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Implementation of PWM Soft Single Switched DC-DC Converters with Coupled Inductors

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ABSTRACT

This paper proposes a novel family of pulse width modulation of soft-single-switched dc-dc converters without high voltage and current stresses. These converters do not require any extra switch to achieve soft switching, which considerably simplifies the control circuit. In all converter family members, the switch is turned on under zero-current condition and is turned off at almost zero-voltage condition. From the proposed converter family, the boost topology is analyzed, and its operating modes are explained. The proposed circuit is simulated using MATLAB/Simulink.

Keywords: ***dc to dc converter, pwm, boost converter, pi controller***

I .INTRODUCTION

In order to reduce the size and weight of switching converters and increase power density, a high switching frequency is required. However, in hard-switching converters, as the switching frequency increases, switching losses and electromagnetic interference increase. To solve this problem, soft-switching converters are indispensable. In recent years, great amount of research is done to develop soft-switching techniques in dc-dc converters. In these converters, it is desirable to control the output voltage by pulse width modulation (PWM) because of its simplicity and constant frequency. A low number of components, particularly active components, is also desirable. Quasi-resonant converters do not have any extra switch to provide soft-switching conditions; however, they must be controlled by the variation of switching frequency. Furthermore, zero-voltage transition, zero-current transition, and active clamped converters are PWM controlled but require at least two switches, which increases the complexity of power and control circuits. PWM soft-single-switched (SSS) converters and lossless passive snubbers, enjoy all the mentioned advantages, usually at the cost of additional current and voltage stresses. However, they usually have a large number of passive elements, which makes the converter implementation difficult. The lossless passive snubber circuit is simple and easy to implement. However, in this converter, a soft-switching condition is not achieved for the switch turnoff instant. Furthermore, an additional diode is added in the main power path, which would further increase the converter conduction losses. In this project, a family of PWM SSS converters without any substantial increase in voltage and current stresses is presented. Furthermore, in this converter family, the number of additional components is not high. The switch in all proposed converters is turned on under zero-current-switching (ZCS) condition and is turned off at almost zero-voltage-switching (ZVS) condition. The converter main diode turns on under ZVS condition and turns off under zero-voltage zero-current switching (ZVZCS) conditions. Furthermore, an auxiliary diode turns on under ZVS condition and turns off under ZCS condition. The proposed method can be easily applied to single-switch converters such as buck, boost, and buck-boost. Cuk, SFP1C, and Zeta. Furthermore, it can be applied to isolated single-switch converters such as

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forward, Flyback, isolated CUK, isolated SFP1C, and isolated Zeta.

II DC-to-DC converter

DC to DC converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. Such electronic devices often contain several sub-circuits, each with its own voltage level requirement different than that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage, and possibly even negative voltage). Additionally, the battery voltage declines as its stored power is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing.

Most DC to DC converters also regulate the output voltage. Some exceptions include high-efficiency LED power sources, which are a kind of DC to DC converter that regulates the current through the LEDs, and simple charge pumps which double or triple the input voltage.

Linear Conversion methods

Linear regulators can only output at lower voltages from the input. They are very inefficient when the voltage drop is large and the current high as they dissipate as heat power equal to the product of the output current and the voltage drop; consequently they are not normally used for large-drop high-current applications.

The inefficiency wastes power and requires higher-rated, and consequently more expensive and larger, components. The heat dissipated by high-power supplies is a problem in itself as it must be removed from the circuitry to prevent unacceptable temperature rises.

They are practical if the current is low, the power dissipated being small, although it may still be a large fraction of the total power consumed. They are often used as part of a simple regulated power supply for higher currents: a transformer generates a voltage which, when rectified, is a little higher than that needed to bias the linear regulator. The linear regulator drops the excess voltage, reducing hum-generating ripple current and providing a constant output voltage independent of normal fluctuations of the unregulated input voltage from the transformer / bridge rectifier circuit and of the load current.

