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Sub-harmonics fluctuations cancellation in LED resonant-switching driver controller using imperialistic competitive algorithm

Abolfazl Zakariapour-Naeini, * Pouya Derakhshan-Barjoei
Department of Electrical Engineering, Naein Branch, Islamic Azad Univesity, Naein, Isfahan, Iran

Abstract
In recent years, light emitting diode technology has been used for many applications. These diodes are available in a variety of colors and are used to create uniform lighting. It means, controlling the current flow of these diodes when using their large voltages is challenging. However, this voltage has a negative temperature coefficient with increasing temperature. Therefore, constant current flow control is required to achieve uniform illumination. In this paper, we applied a circuit model of Marn-Go Kim. An evolutionary approach with discrete-time domain for the LED resonance driver transducer is presented. Using evolutionary methods and optimization of the proportional integrator controller in the feedback circuit of the resonant converter has been investigated. The results indicate that the output waveform of the resonant converter has a higher transient response rate and a decrease in sub-harmonic fluctuations. Proposed evolutionary model shows a good performance.

Keywords: resonant converter, LED driver converter، imperialistic competition algorithm, genetic algorithm

1. Introduction

In recent years, the challenges in power electronics have been recognized as one of the most important scientific debates. Today, power electronic devices are made in a variety of different applications. These include rectifiers, alternating current regulators, printers, inverters, power supplies [1]. Meanwhile, Light Emitting Diodes (LEDs) have been used in a wide range of applications including housing, automotive, decorating, medical applications, and so on. Compared to ordinary light sources, LEDs have smaller dimensions, longer life, high energy savings, and high environmental compatibility [2]. LEDs are also used in different colors. It is concluded that one of the leading challenges is controlling the current of LEDs when they are large in their direct voltage. Also, this direct voltage may be it is large, has a negative temperature coefficient with increasing temperature, so the LEDs need to be controlled to be stable, also uniform illumination in LEDs is considerable [3]. Various researches have been used to create a constant current and control the condition of LEDs. In all of these researches using a resonant transform converter has been attempted to create high-performance and low-cost conditions [4-6]. Also, according to [7], an efficient soft switching scheme based on high voltage and zero current for the LED driver resonant converter is presented, and the effect of its improvement on load feed using the Particle Swarm Optimization (PSO) algorithm is investigated. There are many algorithms such as genetic and imperialistic Competition Algorithm and population optimizations, each of which can be used to achieve the best target function and its satisfaction in terms of adapting the existing problem. The imperialistic competition algorithm continues until a convergence condition is fulfilled, or until the completion of the total number of repetitions. After all, all empires will fall, and we will have only one empire, and the rest of the nations will be under the control of this single empire. Several attempts have been made to describe the current control system in the linear modeling of the low-voltage LEDs, in which the behavior of LEDs is being predicted. However, the common thread of all models is to control the fluctuations of the current. The discrete model is based on numerical methods for design that is not explored in these researches. Using discrete numerical methods for design can lead to higher-frequency models and modifications of it for enhancement. Modeling of the LED resonance transducer has also been figured out by voltage regulation [8-9]. As indicated, all presented scheme for controlling the fluctuations of the current are not used in the discrete model for designation of the LED driver resonant converter. Using this model can make high precision and can work at high frequency. Another concern is the determination of the proportional integrator control coefficients used in the LED driver resonance transducer feedback path, which has the problem of determining these coefficients due to the continuous search space. Therefore, in this paper, with referring to Kim simulation [3], the LED resonance driver transducer modeling and explanation is discussed. Then, for controlling the current of LED driver, evolutionary methods have been used. Finally, the issues raised in a designed converter are investigated and the results are examined.

2. Problem Statement

Several attempts have been made to describe a control of light-emitting diodes. The most commonly used methods are divided into three types of closed loop control, Peak Current Controlled (PCC), Average Current Control (ACC), and hysteresis Current Control (HCC) [8]. In the case of the proposed models for controlling current fluctuations, the discrete model for the design of the LED resonance converter design is not used. In this case, description of the discrete time interval model using by Kim is explained [3]. The sample LED driver is shown in Figure 1.

