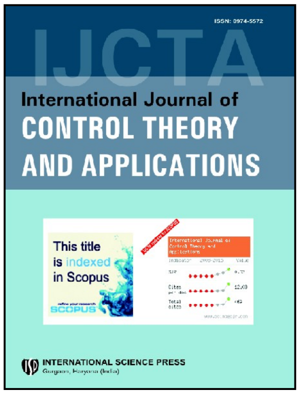

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An Advanced Power Conditioning Unit for Power Management in Grid Connected PV Systems

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Abstract: To design the high efficiency and low cost Photovoltaic (PV) systems Transformer less inverters are inevitable. Various transformers less inverter topologies are recommended to meet the Safety requirements of leakage currents. This paper projected a new isolated three port bidirectional DC–DC converter with two transformers less inverter topologies such as HRE and Improved H6 to reduce leakage currents, common mode voltages separately. HRE and Improved H6 topologies are also combined with 3 port DC-DC converter which is suggested in this paper for simultaneous power management of multiple energy sources. The suggested converter has advantageous of using the main switch which is realized by LCL resonant circuit. The DC-DC bidirectional converter is capable of interfacing number of sources for different voltage-current characteristics with a load and/or micro grid. The performance comparison of grid connected three port bidirectional DC-DC converters with Improved H6 and HRE topologies are instigated in MATLAB/SIMULINK environment and also an investigation has been carried out to select a better topology.

Keywords: Grid-tied inverter, Common-mode voltage leakage current, PV system, bidirectional DC–DC converter, multiport converter, Transformer less inverter topologies.

I. INTRODUCTION

Multiple independent DC-DC converters are used to step up the time- variant low-level source voltages to high-level voltage in order to integrate multiple dc energy sources to a grid. A multiport DC-DC converter is highly preferable for this purpose due to its added advantages of using higher power density, higher efficiency, less cost, and less components, [1]. Multiport converter topologies are categorized into two ways such as non-isolated and isolated topologies respectively . Former converters are mainly used in the places where low voltage regulation ratio is required [2], and later are preferred for the applications which requires a high voltage regulation ratio. At present isolated multiport topologies[3] are used in the isolated full-bridge converter , isolated half-bridge converter, isolated single-switch converter, which uses four controllable power switches, two switches, one switch for each source respectively. In practical to handle applications intermittence of solar and wind energy sources. batteries, are used [4-5]. As it requires at least one port of the multiport converter is bidirectional which was not fulfill by the above topologies as they all are unidirectional [6–8]. Several bidirectional topologies, such as full and half-

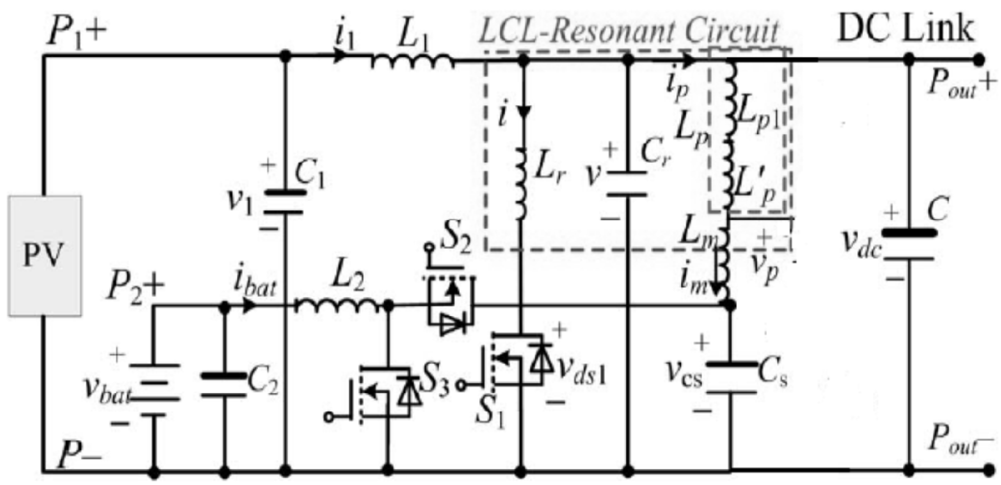

Figure 1: Isolated Three-port bidirectional DC-DC converter

bridge topologies, have been recommended which utilizes many switches with complex control and drive circuits [9]. More recently, a three-port topology has been projected by adding one middle branch to the conventional half-bridge converter that uses less controllable power switches [10] that results zero voltage switching for all main switches [11]. However, the primary voltage source should be maintained at a high value to charge the battery, and it should be charged and discharged within the switching period. Such a high-frequency charge/ discharge has a adverse impact on the battery lifetime [12], [13].

