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Design of Interleaved Inverter Topology for Photovoltaic Applications and Analysing its Performance

*1Y. Sathish Kumar, 2P. J. Chinmayee, 3K. Afreed Baba, 4S. Mahammad Subahan, 5B. Jahnavi, 6K. Indrakshi

**1Y. Sathish Kumar Assistant Professor of EEE Department, SRIT-ATP*
2P. J. Chinmayee student of EEE Department SRIT-ATP
3K. Afreed Baba student of EEE Department SRIT-ATP
4S. Mahammad Subahan student of EEE Department SRIT-ATP
5B. Jahnavi student of EEE Department SRIT-ATP
6K. Indrakshi student of EEE Department SRIT-ATP

Abstract:
Design of interleaved inverter topology for photovoltaic applications is presented in this paper along with performance analysis. This VSI topology has been enduring one of the preliminary issues like shoot-through effect where, two switches of same leg come into contact during operation. This shoot-through leads to damage the whole inverter circuit. To mitigate this type of shoot-through issues in the inverter operation, an interleaved inverter topology is being proposed. Additionally, a single tuned filter is designed to eliminate the dominant odd order harmonics from the system. The interleaved inverter topology construction is contrast from the conformist VSI. The proposed topology is designed and modelled in MATLAB/Simulink environment. The simulation results are showed that the proposed topology is giving satisfactory results for PV application by eliminating the perilous shoot-through effect.

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I. INTRODUCTION

In the world, due to the pollution and continuing depletion of conventional resources such as coal, fossil fuels, diesel. encourage the utilization of renewable energy sources. There are various renewable energy sources like photovoltaic, wind turbine, and tidal are utilized for the generation of energy. Among all the resources, PV is the most popular because of its characteristics like easily available in worldwide, and easy to install and maintain.

The VSI is severely suffering from hazardous conditions, ie., shoot through problem. The shoot through mode occurs when the 2 power switches in the same leg are inadvertently switched on simultaneously. Therefore, extremely high current flows through it which damage the power devices. An interleaved inverter based PV system is proposed in this paper to eliminate aforementioned problems of conventional VSI topology.

II. LITERATURE SURVEY

The perturb and observe (P&O) algorithm is the most commonly used in practice because of its ease of implementation. The method is basically iterative approach, in which operating point of solar PV oscillates around the maximum power point. The introduced approach also uses P&O method to track the MPP of PV panel because it's simple structure to implement in real-time system with low-cost controllers, efficient, and robust [1].

The shoot through phenomena is one of the failure modes in conventional voltage source inverter (VSI) which may damage power switches. The introduced approach was designed and modelled with the interleaved inverter for PV applications to overcome the problems of shoot-through [2].

The performance and economic analysis of on – grid and off – system and the power usage of building, panel required, Inverter rating, charge controller and battery analysis for both on–grid and off-grid system. The introduced approach was incorporated with PV panels to extract electric power from the nonconventional energy resources i.e., solar [3].

The basic designing, analysis and implementation of the L filter for attenuating the grid current harmonics and improving the power quality. The comparative analysis related to stability, complexity, cost and application of L filter has been presented and a step-by-step approach to design a L filter has also been explained. The introduced approach was incorporated with L filter to eliminate the dominant odd order harmonics from the system [4].

III. PERTURB & OBSERVE CONTROL ALGORITHM

The Perturb and Observe (P&O) algorithm is a technique used in maximum power point tracking (MPPT) for photovoltaic (PV) systems. MPPT algorithms are used to optimize the power output of PV systems by continuously adjusting the operating point of the system to track the maximum power point (MPP) of the PV module.

