Harmonic Analysis of Photovoltaic Fed Asymmetric Multilevel Inverter using Modified Artificial Neural Network with Intelligent Optimization Techniques

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Abstract—**This paper presents the harmonic elimination in a Photovoltaic fed Grid connected asymmetric cascaded multilevel inverter (AMLI) supplied with diverse input sources from solar Photo Voltaic's (PV) using the modern intelligent techniques such as Modified Artificial Neural Networks (MANNs) with Enriched chicken Swarm Optimization (ECSO). AMLI topology decreases the quantities of semiconductor switches. The power yield is then sifted utilizing passive inductor part and afterwards synchronized to feed the Grid control framework. In MANN based approach, the switching angles are acquired with the fundamental component kept steady and lower order harmonics are limited or removed. The collection of information with shifting input voltages and exchanging edges are prepared with MANN. The equipped system is coordinated with sun oriented PV framework to decrease the harmonics. Also, the target work for the proposed idea is performed using optimization strategies to get the ideal switching angles required for the inverter switches. The modeling of solar panel is produced which fills in as the contribution to recreation. The Matlab/Simulink simulation results are compared with past reviews. The proposed combination offers a brilliant execution with important outcome in most minimal THD acquired and furthermore empowers the inverter to work under unhinged PV conditions exhaustively.**

Keywords — Power Generation, Multi Level Inverter, AMLI Topology, Artificial Neural Networks (ANN), Enriched Chicken Swarm Optimization (ECSO)

I. INTRODUCTION

The Photovoltaic (PV) power generation structure occupies an important role in the advancement of distributed electric power systems and Micro grids (MGs). Grid Connected Inverter (GCI) forms the core area for power quality enhancement in Distributed Generation Systems (DGSs) and MGs. The advancement in technology has revolutionized its growth by the introduction of new breed of power electronics with high power ratings and methods to reduce losses. In order to achieve low cost and compactness, as well as increased reliability and efficiency, the concept of the transformer less PV grid-connected inverter has been proposed.

The idea of Multi Level Inverter (MLI) is to use the available dc voltage sources to generate a multiple output voltage level. It improves harmonic distortion factor by reducing the lower order harmonics. The input sources used are generally battery, photovoltaic, rectified output from wind generator or a capacitor. The disadvantage of conventional MLI topologies is due to the presence of large number of switching devices. Since each switching device requires separate driver, it will result in large sizing and complexity of the system. The conventional cascaded MLI (AMLI) topology requires separate dc sources for every stepped output. The full bridge or H bridge are connected across the dc source in order to change the polarity across the load. A dead time is provided to avoid the conduction of switches in the same leg that leads to short circuit. The number of semiconductor switches required for m level is 2 (m - 1) and the number of dc sources required is (m -1)/2. Hence for higher level, large number of switches are employed which would result in high switching losses, large size and complexity of the circuit.

Recently, many derivatives of AMLI topology has emerged to reduce the space, size, and cost by improving the efficiency of power conversions design optimization. The topology presented has been used with reduced number of switches to obtain higher output levels. The polarity across the load is changed by full bridge that is connected across a series of dc sources which are added in an appropriate fashion to obtain stepped output across the load.

This paper proposes a new reduced switch topology version of MLI by unequal dc sources. It performs based on an ECSO Switching Scheme that will try to imitate the predefined parameter of a reference sine wave (i.e., amplitude and frequency) or the grid voltage (Vg). The proposed topology adopts reduced number of semiconductor switching devices and harmonic factor is improved when compared with the classical methods. The power output from MLI is then filtered using passive inductor component and then synchronized to feed the grid power system. The simulation results are verified by hardware implementation using an FPGA controller. The proposed grid interfacing technique uses ECSO based MANN to find out the

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frequency of the system and maintain the gird voltage and inverter current phase angle. Thus, it is not required to apply transcendent or palindrome functions for the calculation of the limit angles to interface the inverter to grid. Hence FPGA controller is used to interface the MLI to grid.

II. Literature Survey

A number of studies were carried out to prove the ability to optimize solar based multilevel inverter configurations of renewable energy systems in order to maximize performance while minimizing cost.

