

# **A Novel Approach to Harmonic Minimization Method for Single Phase Inverter without an Output Filter**

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**ABSTRACT:** A PWM technique is used to achieve the low total harmonic distortion (THD) at the output of inverter during the construction of pulses to the converter switches. By using PWM modulation techniques we can minimize harmonics generated by the PWM technique itself. First, we present converter topology characteristics with PWM techniques. Then we describe how a suggested modulation minimizes harmonic generated by switching operation, the inductive nature of the DC source and external point at which the converter is connected. As compared with the previously modulation technique, a suggested modulation achieves the THD is less than 6%.

**KEYWORDS:** Buck-Boost converter, AC to DC converter, Wind energy, Total harmonic distortion.

## **I. INTRODUCTION**

Now a day, there is a demand of power supply. To meet the increased demand, the power generation from renewable sources increases day by day [1]. Most of renewable sources provide electric power in the form of DC. To integrate this generated power from renewable sources to the grid, it requires a cheap, robust, efficient converter, i.e. an inverter (DC to AC converter).

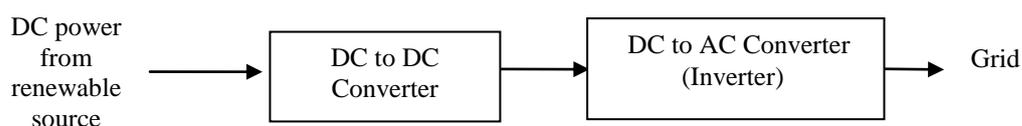


Fig. 1 Buck-Boost converter used to regulate the power obtained from renewable

The voltages obtained from the renewable sources are very low. A DC to DC converter is used to get desired output voltage by using a DC-DC converter (Buck-Boost converter) or transformer. Generally, DC-DC converter used on DC bus and the transformer is used at the AC bus as illustrated in figure 1, 2 respectively.

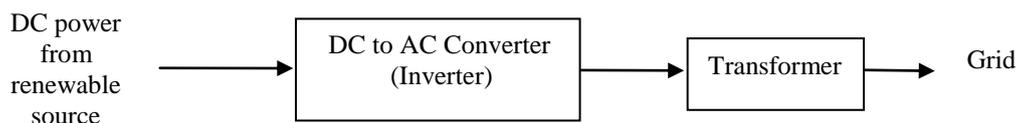


Fig. 2 Transformer used to regulate the power obtained from renewable

By boosting the voltage, less current is needed to deliver a given amount of power to a load, reducing the resistive loss through conductors. The most widely recognized kind of inverter utilized for various applications is full-bridge inverter. The simplicity of the design provides robust operation and simple control. The outputs of boost converter, inverter are rectified sinusoidal wave, pure sinusoidal respectively in case of ideal. But in practice it should not a pure rectified sinusoidal wave, sinusoidal respectively and it contains harmonic. Minimization of harmonic is the major problem in power system to get reliable operation of the converter and power supply.

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## II. CONVENTIONAL METHOD

The harmonic content at output of the inverter can be minimized by using the pulse width modulation technique applied to the switches of inverter during the construction of pulses to the inverter. Converter topology connected to the DC source with inductive nature (i.e. wind turbine) as shown in figure 3.

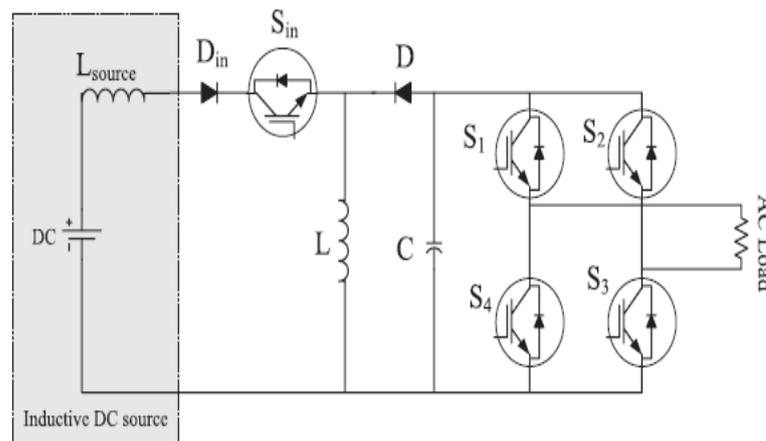


Fig. 3 Converter topology connected to DC nature of the source

A different type of PWM techniques [2]-[7] like sinusoidal pulse width modulation, single pulse width modulation, multi pulse width modulation, selected harmonic elimination, modified carrier wave signal or reference sine wave techniques minimizes the harmonic generated by the pulse width modulation technique itself, because PWM is an open loop control system. The most common type of inverter used is sinusoidal pulse width modulation full bridge inverter [8]. In addition to PWM it requires an output filter to achieve low total harmonic distortion at the output of an inverter.

