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ANALYSIS OF DIFFERENCES VARIOUS GRID-TIED TOPOLOGIES INVERTERS WITH-OUT A TRANSFORMER

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ABSTRACT

Due to the benefits of achieving high efficiency and low cost, transformer-less inverters are commonly employed in grid-connected photovoltaic (PV) generation systems. To meet the leakage current safety requirement, various transformer-less inverter topologies have been developed. The fundamental relationship between the H5 topology, the highly efficient and reliable inverter concept (HERIC) topology, and the proposed H6 topology is also examined in this study. For a detailed investigation of operation modes and modulation technique, one of the suggested H6 inverter topologies is used as an example. Between the H5, the HERIC, and the projected H6 topologies, power losses and power device costs are examined. For each of the three topologies stated, a universal prototype is developed in order to evaluate their performance in terms of power efficiency and leakage currents. The suggested H6 topology and the HERIC achieve equal performance in leakage currents, which is somewhat worse than the H5 topology, but it has a greater efficiency than the H5 topology, according to experimental results.

Keywords: Photovoltaic (PV), Highly Efficient And Reliable Inverter Concept (HERIC), H5,H6 Topology.

I. INTRODUCTION

In recent years, the use of distributed photovoltaic (PV) generation systems in both business and residential buildings has exploded. In comparison to other renewable energy sources, the overall cost of both the investment and generation of a PV grid-tied system is still too expensive. As a result, grid-tied inverters must be meticulously designed to achieve high efficiency, low cost, small size, and low weight, particularly in low-power single-phase systems (less than 5kW). Due to the benefits of achieving high efficiency and low cost, transformer-less inverters are commonly utilised in grid-tied photovoltaic (PV) generation systems from a safety perspective. To meet the safety criterion of leakage currents, other transformer-less inverter topologies have been proposed, such as those defined in the VDE-4105 standard. A family of H6 transformer-less inverter topologies with low leakage currents is presented in this study, as well as the intrinsic relationship between H5 topology, HERIC topology, and proposed H6 topology. For detailed examination, one of the proposed H6 inverter topologies is used as an example, complete with operation modes and modulation method. The power losses and power device expenses of the H5, HERIC, and projected H6 topologies are compared. For each of the three topologies stated, a universal prototype is developed to assess their performance in terms of power efficiency and leakage current characteristics. The suggested H6 topology and the HERIC accomplish equal leakage current performance, which is somewhat worse than the H5 topology, but it has a greater efficiency than the H5 topology.

H5, HERIC, AND THE PROPOSED H6 TOPOLOGIES IN COMPARISON.

The suggested H6 topology, H5 topology, and HERIC topology power losses are estimated using the same parameters as in Table 1. The inductor losses in the three topologies, on the other hand, are identical due to the same VAB modulation. As a result, the inductor losses of these three topologies are indistinguishable. Table 1 summarises the comparison of operational devices in these three topologies. The turn on/off loss, conduction loss, diode freewheeling loss, diode reverse recovery loss, and gate losses are the principal power losses of switches in each operation mode.

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Table 1: Comparison of operating devices in these three topologies

		H5	HERIC	H6
Total device number		5	6	6
Isolated power supply for devices		4	3	4
Switching device number		2	2	2
Conducting device number	$v_g>0$	3	2	3
	$v_g<0$	3	2	2
Diodes number with freewheeling		2	2	2
Diodes number with reverse recovery		1	1	1
Gate drive number		2	2	2

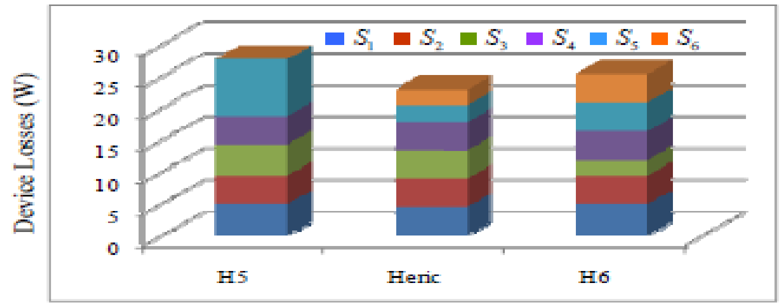

Fig 1: Device losses distribution for these three topologies with 1 KW power rating

The H5 architecture comprises just five power devices, as demonstrated in Tables 1 and 2. As a result, it is the most affordable device. HERIC and H6 both have the same device cost. These three topologies all have the same switching, diode freewheeling, diode reverse recovery, and gate drive losses. The proposed H6 topology, on the other hand, has a larger conduction loss than the HERIC topology.

