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Multi-Input RES Based Interleaving High Frequency Bidirectional Transformer less Inverter

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ABSTRACT

A New Multi-Input Transformerless Photo voltaic inverter with bidirectional capability has been developed where the concept of High Frequency Leg (HFL) is used. This allows the use of high switching frequency which reduces the size of the filter elements. As the number of legs is increased, the power handling capacity of the inverter is increased and the inductor current ripple is reduced. The bi directional feature of this inverter has made it more attractive for PV applications.

***Keywords*- Basic Switching Cells, Photovoltaic Inverters without Isolation Transformer, Bidirectional power flow, High Frequency Leg**

I. INTRODUCTION

Generally, the solar based power systems consist of PV panel, battery, inverter, load or grid. The solar panel produces the DC power during the sunshine hours. The excess power generated is stored in batteries but these batteries add the recurring cost. The DC power is converted to AC with the help of inverter. The AC is then fed into the grid, from where it can be used for the domestic, commercial and industrial applications. During the non-sunshine hours, the user relies upon the batteries. When both panel and battery doesn't work, the bidirectional inverter charges the battery from the energy supplied by the grid.The PV generating system is shown in Fig.1.

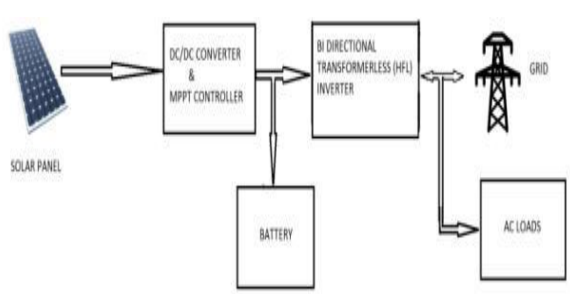

Fig. 1. Block diagram of PV Generating System

To provide a short circuit current path on the DC side carrier-based modulation technique has been used in [1] to magnetize the inductor after every operation mode. The photo-voltaic inverter with no transformer for isolation has become more attractive due to higher efficiency and lower weight. However, the problem is DC offset current which is critical to the power system [2]. To construct a general series and parallel grid-interfacing system, two four leg three-phase inverter circuit together with DC micro-sources and non-linear loads are employed [3]. A single phase series-connected inverter is used to interconnect AC loads with the micro-grid. The control strategy is designed to stabilize the load voltage irrespective of the grid voltage magnitude as well as transfers a specific amount of renewable source based power to the load. Besides, the inverter is forced to operate at leading power factor irrespective of the power factor of the load. To track as well as eliminates the harmonics in the load voltage, a nonlinear Spatial Repetitive Controller (SRC) is used which facilitates the control strategy. The controller is implemented based on position domain of the fundamental micro grid phase angle [4]. Two basic switching cells, the P-NPCC (Positive Neutral Point Clamped Cell), and the N-NPCC (Negative Neutral Point Clamped Cell) for the grid-tied inverter topology generation is used to build NPC topologies. A family of single phase transformer less full-bridge NPC inverter topologies based on the basic switching cell is derived with low leakage current. The (Positive Negative-NPC) PN-NPC topology has the following advantages and evaluated by experimental results. 1) The common-mode voltage is clamped to a constant level, so the leakage current can be well suppressed effectively. 2) The excellent differential mode characteristic is achieved like the isolated full-bridge inverter with unipolar SPWM. 3) The PN-NPC topology features the best conversion efficiency [5].

Transformer less inverters has advantages over the Standard inverters.Standard inverters have a build-in transformer which synchronizes the voltage with that of the grid and the various appliances. Also they have Galvanic Isolation which accounts for the safety. For the Transformer less inverters, the efficiency is high as the losses are reduced due to the absence of transformers. The cost is also less when compared to the standard

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inverters. The complexity is reduced and it improves the reliability of the system.

The Transformer less inverters are checked for the presence of leakage current, to ensure safety.The magnitude of leakage current depends upon the common mode voltage. The common mode voltage is defined as the voltage of equal magnitude and phase component appearing in both the lines of the 2 wire cable. One way of eliminating the common mode voltage is the use of inductor in the bifiliar winding which will eliminate the higher frequency common mode signals.

In order to overcome the drawbacks of conventional inverters, the bi directional Transformer less inverter is proposed which has the following features that increases the power handling capacity of the inverter. The features are:

1. The shoot-through fault is eliminated, which increases the reliability.
2. The leakage current due to common mode voltage is reduced, due to the use of inductor in the bifiliar windings.
3. MOSFET switches are employed, as they operate at high switching frequency. Also they have low conduction and switching losses, which improves the overall efficiency of the system. The size of the filter elements is reduced considerably as they are operated at high switching frequency.
4. Depending upon the demand, the inverter capacity can be increased by adding extra legs (HFL) in the circuit.
5. The most important feature is the bi directional power handling capacity, where it works as inverter when power flows from panel to grid and as the rectifier when the power flows from the grid to the battery.