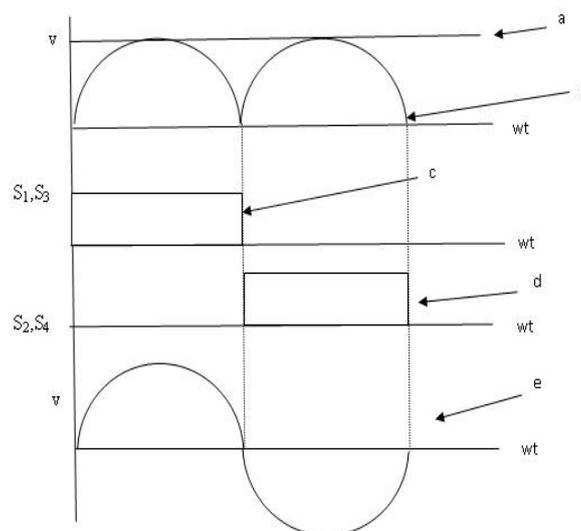


Fig. 4 The operational characteristics of converter topology: a) DC input voltage, b) Output of boost converter, c) Switching pulses to  $S_1, S_3$ , d) Switching pulses to  $S_2, S_4$ , e) Output voltage of inverter

**Operation:** The operational characteristics of converter topology in ideal condition as shown in figure 4. In practical the output of boost rectifier is not a rectified sine wave due to the DC nature of the source, hence the output contains

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harmonics and it is non sinusoidal. Using of sinusoidal PWM technique results output voltage waveform nearly sine wave. The generation of pulses for converter to get nearly sinusoidal wave as shown in figure 5.

Condition for generation of pulses to inverter

- If  $V_c \geq V_t$  the switches are turned on.
- $V_c \leq V_t$  the switches are turned off.

Two disadvantages of this conventional method are the increased size and cost due to the filter and the losses of the semiconductor switches.

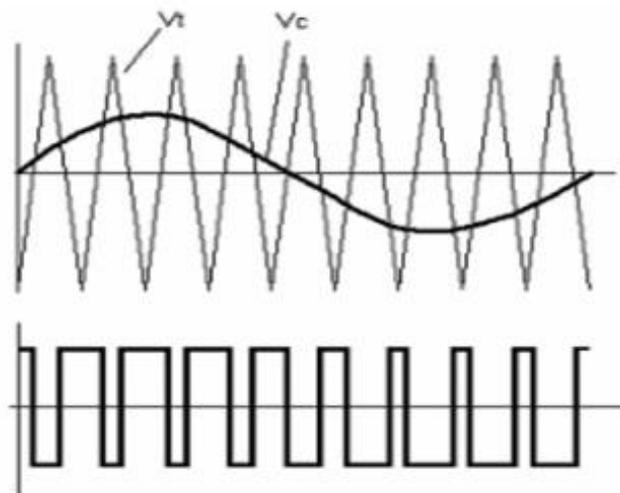


Fig. 5 Generation of pulses for switches

### III. PROPOSED METHOD

In this suggested method, low THD can be achieved by reducing the DC and harmonics present at the output of the inverter.

**Elimination of DC:** The remaining DC voltage at the output of the inverter is minimized by proposing control strategy as shown in figure 6.

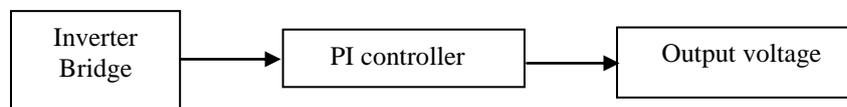


Fig. 6 Proposed control strategy to eliminate DC

**Minimization of harmonics:** Harmonic content is improved, if the remaining DC voltage at the output of the DC-AC converter. Improved harmonic is reduced by injecting the mirror harmonic i.e. it has equal magnitude and anti phase shift angle, during the construction of pulses to the semiconductor switches. The proposed control strategy shows in figure 7, minimizes harmonics at the output of the inverter.

