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Voltage Sensor Based MPPT for Photovoltaic Systems with SEPIC Converter

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***Abstract--*Voltage Sensor based Maximum Power Point Tracking technique is most important in photovoltaic cell to track the maximum power. It employs variable scaling factor for a single-ended primary inductance converter. In this method voltage divider circuit is used to sense the photovoltaic panel voltage. It improves both transient and steady state performance. For sudden change in atmospheric condition, this method leads to faster tracking. In this paper MATLAB/Simulink is used for tracing actual maximum power point of PV cell and SEPIC is used as a digital platform to implement the proposed algorithm for experimental validation. The proposed system is implemented and tested successfully on a PV panel and we got maximum power.**

***Index Terms*—maximum power point tracking (MPPT), photovoltaic(PV), single-ended primary-inductance converter (SEPIC), voltage divider, voltage sensor.**

I. Introduction

Solar power is fast growing and one of the most important renewable energy; this hugely increases global energy consumption rate in India. Photovoltaic (PV) system is belonging to research and technology related application of solar cells. The solar energy is the energy converting sun energy directly into electricity using solar cell. The many techniques are available for achieving the maximum power from solar PV system.

PHOTOVOLTAIC (PV) power generation is evolving as one of the most prominent renewable energy sources because of its merits such as ecofriendly nature, less maintenance, and no noise. The fundamental component of PV system is a PV cell. Series connection of PV cells forms modules, and series and parallel connection of modules forms arrays. The characteristics of a PV module will vary with solar insolation and atmospheric temperature. The efficiency of the PV system mainly depends on the operating point on the characteristic curve of the PV module. The point at which available maximum power can be extracted from the PV module is called maximum power point (MPP). So far, a large number of maximum power point tracking (MPPT) techniques have been developed to increase the efficiency of the PV system.

Thus, an MPPT method with only voltage sensing is more efficient in terms of reduced power loss and low cost. Voltage sensor- based MPPT technique with fixed step size has been developed and is validated for an interleaved dual boost converter. Later, an adaptive voltage-sensor-based MPPT with a constant start-up scaling factor has been developed by considering *dP/Dd*as an objective function, where *P* is the power of the PV module, and *D* is the duty cycle of the converter.

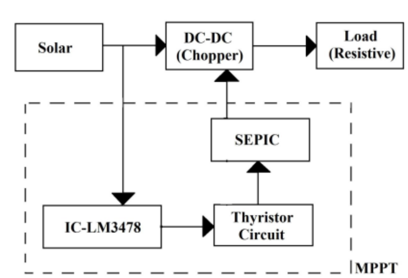

Fig. 01. Block diagram of MPPT

II. History

Paper 1: An Adaptive Voltage-Sensor-Based MPPT for Photovoltaic Systems with SEPIC Converter Including Steady-State and Drift Analysis

MPPT controller is essential to extract the maximum power from the PV module or array. If the load is directly connected to the PV module, then it is not possible to operate at peak power point due to impedance mismatch. A converter acts as an interface to operate at MPP by changing the duty cycle generated from the MPPT controller. In this paper, an adaptive voltage-sensor-based MPPT with variable scaling factor is proposed to reduce the tracking time and power loss in steady state. The two-level operation of the voltage-sensor-based MPPT algorithm reduces the voltage oscillations around the MPP, resulting in power loss reduction compared with three-level MPPT algorithms such as P&O and IncCond.

Paper 2: Designing A SEPIC Converter

It is the voltage regulator IC is used in Controlling of voltage of SEPIC (Single ended Primary Inductance Coil) Converter. We are calculating some parameters for the project. These are as follows.

1 Duty cycle calculation
2 Inductor selection
3 Power MOSFET selection
4 Output diode selection
5 SEPIC coupling capacitor selection
6 Output capacitor selection
7 Input capacitor selection

Paper 3: A Survey of Maximum PPT techniques of PV Systems

Tracking of the maximum power point (MPP) of a Photovoltaic (PV) array is usually an essential part of PV Systems. In general, PV generation systems have two major problems; the conversion efficiency of electric power generation is low (in general less than 17%, especially under low irradiation conditions), and the amount of electric power generated by solar arrays changes continuously with weather conditions. Moreover, the solar cell (current – voltage) characteristic is nonlinear and varies with irradiation and temperature. There is a unique point on the I-V or (power – voltage) curve of the solar array called MPP, at which the entire PV system (array, converter, etc…) operates with maximum efficiency and produces its maximum output power. The location of the MPP is not known, but can be located, either through calculation models, or by search algorithms. Therefore MPPT techniques are needed to maintain the PV array's operating point at its MPP.