Table 2: Parameters of the H6 transformer-less inverter

Parameter	Value
Rate power	1000 W
Input voltage	380~700 V
Grid voltage/frequency	230V/50Hz
Switching frequency	20kHz
Input Capacitance C_{dc}	940uF
Filter inductor L_1, L_2	3mH
Filter Capacitor C_o	0.47uF
Power Devices S_1~S_6 (IGBT)	IRG4PH40U
PV parasitic capacitances C_{PV1}, C_{PV2}	0.1uF

Thermal stress distribution is optimal in the HERIC topology, while it is worse in the H5 topology. HERIC topology has the smallest power loss. In full-bridge transformer-less inverters, many techniques have been presented to achieve CM voltage constant [9.] Using a full-bridge inverter with bipolar SPWM is a conventional way. During all working modes, the CM voltage of this inverter remains constant. As a result, it has a high leakage current capability. Current ripples over the filter inductors, however, are likely to be considerable, as are switching losses. Due to their outstanding differential mode (DM) properties, such as reduced inductor current ripple and improved conversion efficiency, full-bridge inverters with unipolar SPWM control are appealing. However, in a traditional unipolar SPWM full-bridge inverter, the CM voltage fluctuates with switching frequency, resulting in significant leakage currents [4]. This problem has two possible solutions. One alternative is to directly link the PV negative terminal to the utility grid's neutral line, as with the Karschny inverter [2] and inverters based on the virtual dc bus concept [5]. These full-bridge topologies use unipolar modulation techniques to keep the CM voltage constant. Another option is to use the freewheeling modes to disconnect the DC and AC sides of the full-bridge inverter. The H5 topology [3], the highly efficient and reliable inverter concept (HERIC) topology [13], the H6-type topology [6], and the Hybrid-bridge topology, among others, have all been designed and investigated based on this method for maintaining the CM voltage constant. On the DC side of the inverter, the H5 topology has an extra switch. When the inverter output voltage reaches zero, the PV array is removed from the utility grid, and the leakage current route is closed. The HERIC design in Fig. 5 employs two additional switches on the AC side of the inverter, effectively cutting off the leakage current

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path. However, compared to the H5 architecture, its power device cost is higher. Two more switches are used in the DC sides of these two topologies when compared to a full bridge inverter. In addition, the efficiency and leakage currents characteristics of the H5 and HERIC topologies have been studied [1]. These topologies, on the other hand, have never been investigated in terms of topological relationships.

A family of innovative H6 full-bridge topologies for transformer-less PV grid-tied inverters is proposed in this paper. An extra switch is added to the H5 topology to create a new current path and reduce conduction loss. As a result, in the active modes, the proposed H6 topology's inductor current passes through two switches during one half line period and three switches during the other half line period. As a result, when compared to the topologies provided in [3, [5,] and [9], the suggested H6 topology has the lowest conduction loss and low leakage currents. The topological link between H5 and HERIC topology is shown, and methods for producing HERIC topology from H6-type and Hybrid-bridge topologies are described, respectively.

II. SIMULATION OF PROPOSED SYSTEM

The topology of the H6 type is used as a starting point for investigation. Two switches connect the terminal (A) to the PV array's negative terminal, and two more connect the terminal (B) to the PV array's negative terminal, as shown in Fig. As a result, in the active modes of the H6-type architecture, the inductor current is regulated through three switches. The collector of switch S2 is removed from the anode of diode D1, then connected to the terminal (A), as shown in Fig. , to reduce conduction loss. In the active mode during the negative half cycle of the grid voltage, the inductor current flows through S2 and S3 rather than S2, S3, and S6. In the freewheeling modes, the DC and AC sides of the topology remain separated. As shown in Fig. , the switch S4 is connected to the terminal (B) after being detached from the diode D2. As a result of the approaches outlined in Fig. , a HERIC topology circuit structure is obtained. Fig. illustrates the topology. The bi-directional switch in the AC side has a different shape than the HERIC architecture depicted in Fig.

