SINGLE STAGE TRANSFORMER LESS RECONFIGURABLE INVERTER FOR PV APPLICATIONS

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Abstract Solar *photovoltaic system has an important role from the embryonic stage of renewable energy to maintain the electricity demand because of their several peculiarities, so that Photovoltaic system associated with inverters are widely used in several applications. Based on the size and power rating different topologies are familiar with previous studies. This paper proposes a single stage transformer-less reconfigurable inverter for utilizing PV system efficiently, which overcome the drawbacks of conventional topologies. The reconfigurable topology enables the system to be operated in PV-load, battery- load, PV-battery-load, PV-battery. To analyze the system MATLAB/Simulink is used.*

I. INTRODUCTION

In the increasing demand of global energy consumption, fossil fuels are the source of energy for maintains the supply of electricity. They are the non renewable sources, produce energy by the depletion of natural gases, coal, oil etc. But the regaining of these sources of energy is difficult, also they may cause some of the environmental issues, so that alternating energy source have to be adopted instead of fossil fuels. For the growing electricity demand solar PV system has significant role. The attractive features like energy conservation and renewable energy utilization, solar PV still exists even though initial cost of PV panel is little bit more. Nowadays it is used in several applications such as water pumping, electric vehicle, remote areas where the scarcity of utility power or to reduce utility demand and encourage demand side management. The available amount of solar power from a PV module may vary with environmental conditions such as temperature, irradiations etc., also it may change with load variations.

MPPT is a dynamic tracking technique to track maximum power from solar photo voltaic system. Solar PV system can be used in standalone or grid connected systems. In grid connected PV system for utilizing renewable energy resources several inverter topologies are to be existing. Based on the size and power rating they can be classified as central inverter, string inverter, and module integrated inverters etc.

In 1990s self or line commutated central inverters had to be used for large power rating application[5].This inverter utilize single MPPT to obtain maximum power, so that when inverter failed to supply power whole system will be failed. Partial shading also affects the performance of system. Master slave inverter topology suitable for variable irradiance condition, in which PV strings connected parallel to inverters, thus can ensure reliability. But they also have problems in partial shading, power loss due to PV plant mismatch etc. String inverter provides better MPPT, less power loss due to partial shading because of their design, hence they overcome the drawbacks of most of the central inverter.

But they are costly, due to more number of inverters. Multi string inverter similar to two stage inverter, since it use two power conversion stages to obtain maximum output [6][7-8]. They overcome the drawbacks of previous topologies. The dual stage conversion results increasing switching stages, losses, complexity and higher cost. These drawbacks can be overcome by using single stage topology

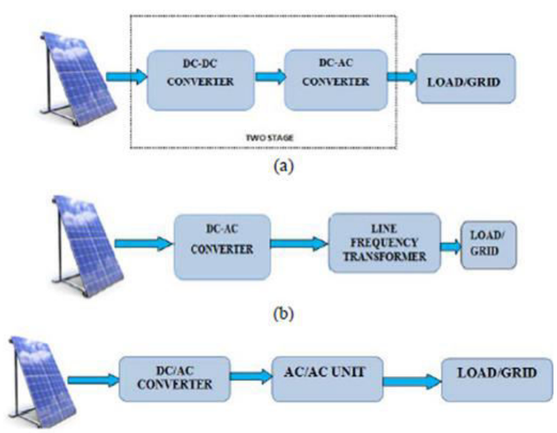

Fig 1: Block diagram shows Topologies of (a) Two stage inverter (b) single stage inverter with transformer(c) Proposed single stage inverter

Photovoltaics

Photovoltaics (PV) covers the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect, a phenomenon studied in physics, photochemistry, and electrochemistry. A typical photovoltaic system employs solar panels, each comprising a number of solar cells, which generate electrical power. The first step is the photoelectric effect followed by an electrochemical process where crystallized atoms, ionized in a series, generate an electric current.[1] PV installations may be ground-mounted, rooftop mounted or wall mounted. They may be mounted in a permanent orientation to maximize production and value or they may be mounted on trackers that follow the sun across the sky. Solar PV generates no pollution.[2] The direct conversion of sunlight to electricity occurs without any moving parts.

