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Design of Buck-Boost Converter for Solar Panels using PID Controller

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Abstract: Currently, there are plenty of technological applications that utilize natural, environmental-friendly sources of energy. However, a disadvantage often found in natural energy sources is that the intensity produced is uncertain. This occurrence is also found in solar panels, wherein the light intensity that enters is not always equal. Light intensity may be affected by various factors such as ones on gloomy or sunny weathers. This irregularity on light intensity leads to deviation of voltage output produced by the solar panel. With the use of buck-boost converters, the amount of output voltage may be set to higher or lower than the input voltage, enabling us to maintain the desired output voltage. The amount of output voltage produced is controlled by a microcontroller program which regulates pulse widths produced by PWM signals. This paper discusses about designing a buck-boost converter for solar panels, with a voltage input range of 10 to 30 V. The regulation of output voltage is the main aim in analysing the success of the design created. The design is simulated with MATLAB12, and yields a voltage output with an efficiency90 to 99%.

Keywords: Pulse Width Modulation, Buck Boost converter, PID Controller, Solar panel.

I. INTRODUCTION

Every Electronic circuit is assumed to operate some supply voltage which is usually assumed to be constant in nature.A voltage regulator is a power electronic circuit that maintains a constant output voltage irrespective of change in load current or line voltage. Many different types of voltage regulators with a variety of control schemes are used. With the increase in circuit complexity and improved technology a more severe requirement for accurate and fast regulation is desired. This has led to need for newer and more reliable design of dc-dc converters.The dc-dc converter inputs an unregulated dc voltage input and outputs a constant or regulated voltage. The regulators can be mainly classified into linear and switching regulators. All regulators have a power transfer stage and a control circuitry to sense the output voltage and adjust the power transfer stage to maintain the constant output voltage. Since a feedback loop is necessary to maintain regulation, some type of compensation is required to maintain loop stability. Compensation techniques vary for different control schemes and a small signal analysis of system is necessary to design a stable compensation circuit.State space analysis is typically used to develop a small signal model of a converter and then depending on the type of control scheme used, the small signal model of converter is modified to facilitate the design of the compensation network. In contrast to a state space approach, PWM switch modeling develops a small signal of switching components of converter.

1.1. DC-DC CONVERTER

DC–DC converters are power electronic circuits that convert a dc voltage to a different voltage level. There are different types of conversion method such as electronic, linear, switched mode, magnetic, capacitive. The circuits described in this report are classified as switched mode DC-DC converters. These are electronic devices that are used whenever change of DC electrical power from one voltage level to another is needed. Generically speaking the use of a switch or switches for the purpose of power conversion can be regarded as an SMPS. A few applications of interest of DC-DC converters are where 5V DC on a personal computer motherboard must be stepped down to 3V, 2V or less for one of the latest CPU chips; where 1.5V from a single cell must be stepped up to 5V or more, to operate electronic circuitry. In all of these applications, we want to change the DC energy from one voltage level to another, while wasting as little as possible in the process. In other words, we want to perform the conversion with the highest possible efficiency.

1.2 BUCK BOOST CONVERTER

A typical buck-boost DC/DC circuit allows the input DC voltage to be either stepped-up or stepped-down, depending on the duty cycle. The output voltage is given as:

$V_{OUT} = -V_{IN} * D/(1-D)$ (FIG 1.1).

As seen from the equation above, the output voltage is always reversed in polarity with respect to the input. Hence, a buck-boost converter is also known as a voltage inverter.