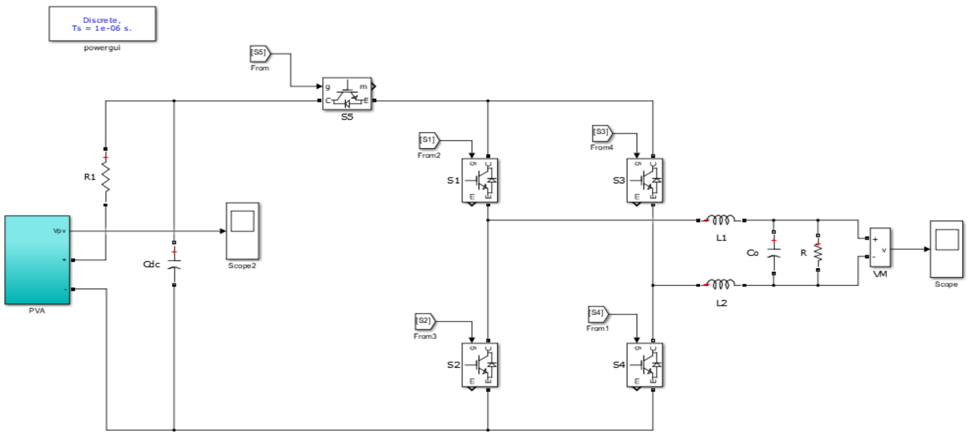

Fig. 2: H5 inverter topology

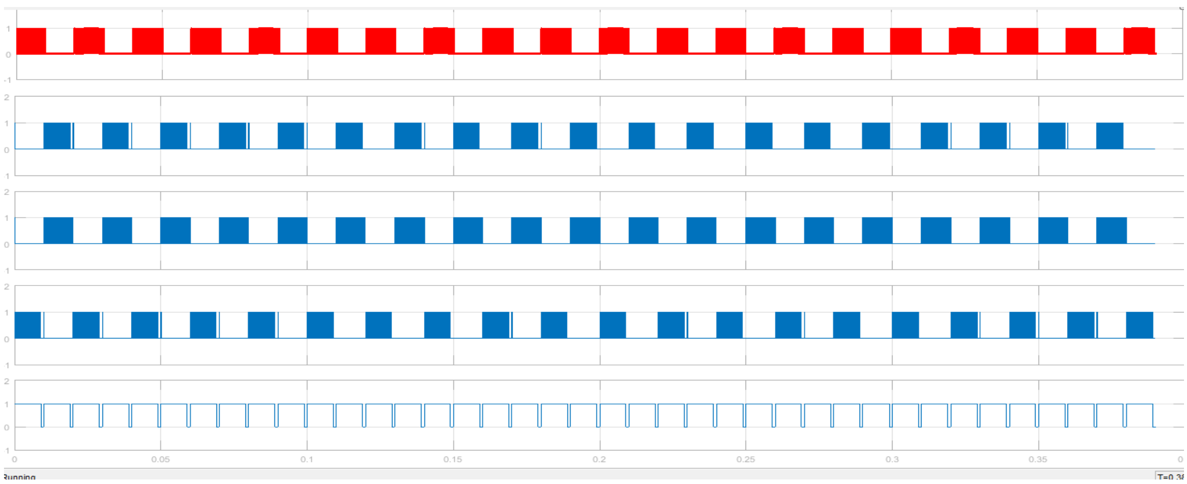

Fig.3: H5 inverter pulses

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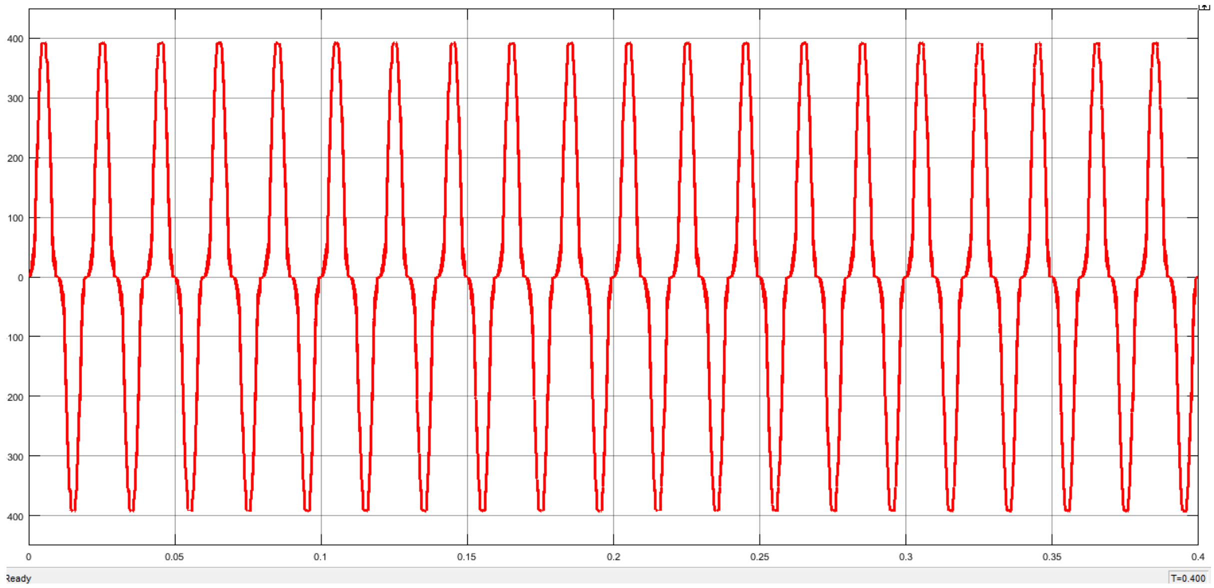