Linear regulators are inexpensive, reliable if good heat sinking is used and much simpler than switching regulators. As part of a power supply they may require a transformer, which is larger for a given power level than that required by a switch-mode power supply. Linear regulators can provide a very low-noise output voltage, and are very suitable for powering noise-sensitive low-power analog and radio frequency circuits. A popular design approach is to use an LDO, Low Drop-out Regulator, that provides a local "point of load" DC supply to a low power circuit.

Switched-mode conversion

Electronic switch-mode DC to DC converters convert one DC voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors). This conversion method is more power efficient (often 75% to 98%) than linear voltage regulation (which dissipates unwanted power as heat). This efficiency is beneficial to increasing the running time of battery operated devices. The efficiency has increased since the late 1980's due to the use of power FETs, which are able to switch at high frequency more efficiently than power bipolar transistors, which have more switching losses and require a more complex drive circuit. Another important innovation in DC-DC converters is the use of synchronous rectification which replaces the flywheel diode with a power FET with low "On" resistance, thereby reducing switching losses.

Most DC to DC converters are designed to move power in only one direction, from the input to the output.

However, all switching regulator topologies can be made bi-directional by replacing all diodes with independently controlled active rectification. A bi-directional converter can move power in either direction, which is useful in applications requiring regenerative braking.

Drawbacks of switching converters include complexity, electronic noise (EMI / RFI) and to some extent cost, although this has come down with advances in chip design.

DC to DC converters are now available as integrated circuits needing minimal additional components. DC to DC converters are also available as a complete hybrid circuit component, ready for use within an electronic assembly.

Magnetic

In these DC to DC converters, energy is periodically stored into and released from a magnetic field in an inductor or a transformer, typically in the range from 300 kHz to 10 MHz. By adjusting the duty cycle of the charging voltage (that is, the ratio of on/off time), the amount of power transferred can be controlled. Usually, this is done to control the output voltage, though it could be done to control the input current, the output current, or maintain a constant power. Transformer-based converters may provide isolation between the input and the output. In general, the term "DC to DC converter" refers to one of these switching converters. These circuits are the heart of a switched-mode power supply. Many topologies exist. This table shows the most common.

In addition, each topology may be:

- Hard switched - transistors switch quickly while exposed to both full voltage and full current.
- Resonant - an LC circuit shapes the voltage across the transistor and current through it so that the transistor switches when either the voltage or the current is zero.
- Magnetic DC to DC converters may be operated in two modes, according to the current in its main magnetic component (inductor or transformer):
- Continuous - the current fluctuates but never goes down to zero.
- Discontinuous - the current fluctuates during the cycle, going down to zero at or before the end of each cycle.

A converter may be designed to operate in Continuous mode at high power, and in Discontinuous mode at low power.

The Half bridge and Fly back topologies are similar in that energy stored in the magnetic core needs to be dissipated so that the core does not saturate. Power transmission in a fly back circuit is limited by the amount of energy that can be stored in the core, while forward circuits are usually limited by the I/V characteristics of the switches.

Although MOSFET switches can tolerate simultaneous full current and voltage (although thermal stress and electromigration can shorten the MTBF), bipolar switches generally can't so require the use of a snubber (or two).

Capacitive

Switched capacitor converters rely on alternately connecting capacitors to the input and output in differing topologies. For example, a switched-capacitor reducing converter might charge two capacitors in series and then discharge them in parallel. This would produce an output voltage of half the input voltage, but at twice the current (minus various inefficiencies). Because they operate on discrete quantities of charge, these are also sometimes referred to as charge pump converters. They are typically used in applications requiring relatively small amounts of current, as at higher current loads the increased efficiency and smaller size of switch-mode converters makes them a better choice.[citation needed] They are also used at extremely high voltages, as magnetics would break down at such voltages.

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Electrochemical

A further means of DC to DC conversion in the kW to many MW range is presented by using redox flow batteries such as the vanadium redox battery, although this technique has not been applied commercially to date.

Terminology

Step up - Also known as a Boost Converter, this is a converter that outputs a voltage higher than the input voltage.

