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International Journal of Current Research
Vol. 10, Issue, 01, pp.73627-73629, January, 2018

INTERNATIONAL JOURNAL OFCURRENTRESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

APPLICATION OF OPTIMIZATION TECHNIQUE FOR BUCK CONVERTER

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ARTICLEINFO

Article History:
Received 22nd October, 2017
Received in revised form
20th November, 2017
Accepted 08th December, 2017
Published online 31st January, 2018

Key Words:

PID controller,
Genetic Algorithm,
Multi objective optimization,
Soft computing Technique.

ABSTRACT

DC-DC converter is used to stabilize or control the DC output voltage. Many optimization techniques have been developed to turn the PID parameters. In this paper, deals with the Genetic Algorithm based Optimization technique for DC–DC Buck converter. Genetic algorithm is proposed latest method for PID controller optimization to develop the dynamic performance of the voltage regulator. The result of simulation shows GA- PID controller provide better performance of the Buck converter than the conventional PID controller.

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***Citation: Achiammal, B,* 2018.** "Application of optimization technique for buck converter", *International Journal of Current Research*, 10, (01), 73627-73629.

INTRODUCTION

DC-DC converters are the devices widely used to change the DC electrical power efficiently from one voltage level to another. DC-DC converters are widely used in computer hardware, power supplies, servo-motor drives and medical equipment's and so that these converters have found significant attention in the recent decades. The main objective of a DC-DC converter is to supply a regulated DC output voltage to a variable-load resistance from an unstable DC input voltage. The problem of regulating the output voltage of these converters have been a subject of great interest for many years, because of the switching property included in their structure DC-DC converters have a non-linear behavior and consequently their controlling design is accompanied by complexity. In addition, due to non-minimum phase nature of the buck converter, much effort has been directed at the control of this design. Transfer function of the DC-DC buck converter is obtained from the state space averaging method for determining switching converter transfer function at steady state condition. In modeling area of DC-DC converters, a variety of models are presented, which comprise desirable responses by the implementation of control methods. Most of the previous research concentrated on design of PID controller for the converter.

The objective of this paper is to use GA algorithm in order to obtain the optimal PID controller gains for the performance of buck convert. The performance indices used in this paper is Integral Squared Error (ISE) and Integral Absolute Error (IAE).

Buck converter: A Buck converter circuit shown in Figure 1 can perform step down DC-DC conversion. During the interval when switch S is on, diode in open and the converter transfer the energy between input and output by using the inductor in this mode. During the interval when the switch S is off, diode conducts the current i_L of the inductor L towards the capacitor C and to the load R.

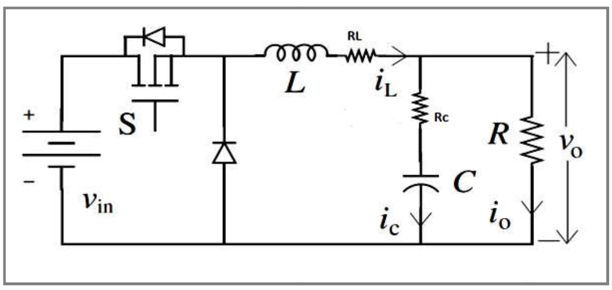

Figure1. Circuit diagram of Buck converter

The transfer function for figure 1 is derived using the standard state space averaging technique. In this approach, the circuits for two modes of operation (ON mode and OFF mode) for the converter are modeled as follows,

$\dot{x}$ =AX + BU
Y= CX+ DU

Where, X = State variable;

U = Input V_{in};
Y = Output V_o.

After modeling, the two modes are averaged over a single switching period T.

Design of PID Controller: The PID controller shown in figure 2 is used to improve the dynamics response and to reduce the steady state error. The derivative controller improves the transient response and the integral controller will reduce steady state error of the system.

