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Simulation of Phase-Shift Operated Interleaved DC/DC Converter with Unfolding Inverter

Savyasachi. G. K[1], Dilkhush. A. K[2], Dharshan. S[3], Garima Bhati[4], Jacob Koshy Varghese[5]
[1,2,3,4,5]Department of Electrical & Electronics Engineering,
Vidyavaradhaka College of Engineering, Mysuru, Karnataka, India.

***Abstract*-In this project a single phase interleaved connected with phase shift operated dc/dc converter with unfolding inverter is proposed. It is suitable for utility interface as well as standalone application based on the mode of control. Two full-bridge square wave inverters are connected in interleaved configuration i.e. inputs are connected in parallel and output is taken in series. These two converter blocks are controlled by giving sinusoidal phase delay, which gives a full wave rectified sinusoidal wave at the dc link. A simple full-bridge unfolding inverter with switching frequency of 50 Hz is used to produce single-phase sine voltage. This simplifies the inversion stage in the form of modulation and switching losses are reduced to great extent. Proposed topology is analyzed by simulating using MATLAB/Simulink.**

Keywords-Interleaved connection, Phase-shift operation, Unfolding, DC/DC converter, Full Bridge.

I. INTRODUCTION

Due to fast depletion of conventional sources, there is paradigm shift towards non-conventional energy sources due to its availability in abundance. But outputs of these sources are non-uniform and discontinuous and therefore cannot be fed directly to the load. Hence, there is an increase in demand for power converters which gives good efficiency with marginal harmonics in it. In order to balance the increasing global energy load demand and generation, solar energy is proving to be one of the most promising solutions.

These energy sources are integrated together with the energy storage for back-up power to form a distributed generating system focusing on long-term sustainability.

Solar photovoltaic generation is a flexible power generation technique which is scalable from small-scale residential application to large-scale solar farms and power plants [1].

In [1], a phase-shift operated interleaved snubberless current-fed half-bridge dc/dc converter with single-phase unfolding inverter is proposed which is suitable for grid tied/ utility interface as well as off-grid/standalone application based on the mode of control

The cost of the grid-connected inverter is, therefore, becoming more visible in the total system price. A cost reduction per inverter watt is, therefore, important to make PV-generated power more attractive. Focus has, therefore, been placed on new, cheap, and innovative inverter solutions, which has resulted in a high diversity within the inverters, and new system configurations.

Various circuit topologies for small distributed power generators are presented, compared, and evaluated against the requirements of power decoupling and dual-grounding, the capabilities for grid-connected or/and stand-alone operations is presented in [2].

In [3], various inverter topologies for connecting PV modules to a single-phase grid are presented, compared, and evaluated against demands, lifetime, component ratings, and cost.

A converters based on the inductive input converters for the design of a power electronic interface for fuel cell applications is proposed in [4].Flexible choice of components, low losses, high efficiency, are characteristics of these converters.

A variable output voltage can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. On the other hand if the dc input voltage is fixed and it is not controllable, a variable output voltage can be obtained by varying the gain of inverter, which is normally accomplished by pulse width modulation control within the inverter.

[5] Presents the implementation of an interleaved boost converter (IBC) using SiC diodes for PV applications. The converter consists of two switching cells sharing the PV panel output current. Their switching patterns are synchronized with 180◦ phase shift.

Different topologies of appropriate inverter systems in the medium power range of 20 kW and higher are presented briefly in [6]. The study includes transformer less inverters as well as two-stage inverter systems with high frequency transformers.

A novel snubberless CFHB front-end isolated dc/dc converter-based inverter for PV applications is introduced in [7]. This converter attains clamping of the device voltage by secondary modulation, thus eliminating the need of snubber or active-clamp.

A novel direct current-fed interleaved phase-modulated single-phase unfolding inverter for fuel-cell applications is proposed in [8].

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II. Methodology

A. Interleaved Connection

Interleaved connection is nothing but the parallel input and series output. In these proposed model in fig. 1, two dc sources are connected in parallel and there output is taken in series, so at the input side current gets divided due to parallel connection so low current rating switches can be used for high current applications and as the outputs are connected in series, magnitude of output voltages get added i.e. it will get doubled. Higher efficiency and reduced harmonic levels are the advantage of this interleaved connection.

