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Multilevel Inverter with Grid Connectivity for Renewable Energy Applications

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Abstract

The growing demand for power has led to a widespread adoption of electrical energy generation from renewable energy sources like the sun, wind, and other sources. An significant factor in energy utilisation is the grid's ability to integrate renewable energy sources. Directly supplying the grid with electricity from renewable energy sources is a challenging task. In order to serve as an interface between renewable energy sources and the grid or load, the system requires power electronic converters. This essay addresses the grid's integration of a three-phase, six-level voltage source inverter. In order to create a three phase, 2000 VA inverter, three single phase, eight switch, six level inverters (in quarter cycle) are used. Three DC voltage sources, which come from renewable energy sources including solar, wind, and fuel cells, are used by each single phase inverter.

Keywords: Grid Integration, Multilevel three phase inverter, THD, Renewable energy sources.

1. Introduction

In order to maximize the use of renewable energy sources, solar and wind power are now connected to the grid. The loads and the grid are unable to directly use the power extracted from renewable energy sources. Power electronic interfaces are utilized as an interface between them, such as DC-DC converters and DC-AC inverters, particularly MLIs. Two options for feeding the grid are voltage/current with fewer harmonics or a pure sinusoidal wave. The frequency of the grid and the signal being injected should coincide [1].

An MLI arrangement with an LC filter is used to produce sinusoidal three-phase voltage and current with fewer harmonics. Initially, conventional MLIs had three level outputs, such as 0V, V_{dc}, and 0V. Subsequently, additional inverter topology variations were released. Enhancing the harmonic profile is also possible because the inverter produces multi-stepped wave output. Additional benefits of MLIs include decreased electromagnetic interference (EMI), decreased dV/dt pressures on the load, and increased efficiency. DC input voltage sources: Photovoltaic arrays with DC-DC converters, induction generators / synchronous generators feeding wind turbines with rectifier configurations, and fuel cells with DC-DC converters are a few examples of renewable energy sources from which the MLIs can be generated [2]. To optimize the harmonic profile of the voltage and current waveform for grid integration there are so many strategies utilized waveform such as hysteresis current control, Multi level H bridge cascaded inverter etc.,[3][4]. Three single phase inverters with three DC sources and eight switches make up the proposed work, which focuses on the formulation of a grid coupled three phase, six level,

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eight switch inverter (per phase)[5][6]. Numerous publications [9–12] discuss grid integration strategies. The suggested inverter is connected in order to power the grid and the 2000W resistive load. The three phase transformer raises the three phase inverter output voltage to 415V Line for the grid integration. The right value of the three phase transformer leakage inductance is chosen in order to lower the output voltage harmonics [13]. The FFT block in MATLAB is used to analyse the THD of the output waveform. In comparison to traditional six- and twelve-pulse inverter topologies, the suggested new three-phase inverter architecture produces a less harmonic three-phase voltage waveform. The suggested topology yields a THD of 0.13%, while the six pulse converter's THD is 31% and the twelve pulse converter's THD is approximately 12% [4]. To obtain a clean sine waveform, an LC filter is required for six- and twelve-pulse converters. However, there is a direct grid and load connection possible for the suggested MLI.

2. Block Diagram of Grid Tied Inverter

The three single phase inverters that are connected in a star configuration to the grid are represented by the suggested design. Renewable energy sources including solar, wind, and fuel cells, which are not the focus of this work, can provide DC supplies. Throughout the output waveform's quarter cycle, the following levels can be obtained: 0, V_{dc}, $2V_{dc}$, $3V_{dc}$, $4V_{dc}$, and $5V_{dc}$. The peak amplitude of an inverter output is 150V since V_{dc} is set to 30V.Two ramp signals that are 180 degrees out of phase with one another are used to create the gate pulse for the switch S1. Every ramp signal is contrasted with various DC values. Their output is added together to create the pulse for switch S1, and switch S1′ is the pulse that is the counterpart of S1's pulse. In a similar manner, pulses were created by the other switches. The single phase inverter's switch switching states are displayed in the following table:1. Table 1 displays the switching state that serves as the basis for the generation of gate pulses. The pulses S1′, S2′, S3′, and S4′ are compliments of S1, S2, S3, and S4, in that order.

Table 1 : Switching states.