Photovoltaic systems have been used for fifty years in specialized applications, standalone and grid-connected PV systems have been in use for more than twenty years.[3] They were first mass-produced in 2000, when German environmentalists and the Eurosolar organization got government funding for a ten thousand roof program.[4] On the other hand, grid-connected PV systems have the major disadvantage that the power output is dependent on direct sunlight, so about 10-25% is lost if a tracking system is not used, since the cell will not be directly facing the sun at all times.[5]

Applications of Photovoltaic Systems

Photovoltaic system A photovoltaic system, or solar PV system is a power system designed to supply usable solar power by means of photovoltaics. It consists of an arrangement of several components, including solar panels to absorb and directly convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories. PV systems range from small, roof-top mounted or building-integrated systems with capacities from a few to several tens of kilowatts, to large utility-scale power stations of hundreds of megawatts. Nowadays, most PV systems are grid-connected, while stand-alone systems only account for a small portion of the market.

II. PROPOSED SYSTM

Proposed system is a PV panel associated single stage buck boost inverter topology, having reconfigurable switch as a mode selector of single stage inverter. To maintain the reliability of inverter a battery is associated with reconfigurable switch. The reconfigurable switch followed by Voltage Source Inverter (VSI) or full bridge inverter which convert the DC power to AC power.VSI act as buck converter, so in order to meet output with required voltage gain a line frequency transformer is necessary. Here the system performs DC-AC power conversion directly without utilization of line frequency transformer or dc-dc boost converter.

Thus system volume, size, complexity etc can be reduced. Instead of transformer AC-AC module is used here, for performing step up operation of inverted ac, hence the system can be called it as a quasi single stage inverter. Here the RSC concept introduces reduced number of mechanical switches to perform different modes of operation. Battery associated system can maintain the reliability whenever PV is failed to supply the inverter, or it can also be used to drive small dc loads. Here RSC as a mode selector switch, to choose the input of inverter, whether it is PV or battery.

This RSC operates in 4 modes of operation, mode1 for PV-battery (Dc-Dc), mode2 for battery to load (dc-ac), mode3 for PV-load(dc-ac) and mode 4 perform PV-battery-load. If sufficient amount of voltage can be obtained from solar PV mode 3 is enough. If excess amount of energy is available, battery can be stored to night time usage by mode 1 operation.

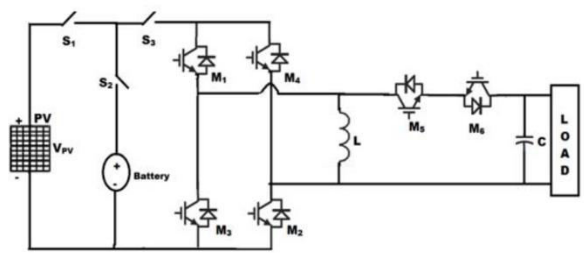

Fig 2: Circuit Diagram of Proposed system

III. OPERATION OF PROPOSED SYSTEM

The proposed system can be operated in both positive and negative half cycle with single power conversion. Fig.2. shows the circuit diagram of proposed system. The output of reconfigurable switch is Vdc. Inorder to avoid dead shoot or shoot through issues two switches in the same leg of VSI operates alternatively. When the switch M1 is triggered its companion M3 will be set as off stage. The whole system will be controlled by sinusoidal pulse width modulation (SPWM) and line frequency signal. During positive half cycle only M4 will be in high frequency stage others are switched with line frequency pulses. Similarly during negative half cycle switch M1 will perform high frequency operation. The system use only one high frequency switch in both positive and negative half cycle, hence losses can be reduced. The output of full bridge inverter is

$$V_0 = DV_{dc} sin\omega t \qquad (1)$$

Where D is the modulation ratio of VSI and Vdc is the input voltage offered by RSC. Eqn (1) shows that output voltage of full bridge inverter depends on the duty ratio D. Here the duty cycle D is obtained by dynamic tracking algorithm to acquire maximum power.

