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GRID CONNECTED BOOST-FULL-BRIDGE PHOTOVOLTAIC MICRO-INVERTER SYSTEM USING PHASE OPPOSITION DISPOSITION TECHNIQUE AND MAXIMUM POWER POINT TRACKING

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ABSTRACT

This paper presents a novel Grid-connected Boost full-bridge photovoltaic (PV) microinverter system and its control implementations. This project is a demonstration model of hybrid photovoltaic microinverter system using Phase Opposition Disposition technique and direct control method of Incremental Conductance. Hybrid input is given and stored in the battery for the future purpose. Direct control method if Incremental Conductance is used which requires only one carrier wave and two sine waves. Z- Source network is used in order to overcome the disadvantage of Voltage Source inverter (VSI) and Current source inverter(CSI). Interleaved Boost Converter (IBC) is used in order to split the path of the current and get better efficiency. Interleaved Boost converter consists of Boost converters connected in parallel and controlled by the interleaving method which has the same switching frequency and phase shift.

Index Terms**:** Boost-Full-Bridge, grid-connected photovoltaic (PV) system, Maximum Power Point Tracking (MPPT), Incremental Conductance (IncCond) Photovoltaic micro-inverter, Phase Opposition Disposition technique

I. INTRODUCTION

Hybrid renewable energy systems are becoming popular in remote area power generation applications due to advances in renewable energy technologies and subsequent rise in process of petroleum products. A hybrid energy system usually consists of two or more renewable energy sources used together to provide system efficiency as well as greater balance in energy supply. Photovoltaic array coupled with a wind turbine would create more output from the wind turbine during the winter, whereas during the summer, the solar panels would produce their peak output. Hybrid energy systems often yield greater economic and environmental returns than wind.

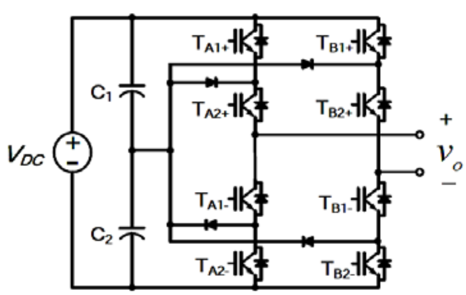
Microinverter are also known as module integrated converter or inverter. It has become a future trend for single phase grid-connected photovoltaic (PV) power system
modules, possibility of individual PV module oriented optimal design, independent maximum power point tracking (MPPT). PV microinverter system is often supplied by a low-voltage solar panel, which requires a high voltage step-up ratio to produce desired output ac voltage. Hence a dc-dc converter cascaded by an inverter is the most popular topology, in which a HF transformer is often implemented within the dc-dc conversion stage.

A photovoltaic microinverter converts direct current (DC) electricity from a single solar panel to alternating current (AC). The combination of various microinverters are fed to the electrical grid. Microinverter contrast with conventional string or central inverter devices, which are connected to multiple solar panels. There are several advantages of microinverter over conventional central inverters. The main advantage being small amount of shading, debris or snow lines on any one solar panel, r even a complete panel failure, does not disproportionately reduce the output of the entire array. Each microinverter harvests optimum power by performing Maximum Power Point Tracking.

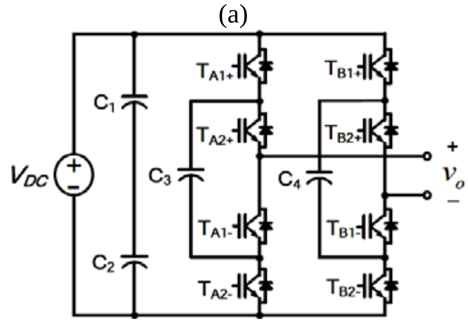
The increasing demand on the renewable energy sources has lead to the importance of grid connected inverter systems. For grid connected inverter operation, the inverter should meet the following requirements:

- The inverter has to generate a pure sinusoidal output voltage.
- The inverter output current should have low total harmonic distortion

