PI CONTROLLER DESIGN FOR DC BUCK CONVERTER CONNECTED TO A PV CELL

DISSERTATION II

Submitted in partial fulfillment of the
Requirement of the award of the
Degree of

MASTER OF TECHNOLOGY
IN
(Electrical Engineering)

By

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Under the Guidance of

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This is to certify that the thesis titled **“PI CONTROLLER DESIGN FOR DC BUCK CONVERTER CONNECTED TO A PV CELL”** that is being submitted by **“ROHIT.V”** is in partial fulfillment of the requirements for the award of **MASTER OF TECHNOLOGY DEGREE (POWER ELECTRONICS)**, is a record of bonafide work done under my /our guidance. The contents of this thesis, in full or in parts, have neither been taken from any other source nor have been submitted to any other Institute or University for award of any degree or diploma and the same is certified.

Mr.R.K.SHARMA

Project Supervisor

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I am grateful to the individuals who contributed their valuable time towards my Dissertation II. I wish to express my sincere and heart full gratitude to my guide **Mr.R.K.SHARMA**, HOD, Department Of Electrical Engineering who guided me to take up this dissertation in sync with global trends in scientific approach.

I am also grateful to Lovely Professional University for providing me an adequate infrastructure and facilities to carry out the investigations.

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CERTIFICATE

This is to certify that **Rohit.V** bearing **Registration no.11311232** has completed objective formulation of thesis titled, “PI controller design for DC buck converter connected to a PV cell” under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the thesis has even been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfillment of the conditions for the award of **MASTER OF TECHNOLOGY (POWER ELECTRONICS).**

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DECLARATION

I, ROHIT.V student of MASTER OF TECHNOLOGY (POWER ELECTRONICS) under DEPARTMENT OF ELECTRICAL ENGINEERING of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report is based on my own intensive research and is genuine.

This thesis does to the best of my knowledge; contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

Date: **ROHIT.V**

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ABSTRACT

This report is concentrated on the modeling and analysis of dc buck converter. The detailed description of the circuit has done and controller has been designed. In this thesis PI controller has been designed. This controller improves steady state response of the system thereby reducing the settling time. Simulation and experiment results show that the response of system has been improved and required performance is obtained. Here the gain values are evaluated based on provided ratings and required mathematical expressions are obtained.

Based on these gain value, required gating pulses are generated and these values are varied accordingly. Hence by varying the width of the pulse, the triggering of switch can be done. In this way, variation in output wave form can be achieved with reduced harmonic and ripple contents.

CHAPTER-1
INTRODUCTION

Now a day's almost for all industrial applications conversion of fixed dc to variable dc source is important. DC choppers are widely used in several of applications such as power supplies, spacecraft power systems, hybrid vehicles, high power transmission, medical electronic and DC motor drives. Choppers are widely used in power electronic applications to serve as DC to DC power converters.

1.1 BLOCK DIAGRAM OF DC-DC CONVERTER:

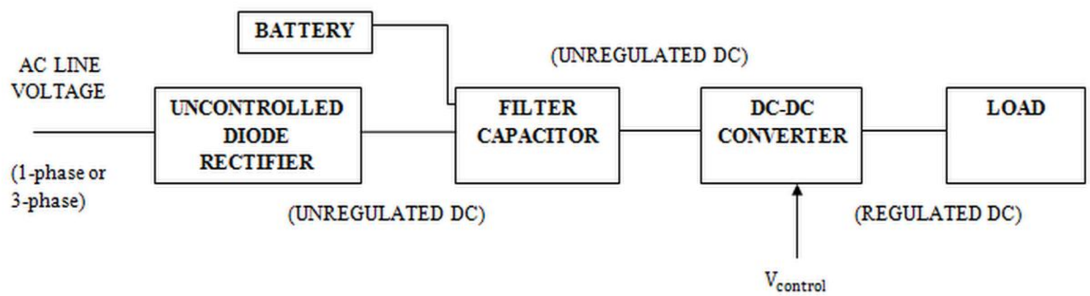

Fig.1.Block diagram of dc-dc converter

1.2 NEED OF DC-DC CONVERTER:

DC-DC converters are mainly used when we require to convert DC electrical power effectively from one voltage level to another. They are highly efficient because unlike AC, DC cannot be simply stepped up or down using a transformer. In many ways, a DC-DC converter is the DC equivalent to a transformer. The basic intention behind any converter is to get a energy level with variations as per requirement along with minimum energy losses and easy control.

The important thing to remember about any DC converters is similar to a transformer; they just vary the input energy into different levels of impedances. That is nothing but stepping up and stepping down of voltage levels. So whatever be the output voltage level, the output power all comes from the input; there is no energy manufactured inside the converter. Some energy is probably used up by the converter circuitry and components while doing their job. They provide fast dynamic response, good acceleration and proper position control along with high efficiency.

The input of these converters are nothing but an unregulated dc voltage which are obtained by rectifying line voltage and therefore it will produce fluctuations due to change in magnitude of line voltage. Switching mode type dc to dc converters are mainly used to transform unregulated dc input into an controlled dc output for a given voltage level. The static conservation principles for these switching converters are one of the main reasons for their 0 increase in the number of applications in electrical systems.

1.3 CLASSIFICATION OF DC-DC CONVERTERS:

The frequent switching operations of dc converters results in the circuit components being connected together periodically change in its configuration. These converters can be synthesized based on topological variations, inductors, and capacitors.

In order to obtain reliability for dc converters, there are two main rules:

(a) Inductor has the capacity to store energy by means of current and also has the property of not allowing sudden changes in current. Hence it should be placed such that mode of operation should not be discontinuous.

(b)Capacitor has the function to store energy by virtue of voltage across it and this voltage won't change suddenly. So it should be placed in such a way that capacitor voltage does not become discontinuous during operation.

Based on above mentioned rules and as per applications, dc converters can be classified as follows:

(a) Step Down or Buck converter

(b) Step Up or Boost converter

(c) Buck-Boost converter

(d) Cuk converter

(e) Fly-back converter

1.3.1 STEP DOWN CONVERTER:

In this converter the average output voltage is less than the input voltage. During switch on, inductor charges rapidly and the same energy is dissipated to load. Filter capacitors used are to be of large value under steady state analysis so as to get constant instantaneous output.

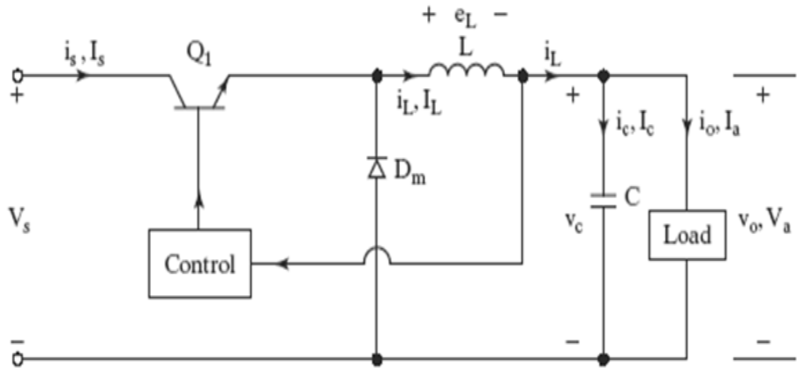

Fig.2.Step down Converter

1.3.2 STEP UP CONVERTER:

In this chopper the load voltage is greater than the source voltage. When switch is on, diode is reversed biased thereby isolating output voltage. The input supplies energy to inductor during on condition. When the switch is off, the output terminal receives energy from inductor as well as input source. For the case of steady state analysis, the output filter capacitor is assumed to be of a very large value to ensure constant output voltage.

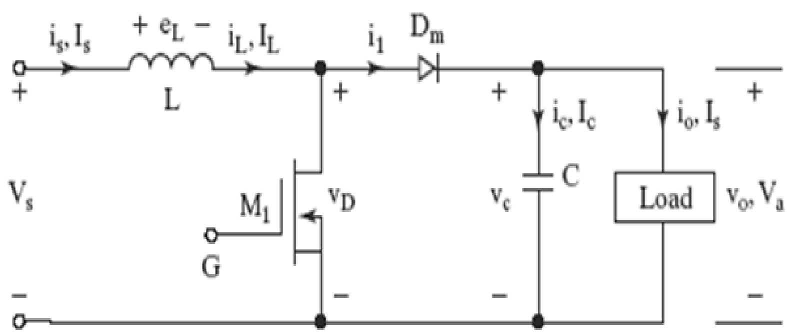

Fig.3.Step up Converter

1.3.3 BUCK-BOOST CONVERTER:

The important purpose of this chopper is in the case of regulated dc power supply, that is where a negative polarity output may be required with respect to common terminal of input voltage and output may be of either higher or lower than the input voltage. It’s a combination of both step up and step down converter. When switch is closed, the input stores energy in inductor and dissipates when switch is in open condition. No input is supplied during this time interval and output is assumed across capacitor.

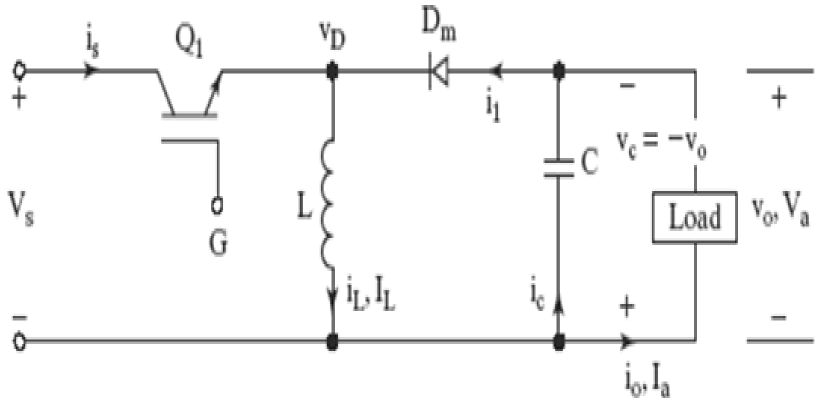

Fig.4.Buck-Boost Converter

1.3.4 CUK CONVERTER:

This circuitry is obtained by using the duality principle on the circuit of buck-boost converter. It provides a negative polarity regulated output voltage with respect to the input terminal voltage.

