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Transformerless Topology for Grid-Conected Inverters With Unipolar PWM Control

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ABSTRACT
Most of the PV systems are designed with transformer for safety purpose with galvanic isolation. However, the transformer is big, heavy and expensive. Also, it reduces the overall frequency of the conversion stage. Generally PV inverter with transformer is having good efficiency. To overcome these problems, transformer less PV system is introduced. It is smaller, lighter, cheaper and higher in efficiency. However, dangerous leakage current will flow between PV array and the grid due to the stray capacitance. There are different types of configurations available for transformer less inverters like H5, H6, HERIC, and Dual paralleled buck inverter. But each configuration is suffering from its own disadvantages like high conduction losses, shoot-through issues of switches, dead-time requirements at zero crossing instants of grid voltage to avoid grid shoot-through faults and MOSFET reverse recovery issues. The main objective of the proposed transformer less inverter is to address two key issues: One key issue for a transformer less inverter is that it is necessary to achieve high efficiency compared to other existing inverter topologies. Another key issue is that the inverter configuration should not have any shoot-through issues for higher reliability.
Key words:MOSFET, High Efficiency, inverter topologies, transformer less PV system

I. INTRODUCTION

Due to the rapid increase in human population and limitation reserve of natural resources such as coal and fuel, solar power is considered to be better option to meet these challenges since it is naturally available, pollution free and inexhaustible. Besides, with the help of government incentives and decrease in PV module prices, grid-connected PV systems play an important role in distributed power generation. The decrease in cost of PV system, the advancement of power electronics and semiconductor technology and incentives from government strongly encourage the growth of grid-connected PV systems [10]-[12].

Grid-connected PV system can be classified into two categories: with and without transformer. Most of the PV systems are designed with transformer for safety purpose with galvanic isolation [1]-[3]. Galvanic isolation ensures no injection of DC current into the grid and reduces the leakage current between PV module and grid. In DC side, high frequency transformer is used whereas bulky low frequency transformer is used in output side of the inverter. However, the transformer is big, heavy and expensive. Also, it reduces the overall efficiency of the conversion stage.

To overcome these problems, transformer less PV system is introduced. It is smaller, lighter, cheaper and higher in efficiency. However, the elimination of the transformer may cause fluctuation of the potential between solar array and the ground which is also known stray capacitance or parasitic capacitance. The value of the stray capacitance depends on the surface of the PV array and grounded frame, distance of PV cell to the module, atmospheric conditions, dust and humidity. This \stray capacitance is energized by the fluctuating potential and leads to leakage current [9]. Electrical hazard occurs when a person touches the PV array. Leakage current flows through the person to the ground. Furthermore, DC current will be injected to the grid causing the saturation of the distribution transformer along the grid.

This CM ground current will cause an increase in the current harmonics, higher losses, safety problems, and Electro Magnetic Interference (EMI) issues[4]-[5]. For a grid-connected PV system, energy yield and payback time are greatly dependent on the inverter's reliability and efficiency, which are regarded as two of the most significant characteristics for PV inverters. In order to minimize the ground leakage current and improve the efficiency of the converter system, transformer less PV inverters utilizing unipolar PWM control have been presented[6]-[8].

II. OPERATIONAND ANALYSIS OF EXISTING AND PROPOSED TOPOLOGY

OH5 is designed and shown in fig.1, where the voltage of the freewheeling path is clamped to half of the input voltage to completely avoid the common mode voltage. In the positive half cycle, S5 is turned on continuously. S1 and S6 commutate simultaneously at switching frequency andcomplementarily to S2 and S5. Current flows through S1, S3 and S6. During the positive zero voltage vector, current freewheels through S3 and anti-parallel diode of S5. S2 is switched on to ensure the freewheeling path is clamped to half of the input voltage.

