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A Survey on Residential Photovoltaic Power System for MPPT Facilitated DC-DC Converter-Based On Bidirectional Inverter

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Abstract: Photovoltaic (PV) residential power system is an significant application of renewable energy. The parallel-connected configuration of PV modules rather than the series-connected configuration become accepted considering the safety necessities and making full use of the PV generated power for the PV residential generation system. In this paper, a novel soft-switching isolated full bridge dc-dc converter with voltage quadruple as a front-end converter-based inverter is being proposed. It has only four primary devices with full bridge dc-dc converter which results in simple and reduced gating conditions. The device voltage is clamped naturally by secondary modulation without active clamping circuit or passive snubbers. Zero-current Switching (ZCS) of primary devices and zero-voltage switching (ZVS) of secondary devices is attained. Soft-switching is inherent owing to proposed secondary modulation, load independent, and is maintained during wide variation of input voltage and power transfer capacity, and thus is suitable for PV functions. Prototype of the converter is being built and tested to demonstrate the converter performance over wide discrepancy in input voltage and output power for PV application.

I. INTRODUCTION

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RENEWABLE energy has knowledgeable impressive growth over the past decade due to the fast reduction of fossil fuels, concern of energy security and green gas emission. According to the report of International Energy Agency, 57% of new power capacity to 2030 will be in the form of renewable technologies [1]. Different renewable energy resources like Wind turbines, solar energy, etc., are integrated together with the energy storage devices and relevant power conditioning, control and management systems to form a hybrid distributed generation system to provide long-term sustainability. Since distributed generation system is close to electricity users, it can overcome the inefficiency and environmental issues from the centralized power plants. Among a variety of renewable energy resources, solar photovoltaic (PV) has been proven to be very promising. Solar PV generation is pretty flexible that is scalable from small-scale residential application to large-scale solar farms/power plants. It will comprise a large amount of share of the new power capacity added to 2030, accounting for almost 27% [1].The residential PV power system plays an increasing important role in solar renewable energy. However, PV modules have highly nonlinear voltage–current characteristics and the maximum power point (MPP) varies dramatically with the ambient environmental factors such as solar irradiance and temperature. For residential applications, the performance of PV inverter system is easily to be affected by partial shadows and mismatch of electrical parameters. The configuration of PV modules and corresponding power electronics design is crucial to draw maximum power from PV modules.

Generally, PV modules configurations are classify into Three classifications: 1) centralized configuration, 2) string/ Multistring configurations, and 3) module integrated converter (MIC) configuration. In conventional centralized [2] and string configuration [3], [4] of PV modules, a number of PV modules are connected in series to obtain sufficient dc-link voltage for inversion operation. However, the presentation of entire series-connected string of PV modules could be considerably impeded due to the module variance or partial shading. Building integrated PV systems

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with several different power configurations have been evaluated considering energy efficiency. Authors in [5] and [6] proposed an AC module technology [see Fig. 1(a)] and PV dc-building-module (PVDCBM) based technology are shown to be suitable for residential building

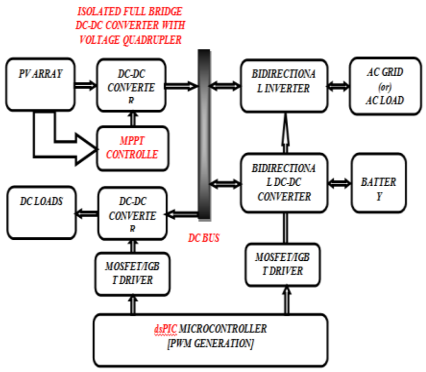

Fig 1. Block Diagram Of Proposed Method

Integrating PV module with dc/ac converter with individual MPP tracking (MPPT) control. Several ac modules are connected in parallel to the grid.