Vphase	S1	S2	S3	S4
$+5\ V_{dc}$	1	0	1	0
$+4\ V_{dc}$	0	0	1	0
$+3\ V_{dc}$	1	0	1	1
$+2\ V_{dc}$	0	0	1	1
$+\ V_{dc}$	1	0	0	0
0	0	0	0	0

3. System Description

The overall system is analyzed as two cases

Case 1: Three phases Multi level inverter connected to the 415V, 2000 W three phase resistive load.

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Case 2: Multi level inverter connected to the 50 W three phase resistive load and to 415V three phase grid.

The three phase voltage produced by the suggested inverter has a maximum value of 150V (3Vdc). The three phase transformer steps up the inverter output in order to integrate it with the 415V grid and load. Steps are the inverter's output format, and they show a greater harmonic profile. The transformer's appropriate leakage inductance is changed to enhance the harmonic profile. The secondary voltage of the transformer is lower than expected because of the tiny increase in transformer inductance. It can be brought to the predicted value by adding a shunt capacitor, which is supposed to be 1μF, and also by slightly raising the turns ratio. In cases 1 and 2, the system's power flow direction is noted. In both situations, the inverter's overall power output is almost equivalent to 2000 W. 0.13% THD of the output waveform is determined to be significantly lower than that of the six- and twelve-pulse converters. The twelve-pulse and six-pulse THDs are 12% and 31%, respectively. The MLI can be utilised directly for the integration of three phase grids because the voltage waveform has less harmonics. By raising the input DC voltage levels, this design can be used in high voltage applications. The input of a traditional three-phase, six-pulse inverter consists of a single DC source. Three DC sources, which can come from three separate renewable energy sources, are employed in the suggested topology.

Case 1 System simulation with resistive load

The proposed system is connected to the three phase resistive load. Fig.1 shows the output voltage of the three phase inverter which has six levels such as 0V, 30V, 60V, 90V, 120V, 150V in quarter cycle i.e for 5 ms. Fig.2 shows the output current flowing through the resistive load i.e. output current of the inverter without integrating to the grid.

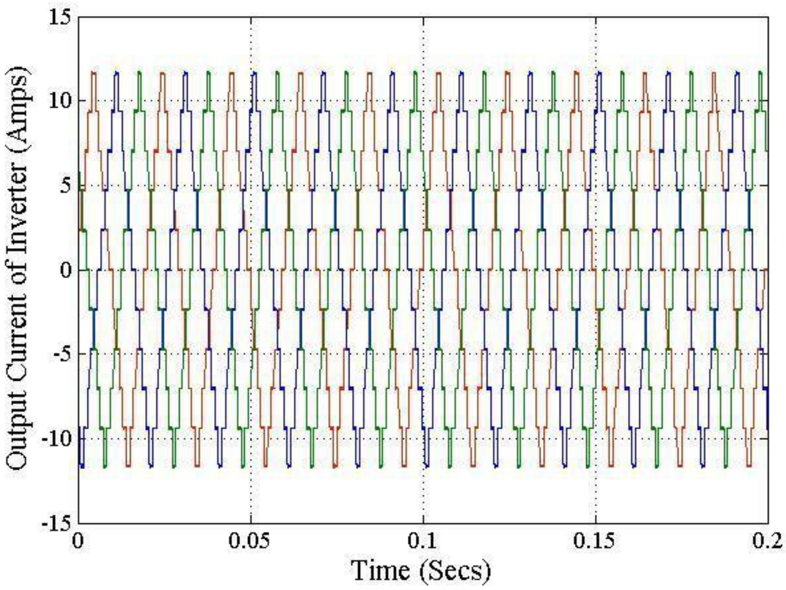

Fig. 1 Output voltage of the inverter

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Case 2 system simulation with grid integration.

In order to integrate, the output of the inverter is connected to the three phase transformer having default transformer leakage inductance and the output voltage of the system is shown in Fig. 3. The system is connected to the grid and also to the 50W three phase resistive load.

