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PI Parameter Optimization By Fairly Algorithm For Optimal Controlling Of A Buck Converter's Output State Variable

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ABSTRACT

In this paper, Buck converter circuit that is a power electronics circuit topology is handled. The dynamic behavior of the DC voltage level which is the output magnitude of the circuit has been optimally controlled. The discrete time PI algorithm is chosen as the controller. In order to keep the control process cost low level, Kp and Ki which are controller parameters were optimized. Firefly algorithm (FA), which is an iterative algorithm for optimization, has been run for the purpose. Concurrent studies of the control process have been realized on Matlab-Simulink platform and the results were argued.

Keywords: fairly algorithm, optimization, parameter, pi controller, descrite time, Buck converter

1. INTRODUCTION

A lot of classical and modern control methods are available for controlling Buck type DC-DC converter output states. In this paper, converter output voltage has been taken under control using discrete time PI controller.

When control parameter values are calculated using modern optimization techniques the results of output dynamics improve significantly [1].

On the solution of optimization problems there are well known classical methods. Because of these kinds of inelasticity methods are intensively the scientists has augmented their effort to increase general purposes and to have high performance methods so they has started to inspire from natural events.

The optimization algorithms that are developed based on natural events have been named as heuristic methods [2]. A parts of the heuristic optimization technique have been named as swarm intelligence algorithms. Swarm intelligence algorithm is developed by examining survival common behaviors of the living beings who lives in swarm at nature [3].

In the firefly algorithm that is one of these algorithms, the objective function of a given optimization problem must be related to the intensity of the flashing light or light which helps to go to bright and more attractive places in the firefly's swarm in order to obtain an efficient optimal solution [4].

Various contemporary works are available in an attempt to Buck type DC-DC converter circuit output with minimum cost is able to bring under control. For instance, Xutao Li and his team have been provided control of a Buck type converter output by using the continuous time PID controller. They had assigned Kp, Ki and Kd parameters proper values in order to keep an audit cost low by use of PSO algorithm [5]. Muhammad Yaqoob and his team have enhanced the Buck type converters' dynamic behavior in the transient time interval by use of a FA algorithm [6]. Abolfazl Jalilvand and his team had appointed best value for PID controller parameters by Bacterial Foraging Algorithm [7].

In this study, the output voltage of a Buck converter is controlled with discrete time PI controller algorithm. The dynamic behavior of the output voltage in transient and continuous time interval with FA optimization is used in order to ensure low overflow, low setting time and faultless desirable level. Benefit from this optimization algorithm suitable values are identified to control parameters. Then, control process and the results run in Matlab-Simulink platform and control success were tested simultaneously.

2. FAIRLY ALGORITHM

The FA are used in an attempt to find the coupling partner of flashlight or pull along the potential hunts. The FA are getting in contact with the opposite sex by checking the flashing speed and the rhythm of the light produced.

The FA were developed by Xin She Yang. Xin She Yang had mooted search strategy, controlled random value production by using Gaussian. Efficient local search and best solution selection processes are better than other heuristic algorithms. FA, which is adapted to the behavior of firefly, has 3 different working phases. In the first phase, all fireflies are of the same sex and will be attracted by other fireflies. The second phase is the process of attracting the opposite side with the glow that fireflies have come from. Two flashes of fire will be drawn towards the brighter one which is brighter than the brighter ones. Charm is proportional to brightness. As the distance increases, both variable values decrease. If the firefly does not see a brighter light than its own light, the mode of movement becomes random.

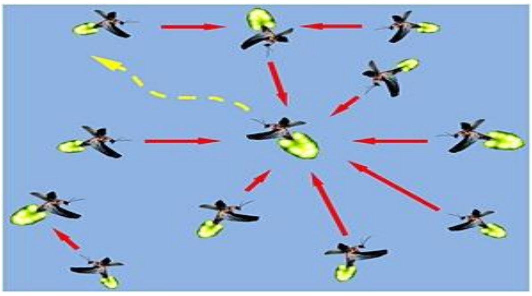

Figure 1. Light beetle heading towards strong light

In the third phase, the orientation to the most intense light environment is initiated.