Step down - A converter where output voltage is lower than the input voltage. ie. Buck Converter.

Continuous Current Mode - Current and thus the magnetic field in the energy storage never reach zero.

Discontinuous Current Mode - Current and thus the magnetic field in the energy storage may reach or cross zero.

Noise - since all properly designed DC to DC converters are completely inaudible, "noise" in discussing them always refers to unwanted electrical and electromagnetic signal noise.

Output Noise - the output of a DC to DC converter is designed to have a flat, constant output voltage. Unfortunately, all real DC to DC converters produce an output that constantly varies up and down from the nominal designed output voltage. This varying voltage on the output is the output noise. All DC to DC converters, including linear regulators, have some thermal output noise. Switching converters have, in addition, switching noise at the switching frequency and its harmonics. Some sensitive radio frequency and analog circuits require a power supply with so little noise that it can only be provided by a linear regulator. Many analog circuits require a power supply with relatively low noise, but can tolerate some of the less-noisy switching converters.

Input Noise - If input noise is not properly filtered, it could escape through long power lines as RF noise.

RF Noise - Switching converters inherently emit radio waves at the switching frequency and its harmonics. Switching converters that produce triangular switching current, such as the Split-Pi or Ćuk converter in continuous current mode, produce less harmonic noise than other switching converters .Linear converters produce practically no RF noise. Too much RF noise causes electromagnetic interference.

DC-DC Converters

There are three kinds of switching mode DC-DC converters, buck, boost and buck-boost. The buck mode is used to reduce output voltage, whilst the boost mode can increase the output voltage. In the buck-boost mode, the output voltage can be maintained either higher or lower than the source but in the opposite

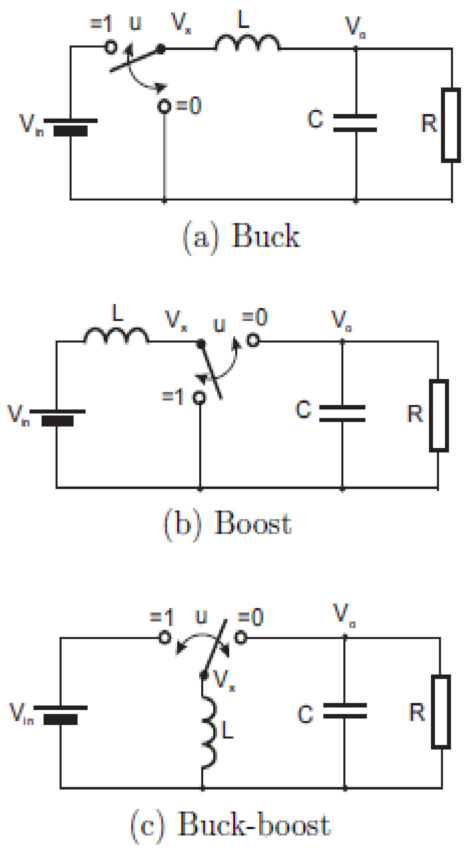

Fig.2.1. Buck, Boost, Buck-Boost Converter Equivalent Circuit Diagram.

PWM TECHNIQUES:

PWM techniques are characterized by constant amplitude pulses. The width of these pulses is modulated to obtain the inverter output voltage control and to reduce its harmonics.

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Pulse Width Modulation

Generate pulses for carrier-based two-level pulse width modulator (PWM) in converter bridge. The PWM Generator block generates pulses for carrier-based pulse width modulation (PWM) converters using two-level topology. The block can be used to fire the forced-commutated devices (FETs, GTOs, or IGBTs) of single-phase, two-phase, three-phase, two-level bridges or a combination of two three-phase bridges. The pulses are generated by comparing a triangular carrier waveform to a reference modulating signal.

