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A Review on Techniques for Reduction of Harmonic Distortion

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Abstract: In recent decades, the growing and widespread use of electronic equipment by different segment of society is perceptible. This equipment present itself as nonlinear impedesdances to its supplying electrical systems and generates harmonics with well-known adverse effects such as low power factor, electromagnetic interface, voltage distortion, etc. These disturbances have required researchers to present solution to minimize or eliminate them. This study has reviewed, the aim and techniques for reduction of harmonic distortion. Wide arrays of approaches have been discussed.

Key words: Harmonic distortion, walsh function, Pusle-width Modulation (PWM), eliminate, equipment, impedesdances

INTRODUCTION

A harmonic is a signal or wave whose frequency is an integral (whole-number) multiple of the frequency of some reference signal or wave. For a signal whose fundamental frequency is f, the 2nd harmonic has a frequency 2 f, the 3rd harmonic has frequency of 3 f and so on. Signal occurring at frequencies of 2, 4, 6 f, etc., are called even harmonics; the frequencies 3 and 7 f etc., are called odd harmonics.

If all the energy in a signal is contained at the fundamental frequency then that signal is a perfect sine wave.

If the signal is not a perfect sine wave then some energy is contained in the harmonics. Examples are square wave, saw tooth wave and triangular wave. As the harmonic spectrum becomes richer in harmonics the waveform takes on more complex appearance indicating more deviation from the ideal sinusoid. A rich harmonic spectrum may completely obscure the fundamental frequency sinusoid making a sine wave unrecognizable. It is well known that any periodic waveform such as that mentioned previously can be represented by Fourier series, an infinite sequence of sine and cosine waves at the fundamental frequency of the waveforms and its harmonics.

These harmonics can cause trouble in several areas particularly in motors and sensitive application. The standard measure for distortion is Total Harmonic Distortion (THD). A single-phase square wave inverter has the least desirable output waveform type; a square wave is sort of a flattened-out version of a sine wave as shown in Fig. 1. Generally, square wave output inverter available in market is simple in design and low cost. Such inverter has some disadvantages. For starters, the peak voltage of a square wave is substantially lower than the peak voltage of a sine wave. In addition, a square wave contains many higher frequencies as well called harmonics which can cause buzzing or other problems. Inverters are widely used in many applications such as in the UPS and ac motor drives. There are many types of inverters.

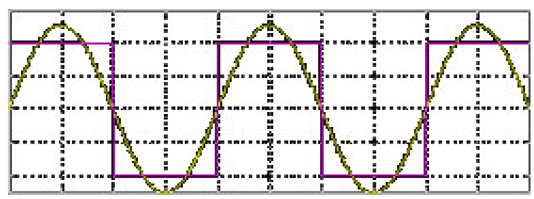

Fig. 1: Square and generated sine waveform from square wave

The Pulse-width Modulated (PWM) inverter is the most favored one for industrial applications. The control schemes of PWM inverters are broadly classified as programmed PWM inverters and sinusoidal PWM inverters. The sinusoidal PWM method is very popular in many applications. However, this scheme is not suitable for microprocessor based implementation when various sinusoidal voltages and frequencies are required in the system. Linear algebraic equations are solved to obtain the switching angles resulting in eliminating the unwanted harmonics.

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MATERIALS AND METHODS

A design procedure in which a generalized method is developed for both the bipolar and unipolar voltage schemes. The performance of the bipolar and unipolar inverters are compared using the Walsh function harmonic elimination method. By using the linear approximation approach, the switching angles are expressed as linear functions of the fundamental amplitude and frequency.

Thus, the switching angles can be computed rapidly on line and the memory space of the large lookup table that would otherwise be needed is not required. It is also very easy to control the amplitude and frequency of the inverter output voltage for the microcomputer-based implementation. This proposes a superior scheme for producing nearly sinusoidal output waveforms using the modified Walsh function harmonicelimination method (Liang *et al*., 1997). There are switching angles to be computed in one quarter period to eliminate harmonics since, one degree of freedom is used to determine the fundamental amplitude.

Generalized methods are developed to eliminate up to 15 harmonics. The results show that the switching angles computed accurately eliminate the selected harmonics for the desired fundamental amplitudes. The algorithm solves the linear algebraic equations off line to obtain the switching angles corresponding to the fundamental amplitude. By using the curve-fitting method, the switching angles are expressed as linear functions of the fundamental amplitude and fundamental frequency. It is shown that the performance of linear approximation results are very good for practical implementations. It is very easy to generate a variable-frequency variable-voltage sinusoidal voltage in a simple manner because the switching angles can be computed on line very easily.

Also, smaller memory is needed and fewer computations are required for the hardware implementation. Bipolar and unipolar switching patterns are investigated and optimized. The results show that the unipolar inverter is a better scheme since, it has the lowest HLF and distortion factor. The high-speed CPU of the TMS320C14 digital signal processor makes the preprogrammed PWM inverter most useful since the switching angles are computed accurately, resulting in precision results. Using filter circuits, the remaining higher order harmonics are relatively easy to filter out giving a nearly sinusoidal output.