The output voltage gain of single stage inverter will be

$$\frac{Vo}{V_{dc}} = \frac{Dsin\omega t}{1-D} \qquad (2)$$

The switches of bridge M4 and M3 triggered in positive half cycle to convert DC power to AC power. At this time its companion M2 and M1will be trigged off. In this mode M4 will be switch with high frequency SPWM pulses to charge the inductor, which is shown in fig 3a.

When the primary switches are off, inductor gets discharged and current passes to load through the switch M6 and body diode M5, as shown in fig.

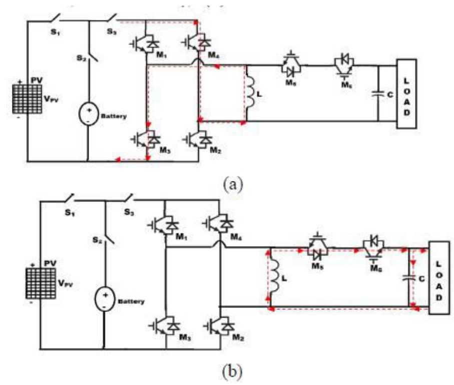

Fig 3: Circuit diagram of proposed system in positive half cycle (a) inductor charging mode (b) inductor discharging mode

The switches of bridge M1 and M3 are triggered in negative half cycle, for the DC to AC power conversion. In this mode M1 will be switch with high frequency SPWM pulses to charge the inductor. Inductor will discharge when the switches of VSI are triggered off. The discharged inductor current flows to load through the path of body diode M6 and switch M5. Fig.4 shows the current flow direction of the proposed system during negative half cycle.

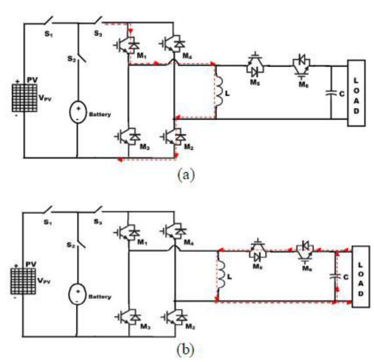

Fig. 4. Circuit diagram of proposed system in negative half cycle (a) Inductor charging period (b) Inductor discharging period

