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GENETIC ALGORITHM METHOD OF MINIMIZING HARMONIC DISTORTION IN PWM CONVERTERS- Part II

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Résumé

Dans cet article nous comparons la méthode conventionnelle pour l'élimination des harmoniques avec une nouvelle méthode proposée pour la minimisation de la distorsion engendrée par les convertisseurs ac/dc. Elle utilise l'algorithme génétique pour l'élimination des harmoniques ciblées. Le spectre de courant obtenu par la méthode basée sur l'algorithme génétique présente un THD minimal. L'optimisation par l'algorithme génétique, nous a permis de confirmer les résultats obtenus par la méthode de résolution numérique.

Mots-clés: *MLI, THD, Algorithme génétique, Harmoniques*

Abstract

Conventional harmonic elimination method is compared with to a recently proposed distortion minimization technique for ac/dc converter. Proposed optimization method uses Genetic Algorithm to eliminate certain chosen harmonics while minimizing harmonic distortion in rectifier input current. In this work we present the specter of rectifier input current compared with to the specter of input current while using a numeric method and another method based on the genetic algorithm (GA). This latter presents an optimal specter and there for a minimum THD and offers good perspectives to eliminate harmonics in the electric networks. Optimization by the genetic algorithm permitted us to confirm results gotten by the numeric resolution method.

Keywords: *PWM, Harmonic, THD, Genetic Algorithm.*

1. Introduction

The massive no - linear load used on a domestic and industrial scale provoked the distortion of tension and the current in the electric network [1]. As a consequence, the harmonic, subs - harmonic, and inter - harmonic [2] are often present in the specter of tension or the current. The harmonic distortion can produce various harmful effects on the electric network and its environment. Numerous publications were about cases or these effects reached some intolerable levels [3]. The excessive warming-up, interference with networks of telecommunications, the electronic dysfunction, and the excitation of resonance can quoted beings like examples. The evolution of the semiconductor technology permitted to answer thanks to the new components as IGBT, GTO, by new solutions to disruption of networks. Among these one can mention pulse width modulation (PWM) rectifiers and the active filters. With these new structures problems bound to the passive facilities (batteries of capacitors and passive filters), as resonance, overcharges and the strong dependence of the environment will disappear. The principle of PWM converter [4] consists to bind two nature different sources by the slant of switches semiconductors to closing and opening ordered, to which is possibly associated of diodes. In this article we present results of the developed numerical algorithm that verify the constraint of realization (angles of unequal positive commutations, and crescents by quarter of period), and at the same time the quality of the specter, and a new method based on the genetic algorithm.

2. Numerical optimization technique

The technique consists in determining according to the number of commutation (C) by quarter of period values of commutation angles optimized that eliminate the harmonic selected. To solve a system of no - linear equations of nature below with constraints are sufficient, multiple solutions are possible.

The equation of the fundamental according to the modulation index *m* is the relation between the amplitude and the continuous current. Equations of selected harmonics will be equal to zero.

The input current of the PWM rectifier is defined as [5]:

$$b_n = 2\frac{I_d}{n\pi}\left[-1+2\sum_{i=0}^{C-1}(-1)^i\cos(n\alpha_i)\right] \quad (1)$$

Where I_d is the continuous current, a_i are commutation angles, *n* is the harmonic rank, and *C* is commutation type.

Constraints of realization verify the following inequality:

$$0 < \alpha_0 < \alpha_1 < \alpha_2 < \alpha_3 < \ldots\ldots < \frac{\pi}{2} \quad (2)$$

The results are used like initial values to minimize the objective function that represents the rate of distortion harmonic THD defines by standard IEEE 519-1992 as:

$$THD = \frac{1}{A_1}\sqrt{\sum_{n=2}^{N=50} A_n^2} \quad (3)$$

It is the second criteria of optimization

Where A_1 is the fundamental current amplitude and A_n is the nth harmonic current amplitude.

3. Optimization by genetic algorithm

The basic principles of Genetic Algorithm (GA) were first proposed by Holland [6]. It is inspired by the mechanism of natural selection where stronger individuals would likely be the winners in a competing environment. In this approach, the variables are represented as genes on a chromosome. GAs feature a group of candidate solutions (population) on the response surface. Through natural selection and the genetic operators, mutation and recombination, chromosomes with better fitness are found. Natural selection guarantees the recombination operator, the GA combines genes from two parent chromosomes to from two chromosomes (children) that have a high probability of having better fitness that their parents. Mutation allows new areas of the response surface to be explored. GAs offer a generational improvement in the fitness of the chromosomes and after many generations will create chromosomes containing the optimized variable settings. Table 1 lists some of the terms frequently used.