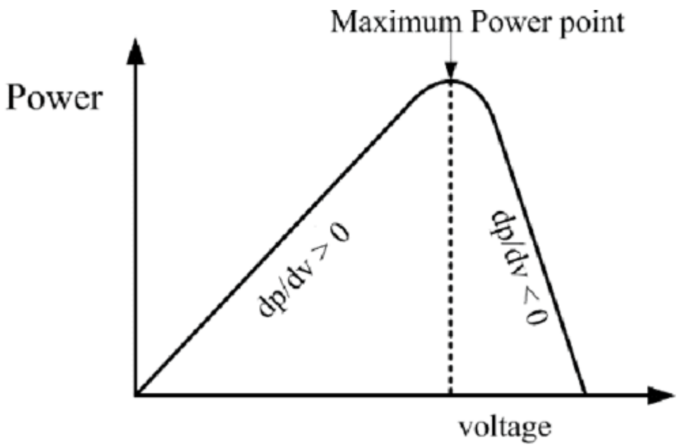

Fig. 3.1: Voltage vs Power curve of a PV array

The P&O algorithm works by perturbing the operating point of the system and observing the effect on the power output. The algorithm starts by setting the operating point to a fixed value and then increasing or decreasing the operating point in small increments. The power output is then observed, and if it increases, the algorithm continues in the same direction. If the power output decreases, the algorithm changes direction and continues in the opposite direction. The algorithm continues to perturb and observe the system until it reaches the MPP.

One of the main advantages of the P&O algorithm is its simplicity, as it only requires the measurement of the voltage and current of the PV module. However, the algorithm can also be sensitive to noise and may oscillate around the MPP, which can result in reduced system efficiency. To address this issue, various modifications have been made to the basic P&O algorithm, such as the use of a moving average filter or a variable step size.

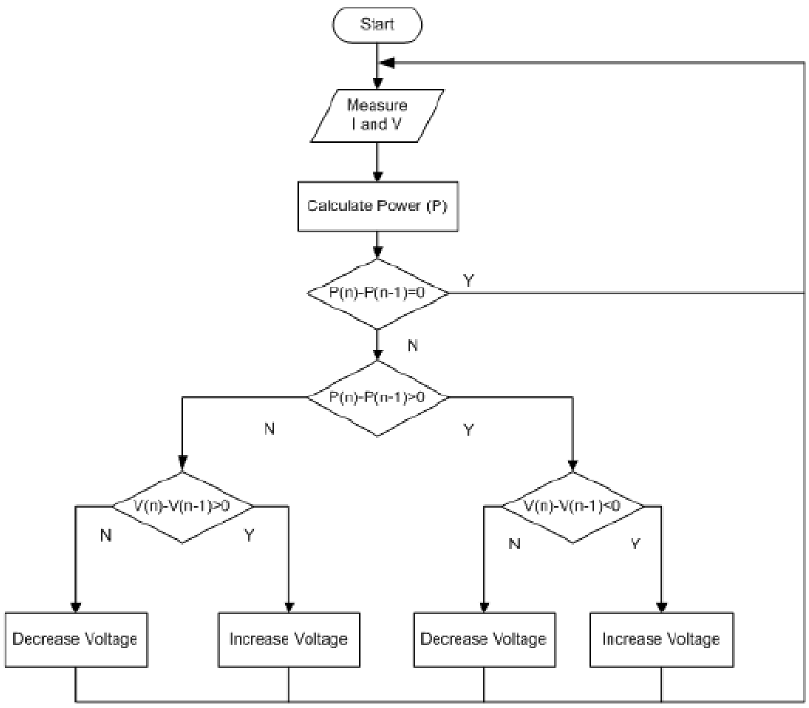

Fig. 3.2: Algorithm of perturb and observe maximum power point technique

IV. PROPOSED METHOD

The conventional VSI bump into one of the perilous problems i.e., shoot-through problem. This shoot-through occurs during switching on and off of the power switches of VSI, and two switches of same leg come into contact due to delay in turning off of the switch. Hence, a huge current will flow in a short duration of time through switches, therefore the power switches will burnout. To mitigate this type of shoot-through issues in the inverter operation, an interleaved inverter topology is proposed.

An interleaved inverter is a type of power inverter that uses multiple power conversion circuits, or "legs," to convert direct current (DC) to alternating current (AC). Each leg is responsible for a portion of the load power, and the legs operate in an interleaved fashion to distribute the load current evenly among them.