2.1. Attractiveness and Light Density

On firefly algorithm are available two basic variable accounts for light intensity and attractiveness. The FA's new position is calculated based upon these two variable values. In Eq. (1) light intensity is defined.

$$I(r) = \frac{I_0}{r^2} \tag{1}$$

Where,

$I(r)$: Light intensity

r : Distance between two fireflies

I_0 : Initial light intensity

denote. In order to remove the singularity in the expression given in Eq. (1), the distance expression in the denominator is formed as exponential coefficient, Eq. (2).

$$I(r) = I_0 e^{-\gamma r} \tag{2}$$

Attractiveness is proportional to the intensity of light seen by neighboring fireflies. The attractiveness of a firefly is represented by β and is calculated as in Eq. (3).

$$\beta(r) = \beta_0 e^{-\gamma r^m} \tag{3}$$

Where,

β_0 : Initial attraction value

γ : Light absorption coefficient

m : Attractiveness control parameter, m≥1

denote.

2.2. New Location

The distance between m_j and m_i must be calculated before the new position of firefly is find out, Eq. (4).

$$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d}\left(x_{i,k} - x_{j,k}\right)^2} \tag{4}$$

After calculating the distance, the new position of the firefly is calculated as in Eq. (5).

$$x_i(t+1) = x_i(t) + \beta_0 e^{-\gamma r_{ij}^2}\left(x_i(t) - x_j(t)\right) + \alpha\varepsilon_i \tag{5}$$

In Eq.(4) and Eq.(5), d, α and ε_i are defined as below.

d: Number of firefly

α: Multiplicity, $0 < \alpha < 1$

ε_i: A random value, obtained from the Gaussian distribution.

3. MODELLING BUCK CONVERTER

The Buck type reducer power electronics circuit topology is reflected in Figure 2.

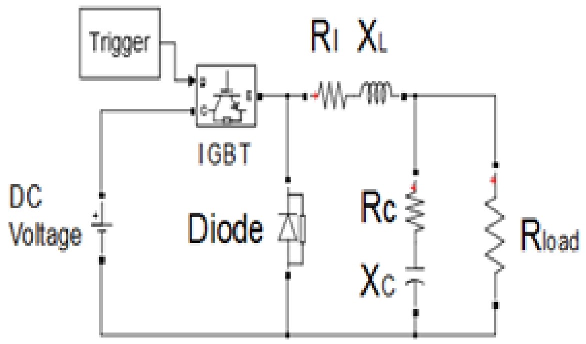

Figure 2.Buck Converter Topology

Basic elements of the circuit are a coil and a capacitor.

Power consumption is performed by Rload load; Battery is used as a power source. A PWM core is used as the pulse source and an IGBT is used for power transmission and cutting.

Also the Buck circuit topology in the simulation environment, for the purpose of to be highly similarity with those of hardware environment is connected with series equivalent resistances (ESR) that belong to the capacitor and the coil elements.

If the ejection of the transfer function T(s) of the system is solved base on electronic circuit analysis, the mathematical relation between input and output voltages is reflected in the Eq. (7) for the Laplace space.

$$T(s) = \frac{(X_c(s)+R_c)//R_{load}}{X_L(s)+R_l+(X_c(s)+R_c)//R_{load}} \tag{6}$$

X statements used in Eq. (6) is defined as,

$X_L(s)$: sL

$X_c(s)$: $(sC)^{-1}$

For the study to be realized in the simulation environment, a capacitor with 470µF/80V/ 280mΩ values produced by the Panasonic Electronic Components Inc. and a coil selection with 300µH/3A/140mΩ values by Murata Power Solutions Inc. had been chosen, figure 4 and figure 5. The transfer function T(s) for a 100 Ω load resistor is regulated to become final numeral form as in Eq. (8).

