A Non Isolated High step up DC to DC Converter with Continuous Input Current For PV System

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Abstract: In a Photovoltaic (PV) or fuel cell based grid connected power system, a high step up DC to DC is required to boost the low voltage of PV or fuel cell to a relatively high bus voltage for the downstream DC to AC grid connected inverter. To integrate the advantages of the high voltage gain of a Coupled Inductor based converter and excellent output regulation of a switching mode DC to DC converter. In recent years solar energy has become one of the most important and promising source of renewable energy, which demands additional transmission capacity and better means of maintaining system reliability.. Solar energy is gaining significant importance in meeting the challenges of the demand in the To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like solar. The need to integrate the renewable energy like solar energy into power system is to make it possible to minimize the environmental impact power sector due to its cleaner and easy setup. Due to different panel orientation and mismatching conditions solar panel may not work efficiently. Here a non isolated DC to DC converter with high voltage gain is presented. Three diodes, three capacitors, an inductor and a coupled inductor are employed in the presented converter. Since the inductor is connected to the input, the low input current ripple is achieved which is important for tracking maximum power point of Photovoltaic (PV) panels.

Keywords: Photovoltaic (PV) cell, Non isolated coupled inductor based converter, High voltage gain, Maximum power point tracking (MPPT).

I. INTRODUCTION

Switching power supplies provide higher efficiency than traditional linear power supplies. The DC to DC converters are widely used in regulated switch mode DC power supplies. Switch mode DC to DC converters is used to convert the unregulated DC input into a controlled regulated DC output with desired voltage level. Energy shortage and environmental, contamination in the present scenario has increased the use of renewable energy sources. In recent years solar energy has become one of the most important and promising source of renewable energy, which demands additional transmission capacity and better means of maintaining system reliability. Among the renewable energy sources the photovoltaic cells plays a important role in meeting the energy requirements. The problem associated with the PV cells which are produces low output voltage and the output power of solar panel depends on solar irradiance, temperature and the load impedance. Thus a high step-up DC to DC converter is provide to boost the low voltage of a PV to obtain high bus voltage for the downstream DC to AC grid connected inverter. Nowadays, renewable energy is increasingly valued and employed worldwide because of energy shortage and environmental contamination. Renewable energy systems generate low voltage output, and thus high step-up DC to DC converters have been widely employed in many renewable energy applications such as fuel cells, wind power generation, and photovoltaic (PV) systems. Such systems transform energy from renewable sources into electrical energy and convert low voltage into high voltage via a step-up converter, which can convert energy into electricity using a grid-by-grid inverter or DC micro grid. A typical renewable energy system as shown in figure below, that consists of renewable energy sources, a step-up converter, and an inverter for AC application.

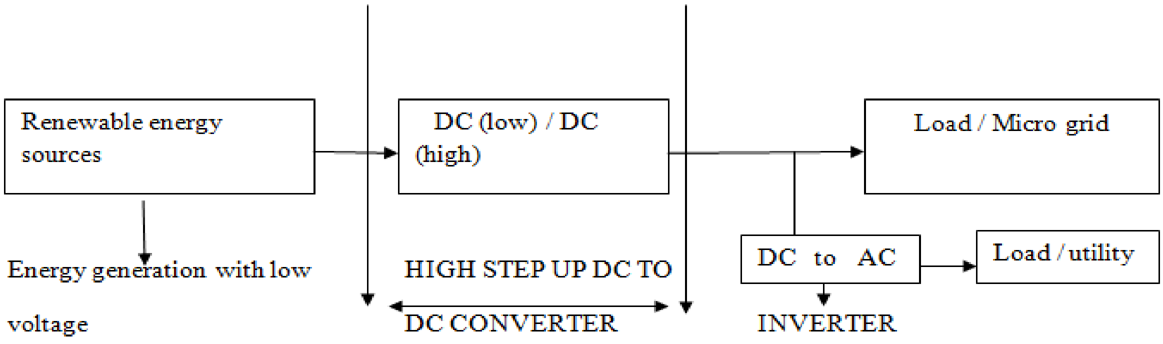

Fig.1.Typical renewable energy system

The output voltages of PV and fuel cells are generally ranged from 25 to 45 V, which are much lower than the bus voltage. Thus a DC to DC converter with high voltage gain is needed to boost the output of renewable energy systems. Among the non isolated DC to DC converters, the boost converter is usually used for voltage step-up.

