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Implementation of Modified Transformerless Voltage Source Inverters for Domestic Applications

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ABSTRACT: Abstract: The PV system, especially the single-phase system demands high reliability, high efficiency, small size, light weight PV inverter. The requirement of stepping up from 12V AC output of a conventional inverter to the required standard 230VAC incurs a considerable loss. Therefore, the transformer- less inverter is becoming widely used because of its intrinsic high efficiency and low cost. They operate at a higher input and output values which reduces the requirement of huge step up operations and the essence of transformers. However, leakage current and harmonics have been a problem in non-isolated inverter. This problem is solved by improving the structure of freewheeling loop in full- bridge inverter. These structures add auxiliary circuits and forcibly change the freewheeling circuit. Thus with a review of the state-of-the-art transformer-less inverter topologies and this paper proposes a transformer-less inverter topology which can solve these problems and improve the performance. The experiment results demonstrate the validity of proposed inverter topology.

KEYWORDS: Transformer-less inverters; Full bridge; PV panel; Load; Leakage current; switching devices

I. INTRODUCTION

In recent years for the purpose of environmental protection and limiting the usage of exhaustible resources, the utilization of solar energy has gained a greater momentum. This is mainly due to its non- exhaustible and pollution free nature. The PV panels are the components that play a vital role in the conversion of solar energy into electrical energy.The PV panels produce DC current. But most of our Appliances operate based on AC input. Thus it becomes mandatory for the conversion of DC to AC. An inverter is a device that converts DC to AC. A conventional inverter has a transformer as a major component. They are used for step up operations and the provision of galvanic isolation.

The main disadvantage of such inverters with transformers are the losses caused. The different types of losses are core losses or iron losses and the copper losses. The core losses may be hysteresis loss and eddy current loss. The hysteresis loss may be due to the magnetization in the transformer core and the eddy current loss is due to the flux linkage in the secondary windings which leads to heat dissipation. The copper losses is due to the resistance in the windings which varies with the load. As rightly said “Less is more”, the convectional inverters have been replaced by modern transformer-less inverters. They do not lead to such losses thus the overall efficiency of inverters is improved. A variety of transformer- less inverter topologies are in existence. They do not have a transformer as a component. The work of a transformer is replaced by power semiconductor devices.

But their major drawback is in the form of leakage current. A new transformer-less inverter topology has been proposed for a improved performance overcoming all the difficulties of the older topologies. The major advancements are in the form of inhibition of effect of leakage current, and the elimination of transformers for larger step up operations. The leakage current is reduced by improving the freewheeling circuit. The elimination of transformers is made possible by improving the arrangement of the solar PV panels. The panels are arranged accordingly such that the input voltage is as per the requirement without the need of boosting operation

II. SYSTEM EVOLUTION

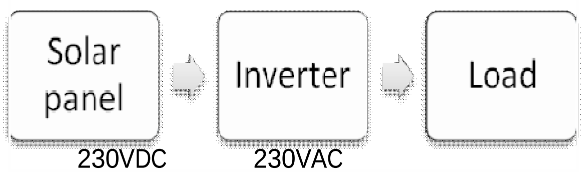

Fig1. Block diagram of PV system

Any solar PV panel would require an inverter for the conversion of DC to AC for any applications. The conventional inverters have line transformer and power conversion stage as a vital part in them. Any solar PV panel would require an inverter for the conversion of DC to AC for any applications. The conventional inverters have line transformer and power conversion stage as a vital part in them.

The line transformers have multiple applications. This includes boost operation, provision of galvanic isolation between load and PV panel. The isolation ensures that there is no continuous current injected in the circuit, the leakage current is less and there is protection to the components and the people .The power conversion stage converts the input DC to the required AC with a considerable amount of losses. The main disadvantages would be the large and robust size of transformers which increases the cost of the whole system. The overall losses due to transformers also decrease the performance of inverters.Thus the concept of transformer-less inverters evolved. They operate on a higher voltage range which gets the input at that range by the modification in the alignment of solar panels .Thus the requirement of transformers for boost operation is neglected. But their main functions must be performed by alternative methods. To eliminate the injection of continuous current a ground fault detection system is employed within the inverters. Similarly MPPT (Maximum Power Point Tracking) technique is employed to get maximum input voltage from PV panels.

