Design and Simulation of a DC - DC Boost Converter with PID Controller for Enhanced Performance



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MAY 2025

DECLARATION

We, hereby, declare that the work presented in this project is the outcome of the investigation and research performed by us under the supervision of Md. Saiful Islam.Lecturer & Asst. Coordinator of Department of Electrical and Electronics Engineering, Sonargaon University (SU). We also declare that no part of this project and therefor has been or is or being submitted elsewhere for the award of any degree.

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I am also thankful to all the faculty members and staff of the Department of Electrical and Electronic Engineering, Sonargaon University, for providing the academic environment and necessary resources for conducting this research.We convey our honor and thankfulness to **Md.Rais Uddin Mollah Assistant Professor & Head (Acting)** of Electrical and Electronics Engineering, Sonargaon University from our deep corner of heart for his support and encouragement.

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ABSTRACT

This study presents the design and simulation of a DC-DC Boost converter integrated with a PID controller to enhance system performance. The primary goal of a DC-DC converter is to ensure a stable output voltage regardless of fluctuations in input voltage, component characteristics, or load current. The design focuses on achieving high conversion efficiency, reduced harmonic distortion, and improved power factor, all while maintaining reasonable size and cost. A basic Proportional-Integral-Derivative (PID) controller is implemented with a standard Boost converter and simulated using MATLAB-Simulink, resulting in better voltage regulation. The proposed closed-loop control system effectively stabilizes output voltage during input variations and minimizes overshoot, thereby enhancing overall efficiency. These results hold promising applications in electric vehicles, industrial systems, communication networks, and renewable energy technologies.

APPROVAL

This is to certify that the thesis on "**Design and Simulation of a DC - DC Boost Converter with PID Controller for Enhanced Performance"**

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has been carried out under my supervision. The project has been carried out in partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Electrical And Electronics Engineering of the year of 2025 and has been approved as to its style and contents.

……..

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TABLE OF CONTENTS

Contents	Page No:
Declaration	ii
Acknowledgment	iii
Abstract	iv
Approval	v
CHAPTER 1	
Introduction	1-4
CHAPTER 2	
Conditional Boost Converter	5-7
CHAPTER 3	
PID Controller	8-9
CHAPTER 4	
Simulation	10-14
CHAPTER 5	
Process Of Tuning Of PID Controller	15-17
CHAPTER 6	
Result	18
CHAPTER 7	
Conclusion	19
CHAPTER 8	
Future Work	20
CHAPTER 9	
Refferences	21-24

LIST OF FIGURE

Figure No:	Figure Content:	Page No:
Fig 1	Block Diagram of a DC-DC Converter	01
Fig 2	PID Boost Converter	03
Fig 3	Conventional Boost Converter	05
Fig 4	Mode of operation of Boost Converter	06
Fig 5	Typical PID control Structure	08
Fig 6	Matlab Simulation model without tuneing	10
Fig 7	Output of the simulation (without tuning)	11
Fig 8	Matlab Simulation model with tuneing	11
Fig 9	Output of the simulation (with tuning)	12
Fig 10	Variation of input voltage	12
Fig 11	Output voltage response	13
Fig 12	View from close	13
Fig 13	When PID controller not functioning.	14
Fig 14	PID Controller functioning	14
Fig 15	Identify new plant	15
Fig 16	changing offset and amplitude	15
Fig 17	Plant Identification	16
Fig 18	Applying Identification	16
Fig 19	Modification of plant and applying it	16
Fig 20,21,22	For smooth tune response modification of transient behavior	17

LIST OF TABLE

Table No	Table Title	Page No
Table 1	Table effect of PID on close loop system	09
Table 2	Simulation Parameters	10
Table 3	Value of KP,KI,KD	18

CHAPTER 1

INTRODUCTION

Power electronics is driving a new wave of industrial transformation due to its adaptability across various applications such as energy conservation, renewable energy systems, large-scale energy storage, electric and hybrid vehicles, and industrial automation. Among power conversion systems, DC-DC converters play a critical role and are widely used in devices like mobile phones, laptops, LED lighting systems, and in optimizing energy output for solar panels, wind turbines, electric vehicles, and hydroelectric power stations [1]-[4]. Given their extensive use, these converters are expected to deliver maximum efficiency, reduced total harmonic distortion (THD), and improved power factor (PF) on the load side, while also being compact, cost-effective, and highly reliable [5]-[8].

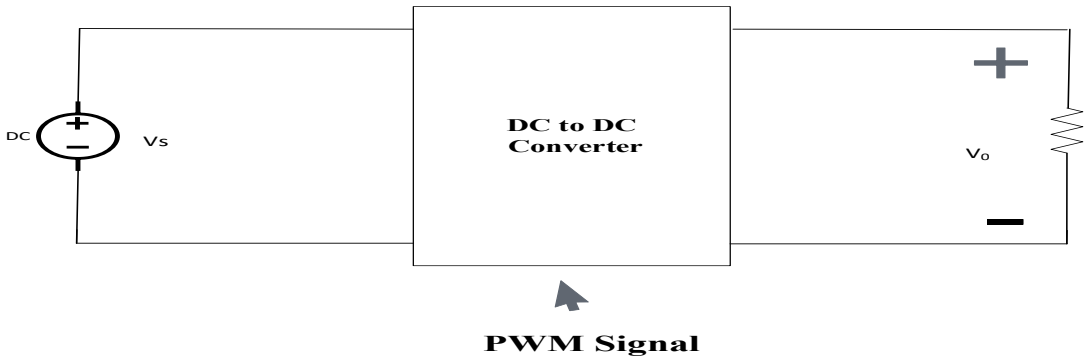


Fig. 1. Block Diagram of a DC-DC Converter

An electric power converter, DC-DC converter or more commonly known as a switched mode DC-DC converter as shown in Fig.1, either steps up or steps down the source voltage, *Vs* according to the requirement of the load connected, by making adjustments in the duty cycle applied to the switching device (in most cases MOSFETs and IGBT's).

In a DC-DC converter it is always desirable that a constant output voltage, *Vo* is achieved despite changes in the source voltage, *Vs*, the load current, *iLoad* and variations in element values of the converter circuit [10], [11]. These disturbances can be originated from second harmonic periodic variations of an off - line power system generated from the rectifier circuit and applied to the DC-DC converter, variation of the source voltage *Vs* due to switching (on/off) of neighboring power system loads and variations in the load current, *iLoad* amongst many. There are various types of DC-DC converters namely – Buck, Boost, Buck-Boost, Cuk, Sepic and Zeta. One of the most prominent research interests in this era is the application of DC-DC converters with high step-up voltage gain.

Several control techniques have been proposed to ensure stability as well as fast transient response namely - Fuzz Logic controller, Artificial Neural Network (ANN), PID controller and PI controller. Several Optimization techniques such as Genetic Algorithm, Particle Swarm Optimization, and Bacterial Foraging Optimization have also been proposed [11], [12], [20], [21].

Amongst all converters, most widely used DC-DC converter is the Boost converter, a step-up converter which provides a higher voltage at the load side, *Vo* compared to the source voltage *Vs*. Open loop mode of operation of Boost converter exhibits substandard voltage regulation and undesirable dynamic response. Therefore, closed loop mode of operation is preferred for proper voltage regulation and performance enhancement.

In this paper proper voltage regulation of Boost converter is achieved employing PID controller, tuned using trial and error method to find appropriate values for the proportional, integral and derivative gains, thereby improving converter performance. Section II of this paper deals with the conventional Boost converter followed by a brief idea about PID Controller in Section III, Section IV depicts the proposed converter and finally the simulation.

And results are presented by comparing the conventional Boost converter with the proposed or modified Boost converter with PID controller in section V. The proposed circuit parameters, simulation and experimental results demonstrate the effectiveness and feasibility of the proposed scheme.

An open-loop boost converter, while straightforward in design and implementation, suffers from poor regulation and instability in response to changes in load or input voltage [28]. This lack of adaptability can cause severe performance issues such as output voltage overshoot, slow transient response, and increased steady-state error, particularly in systems that require precise voltage regulation [29], [30]. Therefore, it becomes imperative to design closed-loop control systems that can enhance converter performance by dynamically adjusting the duty cycle in response to real-time feedback.

