

DEVELOPMENT OF PARTICLE SWARM OPTIMIZATION BASED INTELLIGENT FEEDBACK CONTROLLER FOR DC-DC CONVERTERS

Abstract:

Among the power electronic converters, switch-mode dc-dc converters are used to convert unregulated DC input to a controlled DC output at a desired voltage level. The buck converter and the boost converter are basic topologies of dc-dc converters. These converters are generally used in switched-mode DC power supplies, DC motor drive applications, battery-operated vehicles, photovoltaic solar systems and fuel cell systems etc. The dc-dc converters are generally provided with a feedback controller to achieve good transient response and output voltage regulation.

The general practice of feedback controller design is to obtain an average state space model of converter and then arrive at a linear transfer function and to apply linear control theory. However, the converter operates in different modes and is basically a non-linear and time variant system. Hence, the application of linear control theory based on small signal model identifies the feedback controller only at one operating point. It is found that when the operating point changes, the fixed gain controller designed through conventional techniques at one typical operating point does not guarantee satisfactory dynamic response at other operating points over a wide bandwidth of load and supply variations. The dc-dc converters being switched circuits with variable structure systems, the traditional methods of controller design are not appropriate solutions for feedback controller design. Thus the control of dc-dc converters has been a challenging task for researchers and engineers working in this field. Recently non-linear control techniques such as fuzzy control, sliding mode control etc. have been proposed as viable alternatives for feedback controller design. Controllers designed through such techniques are shown to guarantee high dynamic and static performance over a wide range of operating points.

This project proposes a design of an intelligent Proportional-Integral-Derivative (PID) controller for dc-dc converters for output voltage regulation. The proposed design method utilizes the meta-heuristic features of particle swarm optimization (PSO) method and will not require the model of dc-dc converters to determine the controller gain. PSO is a well-established evolutionary computational method inspired from the social behavior of animals

such as bird flocking, fish schooling and swarm theory and is developed with the aim of building more robust and adaptable solutions.

The output voltage regulation in dc-dc converter is formulated as an optimization process with the PID controller elements as variables. A suitable objective function for output voltage dynamics with a step input reference voltage is tailored with appropriate constraints on the controller constants. Then, optimization problem can be carried out using the PSO method. The optimization algorithm and the PID controller action can be implemented using a low cost digital controller and therefore is very economical. The attributes of the digital control of the power converter together with the concept of swarm intelligence can yield a robust feedback controller which rejects internal and external disturbances and provide excellent static and dynamic characteristics at all operating points.

Methodology

The controller design is now formulated as an optimization problem. The statement of the problem and the procedure of controller identification through PSO is given below:

$$\text{Minimize } F(\phi) = \sum_{t=0}^T (e(t))^2$$

$$\text{Subject to } \phi_l < \phi < \phi_u$$

In the above, ϕ_l and ϕ_u are the lower and upper bounds of variable $\phi = \{K_p, K_i \text{ and } K_d\}$, $e(t)$ is the error between actual signal and reference signal and T is start up time for transient response.

Scheme of the Design

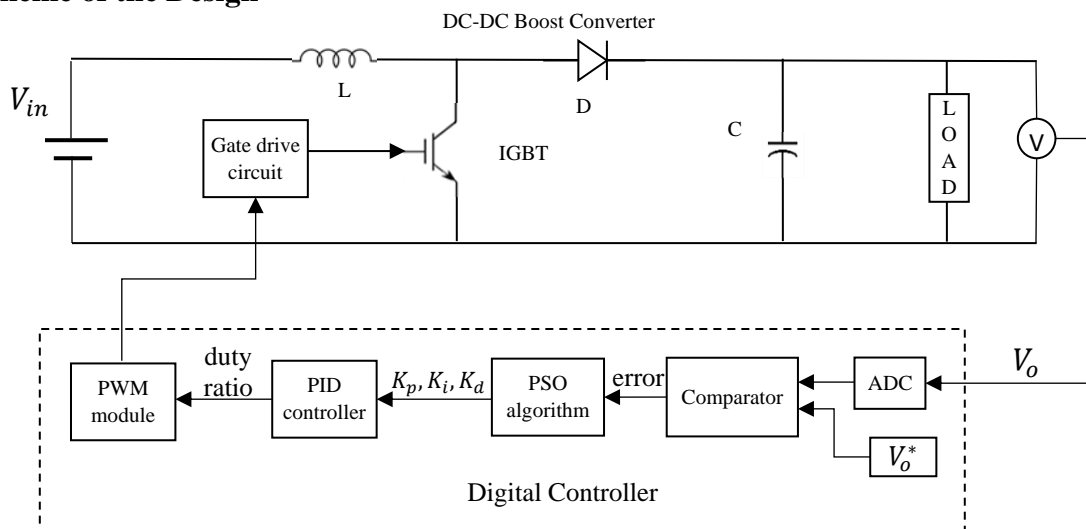


Fig. 1. Closed loop boost converter system with proposed feedback controller.

A closed loop boost converter system is shown in the Fig. 1. In the feedback control system, actual load voltage V_o and reference V_o^* are compared using comparator. The error value so obtained is given to the PSO algorithm, which is the value of objective function. Then, the PSO algorithm will search and determine the optimum value for controller gains that minimize the objective function. The output of the PID controller is appropriately converted into gating pulse to the switch with desired duty cycle. This task is performed by the PWM modulator in the digital controller. Thus, the feedback controller design for boost converter is formulated as an optimization problem and the solution is sought through steps of PSO.

The following are the summary of main objectives of the project proposal:

- To design a robust feedback controller for a boost type dc-dc converter.
- The control parameters of the feedback controller design for boost converter should be formulated as an optimization problem and the solution has to be sought through steps of Particle Swarm Optimization (PSO).
- The proposed controller has to be validated by comparing it with the conventional controller.
- The design should reject internal and external disturbances over a wide range of operating points to make the controller more suitable for various power electronics applications.