Harmonic Optimization of Multilevel Inverter using a Hybrid Optimization Algorithm

Tikeshwar Gajpal[1], Nivedita Hedau[2]

[1]*Dept. of Electronics and Telecommunication Engineering, Raipur Institute of Technology, C.G., India*
[2]*Dept. of Electronics and Telecommunication Engineering, Raipur Institute of Technology, C.G., India*

Abstract— Multilevel Inverters have several benefits consisting of low price, right performance and some application that embody PV panels and gas cells. Cascaded H-bridge MLI is one of these MLIs. In contrast to the normal electrical inverter, the MLI's output voltage incorporates a reduced ThD with higher harmonic profile. Mathematical techniques for harmonic elimination square measure offered in a number of the literatures but resolution a non-linear transcendental equation set describing the SHE downside exploitation these strategies aren't appropriate for multi level inverters. A hybrid optimization set of rules to find the foremost reliable change angles in a very structure electrical converter (MLI) is planned during this paper. The change angles square measure optimized to measure low frequency harmonics. Further a hybrid algorithm that combines Particle swarm optimization (PSO), a global search method with gradient search (GS), a local search method, is proposed in this paper to enhance the performance. Simulation is presented to validate the approach.

Index Terms— cascaded multilevel inverter, particle swarm optimization (PSO), genetic algorithm(GA), step modulation, multiple carrier sine pulse width modulation.

1. INTRODUCTION

In recent decades, the studies on Multilevel Inverters (MLI) were increasing as it turns into a viable answer for high power applications, along with HIGH motor drives, railway traction programs, high-voltage DC transmissions (HVDC), STATCOM and static VAR compensators. An advantage of MLIs is that their switching frequency is lower than traditional inverters meaning the switching losses are reduced. These MLIs has increased the output voltage and brought a way to limitation of classical semiconductor switches. Fig.1 illustrate some of advantage of the H-bridge MLI. The technology of MLIs is based totally on production special DC voltage levels composition of these stages to acquire higher output voltage composition of these stages to acquire higher output voltage waveform. The output voltage waveform by means of including step has lower total harmonic distortion (THD) and reduced the harmonics in contrast to square wave inverters[1]. In excessive power Systems, Multilevel Inverters can appropriately replace the existing system that uses conventional multi-pulse converters without the need of the transformers. Some of the advantages of cascaded H-bridge inverters are,

- Better Efficiency
- Good power quality
- Better harmonic elimination
- Low cost
- Reliability
- Low THD

All the three multi-level inverter topologies (diode clamped, flying capacitors, and cascaded multi level inverter) can be used in reactive power compensation without having the voltage unbalance problem. But the Cascaded multi level inverter uses simple H-Bridge configurations which are connected in series, utilizes fuel cells, solar cells & biomass energy as DC sources. Multilevel seeks to synthesize a waveform much more similar to a sinusoidal signal, which, relying on the DC number of resources available, the distortion might be decrease. Among its important advantages we are able to highlight:

- The arrangement of the input voltage into multiple stages can increase several times the voltage converter work using the identical switches in a conventional converter.
- Power converters increases to use better voltages, without increasing current, therefore avoiding further losses and therefore improve performance of Converter.

2. HARMONICS

In power quality elements are the harmonic contents within the electrical system. Normally, harmonics may be divided into two types: 1) voltage harmonics, 2) current harmonics. Current harmonic are typically generated by harmonics contained in voltage supply and depends on the type of the load along with resistive load, capacitive load,

and inductive load. Load harmonics can cause the overheating of the magnetic cores of transformer and vehicles [2]. On the other hand, source harmonics are especially generated by power supply with non sinusoidal voltage and non-sinusoidal current waveforms. The frequency of each harmonic component is a multiple of its fundamental frequency. For the purpose of a steady state waveform with equal positive and negative half cycles [3], the Fourier series can be expressed as follows:

$$F(T)=\sum_{n=0}^{\infty} A_n . \sin\left(\frac{n\pi t}{T}\right) \qquad (1)$$

There are several methods to indicate the quantity of harmonics contents. The most widely used measure is the total harmonics distortion (THD), which is defined in terms of the magnitudes of harmonics:

$$THD(\%) = \sqrt{(ID_1^2 + ID_2^2 + \ldots\ldots\ldots ID_n^2)} \qquad (2)$$

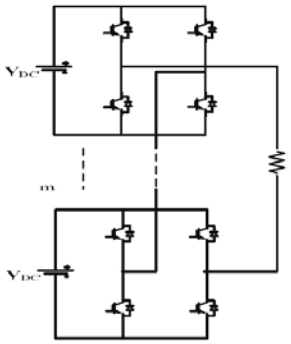
ID_n is the magnitude of the nth harmonic as a percentage of the individual distortion.

