Paper On The Elimination Of Harmonics In Cascaded H-Bridge Multilevel Inverters Using Bioinspired Algorithms

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Abstract - Cascaded H-bridge multilevel inverter is highly capable of achieving higher quality output voltage waveforms and higher rating with the help of their multilevel structure. They have been of great interest in the field of power industry and are best suited for reactive power compensation. Cascaded H-Bridge Multilevel inverter is capable of operating at high voltage with less electromagnetic interference and results in higher efficiency. The harmonic elimination in a Cascaded H-bridge multilevel inverter is most important and different types of modulation techniques can be applied to the inverters to eliminate these harmonics. Selective harmonic elimination method best for lower order harmonic. This paper gives a review on the various optimization algorithms that is been used for the SHEPWM technique.

Keywords: Cascaded H-Bridge multilevel inverter, selective harmonic elimination pulse width modulation (SHEPWM), Optimization algorithms

I. INTRODUCTION

Cascaded H-Bridge multilevel inverter is very much significant to the power industries due to the need of increasing the power levels. The multilevel inverter structure of these inverters is capable of handling kilovolts and megawatts voltage ranges[1]. The advantages of the multilevel inverters are their higher efficiency, low electromagnetic interference and switching losses, no voltage sharing problems for switching devices, power factor close to unity, high voltage operation and greater.

Power quality when compared to the two level inverters. They eliminate the need of step up transformers in the circuit and are suitable for reactive power compensation. The output power rating and output voltage rating of the multilevel inverter boost with increase in the number of levels. Addition of voltage level adds a switching device to each phase [2].

Multilevel inverters have many potential applications because of their advantages in increasing the power level. They can be applied to utility interface systems, medium voltage drives, distributed generation system and flexible AC transmission system equipments. They can be extensively applied to adjustable speed drives where electromagnetic interference problems can be reduced and can avoid high switching frequency voltage induced motor failure [2, 3]

The elimination of harmonics in the output voltage of a Cascaded H-Bridge multilevel inverter is vital and there are many switching modulation strategies to eliminate them with respect to the inverter switching frequency. Different iterative methods or optimization algorithms are applied to the switching modulation strategies to solve the nonlinear transcendental equations formulated by these modulation strategies. This paper reviews the selective harmonic elimination PWM strategy and the different optimization algorithm techniques used to solve SHEPWM.

II. CASCADED H-BRIDGE MULTILEVEL INVERTER

In H-bridge inverter it uses more than one DC sources. Every inverter generates output at different levels. The output voltage is the sum of all voltage levels generated by each cell. The number of levels in output voltage is = 2n+1Where 'n' is the number of input sources. Especial feature of this inverter is that it requires lesser no of switches than diode clamped multilevel inverter. The circuit diagram shown in Fig.1 below.

In [4] proposed novel design of cascaded H-bridge building block by newly developed emitter turn off thyrister to show the superior act of the ETO and this can be used in reactive power compensation application. The h-bridge blocks can beaded or removed based on requirement of the power. And also proposed the new air core snubber inductor design which is lighter than conventional iron-core inductor and also decreases the losses. In [5] proposed the control procedure of the cascaded MLI used in shunt active filter and this can be expanded to more levels. and according to the design controller is proposed to suppress the harmonics and reactive power for non-linear load. In [6] proposed the general structure of the h-bridge. Where voltage sources are connected in series and equations are to be introduced to choose the voltage ratios of the capacitor or sources to maximize the output voltage level. In [7] proposed novel

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cascaded multilevel inverter which considerably reduces the voltage ripples in the dc- link and this topology includes single diode joined for each basic H-bridge. In [8] proposed novel design of cascaded H-bridge which is combined with number of H-bridge cells as compared with conventional cascaded H-bridge. This design reduce the cost as well as simplifies the circuit and THD is also limited here than conventional one. In [9] H- bridge inverter causes some oscillations under light load and these oscillations are analyzed and novel mitigation method is proposed. In [10] a new control algorithm is investigated for inverter operating under faulty conditions.