The modulating signals can be generated by the PWM generator itself, or they can be a vector of external signals connected at the input of the block. One reference signal is needed to generate the pulses for a single- or a two-arm bridge, and three reference signals are needed to generate the pulses for a three-phase, single or double bridge.The amplitude (modulation), phase and frequency of the reference signals are set to control the output voltage (on the AC terminals) of the bridge connected to the PWM Generator block. The two pulses firing the two devices of a given arm bridge are complementary. For example, pulse 4 is low (0) when pulse 3 is high (1). This is illustrated in the next two figures. The following figure displays the two pulses generated by the PWM Generator block when it is programmed to control a one-arm bridge.

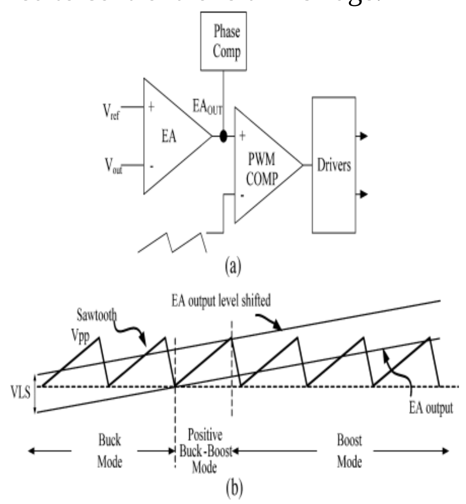

Fig.2.19. ***(a). General block diagram of error amplifier and drivers, (b). Operation modes.***

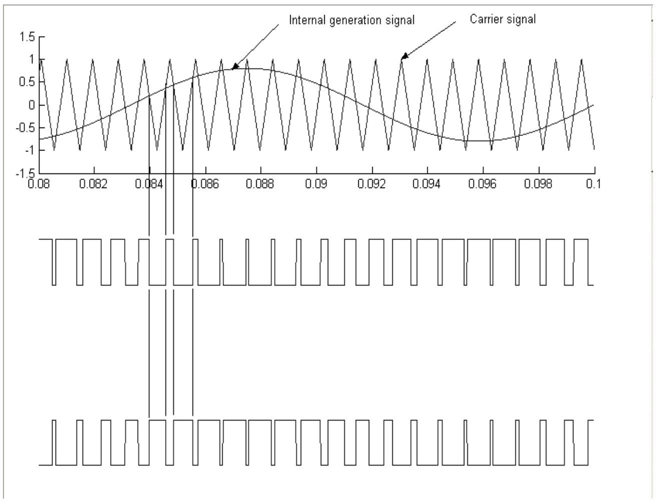

Fig.2.20. ***Pulse Width Modulation Technique***

The triangular carrier signal is compared with the sinusoidal modulating signal. When the modulating signal is greater than the carrier pulse 1 is high (1) and pulse 2 is low (0).For a single-phase two-arm bridge the modulating signal used for arm 2 is the negative of modulating signal used for arm 1 (180 degrees phase shift).

III ZERO VOLTAGE SWITCHING PWM CONVERTERS

As one of the typical resonant- type ZVS techniques, the ZVS-QRC technique eliminates the capacitive turn on loss which plagues zcs-QRCS and pwm converters. the drain-to-source voltage of the power MOSFET in a ZVS-QRC is shaped to zero prior to turn on, thus eliminating turn-on switching loss and the miller effect. In addition the active switch in a ZVS-QRC technique for high frequency conversion where MOSFETS are employed. however,the ZVS-QRC technique has several limitations first,the power switch in a single-ended ZVS-QRC suffers from a high voltage stress which is proportional to the load range. Using the buck ZVS-QRC as an example, for a 10% to 100% load range, the peak voltage stress of the power switch can be 11 times the input voltage. Therefore, a high voltage MOSFET accompanied by on resistance and large input capacitance has to be used, resulting in a substantial increase in conduction losses and the gate drive loss.

