COMPARISION OF THD ANALYSIS ON NEW TOPOLOGY MULTILEVEL INVERTER WITH SPWM & GA OPTIMIZATION TECHNIQUES

P. Jagadeesh[1], Dr.G.V.Marutheswar[2]

[1]M.Tech, Dept. of EEE, SVUCE, Sri Venkateswara University, Tirupati, India.
[2]Professor&HOD,Dept. of EEE, SVUCE, Sri Venkateswara University, Tirupati, India.

ABSTRACT

The emergence of multilevel inverters has been in increase since the last decade. This project presents a new technique for getting a multilevel output instead of cascaded H bridge inverter and also uses SPWM control technique. In this technique, the number of switches used for the dc to ac conversion is reduced. So this dc to ac conversion significantly reduces the initial cost. The main challenge associated with HR-PWM techniques is to obtain the analytical solution of the system for nonlinear transcendental equations that contain trigonometric terms which in turn provide multiple sets of solutions. An optimization technique assisted with a hybrid genetic algorithm was successfully applied to find the switching transitions (i.e. ., switching angles) of the HR PWM . More recently, a general genetic algorithm using Matlab GA optimization Toolbox was applied to solve the same problem of HR-PWM

Keywords: *Cascaded H-bridge multilevel inverter, New topology multilevel inverter, Hybrid Genetic Algorithm, Sinusoidal Pulse width modulation, Selective Harmonic Elimination.*

---

1. INTRODUCTION

Multilevel converters have drawn tremendous interest in recent years and have been studied for several high voltage and high-power applications[1-2]. Switching losses in these high-power high-voltage converters represent an issue and any switching transitions that can be eliminated without compromising the harmonic content of the final waveform is considered advantageous. The term multilevel starts with the introduction of the three-level converter. By increasing the number of levels in a given topology, the output voltages have more steps generation a staircase waveform, which approaches closely the desired sinusoidal waveform and also offers reduced harmonic distortion. One promising technology to interface battery packs in electric and hybrid electric vehicles are multilevel converters because of the possibility of high VA rating and low harmonic distortion [3]without the use of a transformer.

Harmonic Reduction-pulse-width modulation (HR-PWM) has been mainly developed for two- and three-level converters in order to achieve lower total harmonic distortion (THD) in the voltage output waveform. The main challenge associated with HR-PWM techniques is to obtain the analytical solution of the system for nonlinear transcendental equations that contain trigonometric terms which in turn provide multiple sets of solutions. Genetic algorithm has been recently introduced to optimize the sequence of the carrier waveform of the PWM as to minimize the THD and the distortion factor (DF) of output line voltage. An optimization technique assisted with a hybrid genetic algorithm was successfully applied to find the switching transitions (i.e. ., switching angles) of the HRPWM ac/ac converter. More recently, a general genetic algorithm using Matlab GA optimization Toolbox was applied to solve the same problem of HR-PWM.

2.PROBLEM FORMULATION:

2.1 Cascaded Multilevel inverter

In cascaded multi level inverter each single DC sources is associated with a single H-bridge converter[4]. The AC terminal voltages of different level converters are connected in series. Through different combinations of the four switches, S1-S4, each converter level can generate three different voltage outputs ,+Vdc, -Vdc and zero. The AC outputs of different full-bridge converters in the same phase are connected in series such that the synthesized voltage waveform is the sum of the individual converter outputs[5] .Note that the number of output waveform is the sum of the individual converter outputs .Note that the number of output-phase voltage levels is defined in a different way from those of the two previous converters .In this topology, the number of output-phase voltage levels is defined by m=2N+1,where N is the number of DC sources .A five level cascaded converter ,For example ,consists of two DC sources and two full bridge converters. Minimum harmonic distortion can be obtained by controlling the conduction angles at different converter levels.

