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Comparative Performance of PI And PID Controllers for Buck-Boost DC/DC Converter

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Abstract: This paper describes design and implementation of a buck-boost DC-DC converter to control voltage regulation and achieve high efficiency using a proportional integral derivative (PID) and proportional integral (PI) method in MATLAB/Simulink. The converter is characterized by its ability to adjust the input voltage, either by increasing or decreasing it, to maintain a constant output voltage that meets the needs of various applications that require voltage stability under variable operating conditions, such as portable electronic systems and renewable energy systems. This paper describes an evaluation comparison of PID and PI for the performance of a buck-boost converter and to achieve high power quality.

Keywords: Buck-Boost Converter, Proportional Integral, Proportional Integral Derivative, Power Quality Voltage Regulation

Introduction

DC-DC converters find widespread usage in a variety of applications that call for galvanic separation and a range of output and input voltages., boost, buck-boost and buck converters are the three main forms of dc/dc converters [1-4]. Using a buck converter to lower the voltage is possible, but The efficiency diminishes as the voltage conversion ratio lowers. Conversely, a boost converter may raise the voltage conversion ratio, which leads to a decrease in efficiency. So, when it comes to voltage range and conversion efficiency, standalone buck or boost converters are rigid. [5] One example would be the maximum power point converters seen in systems that generate renewable energy. When using an boost converter, the voltage open-circuit of renewable energy sources, for example solar energy (photovoltaic), thermoelectric fuel-cell generators, is usually where the efficiency of the conversion is at its peak thus the voltage is much greater than the maximum power voltage point. This situation makes it impossible to ensure the renewable energy system's critical efficiency high at the peak power point. When it comes to applications that charge or discharge batteries, a high conversion efficiency across the board is crucial [6-7]. Therefore, there is a lot of interest in studying how to convert power efficiently over a wide range of voltages, particularly for power systems that use renewable energy with batteries. This makes it a popular choice as a front-end converter for battery sources, since it achieves a voltage that exceeds the input voltage. The input voltage may be acquired using boost converters. The input voltage is always less than the output potential in this kind of device. To the contrary, the PID controller is an extremely strict mechanism that yields excellent system performance in a number of areas. One possible substitute for processing switching power converters is a PI, which acts as a regulator and offers an improved method for device management. The fundamental benefit of the PI control system is that it can stop the converter's parameters from causing static and dynamic reactions to unanticipated changes, including changes in load. As an alternative to traditional methods of processing switching power converters, PIs serve as regulators and provide better approaches to device management. In addition to its straightforward design and efficient performance, the principal benefit of the PI control scheme is that it can do away with the impacts of the parameter converter settings that cause static and dynamic reactions to unexpected changes, including fluctuations in load [8]. put forth a boost converter closed-loop system that makes use of a PID controller.

This mechanism regulates the voltage despite fluctuations in the load[10] the PI controller is used as feedback for the converter to maintain a consistent voltage.

This study focusses on evaluating the performance of PI and PID controllers as feedback loop control mechanisms for managing the voltage of the DC/DC buck-boost converter, a component commonly utilised in various control applications.

Methodology

CONVERTER DC-DC

DC-DC BUCK-BOOST CONVERTER

Figure 1 shows the basic schematic of the Buck-Boost converter, or called a step-up/ step down converter. This converter is a common example of a non-isolated voltage-converting power design; the parts S , L , D , C , and R stand for the switching component, inductance winding, fast diode, output capacitor, and load resistance, respectively. Integrated boost and buck converter topologies, a buck-boost converter is a hybrid device. Therefore, the output voltage may be raised or lowered by the buck-boost converter design in response to changes in the input voltage. The voltage output is specified by duty cycle(d) and frequency switching (fs) . Similar to a buck converter, the output voltage will be lower than the voltage input voltage if d is less than 0.5. Like a boost converter, voltage output will be higher than the input voltage if d is more than 0.5. Simultaneous amplitudes of the input and output voltages are achieved when d=0.5. There is no ongoing current through the diode (iD) when switch is turned -on because the voltage across the diode is inverted. When operating in conduction mode, an inductor's current (iL) grows as it absorbs voltage from a source. Whenever the switch is turned -off, the source and inductor are disconnected. In this case, iL is equal to S1 and iD As shown fig2 . The equation following for any operating mode shows how on and off states are used in analysis steady-state [11] .To get the output voltage, we can simply plug in the changes duty cycle and input voltage

