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# RESEARCH ARTICLE

# TUNING OF PID CONTROLLER FOR BUCK CONVERTEUSING MODIFIED BACTERIAL FORAGING ALGORITHM

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**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 Modified Bacterial Foraging based Optimization technique for DC–DC Buck converter. MBF algorithm is proposed new method for PID controller optimization to improve the dynamic performance of the voltage regulator. The result of simulation shows MBF- PID controller provide better performance of the Buck converter than the conventional PID controller.

## 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 complexities. In addition, due to non-minimum phase nature of the buck converter, much effort has been directed at the control of this configuration. 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 PI and PID controllers for the converter. The objective of this paper is to use MBF 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.

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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. 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,

$$\dot{x} = AX + BU$$
$$Y = CX + DU \quad (1)$$

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.

***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.

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

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

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,

$$k_p e + k_i \int e dt + k_d \frac{de}{dt} \quad (3)$$

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 ($K_p$, $K_i$, $K_d$).

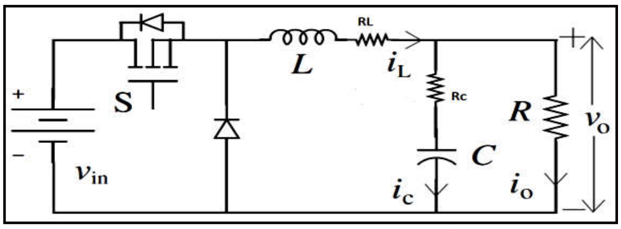


**Figure 1. Circuit diagram of Buck converter**

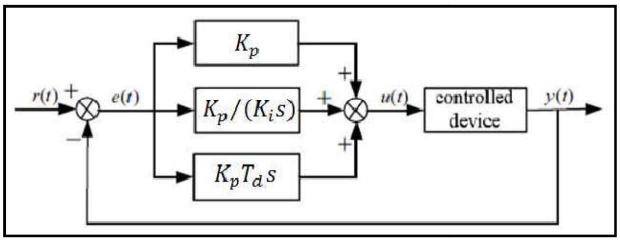


**Figure 2. Schematic diagram of PID controller**

***Modified bacterial foraging optimization technique***

MBFOA emulates the foraging process of bacteria *E. coli* as follows: Within a cycle called generation (P) each bacterium performs a chemotactic step $N_c$ times. After all bacteria went through their chemotactic step, the best bacteria are reproduced while the worst ones are eliminated and new ones are generated at random. It creates a procedure in which the best bacteria among all the chemotactic steps are passed to the subsequent generations. MBFOA is based on the four processes, combining the Chemotaxis and swarming into one loop and simplifying the reproduction and elimination-dispersal. MBFOA uses real-encoding to represent a solution, which is called *bacterium* and is represented by its position as,

$$\theta^i(j,P) = \vec{x_i} \quad (4)$$

Where,

*i* represents the number of bacterium, *j* represents the chemotactic loop number, *P*is the cycle number of the algorithm.

***A. Chemotaxis:*** The chemotactic cycle consists on tumble (search direction at random) and swim movements carried out by bacteria in the search space with the aim to find nutrients. The attractor movement applies twice in a chemotactic loop, while in the remaining steps the tumble - swim movement is carried out. The rules work as criteria in the chemotactic loop in the reproduction step and in the elimination of the worst bacterium in the swarm. The chemotactic process consists on tumble -swim movements carried out by bacteria in the current swarm.
The tumble movement is represented by

$$\phi(i) = \frac{\Delta(i)}{\sqrt{\Delta(i)^T \Delta(i)}} \quad (5)$$

Where,

$\Delta$ (i) is a randomly generated vector of size $m$ with elements within the following interval: [−1, 1]. After that, each bacterium i modifies its positions by swimming and is represented as

$$\theta^i(j+1,P) = \theta^i(j,P) + B(i)\emptyset(i) \quad (6)$$

Where,

$\theta^i(j+1,P)$ is the new position of bacterium i (new solution) at chemotactic step j + 1, $\theta^i$ (j,P) is the current position of bacterium i at chemotactic step j. In MBFOA the step size values in vector B(i) are calculated using Eq. 7 by considering the valid limits per each design variables.

$$B(i)_k = S * \left(\frac{\Delta x_k}{\sqrt{m}}\right), k = 1, \ldots.. m \quad (7)$$

Where,

$\Delta x_k$ is the difference between upper and lower limits for design parameter $x_k$: $U_k - L_k$,$m$ is the number of design variables and S is a user-defined percentage of the value used by the bacteria as step size. MBFOA implements an attractor movement so as to let each bacterium in the swarm to follow the bacterium located in the most promising region of the search space and is represented as

$$\theta^i(j+1,P) = \theta^i(j,P) + \beta\left(\theta^B(P) - \theta^i(j,P)\right) \quad (8)$$

Where,

$\theta^i(j+1,P)$ is the new position of bacterium i, $\theta^i(j,P)$ is the current position of bacterium i,$\theta^B$ (P) is the current position of the best bacterium in the swarm so far at generation P, and β defines the closeness of the new position of bacterium i with respect to the position of the best bacterium $\theta^B$ (P). The attractor movement applies twice in a chemotactic loop, while in the remaining steps the tumble-swim movement is carried out. The aim is to promote a balance between exploration and exploitation in the search.

***B. Reproduction:*** The reproduction process consists of sorting the swarm according to the rules of the constraint-handling technique.The first half of the population is cloned to maintain the same population size for the next generation. It consists of eliminating the second worst bacterium and replacing it with a copy of the best bacterium in the current population, while the worst bacterium is also eliminated and replaced with one generation at random.