The half bridge transformer-less inverter consists two switching devices in the place of four. Here two switching devices are in use while the remaining are replaced by a capacitor. The sinusoidal pulse width modulation (SPWM) is used for the generation of pulses.It also aims at reducing the total harmonic content of the output AC signals.

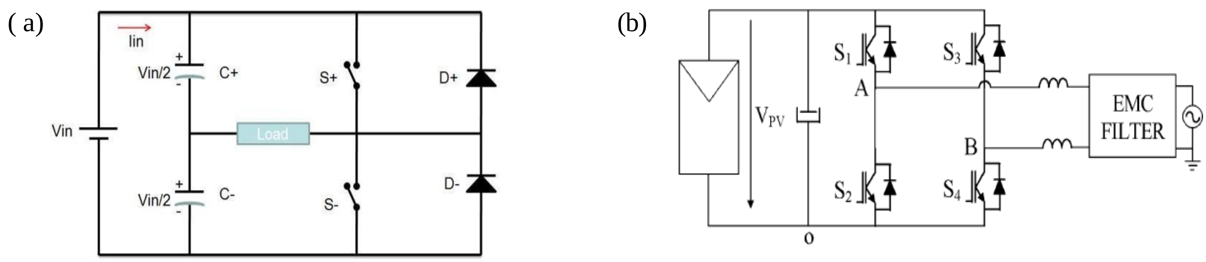

Fig 2 . - (a) Circuit diagram of normal Half bridge Inverter; (b) Circuit diagram of normal Full bridge inverter

The main drawback of the half bridge topology which needs to be addressed is the requirement of high value of input voltage. Thus the full bridge transformer-less comes into existence which requires only half of the half bridge input.

To reduce the effect of leakage current and the switching loss, the freewheeling branch is modified. Based on this there are different topologies. They include the H5, HERIC, H6 and Hybrid. This classification is based on the number and alignment of switching devices. The H5 has 5 switching devices at DC side and H6 with 6 switches, while the HERIC has additional switches at the AC side which improve the complexity of the circuit.

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Power	H5	HERIC	H6
1000W	98.77	98.65	98.93
2000W	99.15	99.12	99.15
3000W	99.16	99.18	99.15
4000W	99.08	99.14	99.07
5000W	98.97	99.08	99.97
Average Efficiency	99.03	99.03	99.25

Table1. Comparative study of full bridge topologies

Based on the comparison with various parameters of complexity, efficiency and leakage current characteristics it is concluded that the H6 topology is best suited for all applications.

III. WORKING

3.1 Proposed topology

Based on various analyses, the H6 topology is said to be more efficient .Thus a modified H6 topology for the transformer-less inverters of the proposed system is taken into consideration.

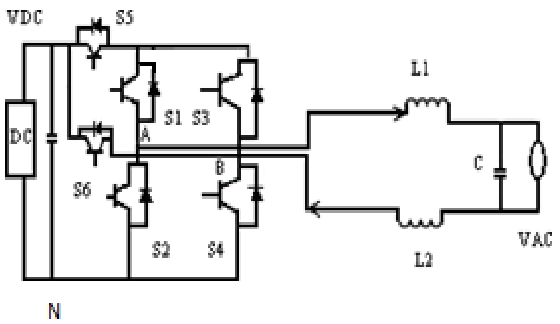

Fig.3. Circuit diagram of proposed H6 inverter

Inverter Parameter	Value
DC voltage	230V
AC voltage	230V
Switching frequency	20KHz
Capacitor	3µF
Inductor L1, L2	3mH
Frequency	50Hz

Table2. Specifications of proposed topology

The proposed inverter topology has 6 switching devices along with freewheeling diodes. It is based on the unipolar mode of operation. The common mode voltages are kept constant in order to reduce the leakage current.

