Research Presentation 2021-22

Recent Advancements in the Control Strategies of Various Converter Topologies

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The Problem Statement

"To analyze the performance of fractional order PID controller in terms of settling time and peak overshoot and compare it with that of classical PID controller."

Previous Semester Work

PI and FOPI Control of Boost Converter

Methodology

The boost converter was connected in a close loop configuration. A reference of 40 volts was set which was desired in the output.

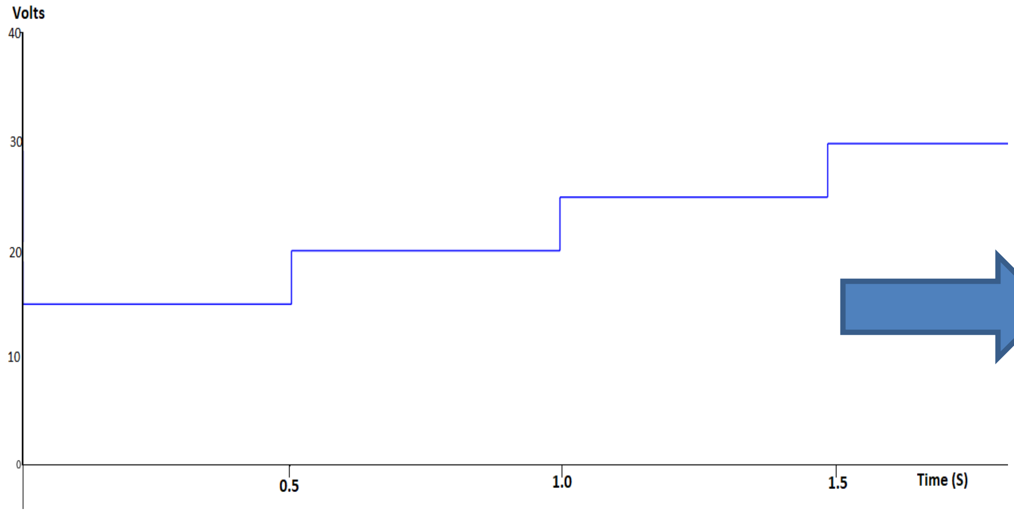
Step 1
The model was tuned with an integer order PI controller by **Ziegler Nichols** [1] method of tuning and the controller parameters were obtained.

Step 2
PI controller transfer function was formed by the obtained parameters and fed into the transfer function block in MATLAB. Then, the model was run at various inputs.

Step 3
The controller transfer function was given a fractional order [2] and the model was again run on various inputs (Equivalent transfer function was generated using the **FOMCON** Toolbox).

Step 4
The performance of PI and FOPI controller was compared.

Observations



Boost Converter input

Type of Controller	Peak Overshoot	Settling Time
PI	20%	0.25 sec
FOPI	35.7%	0.2 sec

- FOPI control suffered from more peak overshoot than PI control.
- FOPI control offered less settling time than PI control.
- PI control caused the output to settle at the set value while FOPI control ceased to offer it.
- FOPI control caused the output to settle at some value at low inputs also which was not seen in PI control.

Present Work

1. PI and FOPI Control of Buck Converter

$K_p = 0.45\ K_u = 0.45\times0.86 = 0.387$
$K_i = 1.2\ K_p/T_u = 1.2\times0.387/0.09 = 5.16$

$$T(s) = \frac{0.387\,s + 5.16}{s}$$

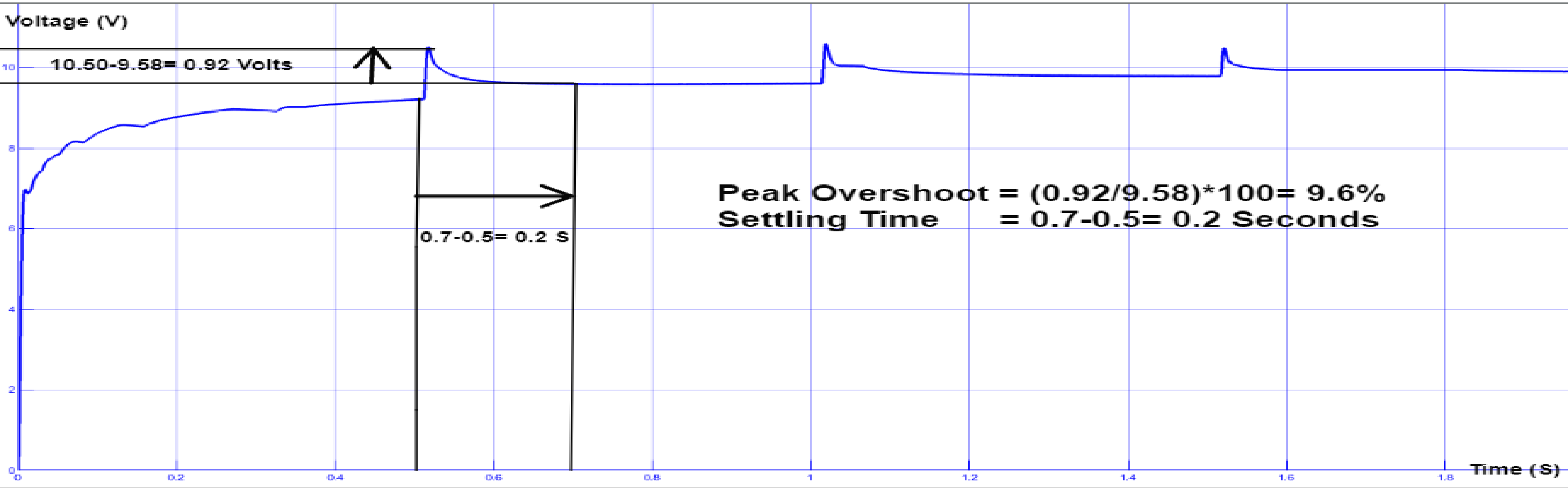
PI Controller TF

Buck Converter in close loop configuration tuned by Ziegler-Nichols Method.
(Ref. Voltage = 10 volts)
(Same input voltage profile)

