SELECTIVE HARMONIC ELIMINATION ON A MULTILEVEL INVERTER USING ANN AND GENETIC ALGORITHM OPTIMIZATION

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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 paper presents the selective harmonic elimination in voltage output of 11-level cascaded multilevel inverter by considering varying dc sources. Genetic algorithm (GA) is used to obtain the switching angles and artificial neural network (ANN) is trained to determine the switching angles in an 11-level cascaded multilevel inverter. This proposed method can be applied even when the number of switching angles is increased. This results show the elimination of harmonics.

Index Terms— Multilevel inverter, Cascaded multilevel inverter ANN, Genetic algorithm, Roulette wheel selection, mutation, crossover.

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1 INTRODUCTION

Multilevel inverter (MLI) has got vast applications in industrial drives, reactive power compensation, selective harmonic compensator etc. it also have got a high power rating and high quality output waveforms. Among different types of multilevel inverter, cascaded multilevel inverter is used. Cascaded multilevel inverter would provide a possibility to connect a high separate DC source for getting high output voltages which do not exceed the limits. Fast Fourier transforms (FFT) based extraction is used in the MLI voltage waveform. Harmonic pattern of the waveform during the fault condition is used as a feature and neural network is trained using these features. Techniques like Particle swarm optimization (PSO) and Genetic algorithm (GA) used for training neural network is to reduce the errors and time taken for training. An approach to determine optimum switching angles for unequal DC sources is to calculate switching angles off-line and store the solutions in the lookup table. As the levels increases, requirement increases. Problems may occur and this leads to result in which solution becomes bigger. For some operating points, solutions might be missing and hence lookup table is replaced by artificial neural network (ANN) which, if well trained has the capacity to generalize the solutions. Since ANN runs fast, it is possible to quickly determine switching angles to establish real-time control.

2 PROPOSED SYSTEM

2.1 MULTILEVEL INVERTER (MLI)

Multilevel inverter is like an inverter and it is used for industrial applications as alternative in high power and medium voltage situations.

TYPES OF MLI

It consists of three types
1. Diode clamped multilevel inverter
2. Flying capacitors multilevel inverter
3. Cascaded H-bridge multilevel inverter

2.2 COMPARISION BETWEEN DIFFERENT TYPES 0F MULTILEVEL INVERTER

DIODE CLAMPED MLI	FLYING CAPACITORS MLI	CASCADED H-BRIDGE MLI
Its concept is to use diodes and provides multiple voltage level through different phases to capacitor banks, which are in series.	Its concept is to use capacitors and transfer the limited amount of voltage to electrical devices.	Its concept is to use capacitors and switches. Combination of switch pairs and capacitors gives separate input DC voltage.
It requires more components.	It requires more components.	It requires fewer components.
Output is half of the input DC.	Output is half of the input DC.	Output is independent of the input.
Switching losses will take place slightly.	Switching losses are more.	Switching losses will not occur.

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This needs bulky transformer.	This also needs bulky transformer.	Eliminates bulky transformer, clamping diodes, flying capacitors.

By comparing the three MLIs, cascaded H-bridge multilevel inverter is used because of its vast applications and advantages.

2.3 CASCADED H-BRIDGE MULTILEVEL INVERTER

Structure of an 11-level cascaded multilevel inverter is shown in fig (a). Each separate dc sources is connected to H-bridge inverter. Each inverter level can generate three different output voltages, +V dc,0, and –V dc by connecting the dc source to the AC output by different combinations of the four switches Q11,Q12,Q13, and Q14. Switches Q11 and Q14 are turned on to obtain +V dc. Switches Q12 and Q13 are turned on to obtain –V dc. To obtain 0 voltages switches Q11, Q12 or Q13, Q14 are turned on. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output voltage level m in a cascaded inverter is defined by m=2s+1, where s is the number of dc sources.