This topology has 4 legs where each leg is consisting of insulated-gate bipolar transistor (IGBT) switch and fast recovery diode. These diodes are also called as body diodes of the interleaved inverter. The body diodes are connected in such a way that there is no shoot□through mode in the circuit operation. Hence, the proposed interleaved inverter avoids conduction through the same leg switches at the same time. Therefore, the shoot□ through phenomena does not occur.

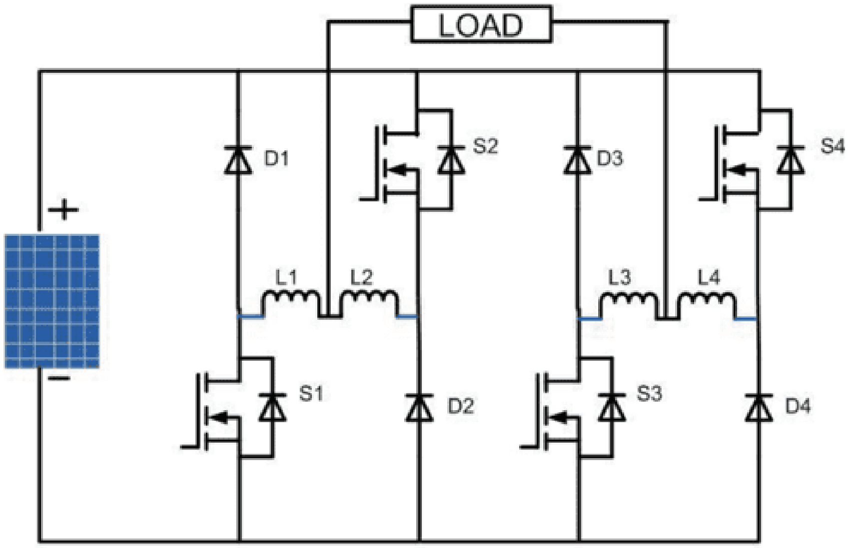

Fig. 4.1: Circuit diagram of Interleaved Inverter Topology

Operation of Interleaved Inverter

The complete circuit operation of interleaved inverter is shown in below figures. This interleaved cell consists of one power switch and series diode. The direction of current into the phase-leg is taken as a reference current. If the reference current (or compensating) is positive, the switch S1 is ON and if the reference current direction is negative, the switch S1 will be OFF and diode D1 will be switched ON. It can be observed that this type of connection doesn’t lead to any shoot-through problem in the circuit operation.

The IGBT has advantages over the power MOSFET and BJT. It has a very low ‘ON’-state voltage drop and better current density in the ‘ON’ state. This allows for a smaller die size with the possibility of more economical manufacturing costs. Driving IGBTs is simple and requires low power. IGBTs are much more efficient thermally and do not require heat sinks.

The Flyback diode will make the inductor to draw current from itself in a form of loop until the whole energy is dissipated in wires and diode. The Flyback diode makes inductor to draw current from itself in a loop until the energy is dissipated in diode and wires. In the absence of “freewheeling diode” the voltage may go very high and can damage the switching device IGBT, Thyristor, etc. By this, the reverse current is allowed to flow through the diode and dissipate.

