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ZVS based current fed converter for PV system with voltage doubler

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ABSTRACT: In this paper Incremental Conductance (IC) algorithm for photovoltaic (PV) system with full bridge isolated current fed DC/DC converter with output voltage doubler is proposed. This algorithm is used to obtain the high efficiency and to protect the systems from the variations of the temperature and irradiance. In this paper maximum output power tracking and different modes of operations of proposed DC/DC converter is presented. The PV output is fed to the current fed DC/DC converter to obtain the high output voltageand it is controlled by the Proportional Integral (PI) controller. Soft switching technique is also implemented to improve the performance of converter. The Zero Voltage Switching (ZVS) is maintained for all switches in the converter. Voltage doubler is connected in the high voltage side which results in twice the amount of input voltage with reduced components. The MATLAB/Simulink toolbox is used to model the PV system with full-bridge isolated current fed DC/DC converter and simulation results validate the working of the proposed DC/DC converter

Keywords: Incremental Conductance, PV array, current fed DC/DC converter, voltage doubler,PI controller.

I.INTRODUCTION

The entire world is facing a challenge to overcome the energy demand because of non-renewable energy sources such as gas, oil, fossil fuel etc., are rapidly decreasing and it will be depleted in few decades. In order to overcome this problem, the solar energy is an alternative energy source and which is available in the free of cost. If there is a sufficient irradiance condition efficiently will generate maximum power while MPPT algorithm is widely used with PV system. A lot of MPPT algorithm has been developed by the research and industrial persons. They are perturbation and observation method,voltage feedback method, hill clamping method, Incremental Conductance (IC) method and so on. In this paper IC method is used and it is based on the incremental and instantaneous conductance. The photovoltaic system is directly converts sunlight into electricitybased on thephotovoltaic effect. The photovoltaic array is group of panelsor modules. The solar cells are grouped into form a panel ormodule. The PV effect consists ofvarious processes involved i.e., subsequent separation of the photo generated chargecarrier and collection of photo-generated charge carrier in the junction.[2]

In general, solar cell structure consists of absorptions layer which are efficiently absorbs the photons results in creation of electron-hole pair. The generated electron and holes are separated by the semi permeable membrane. The important requirement of semi permeable membrane is that they allow only selected one type of charge carrier pass through. The major issue in the design of solar cell requires thickness of the absorption layer of smaller than the diffusion length of the charge carrier. The different parameters are used, to characterize the solar cells. They are open circuit voltage (V_{oc})short circuit current (I_{sc}) and Fill Factor (FF). The short-circuit current (I_{SC}) is the current that flows through the external circuit when the electrodes of the solar cell are short circuited. It gives the maximum current of that solar cell. The open-circuit voltage (V_{oc}) is the voltage at which no current flows through the external circuit. It is the maximum voltage that a solar cell can deliver. The Fill Factor is defined as the ratio between the maximum power generated by a solar cell and the product of V_{oc}andI_{SC}. The voltage generated from the solar cell is low which is directly used for small loads such as lighting system and DC motors. For other applications it must be boosted. This requires the converter to boosting output of PV system. There are two major types of converters are available. They are non-isolated and isolated

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converters. In this paper isolated full-bridge current fed DC-DC converter is used for boosting operation and it can be achieved without using high turns- ratio in transformer with implementation of soft switching techniques.
This current fed converter has advantages over the voltage fed converter such as high conversion ratio, simple construction, reduction of component stress and minimization of conduction loss [6]. A new active clamping ZVS Pulse Width Modulation (PWM) current fed half bridge converter. This converter does not require any clamp winding and auxiliary circuit. Therefore, this converter operating at higher operating frequency, smaller sized reactive components, lower cost of production and easier implementation [12].

The DC-DC converter has been presented in [1] is hard switched converter. It does not able to maintain soft switching. Itwill operate at high duty cycle and limited switching frequencywhich results in reduced efficiency. These drawbacks are eliminated by using soft switching [10] converter in power converter operation. In the soft switching converter voltage or current across the switches zero during transitions, which results it eliminates the requirement of large magnetic components and filter.Active clamp circuit is presented in the primary side to achieve the ZVS for the main switches.