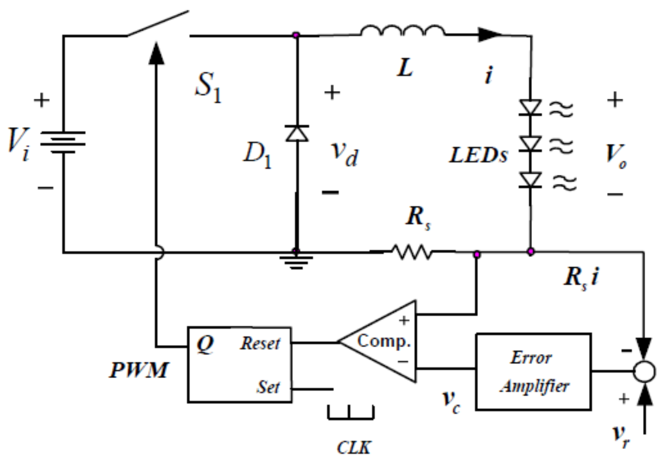


Fig 1: Buck resonator converter with peak current control [3]

According to the reference [3], Buck resonator converter with peak current control is being figured out. With applying imperialistic competitive algorithm and genetic algorithm on the cost function and considering limitation of parameters and their ranges the simulation has been done and a comparative result has been figured out.

3. Simulation of the proposed structure and results

A Bucket converter LED driver is used to evaluate the proposed method [9]. A simulation of a LED driver resonant converter with peak current control using evolutionary algorithm has been done. In Figure 2, a LED converter is used to evaluate the proposed method. It is evident that the load of this dimming converter is light emitting diodes. Also, the simulated circuit is shown. As shown in Figure 2, a MOSFET is used to simulate the transmitter switch. A resonant proportional integrator controller is used in the resonant converter feedback to increase the output error of the converter to generate pulses for the MOSFET in the converter. It should be noted that the simulated circuitry has 5 LEDs that are connected in series, each of which has a V25 / 16 series voltage.

In this section, using the genetic algorithm and Imperialistic competitive algorithm in the continuous environment, optimization of the coefficients of the controller has been investigated in order to reduce or eliminate the sub-harmonic fluctuations and appropriate responses by using the tuning-transformer controller values [10, 11].

Here, the coefficients of the proportional integrator controller are unknown to us in solving the optimization problem. Therefore, the coefficient of proportional (K_p) and the integral coefficient (K_i) of this controller are used as evolutionary algorithm variables.

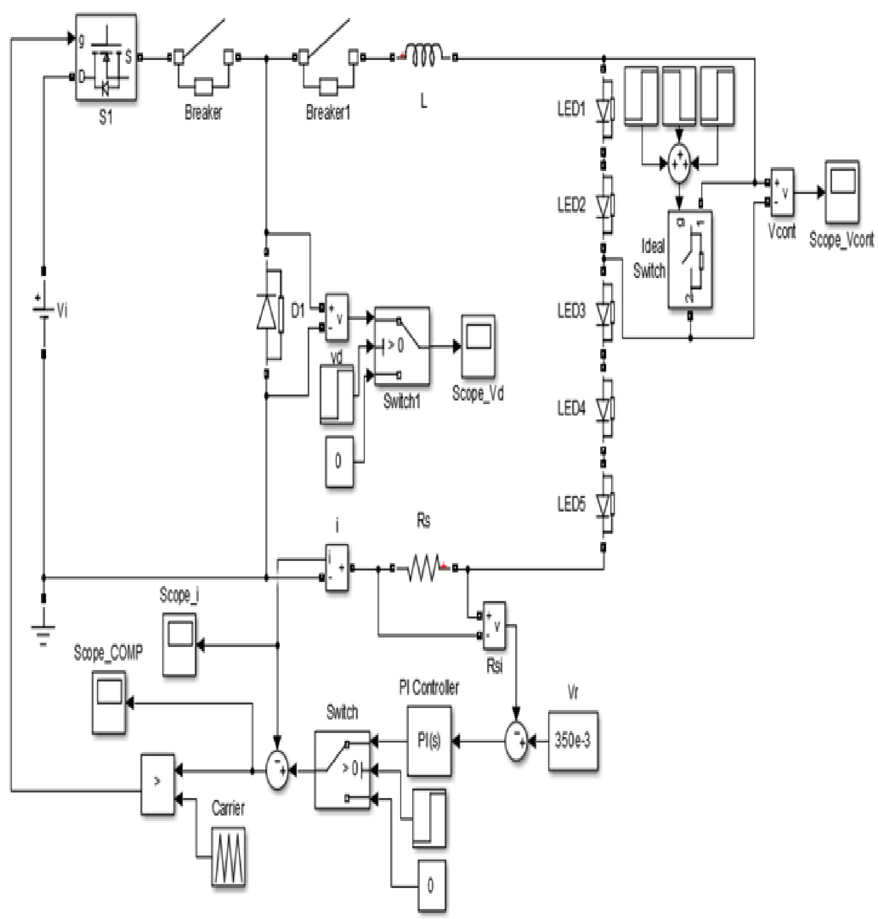


Fig 2: Simulated Circuit

In the application of the genetic algorithm, the initial population is considered for optimization is 10, in other words, in each step of the genetic algorithm, different amounts are considered for the chromosomes. The number of iteration is 100, which, given the sample space of the search, will have a number of repetitions of satisfactory results. Also in Table 1, the parameters of the selected genetic algorithm are shown.