This paper proposes a new isolated three-port bidirectional DC-DC converter for HRE and Improved H6 Inverter [14], [15] which is shown in Figure. 1. Zero-current switching (ZCS) [16]for the main switch can be attained by the inductor capacitor inductor (LCL) resonant circuit shown in Figure 1. This proposed converter uses only three switches which is less compared to the converter in [17] using five controllable switches, moreover, the same renewable energy source are using to charge a battery, then the nominal voltage of the battery connected to the proposed converter can be higher than that connected to the converter . The proposed converter is implemented for simultaneous management of power of a grid connected PV systems with a battery. The most common Perturb and Observe Maximum Power Point Tracking (MPPT) algorithm is programmed to generate the maximum power when irradiation is available to the PV panel. A charge controller was designed to charge/ discharge battery during surplus/deficiency of power from the solar panel.

II. GRID CONNECTED PHOTOVOLTAIC SYSTEM

The schematic diagram of overall Grid Connected PV system is shown in Figure. 2. In this system to increase the required DC link voltage, PV array is connected to a DC-DC boost converter. The battery connected to a bidirectional charge controller which increases the battery voltage to higher level to the DC link, and it allows power to flow either from the DC link to the battery or from the battery to the DC link . This is called as charging and discharging operations. Further to produce AC power, an inverter is connected to the DC link and it is connected to LCL filter to reduce the harmonics.

Above Figure 2. shows a grid-connected PV System which is an electrical generation system that is connected to the utility grid. In this grid-connected PV system the bidirectional 3 port DC-DC converter is connected to the transformer less inverters which gets the power from the photovoltaic modules. To track and boost the maximum power the Perturb and observe method, Boost converter was used respectively. After boosting this DC power which comes from DC-DC Converter [18] is utilized to convert into AC power by grid tied inverters which finally fed to Grid .

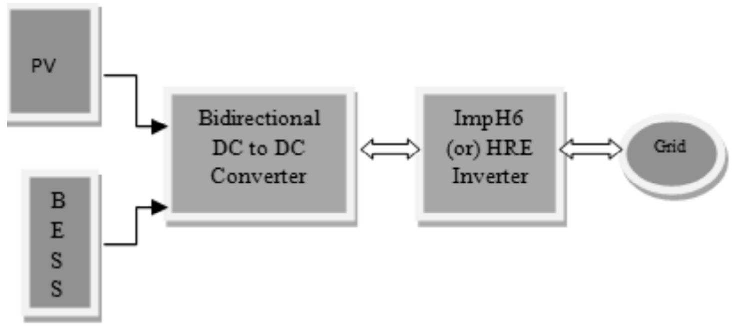

Figure 2: Overall block diagram of the Grid Connected PV System

III. TRANSFORMER LESS GRID-TIED INVERTERS

In the low-power (less than 5 kW) single-phase systems, the grid-tied inverters[18] is carefully designed for achieving the purposes of high efficiency, low cost, small size, and low weight, especially. In the past most of the PV grid-tied inverters employ line-frequency transformers to provide galvanic isolation in commercial structures for safety purpose but they are very large, heavy and hard to install. Whereas inverters with high-frequency isolation transformers have lower cost, smaller size and weight but they have several power stages, which enlarge the system complexity and reduce the system efficiency. Because of this reason the transformer less PV grid-tied inverters, are extensively installed in the low-power distributed PV generation systems. Regrettably, the common mode (CM) leakage currents ($i$leakage) may appear in the system whenever the transformer is removed, and it may flow through the parasitic capacitances between the PV panels and the ground. Moreover, the leakage currents lead to serious safety and radiated interference issues. Therefore, they must be limited within a reasonable range . By using the following power conditioning unit the leakage currents are reduced which is explained in the below section.