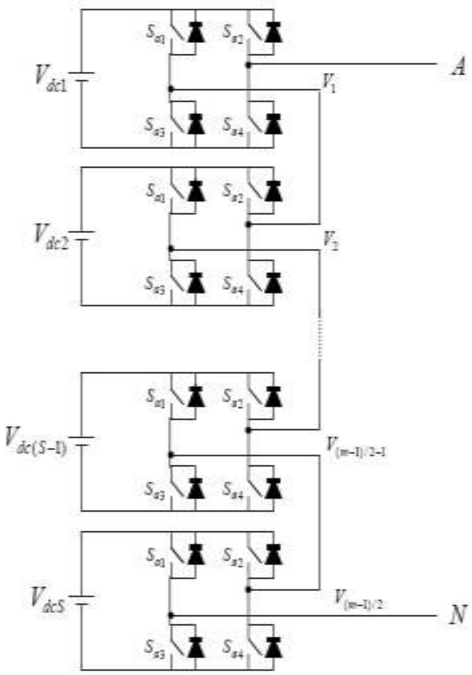

Fig1.cascaded H-bridge MLI

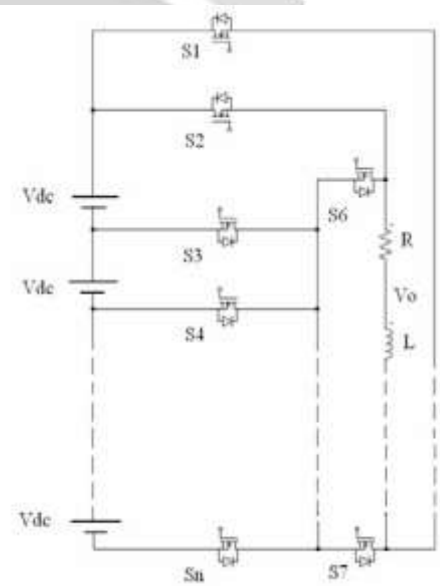

Fig2.new topology MLI

2.1.1 Advantages

1. The series structure allows a scalable, modularized circuit layout and packaging since each bridge has the same structure.
2. Switching redundancy for inner voltage level is possible because the phase voltage output sum of each bridges output.
3. Potential of electrical shock is reduced due to separate DC sources.
4. Requires less number of components when compared to other two types.

2.1.2 Disadvantages

1. Limited to certain applications where separate DC sources are available.
2. Usage of the power semiconductor switches increases exponentially whenever the level is to be increased

3.PROPOSED APPROACH

3.1.New topology Multi level inverter

The general circuit diagram of the proposed multilevel inverter is shown in the fig-2[6-7]. The switches are arranged in the manner as shown in the figure. For the proposed topology, we just need to add only one switch for every increase in levels. So initial cost get reduced.

3.1.1 Advantages

1. Because of the reduction in the number of switches the initial cost reduces.
2. Controlling becomes easier.
3. Losses becomes less due to the elimination of the harmonics.
4. Apt structure for industrial applications.
5. Overall weight reduces because of the usage of less number of components.

3.2.2 Comparison between the Proposed Multilevel Inverter and the Cascaded MLI

The table-1 shows the comparison between the proposed inverter with the cascaded multilevel inverter. The proposed converter exhibits a significant outcome such as reduction in the number of switches and an easy control is possible.

Table -1 comparison of no of switches required for different levels

Parameters	Cascaded				New topology			
Levels	7	9	11	13	7	9	11	13
Switches required	12	16	20	24	7	8	9	10

3.2. ESTIMATION OF SWITCHING ANGLES

As per the Fourier theorem the periodic output voltage V (ωt) can be described by a constant term plus an infinite series of sine and cosine terms of frequency nω, where n is an integer[8]. Therefore V (ωt) in general, can be expressed as

$$f(\omega t) = \frac{a_0}{2} + \sum_{n=1}^{\infty}(a_n \cos n\,\omega t + b_n \sin n\omega t) \qquad \text{……… (1)}$$

Because of the output voltage of the multilevel inverter is quarter wave symmetry, the Fourier series constants a_n and $a_n$an become zero and only bn is to be calculated. The value of bn is found using the equations (2)

$$\text{bn}= \frac{1}{\pi}\int_0^{2\pi} V_0(\omega t)\sin n\omega t \, d(\omega t), \qquad \text{……… (2)}$$

Fourier series of the quarter-wave symmetric H-bridge multilevel inverter output waveform is written as given in equation (6) in which θs are the optimized switching angles, which must satisfy the following condition

$$\theta_1 < \theta_2 < \theta_3 \dots\dots \theta_s < \frac{\pi}{2} \qquad \text{………..(3)}$$

