An Improved Artificial Bee Colony Algorithm based Harmonic control for Multilevel Inverter

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Abstract: In this paper, an Improved Artificial Bee Colony (IABC) Algorithm is proposed for eliminating voltage harmonics in the Multilevel Inverter (MLI). It is achieved by reducing the THD present in the MLI output voltage. In an MLI, the harmonics can be eliminated by an optimal selection of switching angles. The proposed IABC technique utilizes an Artificial Bee Colony (ABC) Algorithm and Recurrent Neural Networks (RNN) for the optimal selection of switching angles. An IABC algorithm is used to evaluate the optimum switching angles that are obtained from the iteration as well as the RNN. Here, the voltage variation of the MLI is determined from the actual load voltage and the reference voltage. The voltage variation at different time interval has been applied to the IABC algorithm. According to the voltage variations, the switching angles can be generated from the RNN. These switching angles can make the MLI output voltage with reduced THD. The proposed algorithm is tested with a seven-level inverter, and the resultant fundamental and harmonics voltages are analyzed. The experimental result shows the efficiency of the proposed algorithm in eliminating the harmonics that are generated by the inverter. The proposed algorithm is instructed in the MATLAB/Simulink working platform. The effectiveness of the suggested algorithm is evaluated by the MLI output voltage with some traditional techniques like a genetic algorithm (GA), ABC.

Keywords: Harmonic control, ABC algorithm, RNN, THD, MLI, switching angle, selective harmonic elimination (SHE), voltage.

1. INTRODUCTION

Multilevel inverters have acknowledged more and more attention due to their skill of high voltage operation, high effectiveness, and low electromagnetic interference (EMI). The entire attractive structures of multilevel inverters are as trails. (a) They can produce output voltages with enormously low distortion and dv/dt, (b) They lure input current with very low distortion, (c) They produce lesser common-mode (CM) voltage, (d) thus decreasing switching losses and augmented efficacy; respectable electromagnetic compatibility (Govindaraju and Baskaran, 2010). It can produce an anticipated output voltage from numerous levels of dc voltages as inputs. When an adequate number of dc sources is utilized, an approximately sinusoidal voltage waveform can be amalgamated (Jagdish Kumar et al., 2008). The unequal DC sources are anticipated to increase the quantity of the output voltage levels. Therefore, the harmonics issue is elevated if juxtaposed with a similar source topology (Kumar and Nishant, 2013). The different circuit configurations, specifically multilevel inverters, have been measured. The best-known topologies of the MLI are the flying capacitor inverter, the H-bridge cascaded inverter, and then the diode-clamped inverter (Balamurugan et al., 2012). Intended for the high voltage implementations, the output voltage of the converters must meet maximum THD restrictions. A switching angle optimization technique is mandatory to surmount this issue. Consequently, a similar type of technique must be utilized to regulate the harmonics (Zhao and Wang, 2016).

Multiple harmonic eradication approaches are utilized using the harmonic elimination method in high power inverters; it bids heightened operations at low switching frequency while decreasing cost and bulky size filters. They have been efficaciously espoused in different multilevel inverter topologies (Govindaraj and Vijayakumar, 2014). Arithmetical iterative methods, like Newton-Rapson (NR) method, genetic algorithm (GA), Artificial Neural Network (ANN), and particle swarm optimization (PSO), bacterial forage optimization (BFO) differential evolutionary (DE) algorithm and are used to augment the switching angles and eradicate the harmonics (Farhadi et al., 2015; Karaca and Bektas, 2016). Nevertheless, by accumulative, the number of switching angles, the density of search space upsurges intensely and the above approaches trap the local optima of search space. Of course, the accurate result or the no. of switching angles cannot be intended by evolutionary based algorithms; though, it can be said that as the amount of switching angles upsurges, also diminution the finding optimum switching angles (Jorge Luis Diaz Rodriguez et al., 2015). Lately, a novel active harmonic eradication technique is also used to eradicate higher order harmonics in multilevel inverters. In this technique, primarily, the switching angles to eliminate the lower order harmonics of staircase voltage waveform are intended that is known as essential switching frequency technique.

At that time, residual sophisticated order harmonics are eradicated by new PWM switching designs (Seyezhai, 2011). A diversity of pulse width modulation (PWM) systems frequently utilized for cascaded multilevel inverters are on the basis of the subsequent approaches: 1) sinusoidal PWM (SPWM), 2) space vector PWM (SVPWM), 3) non sinusoidal carrier PWM, 4) mixed PWM, 5) exceptional structure of cell connections and 6) SHE-PWM (Ashok and Rajendran, 2013). Due to multilevel inverters frequently function with a low switching frequency, SHE-PWM bids several advantages over the other approaches like a low switching frequency with a large converter bandwidth, direct control over lower order harmonics and improved DC source exploitation (Baharuddin Ismail et al., 2014). Inappropriately, this technique utilizes very high frequency swapping to eradicate higher order harmonics; also, it necessities a much intricate control process to produce the gate signals for power switches. The main disadvantages of available harmonics approaches are their mathematical complexity and the hefty computational loads, a subsequent high cost of the hardware desired for a real-time application (Ragunathan and Rajeswari, 2014).

At this time, I have envisioned to suggest a heightened method for augmenting the switching angle and decreasing the harmonics of a multilevel inverter (MLI). At this time, the higher order MLI is analyzed, and the control strategy is intended on the basis of the IABC algorithm. The ABC algorithm is one among the swarm intelligence algorithms utilized to resolve optimization issues that are enthused using the rummaging behavior of the honey bees. For enhancing the function of the ABC algorithm, the expression of the scout bee will be improved by the Artificial Intelligence (AI) technique. From the output of the AI technique, the optimal solutions will be attained, due to the scout bee procedure hinge on the rate of change on the performance graph, substitute the parameter limit. At this time, the harmonic elimination issue is resolved in a simple manner, if the number of switching angle is augmented; the harmonics can be distributed without complexity. The projected method will be dogged the optimum switching angles of the MLI while amassed the number of switching angles. Primarily, the voltage and inverter switching angle will be analyzed. Following that, the switching loss will be evaluated with fewer harmonics. Similarly, for a low number of switching angles, the projected method will be lessened the computational burden to determine the optimal result.

2. RECENT RESEARCH WORKS: A BRIEF REVIEW

Numbers of research work have heretofore occurred in the literature that on the basis of the harmonic eradication in the multilevel inverter. Some of the works are revised here.

