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Two Mode Control Scheme for Two Switch Buck-Boost DC-DC Converter

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Abstract: For wide voltage range of input changes, buck-boost converter is suitable for getting a regulated voltage in the output (load) side. The single switch buck-boost converter produces an inverting output. So the buck-boost topology is improved with two switches. The two switch buck-boost converter produces a non-inverting dc output. Input voltage feed forward method is used to select the buck or boost mode according to the input voltage level. In this work the two switch buck-boost converter is designed and modeled with different controllers [PI, PID&IMC]. In the proposed system, a new control scheme 'Internal Model Control' is implemented to compare the performance of the two mode converter. The two mode converter is modeled in the MATLAB environment with PI & PID controllers and as well as Internal Model Control. The system is designed for 18-32V input, 24-V output and 48W-rated power. The entire performance of the buck-boost converter is compared.

Key words: Buck-boost converter · Non inverter dc output · Voltage level · Internal model control

INTRODUCTION

The role of a DC-DC converter is very important where we need a constant DC voltage from a variable DC source like solar, fuel cells, etc. On the other hand we can get a variable DC voltage from a fixed DC source by using DC-DC converter. There are so many types of dc-dc converters available, Buck converter - to get a reduced output voltage. Boost converter - to get the output voltage more the input. Buck-boost - to do both the operations buck and boost. In this paper, the performance of buck-boost converter is analyzed. Normally, buck-boost converter consists of single switch to do both the operations buck and boost according to the duty cycle of the gate pulse. Single switch buck-boost converter produces an inverting output with respect to input. This is a disadvantage of this converter. To get a non-inverting output voltage the converter is designed with two switches one for buck operation and another one for boost operation. The two mode control is achieved by implementing the input feed forward method. According to the input voltage level, buck or boost switch is selected [1,2].

Analysis of Buck-Boost DC-DC Converter: This paper is started with the analysis on the basic buck boost DC-DC converter in a continuous. The Basic buck boost converter consists of a simple design shown in Fig. 3.1. The switching period is T and the duty cycle is D [3]. Assuming continuous conduction mode of operation, when the switch is ON, the state space equations are given by,

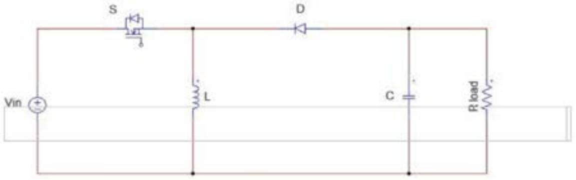

Fig. 1: DC-DC Buck-Boost

MATLAB simulation model of Buck Boost DC-DC Converter with R Load:

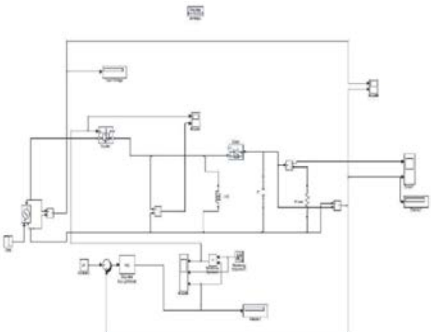

Fig. 2: Matlab Simulation diagram for inverting buck-boost converter

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Simulation results:

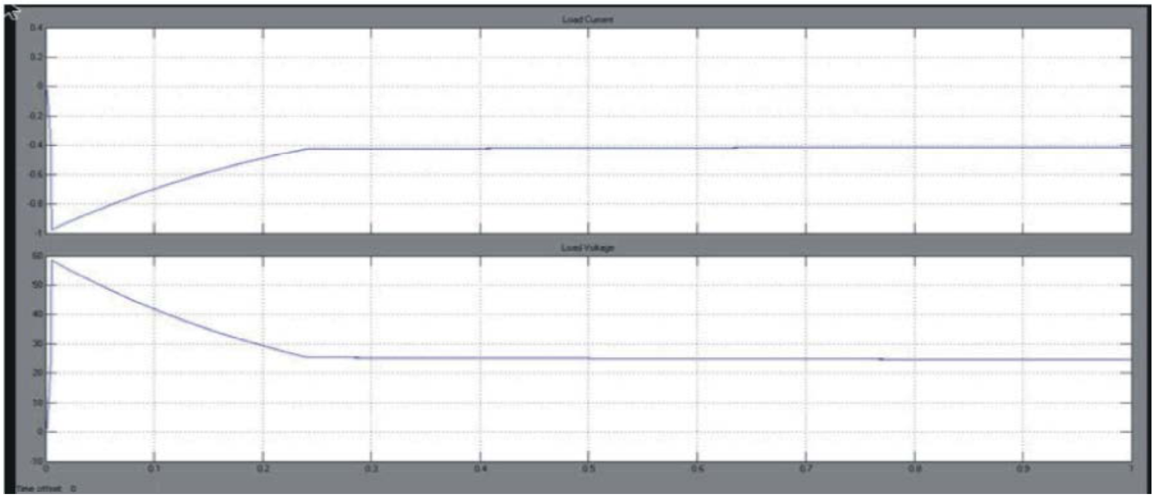

Fig. 3: Simulation results for buck boost converter

Table 1: Line regulation for buck boost converter

Line regulation		Load=60ohms
S.NO	Input Voltage(vin)	Output voltage(vo)
1	32	-25.4
2	28	-25.3
3	24	-25.2
4	20	-24.9
5	18	-24.7