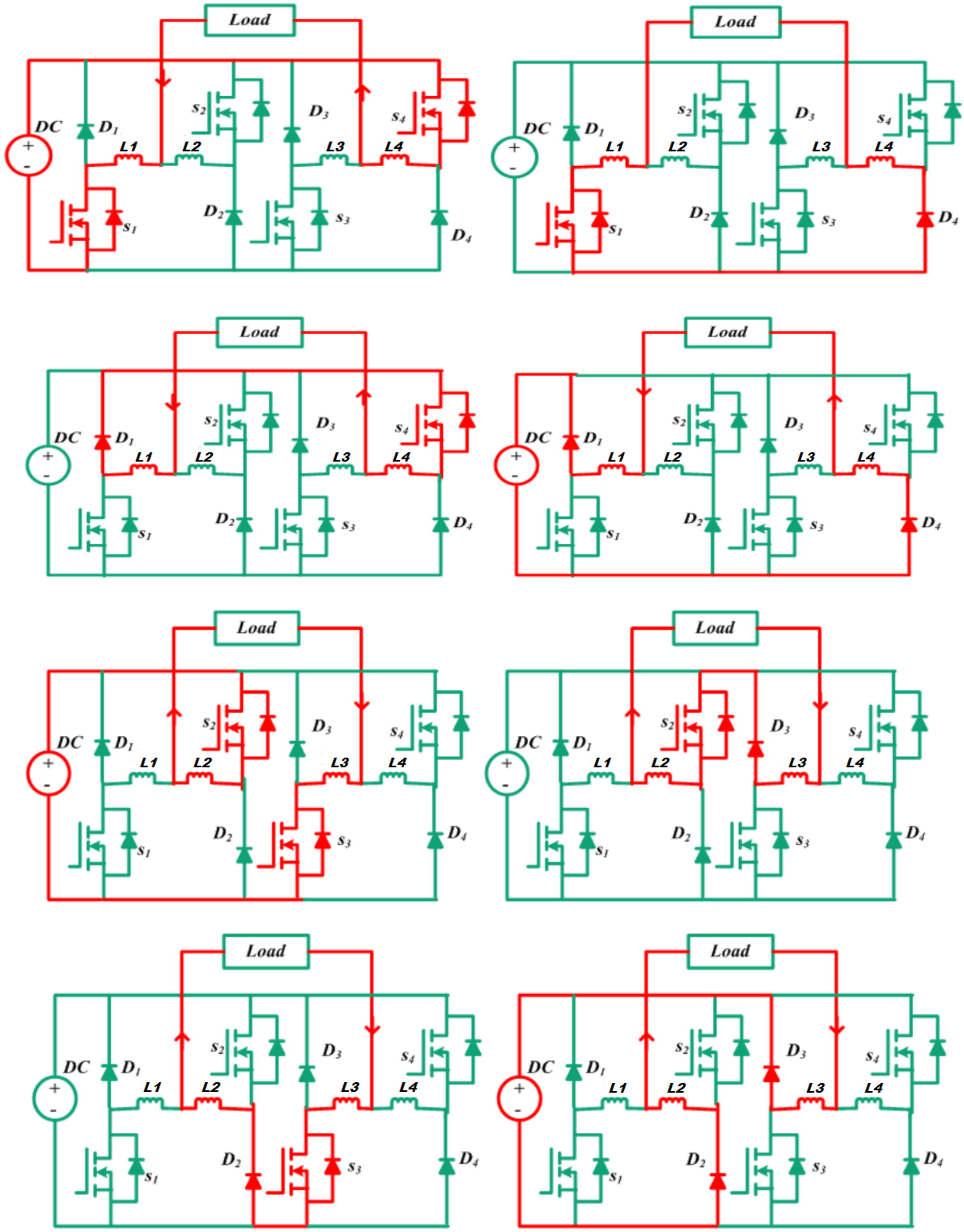

Fig. 4.2: Switching states of Interleaved inverter

Overall, the operation of an interleaved inverter involves multiple power conversion circuits that operate in an interleaved fashion to provide high-power, efficient, and reliable DC-AC conversion.

V. SIMULATION RESULTS AND DISCUSSION

MATLAB/Simulink is used to simulate the suggested interleaved PV inverter model. Tracking the MPP of PV panels under varying solar irradiation levels has been done using a P&O MPPT approach. Figure 6 displays the interleaved led current waveform simulation outcome. As the interleaved inverter does not contain an active

power electronic switch in the same leg, there is no possibility of a shoot through effect. Hence, the inverter output is more efficient.
There are four power electronic switches in the interleaved inverter circuit, connected individually with a diode in the same arm. Here, Switches S1 & S2 operate similarly and likewise Switches S3 & S4. As there is no other active power electronic switch in the same leg, shoot-through effect will not occur and hence the efficiency is improved.