IV. METHODOLOGY OF PROPOSED POWER CONDITIONING UNIT

In this paper the three port DC-DC converter [10] with HRE and improved H6 topologies [11] are used to reduce the leakage currents and also to improve the efficiency along with the effective converter power management. Two controllers are required to maintain constant output dc link voltage and power management of two sources. The following three working scenarios of the converter are explained with the help of Figure. 3.

(A) Three Working Scenarios

Scenario- 1 ($p1$ *e"* $p$out): If the available solar power is more than the actual load demand, the PV converter works in the MPPT mode. During this time the battery is charged in order to maintain a constant dc-link voltage.

Scenario 2 ($0 < p1 < p$out): If the solar power is unable to meet actual load even in effective solar radiation. In this situation MPPT took controlling task in MPPT mode to control the PV panel . On the situation, the lacking power is supplied by the battery, through the boost converter, to maintain the constant dc-link voltage .

Scenario 3 ($p1 = 0$): If there is no availability of solar power the battery is discharged to supply the load, in this time the switches $S1$ and $S3$ are active.

Thus the proposed topologies for multiple sources holds good with the boost and buck operation having battery charging and discharging operations to manage the power efficiently and effectively.

For effective utilization of micro grid applications the controlled DC link capacitor will be connected to HRE & Improved H6 Inverter [19]. The HRE & Improved H6 Inverters [20-21] are clearly mentioned in below Figure 4, Figure 5 respectively which are used with the combination of three port DC-DC converter.

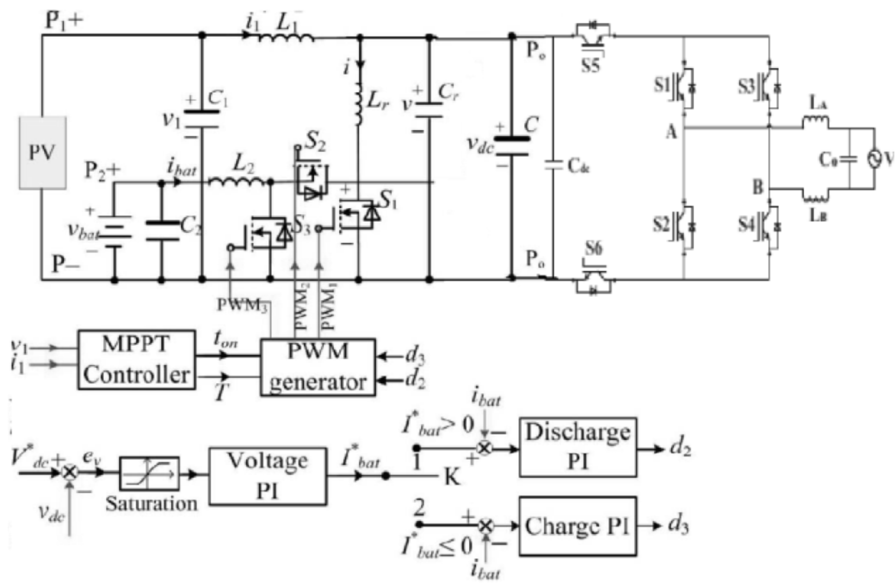

Figure 3: Overall block diagram of the DC - DC Converter system with Inverter topologies