3.2 MODES OF OPERATION

The operation modes of the H6 topology are discussed below. There are four different modes to be discussed. The common mode voltage is represented as VCM

Mode1 (Positive half cycle):

The switches S1, S4 and S5 are in on condition. Since S3 and S6 are in off condition the current through the S5, S1 and S4 increases and VAN=VDC. The common mode voltage is given as VCM =(VAN+VBN)/2 where VAN=VDC and VBN=0,thus VCM=VDC/2.

Mode2 (Freewheeling):

The switches S1and S3 are on. The freewheeling current passes through S1 and diode of S3.Since there is no current through other switches, the voltage through VAN and VBN becomes VDC/2. Thus the common mode voltage becomes VCM=(VAN+VBN)/2 where VAN=VDC/2 and VBN=VDC/2,thus VCM=VDC/2.

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Mode3 (Negative half cycle):

The switches S2, S3 and S6 are in on condition and S1 and S4 are in off condition. The current passes through the S2 and S6 only. And so its value decreases and VAB=-VDC. The common mode voltage is given as VCM=(VAN+VBN)/2 where VAN=0 and VBN= VDC, thus VCM=VDC/2

Mode4 (Freewheeling):

The freewheeling current passes through S3 and diode of S1. All other switches are in off position. The voltage through VAN and VBN becomes VDC/2. The common mode voltage is given as VCM=(VAN+VBN)/2 where VAN=VDC/2 and VBN=VDC/2, thus VCM=VDC/2

From the equations mentioned above it is clear that there is no leakage current as the common mode voltages has no changes in different modes.

IV. EXPERIMENTAL SETUP

The experiment is represented by using MATLAB simulink. The input DC voltage is obtained from the solar panel which is then given as input to the proposed inverter for the output voltage to be in the form of AC.The standard voltage of 230V is obtained as a result of this topology. The obtained AC voltage can be used for any domestic applications which usually operate only on AC voltage.The simulink model as shown in Fig.4 consists of current measurement block connected in series and a voltage measurement block connected in parallel. They are connected to a scope for graphical output at desired points.

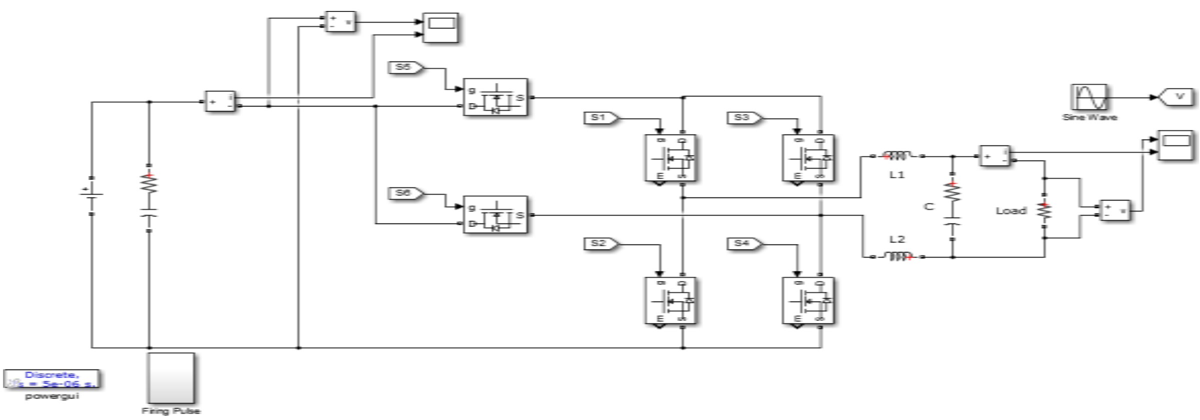

Fig.4. Simulink model of proposed topology

V. RESULT AND DISCUSSION

The inverter uses SPWM technique for the generation of gate pulses. It refers to sinusoidal pulse width modulation. The harmonics of inverter is reduced by SPWM technique. The gating pulse is generated by comparing the sine wave as reference signal and triangular wave as carrier waves. When the Vr is greater than Vc then the pulse corresponding to +VDC else –VDC is generated.The method of gate pulse generation is shown in Fig.5(a)

