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Selective Harmonic Elimination on a Multilevel Inverter Using Ann and Genetic Algorithm Optimization Techniques

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Abstract-The multilevel inverter is an electronic device which converts DC to AC used for high power utility applications. But the inverter output waveform contains harmonics that has to be eliminated to give sinusoidal waveform with low harmonics less than 3%. This project shows the selective harmonic elimination in voltage output of eleven-level cascaded multilevel inverter by considering varying the values of dc sources. Genetic algorithm (GA) is used to obtain the switching angles and the angles are determined by training neural network (ANN). Even when the switching angles are increased this proposed strategy can be withstood. Results obtained show the elimination of harmonics. Proposed system is simulated using MATLAB/SIMULINK.

Keywords- DC, AC, GA, ANN, MATLAB/SIMULINK.

1. INTRODUCTION

An inverter is a device which is able to change dc to ac. Multilevel Inverter (MLI) is one of the types of inverter. In this project 11-level cascaded MLI is used, which is useful for high power quality applications. The output voltage waveform of MLI will have harmonics and the waveform is not sinusoidal due to fault occurrence. Analysis is done using FFT (fast Fourier transform analysis). FFT based extraction is used on the MLI waveform. The harmonic pattern of the waveform during the fault condition is used as the feature and artificial neural network (ANN) is edified (trained) using these features. Short circuit and open circuit of switches are considered as faults for analysis. The strategies like molecule swarm advancement (PSO) and hereditary calculation or modified genetic algorithm (GA) utilized for preparing the neural system is to decrease the blunder and time taken for preparing. These adjustments in the deficiency conclusion framework would incredibly decrease the multifaceted nature in calculation in the forecast framework.The analysis and comparison is performed on cascaded (Parallel) H-bridge multilevel inverter as it has got application in drives. CMLI may have more potential than others since information perhaps normally hook up (interfaced) to the MLI to give more advanced yield voltages. This may endeavor (offer) a tremendous (high) transformer less MLI in network associated application (uses). It contains more number of switches relying upon number of yield voltages; subsequently high exchanging misfortunes will be wiped out.Exchanging points are ascertained utilizing GA and arrangements are put away gaze upward table. But some working qualities would be missed .consequently rather than gaze upward table ANN is utilized, which if all around prepared, can explain the unpredictable arrangements and runs quick and gives comes about rapidly.

1.1 INVERTER

Inverter is a gadget which changes over dc to ac and it is utilized as a crisis move down to home.
Multilevel inverter (MLI) is one of the sorts of inverter. A few applications require high power. Some need low voltage low power. Be that as it may, high power may not be reasonable for all applications. It might make harm different burdens. Henceforth MLI is presented for high power medium voltage conditions.

1.2 CLASSIFICATION OF MLI

MLI is classified into three kinds
1. Diode clamped multilevel inverter
2. Flying capacitors multilevel inverter
3. Cascaded h-bridge multilevel inverter

2. GENETIC ALGORITHM

Genetic algorithm is roused by Darwin's hypothesis about development, for example, legacy, change, determination and hybrid. It is a populace based inquiry strategy utilized as a part of

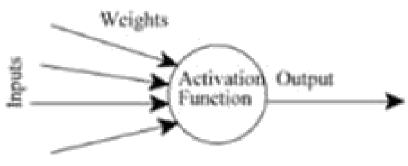

Fig.3.1 Natural neuron

figuring to discover genuine answers for improvement and pursuit issues.

The features of GA (genetic algorithm) are

- It is a populace based
- Uses recombination for blending data of c Competitor arrangements to another one.

Hereditary calculation begins with an arrangement of arrangements called populace (chromosomes). Arrangement from that populace are taken by wellness and used to shape another arrangement trusting that the new arrangement will be superior to the old one. This is rehashed until we get the best arrangement.

2.1 REPRESENTATION

Objects framing conceivable arrangement inside unique issue setting are known as phenotypes, the people inside the GA, are known as genotypes.

2.2 SELECTION

Arrangements are chosen however wellness based procedure, where fitter arrangements are commonly more inclined to be chosen. This is done by wheel determination. i.e., people are given a likelihood of being chosen that is specifically relative to their wellness.

The part of guardian determination (mating choice) is to recognize among people in view of their quality to permit the better people to wind up guardians of the people to come. Guardian determination is probabilistic. In this manner, fantastic people get a higher opportunity to wind up guardians than those with least quality.

