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SYNCHRONOUS BUCK DC-DC CONVERTER USING FIREFLY OPTIMIZATION ALGORITHM

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Abstract **-A novel meta-heuristics algorithm, namely the Firefly Algorithm (FA) is applied to the Proportional Integral Derivative (PID) Controller parameter tuning for Buck converter System. The main goal is to increase the time domain characteristics and reduce the transient response of the converter systems. This paper described in details how to employ Firefly Algorithm to determine the optimal PID controller parameters of an SBC system. The proposed algorithm can improve the dynamic performance of SBC system. In this proposed system an optimal PID controller using firefly algorithm for dual mode control scheme to improve power efficiency is employed. In existing method occur low step performance and high overshoot problems. These problems can be overcome by using optimal PID controller using firefly algorithm. There are three important parameters seen in firefly algorithm, that are attractiveness, distance and movement. The proposed approach has superior features including easy implementation, stable convergence characteristic and good computational efficiency. The FA parameters are problem-oriented and specifically chosen to achieve an adequate and accurate decision. It is demonstrated that the FA provides simple, efficient and accurate approach based on PID controller. As a result, a set of optimal PID controller parameters is obtained. Thus, a good closed-loop system performance is achieved. The comparison of both meta-heuristics shows superior performance for FA PID controller, tuning of the considered nonlinear control system than existing controller method.**

***Index Terms*— Firefly Algorithm (FA), Proportional Integral Derivative (PID), Synchronous Buck Converter (SBC).**

I. INTRODUCTION

Most commonly electric utilities, operate their power systems at full power and very nearer to stability limits. The drawback of such operation is that it can render the entire power system into damage very easily. They will be easily subjected to overvoltage or under voltage conditions. In order to avoid such phenomenon SBC is used. The function of automatic voltage regulator is, it allows the alternator to make enough power to maintain proper voltage level, but not allow the system voltage to rise to a harmful level and to control the reactive power flow. Although there are various possible modern control techniques exists, the Proportional Integral Derivative (PID) type controller is still commonly used for SBC system. PID controllers are used to improve the dynamic response as well as eliminates the steady state error. In this paper a Firefly algorithm is proposed for the practical higher order SBC system with PID controller to investigate the performance of the proposed method. Firefly Algorithm (FA) is one of the nature inspired computing algorithm. It has been found to robust in solving continuous non-linear optimization problems. In the PID controller design, the FFA algorithm is applied to search an optimal PID control parameters.

II. PROPOSED SYSTEM AND ITS OPERATING PRINCIPLE

The proposed block diagram of synchronous buck dc-dc converter using firefly algorithm is given in figure1(a) and the figure 1(b) presents the block diagram of the proposed control scheme, including a fixed-frequency PWM controller and an LZC. To achieve ZVS while avoiding reverse inductance currents, an external current transformer and a zero-hysteresis comparator must be used when inductance current levels are less than zero in order to generate signals to turn off the synchronous switch (M_B).

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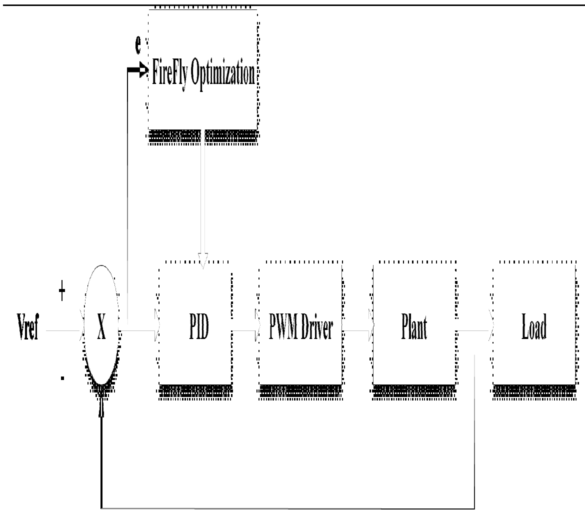

