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SIMULATION OF A CASCADE CONNECTED H–BRIDGE MULTI LEVEL INVERTER USING PSO TECHNOLOGY FOR HARMONICS ANALYSIS

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ABSTRACT

A Single Phase Cascade connected H – Bridge Five Level Voltage Source Inverter is realized, using Pulse Generator and Sine PWM Firing Technique. The Inverter is of type fixed voltage and variable Frequency converter s. These inverters do not use a transformer for their operation, reduce harmonic losses and give fewer disturbances. In recent times the power demand of the industries is increasing very rapidly because many industries are using higher power apparatus and drives, this apparatus worked on high power and medium voltage, to supply energy to this apparatus or drive multilevel inverter is used. A multilevel inverter is a power electronic system which gives the desired output voltage from several DC voltage sources as input.

This Paper deals with study and analysis of single phase multilevel inverters with various topologies. The major purpose of the study is to understand the performance of inverter and harmonic analysis with different levels. In this thesis concentrates cascade H-bridge multilevel inverter. As we know there are three topologies and from that we are using cascade H-bridge type topology, to find the firing angle of the multi level inverter. In this thesis, we proposed a topology name PSO to calculate the optimized switching angle for minimization of harmonic.

***Index Terms*------ Multi Level Inverter, Firing Techniques, Sine PWM, Pulse Generator,PSO**

I.INTRODUCTION

nverter is a Power Electronic module, which is a DC to AC converter. DC input to an inverter could be from batteries, fuel cells, solar cells or rectified dc [1-3]. The output of these dc sources can be utilized on AC loads using Inverters. For some AC loads it is required to have variable voltage and variable frequency power supply, but
available supply voltage levels and frequency are limited, for these Variable Voltage and Variable Frequency power supply 'Inverters' are used. While comparing a basic two level inverter and multi level inverter, the multi level inverter always have better Total Harmonic Distortion (THD).

The concept of multilevel inverter was first introduced back in 1975. The term "multilevel" in multilevel inverters was associated with the voltage levels observed in output voltage waveform .]. A basic two Level Inverter have only two voltage levels i.e. $+V_m$, while an 'n' level inverter will have n levels for example: If n = 5 then, $+2V_m$,$+V_m$,0, —V_m,—$2V_m$ will be the output voltage levels.

Early Inverters used Thyristor switches, having switching frequency a few hundred Hertz, while the present day switches like IGBT have switching frequency of several Kilohertz. Also Thyristor requires a commutation circuit while using with DC, so self commutated switches like IGBT are preferred over Thyristor. Normally electronic switches have unidirectional current carrying property; to make them bidirectional an antiparallel diode is connected.

In general three different types of multilevel inverters are used, which are as follows -

- Cascaded H Bridge Inverter
- Diode Clamped Inverter
- Flying Capacitor Inverter.

A. Advantages & Disadvantages of H-Bridge Multi Level Inverter-

- Among multilevel inverter topologies Cascaded H Bridge Inverter is a modular one and simplest to control[5]
- Though it have the disadvantage of using multiple dc sources.
- But it does not require extra capacitors and diodes.
- The number of possible output voltage levels (nj) is more than twice the number of identical DC sources or single phase inverters (n_s) used.[7]

$$n_i = 2n_s + 1. \quad (1)$$

B. Advantages & Disadvantages of Diode Clamped Multilevel Inverter [6]-

- Diode Clamped Multilevel Inverter has high efficiency when compared to other types, as all the switches are fired at the fundamental frequency.
- The Diode Clamped Inverter has simple firing control.
- But the disadvantage of the Diode Clamped Inverter is excessive need of clamping diode.
- Also the controlling of real power flow is difficult for individual block of multilevel inverter.

C. Advantages and Disadvantages of Flying Capacitor Multilevel Inverter [6]-

- Flying Capacitor Multilevel Inverter has advantage of switch combination redundancy for the balance of different voltage levels.
- The control of real and reactive power control is not a problem like Diode Clamped Inverter.
- Number of storage capacitors needed increases with the increase in number of levels of a multilevel inverter.
- The efficiency of the inverter reduces with increase in real power transmission.
- The Flying Capacitor Inverter control is complicated as compared to the Diode Clamped Inverter.

For controlling multilevel inverters various techniques has been proposed, among these three controlling techniques are majorly used-

- Sinusoidal Pulse Width Modulation (SPWM)
- Selective Harmonic Elimination (SHE-PWM)
- Space Vector Modulation (SVM)

For simple 2 level single phase inverter, Sine PWM technique consists of a sinusoidal modulating signal of desired output frequency and a triangular carrier signal of desired switching frequency. These two signals are compared for switching signals. Fig. 2 shows the implementation of the SPWM technique. The peak magnitude of the sinusoidal signal (V_m) is less than or equal to the peak magnitude of the carrier signal (V_c). An important parameter of Sine PWM is Modulation Index.

$$\text{Modulation Index} = V_m / V_c \quad (2)$$

Modulation Index controls the harmonic content of the output voltage waveform. The magnitude of the output fundamental component is proportional to the Modulation Index, but Modulation Index is always less than unity.