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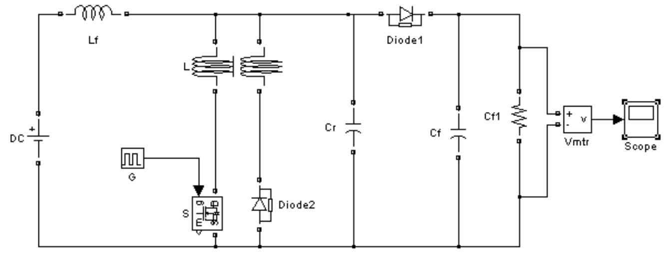
Second, a wide switching frequency range is required for ZVS-QRC to operate with a wide input voltage and load range. The wide frequency range makes optimization of the power transformer, input and output filters, control circuit, and gate drive circuit difficult. For example, to decrease the conduction loss power MOSFET's with a low on resistance are preferred. However, MOSFET'S with low on resistance are accompanied by large input capacitances which can cause significant drive losses at high frequency operation especially at high line and light load.

Another n limitation of the ZVS-QRC technique is severe parasitic ringing between the resonant inductor and the diode junction capacitance. Due to the presence of the large resonant inductor, this parasitic ringing is enhanced as compared to its PWM counterpart. In a practical circuit, the severe parasitic ringing not only increases switching loss and switching loss and switching noise, but may result in possible instability in the closed-loop system.

In principle, the voltage stress of the power switch in a ZVS-QRC can be reduced at the expense of a partial loss of ZVS at light load. This may not cause a thermal problem, since the switch conduction loss is low at light load. In a real circuit, however to operate a ZVS-QRC in an adequate frequency range, an external capacitor as part of the resonant capacitor usually needs to be placed in parallel with the power switch. In this case, the partial loss of the ZVS at light load may not be allowed, considering both high switching loss and high switching noise. In particular, the switching frequency increases as load current decreases, thus the capacitive turn-on loss can easily become intolerable at light load. With a wide load range, optimization of ZVS-QRCs is very difficult to achieve. Employing an auxiliary switch across the resonant inductor in a ZVS-QRC allows the new converter to operate with much reduced circulating energy and with a constant frequency. It is also shown that the use of a saturable inductor can further improve the performance of the proposed ZVS-PWM converters.



3.1 Proposed Circuit Diagram

IV SIMULATION RESULTS

The PWM controlled soft single switched boost converter circuit diagram as shown in the fig.5.1a. It is used to less DC voltage to high DC voltage with minimum switching loss and less voltage stress. 5.1b shows the input voltage and fig.5.1c shows the gate pulse and V_{ds} voltage across switch. fig 5.1d shows the output voltage and fig.5.1f shows the comparison graph between input (vs) output voltage.