Table 1: Genetic algorithm setting parameters

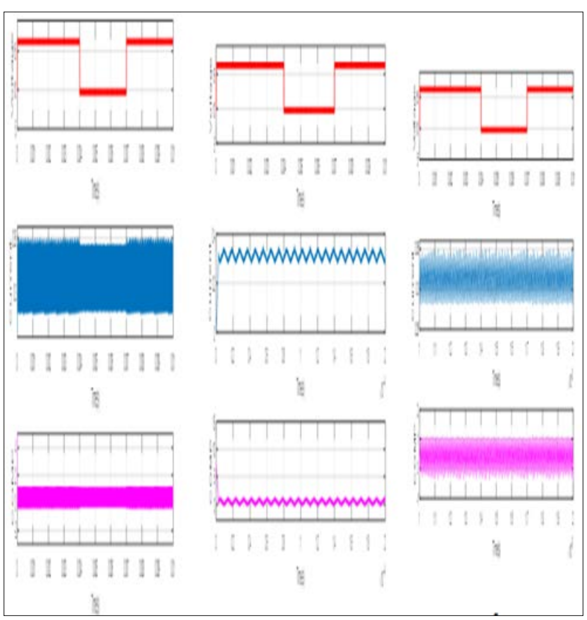
Parameter	Amount
Iteration	100
Population	10
Cross over	0.8
Mutation	0.1
Mutation rate	0.02

In Table 2, the values obtained from the genetic algorithm for a given interval and constraints are shown. In this optimal optimization and simulation, the values of the proportional-analytical controller coefficients have been optimized in this selective range. In this case, the acceptable values for the chromosome of the genetic algorithm are simulated in the range of 0-20, which results According to Table 2.

Table 2: Different results of simulating the genetic algorithm

Cost dependent	The values obtained from the algorithm		Functional range	
	K_{ni}	K_P	K_{ni}	K_P
18.294	17.2	19.87	$0 < K_{ni} < 20$	$0 < K_P < 20$

In Figure 3, the shape of the voltage, current, and output signal of the proportional integral controller is shown after comparing the resonant converter load current used to generate pulses. These waveforms are extracted using the values obtained from Table 2.



a) b) c)

Fig 3: Waveforms of voltage, current and comparison

Table 3 shows the parameters of the Imperialistic competitive algorithm for optimizing the LED drive resonance converter. The number of primitive empires is 5, and the total number of countries and colonies is 10. The reason for this choice is to partially repeat the same algorithm as the frequency of repetition of the genetic algorithm in the previous section, so that the possibility of comparison in the final sections of this study is feasible and we can make a better conclusion.

Table 3: Setting parameters Imperialistic competitive algorithm (ICA)

Parameter	amount
Iteration	100
Number of Countries	10
Number of Empires	5
Colonial impact	0.3

The Imperialistic Competition Algorithm (ICA) is simulated for the state mentioned in the table.

Different methods of comparing the best answer, comparing the convergence rate, comparing the time of convergence, comparing the number of function evaluation recall (NFE) and comparing the evolutionary algorithms are used. In most articles and references, the frequency of calling the target function as a criterion for estimating optimization algorithms and an algorithm that achieves the optimal response with less number of calls is a more appropriate algorithm to solve the problem. In our simulation a comparative scheme is figured out.

Table 4: Results of Imperialistic competitive algorithm

Cost Dependent	The values obtained from the algorithm		Functional range	
	K_{ni}	K_P	K_{ni}	K_P
18.291	17.64	19.9	$0 < K_{ni} < 20$	$0 < K_P < 20$

In Figure 4, the waveforms of the voltage, current and the output signal of the integral proportional controller are shown after comparing the resonant converter load current used to generate pulses. These waveforms are extracted using the values obtained in Table 4. In figure 4, a widespread display of waveforms is shown.

