

# Sustainable Energy Harvesting with the Help of Boost Converter by MPPT Technology

Shilpa C<sup>1</sup>, S. Zabiullah<sup>2</sup>

**Abstract:** In the present day fossil fuels continue to be depleted and climate changes, a problem grows severe day by day. A photo-voltaic (PV) power generation system which uses renewable resources has been extensively used in emergency and generating facility. So overcome these problems we are proposing a new concept called sustainable energy harvesting with the help of boost converter by maximum power point tracking (MPPT) Technology in an ac distribution System by the use of bidirectional inverter. The Bidirectional Inverter input is obtained from the solar power conventional boost converter that efficiently harvests maximum energy from the solar panel. By the use of coupled inductor and switched capacitor technologies to obtain maximum voltage gain, the leakage inductor energy from the coupled inductor can be recycled. The voltage stress on active switch is reduced, which means the coupled inductor employed in combination with the voltage multiplier technique successfully accomplishes the higher voltage gain. There are various MPPT techniques among the various techniques we are chosen IC (Incremental Conductance). This will help to improve the system efficiency by a low voltage rating and low conductance resistance. The duty ratio is modulated by the MPPT algorithm, designing and modeling of the proposed work is carried out and results are verified with the help of MATLAB/Simulink.

**Keywords:** Maximum voltage gain, photo-voltaic (PV) array, solar power optimizer (SPO), maximum power point tracking (MPPT), sinusoidal pulse generator (SPWM) bidirectional Inverter.

## 1. Introduction

One of the major concerns in the power sector is the day-to-day increasing power demand but the unavailability of enough to meet the power demand using conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with the conventional systems to meet the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard. Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar to electrical energy conversion can be done in two ways, namely solar thermal and solar photovoltaic. Solar thermal is similar to conventional AC electricity generation by steam turbine excepting that instead of fossil fuel.

The use of a micro inverter or ac module has recently been proposed for individual PV panels. Although this discrete PV power generation solution may partially eliminate the shadow problem, a micro inverter structure constrains the system energy's harvesting efficiency and entails high costs. A solar power optimizer (SPO) was developed as an alternative to maximize energy harvest from each individual PV module. An SPO is used as a dc-dc converter with maximum power point tracking (MPPT), which increases PV panel voltage to optimum voltage levels for a dc micro grid connection or through ac-ac inverter for electricity. Fig. 1 shows a single PV panel's energy, which passes through an SPO to a dc micro grid system.

A 400 V dc-micro grid system was proposed as an energy-efficient distribution option for data center systems and telecommunication facilities. The SPO attempts to improve the use of distributed renewable resources and lower system cost. It may also potentially improve the efficiency of PV systems, has shadow effect, and can monitor the status of PV modules. Moreover, the dc-grid voltage is regulated by bidirectional inverter and battery tank. In case of low-loading condition, the redundant energy will store into battery or through bidirectional inverter to ac grid. The

maximum power point (MPP) voltage range of a single PV panel ranges from 15 to 40 V and has a power capacity of about 100W to 300W.

An SPO has a high step-up converter that increases low-input voltage to a sufficient voltage level. Various step-up dc-dc converter topologies include a conventional boost and fly back converters, switched inductor converter, and switched capacitor converter, as well as a transformer less switched capacitor types, voltage-lift types, capacitor-diode voltage multipliers, and boost types that are integrated with coupled inductors. With increasing voltage gain, recycling the leakage inductance energy of a coupled inductor will reduce the voltage stress on the active switch, which enables the coupled inductor and voltage multiplier or voltage-lift technique to realize high-voltage gain.

## 2. Proposed System Model

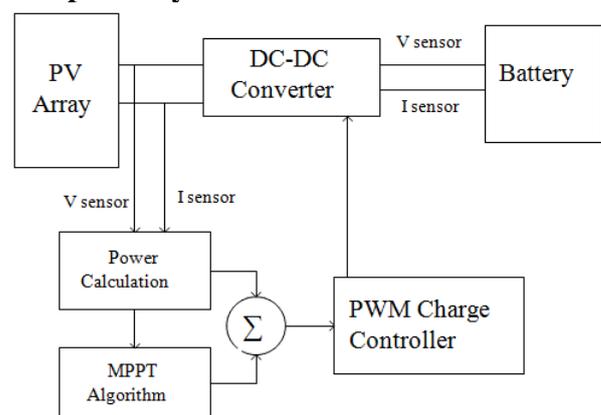
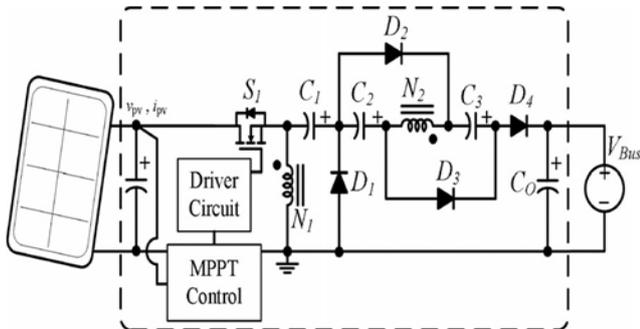