The over modulation schemes reported in the literature [6], [8], [10], [11] uses the fundamental geometrical understanding which is stated in [3]. However, these methods change from each other in the way they actualize the over modulation switching strategy. The method presented in [6] is the quickest one which depends on the processing time. It leads to distorted current and flux waveforms due to the significant harmonic content in the voltage waveform. The technique depicted in [10] utilizes computationally intensive algorithms to accomplish over modulation. As an alternate to pre-process the voltage vector, approximated piecewise linearized equations have been used in [8], [11] to achieve over modulation switching. All these methods have been extended for the dc bus utilization of the inverter until the six stage mode and all the strategies are tested for the open loop v/f drives. Throughout over modulation, lesser order harmonics are contributed to improve the fundamental voltage gain of the modulator. These harmonics interfere with the current linear controllers, when it is used as a part of a closed loop torque and flux vector control scheme [9]. A compensation method [9] is suggested that uses a different model to evaluate the harmonic component of the current vector in case of over modulation. The harmonic substance is then removed from the inputs to the linear controllers. During dynamics at higher angular velocities, the strategy proposed in [2], chooses the voltage vector that is nearest to the reference. This is attained by designing the reference voltage vector tip point on the closest inverter hexagon side. An additional strategy carried out in [4], utilizes neural networks for implementation [2]. This methodology fails to use the voltage capability and requires a computationally intensive control algorithm. The concept in the reference [5] an endeavor is prepared to conquer the adverse impact of the nonlinear gain on the current linear controllers by using the non-linear inverter gain capacity model. This technique seems to give an execution that is similar and much simpler approach using LUT that are proposed as a part of [3].

A class of discontinuous PWM methods has been discussed along with the SVM-based modulation methods [7]. This extends to the linear range of working principle using the sine-triangle PWM method. Likewise, the more traditional technique is tested for v/f induction motor drives in [1]. The uses of these strategies have been presented by hybrid method that consolidates and is presented in [7]. The utilization of these methods in the over modulation range is appeared to be oscillatory in the steady state of FOC drive performance.

The location of the reference vector and figures are described in the proposed scheme quickly on time [12]. Numerous multiphase MSVPWM algorithms have been developed in the recent couple of years [13]-[18]. The MSVPWM issue for the multilevel converters is tended in [13] and [18], where two different algorithms for converters are presented. The algorithm presented in [13] and [18], can also work with the multi-frequency with the use of multidimensional approach in [17]. The impact of modulation on total harmonic distortion (THD) in the line current has been scrutinized in [14] and [16-19].

The optimization methods such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and bee algorithm for Selective Harmonic Elimination (SHE) are introduced [20–22]. These methods require maximum number of iterations to terminate the process. GA based method is applied only to equal DC sources and needs considerable computational time. Artificial Neural Network (ANN) based method for an eleven level cascaded multilevel inverter is introduced in [20-21] which uses the Genetic Algorithm to obtain datasets. A nondeterministic method is used to solve the system for the angles in order to obtain dataset for ANN training. The coefficients of objective function are to be set based on trial and error basis, in this method. Also, GA requires fixed voltage in four of the five input voltages and the fifth one is to be varied of its range, whereas in real time, all the input DC voltages vary owing to temperature and irradiance of solar panels. Likewise, while considering the energy storage system with batteries, the voltages of batteries change due to their states of charge [23-25].

III. Proposed Solar Fed Multilevel Inverter Methodology

In this paper, a new diminished switch topology rendition of MLI by different dc sources with is proposed, as appeared in Fig. 1. It performance is based on an ECSO Switching Scheme that will attempt to impersonate the predefined parameter of a reference sine wave (i.e., abundancy and recurrence) or the grid voltage (Vg). The proposed topology receives the diminished number of semiconductor switching devices, and the harmonic component is enhanced when compared with the established techniques. The power yield from MLI is then separated utilizing passive inductor filter and after that synchronized to encourage the grid control framework. The reproduction results are checked by the execution using an FPGA controller. The proposed grid interfacing strategy utilizing ECSO based MANN on discovering the recurrence of the framework and keeping up the brace voltage and inverter current stage point. Subsequently, it is not required to apply otherworldly or palindrome capacities for the computation of the restrict edges to interface the inverter to grid. Henceforth FPGA controller is sufficient to interface the MLI to the network.

