# Different Type of Inverter Topologies for PV Transformerless Standalone System

[1]Chiragsinh Raj,[2]Mr. Hitesh Lade,
[1]M. Tech. Student,[2]HOD Electrical & Electronics Engineering Department,
[1]Electrical Engineering Department,
[1]Surabhi College of Engineering & Technology, Bhopal, India

***Abstract*—Nowadays, the transformer less inverters need get to be An broad pattern in the single-phase grid-connected photovoltaic (PV)System due to the low expense and high efficiency concerns. In this paper HERIC, H5 and H6 transformerless 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 H6 topology has been discussed as well. Inverter topologies is taken as a sample for point of interest Investigation for operation modes and modulation strategy. MATLAB Simulation of all inverter Topologies and also get output result. Simulation results show that HERIC topology performance is better than H5 and H6in power losses topology.H5 topology performance is better than HERIC and H6 in leakage currents.**

***IndexTerms*— Mode voltage; grid-tied inverter; leakage Current; photovoltaic (PV) ge4neration system; transformerless inverter.**

## I. Introduction

Photovoltaic (PV) ac modules might get a pattern for future PV system due to their more terrific adaptability over disseminated system expansion,easier installation due to their "plug and play" nature, and higher system-level energy harnessing capabilities under shaded or PV manufacturing mismatch conditions as compared to the single or multistring inverters [1]–[4]. 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.

However, the inverters with high-frequency transformers have several power stages, which increase the system complexity and reduce the system efficiency [1]–[6]. As a result, the transformerless PV grid-tied inverters are widelyinstalled in the low-power distributed PV generation systems.

In the transformerless grid-connected PV systems, many topologies have been proposed to eliminate the leakage current, including the full-bridge inverter with the bipolarSPWM, many special topologies with unipolar SPWM such as HERIC, H5, H6 [1]. The full-bridge inverter with bipolar SPWM can guarantee to generate a constant commonmode voltage and no leakage current, but the required output filter is large due to the two-level output voltage, which increases the losses and reduces the power density.

However, a high DC bus voltage is required to supply the grid, which limits the operating voltage range of the PV panels. HERIC, H5 and H6 inverters can operate with the unipolar SPWM strategy and only require the same low DC bus voltage as that in the full-bridge inverter.

In this paper, a novel inverter topology for transformerlessPV systems is proposed, which guarantees no ground leakage current and requires the same low input DC voltage as theabove special transformerless inverters such as HERIC, 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 H5, H6, and HERIC topologies. A universal prototype is built for these three topologies mentioned for evaluating their performances in terms of power efficiency and leakage currents characteristics. Simulation results show that HERIC topology performance is better than H5 and H6 in leakage currents and power losses topology.

## II. Basic Block diagram of pv System

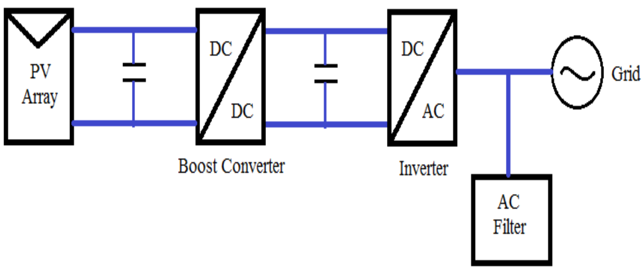



Figure 2.1 Basic Block Diagram

Figure 2.1 shows the block diagram of the PV system. Since the output voltage of PV panel is very low and practically it is not possible to keep large number of panels because it is not cost effective hence an additional boost stage is required in order to increase the voltage level. For low power application single phase full bridge inverter is used, but the efficiency of it is very low. Output from the inverter is not sinusoidal hence it cannot be connected directly to the grid, thus a filter stage is required. The most essential requirement in order to interface the grid with the system is to have sinusoidal voltage and current at the output terminal. So to convert the DC into AC an inverter stage is required. In this project HERIC, H5, H6 inverter with suitable control technique is used to improve the efficiency of the system.

