PERFORMANCE ENHANCEMENT OF SOLAR ENERGY USING PID CONTROLLER BASED DC-DC BOOST CONVERTER

by

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List of Acronyms

PV	Photo Voltaic
PID	Proportional Integral Derivative
REN	Renewable Energy Systems
GWEC	Global Wind Energy Council
PES	Personal Energy Systems
CES	Community Energy Systems
BFO	Bacterial Foraging Optimization
PSO	Particle Swarm Optimization

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Abstract

Solar systems, as the name implies, combine two or more modes of electricity generation together, usually using renewable technologies such as solar photovoltaic (PV) and wind turbines. Renewable energy based solar power system is becoming the topic of attraction to the power system designers because of its economic feasibility and environmental friendliness. Solar systems provide a high level of energy security through the mix of generation methods, and often will incorporate a storage system (battery, Fuel cell) or small fossil fueled generator to ensure maximum supply reliability and security. The places where there is no supply of electricity from the main grid and the places where there is pretty high load shedding due to irrigation and other reasons are more viable for renewable energy based solar power station. The main purpose of our thesis is to introduce an approach to design a DC-DC boost converter with constant output voltage for grid connected photovoltaic application system. The boost converter is designed to step up a fluctuating solar panel voltage to a higher constant DC voltage. It uses voltage feedback to keep the output voltage constant. To do so, a PID controller is used as the heart of the control system. It tracks and provides pulse-width-modulation signal to control power electronic device in boost converter. The boost converter will be able to direct couple with grid-tied inverter for grid connected photovoltaic system. Simulations were performed to describe the proposed design. Works were carried out with the designed boost converter which has a power rating of 800 W and 200 V output voltage operated in continuous conduction mode at 5 kHz switching frequency.

Chapter 1
Introduction

1.1 Basic Functionalities of Solar Power System

Solar photovoltaic (PV) modules generate electricity from sunlight, which can be fed into the mains electricity supply of a building or sold to the public electricity grid. Reducing the need for fossil fuel generation, the growing grid-connected solar PV sector across the globe is helping create jobs, enabling families and businesses to save money, and cut greenhouse emissions.

Most grid-connected PV systems are installed on the roof or walls of a building. This does not take up land that could be used for other purposes like agriculture. Ideally the PV faces towards the equator but the exact direction is not critical. However, it is important to make sure that there is minimal shading of the PV. If the PV electricity production exceeds building demand then the excess can be exported to the grid, and vice versa.

Where space and sun are available, large stand-alone PV arrays can be built and connected to the public grid. In 2016, several solar farms in excess of 500 MWp were in operation around the world, with many more planned.

Until recently, grid-connected systems have not usually included batteries for storage, because the mains grid can accept or provide power as needed. However, if rechargeable batteries are included, a grid-connected PV system can be used as a standalone ac supply in the event of a power cut, to allow essential loads to keep working.

By reducing the need for fossil-fuel generation, grid-connected PV cuts greenhouse gas emissions (and other air pollution), because no emissions are produced during PV operation.

In the past there has been concern about the greenhouse gases emitted ('embodied') in the manufacture of PV systems, particularly in the production of ultra-pure semiconductors. With current production techniques, these embodied greenhouse gases are saved within 0.7 to 2 years of use of grid-connected operation, depending on the amount of sunlight.

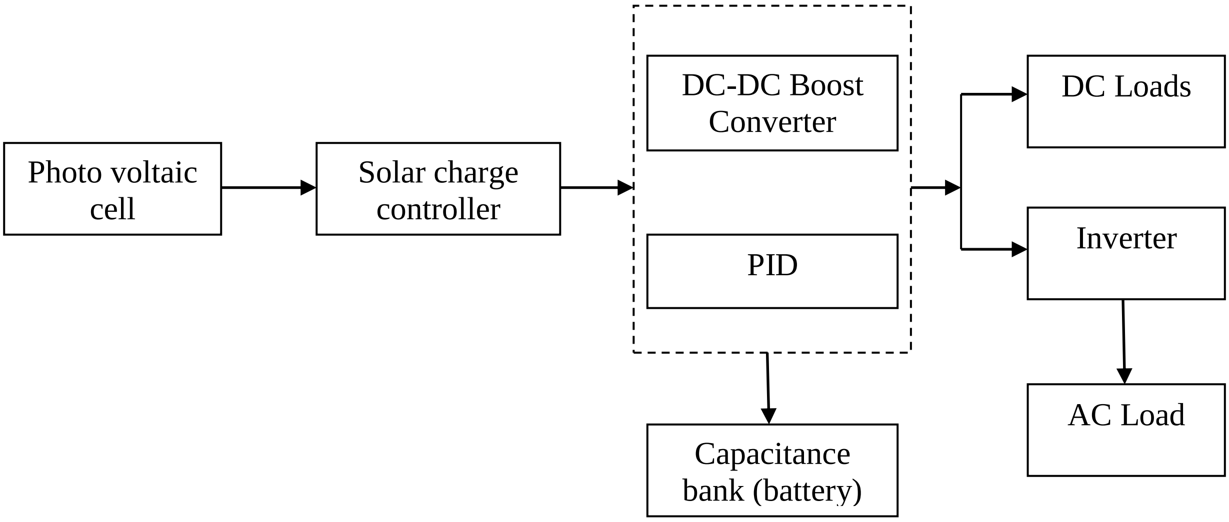


Fig.1. Block diagram of the proposed system

1.2 Aspects of Solar Power System

There are several aspects of renewable energy based power system.

1.2.1 Economic

As a solar power system requires many components, its installation cost is pretty high. Cost of these components sum up to the total cost. But once installed, power can be generated at a much lower cost as most of the components do not require operating cost.

1.2.2 Environmental

Power generation in conventional method has noticeable impact on environment. This is because carbon dioxide and other emissions spread in the environment resulting pollution. But in renewable energy based solar power generation system, there is less emission, reduced carbon dioxide and as such ignorable environmental pollution occurs.

1.3 Background

The booming market for renewable energy generation, especially solar power, can only help reduce our reliance on fossil fuels, and cut global CO_2 emissions. However, connecting the output of thousands of discrete solar systems to the grid entails overcoming a number of technical challenges. Not least is the fact that most renewable energy-generation sources, such as sun and wind, are intermittent.

Issues such as grid stability and resiliency, energy storage, and buffers to cover peak demand, are being addressed with technologies such as smart inverters, micro inverters, and DC optimizers. Smoothing out voltage fluctuations while ensuring the energy from inverters can be directed to where it is in demand requires increasingly sophisticated circuitry.

Utility companies and grid operators have become increasingly concerned about managing what can potentially be wildly fluctuating levels of energy produced by the huge (and still growing) number of grid-connected solar systems, whether they are rooftop systems or utility-scale solar farms. Intermittent production due to cloud cover or temporary faults has the potential to destabilize the grid. In addition, grid operators are struggling to plan ahead due to lack of accurate data on production from these systems as well as on true energy consumption.

1.4 Why renewable energy based power system

There are inadequate sources of primary energy but renewable energy is sustainable and so will never run out. Less maintenance is required in electricity generation than traditional one and so it is economically beneficial. Failure in increasing electricity generation is proportional to the demand and tremendous fiscal pressure exists due to rental Power. There is high pollutant emission during electricity generation from natural gas, oil and coal whereas renewable energy causes minimum impact on environment as it produces very negligible amount of carbon dioxide and other chemical pollutants.

1.5 Motivation

The total amount of solar energy that hits Earth in just two hours is more than enough to meet current global energy consumption for an entire year. Just imagine if we could use all of these available energy sources and that is why we decided to take on the challenge and the fact that PID control algorithm is a robust and simple algorithm that has sufficient flexibility to yield high accuracy and better performance than many other control systems and thus it serves our purpose of acquiring an accurate constant voltage output.

1.6 Thesis Layout

In chapter 1, the basic functionalities of Solar power system and its background are discussed. Two aspects of solar power system- economic and environmental are highlighted.

