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A COMPARATIVE ANALYSIS OF NEWTON-RAPHSON AND DRAGONFLY ALGORITHMS FOR SHEPWM OPTIMIZATION

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ABSTRACT
Harmonics is the major power quality problem caused by nonlinear devices, leading to malfunction or operational halt of the system. Low-order harmonics increase vibration and heat generation in motors. Therefore, controlling harmonics in the output waveform is the prime target for industrial applications to avoid economic loss. Selective harmonic elimination pulse width modulation (SHEPWM) is one of the techniques used for eliminating or minimizing selected harmonics in the output voltage waveform. This paper utilizes the Newton-Raphson (NR) method and Dragonfly Algorithms (DA) to calculate optimum switching angles for a Cascaded H-bridge Multilevel inverter (CHBMLI). The simulation is performed using MATLAB SIMULINK software for both 5-level and 7-level CHBMLI configuration. The Dragonfly algorithm achieves THD 15.29% when the modulation index (M) is equal to 0.8 for a 5-level inverter and THD 9.18% when M is equal to 14.91% for a 7-level inverter and effective in minimizing third and fifth-order harmonics.

KEYWORDS
Selective harmonic elimination pulse width modulation, Newton-Raphson algorithm, the Dragonfly Algorithm, Artificial Neural Network, and Neural Fitting Tool.

1. INTRODUCTION
Harmonic distortion is a serious concern due to the rapid growth of nonlinear loads, which include power electronics, variable frequency drives, and inverters. Switching devices such as metal-oxide-semiconductor field-effect transistors (MOSFET) and insulated-gate bipolar transistors (IGBT) within inverters turn on and off quickly using methods like pulse width modulation (PWM) to create pulses, which approximate a sine wave.

When these devices turn on, there is a sudden increase in the waveform. When they turn off, it causes an abrupt stoppage of the current flow, which means the waveform suddenly drops. High-frequency components are created by the rapid transitions from on to off in all the switches. These harmonics harm the power quality and system performance [1].

Hence, mitigation of the harmonics is necessary. Several methodologies in PWM have been developed to reduce undesirable harmonics they are carrier-based PWM, space vector PWM, and SHEPWM [2]. SHEPWM eliminates certain harmonics that can reduce distortions and improve power quality. The SHE is a mathematical technique, that generates the required switching angles by solving nonlinear equations [3]. These nonlinear equations are obtained from the Fourier series expression of the output voltage waveforms for the Cascaded H-bridge multilevel inverter. The Newton Raphson and Dragonfly Algorithm can be used to find the optimum switching angles for a CHBMLI by solving non-linear equations [4][5]. These switching angles are given to the CHBMLI for precise harmonic elimination.

The Newton-Raphson method represents an iterative technique through which, from nonlinear equations, the roots can be obtained. It is a very suitable method for exploitation because it refines and continuously improves known solutions to give better overall performance. It has no mechanisms to study the entire solution space, therefore, it can never guarantee global optimum.

The Dragonfly algorithm is a Bio-inspired method. In this algorithm, the switching angles are repeatedly modified or finally converge to a solution giving a minimum %THD. The switching angle with maximum power deviation is efficiently found by the Dragonfly algorithm within a search region.