2.3 CROSSOVER

Hybrid the guardians to shape another posterity. On the off chance that hybrid was not performed, posterity is a precise of guardians.

A twofold variety administrator is called recombining or hybrid. This administrator consolidates data from the guardian genotypes to maybe a couple posterity genotypes. Guidelines of hybrid are basic: by mating 2 people with various however alluring components, we can deliver a posterity which joins both of those elements.

2.4 MUTATION

After the above two methods are done, process will have a new population, some will be copied and others are produced by crossover. To confirm that individuals are not same, mutation is performed.

a. PSEUDO CODE OF GENETIC ALGORITHM

Begin
INITIALIZE population with random candidate solutions;
EVALUATE each candidate;
Repeat
SELECT parents;
RECOMBINE pairs of parents;
MUTATE the resulting children;
EVALUATE children;
SELECT individuals for the next generation
Until TERMINATION-CONDITION is satisfied
End

3. ARTIFICIAL NEURAL NETWORK

There will be so many complex problems. These can be solved by converting them into simple elements so that these complex problems will be solved in easier way where we can understand in a simple manner. Networks are used to achieve this.

There are so many different types of networks. Every network consists of nodes; each node is connected by links. From that connection each node receives the input signal, process them and output is obtained finally. Connection can be unidirectional or bidirectional.

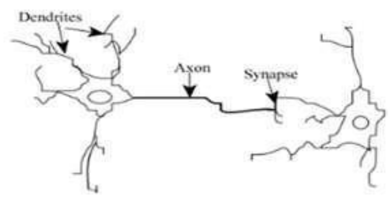

Fig.3.2 Artificial neuron

The nodes can be seen as artificial neurons which are called artificial neural networks (ANNs). Signals are received by natural neurons through synapse which are placed on dendrites or membrane of neuron.

Neuron will activate if the strong signals are received. Once the neuron is activated through axon, signal is emitted. Another synapse receives the emitted signal and other neurons get activated.

Here inputs resemble neural connection and those are duplicated by weights. Weights are called signal quality. Actuation of neuron is controlled by scientific capacity. ANN joins counterfeit neurons to prepare the data.

ANN calculations are like human cerebrum. ANN is a framework made out of numerous straightforward handling components working in parallel which can gain, store and use trial learning.

Every component of NN is a hub called unit. Units are associated by connections. Every connection has a numeric weight. It can sum up the nonlinear issues that are perplexing in nature and requires tedious estimations. As the quantity of dc sources builds, gaze upward table likewise expands prompting tedious calculations. Here feed forward ANN with sigmoid capacity, shrouded layer and direct yield capacity layer. ANN takes genuine dc source values and gives plots for control framework.

3.1 APPLICATIONS OF NEURAL NETWORK

1. Biomedical Signal Processing
2. Biometric Identification
3. Framework Reliability
4. Business
5. Inductor Modeling

3.2 COMPUTATIONS OF NEURAL NETWORK

There are 2 types of computations
1. Linear network
2. Nonlinear network

Linear network: It is an input function which calculates the weighted sum of all inputs.
Nonlinear network: It is an activation function which transforms sum into activation function.

$In_i = \sum_{j,i} a_j = W_i . a_i$……input function
$a_i \leftarrow g(in_i) = g(\sum_{j,i} a_j)$………activation function

3.3 ACTIVATION FUNCTION

There are 3 types of activation function
1. Sigmoid function
2. Sign function
3. Step function

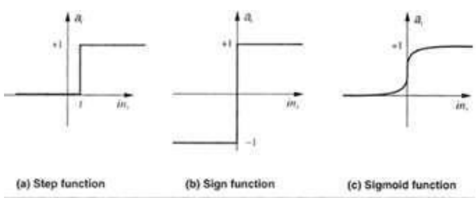

Fig.4.4 Activation types

3. 4 STRUCTURE OF ARTIFICIAL NEURAL NETWORK

The structure of ANN consists of three units
1. Input unit
2. Hidden unit (activation function)
3. Output unit

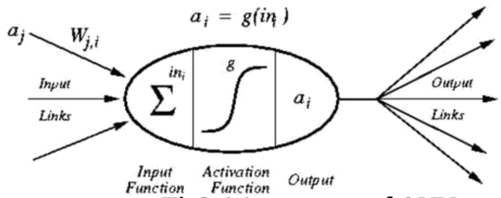

Fig3.4.1 structure of ANN

3.4 NETWORK STRUCTURES

1. Recurrent network structure
2. Feed-forward network structure

3.5.1 Recurrent network structure

Its inward state is put away in its enactment level and permits actuation to be sustained back to the more established unit. It can get to be temperamental and sway. Time taken to register the outcome is increasingly and trouble in learning. Complex outlines can be actualized furthermore it can demonstrate certain frameworks with inner state.

