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(RESEARCH ARTICLE)

Performance analysis of H6 topologies for transformerless inverter photovoltaic grid tied system

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Abstract

One of the most important and common parts of the modern power systems is the grid-connected photovoltaic (PV) systems. Recently, these systems have gotten a big revolution due to the introduction of the transformerless inverters. The introduction of transformerless inverters has indeed brought about advantages such as small size, low cost, and high efficiency, but it has also raised safety concerns, particularly with leakage current. Various researches were directed toward evolving their performance and diminishing the leakage current to the standard limits. This paper presents an H6 inverter topology that reduces leakage current, conduction losses and improves inverter efficiency. In order to verify the theoretical explanations, the proposed topologies are simulated in MATLAB/Simulink. Simulations have been conducted to compare the performance of H6 topology with conventional topology.

Keywords: PV System; Leakage Current 2; Transformerless Inverter; H6 topology; Common mode voltage

1. Introduction

Solar photovoltaics provide a renewable source of energy that is essential to today's growing demand for energy worldwide. Free and clean solar energy is abundant and available everywhere. In comparison with other renewable energy sources, it is becoming more popular. PV technology has advanced significantly in recent years, resulting in lower production costs. PV systems convert the energy of the sun into DC power. Depending on whether or not a transformer is present in the grid-connected PV system, there are transformer-based PV systems and transformerless PV systems. The PV and grid are galvanically separated when a transformer is present and there is no current leakage and no direct current is supplied to the network. However, it is heavy, bulky and expensive to include a transformer in the circuit. As a result, PV systems are less efficient when a transformer is present. The result was grid-connected transformerless photovoltaic systems. Besides being light and small, they are also cheaper. They also provide better efficiency than grid-connected PV systems with transformers. However, its main disadvantage is that it cannot provide galvanic isolation. A large common current is present from the PV to the grid, which presents a safety concern.

Changes in PV potential and ground potential create stray capacitance (Cpv) in transformerless systems. The common voltage (Vcm) relates to this potential change. A number of factors can affect the stray capacitor, including moisture and dust, grounded PV cell frames and surfaces, and the distance between solar cells and modules. By charging and discharging the parasitic capacitance, common mode voltages generate leakage currents called common mode currents (Icm). There are system losses, electromagnetic interference and network ripple due to leakage currents.

Since three-voltage levels are generated across the filter, unipolar modulation causes low losses. Comparing the bipolar and unipolar SPWM techniques, the unipolar SPWM technique provides higher efficiency. Due to the two voltage levels

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generated by bipolar modulation, filter inductor suffers from high core losses and switching losses. Compared to unipolar modulation, it has lower efficiency. Low losses and high efficiency make this technique ideal.

The H6 inverters are discussed in detail in this paper. The introduction of the H6 inverter concept overcomes the disadvantages of the H4 and H5 inverters, such as low efficiency and high conduction loss. When operating in active mode, in order to mitigate voltage fluctuations and leakage current, the H6 topology is designed with SPWM modulation strategies. There is a structure that ensures that only two switches are activated. The results of this study show that H6 inverters have lower conduction loss than H4. MATLAB/Simulink is used for all simulations in this Paper.

2. Methodology

2.1. H6 Inverter topology

In this paper, a transformerless H6 converter without leakage current has been designed, which reduces losses while increasing efficiency. Figure 1 shows the circuit for this inverter. Solar arrays become disconnected from the grid during freewheeling. Conduction loss has been comparatively reduced and efficiency has also improved, despite the increased number of switches. Keeping the common mode voltage constant helps eliminate leakage current.

