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# Implementation Hardware of single phase H-Bridge Inverter with Selective Harmonic Elimination Pulse Width Modulation Technique

**Arati Gokul Anandkar, K.S.Gadgil,**

***Abstract:** Recently the use of high power Voltage Source Inverter is increased but the problem of harmonic and switching losses in inverter are also increased because of the use of power electronic switches, which are used for fast and efficient operation. In this paper, for eliminating the harmonics presented in H Bridge inverter during switching operation of the power electronic switches the Selective Harmonic Elimination Pulse Width Modulation (SHEPWM) Technique is used. For H-Bridge operation specific switching angles are calculated by solving nonlinear equation using Newton Raphson method. The result of H-bridge single phase inverter are implemented on hardware with and without SHEPWM technique for eliminated specific $3^{rd}$,$5^{th}$,$7^{th}$,$9^{th}$,$11^{th}$,$13^{th}$ voltage harmonics are obtained. Comparison of harmonic analysis of H bridge inverter with and without SHEPWM technique is done. In this paper Modulation index (m) is varied to control output voltage amplitude and the results are observed for maximum modulation index.*

***Keywords:** H-bridge Inverter, Selective Harmonic Elimination (SHE), Pulse width modulation (PWM), Voltage harmonics.*

## I. INTRODUCTION

The use of renewable energy sources has increased day by day and most of the renewable sources generate DC power output. But the applications mostly used in industry and home appliances require AC supply. It is therefore needed to convert DC to AC, for this purpose inverters are used. In these inverters for conversion the use of power electronics devices are increased drastically. As per the classification of inverter the Voltage source inverter (VSI) are used most due to simple construction and less price. In VSI inverter, the output voltage is varied by changing the duty ratio of its switch. The inverter output are depend on exact turn-on and turn-off power electronics devices (e.g. BJTs, MOSFETs, IGBTs, and GTOs) depending on their applications. In ideal inverter the waveform attain is sinusoidal but in practical that contains undesirable harmonics. The presents of total harmonic distortion (THD) in output waveform decided character of the output signal. For these purpose different pulse width modulation techniques used and achieve required output voltage. By using higher frequency of switching we get less THD and sinusoidal output but the losses of switching also increased.

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For reduced loss and to get constant output voltage use of low switching frequency is preferred. SHEPWM method has advantage of specific harmonic elimination and minimum switching frequency losses. In SHEPWM method the selected harmonics are eliminated.

## II. IMPLEMENTATION OF SELECTIVE HARMONIC ELIMINATION PULSE WIDTH MODULATION TECHNIQUE

H -bridge is the main switching circuit there are two legs of MOSFET with the load between them. Each leg has two MOSFET attached to it. This can be seen in Fig.1.The MOSFET form the switching elements and are labelled S1 to S4. At the gate of each MOSFET are the inputs from the switching control circuit. The switching control circuit is the brain of the inverter and controls the switching of the H Bridge. To achieve desired output voltage the H-bridge MOSFET turn on and off at accurately at the right time. The turning On and Off of the MOSFETS is controlled by different PWM techniques such as Sinusoidal pulse width modulation (SPWM),SHEPWM.SPWM is normally is used in high switching frequencies, but the switching losses become comparable to the total inverter losses to minimize the switching losses SHEPWM method is used. And SHEPWM method is used to eliminate specific $3^{rd}$,$5^{th}$,$7^{th}$,$9^{th}$,$11^{th}$,$13^{th}$ lower order harmonics. The switching angles are calculated by solving Fourier series voltage waveform nonlinear equation by Newton Raphson technique. Calculated angles in degree are fed to H-Bridge are converted in time base by Arduino Nano controller and are given as input to switch gate terminal of H – Bridge .H-Bridge output is $+V_{dc}$,0,$-V_{dc}$. The DC input to H-Bridge inverter is given either from battery or DC to DC converter.

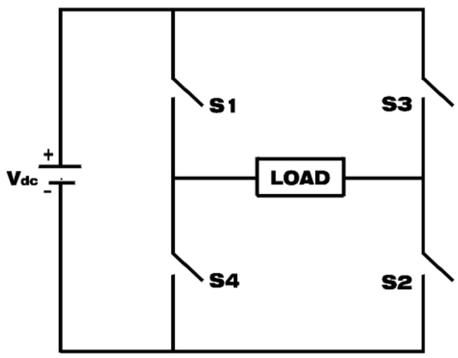


**Fig.No.1- H-Bridge Inverter circuit**

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The output of H-Bridge inverter using SHEPWM method shown in Figure No.2 the output waveform.