3. HARMONIC ELIMINATION

The multilevel fundamental switching scheme inherently affords the opportunity to do away with certain lower order harmonics by means of various instances at which positive switches are became ON and became OFF (i.e. varying the switching angles).here 5th ,7th ,11th and 13th harmonics are minimized.

4. CASCADED H-BRIDGE

A Cascaded bridge inverter is known as an H-bridge cell. The inverter circuit includes four primary switches and 4 freewheeling diodes. Multilevel concept is employed to decrease the harmonic distortion within the output waveform while not decreasing the electrical inverter power output. The utmost number of line voltage levels is 2m-1, here m is that the number of phase voltage levels. The advantage of three-phase system is that every one triplen harmonic components within the line voltage are going to be eliminated by one-third cycle part shift feature[3] [4].



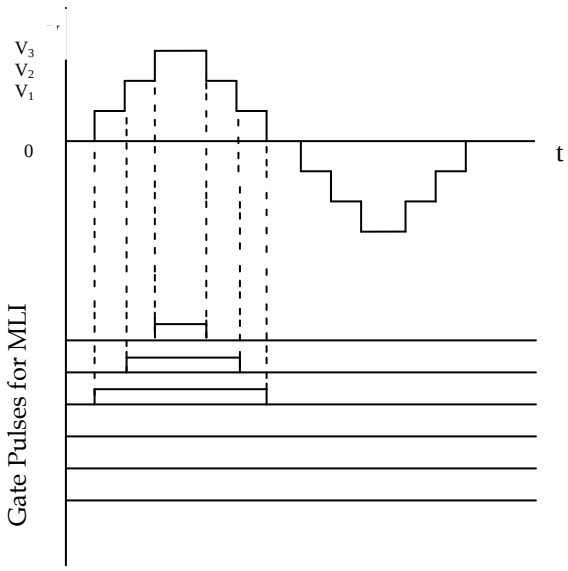


Figure1: Cascaded H-Bridge Inverter with its voltage waveform

5. LITERATURE REVIEW AND RESEARCH MOTIVATION

Any system designed aims in achieving a maximized output with least resources and thus the potency. As known the traditional cascaded construction electrical converter consists of many number of dc sources. Here are some methods describes to eliminate harmonics in a Multilevel Inverter. Which are given below:

A. FUZZY LOGIC CONTROLLER

In Fuzzy multi-objective method included with Differential Evolution (DE) has been carried out to optimize electricity issue and total Harmonic Distortion. A strive to boom the energy issue can also result in boom of THD. Such trouble is solved via this method. Multi-goal inside the experience strength aspect and general Harmonic Distortion has been optimized preserving selective Harmonic distortion within limits. The blessings of DE are finding global minimal irrespective of initial parameter values, speedy convergence and few control parameters [7].

B. GENETIC ALGORITHM

The minimization of harmonics using Genetic Algorithm is performed in this paper using Genetic Algorithm to improve the Power Quality of the inverter. This paper uses Genetic Algorithm to optimize a multi-PWM modulation and minimizing Total Harmonic Distortion (THD) to almost zero.This type of optimization approach to obtain a math expression that calculates THD in the 9 step multilevel PWM waveform. This optimization method measures the switching angles and the position of the levels in the modulation.

C. HYBRID BBO/DS ALGORITHM

In this paper, a hybrid optimization algorithm is used to find the switching angles in a Multilevel Inverter. These switching angles can be optimized to eliminate the harmonics. The optimum switching angles are found by Hybrid Biogeographical based optimization search (BBO) / Mesh Adaptive Direct Search (MADS) algorithm. In order to reduce the switching losses the low frequency Selective Harmonic Elimination-Pulse Width Modulation (SHE-PWM) technique and Optimal Minimization of Total Harmonic Distortion (OMTHD) technique are applied With the help of SHE-PWM technique lower order harmonics are reduced and fundamental component of output voltage is maintained at required value. In this method a global search method Biogeographical based optimization search (BBO) is used with a local search method to enhance the performance.