There are several isolated DC/DC converter topologies proposed, by the increasing the turns ratio of the high frequency transformer which can provide high voltage gain. The phase-shift full bridge converter is by far one of the most popular ones, where it is possible to achieve zero voltage switching over a wide load range by using the high leakage inductance of the transformer. But it have significant drawbacks exist, such as high circulating current, the voltage stress across the output diode becomes much higher than the output voltage, and efficiency is reduced in applications where the output voltage is high. Besides, the pulsating input current is prohibitive in some applications, for example PV systems because it can reduce the useful life of arrays, as large electrolytic capacitors are necessary to reduce the appreciable input current ripple. Many converter structures with different novelties have been proposed recently with high voltage gain and improved conversion efficiency. There have been applied some techniques such as switched capacitors and voltage lift to obtain high voltage gain. Flowing high charging current through the main switch is the most important drawback of these converters which decreases the efficiency. Coupled inductor based converters can achieve high voltage gain by adjusting the turn ratios. However, the leakage inductor of the coupled inductor makes some problems like voltage spike on the main switch and high power dissipation. In order to solve these problems, the energy stored in the leakage inductor should be recovered. Therefore, a voltage clamp is necessary for these kind of converters. Many coupled inductor based converters with different voltage clamps have been proposed recently. High voltage gain, recovery of the leakage inductors energy, low voltage stress of the main switch and appropriate energy are the main feature of these converters. These converters have the main drawback of high input current ripple. In order to solve this problem coupled inductor based high step up DC to DC converter is presented.

II. COUPLED INDUCTOR BASED CONVERTER CONFIGURATIONS

A. Conventional two stage boost converter:

The conventional two stage boost converter as shown in fig.2. It consists of four capacitors, five diodes, and two inductor. The traditional 2-stage cascaded boost converter is not good at boosting the voltage in high duty ratio upper 0.7 because of the parasitic element in inductors. It has high voltage stress during conducting the switching device and high surge current caused by additional voltage doubling circuit. Also this converter takes disadvantage the bigger size of passive element including inductors and output capacitors. Due to the parasitic element of resistance, there is voltage drop and power loss.

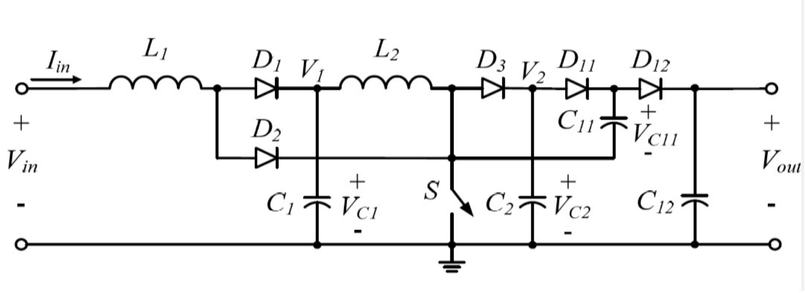

Fig. 2: conventional two stage boost Converter

B. Switched capacitor converter:

The circuit of switched capacitor converter as shown in fig.3. It have large number of switches. When switches Q1,Q2,Q4,Q5, . . . , Q3n2,Q3n1 conduct, and Q3, Q6, . . . , Q3n are turned off, the input voltage source charges the SCs C1, C2, . . . , Cn in parallel. When Q1,Q2,Q4,Q5, . . . , Q3n2,Q3n1 are turned off, and Q3,Q6, . . . , Q3n conduct, C1, C2, . . . , Cn and the voltage source are connected in series to supply the load. Therefore, the output voltage is (n + 1)Vg, where n is the number of the switched capacitors, and Vg is the input voltage. It can be seen that it is effective to increase the voltage gain by charging the switched capacitors in parallel and discharging in series. However, the output voltage of this step-up SC converter cannot be regulated, and it varies with the input voltage.