A boost-multilevel inverter design with combined battery energy storage scheme for standalone implementation was given by (Sze Sing Lee et al., 2016). The inverter comprises of modular switched-battery cells and then a full-bridge. It was multifunctional and had two modes of operation: the charging mode that charges the battery bank and the inverter mode that provisions AC power to the load. Their inverter topology necessitates meaningfully fewer power switches associated with conventional topologies like cascaded H bridge multilevel inverter, prominent to abridged size/cost and amended reliability. To selectively eliminate low-order harmonics and control the anticipated basic constituent, nonlinear system equations were characterized in fitness function via the manipulation of the modulation index and the GA was engaged to detect the optimum switching angles.

A technique to eradicate harmonics in a solar driven CHMLI (cascaded H-bridge multilevel inverter) was elucidated by (Shimi Sudha Letha et al., 2016). The issue utilizes Newton Raphson, and PSO grounded SHE methods for resolving the non-linear transcendental equations and to attain the optimal switching angles. The augmented switching angles attained offline were used to diminish the THD. The main apprehension in the harmonic elimination issue in the non-equal dc sources scheme was the result of the nonlinear transcendental equations. Though, their projected technique can easily resolve this issue, by just renovating non-equal dc sources into same dc source with the help of the ANFIS (Adaptive Neuro-Fuzzy Inference System)/Constant Voltage Maximum Power Point Tracker algorithm intended for the Photo-voltaic system.

A method for minimization of THD of a multilevel flying capacitor inverter (MFCI) on the basis of the SHE named stochastic THD (STHD) approach was deliberated by (Hamid Reza Massrur et al., 2016). In the STHD approach, the stage voltage levels of multilevel inverter were deliberated to be fluctuating because of unbalanced capacitor voltages. Besides, it amended modelling of harmonic abolition by seeing the effects of the dissipative snubber, gate-drive circuits, blanking time, and computation time in microcontrollers on the THD calculation. Switching instants were deviated from the anticipated moments by concerning the declared properties. The switching angle variations and unbalancing of flying capacitor voltages were assessed by 2m+1 point estimate approach in their proposed strategy. Formerly, the formulation was associated with modified cuckoo search algorithm and a self-adaptive mutation tactic for the establishment of a robust algorithm for minimization of the THD.

To detect the inverter switching angles by implementing altered fast recursive algorithm provided that a precise online result for the Harmonic Elimination (HE) issue was deliberated by (Jamal Abdul Kareem Mohammed, 2016). The recommended optimized algorithm method has been utilized to detect optimum switching angles required to eradicate any number of lowest order harmonics and preserve the anticipated basic voltage for driving an AC motor. An unassuming and truncated cost single-phase multilevel cascade inverter with no transformers could be applied by an only single-DC source with n-1 DC resources epitomized by capacitors and with condensed switches. So, current inverter hardware cost could be summarized snappishly as associated with a conventional one. When the number of DC sources was amplified, inverter output has higher harmonic content categorized using their inspirational equations that become more complex and obligatory more time to be resolved.

A PWM method with the performance of the variable switching cycle to decrease the current harmonics in grid-connected inverters was projected by (Quang-Tho Tran et al., 2016). The weights of this performance are unwavering with the help of a GA under the constraint of constant switching loss. The accumulative implementation of dispersed power generation into the power scheme produces grid interconnection necessities of power quality more and more rigorous. The decline of current THD of grid-connected inverters to attain the grid code by an aggregate of switching frequency in PWM of inverters was one among the general approaches; nonetheless, this upsurges the switching loss.

Generally, the multilevel inverter comprises an implausible number of levels that raise the quantity of switching diodes, devices, and other passive constituents. Henceforth, it sources control trouble and jolts voltage- imbalance setbacks. Consequently, these multilevel inverter provisions are not proper for increasing the produce voltage levels as of their great number of switching tools. The unsatisfactory DC sources are anticipated to increase the quantity of the output voltage levels. Subsequently, the harmonics issue is elevated if juxtaposed with the analogous source topology. A switching angle optimization technique is obligatory to overcome this issue. The appraisal of the current research work displays that, harmonic eradication and switching angle optimization is an issue of a multilevel inverter. Different parameters are measured like the voltage, switching angle & level, etc. for resolving these issues. Conservatively, the N-R method, SPWM, and SVM methods are utilized to regulate the output voltage and decrease the undesired harmonics, but still, some difficulties are offered namely, time overwhelming as they are iterative and necessity heavy computation burden and slow convergence. With the help of N-R technique, it functions appropriately when a respectable preliminary guess is existing, given that a reasonable estimate is very challenging in most cases. This is due to the search space of the harmonics issue is unknown, and one does not distinguish the result is consequently not, in case if it exists; this is the good preliminary guess or not. In literature, the soft computing approaches such as ANFIS, PSO, GA, ABC algorithm and DE algorithm, etc. are utilized for resolving these issues. By using GA, the conceivable group of results for switching angles of MLIs is revealed. Though, the quality of result depreciates with the help of GA as the level of inverter upsurges in MLI. Furthermore, the convergence speed of the GA algorithm is low, and each stage to detect the switching angles is a lengthy procedure. In another aspect, PSO has been demonstrated to have excellent universal searchability. The velocity equation comprises of stochastic variables than in PSO algorithm, so the standard best value is fluctuating hesitantly. In literature, very few methods based works are offered to resolve this issue; these disadvantages and effects have interested to do this research article.

3. HARMONIC ELIMINATION OF THE MLI USING IABC

The multilevel inverter has better working execution contrasted with the PWM inverters. It gives even voltage sharing, both statically and progressively; lessen the size and volume because of the end of the cumbersome coupling transformers or inductors. The consonant end is the troublesome errands of the multilevel inverter, on the grounds that the direct and nonlinear burden causes music in the output voltage. Make something as small as possible/treat something important as unimportant to THD of the output voltage; it ought to portray the output power nature of multilevel inverter. The power quality compensation procedure should be possible by the proposed IABC strategy. The general system of the proposed harmonic elimination technique is portrayed in the accompanying fig. 1. In the proposed consonant end utilizing IABC procedure can be utilized to produce the controlling beats of the electronic force switches, i.e., IGBT (Insulated Gate Bipolar Transistor). The controlled exchanging pulses are being used to minimize the THD displaying the multilevel inverter output voltage (V_{out}) since the lessening of THD prompts dispose of the music present in the inverter output voltage and enhance the forced quality.