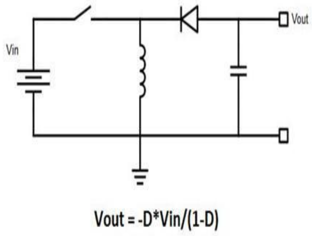


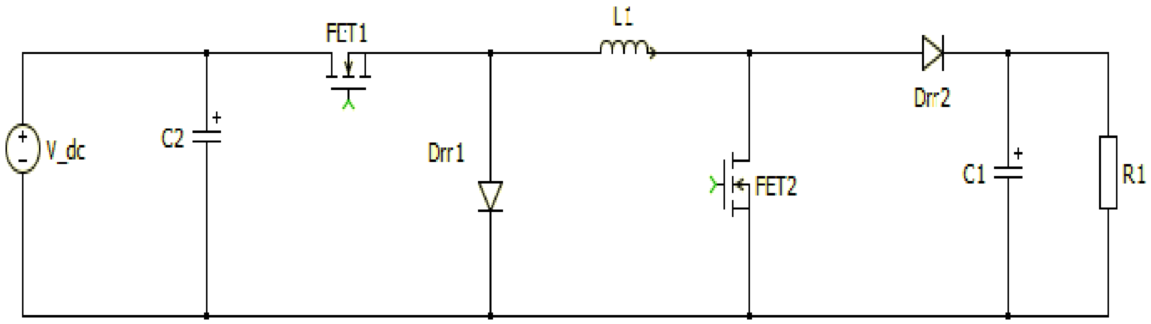
Fig 1.2: A typical buck-boost DC/DC converter topology.

II. DESIGN OF CONVERTERS

Buck-boost (step-down and step-up) converters are widely used in industrial personal computers (IPCs), point-of-sale (POS) systems, and automotive start-stop systems. In these applications, the input voltage could be either higher or lower than the desired output voltage. A basic inverting buck-boost converter has a negative output voltage with respect to ground. The single-end primaryinductor converter (SEPIC), Zeta converter and two-switch buck-boost converters have positive or non-inverting outputs. However, compared with a basic inverting buck-boost converter, all three non-inverting topologies have additional power components and reduced efficiency. This article presents operational principles, current stress and power-loss analysis of these buck-boost converters, and presents design criteria for an efficient non-inverting buck-boost converter.

2.1. TWO-SWITCHBUCK-BOOST CONVERTER

The two-switch buck-boost converter is a cascaded combination of a buck converter followed by a boost converter. Besides the aforementioned buck-boost mode, wherein Q1 and Q2 have identical gate-control signals, the two-switch buck-boost converter also can operate in either buck or boost mode. By operating the converter in buck mode when VINis higher than VOUT , and in boost mode when VIN is lower than VOUT, the buck-boost function is then realized.



2.2. IMPLEMENTATION OF AN EFFICIENT TWO-SWITCH BUCK- BOOST CONVERTER

The two-switch buck-boost converter can function in buck-boost, buck or boost modes of operation. Various combinations of operating modes can be used to accomplish both a step-up and step-down function. Appropriate control circuitry is required to ensure the desired modes of operation. Table 1 summarizes a comparison between four different combinations of operating modes. The buck boost mode alone features the simplest control, but has low efficiency for both step-up and step-down conversion over the VIN range.

0perating modes	Control complexity	Efficiency (Vin>Vout)	Efficiency (Vin<Vout)
Buck-Boost	simple	Low	Low
Buck and Buck-Boost	moderate	High	Low
Boost and Buck-Boost	moderate	Low	High
Buck ,Boost, Buck-Boost	complex	High	High

Table 2.2 Comparison of the buck boost topologies

The combination of buck, buck-boost and boost modes has the potential to achieve high efficiency over the VIN range. However, its control is very complicated due to multiple modes of operation and the resulting transitions between different modes. In many applications, the input voltage usually drops below output for only a short period of time. In such applications, the efficiency of step-up con version is not as critical as step-down conversion. As such, the combination of buck and buck-boost modes is a good trade-off between control complexity and efficiency

III. CONSTRUCTION AND ANALYSIS OF CONVERTER

3.1 CONSTRUCTION OF BUCK BOOST CONVERTER

Most of the electrical and electronic technologies require voltages of differing levels supplied from a single available source voltage such as a battery thus direct current circuits present a different challenges when one DC source voltage is available and another voltage level is required. In addition to this, there is a need to supply a regulated load voltage for a variable input battery voltage source is a very essential need for portable applications like cellular phones, personal digital assistants (PDAs), DSL modems (digital subscriber line), and digital cameras. Linear power supply provides a regulated DC voltage without employing switching technique. The linear power supplies a simple and cost effective for a low power ratings and absence of EMI (electromagnetic interference/ noise) but these power supplies uses large transformer there by space occupied is more, there efficiency is very low (30-60%) and also power is dissipated in the form of heat. Switching power supply employs switching techniques to avail a constant DC output voltage. Switching power supplies are very important in DC powered applications. Now days due to advancement in Electronics more and more research is happening in SMPCs that to switch mode power supplies with tight regulations. The efficiency of the power supply is high, they are smaller in size hence are adaptable for space constrained environments. In SMPCs the changeover of DC voltage from one level to another is generally accomplished by means of DC/DC power converter circuits. The power converter serves as a dc transformers. There are two basic power converters such as buck converter and the other is a boost converter