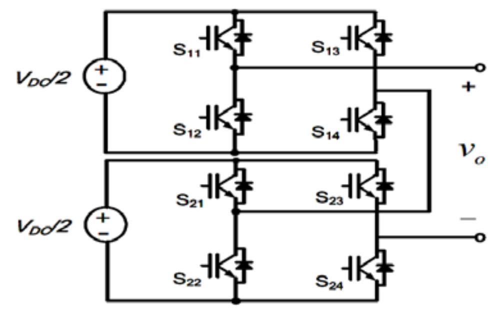
Traditionally, two-level PWM inverter is used for grid-toed operation. In case of a two-level inverter, the switching frequency should be high or the inductance of the output filter inductor need to be big enough to satisfy the required THD. To cope with the problems associated with the two-level inverter, multi-level inverters (MLIs) are introduced for grid connected inverter. Several MLI topologies have been suggested so far and they can be mainly classified as three types as shown in the Fig. 1.
Advantage of the MLIs is that their switching frequency and device voltage rating can be much lower than those of a traditional two-level inverter for the same output voltage. Therefore, IGBT switching loss can be reduced significantly and thus the inverter system efficiency can be increased.



(a)



(b)



(c)

Fig. 1. Topologies of multi level inverter (a) Neutral Point Clamped (NPC) (b) Flying capacitor (c)cascade type

In this paper a circuit based on a H-bridge topology with four switches connected to the dc-link is proposed as a MLI topology. Also it is simple because the proposed PWM method uses one carrier signal for generating PWM signals. In addition a switching sequence considering the voltage balance of dc-link was proposed. Finally, the proposed topology of the multi-level inverter is verified by showing the feasibility through the simulation and the experiment.

II. MAXIMUM POWER POINT TRACKING

Maximum Power Point Tracking is a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels. It is one of the key function that every grid-connected PV inverter should have. There is a large amount of publications that deals with MPPT, and trackers in the majority of the commercial PV inverters are able to extract around 99% of the available power from the PV plant over a wide irradiance and temperature range, at least in steady state.

A. Incremental conductance method

Incremental conductance (IncCond) maximum power point tracking (MPPT) is proposed in this paper. Simulation and hardware implementation of incremental conductance used in solar array power systems with direct control method are presented. This system is capable of tracking maximum power more accurately and rapidly without steady state oscillation and also its dynamic performance is satisfactory. The IncCond algorithm is used to track MPPs because it performs precise control under rapidly changing atmospheric conditions.

B. Direct control method

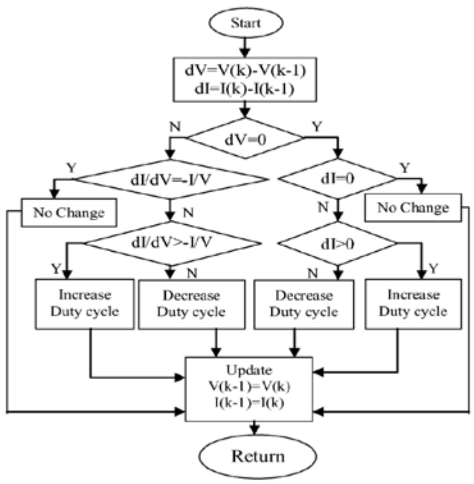


Fig 2. Direct method in Incremental conductance

There are two independent control loops in MPPT. First control loop contains the MPPT algorithm, and the second one is usually a proportional (P) or P-integral (PI) controller. The IncCond method uses instantaneous and IncCond to generate an error signal, which is zero at the MPP; however it is not zero at most of the operating points. The main purpose of the second control loop is to make the error from MPPs near to zero. In this paper, the IncCond method with direct control is selected. The flow chart of direct control method is as shown in Fig. 2.

III. Z SOURCE NETWORK

For the traditional V-source inverter, the dc capacitor is the sole energy storage and filtering element to suppress voltage ripple and serve temporary storage. For the traditional I-source inverter, the dc inductor is the sole energy storage/filtering element to suppress current ripple and serve temporary storage. The Z-source network is a combination of two inductors and two capacitors. This combined circuit, the Z-source network is the energy storage/filtering element for the Z-source inverter. The Z-source network provides a second-order filter and is more effective to suppress voltage and current ripples than capacitor or inductor used alone in the traditional inverters.