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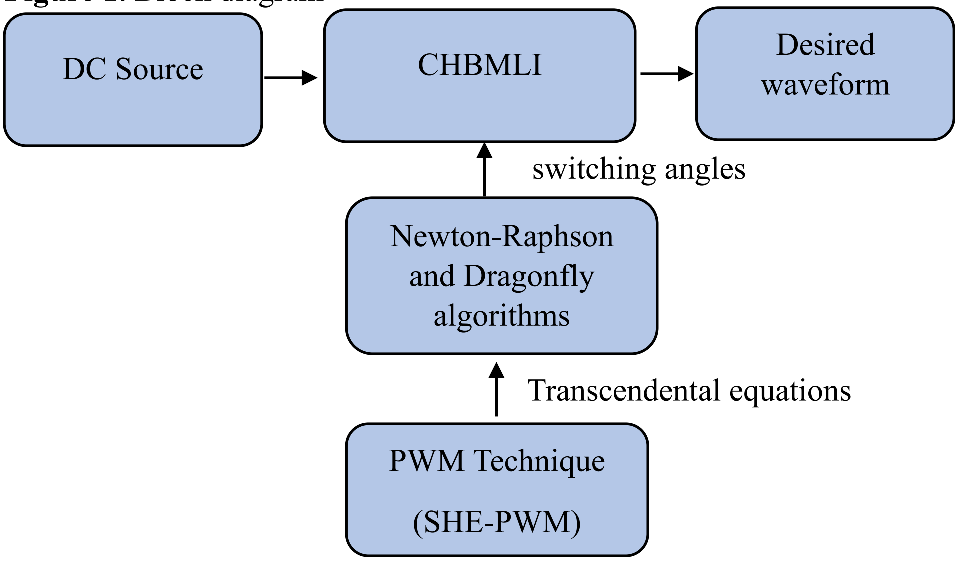
This algorithm finds a global optimum rather than a local optimum solution. Since it is a metaheuristic, the Dragonfly algorithm requires more iterations to converge to an optimum or near-optimum solution [6].

Figure 1. Block diagram



This paper presents the implementation of the Newton Raphson and the Dragonfly algorithms for effective harmonic elimination in the output waveform of five and seven -level CHBMLI and presents the comparison of the Total Harmonic analysis.
This research paper is organized as follows: Section 1: Explains gives an overview of this paper including the block diagram of the system. Section 2: Explains the total control methodology of CHBMLI and its basic operation. And gives details about the SHEPWM technique. Section 3: Explains the implementation of Newton Raphson and the Dragonfly algorithms and explains their application within the context of solving SHEPWM equations for CHBMLI.Section 4: discuss about the results and discussion.

2.1 CASCADED MULTILEVEL INVERTER:

one reason for the widespread use of Multilevel Inverters (MLIs) in industry is their ability to handle higher voltage and power levels. Additionally, the waveform produced by a 3-level inverter (or any inverter with more than two levels) is closer to a sinusoidal shape compared to a 2-level inverter. They divide the total voltage among several devices, reducing the voltage stress on each power device. The major MLI topologies are Cascaded H-bridge, Diode Clamped, and Flying Capacitor MLIs. Among these, the cascaded H-bridge has advantages such as fewer components, lower weight, and lower cost. A 5-level cascaded H-bridge MLI needs only two single-phase full-bridge inverters connected in series to achieve an output voltage, $V_{out} = V1 + V2$. That means $L = 2m + 1$ voltage levels and $n = (L – 1)/2$ switching angles for an L–level inverter.