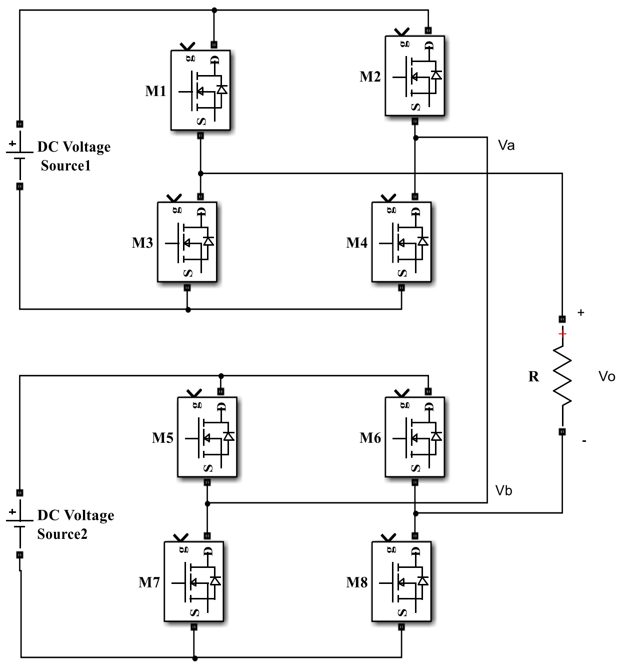

Fig.1: Interleaved Connection

B. Unfolding Inverter

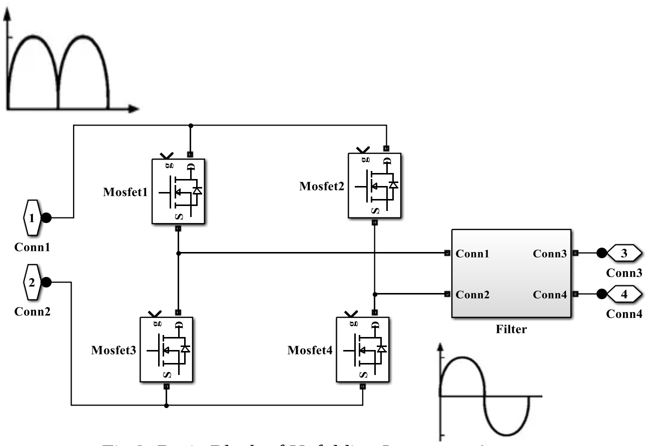

Fig.2: Basic Block of Unfolding Inverter

Main function of unfolding block is to unfold or invert the particular portion of a waveform. The unfolding bridge inverter can be generally build using four MOSFET switches, which is switching at the grid frequency. Mainly it consist of four switches, which operates alternatively as per sine wave phase shift given and inverts the portion of output.

C. Phase Shift Operation

The two inverters are connected in parallel. Output of one inverter is phase shifted w.r.t another inverter. The net output depends upon phase shift between the two inverter outputs V_{01} and V_{02}. The voltage levels of output are $\frac{V_S}{2}$ in both the inverter outputs. Output of second inverter is phase shifted w.r.t first inverter β. The final output is the addition of two inverter output. i.e, $V_o = V_{o1} + V_{o2}$

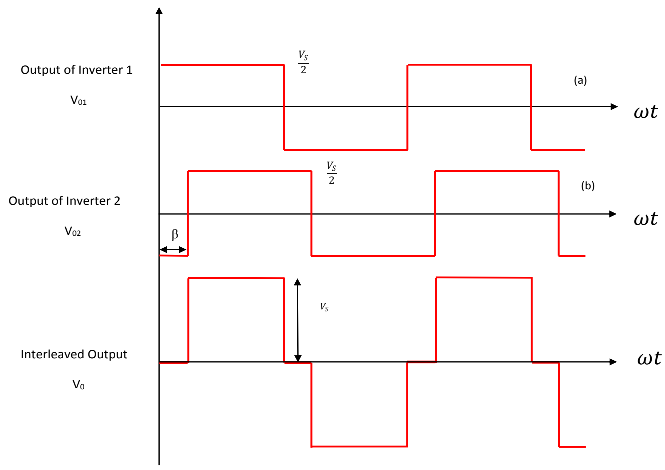

Fig. 3: Waveform of Phase Shift Operation

Note that $V_o = V_s$ when the two inverter outputs are in phase. Output voltage can be controlled by varying the phase shift β.