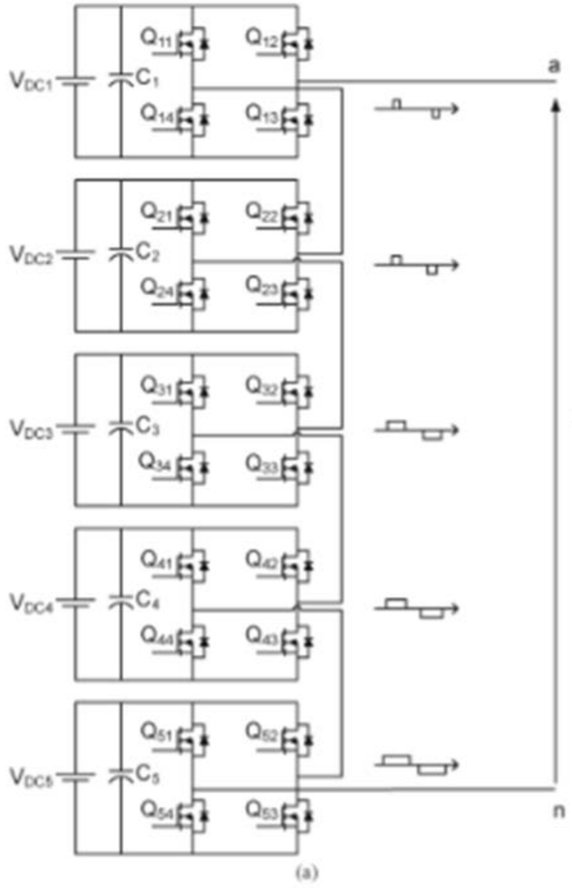

Fig (a). Eleven level cascaded inverter

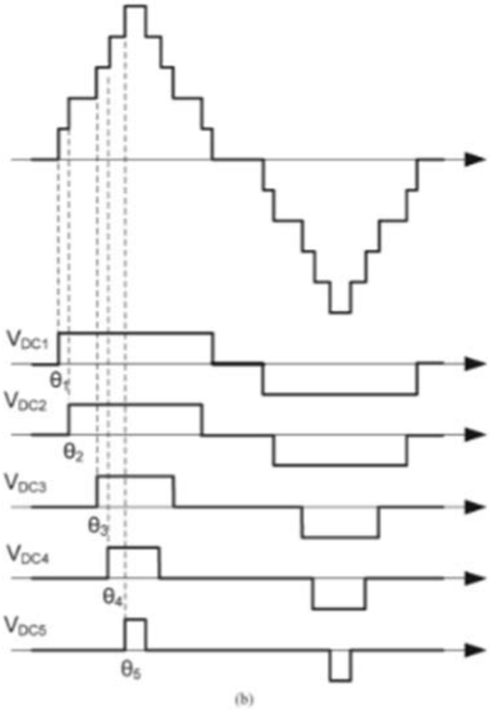

Fig (b). Voltage output waveform

3 GENETIC ALGORITHM

Genetic algorithms are inspired by Darwin's theory about evolution, such as inheritance, mutation, selection and crossover. It is a population based search method used in computing to find true solutions to optimization and search problems.

FEATURES

1. It is a population based

2. Uses recombination to mix information of candidate solutions into a new one

3. It is a stochastic

Genetic algorithm starts with a set of solutions called population (chromosomes). Solution from that population are taken according to their fitness and used to form a new solution hoping that the new solution will be better than the old one. This is repeated until we get the best solution.

Selection: Solutions are selected though fitness based process, where fitter solutions are typically more likely to be selected. This is done according to roulette wheel selection. i.e., individuals are given a probability of being selected that is directly proportional to their fitness.

Crossover: Crossover the parents to form a new offspring. If crossover was not performed, offspring is an exact copy of parents.

Mutation: After selection and crossover, process will have a new population, some are copied and others are produced by crossover. In order to confirm that individuals are not same, mutation is performed.

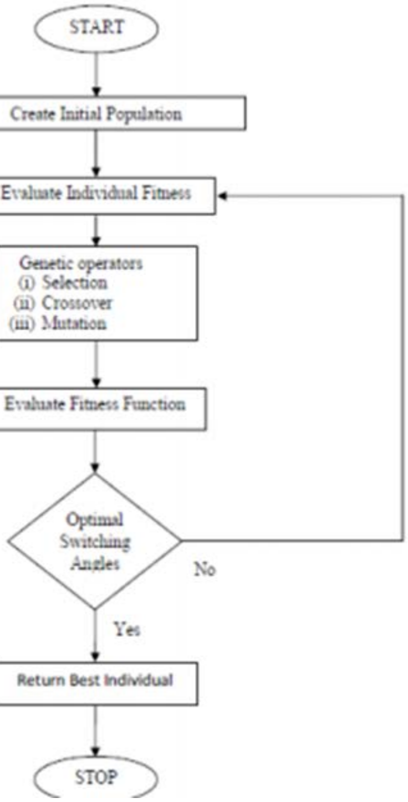

Fig (c). Flowchart of Genetic algorithm

The output equation of waveform shown in fig (b) can be expressed in the Fourier form as

$V_{an}\ (wt) = \sum_{n=1,3,5,7....}^{\infty} \frac{4}{\pi.n}(V_{dc1}\cos(n.\theta_1) + V_{dc2}\cos(n.\theta_2) + V_{dc3}\cos(n.\theta_3) + V_{dc4}\cos(n.\theta_4) + V_{dc5}\cos(n.\theta_5)).\sin(nwt)$............ (1)

Where

V_{dc1}… Vdc5 input dc sources;

θ1….θ5 inverter switching angles;

V_{an} inverter output voltage.

