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PV MICROINVERTER TOPOLOGY USING SOFT SWITCHING HALF-WAVE CYCLOCONVERTER

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ABSTRACT

This paper deals with the development of a micro inverter for single phase photovoltaic applications which is suitable for conversion from low voltage DC to high voltage AC. The circuit topology is based on half-wave cycloconverter and grid connected micro inverter with a very less number of conversion stages and passive components. To interface the full bridge converter to the half-wave cycloconverter a high- frequency transformer and series-resonant tank are used. To determine the average output power of the inverter, a steady state analysis is used and to control the output power of the inverter, phase-shift power modulation is used. The operational characteristic is analyzed and multidimensional control technique is used to achieve high efficiency voltage gain, quality factor and phase shift of the inverter. The micro inverter and converter have light weight and reduced switch count. The operation of proposed micro inverter in grid-connected mode is validated using MATLAB simulation.

Keywords: half-wave cycloconverter, full-bridge inverter, photovoltaic (PV), high frequency transformer, series-resonant tank.

1. INTRODUCTION

In renewable energy research centre solar energy plays a vital role as a sustainable and low environment impact energy source [5]. A photovoltaic (PV) system plays a major role and set to grow fast among all potential solar power generation systems. In grid connected PV energy systems PV inverter is a key element. To convert PV-generated dc power into grid synchronized ac output, inverter plays a main function [2]. And to increase efficiency we consider more techniques among all soft-switching is choose to increase efficiency of inverter because it reduces the loss of switching of semiconductor devices [6]. Zero voltage switching (ZVS) is used, to set the device when it is instantaneously blocking close to zero volts. To simulate and implement half-wave cycloconverter: the number of power switches should be reduced which result in reduced switching and conduction losses, resonant tank is used to implement soft-switching at the turn on of the power switches to reduce switching losses due to the increased switching frequency, to reduce the conversion stages, and to reduce energy storage capacitance value [3].

2. CONVENTIONAL DC/AC POWER CONVERTER

A. Circuit description

The full-bridge inverter is used as the primary side inverter of the micro inverter due to its higher voltage gain compared to the half bridge inverter, although the number of switches in the full bridge circuit is twice that of the half-bridge [9]. The turns ratio of the high frequency transformer can be reduced by half, and hence, the size of the transformer can be reduced [10]. By using a half-wave cycloconverter, the number of switches in the secondary side can be reduced by half compared to a full-wave cycloconverter as shown in the Figure-1.

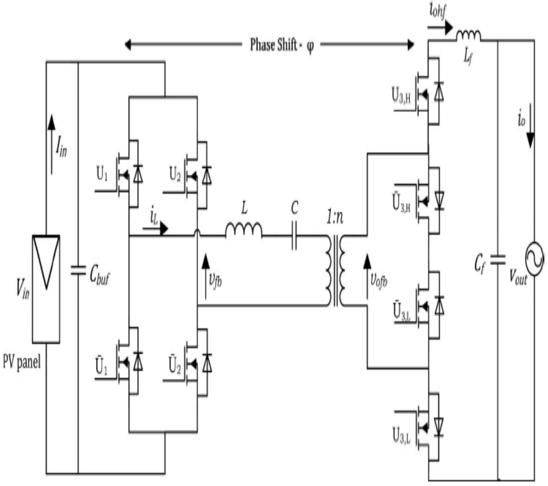

Figure-1. Conventional circuit diagram.

Advantage of conventional system:

- Single power conversion stages and therefore number of power switches is reduced.
- Passive components of proposed system consist of reduced size and weight of passive component.
- Switching loss of micro inverter topology is minimized using soft-switching due to high-frequency transformer.
- The stress on the active switches is reduced due to the leakage inductance of the transformer.

3. PROPOSED BOOST INVERTER SYSTEM

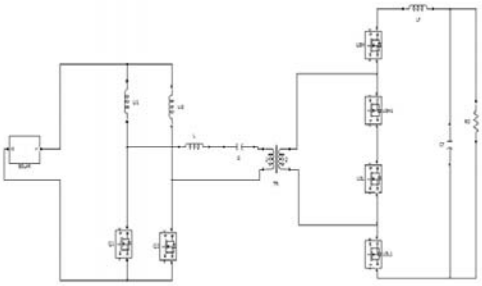

Figure-2. Proposed circuit diagram.