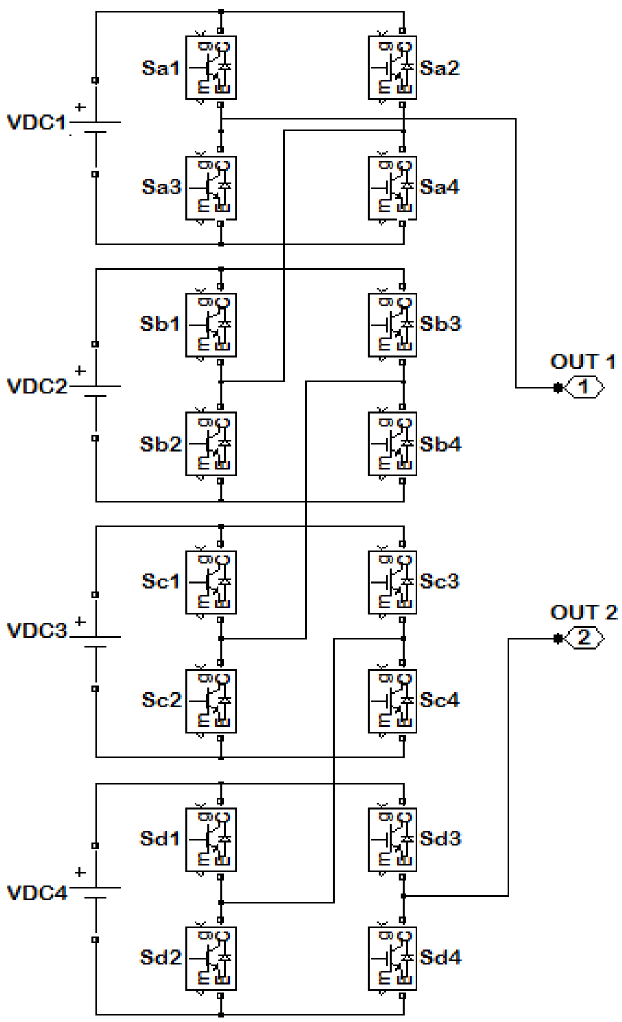

Fig.1 Cascaded H-Bridge Multilevel Inverter

III. MODULATION TECHNIQUES FOR CASCADED H-BRIDGE MULTILEVEL INVERTER

The reduction of harmonics in the output voltage waveforms of a multilevel voltage source inverter is an important criterion.Inorder to eliminate the harmonic contents in multilevel inverters different modulation techniques can be used. Various optimization algorithms can be applied to these modulation strategies to solve the transcendental nonlinear equations. According to the multilevel voltage source inverter switching frequency, the modulation strategies can be categorized mainly into two categories. (a) High Frequency Switching Modulation which include (i) Classic Carrier based Sinusoidal PWM, (ii) Multicarrier Pulse Width Modulation – Phase Disposition(PD) PWM and Phase Opposition Disposition PWM, and (iii) Space Vector Modulation. (b)Low Frequency Switching Modulation which include (i) Staircase Modulation, (ii) Stepped Modulation and (iii) Selective Harmonic Elimination (SHE) PWM [11].

(I) Sinusoidal PWM:

In SPWM technique, a reference sinusoidal wave is compared with a triangular carrier wave. Whenever the reference wave is larger than the carrier wave, pulses (gating signals) are produced. These gating signals are given to the multilevel inverter switches to generate the output voltage waveforms. The output rms voltage can be varied by varying the modulation index [12].

(ii) Phase Disposition (PD) PWM:

The PD-PWM method optimizes the harmonic voltages of a multilevel converter. The method adjusts the position and amplitude of the carrier signals to find the optimum values. This minimizes the total harmonic distortion of the output voltages. Optimization algorithms like Gradient Optimization method can be applied to the PD-PWM method [13].

(iii) Space Vector Modulation:

SVPWM is a modulating strategy of digital type. The main purpose of SVPWM is to produce PWM load line voltages which are identical to the reference load line voltages. In the inverter space vector diagram, the output voltage can be approximated by using the nearest three output vectors. A variation in the output vector is induced when the reference vector changes from one region to another. At every the reference voltage location change, the switching sequence and switching time of the state need to be calculated [12].

(iv) Staircase Modulation:

This method is used in higher voltage and higher power energy conversion applications to eliminate device stresses and switching losses. It finds the optimal primary values of the switching angles. It attains global optimization and quadratic convergence. Optimization techniques like Particle Swarm Optimization can be applied to solve the transcendental equations in this modulation [14].

(v) Stepped Modulation:

In this modulation technique, a stepped wave is the modulating signal. The wave is divided into several precise intervals and each interval is controlled separately so that magnitude of fundamental component can be controlled and specific harmonics can be minimized. This technique gives much lower distortion than normal PWM method but with higher fundamental amplitude [12].

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(vi) Selective Harmonic Elimination (SHE) PWM:

SHEPWM, also called fundamental switching frequency method is a well known technique used to eradicate the lower order harmonics from the output voltage waveform of a multilevel inverter [15]. Many optimization algorithm techniques can be employed to solve the transcendental equations associated with SHEPWM. This paper gives a review of the various optimization algorithm techniques applied for SHEPWM in the following section.

B. OPTIMIZATION ALGORITHMS FOR SELECTIVE HARMONIC ELIMINATION PWM

Selective harmonic elimination PWM is a best suited technique for harmonic elimination in multilevel inverters. It has several advantages over the other modulation strategies. It offers direct control over the harmonics in output voltage, has suitable performance with the low switching frequency to fundamental switching frequency ratio and has higher converter bandwidth. The main dare associated with SHEPWM is to find the arithmetic solutions (switching angles) of transcendental nonlinear equations which exhibit multiple solutions set [15]. These equations can be solved by different Optimization algorithms.

(i) Newton Raphson Iterative Method:

Newton Raphson method is used to crack the nonlinear equations iteratively or analytically. These methods are sensitive and they need a good initial guess to solve the solution and this guess should be close to the exact solutions. Only one set of solution can be solved depending on the initial guess. The chance of divergence in the NR method is very high and may end in local optima solutions. So these methods are not suitable for SHE if there is no availability of good initial guesses [16].