3.2 ANALYSIS OF NONINVERTING BUCK-BOOST CONVERTER

The supply system shown above is the figure of a switch mode power supply system, the DC input is been connected to the dc-dc converter to give a regulated dc supply to the load. The dc-dc converter is been controlled by a controller. Dc source may be a battery, unregulated dc supply source (obtained from the rectification of the ac line voltage), solar cell etc., these sources provides an unregulated voltage. This unregulated voltage is regulated by means of a dc-dc Converter. DC to DC converter is a device that provides a varying voltage levels different than that supplied. These DC-DC converters are made to avail the needed voltage then the regulated voltage is supplied to the load. The controller controls the power circuit of the supply system. The signals to controller are supplied from the input and the output of converter circuit. Thus the controller controls the pulse signal of the switch based on its input and output voltage. Based on the input signals across the controller the pwm signals to the switches are generated. The operation of non-inverting circuit in buck/boost mode is based on the signals generated from the controller circuit. Various DC to DC converter circuits are designed with different operating characteristics depending on the required application.

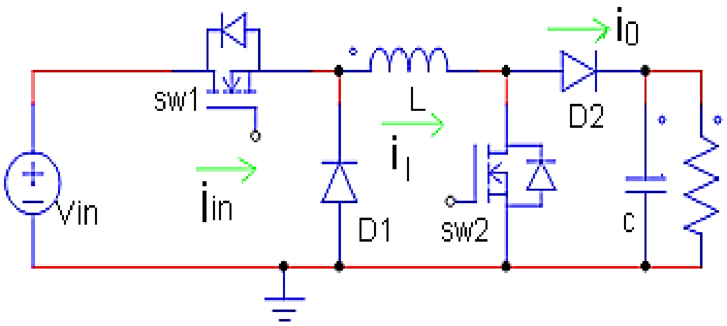


Fig 3.2(1) Non invertingbuck-boost converter.

IV. OPERATING MODES

4.1.A Buck Mode

The buck converter steps down the output voltage. The switch (Sw1) is controlled through the gate pulses, sw2 is completely OFF, D is completely ON. The buck operates in two modes namely sw1 is on and when sw1 is off. The average output voltage is calculated in terms of duty cycle. The duty cycle is given by

$$D = \frac{v_0}{v_{in}}$$

4.1.B Charging Mode

The operation of the circuit is described as follows, when the switch is closed the input voltage Vin causes the diode D1 to go into the reverse bias region and hence it is open.The equivalent circuit is as shown in fig3.thus the inductor charges lineraly. The input supplies the load. The voltage across the inductor is given as follows

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$$v_L = v_{in} - v_0$$

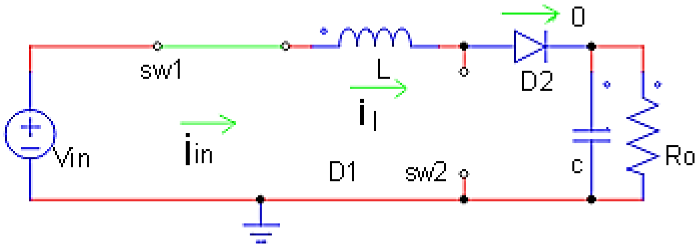

Fig 4.1.B. Equivalent circuit of converter in buck mode with switch1 closed
The equivalent circuit of converter in buck mode with switch (Sw1) closed.

4.1.CDischarging Mode

The operation of the circuit is described as follows, based on duty cycle the switch will be off for 1-DT time period. Due to inductor voltage diode D1 starts conducting thus inductor starts discharges energy stored during switch1 ON. The voltage across the inductor is given by

$$v_L = -v_0$$

The equivalent circuit of converter in buck mode with switch (Sw1) opened is shown in fig4.

