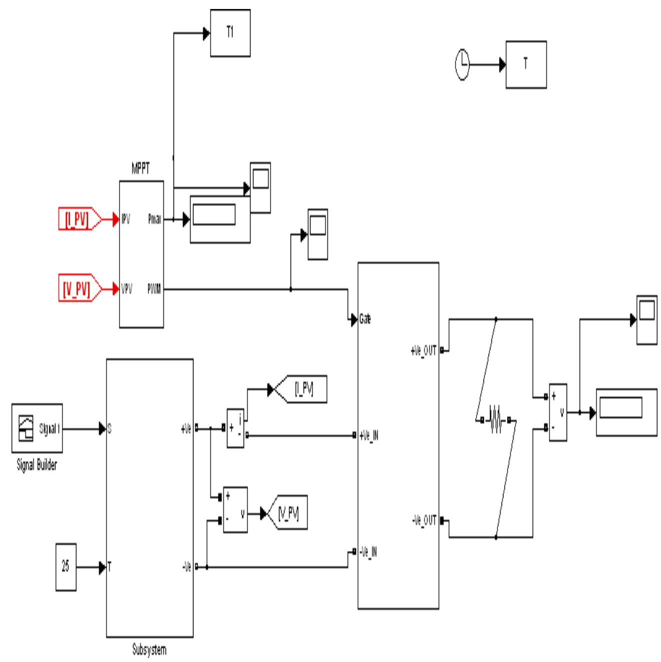


Fig. 7: MPPT Implementation Based Sliding Mode

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].

1. SIMULATION RESULT

The suggested system was created using MATLAB and can be shown in Figure 8 together with the PV circuit model, SEPIC converter, and MPPT algorithm. The electrical circuit model of the solar array determines the output power of the PV panels. The converter and controller receive voltage and current from the PV array at the same time. Direct duty cycle adjustment will be made using the SEPIC converter. Figure 8 displays the Simulink diagram. The MPPT algorithm contains the sliding surface[13]-[15].



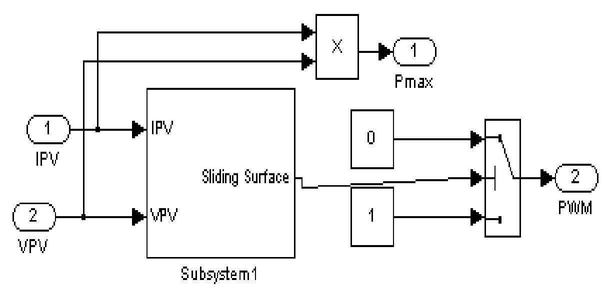


Fig. 8: Simulink Diagram for the Proposed System

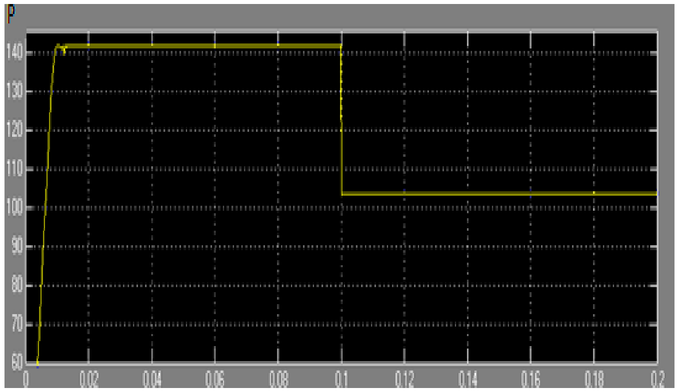
Fig. 9: Simulation for the Sliding Surface

The voltage and current from PV panel is given to the sliding surface. Maximum power is used to calculate the product of voltage and current. The output from the sliding surface is given to the gate drive of SEPICconverter.

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, cubic equation. In this work it matches for cubicequation.

(i) Maximum power point output Power for T=24°C and S=700 to 500w/m^2

Fig. 10: MPPT Output for T=25°C



The MPPT output is seen in the above graphic. Power will begin to grow as the temperature rises. Power begins to rise where T=25°. If there is an increase in radiation, the output power will rise.

