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Comparative Analysis Different Topologies of Grid-tied Transformer Less Inverters for Photovoltaic system.

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Abstract: *Transformer less inverters are widely used in grid-tied photovoltaic (PV) generation systems, due to the benefits of achieving high efficiency and low cost. Various transformer less inverter topologies have been proposed to meet the safety requirement of leakage currents. In this paper, a family of H6 transformer less inverter topologies with low leakage currents is proposed, and the intrinsic relationship between H5 topology, highly efficient and reliable inverter concept (HERIC) topology, and the proposed H6 topology has been discussed as well. One of the proposed H6 inverter topologies is taken as an example for detail analysis with operation modes and modulation strategy. The power losses and power device costs are compared among the H5, the HERIC, and the proposed H6 topologies. A universal prototype is built for these three topologies mentioned for evaluating their performances in terms of power efficiency and leakage currents characteristics. Experimental results show that the proposed H6 topology and the HERIC achieve similar performance in leakage currents, which is slightly worse than that of the H5 topology, but it features higher efficiency than that of H5 topology.*

Keywords: Photovoltaic (PV), Highly Efficient and Reliable Inverter Concept (HERIC).

I. INTRODUCTION

The applications of distributed photovoltaic (PV) generation systems in both commercial and residential structures have rapidly increased during recent years. Although the price of PV panel has been declined largely, the overall cost of both the investment and generation of PV grid-tied system are still too high, comparing with other renewable energy sources. Therefore, the grid-tied inverters need to be carefully designed for achieving the purposes of high efficiency, low cost, small size, and low weight, especially in the low-power single-phase systems (less than 5kW). From the safety point of Transformer less inverters are widely used in grid-tied photovoltaic (PV) generation systems, due to the benefits of achieving high efficiency and low cost. Various transformer less inverter topologies have been proposed to meet the safety requirement of leakage currents, such as specified in the VDE-4105 standard. In this paper, a family of H6 transformer less inverter topologies with low leakage currents is proposed, and the intrinsic relationship between H5 topology, HERIC topology and proposed H6 topology has been discussed as well. One of the proposed H6 inverter topologies is taken as an example for detail analysis with operation modes and modulation strategy. The power losses and power device costs are compared among the H5, the HERIC and the proposed H6 topologies. A universal prototype is built for these three topologies mentioned for evaluating their performances in terms of power efficiency and leakage currents characteristics. Experimental results show that the proposed H6 topology and the HERIC achieve similar performance in leakage currents, which is slightly worse than that of the H5 topology, but it features higher efficiency than that of H5 topology

II. COMPARISONS OF H5, HERIC AND THE PROPOSED H6 TOPOLOGIES

The power losses of power switches of the proposed H6 topology ,H5 topology and HERIC topology, are calculated with the same parameters as given in Table 1 , On the other hand, the inductor losses in the three topologies are the same due to the same VAB modulation. Therefore, the inductor losses of these three topologies are regardless. The comparison of operating devices in these three topologies are summarized in Table 1. The main power losses of switches in each operation mode include the turn on/off loss, conduction loss, diode freewheeling loss, diode reverse recovery loss, and gate losses.

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

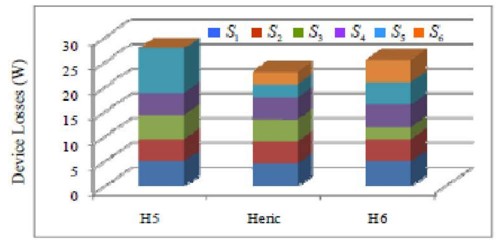

Fig. 1. Device losses distribution for these three topologies with 1 KW power rating

From Table 1 and Table 2, it can be seen that the H5 topology only has five power devices. Thus, it has the lowest device cost. The device cost of HERIC and H6 is the same. The switching loss, diode freewheeling loss, diode reverse recovery loss, and gate drive loss of these three topologies are the same. However, H5 topology has the highest conduction loss, and the conduction loss of the proposed H6 is higher than that of 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

HERIC topology has the best thermal stress distribution, while the H5 topology is the worst. The power loss of HERIC topology is the lowest. Many solutions have been proposed to realize CM voltage constant in the full-bridge transformerless inverters [9]. A traditional method is to apply the full-bridge inverter with the bipolar SPWM. The CM voltage of this inverter is kept constant during all operating modes. Thus, it features excellent leakage currents characteristic. However, the current ripples across the filter inductors and the switching losses are likely to be large.