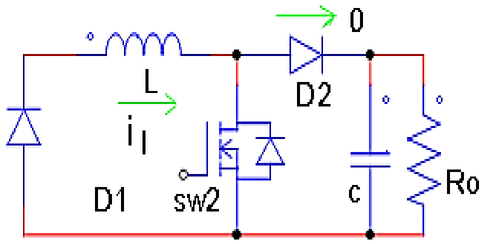

Fig 4.1.C Equivalent circuit of converter in buck mode with switch1 open

4.2.A. Boost Mode

Boost converter always step up the output voltage. In this mode the Sw1 will be continuously on while D1 is off whereas the Sw2 will be given with the controlled gate pulses, the boost converter operates in two modes based on sw2 ON or OFF. The average output voltage is calculated in terms of duty cycle. The duty cycle is given by

$$D = 1 - \frac{v_{in}}{v_0}$$

4.2.B Charging Mode

The operation of the circuit is described as follows, when sw2 is closed the diode D2 is reverse biased and the current flows only through the inductor and the switch. Thus the energy is stored in the inductor. The cycle repeats when the switch is turned on again. The voltage across the inductor is given by

$$v_L = v_{in}$$

The equivalent circuit of converter in buck-boost mode with switch (Sw2) closed.

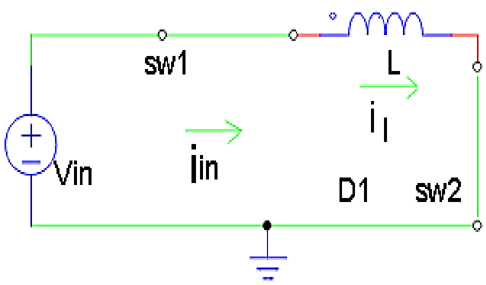

Fig 4.2.B. Equivalent circuit of converter in boost mode when Sw1 and sw21 are closed.

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4.2.C Discharging Mode:

The operation of the circuit is described as follows, at t=DT, the switch goes off and the equivalent circuit is as shown in fig 6. Now D2 will be forward-biased. The input current along with current accumulated in the inductor then starts flowing through the diode as well as load. The cycle repeats when the switch is turned on again. The voltage across the inductor is given by

$$v_L = v_{in} - v_0 \quad (3.6)$$

The equivalent circuit of converter in boost mode with switch (Sw2) open .

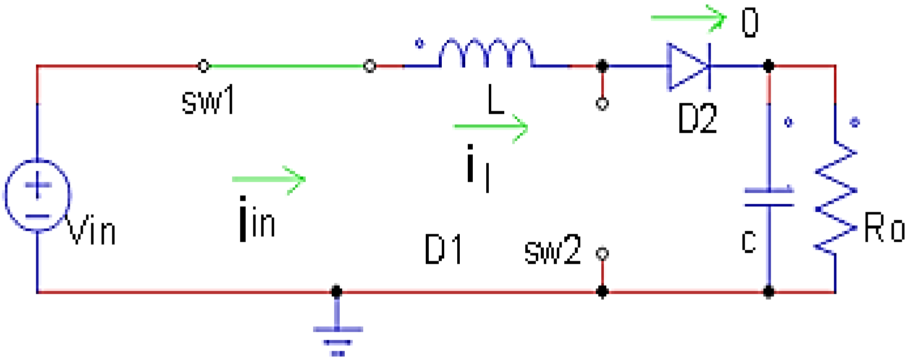

Fig 4.2.C. Equivalent circuit of converter in boost mode when sw2 opened.

V. SIMULATION WORK

5.1 OPEN LOOP CONTROL

In order to validate the performance of the Buck-Boost converter, the system is designed with the source modeling in MATLAB /Simulink and the experimental waveforms are obtained. The performance of the converter is studied under steady state condition. The performances of the converter are validated with the models to their efficiency conditions.