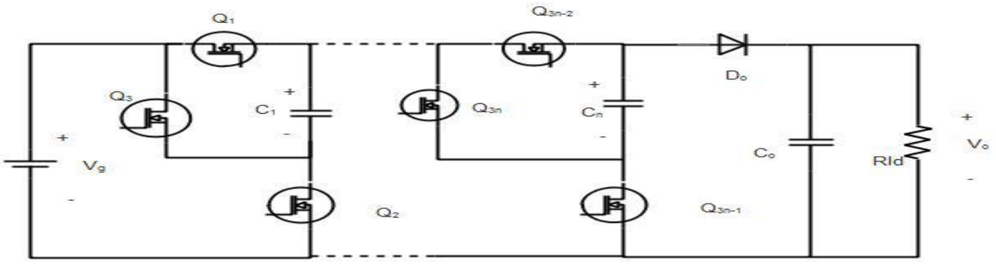

Fig. 3: Switched capacitor Converter

C. Coupled Inductor based Converter (Proposed converter):

A coupled inductor based high step-up DC-DC converter is proposed. Main specialty of this converter has a coupled inductor and also an inductor is connected in series across the input, therefore it have continuous input current and reduce the current ripple, then we get a regulated DC output voltage. It consists of three diodes, three capacitors, an inductor and a coupled inductor. As shown in this figure. 3.1, an inductor is connected in series to the input, the low current ripple is achieved which is important for tracking maximum power point of Photovoltaic (PV) panels. The voltage across the main switch S is clamped by diode D1 and capacitor C1. This causes a switch with low ON resistance RDS to be used in this converter to reduce the conduction loss. Moreover, the main switch is turned ON under zero current which reduce switching loss.

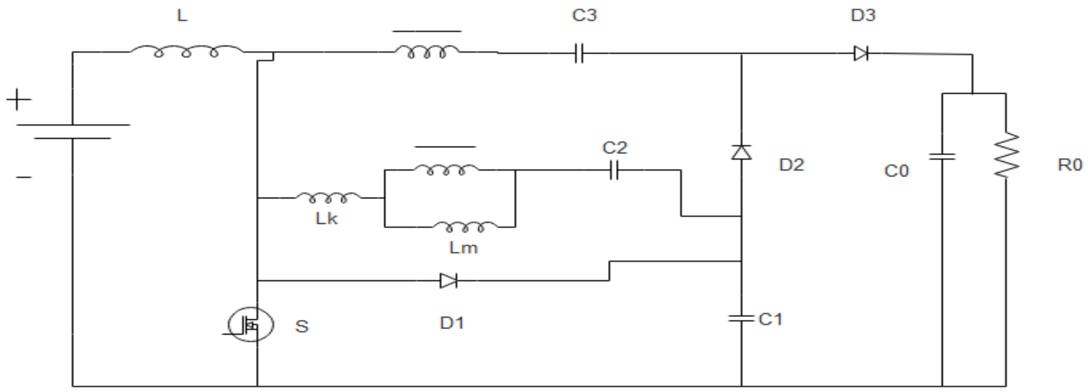

Fig. 2: Coupled inductro based converter

III. OPERATING PRINCIPLE

A. MODE 1 ($t_0 < t < t_1$)

In this time interval, the main switch is turned on. Diode D_3 is also on. The leakage inductor current I_{Lk} is increased to equal magnetizing inductor current I_{Lm}. This mode ends when the currents of leakage and magnetizing inductors of the coupled inductor are equal. Since the voltage across the leakage inductor is high and the value of leakage inductor is low, the time interval of first mode is too small. Inductor L is magnetized by the input power supply. At the end of this time interval, the current of the secondary side of the coupled inductor and as a result, the current of diode D_3 reaches zero.

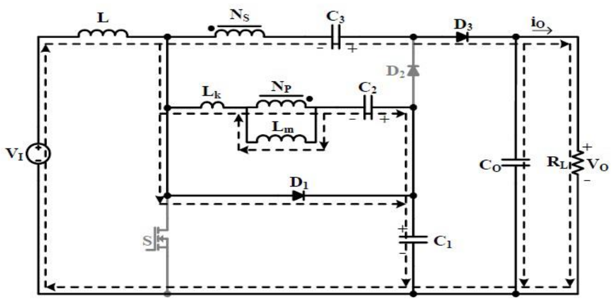

Fig. 3.1.MODE 1

B. MODE 2 ($t_1 < t < t_2$)

In this time interval, the switch is still on. The leakage inductor current ILk increases linearly and exceeds magnetizing inductor current ILm. The secondary side current of the coupled inductor flows through diode D2 and turns it ON. Thus, the current of diodeD2 increases linearly form zero. Capacitor C3 is charged by the secondary side current of the coupled inductor. The energy stored in capacitor C1 is discharged to the coupled inductor and capacitor C2. Inductor L is also magnetized by the input power supply. This mode ends when the switch turned OFF. In this mod, by applying Kirchhoff's Voltage Law (KVL) on the proposed converter, the following equation can be obtained as,