Duty Cycle:

$$D = \frac{Vo}{Vo + Vin} \qquad (1)$$

Inductance L

$$L = \frac{R(1-D)^2}{2fs} \qquad (2)$$

Capacitance C :

$$C = \frac{\mathrm{D}}{fs\,.R\,.r} \qquad (3)$$

Where

Vo: Output voltage **Vin**: Input voltage

r: Possibly a ripple factor fs : Nominal switching frequency

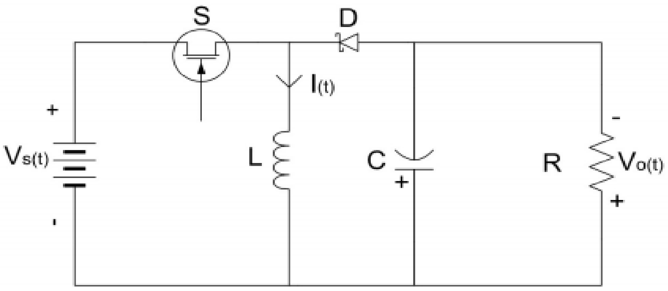

Figure 1. Buck-Boost converter [12].

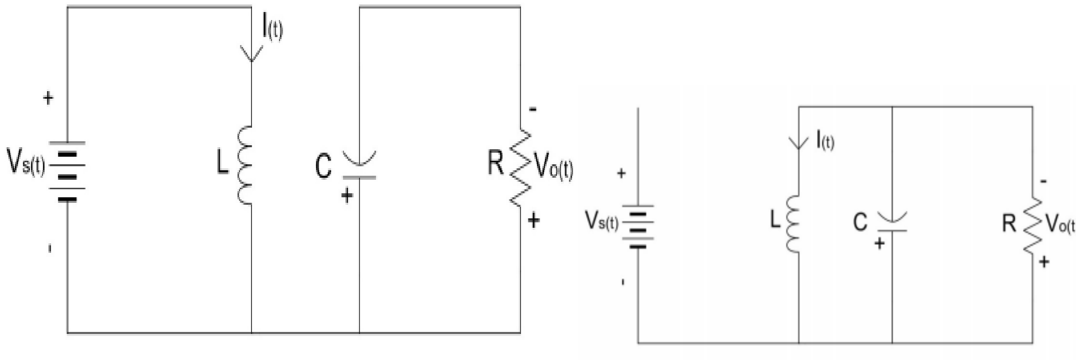

Figure 2. Configuration converter when the switch a) turned off b) turned on [12].

PI :Proportional Integral Controller

The PI regulator aims to achieve the desired operating point for the boost converter, therefore regulating the converter's output to closely align with the operating point amidst unexpected load disturbances and set point variations.

PID : Proportional Integral Derivative Controller:

The proportional gain Kp and the error signal have a direct relationship with the control signal. While a proportional controller may reduce a system's rise time, it cannot eliminate it entirely. The control signal, when an integrator is present, is immediately proportional to the integral of both the error and the gain, Ki. [13]. Theoretically, the steady-state error may be reduced to zero by applying integral action, which is the goal of integral control. By adjusting the course of action in response to changes in the error signal, derivative control is able to foretell how the signal will behave in the future. The derivative of the error, denoted as Kd, has a direct proportional relationship to the control signal. Improved transient responsiveness, less overshoot, and increased stability are all benefits of derivative control. Since the Derivative control action is only effective over short periods of time, it cannot be employed alone [13] as shown fig3.

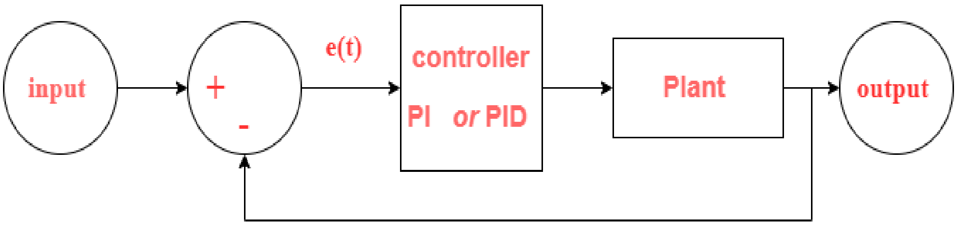

Figure 3. Basic block diagram of Controller.