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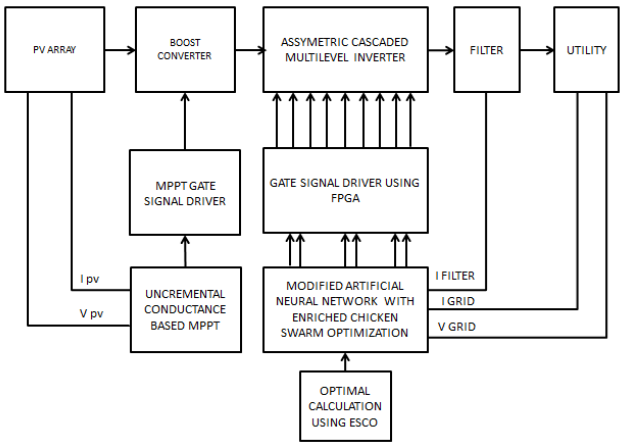


Figure 1. Block diagram of proposed SOLAR FED ASSYMETRIC MLI

In this paper, a solar fed fifteen level cascaded multilevel inverter with a novel, creative techniques such as modified Artificial Neural Network (MANN) optimized with ECSO Optimization is formulated to reduce the harmonic distortions. The datasets required for the ANN is obtained by solving the harmonic equations by considering changes in all the input DC voltages which provide the simplest form of approach and it does not require any sophisticated methodologies. The objective function and its related constraints developed for ECSO with detailed procedures are also given.

3.1 Photovoltaic System Model with MPPT For Input Voltage Control

To ensure the MPPT from the PV panels, the Incremental Conductance (IC) method is used to control the boost converter. A novel controller is then used to monitor the MLI inverter's input voltage and to generate the grid current reference's magnitude to be employed by the MANN with ECSO algorithm. The phase angle (θ_{grid}) of the reference current is obtained from a conventional phase-locked loop (PLL) to ensure the grid synchronization.

Solar based radiation information are gathered on a level surface. The created control from PV framework could be expanded significantly if the PV cluster is introduced confronting the sun. Numerous designs can be utilized as a part of this respect. The least difficult and least expensive route is to pick the yearly best tilt angle. The best angle edge is the scope points of the site; the PV exhibit tilted best case scenario tilt edge, some different setups utilized one pivot or two hub sun trackers to expand the created control from PV framework yet it will build the cost and structure complexities. Most extreme power point tracker ought to be utilized to track the greatest power generated from PV structure.

The global solar radiation on the best tilt angle can be obtained from the following equation:

$$G_{G,tilted} = G_{dir,tilted} + G_{diff,tilted} + G_{ref,tilted}$$

where Gdir,tilted, Gdiff,tilted, and Gref,tilted are the hourly direct, diffuse, and reflected radiations on the tilted surface. Values of these variables can be calculated from hourly solar radiation on a horizontal surface. The modified radiation data on a tilted surface and the hourly output power from PV array is given by the following equation:

$$P_{pv} = P_R f_{pv} \left(\frac{\bar{G}_T}{G_{T,STC}}\right)\left[1 + \alpha_P (T_c - T_{c,STC})\right]$$

where f_{pv} is the PV module derating factor, P_R is the PV module capacity, G_T is the incident irradiance on the tilted PV module, $G_{T,STC}$ is the incident irradiance at standard conditions, α_P is the temperature coefficient of power, Tc is the PV temperature, and $T_{c,STC}$ is the PV temperature under standard conditions.

3.2 Asymmetrical configuration of H-Bridge MLI Topology

The dc voltages of the H-bridge power cells are the same as introduced in the preceding section. Alternatively different dc voltages may be selected for the power cells. Fig. 2 is constructed with unequal dc voltages, but with integer multiples of magnitude dc sources. A switching scheme is implemented that renders an equal voltage stepped waveform. With (m - 1)/2 number of dc sources, m levels are obtained and (m -1) numbers of odd harmonics are eliminated. As a result, a number of sources required are halved.

Conversely, Fourier expansion of equal voltage steps is given by the following:

$$V(t) = \frac{4V_{dc}}{\pi} \sum_{n=odd}^{\infty} cosn\alpha_n \frac{sinn\omega t}{n} (3)$$

However, if voltage steps are unequal then,

$$V(t) = \frac{4V_{dc}}{\pi} \sum_{n=odd}^{\infty} \sum_{j-1}^{m-1} V_j \, cosn\alpha_n \frac{sinn\omega t}{n} (4)$$

where Vj is the least common factor of voltages. On the other hand, if the voltages are integer multiples, then the above equation can be written as

$$V(t) = \frac{4V_{dc}}{\pi} \sum_{n=odd}^{\infty} \sum_{j-1}^{m-1} j \cos(n\alpha_n)_n \frac{sinn\omega t}{n} (5)$$

Equation is solved for the values of α_n

Thus, with the help of switching scheme, a number of voltage levels can be increased without necessarily increasing the number of H-bridge cells in the cascade. This permits increased voltage steps in the inverter and hence yields improved voltage waveform for the same number of power cells. In the present structure the dc voltages for H-bridges are chosen as V_{DC}, $2V_{DC}$, and 3 V_{DC} respectively. The three-cell inverter leg is able to produce 15- level voltage waveform; that is, voltage waveform constitutes $7V_{DC}$,$6V_{DC}$,5 V_{DC}, 4 V_{DC}, 3 V_{DC}, 2 V_{DC}, V_{DC}, 0, -V_{DC} ,-$1V_{DC}$, -$2V_{DC}$,-$3V_{DC}$,-$4V_{DC}$,-$5V_{DC}$,-$6V_{DC}$,-7VDC, Simulation Circuit is shown in Fig. 2.