6. CASCADED H-BRIDGE

SELECTIVE HARMONIC ELIMINATION (SHE)

There are unit completely different management techniques applied to regulate the output voltage wave in structure inverters. The classification of those management techniques area unit essentially primarily based on the change frequency. There are two techniques, which are unit a) low (fundamental) switching frequency techniques, and b) high change frequency techniques. The house Vector management (SVC) and Selective Harmonic Elimination (SHE) area unit thought-about low frequency techniques. On the other hand, many pulse width modulations (PWM) area unit enforced as high frequency switching. At low change frequency, the active power switch is commutated only one or double throughout one cycle. However, the facility switch is switched again and again inside one cycle for the high change techniques. Applying SHE to regulate a structure electrical inverter and as a result of low change leads to less change losses. Moreover, the foremost dominant low order harmonic will be elect to be eliminated. This leads to minimum size of required filter at the output. The SHE is wide applied for HVDC applications. In SHE, the change angle area unit precalculated.These angles type the elemental output voltage waveform and eliminate the predominant lower order harmonics [5]. Applying Fourier Transform in the stepped voltage waveform in terms of sine and cosine functions is given by:

$$V(wt) = \sum_{k=1,3,5\ldots}^{\infty} \left(\frac{4V_{dc}}{k\pi}\right)[\cos(k\alpha_1) + \cos(k\alpha_2) + \cdots \cos(k\alpha_s)]\sin(kwt)$$

Where s is the number of H-bride cells of the inverter. In cascaded multilevel inverter the switching angles are less than 900.i.e.

$$0 \le \theta_1 \le \theta_2 \le \theta_3 \le \frac{\pi}{2}$$

Where θ = switching angle.

The transcendental equations for SHE technique is given by,

$$\cos(\theta_1) + \cos(\theta_2) + \cos(\theta_3) = 3m_i$$

$$\cos(5\theta_1) + \cos(5\theta_2) + \cos(5\theta_3) = 0$$

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

Where mj is the modulation index.

7. PSO/GS ALGORITHM

The Hybridization of two types of algorithms enhances the performance of the Multilevel Inverter. In this paper, the PSO/GS optimization techniques are chosen to optimize to obtain optimum value by solving the nonlinear transcendental equations where the PSO employs global search and GS employs local search. The particle swarm optimization is one among the latest population-based improvement strategies, and therefore the members of the entire population area are maintained through the search procedure. The PSO methodology is an adjustive algorithm supported a social psychological metaphor; Particle Swarm has 2 primary operators: velocity update and Position update. Throughout every generation each particle is accelerated toward the particles global best position and the local best position. At every iteration a new velocity value for every particle is calculated supported its current velocity, the distance from its previous best position, and the distance from the global best position. The new velocity value is employed to calculate the succeeding position of the particle within the search area and iterated for a set no of times or till a minimum error is earned. Particle swarm improvement (PSO) optimizes a problem by having dubbed particles population of candidate solutions, and moving these particles round the search-area per simple mathematical formulae over the particle's position and velocity. Gradient Search is a local search algorithm. GS searches around the point where the position of the particle is the best The procedure to implement the PSO/GS Algorithm is given in the following steps:

Step1: The initial position of any particle I at iteration k=0,

Pi^k and velocities Vi^k of each agent are generated randomly within the allowable range. The current searching point is set to pbest for each agent. The best-evaluated value of pbest is set to gbest and the agent number with the best value is stored.

Step2: The objective function value is calculated for each particle. If the obtained value is better than the current local best value pbest of the particle, the new pbest value is

replaced by the current value. If the local best value of pbest is better than the current global best value gbest, then the new gbest is replaced by the best value and the particle number with the best value is stored.