II. MATHEMATICAL MODEL OF PV

The PV module manufacture usually provides the values of their parameters in datasheets. The simple equivalent circuit of PV cell is shown in Fig 1.

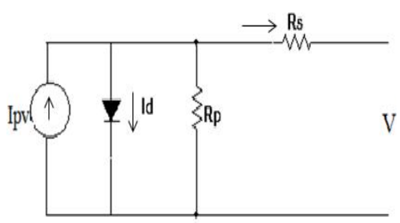

Fig. 1Equivalent circuit of PV cell

By applying kirchoff's current law to this circuit

$$I = I_{sc} - I_d \quad (1)$$

where,
Isc is the short circuit current i.e., equal to the photon generated current
I_d is the current shunted through intrinsic diode.
The diode current I_d is given by the schottky's diode equation

$$I_d = I_0(e^{qv/KT} - 1) \quad (2)$$

Where,
I_0 is the diode saturation current (A)
q is the electron charge $[1.602*10^{-19}\,C]$
k is the Boltzmann constant $[1.3806*10^{-23}\,J/K]$
V is the voltage across the PV cell (V)
T is the junction temperature in kelvin (K)
Combining the equations(1) and(2), we get

$$I = I_{SC} - I_0(e^{qv/KT} - 1) \quad (3)$$

The reverse saturation current (I_o) is constant under constant temperature. Now I=0 substitute in equation (1) and consider the series resistance (R_S) and shunt resistance (R_P), the equation becomes

$$I = I_{SC} - I_0(e^{qv/KT} - 1) - (V + IR_S)/R_P \quad (4)$$

Practical arrays are composed of several connected photovoltaic cells and the observation of the characteristics at the terminals of the photovoltaic array requires the inclusion of additional parameters to the basic equation.

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$$I = I_{PV} - I_0[\exp(\frac{v + IR_S}{V_t a}) - 1] - \frac{V + IR_S}{R_P} \quad (5)$$

Where, a is the diode ideality constant

$V_t = N_s KT/q$, is the thermal voltage of array with N_S cells connected in series.

The equations from (1) to (5) are used to simulate PV model in MATLAB/Simulink.

Advantages:

1) Pollution free in environment.
2) It does not produce any harmful emissions.

Disadvantages:

1) The solar energy is not produced in the night time. It requires storage device to use in night time.
2) Produced voltage must be converted into AC. It requires additional circuits which makes circuit complex.
3) In cloudy conditions not able to produce a sufficient voltage even in day time.

III. INCREMENTAL CONDUCTANCE ALGORITHM

The most frequently used algorithm is to track the maximum power is Perturb and Observe (P&O) because of its simple structure and fewer requirements of parameters. In this method iteratively perturbing, observing and comparing the power generation in the PV modules MPP is achieved is presented in [3]. The P&O method have possibility of miscalculation for determining the perturbing and tracking direction. Thedisadvantageof P&O algorithm is it does not compare the array terminal voltage with the actual MPP voltage. To overcome this drawbacks IC algorithm is proposed [8]. This algorithm has advantages of exact perturbing; tracking direction and the array terminal voltage is always adjusted according to the MPP voltage due to this IC is more competitive than other method. The equation is given below,

$$\frac{dI}{dv} = -\frac{I}{v}, \text{ at MPP}$$

$$\frac{dI}{dv} > -\frac{I}{v}, \text{ left of MPP}$$

$$\frac{dI}{dv} < -\frac{I}{V}, \text{ right of MPP}$$

The MPP of the PV output can be achieved when its dp/dv reaches zero. The controller calculates dp/dv based on measured PV incremental output power and voltage. If dp/dv is not close zero, the controller will adjust the PV voltage step by step until dp/dv approaches zero, at which the PV array reaches its maximum output.When the operating behaviour of PV modules is within the constant current area, the output power is proportional to the terminal voltage [5],[9]. The characteristics of PV cell shown in fig 3.