## III. INVERTER

PVThe PV inverters, efficiently converts the DC source generated from the PV panels to alternating source (AC). In order to feed sinusoidal current and voltage into the grid, the DC link voltage at the output of the boost converter is to be converted into AC thus DC-AC conversion stage (Inverter) is required into the system. In this section three power converter topologies are discussed.

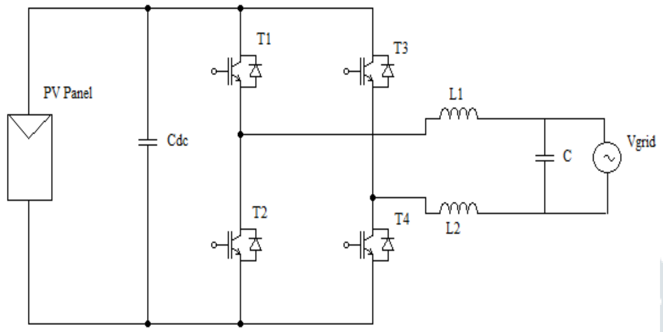



Figure 3.1 A Single Phase Full Bridge Inverter

Full Bridge topology is the most widely used technique for single phase grid connected photovoltaic inverter. As depicted in Fig. 2.2 it is develop by four transistors and through LCL filter it is connected to the grid. This topology is normally used in commercial purpose along with low frequency transformers. However due to lower efficiency and higher cost it is fascinating to study its application to transformerless inverters.

There are two types of modulation schemes which are basically used for this inverter:

1) Unipolar modulation scheme
2) Bipolar modulation scheme.

In transformerless topologies. The most well-known modulation scheme used is unipolar PWM, because it has various advantages over bipolar PWM scheme (for example, better efficiency, lower current ripple at higher frequency etc). However this scheme is less suitable for full bridge transformerless inverter since it requires common mode voltage of high frequency of amplitude $V_{dc}/2$, in order to minimize the leakage current that appears because of photovoltaic panel parasitic capacitance.

## IV. INVERTER TOPOLOGIES

There are three types of inverter topologies schemes which are basically used for this inverter:

1) HERIC
2) H5
3) H6

No indent the most essential requirement in order to interface the grid with the system is to have sinusoidal voltage and current at the output terminal. So to convert the DC into AC an inverter stage is required. In this project, Different inverter topologies with suitable control techniques are used to improve the efficiency of the system.

***HERIC Topology***

The HERIC topology shown in Figure 3.1 employs two extra switches on the ac side of inverter, so the leakage current path is cut off as well [1].