3.5.2 Feed-forward network structure

These are orchestrated in layers, in which every unit is connected just in the unit in next layer. Inner state doesn't exits not at all like intermittent system structure. Calculations can happen from contribution to yield units. Units are not connected between the same layers

3.6. PERCEPTRONS

Network without hidden layer is called perceptron. It is also called as layered feed-forward networks which is first studied in 1950s.

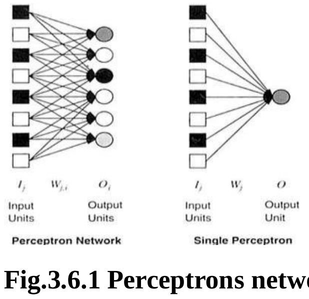

Fig.3.6.1 Perceptrons network

3.6.1 LINEAR SEPARABILITY

It is possible to obtain linearity in AN and OR gates but it is not possible for XOR gate as shown in below figure.

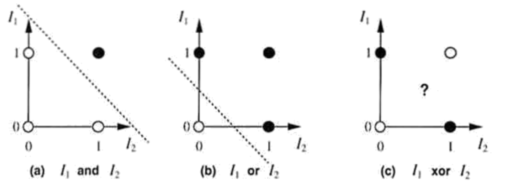

Fig.3.6.1.1 Linear separability in Perceptrons

3.7 FEED-FORWARD NETWORKS

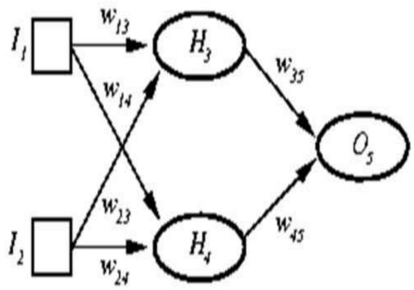

Fig.3.7.1. 2-layer feed-forward example

3.8 HIDDEN LAYERS

Each hidden layer can be a perceptron, learning a separating line. Output units can result in intersection of half planes given by hidden layer.
1st layer is input node
N-1 is hidden layers
Layer N is output node

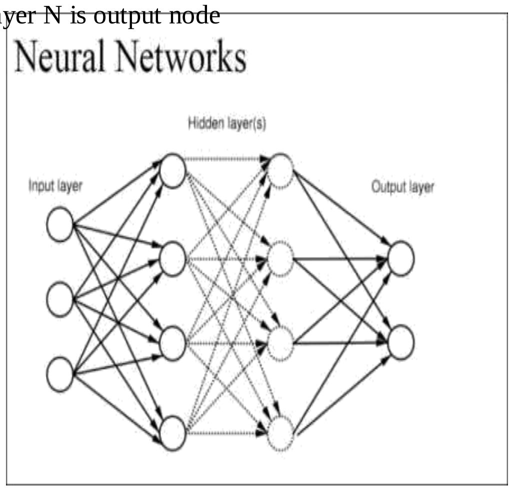

Fig.3.8.1 Feed-forward NN with hidden layer

3.9 BACKPROPAGATION NETWORKS

It is invented by Bryson and Ho in the year 1969. Its working principle is same as perceptrons and is sensible to divide the weight.

3.10 PURPOSE OF USING ANN

Obtaining the switching angles is limited to equal dc sources. But in this paper we can obtain the switching angles for unequal dc sources and solutions will be stored in look up table. But with the look up table some operating points might be missed. Hence instead of look up table artificial neural network is used to store the solutions, which if well trained has the capacity to solve the solutions which are complex in nature. With the ANN process will be very fast and gives the results quickly.

