Review of Selective Harmonic Elimination of Single Phase PWM Inverter by Particle Swarm Optimization and Newton Raphson Method

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Abstract - *In recent years there has been an increased demand for integration of renewable energy into the electricity grid. This has amplified research into power converter solutions required to integrate renewable technology into the electricity supply. One such converter is a H-Bridge Converter. This paper reports particle swarm optimization (PSO) technique and Newton Raphson method for selective harmonic elimination (SHE) in pulse width modulated inverter. To minimize the THD of the output voltage of PWM inverter A PSO optimization technique and NR method is proposed to find best switching angles. This method is applied for the unipolar switching in single phase inverter for five switching angles. The switching angles are calculated to completely eliminate the lower order harmonics. The result of the unipolar case using five switching angles are compared with that of a recently reported work, based on PSO technique, And is observed that the proposed method is effective in eliminating the lower order harmonics specially 3rd, 5th,7th,9th order harmonics and THD is reducing to a greater extent than the previously reported work.*

***Key Words*: Selective harmonic elimination (SHE), particle swarm optimization (PSO), pulse width modulation (PWM)., Total Harmonic Distortion (THD),Newton Raphson (NR) method.**

1. INTRODUCTION

Renewable power generation has been an underlying trend in the energy sector during the last decades. The intermittent nature of such resources necessitates an effective power electronic interface. Different configurations have been reviewed previously to overcome the conversion challenges associated with solar panels. In comparison to 2-level inverters, multilevel ones are proved to provide superior performance in the reduction of harmonic distortions, torque pulsations and voltage stress across the switching devices. Decreased switching loss and Total Harmonic Distortion (THD) are indices of satisfactory performance and they cause further compact design and filters.

One of the most important problems in power quality aspects is that the harmonic contents within the electrical system. Generally, harmonics could also be divided into two types: 1) voltage harmonics, and 2) current harmonics. Current harmonics is usually generated by harmonics contained in voltage supply and depends on the type of load such as resistive load, capacitive load, and inductive load. Both harmonics are often generated by either the source or the load side. Harmonics generated by load are caused by nonlinear operation of devices, for example power converters, arc-furnaces, gas discharge lighting devices, etc. Load harmonics results the overheating of the magnetic cores of transformer and motors windings. On the opposite hand, source harmonics are mainly due to power supply with non-sinusoidal voltage waveform. Harmonic actually cause power losses, pulsating torque in AC motor drives also electromagnetic interference. A periodic waveform can be represented by superposition of a fundamental and a group of harmonic components. By applying Fourier transformation, these components can be extracted. The frequency of every harmonic component is an integral multiple of its fundamental. There are several methods to point of the number of harmonics contents. The THD is mathematically represented by

$$THD = \frac{\sqrt{\sum_{n=2}^{\infty} {H_{(n)}}^2}}{H_1}$$

Where H_1 is fundamental component and H_n is harmonic content, n is integer.

1.1 Modulation techniques

Modulation is the process of switching the power electronic device in a power converter from one state to another. All modulations are aimed at generating a stepped waveform that best approximates an arbitrary reference signal with adjustable amplitude, frequency and phase fundamental component that is usually sinusoidal in steady state. Each topology has different switching configuration to achieve commanded output voltage. Modulation strategies are responsible for synthesizing reference control signals and for keeping all voltage sources balanced.