IV. PROPOSED CURRENT FED DC/DC CONVERTER

Isolated converter has more advantages over the non-isolated converter because which eliminates the conduction losses, input current ripples and therefore efficiency of the converter is increased. In non-isolated converter requires high duty cycle to obtain high output voltage. There are various isolated converters such as push-pull converter, voltage fed converter, forward converter,fly-back converter and current fed converter and so on. Voltage fed converters suffered by duty cycle loss; high switching losses and large input ripple current [4], [11]. It is not a simpler solution to achieve the better efficiency which requires the large filter circuit to mitigate these problems and thereby using current fed full bridge DC-DC converter high efficiency is achieved. The high frequency transformers are used in DC-DC converter. Therefore, high efficiency and output voltage is achieved without using the high number of turns-ratio. In the

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proposed converter Metal Oxide Semiconductor Field Effect Transistor (MOSFET) switches are used due to its low conduction losses and high switching frequencies.

Block diagram of proposed current fed DC/DC converter with PV system is shown in fig2. The input voltage varied with respect to an irradiation and temperature. The voltage across the photovoltaic cellterminal is low. In some applications requires the converter to process the electricity across the photovoltaic cell. In this current fed full bridge converter is preferred for boosting the voltage available across the PV panel. In that full bridge inverter is used to convert DC voltage across the output of PV equivalent into AC which is fed to the transformer. The switches in full bridge are controlled by the pulse signals generated from PWM generator with PI controller.The transformer step-up the voltage with reduced turns ratio ($N_2/N_1 = 6$) and given to the voltage doubler.This selected converter has reduced

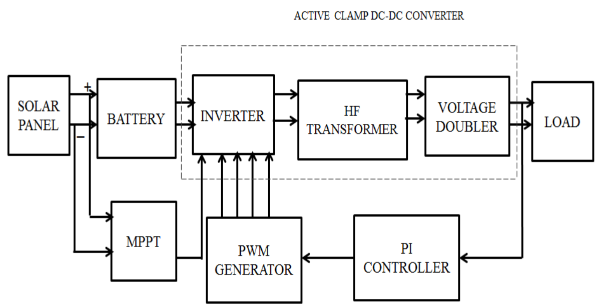

Fig. 2 Typical block diagram of DC/DC converter with PV system

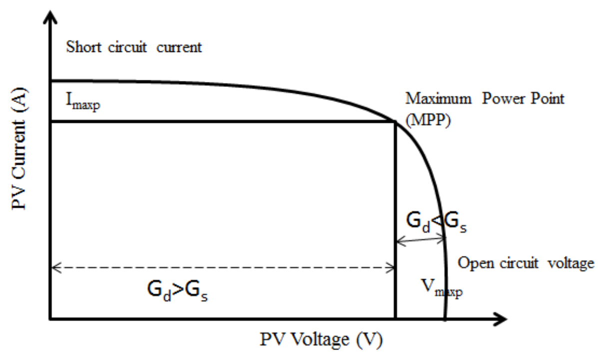

Fig. 3 I-V characteristics of PV cells

switchinglosses,duty cycle loss, EMI and mitigates the diode's reverserecovery problem. The inverter bridge is used along with auxiliary switch and the switch is turned on with twice the main switching frequency. Soft switchingis implemented to avoid the overlapping of this converter.There are two types of soft switching techniques are available. Zero Voltage Switching (ZVS) is preferable over the Zero Current Switching (ZCS) because of operation in high switching frequencies. Isolated converters are most suitable for applications. In this High Frequency (HF) transformer is plays vital role to isolate the source and load and protect the circuit. Thevoltage doubler is converts output voltage across the transformer into DC and it produces twice the AC voltage across the rectifier.

V. SIMULATION OF PV ARRAY WITH DC/DC CONVERTER

The important requirement of DC–DC converter used in the MPPT scheme should have low current ripple. Buck converters will produce ripples on the PV module side currents and it requires a larger filter capacitor. Current fed full bridge DC/DC converter is selected which is shown in Fig 4.