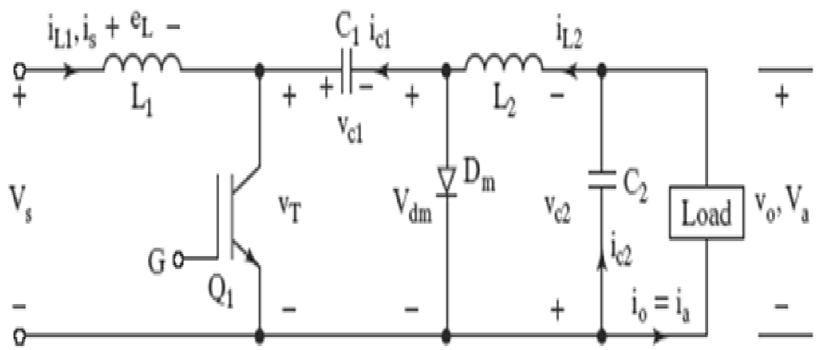

Fig.5.Cuk Converter

1.3.5 FLY-BACK CONVERTER:

This converter is similar to buck-boost but uses transformer instead of single inductor to store energy. When current flows from supply to the primary winding, energy is stored in the magnetic field of transformer. Then when switch is turned off, the transformer tries to maintain the current flow through primary winding by suddenly reversing the voltage across it and thus generating a "fly-back" pulse of back-EMF.

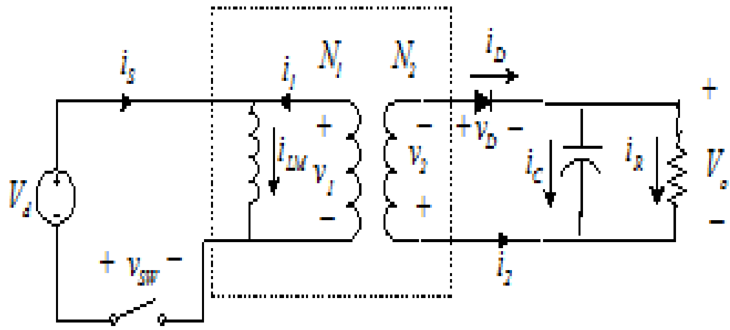

Fig.6.Flyback Converter

1.4 COMPARISION OF DC-DC CONVERTERS:

The above mentioned dc choppers can transfer energy only in one direction as they have the tendency to produce only unidirectional current and voltage. Only a full bridge converter can have a bidirectional power flow both in form of current and voltage. Hence they operate in all four quadrants. From the following data some assumptions are taken, they are as follows:

(a) The average current is at rated value which the desired maximum value. Also ripple present in inductor current is negligible. Hence continuous conduction mode is attained.

(b) The output voltage is at its rated value with negligible ripple content present in the voltage.

(c) The input voltage is allowed to vary. Therefore, the duty ratio of the switch must be controlled in order to hold output voltage level constant.

Hence besides the full bridge converter, all other converters operate in single quadrant thereby allowing unidirectional power flow.

1.5 SWITCHING TECHNIQUES:

The average output voltage can be controlled by frequent opening and closing of switch. Here one or more switches can be used to attain the required output. This can be attained by varying the duty cycle periodically. For this purpose some control strategies are used, they are as follows:

(a) Constant frequency system

In this, the on time is varied but chopping the frequency is kept constant. Varying the time period means varying the pulse width. So this strategy is called pulse width modulation.

(b) Variable frequency system

Here chopping frequency is varied and either on time or off time is kept constant. This method of controlling is called frequency modulation.

Frequency modulation technique has some advantages compared to pulse width modulation. They are as follows:

(i) Varying chopping frequency for large signals to get a controlled output is difficult. This makes the filter design for this circuit complex.

(ii) The control of duty cycle for frequency variation would be wide. This may result in interference with other signals.

(iii) Large off time may lead to discontinuous mode of operation.

1.6 TYPES OF CONTROLLERS:

(a) PID Controller

(b) Sliding Mode Controller

(c) Fuzzy Controller

(d) Neural Networks

(e) Genetic Algorithm

CHAPTER-2
OBJECTIVE

For any kind of controller, the main function is to provide the required output. It also controls and monitors the output voltage and calculates error to determine the duty cycle. This helps us to attain good transient as well as steady state responses. To obtain reliable operation, the main objective is to maintain proper regulation despite of variations occurring in input voltage and output load.

The regulation of variable output voltages can be obtained by using controllers. These controllers can be either analog or digital. In case of analog controller, the change in gain and algorithm are done manually which is time taking. On the other hand, the digital controller implemented by digital processors such as microcontrollers, digital signal processors etc which have advantages like programmability, adaptability and ability to solve any complex algorithms.

These technological advancements have led to microcontrollers, DSP's with other features such as analog to digital converters, PWM to implement digital controllers for all DC converters. The digital implementations of these switching mode power converters have drawbacks that it has limited switching frequency. This problem has occurred due to sampling time delay and processing time of control algorithm in order to calculate new duty cycle.

CHAPTER-3
SCOPE OF STUDY

The main purpose of any control is to provide tuned and ripple free output. The error obtained by comparing the reference value and the output value. The corresponding gain values are determined and accordingly tuning is done. Several of controllers are used for this purpose both linear and non-variable. The types of controllers are decided based on whether the parameters are variable or not. Hence this decides the classification of controllers for dc converters.

For real time application of controllers, output voltages needs to be sampled. The switching action of converter will produce high frequency switching noise and distortion in output voltage. This would result in error in a large scale and makes the system unstable. The controller used in the system plays a key role in sampling the given signal.

CHAPTER-4
REVIEW OF LITERATURE

1. Amir Hassanzadeh, Mohammad Monfared, Saeed Golestan, Reza Dowlatabadi (2011)

DC power converters, which are also known as DC choppers are widely used in various applications such as power supplies, spacecraft power systems, hybrid vehicles and DC motor drives. Buck, Boost, Buck- Boost, Cuk and Sepic are some of the converters most widely used industrial applications. This paper helps us analyze the small signal averaged state-space models of these kind of converters and provide a good understanding of the frequency domain behavior and provides a tool to design and analyze the feedback control loops for the system. The theoretical results can be evaluated by using numerous simulation software. DC choppers are widely used in power electronic applications so as to serve as power converter circuits. Variety of work has been done so as to find the averaged small signal state-space models for the converters. But given that the natural frequencies of the converter, as well as the frequency variations of the converter inputs are much smaller than the rated frequency of switches and then the small signal averaged model is a vile representation of converter performance with respect to small AC variations at the equilibrium operating point. Based on the defined control methodologies, such a general model allows us to derive the expressions for the converter control to output transfer function, input to output voltage transfer function, input impedance, and output impedance, etc. Based on this information, the controller design and performance analysis can be easily determined using the known control techniques such as Root loci and Bode plot.

(2) Jianping Xu (2001)

The systematic method needed for the examination of switching DC-DC converters is proposed. For instance of an application case, the fundamental customary PWM switching DC converters (Buck, Boost, and Buck-Boost) are examined by the new system. Different demonstrating and explanatory methodology for the switching DC converters have been accounted for as of late, out of which most are taking into account the time averaging procedure. The beginning stage of these technique is to form a few networks as indicated by the first system comprising of direct RLC components, free sources, and occasionally switching components, in both "ON" and "OFF" states. Later the time averaging technique takes after to yield the last circuit mathematical statements. The controls included are in this way somewhat complex since they must consider the circuit in general framework. To minimize the demonstrating and examination method of switching DC-DC converters, we have added to a mixture logical system in the present paper utilizing the characterizing comparisons of the frameworks. The new approach is to achieve the characterizing mathematical statements of the switching DC-DC converters which determine the conduct of the frameworks in every switching state, then the DC relentless state investigation can be performed on these characterizing comparisons, while for the AC little flag examination of such frameworks, the bothers are connected to the characterizing comparisons bringing about the AC little flag comparisons of the frameworks from which we can acquire the AC little flag attributes of such frameworks. The new systematic system for the examination of switching DC-DC converters will be expressed and will be utilized to the investigation of essential routine PWM switching DC-DC converters (boost, buck and buck-boost). For the space limit, just the switching DC-DC converters in Continuous Conduction Mode (CCM) are considered here, while for the switching DC-DC converter in Discontinuous Conduction Mode (DCM), they can be broke down by utilizing the new explanatory method as a part of the same route as those in CCM, and subsequently are overlooked here.

(3) S.Baev and Y.Sheessel (2009)

The trouble with the causal yield following in the non-minimum stage boost DC-DC power converter is gotten. The complete plan of stable framework focus (ESSC) is utilized for era of an encased position profile for the inner state on the premise of given progressively yield state reference profile. Sliding mode controller (SMC) is anticipated to track said reference profile, while converter parameters (load resistance and voltage source impedance), which influence the interior progress, are recognized continuously, utilizing the thought of sliding mode parameter eyewitness (SMPO). A numerical reenactment gives the proficiency of the anticipated control technique in the vicinity of inner vulnerabilities and outside aggravations. Exchanged force DC-DC converters are utilized as a part of an enormous mixed bag of genuine applications, including era of an arrangement of DC voltages from one DC power supply, having all the converters been connected through the impedance of the source battery. A consistent DC voltage, as well as given progressively summon voltage profile of the rationed extremity would be created utilizing gave power converters. On account of boost DC-DC converter, the non-minimum stage nature of the previous obliges uncommon consideration. All in all, direct managing of the yield voltage gives temperamental ascending of the stage current and finally causes harm of the converter. This issue has been widely contemplated in the most recent decade and numerous control systems have been proposed.

(4) Zengshi Chen, Jiangang Hu and Wenzhong Gao (2010)

In this article, a consecutive joined controller is arranged and dissected for a non-transforming buck–boost converter. The quicker internal current circle uses sliding mode control. The moderate external voltage circle utilizes the proportional–integral (PI) control. Dependability examination and determination of PI increases are taking into account the nonlinear shut circle blunder progress fusing both the internal and external circle controllers. The shut circle framework is demonstrated to have a non-minimum stage structure. The voltage aggravations because of step changes of information voltage or resistance are normal. The working scope of the reference voltage is talked about. The controller is approved by a reenactment circuit. The reenactment results demonstrate that the reference yield voltage is observation well under framework instabilities or aggravations, affirming the legitimacy of the proposed control.