In chapter 2, overview of DC-DC boost converter is incorporated. In this chapter, details on fossil fuels and renewable resources are highlighted. Different types of data and data generation method are written.

Chapter 3 overview of PID controller is described.

In chapter 4, simulation procedure and the terms of HOMER, the software used are detailed.

Chapter 5 contains the simulation results along with schematic designs and graphical representation of our system.

In chapter 6, procedure of the entire research work is summarized along with simulation results and outcomes.

Chapter 2

Overview of DC-DC Boost Converter

2.1 Introduction

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 get discharged through the load. Hence a higher voltage at the output is obtained than the given input voltage.

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.

In a dc-dc converter application, it is desired to obtain a constant output voltage V_o(t) =V_o, in spite of disturbances in V_i(t) and i_{load}(t), and in spite of variations in the converter circuit element values. The sources of these disturbances and variations are many, the input voltage of an off-line power supply may typically contain periodic variations at the second harmonic of the ac power system frequency (100Hz or 120Hz), produced by a rectifier circuit. The magnitude of V_t(t) may also vary when neighboring power system loads are switched on or off. The load current i_{load}(t) may contain variations of significant amplitude, and a typical power supply specification is that the output voltage must remain within a specification range when the load current takes a step change form

Direct current (DC-to-DC) converters are circuits which convert sources of direct current (DC) from one voltage level to another by changing the duty cycle of the main switches in the circuits. Since DC–DC converters are nonlinear systems, they represent a big challenge for control design. Since classical control methods are designed at one nominal operating point, they are not able to respond satisfactorily to operating point variations and load disturbance. They often fail to perform satisfactorily under large parameter or load variations.

The boost type DC-DC converters are used in applications where the required output voltage needed to be higher than the source voltage. The control of this type DC-DC converters are more difficult than the buck type where the output voltage is smaller than the source voltage. The difficulties in the control of boost converters are due to the non-minimum phase structure since, the control input appears both in voltage and current equations, from the control point of view the control of boost type converters are more difficult than buck type.

Different control algorithms are applied to regulate the DC-DC converters for achieving a robust output voltage. As DC-DC converters are nonlinear and time variant systems. The

application of linear control techniques to control these converters is not suitable. In order to design a linear control system using classical linear control techniques, the small signal model is derived by linearization around a precise operating point from the state space average model. The controllers based on these techniques are simple to implement however, it is difficult to account the variation of systems parameters, because of the dependence of small signal model parameters on the converter operating point. Variations of system parameters and large signal transient such as those produced in the startup or against changes in the load, cannot be dealt with these techniques. A multi-loop control technique, such as current mode control, has greatly improved the dynamic behavior, but the control design remains difficult especially for higher order converter topologies.
Controller design for any system needs knowledge about system behavior. This involves a mathematical relation between inputs to the system, state variables, and output called modeling of the system. This study aims at development of the models for buck boost and chuck converters and studying its open loop response, so these models can be directly used in case of close loop system. Then PID controller is used to form closed loop converter. The State variable approach is a power technique for analysis of switching converters. The state model of a system consists of the state equation and output equation.

2.2 Modeling Construction

The steps to obtain a state space modeling and simulation of Model Construction of DC-DC Switching power electronic converters are

1) Determine the state variables in the power converter e.g. inductor current and capacitor voltage.
2) Determine the modes of operation governing the states of the power semiconductors (Switch ON & OFF states)
3) Assume the main operating modes of the converter (continuous or discontinuous conduction)
4) Apply Kirchhoff's laws and combine together to form state-space model
5) Implement the derived equations with "SIMULINK" blocks (open loop system simulation is then possible to check the obtained model).
6) Design a proper controller or compensator to overcome the deviation of the circuit operation from the desired nominal behavior.

2.3 Mechanism of a DC-DC Boost Converter

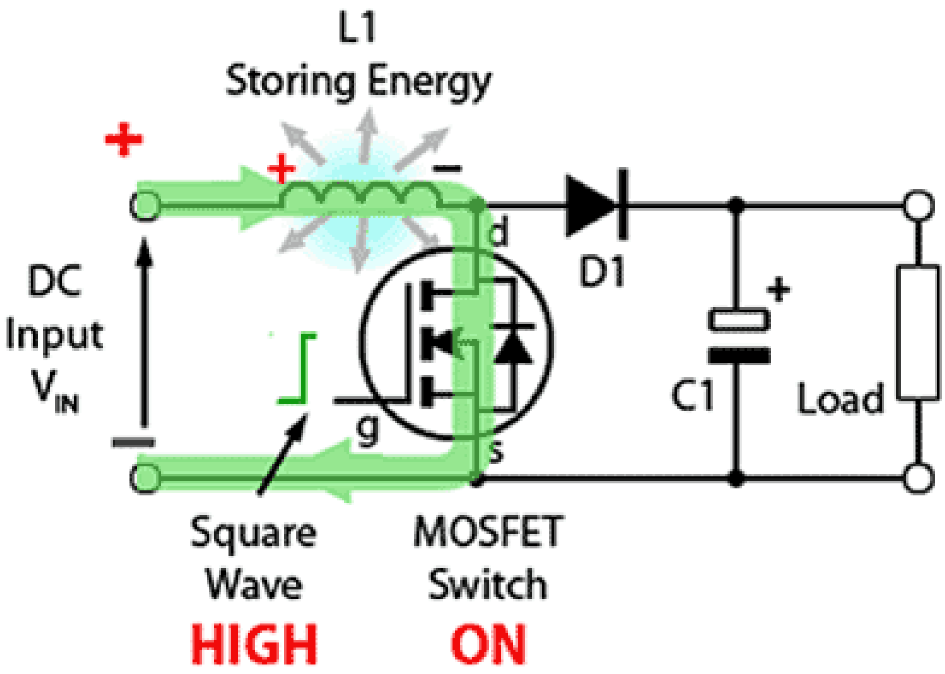


Fig.2. Initial high period square wave applied to the MOSFET gate

Fig 2 illustrates the circuit action during the initial high period of the high frequency square wave applied to the MOSFET gate at start up. During this time MOSFET conducts, placing a short circuit from the right-hand side of L1 to the negative input supply terminal. Therefore, a current flow between the positive and negative supply terminals through L1, which stores energy in its magnetic Field. There is virtually no current flowing in the remainder of the circuit as the combination of D1, C1 and the load represent much higher impedance than the path directly through the heavily conducting MOSFET.

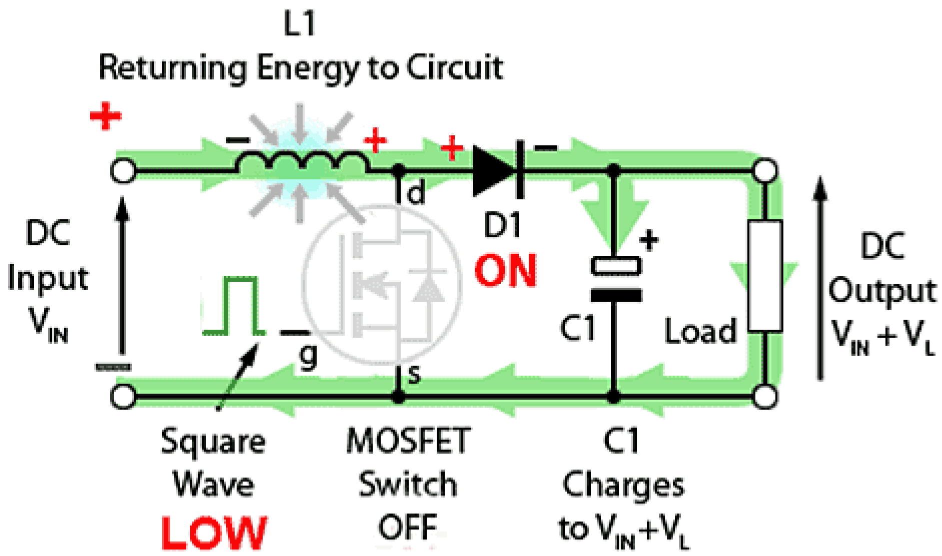


Fig.3. Current path with MOSFET off

Fig.3 shows the current path during the low period of the switching square wave cycle. As the MOSFET is rapidly turned off the sudden drop in current causes L1 to produce a back e.m.f in the opposite polarity to the voltage across L1 during the on period, to keep current flowing. This results in two voltages, the supply voltage V_{IN} and the back e.m.f. (V_L) across L1 in series with each other. This higher voltage (V_{IN} +V_L), now that there is no current path through the MOSFET, forward biases D1. The resulting current through D1 charges up C1 to V_{IN} +V_L minus the small forward voltage drop across D1, and also supplies the load.