Figure 1(a) Proposed system using firefly optimization

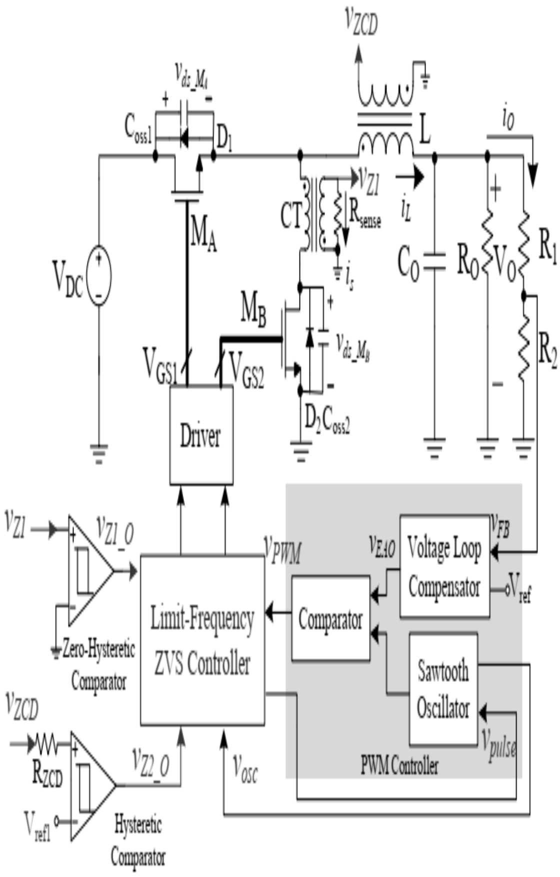

Figure 1(b) Proposed dual mode system

In other words, in the proposed control scheme, the SBC operating mode can be divided into a DCM and a CCM. The error signal v_{EAO} is generated by comparing the feedback voltage v_{FB} of the error compensation amplifiers with the reference voltage V_{ref}. This signal can be used to determine the duty cycle of the main switch. In addition, v_{ZCD} is mainly supplied by an auxiliary winding for detecting the drain voltage of M_B. Furthermore, the negative-edge of v_{Z2_O} triggers LZC to generate v_{pulse} signals, which turn on M_B and the rest of the PWM controller to implement the valley switching of M_B and ZVS of the main switch M_A. Here, V_{ref1} is close to $V_O/2$.

III.BLOCK DIAGRAM DESCRIPTION

DC/DC buck converter

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). The SBC (synchronous buck converters) can be operated at the boundary between continuous conduction mode (CCM) and discontinuous conduction mode (DCM).

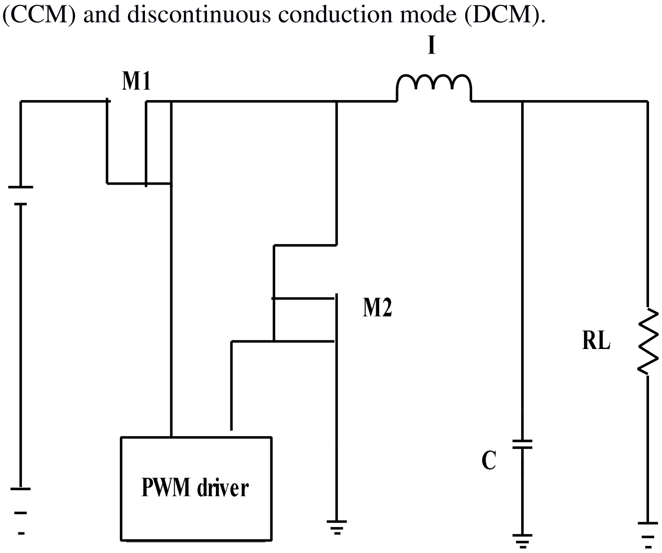

Figure 2 Synchronous buck converter

Firefly PID Controller

Firefly algorithm (FA) for tuning the proportional-integral-derivative (PID) controller parameters in order to achieve a desired transient response The controller is used to control flow rate and to maintain the desired set point. In time domain, the fitness (objective function) can be formed by different performance specifications such as the integral of time multiplied by absolute error value (ITAE), rise time, settling time, overshoot and steady state error. For an optimization problem, the flashing light is associated with the fitness function in order to obtain efficient optimal solutions.

Firefly algorithm

Firefly algorithm (FA) is population –based algorithm to find the global optima of objective inspired by the flashing behaviour of fireflies.

Firefly algorithm is based on two important factors: Attractiveness and Distance

Attractiveness:-

An assumption is made that attractiveness of a firefly is calculated according its Brightness which is associated further with the encoded objective function. The form of attractiveness function of a firefly is the following monotonically decreasing function

$$\beta(r) = \beta_0 e^{-\gamma_r m} \qquad (m\geq 1)$$

Where r is the distance between any two fireflies, β_0 is the attractiveness at r=0 and γ is a fixed light absorption coefficient.

Distance:

The distance between any two fireflies i and j at Xi and Xj respectively is the Cartesian distance as follows:

$$r_{ij} = \|X_i - X_j\| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2}$$

$X_{i,k}$ is the $(k)^{th}$ component of the spatial co-ordinate Xi of (i) th firefly and d is the number of dimensions.

Movements

The movement of a firefly one is attracted to another more attractive (brighter) firefly j is determined by following equation:

$$X_i = X_i + \beta_0 e^{-\gamma r_{ij}^2}(X_j - X_i) + \propto (rand - 0.5)$$

Second term indicates attraction and third term indicate randomization with ∝being the randomization parameter. Rand is a random number generator uniformly distribution in [0,1].For most case in the implementation β_0 =1 and ∝∈[0,1].