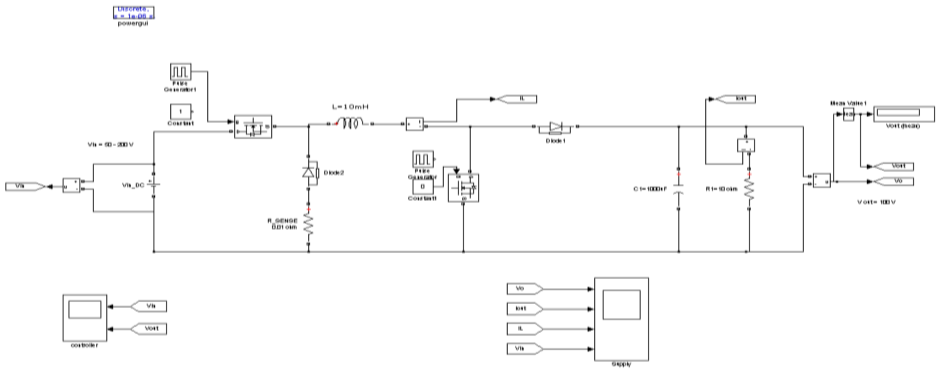

Fig 5.1.A shows the simulation diagram of the buck-boost converter, which consists of two power switches (S1 and S2), two diodes (D1 and D0), single inductors (L1), and one resistive load R.

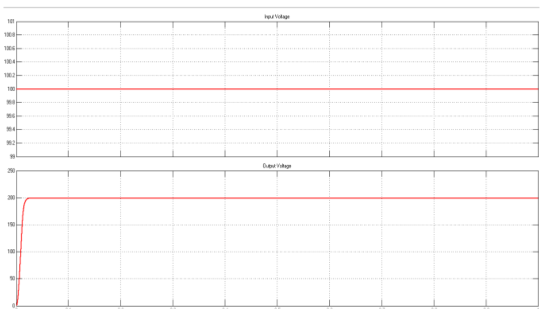

Fig. 5.1.B shows the Input and the Output voltage of the buck boost converter in boost mode.Y axis denoted as buck Voltage and the X axis denoted as Time. It provides a boost operation with Vin= 100V and Vout=200 V.

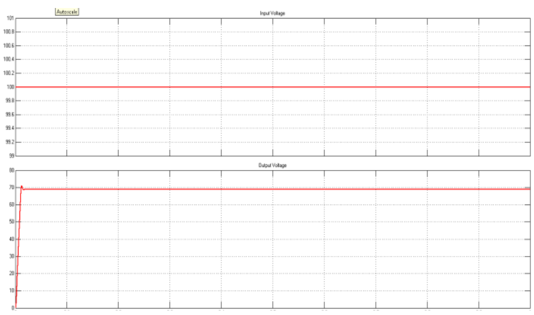

Fig. 5.1.C shows the Input and the Output voltage of the boost converter in buck mode. Yaxis is denoted as Voltage and the X axis denoted as Time. It provides a boostoperation with Vin=100 and Vout=70V

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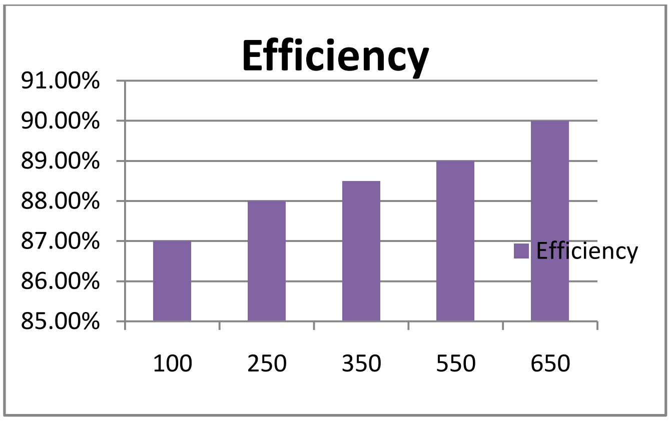

Fig. 5.1.D shows the efficiencies versus Power from 100 to 650. From this Fig, it is obvious that the efficiency in step-up mode is higher than step-down mode and the experimental highest efficiency can be reached 90%.

5.2.CLOSED LOOP CONTROL

In order to obtain a stable output voltage, the PID controller is applied for the proposed buck-boost converter, and the dynamic behaviors are also carried out.