A unipolar sinusoidal PWM modulation technique is used. Vpv stands for photovoltaic panel. Filtration is performed using an LCL filter. Electrical grids are represented by Vgrid. The input DC link capacity is represented by Cpv. Since H-bridge inverters use transformers that do not have leakage current problems, typical inverter designs may not maintain a constant common-mode voltage. In the absence of transformers, the PV and grid are galvanically coupled, leakage currents are resulting from this. Maintaining constant common mode voltages can reduce leakage currents in such a situation.
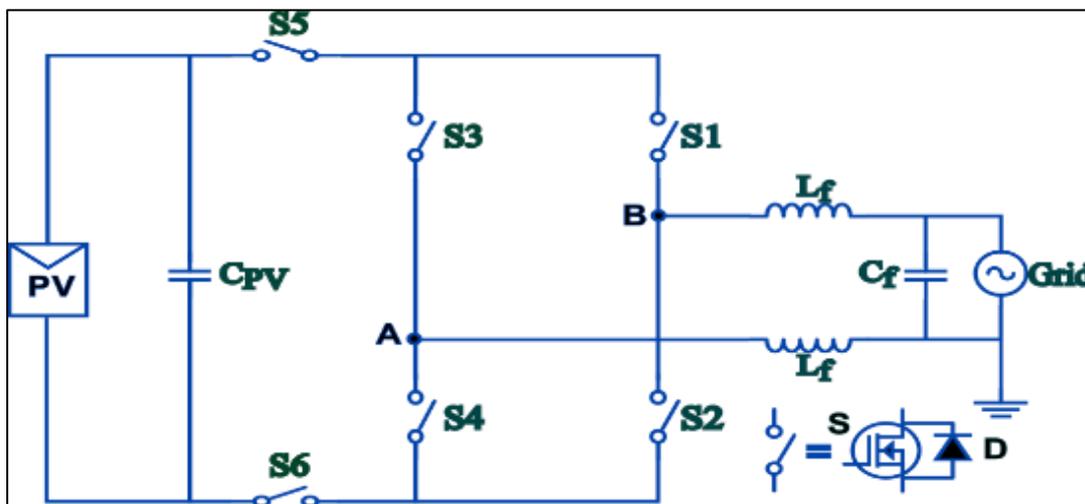

Figure 1 H6 inverter topology

2.2. Mode of operation of H6 Inverter topology

A total of four modes are available, including two active modes and two freewheeling modes.

2.2.1. Mode-1 Active mode

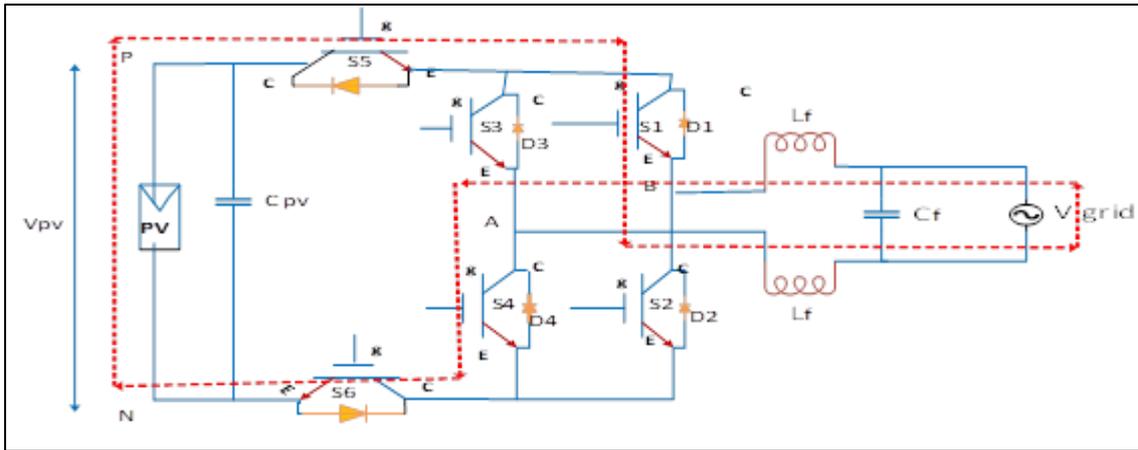In active mode, S1 and S6 are turned on; S4 and S5 are switched to high frequency during the positive half cycle.

Figure 2 First Mode of operation of H6 topology

2.2.2. Mode-2 Freewheeling mode

Current flows through switch S1 in freewheeling mode during positive half and anti-parallel diode D3. The other switches are also all off.
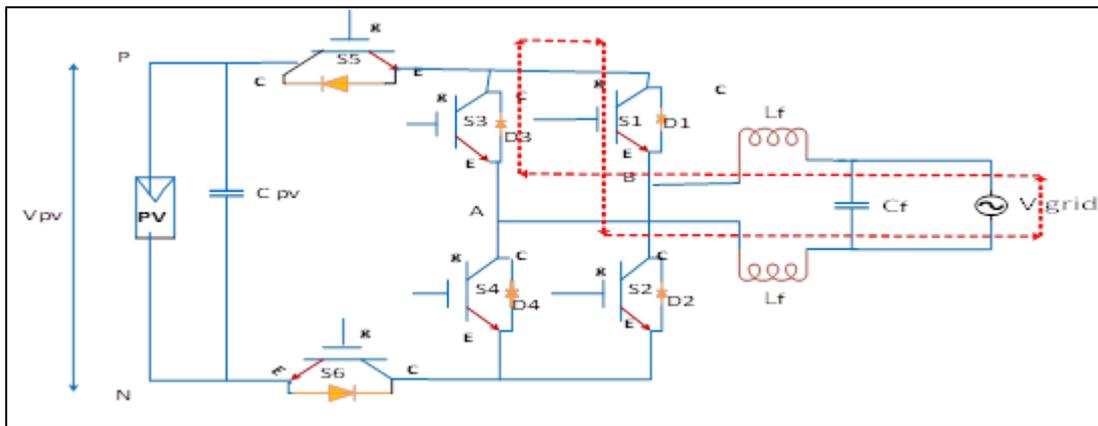