Fig.4: H5 inverter output voltage

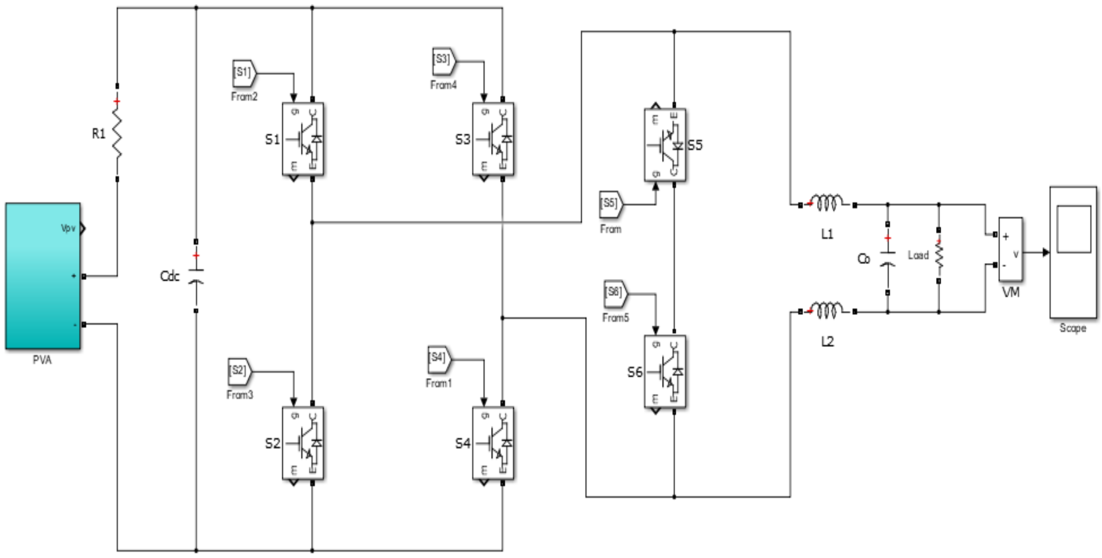

Fig.5: HERIC inverter topology

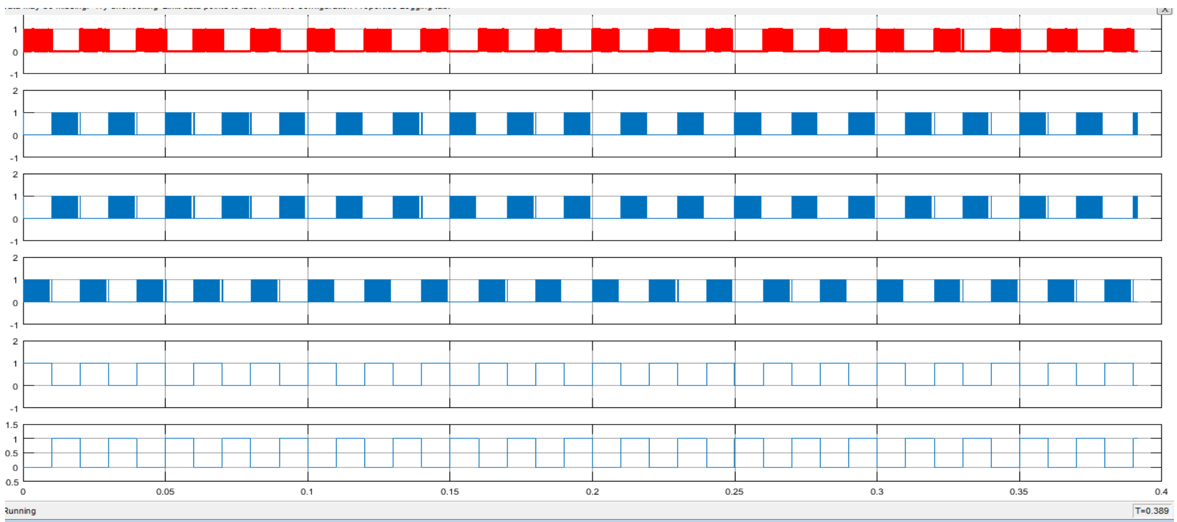

