THOMSON REUTERS ENDNOTE

[RACE: March 2017] ISSN 2348 – 8034
Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

A REVIEW ON HARMONIC REDUCTION WITH RANDOM PWM TECHNIQUE FOR MULTILEVEL INVERTERS

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ABSTRACT

Multilevel inverters have drawn tremendous interest in high power applications. It synthesize a desired output voltage from several levels of dc voltages as inputs. By taking sufficient number of dc sources, a nearly sinusoidal voltage waveform can be synthesized. Several methods have been developed to eliminate or minimize harmonics of multilevel inverter output. The Sine-triangular pulse width modulation (SPWM) scheme is a basic method of this kind for multilevel inverters. SPWM is generated by comparing the reference phase voltage signal with a number of symmetrical level shifted carrier wave. Randomized switching frequency modulation is another popular technique for harmonic reduction in multilevel inverters. The randomized switching frequency modulation can be achieved through randomly varying the slope of the PWM carrier triangular wave. Inorder to improve the performance of random PWM, an optimization based random PWM is also proposed. RPWM optimization is achieved using Genetic algorithm with Total Harmonic Distortion (THD) as performance index. The analysis shows that output voltage using the optimized PWM technique is better than the standard triangular PWM and conventional random PWM methods.

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

I. INTRODUCTION

Multilevel inverters have received more and more attention because of their capability of high voltage operation, high efficiency, and low electromagnetic interference (EMI). These types of inverters are widely used as input supply for induction motors. The desired output of a multilevel converter is synthesized by several sources of DC voltages. With an increasing number of DC voltage sources, the converter voltage output waveform approaches a nearly sinusoidal waveform while using a fundamental frequency switching scheme. This result in low switching losses, and because of several DC sources, the switches experience a lower dV/dt. As a result, the multilevel converter technology is a promising technology for high power electric devices such as utility applications.

Pulse width modulation is a method that is widely used as a switching pulse to turn on and off the thyristors to give alternating current waveform at the output of an inverter circuit [5]. The output waveform of an inverter will be a square-wave and contains harmonics from the 3rd harmonics, and as the 3rd harmonic located very close to the fundamental frequency and very difficult to filter it as we need to design very high order filter, therefore nowadays we prefer to use PWM method to reduce the total distortion because of the harmonics or simply called THD.

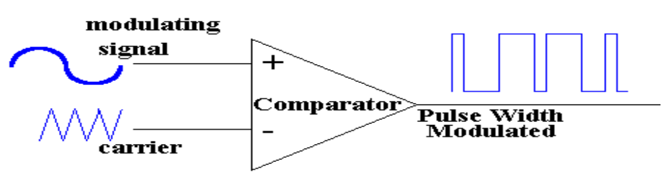
Sine-triangle pulse width modulation (SPWM) is the most popular modulation scheme for multilevel inverters. As compare with square wave inverter the quality of SPWM inverter output is greatly enhanced. The harmonic content in sine-triangle pulse modulation is comparatively less than other modulation schemes. In this method of modulation, several pulses in each half cycle are used. In SPWM, pulse width is a sinusoidal function of the angular position of the pulse in a cycle. For realizing SPWM, a high-frequency carrier wave is compared with a sinusoidal reference wave of desired frequency. The intersection of carrier and reference waves determine the switching instants and commutation of modulated pulse. The carrier wave and reference waves are mixed in a comparator. The comparator output is high only when sinusoidal wave have higher magnitude than triangular wave.

In deterministic PWM the power spectrum is discrete in nature so it produce problems like acoustic noise, input wave form distortion and electromagnetic interferences in motors. These problems are eliminated with the help of Random PWM in which the pulse position or the switching frequency is randomized so that significant noise producing frequencies are suppressed and spread through the spectra more uniformly. In random switching technique the switching frequency is randomized. It is achieved by modulating the slope of the triangular carrier. The spectrum of random PWM is continues. This continuity in the spectrum eliminates the problem of large amplitudes at discrete frequencies. So the entire spectrum spreads over entire range of frequencies with very small amplitudes at particular frequencies except the fundamental frequency.