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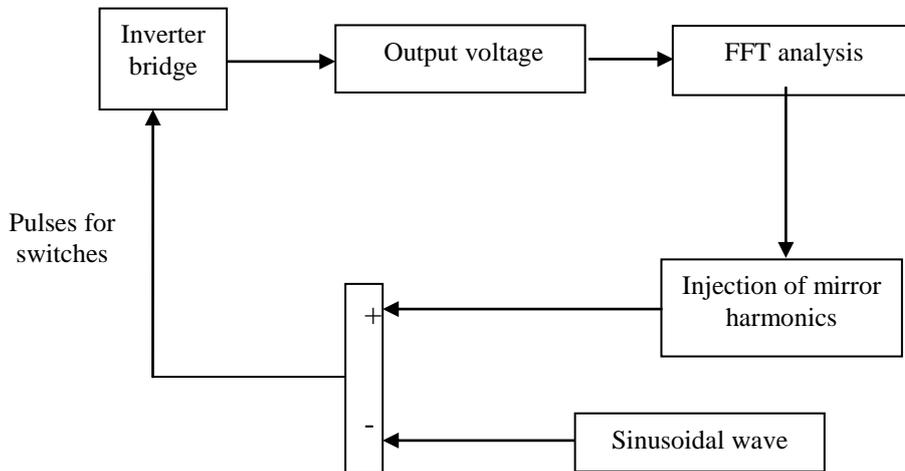


Fig. 7 Proposed control strategy to reduce improved harmonic content

With the use of Fourier analysis, the harmonic content of the output is calculated. Then, we add low-order harmonics (e.g., third, fifth) to the modulation sine wave at the fundamental frequency equal in magnitude, but with a 180° phase difference to the output harmonics to be eliminated.

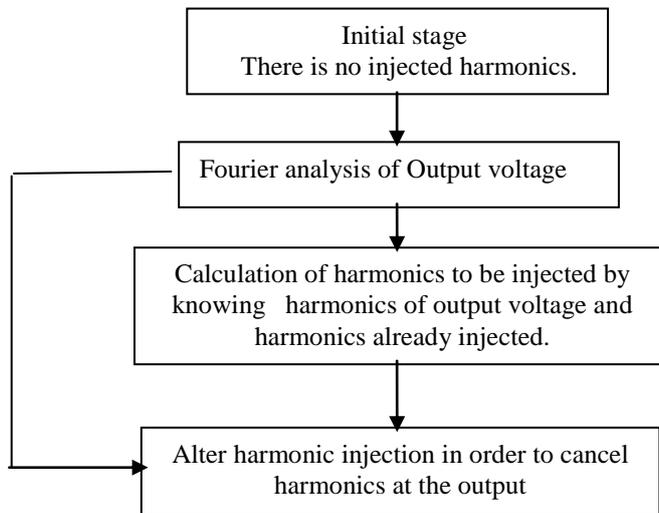


Fig. 8 Suggested algorithm implementation to cancellation of harmonics

The algorithm implementing the cancellation is presented in figure 8. In this First, the harmonic content of the output is analysed. Then, we calculate the harmonics in the output and the harmonics need to be injected to the converter as described.

Let us assume injected harmonic to the grid  $H_a(t)$  and already existing harmonic in grid  $H_b(t)$ , so that the output has resultant harmonic  $H_c(t)$ .

$$\left. \begin{aligned} H_a(t) &= a \sin(2\Pi ft + \Phi_1) \\ H_b(t) &= b \sin(2\Pi ft + \Phi_2) \\ H_c(t) &= c \sin(2\Pi ft + \Phi_3) \end{aligned} \right\} \dots\dots\dots (1)$$

Where a, b and c are the magnitudes, and  $\Phi_1, \Phi_2, \Phi_3$  are the phase shift angles. All harmonics having same frequency f. The resultant harmonic is the summation of the injected and existing harmonics

$$H_c(t) = H_b(t) + H_a(t) \dots\dots\dots (2)$$

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We can rewrite  $H_a(t)$ ,  $H_b(t)$  and  $H_c(t)$  as follows

$$\left. \begin{aligned} H_a(t) &= a\cos(\Phi_1) + j\sin(\Phi_1) \\ H_b(t) &= b\cos(\Phi_2) + j\sin(\Phi_2) \\ H_c(t) &= c\cos(\Phi_3) + j\sin(\Phi_3) \end{aligned} \right\} \dots\dots\dots (3)$$

Then equation 2 becomes,

$$c\cos(\Phi_3) + j\sin(\Phi_3) = b\cos(\Phi_2) + j\sin(\Phi_2) + a\cos(\Phi_1) + j\sin(\Phi_1) \dots\dots\dots (4)$$