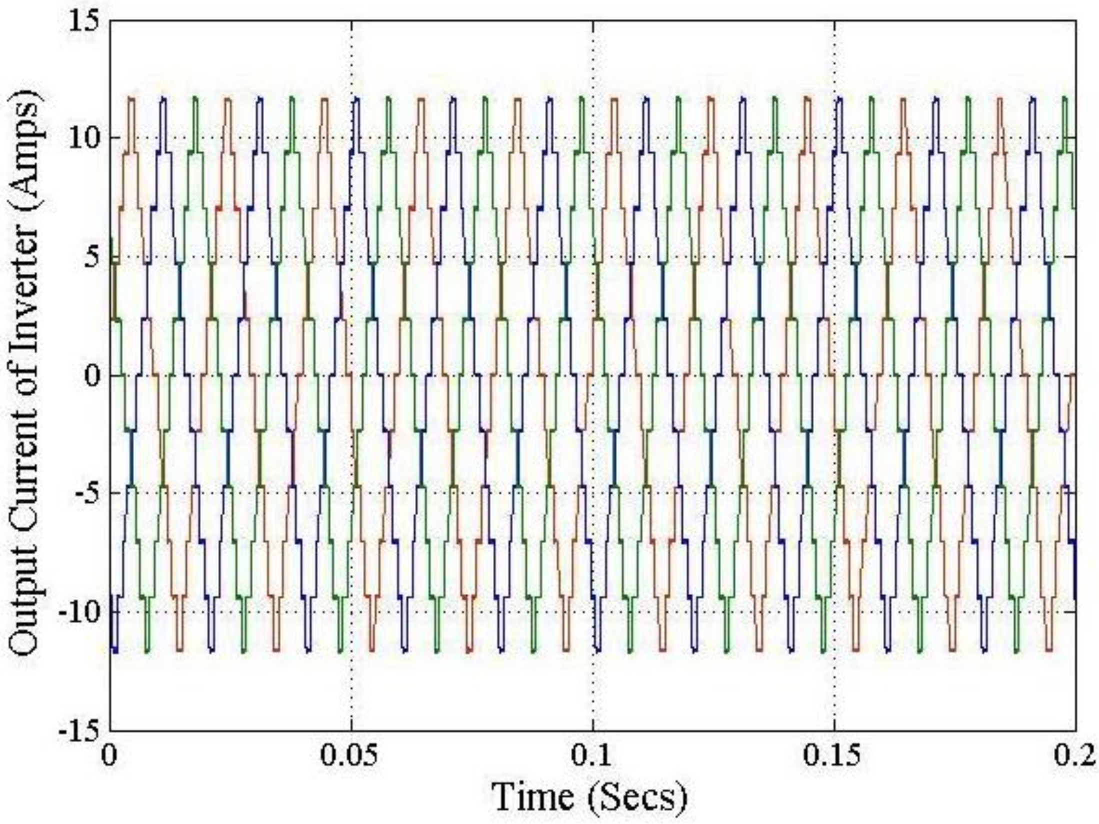

Fig. 2 Output current of the inverter

It is evident that the suggested inverter's output, which is derived without the filter, has a lower voltage THD of 7.46%. More transformer inductance adjustments are made to lower the THD, and the resultant THD of 0.13% is displayed in Fig. 4. The voltage THD of the standard inverter topology, which is derived from the phase output voltage of a simulated three-phase DC-AC converter and displayed in Figure 5, is significantly higher than the THD obtained from the suggested multi-level inverter. When compared to the suggested system, it is found that the three phase converter's output THD is 31% with a lower fundamental voltage. The resistive load current in Fig. 6 is shown to have a maximum value of 0.1A. The grid voltage and current are displayed in Figures 7 and 8, respectively. The active power (368W) and reactive power (1082W) injected into the grid are depicted in Figures 9 and 10, respectively.