One of the most widely adopted control techniques in power electronics is the Proportional-Integral-Derivative (PID) controller, due to its intuitive design, wide applicability, and robustness in various industrial control systems [31], [32]. The PID controller enhances performance by minimizing the error between the reference voltage and the output voltage through proportional, integral, and derivative adjustments. Each component of the PID controller serves a unique role: the proportional term addresses the present error, the integral term mitigates past errors, and the derivative term anticipates future trends by considering the rate of change of error [33]. When properly tuned, a PID controller can significantly reduce overshoot, enhance stability, and improve settling time [34].

Numerous tuning methods have been proposed to optimize the PID controller parameters for nonlinear systems like boost converters. Classical methods such as Ziegler-Nichols [35] and Cohen-Coon [36] are still widely used for their simplicity, but they often fail to provide optimal performance in complex systems. More advanced approaches including particle swarm optimization, genetic algorithms, and fuzzy logic-enhanced PID tuning have been introduced to achieve better control in uncertain and dynamic environments [37], [38], [18]. These intelligent

techniques can automatically adjust controller gains in real-time, resulting in improved transient response and adaptability [39].

Simulation plays a critical role in the analysis and validation of power electronic systems before physical implementation. Software tools like MATLAB/Simulink provide a versatile platform for modeling and simulating both the electrical components and control algorithms of DC-DC converters [40]. By simulating under various operating conditions—such as line disturbances, load variations, and transient start-up states—engineers can evaluate the performance of a controller and optimize the converter design [41], [42]. These simulations offer a cost-effective and safe means to analyze different configurations and tuning strategies without the risks and costs associated with hardware testing. Recent studies have demonstrated the effectiveness of PID-controlled boost converters in maintaining output voltage stability and enhancing system efficiency. For instance, Lee et al. [43] showed that closed-loop PID control significantly reduced output voltage ripple and improved line regulation in a 100W boost converter. Similarly, research by Mattavelli et al. [44] highlighted the benefits of feedforward-compensated PID control in active rectifiers and switching power converters. Furthermore, hybrid control systems that combine classical PID control

with fuzzy logic or neural networks have shown promise in extending control capabilities under non-linear or time-varying conditions [45].

Given the critical need for robust and adaptable voltage regulation in DC-DC boost converters, this study aims to design, simulate, and evaluate a closed-loop PID-controlled boost converter using MATLAB/Simulink. The proposed system is analyzed in terms of key performance indicators including rise time, settling time, overshoot, and steady-state error. Comparative analysis between open-loop and closed-loop configurations is also conducted to illustrate the improvements offered by the PID control approach.

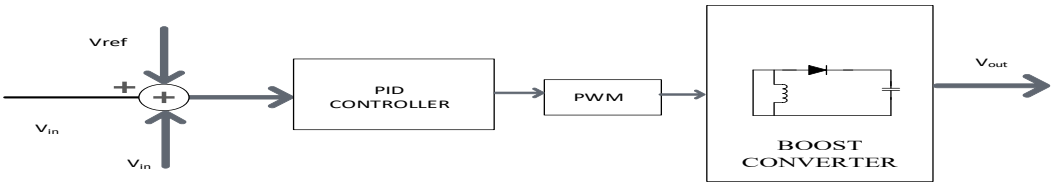


Fig 2: PID Boost Converter

The core contributions of this research include the design and modeling of a DC-DC boost converter tailored for medium power applications, the implementation and tuning of a PID controller to achieve enhanced transient and steady-state performance, and a comprehensive simulation-based evaluation of the system under varying load and input conditions.

By integrating theoretical analysis with practical simulation, this study contributes to the ongoing advancement of power electronics control systems, especially for applications that require high performance, energy efficiency, and system reliability. The findings serve as a valuable reference for engineers and researchers working on embedded systems, renewable energy applications, and intelligent control in power conversion systems.

CHAPTER 2

CONVENTIONAL BOOST CONVERTER

A conventional DC-DC Boost converter is composed of a boost inductor, two semiconductors (a diode and a transistor) and an output capacitor in parallel with the load as shown in Fig. 2. Boost converter also known as an up converter provides an output voltage that is greater than the input voltage. Input for a boost converter can be a simple DC source such as a battery, solar panel or can be obtained directly from an AC source through a rectifier. The inductors tendency to resist current variations due to changes in the magnetic field is the key principle that drives the Boost converter. Boost converter is said to operate in two modes. The switching is achieved using either a Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET)or an Insulated Gate Bipolar Transistor (IGBT).

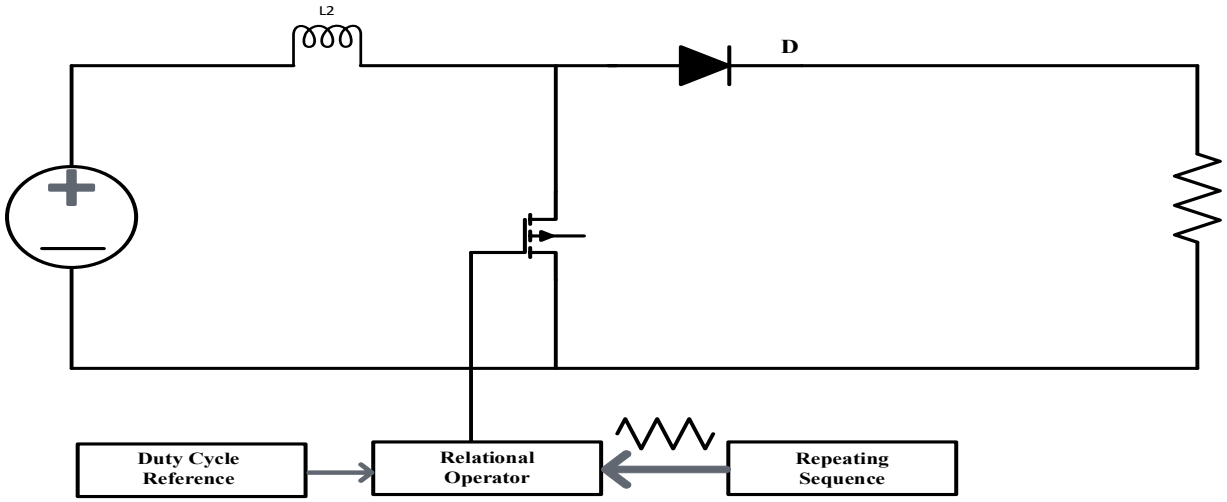


Fig. 3. Conventional Boost Converter

In low voltage applications MOSFET is preferred over IGBT due to its higher computational speed compared to IGBT. Modes of operation of Boost converter is as follows:

- Mode 1 begins at $t = 0s$ when the transistor is switched on causing the rising input current to flow through the inductor L, storing energy in its magnetic field. During this mode of operation as shown in Fig. 3(a) the load side is completely isolated from the source side.

- Mode 2 begins at $t = t1$ when the transistor is switched off. Inductor, L produces a back emf having opposite polarity of the Mode 1 due to rapid drop in current. The voltage across the inductor and the source minus the small forward voltage drop across the diode, D charges the capacitor, C and also supplies the load. The conduction path is shown in Fig. 3(b).