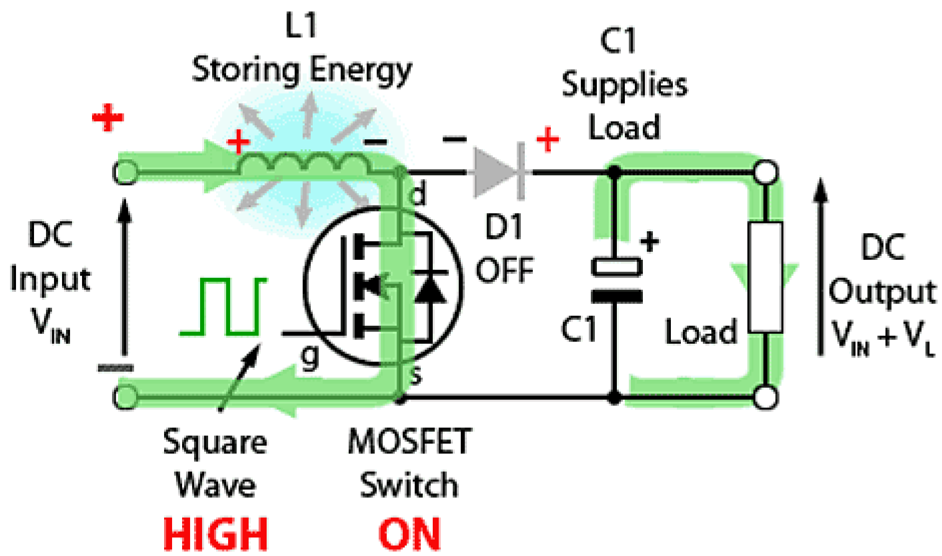


Fig.4. Current path with MOSFET on

Fig.4 shows the circuit action during MOSFET on periods after the initial startup. Each time the MOSFET conducts, the cathode of D1 is more positive than its anode, due to the charge on C1. D1 is therefore turned off so the output of the circuit is isolated from the input, however the load continues to be supplied with V_{IN} +V_L from the charge on C1. Although the charge C1 drains away through the load during this period, C1 is recharged each time the MOSFET switches off, so maintaining an almost steady output voltage across the load.

2.4 Advantages

- Output voltage higher than input voltage can be obtained.
- Switch can be easily driven with respect to ground as compared to high side or isolated drive required for buck or buck-boost converter.
- The input current is continuous which means it is easy to filter and meet electromagnetic interference (EMI) requirements.

2.5 Disadvantages

- High Overshoot and Settling time
- Large output capacitor is required to reduce ripple voltage as output current is pulsating.
- Slower transient response and difficult feedback loop compensation due to presence of right half zero in continuous conduction mode (CCM) boost converter.

Chapter 3
Overview of PID Controller

3.1 Introduction

The PID controller is the most common form of feedback. It was an essential element of early governors and it became the standard tool when process control emerged in the 1940s. In process control today, more than 95% of the control loops are of PID type, most loops are actually PI control. PID controllers are today found in all areas where control is used. The controllers come in many different forms. There are stand-alone systems in boxes for one or a few loops, which are manufactured by the hundred thousand yearly. PID control is an important ingredient of a distributed control system. The controllers are also embedded in many special-purpose control systems. PID control is often combined with logic, sequential functions, selectors, and simple function blocks to build the complicated automation systems used for energy production, transportation, and manufacturing. Many sophisticated control strategies, such as model predictive control, are also organized hierarchically. PID control is used at the lowest level; the multivariable controller gives the set point to the controllers at the lower level. The PID controller can thus be said to be the "bread and butter' of control engineering. It is an important component in every control engineer's tool box. PID controllers have survived many changes in technology, from mechanics and pneumatics to microprocessors via electronic tubes, transistors, integrated circuits. The microprocessor has had a dramatic influence on the PID controller. Practically all PID controllers made today are based on microprocessors. This has given opportunities to provide additional features like automatic tuning, gain scheduling, and continuous adaptation.

3.2 The Algorithm

We will start by summarizing the key features of the PID controller. The "textbook" version of the PID algorithm is described by:

$$u(t) = K\left(e(t) + \frac{1}{T_i}\int e(\tau)d\tau + T_d\frac{de(t)}{dt}\right)$$

Where y is the measured process variable, r the reference variable, u is the control signal and e is the control error (e = ysp − y). The reference variable is often called the set point. The control signal is thus a sum of three terms: The P-term (which is proportional to the

error), the I-term (which is proportional to the integral of the error), and the D-term (which is proportional to the derivative of the error). The controller parameters are proportional gain K, integral time Ti, and derivative time Td. The integral, proportional and derivative part can be interpreted as control actions based on the past, the present and the future as is illustrated in Figure 2.2. The derivative part can also be interpreted as prediction by linear extrapolation as is illustrated in Figure 2.2. The action of the different terms can be illustrated by the following figures which show the response to step changes in the reference value in a typical case.
Rise Time: Rise time is the amount of time the system takes to go from 10% to 90% of the steady-state, or final, value.
Percent Overshoot: Percent overshoot is the amount that the process variable overshoots the final value, expressed as a percentage of the final value.
Settling time: Settling time is the time required for the process variable to settle to within a certain percentage (commonly 5%) of the final value.
Steady-State Error: Steady state error is the final difference between the process variable and set point

3.3 Internal Operation of PID controller

Proportional Response:
The proportional component depends only on the difference between the set point and the process variable. This difference is referred to as the Error term. The proportional gain (Kc) determines the ratio of output response to the error signal. For instance, if the error term has a magnitude of 10, a proportional gain of 5 would produce a proportional response of 50. In general, increasing the proportional gain will increase the speed of the control system response. However, if the proportional gain is too large, the process variable will begin to oscillate. If Kc is increased further, the oscillations will become larger and the system will become unstable and may even oscillate out of control.

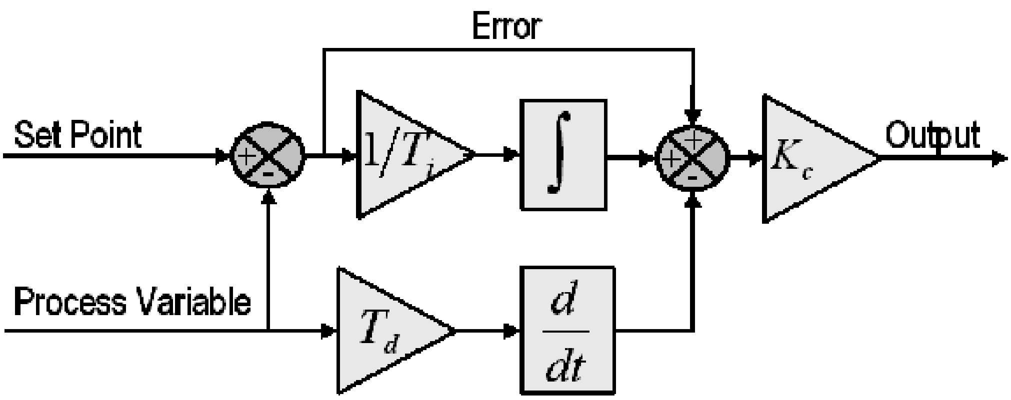


Fig.5. Block diagram of a basic PID control algorithm

Integral Response:

The integral component sums the error term over time. The result is that even a small error term will cause the integral component to increase slowly. The integral response will continually increase over time unless the error is zero, so the effect is to drive the Steady-State error to zero. Steady-State error is the final difference between the process variable and set point. A phenomenon called integral windup results when integral action saturates a controller without the controller driving error signal to zero.