D. RLC Low Pass Filter

The main function of filter is to remove harmonics from the circuit so that linearity of the system can be obtained. Various types of filters are available. We are making use of RLC filter. As per the filter requirement, the R, L and C elements can be arranged in different topologies. All three elements can be connected in series or in parallel or series-parallel combination. One of the issues which are most commonly faced is the need to consider the inductor resistance. From coils of wire, typically inductors can be constructed. The resistance is not usually desirable, but it has some significant effect on the circuit.

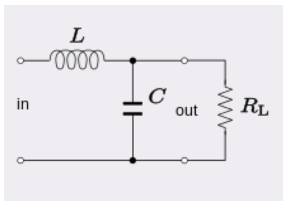

Fig. 4: RLC Circuit as Low Pass Filter

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III. Simulation Of Proposed Topology

A. Simulation of Proposed Interleaved Inverter

The proposed phase-shift operated interleaved FB dc/ac converter with unfolding inverter is shown in Fig.5. Two identical full-bridge dc/dc converter cells are connected in parallel to the input dc source. These two converters are modulated with a phase shift such that the phase difference between these two converters is a sine function at line frequency [8]. A low-pass filter is used to filter high frequency components of voltage to achieve rectified sinusoidal voltage across filter capacitor C_O at twice the line frequency. Single-phase ac voltage is obtained by unfolding the every alternate half cycle of rectified sine wave using the H-bridge inverter with square wave control, switching at line frequency.

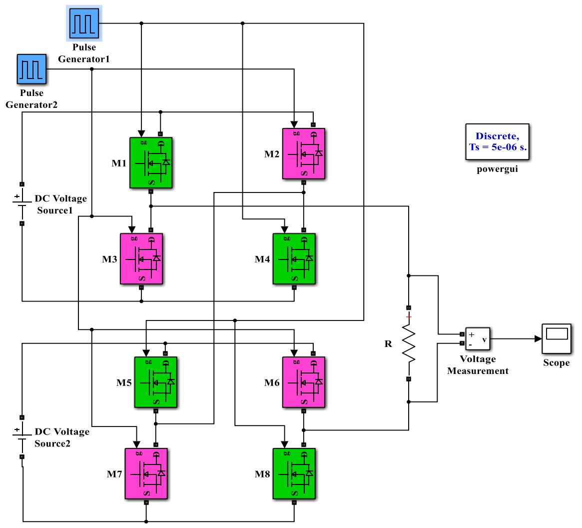

Fig. 5: Simulink Model of Full bridge dc/ac Converter

Inverter converts dc input into ac output. Proposed interleaved inverter is shown in fig. 10 in which input is dc which is fed from PV panel or batteries or from HVDC line.

Two identical full bridge are being used, which are connected in parallel input and series output connection which is nothing but interleaved connection. This bridges consist of switching devices such as MOSFET, IGBT etc.

Delay have been given to the pulse generator. In bridge1, we make use of two pulse generator with a phase delay of 0^0 and 180^0 respectively. During 0-180^0 phase delay, MOSFET M1 and M4 operates and gives positive voltage. During 180-360^0, M2 and M3 operates and due to reverse direction of current it gives negative voltage across load. Thus, combination of positive and negative voltage gives square wave and is represented as V_a in fig. 6 (c). Similarly, bridge2 operates in the same manner as bridge1 and its output is represented as V_b in fig. 6 (d).

As output of both the bridges are connected in series they get added up and the voltage gets doubled as shown in fig.6 (e).

