MODIFIED NINE LEVEL INVERTER USING CASCADED H-BRIDGE CONFIGURATION TRIGGERED WITH OPTIMIZED FIVE LEVEL RANDOM PWM SCHEME

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ABSTRACT

Multilevel inverters are commonly used for high voltage and high power applications. A good number of multilevel inverter topology has been proposed during the last two decades. In reality on comparing with other multilevel inverter topology, cascaded multilevel inverter topology features a high modularity degree and compared to the conventional multilevel inverter topologies modified cascaded h-bridge multilevel inverter requires less number of switches. One of the properties of multilevel inverter is that as the number of voltage level increases harmonic content reduces. Main objective of this work is to develop an optimized random pulse width modulation strategy for multilevel inverters. The proposed optimized pulse width modulation scheme provides an improved performance over random PWM schemes for multilevel power converters. The total harmonic distortion is taken as the performance index for optimization. The harmonic distortion is optimized using the principle of Genetic algorithm.

Keywords—Genetic Algorithm (GA); Random pulse width modulation (RPWM); Total Harmonic Distortion (THD)

INTRODUCTION

Inverter is one of the converter families which are called DC to AC converter which converts DC power to AC power to a symmetric AC output voltage at desired magnitude and frequency. Inverter is widely used in industrial applications such as variable speed AC motor drives, induction heating, standby power supplies and uninterruptible power supplies. The DC power input of inverter is obtained from the existing power supply network. It can be a battery, photovoltaic, wind energy, fuel cell or other DC sources. Traditionally, two-level PWM inverter is used for various applications. To spread the harmonic energy of the output voltage of a two level inverter so as to reduce the acoustic noise [2, 3] and electromagnetic interferences, several random pulse width modulation strategies [1] have been developed. Three basic random strategies are: a) random switching frequency technique b) random pulse position technique c) random switching technique. The switching frequency is randomly changed from cycle to cycle in random switching frequency technique. In random pulse position technique, the switching pulses are randomly placed in individual switching intervals [4]. In the third technique, switching signals are decided by comparing a random fractional number with the desired duty ratio of the switching signals [5].

In random pulse width modulation (RPWM) the harmonic distributions may be different for different random carrier sequences. Random modulation techniques cannot ensure that the output power qualities are optimum at all time. Recently a method for optimizing two-level random PWM, using the random switching frequency technique has been developed.

For high power application, multi-level inverters have become very relevant. There are mainly four types of multilevel inverters. They are diode clamped, flyingcapacitor, cascaded H-bridge multilevel inverter and Open end winding configuration of multilevel inverter [12, 13]. Due to the requirement of less number of components and user friendly nature we use cascadedH-bridge multilevel inverter in our system.

In multilevel inverters, since the output voltage is synthesized with multiple smaller levels, the effects are less. Hence they can be switched at a lower frequency than in the case of two-level inverters. Since the lower switching frequency also mean that the lower order harmonics, which are harmful to the motor, are significant. RPWM schemes have been proposed for spreading the harmonic energy in the case of multilevel inverter. The principle used here is to make several comparisons between the random carrier and the sinusoidal reference with in each sampling period.

The random switching sequences are optimized to achieve optimum THD using genetic algorithm technique. For a given cycle of fundamental frequency, genetic algorithm is used to select an optimum PWM switching sequence, ensuring that minimum instantaneous harmonic distortion with lower modulation indices is achieved in every cycle. Simulation results shows that optimized multilevel inverters are capable of achieving less magnitude of switching harmonics compared with random multilevel inverters.

MODIFIED NINE LEVEL CASCADED H-BRIDGE MULTILEVEL INVERTER

Fig 1shows the modified cascaded five level H bridge multilevel inverter [14]. One switching element and four diodes added in the conventional full-bridge inverter are connected to the center tap of dc power supply. Proper switching control of the auxiliary switch can generate half level of dc supply voltage. It has five output voltage levels that is V, V/2, 0, -V/2, -V. For getting the output voltage V the switches S1S4 need to be turned on. Similarly for output voltage V/2 switches S4S5 need to be turned on, for 0 either S3S4 or S1S2 need to be turned on; for –V/2 switches S2S5 need to be turned on; for –V switches S2S3 need to be turned on. The switching combinations are shown in Table.1