II.HIGH FREQUENCY LEG CONCEPT OF PROPOSED SYSTEM

A. *Basic Switching Cells*

The switching cells are combined to form power electronic circuits. Each cell is made up of a controllable switch (MOSFET,IGBT) and an uncontrolled diode in series to it. It has got three terminals: (+) connected to the source positive, (-) connected to the negative of source and the third terminal at the junction of the two switches which allows bi directional power flow. By using the switching cells in the power electronic circuit, the shoot- through fault is eliminated.The basic switching cells are shown in Fig.2.

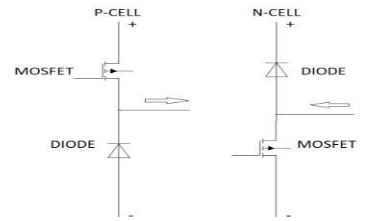

Fig. 2. The basic Switching Cells

The P-cell and N-cell can be connected in parallel to form a phase leg of the bi directional inverter. The advantage of using the above parallel leg in comparison to the conventional IGBT with an anti-parallel diode is that the dead time required between the switching of any two cells is eliminated. Even the IGBT – diode can be used for the construction of parallel leg of the inverter, it is not generally preferred as the IGBT switches have high switching losses.

B. *MOSFET in HFL Technique*

The MOSFET switches are used as they do not suffer from reverse body recovery. The operating frequency is high compared to IGBT switches. The switching losses of the MOSFET switches are relatively low compared to that of IGBT switches. The MOSFET switches used for the construction of the parallel leg is shown in Fig.3.

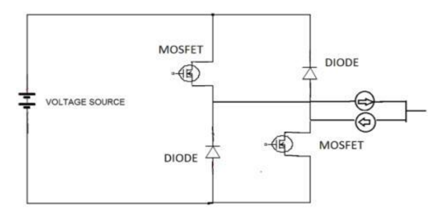

Fig. 3 Parallel Combination Of legs

In this paper, IGBT switches are replaced by MOSFET switches which has better switching performance. The multiple legs of the bridge are integrated and the switches are turned on with high-frequency control signals, hence efficiency is improved.

III.CONVENTIONAL TRANSFORMER LESS PHOTOVOLTAIC INVERTERS

The number of conventional inverter topologies are available. The first example is the Classic Full-

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Bridge Inverter. The advantage of this inverter is that the leakage current is eliminated, but the drawback is the shoot-through fault. The
drawback with Highly Efficient and Reliable *Inverter* Concept *converter (*HERIC) topology is the use of more semiconductors and its reactive power incapability. The disadvantage of H5 inverter structure is the higher conduction losses [6-9].

IV. PROPOSED BIDIRECTIONAL TRANSFORMERLESS INVERTER.

The proposed Inverter topology consist of N-cell legs and P-cell legs. The number of N cell legs with separate inductors are integrated to form a single leg. The N-Cell leg is made up of upper diode and lower MOSFET in series to it. The P-cell leg is made of the upper IGBT switches without antiparallel diode and the lower diode which is connected in series. There are totally eight inductors used. The grid voltage directions are selected by the P-cell legs. The third terminal of the first P-cell leg is connected with the positive port of grid side and the negative N-cell comprising of the inductors L_{n1},L_{n2},L_{n3} and L_{n4}. Similarly the third terminal of the second P-cell leg is connected to the negative of the grid side and to the N-cell with inductors L_{p1},L_{p2},L_{p3} and L_{p4}. The circuit diagram of the proposed system is shown in Fig.4.

The switches S_{nf} and S_{pf} are operated at inverter mode while the diodes are active during the storage mode.

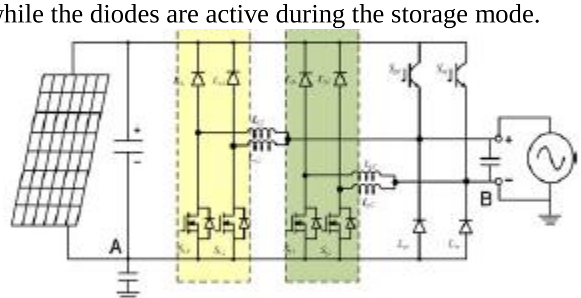

Fig.4. Circuit Diagram

The proposed inverter topology operates in two modes of operation such as PV mode and storage mode.