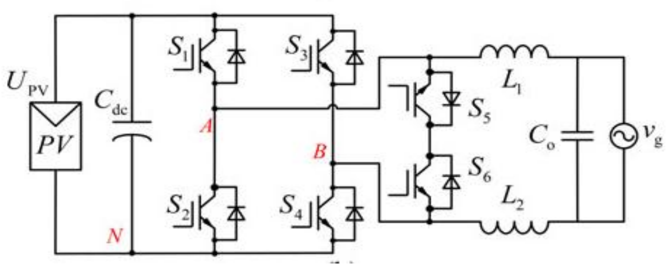



Figure 4.1 HERIC Topology

***Conduction Mode of HERIC Topology***

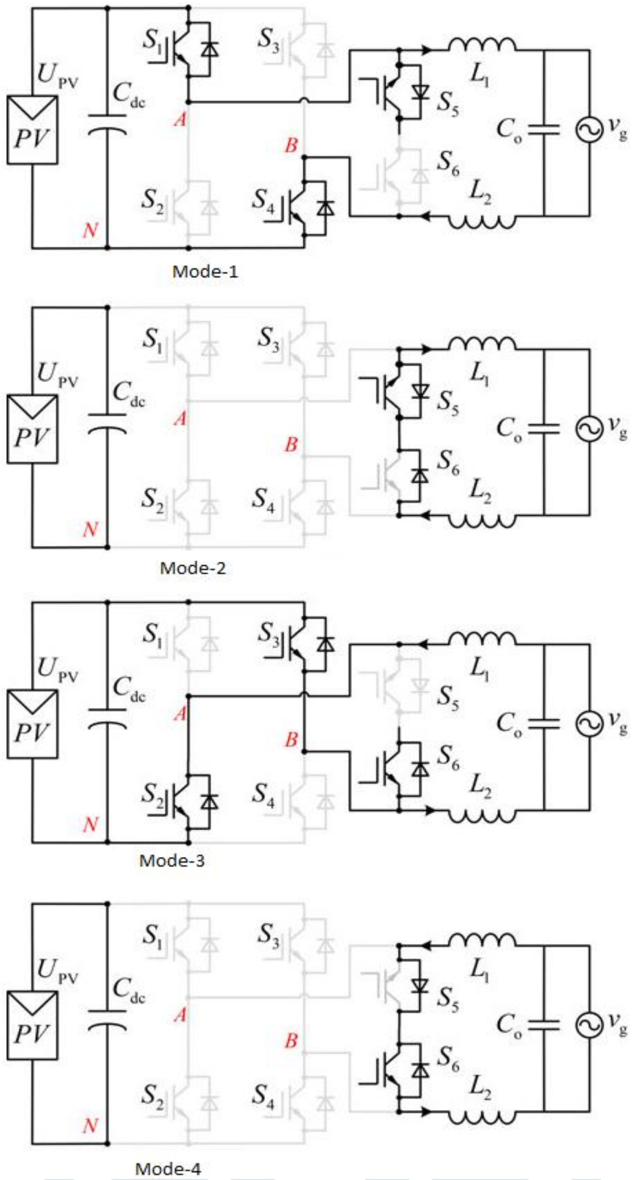



Figure 4.2 Conduction mode of HERIC inverter

There are four operation modes shown in Figure 3.2. In mode (1) S1, S4 Switches conduct so current flowing from S1, L1, Vg and retuning from L2. In Mode (2) S5, S6 Switches conduct which is freewheeling conduction same as in Mode (3) S2, S3 Switches conduct and In Mode (4) S5, S6 Switches conduct.