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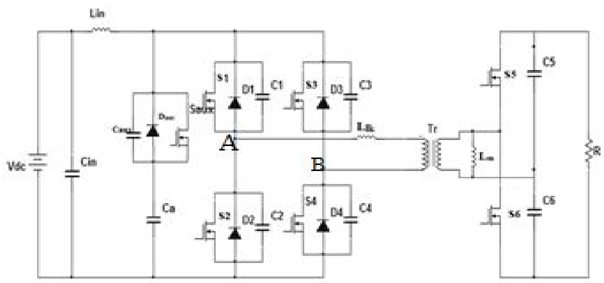

Fig. 4 Proposed converter circuit diagram

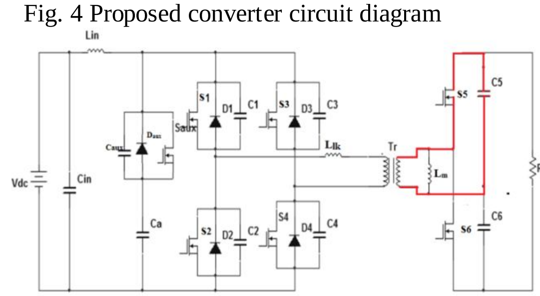

Fig. 5Mode 1 equivalent Circuit of proposed DC/DC converter

A. Modes of Operation

Voltage doubler circuit is shown in fig 6 along with the full bridge converter on the primary side of the transformer.

Mode 1: During this positive half-cycle one of the switch (S_5) conducts and the charges the capacitor (C_5). The equivalent circuit thus can be shown in Fig 5.

Mode 2:During the negative half-cycle the other switch (S_6) conducts negatively to charge the other capacitor (C_6). The equivalent circuit of this mode is shown in Fig 6.

The voltage across the combination is therefore equal to twice the peak voltage.

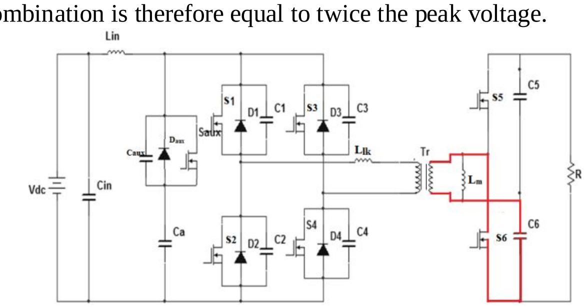

Fig. 6Mode 2 equivalent circuit of proposed DC/DC converter

Boost converters have low ripple on the PV side. So, boost current fed DC/DC converter is used. Simulation of PV array with DC/DC converter is developed by using MATLAB/Simulink toolbox. The PV module is simulated by using the given mathematical equations (3), (4), (5). The MPPT regulates the PWM control signal to the DC/DC boost converter until the converter condition satisfies. When this incremental and instantaneous conductance is equal maximum power is tracked which is used to trigger auxiliary clamp circuit. The simulation of current fed DC-DC converter with MPPT function diagram shown in fig 7. Voltage Doubler output (voltage) is compared with reference value, error signal is produced which is used to generate the pulses that can be useed to control the inverter switches.

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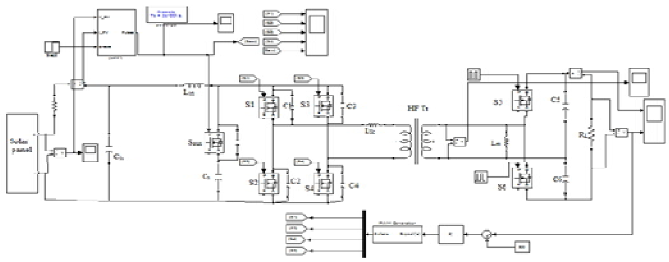

Fig. 7Simulation of DC/DC converter with MPPT function

VI.SIMULATION RESULTS OF PV MODULE AND VOLTAGE DOUBLER

A maximum power point tracker (MPPT) is a power electronic system, DC-DC converter inserted between the PV module and its load to achieve optimum matching. The modelof PV modules used in PV simulation is simulated according to the mathematical equations. The PV module output is given to the DC-DC converter. The tracking of