Figure 1: Block diagram of proposed Circuit

The block diagram of the proposed circuit consists of low level dc input supply from the PV array; the low level dc input is boosted by the DC-DC converter designed with coupled inductor and switched capacitor technologies to obtain maximum voltage gain. The high step up converter is controlled by using PWM controller which helps the

converter to operate in the continuous conduction mode. The leakage inductor energy is recycled to reduce the voltage stress on the active switch and also reduces the power losses. The MPPT is most responsible for extracting the maximum possible power from photovoltaic and feed it to a load via the boost converter which steps up the voltage required magnitude.



**Figure 2:** Configuration of the proposed system.

The boost converter includes a floating active switch S1 and a coupled inductor T1 with primary winding N1, which is similar to the input inductor of a conventional boost converter capacitor C1, and diode D1 recycle leakage inductance energy from N1. Secondary winding N2 is connected to another pair of capacitors C2, and C3, and to diodes D2 and D3. Rectifier diode D4 connects to output capacitor C0 and load R. The duty ratio is modulated by the MPPT algorithm, which uses the particle swarm optimization method that is employed in the proposed SPO. It detects PV module voltage Vpv and current Ipv to determine the increase and decrease in the duty cycle of the dc converter.

The efficiency of a solar cell is very low. In order to increase the efficiency, methods are to be undertaken to match the

source and load properly. One such method is the Maximum Power Point Tracking (MPPT). This is a technique used to obtain the maximum possible power from a varying source. In photovoltaic systems the I-V curve is non-linear, thereby making it difficult to be used to power a certain load. This is done by utilizing a boost converter whose duty cycle is varied by using a MPPT algorithm.

The proposed converter has the following features.

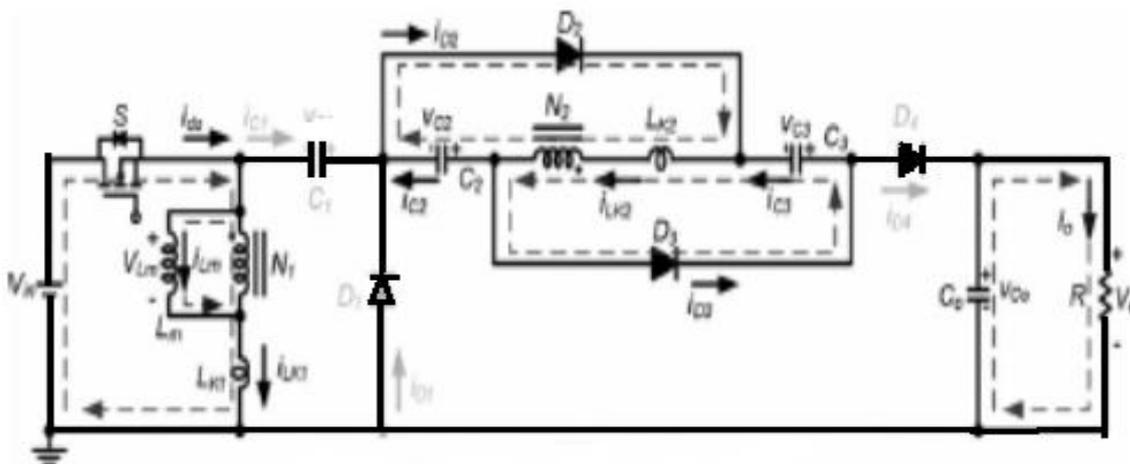
- It is a voltage conversion ratio efficiently increased by using the switched capacitor and coupled inductor technique.
- The leakage inductance energy of the coupled inductor can be recycled to increase efficiency, and the voltage spike on the active switch is restrained.
- The floating active switch isolates the PV panel's energy during non-operating conditions, thereby preventing any potential electric hazard to humans or facilities.