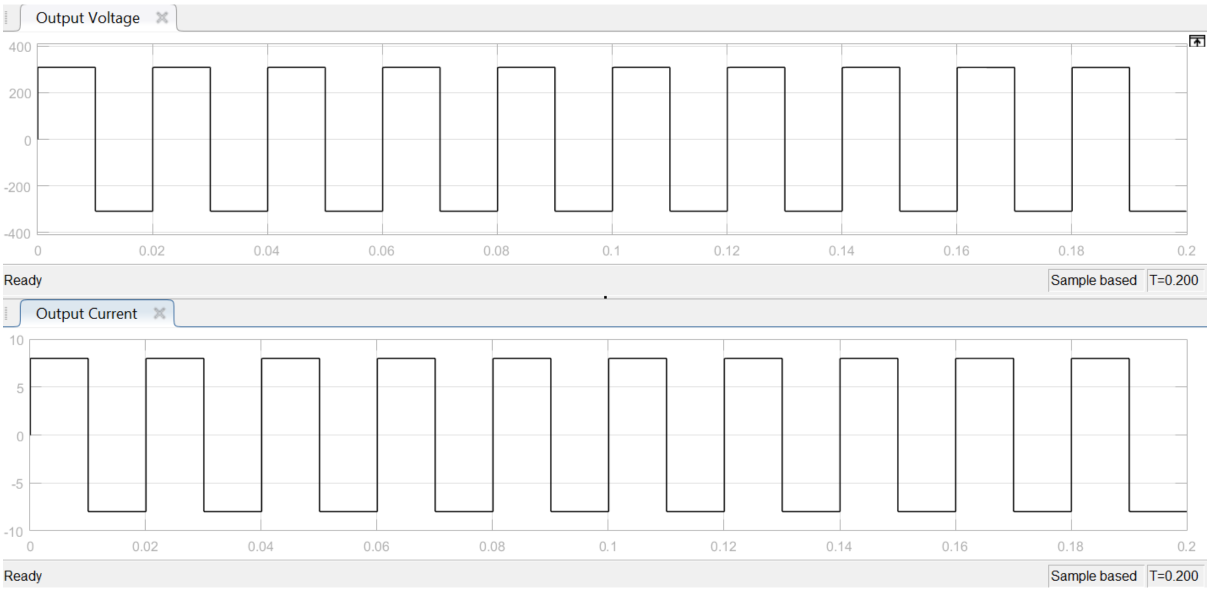

Fig. 5.1: Solar PV inverter output voltage and current waveforms without filter

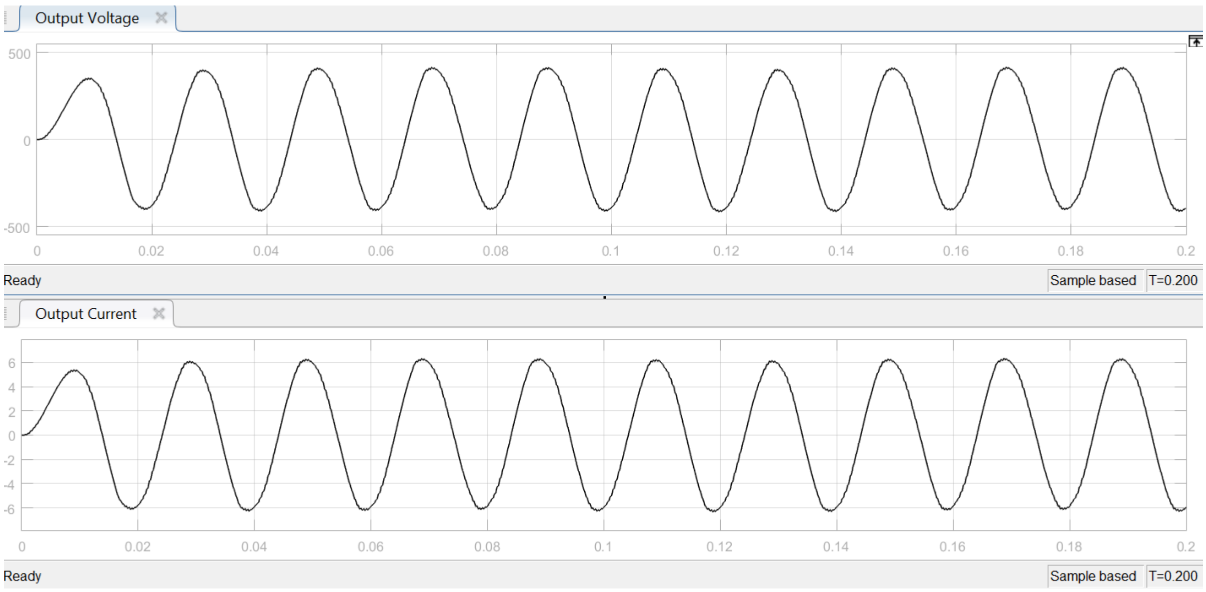

Fig. 5.2: Solar PV inverter output voltage and current waveforms with filter by using MOSFETs