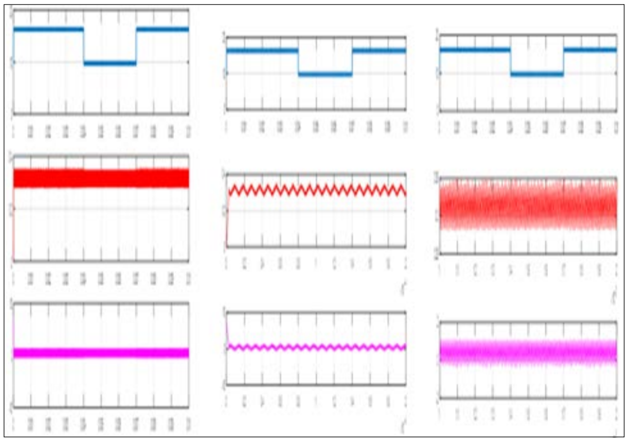


Fig 4: Waveforms of voltage and current, and comparison.

From the result it can be concluded that the optimal response is within the range of converter performance and has a suitable response

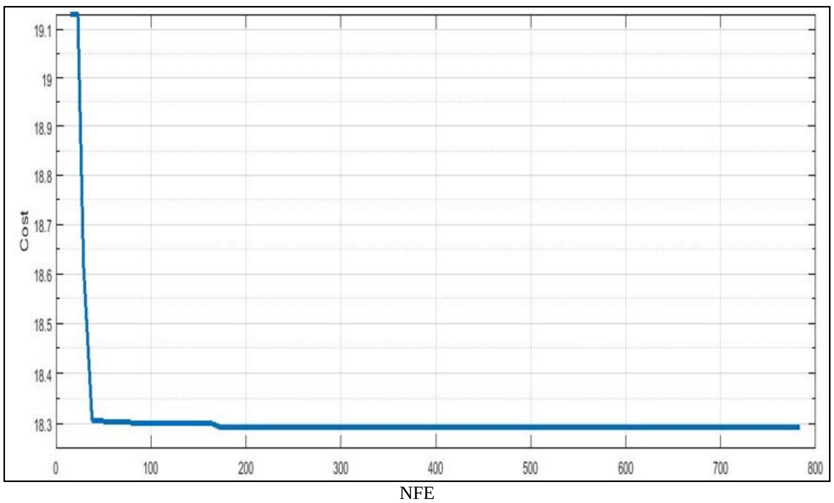


Fig 5: Behavior of cost function by ICA

It is also noteworthy that the transient response obtained for the resonant converter of the sample has come to a steady state at the right time, and on the other hand, the sub-harmonic oscillations have been well reduced, and this result is due to the waveform of the flow current.

However, it shows the answers are valid, by using the MATLAB simulation, the amount of Total Harmony Distortion (THD) simulated circuit using the values of the genetic algorithm and the Imperialistic competitive algorithm is shown in Table 5. As shown in Table 5, the amount of THD in the range is allowed, and this also confirms the proposed method and results from our simulations.

Table 5: Amount of THD for proposed methods

THD	The name of selected algorithm
4.43	Genetic Algorithm(GA)
4.39	Imperialistic competitive algorithm

In Figure 6, the function graph is the cost of the number of recalls, and in Figure 7, the function graph of the cost function of the frequency of repetitions for the genetic algorithms (GA) and Imperialistic competitive algorithm (ICA) is shown. Also, the number of replicated algorithms was 100, which is considered for each population replication of 10. In the various researches, the cost function of recall is used as an estimation of optimization algorithms, and any graph that receives the lowest possible number of recalls to the optimal search query in the search space is the most appropriate algorithm for solving the problem; therefore, according to figure 6 It can be concluded that the Imperialistic competitive algorithm can perform better in less frequent recalls in continuous space, and by simulating several times and adjusting the parameters of this algorithm, the power of the algorithm can be extended to less time and making the optimal answer to approach.