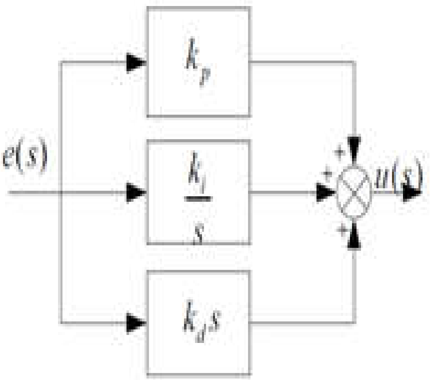

Figure2. Schematic diagram of PID controller

The transfer function of the PID controller is given as follows,

$$k_p + \frac{k_i}{s} + k_d s = \frac{k_d s^2 + k_p s + k_i}{s}$$

The PID controller works in a closed-loop system. The signal u(t) output of the controller is equal to the K_p times of the magnitude of the error plus K_i times integral of the error plus K_d times the derivative of the error as,

$$k_p e + k_i \int e dt + k_d \frac{de}{dt}$$

This control signal will be then sent to the plant, and the new output y(t) will be obtained. This new output will be then sent back to the sensor again to find the new error signal e(t). The controller takes this new error as input signal and computes the gain values (K_p, K_i, K_d).

Design of Genetic Algorithm: GA is a stochastic global adaptive search optimization technique based on the mechanisms of Darwin's principle of natural selection. The searching process is similar to that in nature where a biological process in which stronger individual is likely to be the winner in a competing environment. To use a GA you must initialize the GA with a set of solutions represented by chromosomes called a population. Each solution can be represented by a binary string of ones and zeros, real number or other forms, depending on the application data. In these algorithms the fittest among a group of individuals survive and are used to form new generations of individuals with improved fitness vales. The fitness of an individual is a measure of how well the individual has performed in the problem domain. Using the innovative flair of human search GA can be very useful. Recently, GA has been recognized as an effective and efficient technique to solve optimization problems. Compared with other optimization techniques, GA starts with an initial population containing a number of chromosomes where each one represents a solution of the problem which performance is evaluated by a fitness function. Basically, GA consists of three basic operations: selection, crossover and mutation. Selection gives more reproductive chances to the fittest individuals. During crossover some reproduced individuals cross and exchange their genetic characteristics. Mutations may occur in a small percentage and cause a random change in the genetic material, thus contributing to introduce variety in the population. The evolution process guides the GA through more promising regions in the search space. The application of these three basic operations allows the creation of new individuals which may be better than their parents. This algorithm is repeated for many generations and finally stops, when reaching individuals that represent the optimum solution to the problem. The steps involved in creating and implementing a genetic algorithm.

Generate an initial, random population of individuals for a fixed size. Evaluate their fitness.
Select the fittest members of the population.

- Reproduce using a probabilistic method (e.g., roulette wheel).
- Implement crossover operation on the reproduced chromosomes (choosing probabilistically both the crossover site and the .mates.).
- Repeat step 2 until a predefined convergence criterion.

The implementation of the tuning procedure through GA starts with the definition of the chromosome representation. The chromosome is formed by three values that correspond to the three gains to be tuned in order to achieve a satisfactory behavior. The gains K_p ,K_i and K_d are binary strings numbers and characterize the individual to be evaluated. The structure of a control system with GA-PID as a controller is shown in the figure 3. It consists of a conventional PID controller with its parameter optimized by genetic algorithm.

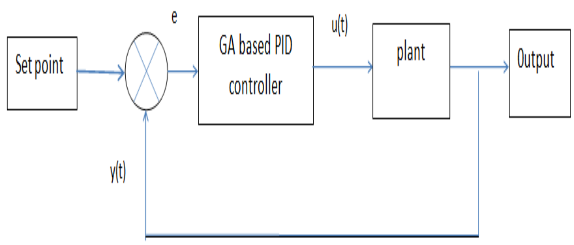

Figure3. Structure of GA-PID controller

Performance Indices: The objective function considered is based on the error criterion. The performance of a controller is best evaluated in terms of error criterion. In this work, controller performance is evaluated in terms of Integral square error (ISE) and Integral Absolute Error (IAE)

ISE = $\int_0^t e^2 dt$
IAE = $\int_0^t |e| \, dt$

The ISE and IAE weight the error with time and hence minimize the error values nearer to zero.

RESULTS

The buck converter parameters are chosen a L=320mH, C=570µF, Rc =0.9Ω, RL=0.9Ω and R=5Ω. A rectified DC of 12V is applied to the buck converter and the reference output value is fixed as 5V. The obtained Buck converter transfer function, calculating the Ziegler Nichols settings value of conventional PID controller shown in table 1.The closed loop servo response of PID controller shown in figure 4, Buck converter Closed loop servo and regulatory response of PI controller shown in figure 5, Buck converter Closed loop servo and regulatory response of PID controller in Figure 7.