***Simulation and Output Result of HERIC Topology***

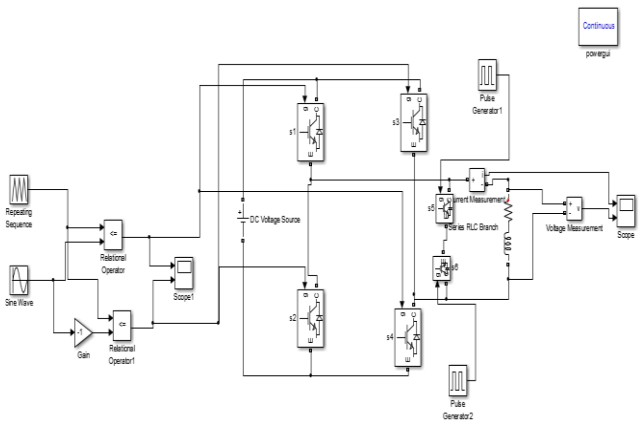


Figure 4.3: Simulation Model of HERIC Inverter

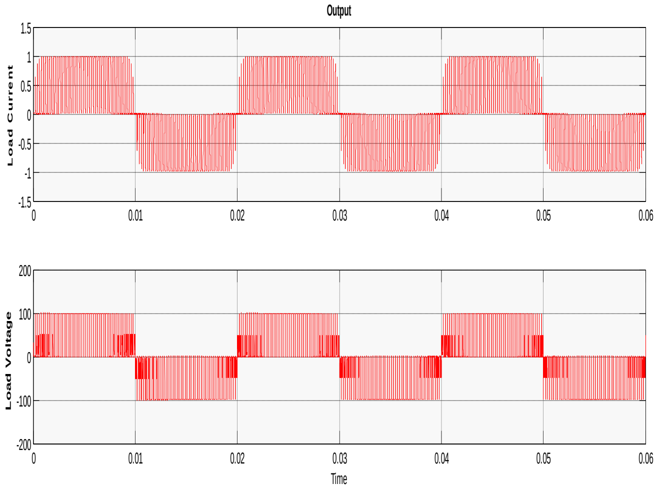



Figure 4.4 Output of HERIC Inverter

***H5 Topology***

The H5 topology shown in Figure 3.5, whereCdc is DC-link capacitor, L1 and L2 are filter inductance at grid side and C0 is the filter capacitor. It 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 [1].

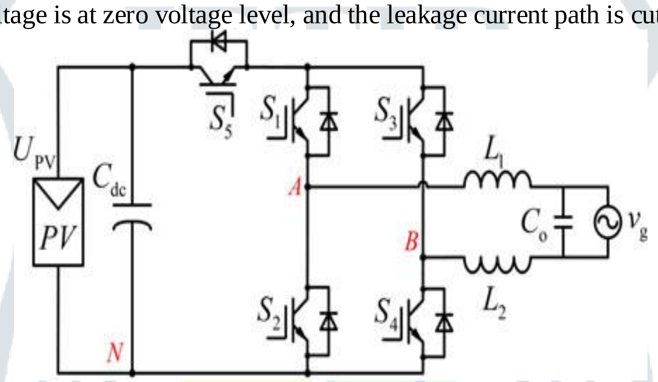
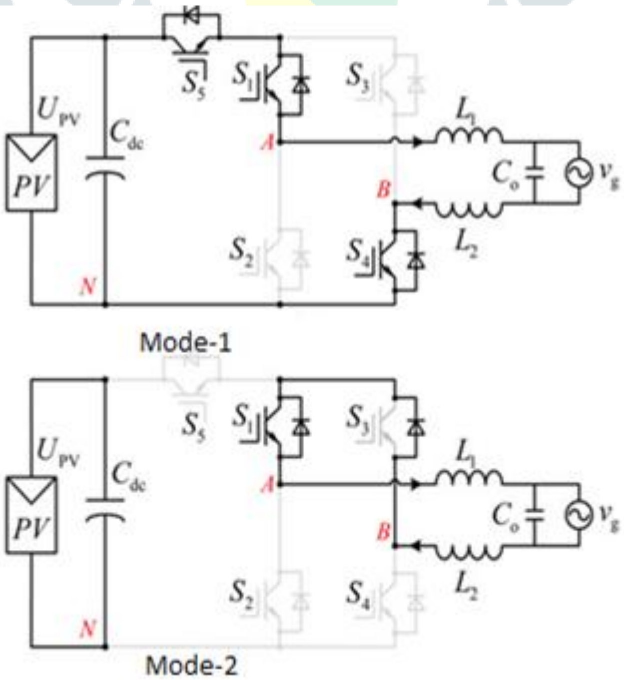