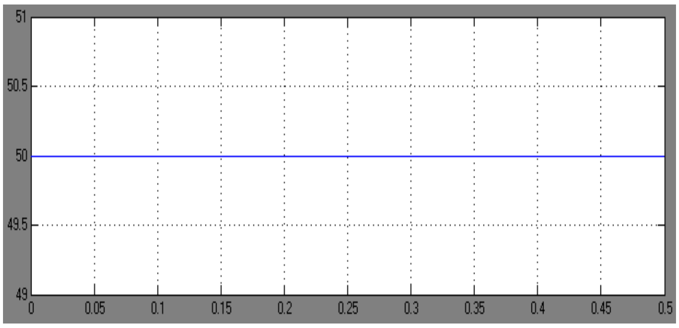


Fig.4.1b.Input DC Voltage

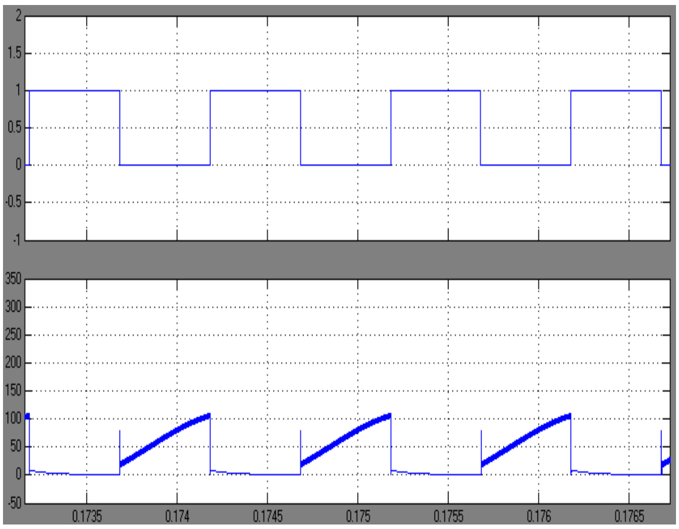


Fig4. 2.Switching Pulse (ii) Corresponding Voltage across the Switch

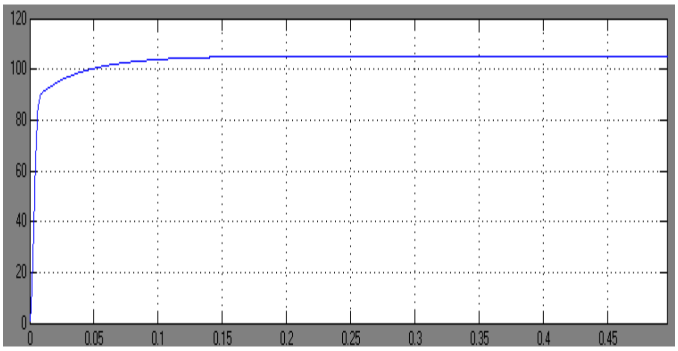


Fig.4.3 .Output Voltage

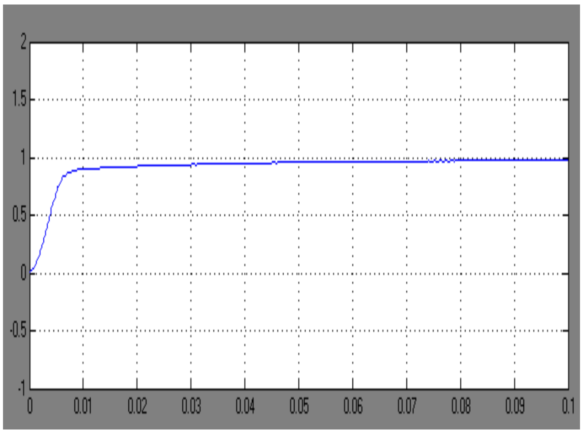


Fig.4.4.Output current

Voltage Stress:

In fig 5.2a and 5.2c shows the convention and propsed boost circuit diagram. Fig 5.2b and 5.2d shows the gate pulse and switch voltage for conventional and proposed circuit diagram. From fig 5.2b conventional circuit has high voltage stress and no ZVS switching. But fig 5.2d active the ZVS and low voltage stress across switch thus the proposed circuit reduce the voltage stress.