Fig.6: HERIC inverter pulses

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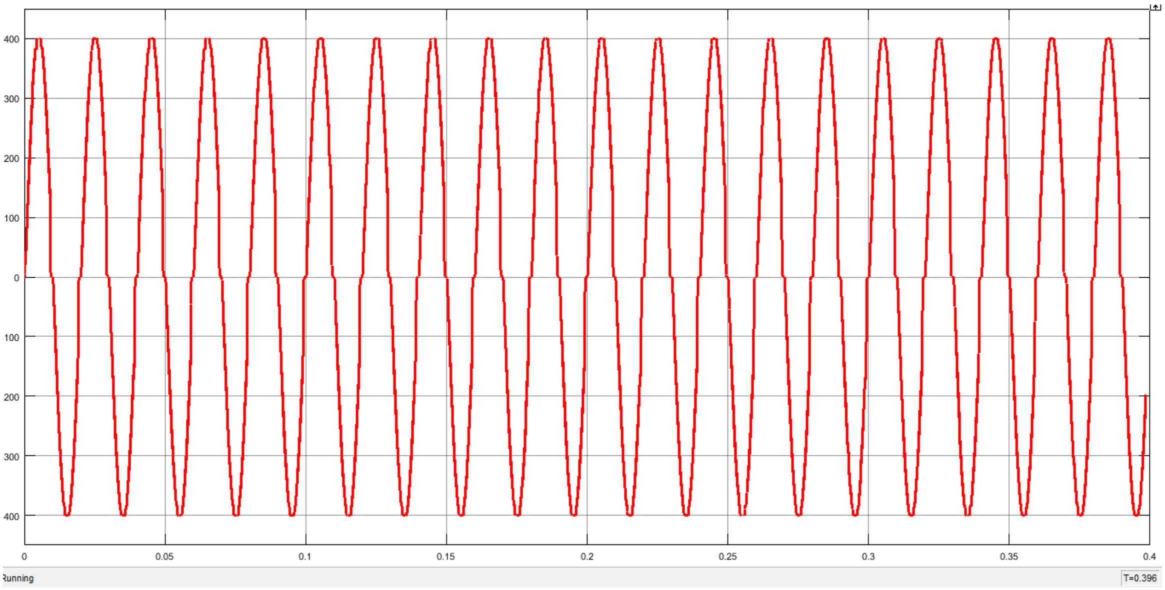

