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Simulation of DC-DC Buck Boost Converter

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ABSTRACT

This project is concern to achieve a high efficiency control strategy for improving the transients in the output voltage of a dc-dc positive buck-boost converter is presented in this paper. The sophisticated control technique can regulate an output voltage for an input voltage, which is higher, lower, or the same as the output voltage. There are several existing solutions to these problems, but all have their disadvantages. The technique introduced here is unique of its kind from the point of view of ripple content in the output voltage and the reliability of the control strategy. The best approach involves a tradeoff among cost, efficiency, and output noise or ripple. The main objective of this work is to have a positive buck-boost regulator that automatically transits from one mode to the other. The method introduced in this paper is a combination of buck, boost, and buck-boost modes. Basic analytical studies have been made and are presented. In the proposed method, instead of instantaneous transition from buck to boost mode, intermediate combination modes consisting of several buck modes followed by several boost modes are utilized to distribute the voltage transients. This is unique of its kind from the point of view of improving the efficiency and ripple content in the Output voltage Theoretical considerations are presented. Simulation results are shown to prove the proposed theory.

I .INTRODUCTION

A very common power-handling problem, especially for portable applications, powered by batteries such as cellular phones, personal digital assistants (PDAs), wireless and digital subscriber line (DSL) modems [1], and digital cameras, is the need to provide a regulated non-inverting output voltage from a variable input battery voltage. The battery voltage, when charged or discharged, can be greater than, equal to, or less than the output voltage. But for such small-scale applications, it is very important to regulate the output voltage of the converter with high precision and performance. Thus, a tradeoff among cost, efficiency, and output transients should be considered.

A common power-handling issue for space-restrained applications powered by batteries is the regulation of the output voltage in the midrange of a variable input battery voltage. Some of the common examples are 3.3 V output with a 3–4.2 V Li cell input, 5 V output with a 3.6–6 V four-cell alkaline input, or a 12 V output with an 8–15 V lead–acid battery input.

This paper describes a new method for minimizing the transients in the output of a DC-DC converter required for small powered portable electronic applications [2]. The transient problem has been the most serious problem for power supplies needing the output voltage in the mid-range of the input voltage. The maximum transient arises when the input voltage becomes almost equal to the output voltage. Selecting the best approach involves a tradeoff among cost, efficiency, and output noise or ripple. There are various techniques used to solve the problem of transients. However, most of the methods have drawbacks such as comparatively higher transients or lower efficiency because of the longer switching operations. This paper describes few methods already

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been used to solve the transient problem and points out the demerits of those methods. In addition, a new combination method, which combines buck and boost modes during the transition mode, is described in this paper to minimize the transients at the output of the converters when the input voltage is near to the output voltage. Mathematical equations have been put forward to support the proposed idea for the transient minimization. Simulation results have been added to make a comparative analysis of transient response of this method with respect to the other methods

With an input voltage range that is above and below the output voltage, the use of a buck or a boost converter can be ruled out unless cascaded. Cascaded combination [3] of converters results in cascaded losses and costs; therefore, this approach is seldom used. In such a range of power demand, the transition of dc voltage from one level to another is generally accomplished by means of dc/dc power converter circuits, such as step-down (buck) or step-up (boost) converter circuits. There are various topologies such as inverting buck–boost converters, single-ended primary inductance converters (SEPICs), Cuk converters, isolated buck–boost converters, and cascaded buck and boost converters [4], which can be implemented to maintain a constant output voltage from a variable input voltage.

The important points of concern for such low-voltage-range power supplies are output ripple, efficiency, space, and the cost. The aforementioned topologies are generally not implemented for such power supplies due to their lower efficiency, higher size, and cost factors.

The most difficult problem is the spikes in the output voltage, which causes the converter to lose efficiency during the transition from buck mode to the boost mode. Cost, size, switching speed, efficiency, and flexibility all need to be considered in designing such power supplies.

The advantage of having higher efficiency is longer runtime at a given brightness level from the same set of batteries.

II. SOLAR AND WIND

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 [5].

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

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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) [6]. 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 [7]. 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 [8]. They are also used at extremely high voltages, as magnetics would break down at such voltages.