Sine PWM technique can be realized with MATLAB/Simulink. For simplicity V_m is considered 0.85 and V_c is unity. Thus, Modulation Index is 0.85 , the frequency of modulating signal is 50 Hz, while that of carrier is taken 1080 Hz.

Applications of Multilevel Inverter can be-

- Uninterrupted Power Supply
- A.C. Adjustable Speed Drives
- Variable Frequency Generator
- Utilization of DC power of Renewable Energy sources

II. PARTICLE SWARM OPTIMIZATION

PSO is a stochastic, population-based EA search method, modeled after the behavior of bird flocks [7]. The PSO algorithm maintains a swarm of individuals (called particles), where each particle represents a candidate solution. Particles follow a simple behavior: emulate the success of neighboring particles and its own achieved successes. The position of a particle is, therefore,

influenced by the best particle in a neighborhood P_{best} as well as the best solution found by all the particles in the entire population G_{best}. The particle position x_i is adjusted
where the velocity component Φi represents the step size. The velocity is calculated by

$$v_{id}^{t+i} = wv_{id}^{t} + C_1 rand_1 (P_{id} - x_{id}^{t}) + C_2 rand_2 \left(P_{gd} - x_{id}^{t}\right) \quad (3)$$

Where,

1. Particle position vector x_{id} : This vector contains the current location of the solution for each particle in the search space.
2. Particle velocity vector v_{id}: This vector represent the velocity of particle i.
3. Best solution P_i: This is the best solution of the objective function that has been discovered by a particular particle i.
4. Best Global Solution P_g : This is the best global solution of the objective function that has been discovered by all the particles of the population.
5. C_1 and C_2: Learning factors or weighting factor or correction factor applied to influence the best position and the global best position, respectively, of a particle. C_1 is the importance of personal best value

C_2 is the importance of neighborhood best value

Usually $C_1 + C_2 = 4$ (empirically chosen value)

6. $rand_1$ and $rand_2$: are uniformly distributed

random numbers
7. w: weighting function.

The following weighting function is usually utilized in (3.2)

$$w = \frac{w_{max} - [(w_{max} - w_{min}) * x_{(iter)}]}{maxiter}$$

Where, w_{max} = initialweight,
w_{min} = final weight,
maxIter = maximum iteration number,
iter = current iteration number.

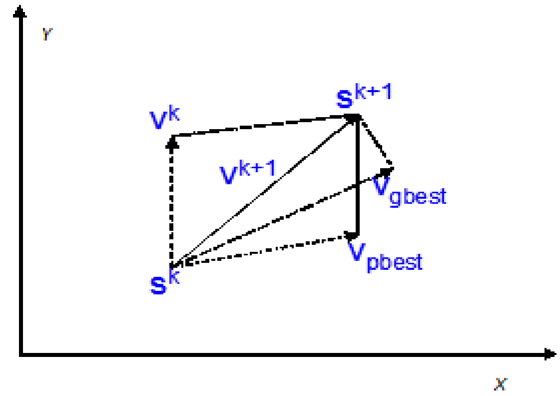

Figure 1 Concept of modification of a searching point by PSO

III. PROPOSED WORK

In the proposed paper, a cascade connected H-Bridge Five level inverter is realized using two different firing techniques. They are:

- Pulse Generator Firing Technique

A.Configuration of Cascade Connected Single Phase H Bridge Five Level Inverter

- In a Five level inverter, two, Single Phase H Bridge Inverter are connected in cascade to get five different voltage levels and is shown in Fig.4. The input dc voltage of the two, single phase module is same, i.e. $E_{dcl} = E_{dc2}$. If the input dc sources are of E_{dc} Volt, then five level of voltage available at output are $+2E_{dc}$, $+E_{dc}$, 0, — E_{dc}, — $2E_{dc}$, Table II.
- The output voltage can be taken across load as V_{op}, while V_{opl} and V_{op2} are output of Inverter 1 & 2 respectively. For these five outputs voltage levels the combinations of eight switches and output voltage is given in Table II. From analysis of Table II, one can realize that the two switches connected in one leg in series have firing sequence complimentary to each other. i.e. Sn = S_{12}, $S_{13} = S_{14}$, $S_{21} = S_{22}$, $S_{23} = S_{24}$.