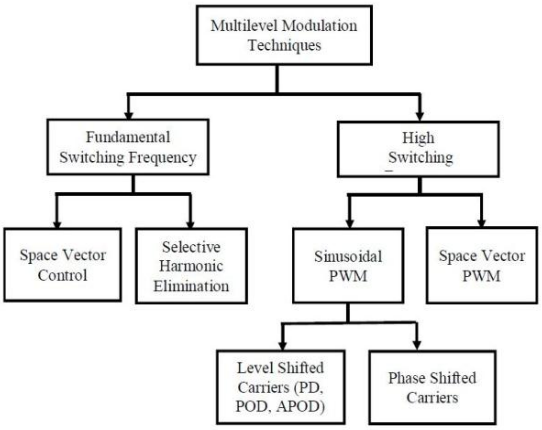

Fig -1: Classification of modulation techniques

2. PROJECT MOTIVATION

1. At first effect of inverter output harmonic on different load like motor heating and power loss etc
2. Comparison between effect of inverter output lower order harmonics and higher order harmonics which is more dominating for different loads.
3. Optimization technique for finding switching angle based on natural phenomenon like particle swarm optimization and artificial neural network, artificial bee colony etc
4. Understanding modeling requirements of power electronic equipment for different studies
5. Understanding causes of harmonics and methods of analysis and enhancement of different low and high power inverters.
6. Understanding different methods and techniques of harmonic elimination technique and their limitations.

3. LITERATURE REVIEW

V.Joshi Manohar, V. Lakshmi Devi, and Adinarayana, "SHE Controlled CHB 7-Level Inverter with Unequal DC Sources using MPSO Algorithm," *2018 IEEE* this paper [1] In this work, the optimum switching angles have been determined for a three phase 7- level CMLI with unequal DC sources by implementing Selective Harmonic Elimination Technique and optimize by MPSO. Author calculates THD for different modulation index also uses solar panel output unequal voltage to the input for inverter.

A. Sharma, D. Singh, and S. Gao, "Harmonic Elimination in Three Phase Cascaded Multilevel Inverter using Genetic Algorithm," *1st IEEE* 2019 In this paper [2] In this work, the appropriated switching angles have been determined for a three phase 15- level CMLI with equal DC sources by implementing Selective Harmonic Elimination Technique and optimize by Genetic Algorithm method. Author calculates dominant order of harmonics for different load.

M. Kumari *et al.*, "Genetic Algorithm based SHE-PWM for 1- ø and 3- ø Voltage Source Inverters," *2019*In this paper [3]in solving of system of SHE equations. The computational results are verified with simulation for single phase and three phase VSI. Hardware is also developed and the correctness of computational and simulations results have been tested Author uses Genetic algorithm for optimization of switching angle.

P. K. Kar, A. Priyadashi, and S. B. Karanki, "Harmonics Mitigation of Single-Phase Modified Source Switched Multilevel Inverter Topology Using OHSW-PWM Technique," *Proc. 2018 IEEE*In this paper [4]In this paper, a modified 7-level source switched MLI has been presented. In order to obtain good output response with reduced harmonic contains in output the proposed topology OHSW switching technique has been operated .Author calculate thd for different multilevel inverter.

S. Kundu, S. Bhowmick, and S. Banerjee, "An Optimized Selective Harmonic Minimization-PWM Scheme for Cascaded H-Bridge Inverter Fulfilling NRS 048-2:2003 Grid code," *Proc. 2018 IEEE*Here in this paper [5]This paper presents, an optimized pulse width modulation (PWM) scheme for a five-level cascaded H-bridge(CHB) inverter that reduces some selective harmonics to satisfy the grid code NRS 048-2:2003 for medium-voltage level three-phase applications.

D. Singh, A. Sharma, P. D. Singh, and S. Gao, "Selective harmonic elimination for cascaded three phase multilevel inverter," *2018 2nd IEEE* In this paper[6] This paper tries to bring relative study of occurrence of harmonics for different types of load such as linear and nonlinear loads and concluded that linear load presence less harmonics with respect to non linear loads.

Routray, R. kumar Singh, and R. Mahanty, "Harmonic Minimization in Three-Phase Hybrid Cascaded Multilevel Inverter Using Modified Particle Swarm Optimization," *IEEE* In this paper [7] The results of convergence rate and harmonic content through MPSO are compare with the results obtain through genetic algorithm (GA) and particle swarm optimization (PSO). It has been concluded that MPSO gives better results in comparison to GA and PSO.

S. K. Bisoyi and N. K. Agarwal, "SHE PWM technique for three phase three level voltage source inverter," *IEEE* In this paper [8] a generalized selective harmonics eliminated pulse width modulation method is applied to three phase three level voltage source inverter to reduce up to nineteenth order harmonic from the output voltage. In his work uses 7 different switching angles for 0.85 modulation index is to be calculated by using Newton-Raphson algorithm for best solution & MATLAB program and the analyze value is verified by P-spice software.

