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Simulation Study of Boost Converter with Various Control Techniques

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Abstract: ***We study in this project the design of controller for the boost converter is perceived as an optimization task and the controller constants are estimated through evolutionary search algorithm. Initially the designs of PID controller parameters for the boost converter were designed based on the conventional. The design of PID controller parameters for the boost converter was finished. By observing the rise time.***

Keywords: algorithms, PID controller, converter, PID compensator, Particle Swarm Optimization:

1. Introduction

Boost converters provide an output voltage higher than the input voltage and are increasingly employed as front end converters for battery sources, photovoltaic solar systems, and fuel cells. When boost converter is employed in open loop mode, it exhibits poor voltage regulation and unsatisfactory dynamic response, and hence, this converter is generally provided with closed loop control for output voltage regulation. The mode of operation of the converter varies from ON to OFF state of the power switch and traditionally small signal linearization techniques have largely been employed for controller design. The electrical energy is converted at the utilization end to required forms of energy. There arises a need for an interface between the available source of electrical power and the utilization equipment. In most situations, the source of available power and the condition under which the load demands power are incompatible with each other. Large number of power converters are being utilized in various industrial applications.

2. Boost Converter

A DC – DC boost converter is used which consists of boost inductor, diode, MOSFET used as a switch, output filter capacitance and resistive load. When supply voltage is given, inductor current increases when the switch is closed. When the switch is opened, both inductor voltage and supply voltage gets discharged through the load. Hence a higher voltage at the output is obtained than the given input voltage.

The schematic block diagram of traditional boost converter is shown in fig1.It consists of constant input voltage Vs .Boost converter is connected between the supply and the load. To maintain constant output voltage a capacitor is connected to the load. The feedback is provided by the controller connected to the output of the boost converter.

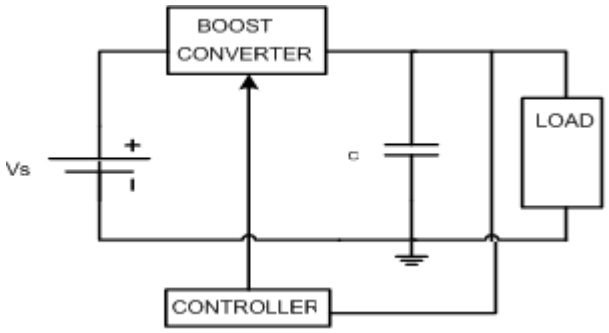


Figure 1: Block diagram of boost converter

2.1 Controller

The major element of the feedback control of DC power supplies is available in IC SG3524. The PWM IC control circuit has been used for the hardware implementation. This monolithic integrated circuit contains all the control circuitry for a regulating power supply inverter or switching regulator. Included in a 16 pin dual-in-line package is the voltage reference, error amplifier, oscillator, pulse-width modulator, pulse steering flip-flop, dual alternating output switches and current limiting and shut down circuitry.

2.2 PID Controller

This introduction will show you the characteristics of the each of proportional (P), the integral (I), and the derivative (D) controls, and how to use them to obtain a desired response. In this tutorial, we will consider the following unity feedback system

The transfer function of the most basic form of PID controller, as we use in ME475, is

$$C(S) = K_p + \frac{K_I}{S} + K_D S$$

Where KP = Proportional gain, KI = Integral gain and KD =Derivative gain.

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2.3 PID parameters affect on system dynamics:

- Rise Time:
- Overshoot:
- Settling Time
- Steady-state Error:

2.4 Ziegler-Nichols Method

PID controllers are probably the most commonly used controller structures in industry. The PID controller encapsulates three of the most important controller structures in a single package. The parallel form of a PID controller (see Figure 1) has transfer function:

$$C(S) = K_p + \frac{K_I}{S} + K_D S$$

$$C(s) = K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$$

where: *Kp* := Proportional Gain , *Ki* := Integral Gain
Ti := Reset Time =*Kp/Ki, Kd* :=Derivative gain *Td* := Rate time or derivative time