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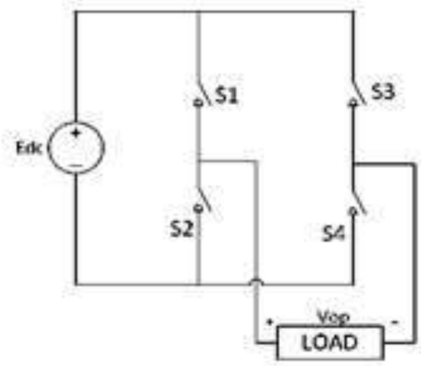

Figure2.Single phase H-bridge Inverter

TABLE I. Switching Sequence and Output Voltage levels of Single Phase H-Bridge Three-Level Inverter

V_{op}	S_1	S_2	S_3	S_4
+ Edc	**1**	**0**	**0**	**1**
0	**1**	**0**	**1**	**0**
	0	**1**	**1**	**0**

TABLE II. Output Voltage levels of Single Phase H-Bridge Five-Level Inverter

S. No.	V_{opl}	V_{op2}	V_{op}
1	*+ Edc*	$+E_{dc}$	*+2Edc*
2	*+Edc*	**0**	*+Edc*
3	**0**	**0**	**0**
4	**0**	*-Edc*	*-Edc*
5	*-Edc*	*-Edc*	—2Edc

This can also be understood from the circuit that if the two switches of one leg are ON, there will be a short circuit across the dc source. This phenomenon is also helpful in generating firing sequence of the switches; only four sequences are to be generated, while other four are complimentary of the generated.

From the available five levels of the output voltage the stepped square AC waveform shown in Fig.5 can be realized; and also for these different voltage levels, the firing sequence can also be drawn.

IV FIRING PULSE GENERATION

The desired sequence of firing and output waveform can be realized in MATLAB/Simulink using various techniques, the two discussed in the proposed work are:

- Pulse Generator Firing

A. Pulse Generator Technique

For the output waveform to have 50 Hz frequency, the time period in the pulse generators (PG11, PG13, PG21 and PG23) is taken 20 Millisecond.

The parameters of PG11, PG13, PG21 and PG23 are described in Table IV. The calculation of Pulse Width is done from the switching waveform with these parameters. 360° = 20ms

E.g. - Pulse Width (PW^0) of PGn, v PW^0 = 247.5° + (360° - 292.5°);

PW° = 315°.

PW(Sec.) = 315° x 20 ^ 360°;

PW (Sec) = 17.5ms

PW(% of Period) = 17.5 ^ 20 x 100 = 87.5%

Phase Delay = 292.5 x 20 ^ 360 = 16.25ms.

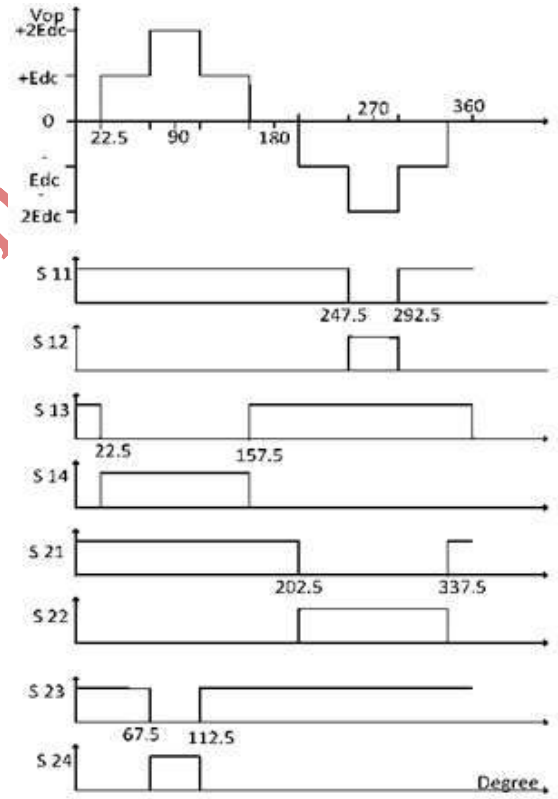

Fig.3.Five level Output voltage and Respective switching sequencing

Similarly parameters for other Pulse Generator can be calculated for any no. of level or Inverter.

V.Mathematical

The output voltage equation

1. $V(t)=\sum_{n=1,2,3....}^{\infty}\frac{4Vdc}{n\pi}[\cos(n\theta 1)+\cos(n\theta 2)+$ ....$\cos(n\theta m)*\sin n\omega t$ (4)

Where m=no of bridge
n= no of level i.e. 5,7,8,9,13,15,….

To solve the harmonic equations by resultant theory, they must be changed into polynomials. First, change the variables, let
$X_n = \cos(\theta_n)$
Where n= no of converter i.e. for 11 level inverter 5 converter are used .

