



- The leakage current due to common mode voltage is reduced, due to the use of inductor in the bifilar windings.
- 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.
- Depending upon the demand, the inverter capacity can be increased by adding extra legs (HFL) in the circuit.
- 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.

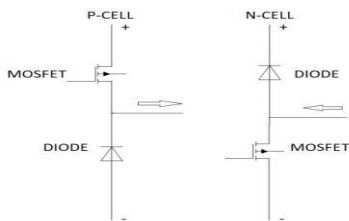


Fig. 2. The basic Switching Cells

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.

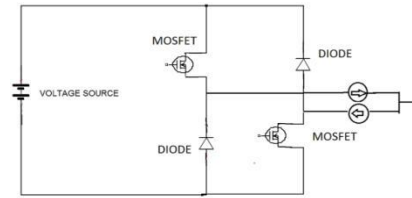


Fig. 3 Parallel Combination Of legs

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-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 TRANSFORMER LESS 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.7.

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

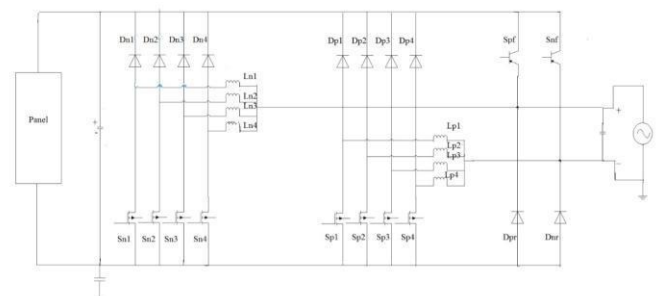


Fig.7. Circuit Diagram

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  $S_{n4}$ . In order 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.7(a)

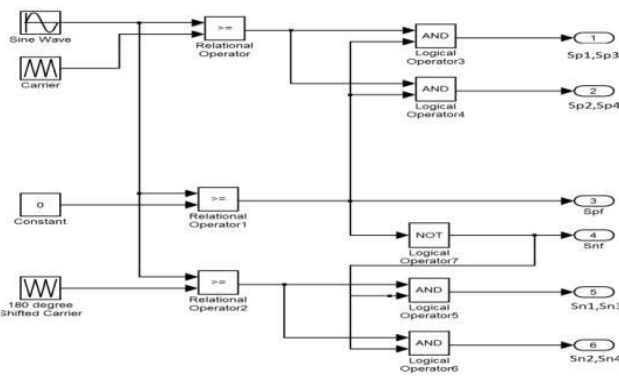


Fig. 7(a). Modulating Technique

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.7(b).