4. CIRCUIT OPERATION

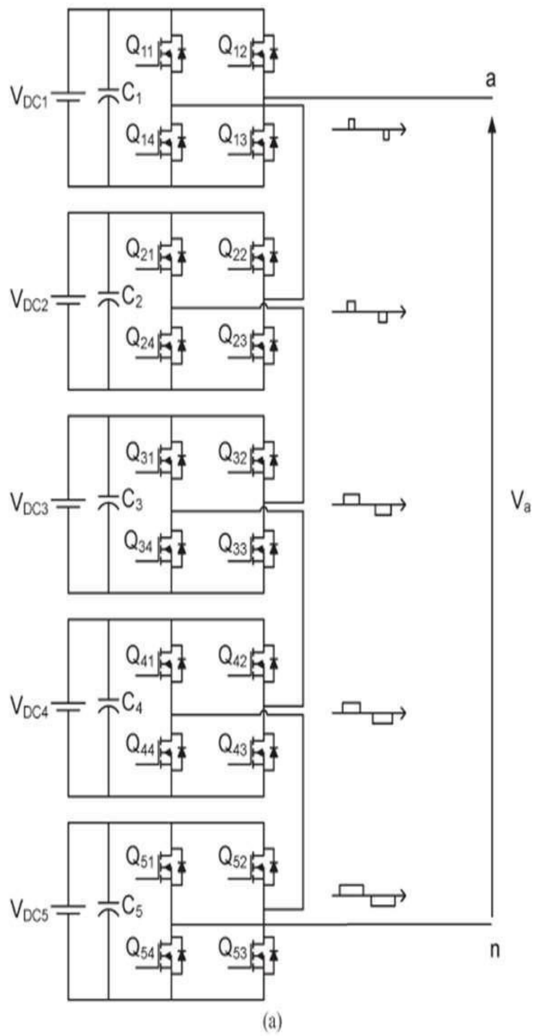

Fig.4.1 Eleven level cascaded multilevel Inverter

Circuit of an 11-level inverter is appeared in above figure. Every different dc sources is associated with H-span inverter. Every inverter level can create three distinctive yield voltages, +V dc,0, and –V dc by interfacing direct current source to AC yield by various mixes of the 4 switches Q11,Q12,Q13, and Q14. Switches Q11 and Q14 are swung on to get +V dc. Switches Q12 and Q13 are swung on to get –V dc. To get 0 voltages switches Q11, Q12 or Q13, Q14 are turned on. The ac yield voltage of each of the distinctive full-connect bridge levels are associated in arrangement such that the combined voltage is the aggregate of the inverter yields. Quantity of output level n in a fell inverter is characterized by n=2k+1, k is the quantity of dc sources.

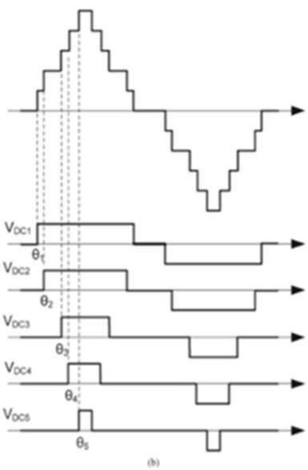

Fig.4.2 Output voltage waveform of 11 level multilevel inverter

$V_{fund} = \frac{4}{\ } \cdot (V_{dc1} \cos(\ _1) + V_{dc2} \cos(\ _2) + \ldots + V_{dc5} \cos(\ _5)) \ldots\ldots$ (5.2)

$V_{5th} = \frac{4}{.5} \cdot (V_{dc1} \cos(5\ _1) + V_{dc2} \cos(5\ _2) + \ldots + V_{dc5} \cos(5\ _5))$ … (5.3)

$V_{7th} = \frac{4}{.7} \cdot (V_{dc1} \cos(7\ _1) + V_{dc2} \cos(7\ _2) + \ldots + V_{dc5} \cos(7\ _5))$ … (5.4)

$V_{11th} = \frac{4}{.11} \cdot (V_{dc1} \cos(11\ _1) + V_{dc2} \cos(11\ _2) + \ldots + V_{dc5} \cos(11\ _5))$ … (5.5)

$V_{13th} = \frac{4}{.13} \cdot (V_{dc1} \cos(13\ _1) + V_{dc2} \cos(13\ _2) + \ldots + V_{dc5} \cos(13\ _5))$ … (5.6)

Set of switching angles are obtained from genetic algorithms to control the multilevel inverter for each value of dc sources using (5.2) - (5.6).