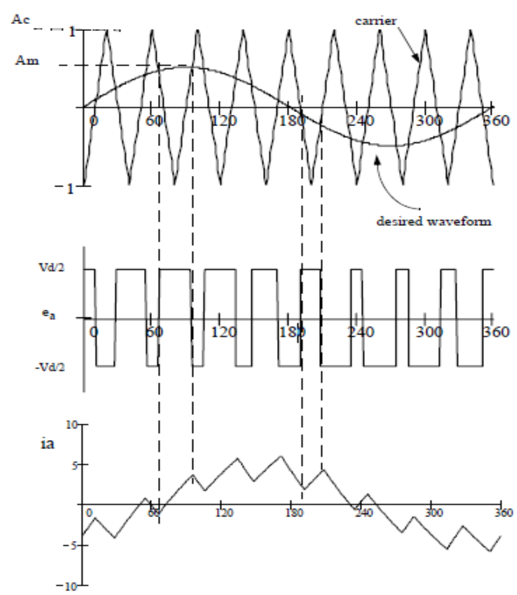
The main disadvantage of random PWM scheme is that the harmonic distribution associated with the RPWM may be different for different random carrier sequences. Random modulation schemes cannot ensure that output power qualities are optimum at all time. We can optimize the random modulation schemes by using genetic algorithm. Genetic algorithm is used to select an optimum PWM switching sequence from a lot of random switching sequences. Total harmonic distortion (THD) is chosen as the performance index for optimization. We can improve the performance of random PWM techniques using this optimization process.

II. HARMONIC ELIMINATION USING STANDARD SINE-TRIANGULAR MODULATION TECHNIQUE

The sine triangle pulse width modulation (SPWM) scheme for multilevel inverter is generated by comparing the reference phase voltage signal with a number of symmetrical level shifted carrier waves [4]. For n level inverter n-1 level shifted carrier waves are required for comparison. Fig.1 shows the sine-triangle pulse width modulation. As compare with square wave inverter the quality of SPWM inverter output is greatly enhanced.



(a)



(b)

Fig 1. Sine triangle pulse width modulation

In this method of modulation, several pulses in each half cycle are used. In SPWM, pulse width is a sinusoidal function of the angular position of the pulse in a cycle. For realizing SPWM, a high-frequency carrier wave is compared with a sinusoidal reference wave of desired frequency. The intersection of carrier and reference waves determine the switching instants and commutation of modulated pulse. The carrier wave and reference waves are mixed in a comparator. The comparator output is high only when sinusoidal wave have higher magnitude than triangular wave. The comparator out-put is then processed in a trigger pulse generator.

Note that over the period of one triangle wave, the average voltage applied to the load is proportional to the amplitude of the signal (assumed constant) during this period. The resulting chopped square waveform contains a replica of the desired waveform in its low frequency components, with the higher frequency components being at frequencies often close to the carrier frequency. Notice that the root mean square value of the ac voltage waveform is still equal to the dc bus voltage, and hence the total harmonic distortion is not affected by the PWM process. The harmonic components are merely shifted into the higher frequency range and are automatically filtered due to inductances in the ac system.

When the modulating signal is a sinusoid of amplitude Am, and the amplitude of the triangular carrier is Ac, the ratio m=Am/Ac is known as the modulation index. Note that controlling the modulation index therefor controls the amplitude of the applied output voltage. The process works well for $m<1$. For $m>1$, there are periods of the triangle wave in which there is no intersection of the carrier and the signal . However, a certain amount of this overmodulation is often allowed in the interest of obtaining a larger ac voltage magnitude even though the spectral content of the voltage is rendered somewhat poorer.

Disadvantages

- Acoustic noise is produced.
- Input signal distortion
- Spectrum of SPWM contains several harmonic distortions.

III. RANDOM CARRIER FREQUENCY METHOD

One of the problems of the PWM controlled AC motors is the acoustic noise that could become unacceptable when used in silent environments. Acoustic noise is caused by the interaction of the fundamental and harmonic flux densities [6]. The maximum noise, is generated when the harmonic flux produced is concentrated at a particular frequency such as the switching frequency. It is desirable then to spread out the frequency spectrum of the harmonic voltage, and therefore current, in such a way as to eliminate the presence of specific tones. Harmonic spectrum can be spread by causing the switching pattern of the inverter to be random. Switching pattern can be randomized by modulating the triangle carrier in sinusoidal PWM with band-limited white noise as shown in fig.2**.**

In random switching frequency technique the switching frequency is randomly changed from cycle to cycle. It is achieved by modulating the slope of the triangular carrier wave with band limited white noise [1]. Let the modulating function, n(t), be a random function, say, Gaussian “white” (i.e., wideband) noise. Modulating with very high bandwidth noise results in a large instantaneous change in the triangle frequency. This eliminates the concentration of energy in a tone. It also results in a very wide spectrum for the output voltage, including substantial content at low frequencies which will cause low frequency currents to flow in the machine.

Randomizing the switching frequency has been found to be the most effective method of RPWM. In converters with fixed switching frequency, the power is concentrated in discrete harmonics of the output voltage. In contrast to that, in converters with randomly varying switching frequency, the harmonic power is transferred to the continuous spectrum.