Derivative Response:

The derivative component causes the output to decrease if the process variable is increasing rapidly. The derivative response is proportional to the rate of change of the process variable. Increasing the derivative time (Td) parameter will cause the control system to react more strongly to changes in the error term and will increase the speed of the overall control system response. Most practical control systems use very small derivative time (Td), because the Derivative Response is highly sensitive to noise in the process variable signal. If the sensor feedback signal is noisy or if the control loop rate is too slow, the derivative response can make the control system unstable.

TABLE.1. Effects of increasing a parameter independently

Parameter	Rise time	Overshoot	Settling time	Steady-state error	Stability
$\boldsymbol{K_p}$	Decrease	Increase	Small change	Decrease	Degrade
$\boldsymbol{K_i}$	Decrease	Increase	Increase	Eliminate	Degrade
$\boldsymbol{K_d}$	Minor change	Decrease	Decrease	No effect in theory	Improve if K_d small

3.4 Tuning

The process of setting the optimal gains for P, I and D to get an ideal response from a control system is called tuning. There are different methods of tuning of which the "guess and check" method and the Ziegler Nichols method will be discussed.

The gains of a PID controller can be obtained by trial and error method. Once an engineer understands the significance of each gain parameter, this method becomes relatively easy. In this method, I and D terms are set to zero first and the proportional gain is increased until the output of the loop oscillates. As one increases the proportional gain, the system becomes faster, but care must be taken not make the system unstable. Once P has been set to obtain a desired fast response, the integral term is increased to stop the oscillations. The integral term reduces the steady state error, but increases overshoot. Some amount of overshoot is always necessary for a fast system so that it could respond to changes immediately. The integral term is tweaked to achieve a minimal steady state error. Once the P and I have been set to get the desired fast control system with minimal steady state error, the derivative term is increased until the loop is acceptably quick to its set point. Increasing derivative term decreases overshoot and yields higher gain with stability but would cause the system to be highly sensitive to noise. Often times, engineers need to tradeoff one characteristic of a control system for another to better meet their requirements.

Different methods of tuning:

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:

Where,
K_p = Proportional Gain
K_i = Integral Gain
T_i = Reset Time =$\frac{K_p}{K_i}$
K_d= Derivative gain
T_d = Rate time or derivative time

John G. Ziegler and Nathaniel B. Nichols introduced Ziegler-Nichols method. In this method, I and D gains are first set to zero. The "P" gain is increased until it reaches the "critical gain (K_c)" at which the output of the loop starts to oscillate. K_c & P_c (oscillation period) are used to set the gains as shown:

Table.2. Ziegler-Nichols method

Control type	K_p	K_i	K_d
P	0.5 k_c	-	-
PI	0.45 k_c	1.2kp/pc	-
PID	0.6 k_c	2kp/pc	Kp.pc/8

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.

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 Chemo taxis, Swarming, Reproduction, and Elimination and Dispersal.

3.5 Limitations of PID controller

While PID controllers are applicable to many control problems, and often perform satisfactorily without any improvements or only coarse tuning, they can perform poorly in some applications, and do not in general provide optimal control. The fundamental difficulty with PID control is that it is a feedback control system, with constant parameters, and no direct knowledge of the process, and thus overall performance is reactive and a compromise. While PID control is the best controller in an observer without a model of the process, better performance can be obtained by overtly modeling the actor of the process without resorting to an observer.

PID controllers, when used alone, can give poor performance when the PID loop gains must be reduced so that the control system does not overshoot, oscillate about the control set point value. They also have difficulties in the presence of nonlinearities, may trade-off regulation versus response time, do not react to changing process behavior (say, the process changes after it has warmed up), and have lag in responding to large disturbances.

The most significant improvement is to incorporate feed-forward control with knowledge about the system, and using the PID only to control error. Alternatively, PIDs can be modified in more minor ways, such as by changing the parameters, improving measurement (higher sampling rate, precision, and accuracy, and low-pass filtering if necessary), or cascading multiple PID controllers.

CHAPTER 4

Proposed System

4.1 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.6.

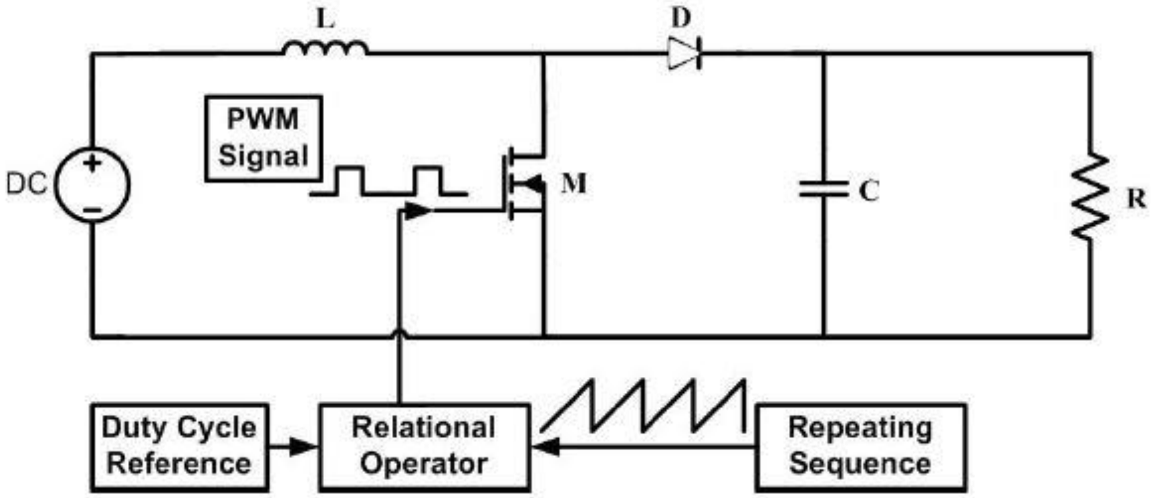


Fig.6. Conventional boost converter

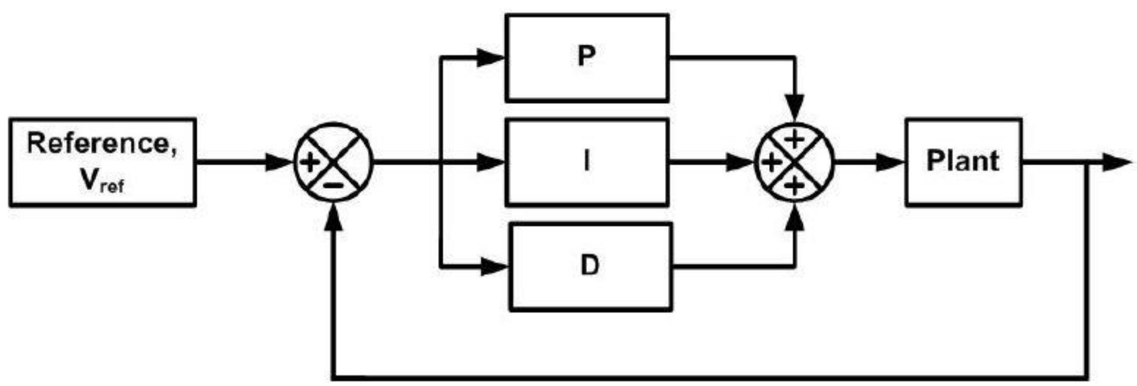
4.2 Block Reduction Diagram

Most physical system can be represented by block diagram-a group of properly interconnected blocks, with each interconnected block representing and describing a portion of the system. In control engineering, the block diagram is a primary tool that together with transfer functions can be used to describe cause and effect relationships throughout a dynamic system. In general, the interrelationship of cause and effect of a system are not straightforward and the simplification of block diagrams is required.