(5) Irfan Yazici, Ayhan Ozdemir, Zekiye Erdem (2009)

This paper presents real time implementation of a digital controlled conventional boost converter works on the fixed frequency driven by the duty cycle control techniques. The digital controller, implemented using ADUC841 microcontroller, monitors the output voltage and calculate the error to determine the next duty cycle value. Simulation and experimental results indicates that the constructed PI controlled boost converter has good transient response as well as stable and accurate steady-state response during the drastically changes occur in input voltage and output load. A digital proportional-integral (PI) controlled boost converter is implemented using a ADUC841 microcontroller from Analog Devices. This microcontroller due to on broad features such as three 16-bit general purpose timers, 2 PWM channels and a 12-bit, 8-channel ADC which facilitates to implementation of boost converter operates at 20 MIPS with an instruction cycle time of 50 ns. Both the sampling frequency and switching frequency were selected to be 15 kHz for this study. The digital controller acquire a sample once every sampling period and calculates the new duty cycle through PI algorithm and changes the duty cycle at the start of the next switching period.

(6) M. F. N. Tajuddin, N. A. Rahim, I. Daut, B. Ismail and M. F. Mohammed (2009)

This paper portrays a digital Proportional-Integral- Derivative (PID) controller system connected to the DC-DC buck converter. The converter is displayed utilizing a state space averaging system. Because of the non-direct of the force converter, the PID controller is intended to disentangle the remuneration of the DC-DC converter. The control algorithm is actualized in Digital Signal Processor (DSP). The relentless state and element reaction exhibitions of the controller are illustrated. Exploratory results are given to exhibit the viability of the configuration. The PID control system can be executed digitally or simple to control parameters of converter, for example, voltage, current, and so forth. In simple control, simple parts, for example, resistors, capacitors, inductors and operational-speakers is utilized for execution of controlling algorithm, while in digital control, microchips are utilized and controlling algorithm can be modified and food to chip. Digital control framework offers numerous favorable circumstances over their simple partners. An imperative playing point offered by digital control is in the adaptability of its change controller qualities, or of receiving the controller if plant progress change with working conditions. The capacity to upgrade the controller by changing the product (instead of equipment) is an essential highlight of digital control as against simple control. Moreover chip are significantly less inclined to natural conditions than capacitors, inductors, and so forth. The programs can scale to the furthest reaches of the memory or storage room without additional expense and parameters of the system can be changed with time. This paper showed the adequacy of the digital PID control connected to the state space averaging DC-DC converter model. The control algorithm is actualized in DSP.

(7) S.Daison Stallon, K.Vinoth Kumar, S.Suresh Kumar, Justin Baby (2013)

According to the present situation there are parcel of force deficiencies in everywhere throughout the world particularly nation like India were the grid exchanging issue is high. Just about the force from the fossil fuels are getting to be so less a percentage of the sample of the fossil fuels are (coal, lignite, oil, and gases).So the vast majority of them looking in forward for the force from green or non ordinary based energies like sun powered, wind, biomass, tidal and so forth. This does not make any contamination to the earth. In this paper the recreation and examination of the PV board furthermore high proficient support converter outline and reenactment is likewise performed. Despite the fact that the sun powered based frameworks are renewable based energies when contrasted with other renewable energies like wind, biomass it doesn't interface with more number of grid associations. Photovoltaic (PV) power-era frameworks are getting to be progressively essential and common in dispersion and era frameworks. An ordinary kind of PV array is a serial association of various boards to acquire higher dc-join voltage for primary power through a dc–ac inverter. The aggregate force created from the PV array is in some cases diminished strikingly when just a couple of modules are free from shadow impacts to beat this issues a few essential steps are taken. Intuitive inverter is independently mounted on PV module and works in order to create the greatest force from its relating PV module.

(8) K.M.Smedley, and Cuk.S (1995)

A nonlinear control methodology is revived to control the duty ratio d of the switch in real time application such that in each cycle the average value of the attenuated waveform at the switch rectifier output diode is exactly equal to the control reference. Experimental results demonstrate that switching converters with this new type of control reject input voltage distortions in only one switching cycle and follow the control values very quickly. This control methodology is very easy and directly applicable to all types of dc-to-dc switching converters in either pulse-width-modulated or quasi-resonant modes.

(9) Sumita Dhali, P.Nageshwara Rao,Praveen Mande, K.Venkateswara Rao (2012)

This paper speaks to planning and simulation of pulse width modulation (PWM) based sliding mode (SM) controller for DC converter working in constant conduction mode. The general parts of the execution characterstics and properties of the sliding mode controller are contrasted and the Proportional Integral Derivative (PID) controller and Proportional Integral (PI) controller. From the simulation results got the sliding mode control plan gives great voltage regulation and is suitable for boost DC-to-DC converters. The inferred controller/converter framework is practical for normal venture up transformation purposes. In spite of the fact that, it is presented to distinctive varieties which may detract this framework from apparent conditions, because of changes happening in the line voltage and parameters at the information considering load as a steady. Direct present (DC-to-DC) converters are circuits which change over direct current (DC) source starting with one voltage level then onto the next by changing the obligation cycle of the primary switches in the circuits. As the DC converters are nonlinear frameworks, they speak to a huge test for control plan. Since established control methods are composed at one ostensible working point, they are not ready to react acceptably to working point varieties and burden unsettling influence. They eventually neglect to perform proficiently under huge parameter or burden varieties. PWM based DC-DC converters are extremely famous from most recent three decades, and they are generally utilized at diverse force levels .Since exchanging converters comprises of an instance of variable structure frameworks, the sliding mode (SM) control strategy can be perhaps be the best choice to control these sort of circuits.

(10) S.C. Tan, Y.M. Lai, C.K.Tse and L.Martinez Salamero (2007)

A group of altered recurrence pulse-width-modulation based sliding-mode voltage controllers for DC–DC converters working in the spasmodic conduction mode is proposed. The proposed topology is created for buck, help and buck–boost converters. Preparatory confirmation and assessment of these controllers are performed through PC recreations utilizing exact models of the systems. The sliding-mode (SM) controller is no doubt understood for its vigor, solidness and great regulation properties in an extensive variety of working conditions. It is likewise regarded to be a superior hopeful than other nonlinear controllers for its relative simplicity of execution. Specifically, the altered recurrence pulse-width-modulation (PWM)-based SM controllers, which are essentially pulse-width modulators that utilize control signs got from SM control procedure, are discovered to be more suited for commonsense execution in force converters. In any case, the outcomes displayed in these papers are substantial for converters in CCM operation. Similarly as with ordinary hysteresis modulation (HM)-based SM controllers, the proposed PWM-based SM controllers are not pertinent to DC–DC converters working in DCM on account of the crucial contrast in the element properties between the two operations. Subsequently, if PWM-based SM controllers are to be received for DC–DC converters in DCM operation, the system models and control laws must be redeveloped with thought of these properties.

(11) Khandker Tawfique Ahmed, Mithun Datta, Nur Mohammad (2013)

A solar based model can't transmit greatest power to the heap without anyone else's input because of impedance varieties. A most maximum power point following (MPPT) system can be utilized to have the greatest power. Another MPPT based system has been created utilizing Buck-Boost sort DC-DC converter. The sort of system is exceedingly effective and vigorous. PIC16F73 microcontroller has been utilized to control the DC converter yield. PV module yield power is measured utilizing microcontroller. The yield power is then contrasted and the past module yield power and the obligation cycle of the converter is differed persistently to track point of greatest power. The same methodology is rehashed unless the yield power achieves the most extreme appraised power point. In this paper, a most extreme power point following (MPPT) system has been developed utilizing two-switch non-transforming buck-support converter. Irritate and watch (P & O) MPPT algorithm is utilized to transfer greatest power from the PV panel which is ordered by a Microcontroller. Lately Photovoltaic (PV) system is picking up prominence among the renewable resources because of its favorable circumstances, for example, nonappearance of fuel expense, low upkeep expense and no brakages because of nonattendance of moving parts. Yet at the same time the high establishment cost and low vitality change productivity influences the unfathomable utilization of PV systems. The yield power of a PV panel relies on upon the working terminal voltage. The most extreme power created by the system changes with the change in insulation and temperature.

To upgrade the yield power it is imperative that the PV panel works at most extreme power point (MPP). The power we gain from the PV module is dc. Henceforth if the most extreme power point is to be seen by changing the voltage of the PV module there ought to be a dc-dc converter. There are comparable topology of dc-dc converter like buck converter, support converter, buck-help converter, cuk converter, SEPIC (Single Ended essential Inductance Converter) and so forth. A buck converter can transfer vitality to load at lower voltage than the source voltage. Help converter transfer vitality to load at higher voltage than the source voltage. Buck-support, Cuk, Sepic can transfer vitality to load above and beneath the evaluated voltage.

(12) Heide Brandtstadter (2008)

Sliding mode control furnishes varieties regarding parameter varieties and disturbances. These robustness properties make this irregular control procedure extremely appealing. Be that as it may, this sort of usage in the vicinity of un-demonstrated flow prompts high-recurrence motions known as jabbering. This impact lessens the control demonstration and accordingly harming the framework. Numerous current usage experience the ill effects of this downside. In this paper, a novel sliding mode control methodology for mechanical frameworks with electric motors as actuators is utilized. The sort of issue is unraveled by including actuator elements, which has so far been overlooked, in the control unit outline. The exchanging control joins the motion of the electrical and the mechanical subsystem. The beat width balance (PWM) utilized as a part of most present day usage is wiped out and the controller straightforwardly drives the force switches. Subsequently, the irregular control inputs are the changed voltages connected to the motor. Moreover, an extensive procedure to understand the proposed control plan is created. It permits the systematic outline of sliding mode controllers for complex electromechanical frameworks. Contrasted with the current configuration systems, it is material to a more extensive class of frameworks. It can deal with nonlinear frameworks represented by an arrangement of coupled differential comparisons of self-assertive request in standard structure, and in addition interminable dimensional frameworks. This proposal recognizes and understands execution issues of the summed up piece control standard. Exhibited are vital onlookers and a strategy to reject disturbances with known structure. The complete configuration strategy is delineated by controlling a reversed pendulum framework driven by a DC and a synchronous motor, and additionally an impelling machine. Simulations and analyses show the elite and the robustness of the proposed control architecture. A key contribution of this theory is the position control of an instigation machine that establishes a framework for building more strong and economical automated frameworks.