Step3: Modification of each searching point Pi^{k+1}. The current searching point Pi^{k} of each particle updated using

$$v_i^{k+1} = v_i^k + \tau_1 . r_1 \left(p_i^{lb} - p_i^k\right) + \tau_2 . r_2 \left(p_i^{gb} - p_i^k\right).$$

$$p_i^{k+1} = p_i^k + v_i^{k+1}$$

Where:

v_i = velocity of particle.
p_i = the particles.
r_1, r_2 = random numbers.
τ_1, τ_2 = learning factors.
p_i^{lb} = best local solution.
p_i^{gb} = best global solution.

Step4: The optimum values are achieved then exit the process, otherwise again go to step2.

The optimum best positions found by PSO algorithm are then applied to GS algorithm to find optimum best particle at local space.

Step5: Select the best particle, among all particles.

Step6: Use gradient search method to determine the minimum value using pbest as the initial solution.

8. Results And Discussion

The plots of various performance indices of Cascaded Multilevel Inverter with respect to Modulation index (M) are discussed.

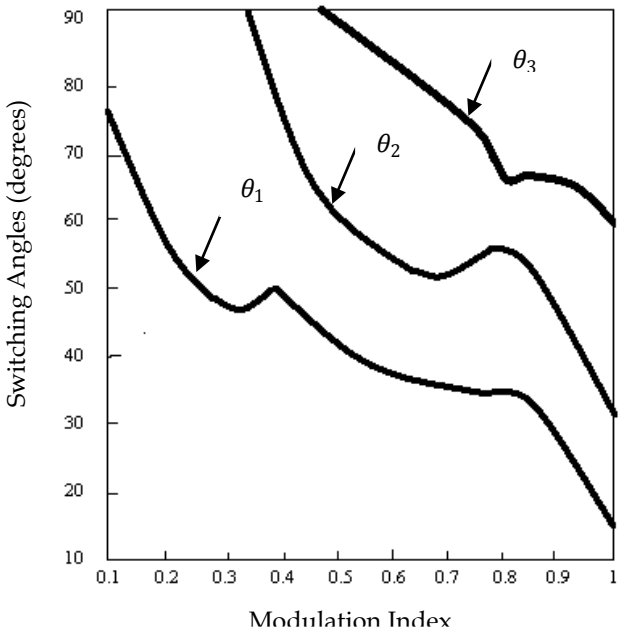


Figure2: Switching Angles versus Modulation Index

The result got from the Figure2, is that switching angles occurs for range of M from 1 to 0.5. For range of M from 0.5 to 0.3 one of the switching angles converges to 90 degrees and for the range of M from 0.3 to 0.1 two of the switching angles converge to 90 degrees. As a result harmonics is reduced.

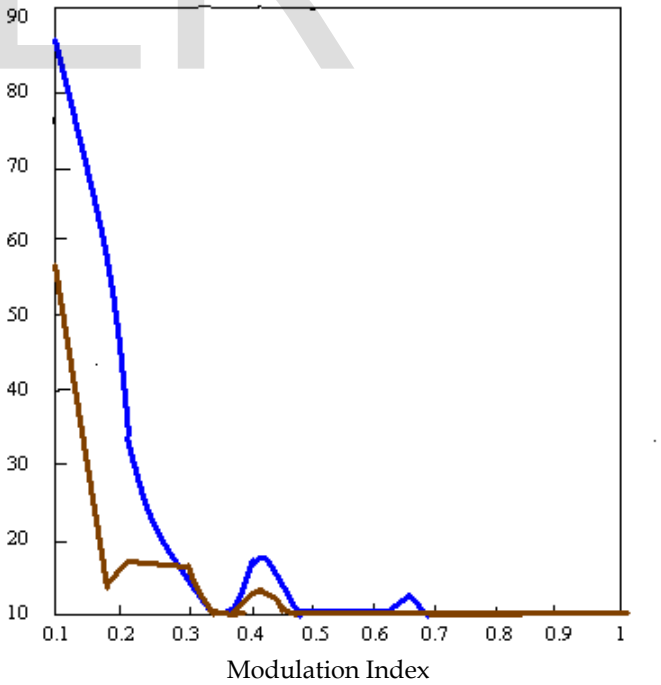


Figure3: Eliminated harmonics % versus Modulation Index

Figure3, is the plot between the percentage of eliminated Individual harmonics, i.e. h5 and h7 of inverter output, and the modulation index. The percentage of harmonics is more for M less than 0.5. This is because of decrease in output voltage levels.