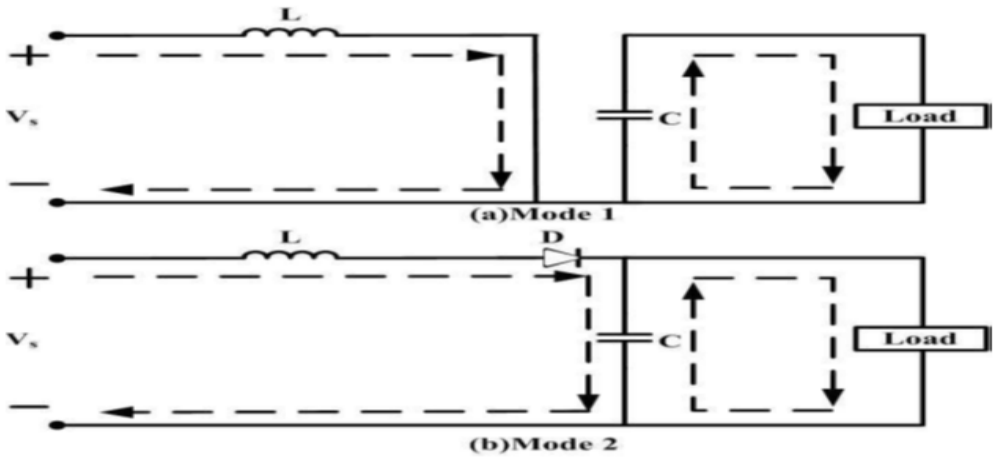


Fig. 4. Mode of operation of Boost Converter

ransistor switching period is given by

Mode 1 $Ton = DTp$ (1)

Mode 2 $Toff = (1 - D)Tp$

Voltage across the inductor

Mode 1 $L\frac{di}{dt} = Vi$

Mode 2 $L\frac{di}{dt} = -(Vi - Vo)$ (2)

Putting equation (1) in equation (2)

Mode 1 $L\frac{\Delta i}{\mathrm{DTp}} = Vi$

Mode 2 $L\frac{\Delta i}{(1-\mathrm{D})\mathrm{Tp}} = Vo - Vi$

Ripple Current Δi , $is\ given\ by$

Mode 1 $\Delta ion = \frac{ViDTp}{L}$ (3)

Mode 2 $\Delta ioff = \frac{(1-D)(Vo-Vi)Tp}{L}$ (4)

Equation the ripple current equ (3) and (4) of Mode 1 and Mode 2

$$\Delta ion = \Delta i\ off$$

$$ViD = Vo - Vi - DVo + DVi$$

$$Vi = Vo - DVo$$

$$Vi = Vo(1 - D)$$

$$\frac{Vo}{Vi} = \frac{1}{1 - D} \quad (5)$$

Where,

Vi	$Input\ Voltage, V$
Vo	$Output\ Voltage$,V
ton	$MOSFET\ on, sec$
$toff$	$MOSFET, off, sec$
Tp	$Switching\ period\ , sec$
D	$Duty\ Cycle$
Δi	$Ripple\ \ current$

$$C(s) = \frac{K_{DS^2} + Kp^s + K_I}{s}$$

$$C(s) = K + \frac{K_I}{S} + KD^s$$

Where,

Kp	$Proportional\ gain$
K_I	$Integral\ \ gain$
K_D	$Derivative\ \ gain$

CHAPTER 3

PID CONTROLLER

One of the simplest and most widely used controller for decades is the PID Controller ,PID stands for proportional (p),integral(I)and derivative (D) controller. Fig 4 shows the block diagram of a typical PID Controller.

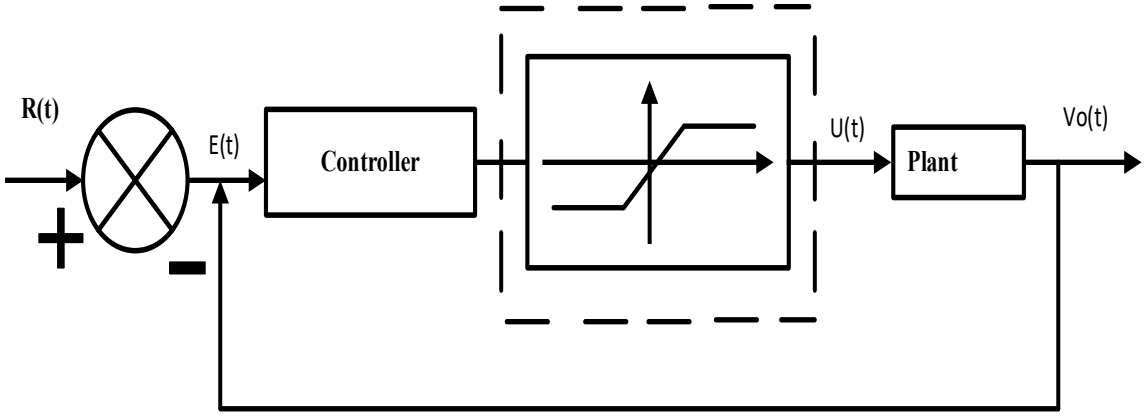


Fig. 5. Typical PID control Structure

The system under study is the plant to which necessary excitation is provided thereby achieving overall closed loop control effectively. A PID can be expressed as –

$$C(s) = \frac{K_{DS^2} + Kp^s + K_I}{s}$$

$$C(s) = K + \frac{K_I}{S} + KD^s \quad (6)$$

Where,

KP Proportional gain

KI Integral gain

KD Derivative Gain

The signal e(t) as shown in Fig. 4 represents the tracking error obtained from the difference between the reference signal which serves as the input R(t) and the actual output signal Vo(t). The tracking error is fed on to the PID controller which computes the derivative and integral of the signal provided. The output of the PID controller u(t) to be applied to the plant is equal to the

proportional gain (KP) times the magnitude of the error signal plus the integral gain (KI) times the integral of the error signal plus the derivative gain (KD) times the derivative of the error signal.

Time domain representation of the signal u(t) fed to the plant is given by –

$$u(t) = K_{p^2}(t) + K_I \int e(t)dt + K_D \frac{de(t)}{dt} \qquad (7)$$

The plant on receiving the signal u(t) will generate a modified output Vo(t) which will be again compared to the reference signal until the desired level is reached thereby forming a close loop system. Effect of proportional, integral and derivative control on close loop system is summarized in the Table I. provided below.

TABLE EFFECT OF PID ON CLOSE LOOP SYSTEM

	Rise Time	Overshoot	Settling Time	Steady State Error
Proportional	Decrease	Increase	Small Change	Decrease
Integral	Decrease	Increase	Increase	Eliminate
Derivative	Small Change	Decrease	Decrease	Small Change

Table1: Table effect of PID on close loop system

The controllers can be implemented individually as well as in combination, with the converters to obtain the desired result.

CHAPTER 4

SIMULATION

Simulation was done in MATLAB-Simulink environment. The parameters used for this simulation are given Table II. As shown below –

Conventional Boost converter as shown in Fig. 3, was simulated at 50% duty cycle and the output wave shapes observed for variations of input voltage from 12V – 14V with increment of 2V. It can be observed that the output voltage fluctuates with variation of input voltage by a large amount. Moreover, the converter exhibits significant increase in overshoot as the input voltage varies as shown in Fig. 5.

Parameter	Value
Input Voltage	12V
Output Voltage	24V
Rated Power	500W
Duty cycle	0.5
Boost Inductor	0.0014µH
Filter Capacitor	0.0043µ
Resistive Load	1.1520Ω