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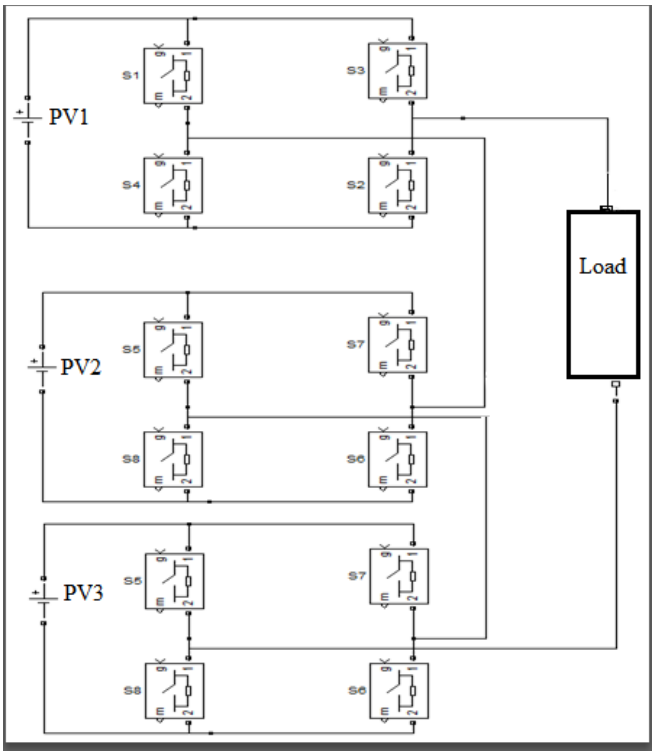


Figure 2. Proposed AMLI Topology

Fig. 2 shows the power circuit of cascaded AMLI fifteen level inverter which consists of 3 independent input sources from PV modules.

A. *Selective harmonic elimination technique*

Generally, to analyse the AMLIs output waveform, Fourier series expansion is applied. According to Fig. 2, the Fourier expansion of the phase voltage can be expressed in (6)

$$V(t) = \begin{cases} \frac{4V_{dc}}{\pi}[\cos(n\alpha_1) + \cos(n\alpha_2) + \cos(n\alpha_3)] & for\ odd \\ 0 & for\ even \end{cases} \quad (6)$$

in which Vdc is the amplitude of the dc sources that are considered to be equal in this paper. α1, α2 and α3 are switching angles of the cell that are limited between 0 and 90°. So, this constraint can be written as follows

$$0 < \alpha_1 \leq \alpha_2 \leq \alpha_3 < \frac{\pi}{2}(rad) \quad (7)$$

Selective harmonic elimination method deals with (6) not only to reduce or eliminate the lowest harmonics of the voltage waveform, but also to satisfy the fundamental component requirement. In this paper, a seven-level inverter is chosen to eliminate fifth and seventh harmonics from voltage waveforms. Triple harmonics will be removed from line voltage because of its symmetric characteristics. Thus, for the proposed inverter the set of equations are formed as follows

$$M = \frac{1}{3}[cos(\alpha_1) + cos(\alpha_3) + cos(\alpha_5)]$$

$$[cos(5\alpha_1) + cos(7\alpha_3) + cos(7\alpha_5)] = 0$$

$$[cos(7\alpha_1) + cos(7\alpha_3) + cos(7\alpha_5)] = 0$$

where M is the modulation index that can be defined as follows

$$M = \frac{V_{desired}}{4S(V_{dc}/\pi)} \quad 0 < M < 1$$

where $V_{desired}$ is the desired value of fundamental component and S is the number of separate dc sources which is set to three in the proposed seven-level inverter. Determining switching angles α1, α2 and α3 satisfying above equation is the main goal of selective harmonic elimination method. Furthermore, the results should satisfy constraints given. Solving these non-linear transcendental equations is a challenging problem noticing that for a certain value M there is no solution. The proposed methods are explained below.