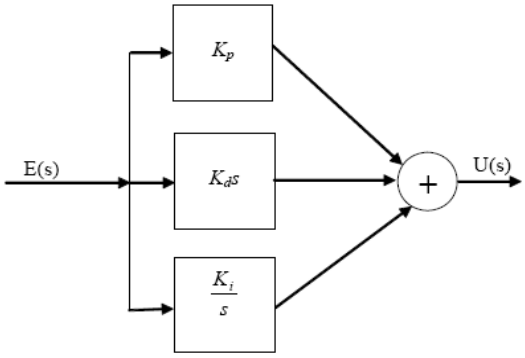


Figure 2: parallel form of the PID compensator

2.5 Ziegler-Nichols Tuning

1) The First Method
The first method is applied to plants with step responses of the form displayed in Figure 4. This type of response is typical of a first order system with transportation delay, such as that induced by fluid flow from a tank along a pipe line. It is also typical of a plant made up of a series of first order systems.

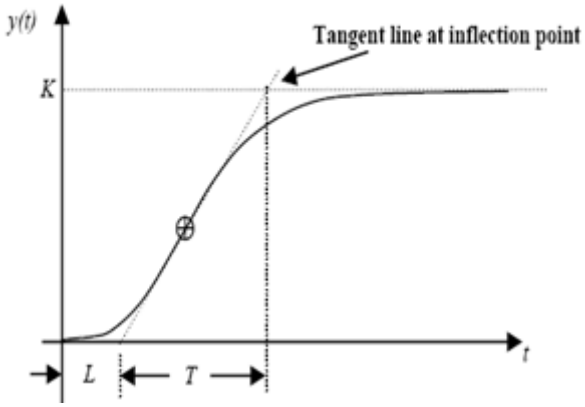


Figure 3: Response Curve for Ziegler-Nichols First Method

2) Second Method:-
The steps for tuning a PID controller via the 2nd method is as follows:
Using only proportional feedback control:
1)Reduce the integrator and derivative gains to 0.
2)Increase *Kp* from 0 to some critical value *Kp=Kcr* at which sustained oscillations occur. If it does not occur then another method has to be applied.
3)Note the value *Kcr* and the corresponding period of sustained oscillation, *Pcr*

The controller gains are now specified as follows:

PID Type	Kp	Ti	Td
P	0.5Kcr	∞	0
PI	0.45Kcr	Pcr/1.2	0
PID	0.6Kcr	Pcr/2	Pcr/8

as we use in ME475, is

$$C(S) = K_p + \frac{K_I}{S} + K_D S$$

2.6 DESIGN OF BOOST CONVERTER

A dc-dc converter must provide a regulated dc output voltage under varying load and input voltage conditions. Hence, for the design of converter the following specifications are considered. specification:

- Input voltage = 26V-36V
- Output voltage = 80V
- Output current = 0.8A
- Switching frequency = 20KHz

3. Optimization Techniques

The objective function which is considered for all the optimization techniques is given as

$$f = \frac{1}{e_r}$$

Where er represents the cumulative error.
er =sum of err.
err=1-Y.
Y represents the output array for each step response obtained by using different methods.

3.1 Genetic Algorithm

3.1.1 Operators of Genetic Algorithm
A basic genetic algorithm comprises three genetic operators.
• Selection
• Crossover
• Mutation
Starting from an initial population of strings (representing possible solutions),the GA uses these operators to calculate successive generations. First, pairs of individuals of the current population are selected to mate with each other to form the offspring, which then form the next generation.