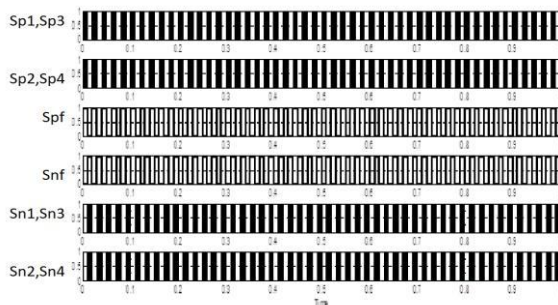


Fig.7(b). PWM Generated Signals

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.8

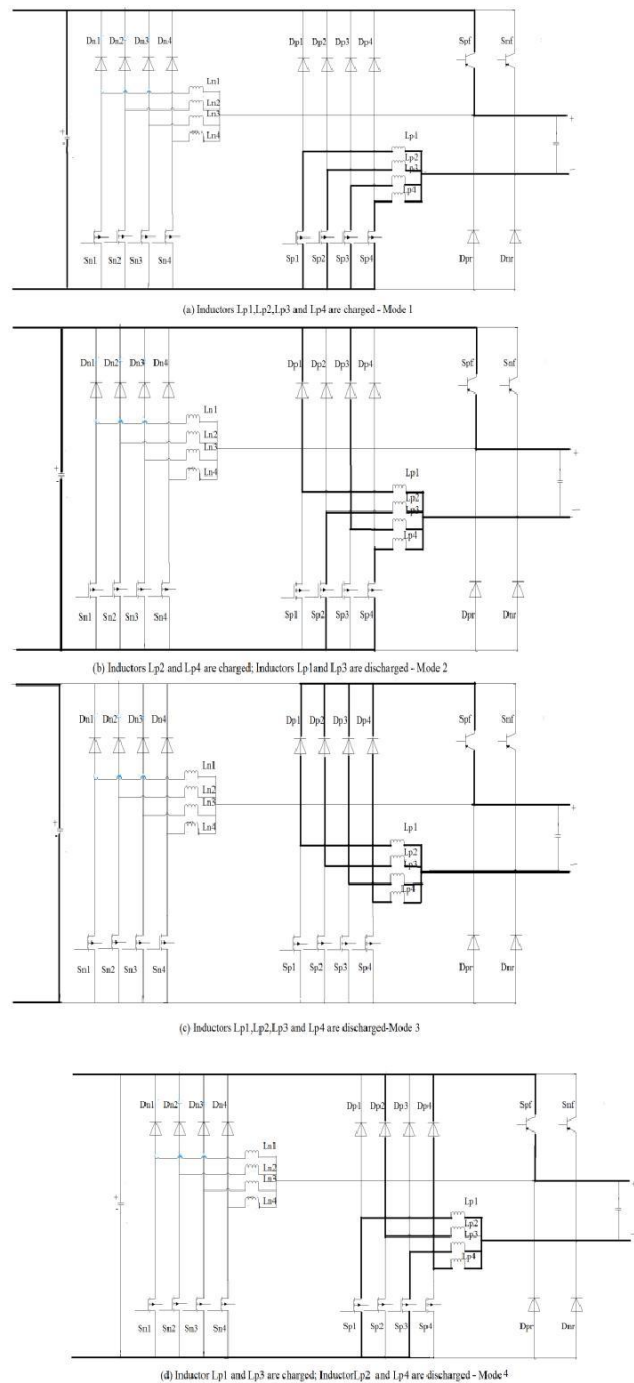


Fig.8. Operating modes in PV mode

**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. 9

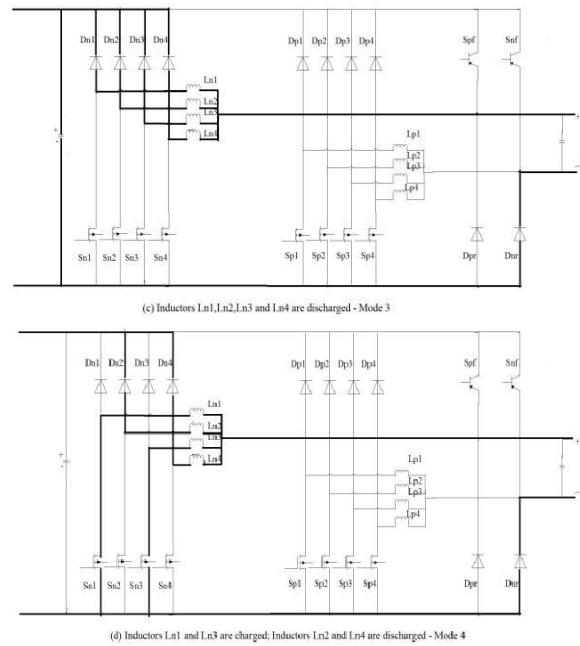


Fig.9 Operating modes in Storage mode

## 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

### A. Simulation of Proposed System with wind energy

The circuit diagram of the proposed system (with two legs) is simulated using MATLAB. The simulation is done for the resistive load and the simulation circuit is shown in Fig.10

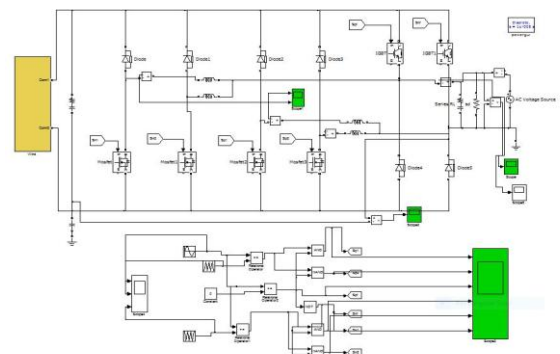


Fig.10. Simulation of Bidirectional Inverter with (wind energy)



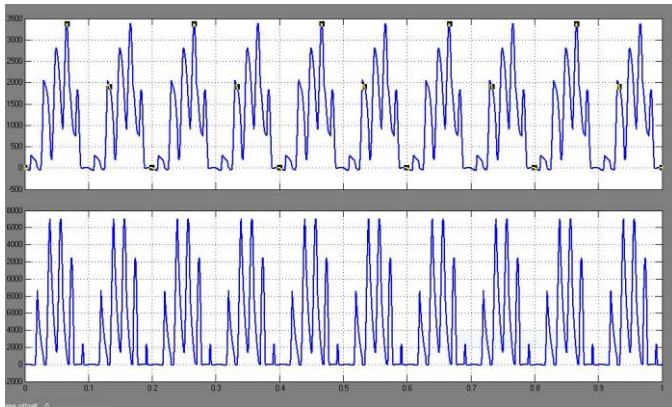


Fig.11: Ripple currents through inductors

Ripple current through inductors may not change however there is an additional power supply delivered by Photovoltaic inverter, To prove there is no effect the following figure will give the nature of ripple current through inductors.