Square wave from interleaved connection is fed to the bridge circuit .Main function of these universal bridge is to converts AC wave in to pure dc signal. Pure DC waveform is show

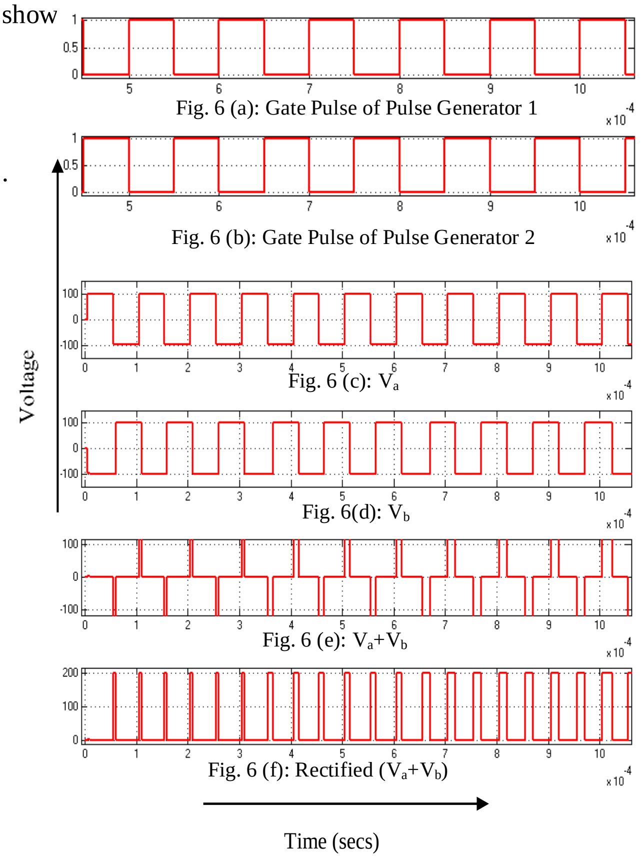

Fig. 6 (a): Gate Pulse of Pulse Generator 1

Fig. 6 (b): Gate Pulse of Pulse Generator 2

Fig. 6 (c): V_a

Fig. 6(d): V_b

Fig. 6 (e): V_a+V_b

Fig. 6 (f): Rectified (V_a+V_b)

We can observe in fig.6 (f), there will be high frequency of improper modulated waveform per cycle. It's necessary to alter the shape for further process. So we make use of LC filter as shown in fig. 4 to get proper signal and the waveform obtained after adding filter is as shown in fig. 7.

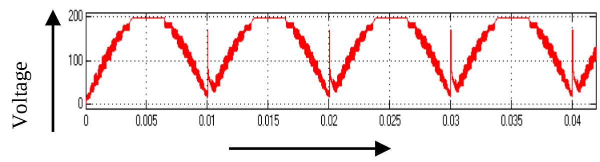

Fig. 7: DC-DC Converter Output with Filter

After getting a dc wave we need to convert it in to pure sine wave. For this purpose we make use of unfolding circuit, which inverts the particular dc signal. This block consist of two pulse generators, to which we had given a delay of 0^0 and 180^0 respectively. Each set of switches operates as per the delay given and helps in inverting signal for particular time period. Unfolded inverter circuit is shown in fig.8 and its output waveform is shown in fig. 9.