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3.2 Flow Chart of GA

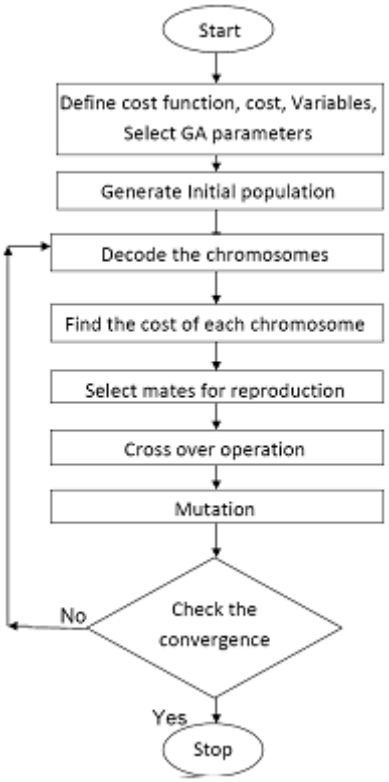


Figure 4: Flow chart of GA

3.3 Particle Swarm Optimization

PSO simulates the behaviors of bird flocking. Suppose the following scenario: a group of birds are randomly searching food in an area. There is only one piece of food in the area being searched. All the birds do not know where the food is. But they know how far the food is in each iteration. So what's the best strategy to find the food? The effective one is to follow the bird, which is nearest to the food. PSO learned from the scenario and used it to solve the optimization problems. In PSO, each single solution is a "bird" in the search space. We call it "particle". All of particles have fitness values, which are evaluated by the fitness function to be optimized, and have velocities, which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles.

When a particle takes part of the population as its topological neighbors, the best value is a local best and is called p-best. After finding the two best values, the particle updates its velocity and positions with following equation given below:

$$V_i^{(u+1)} = W * V_i^u + C_1 * rand( ) * (pbest_i - p_i^u) + C_2 * rand( ) * (gbest_i - p_i^u)$$

$$P_i^{(u+1)} = P_i^u + V_i^{(u+1)}$$

In the above equation,
The term rand ( )*(pbest i -Pi(u)) is called particle memory influence.The term rand ( )*(gbesti -Pi(u)) is called swarm influence.
Vi(u) which is the velocity of ith particle at iteration 'u' must lie in the range Vmin ≤ Vi(u) ≤ Vmaxs

$$W = W_{max} - \left[\frac{W_{max} - W_{min}}{ITER_{max}}\right] * ITER$$

Where w -is the inertia weighting factor
Wmax - maximum value of weighting factor
Wmin - minimum value of weighting factor

3.4 Flow Chart

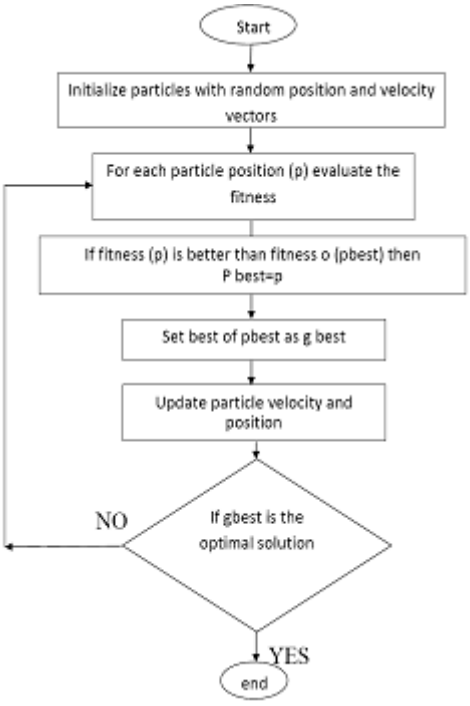


Figure 5: Flow Chart

3.5 Bacterial Foraging Optimization Technique:

Natural selection tends to eliminate animals with poor foraging strategies and favor the propagation of genes of those animals that have successful foraging strategies since they are more likely to enjoy reproductive success. After many generations, poor foraging strategies are either eliminated or shaped into good ones. This activity of foraging is successfully incorporated as an optimization tool in power system harmonic estimation. The *E. coli* bacteria that are present in our intestines also undergo a foraging strategy. The control system of these bacteria that dictates how foraging should proceed can be subdivided into four sections, namely Chemotaxis, Swarming, Reproduction, and Elimination and Dispersal.
a) Chemotaxis:
b) Swarming
c) Reproduction
d) Elimination and Dispersal