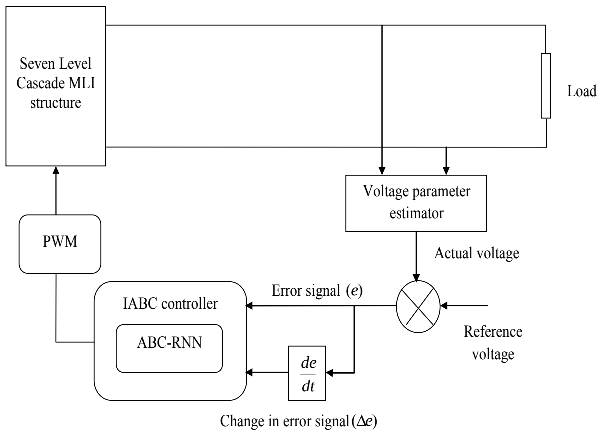


Fig. 1. The structure of cascade H-bridge multi-level inverter.

The proposed algorithm analyzes the inverter output voltage (V_{out}) and a reference voltage (V_{ref}), in light of the fact that the output voltage of the multilevel inverter contains swell and sag. The distinction between the original voltage signal and the standard reference voltage is known by the error signal. The decided error voltage (e) and the change in error voltage de/dt are the contributions of the proposed IABC controller, and it is anticipated with the external voltage signal. At long last, it creates the controlling heartbeats as indicated by the mistaken signal. This procedure can lessen the THD presents in the output voltage and enhancing the output power quality. The proposed control method, including parts, is quickly clarified in the accompanying areas.

3.1. Cascade MLI Structure

Cascade multilevel inverter (CMLI) is one of the critical topologies of multilevel inverter because of numerous focal points of it. A CMLI comprises of various H-span inverter units with discrete dc hotspot for every unit and is associated in course or arrangement for one stage. Course MLIs can produce level staircase voltage wave frames in every stage utilizing separate DC sources (Niknam Kumle et al., 2015). In fig. 2 demonstrates the structure of a solitary stage course inverter supplied by three segregated DC sources to produce seven-level staircase voltage waveform as delineated in fig. 3. Every full scaffold associated with a DC source can go about as a traditional inverter which produces three distinctive output voltage levels $+V_{dc}$, 0 and $-V_{dc}$ as indicated by exchanging states. The stage voltage is acquired by summation of arrangement full scaffold module voltages. It is accepted that all the DC sources are equivalent. Three-stage setup can be accomplished by a cascaded association of three single-stages falls MLI.

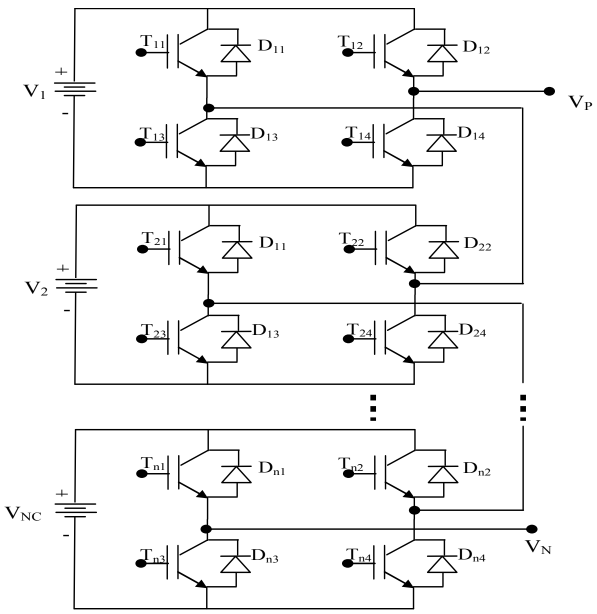


Fig. 2. The structure of cascade H-bridge multi-level inverter.

Likewise, different scaffolds additionally deliver output voltages. The air conditioner output of every H-scaffold has associated in arrangement with the end goal that the blended output voltage waveform is the entirety of the more significant part of the individual H-span yields. By associating the adequate number of H-extensions in a course and utilizing legitimate tweak conspire, an almost sinusoidal output voltage waveform can be integrated. Distinctive dc voltage levels delivered by 7-level CMLI are $V_1 = V_{dc}, V_2 = 2V_{dc}$ and $V_3 = 3V_{dc}$. The gadgets of H-extensions are worked at various exchanging edges α_1, α_2 and α_3 for H1, H2, and H3 H-connects separately (Sourabh Kundu et al., 2018). It might be noticed that the size and THD substance of the output voltage depends especially on these exchanging edges.

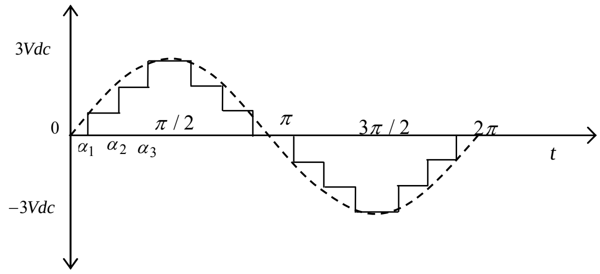


Fig. 3. The seven-level staircase voltage waveform.

3.2. THD Calculation of the MLI

The proposed symphonies end process has been performed in the seven-level inverter. The proposed inverter has three H-spans, which are associated with its own indistinguishable DC sources. Every extension contains four IGBTs, and the yields of the distinctive level of the H-span cells are associated in an arrangement. The aggregate output voltage of the proposed inverter is the seven-level staircase waveform. Any occasional waveform can be appeared to be the superposition of a crucial and an arrangement of consonant parts. By applying Fourier change, these segments can be removed. The recurrence of every consonant segment is an essential difference in it's basic (Santosh Kumar Singh et al., 2016). There are a few techniques to demonstrate the amount of music substance. The principal output voltage *V(t)* of the multilevel inverter can be portrayed in the accompanying equation (1),

$$V(t) = \sum_{n=1}^{\infty} A_n \sin n\alpha_n + B_n \cos n\alpha_n \tag{1}$$

The even music is truant (B_n=0) because of quarter wave symmetry of the output voltage. The n^{th} consonant is communicated with the principal quadrant exchanging edges. $\alpha_1, \alpha_2, ..., \alpha_m$ .The harmonics function is spoken to in equation (2),

$$A_n = \left(4V_{DC} \big/ n\pi \right) \sum_{k=1}^{m} \cos\ n\alpha_k \tag{2}$$

And, the switching angle is represented as the equation (3),

$$0 < \alpha_1 < \alpha_2 < ... < \alpha_m \tag{3}$$

For any odd harmonics, can be extended up to the k^{th} term where M is the quantity of variables relating to exchanging edges α_1 through α_m of the first quadrant. In chose consonant harmonics, A_n is allocated the wanted worth for the central part and likened to zero for the sounds to be dispensed with (Albert Alexander, 2016).