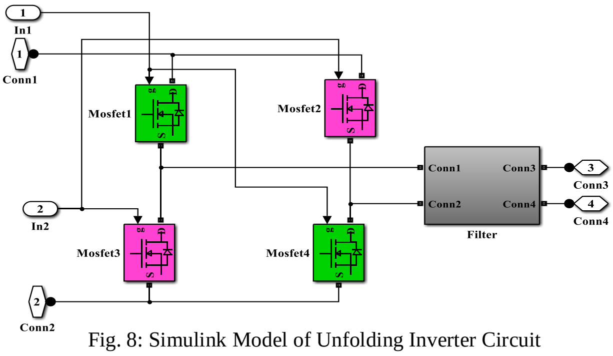

Fig. 8: Simulink Model of Unfolding Inverter Circuit

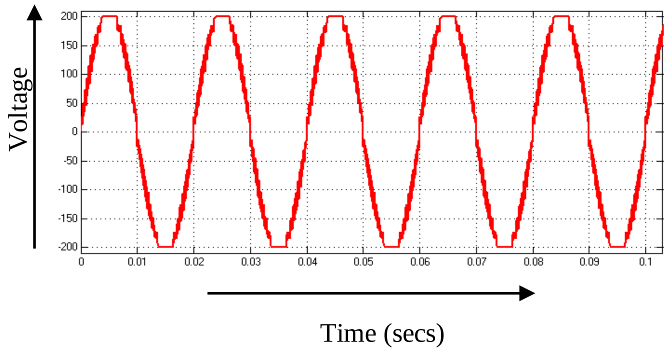

Fig. 9: Output of Unfolding Inverter

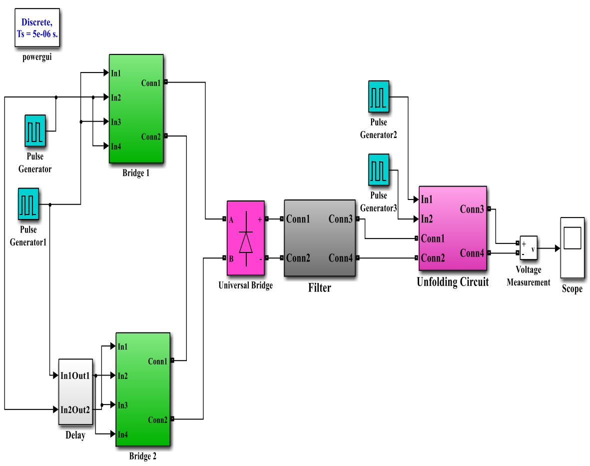

Fig. 10: Proposed Phase-Shift Operated Interleaved FB Dc/Dc Converter with Single-Phase Unfolding Inverter

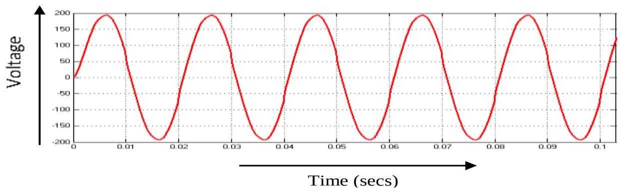

Fig. 11: Output Voltage of Phase Shift dc-dc Converter with Unfolding Inverter

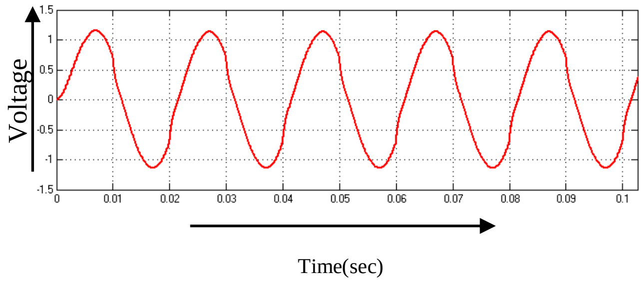

Fig. 12: Output Current of Phase Shift dc-dc Converter with Unfolding Inverter

Fig.13 & 14 shows the result of FFT analysis of the voltage across the load and the current through the load.

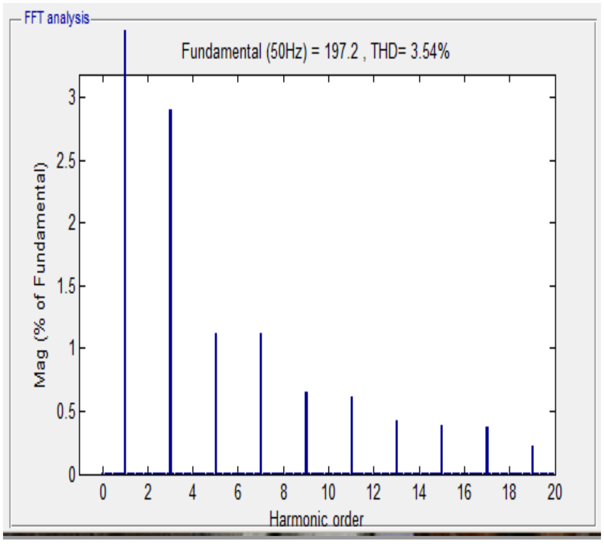

Fig. 13: FFT Analysis of Output Voltage (V_O)