IV. PROPOSED MULTI-LEVEL INVERTER

A. Topology of multi-level inverter

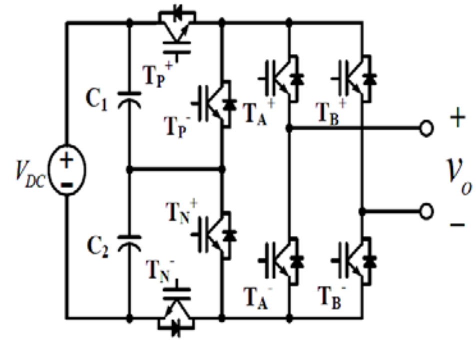


Fig. 3 Proposed single phase multi-level inverter topology

The proposed multi-level inverter topology based on a H-bridge inverter with four switches connected to the dc link is as shown in Fig. 3. As shown in figure the proposed MLI is composed of two dc-link capacitors (C_1, C_2) and four switching devices (T_A^+, T_A^-, T_B^+, T_B^-) comprising a H-bridge, and four active switches (T_P^+, T_P^-, T_N^+, T_N^-) located between dc-link and H-bridge. The voltage across the switching devices in the dc-link (T_P^+, T_P^-, T_N^+, T_N^-) is $V_{DC}/2$ and operated at a switching frequency. Whereas, voltage across the switching devices in the H-bridge (T_A^+, T_A^-, T_B^+, T_B^-) is V_{DC} and the switches (T_A^+, T_A^-, T_B^+, T_B^-) are switched at a frequency of the fundamental component of the output voltage.

TABLE 1
Output voltage according to switching states

Output voltage (V_o)	**Switching condition**					
	T_P^+,	**T_P^-**	**T_N^+**	**T_N^-**	**T_A^+, T_B^-**	**T_A^-, T_B^+**
V_{DC}	ON	OFF	OFF	ON	ON	OFF
$V_{DC}/2$	OFF	ON	OFF	ON	ON	OFF
	ON	OFF	ON	OFF	ON	OFF
0	OFF	ON	ON	OFF	ON	OFF
	OFF	ON	ON	OFF	OFF	ON
$-V_{DC}/2$	OFF	ON	OFF	ON	OFF	ON
	ON	OFF	ON	OFF	OFF	ON
$-V_{DC}$	ON	OFF	OFF	ON	OFF	ON

TABLE 2
Operating mode of the proposed MLI

Operating mode	Reference voltage range	Output voltage
Mode 1	$V_c \le V_{ref} < 2V_c$	$V_{DC}/2$ or V_{DC}
Mode 2	$0 \le V_{ref} < V_c$	0 or V_{DC}
Mode 3	$-V_c \le V_{ref} < 0$	$-V_{DC}/2$ or 0
Mode 4	$-2V_c \le V_{ref} < -V_c$	$-V_{DC}$ or $-V_{DC}/2$

B. Operating modes and proposed PWM strategy

A new PWM strategy based on POD modulation which requires only a single carrier signal ($V_{carrier}$) is proposed and the detailed PWM strategy is depicted. If the reference signal is positive, then the switch pair (T_A^+, T_B^-) are turned on, and if it is negative, then the switch pair (T_A^-, T_B^+) are turned on.

The generation of the PWM signal for dc-link switches (T_P^+, T_N^-) can be explained as follows.

- Mode 1: a signal subtracted from the reference signal by Vc is compared with the carrier signal. If $V_{ref} - V_c > V_{carrier}$, then all switches T_P^+ or T_N^- is turned on. If $V_{ref} - V_c < V_{carrier}$, then the switch T_P^+ or T_N^- is turned off alternately.
- Mode 2: The reference signal is directly compared with a carrier signal. If $V_{ref} > V_{carrier}$, then the switch T_P^+ or T_N^- is turned on alternatively. If $V_{ref} < V_{carrier}$, then all switches T_P^+ or T_N^- are turned off.
- Mode 3: $-V_{ref}$ is directly compared with a carrier signal. If $-V_{ref} > V_{carrier}$, then the switch T_P^+ or T_N^- is turned on alternatively. If $-V_{ref} < V_{carrier}$, then all switches T_P^+ or T_N^- are turned off.
- Mode 4: A signal subtracted from $-V_{ref}$ by Vc is compared with the carrier signal. If $-V_{ref} - V_c > V_{carrier}$, then all switches T_P^+ or T_N^- are turned on. If $-V_{ref} - V_c < V_{carrier}$, then the switch T_P^+ or T_N^- is turned off alternately.