(ii) Resultant Theory:

The theory of resultants can be applied to solve nonlinear equations in SHE where these transcendental equations characterizing the harmonic content can be converted to polynomial equations. These equations can be solved using the resultants method from the elimination theory to get the complete solution. A problem with the resultant theory approach is that the degrees of the polynomial equations become quite large when there are several dc voltage sources. This makes the burden of computation of the resultant polynomials quite large [15, 17].

(iii) Genetic Algorithm:

Genetic Algorithm is a meta-heuristic search method that is helpful in solving combinatorial problems. They can be applied to SHE for solving the nonlinear equations. They optimize the carrier waves sequence of the PWM in order to lessen the total harmonic distortion and distortion factor of the output voltage waveform. It can be applied to multilevel inverters with equal dc voltage sources. As the voltage level of the inverter increases, the quality of the solution gets deteriorated. The speed of convergence is low for genetic algorithm and each step to find out the switching angles is time consuming [18,19].

(iv) Particle Swarm Optimization Algorithm:

PSO is applicable to the SHE with unequal dc sources while the number of switching angles is increased and finding out of these switching angles with traditional iteration methods are impossible. PSO minimizes the computational burden of finding the optimal solution for lower number of switching angles when compared to the other iterative methods [16]. In PSO algorithm, only one fitness value is there and this move towards the global optimal point at the end of each iterations. They are computationally faster and convergence rate is better than conventional iterative methods [19].

(v) Harmony Search Algorithm:

This is a meta-heuristic search process which is based on the process of improvisation of jazz musicians. The musicians try to adjust their pitches to achieve better harmonies. This can be used to derive heuristic searches that can be used to optimize a given objective function. They create new solutions based on past solutions and random modifications. The objective function for HSA is similar to genetic algorithm. GA and HSA will find the nearest possible solution by providing a smooth data set for the range space where there is no analytical solution. But they use computationally time consuming equations to find the switching angles. So the switching angles are calculated offline [20]. In [20], results obtained for HAS and GA are compared and artificial neural networks are trained to get the best solution between them. The result shows that HSA is more accurate than GA.

(vi) Imperialist Competitive Algorithm:

It is a latest global search strategy for dealing with various optimization tasks. It has greater performance in rate of convergence and achieves solutions that are globally optimal [21]. In [22], ICA is used to reduce the lower order harmonics while satisfying the desirable fundamental component. ICA is then compared with PSO and genetic algorithm. Results show that ICA is much faster and has better performance than GA. Implementing ICA is simpler than PSO and converges to global optimal solutions with greater probability. ICA is three to four times faster than PSO.

(vii) Colonial Competitive Algorithm:

CCA adopts the human life social and political evolutionary approach. This method has been adopted to solve a group of optimization problems. It can be used for both equal and unequal dc sources [24]. CCA has higher convergence rate and this may cause the algorithm to be local optima. So the final result will not be a global one. In [23], an improved

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CCA is used to overcome this deficiency with the help of stochastic approaches. Then ICCA is compared with CCA, PSO and GA. The calculation time for ICCA is much lesser than for other algorithms. The number of objective function referrals is less than others. ICCA have greater capability for solving sophisticated problems.

TABLE I COMPARISON OF OPTIMIZATION ALGORITHMS

S.NO	Optimization Algorithms	**Discussions and Conclusions**
1	Newton Raphson Iterative Method	• Sensitive method • Good initial guess required • Only one set of solution can be solved using the initial guess • High chance of diversion • Result in local optimal solutions
2	Resultant Theory Method	• Transcendental equations transformed to polynomial equations • Solved using method of resultants • Degrees of polynomials are large if there are more dc sources • Computational burden is high
3	Genetic Algorithm	• Meta-heuristic search method to solve combinatorial problems • Applied to MLI with equal dc sources • Solution quality gets deteriorated if levels increases • Low convergence speed and time consuming
4	Particle Swarm Optimization	• Computational burden is reduced compared to other iterative methods • Faster computation • Convergence rate is better than other methods
5	Harmony Search Algorithm	• Meta-heuristic process based on improvisation of jazz musicians • Create new solutions based on past solutions • Objective function similar to GA • Computationally time consuming equations • So switching angles calculated offline • More accurate than GA
6	Imperialist Competitive Algorithm	• Greater convergence rate and attains global optimal solutions • Much faster than GA • Three to four times faster than PSO and implementation is simpler
7	Colonial Competitive Algorithm	• Adopted to solve mass optimization problems • Can be used for both equal and unequal dc sources • Calculation time is lesser than other algorithms • Better performance than PSO

IV. CONCLUSION

This paper reviewed various optimization algorithms used to solve Selective Harmonic Elimination Pulse Width Modulation strategy for Cascaded H-Bridge multilevel inverters. Classification of multilevel inverters and the different modulation strategies used for the harmonic minimization of output voltage waveform in Cascaded H-Bridge multilevel inverters are described.

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