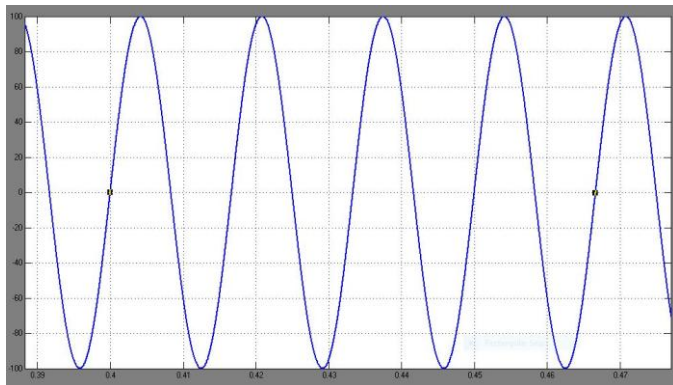


Fig.12: Output voltage across PV inverter

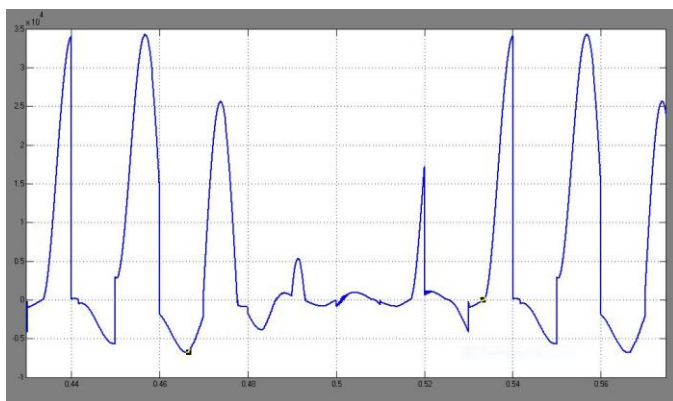


Fig.13: Voltage drop across inductors

Simulation model for Transformer less photovoltaic inverter based on interleaved HFL having bidirectional capability have designed in the MATLAB. Waveforms of current ripples through inductors, voltage drop across interleaved HFL legs, PWM techniques used for the triggering circuit and output voltage across PV inverter have been produced and analyzed. The CM leakage current has also been reduced to a smaller extent and output power delivered by the inverter circuit has improved by providing a wind energy turbine.

From the above tabulation, it is concluded that as the number of legs in the circuit increases, the efficiency is improved. The leakage current is reduced and the harmonic distortion is also reduced.

## 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 which reduces 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, Simulation model for Transformer less photovoltaic inverter based on interleaved HFL having bidirectional capability have designed in the MATLAB. Waveforms of current ripples through inductors, voltage drop across interleaved HFL legs, PWM techniques used for the triggering circuit and output voltage across PV inverter have been produced and analyzed. The CM leakage current has also been reduced to a smaller extent and output power delivered by the inverter circuit has improved by providing a wind energy turbine. has been done by simulating the circuits in MATLAB.

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## REFERENCES

- i. ALAJMI, B.N., AHMED, K.H., ADAM, G.P., WILLIAMS, B.W., —SINGLE-PHASE SINGLE-STAGE TRANSFORMER LESS GRID-CONNECTED PV SYSTEM, // IEEE TRANS. POWER ELECTRON., VOL.28, NO.6, PP.2664-2676, JUNE 2013.
- ii. Guofeng He, Dehong Xu, Min Chen, —A Novel Control Strategy of Suppressing DC Current Injection to the Grid for Single-Phase PV Inverter// IEEE Trans. Power Electron., vol.30, no.3, pp.1266-1274, March 2015.
- iii. W. Fei, J. L. Duarte, and M. A. M. Hendrix, —Grid-interfacing converter systems with enhanced voltage quality for microgrid application-concept and implementation, // IEEE Trans. Power Electron., vol. 26, no. 12, pp. 3501-3513, Dec. 2011.
- iv. S. Dasgupta, S. K. Sahoo, S. K. Panda, and G. A. J. Amaratunga, —Single phase inverter-control techniques for interfacing renewable energy sources with micro grid—Part II: Series-connected inverter topology to mitigate voltage-related problems along with active power flow control, // IEEE Trans. Power Electron., vol. 26, no. 3, pp. 732-746, Mar. 2011
- v. L. Zhang, K. Sun, L. Feng, H. Wu, and Y. Xing, —A family of neutral point clamped full-bridge topologies for transformer less photovoltaic grid-tied inverters, // IEEE Trans. Power Electron., vol. 28, no. 2, pp. 730-739, Feb.2013.

vi. S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, —A review of single-phase grid-connected inverters for photovoltaic modules, // *IEEE Trans. Ind. Appl.*, vol. 41, no. 5, pp. 1292–1306, Sep. 2005.

vii. R. Gonzalez, J. Lopez, P. Sanchis, and L. Marroyo, —Transformer less inverter for single-phase photovoltaic systems, // *IEEE Trans. Power Electron.*, vol. 22, no. 2, pp. 693–697, Mar. 2007.

viii. S.M.Araujo, P. Zacharias, and R. Mallwitz, —Highly efficient single-phase Transformer less inverters for grid-connected photovoltaic systems, // *IEEE Trans. Ind. Electron.*, vol. 57, no. 9, pp. 3118–3328, Sep. 2010.

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