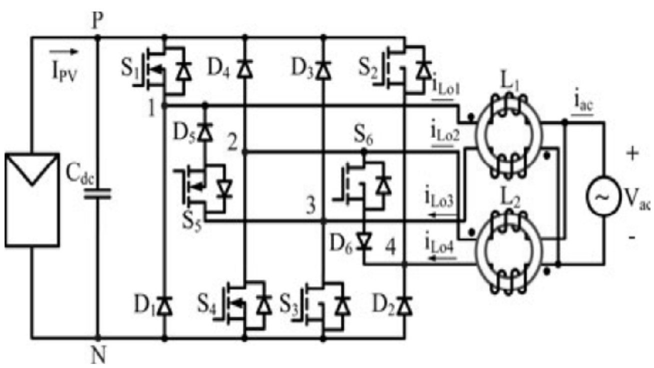

Figure 4: HRE transformer less inverter

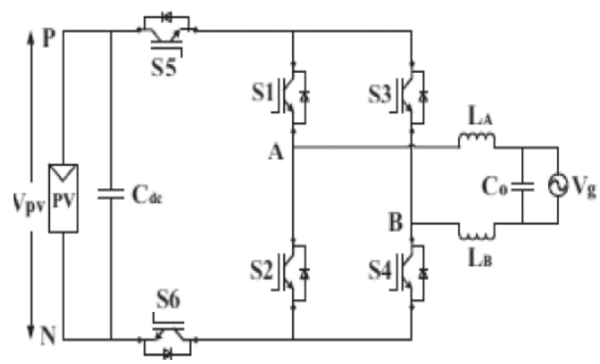

Figure 5: Transformer less Improved H6 inverter

Improved H6 topology

To analyze the effect of switching junction capacitance on the Common Mode(CM) voltage and to achieve an improved grid tied inverter which can meet the condition of constant CM voltage, the improved H6 topology is employed as shown in Figure 5. It requires Two additional switches S5 and S6 that are symmetrically added to the FB inverter as shown in Figure 5. In practical during the commutation process of inverter from one non-decoupling mode to one decoupling mode, the slope of the leg point voltage VAN and VBN completely depends on the junction capacitance of the switches. That results the CM voltage is adversely affected by the junction capacitance. The modulation technique which is used to overcome the above said problem is either unipolar SPWM or double frequency SPWM. It has been shown that the CM voltage will be constant if two extra capacitor switches are connected in parallel to the switches S3 and S4 under unipolar SPWM with the values of 29pF. On the other hand, four extra capacitors with the values of 470pF are connected in parallel to the switches S1, S2, S3, and S4 under double-frequency SPWM. The CM voltage will be constant if Double-frequency SPWM reduces the current ripples across the output filter which is a half when compared to the unipolar SPWM scheme. The drawback of this topology is the additional capacitors which increases the losses. The three port DC-DC converter combined with the HRE and Improved H6 topologies separately to reduce the leakage currents and common mode voltages as well as to increase the efficiency is simulated by using the MATLAB/SIMULINK Environment and the results are analyzed and showed in the following section-V.

V. RESULTS AND DISCUSSIONS

The three port DC-DC converter with the HRE and Improved H6 topologies are simulated through the MATLAB/SIMULINK Environment separately. For this the parameters of the PV panel and battery are taken as follows and these was executed through the SIMULINK model for HRE topology and Improved H6 topology and the results are obtained and analyzed which is shown in the below sections

Open-circuit voltage	*V*oc -22 V
Short-circuit current	*I*sc -3. 15A
The nominal voltage	-7. 5 V
Internal resistance *rb* of the battery	-0. 16 Ω,

The on-time of the switch *S*1, i. e. , *t*on, is 3 μs,

Switching frequency varies in range of 100–170 kHz.

Resistive load	*RL* = 100 Ω.