4. Matlab/Simulink and Hardware Results

4.1 Simulation Results Obtained With Traditional Method

The step response is first analyzed and it is shown in fig. From the response it can be seen that the rise time, settling time ,peak time are observed. The response is peaky with an overshot of 0.0274.It is desirable to have smooth response

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for variation in input and output voltages. In order to determine the output and input voltage regulation the input voltage is changed from one value to another value and it is shown in fig. The controller parameters used for the generation of the above step response is Kp =0.35,Ki=25,Kd=0.0017.

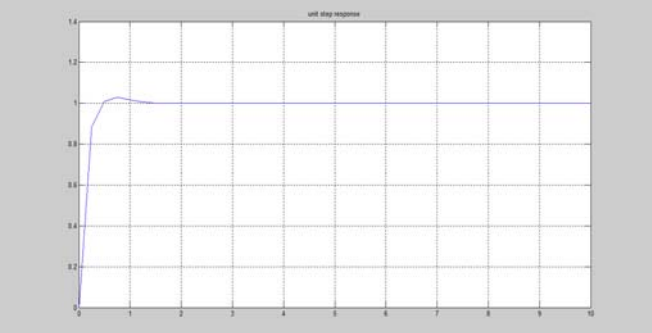


Figure 6: step response with traditionally designed controller

The boost converter with the traditionally designed controller is now simulated in MATLAB/SIMULINK with step change in input voltage from 36v to 26v,and the output voltage observed is shown in the below figure

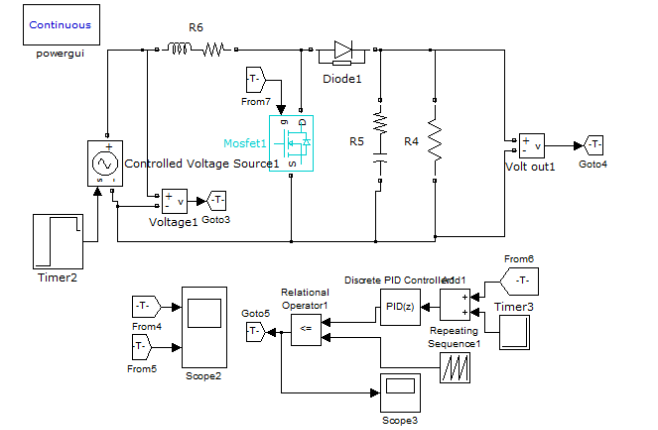


Figure 7: simulink model for step change in i/p voltage

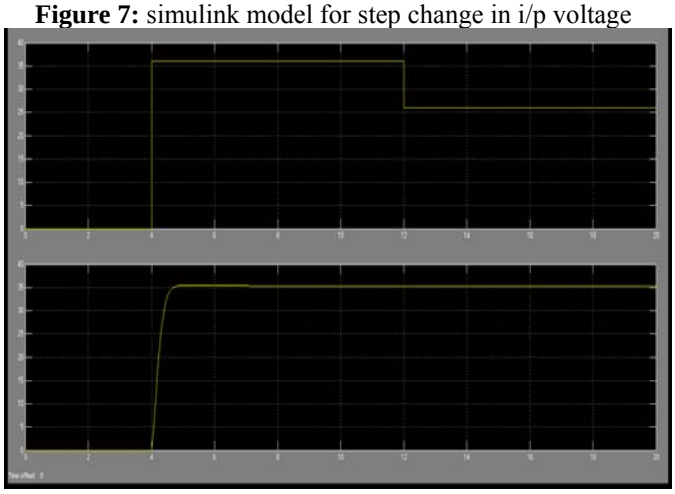


Figure 8: output waveform for step change in i/p voltage

4.2.2 Circuit for Step Change in Load Resistance

The simulink circuit for the boost converter when a step change in load resistance from 100 ohms to 200 ohms is applied the output voltage variation is shown in the below figure.