(13) Li Yanming, Lai Xinquan, Ye Qiang, Yuan Bing, Jia Xinzhang and Chen Fuji (2009)

A current-mode buck DC–DC controller taking into account versatile on-time (AOT) control is introduced. The on-time is accomplished by the system of information nourish forward and yield input and the versatile control is attained to by an example hold and time-ahead circuit. The versatile current-mode control plot acquires incredible transient velocity reaction, as well as accomplishes the freedom of circle security on yield capacitor. Other than this, the AOT current-mode control does not give any sub-consonant swaying sensation seen in altered frequency crest current-mode control, thus there is no need of the incline compensation circuit. The auto-skip beat frequency regulation (PFM) procedure enhances the transformation process for light loads successfully. The controller has been manufactured with BCD prepare effectively and the itemized exploratory results are demonstrated. A current-mode based buck DC–DC controller circuit with versatile on-time control is utilized as a part of this paper, which is taking into account the method of the on-time controlled by info voltage encourage forward and yield voltage criticism. An example hold circuit is actualized to linearise the relationship between data voltage and on-time, and a charging time-ahead circuit is show with a specific end goal to kill the effect of transmission postpone on switching frequency, in this manner guaranteeing that the switching frequency of the converter is free on the inductor, yield capacitor, info voltage, yield voltage and burden. The versatile on-time (AOT) current mode control gives brilliant transient reaction speed, as well as beats the reliance of circle soundness on yield capacitor ESR. Likewise, the AOT current-mode control has no sub-symphonious swaying wonder; accordingly there is no need of any incline compensation. The info voltage is increased through examining the sign of the switch mode when the high velocity switch is on, which assesses the pins of the chip and the application circuit. Considering the productivity, AOT control can change naturally into auto-skip PFM operation mode at light load, and the switching frequency diminishes persistently with lessening in burden, which enhances transformation effectiveness yet does not build yield voltage switching.

(14) Huafeng Xiao, Liang Guo, Shaojun Xie (2007)

The current and voltage bolstered bidirectional DC-DC converter can achieve a ZVS for the switches with the assistance of phase-shift (PS) strategy. Despite the fact that these switches experience the ill effects of high voltage variances and high misfortunes because of exchanging. Henceforth to counter these issues, another phase-shift in addition to PWM (PSP) control ZVS bi-directional DC-DC converter is made, which receives dynamic clipping components and PWM strategy. The given converter can get a handle on ZVS for a wide range of power switches from no heap to full load. The working guideline is broke down and checked by a 28V/270V transformation sample for a given rating of 1.5kW. A double dynamic full bridge dc-dc converter was presented for high power BDC which utilizes two voltage-nourished inverters to drive every sides of a transformer. Its symmetrical structure helps in the bidirectional power stream and ZVS for a wide range of switches. A double dynamic half bridge current-voltage-bolstered delicate exchanging bidirectional dc-dc converter was proposed with minimum power parts. Notwithstanding, the current-encouraged half bridge experiences a high spikes in voltages due to the spillage inductance of the transformer. At the point when the voltage plentifulness of the two sides of the transformer is not coordinated, the current anxieties and circulating conduction misfortunes increments. Also, these converters can't attain to ZVS at low-load condition. These impediments make it not suitable for vast varieties in information or yield voltage condition. An asymmetry bidirectional dc-dc converter with Phase shift in addition to PWM (PSP) control was presented. The circulating conduction misfortunes are minimized, however it brings about current predisposition which diminishes the use of the transformer.

(15) Reza Dowlatabadi, Mohammad Monfared, Saeed Golestan, Amir Hassanzadeh (2011)

Due to its ease, low voltage stress, high reliability, low switch and inductor losses, and small inductor size, the non-inverting buck-boost chopper has caught a lot of attention in applications where it is necessary to step-up or step-down the DC voltage. In this paper, a successful switching strategy for this converter is reported and small signal averaged state-space model is obtained, which let us to think about the control strategy and examine the stability and presentation of the closed loop control system. Appropriate control requirements have been defined and the closed loop performance under several control strategies has been investigated through widespread simulations. As the demand for battery charge controllers increases, so different kinds of design solutions are proposed. Traditionally the buck converter topology is used as a DC to DC converter to provide the controlled output power supply to the batteries. But in many applications such as renewable generations, due to the wide variations of energy source output voltage, it is often necessary either to step-up or step-down the output voltage. Several topologies are capable of both step-up and step-down the voltage. Thanks to its simplicity, low voltage stress, high reliability, low switch and inductor losses, and small inductor size, the non-inverting buck-boost chopper has found a lot of attentions. The non-inverting buck-boost chopper is often implemented with diodes; however, in order to increase the efficiency, it might be advantageous to replace the diodes with transistors.

(16) Jaber Abu-Qahouq and Issa Batarseh (2000)

In this paper, taking into account the exchanging cell strategy, a summed up steady state analysis for families fitting in with delicate exchanging dc-dc converters will be exhibited. Complete summed up outline mathematical statements will likewise be given. The thought of speculation and regulated strategy for the summed up methodology are talked about and connected to choose delicate exchanging families, for example, ZVS-

QRC, QSW-CC, QSW-CV, ZCT-PWM, and ZVT-PWM. Additionally, it has been noticed that all the examined families have one Generalized Transformation Table. The fundamental summed up comparisons will be compressed and the cell-to-cell correlation will be presented. It will be demonstrated that the summed up analysis prompts a few preferences. In this paper, it will be demonstrated that the investigations of the delicate exchanging dc-dc converters can be summed up for a given exchanging system crew. Therefore, as opposed to dissecting every converter topology in a given family independently, stand out exchanging system for every family is expected to be broke down. By utilizing summed up parameters, it is conceivable to produce a solitary change table from which the voltage converter proportions and other imperative configuration parameters for every converter can be gotten straight forwardly.

(17) D.M.Mitchell (1998)

The derivation of the model is obtained from studying the switching network modes of operation and by expressing the switching intervals in terms of the converter design parameters such as gain, normalized frequency, and normalized load. Using the proposed analysis, it is possible to analyze a complete dc-dc converter family as simple as analyzing one converter topology. However the re-design of converter family is made much easier due to the ease in generalized parameter variation. Finally, since the parameters are generalized, it is much easier to obtain steady-state design curves using such simpler mathematical models. Such characteristic curves are used to carry out converter design and provide design information about the converter voltage and current stresses.

Due to simplicity, low voltage stresses, high reliability, low switching and high inductor losses along with small inductor size, the non-inverting buck-boost chopper has obtained a lot of attention in applications where it is necessary to step-up or step-down the DC voltage level. In this paper, a successful switching technique for this converter is found and small signal averaged state-space model is attained, which lets us to decide about the control strategy and analyze the stability and performance of the closed loop control system. Appropriate control requirements have been defined and the closed loop performance under several control strategies has been investigated through extensive simulations. The averaged small signal equations of any non inverting buck-boost converter are derived. According to that small signal equivalent model is to be developed that lets us to decide about the control strategy and how to analyze the stability and performance of the closed loop control system. This converter is of indirect energy transfer type and suffers due to the presence of a right half-plane zero when operated in CCM.

CHAPTER-5

DESIGN CONSIDERATIONS

5.1 DESIGN OF DC BUCK CONVERTER:

DC-to-DC buck converters are direct converters employed for stepping down DC voltage to a desired voltage lower level. These are employed due to their very high efficiency, in places where losses due to their linear counterparts are not tolerated. These converters are mostly based on circuits in which a pulse width modulated (PWM) signal is with an LC network filter.

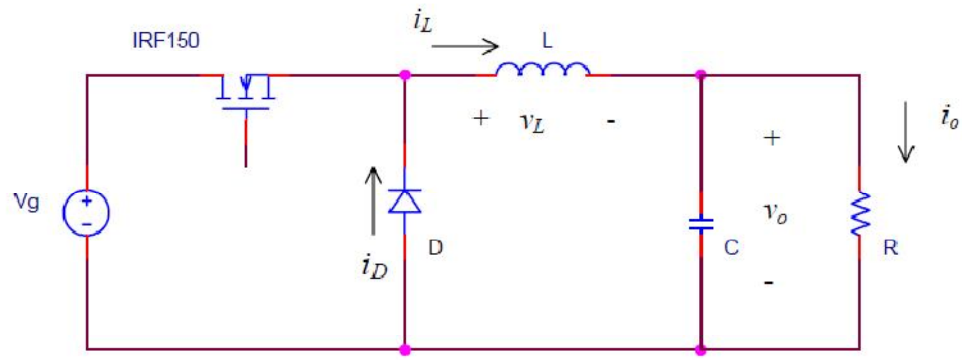

Fig.7.DC Buck converter circuit

For the buck converter circuit shown above the equations during turn off and turn on conditions are given below.

Case(i): For the case of turn on

$$L\frac{di_L(t)}{dt} = v_g(t)\delta(t) - v_c(t)$$

$$C\frac{dv_c(t)}{dt} = i_L(t) - \frac{v_c(t)}{R}$$

$$V_c(t) = V_o(t)$$

Case(ii): For the case of turn off

$$L\frac{di_L(t)}{dt} = -V_c(t)$$

$$C\frac{dv_c(t)}{dt} = i_L(t) - \frac{V_c(t)}{R}$$

For the performance of DC steady state and AC small signal analysis we consider following conditions,

$$v_g = V_g + \widehat{v_g}$$

$$v_c = V_c + \widehat{v_c}$$
$$i_L = I_L + \widehat{i_L}$$
$$\delta = D + \hat{\delta}$$

On substituting the above conditions in both cases and analyzing for both AC and DC responses we get certain equations and hence obtaining the transfer function of the given buck converter.

$$\frac{\widehat{v_o}(s)}{\hat{d}(s)} = \frac{v_o R}{R + SL + S^2 RLC}$$

Here the transfer functions in obtained in terms of output voltage v_o and duty cycle d. Hence the variation in output voltage can be controlled with respect to change in duty cycle. Remaining calculation of R, L, C elements can be made based on given ratings and provided duty cycles.