Figure 3 Second Mode of operation of H6 topology

2.2.3. Mode-3 Active mode

During active mode, S2 and S5 are ON; S3 and S6 switch at high frequency in negative half cycles, while S1 and S4 will remain off during negative half cycle active mode.
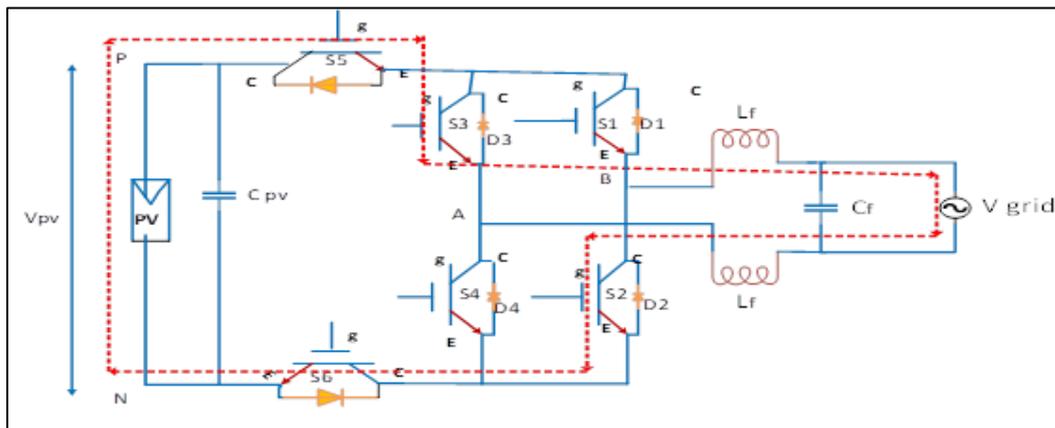

Figure 4 Third Mode of operation of H6 topology

2.2.4. Mode-4 Freewheeling mode

In the negative half-cycle freewheeling mode, current flows through D1 and S3.
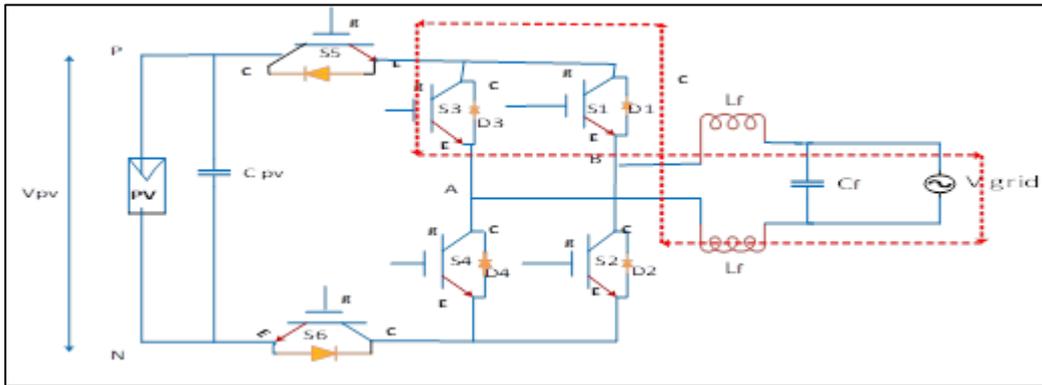

Figure 5 Fourth Mode of operation of H6 topology

3. Simulation result and discussion

MATLAB/Simulink is used for H6 inverters. Simulations are used to analyze inverter performance. Fig. 6. Simulation model for H6 inverter topology with unipolar modulation. Simulation has conducted using the parameters recorded in Table 1.