Figure 2. 5-Level Inverter Circuit

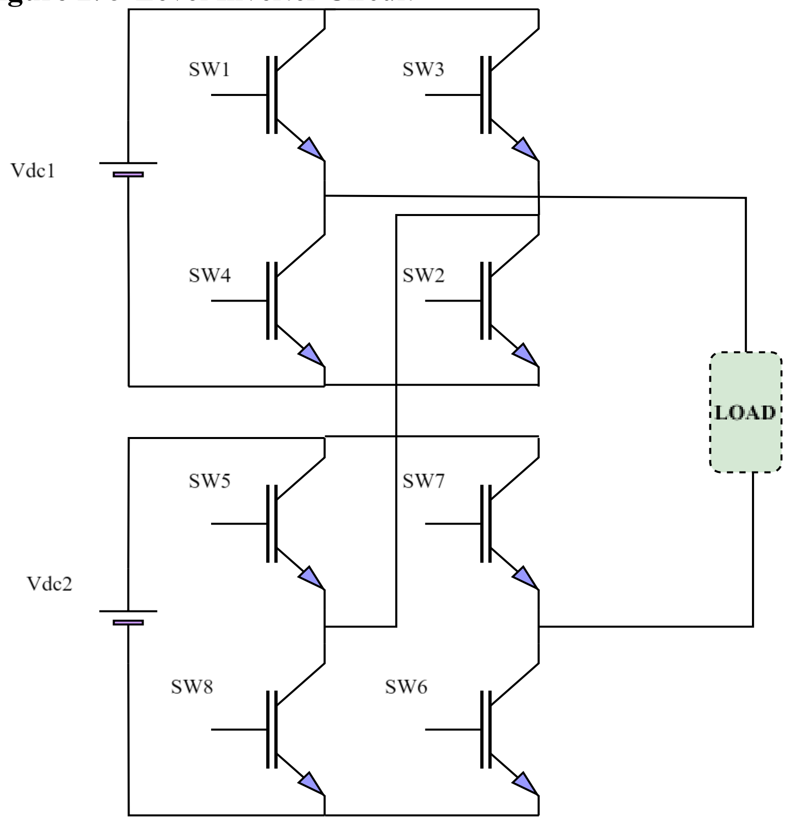


Table 1. Switching Sequence of 5-Level CHB Inverter.

Switches Turn On	Voltage Level
S1, S2, S5, S6	+2Vdc
S1, S2, S6, S8	+Vdc
S1, S3, S5, S7	0
S3, S4, S5, S7	-Vdc
S3, S4, S7, S8	-2Vdc

2.2 SHE-PWM TECHNIQUE

The SHEPWM controls the inverter output by eliminating certain harmonics, using calculated switching angles obtained from nonlinear transcendental equations derived through Fourier analysis. Due to the odd quarter wave symmetry of the waveform, even-order harmonics are inherently eliminated, resulting in odd harmonics being present in the output. For a 5-level inverter, the equations become

$$V_{fun} = \frac{4Vdc}{n\pi}[\cos(\alpha_1) + \cos(\alpha_2)] \quad (1)$$

$$V_{3rd} = \frac{4Vdc}{3\pi}[\cos(3\alpha_1) + \cos(3\alpha_2)] \quad (2)$$

$$V_{5th} = \frac{4Vdc}{5\pi}[\cos(5\alpha_1) + \cos(5\alpha_2)] \quad (3)$$

M=$\frac{\pi V_1}{4nV_{dc}}$(n-number of DC sources; V1 is the amplitude of the fundamental component of the output voltage; $V_{dc}$is the DC input voltage and M is the Modulation index)
To eliminate the third harmonic equation (2) should equate to zero and to eliminate the fifth harmonic equation (3) should equate to zero. The modulation index ranges from 0 to 1, and switching angles (α_1 & α_2) range from 0 to 90 degrees [$0 \leq \alpha 1 \leq \alpha 2 \leq \frac{\pi}{2}$]. For higher-order multilevel inverters, deriving nonlinear equations that determine the optimal switching angles can be computationally expensive and challenging. As a result, numerous algorithms are employed to resolve the equations.

3.1 THE NEWTON-RAPHSON ALGORITHM

Newton-Raphson method is an iterative technique, which is very efficient in determining the roots of nonlinear equations. This technique is highly dependent on initial estimation. Incorrect initial estimation will lead the algorithm to diverge or even converge to some other root than desired. The Jacobian matrix computation becomes more difficult with the number of levels in the inverter. Dragonfly Algorithm performs better than Newton-Raphson in an optimization problem of high dimensionality and complexity using a population-based global optimization approach.

3.2 THE DRAGONFLY ALGORITHM

The Dragonfly Algorithm is based on swarm intelligence, where the behavior of dragonflies is imitated. Dragonflies use two swarms: the migration swarm, which is highly cohesive and low in alignment, travels a huge distance and survives and the feeding swarm, which is high in alignment and low in cohesion, explores an area. Swarm performance is optimized by incorporating key swarm behaviors into the algorithm, including separation, alignment, cohesion, attraction, and distraction.
Separation (S_i): This avoids crowding, allowing the dragonflies to maintain a safe distance from one another.

$$S_i = \sum_{j=1}^{N} X - X_j \quad (4)$$

Where, S_i is the separation for i^{th} individual, X is the position of the current dragonfly, X_j is the position of the j^{th} neighbor and N is the number of neighboring dragonflies.
Alignment (A_i): Synchronizes the directions of the movement of dragonflies for better coordination.