The method to solve the optimized harmonic switching angles will be explained in this section. From equation

1. The amplitude of dc component equals zero.

2. The amplitude of all odd harmonic components including fundamental one, are given by

$$h(n) = \frac{4V_{dc}}{\pi}\sum_{k=1}^{s}\cos n\theta_k \quad \ldots\ldots \quad (4)$$

3. The amplitude of all even harmonics equal zero. Thus, only the odd harmonics in the quarter-wave symmetric multilevel waveform need to be eliminated. The switching angles of the waveform will be adjusted to get the lowest

THD in the output voltage $h(n) = \frac{4V_{dc}}{n\pi}[\cos\theta_1 + \cos\theta_2 + \cos\theta_3 + \cdots]$

If needed to control the peak value of the output voltage to be V1 and eliminate the fifth and seventh order harmonics, the modulation index is given by

M=$\frac{\pi V_1}{4V_{dc}}$ the resulting harmonic equations are

$$\frac{4V_{dc}}{\pi}[\cos\theta_1 + \cos\theta_2 + \cos\theta_3 + \cos\theta_4 \ldots] = V_1 \quad \ldots\ldots \quad (5)$$

$$\cos 5\theta_1 + \cos 5\theta_2 + \cos 5\theta_3 + \cos 5\theta_4 \ldots = 0 \quad \ldots\ldots \quad (6)$$

$$\cos 7\theta_1 + \cos 7\theta_2 + \cos 7\theta_3 + \cos 7\theta_4 \ldots = 0 \quad \ldots\ldots \quad (7)$$

Equation (5) is rewritten as

$$\cos\theta_1 + \cos\theta_2 + \cos\theta_3 + \cos\theta_4 \ldots = M \quad \ldots\ldots \quad (8)$$

Each non H- bridge switch of inverter unit has a conduction angle Which is calculated to minimize the harmonic components the conduction angles are the factors determining the amplitude of the harmonic components. This paper deals with a new topology inverter because its multi-level output voltage can be almost sinusoidal. In that case the conventional method can eliminate the dominant harmonics except for the fundamental wave. In multi level inverter _n' dc sources are needed so that the dc voltage levels are chosen so as not to generate the dominant harmonics while achieving the desired fundamental voltage. This is a system of three simultaneous equations with four unknowns

$\theta_1, \theta_2, \theta_3, \theta_4 \ldots$ .These values are found by solving the simultaneous equations (5-7).

3.3. GA TOOLBOX

Genetic Algorithm (GA) is a method used for solving both constrained and unconstrained optimization problems based on natural selection, the process that drives biological evolution[9-10]. GA repeatedly modifies a population of individual solutions. At each step, GA selects individuals at random from the current population to be parents and uses them to produce the children for the next generation. Over successive generations, the population "evolves" towards an optimal solution. GA uses three main rules at each step to create the next generation from the current population:

Selection rules select the individuals, called *parents* that contribute to the population at the next generation.

Crossover rules combine two parents to form children for the next generation

Mutation rules apply random changes to individual parents to form children.

Calling the function 'ga' at the Command Line To use GA at the command line, call the GA function ga with the syntax

[x fval] = ga (@fitness fun, nvars, options)

Where
@fitnessfun is a handle to the fitness function.
nvars is the number of independent variables for the fitness function.
Options is a structure containing options for the genetic algorithm. If you do not pass in this argument, GA uses its default options. The results are given by
x — Point at which the final value is attained
fval — Final value of the fitness function Using the function GA is convenient if you want to Return results directly to the MATLAB workspace Run the genetic algorithm multiple times with different options, by calling ga from an M-file.