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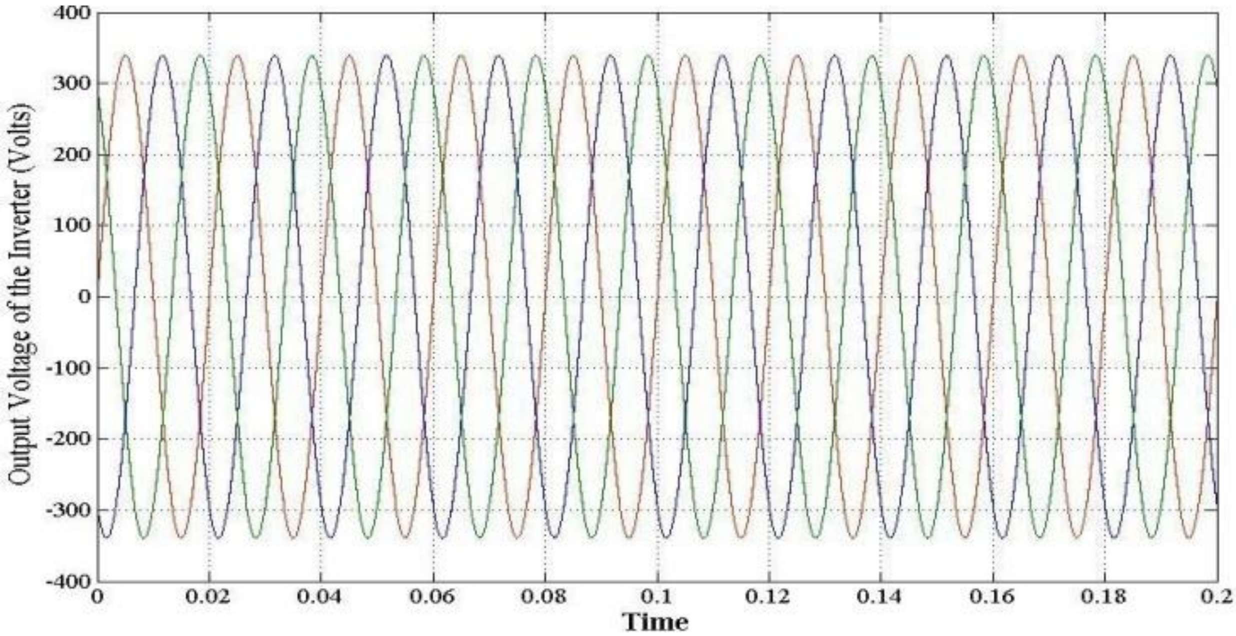

Fig. 3 Output voltage of the grid tied inverter (with proper inductance)