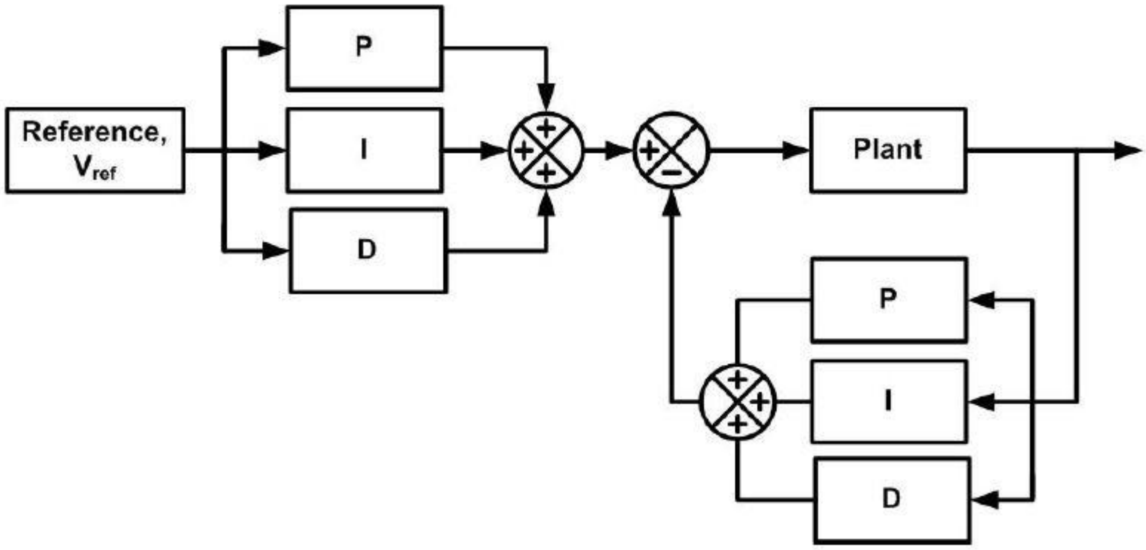
In general, the block diagram of a linear time invariant system consists of four components, namely signal, block (with transfer function), summing point and pickoff. The basic block diagram algebra involves algebra with regard to series/cascaded blocks, parallel blocks and a general feedback loop. Series blocks combine with each other by multiplication and parallel blocks combine with each other by algebraic addition. The combined block is interchangeable in sequence in both cases. The simplification of the general feedback loop can be obtained by performing simple algebraic operation around the loop. The understanding of the properties of summing junction in series is crucial in the simplification of some block diagrams: summing points in series can be interchanged, combined and separated algebraically. The equivalency of summing junction in series to mathematical summer is self-explanatory. The block diagram is in general complicated by the existence of the summing/pickoff point(s) within a loop. However, the simplification of the block diagram can always be achieved through the relocation of such summing/pickoff point(s) appropriately. In the current practice of simplifying block diagrams using block diagram algebra, in addition to the three basic rules described, various numbers of other rules are introduced with regard to the relocation of the summing/pickoff point(s). Each rule involves a pair of equivalent block diagram. The equivalency is not hard to verify by tracing the signals at the input through to the output and recognizing the output signal is identical in the corresponding cases. The main/branch stream is defined as following: At a summing point or pickoff point, there are signals flowing in and out. The signal flow that goes in the unique direction, either into or out of the summing/ pickoff point, is defined as the mainstream and the rest of the signal flows are defined as branch streams. With the introduction of the main/branch stream concepts, summing/pickoff point(s) can be easily relocated for the purpose of simplification by simply following the shifting rule described below: To remove a block G away from a main stream, a block G is to be added to each branch stream; to remove a block G away from a branch stream, a block G is to be added to the main stream and a block 1/G to be added to each of the rest branch streams. It is not hard to see that the new main/branch stream concepts and the corresponding shifting rule eliminate the necessity of the introduction of dozens of block diagram algebra related rules in the simplification of block diagrams. As a result, it greatly simplifies the complexity of the rules of the block diagram algebra and makes the simplification of block diagrams a much easier task.

4.3 Modified Diagram

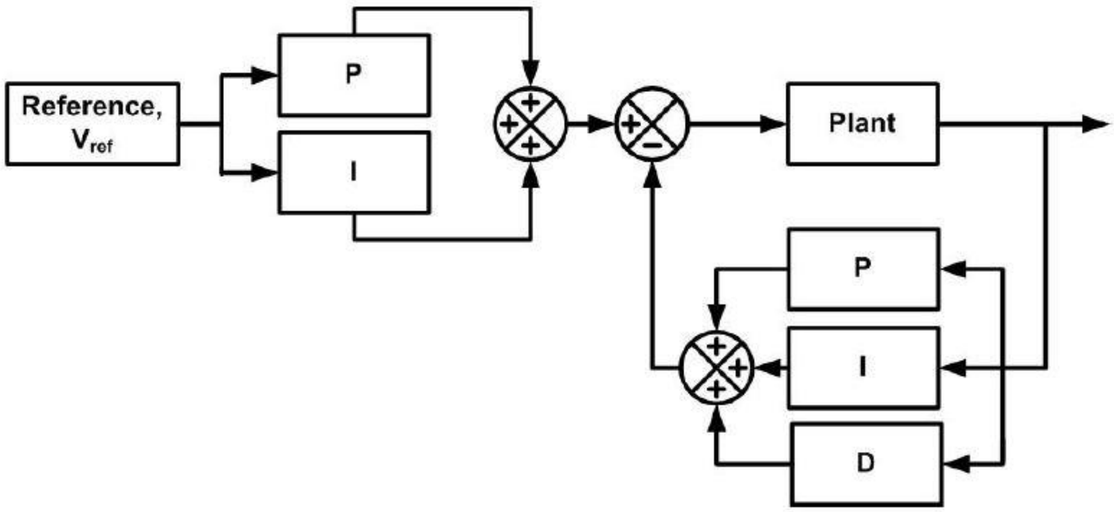
The proposed converter is similar to the conventional Boost converter as shown in Fig.6 but differs only in the incorporation of a PID controller which is extensively used in many practical applications for better performance. The proposed PID controller has been obtained by block diagram reduction method in four stages as shown in Fig.7.



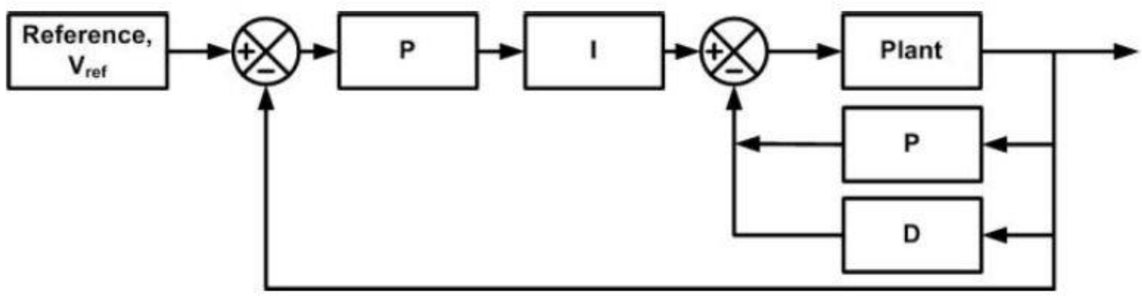
(a)



(b)



(c)



(d)

Fig.7. Block diagram reduction of proposed PID controller

The first figure Fig. (a) depicts a conventional PID controller block diagram when in successive stages as shown in Fig. (b), Fig. (c) and Fig. (d), by block diagram reduction technique the proposed control scheme for the Boost converter was obtained as shown in Fig. (d) which is feasible for proposed converter. Initial overshoot is a prime concern for operating machines in industries and researchers aim for designing a converter with good voltage regulation and overshoot reduction.