A proposed new two inductor,two switch boost inverter topology that can achieve output voltage regulation from full load to no load in a wide input voltage range using constant frequency control.This topology employs transformer with a unity turns ratio to couple the current path of the two boost inductor so that the both inductors conductidentical currentS. Due to this current mirror effect of the transformer no energy is stored in the inductors where there is no overlapping of conduction time of two switches i.e. when D=0. This transformer approach can be applied to isolated or non-isolated two inductor, two switch topologies with any type of output rectifier.The input side of the circuit consist of two switches Q_1 & Q_2,two boost inductor L_{11}& L_{12},transformer TR.

4. MODES OF OPERATION

Mode 1 – Positive

During the positive mode of conduction,the switch Q_1 starts conducting and inductor L_{11} get charged.Thus the current flows in the primary side of the transformer induces the current in the secondary taping.And U_3H_1 and U_3L_1 are also turned ON and produces positive half-cycle.

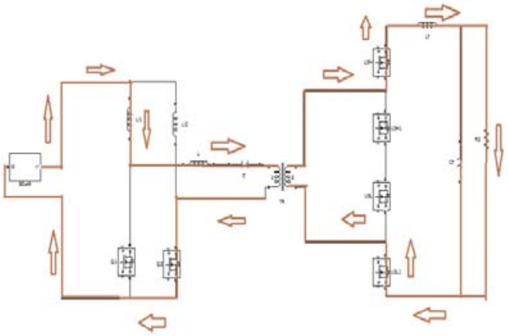

Figure-3. Circuit diagram of mode 1 operation.

Mode 2 – ZCS condition

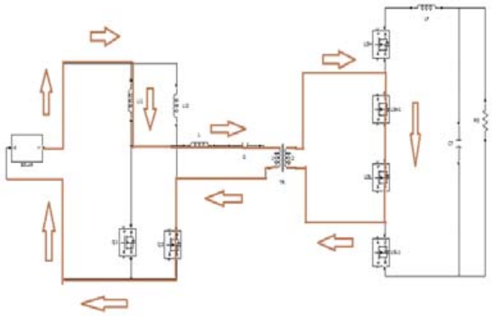

Figure-4. Circuit diagram of mode 2 operation.

During this mode of conduction the switch Q_2 conduct and inductor L_{12} is charging,thus the current flows in the primary side of the transformer induces current in the secondary tapings.And U_3H_1 and U_3L are also turned ON.In this mode the resonant current leads the cycloconverter input voltage *vofb* then ZCS occurs in the half-wave cycloconverter.

Mode 3 – Negative

During the negative mode of operation the switch switch Q_1 Conducts and inductor L_{12} is charging, thus the current flow in the primary of the transformer induces current in the secondary tapings. And U_3L_1 and U_3H_1 are also turned ON and produces negative half cycle.

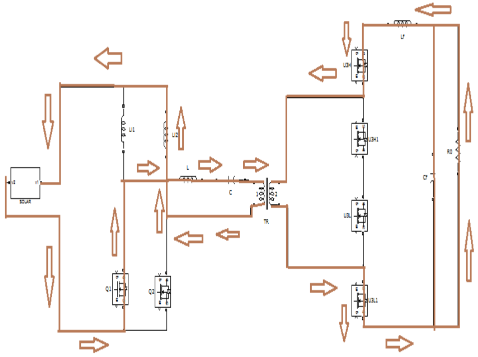

Figure-5. Circuit diagram of mode 3 operation.

5. CIRCUIT TOPOLOGY DESCRIPTION

a) Topology description and switching sequence of cycloconverter

The proposed micro inverter consists of full-bridge inverter which is used as the primary side of the circuit. The high-frequency transformer is used to reduce the turn’s ratio by half and the transformer size is also reduced. To integrate the micro inverter to the grid at the secondary side, a half-wave cyclo converter is used. Therefore this may results in reduced switching and conduction losses in the overall inverter. To eliminate the switching frequency ripple in the output current, the output filters capacitor and inductor in secondary side.