The full-bridge inverters with uniploar SPWM control are attractive due to the excellent differential mode (DM) characteristics such as smaller inductor current ripple, and higher conversion efficiency. However, the CM voltage of conventional unipolar SPWM full-bridge inverter varies at switching frequency, which leads to high leakage currents [4]. Two solutions could be applied to solve this problem. One solution is to connect the PV negative terminal with the neutral line of the utility grid directly, such as the Karschny inverter derived from buck-boost converter [2], and the inverters derived from virtual dc bus concept [5]. The CM voltage is kept constant by these full-bridge topologies with unipolar modulation methods. Another solution is to disconnect the DC and AC sides of the full-bridge inverter in the freewheeling modes. Various topologies have been developed and researched based on this method for keeping the CM voltage constant, such as the H5 topology [3], the highly efficient and reliable inverter concept (HERIC) topology [13], the H6-type topology [6], and the Hybrid-bridge topology, etc., are shown in.

H5 topology employs an extra switch on the DC side of inverter. As a result, the PV array is disconnected from the utility grid when the inverter output voltage is at zero voltage level, and the leakage current path is cut off. The HERIC topology shown in Fig. 5employs two extra switches on the AC side of inverter, so the leakage current path is cut off as well. However, its power device cost is higher than that of the H5 topology.. Comparing with a full bridge inverter, two extra switches are employed in the DC sides of these two topologies. Furthermore, both the H5 topology and the HERIC topology have been compared in terms of efficiency and leakage currents characteristic [1]. However, these topologies have never been analysed form the point of view of topological relationships.

In this paper, a family of novel H6 full-bridge topologies is proposed for the transformer less PV grid-tied inverters. An extra switch is inserted to the H5 topology for forming a new current path and for the purpose of reducing conduction loss. Therefore, in the active modes, the inductor current of the proposed H6 topology flows through two switches during one of the half line periods, and flows through three switches during another half line period. As a result, for comparing with the topologies presented in [3], [5] and [9], the proposed H6 topology has achieved the minimum conduction loss, and also has featured with low leakage currents. On the other hand, the topological relationship between H5 topology and HERIC topology is revealed, and the methods for generating HERIC topology from H6-type topology and from Hybrid-bridge topology are presented respectively.

III. SIMULATION OF PROPOSED SYSTEM

The H6-type topology is taken as an example to analysis first. From Fig. 6 , it can be seen that there are two switches between the terminal (A) and the negative terminal of the PV array, and there are another two switches between the terminal (B) and the negative terminal of the PV array. Therefore, the inductor current is controlled to flow through three switches in the active modes of H6-type topology. In order to reduce the conduction loss, the collector of switch S2 is disconnected from the anode of diode D1, and then it is connected to the terminal (A), as shown in Fig. 5.3.