4.4 Proposed Converter

Incorporating a PID controller with the converter improves the dynamic response and reduces the steady-state error. The derivative controller (KD) ameliorates the transient response and the integral controller (KI) will reduce the steady state error of the system. Our proposed system maintains an output of 200V when the input is in the range of 90V-110V which makes it quite feasible to apply in different industrial purposes.

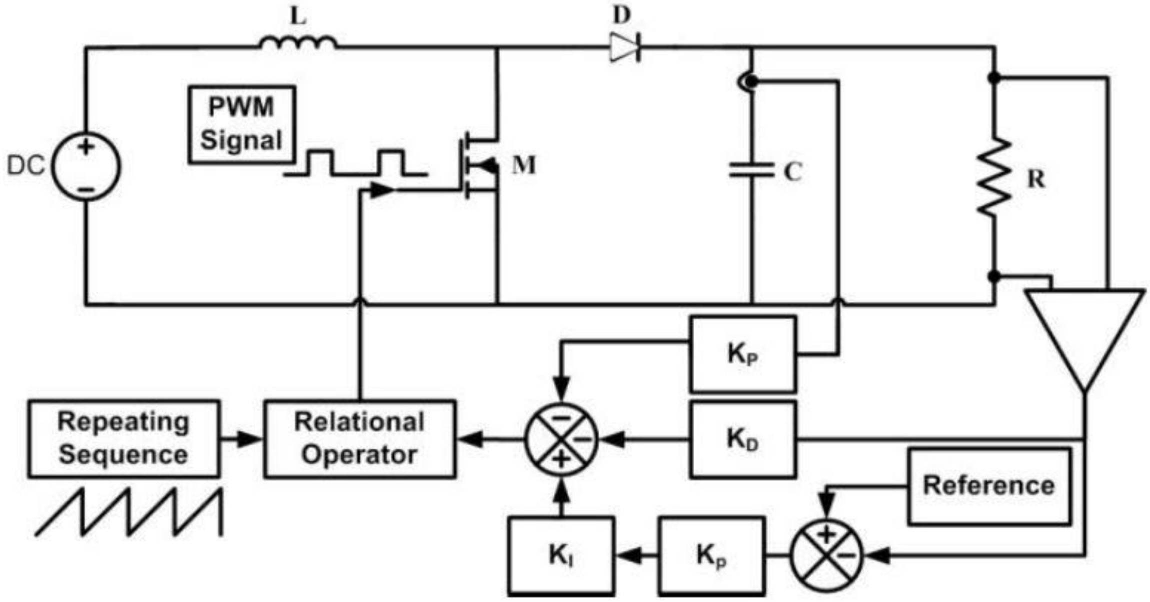


Fig.8. Proposed Boost converter with PID controller

Chapter 5
Simulation Results

5.1 Result Basis

Simulation was done in MATLAB-Simulink environment. Which is developed by The MathWorks, is a commercial tool for modeling, simulating and analyzing dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries.

5.2 Conventional Boost Converter

Conventional boost converter as shown in Fig.9, was simulated at 50% duty cycle and the output wave shapes observed for variations of input voltage of 90V. 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. 10.

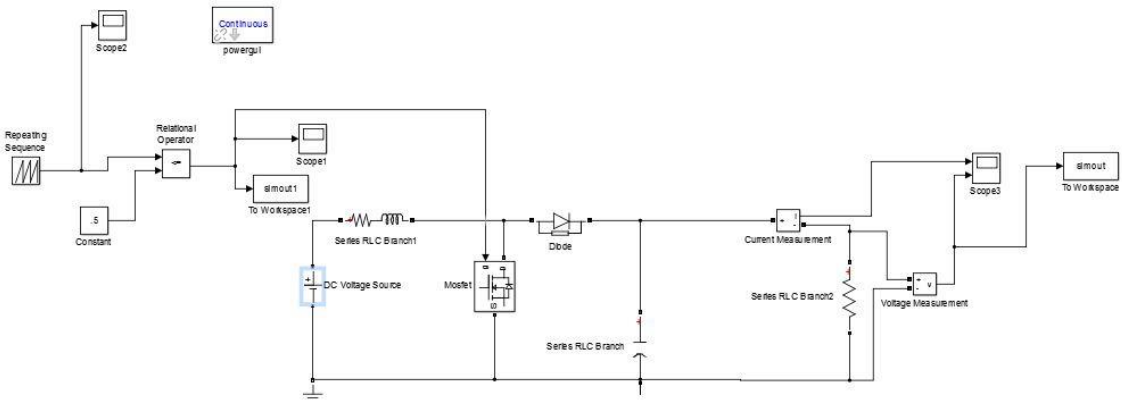
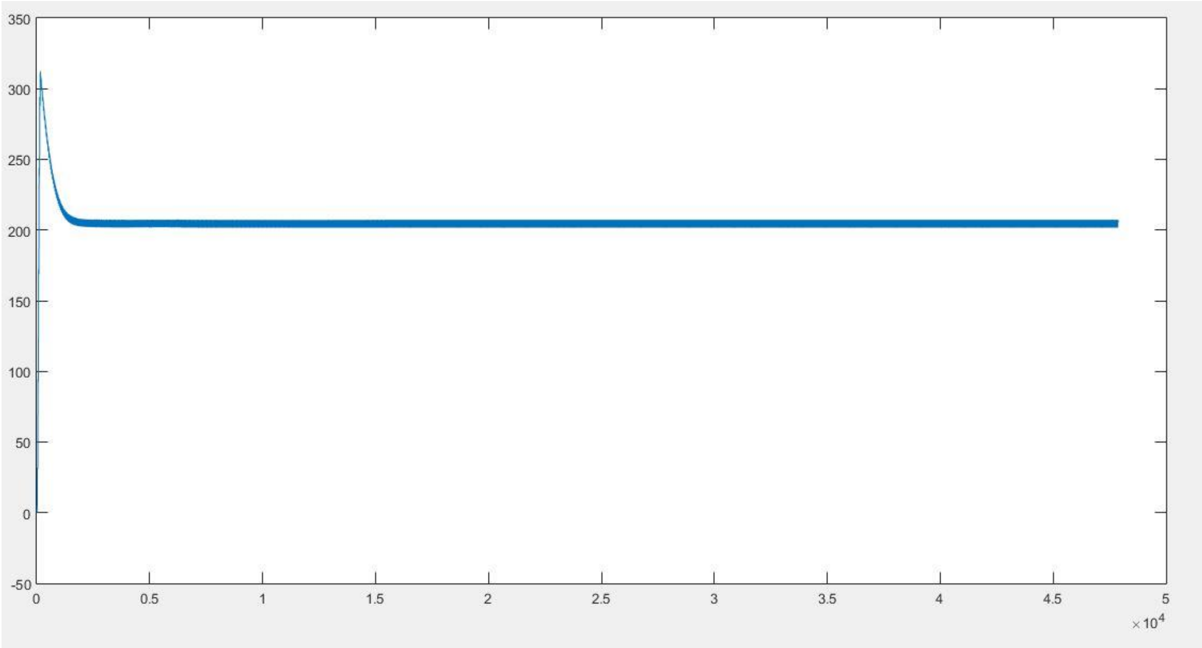