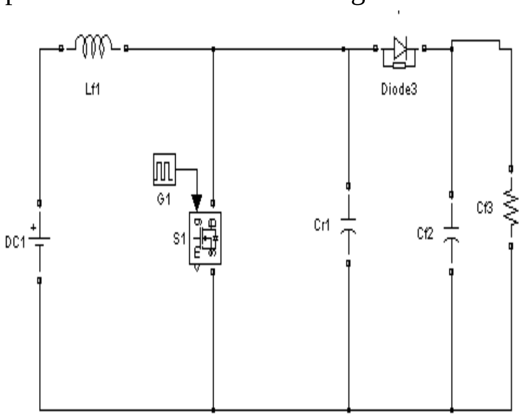


Fig4.5 .Conventional boost converter

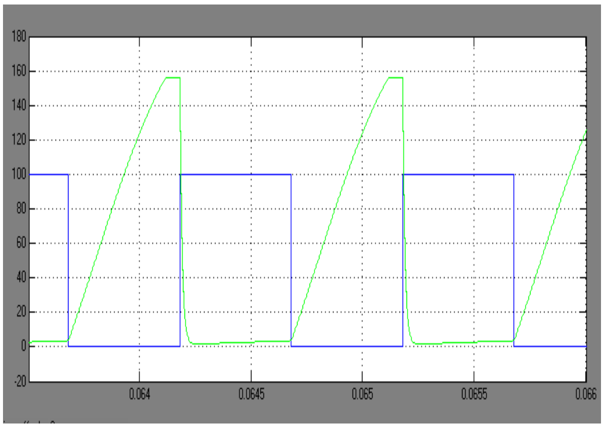


Fig.4.6 Gate pulse and Vds voltage

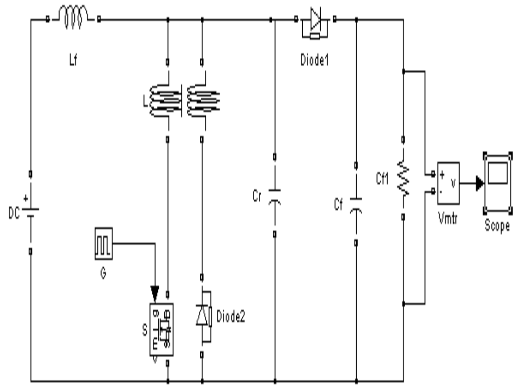


Fig.4.7 Proposed circuit diagram

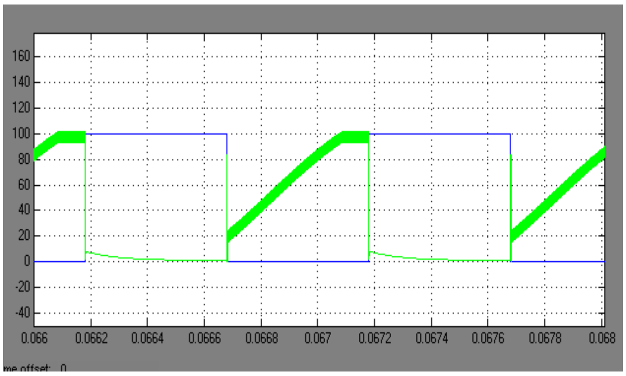


Fig.4.8 Gate pulse and Vds voltage

Open loop system:

The output voltage change with respect to input voltage. It is shown in fig. 5.3b and 5.3c. fig 5.3a shows the open loop system circuit diagram. In this circuit initially 50v is applied after 0.4 sec 10% voltage should be rised . thus changes shown in fig.

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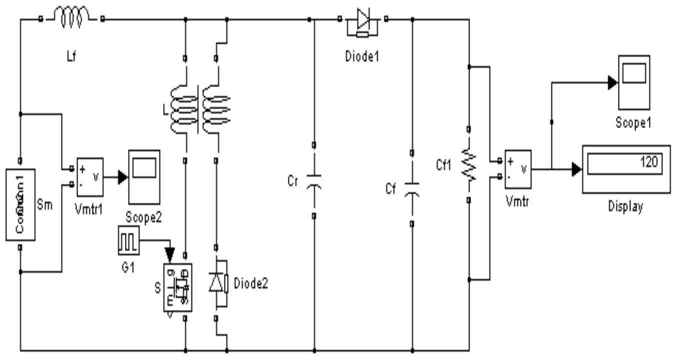