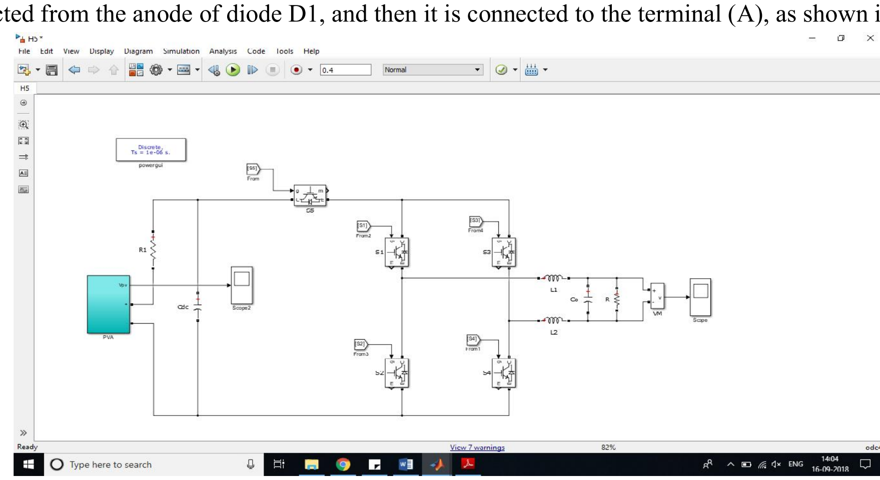

Fig. 6. H5 inverter topology

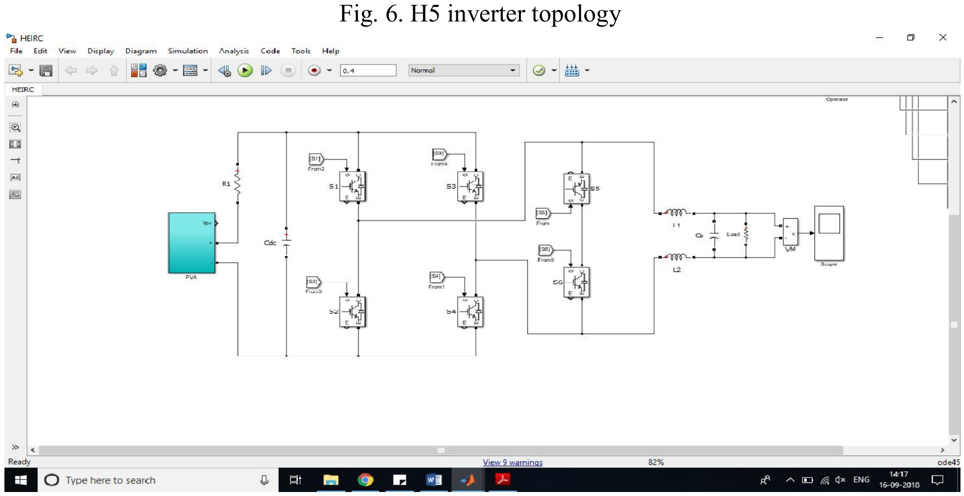

Fig. 7. HERIC inverter topology

As a result, the inductor current flows through S2 and S3 instead of S2, S3 and S6 in the active mode during the negative half cycle of the grid voltage. The DC and AC sides of this topology are still disconnected in the freewheeling modes. The same means are applied to another leg, where the switch S4 is disconnected from the diode D2 and then connected to the terminal (B), as shown in Fig. 5.3. Hence, a circuit structure of HERIC topology is derived by the methods described in Fig. 5.2. The topology is shown in Fig. 5.3. Compared with the HERIC topology shown in Fig. 5.2, the form of the bi-directional switch in AC side is changed.