The formula for controller PI :

$$U(t) = K_p \ e(t) + K_i \int e(t)$$

The formula for   controller PID :

$$U(t) = K_p \ e(t) + K_i \int e(t) + K_d \frac{de(t)}{dt}$$

Error e(t) (Discrepancy between the intended and actual output values).

K_P =Proportional element reduces rising time.

K_i =The integral element is used to mitigate overshoot.

K_d= The derivative element is used to mitigate overshoot.

Results and Discussion

The result of this work is based on modelling and control of a buck-boost converter, integrating controller techniques to ensure optimal performance. The converter will be modelled mathematically and simulated using MATLAB/Simulink to analyse its behaviour under different operating conditions as shown fig 4 & fig 9.

Control of a Buck-Boost Converter for Dynamic   voltage regulation DC using PI:

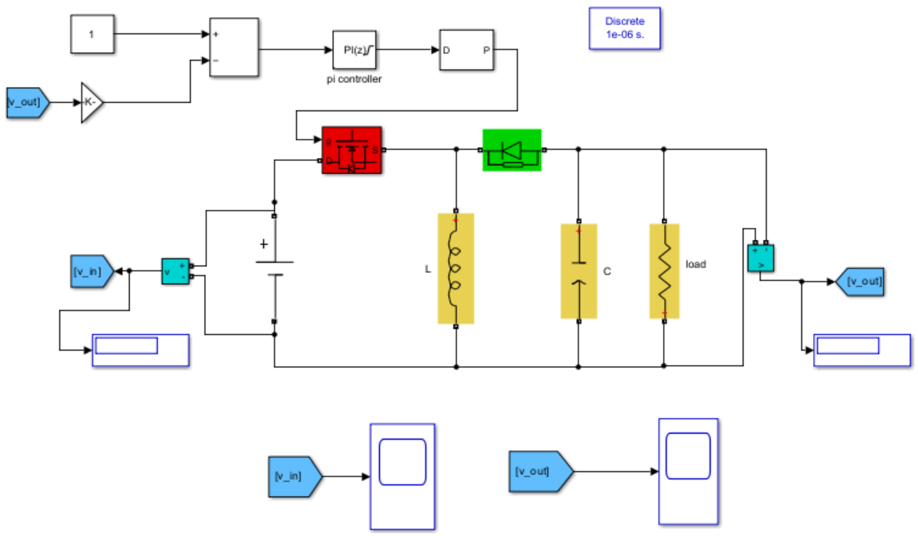

Figure 4. The simulation diagram of converter   by PI controller.

Case 1: PI controller with buck-boost converter (buck mode)

The function of a Buck Converter is to reduce the voltage. as shown table1.The output voltage is controlled using a parameter called   duty cycle, which is the percentage of time for switch is ON through any cycle switching . For example, if 50%, for   duty cycle voltage output will be roughly half of the input voltage as shown   fig 5 &fig6.

Table 1. Case 1 circuit parameters.

Parameters name	symbol	value
Voltage input	Vin	12v
Voltage output	Vo	5 v
inductor	L	28uH
capacitor	C	100uF
Nominal switching frequency	Fs	50KHZ
Resistance load	R	9 Ω
Proportional	P	0.7
Integral	I	100