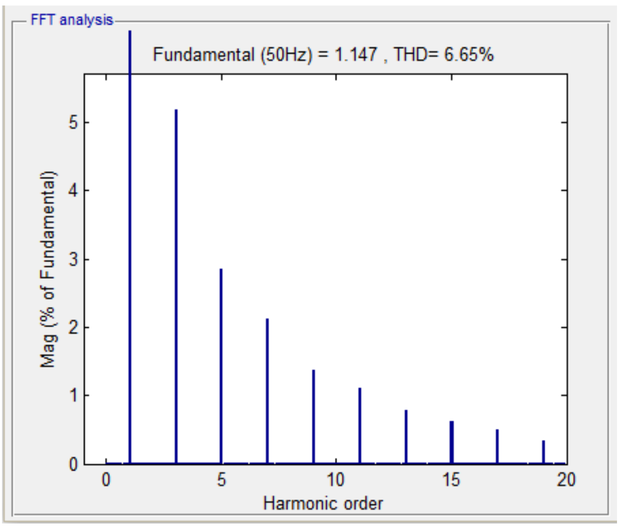

Fig. 14: FFT Analysis of Output Current (I_O)

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From simulation results/waveforms, harmonics of the proposed converter is given in Table I.

TABLE I. HARMONICS

Parameter	Fundamental(50Hz)	THD(%)
Output Voltage(V_O)	197.2V	3.54
Output Current(I_O)	1.147	6.65

From Table I, it can be seen that the proposed topology has less THD. By fine tuning the filter, THD can be further reduced. As the rating of the converter increases the THD reduces.

B. Simulation of Nineteen Level PWM Inverter

The most widely used technique of generation of pure-sine wave is pulse-width modulation (PWM). PWM technology is used in inverters to provide a steady output voltage of 230 or 110 V AC. The Inverters based on the PWM technology are more superior to the conventional inverters. Pulse width is modulated as per the requirement in order to obtain controlled output voltage and reduced harmonic levels. For comparison purpose nineteen level inverter has been developed. At first, started with three level, then five level then further more level has been developed. As levels increases its harmonics decreases but complexity increases. So keeping a view of economic factor nineteen level PWM inverter has been choosed for comparison purpose. The output of PWM inverter with and without filter is as shown in fig. 15(a) and fig. 15(b).

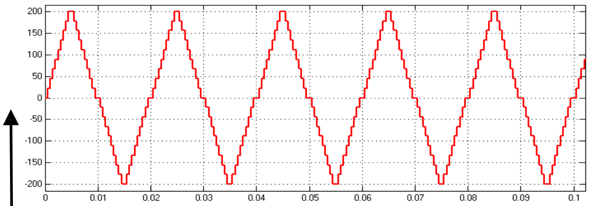

Fig. 15(a): Output Voltage of Nineteen Level PWM Inverter without Filter

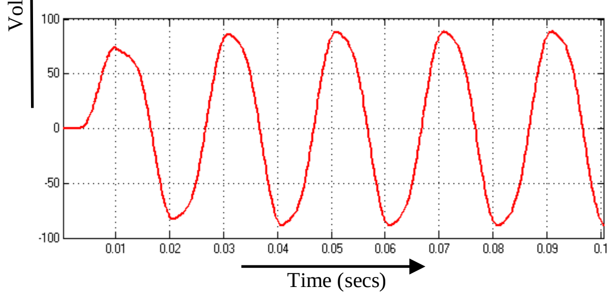

Fig. 15(b): Output Voltage of Nineteen Level PWM Inverter with Filter

IV. SUMMARY

The two full-bridge converters have been used to generate complete sinusoidal voltage at the dc link.

The analysis of the interleaved inverters is carried using MATLAB and Simulink software. Simulation results/waveforms are analyzed and performances are tabulated. This project briefly explains efficient and effective method of converting dc voltage to ac voltage using phase shift operation.