AC Module based technology in the residential applications was illustrated consisting of PV modules, full bridge inverter as front-end converters, voltage quadruple, with inverter and energy storage battery packs with bidirectional dc/ac inverter. For a typical PV module, the MPP voltage range from 20 to 50 V. The full bridge inverter is used to converter dc/ac voltage of the PV modules with MPPT operation. Several PV modules are connected in parallel to reach high power level. Centralized inverter is utilized to generate ac voltage for local load or utility grid. Energy storage is used to overcome the intermittency of solar energy or grid instability and provide the function of power conditioner, active power filter and uninterruptible power supply. High frequency (HF) transformer isolated dc/dc converter is preferred to obtain high step-up ratio and the galvanic isolation between the PV modules and the utility. For voltage-fed topologies, considerably large electrolytic capacitor is generally required to suppress the large input current ripple, resulting large size, high cost, and shortened lifetime of PV system. Compared with voltage-fed topologies, current-fed Topologies exhibit following advantages: 1) smaller input current ripple; 2) lower transformer turns ratio; 3) capacitive

Output filter; and 4) no flux-imbalance problem. However, it is well known that the current-fed converter suffers from high Voltage spike across the switches at their turn-off. Passive resistor-capacitor-diode (RCD) snubber is used to absorb the voltage spike leading to low efficiency. A non-dissipative snubber is proposed in [18] to recycle the absorbed energy but increases the complexity. Active clamping is popularly used due to high efficiency and achieves ZVZCS of the devices at the same time [19]–[22].

In this paper, a bidirectional dc/ac inverter was proposed that is composed of high step-up snubber less voltage fed with isolated full bridge dc to dc converter with voltage quadruple as a front-end converter and standard full-bridge inverter. Voltage quadruple is selected to reduce number of the switches and the transformer turns ratio. A novel secondary modulation technique is proposed to clamp the voltage across the primary side devices and therefore eliminates the necessity for snubbers. Switching losses are reduced significantly owing to zero-current switching (ZCS) of primary switches and zero voltage switching (ZVS) of secondary switches. Soft switching is inherent, load independent, and is maintained with wide variation of input voltage and power, and thus is suitable for PV applications. Voltage spike leading to low efficiency. A non-dissipative snubber is proposed in to recycle the absorbed energy but increases the complexity. Active clamping is popularly used due to high efficiency and achieves ZVZCS of the devices at the same time.

II. Operation And Analysis Of The Proposed Converter

In this section, operation and analysis of proposed isolated full bridge dc to dc converter with voltage quadruple as a front-end converter had been explicated. To simplify the analysis, the following assumptions were made: 1) boost inductor *L* is large enough to maintain constant current through it; 2) all the components are ideal; 3) inductors $Llk1$ include the leakage inductances of the transformer; the total value of $Llk1$ is represented as $Llk\ T$; and 4) magnetizing inductance of the transformer is infinitely large. The primary switches $S1$ and $S2$ are operated with identical gating signals phase shifted with each other by 180◦ with an overlap using fixed-frequency duty cycle modulation. The overlap varies with duty cycle, and the duty cycle should be kept above 50%. Steady-state operation of the converter during different intervals in a one half HF cycle is explained using equivalent circuits shown in Fig. 3. For the rest half cycle, the intervals are repeated in the same sequence with other symmetrical devices conducting to complete the full HF cycle.

The proposed photovoltaic power system consists of PV array, battery energy storage system, isolated full bridge dc-dc converter, MPPT controller, bidirectional

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inverter, dc loads and ac loads. Here full bridge dc-dc converter is used as front end dc-dc converter to achieve high voltage gain with maximum power tracking capability from solar array and reduced no of turns .Full bridge dc-dc converter consists of full bridge inverter, high frequency transformer and voltage quadruple rectifier. Bidirectional inverter is used to make connection between dc and ac grid.