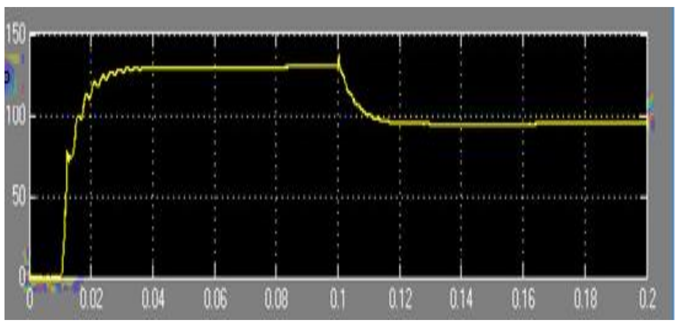


Fig. 11: Output Power for T=25°C

(ii) (i) Maximum power point output Power for T=50°C and S=700 to 500w/m^2

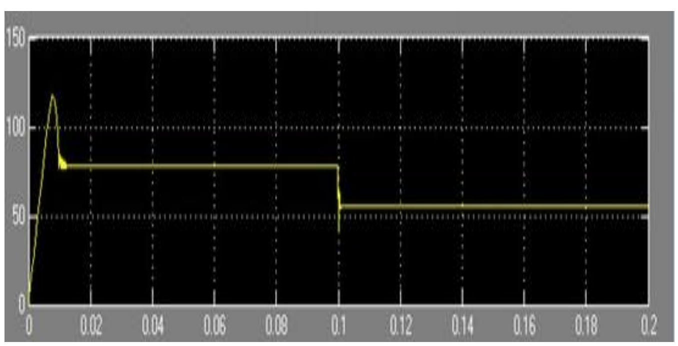


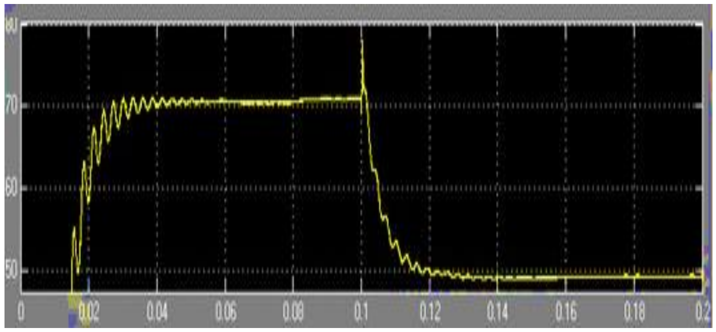
Fig. 12: MPPT Output for T=70°C

The MPPT output is seen in the above graphic. Power will begin to grow as the temperature rises. Power begins to decline when T reaches 70 degrees. The output power will grow if the irradiation increases. The output is measured at various temperatures.

Fig. 13: Output Power for T=70°C

The maximum power values at various irradiation (S) levels with a constant temperature of 25o are shown in Table 6.1. The power starts to rise as the irradiation rises. The amount of energy that the sun emits as electromagnetic radiation per square metre is known as solar irradiance. It measures how quickly solar energy hits the surface.

1: Different Irradiation (S) with constant Temperature at T = 25º



2: Different Temperature (T) with Irradiation at S=800 to 600 w/m^2

S.No	*Temp, T (ºC)*	*Maximum power, P_{max}(W)*
1	25	95
2	70	50
S.No	Irradiance, S (w/m2)	Maximum power, Pmax(W)
1	800-600	95
2	800-400	65
3	600-200	40
4	400-800	130
5	400-600	95

The power begins to decrease as the temperature rises. This is due to the fact that a semiconductor's band gap shrinks as temperature rises, resulting in a drop in open circuit voltage (Voc) and a minor increase in short circuit current (ISC). hence, power is decreased.

CONCLUSION

This study demonstrated how to build several Sliding Mode Controller Algorithms for Photovoltaic (PV) applications that are similar to Maximum Power Point Tracking using MATLAB/ SIMLINK. A mathematical model is used to apply the SM Control strategy to a Single Ended Primary Inductor Converter. The proposed Single Ended Primary Inductor Converter's Sliding Mode Controller technique was developed using a variety of temperature and irradiation conditions. The experiment or investigation shall be very beneficial too all the student, research scholars to understand the in-depth concept and working model. Efficient DC-DC solar Photovoltaic based converter is the need of the hour and a small step towars sustainable development.

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