$V_L = V_1$

$V_{Lm} = V_{C2} - V_{C1} - V_{Lk2}$

$V_{C3} = (n + 1)V_{C1} - nV_{C2} - nV_{Lk2}$

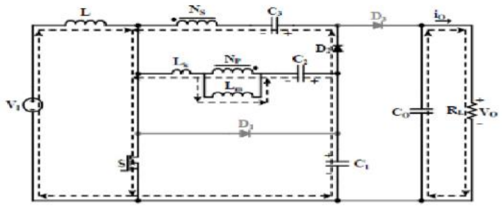

Fig. 3.2.MODE 2

C. *MODE 3 ($t_2 < t < t_3$)*

In this time interval, the switch is turned OFF. The inductor current IL flows through diode D1 and turns it on. The leakage inductor LK is demagnetized until its current equals the magnetizing inductor current ILm. At this moment the current of diode D2 becomes zero. The following equation can be written for the leakage inductor,

$I_{Lk} = V_{C3}/ n - V_{C2}$

According to this equation, a high negative voltage and low value of leakage inductor causes its current slope to be high. Thus, this time interval will also be small. Capacitor C1 is charged by the energy of input source and by demagnetizing inductor L. This mode ends when diode D2 is tuned OFF.

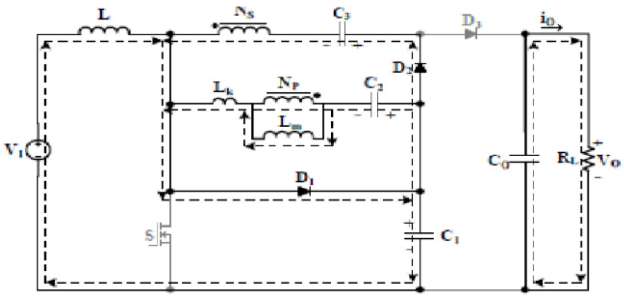

Fig.3.3.MODE 3

D. *MODE 4 ($t_3 < t < t_4$)*

In this time interval, capacitor C1 is charged by input source and the energy stored in inductor L. The output capacitor is charged by the secondary side current of the coupled inductor. This mode ends when the current of diode D1 reaches zero. Moreover, Since the slope of leakage inductor current is more than magnetizing inductor current, the current slop of diode D3 is positive. The following equations can be achieved in this mode as,

$V_L = V_1 + V_{C1}$

$V_{Lm} = -V_{C1} - V_{Lk4}$

$V_0 = V_{C1} + V_{C3} + nV_{C2} + nV_{Lk4}$

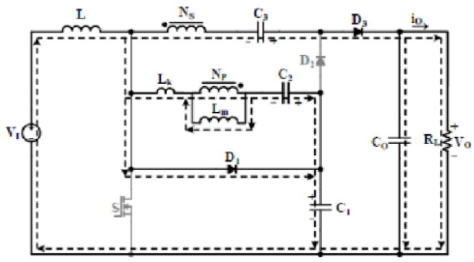

Fig.3.4.MODE 4

E. MODE 5 ($t_4 < t < t_5$)

In this time interval, diode D3 is still ON. The output capacitor is charged by the current of diode D3.

$I_{D3} = I_L + I_{Lm} / n + 1$
$I_{Lk} = I_L - I_{Lm} / n$

According to this equation, the current slop of diode D3 and the leakage inductor depends on the current slop of inductors L and Lm. neglecting the current ripples of inductors L and Lm yields the current slop of diode D3 and the leakage inductor to be zero. Thus, the voltage across the leakage inductor (VLk5) in this mode will be zero. According to this equation, when the switch is turned on at the beginning of first mode, its current is zero. Therefore, the switch is turned on under zero current. The following equations can be obtained by applying KVL on the proposed converter.

$V_{Lm} =(n / n + 1) VLk4 - VC2$
$V_L = -n\{(VLk4 - VLk5) / n + 1\} - V1 - VC1$

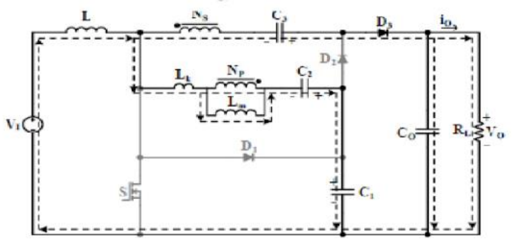

Fig.3.5.MODE 5

IV. WAVEFORMS OF THE CONVERTER AT CCM OPERATION

The converter operation under CCM consists of five time interval in one switching period. The waveforms of converter as shown in figure.4.