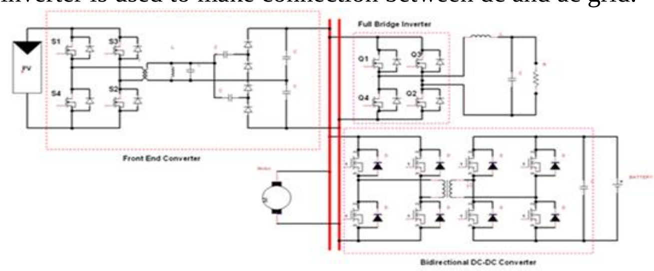

Fig 2 Circuit Diagram of Proposed Method

III. VOLTAGE QUADRUPLE

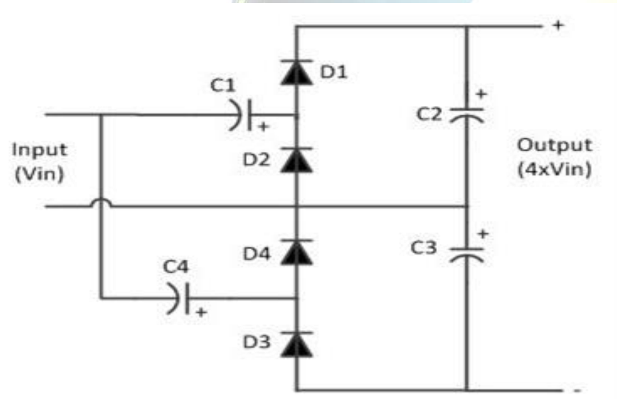

Fig 3. Circuit Diagram of Voltage Quadruple

A Voltage Quadruple would be a DC circuit, which consists of four diodes, and four capacitor. A transformer would be used to increase the voltage in an AC circuit. The above voltage quadruple circuit uses minimum components to approximately multiply (quadruple) the AC voltage (V_{in}) across the input terminals. The resulting output voltage is DC (Direct Current). Capacitors, C_2 and C_3, charges to double the value of V_{in}. The series combination of C_2 and C_3 produces a DC voltage equivalent to two batteries connected in series. The result is an output DC voltage that is four times the value of V_{in}. The voltage rating of the diodes and capacitors used should be within safe level, preferably, double the value of the input voltage. You may use capacitance values of 1000mF or higher. The higher the value of the capacitance, the smoother (non-fluctuating) the resulting output DC voltage. Thus the output of voltage quadruple is fed to Dc bus and it is converted in to AC by inverter and then it is used for residential applications and to charge the battery.

IV. BUCK-BOOST CONVERTER

A buck boost converter provides an output voltage which may be less than or greater than the input voltage, the output voltage polarity is opposite to the input voltage. During mode 1, switch is turned on and the diode is reversed biased. The input current flows through the inductor and switch. During mode 2, the switch is turned off, the energy stored in the inductor would be transferred to the load.Since the duty ratio “D” is between 0 and 1 the output voltage can vary between lower or higher than the input voltage in magnitude.

$$V_{in} t_{on} + V_0 t_{off} = 0$$

This gives the voltage ratio

$$\frac{V_0}{V_{in}} = \frac{-D}{(1-D)}$$

V. MODES OF OPERATION

Mode 1[t0, t1]:

In this mode, the source is from the PV array then the DC source will be sent through the switches S_3 & S_4. Then the switched source will be sent to the primary side of the transformer winding. After the transformer the flow will be in positive half cycle, in it the capacitor will get charged and then returns to the negative secondary side. By this step the two capacitor will get charged and in the same next cycle the voltage will get doubled and then after the negative half cycle the voltage will get four times and tit then goes to the output

$$iLlk1 = iS1 = VDC\ n \cdot Llk\ T \cdot (t - t2) \quad (1)$$

Mode 2[t1, t2]:

In this mode the switches S_1 & S_2 will get ON and then it goes to the primary side of the transformer. Then the flow after the secondary transformer will be the negative half cycle. In this flow the capacitors will get charged and then it returns to the positive side of the secondary side of the transformer. The in the next step the capacitor will start

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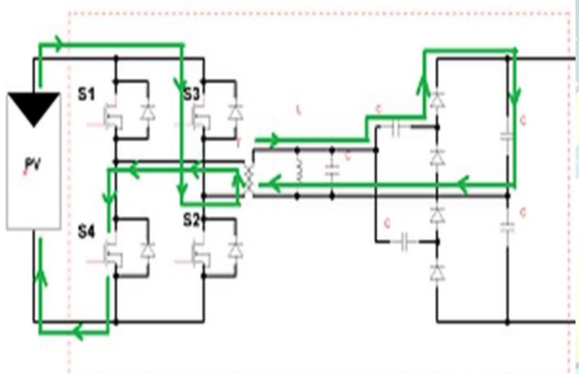
to discharge at that time the voltage level will be increased twice as that of the flowing voltage.