Fitness Function:-

To improve the step transient response of an AVR system, the main goal of the proposed FA-PID controller is to adjust optimally as fast as possible the PID controller parameters by minimization of predetermined fitness function.

In time domain, the fitness (objective function) can be formed by different performance specifications such as the integral of time multiplied by absolute error value (ITAE), rise time, settling time, overshoot and steady state error.

$$F(K) = ITAE\left((1 - e^{\rho})(M_p + E_{ss}) + e^{\rho}(T_s - T_r)\right)$$

where K = [KP ,KI ,KD] is a parameter set of PID controller, is a weighting factor, ITAE, Mp, Ess , Ts and tr are respectively the integral of time multiplied by absolute-error value, the maximum overshoot, the steady state error, the settling time and the rising time of the performance criteria in the time domain

Performance analysis

In the performance analysis, the efficiency of the proposed approach is compared with the existing method and the comparison is shown as follows.

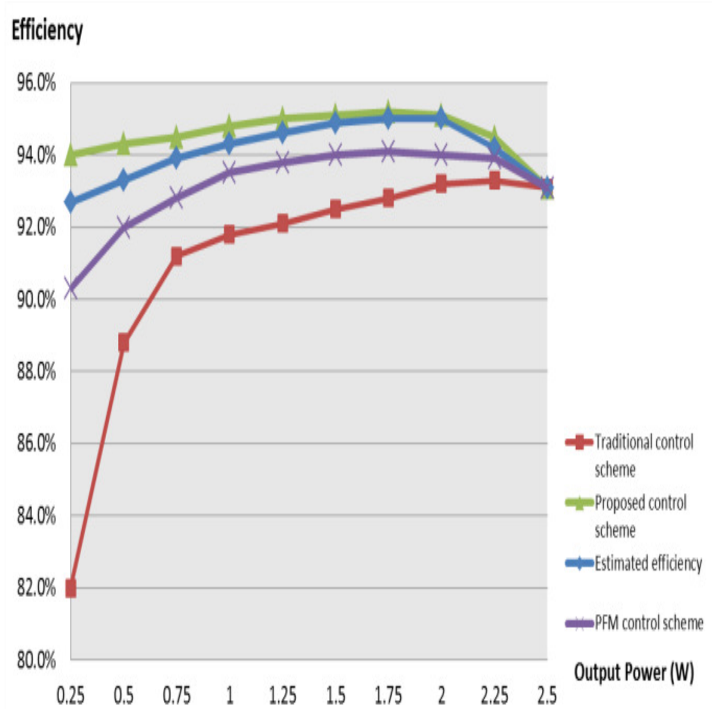

Figure3 Efficiency comparison between the novel and conventional scheme

Figure 3 compares the efficiencies of the SBCs utilizing the novel and conventional control strategies. The blue and red lines represent the proposed control technique and the conventional control technique (with data detailed in Table III), respectively. The green line is the efficiency estimated according to the data in Table III. The yellow line in the plot shows the efficiency of the SBC with the most popular PFM technique. The experimental results confirm that the proposed control strategy can boost the light-load efficiency of SBCs considerably.

Data Flow Diagram

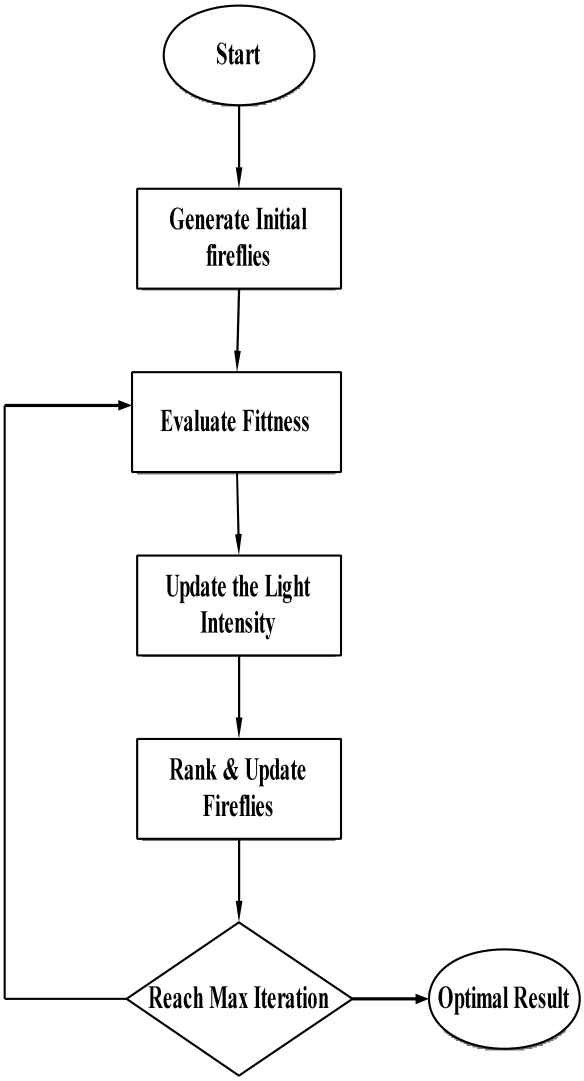

Figure 4 Data flow diagram

IV EXPERIMENTAL RESULTS

To verify the feasibility of the proposed strategy, simulation is carried out.