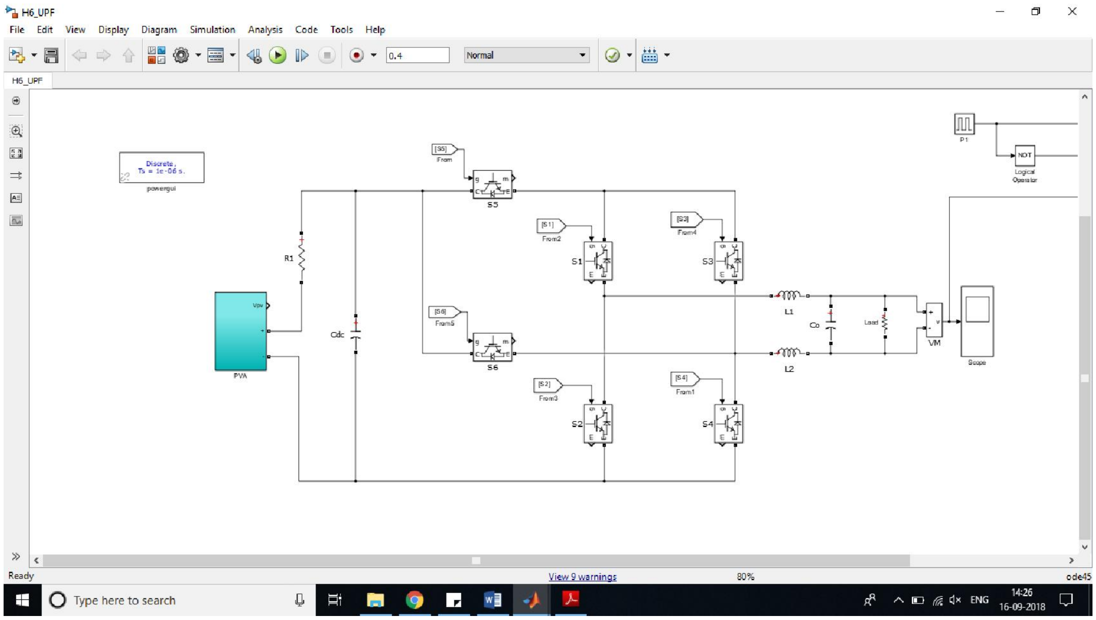

Fig. 8. H6 UPF inverter topology

IV. RESULT

The principle and operation of proposed system is presented using MATLAB/SIMULINK. The simulation waveforms observe in MATLAB Simulink.