By using the following trigonometric identities:
$\cos(5\theta) = 5\cos(\theta) - 20\cos^3(\theta) + 16\cos^5(\theta)$
(5)

Then, apply them to the transcendental harmonic equations above, and the following polynomial harmonic equations can be found.
$P_1(X_1, X_2) = \sum_{n=1}^{2} X_n - m = 0$ (6)

$P_2(X_1, X_2) = \sum_{n=1}^{2} 5X_n - 20(X_n)^3 +$
$16Xn5$ (7)

The value of firing angle is calculated with the help of PSO for the pulse generator.

VI.SIMULATION IMPLEMENTATION

Multi Level inverter made up by no of Single phase full bridge Inverter. The no of inverter Required by i= i-3 where i is no of level inverter , there one bridge four IGBT for switching purpose. The Simulink model of five, seven, Nine, Eleven, Thirteen, and fifteen level cascade H bridge multilevel inverter is shown in fig 4. to fig 8 respectively.

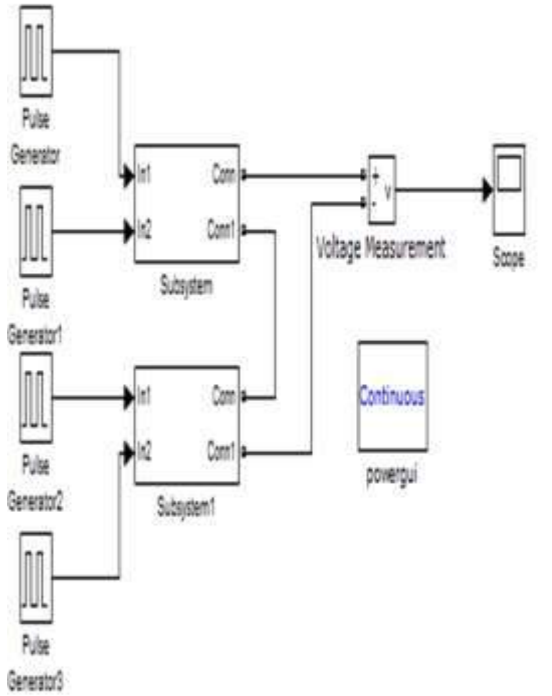

Fig .4 Five Level Cascade H-Bridge Multilevel Inverter

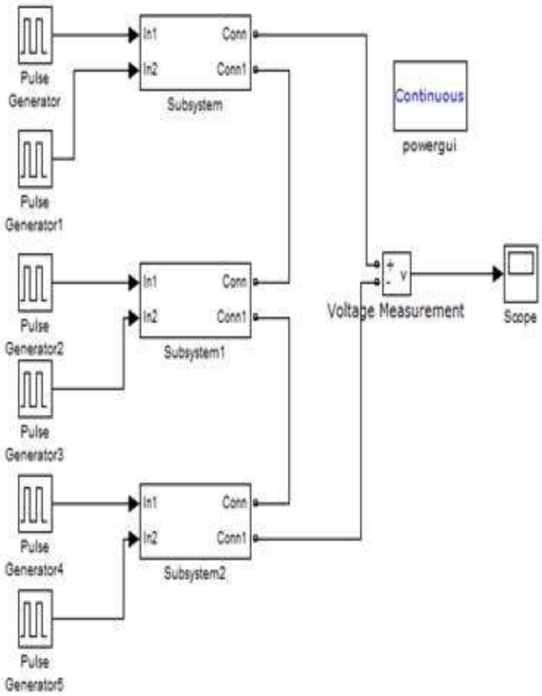

Fig.5.Seven Level Cascade H-Bridge Multilevel Inverter