Figure 4. 300µH/3A/140mΩ coil

Figure 5. 470µF/80V/280mΩ capacitor

$$T(s) = \frac{908.2s+6.901*10^6}{s^2+1582s+6.998*10^6} \tag{8}$$

Accuracy of the derivation process that belongs to the transfer function of T(s) must be tested to ensure that the next step of the control process can be passable. For this reason, the Buck circuit, which was designed with T(s) transfer function and power electronic elements, was run together in the simultaneous Matlab-Simulink environment, figure 6.

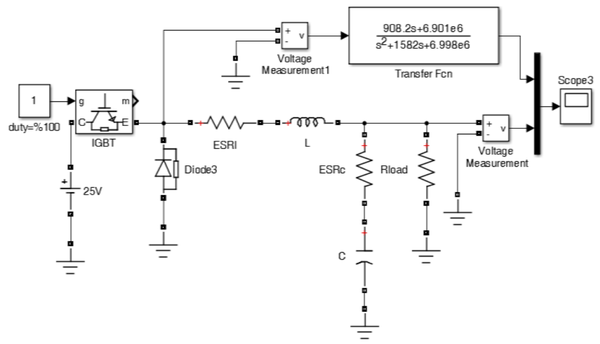

Figure 6. Simulation platform for T(s)'s accuracy test

Both systems in figure 6 are run for %100-duty value. As a result, obtained overlap output voltage waveforms has been reflected in figure 5.

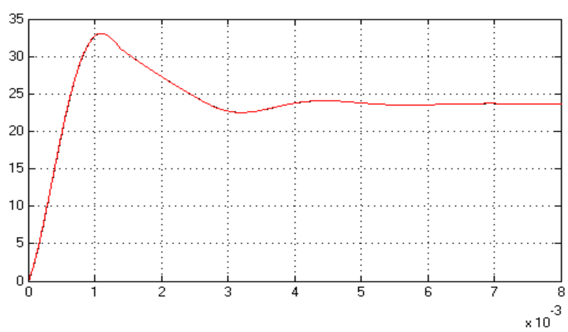

Figure 7. For %100 duty input voltages, T(s) and power system outputs

4. CONTROL STRUCTURE

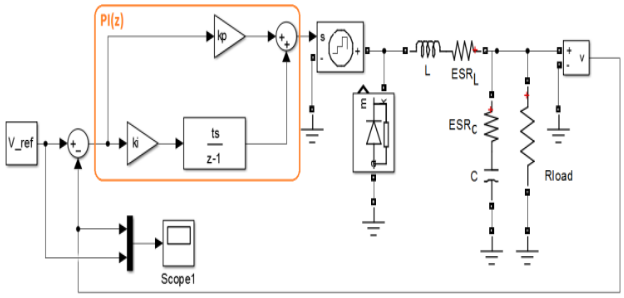

Figure 8. PI(z) based Buck converter control block diagram

In figure 8, output voltage belongs to Buck circuit has been harnessed with the reference base of the discrete time PI controller. The signal has been obtained with controller output. DC voltage level an addicted power source input has been applied. On figure 8, discrete time integral transfer function has been derived by Euler's method.

5. PARAMETER CALCULATION

In this study, Kp and Ki parameters are optimized by a heuristic optimization algorithm called FA. FA algorithm has to observe cost value belong to control process for optimum Kp and Ki parameters. The ISE, IAE, ITAE and dTISDSE discrete time cost functions [8]. Mathematical equations for cost functions are reflected in Eq. (9, 10, 11 and 12) respectively.

Eq. (9, 10, 11 and 12) respectively.

$$ISE(e) = \sum_{k=0}^{t_{sim}/T_s} e_k^2 \tag{9}$$

$$IAE(e) = \sum_{k=0}^{t_{sim}/T_s} |e_k| \tag{10}$$

$$ITAE(e) = \sum_{k=0}^{t_{sim}/T_s} k|e_k| \tag{11}$$

$$dTISDSE(e) = \sum_{k=0}^{t_{sim}/T_s} k\left(e_k^2\right)^2 \tag{12}$$

Optimization process belongs to of controller parameters have specified below which by way of the flowchart is able to sum up, figure 9.