A. *PV mode(Inverter mode)*

In this mode of operation, the switches S_{pf},S_{nf} are active. Since there is no parallel diode in IGBT, the dead time requirement is reduced. During the positive half cycle, the switch S_{pf} is turned on, where the switches S_{p1},S_{p2},S_{p3} and S_{p4} are controlled by the gating signals. During the negative half cycle, the switch S_{nf} is turned on, which controls the firing of S_{n1},S_{n2},S_{n3} and S_{n4}. Inorder to reduce the current ripple at the AC side, the carrier signal during the negative half cycle is given a phase shift of 180 degree. The Interleaving modulating technique is shown in Fig.4(a).

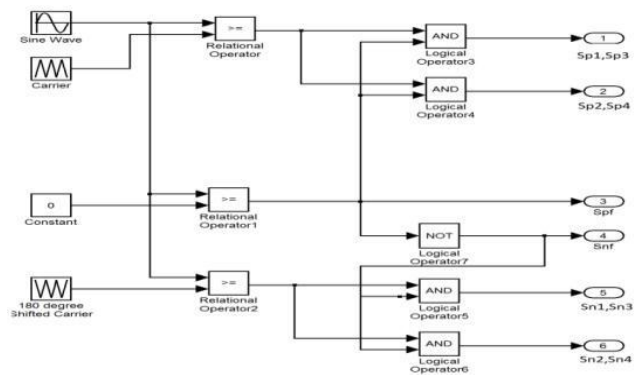

Fig. 4(a). Modulating Technique

The reference wave is compared with the carrier and the outputs are generated for the P-cell switches. The carrier is phased shifted by 180 degree and is compared with the reference wave. The outputs generated from the later comparison are used as the gating signals for the N-cell switches.The modulating signals based on the above modulating circuit is shown in Fig.4(b).

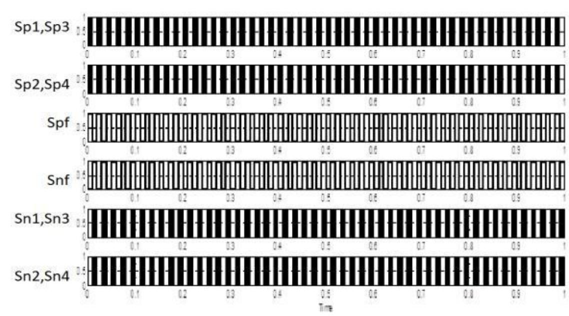

Fig.4(b). PWM Generated Signals

There are four modes of operation. In the first mode of PV mode, all the four switches are turned on. The voltage across the inductor is increasing steadily. In the second mode of PV mode, two switches(S_{p2},S_{p4}) are turned on, the voltage across the inductor decreases. The free wheeling path is provided by the diode D_{p1},D_{p3}. In the third mode, all the controllable switches are turned off while the diodes are conducting. The voltage across the inductors is increasing. In the fourth mode, the two switches S_{p1}, S_{p3} are turned on, while the free wheeling path is provided by diodes D_{p2} and D $_{p4}$. The voltage across the inductors are decreasing. The various operating modes of PV mode is shown in Fig.5.