For first harmonics component is described as equation (4),

$$A_1 = \left(4V_{DC} \big/ \pi \right) \sum_{k=1}^{m} \cos\ \alpha_k = M \tag{4}$$

For fifth harmonics element is depicted in equation (5),

$$A_5 = \left(\frac{4V_{DC}}{5\pi} \right) \sum_{k=1}^{m} \cos 5\alpha_k = 0 \tag{5}$$

For n[th] harmonics element is invent as equation (6),

$$A_n = \left(\frac{4V_{DC}}{n\pi} \right) \sum_{k=1}^{m} \cos n\alpha_k = 0` \tag{6}$$

Where, $n = 3N - 1,$ when N is even $n = 3N - 2,$ when N is odd. M is the modulation index and is distinct as equation (7), To decide the switching angles, it N will be the quantity of partitioned DC sources used to comprehend. Contingent upon the adjustment record M, there are two locales: (i) possible area in which there are a set or a different arrangement of answers for exchanging edges and the specific symphonies end strategy can be effectively acknowledged, and (ii) the infeasible district in which there is no answer for the equations in (4), and accordingly, the low-arrange sounds can't be dispensed with from the ventured voltage waveforms. Nonlinear supernatural equations are in this manner framed and in the wake of comprehending these equations, α_1 through α_k are registered (Nami et al., 2011).

$$M = \frac{V_{req}}{4NV_{DC}/\pi}, (0 < M \leq 1) \tag{7}$$

The nature of a VSI output voltage is benchmarked by the THD that it created. The THD is characterized as equation (8),

$$THD = \frac{\sqrt{\sum_{i=2}^{n} (V_i)^2}}{V_1} \tag{8}$$

Much of the time, the THD is dealt with as the adequacy of the DC–AC vitality change frameworks. Where V_{req} is the craved estimation of the central segment and N is the quantity of partitioned DC sources which is set to three in the proposed seven-level inverter. Deciding exchanging edges, α_1, α_2 and α_3 fulfilling the fundamental objective of SHE technique (Lou et al., 2014). Besides, the outcomes ought to fulfil the limitations given in the above equations. Tackling these non-straight supernatural equations is a testing issue seeing that for a specific worth M there is no arrangement. The proposed controlling algorithm for this paper is introduced in taking after the segment.

3.3. Switching Angle Optimization using IABC Algorithm

In this area, we talked about advancing the switching angles taking into account the output voltage of the multi-level inverter. Here the IABC calculation is utilized for upgrading the switching angles and lessen the THD of the voltage signal. The IABC advanced calculation is utilized to enhance the execution of ABC calculation; the conduct of scout honey bee will be improved by using the RNN. From the yield of RNN, the typical results will be accomplished, on the grounds that the scout honeybee process relies on upon the rate of progress on the execution diagram, supplant as far as possible.

3.3.1. Performance of ABC Algorithm

The ABC calculation is a swarm based meta-heuristic calculation, which was presented for improving high dimensional numerical issues (Karaboga et al., 2012). It was enlivened by the insightful scavenging conduct of bumble bees. Regarding ABC, the potential arrangements are nourishment wellsprings of bumble bees. The wellness is resolved as far as the quality (nectar sum) of the nourishment source. There are three sorts of honey bees in the state: passer-by honey bees, utilized honey bees, and scout honey bee. A number of utilized honey bees or a spectator honey bee is equivalent to the sustenance sources. Utilized honey bees are connected with sustenance sources while spectator honey bees are those honeybees that stay in the hive and utilize the data accumulated from utilized honey bees to choose the nourishment source. One of the utilized honey bees, whose sustenance source is depleted, gets to be scout honey bee and she seeks the new nourishment source arbitrarily. Like the other swarm-based calculations, ABC is an iterative procedure. There are two basic procedures which infer the advancement of an ABC populace: the variety procedure, which empowers investigating diverse ranges of the hunting space and the choice procedure, which guarantees the misuse of the past encounters (Soma Biswas et al., 2013). In any case, it has been proved that ABC may once in a while quit continuing toward the worldwide ideal even though the populace has not joined to a neighbourhood ideal. ABC process requires a cycle of four stages: statement stage, utilized honey bees stage, passer-by honey bees stage and scout honeybee stage, each of which is clarified beneath:

(a) Initialization of the Population

In the underlying stride, the ABC creates a subjectively circled beginning people of NP courses of action using the going with equation (9),

$$y_{ij} = L_j + rand(0,1) \times (U_j - L_j) \tag{9}$$

Where, $i = \{1, 2, ..., NP\}$ $j = \{1, 2, ..., D\}$ L_j and U_j are the minimum and maximum bound of the arrangement variable, separately, is the measure of a populace, and is the number of advancement variables. After an introduction, the number of inhabitants in the arrangements is subjected to rehashed cycles of the inquiry procedure of the utilized honey bees, the passer-by honey bees, and scout honey bees. A counterfeit utilized or spectator honey bee probabilistically creates an adjustment of the arrangement in her memory for finding another nourishment source and assesses the nectar sum (wellness quality) of the new reference (new method).

(b) Employed Bees Phase

In this stage, utilized honey bees adjust the present arrangement in light of the data of individual encounters and the wellness esteem (nectar sum) of the new arrangement. On the off chance that the wellness estimation of the new nourishment source is higher than that of the old sustenance source, the honey bee redesigns her position with the new one and disposes of the old one (Bansal et al., 2013). The position redesign equation for j^{th} a dimension of i^{th} measurement of a competitor in this stage is appeared in taking after equation (10),

$$v_{ij} = y_{ij} + \varphi_{ij}(y_{ij} - y_{kj}) \quad (10)$$

Where, $k = \{1, 2, ..., NP\}$ NP is the number of utilized honey bees and $j = \{1, 2, ..., D\}$ are arbitrarily picked files. Although it k is resolved arbitrarily, it must be not quite the same as. Is an arbitrary number between [−1, 1]. It controls the generation of a neighbour nourishment source position around y_{ij}, and the change speaks to the examination of the neighbour sustenance positions outwardly by the honey bee. In equation (3) demonstrates that as the distinction between the parameters y_{ij} and y_{kj} of and abatements, the annoyance on the position y_{ij} diminishes, as well. Subsequently, as the pursuit ways to deal with the ideal arrangement in the inquiry space, the progression length is adaptively diminished. On the off chance that a parameter delivered by this operation surpasses its foreordained point of confinement, the parameter can be set to an adequate worth. In this work, the estimation of the parameter exceeding its breaking point is set as far as possible quality.