$$A_i = \frac{\sum_{j=1}^{N} V_j}{N} \quad (5)$$

Where, A_i is the alignment for i^{th} individual, V_j is the velocity of the j^{th} neighbor and N is the number of neighboring dragonflies.
Cohesion (C_i): Cohesion leads them to move closer to each other in achieving a common goal.

$$C_i = \frac{\sum_{j=1}^{N} X_j}{N} - X_j \quad (6)$$

Where, C_i is the cohesion for i^{th} individual, N is the neighborhood's size, X_j is the position of the j^{th} neighboring dragonfly and X is the current dragonfly individual.
Attraction: The process of attraction guides dragonflies toward sources of food.

$$F_i = X^+ - X \quad (7)$$

Where, F_i is the attraction of the food for i^{th} dragonfly, X^+ is the position of the source of the food and X is the position of the current dragonfly.
Distraction: keeps dragonflies away from dangers and directs them to safer places.

$$E_i = X^- + X \quad (8)$$

Where, E_i is the enemy's distraction motion for i^{th} dragonfly, X^- is the enemy's position and X is the position of the current dragonfly individual.
Dragonflies update their positions by group behaviors such as Levy flight patterns or swarm interactions. Before updating the position of dragonflies, the step factor needs to be calculated, describing their movement, and the position vector, represents the current location. This algorithm is computationally intensive but reaches the optimal solution in minimizing %THD.

Table 2. Parameters of the Dragonfly algorithm

S.no	Parameters	Values
1.	Number of agents	100
2.	Number of iterations	200
3.	Separation factor	0.6
4.	Alignment factor	0.8
5.	Cohesion factor	0.5
6.	Food attraction factor	0.9
7.	Enemy distraction factor	1

4. RESULTS AND DISCUSSIONS

The 5-level and 7-level MLI simulation models were designed in MATLAB/Simulink using pulse generators, DC voltage sources, and Insulated Gate Bipolar Transistors (IGBTs). A 100V supply is provided to each H-bridge DC input, and an R load is used. The scope is connected to the voltage measurement block, which is parallel to the load, and the current measurement block is connected in series with the load. After running the simulation, the following outputs were obtained.