Table 2 :Simulation Parameters

Matlab Simulation model without tuneing

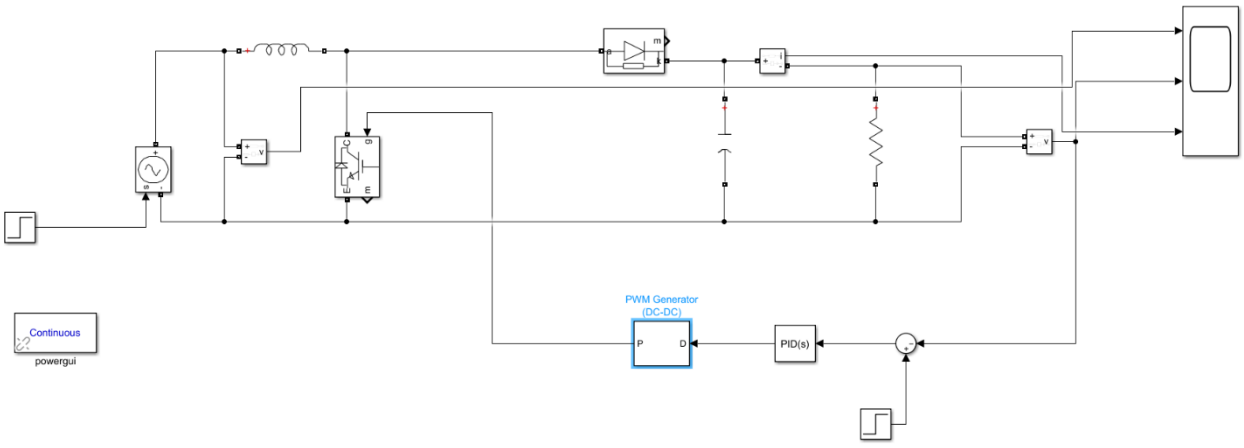


Fig 6: Matlab Simulation model without tuneing

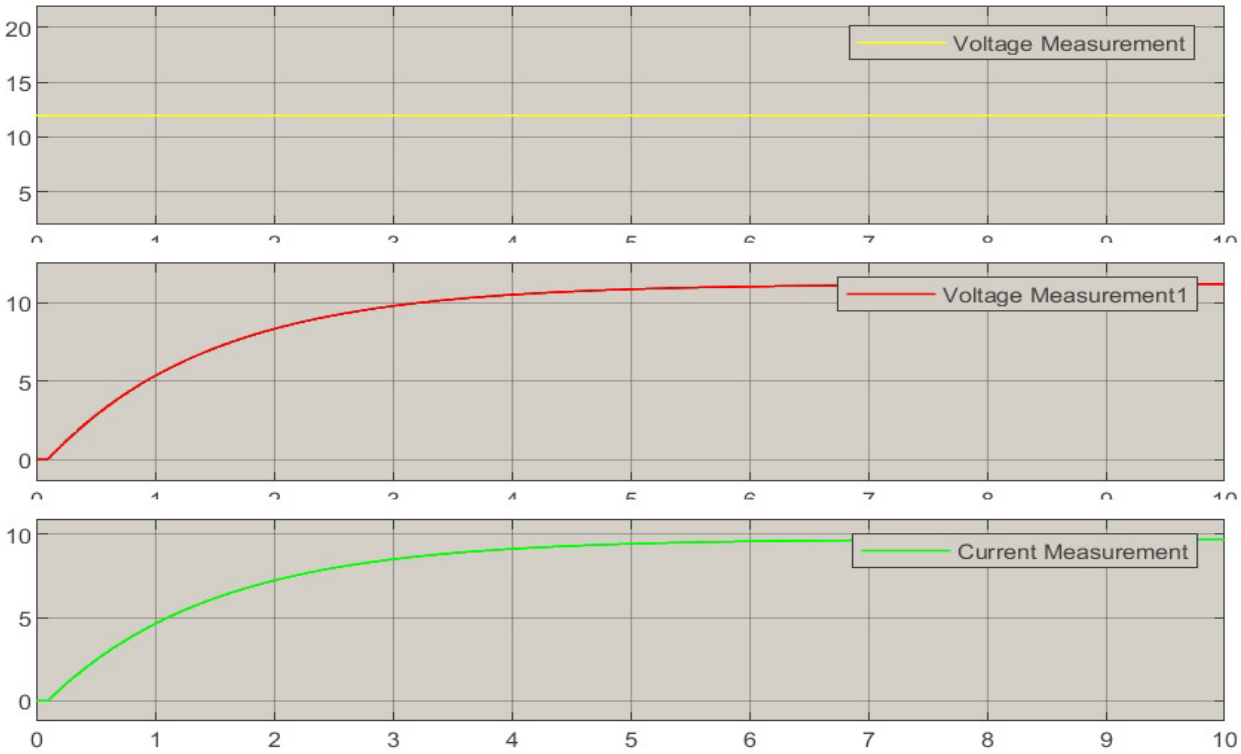


Fig 7: Output of the simulation (without tuning)

Our proposed Boost converter (Tuned)

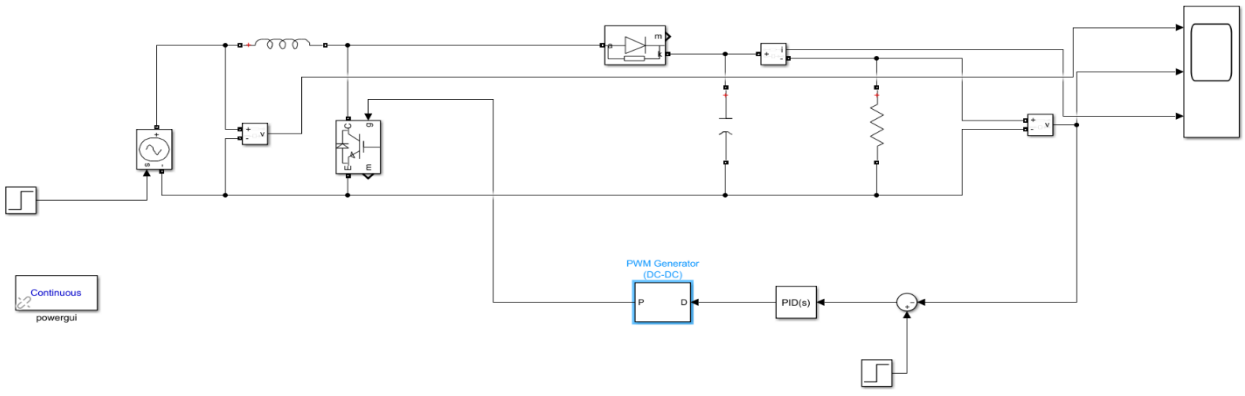


fig 8: Matlab Simulation model with tuneing

It shown desired output and its when my input voltage are constant 14. Then our output of the Simulink is sown in fig.

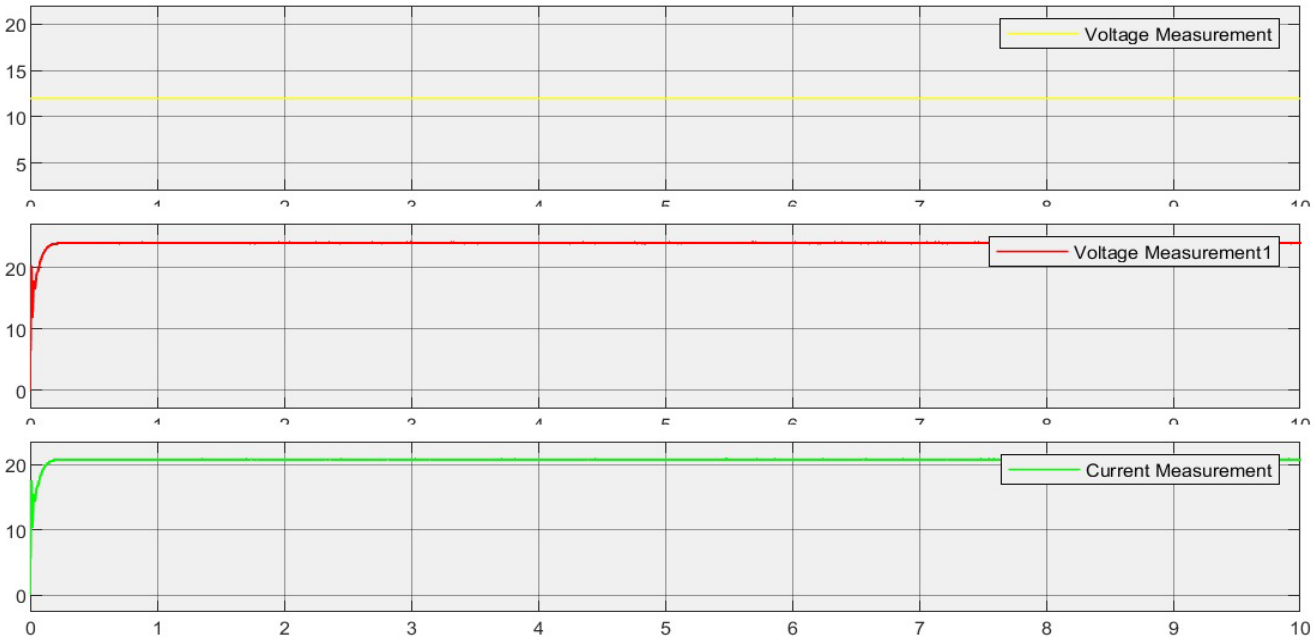


Fig 9: Output of the simulation (with tuning)

And when we give voltage variation, step time 5 change input voltage from 12V-15V then check the output response of the system.