Switching sequence of cycloconverter consist of grid voltage and PV input voltage are constant among only one switching period of the micro inverter

Table-1. Cyclo converter switching sequences.

		$u_{3,H}$	$\bar{u}_{3,H}$	$\bar{u}_{3,L}$	$u_{3,L}$
$v_{out}(+)ve$	$i_L(+)ve$	ON	OFF	OFF	ON
	$i_L(-)ve$	OFF	ON	ON	OFF
$v_{out}(-)ve$	$i_L(+)ve$	OFF	ON	ON	OFF
	$i_L(-)ve$	ON	OFF	OFF	ON

b) Parameters of micro inverter

Table-2. Micro inverter parameters.

Parameters	Value	Unit
Resonant capacitor	120.9	nF
Resonant inductor	84.6	µF
Input voltage	40	V
Transformer turns ratio	8	
Quality factor	4	
Switching frequency	42.2	Hz
RMS output voltage	230	V

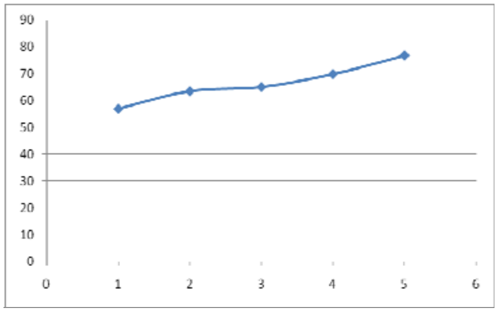

Figure-6. Input power and output power during MPPT test.

Solar array simulator is used to test the capability of maximum power point tracking in micro inverter. Power level and voltage level of micro inverter is measured as shown in the figure 6.Therefore MPP is tracked more than 95% accuracy using MPPT. And to restrict the variation of Q the resonant components L and C should be selected appropriately. And the total impedance of cyclo converter is given as,

$Z = (2/_{3.14}V_{out})/I_{res.}$

And, $M = V_{out}/nV_{in}$

Where M is the instantaneous voltage gain of the inverter.

6. SIMULATION RESULTS AND DISCUSSION

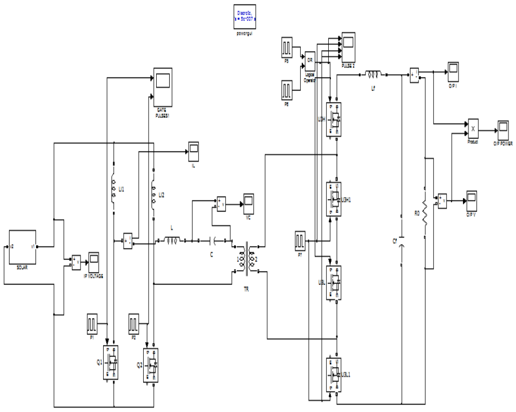

Figure-7. Simulation diagram of proposed system.

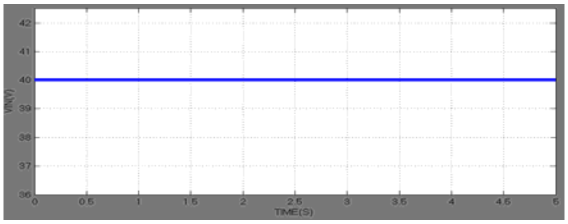

Figure-8. Simulated waveform of Input voltages of a Proposed Half-wave cycloconverter.

The input voltage of both conventional and proposed half wave cycloconverter is given as 40V as shown in the figure.

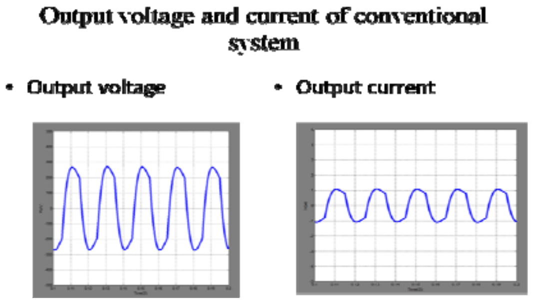

Figure-9. Simulated waveform of output voltage and current of conventional system.

