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Improved power factor in a low-cost PWM single phase inverter using genetic algorithms

Erhan Butun [a,*], Tarık Erfidan [a], Satılmıs Urgun [b]

[a] Electrical Engineering Department, Faculty of Engineering, Kocaeli University, Veziroglu Campus, Izmir, 41650 Kocaeli, Turkey
[b] Civil Aviation College, Kocaeli University, Izmir, 41650 Kocaeli, Turkey

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Abstract

In this paper, a method for voltage harmonic elimination in a pulse width modulated (PWM), single phase inverter using genetic algorithms (GAs) is proposed. We explain the resolution method procedure of the non-linear equation systems in order to achieve the appropriate switching angles. The output voltages with k pulses per half cycle are written in terms of switching angles using Fourier series, and the best switching angles are calculated off line to eliminate the third, fifth and seventh harmonics. Then problem is redrafted as an optimization task, and a solution is sought through GAs. For performance comparison with GAs, the Newton–Raphson method is also applied to the present problem. Comparison shows that the genetic algorithm method has some advantages such as a reduced computational burden, faster convergence and guaranteed global optima in most cases relative to the Newton–Raphson method. The developed analysis is experimentally verified by an experimental implementation.

Keywords: Harmonic; PWM; Single phase inverter; Genetic algorithms

1. Introduction

Ideally, electrical signals are purely sinusoidal, and all phenomena resulting in modifications of this ideal shape are referred to as disturbances. Harmonic disturbances are modeled by adding to the fundamental wave a series of periodic signals of pulsations whose frequencies are multiples of the frequency of the fundamental. Recent years have witnessed a multiplication in the number of polluting electrical loads responsible for the appearance of harmonic signals in electrical networks. The problem of reducing these disturbances in switching converters has been the focus of research for many years. If the switching loses in an inverter are not a concern, then the sine triangle PWM method and its variants are very effective for controlling the inverter. On the other hand, for systems where high switching efficiency is of utmost importance, it is desirable to keep

* Corresponding author. Tel./fax: +90 262 351 33 11.
E-mail address: ebutun@kou.edu.tr (E. Butun).

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the switching times, or angles, such that a desired fundamental output is generated and specifically chosen harmonics of the fundamental are suppressed. This is referred to as harmonic elimination as the switching angles are programmed to eliminate specific harmonics. The harmonic elimination methods used in PWM inverters are proposed in Ref. [1]. The common characteristic of this method is that the waveform analysis is done in the Fourier domain. A set of non-linear, transcendental equations are then derived, and the solution is obtained using an iterative procedure, mostly by the Newton–Raphson method. This method is derivative dependent and may end in local optima; further, a judicious choice of the initial values alone will guarantee convergence. Another approach uses Walsh functions. A PWM inverter using the Walsh function harmonic elimination method is presented in Ref. [2]. By using the Walsh function method, the switching angles are optimized by linear equations, instead of solving non-linear transcendental equations. An analysis of the PWM waveform shows that piecewise linear solutions can be obtained between the switching angles and the fundamental amplitude. A method of voltage harmonic elimination in a pulse width modulated AC/AC voltage converter using GAs is proposed in Ref. [3].

From the above brief review, it is possible to conclude that only the Newton–Raphson method is extensively used for harmonic elimination in power converters, followed by the Walsh function method. This paper proposes the application of GAs for harmonic elimination in a low-cost PWM single phase inverter. This system should have the capability to meet the user's various demands without compromising the easiness of programming different tasks. Also, it would be desirable to have an open modular structure, which permits flexibility and integrability with different hardware elements. Harmonic elimination is reframed as an optimization task, and the switching instances are identified through the steps of the GAs. Further, the Newton–Raphson method is also applied under identical conditions. A comparative evaluation between the GAs and Newton–Raphson methods is then effected. The formulation of the problem of harmonic elimination in the PWM single phase inverter and the application of the GA are discussed. There are only a few examples of GAs applications, for power electronics in the literature [3–7].

A three phase diode rectifier with an add on simple cell with line frequency commutated ac switches that is able to improve greatly both the power factor and output voltage regulation of rectifiers with passive L-C filters is presented in Ref. [9]. A new application of a simulated annealing (SA) optimization algorithm for harmonics and frequency evaluation for power system quality analysis and frequency relaying is presented in Ref. [10]. An objective function based on the sum of the squares of the error is minimized to identify the amplitude and phase angle of each harmonic component as well as the fundamental frequency of the voltage signal. The proposed algorithm uses digitized samples of the voltage signal at the place where the power quality and frequency relaying are to be implemented. The proposed algorithm has an adaptive cooling schedule and a variable discretization to enhance the speed and convergence of the original SA algorithm [10]. The problem of eliminating harmonics in a switching converter is also considered in Ref. [11]. That is, given a desired fundamental output voltage, the problem is to find the switching times (angles) that produce the fundamental while not generating specifically chosen harmonics. This is done by first converting the transcendental equations that specify the harmonic elimination problem into an equivalent set of polynomial equations. Then, using the mathematical theory of resultants, all solutions to this equivalent problem can be found. In particular, it is shown that there are new solutions that have not been previously reported in the literature.

In this paper, genetic algorithms are used for harmonic elimination instead of the Newton Raphson (NR) and Walsh series methods. The GAs provide two main advantages. They do not require that (1) the roots must be known or defined in a limited range or (2) complex differential and matrices operations must be done as in the NR and Walsh series methods. From the above brief review, it is possible to conclude that only the NR method is extensively used for harmonic elimination in inverters. Contrary to related work, this paper proposes the application of genetic algorithms for harmonic elimination in the speed control of a single phase inverter by using a low-cost micro-controller with a flexible and modular structure. The dual objectives of harmonic elimination and output voltage regulation are reframed as an optimization task, and the switching angles are calculated through the steps of the GA. The formulation of the problem of harmonic elimination in the single phase inverter and the application of GAs are discussed. In our work, a method of choosing the best starting point is not necessary in the GAs for obtaining these points, which is one of most difficult tasks in the NR method as done in related papers. A comparison is also made with the NR iterative procedure.