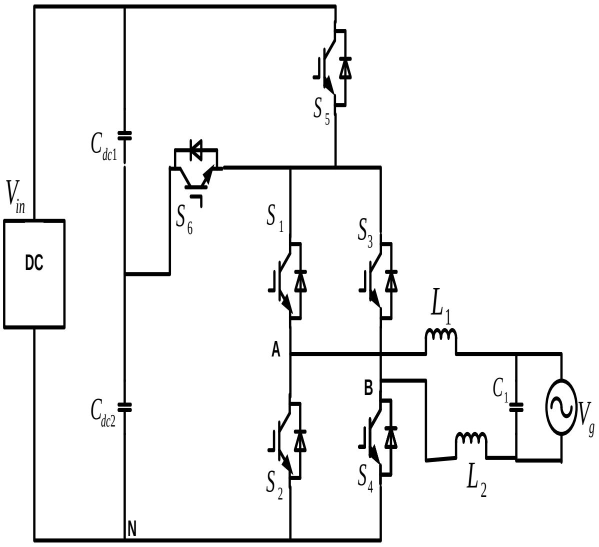

Fig -1:OH5 topology circuit

On the other hand, in the negative half cycle, S3 is turned on continuously. S1 and S4 commutate simultaneously at switching frequency and complementarily to S2 and S3. Current flows through S1, S5 and S4. During the negative zero voltage vector, current freewheels through S5 and anti-parallel diode of S3. S2 is switched on to ensure the freewheeling path is clamped to half of the input voltage.

As shown in Fig 3, the output voltage of the oH5 topology consists of three levels and the voltage to ground. Leakage current is very small due to constant common mode voltage as shown in Fig 4. This topology combines both advantages of unipolar modulation and bipolar modulation. High efficiency is achieved without compromising the common mode behaviour. In conclusion, oH5 topology is suitable for transformer less grid connected PV system

a) OH5 topology proposed in[4] can be shown in thefig(1) the problem with this topology is as discussedearlier S5 and S6 make Cd1 to get short circuit due toswitching patterns. The path of current flow inpositive half cycle can be treated as Cd1 (+) — S5—S1—L1—Vg—L2—S4—Cd2 (-), negative half cyclecurrent path is Cd1 (+) —S5—S3—L2—Vg—L1—S2—Cd (-)

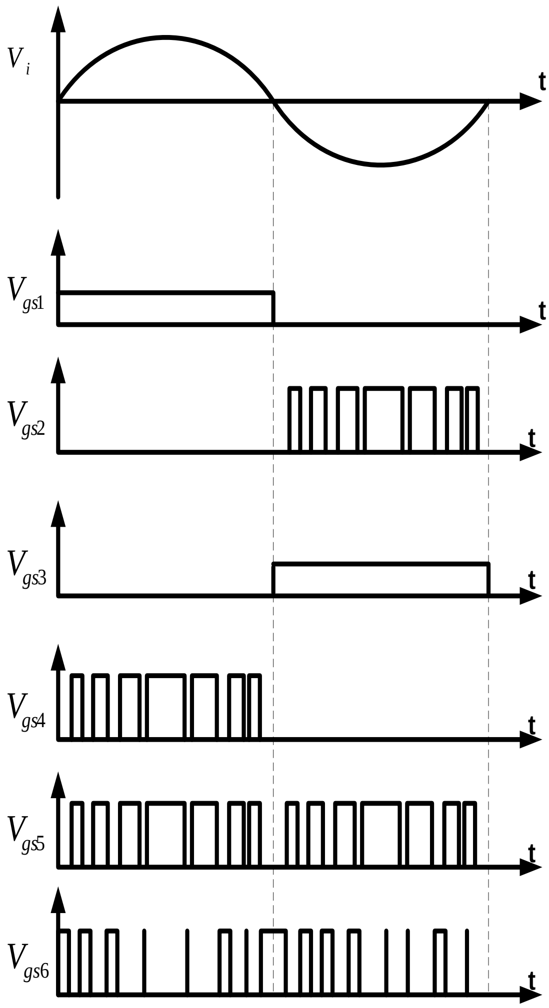

Fig-2: Existing OH5 topology and its firing pulses

b)This topology giveshealthier operation. OH5 isbecausefreewheeling mode depends on switching speed ofindividual diodes. The path of conduction duringpositive mode is Cd1 (+) — S5—S1—L1—Vg—L2—S4—S6—Cd2 (-), and negative mode is Cd1 (+)—S5—S3—L2—Vg—L1—S2—Cd (-). Duringfreewheeling modes D1, D2 helps to form the pathfor inductor current.

c) Operation: unity power factor is maintained when an inverter is tied to grid. Gate drive pulses areshown for Positive Neutral Point Clamping Cellas in Fig (4) with unity powerfactor. One leg of PNPCC is fitted with P-NPCCand second leg is fitted with Negative Neutral Point Clamping Cell(N-NPCC) to formrequired PN-NPC. This arrangement can be observein fig (1), where S7, S1, S2 forms P-NPCC and S8,S5, S6 forms N-NPCC. There are four modes ofoperations.