Fig.9. MATLAB-Simulink model of conventional Boost converter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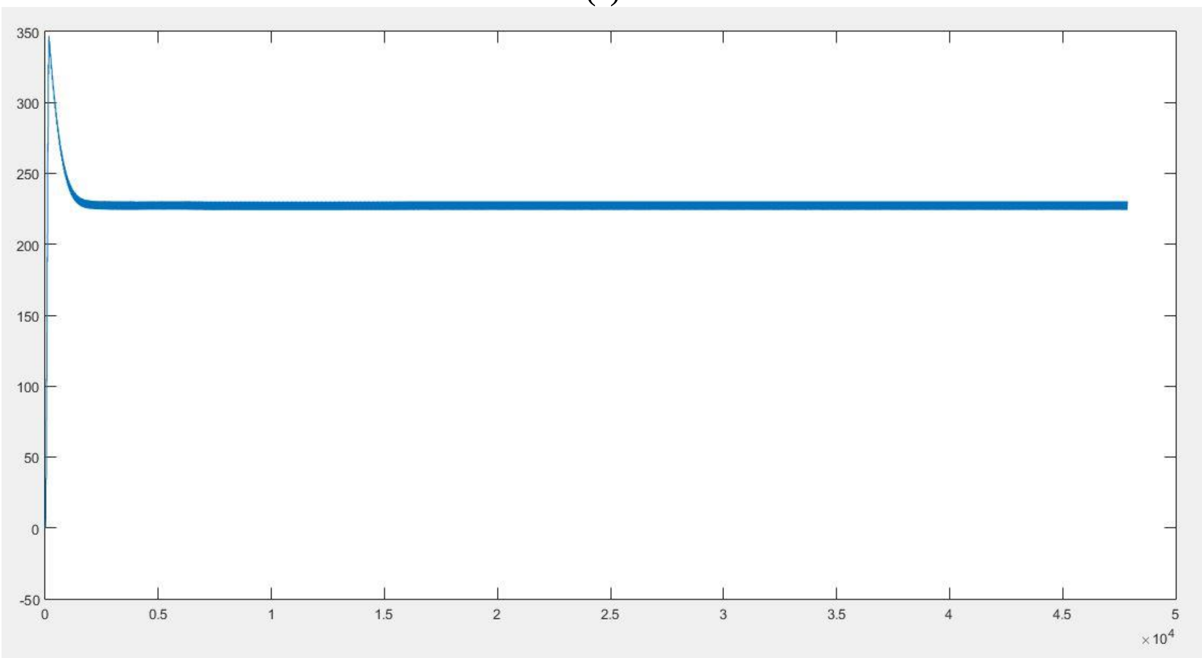
5
×10^4

(a)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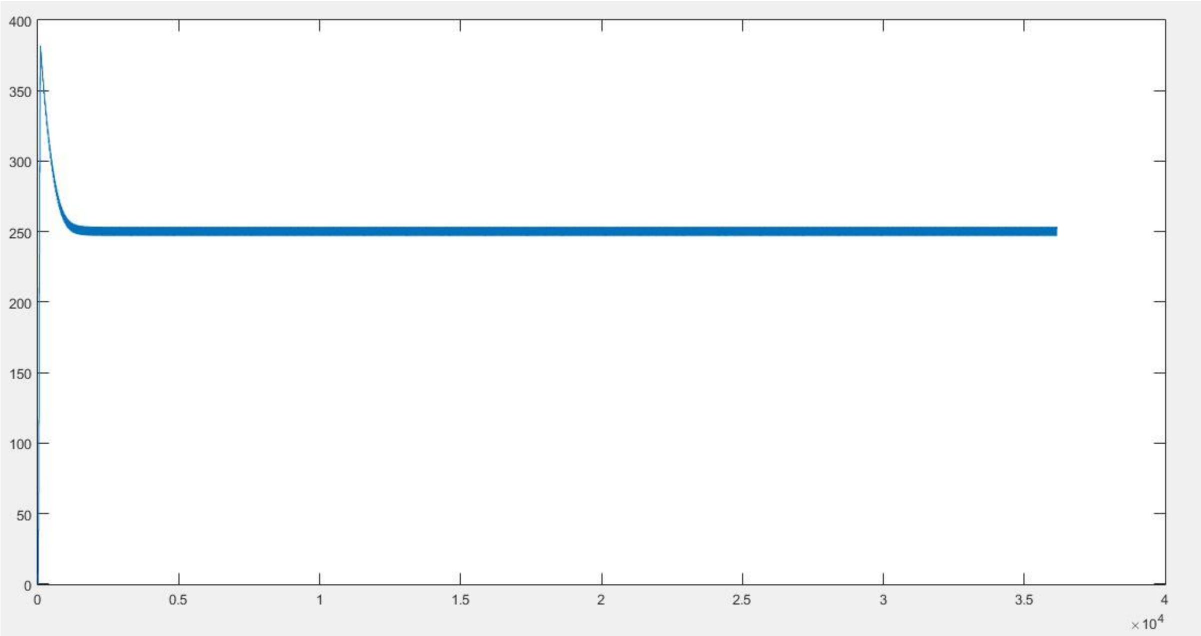
×10^4

(b)



(c)

Fig.10. Output voltage plot of conventional Boost converter operating at 50% duty cycle for input voltages (a) 90V, (b) 100V and (c) 110V

5.3 Proposed Boost Converter

For proper voltage regulation and overshoot reduction the proposed Boost converter as shown in Fig.11, was simulated for input voltage 90V – 110 V with increments of 10V and output wave shapes observed as shown in Fig.12. It can be observed that the output voltage remains constant at the desired voltage of 200V and does not vary with variation of input voltage. Moreover, a significant reduction is overshoot has also been observed.

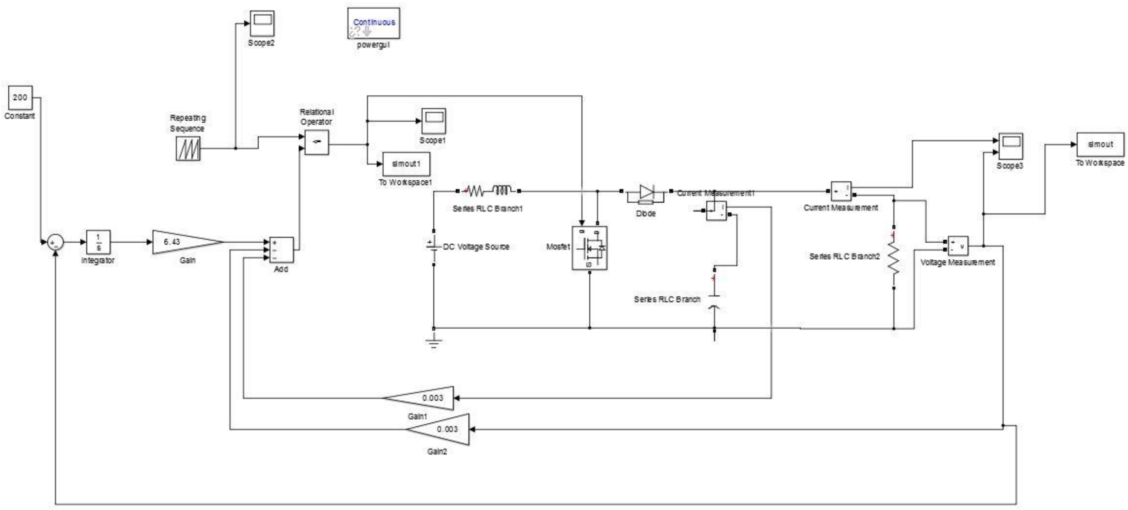
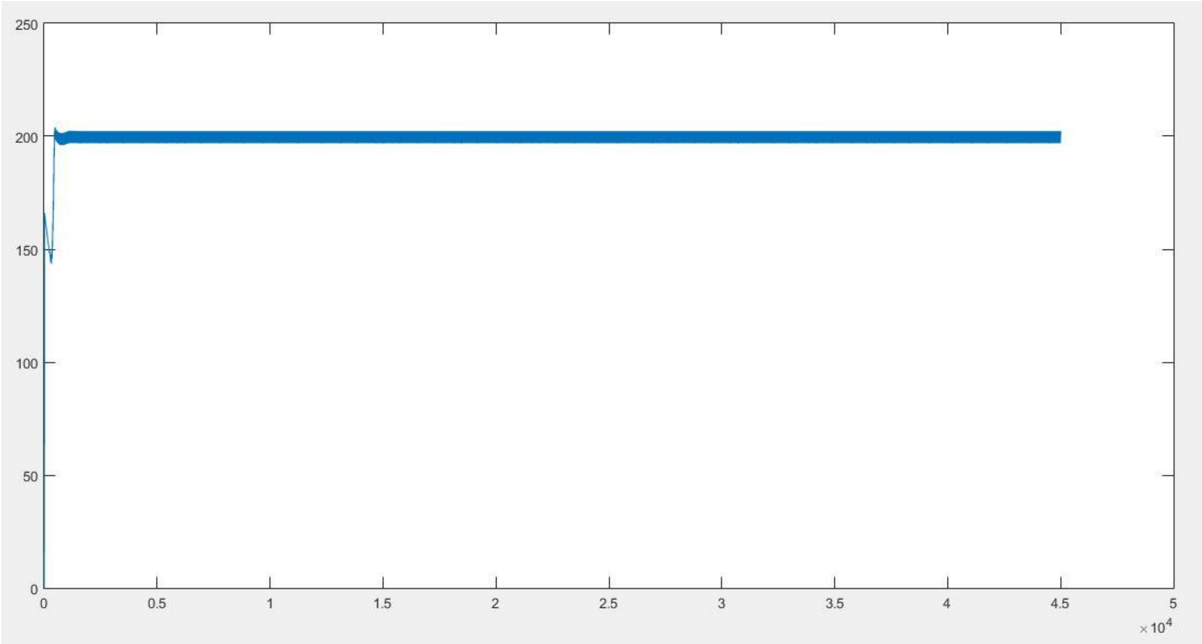