From equation 4, we get

$$\begin{aligned} c\cos(\Phi_3) &= a\cos(\Phi_1) + b\cos(\Phi_2) \\ c\sin(\Phi_3) &= a\sin(\Phi_1) + b\sin(\Phi_2) \end{aligned}$$

$$\left. \begin{aligned} \text{Phase angle for Harmonic to be injected to cancellation } \Phi_1 &= \tan^{-1} \frac{(c\sin \Phi_3 - b\sin \Phi_2)}{c\cos \Phi_2 - b\cos \Phi_2} \\ \text{Magnitude Harmonic to be injected to cancellation } a &= \frac{c\cos(\Phi_3) - b\cos(\Phi_2)}{\cos(\Phi_1)} \end{aligned} \right\} \dots\dots\dots (5)$$

During the initial iteration there is no harmonic injection, i.e.  $b = 0$ . In this case, according to (4) and (5),

$$H_a(t) = H_c(t) \quad \text{and} \quad \Phi_1 = \Phi_3.$$

In following iterations, we set  $b = a$ , and  $\Phi_2 = \Phi_1 - 180^\circ$ .

## IV. SIMULINK MODEL AND RESULTS

A simulation design of minimization method for single phase inverter without an output filter is implemented in MATLAB SIMULINK with the help of wind energy, boost rectifier, universal bridge, controllers and FFT as shown in figure 9. The basic elements of the proposed simulink are described in Table 1.