III. RESULTS AND DISCUSSIONS

The firing pulses generated for the circuit, the output voltage and the common mode voltage are shown in fig.3.fig.4 and fig.5 respectively.

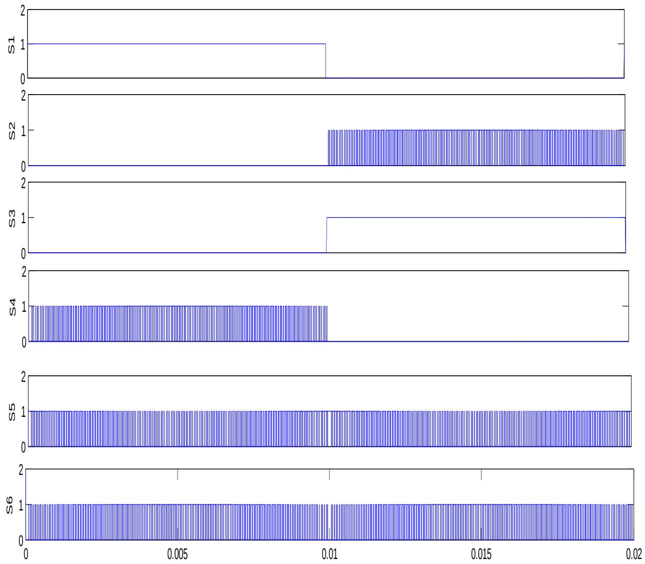

Fig-3: Firing pulses of OH5 topology

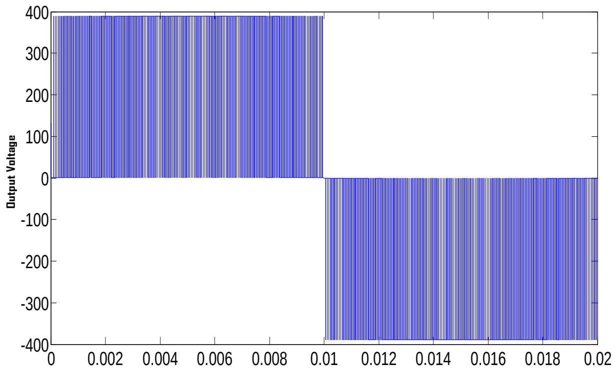

Fig-4: Output voltage of OH5 topology

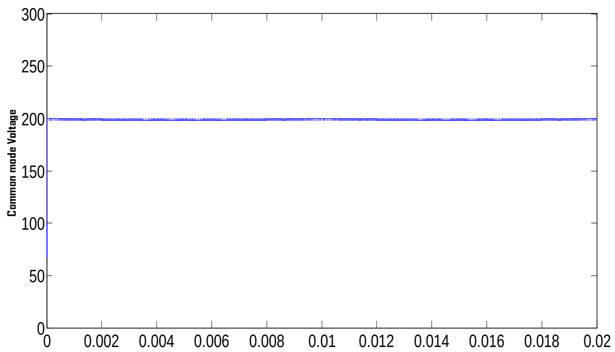

Fig-5: Common mode voltage of OH5 topology

All the simulation results can be compared as follows. TABLE-I is compares THD, output voltage V_{out}in each topology. We can understand FB-DCBP is having more conduction losses as higher rating devices present in it is more during active mode of its operation. In TABLE- II simulation parameters are indicated.

Table -1: Calculated output THD and voltage of oh5.

S.No	THD	Output Voltage
1	0.59%	389(Peak), 254(Rms)
2	0.53%	376(Peak), 247(Rms)
3	0.48%	364(Peak), 239(Rms)

Table -2: oh5 topologySimulation parameters

Parameter	Value
Rated power	1000W
Input Voltage	330-750V
Switching Frequency	25KHz
Filter Inductance	100mH
Capacitor	10uf
Grid Voltage/Frequency	230v/50Hz

IV. CONCLUSION

This type ofproposedtopology yields effective results existingtopologies. By further modifying usage of switching cells there is chance to extend this topology. UsingMATLAB all results are validated. THDusing this topology is reduced to a greater extend and otheradded advantage is during all modes of operation it ismaintaining the common mode voltage as half of the inputsupply voltage which leads to the excellent leakage currentcharacteristics.

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