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Minimization of Harmonics in PWM Inverters Based on Genetic Algorithms

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Abstract: This study describes a new approach based on genetic algorithm to suppress the current harmonic contents in output of an inverter. A genetic algorithm is applied to optimize a pulse width modulation (PWM) inverter, which can not only spread harmonic energy but also reduce harmonic distortion. A feasible test is implemented by building a proto type three phase voltage source inverter which is designed and controlled on the basis of proposed considerations. It is verified from a practical point of view that these new approach are more effective and acceptable to minimize the harmonic distortion. Due to the complex algorithm, their realization often calls for a compromise between cost and performance.

Key words: Harmonic distortion, voltage source inverter (VSI), pulse width modulation (PWM), genetic algorithm (GA)

INTRODUCTION

In recent years, a variety of power electronics equipment with voltage fed pulse width modulation (VSI-PWM) inverters used widely in industrial applications and power network systems have caused significant inherent problems, such as generation of reactive current and power, as well as higher harmonic distortion in the utility power sources. To reduce the harmonic distortion it is advantageous to have a complete inverter system that introduces genetic algorithm to suppress the harmonic distortion. In many previous papers (Trzynadlowski *et al*., 1994; Bech *et al*., 1999) random pulse width modulation techniques have been presented. However these previous methods have been mainly concerned with an active reduction policy for all harmonic components based on PWM pattern generations. There are two issues in random PWM method, first, output harmonic distortion have not been alternatively improved and second, the output harmonic intensity of the inverter may always be randomly changed with various random sources.

These random harmonic distributions may be different at every sinusoidal cycle which may be observed from a spectrum analyzer. Hence the random modulation may not ensure that the power quality of the inverter output is optimum at all times. The proposed approach is able to lower the total harmonic distortion. Compared with standard PWM and random PWM methods, the genetic algorithm based inverter has smaller harmonic distortion and spread harmonic energy that will result in less loss and lower acoustic noise. In addition, the experimental results has been verified by simulation and experimental studies on a voltage controlled inverter with various output frequencies. The proposed strategy may improve variable frequency dc-ac inverters, uninterruptible power supplies (UPS's) and scalar- controlled low performance ac drives.

OPTIMIZED PWM BASED ON GA

Gas have recently been applied to optimize electrical drive systems (Shi *et al*., 2002; Liserre *et al*., 2004). In order to find the best triangular carrier sequence for a DSP based sinusoidal PWM inverter, a real-valued GA (Goldberg, 1989; Wright, 1991) is employed with minimum harmonic distortion as the objective function. In a GA, the objective function is used to provide a measure of performance valuation. For the proposed optimized PWM inverter, the most fit individuals should have a minimum harmonic distortion value. Hence, total harmonic distortion (THD), weighted total harmonic distortion (WTHD) and distortion factor (DF) (Enjeti *et al*., 1990) of output line voltage may be separately selected as an objective function according to customer requirements. The GA procedure for optimizing PWM is shown in Fig. 1 with the following operations (Shi and Li, 2003)

- Initial generation;
- Performance evaluating;
- Fitness calculation;
- Selection;
- Recombination (crossover);
- Mutation;
- Reinsertion.

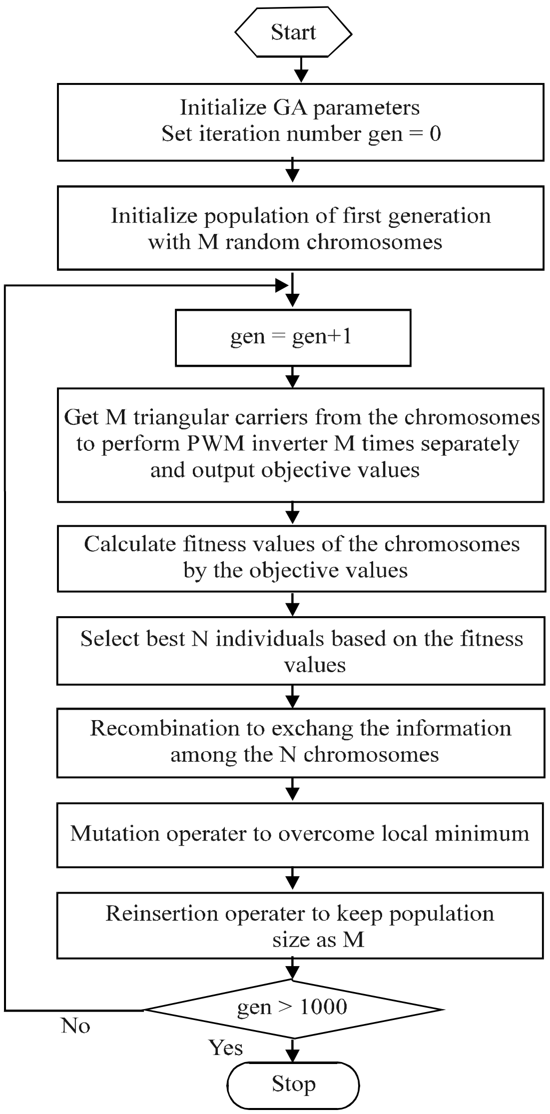

Fig. 1: Ga operation flowchart

In this study the real-valued GA is performed on an offline PC with Matlab software. In simulation studies, the following GA program parameters may yield satisfactory results:

Initial population size-1000;
Maximum number of generations-500;
Probability of crossover-0.7;
Mutation probability-0.05;
Mean of the carrier frequencies-about 10 kHz;
initial range of real-valued
Strings-[0.000 067; 0.0002];

performance measure-one of THD, WTHD and DF of PWM inverter output voltage

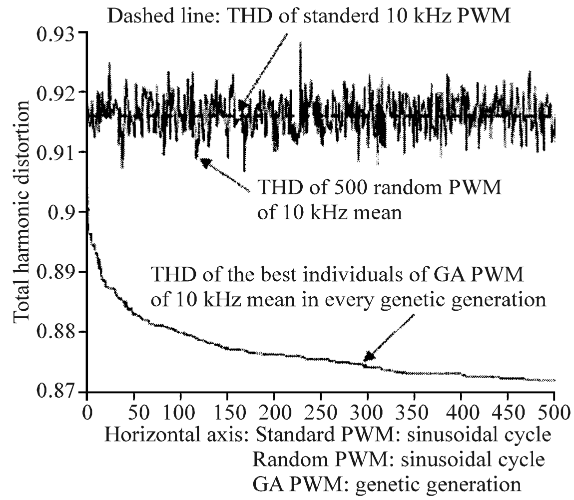

Fig. 2: Line-line voltage THD (2048th) of various PWM strategies

With gradient convergence processing, the THD of the PWM inverter output voltage is reduced about 5% (from 0.9141 to 0.8715) at the 500th generation as shown in Fig. 2 and the optimized carrier sequence is yielded. Figure 2 also includes the THD of standard PWM (dashed line) and THD of random PWM (around dashed line) in 500 sinusoidal cycles for comparison. For the standard PWM and random PWM, the x-axis refers to the number of sinusoidal cycles. For the GA-optimized, the x axis represents the number of genetic generations. The harmonic distortions of random PWM are various in different sinusoidal cycles. In order to compare it with other PWM strategies,

The averaged value of harmonic distortions of the random PWM are calculated by:

$$ATHD = \frac{\sum_{i=1}^{M} THD(i)}{M} \quad (1)$$

$$AWTHD = \frac{\sum_{i=1}^{M} WTHD(i)}{M} \quad (2)$$

$$ADF = \frac{\sum_{i=1}^{M} DF(i)}{M} \quad (3)$$

M = 500. Applying the GA to different carrier frequencies, the corresponding optimized PWM carrier sequences are obtained. The GA-optimized PWM strategy not only spreads harmonic energy, but also achieves the best THD (reduced about 5%) compared with other strategies at different carrier frequencies. If WTHD is selected as the optimized target, the GA-optimized PWM strategy has better WTHD than other PWM strategies but the improvement is not significant when the switching frequency is higher than 5 kHz. If DF is used as the optimized target, the GA-optimized PWM strategy also has the best DF compared to other PWM strategies

EXPERIMENTS WITH VARIOUS PWM STRATEGIES

The hardware setup is shown in Fig. 3. The experimental facility consists of a TMS320F2812 DSP board, an IRAMX16UP60A inverter module, a digital oscilloscope, a PC host computer and a set of power supplies. In order to compare the performances of standard PWM, random-carrier-frequency PWM and GA-optimized PWM, the normalized output voltage of the PWM inverter and the corresponding harmonic.

Spectrum are derived experimentally and displayed on a digital oscilloscope, as shown in Fig. 4. On all oscilloscope screens, the upper trace is the normalized line-line voltage, time base of 4ms/div, and magnitude of 2 V/div, while the lower trace is the spectrum with a frequency base of 2.5 kHz/div and magnitude of 300 mV/div.