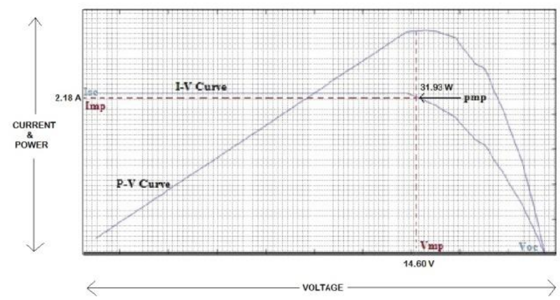

Fig. 02.Graph of Maximum Power Point Tracking

Paper 4:Modeling/Simulation of MPPT Techniques for Photovoltaic Systems Using MATLAB

The aim of this research work is to increase the power output and efficiency of the PV system. It is also needing of the constant voltage be supplied to the load irrespective of the variation in solar temperature and irradiance. Parallel and series combination of PV arrays are used to generate electricity depending upon the environmental effects (e.g temperature and solar irradiation)

It deals with simulation/modeling, controlling of maximum power point tracking (MPPT) used in PV systems to maximize the output power of photovoltaic system, irradiation conditions irrespective of the temperature of VI characteristics of load. In this research an important maximum power point tracking technique has been developed, consisting a boost converter, which is controlling pulse given by a microcontroller-based unit. The method used in the proposed PV system for tracking maximum power is perturb & observe algorithm which is directly used to take control action by duty cycle of converter for varying load voltage, thus the complexity of the PV system will be reduced. The result has high-efficiency, lower-cost and can be easily controlled and modified to handle more energy sources. MPPT is a fully electronic system. It varies the electrical operating point of the modules so that they are able to deliver maximum available power

Paper 5: Design of a Sliding-Mode-Controlled SEPIC for PV MPPT Applications

The performances of any photovoltaic (PV) system greatly depend on the maximum power point tracking (MPPT) efficiency. The MPPT control function allows us to extract the maximum available PV power in any operating condition. The low complexity and implementation cost make the perturb and observe (P&O) MPPT technique more widely used in commercial products. The design and implementation of the control algorithm proposed in refer to a boost dc/dc converter, but many PV applications require different topologies. Indeed, step-up/step-down topologies are much more suitable in distributed MPPT (DMPPT) architectures, to the aim of compensating the mismatching effects and in stand-alone applications, in order to match different batteries with a wide range of PV modules. The design methodology presented in this paper is applied to a single-ended primary inductor converter (SEPIC), but its extension to other fourth-order converters.

III. Methodology

A) PV & IV Curve

Definition of MPPT:

There is a point on the knee of the IV Curve where the maximum power output is located & this point is called (MPP). The voltage and current at this maximum power point are designated as Vmp and Imp.

The IV curve is also used to compare the performance of PV/Solar modules. The curve is therefore generated based on the performance under standard test conditions (STC) of sunlight.

IV Curve

Solar cell IV characteristics curves are basically a graphical representation of the operation of a power of solar cell or module summarizing the relationship between the current and voltage at the exciting condition of irradiance and temperature. IV curve provides the information required to configure a solar system so that it can operate as close its optimal peak power point (MPP) as possible.

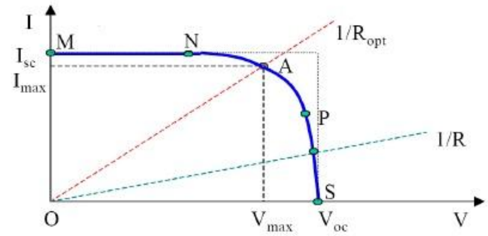

Fig. 03. IV Curve

The above graph shows the current and voltage characteristics of a typical silicon PV cell operating under normal condition. The power delivered by a solar cell is the product of voltage and current. If the multiplication is done, point for point, for all voltage form short circuit to open circuit condition. The power curve above is obtained for a given radiation level.