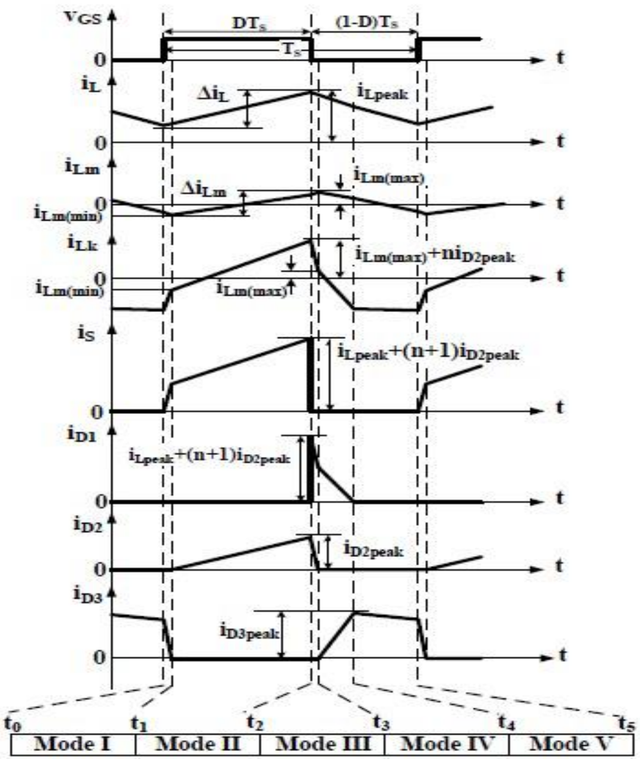

Fig. 4: Waveform of Converter at CCM

V. MAXIMUM POWER POINT TRACKING

The topic of solar energy utilization has been looked upon many researchers all around the globe. It has been known that solar cell operates at very low efficiency and thus a better control mechanism is required to increase the efficiency of the solar cell. In this field researchers have developed a technique to increase the efficiency of the PV system what are now called the Maximum Power Point Tracking (MPPT) algorithms. Many different techniques for maximum power point tracking of photovoltaic arrays. Here Hill climbing or Perturb and Observe algorithm is used. P&O is widely used MPPT technique, because it is intuitive and easy to implement. The P&O method measures the voltage and current from solar panel, and perturbs the operating voltage and compares the power received at old voltage with the power received at new voltage. Direction of new perturbation depends upon the value of measured power; perturbation will be in same direction, if higher power is measured at new voltage, otherwise it will go in the opposite direction. P&O MPPT employs fixed perturbation step size. Larger perturbation size increases the convergence speed, but operating point will oscillate around MPP and slightly reduces the efficiency. Smaller perturbation will reduce the oscillations around MPP, but it results in slower convergence to MPP. Hill climbing method is an alternate name for P&O MPPT technique. If change in Power is positive, it means that the operating point is moving towards MPP. Further voltage perturbations will be provided in the same direction as earlier in order to move operating point much closer to MPP. If change in Power is negative, it means that the operating point is moving away from MPP. Further voltage perturbations will be provided in reverse direction in order to move the operating point much closer to MPP. Fig.5 shows the flowchart of P&O algorithm.

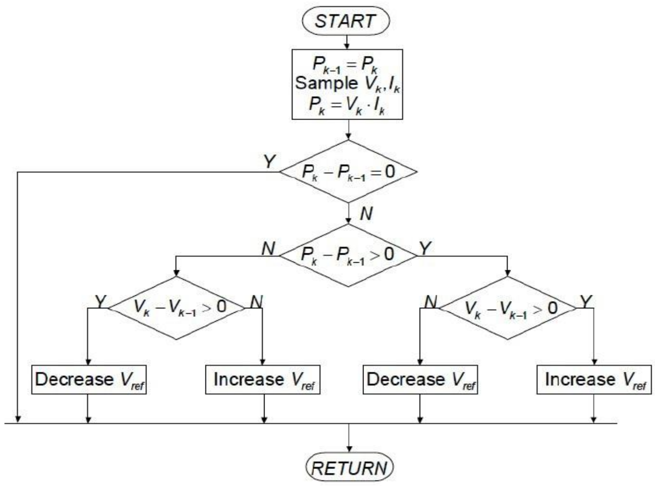

Fig.5.flow chart of P&O method

VI. SIMULATION AND RESULT

The simulation diagram of a non isolated DC to DC converter with DC supply and PV connected in input side as shown in figure below. The simulink model in open loop and closed loop of non isolated DC to DC converter is given below.