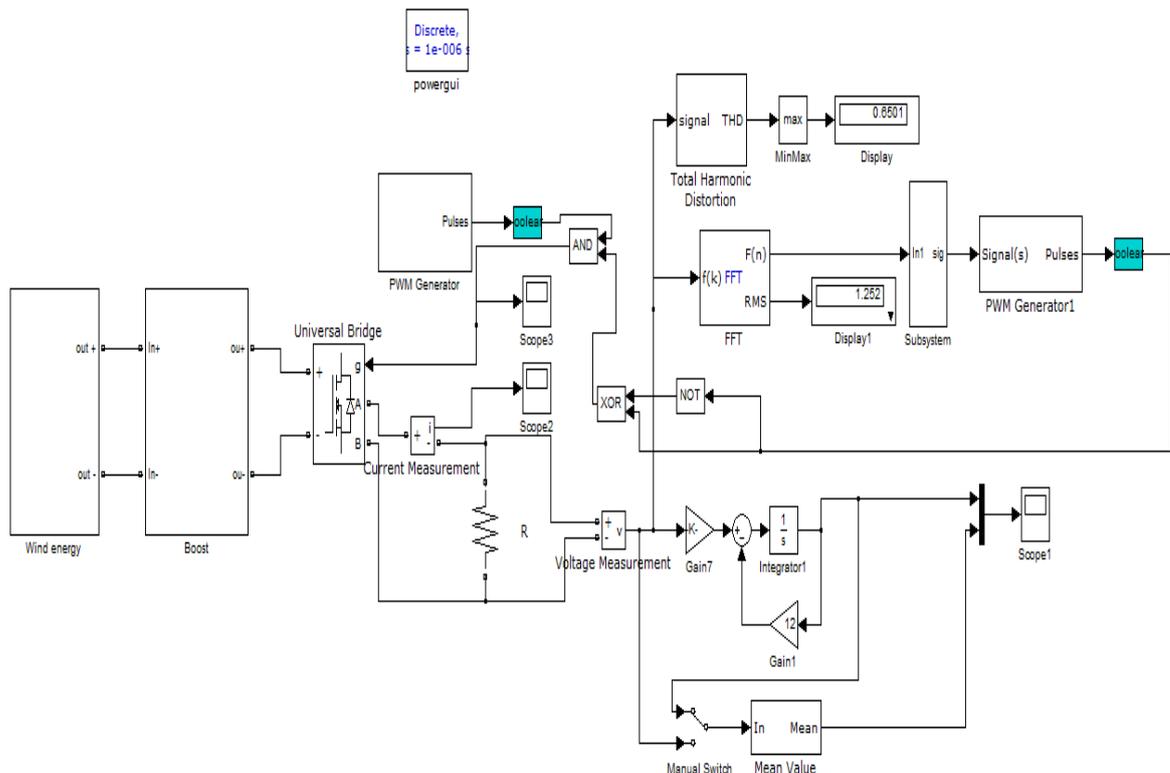


Fig. 9 Simulation model

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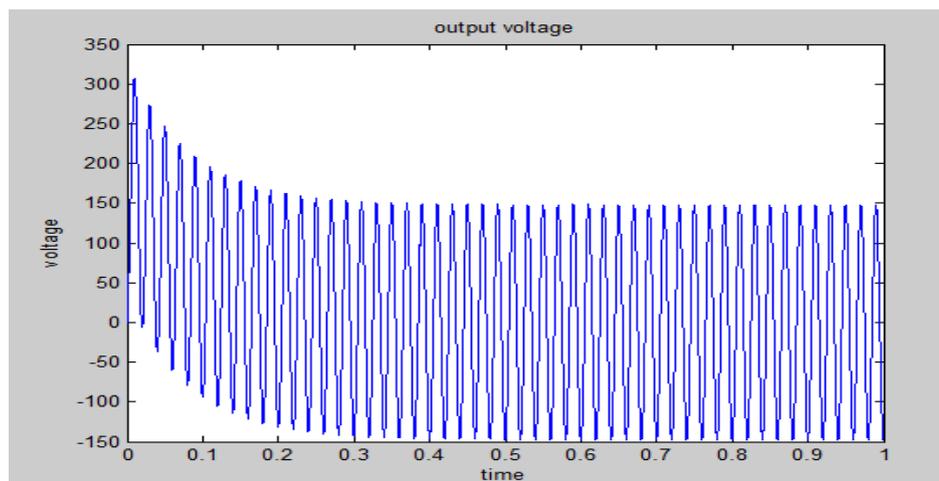
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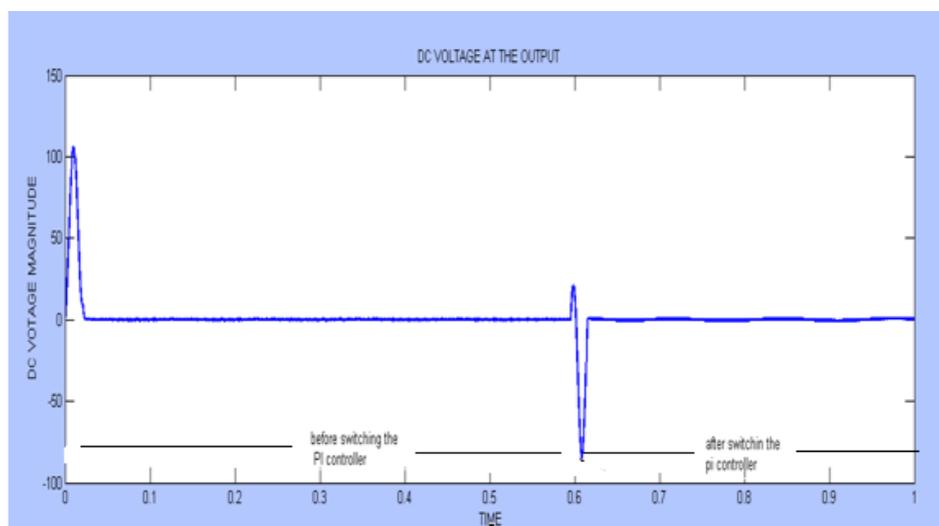
Table 1: Elements of proposed model

load resistance	200 $\Omega$
Snubber resistance	1e5 ohms
Internal resistance of Mosfet/diodes	1e-3
Inductance ,capacitance used in boost rectifier	25e <sup>-3</sup> Henry, 1e <sup>-6</sup> farads
Mechanical output	1.5e6 w
Base power of electrical generator	1.5e6/0.9 VA
Wind speed	12 m/s

The output waveform of inverter output is shown in figure 10a. When manual switch is connect directly to the output of inverter, there is a DC voltage of 1 V appears at the output. After switch connected to PI, the output voltage is minimized as shown in figure 10b.



(a)



(b)

Fig. 10 Output voltage of inverter: a) Inverter output voltage, b) DC at output voltage

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The THD value can be obtained by using FFT analysis is shown in figure 11 and frequency spectrum of proposed system as shown in figure 12. Both are clearly shows harmonics are minimized and THD obtained is 4.24 %, complies with the limit imposed by the standards.