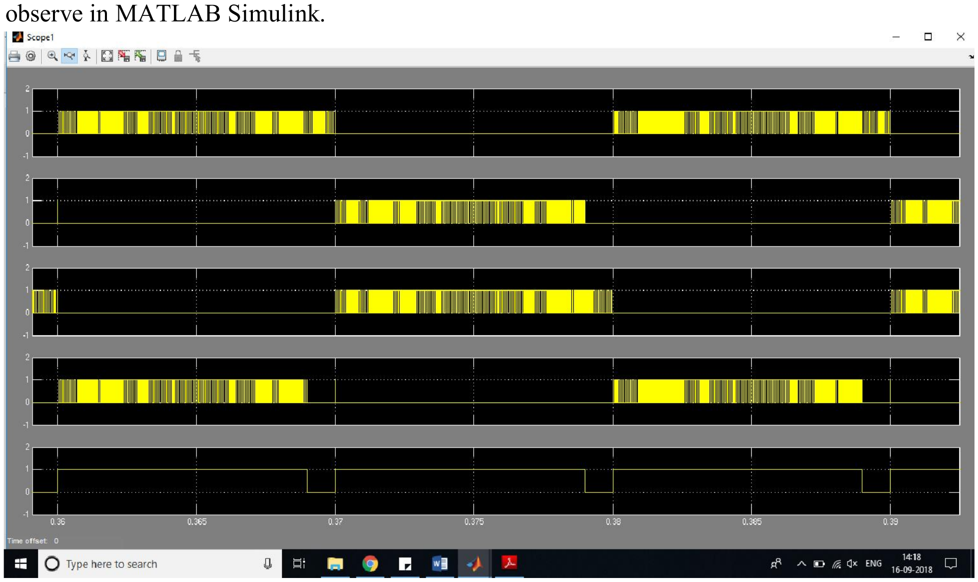

Fig. 9. H5 inverter pulses

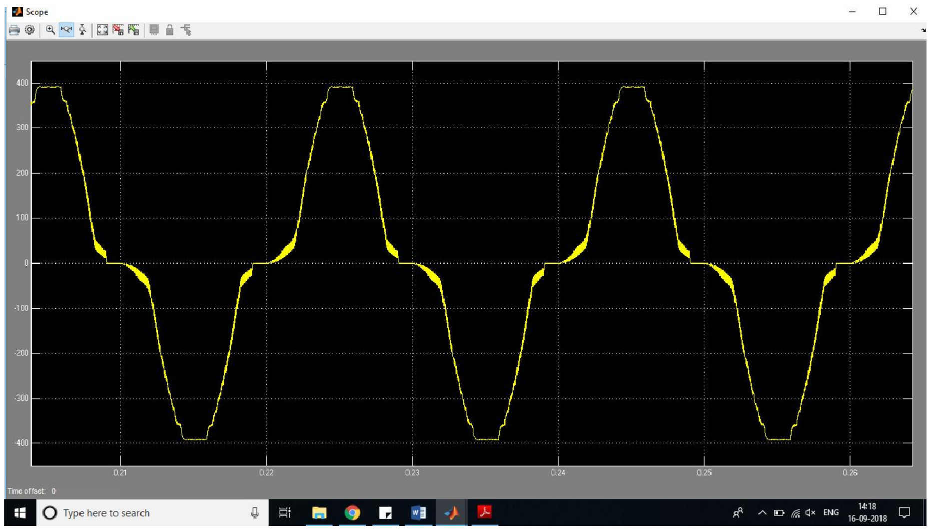

Fig. 10. H5 inverter output voltage

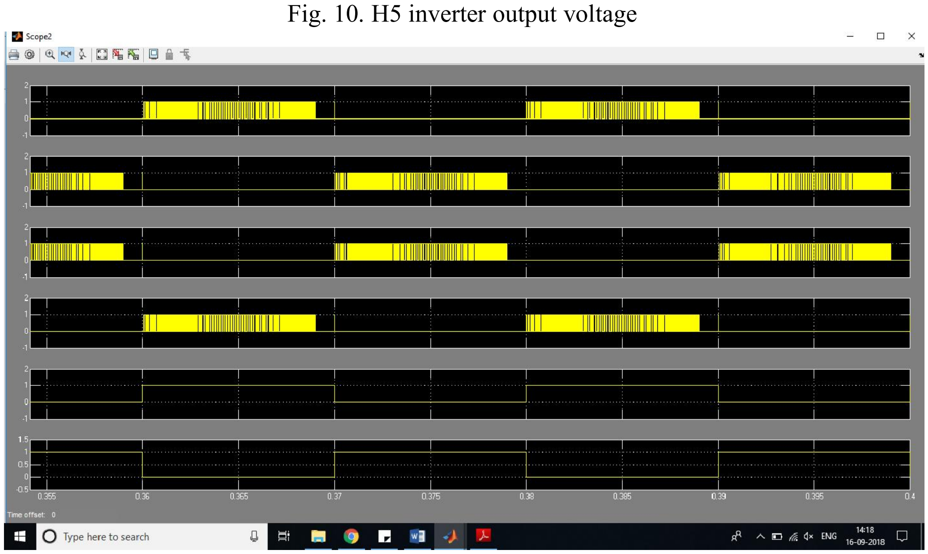

Fig. 11. HERIC inverter pulse

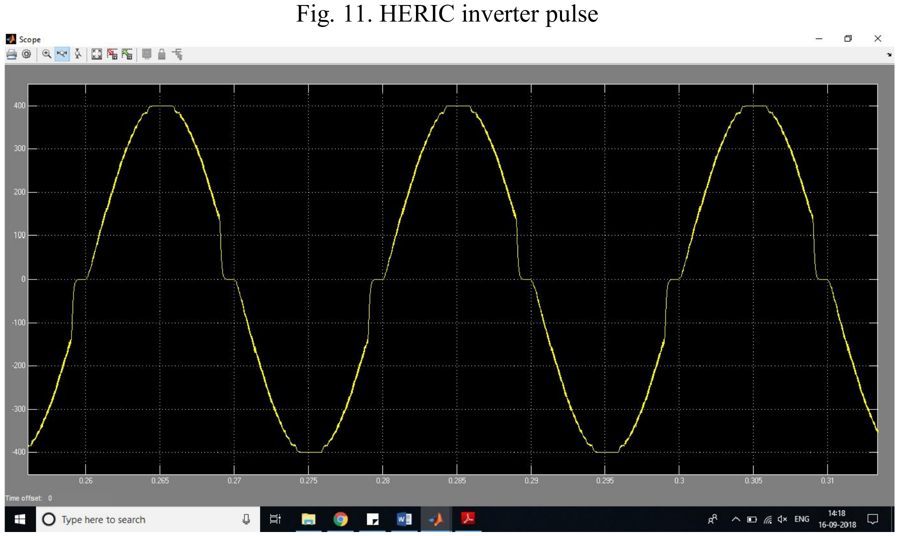

Fig. 12. HERIC inverter output voltage

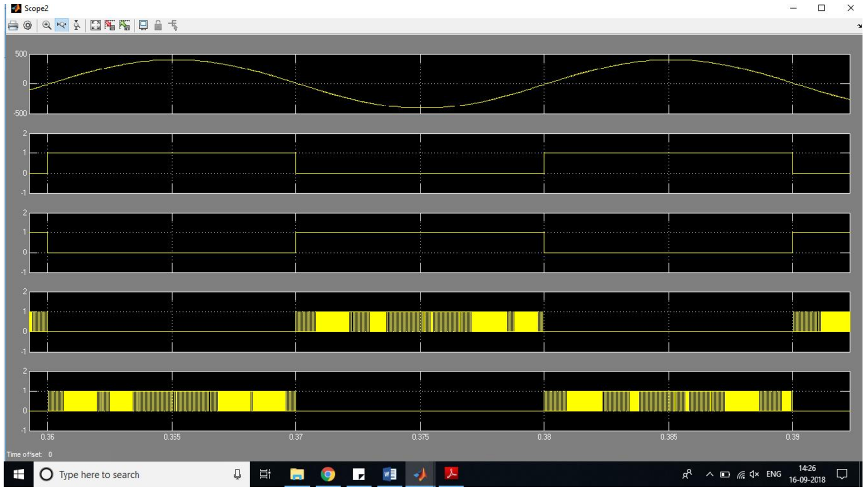

Fig. 13 H6 UPF inverter pulses

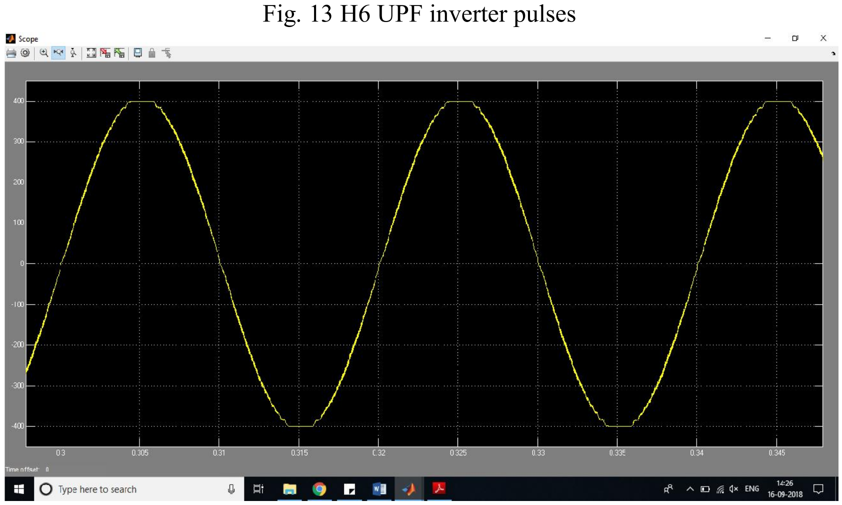

Fig. 14. H6 UPF inverter output voltage

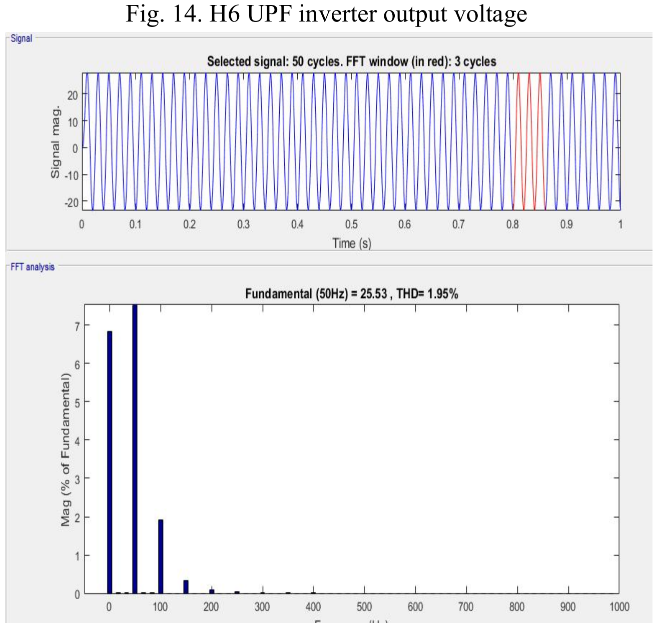

Fig: THD using proposed system

V. CONCLUSION

In this paper, from the topological relationship point of view, the intrinsic relationship between H5 topology and HERIC topology is revealed. The HERIC topology can be derived from H5, H6-type, and Hybrid Bridge topologies by the idea of reducing conduction loss. Moreover, based on the H5 topology, a new current path is formed by inserting a power device between the terminals of PV array and the midpoint of one of bridge legs. As a result, a family of single-phase transformerless full-bridge H6 inverter topologies with low leakage currents is derived

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