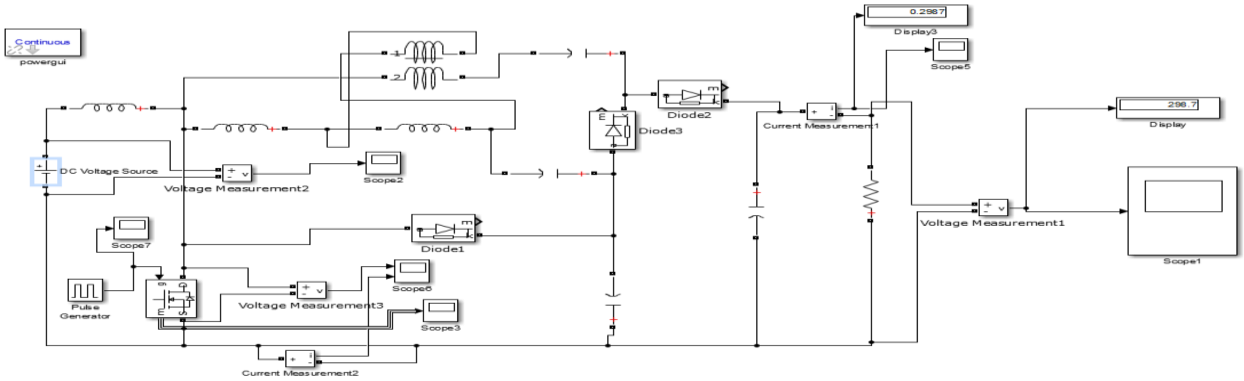

Fig.6.1.open loop of proposed converter

The closed loop of proposed converter which connected input as PV panel and the switch is controlled by MPPT algorithm and duty cycle.

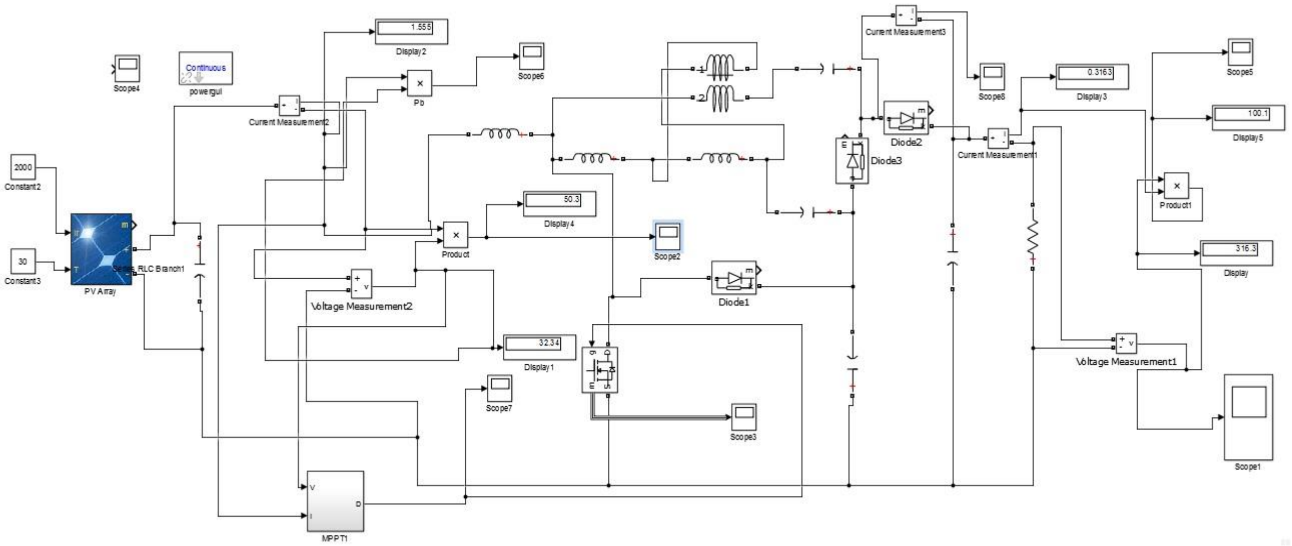

Fig.6.2.closed loop with PV connected of proposed converter

The result of closed loop observed that the converter produce output voltage 300.3 V, output current 0.29 A at a duty cycle 0.65. The input voltage and output voltage waveform as shown in figure below.