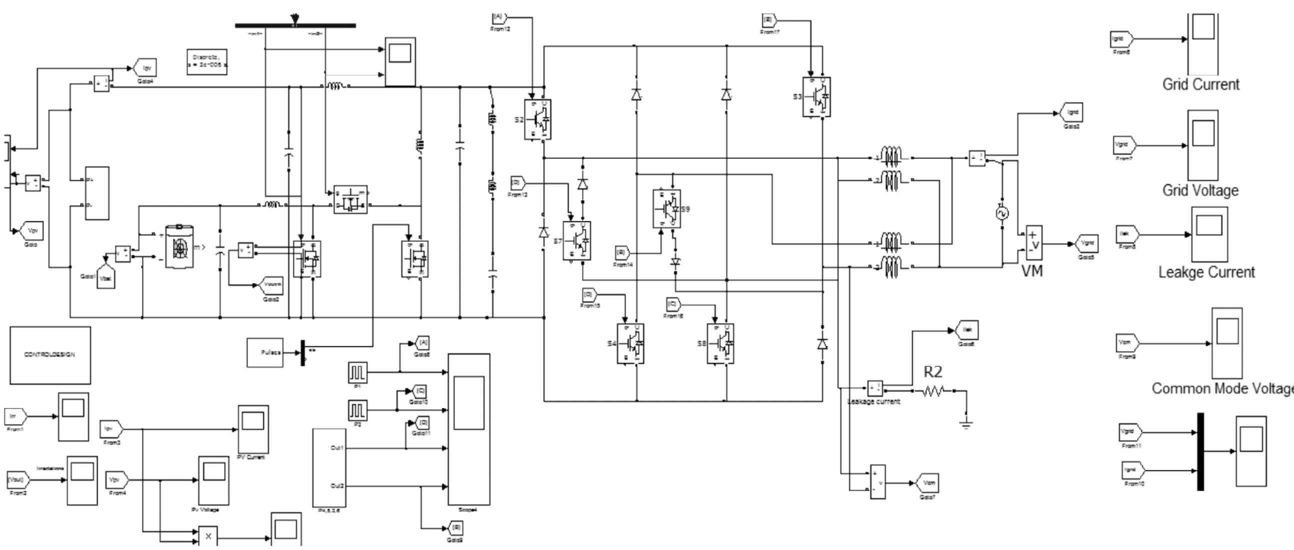

Figure 6: Simulink Model of the Proposed system

By using the above shown SIMULINK MODEL in Figure 6. the HRE topology employed with 3 port DC-DC converter for execution and the results are displayed in the below Figure 7, Figure 8, Figure 9 and Figure 10.

From the above Figure. 7, the Grid voltage of proposed converter with Highly Reliable and Efficient topology (HRE) is shown as 230V and from Figure 8, the current noted as 4. 5A. The obtained Common mode voltage and leakage current of with Highly Reliable and Efficient topology is 450V and 0. 35A are shown in Figure. 9 and Figure. 10 respectively. From the above waveforms it is clearly observed that common mode voltage is made constant as 450V but some ripple are observed during the freewheeling mode operation and the leakage currents magnitude 0. 35A. After this to improve the efficiency and to reduce the leakage currents and common mode voltage the next topology which is the H6 topology was executed and the results are shown in the below figures. 11, 12, 13, 14.