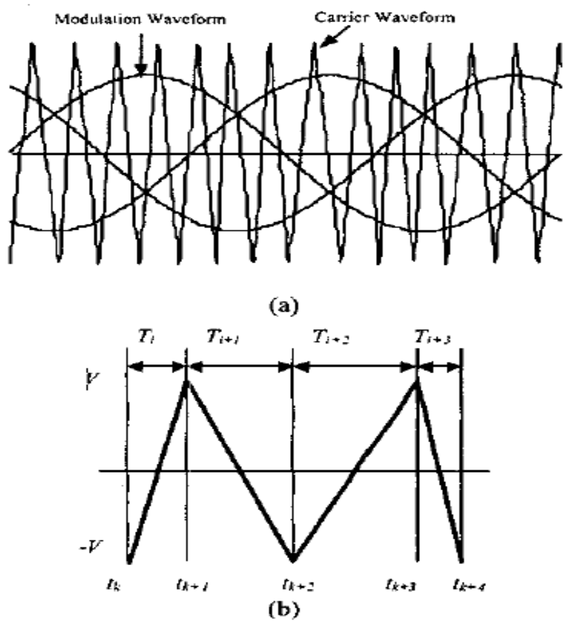


Fig 2. Random switching frequency technique
(a) Modulating wave forms and carrier wave form (b) carrier wave form

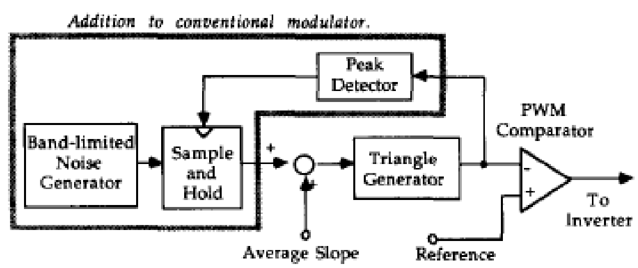


Fig 3.Block diagram illustrating implementation of random carrier sinusoidal PWM

The fig.3 illustrates the implementation of the proposed random modulated sine-triangle PWM regulator.As can be seen from the figure, the random modulation is a very simple addition to an existing sine-triangle regulator. A sample and hold element is clocked at each peak of the triangle wave to hold the value of slope for the next segment. The bandwidth limited noise source can be any Gaussian wide band white noise generator followed by a low pass filter, or a periodic noise generator. The white noise source can be obtained quite simply in a number of different manners, such as monolithic noise generator circuits, zener diode voltage, or a number of other semiconductor-based methods. However, the low pass filter requires a number of components including reactive elements. Also, the low pass filter should have a sharp cutoff in order to define the band of the output voltage as precisely as possible.

Disadvantages

- Output harmonic distortions have not been alternatively improved.
- Output harmonic intensity of the inverter may always be randomly changed with various random sources so inverter output is not optimum at all times

IV. OPTIMIZED RANDOM PWM STRATEGY BASED ON GENETIC ALGORITHM

In random pulse width modulation the harmonic distributions may be different for different random carrier sequences. Random modulation technique cannot ensure that the output power qualities are optimum at all time [4]. This is the main problem with random pulse width modulation technique.

An optimized random PWM strategy has been introduced to solve this problem. The random PWM is optimized using the principle of Genetic algorithm (GA). Genetic algorithm is used to select an optimum PWM switching sequence from a lot of random switching sequences [2]. The off-line GA -optimized PWM switching sequence will then be repeatedly applied to control the PWM inverter. Hence, a minimum instantaneous harmonic distortion is achieved in every cycle.

In order to find the best triangular carrier sequence for a PWM inverter, a real valued GA is employed [7]. The real valued GA has many advantages in numerical function optimization over binary encoding such as efficiency of the real-valued GA is increased, as there is no need to convert chromosomes to phenotypes before each fitness evaluation; less memory is required; and there is no loss in precision by the conversion between binary and real values.

Total Harmonic Distortion (THD) is taken as the performance index for optimization. Total harmonic distortion is the summation of all harmonic components of the voltage or current waveform compared against the fundamental component of the voltage or current wave.

Genetic Algorithms (GA) are adaptive methods which may be used to solve search and optimization problems. They are based on the genetic processes of biological organisms. Over many generations natural populations evolve according to the principles of natural selection and survival of the fittest first clearly stated by Charles Darwin in The Origin of Species. By mimicking this process genetic algorithms are able to evolve solutions to real world problems if they have been suitably encoded.