$$T(s) = \frac{0.387\,s^{\frac{1}{2}} + 5.16}{s^{\frac{1}{2}}}$$

FOPI Controller TF

Buck Converter under PI Control



Buck Converter under FOPI Control

Comparison between Buck and Boost Converters' Response

Converter Type	Controller Type	Peak Overshoot	Settling Time
Buck	PI	13 %	0.35 seconds
	FOPI	9.6 %	0.2 seconds
Boost	PI	20 %	0.25 seconds
	FOPI	35.7 %	0.2 seconds

- Boost converter's output response has less settling time than that of buck converter.
- Boost converter has less peak overshoot than that of buck converter.
- Buck converter had an advantage of output settling at the reference value in both modes of control.

2. Recent Advancements in the Control Strategies of Various Converter Topologies: A Review

2.1. PID Control

- PID control is a commonly used technique used for controlling converters but as it is a type of linear control, it suffers from some problems. One of the problems of using PID control technique is its slow response time.
- To improve it, some researchers have developed a discrete auto tuning PID scheme [3] and moreover to maintain a constant output voltage at the load side while some have worked on obtaining the optimum PID controller parameters more effectively by using Bio-inspired optimization techniques like Whale Optimization algorithm, Cuckoo Search Algorithm, Genetic Algorithm and Particle Swarm Optimization [4].
- Some have compared Ant Colony Optimization (ACO) and Genetic Algorithm (GA) in terms of lessening the overshoot and settling times [5] while some have worked on improving the phase margin and crossover frequency [6].

2.2. FOPID Control

- Yichen et al have designed a fractional order control which has advantages like fast response, strong adaptability, etc. and can also eliminate the ripple caused in the output voltage if the system is disturbed [7].

- Tiwari et al have focused on designing a Fractional order Proportional Integral Derivative (FOPID) controller using the Genetic Algorithm (GA) which minimizes the weighted sum of the error specifications i.e., Integral Time Absolute Error (ITAE), Integral Absolute Error (IAE) and Integral Square Error (ISE) [8].

- Chowdhury et al have optimized Fractional Order PID Controller parameters using a Soft Computing Technique i.e., Bacterial Foraging Optimization Technique (BFO). They have minimized a non linear function proposed with integral square error, settling-time, rise time and maximum overshoot to get the optimal parameters of Fractional Order PID Controller [9].

2.3. Neural Network Control

- Divyasharon et al have designed MPPT controller using Artificial Neural Network for a solar structure using Boost and Cuk converter topology and their performances have been analyzed under uniform and varying climatic (both irradiance and temperature) conditions. The results have shown that ANN based MPPT provide good performance with accurate tracking, high efficiency and low oscillation under uniform and rapidly changing climatic conditions for both the converters [10].

- Xi et al have proposed a type of adaptive controller based on Back Propogation Neural Network combined with traditional PID control. Based on this proposed control, the Boost converter is controlled more effectively, the overshoot of its output voltage is reduced, and the stability of the system is improved [11].

- Noriega et al have proposed a control strategy based on artificial neural networks, that regulates the output voltage of a DC-DC Forward converter. The use of this neural network-based controller has achieved effective tracking of the desired reference voltage, even after abruptly varying the load resistance and certain parameters within the neural network [12].

2.4. Sliding Mode Control

- The first order sliding mode control method regulates the output voltage to the desired value but suffers from the phenomena called chattering. Deshmukh et al have implemented Second order Sliding mode controller by using the Super Twisting Algorithm and have compared results for the second order control with the first order control with and without boundary layer control [13].

- Chafekar et al have devised a Discrete Sliding Mode Control for buck converter and have verified its robustness against parameter uncertainty, disturbances in input voltage and load changes [14].

- Xianbao Lan et al have studied boost converter based on incremental sliding mode control in order to solve the problems of poor anti-interference performance and large output ripple of boost converter. They have shown that the new sliding mode control method effectively improves the dynamic response speed of the system, greatly reduces the overshoot of the system, reduces the output ripple of the system and improves the robustness of boost converter [15].

2.5. Some Other Control Techniques

- Sarif et al have presented modeling, design and control of a DC-DC converter using state-space averaging approach. They have used the average voltage mode control for the boost converter operation and the two-loop average current mode control for the bidirectional operation [16].

- Yin et al have proposed, compared and analyzed the advantages and disadvantages of four control strategies for DC-DC buck converters: a single-loop adaptive control strategy (SA), a double-loop adaptive control strategy (DA), a single-loop disturbance observer-based control strategy (SDOB) and a double-loop disturbance observer-based control strategy (DDOB) [17].

- Dan et al have proposed a model predictive control (MPC)-based DTC strategy for a direct matrix converter-fed induction motor to reduce the torque ripple in motors resulting from the use of conventional direct torque control (DTC) and shown the experimental results to verify the reduced torque ripple performance of the proposed MPC-based DTC method [18].

Future Work

- Till now, a review of various control methods of converter topologies has been carried out.
- The upcoming work is to implement some of those control methods which can provide better results for most of the converter topologies in terms of peak overshoot, settling time, voltage ripple content, improved transient response and other system parameters.
- The best of those techniques will be chosen.

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