Fig.7: HERIC inverter output voltage

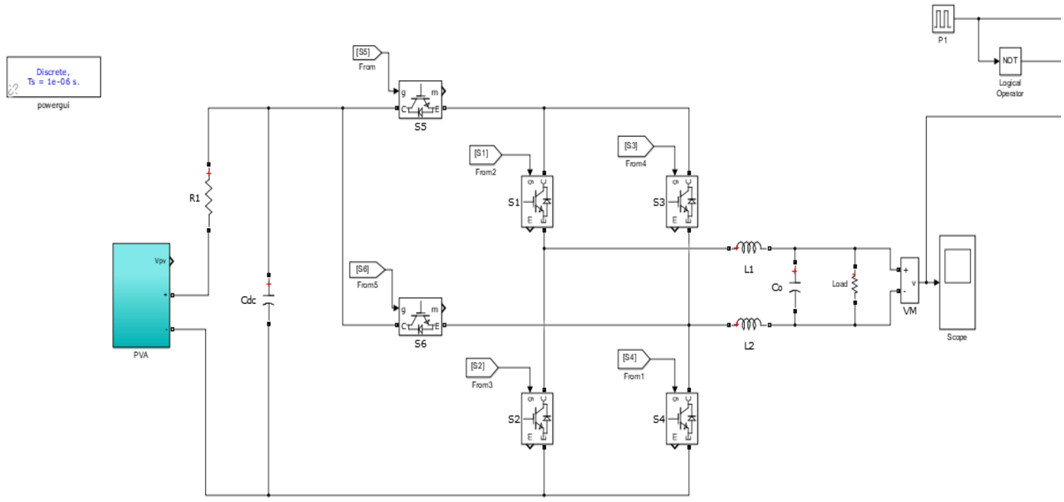

Fig.8: H6 UPF inverter topology

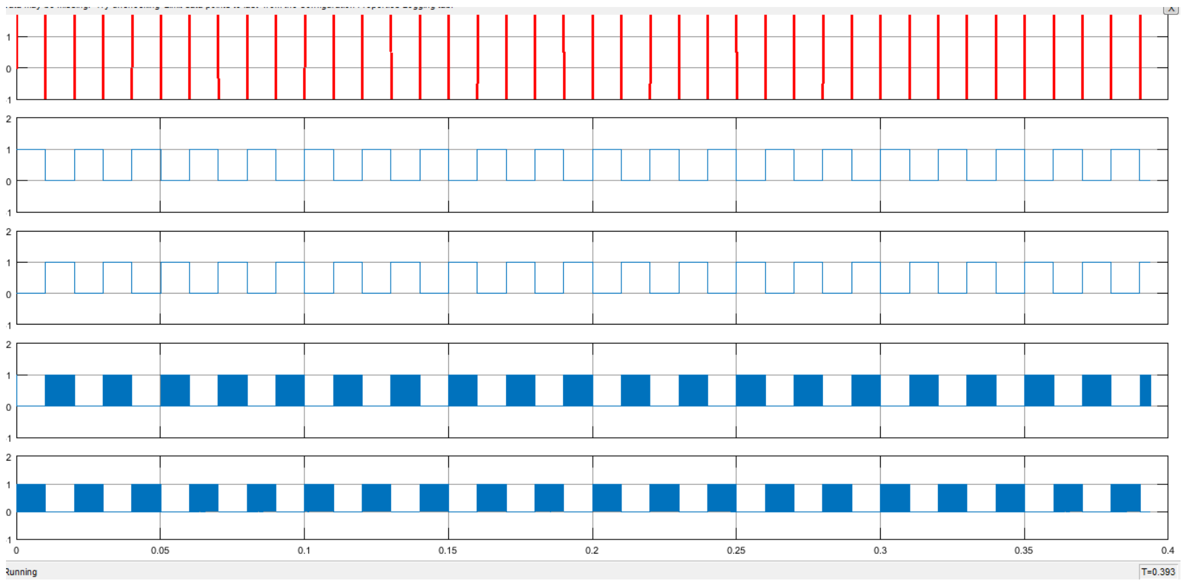

Fig.9: H6 UPF inverter pulses