(c) Onlooker Bee's Phase

After finishing off the utilized honey bees stage, the spectator honey bees' stage is begun. In this stage, all the utilized honey bees share the wellness data (nectar) of the upgraded arrangements (sustenance sources) and their position data with the passer-by honey bees in the hive (Sharma and Bhambu, 2016). Spectator honey bees break down the accessible data and select an answer with likelihood, identified with its wellness. The likelihood might be ascertained utilizing taking after expression (there might be some other however should be an element of wellness) is given in equation (11),

$$P_i = \frac{fit_i}{\sum_{i=1}^{NP} fit_i} \quad (11)$$

Where, fit_i is the wellness estimation of the arrangement assessed by its utilized honey bee. This is relative to the nectar measure of the nourishment source fit_i in the position i. As on account of the utilized honey bee, passer-by honey bee delivers an alteration in the position in her memory and checks the wellness of the hopeful source. If the wellness is higher than that of the past one, the honey bee recollections the new position and overlooks the old one. In the ABC calculation, this is reproduced by arbitrarily creating a position and supplanting it with the relinquished one. In the ABC calculation, if a position can't be enhanced further through a foreordained number of cycles, called limit, then that sustenance source is thought to be surrendered (Xinjian Cai et al., 2016). After every applicant source position v_{ij} is delivered and afterward assessed by the fake honey bee, its execution is contrasted and that of y_{ij}. On the off chance that the new sustenance has equivalent or preferred nectar over the old source, it is supplanted with the old one in the memory. Something else, the old one is held. This procedure is rehashed by various emphases. The best result got amid this procedure is acknowledged as the ideal result.

3.4. Recurrent Neural Network for Learning Parameter Prediction

The RNN is the manufactured preparing and testing calculation, which takes a shot at the premise of a machine learning approach that models a human mind and comprises of various simulated neurons. The exhibited neurons have the inside associations, and every neuron in RNN gets multiple data sources, contingent upon the initiation elements of the RNN brings about the output level of the neuron. The learning undertaking is given as illustrations, which is known as preparing cases (Caihua Wu et al., 2016). Typically RNN has three layers like information layer, concealed layer, and output layer.

Here, the info layer comprises of mistake sign (e) and change of blunder sign (Δe). The output target layer is the control law (I_{abc}^{ref}), which is created for directing the heap reference voltages. The RNN yield is given to the inverter voltage controller. Additionally, the RNN has connection layer, which holds exercises of the repetitive layer from past time step. By utilizing the actual yield and the relating input, the RNN has been prepared.

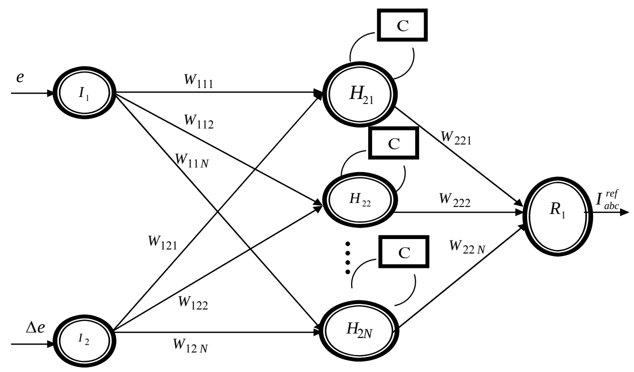


Fig. 4. Training structure of proposed recurrent layer neural network.

This preparation procedure uses the regulated learning process. Amid the preparation procedure, the shrouded layer gets the weight at a particular time delay from the setting layer. The RNN structure is clarified in the accompanying fig. 4. The preparation procedure is specified in the accompanying segment

(i) Supervised Learning and Training Process

The RNN is prepared by utilizing back engendering through time delay (BPTT) calculation with Bayesian control. The RNN procedure depends on the forward and in reverse pass. This area portrays about the preparation procedure of the RNN. Here, the administering learning law of the angle plunge is utilized to prepare the RNN amid the end of the statement procedure (Adam P.Trischler and Gabriele M.T.D.

Eleuterio, 2016). The determination is like the back spread calculation. It is utilized to guarantee the weight changes w_{bc}^3, w_b^2 and w_{ab}^2 of the RNN by utilizing the preparation datasets. By utilizing the chain administer, every layer blunder pace is figured and redesigned. The principle motivation behind the directing learning calculation is to minimize the blunder capacity, which is clarified in the accompanying equation (12),

$$E = \theta_d - \theta_{nor} \tag{12}$$

Where θ_{nor} is the real exchanging edge, θ_d is supplied by the Newton Raphson Algorithm and E is the blunder capacity. The blunder computation and weight redesigning are clarified in the accompanying.

Layer 1: This layer is employed to update the weight of the w_{bc}^3 m. At this juncture, the updated weight is offered by the subsequent equation (13),

$$w_{bc}^3(n+1) = w_{bc}^3(n) + \eta_{bc}\Delta w_{bc}^3(n) \tag{13}$$

Where instant weight function is computed as equation (14) and the error term is devised as equation (15),

$$\Delta w_{bc}^3 = -\frac{\partial E}{\partial R_c^3} = \left[-\frac{\partial E}{\partial R_c^3}\frac{\partial R_c^3}{\partial Net_c^3} \right] = \delta_c R_b \tag{14}$$

With,

$$\delta_c = -\frac{\partial E}{\partial R_c^3} = \left[-\frac{\partial E}{\partial e_s}\frac{\partial e_s}{\partial R_c^3} \right] \tag{15}$$

Where δ_c is proliferate the error term, η_{bc} is the learning rate for fiddle with the parameter w_{bc} .