The gate pulse generated is applied to each of the 6 switches present in the circuit. The hardware pulse generation is by using the PIC controller. The voltage across each switch is represented using a simulink model as shown in Fig.5(b). The waveform corresponds to the general voltage, voltage through switch S1, switch S3, switches S4 S5 and the switches S2 S6 respectively.

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(a) (b)

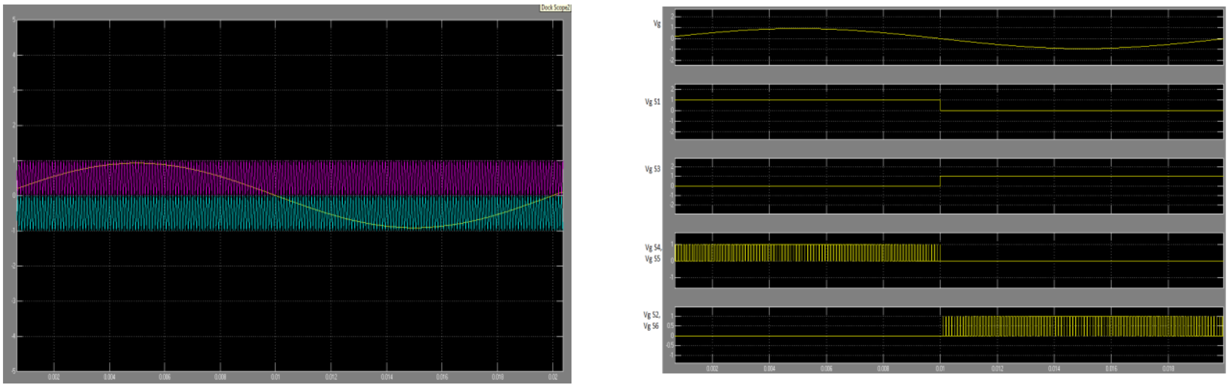

Fig.5 - (a) Waveform of gate pulse generation using SPWM; (b) Waveform gate pulse on each switch

The switching operations of the power semiconductor devices are varied accordingly to the gate pulses. As a result of the switching operation the AC waveforms are generated from the input DC waveform. Based on the proposed topology the current up to 1 amp can be utilized at the load side. And the voltage of 230V is obtained which can be used for all applications. The expected value of voltage and current is shown in Fig. 6(a)

The semiconductor devices connected to the capacitors, conduct a small amount of current even when it is in off condition. This current may be very small in magnitude but continuous conduction leads to the gradual discharge of capacitors. This is known as the leakage current. This has been a greater drawback of all the transformer-less inverter topologies. This paper proposes a topology which has a very limited leakage current of the range 1.8mA. This is shown in Fig. 6(b)