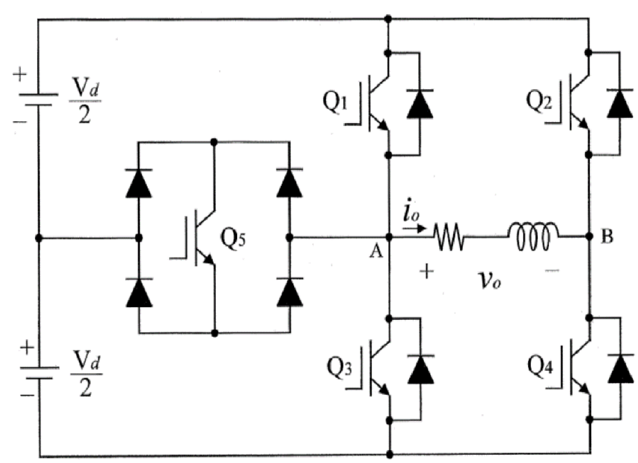

Fig. 1. Modified cascaded five level H bridge multilevel inverter

Table1.Switching combinations for Modified cascaded five levels H bridge multilevel inverter

Output	Q1	Q2	Q3	Q4	Q5
V	ON	OFF	OFF	ON	OFF
V/2	OFF	OFF	OFF	ON	ON
0	OFF	OFF	ON	ON	OFF
-V/2	OFF	ON	OFF	OFF	ON
-V	OFF	ON	ON	OFF	OFF

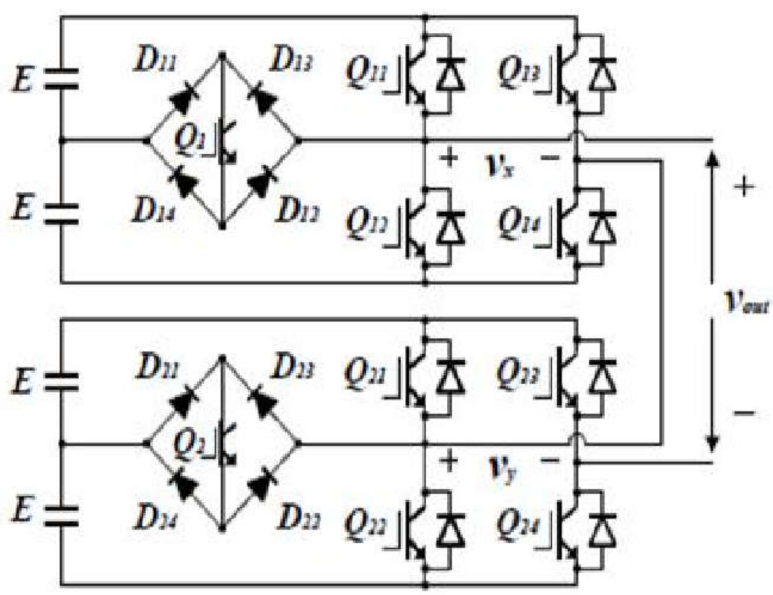

Fig. 2. Modified cascaded nine level H bridge multilevel inverter

In the circuit shown in fig 1, single H-bridge module is capable of producing five level output voltage. Each inverter module is capable of producing 2E, E, 0, -E, -2E. That means by using two bridges 9 level output voltage is produced. The total output voltage is sum of the outputs of the inverter modules and the nine voltage levels are 4E, 3E, 2E, E, 0, -E, -2E, -3E, -4E. The advantages of this proposed circuit is number of switches are reduced. The cost and complexity is less in this circuit. To synthesize nine output voltage levels, it employs two independent dc voltage sources of 2E which are divided into two input sources E in order to secure an additional dc voltage source of E. The inverter module having a bidirectional switch produces 5-levels of output voltage (- 2E, -E, 0, E, 2E) by controlling of the switches. Since every output terminal of the inverter module is connected in series, the output voltage becomes the sum of the terminal voltages of each inverter. The circuit for nine level cascaded H-bridges is shown in figure 2, the gating signals for the modified nine level inverter is generated by using optimized FIVE LEVEL random PWM technique.

Table2. Switching combinations for modified nine-level inverter

Q11	Q12	Q13	Q14	Q21	Q22	Q23	Q24	Q1	Q2	Vout
0	1	0	1	0	1	0	1	0	0	0
0	0	0	1	0	1	0	1	1	0	E
1	0	0	1	0	1	0	1	0	0	2E
1	0	0	1	0	0	0	1	0	1	3E
1	0	0	1	1	0	0	1	0	0	4E
0	1	0	1	0	1	0	1	0	0	0
0	0	1	0	1	0	1	0	1	0	-E
0	1	1	0	1	0	1	0	0	0	-2E
0	1	1	0	0	0	1	0	0	1	-3E
0	1	1	0	0	1	1	0	0	0	-4E