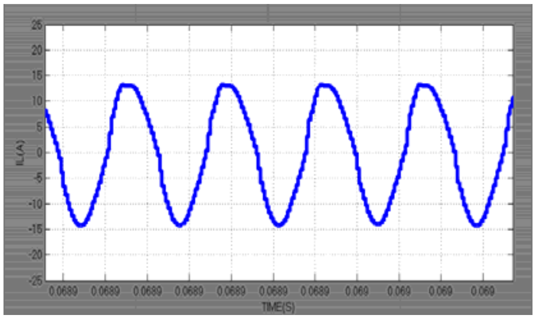

Figure-10. Simulated waveform of inductor current.

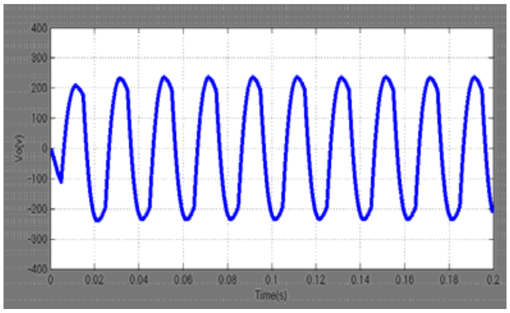

Figure-11. Output voltage of a proposed Half-wave cycloconverter based photovoltaic micro inverter.

The output voltage obtained here is in the level of 200 V which is said to be same voltage obtained in the conventional system.

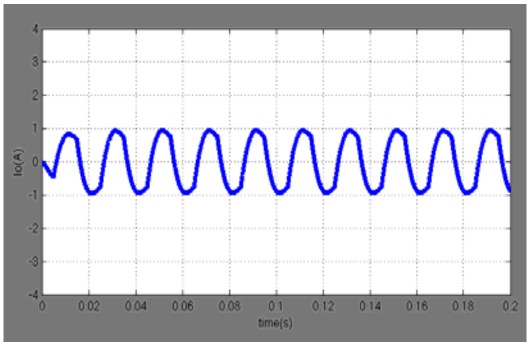

Figure-12. Output Current of a proposed Half-wave cycloconverter based photovoltaic micro inverter.

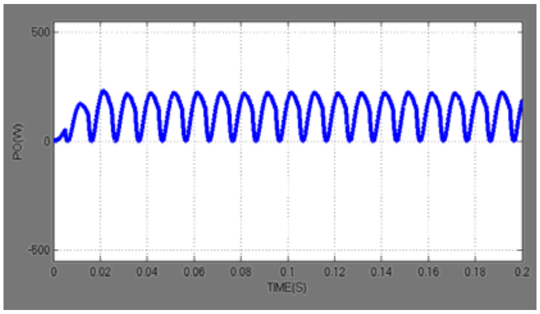

Figure-13. Output power of proposed circuit.

And the above simulation of output power is based photovoltaic based microinverter with R load.

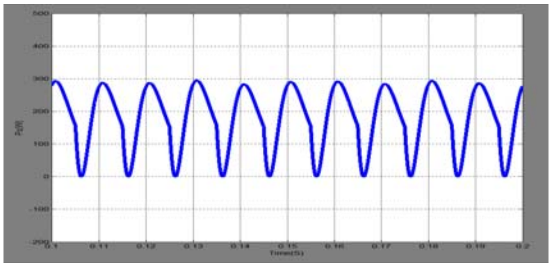

Figure-14. Output power of conventional system.

Thus from the above figure we come to a conclusion that the output power of both the conventional and proposed system are seen to be same which is greater than 250 V even the number of switches are reduced in the proposed system.

7. CONCLUSIONS

A micro inverter topology is proposed with a half-wave cyclo converter and a two inductor with two switches. A relationship between the inverter phase shift, the full-bridge phase shift, the voltage gain of the inverter, the quality factor of the series-resonant tank, and the delivered power is derived. The soft-switching operation of the full-bridge and the half-wave cyclo converter is analyzed using the derived resonant current equation for the three stepped full-bridge output voltage and the half-wave cyclo converter input voltage. Simulation results are presented to verify the design process and the operation of the inverter. In future the number of power switches can be reduced which results in reduced switching and conduction losses.

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