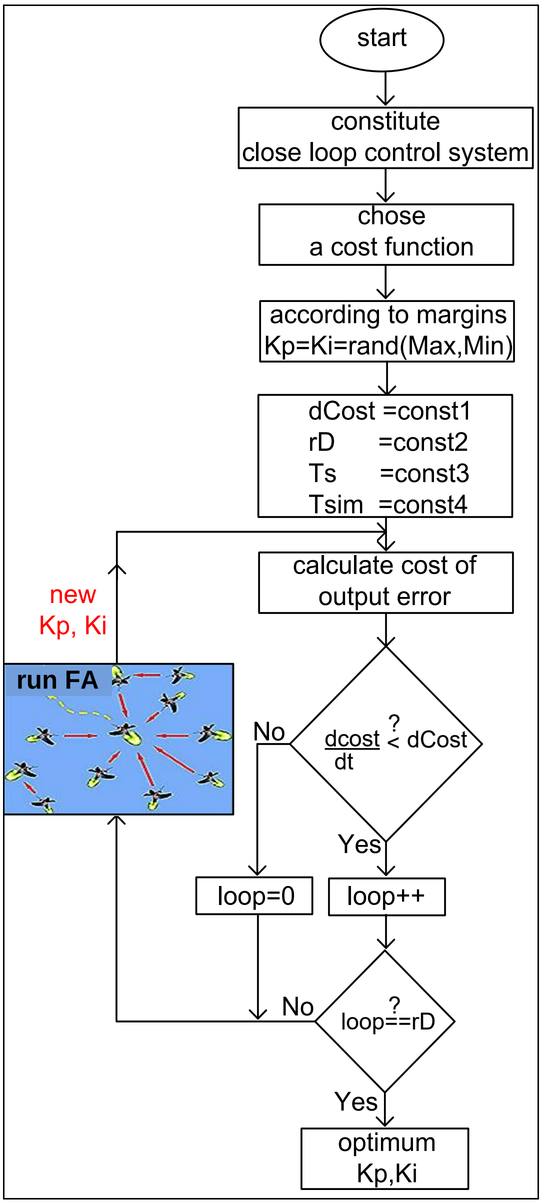

Figure 9. Kp ve Ki optimization process

Flowchart which Figure 9 with given for four different cost function as a result of four different run obtained cost function graphics has been reflected below, Figure 10,11,12 and 13. The initialization parameters for optimization are given in Table 1.

Table 1. Initial parameters of optimization process

Parameter	Value
Tsample	10µs
Tsim	1000µ
Iteration	80
Number of fireflies	75
γ	50
β	%20
α	%10