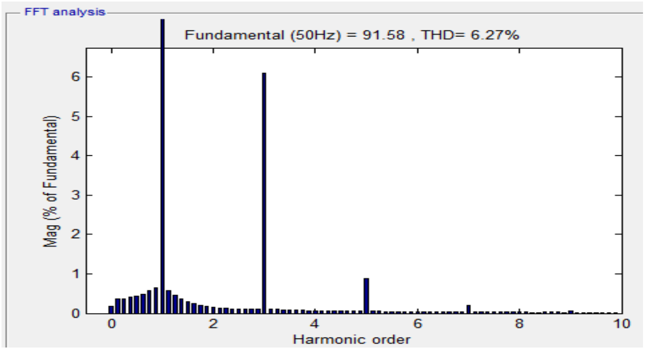

Fig. 16: FFT Analysis of Output Voltage Nineteen level PWM Inverter

The result of interleaved inverter is compared with that of PWM inverter as shown in Table II. The THD level of interleaved inverter is 3.54% and that of PWM inverter is 6.27%.The components required and cost of proposed inverter is cheaper than PWM inverter. Even the efficiency of proposed inverter was found to be better. Therefore, the performance of interleaved inverter is better than PWM. Sine wave with much reduced distortions and THD is obtained at the output.

Since multilevel inverters uses low rating devices, its cost is comparatively less than that of high rating devices. This kind of inverter can overcome limitations of using high rating switches of devices. Hence this type of inverter can be used in Solar Photovoltaic applications either for standalone or grid connected operations.

Advancement in semiconductor technology and scaling of devices leads to reduction in size of semiconductor switches. Thus overall size of the circuit is reduced.

TABLE II. COMPARISION BETWEEN INTERLEAVED INVERTER AND PWM INVERTER

Converter	Voltage (Volts)	THD (%)	Harmonic Level (%)			
			3	5	7	9
Interleaved Inverter	197.2	3.54	2.90	1.12	1.12	0.65
PWM Inverter	91.58	6.65	6.11	0.87	0.19	0.07

REFERENCES

[1] Savyasachi. G. K, Radha. R, Dr. A. D. Kulkarni, “Simulation of a Novel Phase-Shift Operated Interleaved Snubberless Current-Fed Half-Bridge Dc/Dc Converter”, IJERT, vol.3 Issue 6, pp. 1998-2006 June 2014.

[2] Y. Xue, L. Chang, S. B. Kjaer, J. Bordonau, and T. Shimizu, “Topologies of single-phase inverters for small distributed power generators: An overview,” IEEE Trans. Power Electron., vol. 19, no. 5, pp. 1305–1314, Sep. 2004.

[3] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, “A review of single-phase grid-connected inverters for photovoltaic modules,” IEEE Trans. Ind. Appl., vol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2005.

[4] Y. Lembeye,V. D. Bang, G. Lefevre, and J. P. Ferrieux, “Novel half bridge inductive dc-dc isolated converters for fuel cell applications,” IEEE Trans. Energy Convers., vol. 24, no. 1, pp. 203–210, Mar. 2009.

[5] C. N. M. Ho, H. Breuninger, S. Patterson, G. Escobar, L. A. Serpa, and A. Coccia, "Practical design and implementation procedure of an interleaved boost converter using SiC diodes for PV applications," IEEE Trans. Power Electron., vol. 27, no. 6, pp. 2835–2845, Jun. 2012.

[6] M. Mohr, W. T. Franke, B. Wittig, and F. W. Fuchs, "Converter systems for fuel cells in the medium power range—A comparative study," IEEE Trans. Ind. Electron., vol. 57, no. 5, pp. 2024–2032, Jun. 2010.

[7] Udupi R.Prasanna and AkshayK.Rathore "Analysis, Design, and Experimental Results of a Novel Soft-Switching Snubberless Current-Fed Half-Bridge Front-End Converter-Based PV Inverter," IEEE Trans. Power Electronics, vol. 28, no. 7, pp. 3219-3230, Jul. 2013.

[8] Udupi R. Prasanna and Akshay K. Rathore, "Current-Fed Interleaved Phase-Modulated Single-Phase Unfolding Inverter: Analysis, Design, and Experimental Results", IEEE Trans. Ind. Electron., vol. 61, no. 1, pp. 310-319, Jan 2014.