Figure 4.5 H5 Topology

***Conduction Mode of H5 Topology***



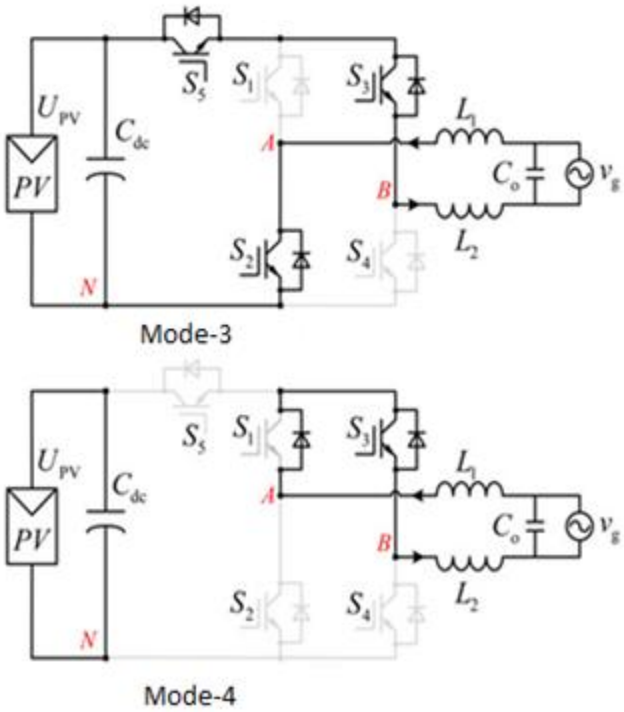



Figure 4.6 Conduction mode of HERIC inverter

There are four operation modes shown if Figure 3.6, In mode (1), S5, S1, S4 Switches conduct and current flowing from S5, S1, L1 , L2 and S4 . In Mode (2) S1 & freewheeling diode conduct for dissipating energy. same as in Mode (3) S5, S2, S3 Switches conduct. And In Mode (4) S3 & Freewheeling diode conduct.

***Simulation and Output Result of H5 Topology***

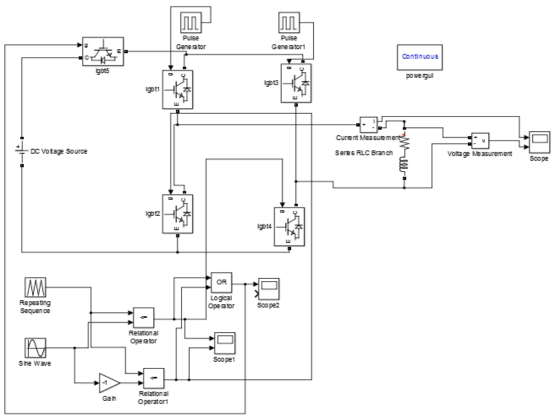



Figure 4.7 Simulation Model of H5 Inverter

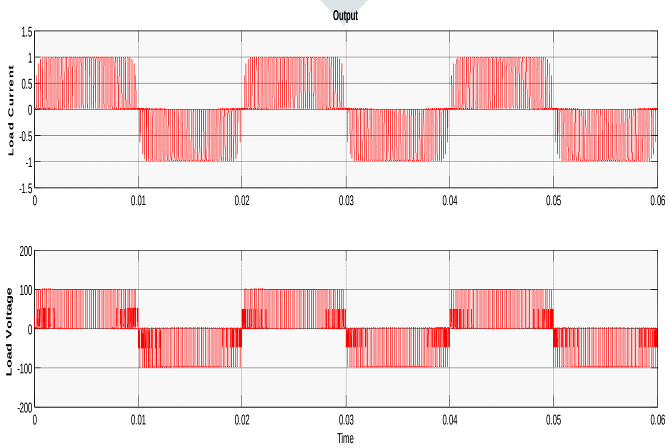



Figure 4.8 Output of H5 Inverter

***H6 Topology***

The H6 topology shown in Figure 3.5.whereCdc is DC-link capacitor, L1 and L2 are filter inductance at grid side and C0 is the filter capacitor. One extra switch connected in each leg which is S6 & S5 [4].