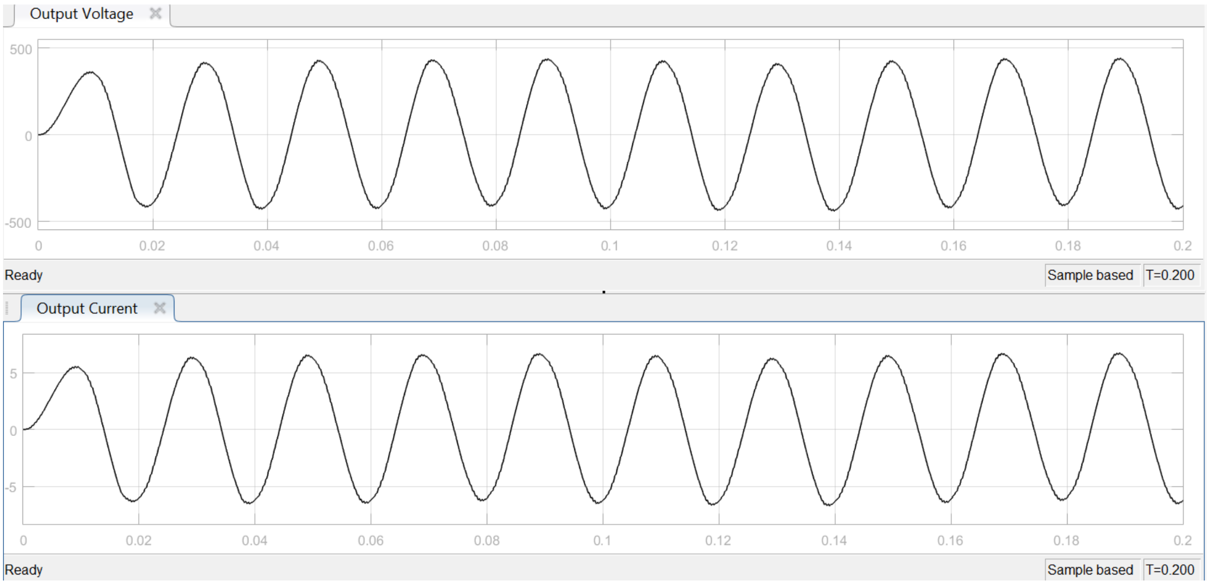

Fig. 5.3: Solar PV inverter output voltage and current waveforms with filter by using IGBTs