Figure 3. Output voltage waveform of 7-level CHBMLI

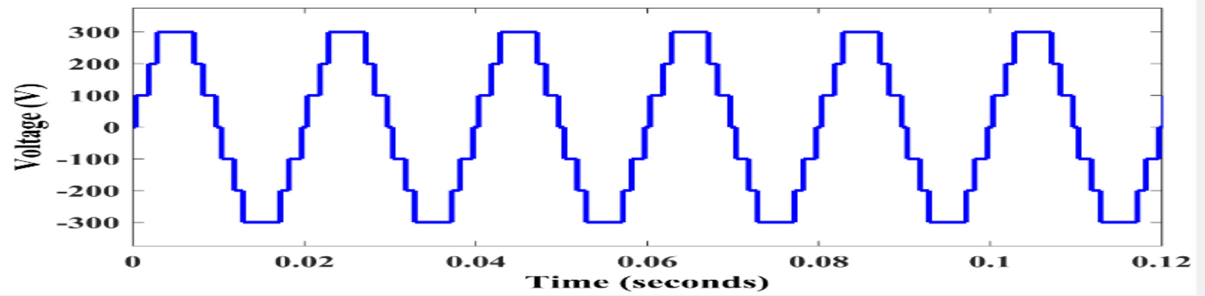


Figure 4. Output current waveform of 7-level CHBMLI

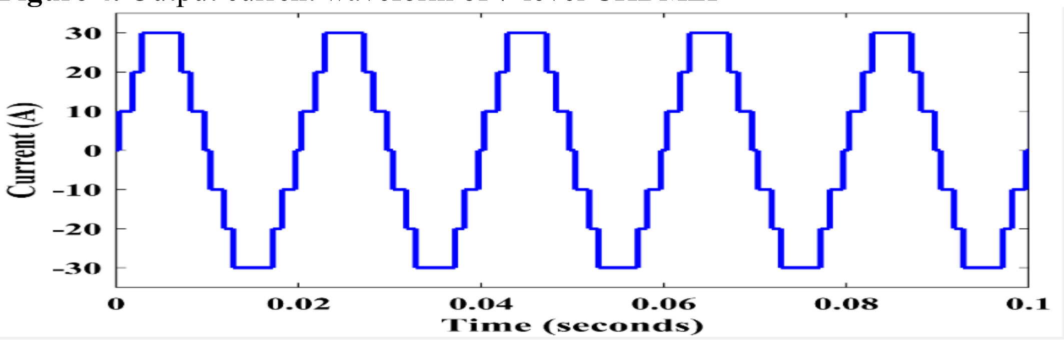


Figure 5. Output Voltage Waveform of 5-Level inverter

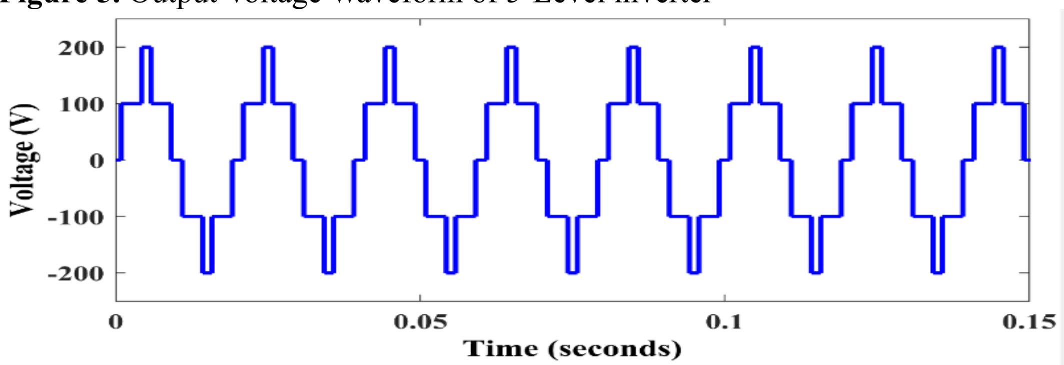
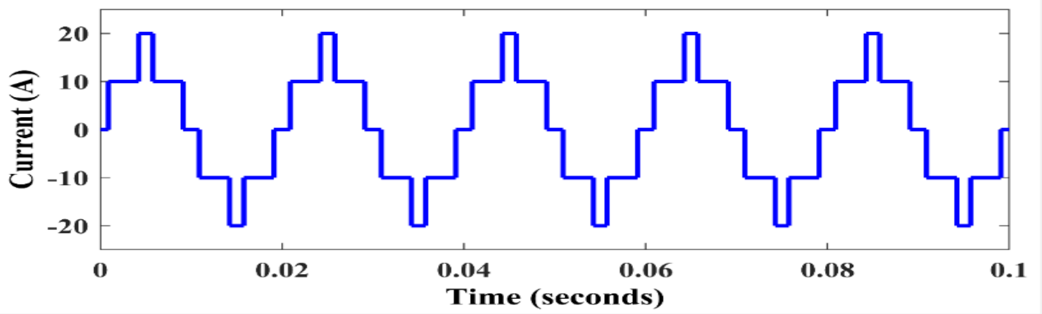


Figure 6. Output current waveform of 7-level CHBMLI



The following is the FFT analysis on 5 and 7-level MLIs using the dragonfly algorithm and dragonfly