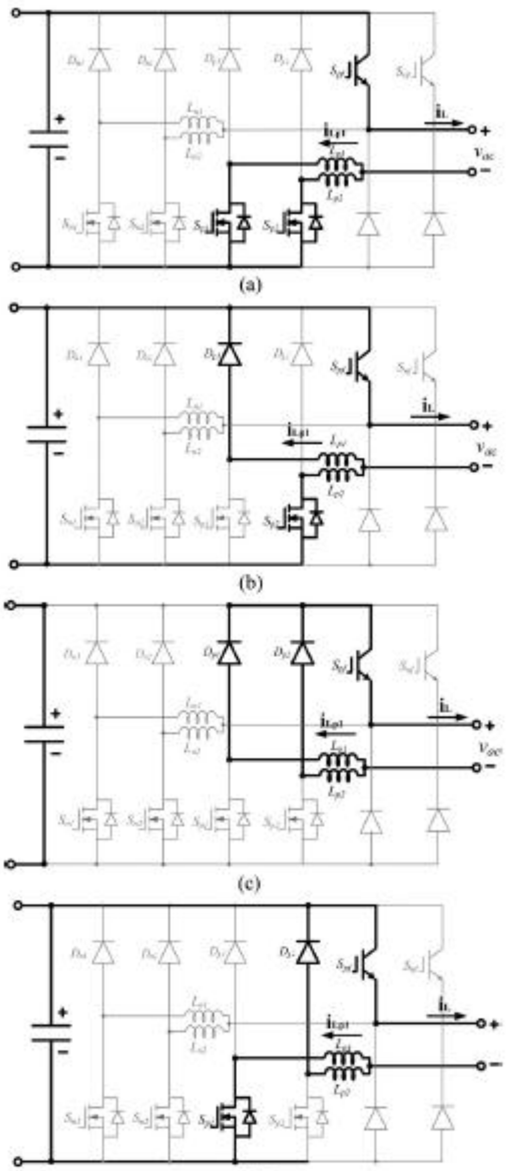

Fig.5. Operating modes in PV mode

B. *Storage Mode (Rectifier Mode)*

In this mode of operation, the diodes D_{pr},D_{nr} play an important role whereas the switches $S_{pf}$and $S_{nf}$are turned off. Similar to the previous operating mode, the storage mode also has got four operating modes. Even during this mode of operation, all the features of the proposed system are achieved.

The operation can be explained as follows. During the first interval, the diode D_{nr} is turned on, and the controllable switches S_{n1},S_{n2},$S_{n3}$and S_{n4} are conducting. The inductors L_{n1},L_{n2},L_{n3} and L_{n4} are charged. In the second mode, the switch S_{n2} and S_{n4} are conducting. The diodes D_{n1} and D_{n3} provide the freewheeling path. The inductor L_{n2} and L_{n4} are charged while the inductors L_{n1} and L_{n3} are discharged. In the third mode, the diodes D_{n1},D_{n2},D_{n3} and D_{n4} are conducting while all the switches are turned off. The inductors L_{n1},L_{n2},L_{n3} and L_{n4} are discharged. In the fourth mode, the switches S_{n1} and S_{n3} are conducting while the diodes D_{n2} and D $_{n4}$ are provide the return path. The inductor L_{n1} and L_{n3} are charged while the inductor L_{n2} and L_{n4} are discharged. The various operating modes in Storage mode(rectifier mode) is shown in Fig. 6

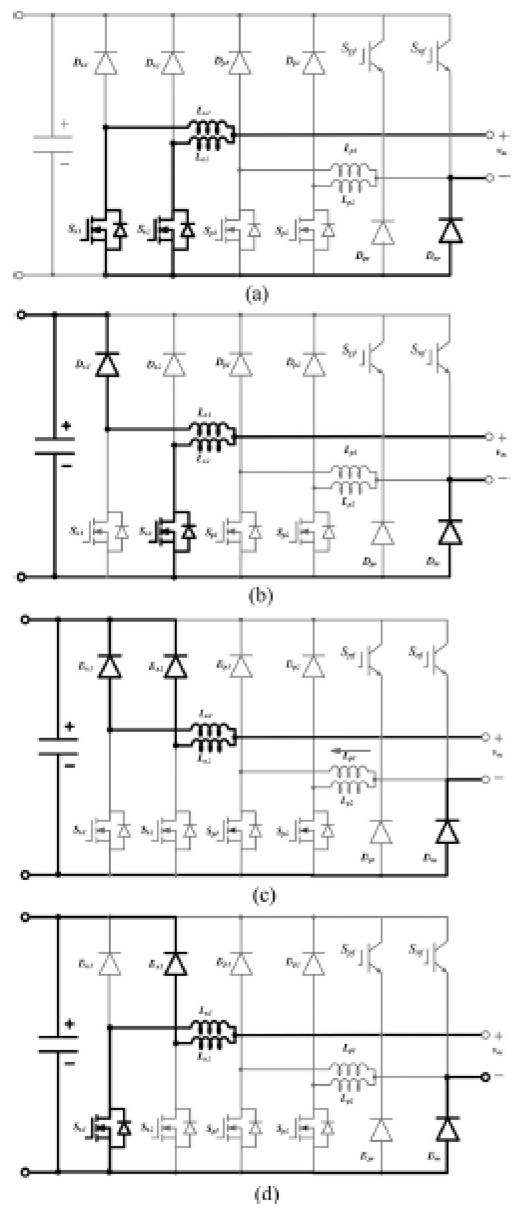

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Fig.6. Operating modes in Storage mode

V. SIMULATION RESULTS

The simulation is done using the MATLAB/SIMULINK. The input DC voltage from the PV panel is approximately 380V. As the number of legs increases, the capacity of the inverter also increases. The various parameters like efficiency, leakage current , THD of output voltage are obtained. The simulation is done for the Resistive load.