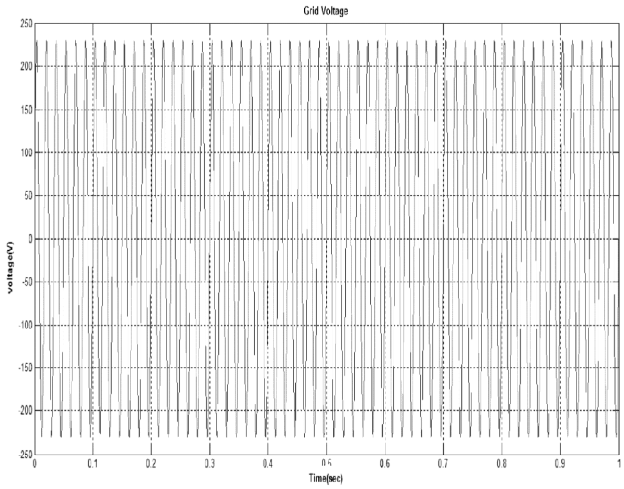

Figure 7: Grid Voltage of proposed converter with HRE topology

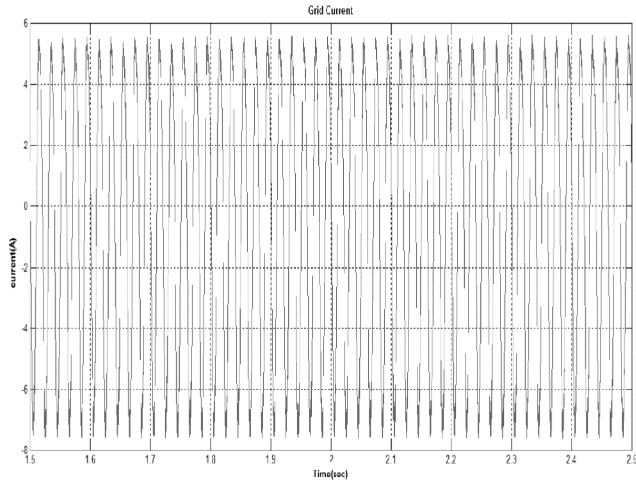

Figure 8: Grid Current of proposed converter with HRE topology

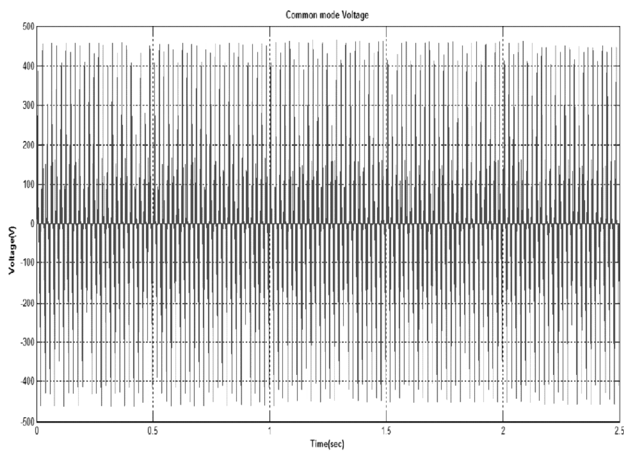

Figure 9: Common Mode Voltage of proposed converter with HRE

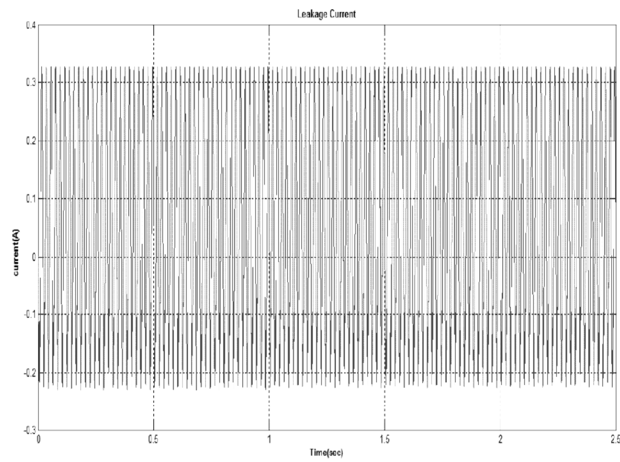

Figure 10: Leakage current of proposed converter with HRE

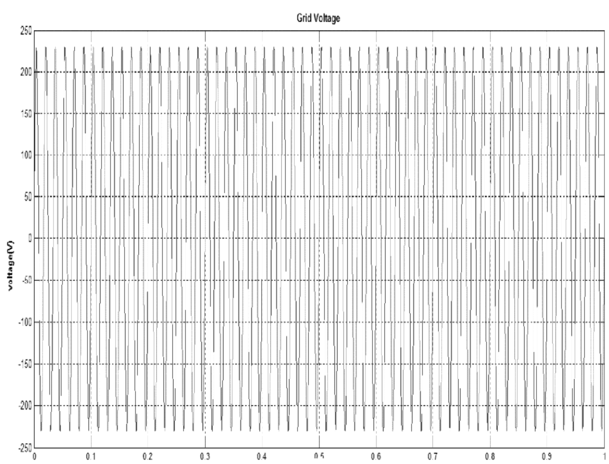

Figure 11: Grid voltage of proposed converter with Improved H6

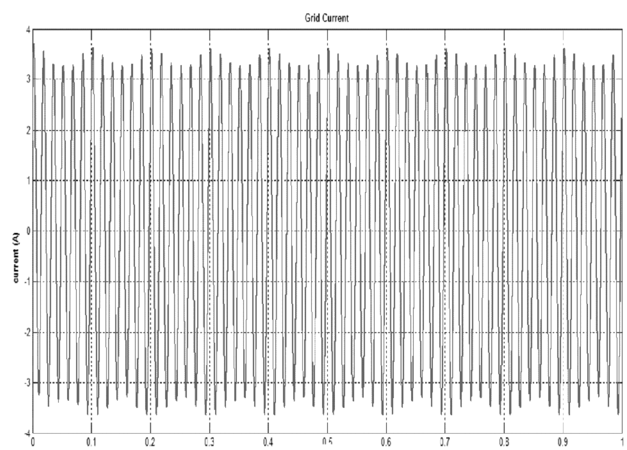

Figure 12: Grid current of proposed converter with Improved H6

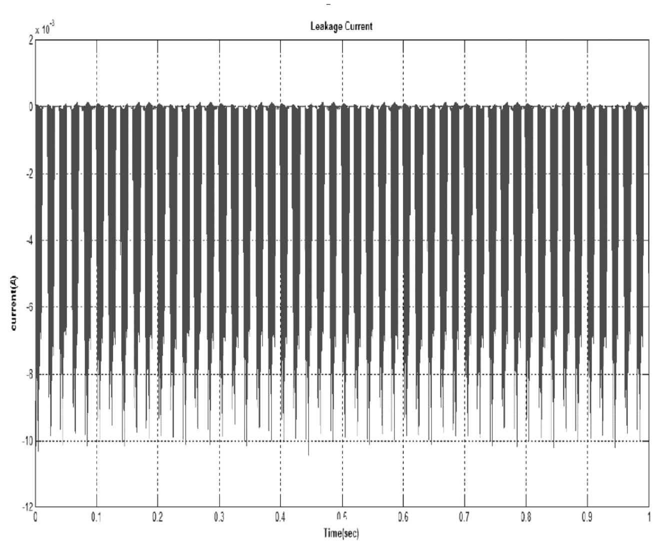

Figure 13: Leakage current of proposed converter with Improved H6

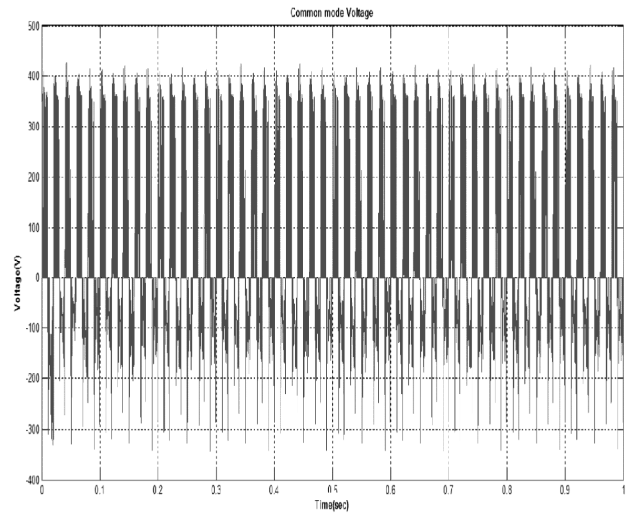

Figure 14: CMVoltage of proposed converter with Improved H6

The Grid voltage and current of proposed converter with Improved H6 topology obtained from the above Figure. 11, Figure. 12 as 230V and 4. 5A. Leakage current and Common Mode voltage also noted for Improved H6 as 0. 1mA, 350V which is shown in Figure. 13 and Figure. 14 respectively. From the above waveforms it is clearly observed that common mode voltage is made constant as 350V but some ripples are observed during the freewheeling mode operation and the leakage currents magnitude noted as nearly zero. By analyzing the common mode voltage with increasing time period it appears like square waveform. The efficiency calculated by using bridge RMS output power to the average input power and it is obtained as maximum 95. 32%, 97. 23% for HRE, H6 topology respectively. The analysis of the above graphs have been given in the table . 1. for comparison purpose and from this table. 1, it is observed that the improved H6 topology with three port DC-DC converter has given better results.