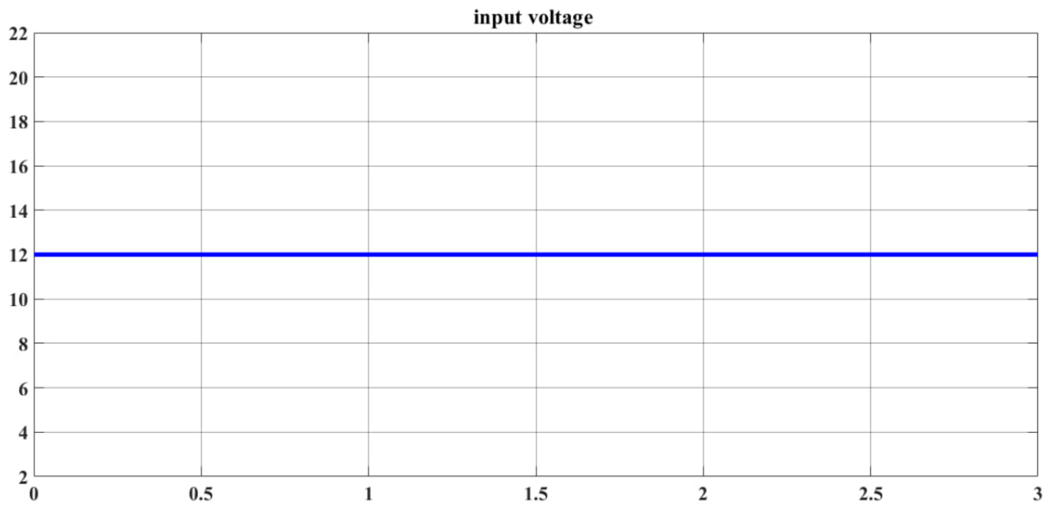

Figure 5. Input voltage for converter by PI (buck case).

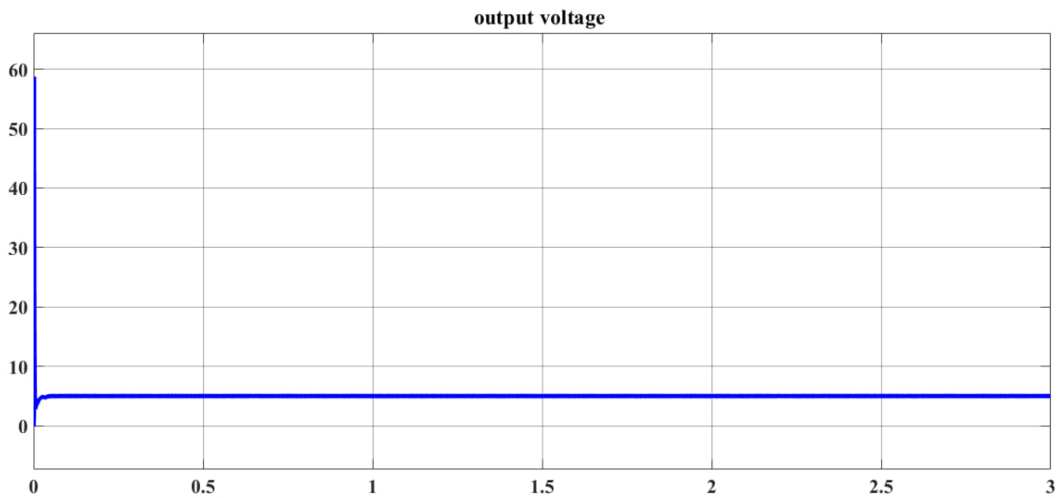

Figure 6. Output voltage for converter by PI (buck case).

Case 2: PI controller with buck-boost converter (boost mode)

A boost converter is designed to increase the voltage level as table 2. voltage output is regulated by a parameter called the duty cycle, which is the percentage of time for switch is ON by every switching cycle.as shown in fig 7&fig8

Table 2. Case 2 circuit parameters.

Parameters name	symbol	value
Voltage input	Vin	5v
Voltage output	Vo	12 v
inductor	L	100uH
capacitor	C	470uF
Nominal switching frequency	Fs	100KHZ
Resistance load	R	12 Ω
Proportional	P	0.1
Integral	I	100