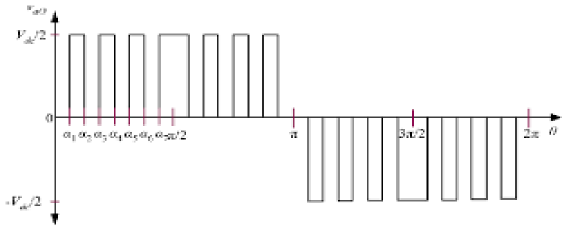

**Fig.2 H-bridge inverter with SHEPWM output waveform**

To set N-1 nonlinear equation the fourier series expansion apply to output waveform as follows:

$$V_{out} = \sum_{n=1}^{\infty} V_n Sin(nwt) \qquad (1)$$

$$V_n = \frac{4Vdc}{n\pi} \sum_{k=1}^{N} (-1)^{k+1} \cos(n\alpha_k) \text{ , n=1,3,5,7,9,11} \qquad (2)$$

Where:
N is the Switching angles per quarter numbers.
$V_{dc}$ is the DC source amplitude.
n is the odd harmonic order.
$\alpha_k$ is switching angles, conditioned by equation (3)

$$\alpha_1 \prec \alpha_2 \prec \alpha_{3...} \alpha_n \prec \frac{\pi}{2} \qquad (3)$$

From (2), the amplitudes of Vn of the quarter-wave symmetric SHEPWM inverter is given as

$$V_n = \frac{4V_{dc}}{n\pi} \sum_{k=1}^{N} (-1)^{K+1} COS(n\alpha K) \text{, n=1,3,5} \qquad (4)$$

The even harmonics are absent due to output voltage waveform are quarter wave symmetry. To mitigate the specific low order odd(***3^rd^,5^th^,7^th^,9^th^,11^th^,13^th^***) harmonics and to control the fundamental amplitude, the seven nonlinear equations are solved. The fundamental output voltage and specific harmonic elimination for modulation index 0.9 are solved and the angles are given below table 1.

Table 1-optimum switching angles in degree for modulation index

| α1 | α2 | α3 | α4 | α5 | α6 | α7 |
|---|---|---|---|---|---|---|
| 17.72 | 24.32 | 35.99 | 48.92 | 55.58 | 74.69 | 78.19 |

## III. HARDWARE DESIGN AND RESULT

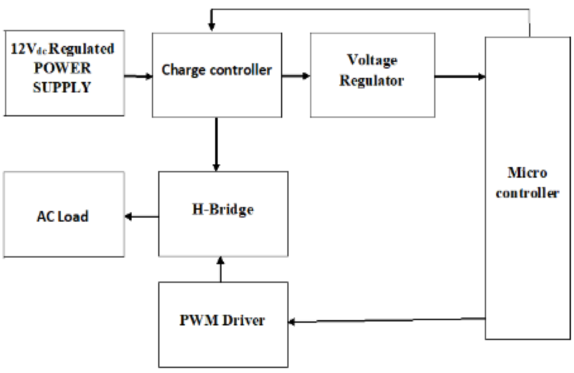


**Fig.3. Proposed system Block Diagram**

In this proposed system 12V DC regulated supply is given to H-bridge inverter though charge controller. For the Arduino nano 5 V DC supply is given through voltage regulator which gets 12 V as its input from charge controller. For voltage monitoring and protection voltage sensor is connected. To eliminate selective harmonics in inverter, the duration of switch on and off are decided by calculating angles which feed are to ardino nano controller. This PWM signals generated by arduion nano are used to trigger gate terminal of MOSFET switches through the PWM driver. In PWM Driver the optical isolator are used to isolate and give constant voltage required to MOSFET switches. H-Bridge output is connected to AC Load which gives constant voltage with mitigation of harmonic.