IV SIMULATION RESULTS

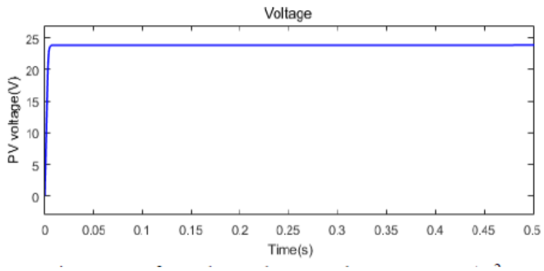

Fig. 5. Waveform shows the PV voltage at 1000w/m2 isolation

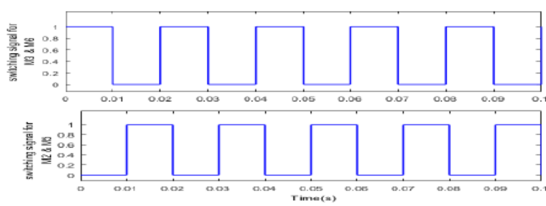

Fig. 6. Waveform shows the switching pulses of line frequency

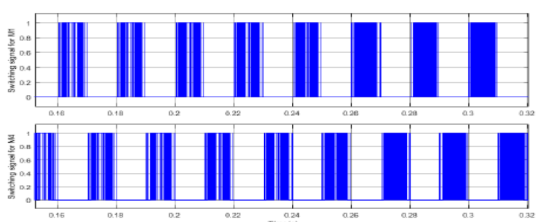

Fig. 7. Waveform shows the switching pulses for M4 & M1

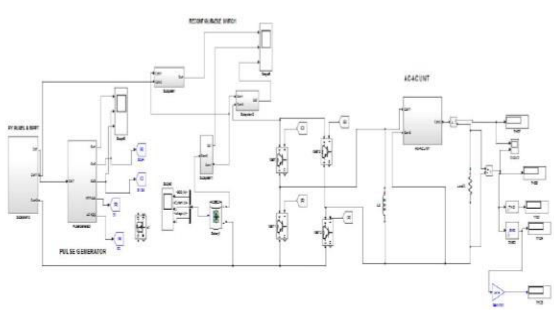

Fig. 8. Overall Simulation diagram of proposed system in MATLAB-simulink

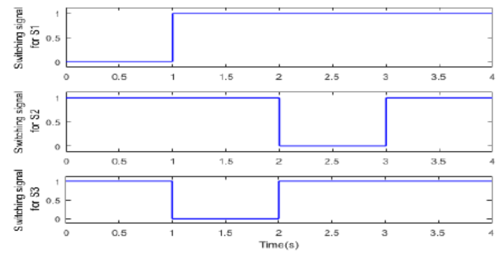

Fig. 9. Waveform shows the switching pulses of mode selector switch

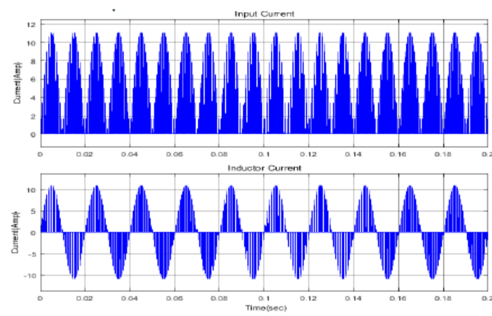

Fig. 10. Waveform shows the input current and inductor current of proposed inverter

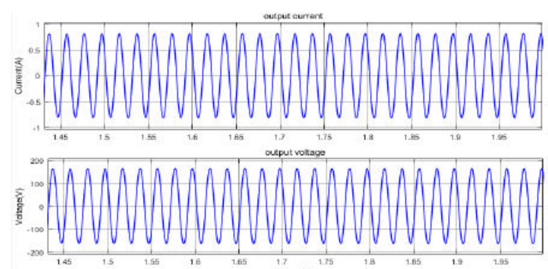

Fig. 11. Waveform shows the output of single stage inverter in mode 3 of reconfigurable switch

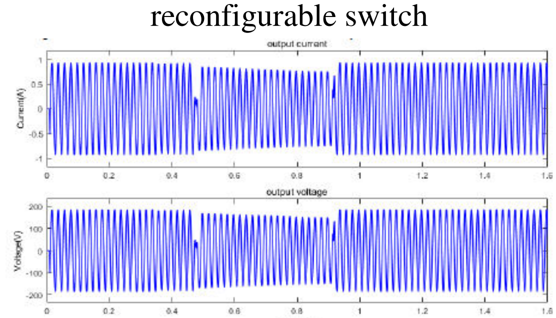

Fig. 12. Waveform shows the output of proposed system for different mode of RSC

V CONCLUSIONS

The proposed single stage inverter for solar power extraction can be operated in different modes based on the operation of reconfigurable switch and battery. The system ensures reduced switching loss by utilizing single high frequency switch in both half cycles. Also the harmonic distortion of single stage inverter is within the standard acceptance limit(less than 5% of fundamental).The system offers the advantages of simple, compact, low weight, reduced losses and high voltage gain without utilizing line frequency transformer or cascaded structure.

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