IV. PROPOSED MANN WITH ECSO CONTROLLER STRATEGY

While interfacing the AMLI to the renewable energy sources, for example, PV panel or battery cells, the yield voltage will differ because of temperature, light and different elements. In AMLI based photovoltaic frameworks, the working DC voltages of standard PV modules go from 12 to 48V and from the AMLI based vitality stockpiling framework with batteries, the voltages of batteries additionally change because of their conditions of assessment. Hence, the different voltages arrive at the inverter stages will cause unregulated fundamental with a higher magnitude of low order harmonics.

To avoid this, a DC-DC converter is required at each stage to regulate the voltage which increases the complexity when a separate duty ratio control algorithm is incorporated at each stage. This section focuses on the determination of switching angles for the solar fed AMLI to cancel the low order harmonics using MANN. Initially, MathCAD Prime 2.0 software is used to obtain various datasets for the different set of input voltages by solving the harmonic elimination equations.

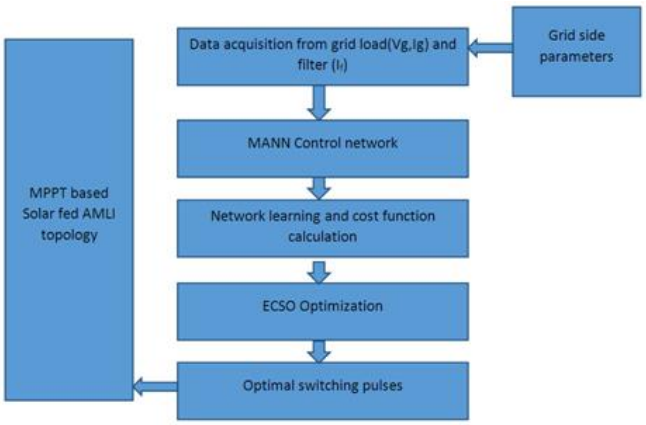


Figure 3. Proposed Controller method

The obtained datasets are utilized for training the neural system. The trained system is then executed to create the relating switching angles to the inverter switches based on

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the input voltages. The MANN is utilized to create the switching angles which are then given to the AMLI. The dataset required for the MANN preparing is obtained by comprehending the harmonic disposal conditions given in underneath by considering the variety of input voltages at all the sun powered boards. This variation is obtained from the perception of boards at different light levels with the test setup clarified in seconds. Harmonic elimination conditions are solved in the linear and non-linear arrangement of conditions inside a few seconds.

ECSO is a populace based meta-heuristic calculation that coupled a global investigation strategy to a neighborhood abuse procedure to give a decent harmony amongst sweeping statement and issue specificity. This calculation has been broadly utilized as a part of an electrical building, particularly in multi-target streamlining issues.

4.1 Tuning of weighting factor in Harmonics Reduction using MANN with ECSO

Artificial Neural Network is used to predict the switching angles and to control the AMLI. The advantage of an ANN approach is its capability to auto tune the application without the requirement of explicit function for the control. The Modified artificial neural network is well trained by means of the extorted features. The innovative MANN architecture consists of three input units, n hidden units and one output unit as shown in figure.4. It is trained based on the dataset supplied to perform a particular function which is performed by adjusting the values of connection "weights" between the elements input voltages (V) from the solar panels the required set of switching angle (radians) values are obtained using Back Propagation (BPN) algorithm. The neural network works make use of two phases, one is the learning phase and the other is the optimal tuning phase.

A. Learning Phase

In the Learningphase, nearly, 1500 datasets are collected in such a way that for the corresponding input voltages (V) from the solar panels, the required set of switching angle (radians) values are obtained using Back Propagation (BPN) algorithm. Initially, the nodes are given random weights. As the output is already known in the training phase, the output obtained from the neural network is compared to the original and weights are varied so as to reduce the error. This process is carried for a large data so as to yield a stable system having weights assigned in the nodes.

Modified Artificial neural Network is used in our methodology. The structure is delineated in Fig. 4. The input (From PV panels) layer has neurons, the hidden layer has neurons and the yield layer has neurons i.e. the quantity of values extending from 0 to 1. Back propagation calculation is utilized to prepare the neural system, which is portrayed beneath.

Step 1: Produce subjective weights inside the interim [0, 1] and role out to the concealed layer neurons and the yield layer neurons. Keep up a solidarity esteem weight for all neurons of the information layer.