5.2 SWITCHING WAVEFORMS:

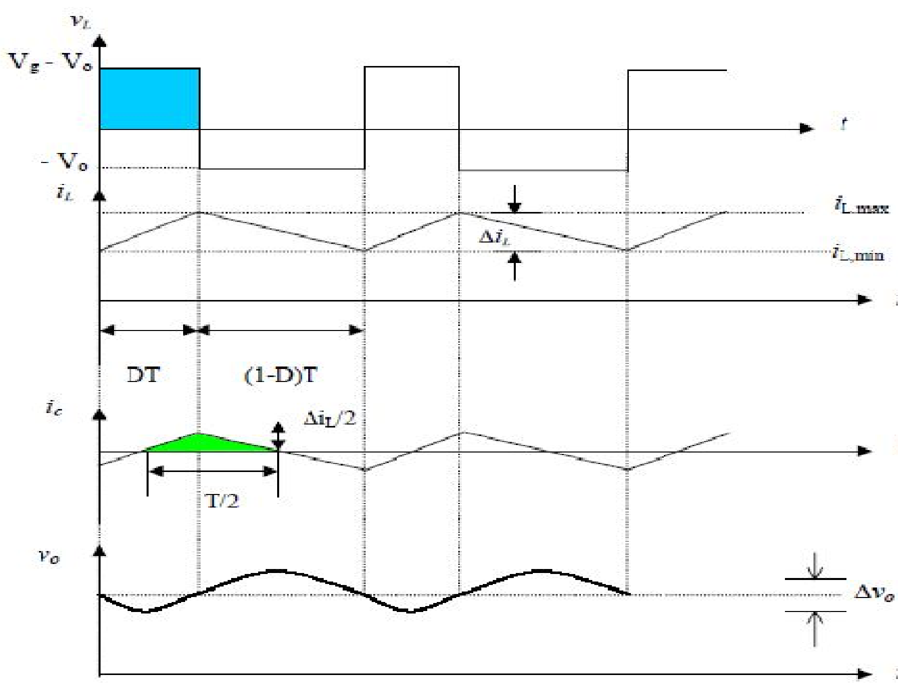

Fig.8.Output response of DC buck converter

Assumptions to be made about the operation of converter are as follows:

1. The circuit operation is in steady state.
2. The circuit operates for continuous conduction mode.
3. The capacitor is large enough to assume constant output voltage.
4. The components are assumed to be ideal.

5.3 PID CONTROLLER DESIGN:

Conventional PI controllers depend on precise mathematical models which have assured reliability, stability and controllability. They have simple structure and robust performance. The error obtained is fed to the controller and based on that Kp and Ki values determined. The corresponding values along with error signal are fed to PI controller thereby obtaining command over duty ratio.

PID controller is most commonly used feedback control system mostly for linear system. The error obtained is the measure of measured and reference value. The function of controller is to minimize the error by varying inputs of controller.

PID is a combination of proportional, integral and derivative controller where Kp, Ki and Kd are the proportional, integral and derivative gain constants respectively. A large proportional gain will result in a large change in output for a given change in error. But if the proportional gain is too high then system becomes unstable.

Similarly a small gain will result in a small output response for a large input error. If Kp value is too low, the control action may be too low and hence the control action may be too low when it responds to system disturbances.

The Ki value accelerates the movement of process towards set point and eliminates the residual steady state error that occurs with pure proportional controller. The sole purpose Kd is to reduce the magnitude of overshoot produced by integral component and improve the combined controller stability. However it slows the transient response of system.

The Proportional-Integral-Derivative (PID) control is the most commonly used control technique used in industries now a days. Mostly people use PID technique to control processes that include heating and cooling systems, fluid level monitoring, flow control, and pressure control. In PID control, we must specify a variable process and a set point.

The process variable is the system parameter that you want to control, such as temperature, pressure, or flow rate, and the set point is the desired value for the parameter we are controlling. The controller applies the controller output value to the system, which in turn drives the process variable toward the given set point value.

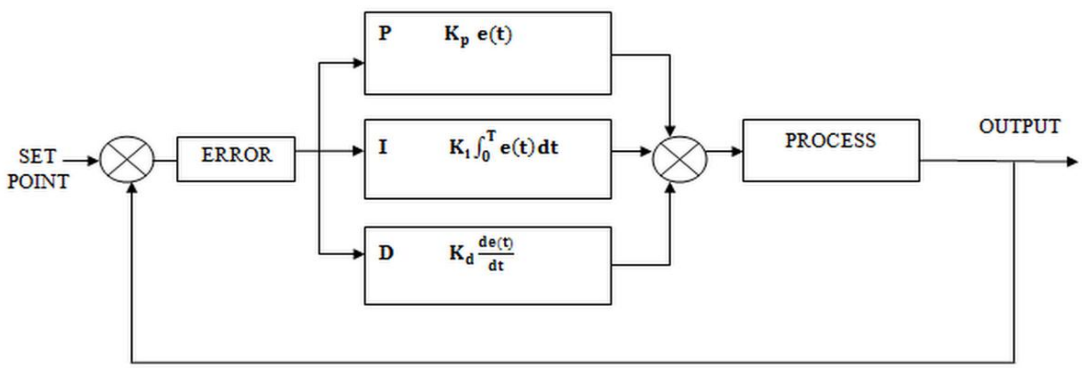

Fig.9.Schematic representation of PID controller

The basic schematic representation of PID controller is shown above with three separate constant parameters: the proportional, the integral and derivative values. These values are considered with respect to time i.e P depends on present error, I on calculated past error, D is the predicted future error based on rate of change of current. The weighted sum of three actions is used to vary and adjust the process.

$$U(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(\tau)}{dt}$$

Here Kp, Ki and Kd are the proportional, integral and derivative gain constants respectively.

The digital control circuit is composed of the PID control calculator with DSP, A/D convertor and Digital PWM Generator. There are PID control calculations also present. Each of control calculation have original A/D converter. Each A/D converter has respectively sampling frequency. The output voltage is sent to the digital converter through the A-D converter. In the conventional control methods, the sampling rate is single in the A-D converter and the calculation process of P-I-D control is series.

The sampling interval and points for I-D control are same as the conventional method present. However, the sampling point for P control is oversampling. The A-D converter can sample the output voltage during the short interval because the calculation process of P control is very simple. The sample data for P control are received by the digital control circuit

CHAPTER-6
RESEARCH METHODOLOGY

6.1 CONTROLLER ASPECTS

The conventional PID controller based on averaging state space model is now a day's popular in industries for case buck convert. It is useful to compare PID and sliding mode controller (PID&SMC). It can be known from comparison that the buck converter under both controllers has similar system responses such as stability, robustness, insensitivity, rising time, output ripples, settling time, transient amplitude, overall behavior of a transient (overshoot or undershoot) and the phase structure (minimum or non-minimum) of the obtained transient.

Designers often have problem to obtain a phase margin of requirement for a buck converter under the conventional PID controller. There are many other complex nonlinear controllers such as neural network, fuzzy logic, H-infinity, feedback state linearization, input-output linearization, flatness, passivity-based control, dynamic feedback control by input-output linearization, exact tracking, and error passivity feedback system. A buck converter may perform satisfactorily under these controllers but sometimes an expensive DSP implementation and a pulse modulator are to be required.

To design or analyze these type of complex circuit, nonlinear controllers may require advanced control knowledge for a technician or a user. However, only simple modern control theories that are taught in every introductory control course are required for PI and SMC design. It may be hard to synthesize some nonlinear controllers to most DC-DC controllers. PI and SMC can be applied to buck, boost, buck-boost, Cuk, Sepic, Zeta, quadratic and many other DC-DC converters. An important answer for PI and SMC to be an alternative control method to the other controllers could be that the sliding mode control signals are naturally fit for the discontinuous nature of buck converters and can be implemented economically with microcontroller technology.

6.2 ADVANTAGES OF PI AND SMC:

1) A PWM technique can be replaced since SMC directly acts as the input signal and they are the gate signals for the semiconductor switches.

2) Switching efficiency of IGBT switches can be improved by variable pulse width of SMC.

3) In case of high power applications, frequent switching reduces power loss as more power is lost in the switching mode than during the conducting mode of IGBT switches. In some cases, the pulse width is fixed for the modulator under the conventional PID controller.

4) Two PI gains are used and they are compared to at least four PID gains of the conventional PID controller. Hence, PID is replaced by PI and SMC and making the controller easier for operation and more practical application.

5) The closed-loop analysis with equivalent control makes PI gains easily obtain.

6) The PI gains obtained for PI and SMC are suitable for case of the conventional PID controller and thereby providing a tuning guide for the conventional PID controller.

7) Generally gain and phase margins are easily generated and compared with the conventional PID controller.

6.3 DISADVANTAGE OF PI AND SMC:

1) The output voltage ripples can eliminated by selecting an appropriate inductance or capacitance value and thus increasing the complexity of the given circuit.

2) Variable inductance and capacitance values will also affect the switching frequencies in an adverse manner.

6.4 PHOTOVOLTAIC (PV) CELL:

The development in new energy sources mainly renewable have led to a new era in power system. Their contribution is around 20% to 25% of total energy consumed since past 20 years. In recent years many active research development have taken place in order to improve cost effectiveness, efficiency and reliability. As PV system doesn't contain emission of any pollutant particle, they are eco friendly and hence directly convert sunlight to electricity. These cells are basically nothing but combination of different pn junctions and their function is based on principle of photocurrent generation.

When sunlight falls on the cell, the photons get absorbed by semiconductor atom which frees electrons from negative layer. This free movement of electrons through external circuit towards positive layer results in this process.

Generally a PV cell produces a voltage range of 0.5V to 0.8V depending on the type of semiconductor device used and type of built up technology. As individual cells produce very minute values of potential across them, combination of cells are required for large ratings.

These combinations can be either in series or parallel in order to form a panel. In case of series combination, the voltages are added with same current whereas for parallel combination, currents are added with same voltage profile.

The major families of PV cell are as follows:

a) Monocrystalline structured cell

b) Polycrystalline structured cell

c) Thin film structure

6.5 EQUIVALENT CIRCUIT OF PV CELL:

The equivalent circuit of PV cell is shown in the below figure. It mainly consists of a current source, a diode, shunt resistor and a series resistor.