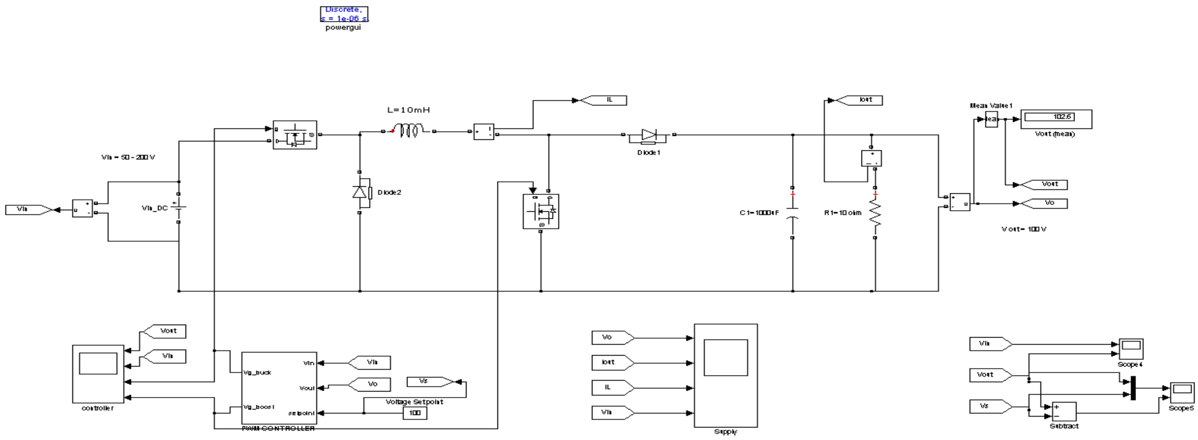

Fig 5.2.A shows the simulation diagram of the buck-boost converter with PID controller.

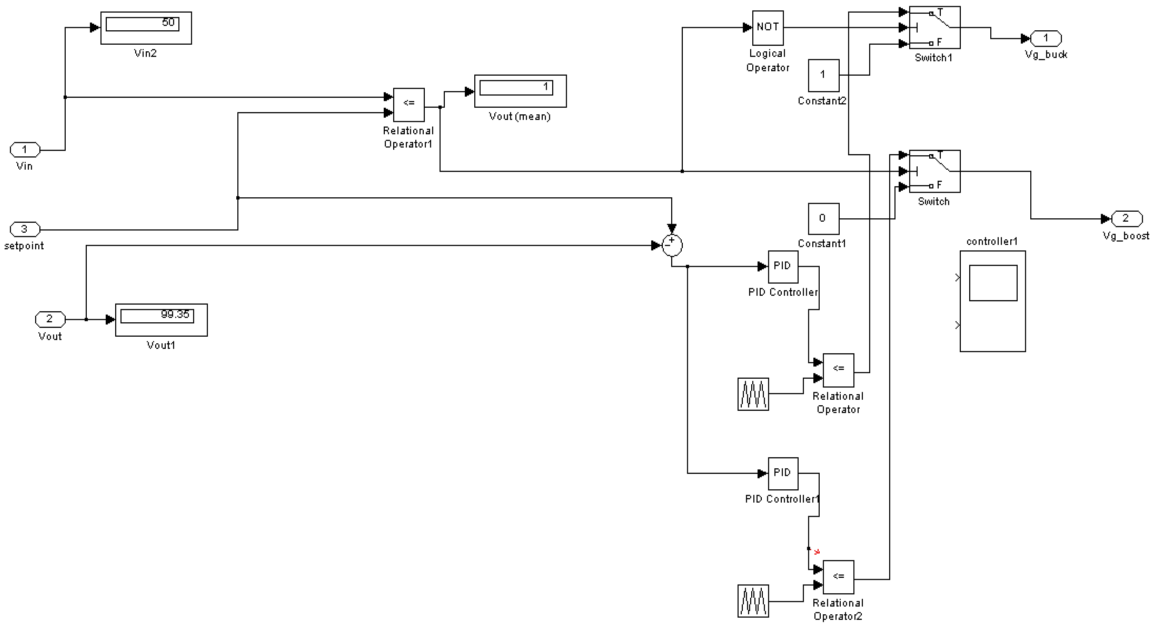

Fig 5.2.B shows the control block of the proposed method.