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

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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

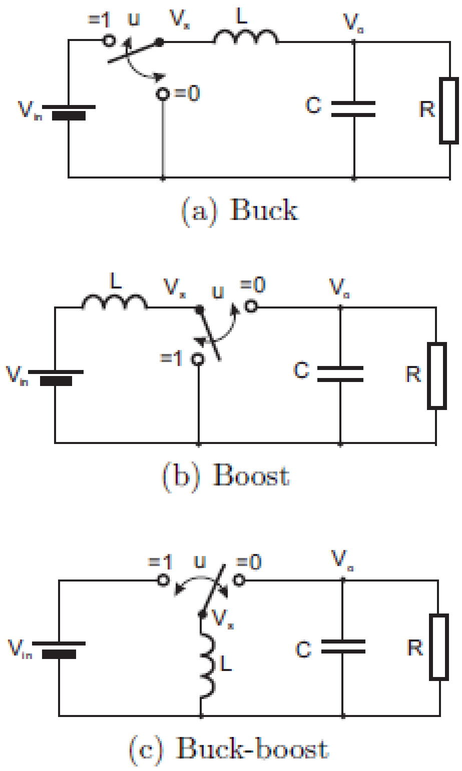

Fig.2.1. Buck, Boost, Buck-Boost Converter Equivalent Circuit Diagram.

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.

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 [5-8].

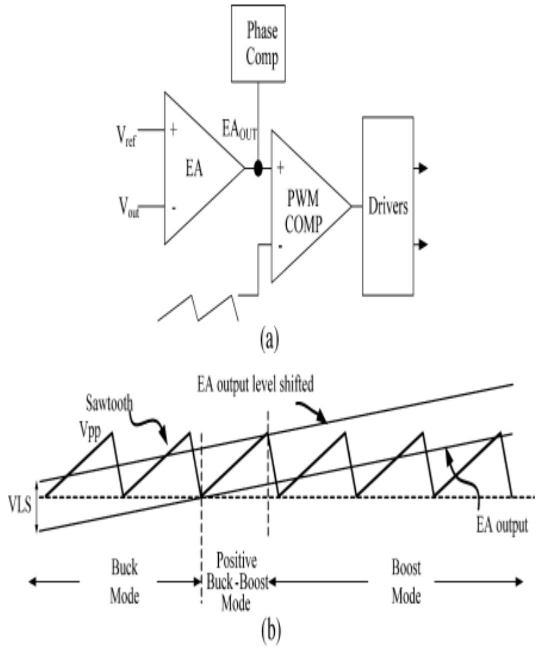

Fig.2.19. (a). General block diagram of error amplifier and drivers, (b). Operation modes.

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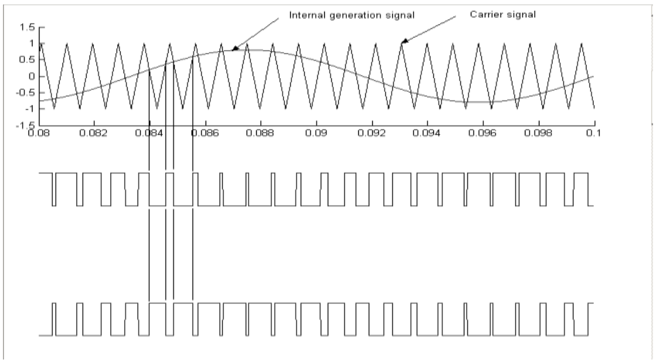

Fig.2.20. Pulse Width Modulation Technique

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).

Positive Buck-Boost Converter:

3.1 Circuit Topology:

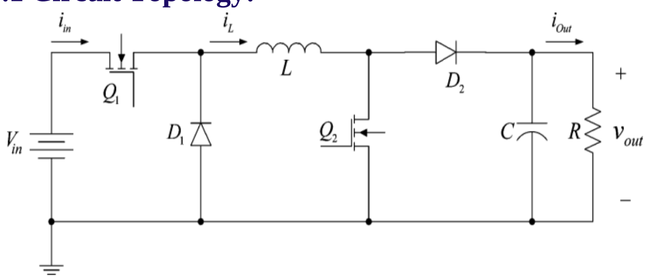

Fig.3.1. Circuit Topology of a Positive Buck-Boost Converter

3.2 Operation of a positive Buck-Boost Converter:

The circuit topology of a positive buck–boost converter is shown in Figure. In buck–boost operating mode, always, two switches, $Q1$ and $Q2$, and two diodes,$D1$ and$D2$, are switching in the circuit. A positive buck–boost converter can operate as a buck converter by controlling switch $Q1$ and diode $D1$, when $Q2$ is OFF and $D2$ is conducting. It can also work as a boost converter by controlling switch $Q2$ and diode $D2$, while $Q1$ is ON and $D1$ is not conducting. When the voltage of the battery is more than the output reference voltage, converter operates as a buck converter. As soon as the voltage of the battery drops to a value less than the output reference voltage, the converter should switch to boost mode. The added advantage of the converter is that the output of such a converter is always positive.