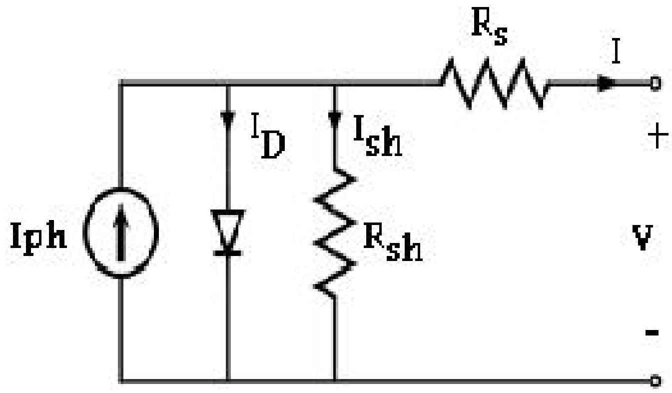

Fig.10.Equivalent circuit of PV cell

Considering the above circuit, the current to the load can be given as below

$$I = I_{ph} - I_s \left[\exp\left(\frac{q(V+IR_s)}{NKT}\right) - 1\right] - \frac{(V+IR_s)}{R_{sh}}$$

In this equation, *Iph* is the photocurrent, *Is* is the reverse saturation current of the diode, *q* is the electron charge, *V* is the voltage across the diode, *K* is the Boltzmann's constant, *T* is the junction temperature, *N* is the ideality factor of the diode, and *Rs* and *Rsh* are the series and shunt resistors of the cell, respectively. As a result, the complete physical behavior of the PV cell is in relation with *Iph, Is*, *Rs* and *Rsh* from one hand and with two environmental parameters as the temperature and the solar radiation from the other hand.