Only one carrier signal is used to generate eight PWM signals in the proposed PWM method. Thus it is quite simple.

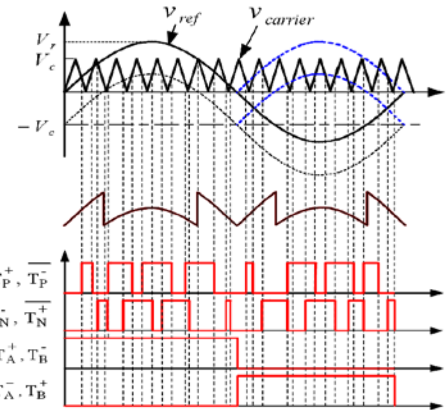


Fig. 4 PWM strategy based on POD with single carrier signal

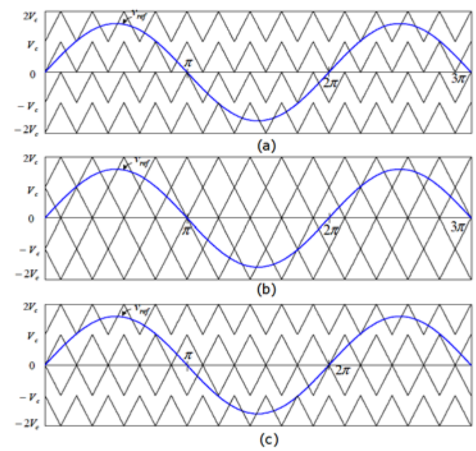


Fig. 5. Carrier and reference signal arrangement for: (a) Phase Disposition (PD) (b) Alternative Phase Opposition Disposition (APOD) (c) Phase Opposition Disposition (POD)

V. FULL BRIDGE BOOST CONVERTER

A Boost converter (Step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

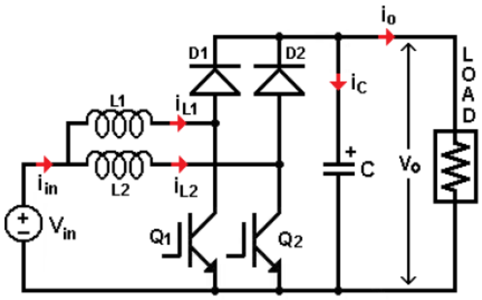


Fig. 6 Interleaved Boost DC-DC converter

A. Interleaved Boost converter

Interleaved Boost dc-dc converter is proposed for current sharing on high power application. The schematic of the interleaved boost dc-dc converter is as shown in Fig. 6.A basic boost converter converts a DC voltage to a higher DC voltage. Interleaving adds additional benefits such as reduced ripple currents in both the input and output circuits. Higher efficiency is realized by splitting the output current into two paths, substantially reducing I^2R losses and inductor AC losses.

VI. BLOCK DIAGRAM DESCRIPTION

The Schematic block diagram of the proposed system is as shown in the Fig. 9. solar energy and wind energy are the main input source of this system. Solar energy gives Direct current and wind gives alternating current. The maximum power is tracked using Maximum Power Point Tracking. Solar and the wing energy are combined together. Wind energy gives alternating current which is converter into dc using a rectifier. The dc from solar and the wind combine together and the average dc supply is given to the Z source network which is used to overcome the disadvantage of Voltage Source Inverter(VSI) and Current Source Inverter(CSI). It constitutes of two inductors and two capacitors. The main purpose of using Z source network is that it can perform both Buck and boost operation.

The Boosted output from the Z-source network is given to the inverter which converts the DC into AC. Step up transformer is used to step up the voltage applied to it. It is then given to the rectifier which converts AC into DC and then gives the output to the multilevel inverter which uses the POD technique and hence the harmonics gets reduced. The output of the above process can be viewed through the Cathode Ray Oscilloscope(CRO).