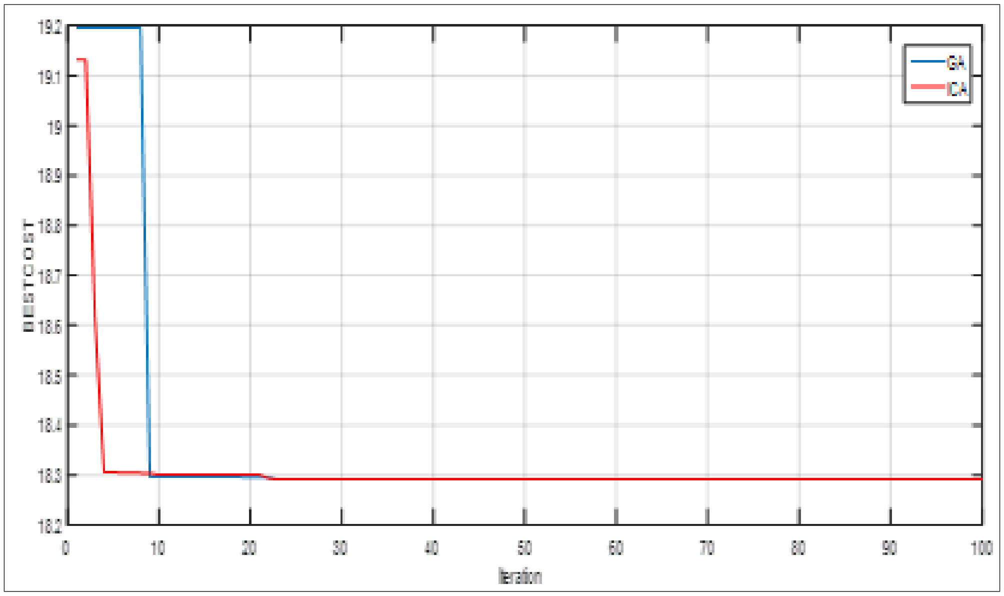


Fig 6: Comparison of the cost chart of selected algorithms

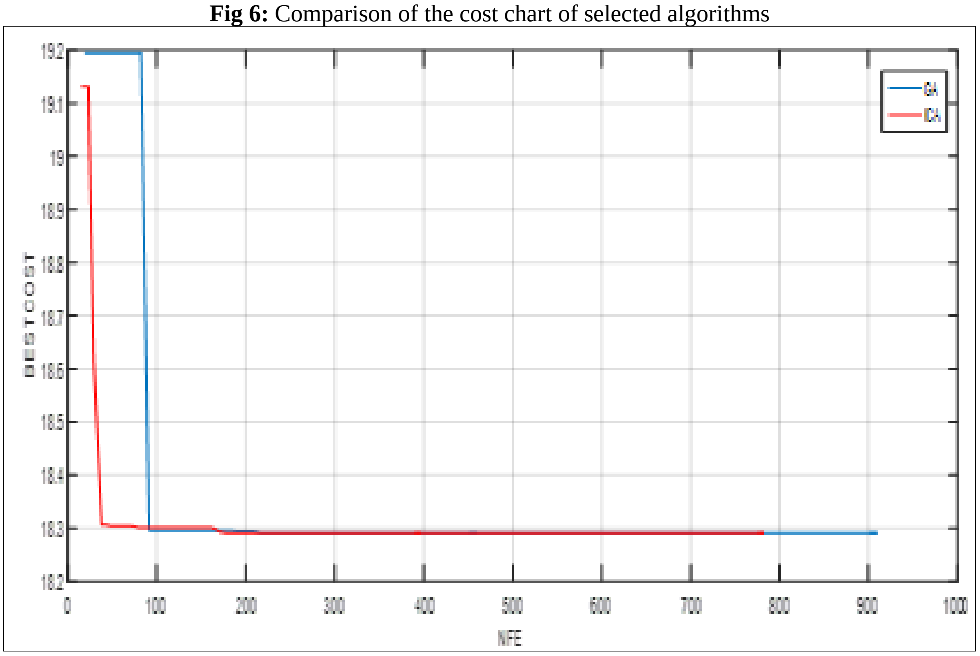


Fig 7: Comparison of cost-number of times repetition selected algorithms

4. Conclusion

As mentioned, in various researches, numerous attempts have been made to describe the current control system in the linear modeling of the low-voltage diodes of the light emitting diodes, which predicted the behavior of these diodes using these models successfully. However, the common theme of all models that can control current fluctuations is the use of a discrete model for design. In this paper, a systematic, discrete-temporal domain approach was first introduced that was simulated using MATLAB software. Using the evolutionary methods, the optimization of the proposed evolutionary controller in the feedback path of the LED driver resonant converter was also discussed. In order to be able to reduce the sub-harmonic fluctuations of the load current by changing the coefficients of the controller, the load flow waveform has a fast and suitable response. So that the converter can quickly change its load condition to its steady and constant value. Finally, the comparison of the applied evolution algorithms showed that Imperialistic competitive algorithm deals with the reduction in the number of recalls and accurate precision to the optimization of the resonance converter in comparison with the genetic algorithm.

5. References

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