Programmed PWM Technique For Asymmetric Cascaded Multilevel Inverter Using PSO
S.Nanda Kumar1, Dr.S.Vijayan2, E.Nanda Kumar3, N.Vinoth4

Abstract—In this paper, the PSO method used to calculate the required switching angles to eliminate low order harmonics up to the 11th order from the inverter voltage waveform while maintaining the magnitude of the fundamental at the desired value. Theoretical results are verified by MATLAB simulations for a 7-level Asymmetrical cascaded Hybrid multilevel inverter. Results have shown that the proposed method effectively eliminates a great number of specific harmonics, and the output voltage is resulted in minimum total harmonic distortion (THD) at different modulation index values.

Index Terms—Asymmetrical cascaded Hybrid multilevel inverter, PSO (Particle Swarm Optimization), SHE (Selective harmonic elimination), THD (Total Harmonic Distortion).

I. INTRODUCTION

Variable speed drives are very commonly used for many industrial applications in the industrial sectors. The problem with these drives is even though it improves efficiency, it pollutes the quality of supply by introducing harmonics. Therefore to reduce the effect of harmonics in the system, appropriate techniques are needed to eliminate dominant harmonics.[1] Selective harmonic elimination (SHE) is a well-known technique for generating PWM signals that can eliminate specific low-order harmonics from a voltage waveform generated by a voltage-source inverter (VSI). Traditional analytical methods for solving the SHE problem are conducted based on the Newton Raphson method. The method requires proper initial values to converge to a proper solution.[2]-[5]. Recently, non-traditional methods based on evolutionary algorithms, such as Genetic Algorithms (GA), Ant Colony Systems (ACS), Particle Swarm Optimization (PSO) have been employed for inverter harmonic elimination. There are different type of approaches used to the selection of switching techniques for reduce the harmonics in the voltage source multilevel inverters. One of the approaches to compute the switching angles by solving the SHE(Selective Harmonic Elimination) equations, but solving the SHE equations are very difficult because of their nonlinear characteristics. Due to nonlinear in nature, solution of these equations may be multiple or even no solution for a particular value of modulation index (m). The main scope of this work lies in the application of PSO algorithm to eliminate any desired number of harmonics and improves the power quality of the system. The results prove that the PSO algorithm converges successfully to the global solution faster than other algorithms.

II. MULTILEVEL INVERTER

Multilevel inverters are important for power electronics applications, such as flexible AC transmission systems, renewable energy sources, uninterruptible power supplies and active power filters. The advantages of multilevel inverters are an enhanced output voltage, reduced total harmonic distortion, and reduced voltage stress on semiconductor switches and a decrease in EMI problems. Multilevel voltage source Inverters are emerging as a new breed of power Inverter options for high-power applications. The multilevel voltage source Inverters typically synthesizes the staircase voltage wave from several levels of dc voltages. There are some multilevel voltage source converters which are

1) Diode-clamp.
2) Flying capacitors.
3) Cascaded-inverters.

A. Hybrid Cascaded Multilevel Inverter

Cascaded H-Bridge (CHB) configuration has recently become very popular in high-power AC supplies and adjustable-speed drive applications. A cascade multilevel inverter consists of series of H-bridge (single-phase full bridge) inverter units in each of its three phases. Each H-bridge unit has its own dc source, which for an induction motor would be a battery unit, fuel cell or solar cell. Considering the configuration of hybrid topology of multilevel inverters, a general hybrid topology of the single-phase N-level K-module cascaded inverter is presented. Basic element of the general topology is Ni -level full-bridge module. The level number of each full bridge module and the DC voltage proportional relation of the adjacent modules.

Fig 1: Single phase Asym.Cascaded ML1 with R load

The selections of these degrees of freedom (to change certain degree of freedom or combine several degrees of freedom) can produce different hybrid topologies. The hybrid topologies given in can be considered special cases of the general hybrid topology. The DC voltage proportional relation between adjacent modules is one of the degrees of
freedom of the general hybrid topology. This can be divided into two types: in the first type the DC voltages proportional relation between adjacent modules, in the second type, the DC voltage proportional relation between adjacent modules changes in a geometric proportion. Many new hybrid topologies can be constructed through the controllable degree of freedom of the DC voltage proportional relation. The number of output phase voltage levels in a cascade inverter is defined by

\[ m = 2s + 1 \]

Where, \( s \) is the number of dc sources.

The total output voltage is given by

\[ v_{o} = v_{1} + v_{2} + v_{3} + \ldots + v_{m} \]

with respect to switching angles \( \theta_{1} \), \( \theta_{2} \), \ldots \( \theta_{m} \), and \( \theta_{1} \) i.e. the multilevel inverter results in an output voltage that is almost sinusoidal with a low THD with each of the active devices subjected to a single dc source. This reduces both the voltage stress and the switching losses of the semiconductor devices, resulting in a better utilization and high overall efficiency.