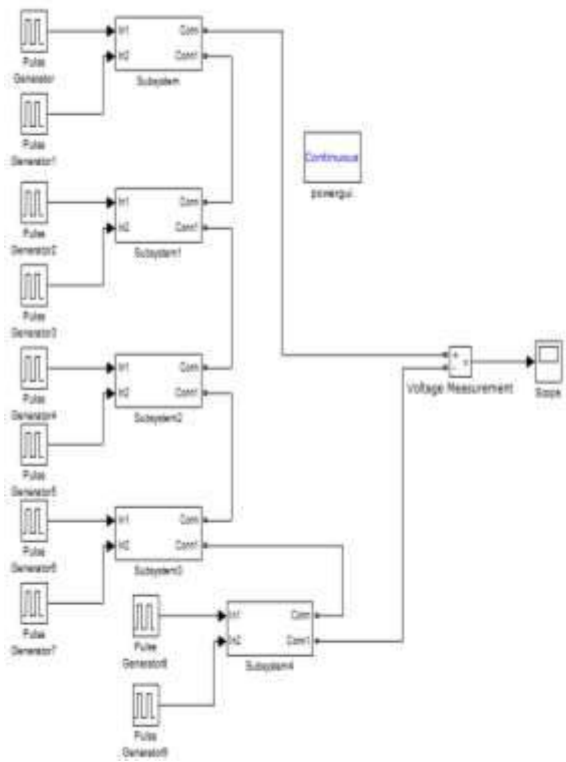

fig.6.Eleven Level Cascade H-Bridge Multilevel Inverter

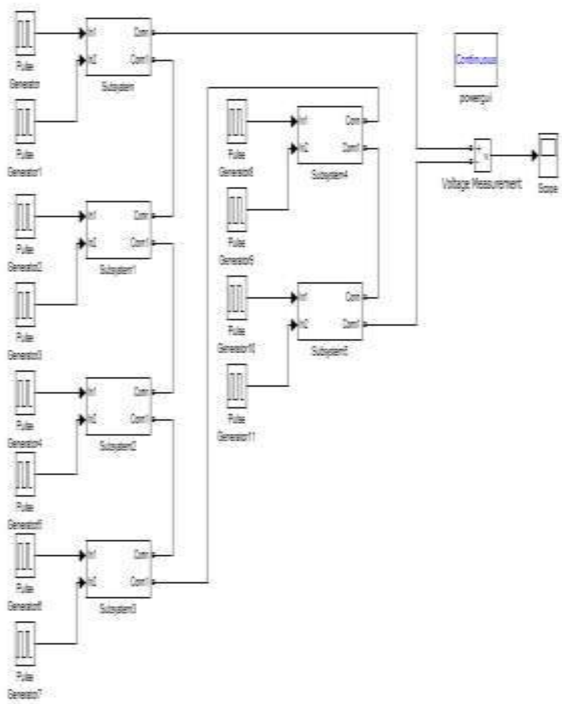

fig.7.Thirteen Level Cascade H-Bridge Multilevel Inverter

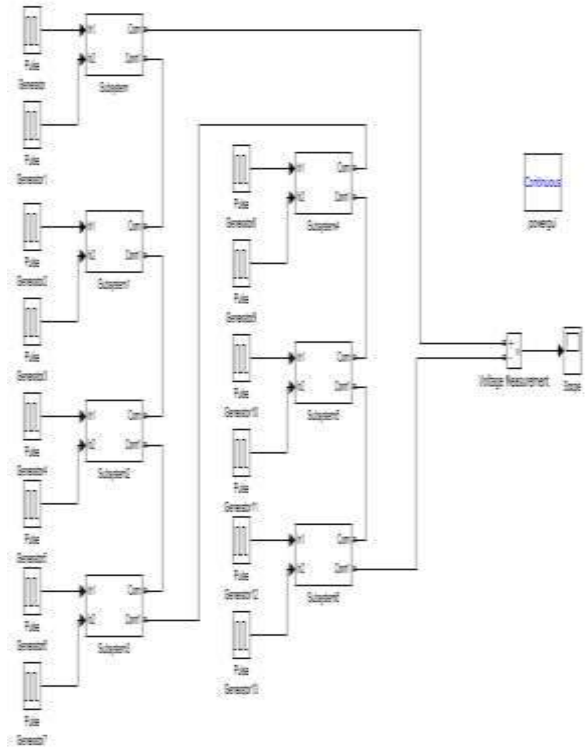

fig.8.Fifteen Level Cascade H-Bridge Multilevel Inverter

VII. RESULT

Angle obtain from the PSO program is put in following simulation models of Different level cascade H-bridge inverter and resultant graph of angle and THD is shown fig.9 to fig. 19

The Parameter of PSO for each multilevel inverter given in table no.III

Table III Parameter used in the Implementation of PSO

S. No.	Parameter	Value
1.	Dimension of Function D	2
2.	Population Size N	40
3.	Maximum Iteration $iter_{max}$	100
4.	Learning Factor C_1 & C_2	2
5.	Weight Factor w_{max}	0.9
6.	Weight Factor w_{min}	0.4

Five Level , Seven Level Nine Level ,Eleven Level, Thirteen Level and fifteen Level Output voltage Level Wave form and FFT Analysis (Total Harmonics Distortion) show in fig.9 to fig.19 Respectively.