### 3. Circuit Operating Principles

The operating principles for Continuous Conduction Mode (CCM) are presented in detail. It illustrates a typical waveform of several major components in CCM operation during one switching period.

#### Continuous Conduction mode (CCM)

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**Figure 3:** Circuit diagram of the proposed SPO

Mode 1: S1, D2 and D3 are conducted; D1 and D4 are turned OFF. Lm continues to release energy to C2 and C3 through N2 of T1. Lk1 denotes the stored energy from source energy Vin. The energy stored in Co is constantly discharged to R.

$$v_{lm} = v_{in} \quad (1)$$

Mode 2: S1 and diode D4 are ON, Vin is serially connected to C1, C2, and C3, and N2; Lk2 discharges the energy stored in Co and R. Lm also receives energy from Vin.

$$v_{Lm} = (V_o - V_{in} - V_{C1} - V_{C2} - V_{C3}) / n \quad (2)$$

$$n = N_2 / N_1 \quad (3)$$

Mode 3: S1 and D2 and D3 are turned OFF, and D1 and D4 are conducted. The energy stored in Lk1 instantly flows through the D1 to charge C1. The energy is released to Lm through T1, which is serially connected to C1, C2, and C3, and N2; Lk2 discharges the energy that is stored in charge Co and R.

$$v_{lm} = -V_{in} \quad (4)$$

Mode 4: S1 and D4 are turned OFF, and D1, D2 and D3 are conducted. Lk1 continues to release energy to charge C1 through D1. Lm through T1 transfers energy to C2 and C3. The energy that is stored in capacitor Co is constantly discharged to load R.

$$v_{lm} = -V_{in} \quad (5)$$

Mode 5: D2 and D3 are conducted. Lm constantly transfers energy to N2, and charges C2 and C3. The energy stored in capacitor Co is constantly discharged to R.

$$v_{Lm} = (-V_{C2}) / n = (-V_{C3}) / n \quad (6)$$

#### 4. Design Considerations of the Proposed Converter

A 300 W SPO prototype is presented to verify the feasibility of the proposed converter. The basic specifications are shown in Table I. The considerations for component parameter design and selection are described as follows.

**Table 1: Specifications of the Prototype**

PV output power	300W
Input voltage, $V_{in}$	20-40V
Output voltage, $V_o$	400V
Switching frequency, $f_s$	50KHz

##### A. Duty Ratio and Turns Ratio

The largest voltage gain is 20 (Table I). The turns ratio can be set to 2–6. When  $n = 2$ , the duty ratio is equal to 77.2%. When the duty ratio is larger than 70%, conduction losses significantly increase. If turn ratio  $n \geq 5$  results in a small duty ratio and low magnetizing inductance, but a high peak current over the active switch occurs. Therefore,  $n = 4$  is the appropriate choice of duty ratio D is 62.5%.

$$V_o / V_{in} = (n \cdot D + n + 1) / (1 - D) \quad (7)$$

##### B. Magnetizing Inductor

Substituting the values of duty ratio, turns ratio, and operating frequency into (8) yields a boundary magnetizing

inductance of 20.86  $\mu$ H. However, the actual magnetizing inductance is 21.87  $\mu$ H and the leakage inductance is about 0.22  $\mu$ H.

$$T_{Lm} B = [D(D-1)^2] / [2(2n+1)(nD+n+1)] \quad (8)$$

Where  $T_{Lm} B$  is boundary magnetizing inductance time constant.

##### C. Active Switch and Diodes

The highest input voltage is 40 V and its corresponding duty ratio is 35.7%. The voltage stress of diodes D1 to D4 can be obtained by

$$V_{D1} = [1 / (1 - D)] \cdot V_{in} = [1 / (1 - 0.357)] \cdot 40 = 62.2V \quad (9)$$

$$V_{D2} = V_{D3} = [n / (1 - D)] \cdot V_{in} = 62.2 \cdot 4 = 248.8V \quad (10)$$

$$V_{D4} = [(n + 1) / (1 - D)] \cdot V_{in} = 62.2 \cdot 5 = 310V. \quad (11)$$

The voltage stresses of switch S is shown as follows:

$$V_{DS} = [1 / (1 - D)] \cdot V_{in} = 62.2V \quad (12)$$

The voltage rating of MOSFETs is higher than the calculated value. The nominal voltage of drain-source (S1) is 150V, Diode D1 has a voltage rating of 100 V. Diodes D2 and D3 the voltage rating is 300 V and 600 V of diode D4.