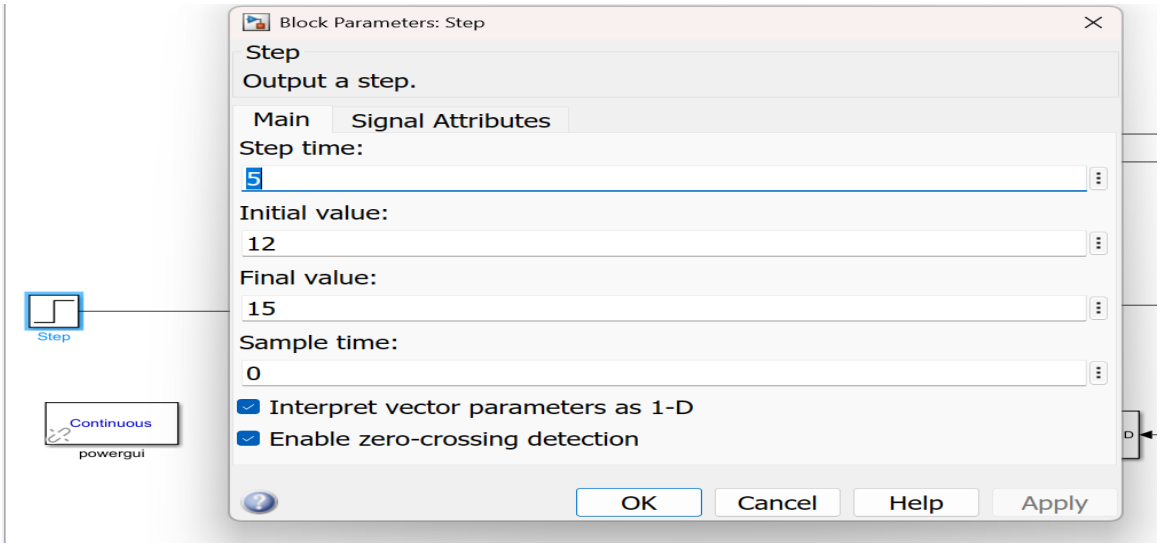


Fig 10: Variation of input voltage

And output of the system shown in below figures :

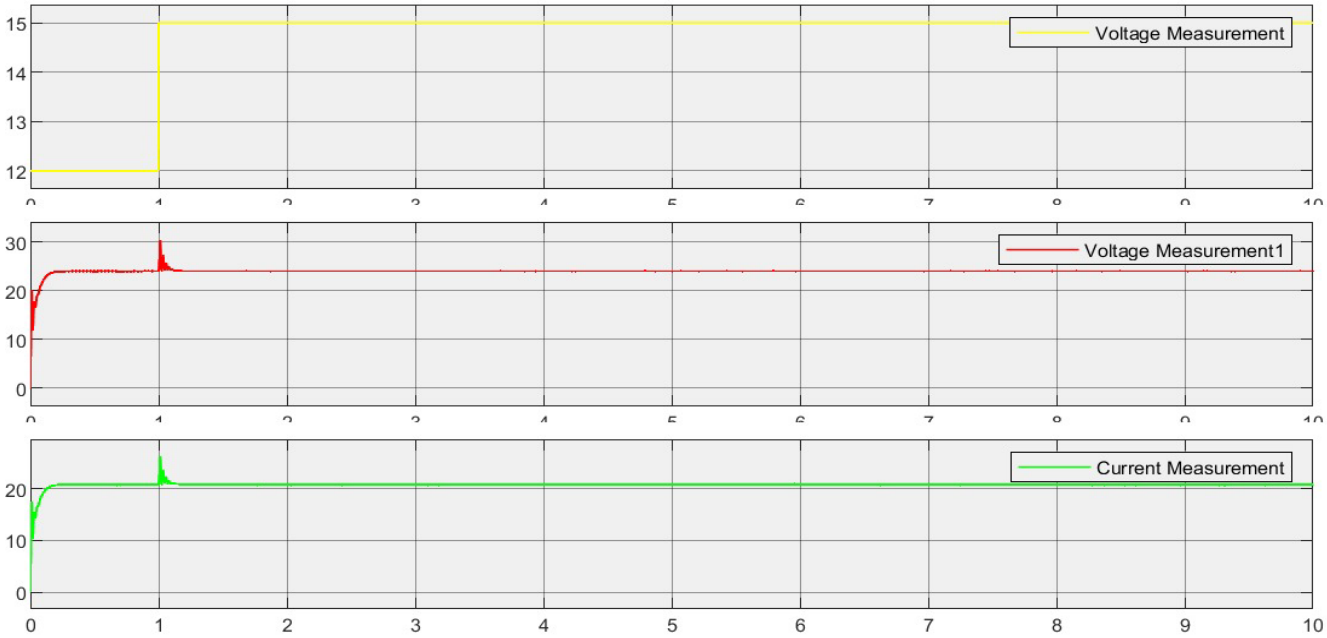


Fig 11: Output voltage response

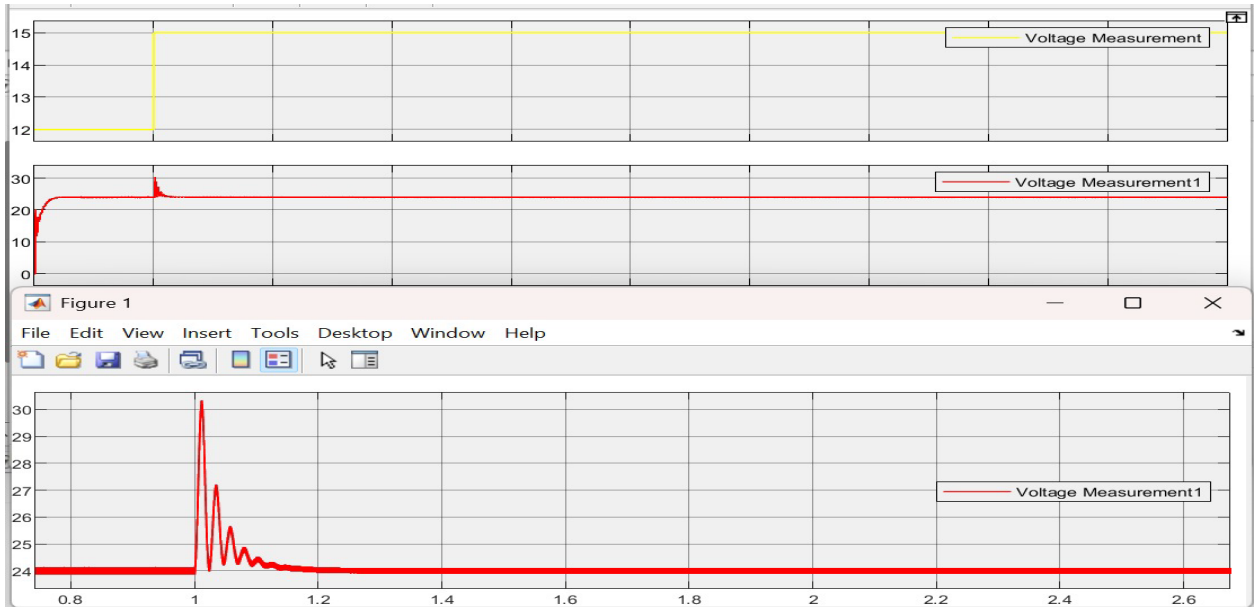


Fig 12: View from close

Here we can see that maintain at 24V and it has variation. During voltage change from 12V to 15V that system maintained at the 24V only. During that change right we have some oscillation right dumped oscillation then its settled to 24V.So the disturbance occur in the 5 seconds and sattle in to 5.2 second. So it will take 0.2 second to settle that to reference value.