Step 2: Input the training dataset I to Learn and decide the BP error as takes after

$$BP_{err} = C_{tar} - C_{out} \tag{8}$$

In Eq. (8), C_{tar} is the objective output and C_{out} is the system output, which can be determined as $C_{out} = [Y_2^{(1)}\ Y_2^{(2)} \ldots Y_2^{(N)}]$, $Y_2^{(1)}, Y_2^{(2)}, \ldots, Y_2^{(N)}$ are the grid system outputs. The network outputs can be determined as

$$Y_2^{(l)} = \sum_{r=1}^{N_H} w_{2r1} Y_1(r) \tag{9}$$

where,

$$Y_1(r) = \frac{1}{1 + \exp(-w_{11r} \cdot C_{in})} \tag{10}$$

Eq. (9) and Eq. (10) signifies the initiation function performed in the output layer and hidden layer respectively.

Step 3: Regulate the weights of all neurons as $w = w + \Delta w$, where, Δw is the change in weight which can be determined as

$$\Delta w = \gamma . \mathrm{Y}_2 . \mathrm{BP}_{\mathrm{err}} \tag{11}$$

In Eq. (11), γ is the learning rate, usually it ranges from 0.12 to 0.7.

Step 4: Replicate the procedure from step 2, until BP error gets minimalized to a smallest value. Nearly, the standard to be satisfied is $BP_{err} < 0.1$.

For a fifteen level inverter, the above conditions are explained. In the above requirements, obviously by furnishing the necessary voltage with desired esteem and other harmonic parts equivalent to zero, the lower arrange consonant substance, for example, third, fifth, seventh, ninth, eleventh, and thirteenth are dispensed to such an extent that the sought major is kept consistent. A portion of the datasets acquired is recorded in Table I.

TABLE I. SAMPLE DATASET FOR MANN TRAINING

S.No	***Input voltage***	***Switching angles(rad)***
1	[42.4, 52.6, 52.7, 43.6, 53.7, 45.8, 42.5]	[0.111, 0.211, 0.413, 0.559, 0.798, 1.1, 1.535]
2	[44.4, 40.6, 41.7, 42.6, 52.7, 40.8, 44.5]	[0.117, 0.196, 0.427, 0.584, 0.802, 1.093, 1.526]
3	[44.4, 52.6, 52.7, 45.6, 53.7, 40.8, 44.5]	[0.136, 0.19, 0.444, 0.594, 0.834, 1.117, 1.533]
4	40.4, 52.6, 52.7, 41.6, 53.7, 42.8, 42.5]	[0.112, 0.198, 0.432, 0.587, 0.812, 1.104, 1.53]

B. Optimal Tuning Phase of Switching pulse

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In the optimal tuning phase, the PV input voltage is fed to the trained neural network with particular weights in the nodes and the respective output is calculated based on the trained dataset. In ordinary neural network the process will be stopped after tuning. In the proposed modified neural network, testing process has been incorporated in the optimization algorithm in order to optimize the weight used for testing. In our proposed method the weights are optimized with the help of the Enriched Chicken Swarm Optimization Algorithm. By incorporating optimization process the switching angles calculation fed MLI provides better tuning of the switching angles. The structure of the artificial neural network is illustrated in Fig.4.

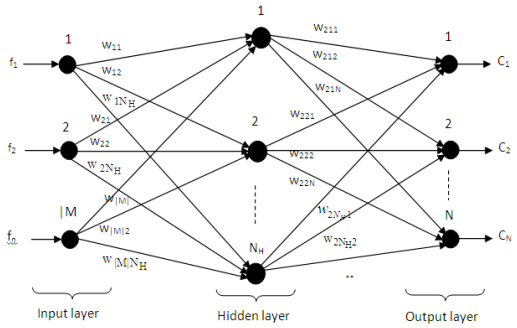


Figure 4. Structure of Modified Artificial Neural Network

4.2 ECSO algorithm for optimizing weights in ANN

The chicken swarm enhancement impersonates the hierarchal request in the chicken swarm and the practices of the chicken swarm, which originates from the perception of the flying creatures scrounging conduct. The chicken swarm can be separated into a few gatherings, each of which comprises of one chicken, many hens, and a few chicks. At the point when scrounging, the chickens can simply discover sustenance especially. The hens dependably take after the chickens to search for food, and the chicks took after their mom looking for nourishment. The unique people inside the chicken swarm take after various laws of movements. There exist rivalries between the individual people inside the chicken swarm under the particular hierarchal request.