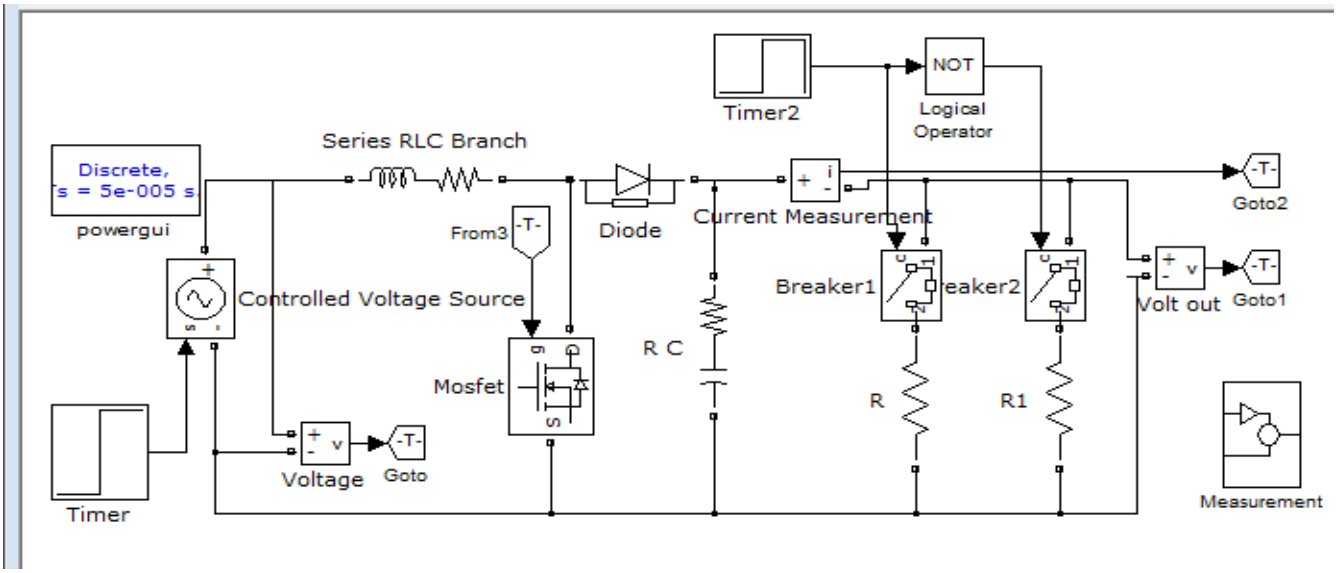


Figure 9: Simulink circuit for step change in load resistance.