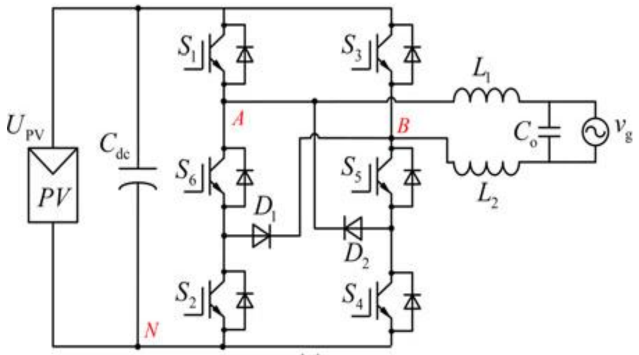



Figure 4.9 H6 Topology

***Conduction Mode of H6 Topology***

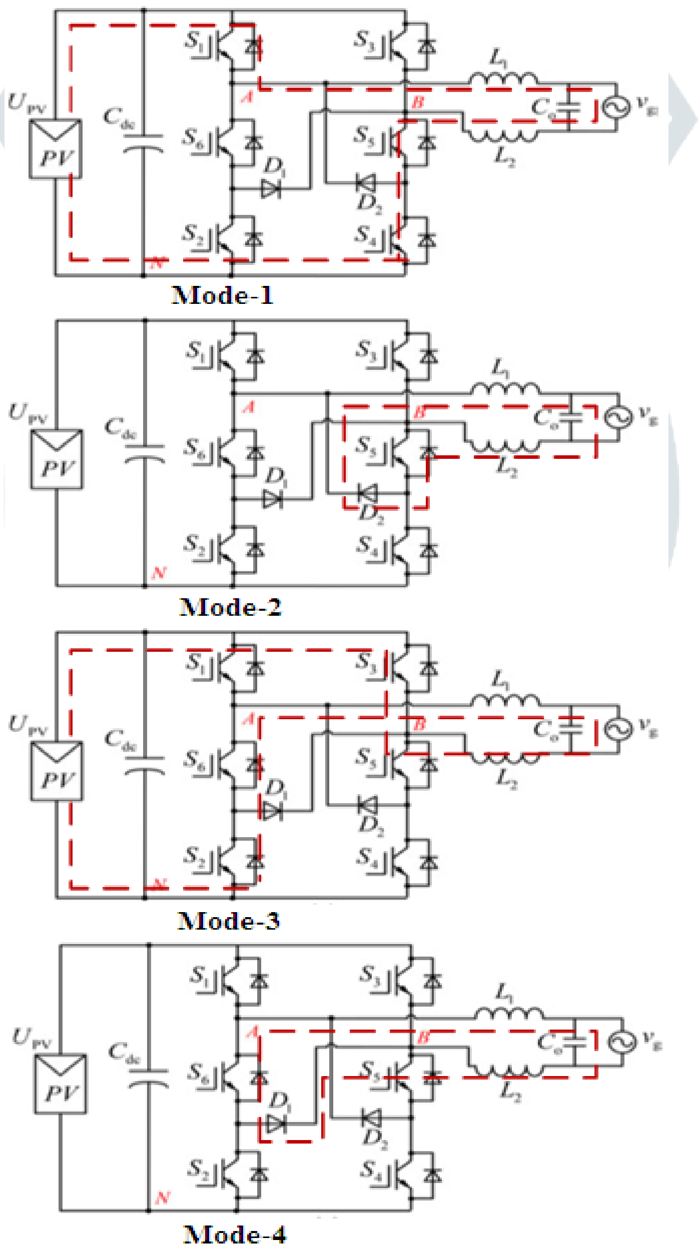



Figure 4.10 Conduction mode of HERIC inverter

There are four operation modes shown if Figure 3.10 In mode (1), S1, S5, S4 Switches conduct and current flowing from S5, S1, L1, L2 and S4. In Mode (2) S5& freewheeling diode conduct for dissipating energy. Same as in Mode (3) S3, S2, S6 Switches conduct and In Mode (4) S6& Freewheeling diode conduct.