##### D. Switched Capacitors

The voltage ripple is set to 2% of the capacitor voltage. The voltage across capacitors C1 to Co can be obtained by

$$C1 = I_o T_s / \Delta V_{C1} = (0.75 \cdot 20 \times 10^{-6}) / [0.02 \cdot (0.625) / (1 - 0.625) \cdot 20] = 22.5 \mu F \quad (13)$$

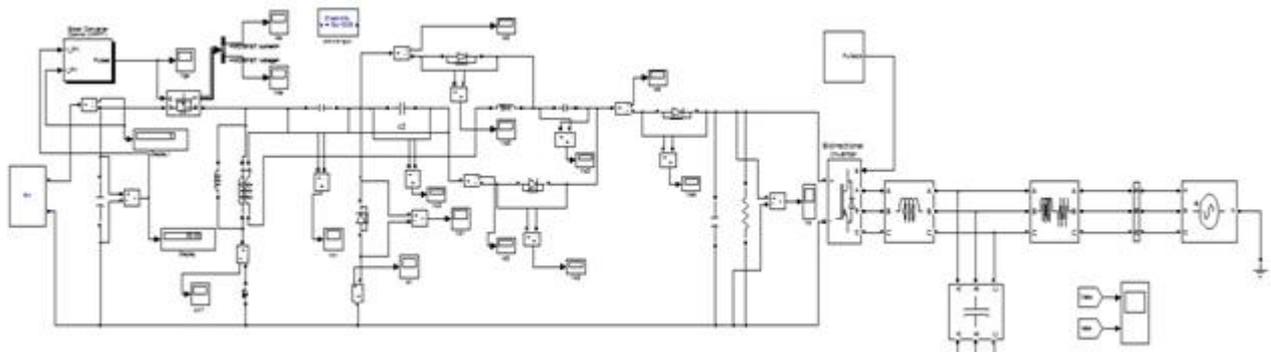
$$C2 = C3 = I_o T_s / \Delta V_{C2} = 4.5 \times 10^{-6} / 4 \sim = 5.6 \mu F \quad (14)$$

$$C_o = I_o D T_s / \Delta V_o = 0.75 \cdot 0.625 \cdot 20 \cdot 10^{-6} / 0.02 \cdot 400 \sim = 1.2 \mu F \quad (15)$$

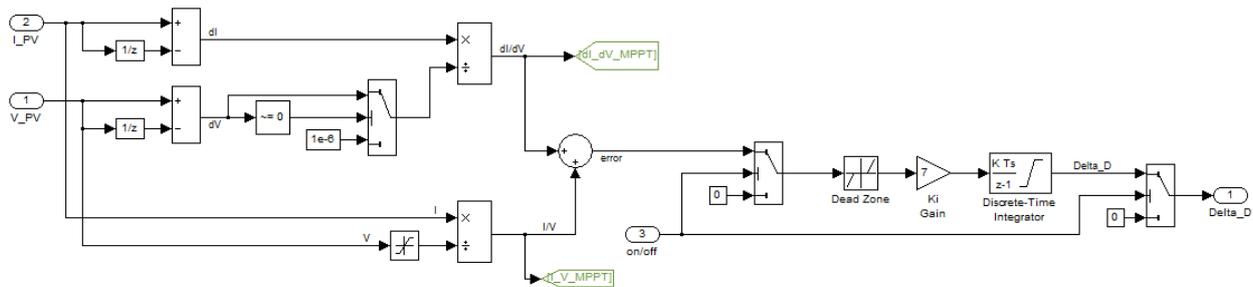
Because a high capacitance is linked to low ESR, the actual capacitance that is considerably larger than that calculated is selected; C1 is 68  $\mu$ F, C2 and C3 are both 220  $\mu$ F, and Co is 100  $\mu$ F.

#### 5. Simulation Circuit

The simulation of the proposed circuit is done using MATLAB software. The simulation circuit consists of two parts, one is proposed system and another is the maximum power point tracking (MPPT) control circuit. The simulated circuit of proposed system is shown as in Fig. 4.