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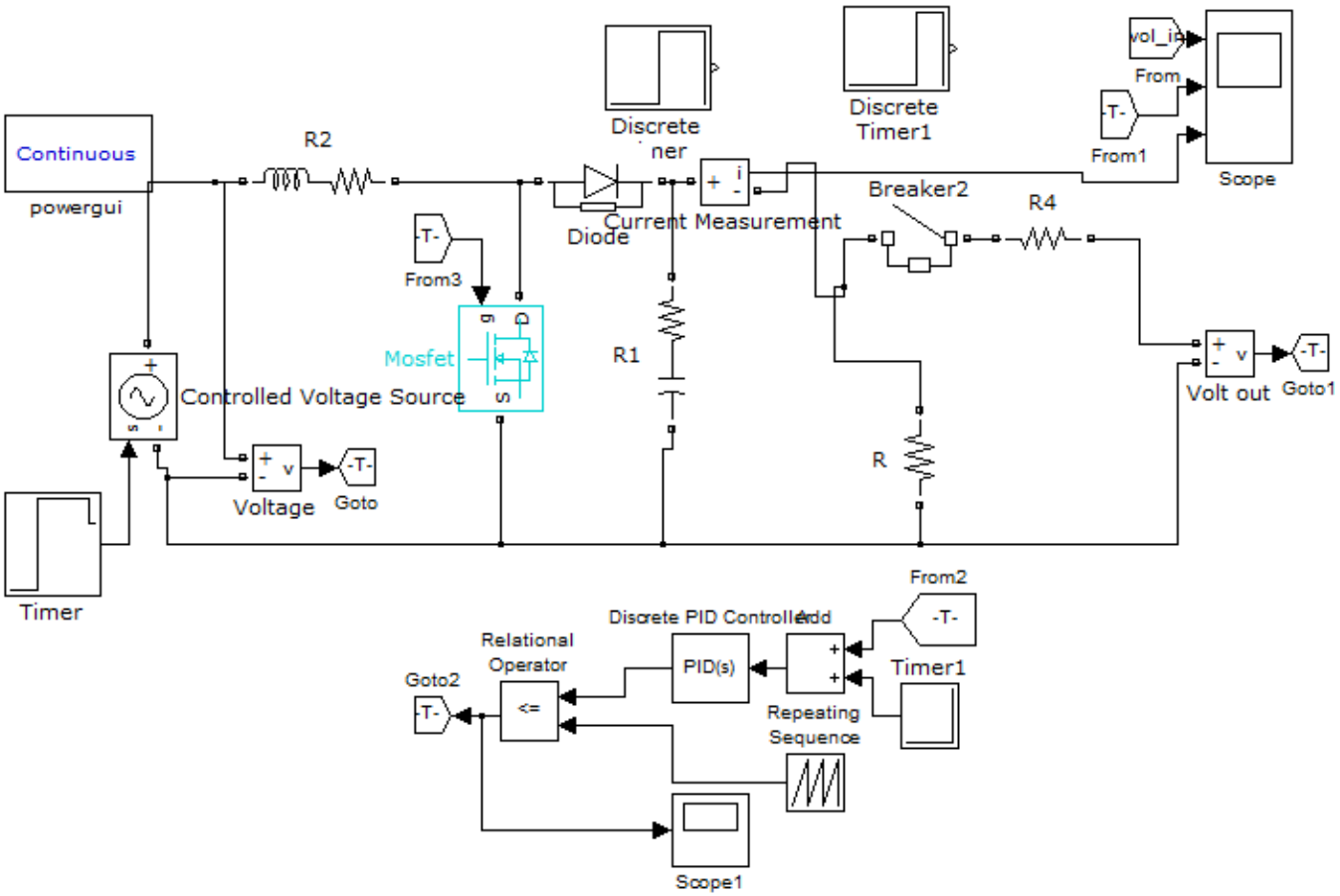


Figure 10: step response obtained with the GA controller

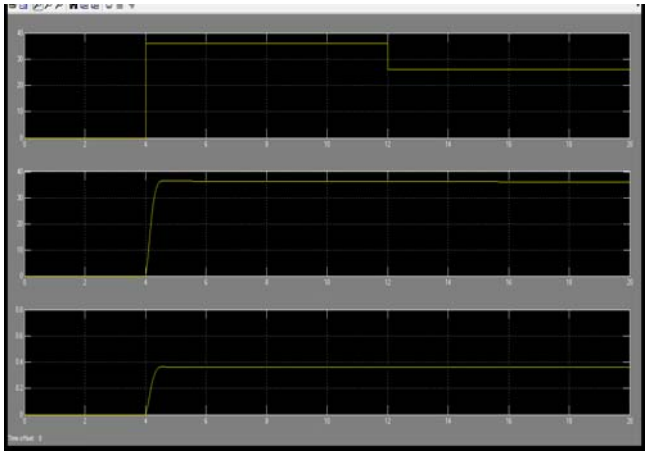


Figure 11: out waveform

5. Conclusion

The design of controller for the boost converter is perceived as an optimization task and the controller constants are estimated through evolutionary search algorithms. Initially the design of PID controller parameters for the boost converter were designed based on the conventional method i.e. ziegler-nicholos method the design of PID controller parameters for the boost converter was finished. By observing the rise time, settling time, peak overshoot from the step response curves .

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