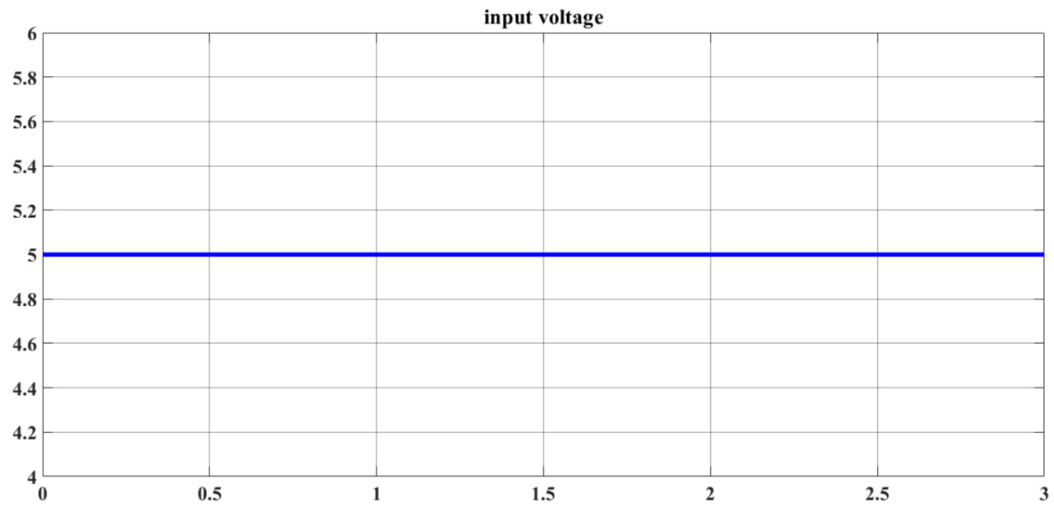

Figure 7. Input voltage for converter by PI (boost case).

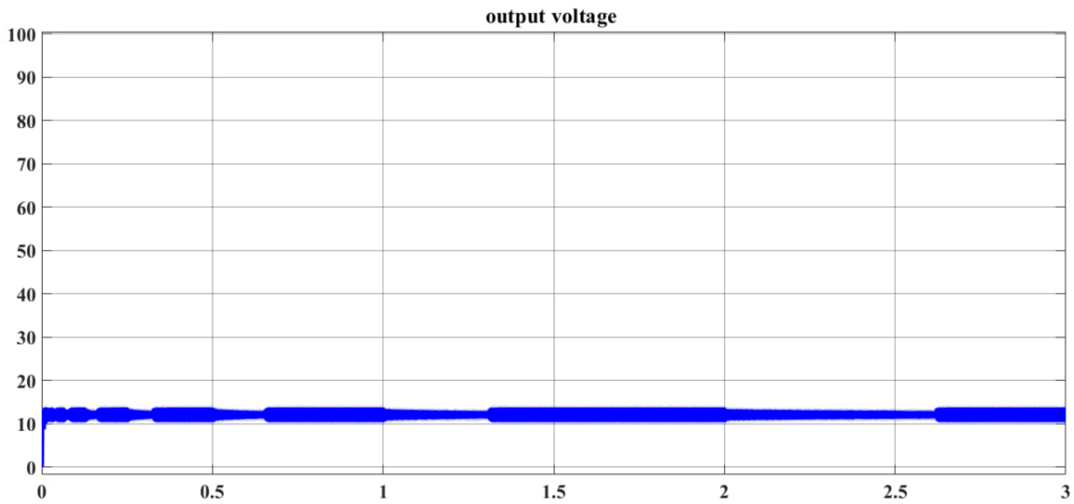

Figure 8. Output voltage for converter by PI (boost case).

Control of a Buck-Boost Converter for dynamic voltage regulation DC using PID

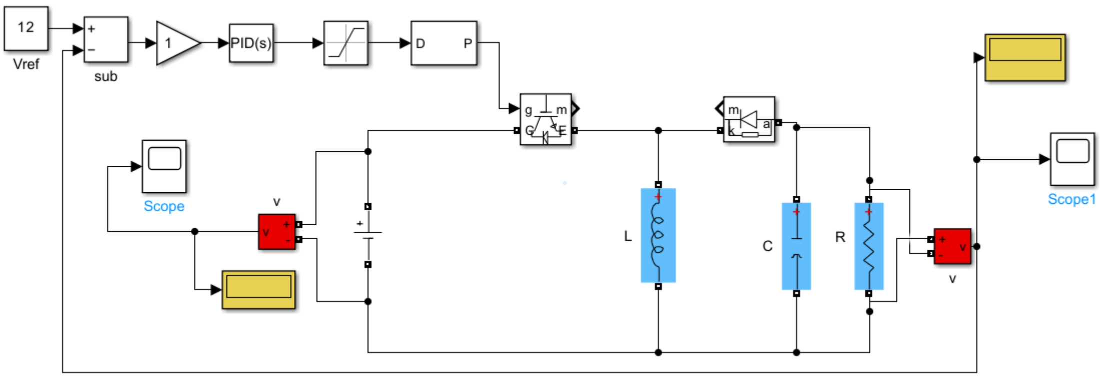

Figure 9. The simulation diagram of converter using pi controller.

Case 3: PID controller with buck-boost converter (buck mode)

The function of a Buck Converter is to reduce the voltage. as shown table3 .The output voltage is controlled using a PID Controller as shown figures (10 &11).

Table 3. Case 3 circuit parameters.