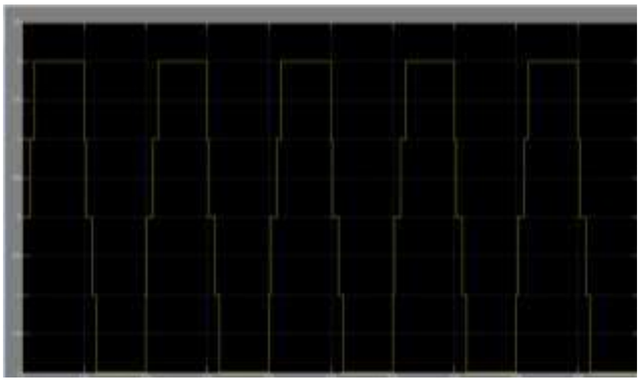

Fig.9 Output Waveform of Five Level Cascade H-bridge Multilevel Inverter

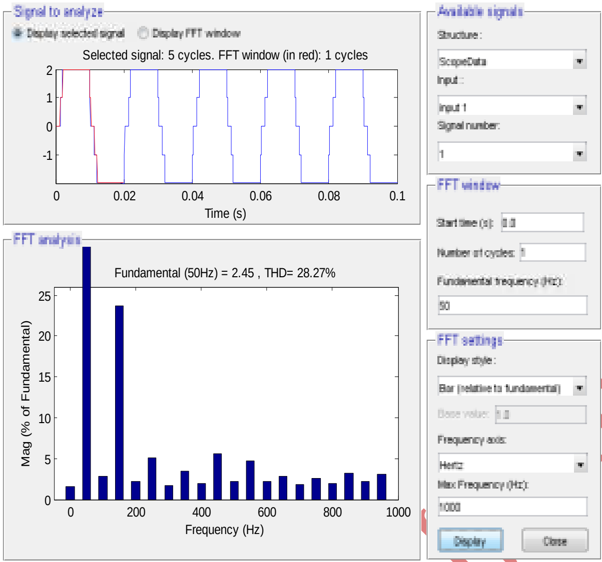

Fig.10 FFT Analysis of Five Level Inverter

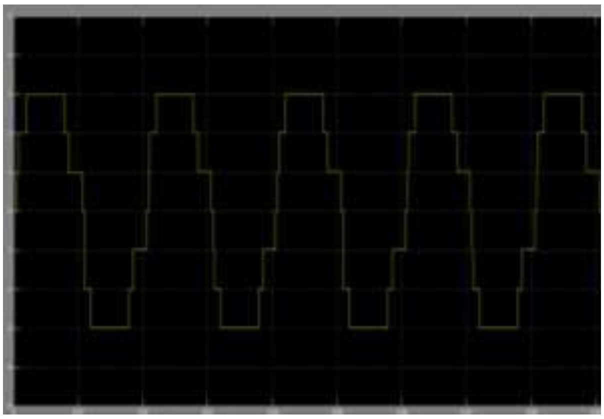

Fig. 11 Output Waveform of Seven Level Cascade H-bridge Multilevel Inverter

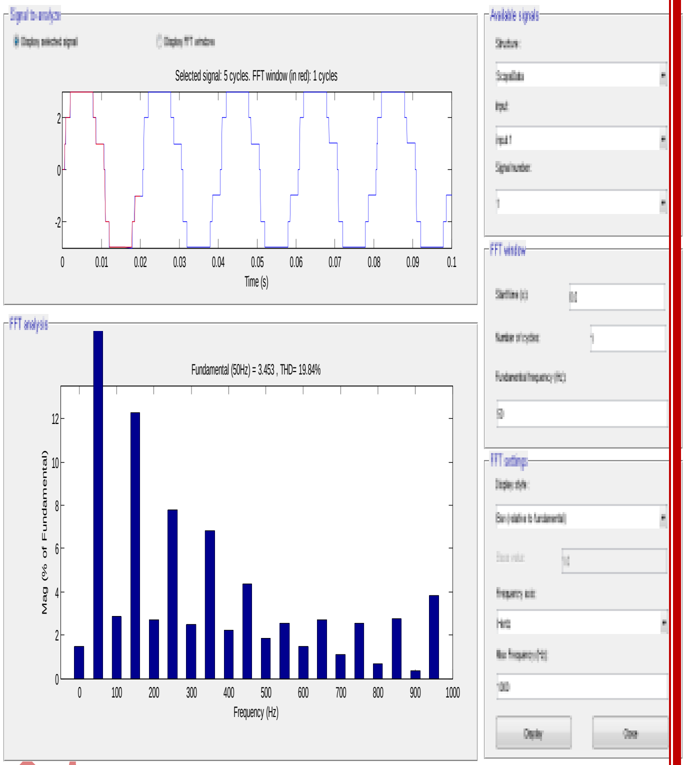

Fig. 12 FFT Analysis of Seven Level Inverter

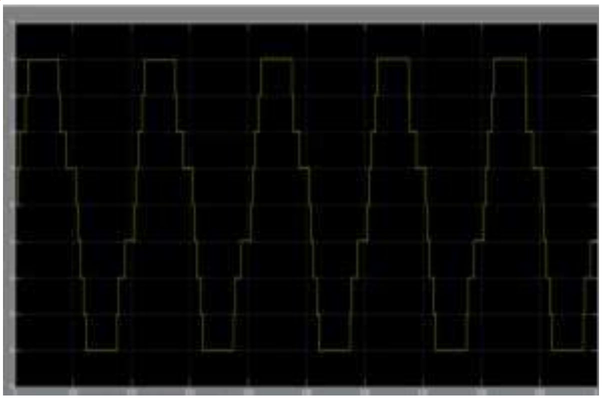

Fig. 13 Output Waveform of Nine Level Cascade H-bridge Multilevel Inverter

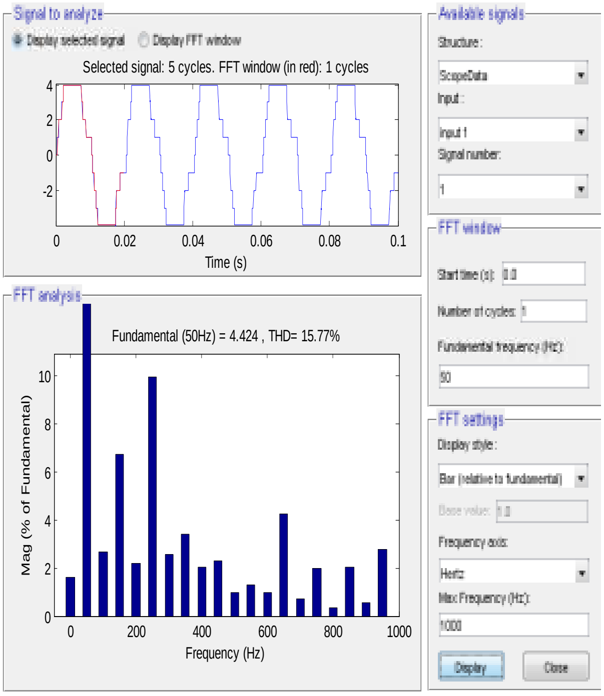

Fig. 14 FFT analysis of nine level inverter

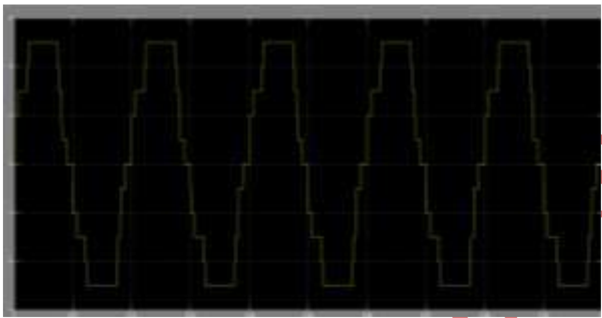

Fig. 15 Output Waveform of Eleven Level Cascade H-bridge Multilevel Inverter

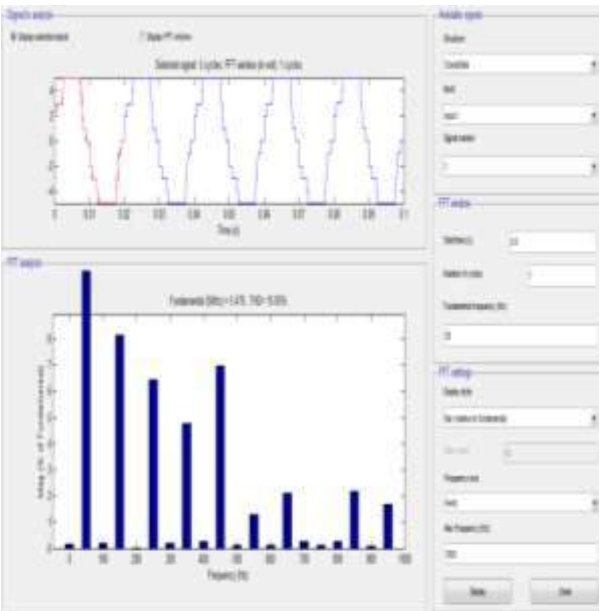