MODE 3 [t3,t4]:

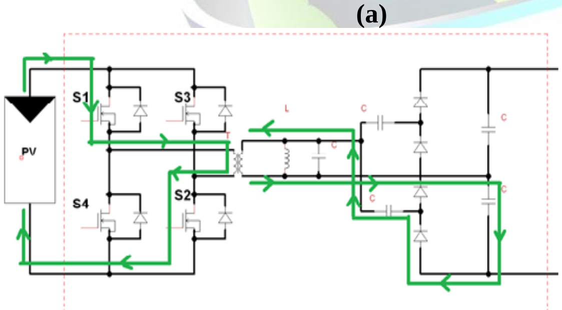
Again in next cycle, switches S_3 and S_4 are turned on, and again the transformer the flow will be in positive half cycle, in it the capacitor will get charged and then returns to the negative secondary side. By this step the two capacitor will get charged and in the same next cycle the voltage will get doubled and then after the negative half cycle the voltage will get four times and tit then goes to the output.

$$iD2 = -iLlk2 = VDC\, n \cdot Llk\, T \cdot (t - t4) \quad (5)$$

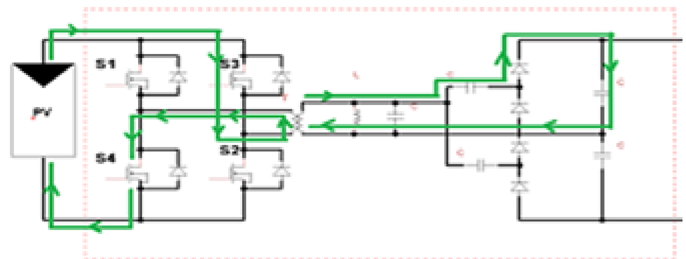
$$iS3 = I\text{in}\, n + 2 \cdot VDC\, n2 \cdot Llk\, T \cdot (t - t4).$$



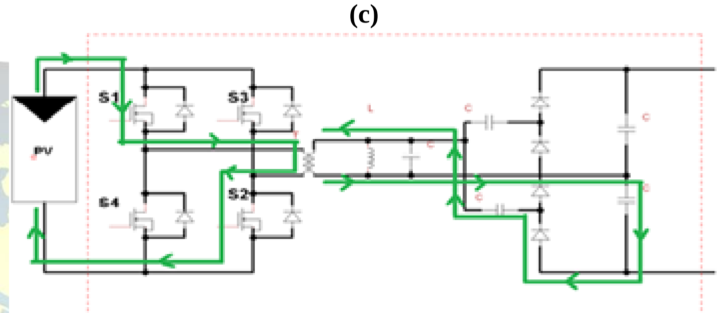
(a)



(b)



(c)



(d)

Fig 4 Equivalent Circuits During Different Intervals Of The Operation Of The Proposed Converter

VI. CHARACTERISTICS OF PV CELL

A solar cell is comprised of a P-N junction semiconductor that produces currents via the photovoltaic effect. PV arrays are constructed by placing numerous solar cells connected in series and in parallel. A PV cell is a diode of a large-area forward bias with a photo voltage and the equivalent circuit was shown. The current-voltage characteristic of a solar cell is derived as follows: $\boldsymbol{I = Iph - ID}$, $\boldsymbol{I = Iph - I0\ exp\ q\ V{+}RsI\ ATkB - 1 - V{+}RsI\ Rsh}$
Where Iph = photocurrent, ID= diode current, IO= saturation current, A = ideality factor, q = electronic charge 1.6x10-9, Kg = Boltzmann's gas constant (1.38x10-23) T = cell temperature, Rs = series resistance, Rsh = shunt resistance, I = cell current,
V = cell voltage