PWM SCHEMES FOR INVERTER

STANDARD PWM FOR FIVE-LEVEL INVERTER

A five-level inverter [9] scheme employs four level shifted triangle carriers with a fundamental modulating sinusoidal signal.

$$z(t) = \begin{cases} 2, & \text{if } s(t) \geq x_1(t) \\ 1, & \text{if } s(t) \geq x_2(t) \\ 0, & \text{if } s(t) \geq x_3(t) \\ -1, & \text{if } s(t) \geq x_4(t) \\ -2, & otherwise \end{cases} \qquad (1)$$

Where$x_1(t)$, $x2(t)$, $x3(t)$ and $x_4(t)$ are the four triangular carrier signal levels and s(t) is the modulating signal.

In this paper, the binary value one is used to represent one cycle of four simultaneous triangular waves, which are in same phase and zero for one cycle of the inverted triangular waves. With this technique we can construct continuous triangular carrier waves [10,11] corresponding to a pattern of binary values. Placing alternate binary values will result in four level shifted triangular waves which can be used to generate sine-triangle PWM. The sine-triangle PWM method using triangular carrier waveforms and a sinusoidal modulation waveform with modulation index 0.8 is shown in Fig.3 (a).

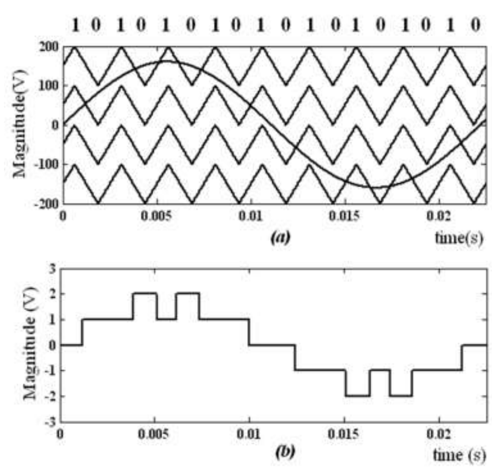

Fig. 3. (a)Sine-triangle PWM reference and carriers (b) PWMOutput

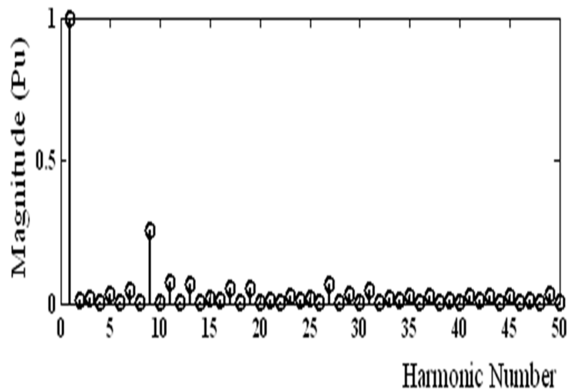

Fig 4.Normalized Harmonic Spectrum (THD=0.3256)

Total Harmonic Distortion (THD) is the ratio of the sum of the powers of all harmonic frequencies above the fundamental frequency to the power of fundamental frequency.

$$THD = \frac{\sum harmonicpowers}{fundamentalharmonicpower}$$

$$= \frac{P_2 + P_3 + ... + P_n}{P_1} \qquad (2)$$

The sine-triangle PWM output and the corresponding normalized harmonic spectrum of a five-level PWM inverter are shown in Fig.3 and Fig.4 respectively. Thetotal harmonic distortion (THD) of the corresponding PWM is found to be 0.3256.

RANDOM PWM FOR FIVE-LEVEL INVERTER

To reduce the THD of sine-triangle PWM inverter, the principle proposed in the paper is to use carrier waves generated by a random pattern of binary values. Thus the shape of carrier is varied in accordance with the instantaneous binary values. An example of the modulating waveform, the level shifted random carrier waveforms and random PWM output are shown in Fig.5, where the carrier wave is generated using a sequence of 000000101111110010. The corresponding normalized harmonic spectrum of a PWM inverter is shown in Fig 6.

The total harmonic distortion of the corresponding PWM is found to be 0.2505. Figure shows that the random PWM technique can provide lower values of THD when compared to sine-triangle PWM technique.