CHAPTER-7

RESULT AND ANALYSIS

7.1. SIMULATIONS AND OUTPUT WAVEFORMS:

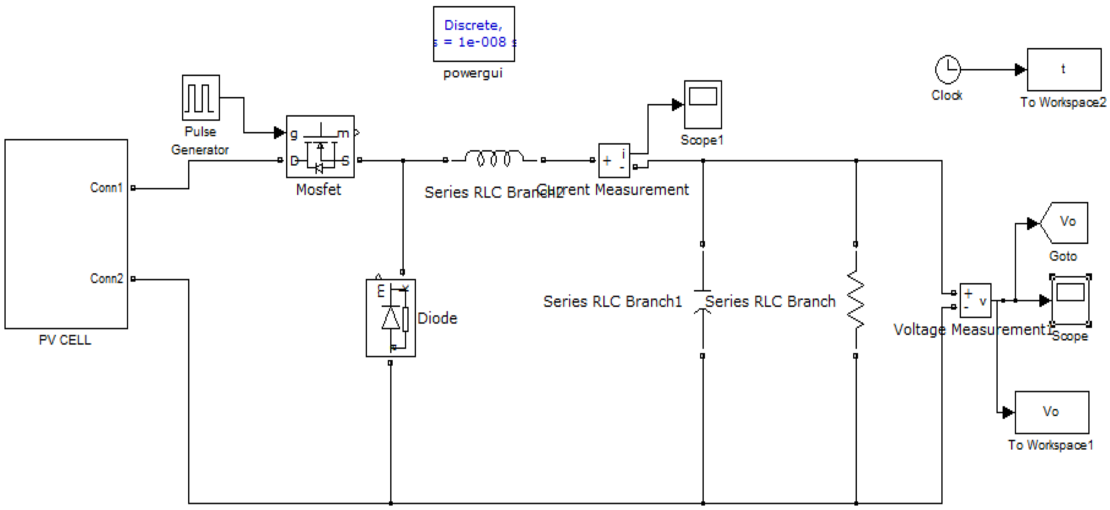

Fig.11.Simulation without PI controller

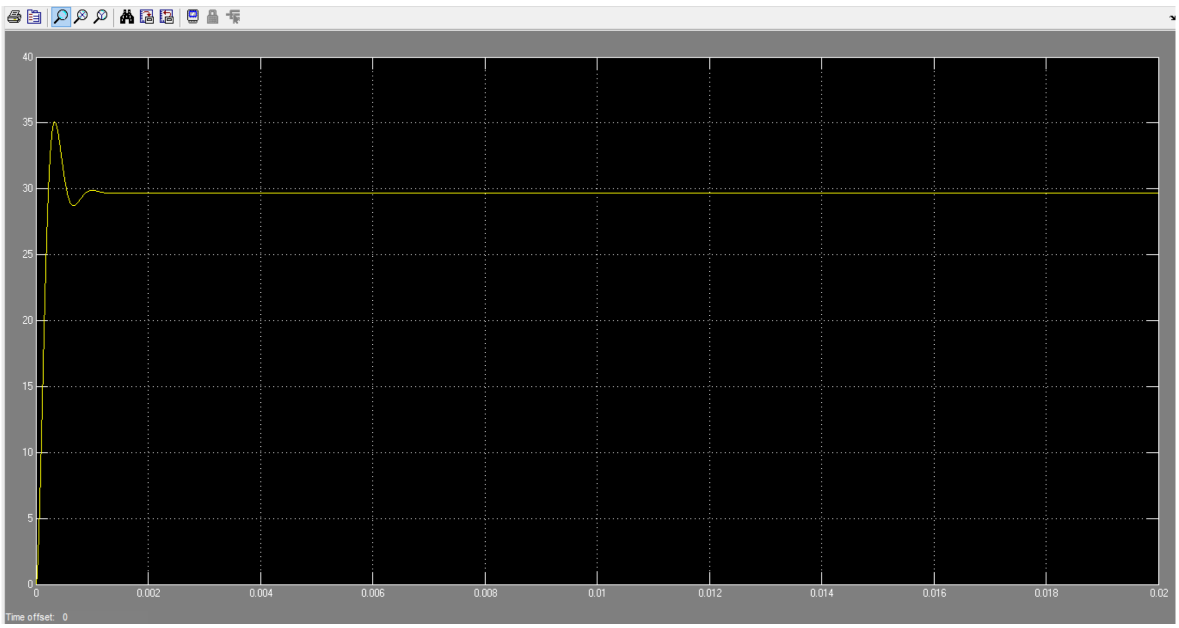

Fig.12.Output voltage response of dc buck converter without PI controller

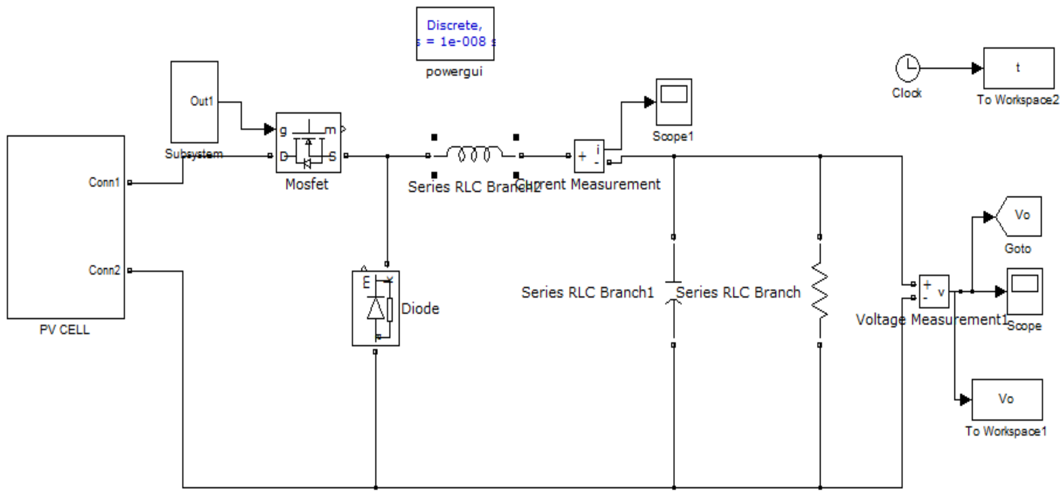

Fig.13.Simulation of dc buck converter with PI controller

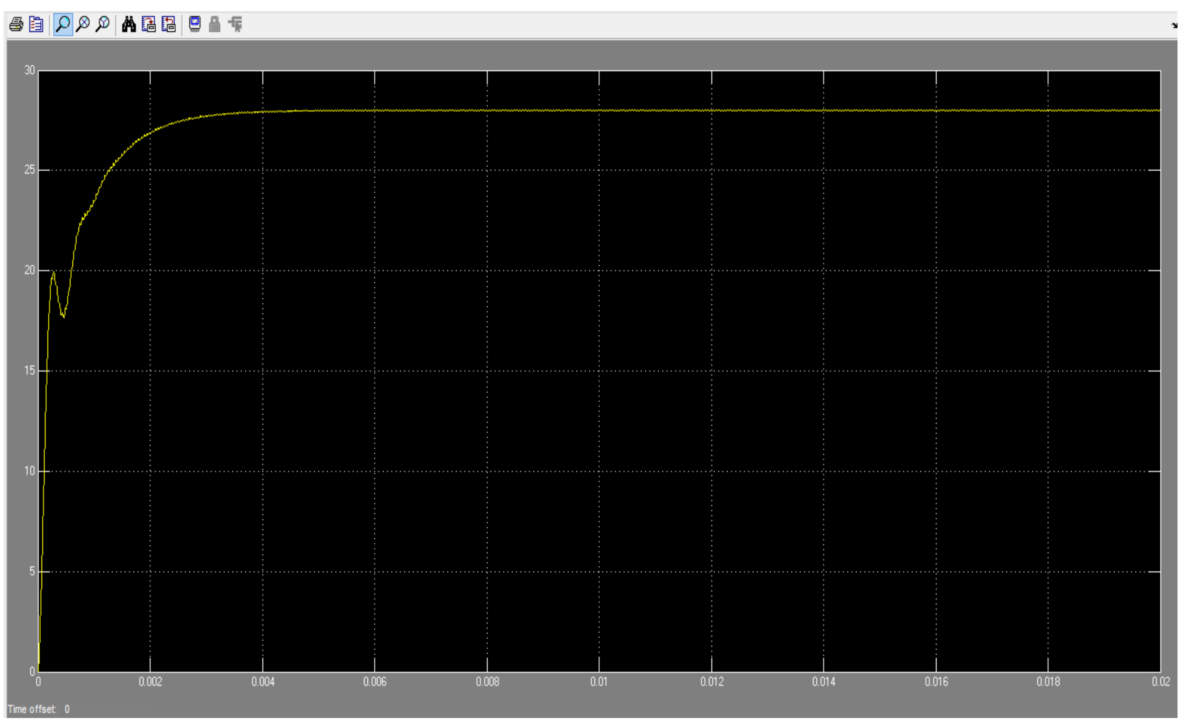

Fig.14.Output voltage of dc buck converter with PI controller

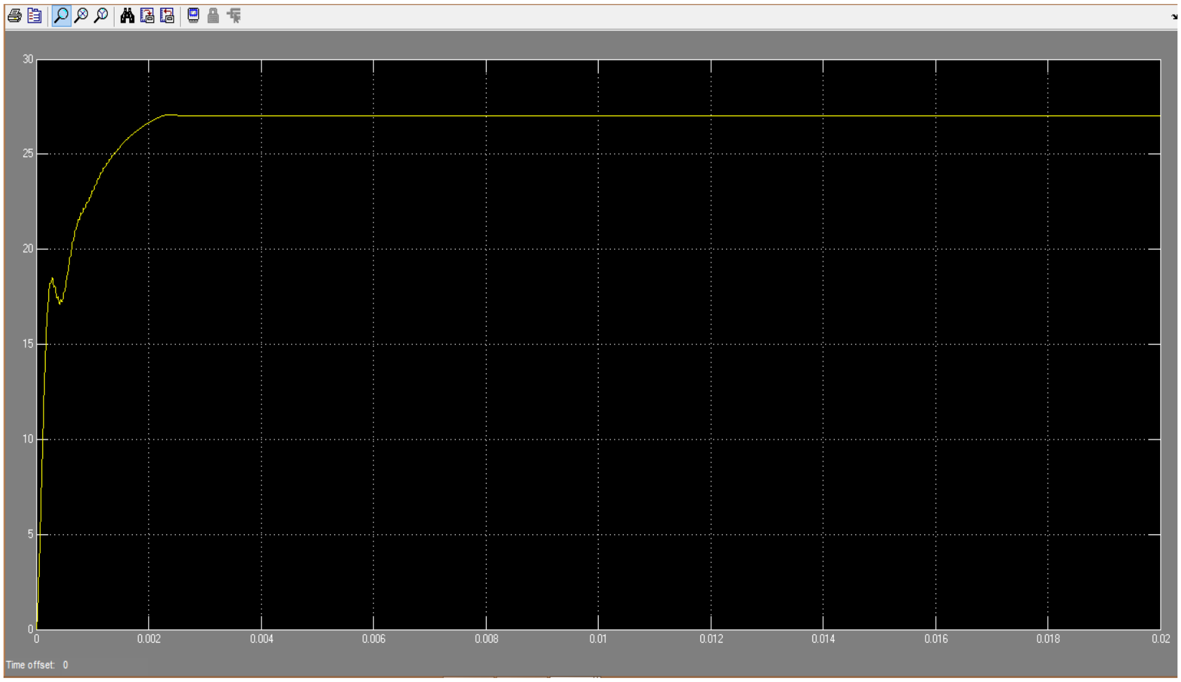

Fig.15.Output voltage response of system with resistance R in series with L

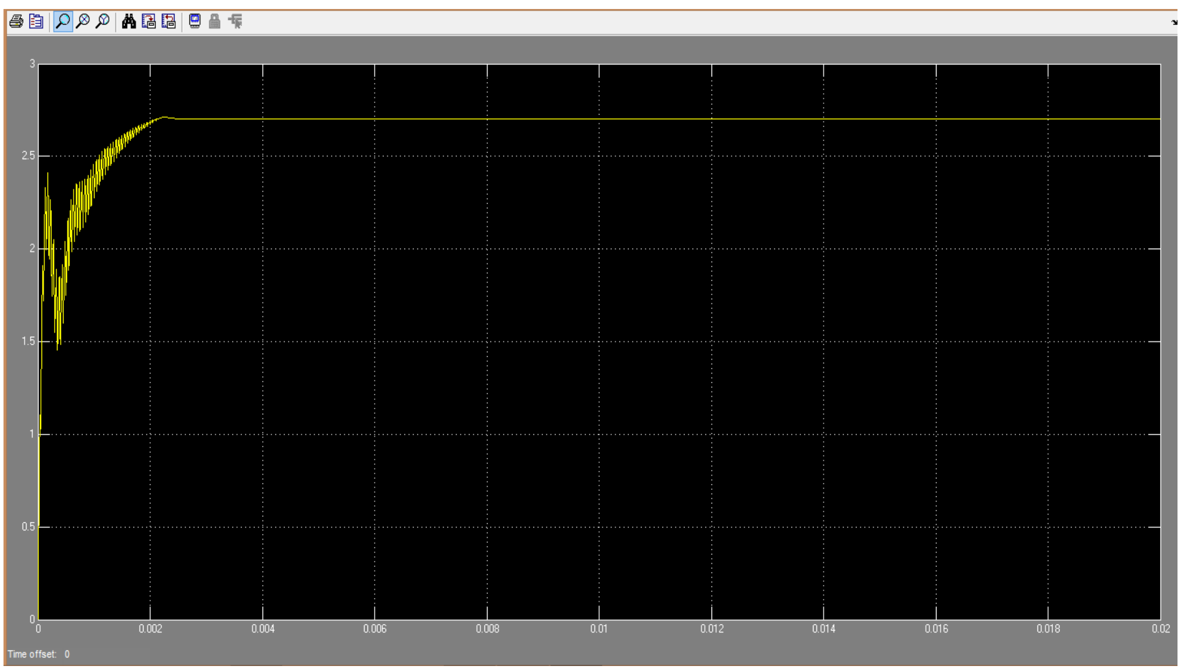

Fig.16.Inductor current when controller is connected

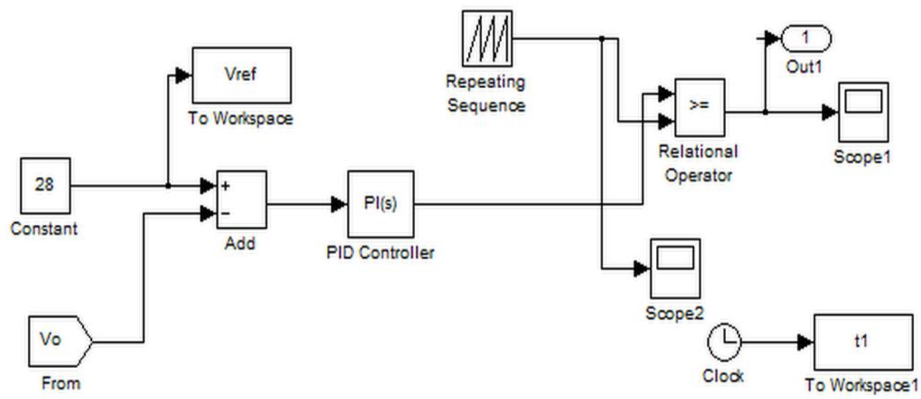

Fig.17.PI controller design

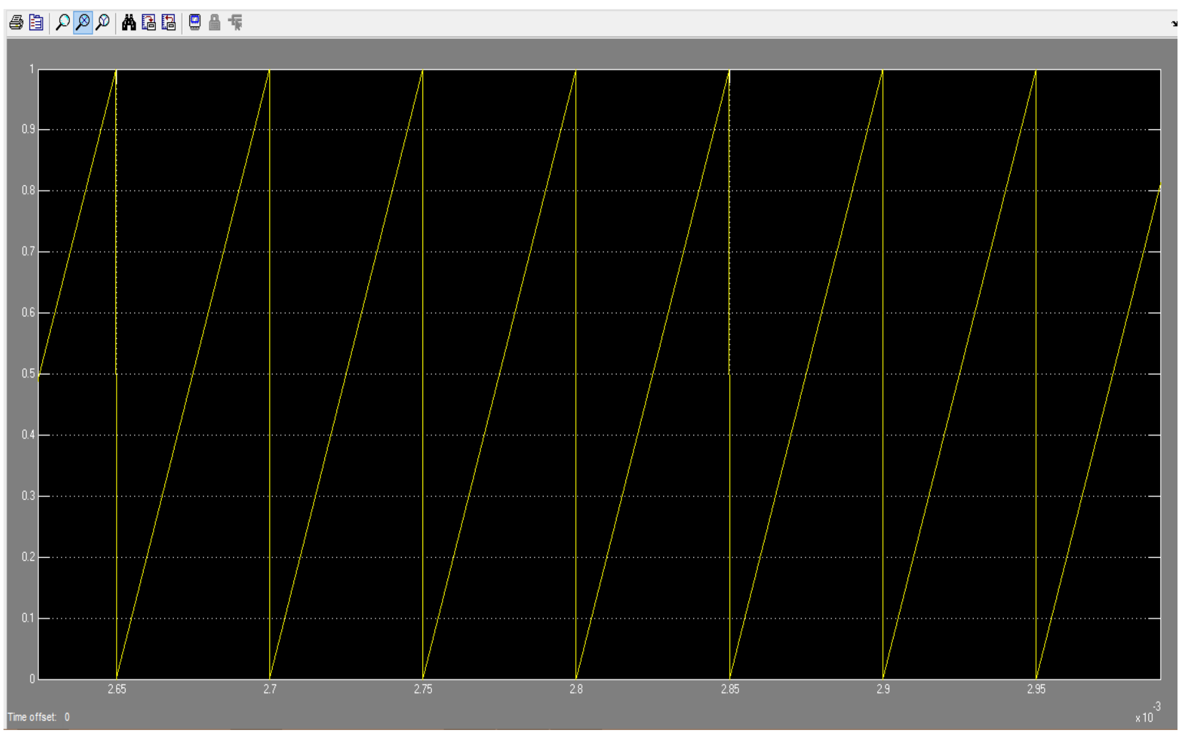

Fig.18.Sawtooth response given to system

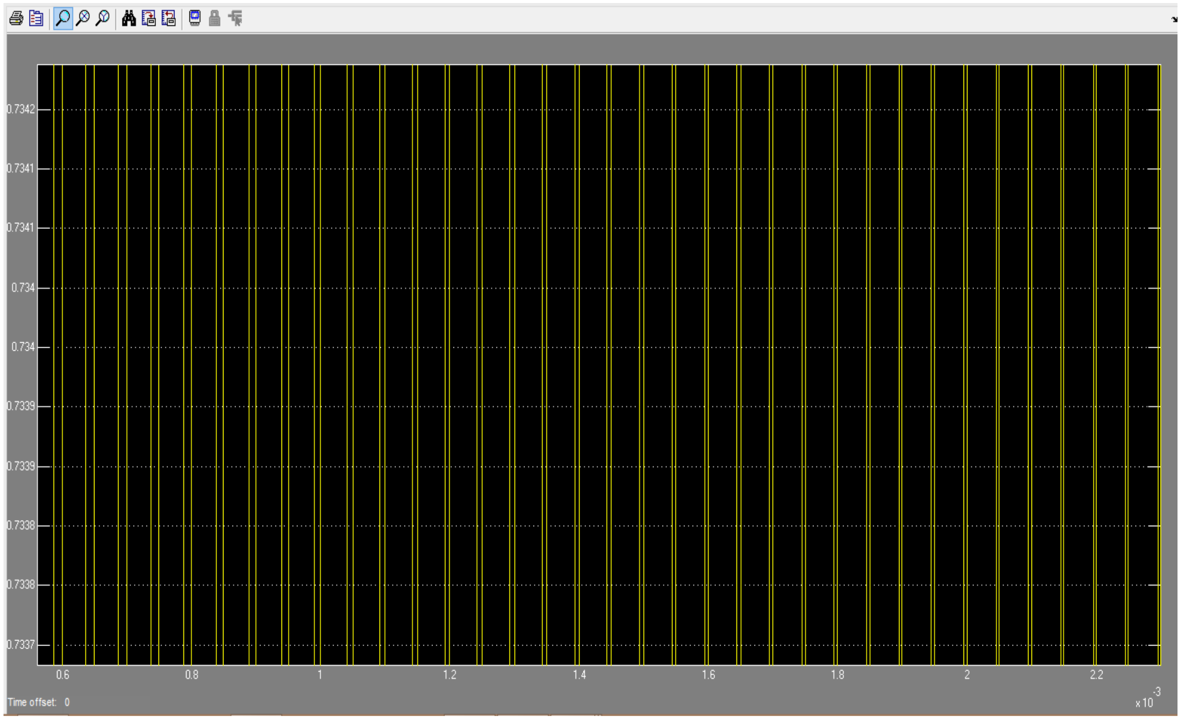

Fig.19.Pulses generated for switching

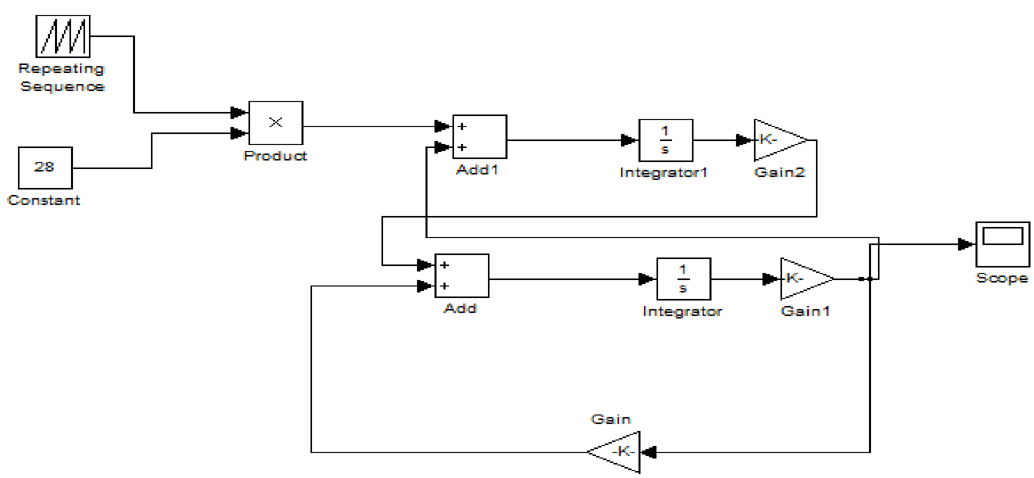

Fig.20.Steady state representation of DC buck converter

7.2. BODEPLOT FOR OBTAINED TRANSFER FUNCTION:

With PID Controller:

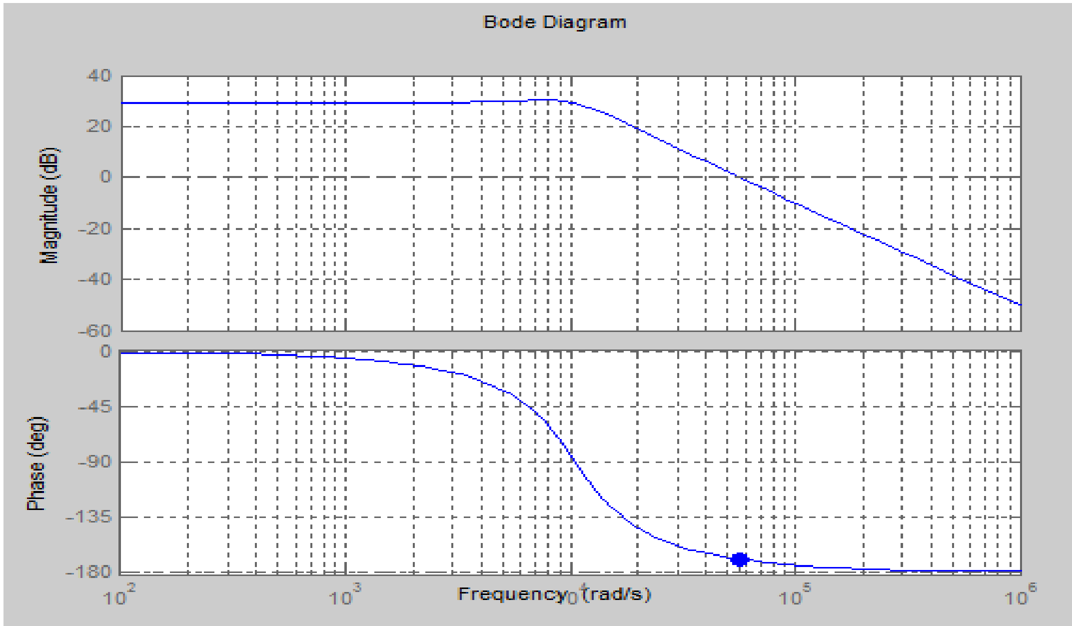

Fig.21.Bode plot of buck converter with PI controller

Without PID Controller:

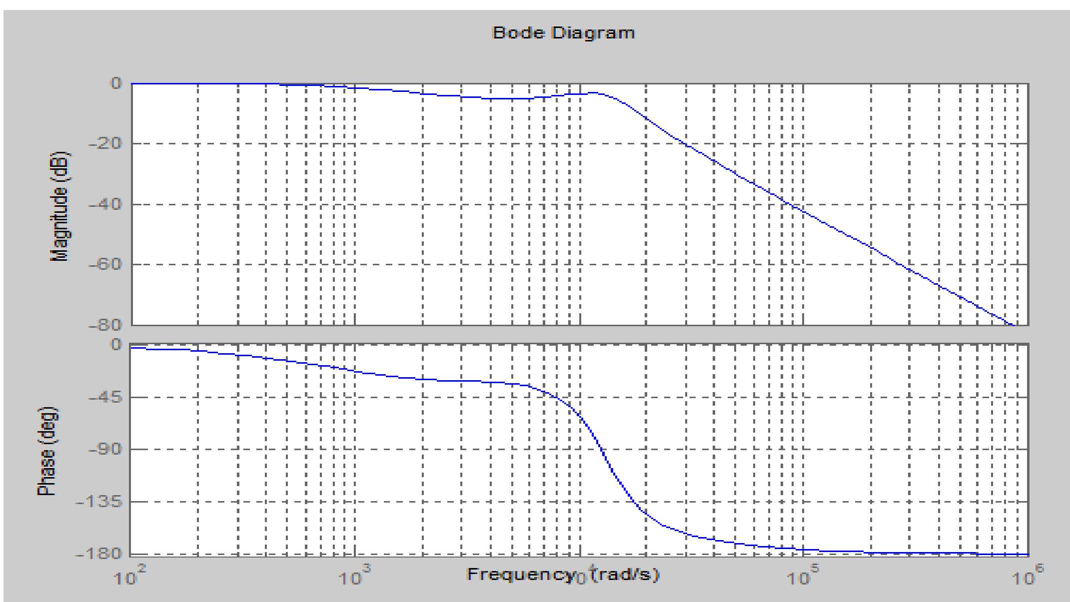

Fig.22.Bode plot of buck converter without PI controller

CHAPTER-8
CONCLUSION

The main purpose of dc buck converter is to step down the supply input voltage to the required level. The main function behind any controller in this system to obtain a good steady state response. Hence here we use conventional PI controller for this pupose which generates the required gate pulse for the given circuit and reduces peak overshoot and the rise time.

The function of photovoltaic cell which is a constant current source in this circuit provides the required potential to drive the dc buck converter. Some modifications have been done in the conventional circuit in order to minimize the harmonic contents present in the system and required constant steady state response is obtained.

Furthermore, if we use any variable structured controller or robust controllers, the response can be further increased and settling time can be reduced. Some of such controlling techniques are fuzzy logic, neural networks, genetic algorithm, sliding mode control, DSP etc.

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APPENDIX

PWM – Pulse Width Modulation

CCM – Continuous Conduction Mode

DCM – Discontinuous Conduction Mode

ESSC – External Method Of State System Centre

SMC – Sliding Mode Control

SMPO – Sliding Mode Parameter Observer

PI – Proportional Integral

PID – Proportional Integral Derivative

IGBT – Insulated Gate Bipolar Junction Transistor

ADC – Analog to Digital Converter

DSP – Digital Signal Processing

PV – Photovoltaic

VSS – Voltage Structure System

MPPT – Maximum Power Point Tracking

SEPIC – Single Ended Primary Inductance Converter

PFM – Pulse Frequency modulation

AOT – Adaptive On Time

PSP – Phase Shift Pulse

ZVS – Zero Voltage Switching

ZVT – Zero Voltage Transition