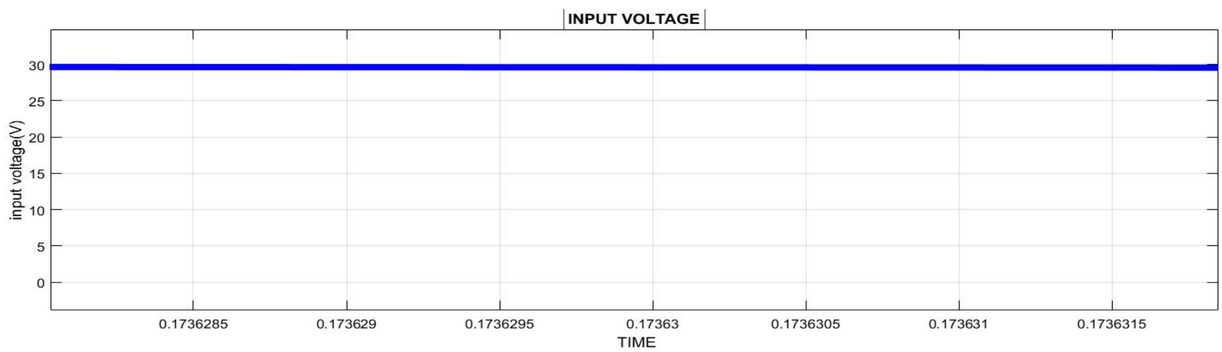

Fig.6.3.input voltage waveform

The simulation result of converter as continuous input current is obtained as shown in figure below. It is clearly observed that , converter has low ripple current.

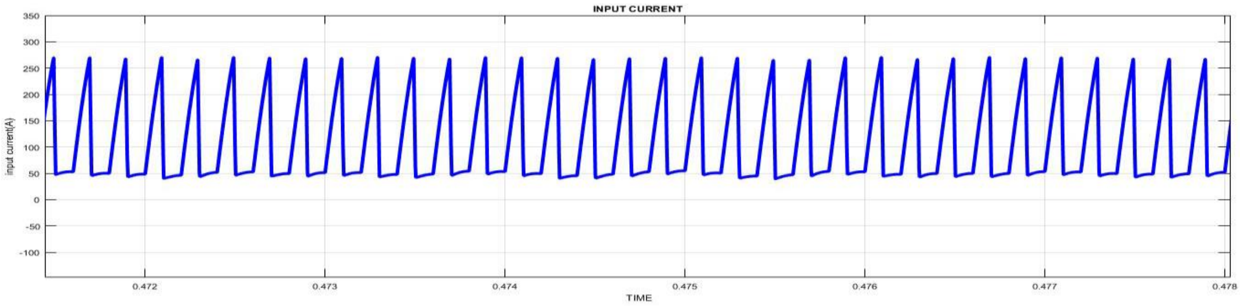

Fig.6.4.input current waveform

When input 27 V is connected from PV panel, the boosted output voltage 300 V is obtained as shown in figure below. The output current 0.298 A and output voltage 300 V at duty cycle D = 0.65. The voltage stress across the switch 80 V is obtained. Therefore compared to conventional converter, the proposed converter has low input ripple current, low voltage stress and high gain voltage.