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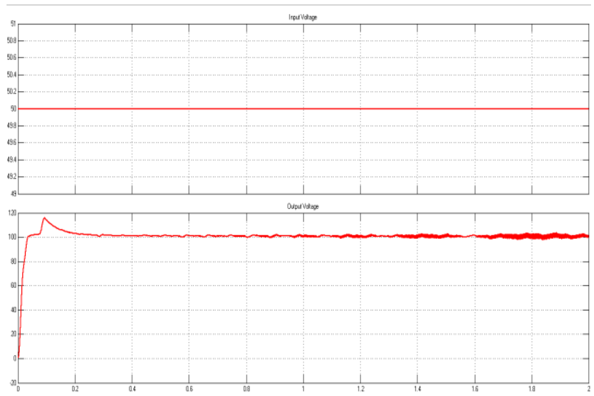


Fig. 5.2.C shows the Input and the Output voltage of the buckboost converter with PID controller in boost mode Y axis denoted as Voltage and the X axis denoted as Time. It provides a boost operation with Vin= 50V,Vout=100V.

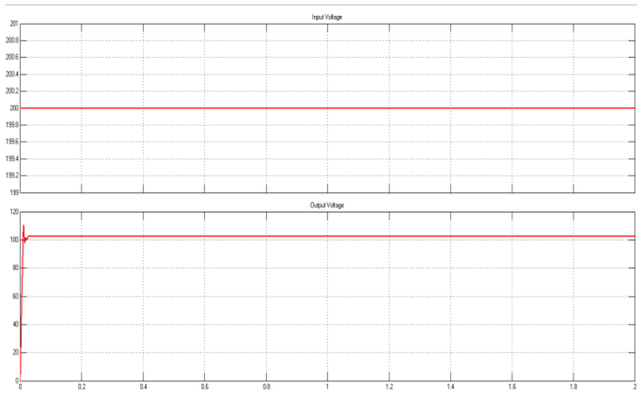


Fig. 5.2.D shows the Input and the Output voltage of the buck boost converter with PID controller in buck mode. Y axis denoted as Voltage and the X axis denote as Time. It provides a boost operation with Vin=200V,Vout=100V

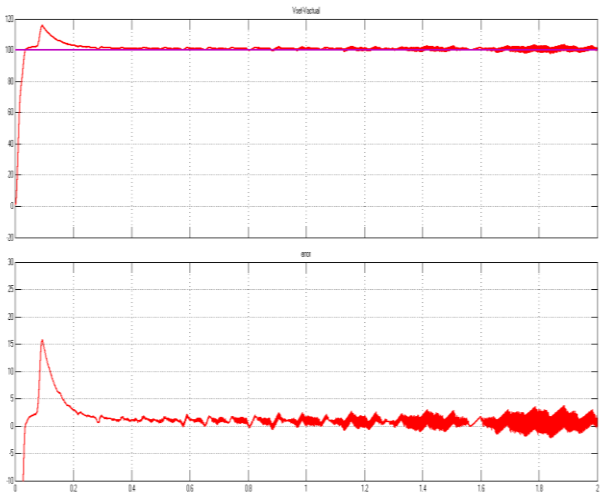
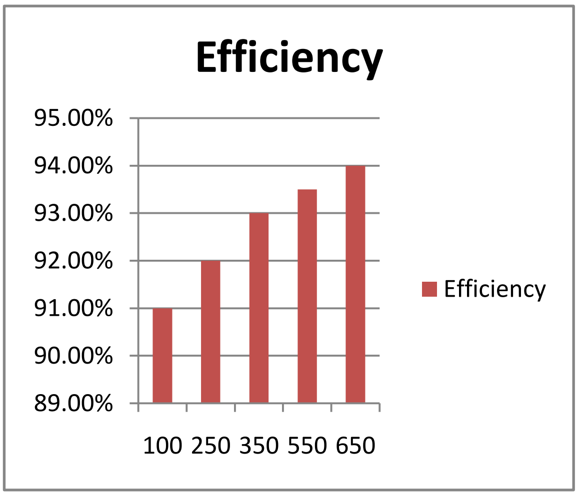


Fig 5.2.E represents the set point voltage, actual voltage and error. The set point voltage is 100V. The PID controller tries tomaintain the actual voltage at 100V.Thus the error is less than 2%



In this Fig. the efficiency in step-up mode is higher than step-down mode and the efficiency can be reached 94%.