Table 2: Load regulation for buck boost converter

Load regulation		Input voltage=32v
S.no	Input voltage(vin)	Output voltage(vo)
1	60	-25.4
2	50	-25.5
3	40	-25.6

Transient Performance
Settling time: 0.28s
Peak overshoot: 58V

From the simulation results, the output buck-boost converter is inverted.

Discusssion On Existing Two Mode Control Scheme for Two Switch Buck Boost DC-DC Converter using PI & PID Controller [4].

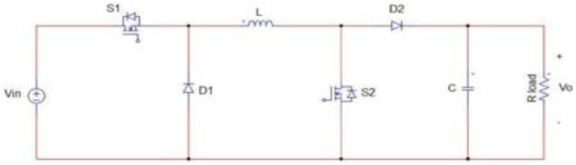

Fig. 4: Power circuit of Two-switch buck-boost converter

Operation: There are two active switches in the TSBB converter, which provides the possibility of obtaining various control methods for this converter. If $S1$ and $S2$ are switched ON and OFF simultaneously, the TSBB converter behaves same as the single switch buck-boost converter. This control method is called one mode control scheme. $S1$ and $S2$ can also be controlled in other manners. For example, when the input voltage is higher than the output voltage, $S2$ is always kept OFF and $S1$ is controlled to regulate the output voltage and as a result, the TSBB converter is equivalent to a buck converter and is said to operate in *buck mode*. When the input voltage is lower than the output voltage, $S1$ is always kept ON and $S2$ is controlled to regulate the output voltage and in this case, the TSBB converter is equivalent to a boost converter and is said to operate in *boost mode*. Such control method is called two-mode control scheme. Compared with one-mode control scheme, two-mode control scheme can reduce the conduction loss and switching loss effectively, leading to a high efficiency over a wide input voltage range [5, 6].

Control Scheme: The voltage conversion of the TSBB converter operated in continuous current mode (CCM) In the two-mode control scheme, $d1$ and $d2$ are controlled independently. When the input voltage is higher than the output voltage, the TSBB converter operates in *buck mode*, where $d2 = 0$, i.e.$S2$ is always OFF and $d1$ is controlled to regulate the output voltage; when the input voltage is lower than the output voltage, the TSBB converter operates in *boost mode*, where $d1 = 1$, i.e., $S1$ is always ON and $d2$ is controlled to regulate the output voltage. Thus the voltage conversion of the TSBB converter with two mode control scheme is.

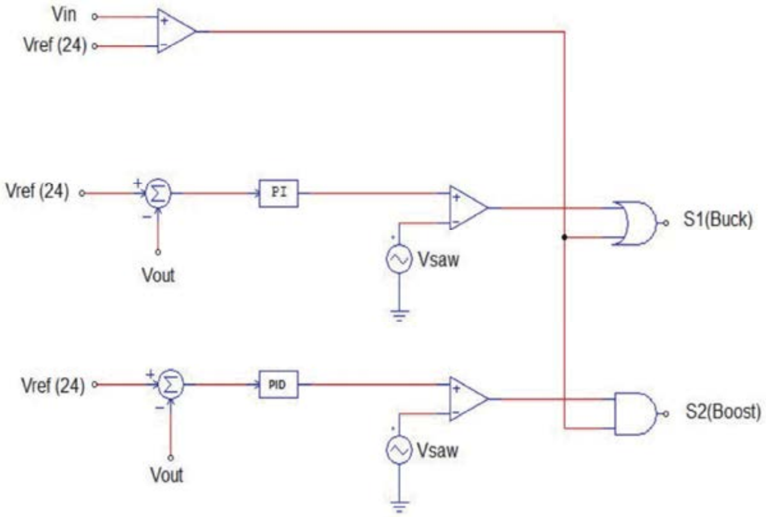

Fig. 5: Control circuit for TSBB converter

MATLAB simulation model of TSBB DC-DC Converter using PI & PID Controller.