Table 1 Simulation parameters

DCinput _voltage	400Vdc
Vg	1 Ph 230 V (RMS), 50 Hz
Grid _frequency	50 HZ
Rated Power	2KW
Switching _Frequency	10KHZ
Dc-Link _capacitors	2200 µF
Inductors(Filter)	3 mH
Capacitor (Filter)	6 nF
Stray _capacitor	300 nF
Ground _Impedance	11Ω

According to Figure 7, the simulation of inverter H6 shows minimum leakage current and maintains constant common-mode-voltage. The leakage-current is reduced and the inverter is more efficient. Compared H6 inverter with conventional inverters, it achieves a lower leakage current and a more stable common mode voltage during operation. Matched to conventional topology, H6 inverters have relatively low conduction loss. H6 inverters therefore perform better than conventional topologies.

The table 2. below records the change in leakage current value from the minimum load of 200W to the full load possible for the given panel, i.e., 2kW.

Table 2 Variation of Leakage Current with load

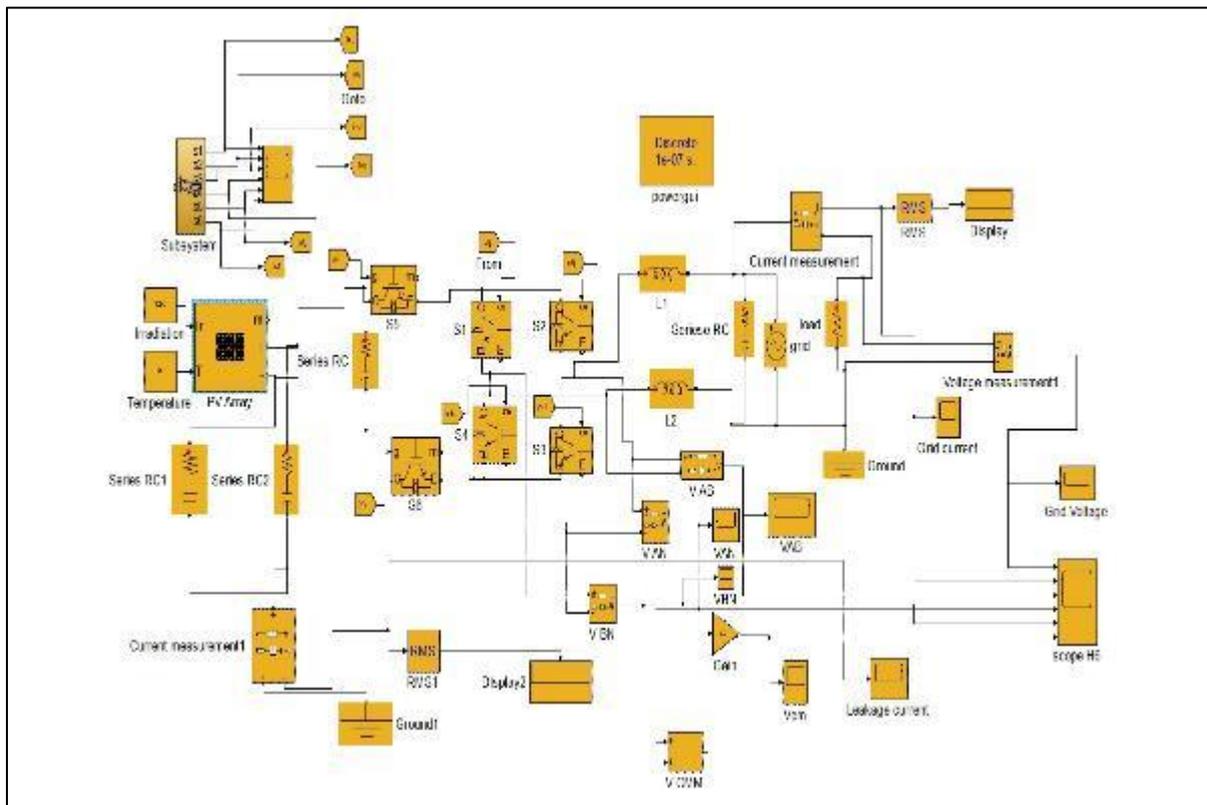| Load (W)	Leakage Current (mA)_RMS
200	149.1
400	108.1
600	83.9
800	69.95
1000	61.41
1200	55.89
1400	52.14
1600	49.5
1800	46.13
2000	42.47