Layer 2: This layer performs multiplication function, the updated rule for w_b^2 and w_{ab}^2 is depicted by the subsequent equation (16) and (17),

$$w_b^2(n+1) = w_b^2(n) + \eta_b\Delta w_b^2(n) \tag{16}$$

$$w_{ab}^2(n+1) = w_{ab}^2(n) + \eta_{ab}\Delta w_{ab}^2(n) \tag{17}$$

Where, the instant weight is approximate an equation (18) and (19),

$$\Delta w_b^2 = -\frac{\partial E}{\partial w_b^2} = \left[-\frac{\partial E}{\partial R_c^3}\frac{\partial R_c^3}{\partial R_b^2}\frac{\partial R_c^3}{\partial R_b^2} \right] = \delta_c w_{bc}^2 P_b^2 \tag{18}$$

And,

$$\Delta w_{ab}^2 = -\frac{\partial E}{\partial w_{ab}^2} = \left[-\frac{\partial E}{\partial R_c^3}\frac{\partial R_c^3}{\partial R_b^2}\frac{\partial R_b^2}{\partial w_{ab}^2} \right] = \delta_c \partial w_{bc}^2 Q_{ab}^2 \tag{19}$$

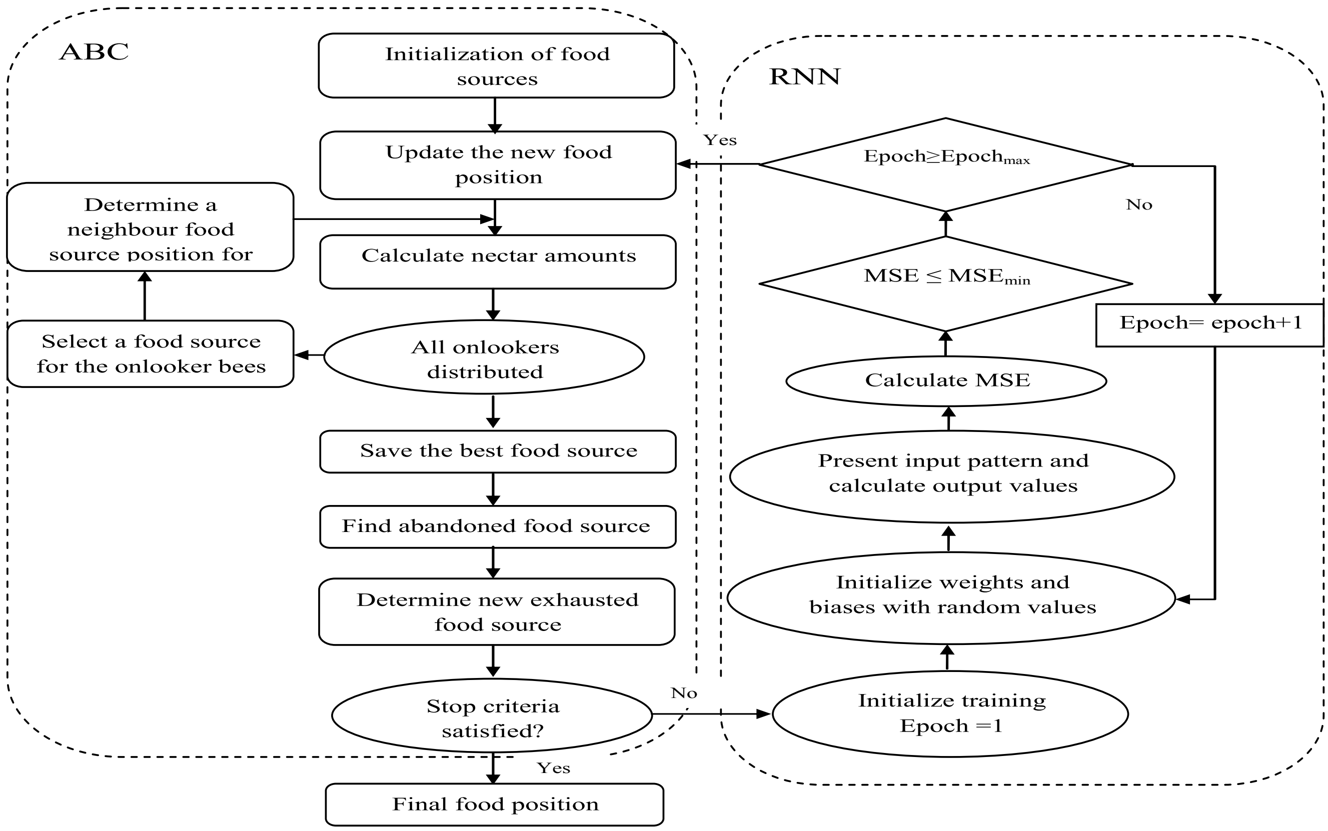
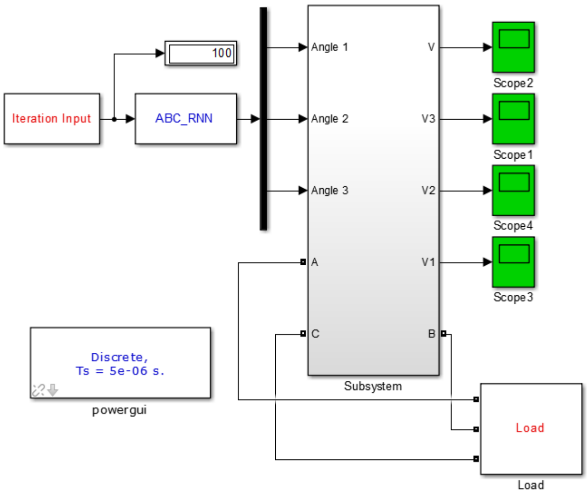


Fig. 5. Structure of the proposed algorithm.

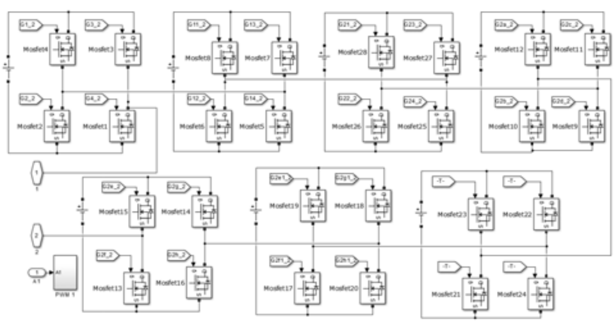
With η_b and η_{ab} i is the learning rate for changing the parameter w_b^2 and w_{ab}^2 individually, w_b^2 w_{ab}^2 and w_{bc} are the tuning parameters. We can infer a learning calculation that drives E to zero. Once the procedure is done, the RNN is prepared to given the switching angles. At last the RNN yield is given to the PWM. The proposed method structure is portrayed in the accompanying fig. 5. The detailed procedure is tried under the MATLAB/SIMULINK stage, and the adequacy of the proposed approach is investigated through the examination with alternate methods. The usage comes about, and the comparing talk is quickly depicted in the accompanying area.

3. RESULT AND DISCUSSIONS

In the segment, the thorough investigation of projected and available approaches is detailed. The planned method is applied in the MATLAB/Simulink platform. The Simulink model of the expected model with a controller as well as the seventh-level cascaded inverter is exemplified in fig. 6. At that time, the switching angles of the inverter θ_1, θ_2.... θ_n are enhanced using the projected IABC algorithm. Rendering to these switching angles and the harmonic voltages are assessed.