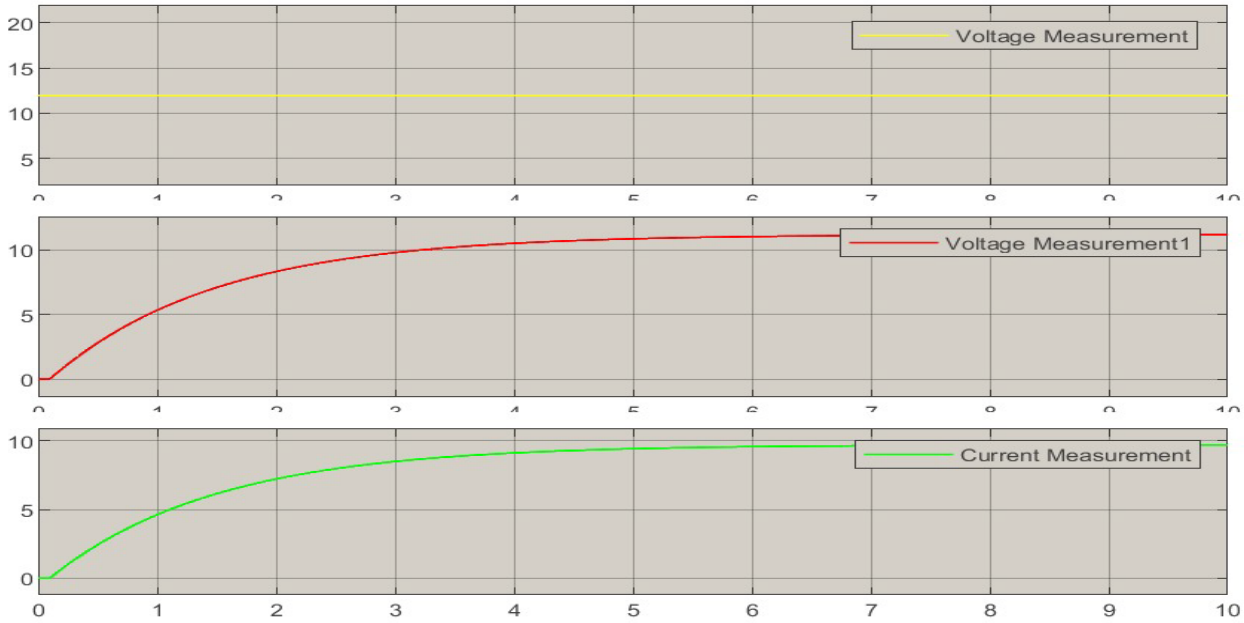


Fig 13: when PID controller not functioning.

We may observe that our system is malfunctioning and not producing the intended results. and we get the desired output of 24V when our PID controller is fine-tuned.

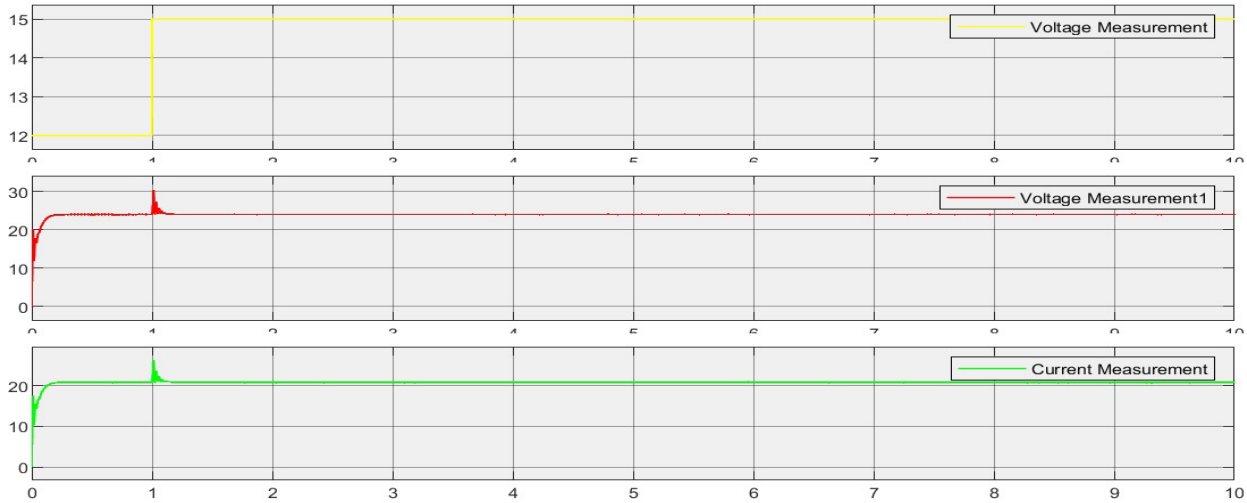


Fig 14: PID Controller functioning

CHAPTER 5

PROCESS OF TUNING OF PID CONTROLLER

To Process of tuning PID controller go to PID controller and Identify new plant and plant identification and change its offset 0.3 and amplitude 0.2. identify the plant and apply it. it will automatically process the model identification. To smooth our tune response, we manipulate the Transient Behavior.