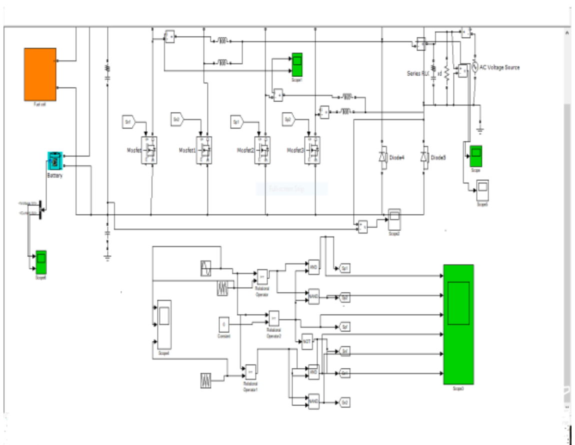

Fig.7. Multi-input Simulation Circuit

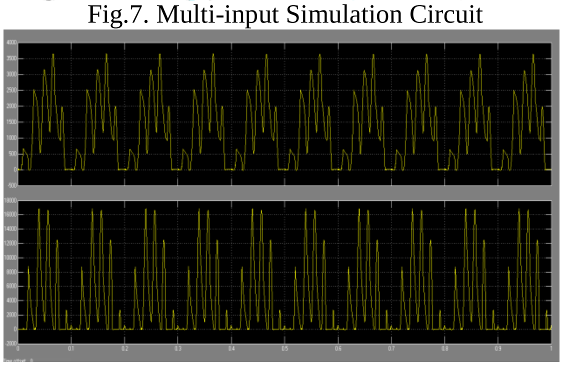

Fig 8. Current across Lp1, Ln1 inductors waveform

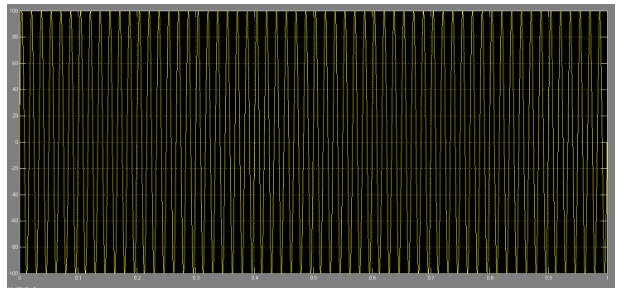

Fig 9. Output voltage across load

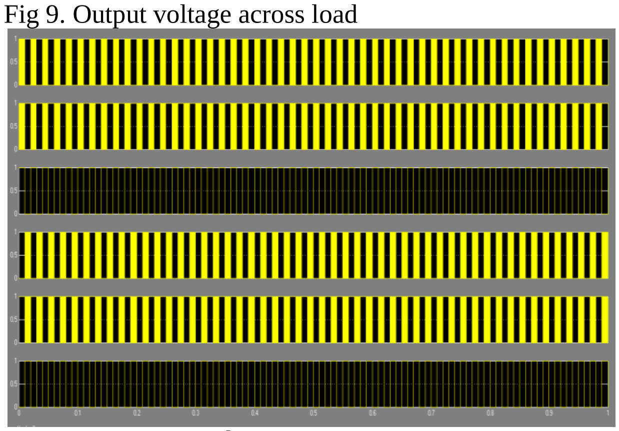

Fig 10. Gating Signals

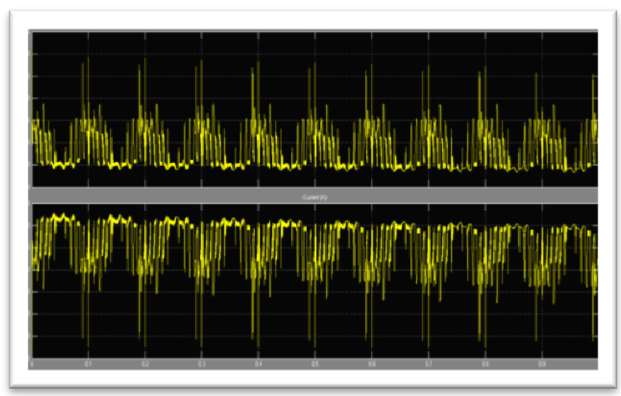

Fig 11. Output across fuel cell

VI. CONCLUSION

The smooth AC current is achieved using the High Frequency Leg concept. The switching frequency is increased which reduces the inductor current ripple. There is no dead time required between the switching period whichreduces the distortions in the AC output current. Also the capacity of the inverter is increased easily by increasing the number of high frequency legs. Additionally this topology can work under the rectifier mode having the bi directional power capability, which is attractive for PV application. In this paper, the comparison between the bi directional inverter with 2 and 4 legs has been done by simulating the circuits in MATLAB.

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