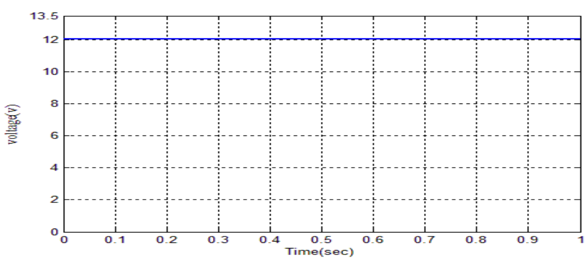

Fig. 8Output voltage of PV cell

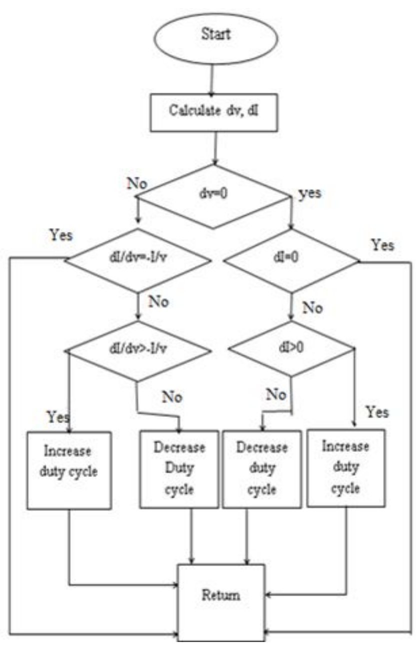

Fig. 9 Incremental conductance algorithm flow chart

maximum power using Incremental Conductance is explained through flow chart shown in the fig 9. The output voltage (12V) of PV cell is shown in fig 8. It is generated based on the standard values provided for poly crystallinesolar cell in the data sheet. The temperature is 25°C. The voltage is fed to the converter and controller simultaneously. The duty cycle is adjusted directly in the algorithm. Then which is used to turn on and off the auxiliary switch. The inverted output is given to the HF transformer. Secondary voltage of transformer waveform is given in fig10. Finally, the voltage available across the transformer secondary converted into DC and it is doubled by the voltage doubler. Output voltage and current waveform of voltage doubler is shown in fig 11.

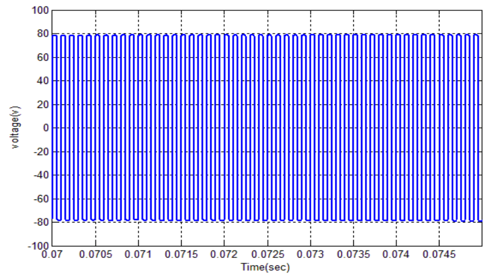

Fig. 10 Secondary voltage of transformer

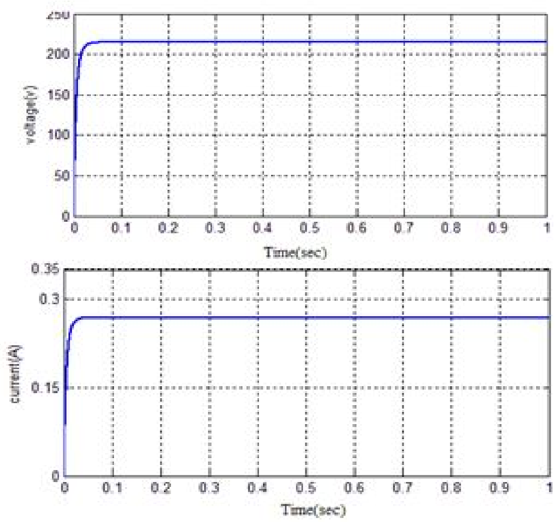

Fig. 11 Output voltage and current waveform for voltage doubler

VII.CONCLUSION

In this paper, Incremental Conductance method of MPPT for photovoltaic system with isolated current fed DC-DC converter is proposed and simulation results are shown. This method offers good tracking efficiency and high response. The PV module output is generated which is fed to the isolated current fed DC-DC converter, Full bridge inverter is controlled by the pulses generated from the PWM generator with the help of PI controller. Soft switching is implemented in the main switches of inverter.High output voltage is obtained from the voltage doubler (typically a set of capacitor and diode or any switches) which is twice as the AC input voltage of rectifier. This proposed DC/DC converter explained with different modes and it provides reduced number of components compared to conventional system which results low cost and high efficiency.

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BIOGRAPHY

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