Table 1: Technical terms used in GA literatures

Chromosome	Vector which represents solutions of application task
Gene	Each solution which consists of a chromosome
Selection	Choosing parents' chromosomes for the next generation
Individual	Each solution vector which is each chromosome
Population	Total individuals
Population size	The number of chromosome
Fitness function	A function which evaluates how each solution suitable to the given task
Phenotype	Expression type of solution values in task world
Genotype	Bit expression type of solution values used in GA search space.

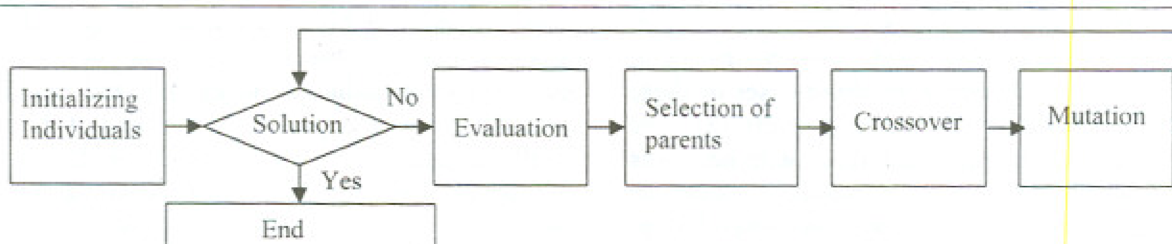

Figure 1. The flow of GA process

The GA operations are explained in the following sections.

3.1 Selection

Selection is an operation to choose parent solutions. There are several selection methods. Roulette wheel is a typical selection method. The probability to be a winner is proportional to the area rate of a chosen number on a roulette wheel.

3.2 Crossover

Crossover is an operation to combine multiple parents and make offspring. The crossover is the most essential operation in GA. There are several ways to combine parent chromosomes. The simplest is called *one-point crossover* [7]. Crossover that uses two cut points is called *two-point crossover*. Their natural expansion is called *multi-point crossover* or *uniform crossover*.

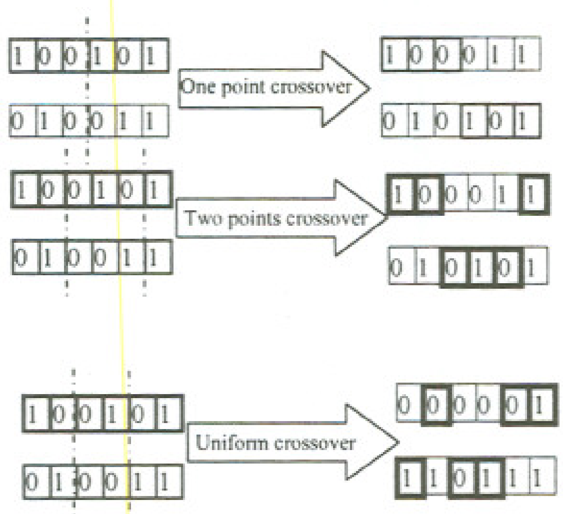

Figure 2. Several variations of crossover

3.3 Mutation

Mutation is employed to give new information to the population and also prevents the population from becoming saturated with similar chromosomes.

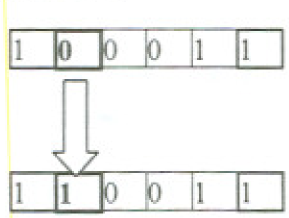

Figure 3. Example of mutation

4. Simulations and discussions

The figures 1, 2, 3 explain stages of the genetic algorithm and its operations that are the selection, the crossover, and the mutation. The figure 4 shows the form in trapeze of the current absorbed by a conventional converter ac/dc in bridge of Greatz, the voltage to its boundary marks, and on the figure 5 its specter for harmonics 5 and 7. The firing angles according to modulation index in the case two commutations (control C2) for the minimization of the harmonic 5, 7 are presented on the figure 6 (control C2, type1). The figure 7 shows the comparison of results of specters of the type 1 between the conventional converter ac/dc and the PWM rectifier optimized by the numeric algorithm (HRPWMN) that presents a specter to harmonic selected 5, 7 attenuated. The PWM rectifier optimized by GA (HRPWMG) presents the optimal specter than HRPWMN because optimization is pushed more with GA since it looks for the global minimum (figure 8). We widened the number of the harmonic to minimize from the rank 5 at 23, this to make the technique more interesting, and to have a minimal THD. The figures 9, 10, 11 show the comparison of specters. The specter of the HRPWMG control 2 type 2 is optimal with an equal THD to 0,1629 (Table 4) that is relatively less of 43,33% in relation to the THD of the conventional rectifier, and of 24,33% to the THD of the HRPWMN rectifier. The increase of the number of commutations (Control 11 type 2) from 2 to 11 commutations by quarter of period gave an optimal result in relation to the control C2 type 2 (Figure 12, 13). The THD of the HRPWMG rectifier is more optimal (Table 4) that the one of the HRPWMN.