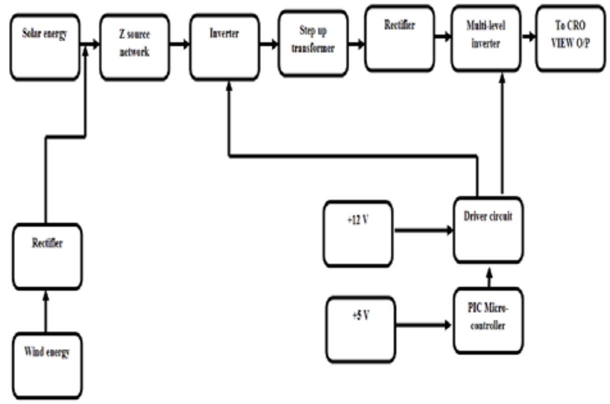


Fig. 9. Block diagram of the proposed system

VII SIMULATION

The simulation is mainly carried out under three categories.

- With interleaving and proposed cascaded H-bridge MLI using POD technique as shown in Fig. 10.
- With interleaving and normal MLI as shown in Fig. 11.
- Without interleaving and proposed cascaded H-bridge MLI using POD technique as shown in Fig. 12.

A. *With interleaving and proposed cascaded H-bridge MLI using POD technique.*

The simulink model of the proposed system is as shown in fig. 10. The solar and the wind input are combined together and given to the Z source network which acts as the boost up the voltage and then passes through the interleaved circuit which splits up the voltage and gives higher efficiency. The DC output is given to the MLI which along with POD technique reduces the harmonic distortions.

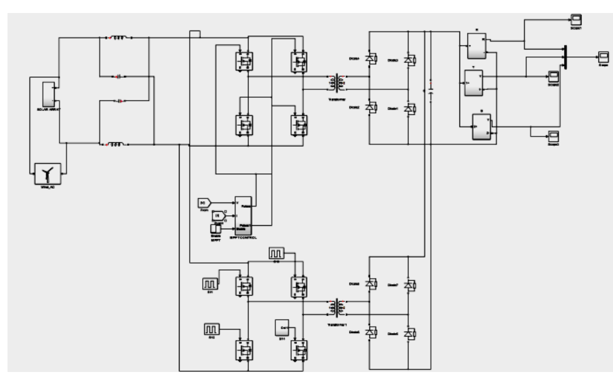


Fig. 10. Simulink model with interleaving and POD technique

B. *With interleaving and normal MLI*

The simulink model of the system with interleaving and the normal Multi-level inverter is as shown in Fig. 11. Normal 5 level inverter is used.

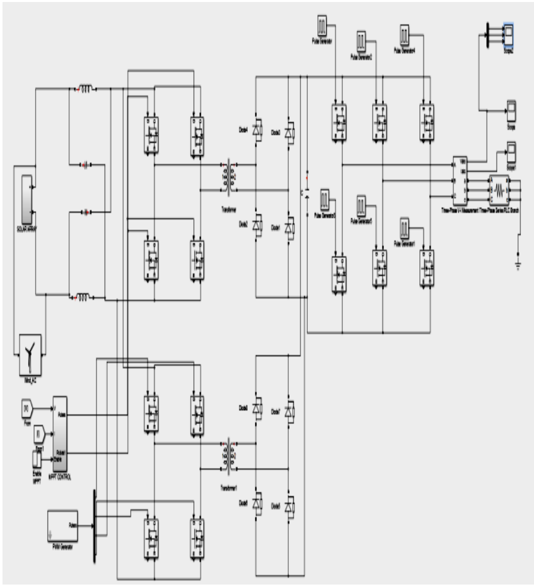


Fig. 11. Simulink model with interleaving and normal MLI

C. *Without interleaving and proposed MLI*

The simulink model Of the system without interleaving
and the proposed MLI is as shown in Fig. 12. MLI with phase opposition Disposition technique is used.