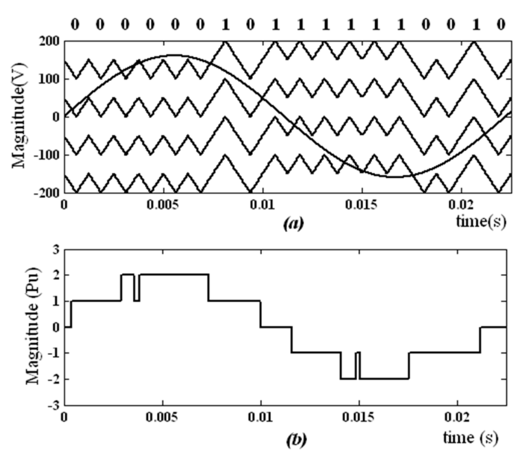

Fig. 5(a) Random PWM reference and carriers (b) PWMOutput

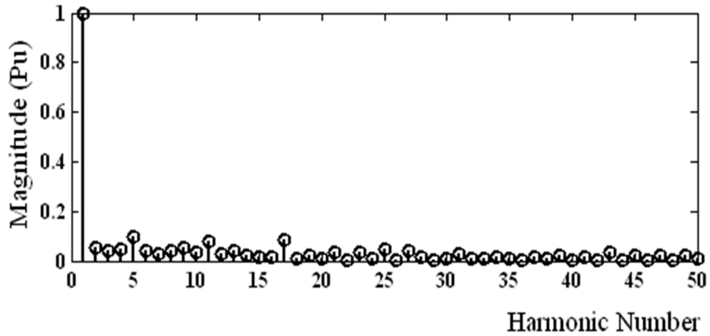

Fig 6.Normalized Harmonic Spectrum (THD=0.2505)

OPTIMIZED PWM FOR FIVE-LEVEL INVERTER

The problem with the conventional random PWM is that the THD's corresponding to each of the random sequences can give either higher or lower values compared to that obtain with sine-triangle PWM. Hence genetic algorithm is used to select a sequence from a lot of random sequences that can achieve a minimum THD value at all time.

In order to find the best random triangular carrier sequence for a PWM inverter, a binary-valued Genetic Algorithm (GA) [6, 7] is employed with THD as the objective function. The procedure of binary-valued GA for optimizing PWM using THD as the objective function as shown Fig.7. It begins with the generation of an instantaneous period sequence which will be coded into a long binary-valued string, called chromosome. An initial population consisting of M chromosomes is generated. The fitness values generated are evaluated with a linear ranking method. Parent structures are selected to form new offspring by the next process called reproduction. The single-point recombination method is used to exchange the information among the chromosomes, referred to as crossover. Mutation process is done along with the above process. The generation process is repeated until the optimized population is achieved i.e. the maximum number of iterations are done above which the THD remains a constant lowest value.

GA optimization steps are given below:

1: Create random population of *M* chromosomes

2: Evaluate fitness *f(x)* of each chromosome in the population

3: New population is selected by using the following steps:

- Selection: Based on *f(x)*
- Recombination: Cross-over chromosomes
- Mutation: Mutate chromosomes
- Acceptation: Reject or accept new ones

4: Replace old with new population

5: Test the problem

6: Continue Step *1 – 4* until the optimum condition (minimum THD) is achieved.