Table 2. Controller Parameters

Controller	K_c	T_i	T_d
PID	4.46	0.0059	0.001475
GA-PID	17.98	0.91	0.001

Table 2, shows the controller parameter values of the conventional PID controller and GA-PID controller. After designing the controllers, closed loop responses for Buck convertor are obtained. Closed loop Servo response, servo and regulatory responses of PID as shown in below Figure 4,5,6&7.

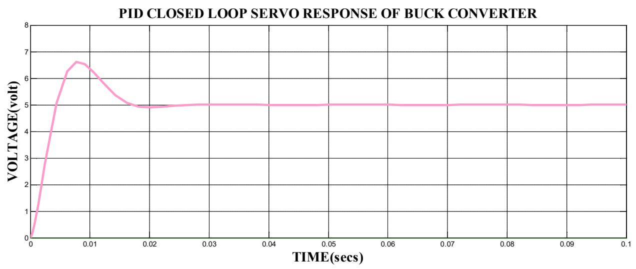

Figure 4. Closed loop response of buck converter for PID controller

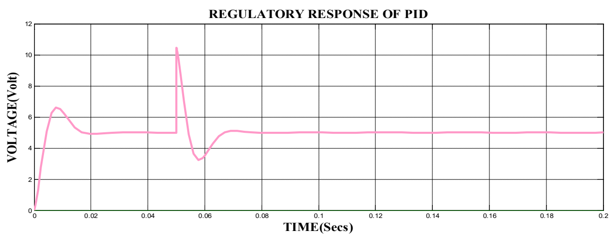

Figure 5. Buck converter Closed loop servo and regulatory response of PID controller

The responses of Buck converter using conventional PID controller and GA-PID controllers are shown in figures 4, 5,6 and 7.The figures show that GA-PID controller will drastically reduce the overshoot, ISE and IAE values as compared to the conventional PID controller. Table 3 shows the performance analysis of the buck converter using conventional PID controller and GA-PID controllers.

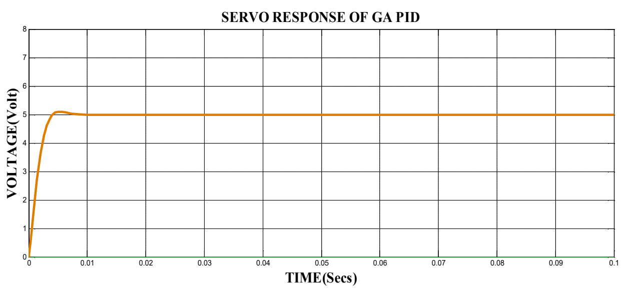

Figure 6. Closed loop response of Buck converter for GA-PID controller

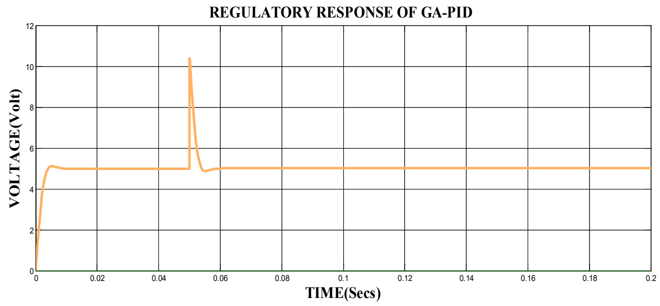

Figure 7. Buck converter Closed loop servo and regulatory response of GA-PID controller

Table 3. Performance analysis of Buck Converter

Parameters	PID	GA- PID
Peak amplitude	6.61	5.1
Peak Time(t_p)	0.00773	0.005
Settling Time(t_s)	0.035	0.01
Peak Overshoot	0.05345	0.0123
ISE	0.02309	0.009163
IAE	6.61	5.1

Conclusion

In this work, Genetic algorithm (GA-PID) is developed to tune the PID controller parameters which control the performance of DC-DC Buck converter. The simulation results confirm that PID controller tuned with GA algorithm rejects satisfactorily both the line and load disturbances. Also the results proved that GA-PID controller gives the smooth response for the reference tracking and maintains the output voltage of the buck converter according to the desired voltage.

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