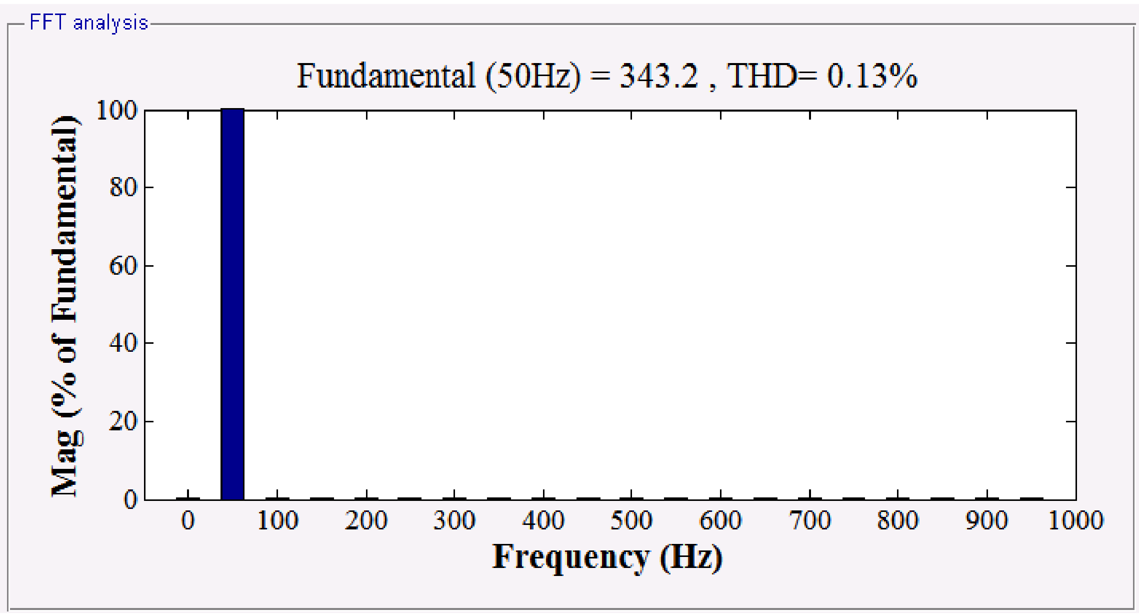

Fig. 4. THD of proposed inverter output voltage

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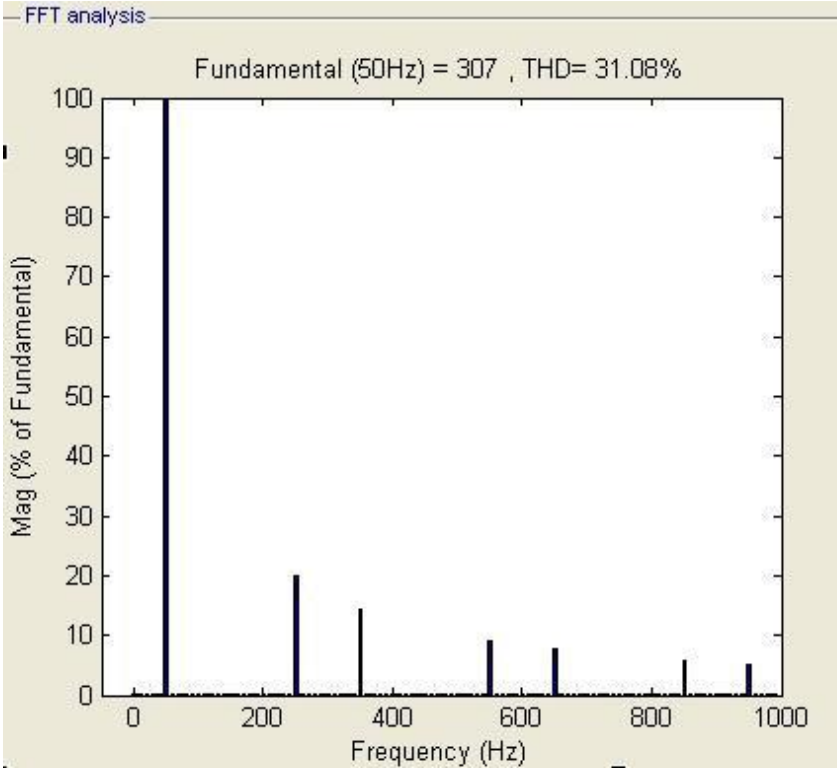

Fig. 5. THD of the conventional inverter's output voltage

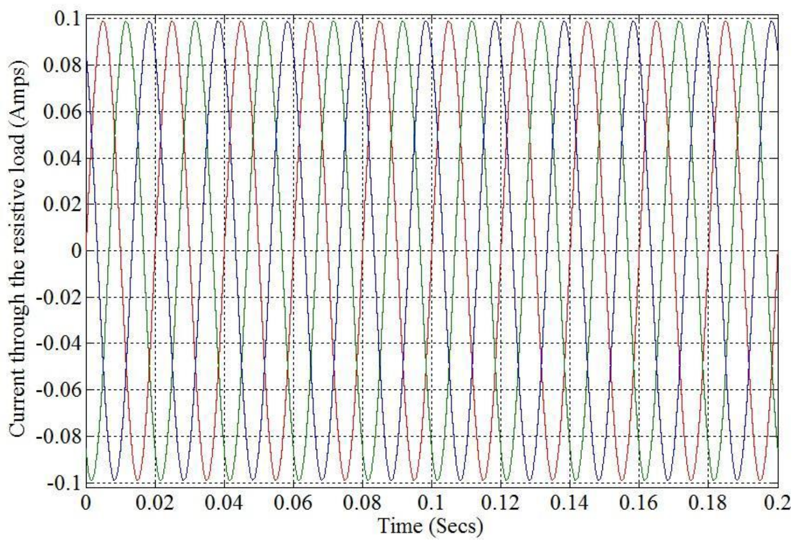

Fig. 6. Current through the resistive load (50W,415V)

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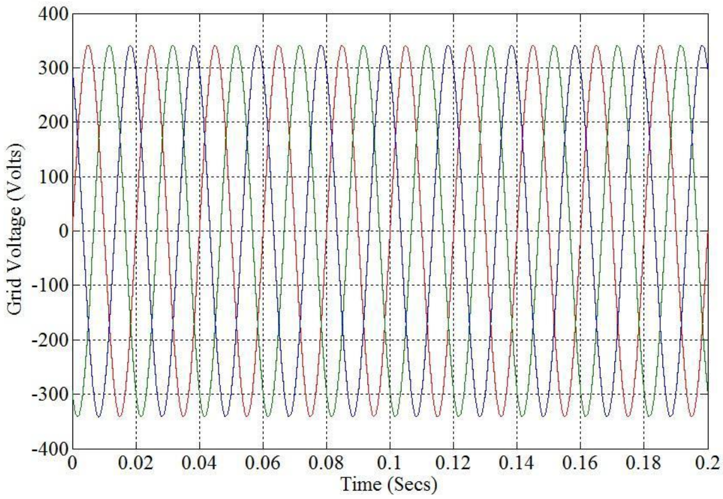