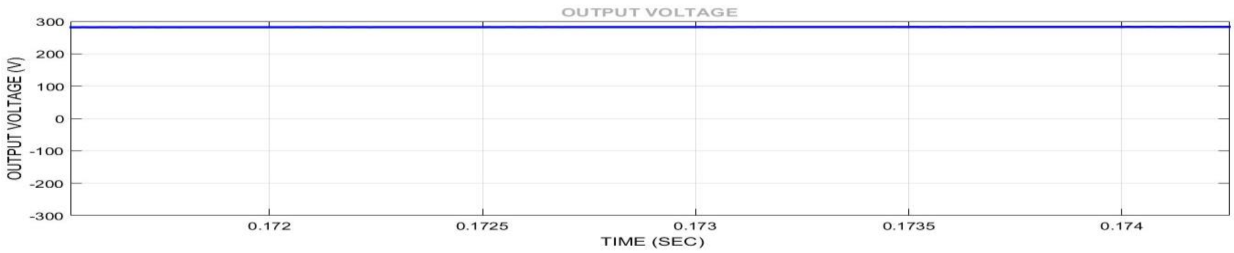

Fig.6.5.output voltage waveform

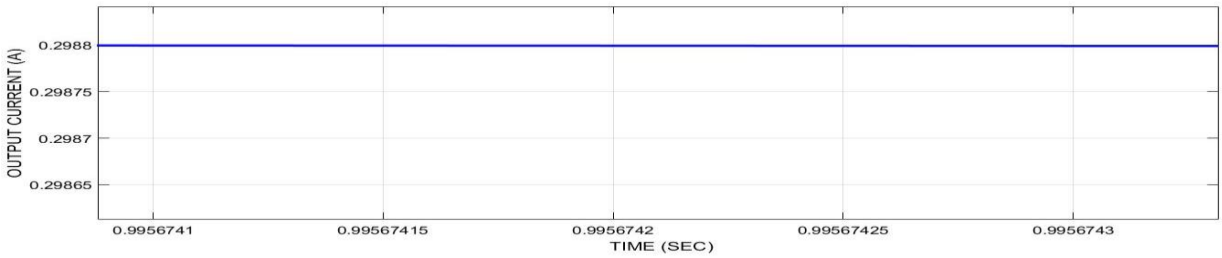

Fig.6.6.output current waveform

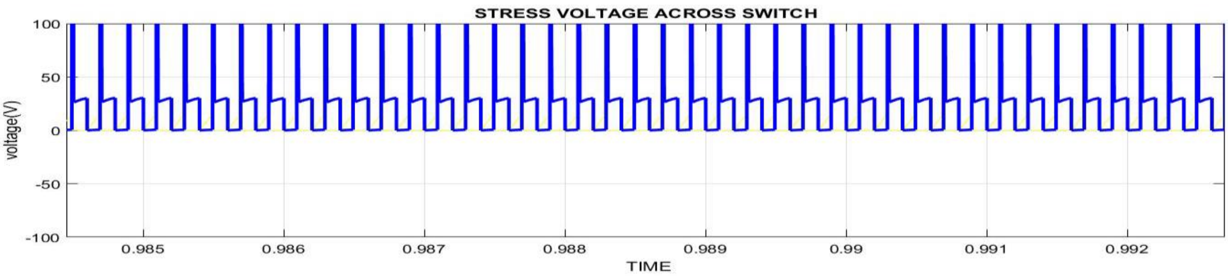

Fig.6.7.stress voltage waveform

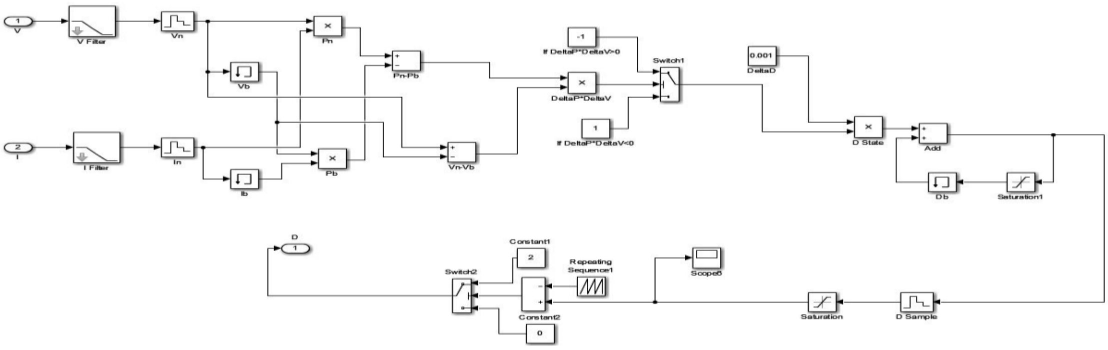

Fig.6.8.simulink model of MPP(P&O)

The voltage and current generated by PVA are inputs of the MPPT system and the task of the MPPT algorithm is to calculate the reference voltage. The MPPT systems contain two control loops to achieve maximum power. The inner loop contains the MPPT algorithm block and comparator to generate the switching pulses. The external control loop contains the PI controller, which controls the input voltage of the converter. The PI controller works towards minimizing the error between Vref (generated by MPPT block) and the output voltage of DC-DC converter by vary the duty cycle.

Specification of PV Pannel

PARAMETER	**ATTRIBUTES**
Open circuit voltage	28.5
Voltage at maximum power point	25
Short circuit voltage	7.97
Current at maximum power point	7.47
Cell per module	60
Irradiance	1000
Parallel rings	1

VII. CONCLUSION

The disadvantages of existing system have charging current of the output capacitor is discontinuous resulting in larger capacitor size and EMI issues. As similar to the buck-boost converter, efficiency is poor for high gain i.e. very large duty cycle. Therefore, high gain operation cannot be achieved with this converter. This converter cannot step down the voltage which is crucial for many applications like PV. To extract the maximum power from a PV panel there can be sometimes where you may need to step down. Hence, this converter cannot provide you a large limit of maximum power point tracking. Those problem overcome by introduced as coupled inductor based converter. The non isolated high step up converters welcomed in order to reduce the system cost and to improve the converter efficiency since the common mode current will the large PV area in these application can be solved effectively. Furthermore, the switch voltage stress is reduced compared with the conventional boost converter.

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