Parameters name	symbol	value
Voltage input	Vin	12v
Voltage output	Vo	5 v
inductor	L	84.1uH
capacitor	C	56.8uF
Nominal switching frequency	Fs	25KHZ
Resistance load	R	50Ω
Proportional	P	0.5
Integral	I	6
Derivative	D	0.01

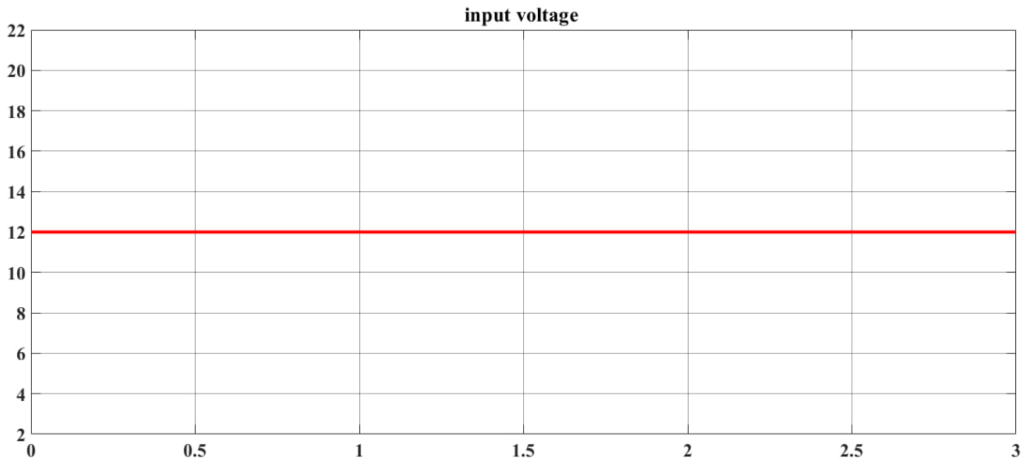

Figure 10. Input voltage for converter by PID (buck case).

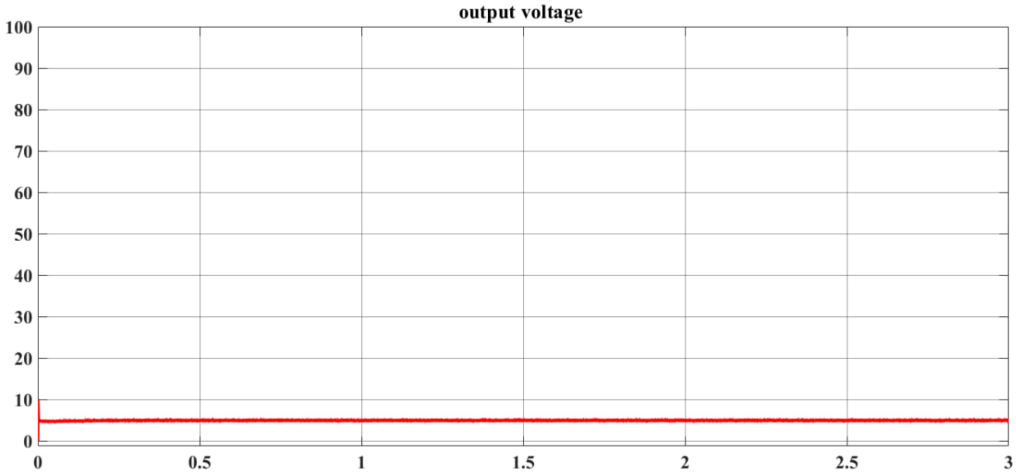

Figure 11. Output voltage for converter by PID (buck case).

Case 4: PID controller with buck-boost converter (boost mode)

In this case, The function of a Buck Converter is to increase the voltage. as shown table1 and figures (12&13) .The output voltage is regulated by a PID Controller . The power quality for controller PID is good by compare between fig 6 for case 1 and fig13 for case 4 as example .

Table 4. Case 4 circuit parameters.