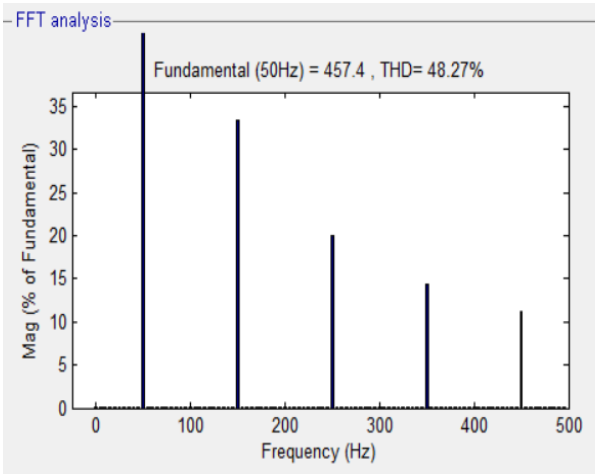

Fig. 5.4: Harmonic spectral diagram of output voltage without filter

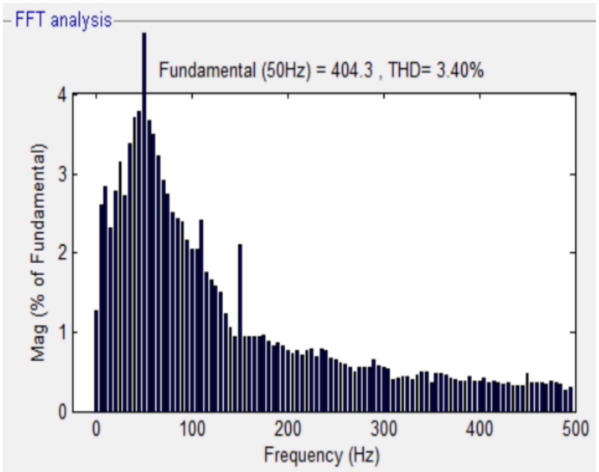

Fig. 5.5: Harmonic spectral diagram of output voltage without filter by using MOSFETS

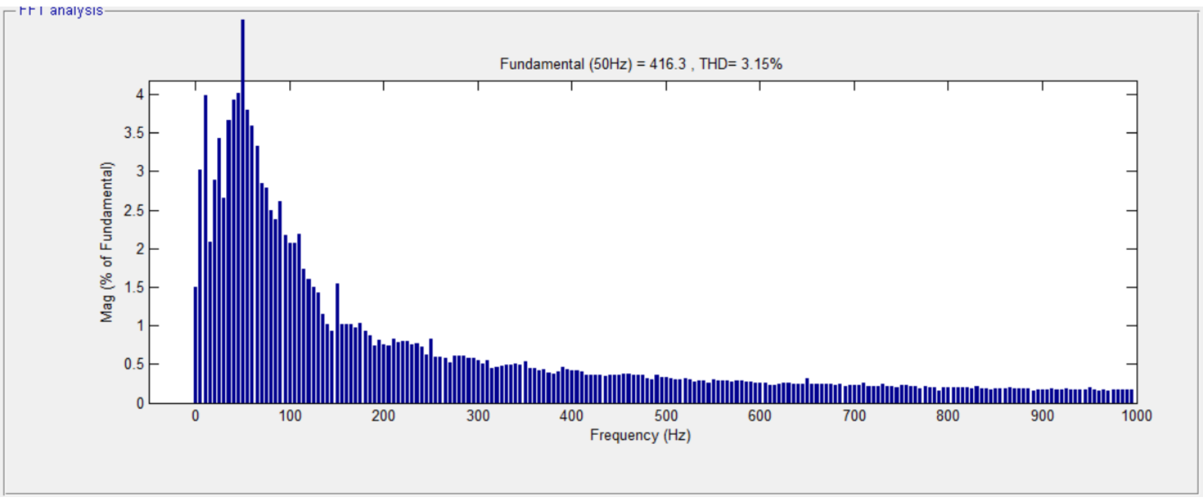

Fig. 5.6: Harmonic spectral diagram of output voltage without filter by using IGBTS

VI. CONCLUSION

In the Conventional VSI topology, the major drawback is shoot-through effect. To avoid the shoot through effect for PV applications, an interleaved inverter circuit is proposed. This interleaved inverter topology is connected in such a way that a switch and a diode are in the same leg. The power diode blocks the flow of current in same direction. Therefore, the shoot-through effect is eliminated in the circuit. This proposed system uses P&O method of MPPT algorithm for Maximum Power Point of PV array with respect to solar irradiation. Additionally, a single-tuned L filter is used to eliminate the odd order harmonics. This proposed interleaved inverter topology is designed in MATLAB/Simulink software to test its operation and performance.

From the Simulink results, it can be concluded that the proposed interleaved inverter topology is successfully working in eliminating the shoot-through problem. Also, the single-tuned L filter has also eliminated the dominant harmonics from the voltage waveform by bringing its effect within the range of IEEE-519 standards. The THD value of the output voltage using IGBTs is lesser than the THD value of the output voltage using MOSFETs. IGBTs have higher switching frequencies compared to other power electronic switches. IGBTs also have lower conduction losses due to which the system performance can be increased. Hence, IGBTs are advised for higher voltage applications.

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