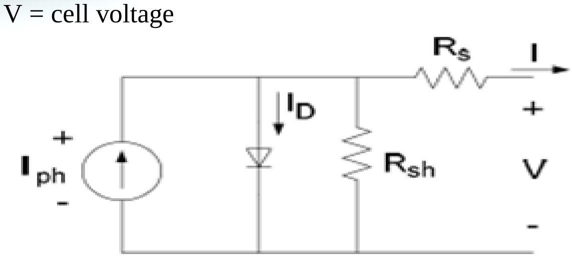


Fig 6 Pv Cell Equivalent Cell

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Typically, the shunt resistance (Rsh) is very large and the series resistance (Rs) is very small. Therefore, it is common to neglect these resistances in order to simplify the solar cell model. The resultant ideal voltage-current characteristic of a photovoltaic cell is given below

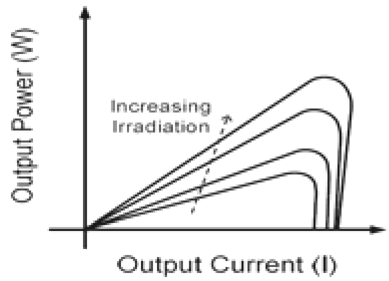


Fig 7 PV Cell Power Characteristics

VII. GENERAL MPPT FLOW CHART FOR PV

P&O is simple to implement and thus can be employed quickly. The major drawbacks of the P&O method are that the power obtained oscillates around the maximum power point in steady state operation

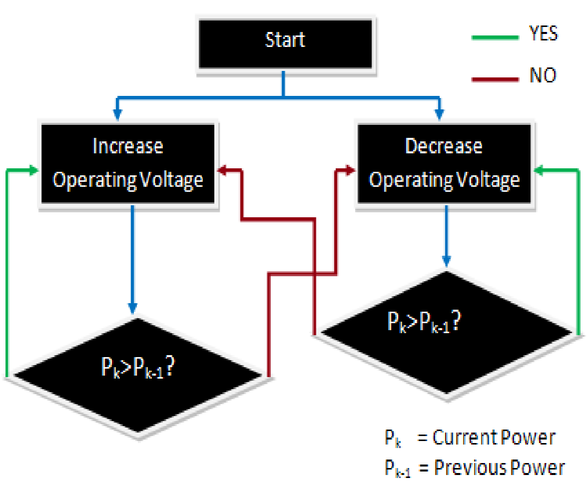
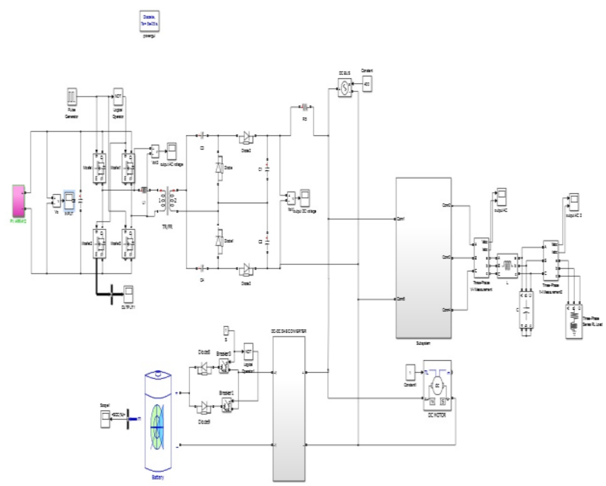


Fig 8 Flow Chart Of Mppt

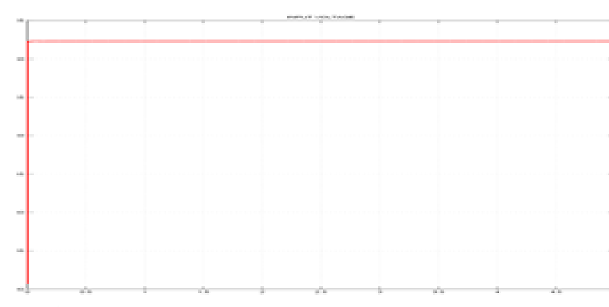
It can track in the wrong direction under rapidly varying irradiance levels and load levels, and the step size (the magnitude of the change in the operating voltage) determines both the speed of convergence to the MPP and the range of oscillation around the MPPT at steady state operation