7.1 The tuning procedure displayed below:

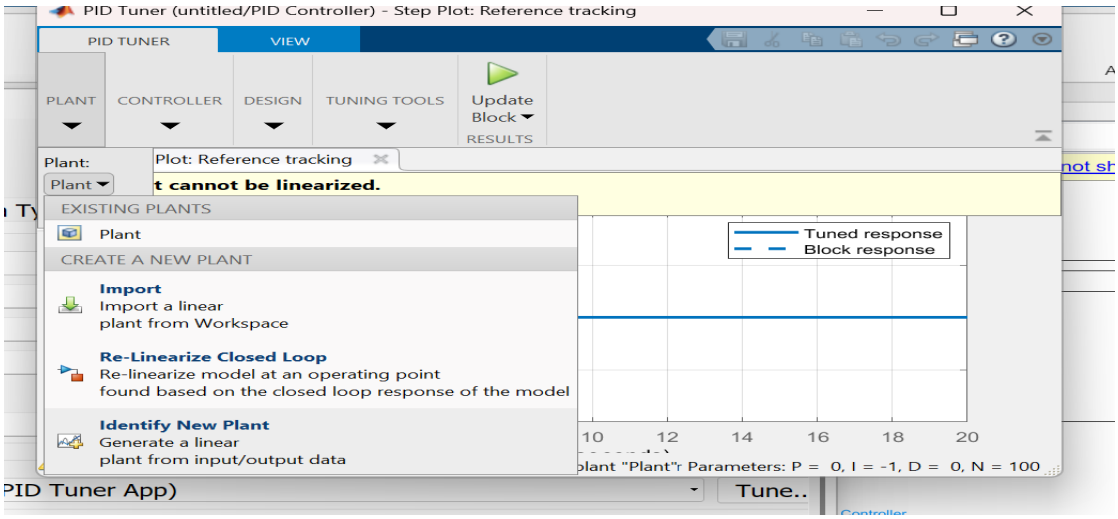


Fig 15: Identify new plant

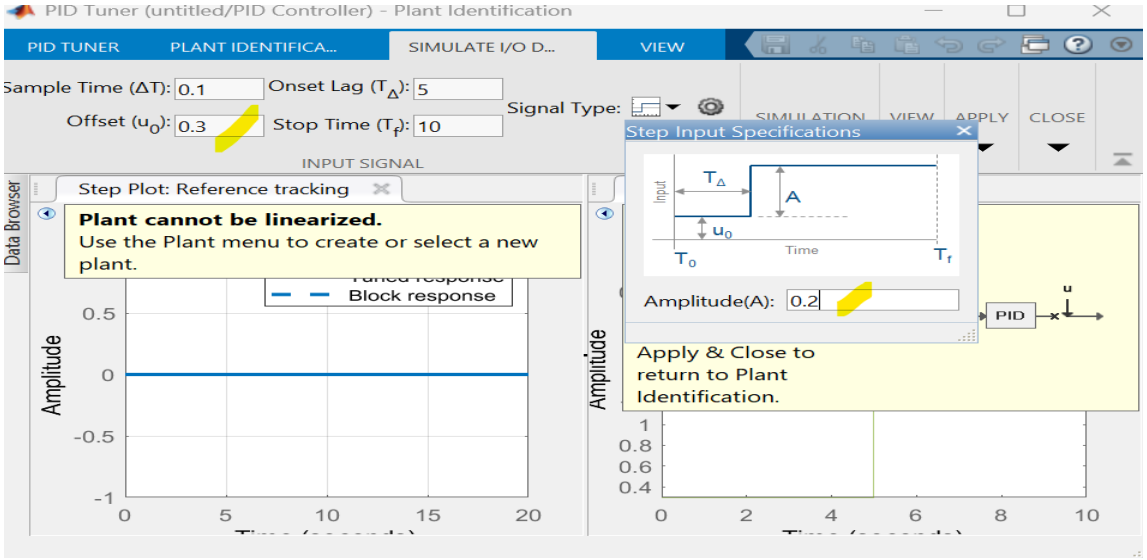


Fig 16: changing offset and amplitude

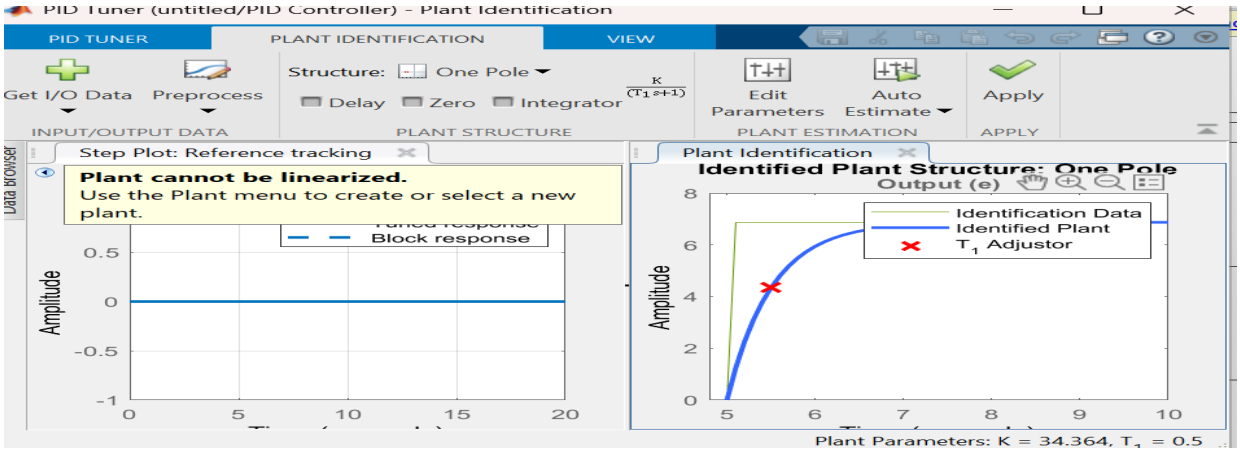


Fig 17: Plant Identification

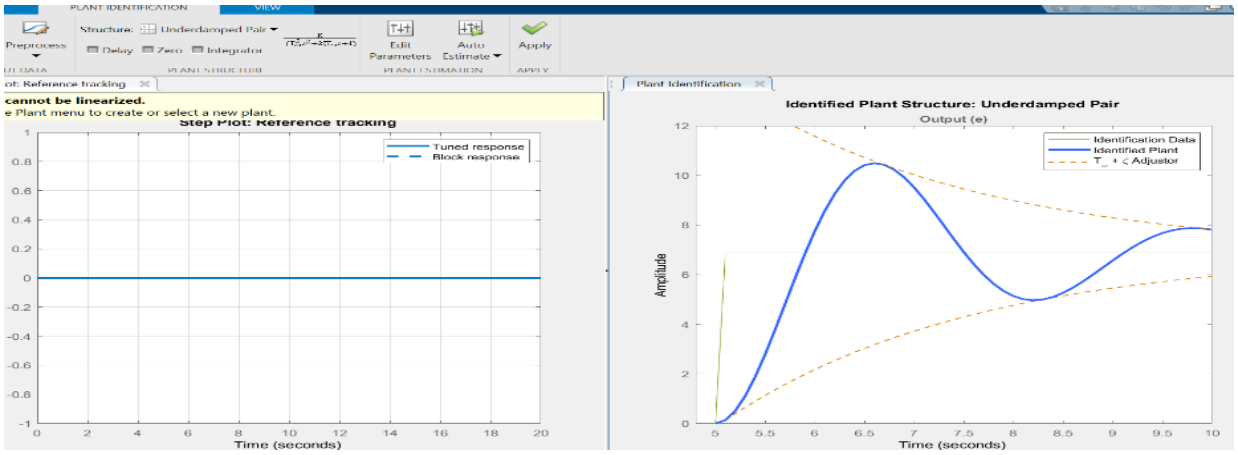


Fig 18: Applying Identification

7.2 Modification of plant and applying it

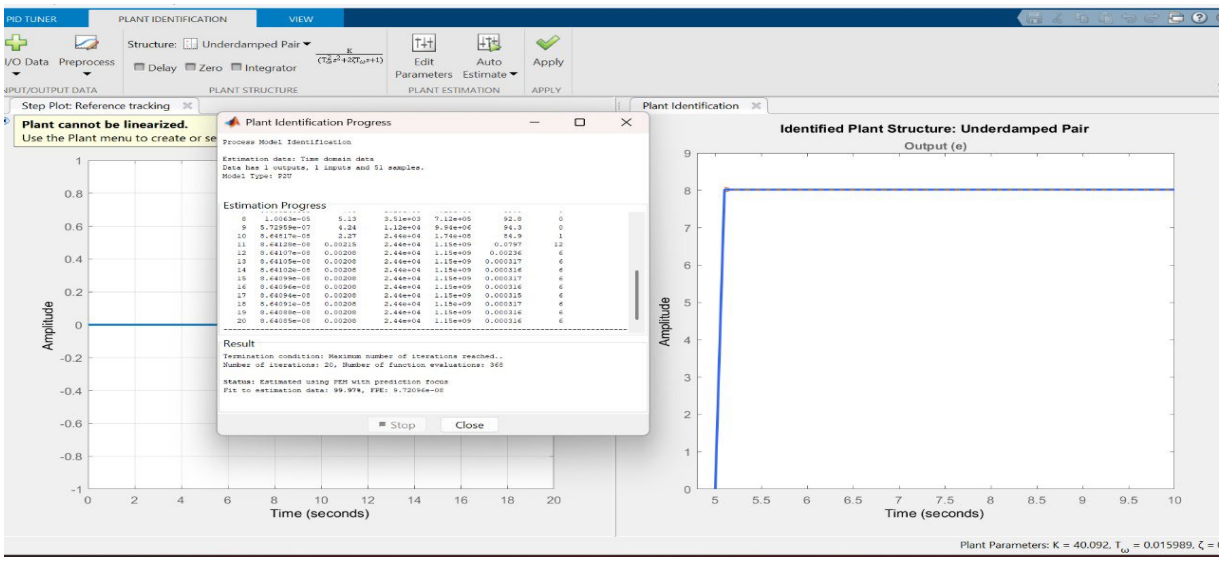


Fig 19: Modification of plant and applying it

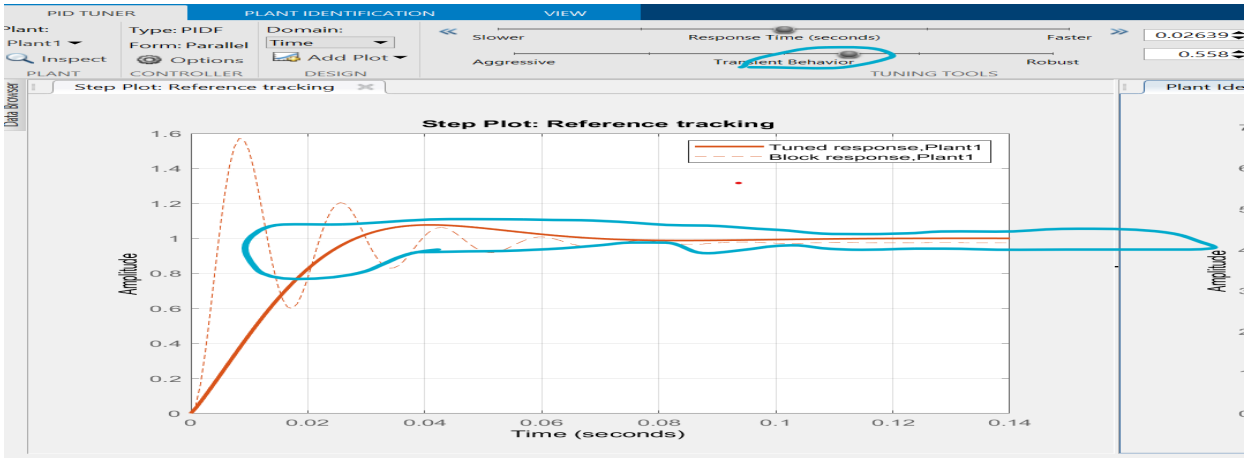


Fig:20

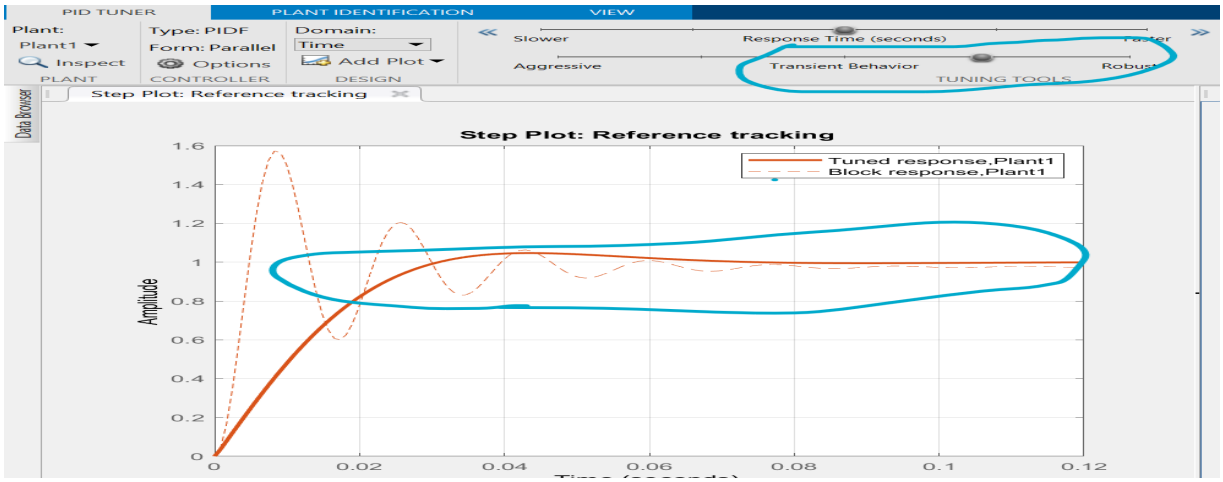


Fig:21

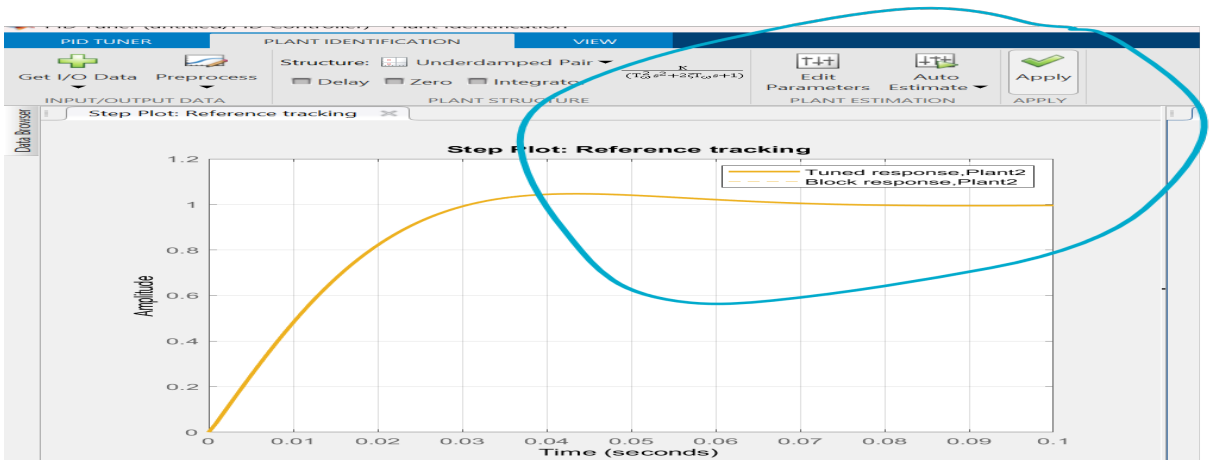


Fig:22

Fig :19,20,21 For smooth tune response modification of transient behavior

CHAPTER 6

RESULT

- **Value of KP,KI,KD :**

Name	**Value**
KP	0.0105468949696717
KI	**0.572583974008234**
KD	**0**

Table 3: Value of KP,KI,KD

- **FINDING TRANSFER FUNCTION FROM MATLAB :**

$$\frac{K}{(T^2\omega^2 + 2\tau_{\omega^2} \quad + 1}$$

CHAPTER 7

CONCLUSION

The integration of PID (Proportional-Integral-Derivative) control in boost converters offers significant advantages over traditional methods, particularly in terms of voltage regulation, overshoot reduction, and overall system performance. Boost converters are widely used in power electronics to step up DC voltage levels, but they often suffer from transient issues and voltage instability, especially under varying load conditions. The PID controller addresses these challenges by dynamically adjusting the duty cycle based on feedback from the output voltage. This results in improved stability, faster response times, and reduced voltage overshoot, ensuring that the output voltage remains consistent regardless of input or load variations.

This work presents a straightforward and practical PID-controlled boost converter design that effectively meets the primary goal of maintaining a stable DC output voltage. The proposed circuit is not only efficient but also simple in construction, requiring no additional complex components. This simplicity contributes to reduced manufacturing costs and compact converter size, making it suitable for various real-world applications where space and cost are critical factors. Furthermore, the design's clarity and ease of implementation make it accessible for both academic research and industrial use. Overall, the PID-controlled approach significantly enhances the performance and reliability of DC-DC boost converters.