Fig. 7 Grid Voltage

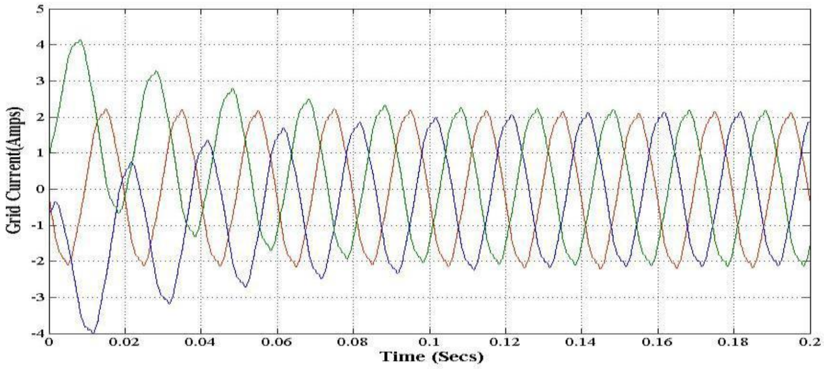

Fig. 8 Grid current

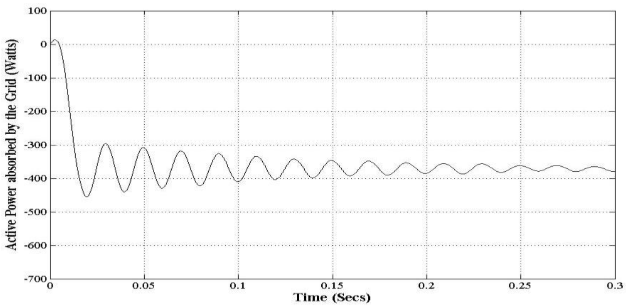

Fig. 9 Active power received by the grid

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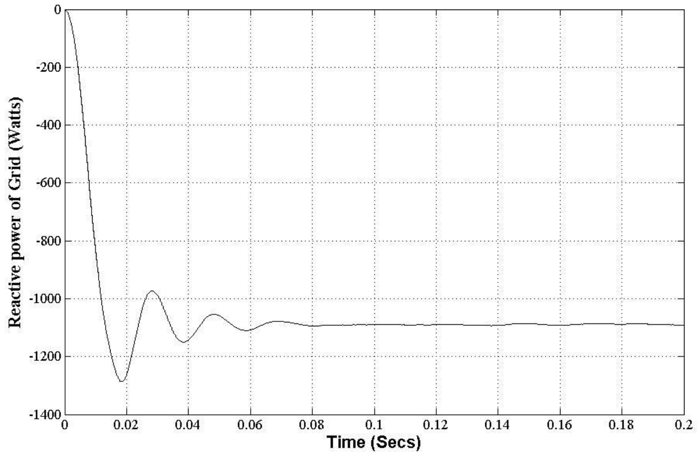

Fig.10. Reactive power absorbed by the grid

From the simulation results, it is observed that the proposed cascaded H-bridge three phase MLI is suitable for grid integration and it can be fed by three DC voltages derived from different renewable energy sources like solar, wind and fuel cell simultaneously unlike three phase conventional inverter.

4. Conclusion

The three-phase resistive load and the grid are connected to the proposed and simulated three phase MLI topology, which makes use of three single phase inverters. It is noted that power is injected into the grid through the three phases of MLI from renewable energy sources. By carefully choosing the transformer leakage inductance, the inverter's output is smoothed and its voltage waveform's THD is lowered to 0.13%, which is significantly lower than that of traditional three-phase, six-pulse inverters, which have a THD of 31%. It is discovered that the suggested method works well at the interface between the grid and three distinct kinds of renewable energy sources (hybrid).

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