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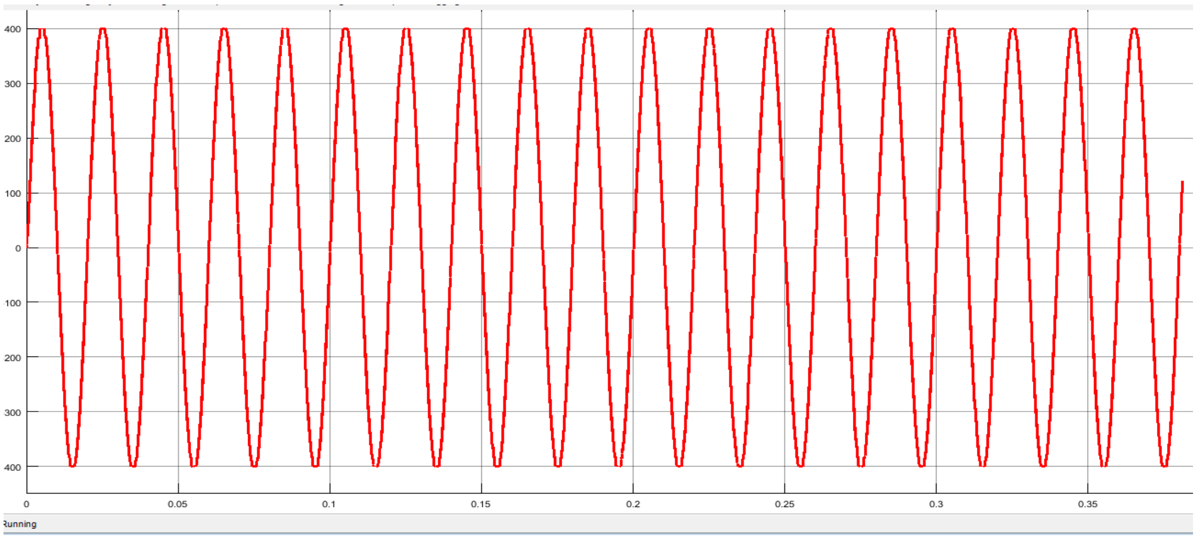
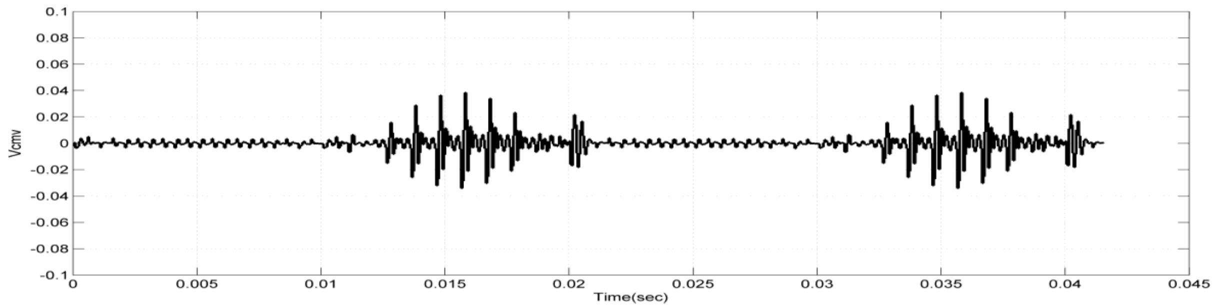
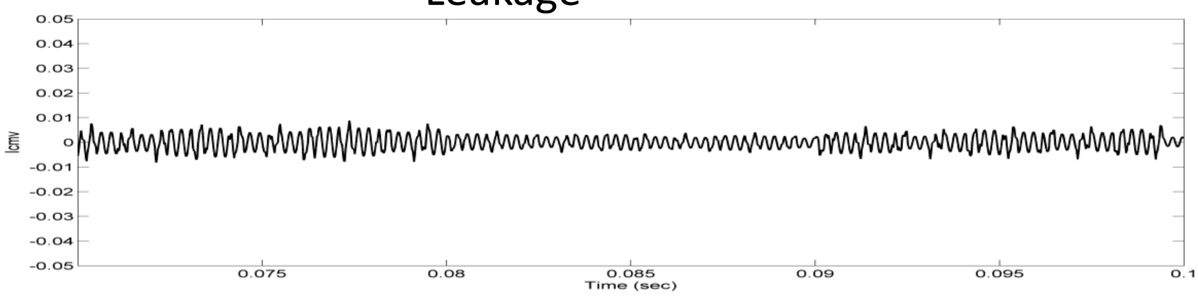