GAs uses a direct analogy of natural behavior. They work with a population of individuals each representing a possible solution to a given problem. Each individual is assigned a fitness score according to how good a solution to the problem it is. The highly fit individuals are given opportunities to reproduce by cross breeding with other individuals in the population. This produces new individuals as offspring which share some features takenfrom each parent. The least fit members of the population are less likely to get selected for reproduction and so die out.A whole new population of possible solutions is thus produced by selecting the best individuals from the current generation and mating them to produce a new set of individuals. This new generation contains a higher proportion of the characteristics possessed by the good members of the previous generation. In this way over many generations good characteristics are spread throughout the population being mixed and exchanged with other good characteristics as they go. By favoring the mating of the more fit individuals the most promising areas of the search space are explored. If the GA has been designed well the population will converge to an optimal solution to the problem. The steps involved in GA for optimization is as shown in fig.4.

The procedures of the real valued GA for optimizing PWM are outlined as follows:

1. **Population representation of the natural parameter:** The instantaneous periods in a sinusoidal cycle can be Expressed as a sequence, (4 ,i = l , ..., n). The instantaneous period sequence will be coded into a long real-valued string, called chromosome.
2. **Initial generation:** It starts by randomly generating an initial population of the long real-valued strings. The initial population includes M chromosomes.
3. **Fitness evaluation:** In the current generation, all triangular carrier signals are generated by each of the strings. Then, these carrier signals are sent to the PWM inverter to operate to be assigned individually with a special fitness value. These fitness values are generated from a measure index and then evaluated with a linear ranking method. Here THD of inverter output voltage is taken s the measure index.

4. **Reproduction:** Reproduction is a process through which parent structures are selected to form new offspring.
5. **Recombination (crossover):**The single-point recombination method is used to exchange the information among the chromosomes.
6. **Mutation:**Breeder Genetic Algorithmis used to implement the mutation operator for the real valued GA, which uses a non-linear term for the distribution of the range of mutation applied to gene values.
7. **Iteration:** The real-valued GA runs iteratively repeating the processes 3) to 7) until a population convergence condition is met or the given maximum number of iteration number is achieved.

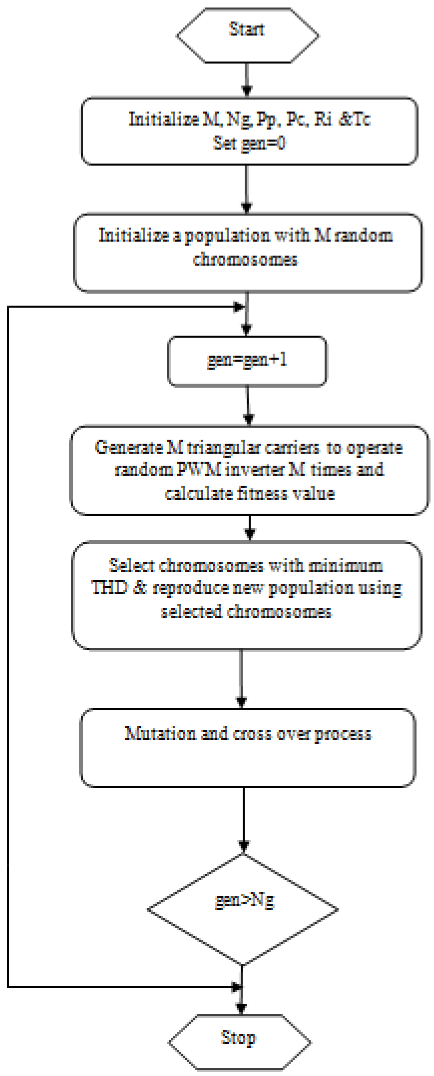


Fig 4.GA operation flow chart to optimize a random PWM inverter.

ISSN 2348 – 8034
Impact Factor- 4.022

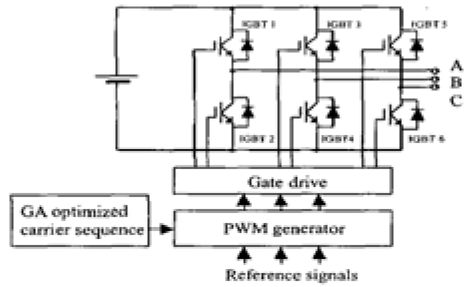


Fig 5.Implementation of optimized PWM inverter.

Fig.5 shows the implementation of optimized random PWM scheme for inverters. Here the carrier sequence selected through optimization process using Genetic algorithm is applied to the PWM generator. The comparison of this carrier sequence with reference sinusoidal signal generate random PWM signal and is applied to inverter for induction motors.

V.CONCLUSION

Different methods for the elimination of the harmonics distortions at the output of the inverter have been discussed. Random pulse width modulation (RPWM) techniques provide better output quality than conventional sine- triangle PWM and reduce acoustic noise and harmonic losses. RPWM scheme can be improved by using an optimization process. Genetic algorithm has been used for the optimization of RPWM with total harmonic function as performance index. From the discussions it has been found that optimized random PWM techniques are the best choice for multilevel inverters.

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