- Voc :- This is the maximum voltage that the array provides when the terminals are not connected to any load. This value is much higher than Vmp which relates to the operation of the PV array which is fixed by the load. This value is depends upon the number of PV panels connected together in series.
- Isc:- The maximum current provided by PV array when the output connections are shorted together. This value is much higher than Imp which relates to the normal operating current condition.
- MPP:- This relates to point where the power supplied by the array that is connection to the load(battery and inverter) is at its maximum Value, where MPP=Imp*Vmp
- Percentage Efficiency: - The efficiency of a photovoltaic array is the relation between the maximum electrical powers that the array can produce compare to the amount of solar irradiance hitting the array.

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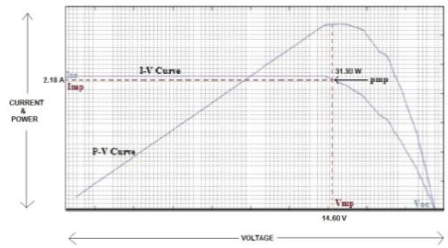

Fig. 04.PV and IV curve

B) SEPIC Converter

The single ended primary inductor converter (SEPIC) is a type of DC/DC converter that allows the electrical potential (voltage) at its output to be greater than, less than or equal to that at its input. The output of SEPIC is controlled by the pulse width of MOSFET.

A SEPIC is essentially a boost converter followed by Buck-Boost converter, therefore it is similar to a traditional buck boost converter, but has advantages of having non inverted output, using a series capacitor to couple energy from the input to the output, and being capable of true shutdown. When the switch is turn off, its output drops to 0V.

SEPIC's are useful in application in which a battery voltage can be above and below that of the regulators intended output. The circuit diagram of SEPIC converter is shown below.

Sr. No.	Output Voltages of PV Model	Pulse Width
1.	11 V	51.3+3*3.51=60.75%
2.	12 V	51.3+2*3.51=58.32%
3.	13 V	51.3+1*3.51=54.81%
4.	14.60 V	51.3+0*3.51=51.3%

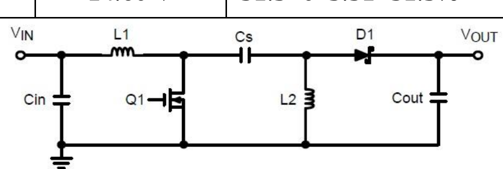

Fig. 05.SEPIC Converter

C) Simulation

Model and simulate dynamic system behavior with MATLAB, Simulink and Simcape. Modeling is a way to create a virtual representation of a real world that system includes software and hardware. Common representations for system modules include block diagrams schematic and statecharts.

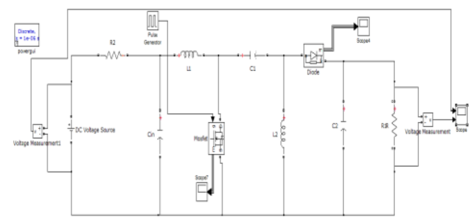

Fig. 06.Simulation of PV system

In this simulation PV panel is replaced by DC voltage source and load is connected as a resistive load. Our project aim is to getting output constant as 14.60V at normal and abnormal (Buck and Boost) condition. For voltage 14.60V pulse width of MOSFET is to be 51.3% standards. Whenever voltage is getting low or high then the pulse width of MOSFET will be change and achieved standard 14.60V at output side by using following formula:

Pulse Width = $K+V_d*C$

Where,

K= Standard pulse width for 14.60V=51.3%
V_d= Difference between standard and actual voltage
C = Standard pulse width for 1V=3.51%

- **Pulse Width for Boost**

Table No.01 Pulse Width for Boost

In this simulation standard output voltage is 14.60V. The output voltage is getting 14.60V for pulse width 51.3%. If the voltage is less than standard voltage 14.60V then the pulse width will be change respectively referring by above formula. The result for input voltage 12V, the output voltage will be same as standard voltage by triggering pulse width of 58.32% is shown in below graph.

Result of SEPIC converter

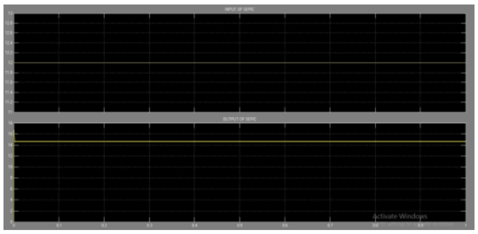

Fig. 07. Result for Boost

- **Pulse Width for Buck**

Table No.02Pulse Width for Buck

Sr. No.	Output Voltages of PV Model	Pulse Width
1.	15 V	51.3-0.2*3.51=50.59%
2.	16 V	51.3-1.2*3.51=47.08%
3.	17 V	51.3-2.2*3.51=43.57%

If the voltage is greater than standard voltage 14.60V then the pulse width will be change respectively referring by above formula. The result for input voltage 17V, the output voltage will be same as standard voltage by triggering pulse width of 43.57% is shown in below graph.