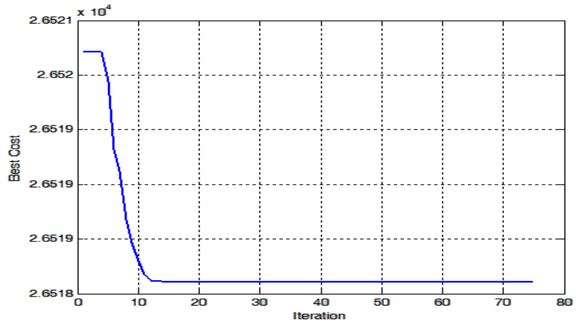

Figure 10. The value decreasing of ISE

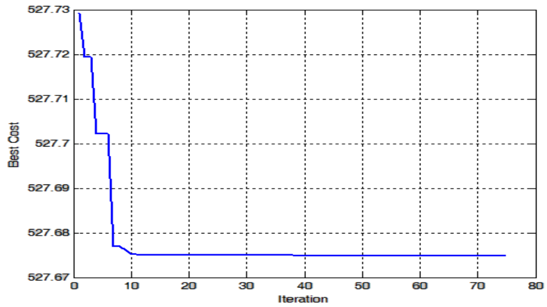

Figure 11. The value decreasing of IAE

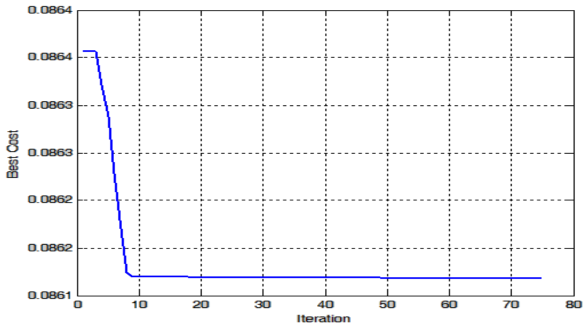

Figure 12. The value decreasing of ITAE

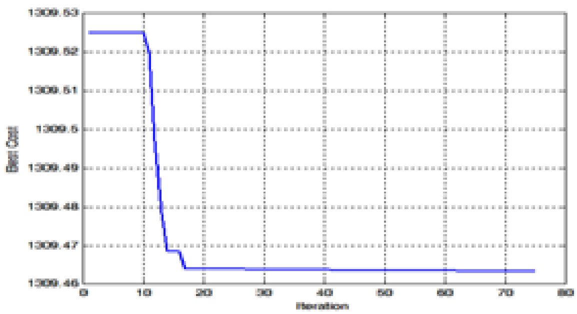

Figure 13. The value decreasing of dTISDSE

Based on four different cost function had been optimized. Kp and Ki controller parameter numerical values are given in table 2.

Table 2. Kp and Ki values based on cost functions

Parameter	IAE	ISE	ITEA	dISDSE
Kp	51.59	46.86	49.87	25.12
Ki	56.88	50.23	60.00	48.99

6. SIMULATION RESULTS

The closed loop control system shown in figure 8 was installed with 4 different control systems in Matlab-Simulink simulation environment for 4 different optimum controller parameters obtained by using 4 different cost functions, figure 14.

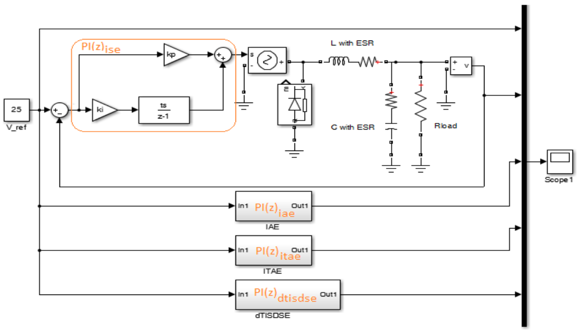

Figure 14. 4 control systems with 4 different controller's parameters

For reference output voltage 25V discrete time pi controller on the part of taken something in hand dynamic behaviors belong to Buck converter's output voltage are reflected on fig 15.

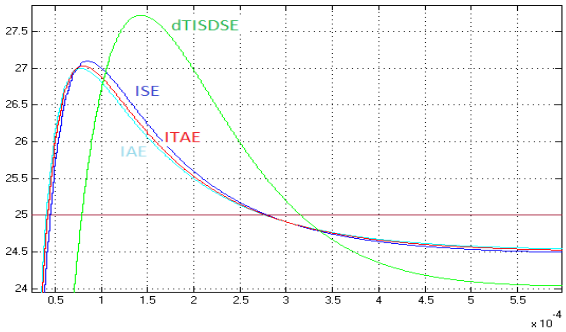

Figure 15. Control results for 4 different Kp and Ki parameters

7. CONCLUTIONS

In this study, a Buck type power electronic circuit was investigated. Due to the circuit structure of the Buck converter, voltage drop can be realized with high efficiency. However, an additional circuit, which necessarily includes a control algorithm, will be needed so that the circuit output voltage magnitude can be fixed at a desired reference value. Added circuit parameters have to be optimized for high efficiency output. In our study, we used the FA heuristic algorithm for optimization controller parameters. It is seen from the experiments performed in the simulation environment that if the FA heuristic optimization algorithm run with IAE cost function, controller parameters will have the most optimum values. Discrete time PI control algorithm with optimum calculated parameters stabilizes the Buck converter output voltage with the lowest overflow and with the lowest habitation time.

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