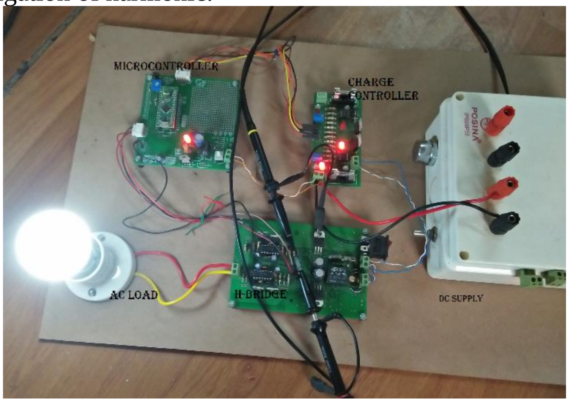


**Fig.4 Hardware of H bridge inverter with and without SHEPWM**

**RESULT OF H-BRIDGE INVERTER WITHOUT SHEPWM TECHNIQUE**

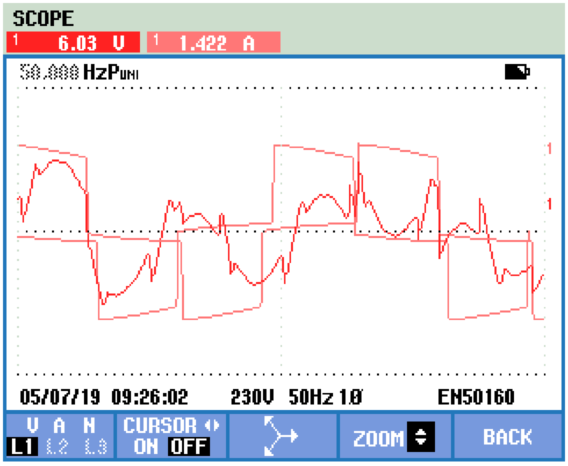


**Fig.5 Voltage and Current waveform of H bridge inverter without SHEPWM technique**

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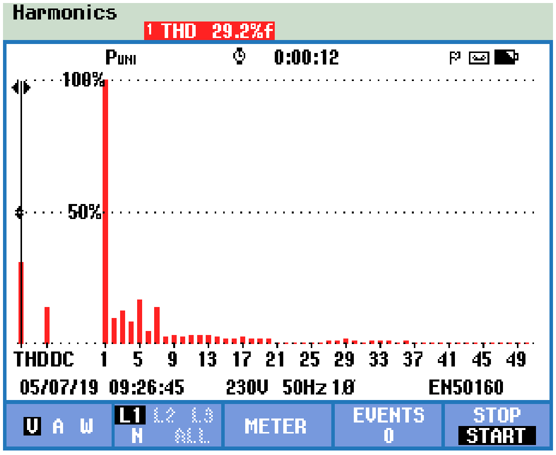