The tables (2, 3) present the numeric values of parameters of the GA for the different controls. For the control C11 type 2 (Table 3) with eleven variables, the rate of mutation is weak (0,003), does not to increase the diversity of the population, the rate of crossover (0,8) is big, this to combine parents better, and to permit the convergence.

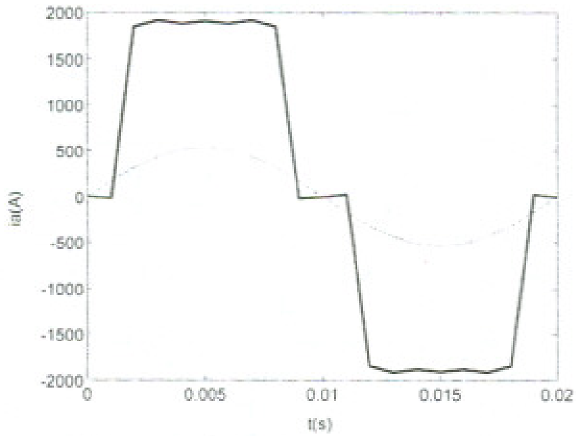

Figure 4. Input current and voltage of conventional ac/dc converter

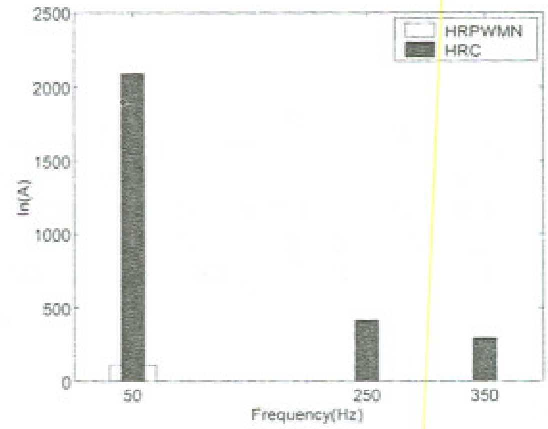

Figure 7. Spectre of input current of ac/dc converter (Conventional, HRPWMN, control C2, type 1).

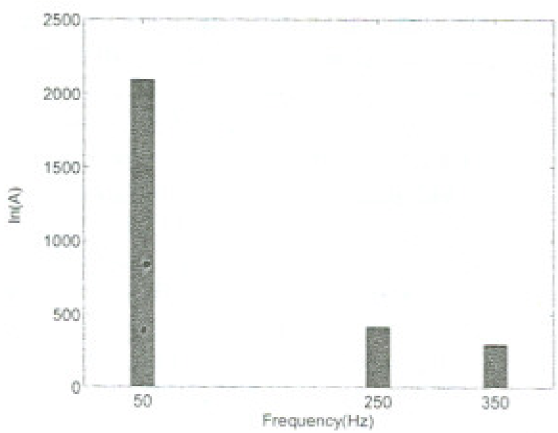

Figure 5. Spectre of input current of conventional ac/dc converter.

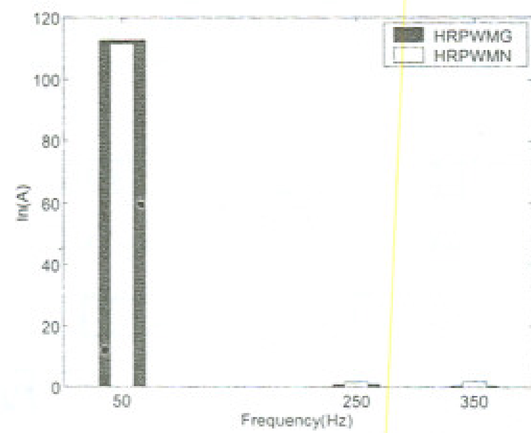

Figure 8. Spectre of input current of ac/dc converter (HRPWMN, HRPWMG, control C2, type 1).