***Simulation and Output Result of H6 Topology***

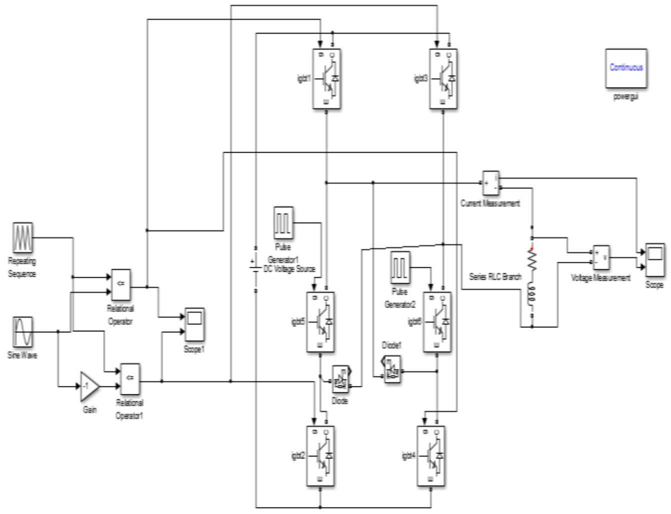



Figure 4.11 Simulation Model of H6 Inverter

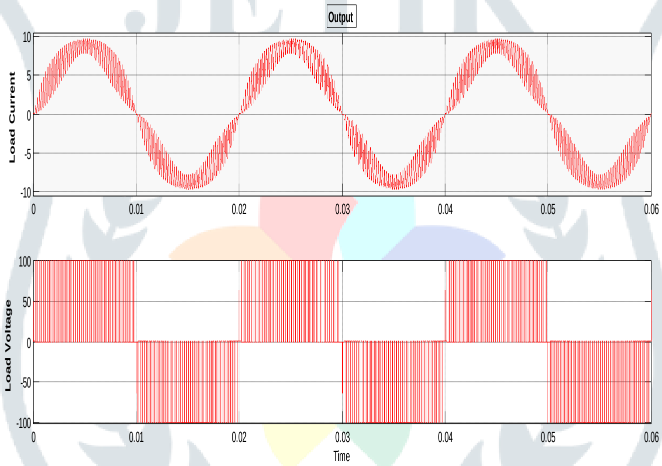



Figure 4.12 Output of H6 Inverter

## V. COMPARISION BETWEEN HERIC, H5 & H6 TOPOLOGY

***Operating Devices in there Three Topology***

TABLE I. Operating of Devices

| Inverter | S1 (W) | S2 (W) | S3 (W) | S4 (W) | S5 (W) | S6 (W) | Total Loss(W) |
|---|---|---|---|---|---|---|---|
| H5 | 4.911 | 4.472 | 4.911 | 4.472 | 8.944 | N.C. | 27.71 |
| HERIC | 4.472 | 4.472 | 4.472 | 4.472 | 2.571 | 2.571 | 23.03 |
| H6 | 4.911 | 4.472 | 2.571 | 4.472 | 4.472 | 4.472 | 25.37 |
| Note:Upv=380v | | | | | | | |

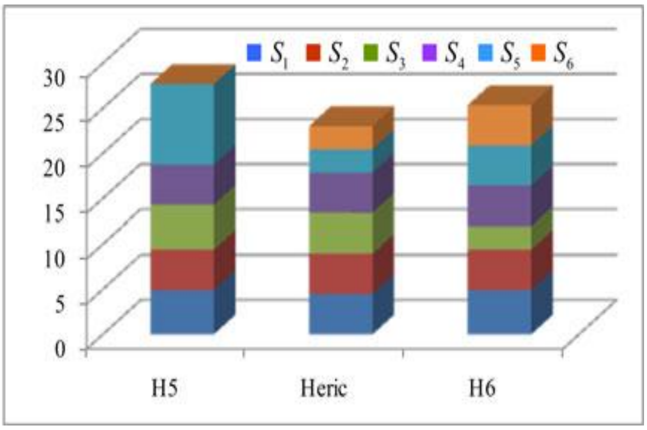



Figure 5.1 Losses of Device in Topology

TABLE II. COMPARISION

| | | HERIC | H5 | H6 |
|---|---|---|---|---|
| **Total Device Number** | | 6 | 5 | 6 |
| **Isolated Power Supply for devices** | | 3 | 4 | 4 |
| **Switching Device Number** | | 2 | 2 | 2 |
| **Conducting Device Number** | **$V_g > 0$** | 2 | 3 | 3 |
| | **$V_g < 0$** | 2 | 3 | 2 |
| **Diodes Number with freewheeling** | | 2 | 2 | 2 |
| **Diodes Number with reverse recovery** | | 1 | 1 | 1 |
| **Gate drive number** | | 2 | 2 | 2 |