The hardware results compare very favorably with computer simulation results. The main challenge of solving the associated nonlinear equations which are transcendental in nature and therefore have multiple solutions is the convergence. In this research, a SHEPWM model of a multilevel series-connected voltage-source inverter is developed which can be used for an arbitrary number of levels and switching angles (Li *et al*., 2000). Simulation and experimental results for a 5-level (or double-cell) 22-angle single-phase inverter and a 5-level 20-angle 3-phase inverter are presented. Simulation results for an 11-level (5-cell) 45-angle 3-phase inverter are also given.

A reduced-order SHEPWM method by mirror surplus harmonic shaping for 5-level inverters is proposed and experimentally verified. A multilevel selected harmonic elimination PWM method has been proposed. The computational difficulties of multilevel SHEPWM methods are overcome by development of an inverter model for nonconstraint optimization. The optimization starting point is obtained using a phase-shift surplus harmonic suppression technique. Simulation and experimental results are presented for a double-cell series-connected voltage source PWM inverter in single-phase and 3-phase configuration. Simulation results for a 3-phase 5-cell inverter are also given. The multi-level SHEPWM method is capable of providing very high-quality output waveforms.

A new reduced-order method of mirror harmonic suppression in a double-cell series-connected PWM inverter is also suggested. Instead of using a difficult-to-solve system of nonlinear equations, the 2 inverter cells are considered separately. Low-order harmonics in the 1st cell are eliminated with a standard SHEPWM harmonic elimination scheme. An additional switching angle is allowed in the 2nd cell to shape its frequency spectrum in such a way that it mirrors the spectrum of the first cell. The results obtained from the solution of the 2 systems of equations of order and closely approximate the solution of a system of equation. Hence, the difficulty and amount of calculations are greatly reduced.

Experimental tests, conducted for an inverter with switching angles per quarter wave in the first cell show harmonic suppression that is comparable with that for a multilevel SHEPWM. In this research series active filter for harmonic reduction is proposed (Ribeiro and Barbi, 2006). A sinusoidal waveform, from a distorted voltage source was delivered to the load after being process by filter. In result, it shows total harmonic distortion of the outputvoltage compared to the input voltage is much less (THD = 1.91%). High performance Constant Voltage Constant Frequency (CVCF) Pulse-width Modulated (PWM) inverters should accurately regulate the output ac voltage/current to the reference sinusoidal input with low Total Harmonics Distortion (THD) and fast dynamic response. Nonlinear loads such as the rectifier loads that case periodic distortion are major sources of THD. In this study, a zero-phase odd-harmonic repetitive control scheme is proposed for pulse-width modulation inverters (Zhou *et al.*, 2006). The proposed repetitive controller combines an odd-harmonic periodic generator with a non casual zero-phase compensation filter. It occupies less data memory than a conventional repetitive controller does. Moreover, it offers faster convergence of the tracking error and yields very low Total Harmonics Distortion (THD) and low tracking error. The results show that the odd-harmonic RC control offers very low THD (<2%) under both liner load (resistor and no load) and nonlinear rectifier load. A 5-level SHEPWM technique for voltage source converter has been proposed in letter the problem of finding the switching transitions is reformulated without requiring quarter and half-wave symmetry for the output waveform (Dahidah *et al.*, 2006). An efficient optimization/minimization technique assisted with a hybrid genetic algorithm is applied to find the switching transitions for a valid modulation index value of the fundamental component.

A minimization technique to solve the SHEPWM control method for inverts has been discussed in the study (Agelidis *et al.*, 2006). The method finds the complete set of solution of given problem and confirms that multiple ones exit. The advantage of this method is that no conversion of the problem to set of polynomial equations is needed further reducing the computational and/or human effort. Moreover, an optimum solution is always guaranteed even though when other methods may fail to coverage. This is simply because the problem is formulated in a way that the equations do not need to become zero but rather one function needs to be minimized. Selective harmonic elimination is a long established method of generating Pulse-width Modulation (PWM) with low baseband distortion.

Originally, it was useful mainly for inverter with naturally low switching frequency due to high power level or slow switching devices. In this study, SHE method based on modulation is proposed (Wells *et al.*, 2007). A modified triangle carrier is identified that is compared to ordinary sine wave. In place of the conventional offline solution of switching angles, the process simplifies to generation and comparison of the carrier and sine modulation which can be done in minimal time without convergence or precision concerns. This method is based on modulation rather than solution of nonlinear equations or numerical optimization. The approach is based on a modified carrier waveform that can be calculated based on concise functions requiring only depth of modulation as input. It rapidly calculates the desired switching waveforms while avoiding iteration and initial estimates. Calculation time is insensitive to the switching frequency ratio so elimination of many harmonic is straightforward. It is conceivable that the technique could be realized with low-cost microcontroller for real-time implementation. Once carrier is computed a conventional carrier-modulation comparison process produces switching instants in real time.

CONCLUSION

In this review, Different methods discussed for reduction of Harmonic Distortion (THD) and all described scheme shows the result THD less than two percentages. But presently no method gives sinusoidal wave output waveform with zero percentage THD.

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