The percentage of selective harmonics is also increased for lower modulation index as shown in Figure4.

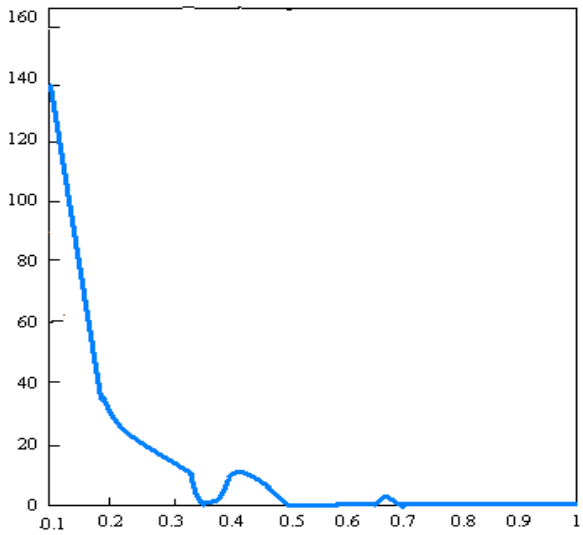


Figure4: SHE % versus Modulation Index

9. CONCLUSION

A Hybrid algorithm is proposed to improve the performance of cascaded multilevel inverter. The hybrid PSO/GS algorithm has proven to have better convergence rate. The output obtained by SHE-PWM method has reduced lower order harmonics.

References

1. A. A. Khodadoost Arani; H. R. Zaferani; M. J. Sanjari; G. B. Gharehpetian, “Using genetic algorithm and simulated annealing for 27-level PV inverter THD minimization”Smart Grid Conference (SGC), 2014.
2. N. Suresh and R.Samuel Rajesh, “Review on Harmonics and its Eliminating Strategies in Power System” Indian Journal of Science and Technology, Vol 8(13),56641,july 2015.
3. S. S. Jasper and K. Priyanka, "Analysis & reduction Of THD In multilevel inverter using PSO algorithm," Green Computing Communication and Electrical Engineering (ICGCCEE), 2014 International Conference on, Coimbatore, 2014, pp. 1-8.
4. Brindha R and R. Kavitha, "Harmonic optimization in seven level inverter employing hybrid BBO/MADS algorithm," Innovations in Information, Embedded and Communication Systems (ICIIECS), 2015 International Conference on, Coimbatore, 2015, pp. 1-6.
5. Reza Khamooshi and J. SH. Moghani, “Comprehensive Harmonic Optimization in Cascaded H-bridge Multilevel Inverters Using Variable DC Sources”,The Power Electronics,Drive systems and Technologies Conference(PEDSTC),2014,Tehran,Iran.
6. R. Basak, P. Nishita, Z. Elias and S. Sreejith, "Harmonic elimination in common arm three phase isolated H-Bridge multi level inverter," Control, Instrumentation, Communication and Computational Technologies (ICCICCT), 2014 International Conference on, Kanyakumari, 2014, pp. 646-650.
7. R. H. Alabbasi and S. M. Salih, "Control of cascade multilevel inverter using fuzzy logic technique," Power Electronics for Distributed Generation Systems (PEDG), 2010 2nd IEEE International Symposium on, Hefei, China, 2010, pp. 96-101.
8. S. M. R. Tousi and S. Aznavi, "Performance optimization of a STATCOM based on cascaded multi-level converter topology using multi-objective Genetic Algorithm," Electrical Engineering (ICEE), 2015 23rd Iranian Conference on, Tehran, 2015, pp. 1688-1693.
9. B. Alamri, A. Sallama and M. Darwish, "Optimum SHE for Cascaded H-Bridge Multilevel Inverters Using: NR-GA-PSO, Comparative Study," AC and DC Power Transmission, 11th IET International Conference on, Birmingham, 2015, pp. 1-10.
10. H. R. Mohammadi and A. Akhavan, “A new adaptive selective harmonic elimination method for cascaded multilevel inverters using evolutionary methods,”2014 IEEE 23rd International Symposium on Industrial Electronics (ISIE), Istambul, 2014, pp. 1484-1489.