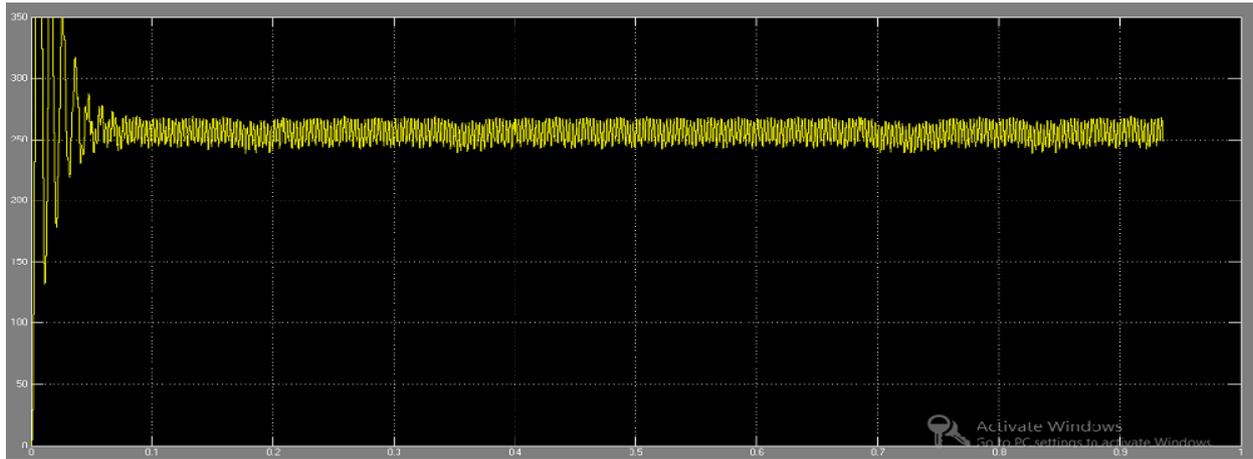
**Figure 4: Simulation Model of proposed system**



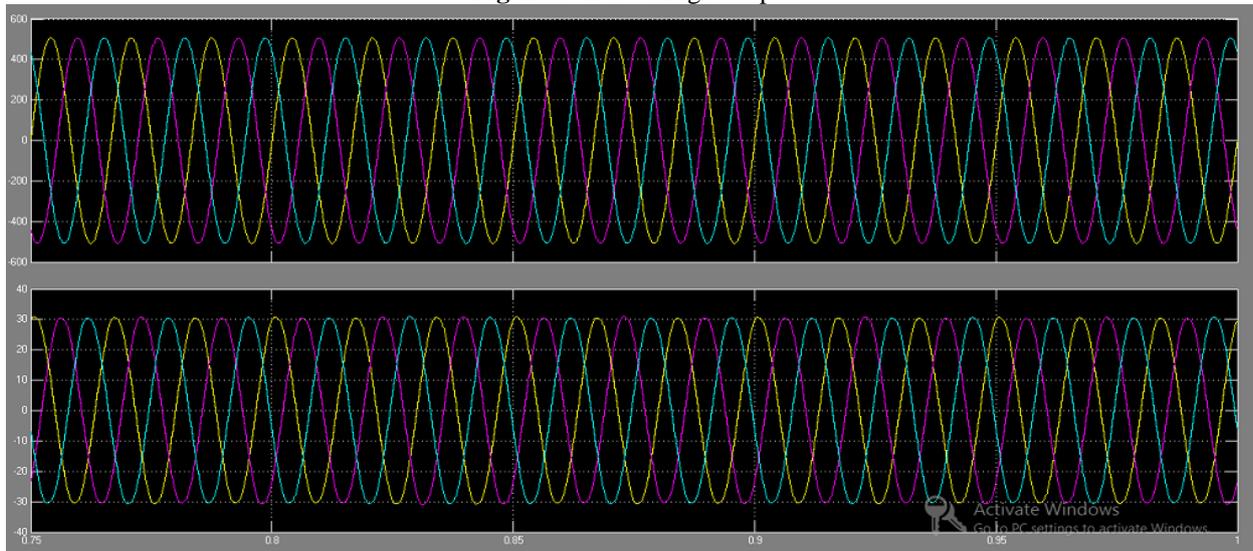
**Figure 5:** Simulation circuit of incremental conductance method of MPPT.

The simulation results of the proposed circuit as shown below

## 6. Simulation Results



**Figure 6:** DC Voltage Output



**Figure 7:** AC Output Voltage and AC Output current

## 7. Conclusion

The high step-up SPO uses the coupled inductor with an appropriate turns ratio design and switched-capacitor technology to achieve a high-voltage gain that is 20 times higher than the input voltage. Because the leakage inductance energy of a coupled inductor is recycled and the voltage stress across the active switch  $S_1$  is constrained, As a result, full load efficiency reaches 92.8%. The highest MPPT accuracy is 99.9% and a300 W SPO with a high step-up voltage gain and MPPT functions are implemented and verified.

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