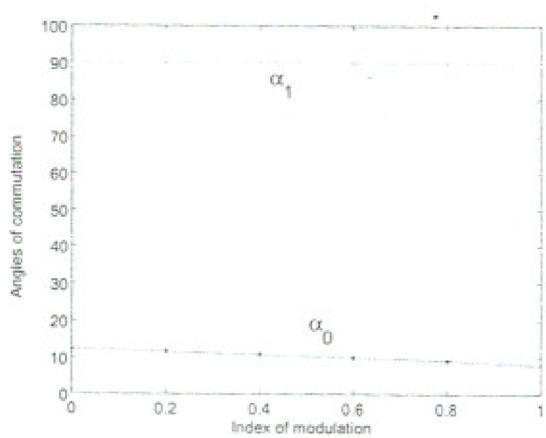

Figure 6. Angles of commutations for HRPWMN rectifier (control C2)

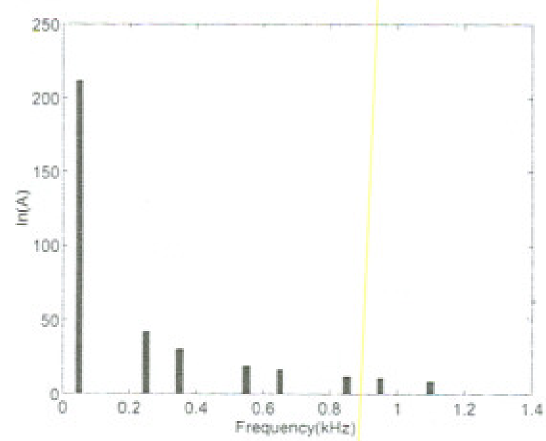

Figure 9 Spectre of input current of conventional ac/dc converter (type 2).

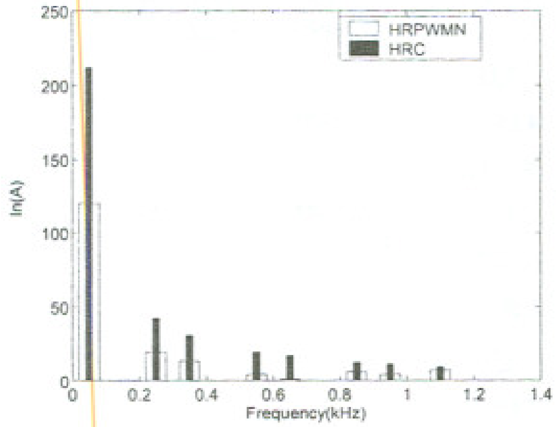

Figure 10. Spectre of input current of ac/dc converter (Conventional, HRPWMN, control C2, type 2).

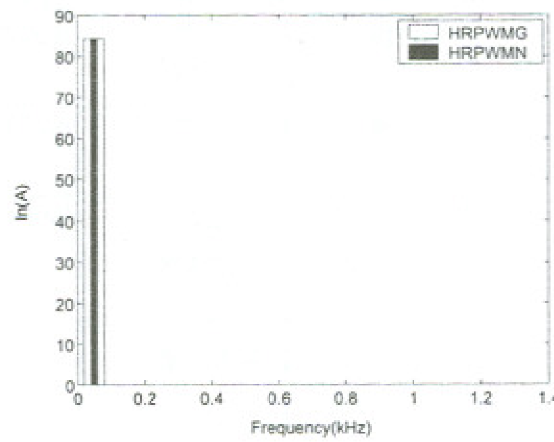

Figure 11. Spectre of input current of ac/dc converter (HRPWMN, HRPWMG, control C2, type 2).

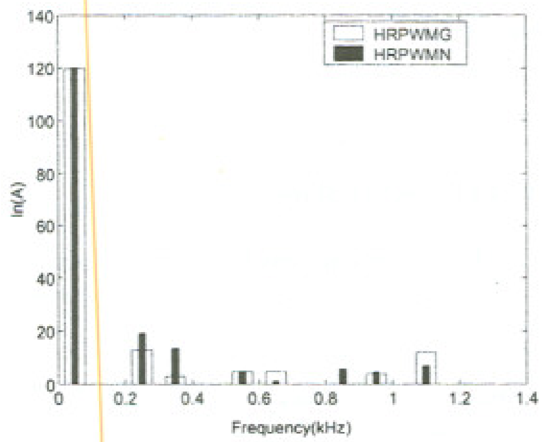

Figure 12. Spectre of input current of ac/dc converter (Conventional, PWMN, control C11, type 2).