Parameters name	symbol	value
Voltage input	Vin	5v
Voltage output	Vo	12 v
inductor	L	100,8uH
capacitor	C	58uF
Nominal switching frequency	Fs	25KHZ
Resistance load	R	10 Ω
Proportional	P	40
Integral	I	0.01
Derivative	D	0.01

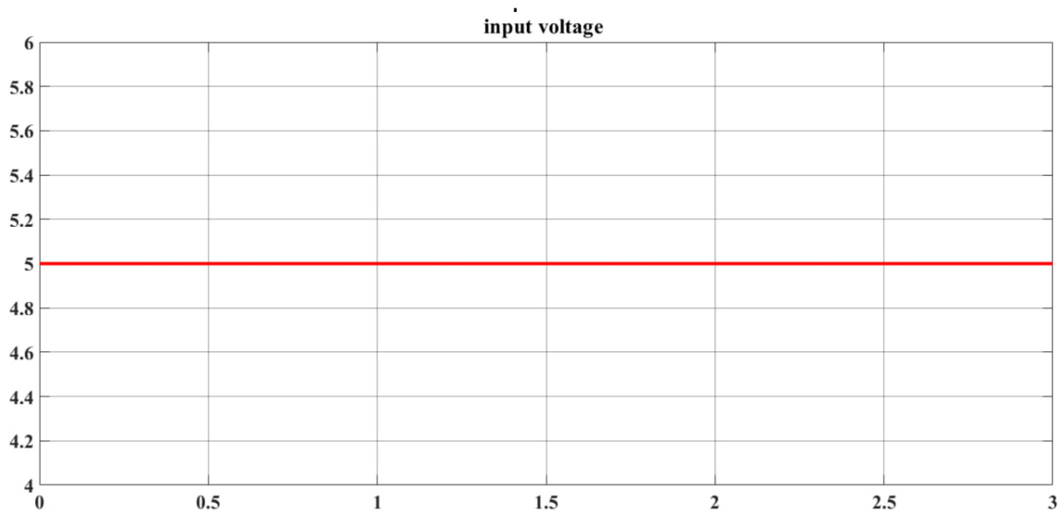

Figure 12. Input voltage for converter by PID (boost case).

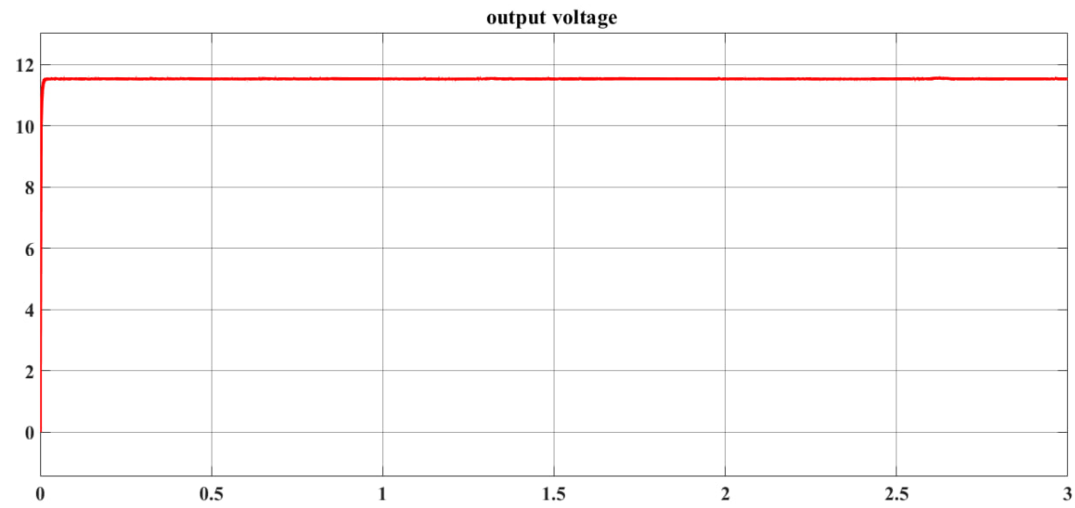

Figure 13. Output voltage for converter by PID (boost case).

Conclusion

This work presents the implementation and analysis of a buck-boost dc/dc converter using controlled PI and PID techniques. The buck-boost converter with a PID controller offers an efficient and versatile solution for voltage management across many applications. The buck-boost converter that may either step up /step down voltage based on application needs, is essential in several power electronic systems. The integration of the converter's voltage adjustment capability with the precision of PID control enables the achievement of high-efficiency performance with remarkable stability as compared to the PI controller. The simulation results indicate that the suggested PID controller effectively adjusts the output voltage of the boost converter, enhancing power quality regardless of load disturbances.

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