(i)



(ii)

Fig. 6. Simulink diagram for (i) Proposed model (ii) Seventh-level cascaded structure-MLI for single phase using a proposed algorithm.

The input of the IABC algorithm is characterized by the switching angles and the output using the harmonic voltages that are fashioned as a dataset. These datasets are skilled with the RNN and produce the control signals of the inverter. The efficiency of the projected hybrid method is associated with the conventional methods, namely, the GA algorithm and the ABC algorithm. The Key problems that ascend are related to the THD in the accomplishment of voltage sources control.

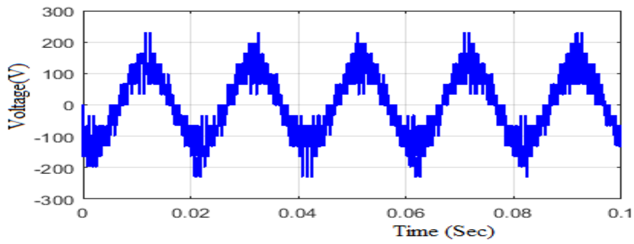
The seven-level inverter can attach with the projected controlling method of regulating the function of the inverter for associated with the load. The role of the inverter output voltage more than the grid voltage to safeguard power flow into the grid. From the output voltage, the projected controller controls the switching angle of the voltage signal. The variation of the switching angle is given to the PWM for generating the control signal to the inverter. PWM is utilized as it is one among the most effective approaches to generate the control signal. The PWM is attained by associating a high-frequency carrier along with a low-frequency sinusoid that is the modulating or else reference signal.

4.1. THD Elimination Analysis and Comparison with Proposed Algorithm

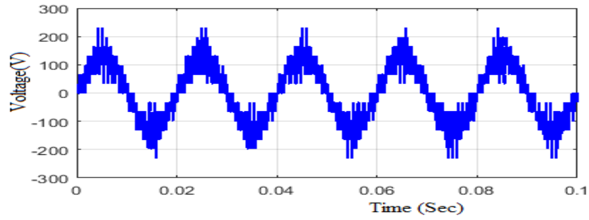
The projected method was applied in the MATLAB working platform, and the efficiency is unwavering by associating the available method. The input supply of the projected MLI is 230V, 50 Hz, and the design parameters are defined in the following table 1. Primarily the maximum time interval utilized in the projected method is T= 0.1 s. Firstly the voltage is produced for various intervals with amplitude 230 V that is taken into account as the reference voltage. The harmonic exclusion has been accomplished in the control methods namely GA, ABC, and projected IABC. The MLI output voltage waveform of every stage is provided in fig. 7.

Table 1. Parameters used in a proposed model.

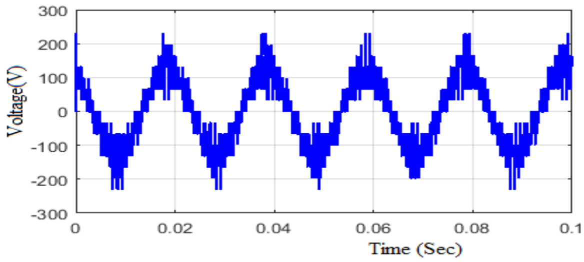
Proposed model (IABC) Parameters			
ABC		RNN	
Parameter	Values	Parameter	Values
Maximum iteration	10	Hidden layer	20
Bee length	100	Epochs	50
Population size	(100,3)	Delay	2



(a)

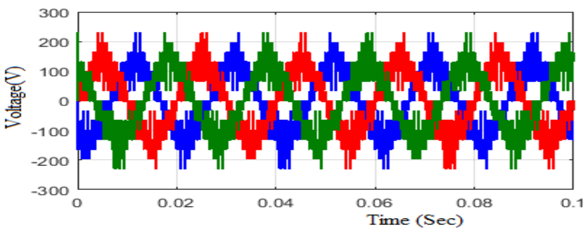


(b)

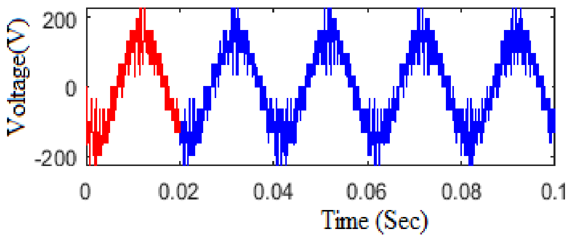


(c)

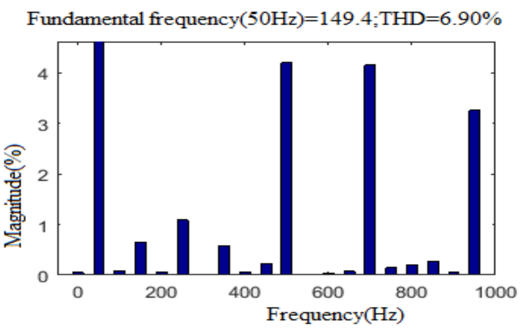
Fig. 7. The measured output voltage (a) phase-A voltage (b) phase-B voltage (c) phase-C voltage for the proposed system.



(a)



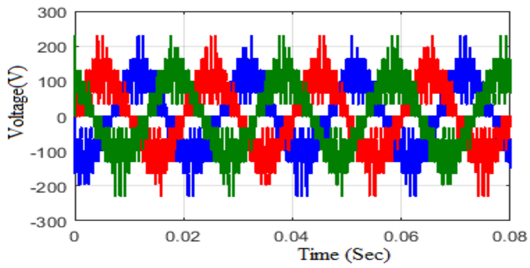
(b)



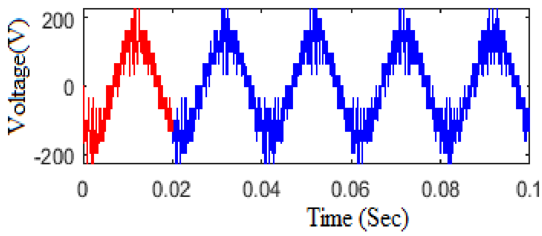
(c)

Fig. 8. The performance of GA with (a) the three-phase voltage (b) the sampled voltage signal and (c) FFT analysis of output voltage for THD.