It is important to have the genuine source values and the yield voltage to the above conditions utilizing GA. In the wake of measuring the genuine estimations of the DC source values, set of exchanging edges is discovered so that the yield voltage will be at steady value and the fifth, seventh, eleventh and thirteenth music are wiped out. A target capacity for the GA that assesses and characterizes every person in the populace was characterized by the condition,

$f(V_{fund}, V_{5th}, V_{7th}, V_{11th}) = k_1|V_{fund} – 110| + k_2|V_{5th}| + k_3|V_{7th}| + k_4|V_{11th}| + k_3|V_{13th}|$….(5.7)

In the above equation, coefficient k_1 should have lesser value than the coefficients k_2 to k_5. Assume $k_2=k_3=k_4=k_5=100$ and $k_1=10$. Range from 24 to 40 V is preferred for each DC source .

5. SIMULINK MODEL

Simulation of 11 level inverter consists of pulse generators, one voltage measurement, one scope, one powergui. Each part of source is associated to a 1- phase H-bridge inverter. The total yield (output) voltage is the addition of all 11 voltages obtained by bridge.

In this simulation, simulink block is used in which MOSFET switch is chosen since it has good features. Simulink model of 11 level bridge is shown. While Simulating this 11-level MLI, 5 DC sources are used where the voltages are unequal.

Harmonic calculation is done by Fast Fourier transform analysis using powergui. Diagonally MOSFETs are in operation in each level of inverter for positive and negative cycle. Phase delays for 11 levels are taken and which are switching angles calculated from GA.

output graph of genetic algorithms shows fitness in y-axis and iteration in x-axis, where fitness corresponding best individual.