a b

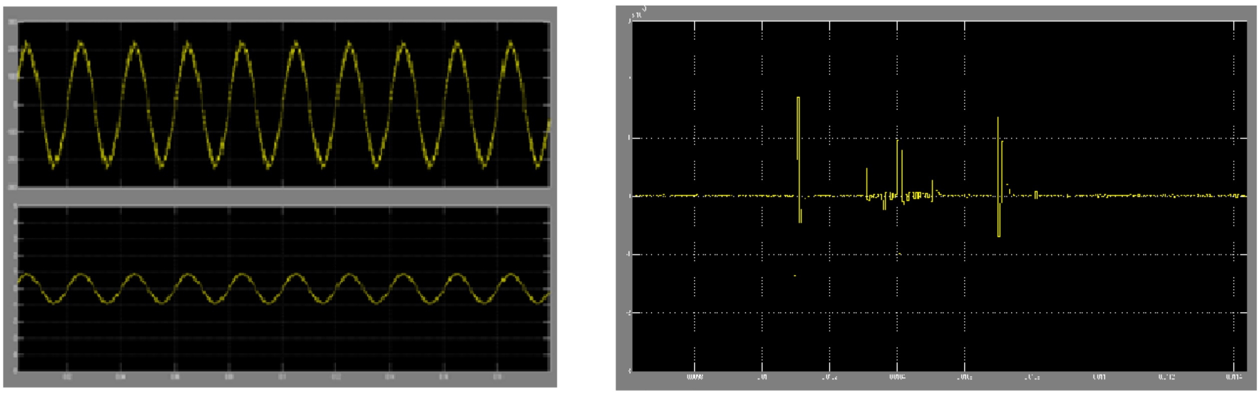

Fig.6. - (a)Simulation waveform of AC voltage and AC current; (b) Simulation waveform of leakage current

The harmonics has been a serious problem in the generation of sine waves. The lesser the harmonics the greater is the possibility of generation of sinusoidal pulses while the greater harmonic levels leads to the generation of square waves which is not suitable for inductive loads. Thus the SPWM technique comes into play. By using this technique along with a filter,the harmonics has been estimated to be 8.5% which is almost closer to the 5% which is the maximum harmonics level for all AC applications as shown in Fig.7(a) and 7(b).

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(a) (b)

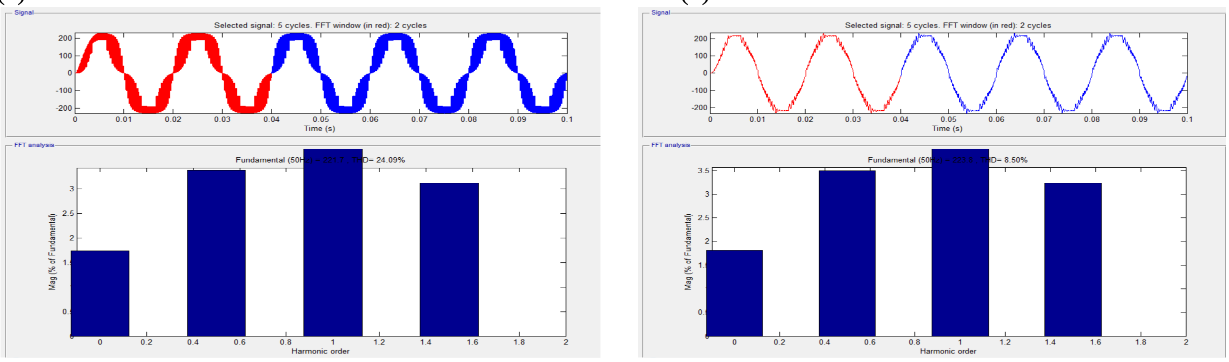

Fig.7.- (a) Harmonic distortion in SPWM without filter ; (b) Harmonic distortion in SPWM with filter

Another important factor to be considered for the inverter design is the power factor. The proposed topology is estimated to have a power factor of 0.8 which is the accepted range.

VI. CONCLUSION

Thus a new transformer-less inverter topology has been proposed for a improved performance overcoming all the difficulties of leakage current of older topologies. The major advancements is in the form of inhibition of effect of leakage current, reduction in harmonics and the elimination of usage of transformers for input by adjusting the arrangement of solar panels. Thus the proposed topology can be useful during power conversion stage for transformer-less PV system for domestic applications.

VII. FUTURE SCOPE

Further improvements can be made in accordance with the proposed topology in many ways. They could be synchronization with the grid. ,implementation of MPPT techniques for the PV panels and usage of battery for storage.

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