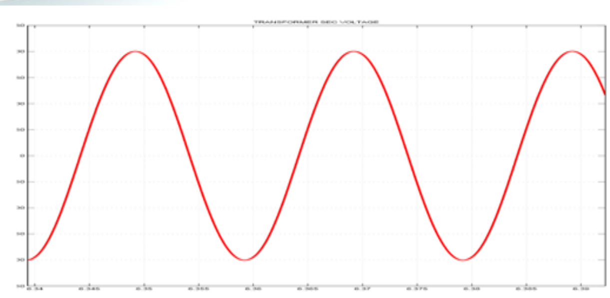
VIII. SIMULATION CIRCUITS & RESULTS



This project proposes the use of the isolated full bridge dc to dc converter to achieve higher efficiency in a wide output power range. The ripple magnitude is considerable low.Since MPP of PV modules is sensitive to current ripple, low ripple current will increase the utilization of PV modules. This shown clearly at the output voltages.

PV INPUT VOLTAGE





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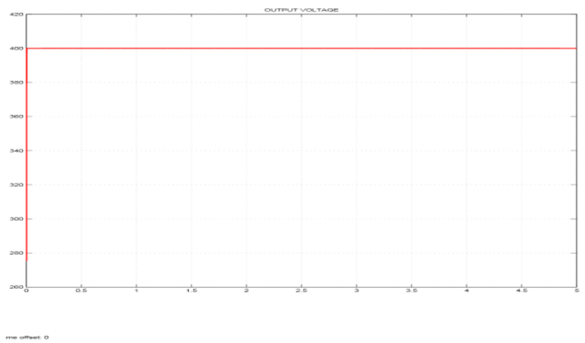
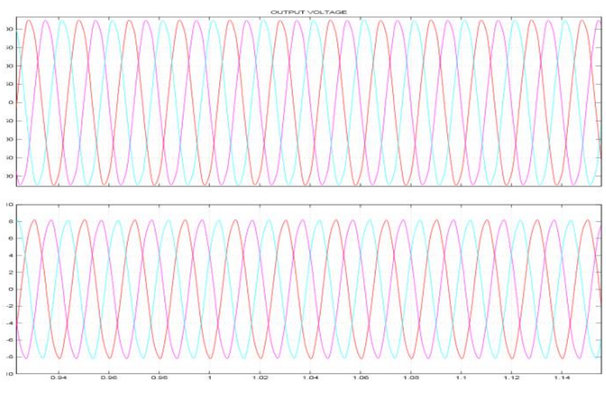
TRANSFORMER SECONDARY VOLTAGE



OUTPUT VOLTAGE



3PHASE LOAD VOLTAGE

IX. Conclusion

This work produces an isolated full bridge dc-dc converter with voltage quadruple as front end converter to achieve high voltage gain with maximum power tracking capability from solar array and reduced no of turns. Full bridge dc-dc converter consists of full bridge inverter, high frequency transformer and voltage quadruple rectifier. The proposed inventive secondary modulation attains the soft-switching of all semiconductor devices (ZCS of primary side and ZVS of secondary devices) without modifying the topology. It solves the basic problem of device turn-off in current-fed converter and is absolutely new and innovative. The modulation also achieves zero current commutation and natural voltage clamping of the devices without snubber or any auxiliary circuit. It relieves the need of extra reactive snubber or active clamping circuit making it original and snubber less. Switching losses were condensed significantly owing to ZCS of primary switches and ZVS of secondary switches. In addition, soft switching, inherents, independent of the load and is maintained with variations in source voltage. Soft switching permits high switching frequency operation leading to design compact, low cost, light weight system and high efficiency over wide range of loads and input voltages.

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