The Fourier series expansion of output voltage waveform is given by:

\[ V(\omega t) = 4 \frac{V_{dc}}{\pi} \sum_{n=1,3,5} \sin(n\omega t)(\cos(n\theta_{1}) - \cos(n\theta_{2}) + \cos(n\theta_{3}) - \cos(n\theta_{4}) + \cos(n\theta_{5})) \]

The problem is to find the unknown angles with transcendental equations as follows:

\[
\begin{align*}
\cos(\theta_1) - \cos(\theta_2) + \cos(\theta_3) + \cos(\theta_4) + \cos(\theta_5) &= 0 \\
\cos(3\theta_1) - \cos(3\theta_2) + \cos(3\theta_3) - \cos(3\theta_4) + \cos(3\theta_5) &= 0 \\
\cos(5\theta_1) - \cos(5\theta_2) + \cos(5\theta_3) - \cos(5\theta_4) + \cos(5\theta_5) &= 0 \\
\cos(7\theta_1) - \cos(7\theta_2) + \cos(7\theta_3) - \cos(7\theta_4) + \cos(7\theta_5) &= 0 \\
\end{align*}
\]

Where modulation index is given by

\[ M = \frac{4V_{dc}}{\pi V_{1}} \]

\[ V_{dc} = \text{input voltage} \]

\[ V_{1} = \text{fundamental harmonic component.} \]

This formulated problem will be solved using optimization method whose objective function aims to minimize the harmonic equations subject to the constraints.

\[ \theta_1 < \theta_2 < \theta_3 < \theta_4 < \theta_5 < \frac{\pi}{2} \]

In line to line voltage even harmonics are eliminated naturally. A process of Selective Harmonic Elimination (SHE) selects suitable pulse positions per quarter cycle to eliminate any \( M \) harmonics. The voltage variations are obtained by controlling the pulse-width symmetrically around these pulse-positions. Principally, all the pulse-widths are arranged to be equal. In order to eliminate complete lower order of harmonics, i.e., 3rd, 5th, 7th, 9th & 11th, above set of equations gets converted into a set of nonlinear simultaneous equations with multiple unknowns.

### B. Particle Swarm Optimization (PSO)

In the basic particle swarm optimization algorithm, particle swarm consists of “\( n \)” particles, and the position of each particle stands for the potential solution in \( D \)-dimensional space. The particles change its condition according to the three principles: (1) to keep its inertia (2) to change the condition according to its most optimist position (3) to change the condition according to the swarm’s most optimist position. The position of each particle in the swarm is affected both by the most optimist position during its movement (individual experience) and the position of the most optimist particle in its surrounding (near experience). When the whole particle swarm is surrounding the particle, the most optimist position of the surrounding is equal to the one of the whole most optimist particle; this algorithm is called the whole PSO.

**Algorithm steps:**

1. Initialize the population - locations and velocities.
2. Evaluate the fitness of the individual particle (pBest).
3. Keep track of the individual’s highest fitness (gBest).
4. Modify velocities based on pBest and gBest position.
5. Update the particles position.
6. Terminate if the condition is met.
7. Go to Step 2.
IV. RESULTS AND DISCUSSION

The PSO algorithm used to finding the optimal switching pulses and ability to solve selective harmonic orders & Analyzed the THD value for different modulation index of PWM inverter. When improve MI, corresponding output voltage & THD also adjusted.

V. CONCLUSION

The PSO technique applied to solve non linear transdecial has been proposed to solve the SHE problem for 7 level Asymmetric cascaded multilevel inverter & also low order Harmonics Elimination technique has been investigated. Simulation results shows accuracy and ability of PSO for convergence objectives. The Proposed algorithm easily to eliminate any desired number of harmonics and improves the power quality of the system.

REFERENCES


**AUTHOR BIOGRAPHY**

**E.Nanda Kumar** obtained his Bachelor degree (B.E) in Electrical and Electronics Engineering from the Bharathidasan University, Trichy, India in 1998 and the Master of Engineering (M.E) degree in Power Systems Engineering from the Anna University, Chennai, India in 2007. Currently he has been working toward the Ph.D degree in the Department of Electrical Engineering, Anna University; Chennai. His research interests include Power System Optimization Techniques, Power Electronics, Power Flow Analysis, Economic Load Dispatch and Power Quality.

**N.Vinodh** obtained his Bachelor degree (B.E) in Electrical and Electronics Engineering from the Anna University, Chennai and pursuing Master of Engineering (M.E) degree in Power Electronics & drives from the Anna University, Chennai.

**S.Nanda Kumar** obtained his Bachelor degree (B.E) in Electrical and Electronics Engineering from the Bharathiar university, Coimbatore, India and the Master of Engineering (M.E) degree in Power Electronics & Drives from the Anna University, Chennai. Currently he has been working toward the Ph.D degree in the Department of Electrical Engineering, Anna University, Chennai. His research interests include PWM, Multi level inverter, FACTS, Harmonic Optimization Techniques, Power Quality, Smart & Micro grid.

**Dr.S.Vijayan** He received the B.E. degree from Mepco Schlenk Engineering College, Sivakasi, in 1989 and the M.E. degree in Power System from Annamalai University, Chidambaran, in 1993. He was awarded Ph.D in Electrical Engineering from College of Engineering Guindy, Anna University Chennai in 2008. He has published 6 papers in International Journals and 10 papers in International Conferences.