Table 1
Comparison of proposed topologies

Proposed Converter	*Diodes*	*Leakage Current*	*Common Mode Voltage*	*Efficiency*
HRE topology	6	0. 35 A	450V	95. 32%
Improved H6 topology	0	0. 0001 A	350 V	97. 23%

From the above table. 1, it is clearly observed that the leakage currents were reduced to nearly 0. 0001A which is obtained from Improved H6 topology. Hence it is proved that this topology is better than HRE topology. The comparison is also made with the common mode voltage that is for proposed improved H6 topology is 350V and with the HRE topology is 450V and the obtained efficiency is comparatively higher that is 97. 23% when compared with the proposed HRE topology that is 95. 32%.

VI. CONCLUSION

In this paper, a new isolated three port bidirectional DC-DC converter with Improved H6 & HRE Inverter had been proposed because of its minimum number of switches, the Grid Connected PV system had taken for testing the topologies of improved H6 & HRE. It has been used for simultaneous power management of multiple energy sources, i. e. , a PV panel and a battery. Simulation results have shown that the converter is not only capable of boosting the voltage to maximum power from the PV panel by using the MPPT when there is solar radiation but also can control the charge/discharge of the battery to maintain the dc link voltage at a constant value. This work proved that the improved H6 topology is better than HRE topology by comparing the common mode voltage, Leakage currents and efficiency.

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