Figure 8.FFT analysis on a 7-level inverter using the Dragonfly algorithm

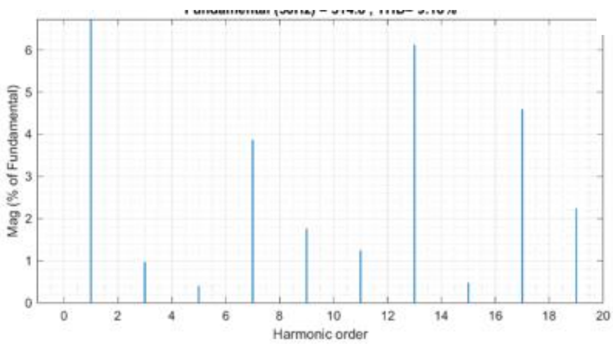


Figure 7. FFT analysis on a 7-level inverter using Newton Raphson

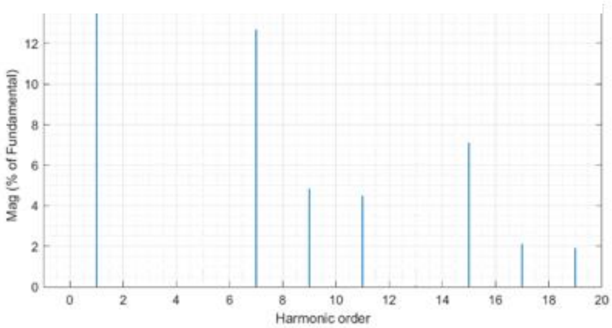


Figure 9. FFT analysis on a 5-level inverter using the Dragonfly algorithm

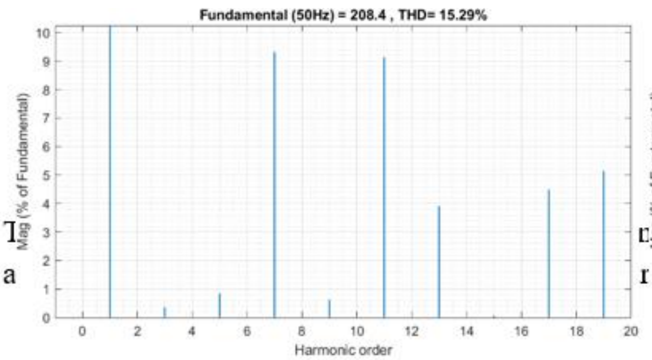
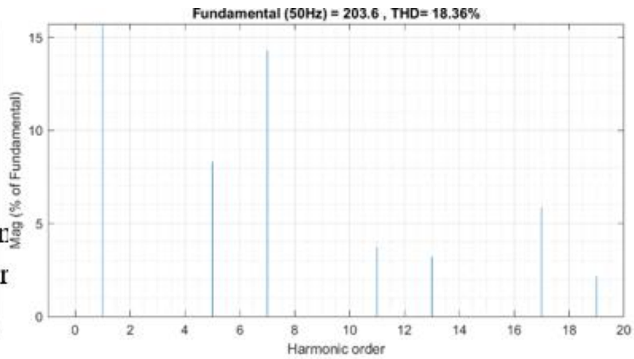


Figure 10. FFT analysis on a 5-level inverter using Newton Raphson



The FFT analysis is performed for both 5-level and 7-level inverters using Newton-Raphson and Dragonfly algorithms. The following values are taken for a modulation index of 0.8.

Table 3. FFT analyses for 5-level and 7-level inverters using the Dragonfly and the Newton-Raphson algorithms

S. no	Algorithm	% THD of 5-Level CHBMLI	% THD of 7-Level CHBMLI
1.	Newton Raphson algorithm	18.36%	16.22%
2.	Dragonfly algorithm	15.29%	9.18%

5. CONCLUSION

In this paper, the SHEPWM technique is employed to reduce selected low-order harmonics in 5-level and 7-level Cascaded H-Bridge Multilevel Inverters (CHBMLI) using both the Newton-Raphson and Dragonfly algorithms to determine optimal switching angles. The simulation is performed using

MATLAB SIMULINK software for both 5-level and 7-level CHBMLI configuration. %THD decreased from 18.36% using the Newton Newton-Raphson algorithm to 15.29% when using the Dragonfly algorithm for a 5-level inverter. %THD decreased from 16.22% using the Newton-Raphson to 9.18% using the Dragonfly algorithm for a 7-level inverter. It is observed that the Dragonfly algorithm yields lower THD compared to the Newton-Raphson algorithm. The Dragonfly algorithm demonstrates its effectiveness in reducing harmonics and improving the quality of the output waveform.

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