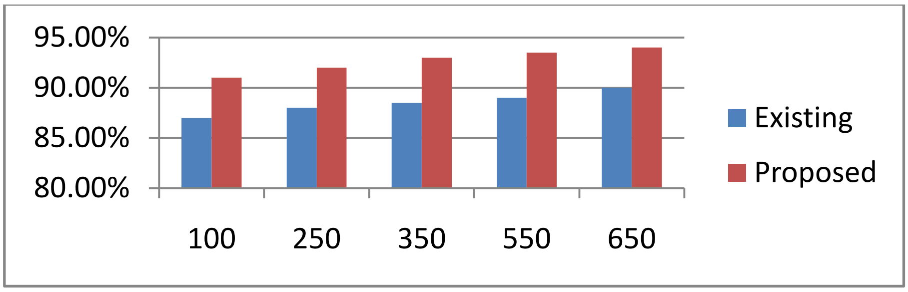


Fig 5.2.G shows the efficiency comparison between existing and proposed method.

VI. CONCLUSION

The design and the implementation of the buck boost converters has been carried out . The study of the converter under both buck and the boost modes are done , and the integration of the buckand boost with a 2 switch mode operation has been carried out. Results are obtained from the both the methods the boost and the buck converters show a better efficiency . To make the voltage output as constaht a closed loop control has been developed based on the PI controller where the dc output voltage has been made as constant from a set point voltage . The PI controller is validated with the integrated buck boost 2 switch converter the operation and the swapping of the control modes are been verified. The converter operates with a better efficiency under both the modes of operation and makes the converter efficient under

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both the cases . Finally a protype model has been built based on the observations of the matlabmodel , also provides the closed loop functions with a better voltage control with an error around 2%.

VII. FUTURESCOPE

The design of the buck boost converter with a 2 switch configuration has been carried out , the converter operation has been studied under various operating modes , the control of the converter has been done through a PI controller which settles the voltage with an error around 2% , which could be larger under critical limits . The settling time is also an another concern to be identified. Hence migrating towards advanced control schemes would be future scope to this work at this condition.

VIII. HARDWARE

REFERENCE

[1] Kazimierczuk, Marian. Pulse-Width Modulated DC-DC Power Converters. USA: Wright State University, 2008.
[2] J. Hong, H. Lee, K. Nam, ―Charging Method for the Secondary Battery in Dual-Inverter Drive Systems for Electric Vehicles,‖ IEEE Trans. Power Electronics, vol. 30, no. 2, pp. 909-921, Feb. 2015
[3] Wang Yuxi, Liu Wei, Ma Hao, Chen Longyu, ―Resonance Analysis and Soft-Switching Design of Isolated Boost Converter With Coupled Inductors for Vehicle Inverter Application,‖ IEEE Trans. Power Electronics, vol. 30, no. 3, pp. 1383-1392, March 2015.
[4] E. Chu, X. Hou, H. Zhang, M. Wu, X. Liu, ―Novel Zero-Voltage and Zero-Current Switching (ZVZCS) PWM Three-Level DC/DC Converter Using Output Coupled Inductor,‖ IEEE Trans. Power Electronics, vol. 29, no. 3, pp. 1103-1117, March 2014.
[5] E. M. Amiri, J. S. Moghani, G. B. Gharehpetian, S. S. H. Yazdi,―Novel Two Stage Buck-Boost Converter with Zero-Voltage- Transition operation,‖ in 5th Power Electronics, Drive Systems and Technologies Conf. (PEDSTC), Tehran, 2014, pp. 143 – 147.
[6] L. Kui-Jun, P. Byoung-Gun, K. Rae-young, H. Dong-seok, ―Nonisolated ZVT Two-Inductor Boost Converter with a Single Resonant Inductor for High Step-Up Applications,‖ IEEE Trans. Power Electronics, vol. 27, no. 4, pp. 1966 - 1973, April 2012.
[7] M. Pavlovsky, G. Guidi, A. Kawamura, ―Buck/Boost DC-DC Converter Topology with Soft Switching in the Whole Operating Region,‖ IEEE Trans. Power Electronics, vol. 29, no. 2, pp. 851-862, Feb. 2014.
[8] R. Lin, S. K. Chung, ―New Parallel ZVS Converter with Less Active Switches and Smaller Output Inductance,‖ IEEE Trans. on Power Electronics, vol. 29, no. 7, pp. 3297-3307, July 2014