Result of SEPIC converter

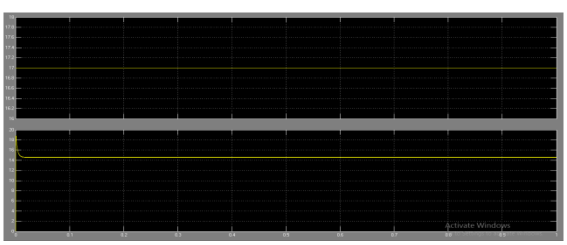

Fig. 08. Result for Buck

IV. Calculation

1. Duty cycle calculation

$$Dmax= \frac{Vout+VD}{Vin(min)+Vout+VD}$$

$$Dmin= \frac{Vout+VD}{Vin(max)+Vout+VD}$$

2. Inductor selection

$$L1=L2=L=\frac{vin(min)}{\Delta IL * fsw}*Dmax$$

3. Output Capacitor

$$C_{out}=\frac{Iout*Dmax}{Vout*Vripple*0.5*fsw}$$

V. Overall Circuit Diagram

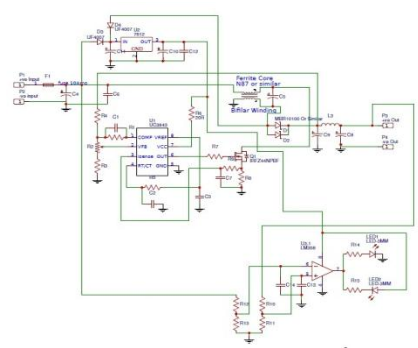

Fig. 09. Overall Circuit Diagram of MPPT

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VI. Final Results

Pulse width Waveform for Input Voltage:

1) 12.2 V

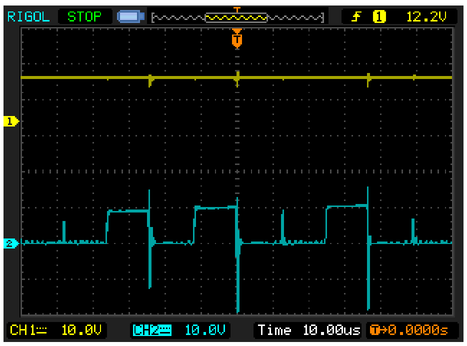

Fig. 10. Result for input 12.2V

2) 18.0 V

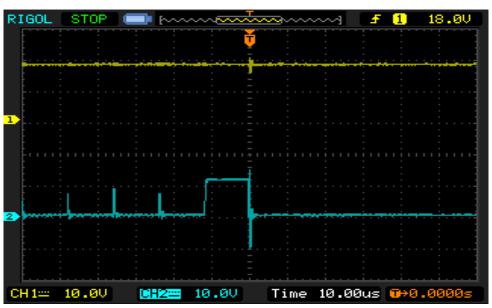

Fig. 16. Result for input 18.0V

Result for Input 14.6 V standard:

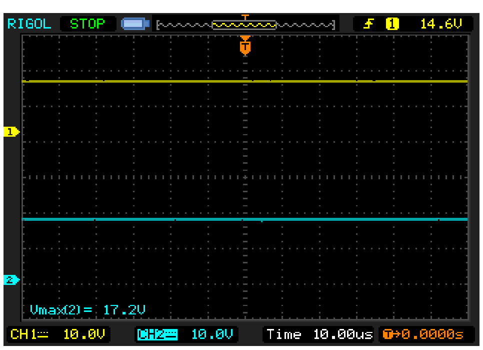

Fig. 17.Result for Input 14.6 V standard

VII. Conclusion

From this project we track the Maximum Power Point. From that point we find out the Vmp and Imp. Hence we can easily Buck or Boost the voltage by referring the Vmp. By using SEPIC converter load is directly connected to the PV module. It also increases the range of operation of PV voltage. Hence it reduces steady state oscillations.

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