**Fig.6 Voltage harmonics of H Bridge inverter without SHEPWM**

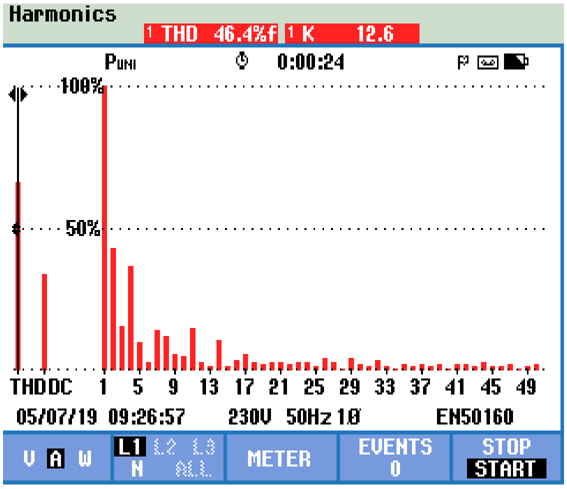


**Fig. 7 Current harmonics of H bridge inverter without SHEPWM technique**

**RESULT OF H-BRIDGE WITH SHEPWM**

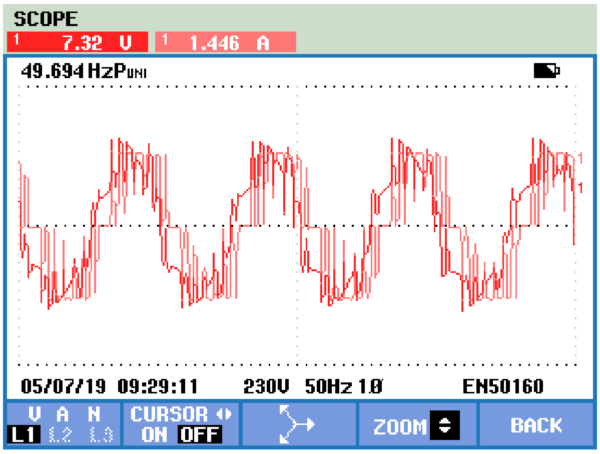


**Fig. 8 Current and voltage waveform of H bridge inverter with SHEPWM Technique**

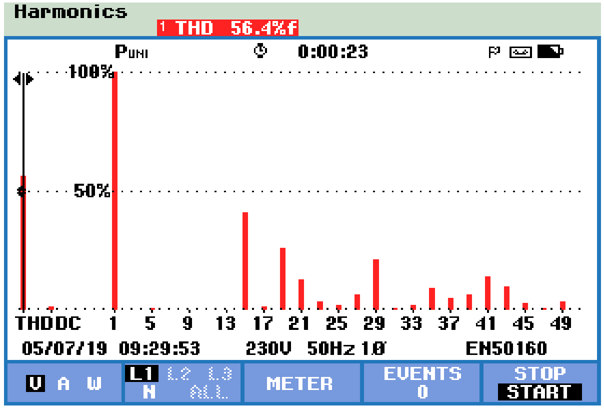


**Fig. 9 Voltage harmonics of H bridge inverter with SHEPWM Technique**

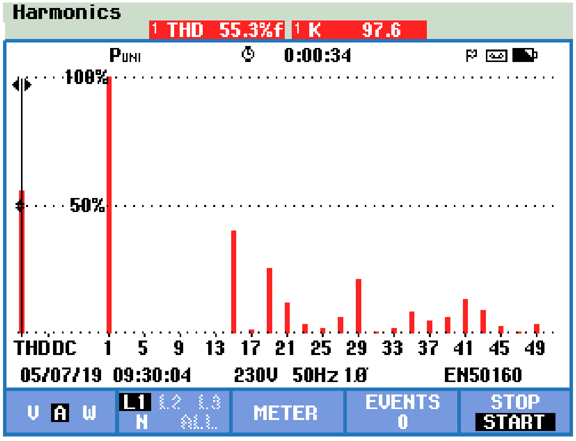


**Fig. 10 Current harmonics of H bridge inverter with SHEPWM Technique**

It is observed in these proposed system the individual specific value of 3rd,5th,7th,9th,11th and 13th voltage harmonics in H-Bridge with and without SHEPWM Technique are shows and listed below:

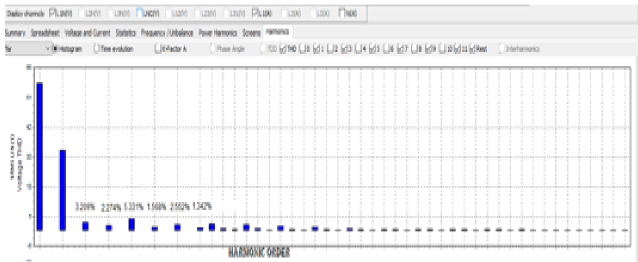

**Fig.11 percentage values of 3rd,5th,7th,9th,11th and 13th voltage harmonics in H-Bridge inverter without SHEPWM technique.**

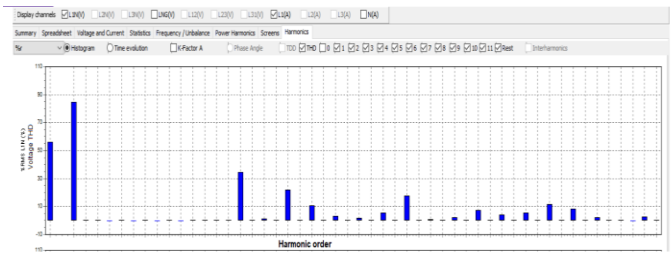


**Fig.12 percentage values of 3rd,5th,7th,9th,11th and 13th voltage harmonics in H-Bridge inverter with SHEPWM technique.**

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Table 2 : Percentage of individual 3rd,5th,7th,9th,11th and 13th voltage harmonic

| Harmonic Order | H bridge harmonic without SHEPWM(Voltage) | H bridge harmonic with SHEPWM(Voltage) |
|---|---|---|
| 3rd | 3.209% | 0.2% |
| 5th | 2.274% | 0.2% |
| 7th | 5.331% | 0.08% |
| 9th | 1.568% | 0.08% |
| 11th | 2.552% | 0.09% |
| 13th | 1.342% | 0.16% |
| Total THD | 59.92% | 56.27% |

## IV. CONCLUSION

Selective Harmonic Elimination Pulse Width Modulation Technique for Specific low order harmonic elimination has been implemented in these paper sucessfully. For eliminating low order harmonics 3rd,5th,7th,9th,11th and 13th seven switching angles are calculated for MOSFETs switching. Harmonic analysis of output voltage and current of H Bridge inverter is done and comparison between the output voltage of H bridge inverter with and without SHEPWM Technique shows that the percentage of specific odd harmonics in voltage waveform is reduced and THD is also reduced from 59.92% to 56.27%.So required size and cost of filter can be reduced.

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**Arati Anandkar** completed diploma in electrical from government polytechnique pune. India,in 2014 and received the Bachloer degree in electrical engineering from Jaywantraw sawant college of engineering, pune, India in 2017 and appearing for Master degree in electrical engineering specialization in power electronic and drive from All India Shri Shivaji Memorial Society institute of Information Technology, Pune, India. Her research interests include Power converters, Harmonics, and renewable energy source.

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