Figure 5 shows the output load voltage ,in which peak overshoot value has been reduced. The red line indicates the existing system and the blue line indicates the proposed system.

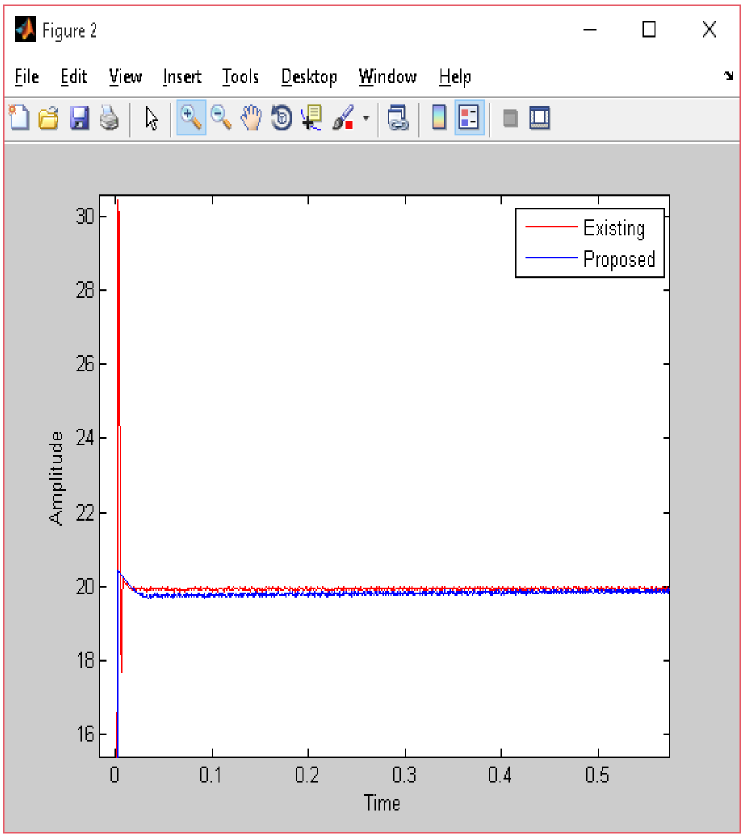

Figure 5 Output voltage of SBC

Table I shows the results obtained by MPPT algorithm and firefly algorithm. From the observation we can conclude that the proposed system using firefly algorithm have better values.

The overshoot value and the settling time have reduced. Hence, the time domain characteristics is improved.

Values obtained from using MPPT algorithm	Values obtained from using Firefly algorithm
Rise Time: 0.0010	Rise Time: 0.0012
Settling Time: 0.0068	Settling Time: 0.0045
Settling Min: 17.6782	Settling Min: 18.0092
Settling Max: 30.4140	Settling Max: 20.4557
Overshoot: 52.4590	Overshoot: 2.3744
Undershoot: 0	Undershoot: 0
Peak: 30.4140	Peak: 20.4557
Peak Time: 0.0026	Peak Time: 0.0023

Table I Comparison of Existing and proposed system

V CONCLUSION

This Paper, proposes a novel tuning method for the PID controller parameters using Firefly algorithm (FA) based voltage regulation of SBC. The fitness function of the proposed FF algorithm is designed according to the required control Characteristics of SBC system. The proposed FA tuning method has better dynamic performance compared with the conventional ZN tuning method and PSO method. The results of the simulating SBC system is proved to be better than the tuning the controller after approximation or by any traditional existing methods. The main goal is to increase the time domain characteristics and reduce the transient response of SBC systems is obtained. Here the peak overshoot and settling time have been reduced. This paper described in details how to employ Firefly Algorithm to determine the optimal PID controller parameters of an SBC system. The proposed approach has superior features including easy implementation, stable convergence characteristic and good computational efficiency. The FA parameters are problem-oriented and specifically chosen to achieve an adequate and accurate decision. It is demonstrated that the FA provides simple, efficient and accurate approach based on PID controller. As a result, a set of optimal PID controller parameters is obtained. Thus, a good closed-loop system performance is achieved. The comparison of both meta-heuristics shows superior performance for FA PID controller tuning of the considered nonlinear control system than existing controller method.

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