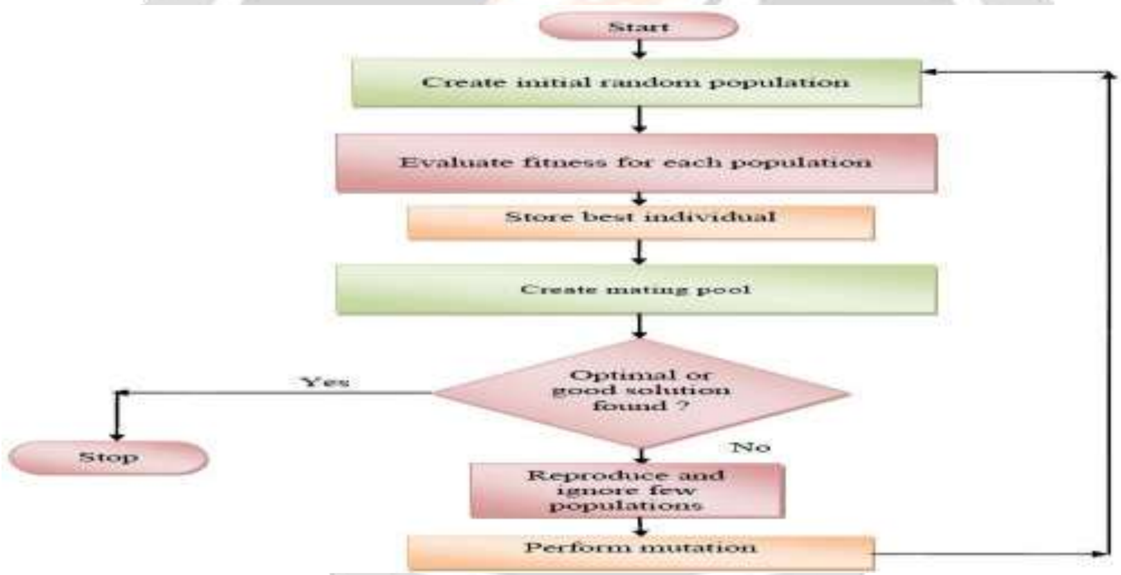

Fig3.flow chart of GA

Using GA Tool The Genetic Algorithm tool is a graphical user interface that enables you to use the genetic algorithm without working at the command line. To open it, enter *gatool.* at the MATLAB command prompt. The tool opens . To use the GA tool, the following

information is entered,

Fitness function — The objective function is to minimize. Enter the fitness function in the form @fitnessfun, where fitnessfun is an M-file that computes the fitness function.

Number of variables — The length of the input vector to the fitness function. Enter constraints or a nonlinear constraint function for the problem in the **Constraints** pane. If the problem is unconstrained, leave these fields blank. To run the GA, click the Start button. The tool displays the results of the optimization in the Status and results pane. We can change the options for the genetic algorithm in the Options pane.

4. RESULTS

GA results:

The optimal firing angles are,

For seven level

α_1=12.68^0, α_2=23.32^0 , and α_3 =54.18^0

For nine level

α_1=6.84^0, α_2=16.47^0, α_3=30.33^0 and α_4=49.32^0

For eleven level

α_1=5.49^0, α_2=16.68^0, α_3=28.58^0, $_4$=42.06^0 and α_5=59.46^0

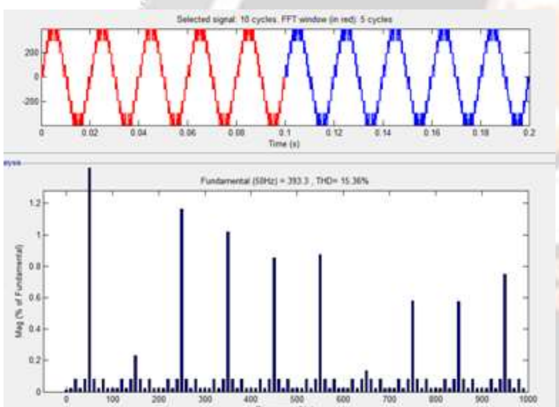

Fig4.FFT plot for 9 level SPWM technique

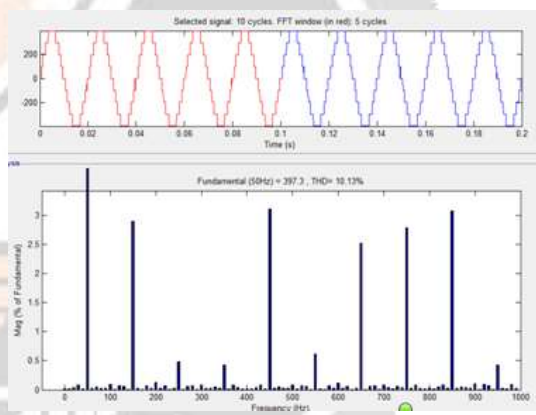

fig5.FFT plot for 9 level GA technique

Table2: Comparison of simulation results

No. of levels	THD% using SPWM technique	THD% using Genetic Algorithm
7-level	19.65%	14.72%
9-level	15.36%	10.91%
11-level	13.81%	7.84%