Fig.10: H6 UPF inverter output voltage

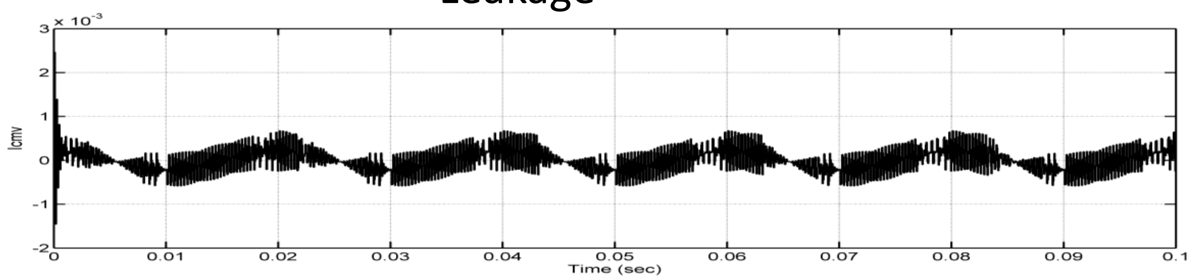
Leakage current H5,H6 & HERIC



Leakage



Leakage



Leakage

Leakage current

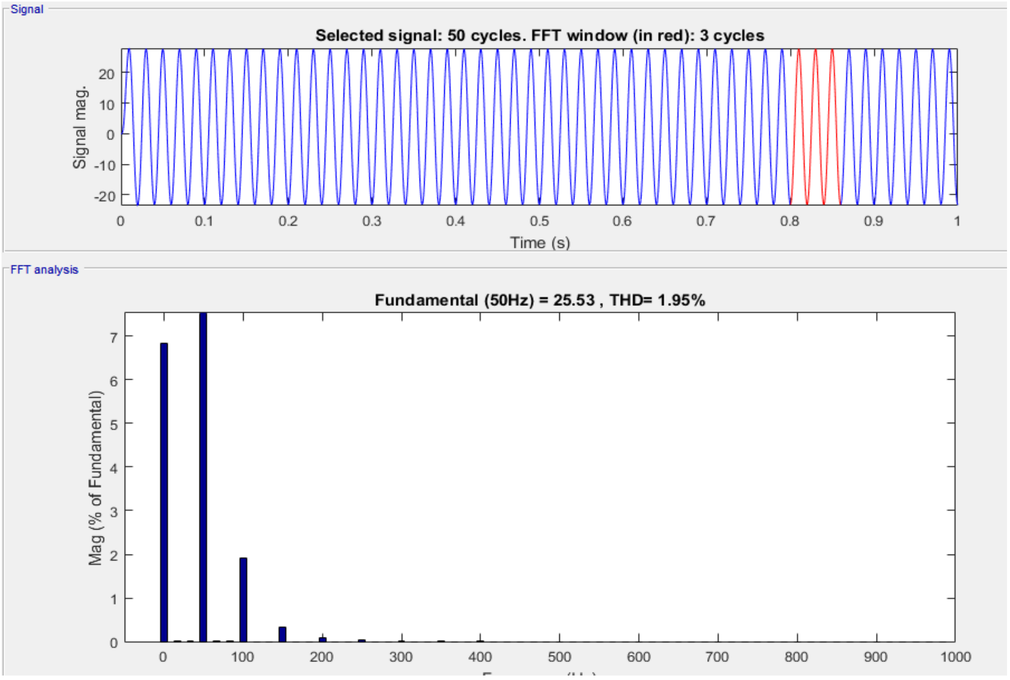


Fig.11: THD using proposed system

III. CONCLUSION

The intrinsic relationship between H5 topology and HERIC topology is disclosed in this research, from the standpoint of topological relationships. By minimising conduction loss, the HERIC topology is derived from H5, H6-type, and Hybrid Bridge topologies. Furthermore, by inserting a power device between the PV array terminals and the middle of one of the bridge legs, a new current path is constructed based on the H5 architecture. As a result, a family of low-leakage current single-phase transformer-less full-bridge H6 inverter topologies is developed.

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