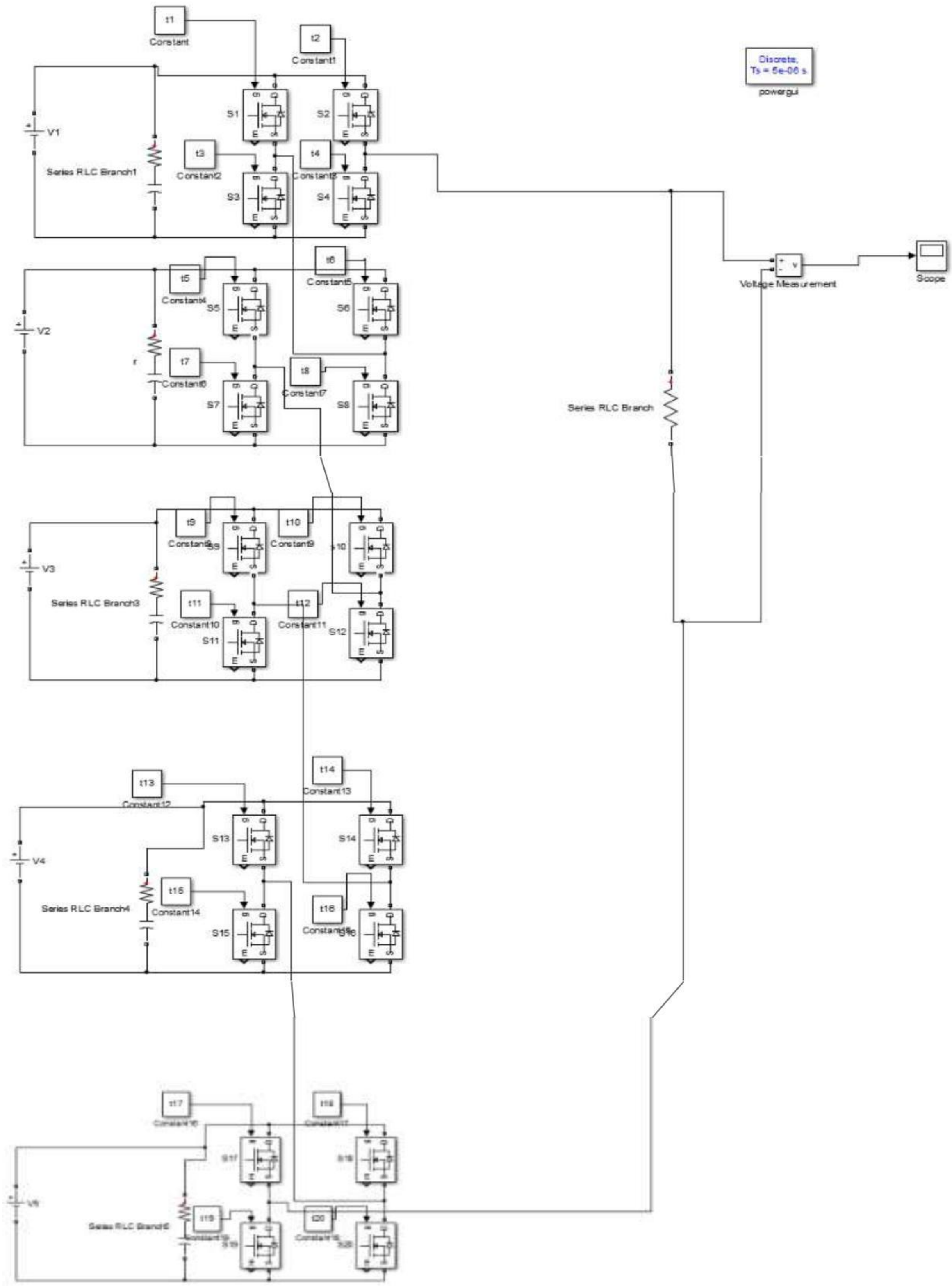

Fig.5.1 Simulation circuit

6. SIMULATION RESULTS

6.1.Input voltages: 25 26 27 28 29
Best solution(Angles): 12.31 29.82 26.68 56.67 50.83