Fig.11. MATLAB-Simulink model of proposed Boost converter with PID controller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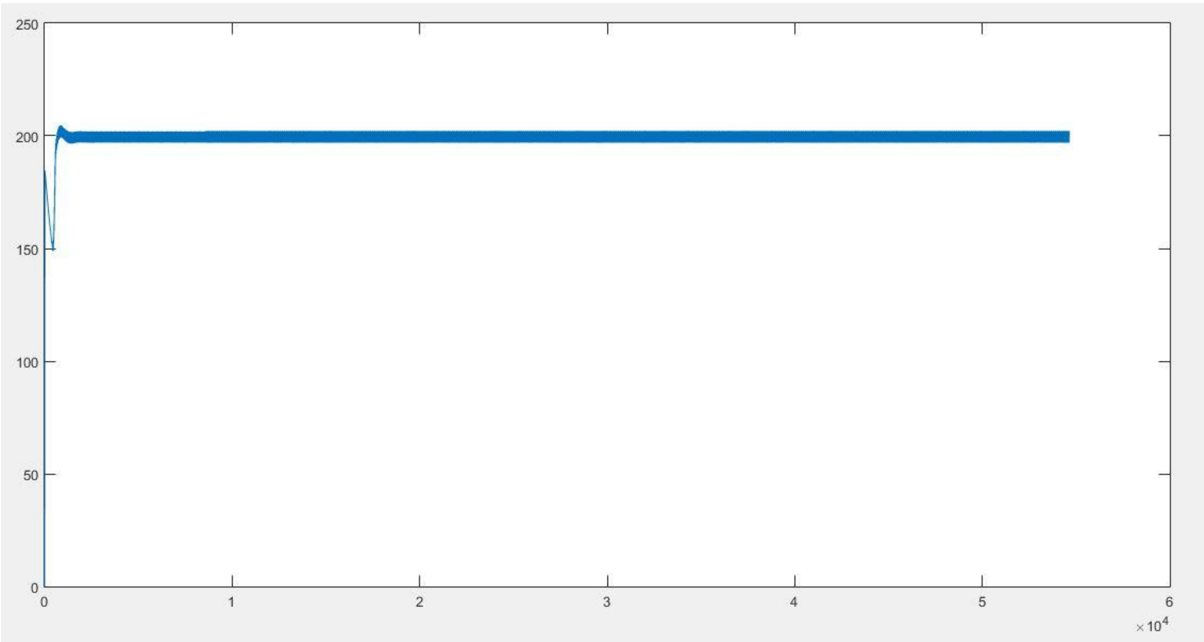
(a)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2
3
4
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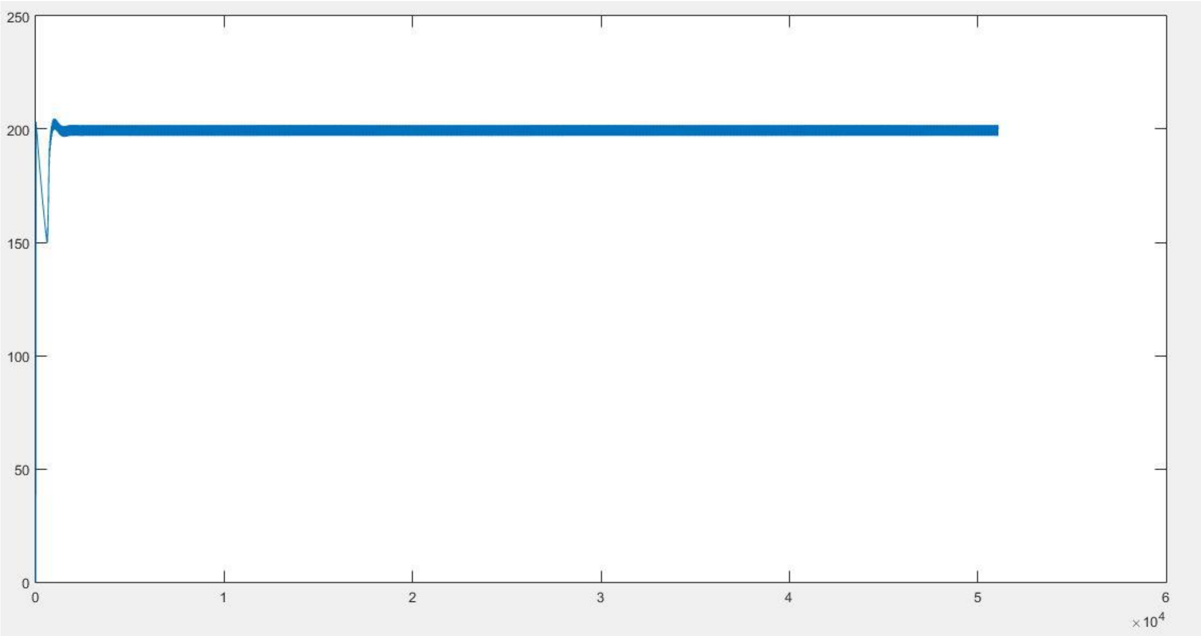
6
×10^4

(b)



(c)

Fig.12. Output voltage plot of proposed Boost converter with PID controller operating at 50% duty cycle for input voltages (a) 90V, (b) 100V and (c) 110V

5.4 Comparison of Results

Simulation data obtained as shown in Table.3 was plotted in MATLAB and comparison was done between conventional and proposed Boost converter in terms of output voltage and percentage overshoot.

TABLE.3 Comparison between conventional and proposed boost converter.

	Conventional		Proposed	
Input Voltage (V)	Output Voltage (V)	Percentage Overshoot (%)	Output Voltage (V)	Percentage Overshoot (%)
90	205.75	51.54	199.59	2.36
100	228.67	51.58	199.57	2.12
110	252.27	51.45	199.60	2.35

Experimental results show that the proposed PID controller when used with Boost converter provides better output voltage regulation and overshoot reduction, thereby improving the performance of the system.

Chapter 6
Conclusion

This paper explores designing principles and efficiency of PID controlling of DC-DC boost converter. Using averaging principle equivalent mathematical model of the converter is obtained. It provides useful system parameters, with the appropriate accuracy for the purpose of PID tuning. Based on these parameters and Trial & Error Method for PID tuning, a simple tuning method is proposed for the DC-DC boost converter control design. Theoretical assumptions are confirmed by simulation in Matlab Simulink and high efficiency of proposed method too. The control system robustness due to uncertainty of system parameters is also explored. The result of simulation establishes maximal gain of DC-DC boost converter as basic factor of limitation. The gain is physical property of the converter and can't be improved by control law. Despite of high robustness, it is noticeable decreasing of step response performance with the changing of system parameters. Because of this, future work could be oriented to deploying of adaptive control, based on proposed method, which could provide real time adjusting of the PID controller.

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