Fig. 16 FFT Analysis of Eleven Level Inverter

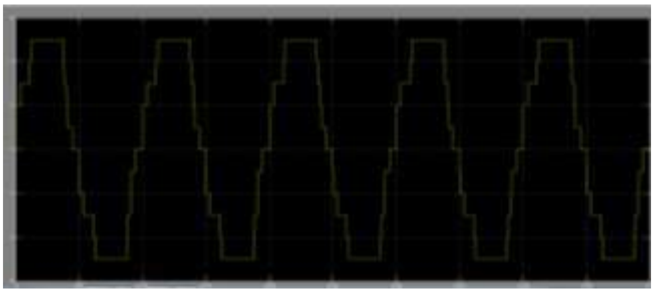

Fig. 17 Output Waveform of Thirteen Level Cascade H-bridge Multilevel Inverter

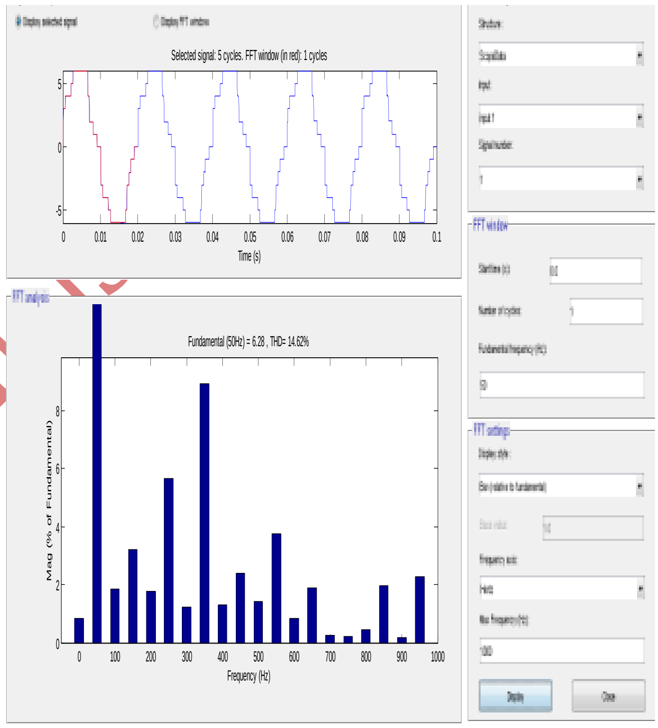

Fig. 18 FFT Analysis of Thirteen Level Inverter

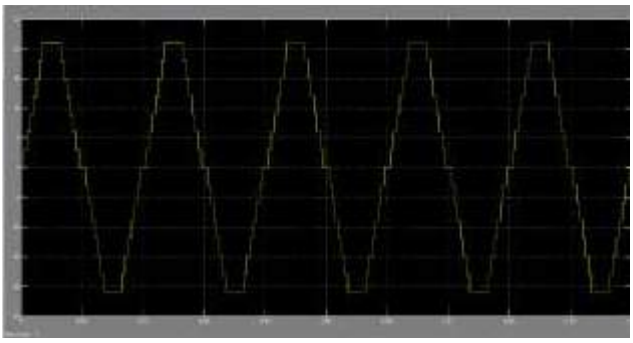

Fig. 19 Output Waveform of Fifteen Level Cascade H-Bridge Multilevel Inverter

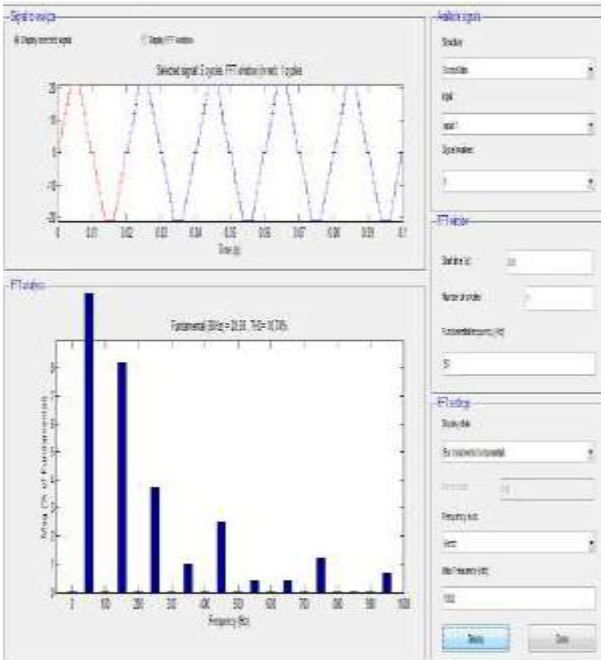

Fig. 20 FFT Analysis of Fifteen Level Inverter

Table III present the THD obtained for the different level of multilevel inverter. As the level of inverter are increases, THD contain in the output waveform is deceases.

Table III Tabulation of THD for Different level of Multilevel Inverters

S. No.	Number of Level	THD
1.	Five Level	28.27%
2.	Seven Level	19.84%
3.	Nine Level	15.77%
4.	Eleven Level	15.05%
5.	Thirteen Level	14.62%
6.	Fifteen Level	10.74%

VIII.CONCLUSION

In this Paper Obtain output voltage and calculated Harmonics Table no III show the different level THD and when the level increases harmonics Reduces.

All cascade H-bridge multilevel inverter and reducing harmonic by using MATLAB Simulink Software. THD analysis is done using the FFT tool of powergui in the Simulink. The optimized firing angles for reducing harmonic are calculated using PSO in MATLAB environment. Table no III shown the Total harmonic distortion of multilevel inverter is reduced by cascading H bridges up to fifteen levels and after fifteen levels THD may be decreased.

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