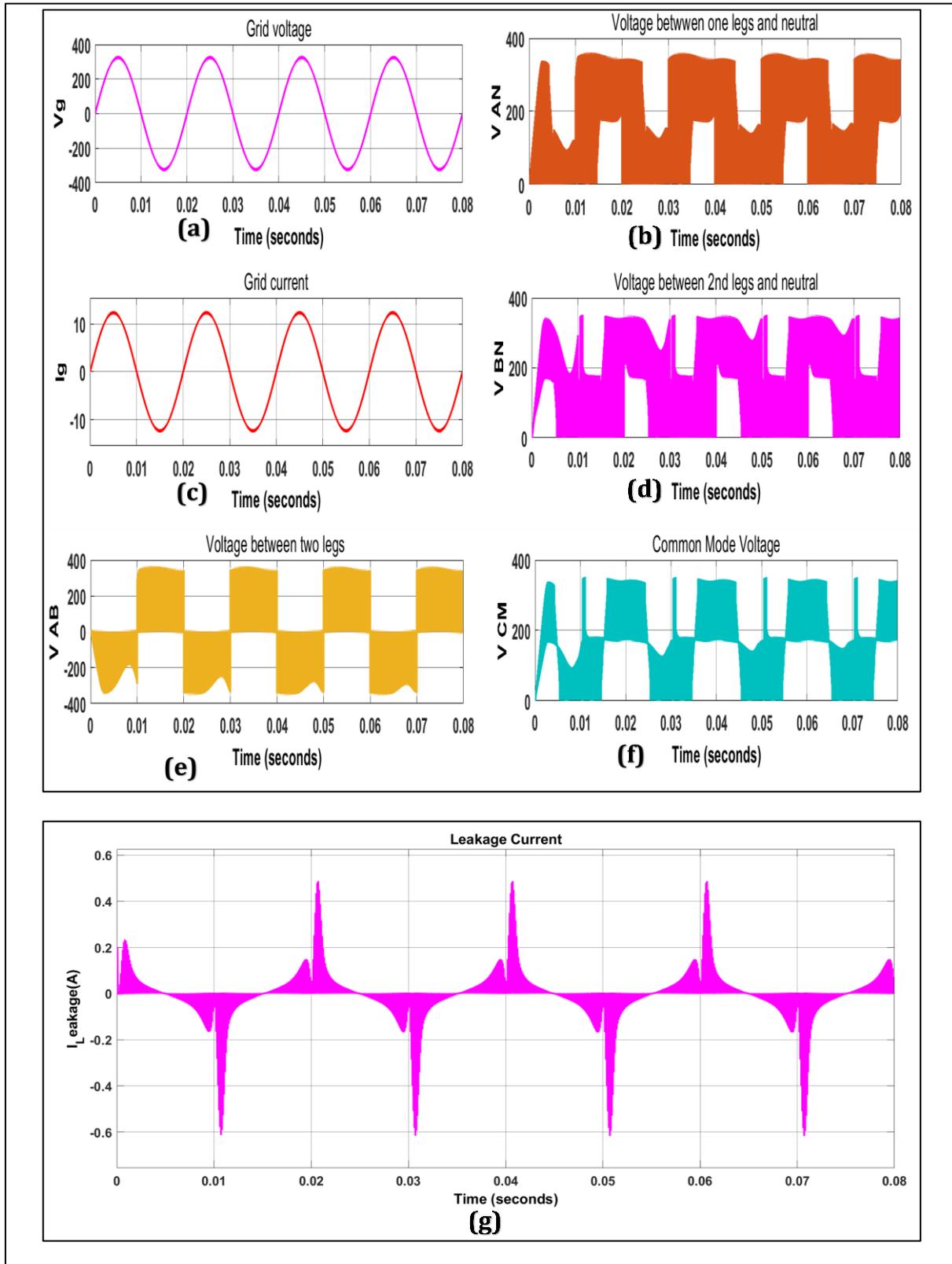**Figure 6** Simulation model for H6 inverter topology with unipolar modulation

Figure 7 (a) V_g, (b) V_{AN}, (c) I_g, (d) V_{BN}, (e) V_{AB}, (f) V_{CM}, and (g) leakage current waveforms for H6 inverter topology with unipolar modulation

4. Conclusion

This paper presents an H6 inverter topology that reduces leakage current, conduction losses and improves inverter efficiency. A detailed analysis of H6 inverters is performed in order to minimize leakage currents in grid-connected transformerless inverter circuits. Simulation results show that even though there are six switches in the circuit, the H6 inverter performs much better in suppressing leakage current than conventional inverters. Therefore, the H6 inverter is a promising topology as it reduces losses, eliminates leakage current, and increases inverter efficiency. The H6 inverter shows better performance than the conventional inverter topologies.

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