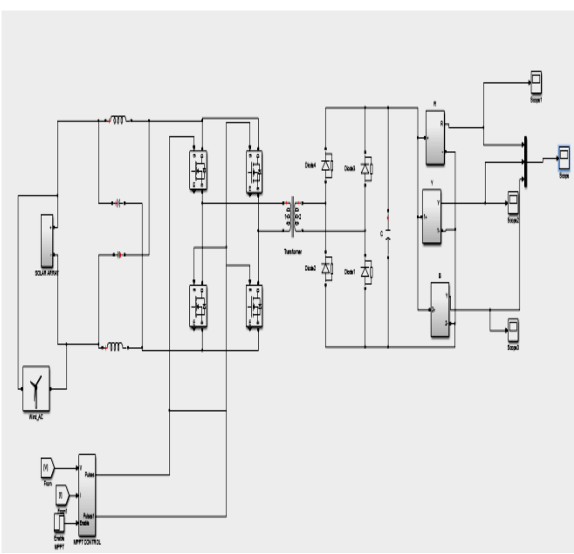


Fig. 12. Simulink model without interleaving and POD technique

VIII. RESULTS

A. *With interleaving and POD technique*

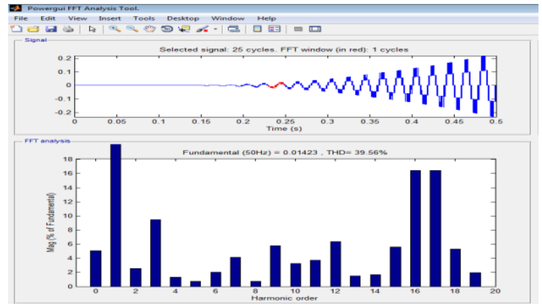


Fig. 14: O/P - with interleaving and with POD technique

B. *With interleaving and normal MLI*

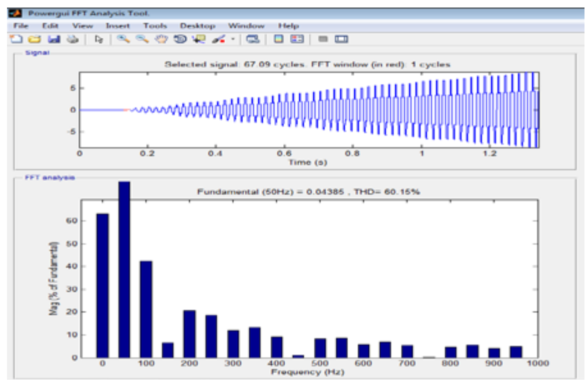


Fig. 16: O/P - with interleaving and normal MLI

C. *Without interleaving and POD technique*

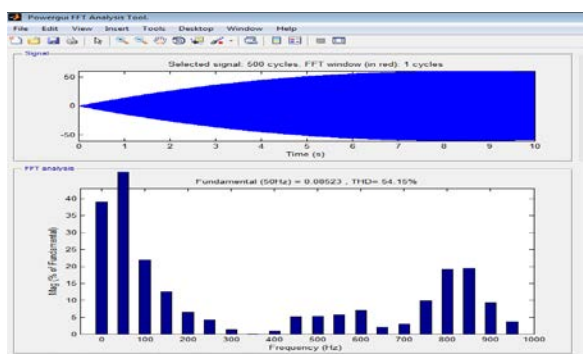


Fig. 15. Without interleaving and POD technique

IX. CONCLUSION

This project presents the hybrid photovoltaic microinverter system using Z source network, Phase Opposition Disposition network and Maximum Power

Point Tracking. Wind energy is used to give the backup energy when there is a lack of solar energy. Z source network or the impedance source network is used in order to overcome the disadvantage of Voltage Source Inverter and Current Source Inverter. It constitutes of two inductors and two capacitors. IBC (Interleaved Boost Converter) is used to get the better efficiency. Interleaved Boost Converters are those in which the Boost converters are connected in parallel. Interleaved Boost converters splits the current path and hence reduces the efficiency. Maximum Power Point Tracking is used to grab the maximum power from one or more photovoltaic devices typically solar panels. Incremental conductance method is used with direct control technique. A new Multi Level Inverter topology with 4 switches is used. Phase Opposition Disposition Technique is used which requires only one carrier wave. The comparison is made with the normal Multi Level Inverter along with Interleaved Boost Converter and with new Multi Level Inverter topology without interleaving the Boost converter.

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