Table 3.1. presents the values of $\alpha1$, $\beta1$, and $\gamma1$ for the conventional method of transition from buck to buck–boost and the values of $\alpha2$, $\beta2$, and $\gamma2$ from buck–boost to the boost operating conditions.

Table-3.1Transition model control parameters (α, β, and γ) for the Conventional method of transition from a buck to boost Operating topology

Buck to Buck-boost transition	$\alpha_1 = \beta_1 = \gamma_1 = 1$
Buck-boost to Boost transition	$\alpha_2 = \beta_2 = \gamma_2 = 1$

Table-3.2 Parameters of Positive Buck–Boost Converter

Variable	Parameter	Value
L	Magnetizing inductance	100 μH
C	Output filter capacitance	330 μF
V_{in}	Input voltage	3.6V-6V
V_{ref}	Output voltage	5 V
f	Switching frequency	100 kHz
R	Output resistance	20 Ω

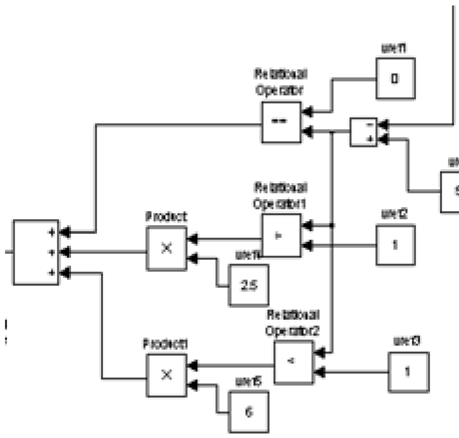

Fig.3.2. Closed loop control strategy for the proposed method

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3.3. What is Duty cycle?

Duty cycle of buck (D_{buck}) = $V_{out}/V_{in.}$ …………… (2.1)

Duty cycle of buck and boost ($D_{boost-bust}$) = $V_{out}/V_{out}+V_{in.}$ …………… (2.2)

Duty cycle of boost (D_{boost}) = 1- $V_{in}/V_{out.}$ …………… (2.3)

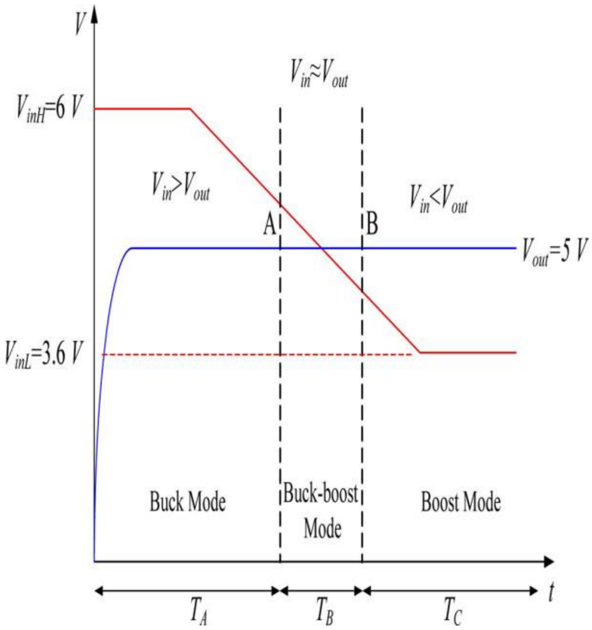

Fig.3.3. Input–output curve for the power supply.

Computer Simulation:

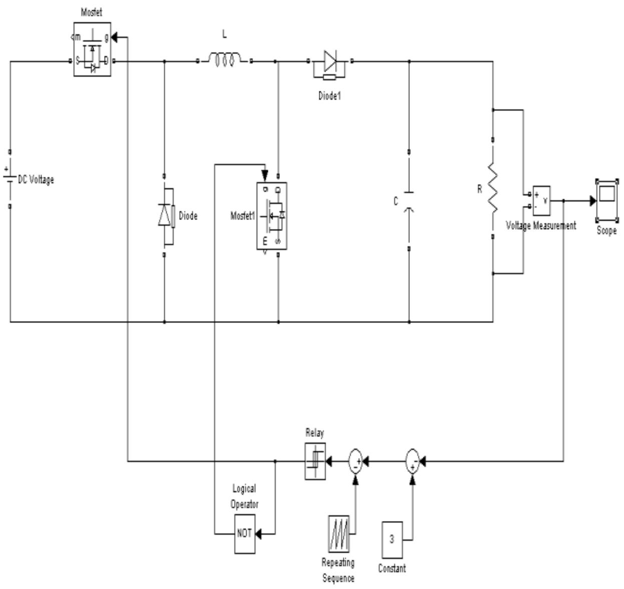

Fig.5.1. Simulation Model for Positive Buck-Boost Converter.