5.CONCLUSIONS

The simulation of the different-level multilevel inverters is successfully done using pulse width modulation technique. From the simulation, it is noted that the new multilevel inverter topology works well and shows hope to reduce the initial cost and complexity. When we increase the levels, the number of switches used is very less compared to the other topology.

A generalized formula of Harmonic Reduction-Pulse width Modulation (HR-PWM) suitable for high-power high-voltage cascaded multilevel converters with equal dc voltage sources was proposed and demonstrated in this project. Using this GA optimal firing angles have been determined for various multi-level cascaded inverter topologies. These optimal firing angles are used for triggering the power devices (IGBT/diode).With this switching angles approximate sinusoidal output voltage and current waveforms with minimum amount of Total Harmonic Distortion (THD) have been achieved. The percentage of THD obtained in the output of multilevel inverter topologies using PWM technique is compared with that obtained in the output of multilevel cascaded inverters in which advanced Genetic Algorithm optimization technique is used. It is observed that nearly 25-45% THD in the output has been reduced by using Genetic Algorithm optimization technique as compared to that obtained from inverter topologies using SPWM technique.

6. REFERENCES

[1] J. Rodriguez, J. Lai, and F.Peng, "Multilevel Inverters: A survey of topologies, controls and applications," *IEEE Trans. Ind. Electron.*, vol. 49, no. 4,pp. 724– 738, Aug. 2002.

[2] L. G. Franquelo; J. Rodriguez, J. I. Leon, S. Kouro, R. Portillo, and M. A. M. Prats, "The age of multilevel converters arrives," *IEEE Ind. Electron. Mag.*, vol. 2, no. 2, pp. 28–39, Jun. 2008.

[3] Kehu yang "unified selective harmonic elimination for multi level inverters" *IEEE Transactions on Power Electronics, 32(2), feb, 2017.*

[4] Malinowski, M., Gopakumar, K., Rodriguez, J., & Perez, M. A. (2010). A survey on cascaded multilevel inverters. *IEEE Transactions on industrial electronics*, *57*(7), 2197-2206.

[5] Corzine, K. A., Wielebski, M. W., Peng, F., & Wang, J. (2003, June). Control of cascaded multi-level inverters. In *Electric Machines and Drives Conference, 2003. IEMDC'03. IEEE International* (Vol. 3, pp. 1549-1555).

[6] E. Najafi and A. H. M. Yatim, "Design and implementation of a new multilevel inverter topology," *IEEE Trans. Ind. Electron., vol. 59, no. 11, pp. 4148–4154, Nov. 2012.*

[7] J. Ebrahimi, E. Babaei, and G. B. Gharehpetian, "A new multilevel converter topology with reduced number of power electronic components," *IEEE Trans. Ind. Electron.*, vol. 59, no. 2, pp. 655–667, Feb. 2012.

[8] Qin Jiang, Thomas A. Lipo, "Switching Angles and DC Link Voltages Optimization for Multilevel Cascade Inverters", *Journal of Electric Machines and Power Systems (Taylor & Francis)*, Vol.28, no.7, pp.605-612, 2000.

[9] L.M. Tolbert, J.N. Chiasson, D. Thong, KJl. McKenzie, "Elimination of harmonics in a multilevel converter with nonequal DC sources", *IEEETransactions on Industry Applications*, Vol. 4, No. 1, pp. 75 - 82, Jan.-Feb. 2005.

[10] F. J. T. Filho, T. H. A. Mateus, H. Z. Maia, B. Ozpineci, J. O. P. Pinto and L. M. *Tolbert* "Real-Time Selective Harmonic Minimization in Cascaded Multilevel Inverters with Varying DC Sources", *IEEE Transactions on Power Electronics*, vol.3, pp. 4302—4306, June 2008.