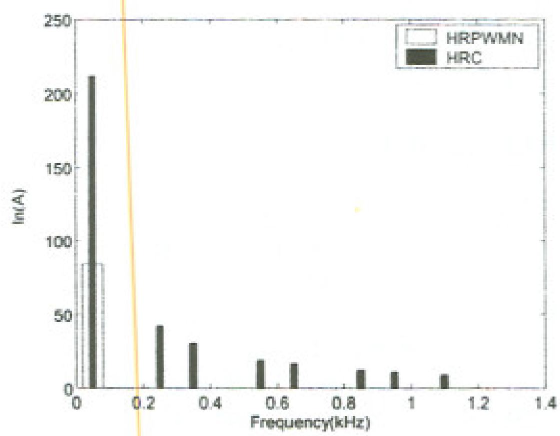

Figure 13. Spectre of input current of ac/dc converter (HRPWMN, HRPWMG, control C11 type 2).

Table 2: Genetic Algorithm Parameters for control C2 type1 and type2

Algorithm Parameter	value
Population Size	20
Selection	Roulette
Mutation Rate	0,005
Crossover Rate	0,4
Max. Generation	500
Tolerance	10^{-6}

Table 3: Genetic Algorithm Parameters for control C11/type2

Algorithm Parameter	value
Population Size	20
Selection	Roulette
Mutation Rate	0,003
Crossover Rate	0,8
Max. Generation	100
Tolerance	10^{-6}

Values of angles optimized by algorithm numeric and the genetic algorithm are given in the following table

Table 4: Values of angles optimized by HRPWMN and HRPWMG

Control	HRPWMN	THD	HRPWMG	THD	THD/HRC.
C2/Type1	$a_0 = 10.7°$ $a_1 = 88,51°$	0,0238	$a_0 = 10,18°$ $a_1 = 87,04°$	0,0098	0,2457
C2/Type2	$a_0 = 4.59°$ $a_1 = 89.67°$	0,2153	$a_0 = 4,18°$ $a_1 = 89,02°$	0,1629	0,2875
C11/Type2	$a_0 = 2,18°$ $a_1 = 10,42°$ $a_2 = 14°$ $a_3 = 20,36°$ $a_4 = 24,85°$ $a_5 = 30,05°$ $a_6 = 32,02°$ $a_7 = 37,92°$ $a_8 = 41,39°$ $a_9 = 65,31°$ $a_{10} = 68,74°$	0,0011	$a_0 = 2,19°$ $a_1 = 10,42°$ $a_2 = 14°$ $a_3 = 20,36°$ $a_4 = 24,85°$ $a_5 = 30,06°$ $a_6 = 32,02°$ $a_7 = 37,93°$ $a_8 = 41,39°$ $a_9 = 65,31°$ $a_{10} = 68,74°$	0,0009	0,2875

4. Conclusions

In general, the PWM is a technique of control in which the application in the domain of converters is commonly used. The PWM optimized presented in this work offers the possibility of the selection of the harmonic to minimize, and by continuation the mastery of the THD wanted. To make this technique more interesting, we have introduced the method of optimization based on the genetic algorithm that is in this case more effective than the numeric methods that present the inconvenience of the local convergence. Angles optimized by AG in the case of the control C11 type 2 give a specter of the current absorbed by the PD3 rectifier without the harmonic selected, and a THD of 0,0009 that is very interesting. According to results of commutation angles, we could conclude that the contribution of the genetic algorithm in this case is not so remarkable for the research of the convergence because of the nature of the objective function to non linear algebraic character and that was solved by the numeric algorithm. Solutions generated by the genetic algorithm confirm the convergence of the numeric algorithm.

Finally, the application of the optimized PWM is tributary of the frequency of commutation of power components.

List of abbreviations

C2: Two commutations by quarter of period.
C11: Eleven commutations by quarter of period
Type 1: Two harmonics selected (5, 7)
Type 2: Seven harmonics selected (5, 7, 11, 13, 17, 19, and 23).
GA: Genetic algorithm.
PWM: Pulse with modulation
HRC: Conventional rectifier (Greatz Bridge)
HRPWMN: PWM rectifier optimized by numeric algorithm
HRPWNG: PWM rectifier optimized by genetic algorithm

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