***C. Elimination and Dispersal:*** The elimination - dispersal process eliminates only the worst bacterium, and a new randomly generated bacterium is inserted as its replacement. A single reproduction step and a single elimination- dispersal step are performed at the end of generation loop. The elimination – dispersal step is simplified because only the worst bacterium in the population is eliminated.

**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)

$$\text{ISE} = \int_0^t e^2 dt \tag{9}$$

$$\text{IAE} = \int_0^t |e|\, dt \tag{10}$$

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

## SIMULATION RESULTS

The circuit parameters of the Buck Converter are shown in the Table 1.

**Table 1. Circuitparameters of buck converter**

| Parameter | Symbol | Value |
|---|---|---|
| Input Voltage | $V_{in}$ | 12 V |
| Output Voltage | $V_o$ | 5V |
| Inductor | L | 320mH |
| Capacitor | C | 570μF |
| Internal resistors | $R_L$, $R_C$ | 0.9Ω |
| Load resistor | R | 5Ω |
| Duty ratio | D | 0.4 |

Table 2, shows the controller parameter values of the conventional PID controller and MBF-PID controller.

**Table 2. Controller parameters**

| Controllers | $K_p$ | $K_i$ | $K_d$ |
|---|---|---|---|
| PID | 4.4642 | 755.9 | 0.0065 |
| MBF-PID | 1.6861 | 470.39 | 19.870 |

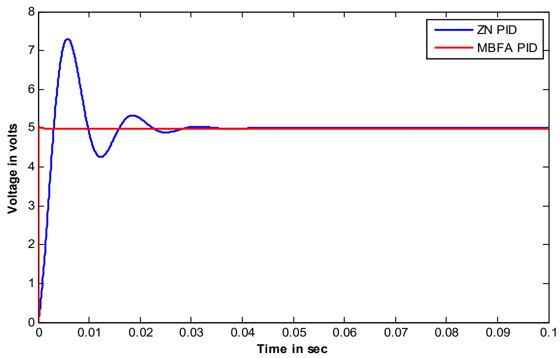


**Figure 3. Closed loop response of Buck converter**

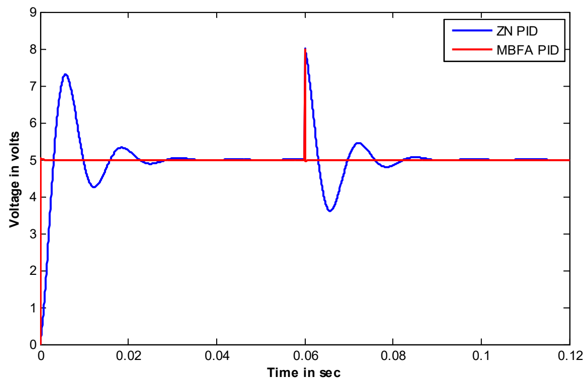


**Figure 4. Closed loop response of Buck converter under sudden change in line voltage of 12V-15V (25%) at 0.06sec**

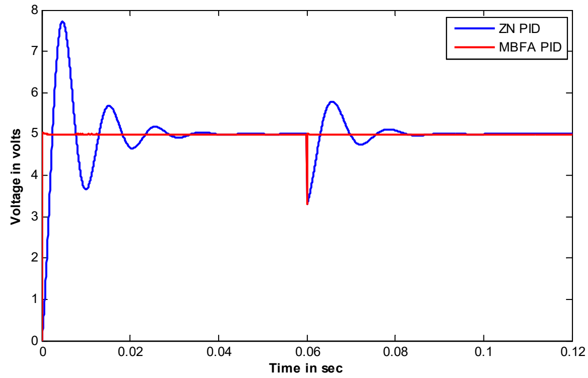


**Figure 6. Closed loop response of Buck converter under sudden change in line voltage of 12V-9V (25%) at 0.06sec**

The responses of Buck converter using conventional PID controller and MBF-PID controllers are shown in figures 3, 4, 5 and 6. The figures show that MBF-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 MBF-PID controllers.

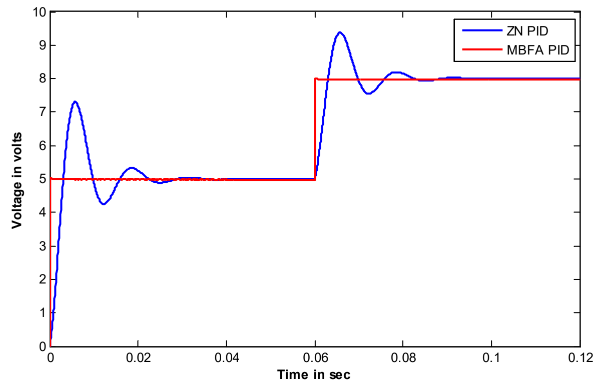


**Figure 5. Servo response of Buck converter from 5V- 8V at0.06sec**

**Table 3. Performance analysis of buck converter**

| Parameters | PID | MBF- PID |
|---|---|---|
| Peak amplitude | 7.30 | 5.054 |
| Peak Time($t_p$) | 0.0057 | 0.000129 |
| Rise Time | 0.00230 | 0.000035 |
| Settling Time($t_s$) | 0.0418 | 0.002049 |
| Peak Overshoot | 31.52 | 1.08 |
| ISE | 104.3014 | 0.4644 |
| IAE | 52.6830 | 2.2382 |

## Conclusion

In this work, Modified Bacterial Foraging algorithm (MBF-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 MBF algorithm rejects satisfactorily both the line and load disturbances. Also the results proved that MBF-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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