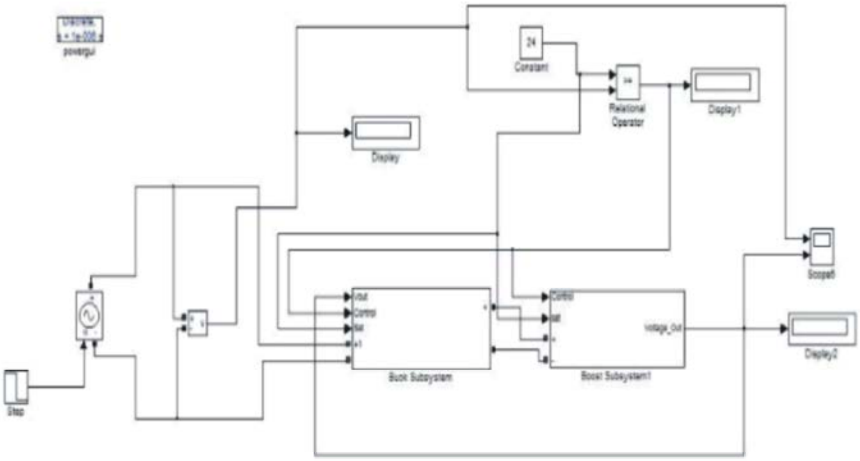

Fig. 6: Simulation diagram of TSBB converter using PI&PID controller

The above simulation consists of two major blocks

- Buck subsystem-PID Controller
- Boost subsystem-PI Controller

Simulation output:

Fig. 7: Simulation results for TSBB converter using PI&PID controllers Steady state performance

Table 3: Line regulation for TSBB using PI&PID

Line regulation		Load=60ohms
S.no	Input voltage vin(volts)	Output voltage vo(volts)
1	32	23.73
2	28	23.74
3	24	23.9
4	20	23.8
5	18	23.8

Table 4: Load regulation for TSBB using PI&PID

Load regulation		Input voltage=32V
S.no	Input voltage vin(volts)	Output voltage vo(volts)
1	60	23.73
2	50	23.75
3	40	23.8

Transient Performance:
Settling time: 0.05s
Peak overshoot: 35V

From the simulation results, the output of the two switch buck boost converter with feed forward is non-inverted and the steady performance is improved.

Internal Model Control: The new control scheme “Internal Model Control” is introduced in the proposed system to analyses the output voltage regulation and transient performance. The PI & PID controllers are replaced by “Internal Model Control” method Internal Model Control(IMC) is a commonly used technique that provides a transparent mode for the design and tuning of various types of control. The ability of proportional-integral (PI) and proportional-integral-derivative (PID) controllers to meet most of the control objectives has led to their widespread acceptance in the control industry. The Internal Model Control (IMC)-based approach for controller design is one of the control technique used in control applications in industries. Also the IMC controller allows good set-point tracking but sulky disturbance response especially for the process with a small time-delay/time-constant ratio. But, for many process control applications, disturbance rejection for the unstable processes is much more important than set point tracking. Hence, controller design that emphasizes disturbance rejection rather than set point tracking is an important design problem that has to be taken into consideration. As the IMC approach is based on pole zero cancellation, methods which comprise IMC design principles result in a good set point responses. However, the IMC results in a long settling time for the load disturbances for lag dominant processes which are not desirable in the control industry [7].

In current study we have taken several transfer functions for the model of the actual process or plant as we have exactly little or no knowledge of the actual process which incorporates within it the effect of model uncertainties and disturbances entering into the process. Also, the parameters of the physical system vary with operating conditions and time and hence, it is essential to design a control system that shows robust performance in the case of the above mentioned situations.

Procedure to Design IMC for two mode TSBB converter:

In the above figure Qc is the IMC controller. The PI controller is replaced with the IMC. The IMC block consists of the Inverse Model of the process (plant).

Procedure:

- The system to be controlled is modeled as a transfer function model.
- The inverse model of the system is derived.
- The Inverse model will act as the controller of the process.
- The transfer function model is used to tune the system for fast performance.

MATLAB simulation model of TSBB DC-DC converter using IMC& PI controller:

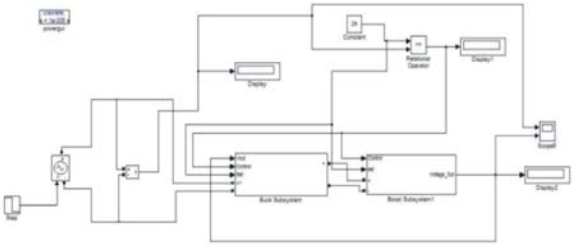

Fig. 8: Simulation diagram of TSBB using IMC and PI controller

Simulation Results:

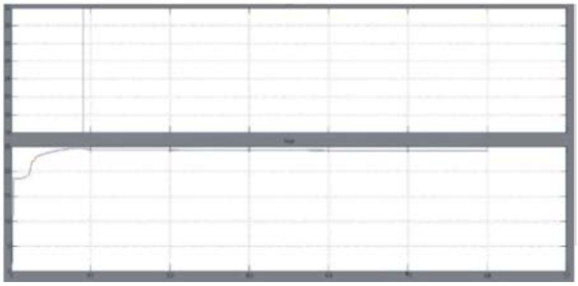

Fig. 9: Simulation results for TSBB converter with IMC&PI controllers steady state performance

Table 5: Line regulations for TSBB converter using IMC&PI controller

Line regulation		Load=60ohms
S.no	Input voltage vin(volts)	Output voltage vo (volts)
1	32	24.40
2	28	24.30
3	24	24.25
4	20	24.20
5	18	24.20

Table 6: Load regulation for TSBB converter using IMC&PI controller

Load regulation		Input voltage=32V
S.no	Input voltage vin(volts)	Output voltage vo (volts)
1	60	24.40
2	50	24.38
3	40	24.35

Transient performance

Peak overshoot: 24.5V

Settling time: 0.08s

From the simulation results, the output of the TSBB converter is non-inverted. Here Peak overshoot is less.

MATLAB simulation model of TSBB DC-DC Converter using IMC technique:

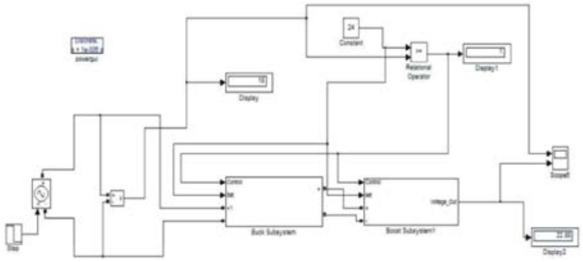

Fig. 14: Simulation diagram of TSBB using IMC controller

Simulation Results

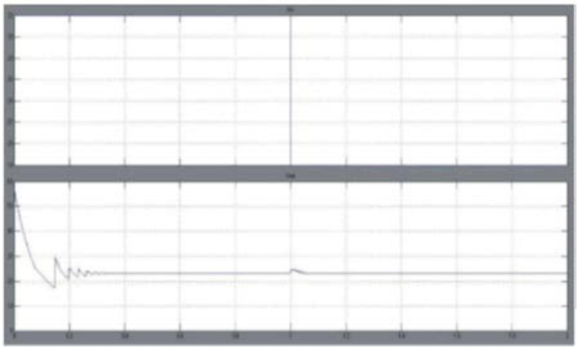

Fig. 10: Simulation results for TSBB converter steady state performance

Table 7: Line regulations for TSBB converter using IMC controller

Line regulation		Load=60ohms
S.no	Input voltage vin(volts)	Output voltage vo (volts)
1	32	23.17
2	28	23.18
3	24	23.19
4	20	24.20
5	18	24.17

Table 8: Load regulation for TSBB converter using IMC controller

Load regulation		Input voltage=32V
S.no	Input voltage vin(volts)	Output voltage vo (volts)
1	60	23.17
2	50	23.17
3	40	23.17

Transient Performance

Settling time: 0.32s

Peak overshoot: 55V

From the simulation results, the output of TSBB converter is non-inverted.

Comparative analysis

Table 9: Comparative analysis of TSBB converter for different controllers

Parameter	Inverting buck-boost	TSBB with PI/PID	TSBB with PI/IMC	TSBB with IMC
Input voltage(v)	18-32	18-32	18-32	18-32
Output voltage(v)	18->(-24.7)	18>(23.8)	18->(24.2)	18>(23.17)
	32->(-25.4)	32>(23.73)	32->(24.4)	32>(23.17)
Peek overshoot(v)	58	35	24.5	52
Settling time(s)	0.28	0.05	0.08	0.26

Hardware Implementation: The hardware implementation diagram is shown in Fig. 1. The results obtained using PI & PID controller are shown in below table.

Table 10: TSBB converter result in buck mode R=66Ω

Input Voltage Vin(volts)	Output Voltage Vo(volts)
26	25.1
27	25.8
28	25.9
29	25.8
30	25.8

Table 11: TSBB converter result in boost mode R=66Ω

Input Voltage Vin(volts)	Output Voltage Vo(volts)
18	24.8
19	24.8
20	24.9
21	24.9
22	24.8

CONCLUSION

In this work, performance of non-inverting two switch buck-boost converter was analysed in MATALB software. Three control techniques (PI & PID and Internal Model Control) are used to regulate the output voltage. From the simulation results it is concluded that performance of TSBB converter is better than the single switch buck-boost converter in both steady state and transient conditions. Among the control schemes used in two switch converter, the performance of PI & IMC Controller is better in transient conditions but in voltage regulation point of view, PI&PID controller is better. In hardware PI & PID controller is implemented and the performance is analyzed.

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