Equation (1) shows the contents of the output voltage at infinite frequencies. For different DC sources, it is necessary to maintain the fundamental output voltage. The set of equations for the genetic algorithm is

$V_{fund} = \frac{4}{\pi}\ .\ (V_{dc1}\cos(\theta_1) + V_{dc2}\cos(\theta_2) + ... + V_{dc5}\cos(\theta_5))$........ (2)

$V_{5th} = \frac{4}{\pi.5}.\ (V_{dc1}\cos(5\theta_1) + V_{dc2}\cos(5\theta_2) + ... + V_{dc5}\cos(5\theta_5))$ … (3)

$V_{7th} = \frac{4}{\pi.7}.\ (V_{dc1}\cos(7\theta_1) + V_{dc2}\cos(7\theta_2) + ... + V_{dc5}\cos(7\theta_5))$ … (4)

$V_{11th} = \frac{4}{\pi.11}.\ (V_{dc1}\cos(11\theta_1) + V_{dc2}\cos(11\theta_2) + ... + V_{dc5}\cos(11\theta_5))$ … (5)

$V_{13th} = \frac{4}{\pi.13}.\ (V_{dc1}\cos(13\theta_1) + V_{dc2}\cos(13\theta_2) + ... + V_{dc5}\cos(13\theta_5))$ … (6)

Set of switching angles are obtained from genetic algorithms to control the multilevel inverter for each value of dc sources using (2) - (6).

It is necessary to have the real DC source values and the output voltage to the above equations using GA. After measuring the real values of the DC sources, set of switching angles is found so that the output voltage is kept constant and the 5th, 7th, 11th and 13th harmonics are eliminated. An objective function for the GA that evaluates and classifies each individual in the population was defined by the equation,

$f\ (V_{fund}, V_{5th}, V_{7th}, V_{11th}) = k_1|V_{fund} - 110| + k_2|V_{5th}| + k_3|V_{7th}| + k_4|V_{11th}| + k_3|V_{13th}|$....(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 defined for each DC source with a step of 1V for the first source.

4 ARTIFICIAL NEURAL NETWORK

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.

TABLE 1. Data set obtained from GA run

Input voltages (V)	Output angles (°)
25 25 25 25 25	0.6 10.2 18.3 11 38.2
26 27 29 30 32	6.0 17.3 21.6 29.7 32.5
…	….
33 35 37 38 39	8.2 30.1 32.9 78.1 81.0
…..	…..
40 40 40 40 40	22.1 39.152.9 6.5 73.2

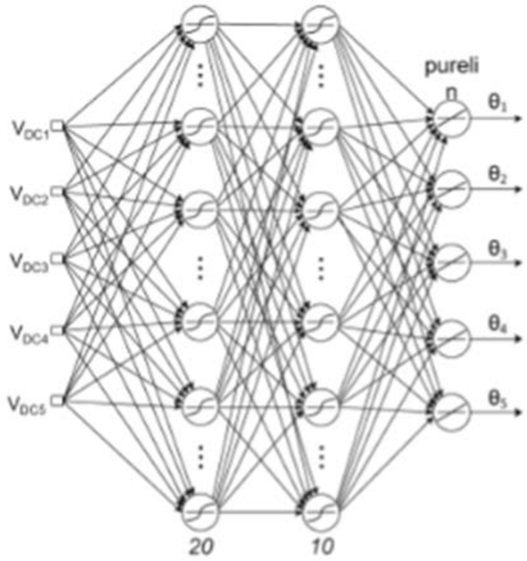

Fig (d). Feedforward ANN topology

5 RESULTS

The experimental results for an 11-level inverter operating with different dc sources are shown with the voltage values indicated.In Fig (f). , the frequency spectrum is shown where it can be noticed that the aim harmonics were minimized to less than 1% with the exception of the 13th harmonic that is around 1.2% with a THD of 8.7%. In this same figure, a high value of the third and ninth harmonics can be noticed; those harmonics were not minimized due to the fact that they will be canceled in line voltage for a three-phase application.

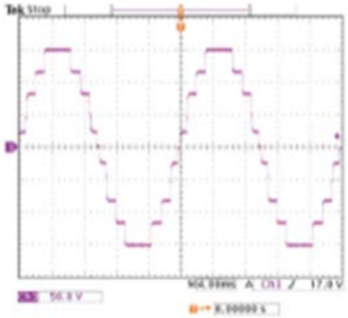

Fig (e). Voltage output waveform

This system has the capacity to modemize the angles in real time at speeds higher than the low switching frequency (1/60 s), but the angle speed update is done at the end of a cycle of the low frequency to avoid even harmonics. It is assumed that a substantial step variation in the magnitude of the dc source inputs may occur for this approach, so that the system should be able to adapt its output.

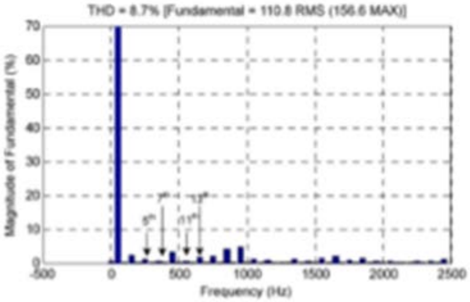

Fig (f). Frequency spectrum

6 CONCLUSION

A new proposal for real-time computation of switching angles using ANNs has been described. This method is very efficient and reliable. The solutions were found offline using Gas to obtain a data set for use during the training process of the neural network and to explore the advantages of approximate solutions obtained by the GA. The tutored neural network is used then for online real-time determination of the angles.

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