Fig.4.9 Open loop circuit Diagram

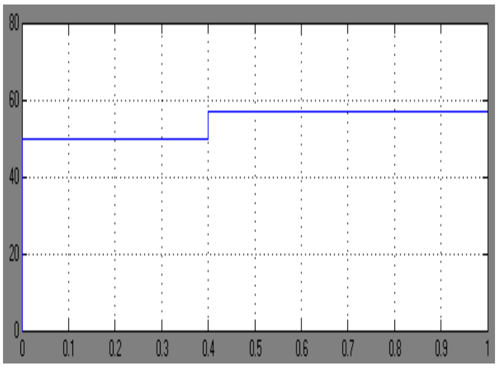

Fig.4. 10.Input voltage with Disturbance

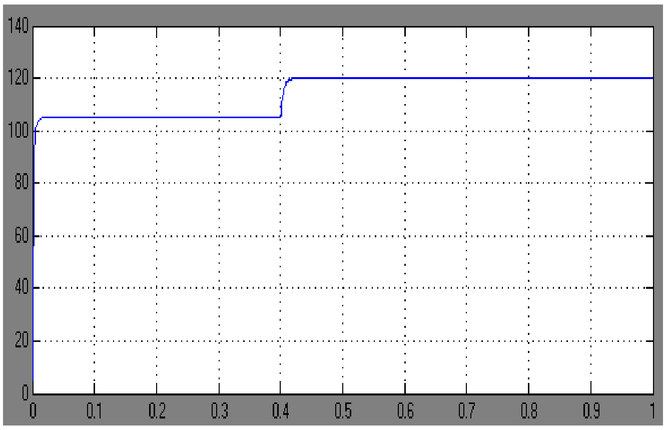

Fig.4.11 Output voltage with disturbance

Closed loop system:

Closed loop system is used to control the output voltage. The output voltage is compared with set value. Commparator gives the difference batween two signals it is called as error. Error signal is given to PI controller. PI controller adjust Kp and Ki gains based on the error signals. It is compared with one triangle carrier signal. It generates a PWM pulse. It is given to MOSFET thus PWM pulse is generated. It is control the output voltage.

Fig.5.4a shows the closed loop system and fig.5.4b shows the regulated output voltage with disturbance.

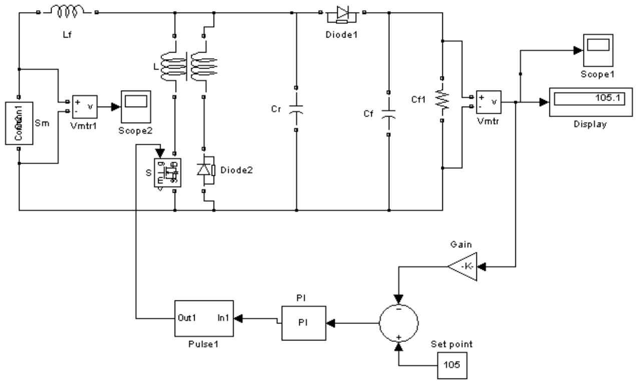

Fig4.12.Closed Loop Circuit Diagram

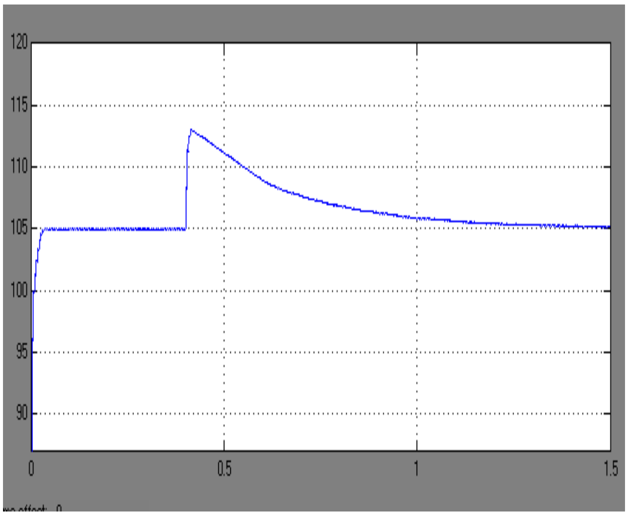

Fig 4.13output voltage with Disturbance

Conclusion

The PWM soft single switched boost converter is simulated in both open and closed loop system. Open loop system explains about switching stress. Voltage stress should be reduced using soft switching technique. This converter does not require any extra switch to achieve soft switching, which considerably simplifies the control circuit. PWM technique is used to control the output voltage. Thus PWM and soft switching technique are improving the proposed converter performance. The output side voltage regulation is achieved through closed loop system.

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