The position of every individual inside the chicken swarm speaks to an attainable arrangement of the enhancement issue. To start with characterize the accompanying factors before portraying area overhaul recipe of the people inside the chicken swarm: RN, HN, CN, and MN are the quantity of chickens, hens, chicks and mother hens, separately; N is the number of the entire chicken swarm, D is the measurement of the hunting space; xi;j(t) iϵ [1;N], jϵ [1; D] is the position of every distinction time t.

In the chicken swarm, the best RN chickens would be thought to be the chickens, while the most exceedingly awful CN ones would be viewed as the chicks. Whatever is left of the chicken swarm is seen as the hens. Chickens with best fitting qualities have to need for nourishment access than the ones with more unfavorable appropriate conditions. The position overhaul conditions of the chickens can be detailed underneath:

$$x_{i,j}(t+1) = x_{i,j}(t)\big(1 + randn(0,\sigma^2)\big), (12)$$

$$\sigma^2 = \begin{cases} 1, & f_i \geq f_k, k \in [1,N], k \neq i \\ \exp\left(\dfrac{f_k - f_i}{|f_i| + \varepsilon}\right), & otherwise \end{cases}$$

where $randn(0,\sigma^2)$ is a Gaussian distribution with mean 0 and standard deviation σ, ε is the small constant to avoid zero-division-error, and k is a rooster's index, which is randomly selected from the roosters group $k \neq i, fi$is the fitness value of particle i. As for the hens, they can follow their group-mate roosters to search for food and randomly steal the food found by other the individuals. The position update equations of the hens are as follows:

$$x_{i,j}^{t+1} = x_{i,j}^{t} + C_1\left(randn\left(x_{r1,j}^{t}, x_{i,j}^{t}\right)\right) + C_2\left(randn\left(x_{r2,j}^{t}, x_{i,j}^{t}\right)\right),$$

Where

$$C_1 = \exp\left(\frac{f_i - f_{r1}}{|f_i| + \varepsilon}\right)$$

$$C_2 = \exp(f_{r2} - f_i)$$

where *rand* is a uniform random number over [0; 1], $r1$ is an index of the rooster, which is the ith hen's group-mate, and $r2$ is the index of the chicken (rooster or hen), which is randomly chosen from the chicken swarm $r1 \neq r2$. With respect to the chicks, they follow their mother to forage for food. The position update equation of the chicks is formulated below:

$$X_{i,j}^{t+1} = X_{i,j}^{t} + F(X_{m,j}^{t} - X_{i,j}^{t})$$

where $X_{m,j}^{t}$ is the position of the chick's mother = [0; 2] is the follow coefficient, which indicates that the chick follows its mother to forage for food.

ECSO calculation is utilized to improve the weight values. The detail procedure for enhanced chicken swarm streamlining is defined beneath:

Step 1: Initialize the chicken swarm x and the related parameter (RN ;HN ;CN ;MN ; _).

Step 2: Evaluate the fitting estimations of the chicken swarm x, and instate the individual best position pbest and the worldwide best position gbest.t = 1.

Step 3: If t mod G is 1, sort the fitting estimations of the people inside the chicken swarm, and assemble the hierarchal request of the chicken swarm; separate the entire chicken swarm into a few subgroups and guarantee the relationship between the hens and the chicks.

Step 4: Renew the position of the chickens, the hens and the chicks utilizing conditions (12)- (14) separately, and compute the fitting estimations of the people.

Step 5: Update the individual best position pbest and the worldwide best position gbest.

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Step 6: t =t +1, if the emphasis stop condition is met, end cycle and fare the worldwide ideal; generally, go to step 3.

By using the ECSO calculation as appeared over, the weights are soled out to the ANN which makes the THD of less twisting achieved. The MANN conveys bring down bends as far as exchanging edges of joining the improvement procedure.

The proposed system is then approved for its execution and thereafter Simulink model is created. To produce demonstration, the system gives the relating exchanging points on furnishing the voltage values. The exchanging edges produced by the neural system are then changed over to the comparing gating signals by activating the circuit and after that fed to the doors of the MOSFET switches in the H Bridge inverter. The activating circuit comprises of a triangular waveform which is contrasted and the balancing signal acquired from the neural system and the beats are created which are then sustained to the doors of the MLI switches. This outcomes is the base of Total Harmonic Distortion (THD) and furthermore the end of particular pre-request values.