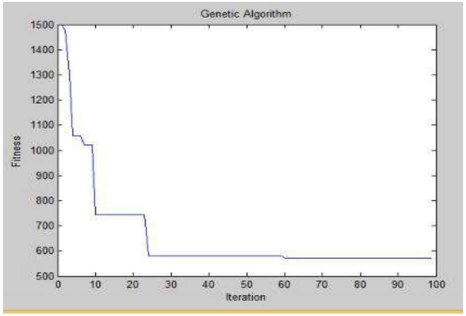

Fig.6.1 Output of GA

Escalation time: 20.03secs
Fitness value: 572.8 THD: 3.12

6.2.Input voltages: 26 27 29 30 31
Best solution: 19.39 25.33 42.50 57.59 68.39

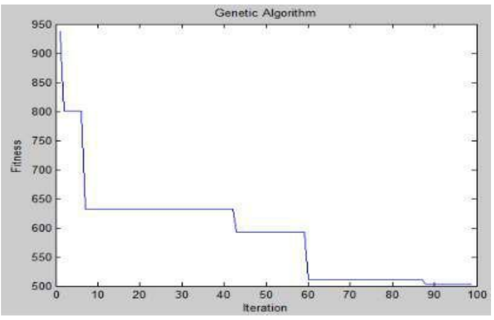

Fig.6.2.1 Output of GA

Escalation time: 19.32secs
Fitness value: 342.46 THD: 0.614

6.3.Input voltages: 30 31 32 33 34
Best solution:12.67 37.91 46.89 56.30 50.83

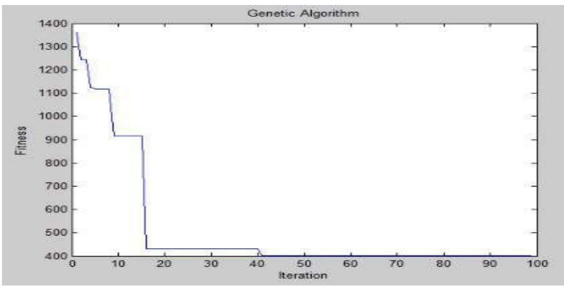

Fig.6.3.1 Output of GA
Escalation time:19.01secs
Fitness value: 576.34 THD: 0.82

6.4. Input voltages: 27 28 29 30 31
Best solution: 0.285 12.7 29.36 43.40 50.172

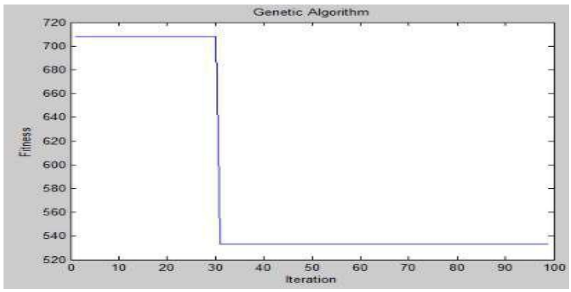

Fig.6.17 Output of GA

Escalation time: 17.67secs
Fitness value: 595.89 THD: 0.37

6.5. Input voltages: 24 26 28 30 32
Best solution: 8.41 37.48 37.6549.70 51.10

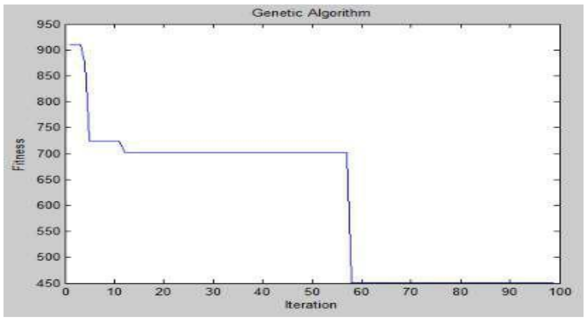

Fig.6.5.1 Output of GA

Escalation time: 15.76secs
Fitness value: 559.117 THD: 3.1

6.6. Input voltages: 25 27 29 31 33
Best solution: 7.47 43.10 38.89 43.50 43.12

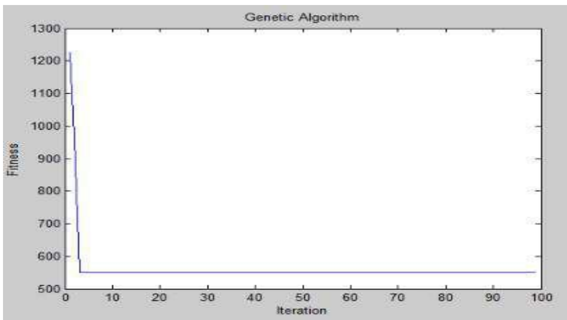

Fig.6.6.1 Output of GA

Escalation time: 12.82secs

6.7. Input voltages: 29 33 35 38 40

Best solution: 21.16 37.52 49.81 42.12 56.36

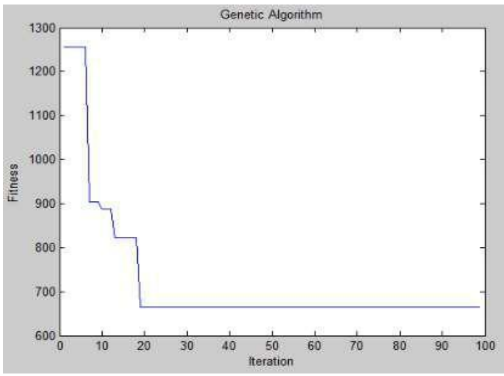

Fig.6.7.1 Output of GA

Escalation time: 11.09secs

Fitness value: 531.78 THD: 0.43

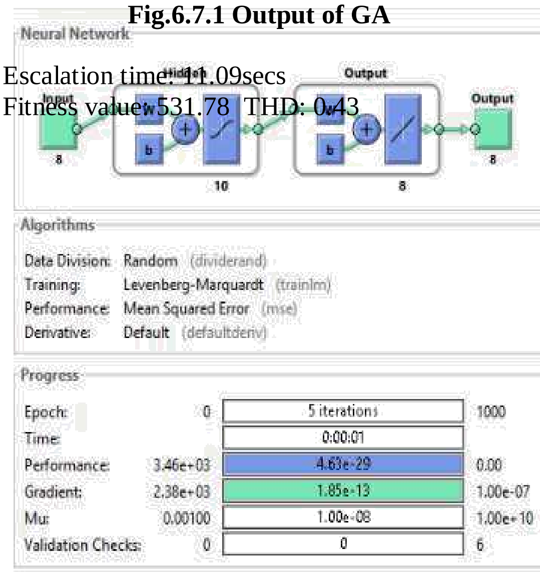

Fig.6.2 Output from ANN

The above simulation results shows the fitness value, harmonic value which is less than 3%. The angles acquired in GA are utilized to train the artificial neural network. Since it takes more time for training process, few set of angles are taken for training ANN. This artificial network takes the genuine fixed DC source values and gives the switching plots for control work. Figure shown below is the output from ANN for some particular voltage and angles.