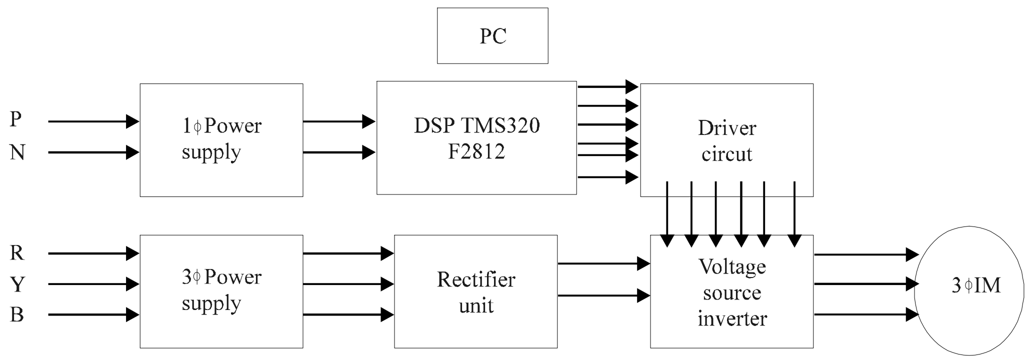

Fig. 3: Block diagram of experimental setup

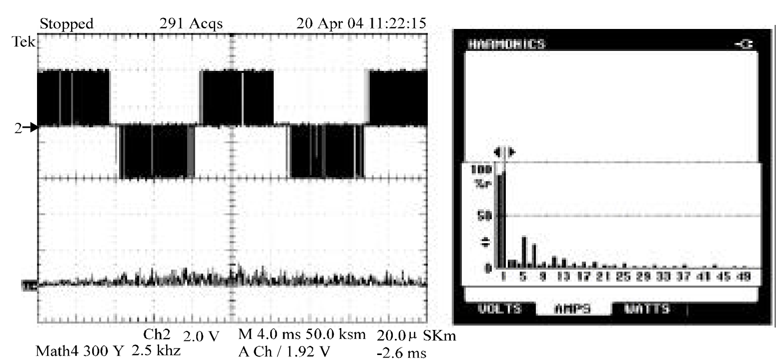

Fig. 4: (A) Inverter output of standard PWM

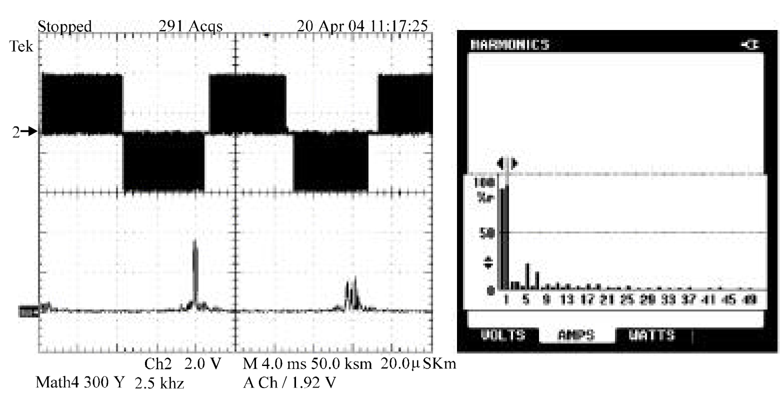

Fig. 4: (B) Inverter output of random PWM

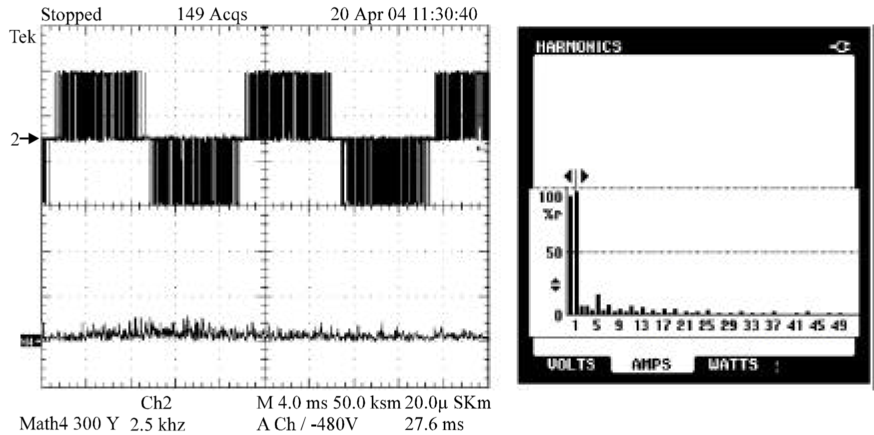

Fig. 4: (C) Inverter output of Ga-optimized PW

CONCLUSIONS

To improve conventional PWM inverter performance by reducing harmonic distortions of output voltage and by spreading harmonic energy, a real-valued GA has been employed to optimize the carrier frequency of the modulation process. Simulation and experimental studies have demonstrated that the GA-optimized PWM technique is a promising method and an economical approach to improve the power quality of PWM inverters. The proposed optimizing strategy may be applied in variable-frequency dc-ac inverter, UPSs and scalar-controlled low performance ac drives.

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