V. SIMULATION RESULTS AND DISCUSSION

The simulated results are shown in figures 6 using MATLAB Simulink. The specifications of simulation parameters are shown in Table.II

TABLE-II SIMULATION PARAMETER SPECIFICATIONS

S.No	*Parameters*	*Function Values*
1	Input layer Neurons	3(PV input)
2	Hidden layer Neurons	10
3	Output layer Neurons	7(switching angles)
4	Network	Back propagation(BP)
5	Training Algorithm	ECSO
6	Learning Rate	0.97
7	Number of iterations	100

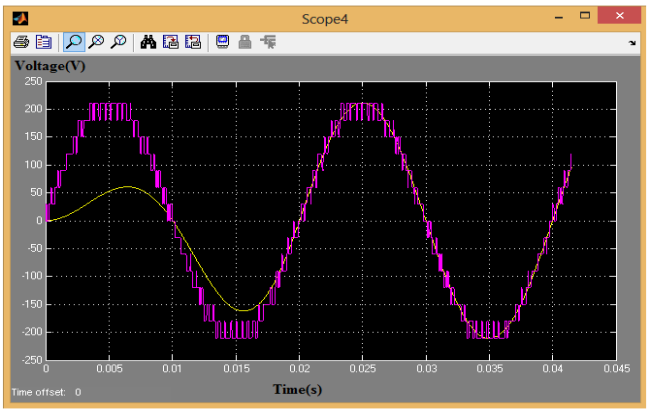


Figure 5. Simulation output voltage for 15-Level MLI using proposed control

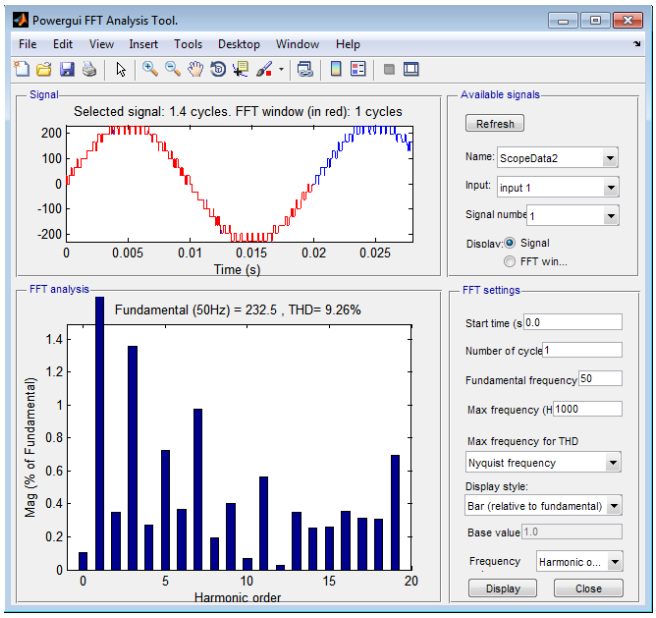


Figure 6. FFT Analysis for 15-level inverter model

6.1 Comparison Results of Various Controllers

Several controller schemes were simulated in various small MLI topology. The harmonic performance is compared based on the THD values. The comparison results are shown in Table III. On comparing the harmonic performance, proposed MANN with ECSO produces better results.

TABLE-III PERFORMANCE COMPARISON OF VARIOUS CONTROLLERS IN 15-LEVEL INVERTER

S.No	*Controller used*	*Levels*	*Number of Switches*	*THD (%)*
1	PI	15	19	20.32
2	Fuzzy	15	18	15.56
3	ANN	15	14	13.12
4	Proposed. MANN with ECSO	15	12	9.26

VI. CONCLUSION

A seven stage fifteen level solar fed cascaded multilevel inverter for the elimination of certain harmonic orders is designed and implemented using intelligent techniques such as MANN with ECSO Algorithm for the required power quality improvement. Based on the results, it is found that the MANN based technique gives better results when compared to other methods This system is well suitable for implementing the solar photovoltaic system. The methods are also compared with the conventional modulation controller approaches, which shows that MANN based method which incorporates harmonic elimination is more suitable in Solar fed MLI systems. The advantages of this method include simple computational algorithm and no requirement of filters, detailed look up

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tables and output transformers. Moreover, this technique can be implemented in both standalone and grid interacted PV systems. While considering the other techniques such as ECSO, it requires the constant input voltage. If it has to be implemented in a solar photovoltaic system requires an additional circuitry to maintain the input at constant level before it is fed to the individual inverter stages. The solar photovoltaic model are modelled considering the variations with respect to the temperature and irradiance, which is used as input source. Power quality analysis for the proposed control algorithm is also included to show the effectiveness of the proposed method.

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