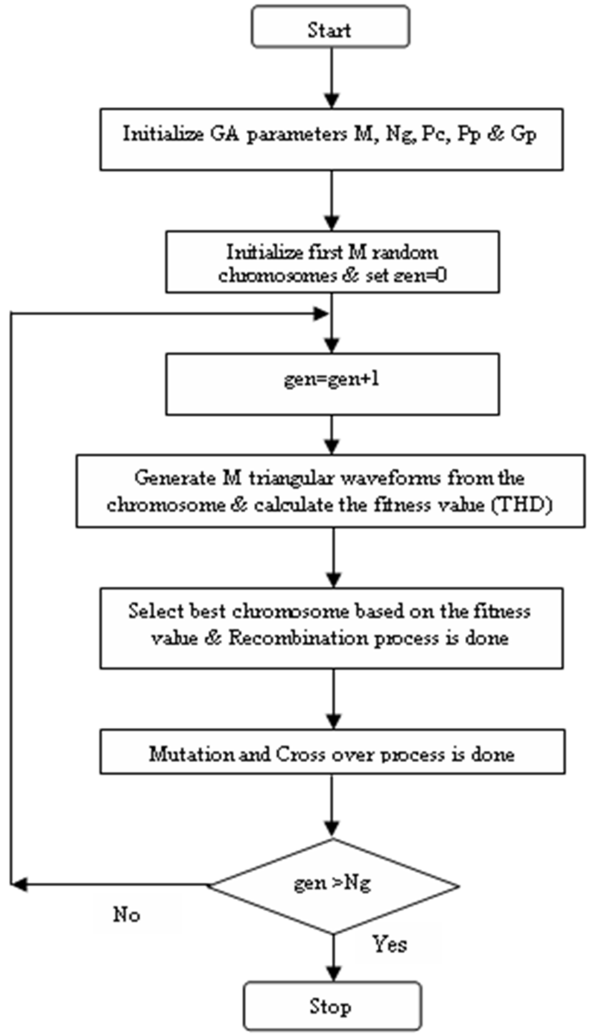

Fig.7. GA operation flowchart to optimize a random PWM Inverter

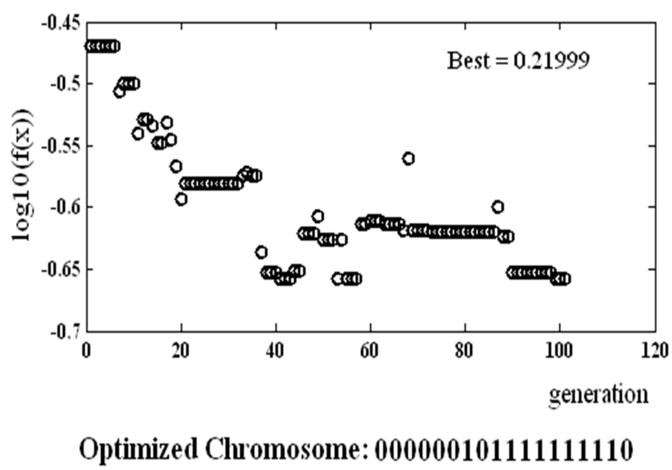

Fig.8. Optimization result of five-level PWM Output Voltage

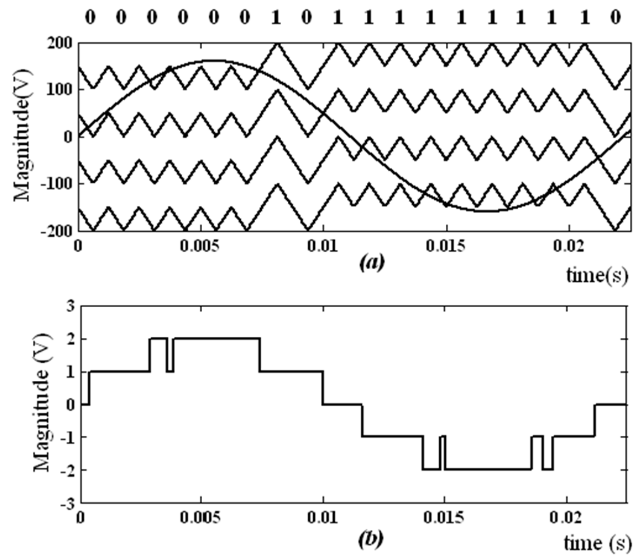

Fig. 9 (a) Optimized PWM reference and carriers (b) *PWM* Output

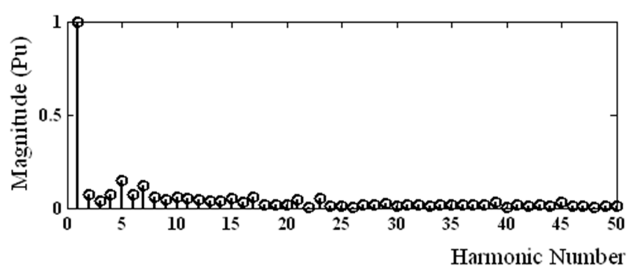

Fig. 10.Normalized Harmonic Spectrum (THD=0.2199)

By using the binary-valued GA, the THD of the optimized PWM output voltage has decreased to 0.2199. The optimized carrier sequence 000000101111111110 is generated at the hundredth population. The simulation results for the PWM inverter with the optimized carrier sequence and its corresponding PWM output are shown by Fig.8 and Fig.9 respectively. The corresponding normalized harmonic spectrum of optimized PWM output voltages shown in Fig10. This optimized five level PWM is used as the switching input of modified nine-level inverter using cascaded H-bridge configuration.

CONCLUSION

In this paper a modified nine level inverter topology is presented with two modified five level inverter topology using cascaded H-bridge configuration. Modified nine level inverter configuration reduces the number of switches of conventional inverter topology. An optimized random PWM strategy for multi level inverter is presented in this paper. In this proposed random PWM scheme the switching sequence are optimized using a binary valued genetic algorithm.Total harmonic distortion is taken as the performance index for optimization. Optimization of five level inverter schemes is presented.The simulation results show that optimized PWM based on GA provide better performance than conventional PWM for multi level inverters.

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