CHAPTER 8

FUTURE WORK

While this study successfully demonstrates the performance enhancement of a DC-DC boost converter using a PID controller, several avenues remain open for further exploration and improvement:

- **Hardware Implementation**: The current work is based solely on simulation using MATLAB/Simulink. Future work can include the development of a physical prototype to validate simulation results and examine practical challenges such as component tolerances, switching losses, and thermal effects.
- **Advanced Control Strategies**: Although PID control provides improved performance, advanced control algorithms such as **Fuzzy Logic Control (FLC)**, **Sliding Mode Control (SMC)**, or **Model Predictive Control (MPC)** could be explored for better adaptability, reduced overshoot, and faster settling times in dynamic environments.
- **Digital Controller Integration**: Implementation of the PID controller using digital platforms such as **microcontrollers (e.g., Arduino, STM32)** or **DSPs (Digital Signal Processors)** could be investigated for real-time control, making the system suitable for embedded applications.
- **Renewable Energy Integration**: The boost converter can be applied to renewable sources like **solar PV or wind turbines**, where input voltages are highly variable. Future research can focus on optimizing performance in these scenarios, possibly integrating **MPPT (Maximum Power Point Tracking)** techniques.
- **Multi-Objective Optimization**: PID tuning can be enhanced using metaheuristic algorithms such as **Genetic Algorithms (GA)**, **Particle Swarm Optimization (PSO)**, or **Artificial Neural Networks (ANNs)** for multi-objective optimization including efficiency, response time, and stability.
- **Thermal and Efficiency Analysis**: A deeper analysis of system **efficiency under varying loads and temperatures** could be conducted, including losses in the MOSFET, inductor, and capacitor to optimize component selection and heat management.
- **High Power and Multi-Phase Designs**: Scaling the design for **higher power levels** or developing **interleaved/multi-phase boost converters** for high-current applications could also be considered.

CHAPTER 9

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