7. HARDWARE IMPLEMENTATION

Fitness value: 274.62 THD: 1.94

7.1. BLOCK DIAGRAM

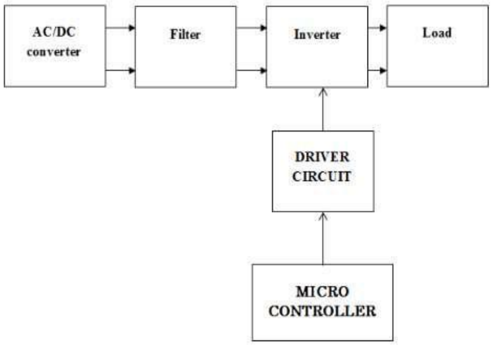

Fig.7.1 Hardware model block

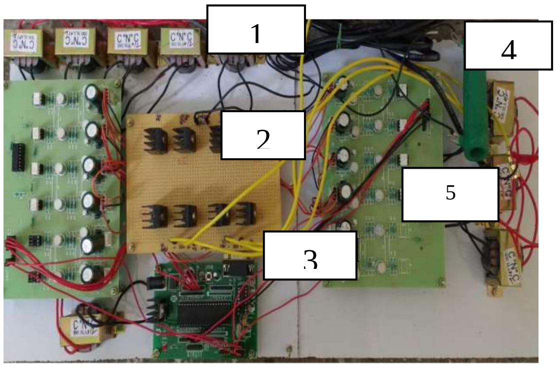

Fig.7.2 Hardware implementation

Hardware consist of

1. Transformer
2. MOSFET switches
3. Control circuit
4. Load
5. Driver circuit

The power circuit is the converter with its corresponding driver circuit for the MOSFET switch and the control circuit consists of the controller with its corresponding bias circuit. The input is the 230V 50Hz single phase. The voltage is stepped down to 12V by the transformer.

Capacitor is used for smoothing the waveform (to remove the ripple). 12V is reduced to 5V using 5V voltage regulator 7805.Microcontroller 8051IC (40 pin) needs 5V DC supply for the board to work. Program has to be dumped to IC to generate PWM pulses. In this project power MOSFETs are used as switches.

More than 10V is required to turn MOSFETs. But microcontroller has only 5V which is not sufficient to generate pulses. Therefore driver circuit is used.

Buffer (CD4050BE) is used in driver circuit to avoid loading. Optocoupler is used for isolation since when he MOSFET is turned ON current will not be proper.ie, when there is current, voltage will we give as reference, we can get 12V which is sufficient for MOSFET to work.

Basically the circuit contains 20 switches but due to space constraint hardware circuit is implemented for 8 switches. In hardware model two single phase multilevel inverters are connected where each single phase inverter will operate separately but there outputs will be added to get the total output.

7.2 HARDWARE RESULTS

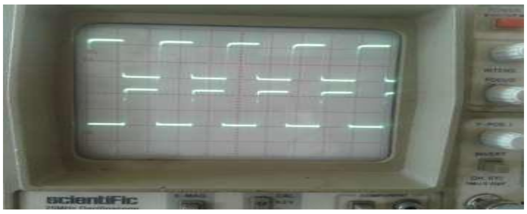

Fig.7.2.1 Output waveform across switch

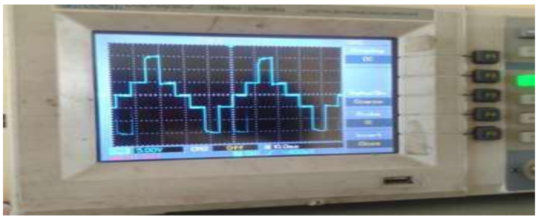

Fig.7.2.2 Output waveform across load

CONCONLUSION AND FUTURE SCOPE

This project is related to selective harmonic elimination on multilevel inverter using genetic algorithm and artificial neural network. MLI is simulated using MATLAB software. Angles are calculated using GA and angles obtained from GA are used to train neural network. This neural network takes authentic source values which gives the plots for the control framework. Hardware model is implemented for open loop of multilevel inverter where output waveform across the load is shown. By increasing number of inverter levels total harmonic distortion will be reduced. There are advantages and disadvantages as well.

The advantage is that this method is more accurate since we r training ANN after finding angles from genetic algorithm.

The disadvantages are training of neural network takes more time, computation cost is more, and computation of complexity is high.

not be there. It has some latching value above which microcontroller will not work. To avoid this optocoupler is used. LED turn ON the base of transistor optically. There is total pole logic, voltage which we wiIl get 12V. Whatever voltage

Future scope is, cuckoo search algorithm and firefly algorithm can be used instead of genetic algorithm where only the best individual will be survived can be used instead genetic algorithm.

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