TABLE III. OPERATING RATING

| **Parameter** | **Value** |
|---|---|
| **Rate Power** | 1000 W |
| **Input Voltage** | 380 – 700 V |
| **Grid Voltage/Frequency** | 230 v/ 50 Hz |
| **Switching Frequency** | 20 kHZ |
| **Input Capacitance $C_{dc}$** | 940 µF |
| **Filter Inductor $L_1$,$L_2$** | 3mH |
| **Filter Capacitor $C_0$** | 0.47µF |
| **Power Devices $S_1 – S_6$ (IGBT)** | IRGPH40U |
| **PV parasitic capacitances $C_{PV1}$, $C_{PV2}$** | 0.1µF |

The calculation methods and theories are studied and verified in details in literatures [1], but not the contribution of this paper. The power losses of power switches of the HERIC topology, H5 topology, and H6 topology are calculated with the same parameters as given in Table III, and are illustrated in Table I and 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 II. 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 loss.

From Tables I and II, 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. It can be seen that HERIC topology has the best thermal stress distribution, while the H5 topology is the worst. The power loss of HERIC topology is the lowest.

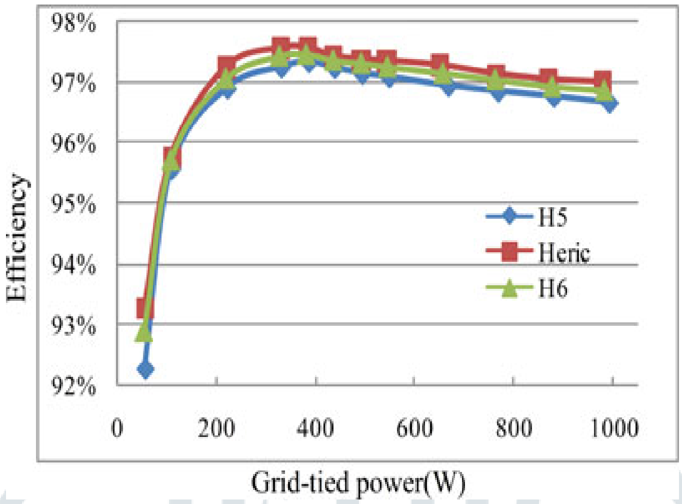



Figure 5.2 Comparision of Losses in Topology

In summary, the H5 topology has the best leakage current characteristic, but its efficiency is the lowest. The HERIC topology has the highest efficiency, but the leakage current characteristic is worse than that of H5 topology. The leakage current characteristic of proposed H6 topology is almost the same as that of HERIC topology. The efficiency of proposed H6 topology is a little less than the HERIC topology, but it is higher than H5 topology.

The conversion efficiency comparison of H5, HERIC, and H6 topologies under the same condition. It is obvious that the the proposed H6 topology takes the second place. The experimental results are in agreement with the power losses analysis. The European efficiencies of H5, HERIC, and H6 are 96.78%, 97%, and 97.09%, respectively.

## VI. CONCLUSION AND FUTURE WORK

The conversion efficiency comparison of H5, HERIC, and H6 topologies under the same condition. It is obvious that the efficiency of the HERIC is the highest and that the efficiency of the H6 topology takes the second place and the H5 takes the third place.

In summary, the H5 topology has the best leakage current characteristic, but its efficiency is the lowest.The HERIC topology has the highest efficiency, but the leakage current characteristic is worse than that of H5 topology.

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