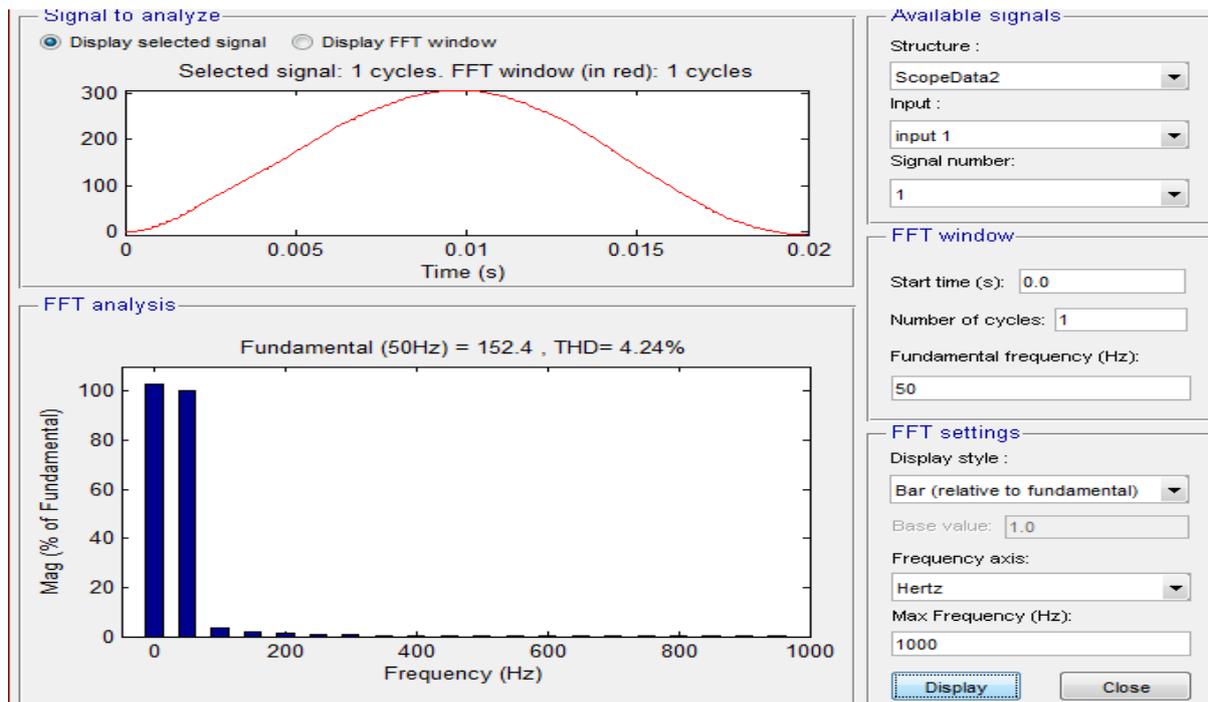


Fig. 11 FFT analysis

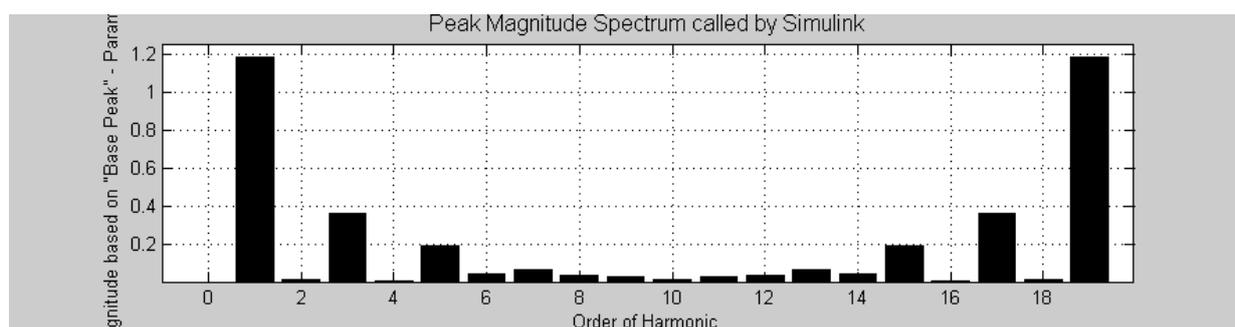


Fig. 12 Frequency spectrum

### V. CONCLUSION

A novel approach to harmonic minimization method for single phase inverter established on mirror injection of harmonic and elimination of DC principle has been proposed. The following conclusions can be drawn after the imaginary analysis and the experimental results reported in this paper. The proposed system minimizes the harmonics generated by the switching operation as well as harmonics generated by DC nature of the source and external point i.e. grid. Improvement of THD, through the cancellation of low-order harmonics and minimization of DC was achieved, so that the output voltage complies with the limit imposed by the standards, without the use of a filter.

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