S. D. Patil and S. G. Kadwane, "Application of optimization technique in SHE controlled multilevel inverter," *2017* In this paper [9]In his work particle swarm optimization algorithm is use to find the best switching angle for three phase 7 level cascade inverter in which unequal dc source is applied and reducing the lower harmonics. To solve this nonlinear equation (pso) particle swarm optimization algorithm is utilized.

M. Steczek, P. Chudzik, and A. Szelag, "Combination of SHE- and SHM-PWM Techniques for VSI DC-Link Current Harmonics Control in Railway Applications," *IEEE* In this paper [10] The paper presents an idea of applying a combination of Selective Harmonic Elimination (SHE) And Selective Harmonics Mitigation (SHM) technique to shape or reform a spectrum of centenary current harmonics, generated by a traction drive system fed with a voltage source inverter. By using this method allows for reducing or eliminating distorting influence of a modern rolling stock abounding by a 3 kV DC centenary on the railway signaling, the command and the control systems.

4. METHODS OF PWM TECHNIQUE

Various types PWM techniques have been intended to minimize harmonics present in output of converters. They are:

1. Carrier signal based pulse width modulation

2. Space vector modulation or digitalized pulse width modulation

3. Third harmonic injection pulse width modulation

4. Selective harmonic elimination or reduction pulse width modulation

4.1 Carrier Signal Based Pulse Width Modulation

Carrier Based PWM(CBPWM) in this type of methods compare a reference signal waveform with a triangular or saw-tooth or ramp carrier at a higher frequency *fs* (sampling frequency) and accordingly make a decision whether to turn a switch on or off.

4.2 Space Vector Modulation Pulse Width Modulation

The direct digital method or the space vector modulation PWM technique was proposed by Pfaff et al in 1984[12].Space Vector Modulation (SVM) is type of pulse width modulation method, which is very different from carrier based PWM methods. Carrier based PWM methods are based on relative comparison of a reference signal waveform with a high frequency carrier signal, whereas in the Space Vector Modulation method switching instants and interval of each switching state are planned from simple equations. Moreover, there is one reference vector is present, in contrast to the three other individual reference waveforms for three different phases of the system. It offers more flexibility as well as a maximum modulation index.

4.3 Third Harmonic Injection Pulse Width Modulation

The Third Harmonic Injection(THIPWM) PWM method was described by Ali (2007) According to them, adding a compute of third harmonic to the output of every phase of a three-phase inverter, it is possible to get a line-to-line output voltage that is greater than15 percent that obtainable when like pure sinusoidal modulation is employed. This method is useful for some dedicated applications, which explain a technique or method of injecting third harmonic and zero sequence current components in the each phase currents, which very much improves the machine torque density. Among all the type of PWM techniques or method only a few PWM strategies have been established and used mainly due to the simplicity and ease of implementation.

4.4 Selective Harmonic Elimination Pulse Width Modulation

Selective harmonic elimination SHE PWM technique or method was introduced by Husmukh and Richard in 1973[11]. The plan of this method is to get basic square waveform output is "chopped are obtained by proper numerical or off-line calculations. By appropriate or good distribution of the switching angles to turn the basic inverter bridge switches on and off, the output voltage waveform of the inverter is controlled and reaches the goal of eliminating or reducing lower order harmonics.

5. CONCLUSION

In this review paper different method of Pulse Width Modulation is analyze for harmonic reduction and on the basis of review Unipolar Pulse Width Modulation Selective harmonic elimination technique is good for eliminating lower order harmonic, low voltage application. In previous work three phase multilevel inverter is used but for low voltage application such as nonconventional energy source like solar power and wind power generally single phase voltage source inverter is uses. For switching angle optimization particle swarm optimization is best because of easy algorithm and also numerical method like Newton Raphson method to solve non linear equation is also a good method as previous work is done for three and seven switching angle.

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