Result:

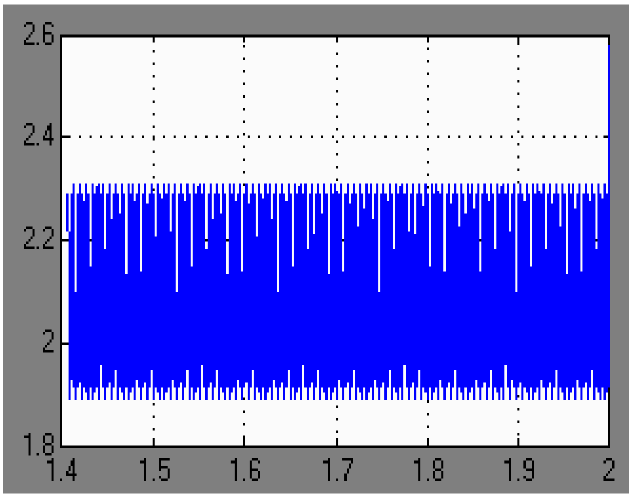

Fig.5.2. Simulation result of positive buck-boost converter for 3v.

Simulation Results of the combination method

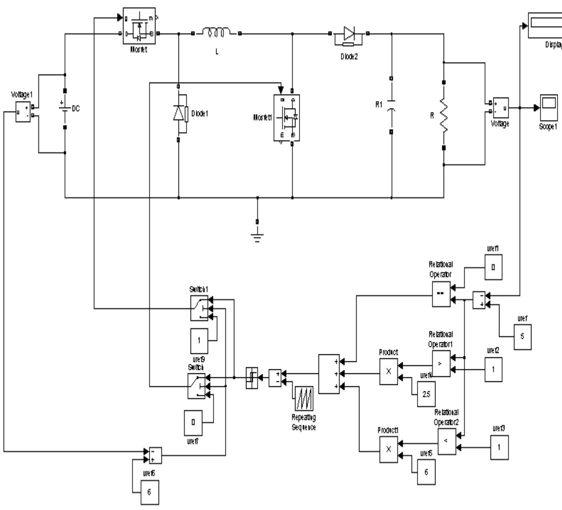

Fig.5.3. Simulation diagram of the proposed method

The objective of the paper is to obtain a constant output voltage independent of input voltage.The output voltage is feed back to a comparator we compare the o/p voltage with the required o/p voltage the error is found and then it is give to another comparator in this it is compared with saw tooth wave the output is given to the driver circuit.The output is given to a relay this allow the only there is output or any voltage .The Not gate inverts the mosfet gate voltage is driven through this.The mosfet in

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the circuit change the states inversely. That means mosfet 1 on then mosfet 2 is off. Mosfet 1 works in buck mode and Mosfet 2 works in boost mode.

Conclusion

By applying the parameter values from Table II for the calculation of buck and boost samples and using (6), just beforevin ≈ $vout$, the rounded ratio of $\alpha 1$ and $\beta 1$ is 3:1. Similarly, just after $vin \approx vout$, the ratio of $\alpha 2$ and $\beta 2$ is found to be 1:2. Thus, we choose $\alpha 1$ = 3or three buck cycles and $\beta 1$ = 1or one boost cycle for the time period in combination mode A and $\alpha 2$ = 1 or one buck cycle and $\beta 2$ = 2 or two boost cycles for the time period in combination mode B. This ratio is presented in termsof block diagram in Fig. 15 for solving the addressed problem.

1) Proposed CombinationMethodWith Buck–BoostMode in the Middle: The simulations were carried out on the converter using the exact combination method along with the buck–boost in the middle. This method improves the ripple content in the output voltage of the converter when the input voltage becomes almost equal to the output voltage and during other transition modes. The waveforms are shown in Fig. 16. It is seen that the peak transient happening during the transition is about 4%.

2) Without Buck–Boost Mode in the Middle: The buck– boost mode, in the middle, was neglected to save the efficiency of the converter, since during this mode of operation, both the switches are operated simultaneously.

By applying this combination method of control and simulating the converter, the results are obtained. The simulation results show that output voltage transients during transition from combination mode A to combination mode B are somehow similar to transients available in transition from combination mode A to buck–boost mode. This voltage variation in this method is about 4%; however, canceling the buck–boost operating mode in between significantly improves the efficiency of the converter.

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