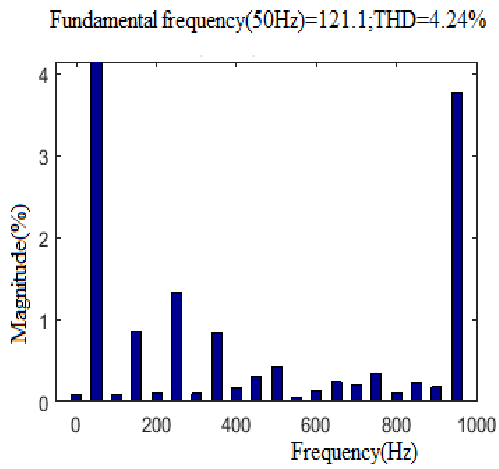
The MLI output voltage of GA monitoring method and the harmonic eradicated MLI output voltage is displayed in fig. 8. In this figure, displays that the three-phase output voltage and the sampled signal that can be utilized for the THD calculation. On the basis of this output voltage, the THD is 6.90% for GA based controlling technique. Then to progress the THD level the ABC is familiarized, the function of the ABC is displayed in fig. 9. In that the THD level of the traditional ABC is achieved as 4.24%, also prerequisite some enhancements it interchanges to a projected method. The projected system is the hybrid method that is the amalgamation of the ABC and RNN algorithm for enlightening the function of the projected method.



(a)



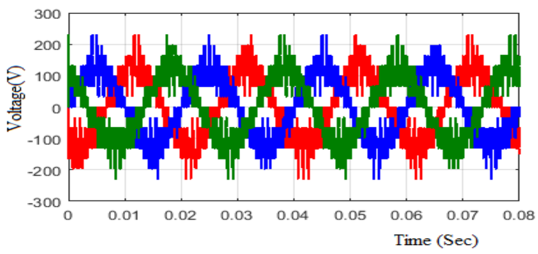
(b)



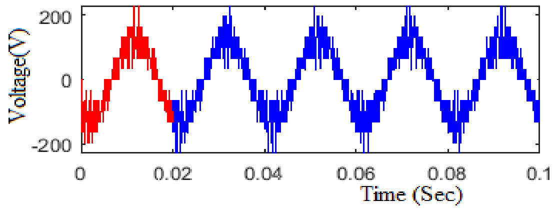
(c)

Fig. 9. The performance of ABC with (a) the three-phase voltage (b) the sampled voltage signal (c) FFT analysis of output voltage for THD.

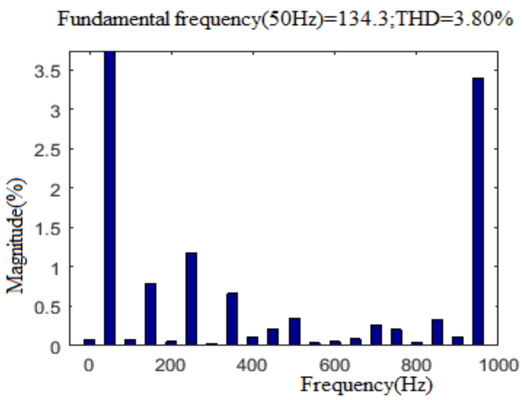
Then the efficacy of the projected method is analyzed with the usage of THD measurement. THD measurement can be performed using the selected cycles from the MLI output voltage. The projected method utilized in the MLI and the conforming THD is demonstrated in fig. 10, and the fundamental frequency also analyzed. The THD level of the projected method is 3.80%, and the investigation is better than the other traditional methods. By relating the available methods, the projected method is providing the better THD level and fair presentation for the load.



(a)



(b)



(c)

Fig. 10. The performance of the proposed technique with (a) the three-phase voltage (b) sampled voltage signal and (c) FFT analysis of output voltage for THD.

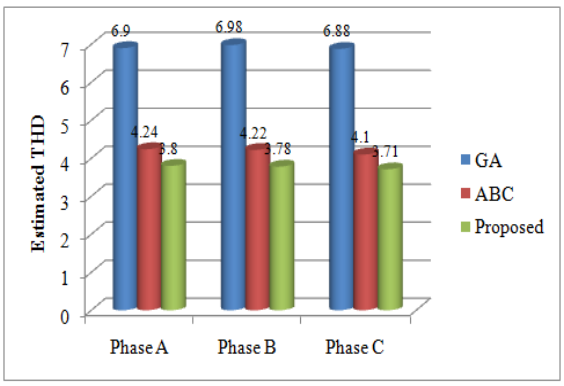


Fig. 11. The comparison analysis of the proposed technique with the existing techniques THD.

In this contrast investigation, three-phase signals can be utilized to compute the THD level with the traditional approaches. The amount of THD available in the output voltage for different signals with numerous control methods is fig.11. The simulation and trial solutions display that the projected modulation system not only aids in improved utilization of dc-link voltage but also retains distortion of the output voltage at a secondary level. The major power devices switch only once per cycle with the help of the planned modulation system, as is appropriate for high-power implementations. The projected modulation system can be implemented to multilevel cascaded inverters that are appropriate for high voltage, high-power applications like, power supplies, HVDC, motor drivers, and FACTS devices. The projected method can produce the required waveforms with a wider range of modulation indices and diminished THD for the voltage.

4. CONCLUSION

In this article, we have deliberated about the IABC based harmonic eradication for MLI, and it is replicated in the MATLAB/Simulink platform. The issue of harmonic elimination in MLI has been addressed given a seven-level gushed H-bridge inverter and suggesting an IABC method for the computation of the switching angles for eradication the harmonic signals. With the RNN prediction grounded the projected method was produced switching angles for the suitable voltage differences. The projected method representations were associated with the MLI output voltage THD with traditional methods such as GA and ABC. Besides, information verified on the three-phase seven-level cascaded H-bridge inverter provides validity and accurateness of the simulation solutions. The simulation solutions disclose that the projected IABC controller out achieves the ABC.

From the comparison, the solution displays that the anticipated practice is the well-enhanced method to eradicate the harmonics that are knowledgeable over the other workouts. While considering the practical consequences, there will be a significant rise in the ripple current whenever the inverter feeds non-linear load, and its major reason is magnetizing current. Due to the sampling time of the hardware prototype, the harmonics will be slightly higher than its simulation results. It will be reduced by either increasing the number of levels of inverter or designing a filter.

Even though the proposed system has satisfactory performance, But an EA, for the most part, comprises an arrangement of arbitrary answers for some enhancement issues. These arrangements associate with each other, and they are liable for irregular changes. For that reason, to get the best-ever arrangement in the selection, a different technique called CuttleFish Algorithm (CFA) will be the future extent of this work.

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