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Research Paper | Engineering

Development Of Control Algorithm To Reduce Harmonics In Buck Converter

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ABSTRACT

The paper will focus on modeling, analysis, and design and simulation buck converter architecture. This architecture is used for automotive dual power system to reduce filters, dynamic response and power. The converter is designed in CCM (continuous conduction mode). The voltage mode control strategy is proposed by using pulse width modulation (PWM) with a proportional-integral-derivative (PID). The effectiveness of the step down converter is verified through simulation results using control oriented simulator like MATLAB/Simulink tools. The proposed circuits operate at constant frequency and are regulated by conventional pulse width modulation (PWM) using dedicated PWM and PID control techniques. The circuit operation, mathematical analysis, designs and simulation results for continuous current mode (CCM) operation are mentioned in this paper.

KEYWORDS:Buck Converter, Power factor, Loss, Total Harmonic Distortion, Pulse width modulation and PID control.

I. Introduction

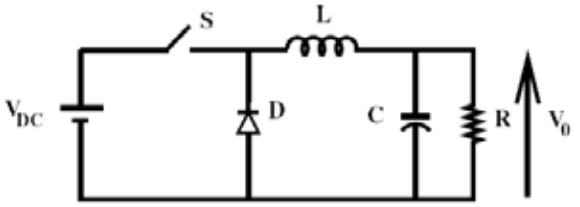
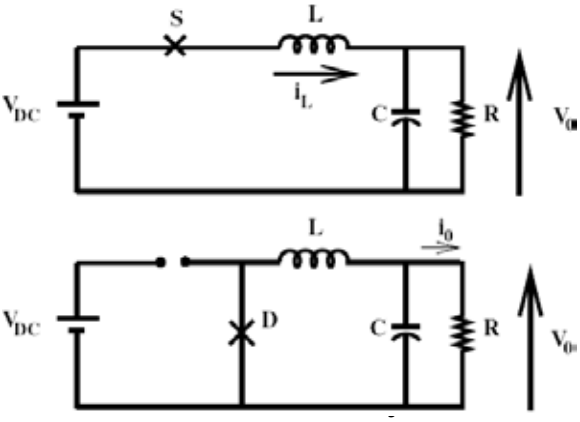


Fig. 1 Basic Block Diagram

Buck converter where L is filter inductor and C is filter capacitor. V0 is assumed to remain constant and S is switched at very high frequency. S is ON for time DT and OFF for (1-D)*T [2].



is included. By employing a constant frequency, continuous current Buck converter design with the switching period is defined below in fig. 2. By T2 – T1 = T. The converter initially has two conducting states defined by periods T1 – T0= DT and T2 – T1 = (1 – D) T, corresponding to the two switching states. [3]

The VDC supply is connected with the duty cycle D, and a complement controlled synchronous switch is applied to complete the connection during the remaining (1 - D) portion of the period. Inductor operating waveform is given below. [6]

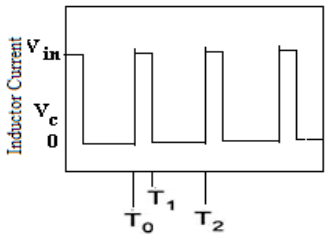


Fig. 3 Inductor operating waveforms

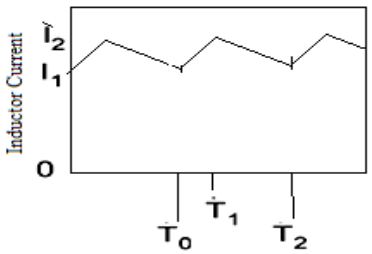


Fig.4 Inductor current

II. THE "BUCK" CONVERTER: STEP DOWN VOLTAGE REGULATOR

The circuit diagram, often referred to as a "chopper"circuit, and its principal waveforms are represented in figure.6

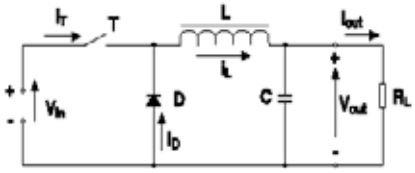


Fig.5 chopper circuit

The output voltage fluctuations are very much diminished using a low pass filter, consisting of inductor and a capacitor,[2]. The corner frequency of LPF is selected to be much lower than the switching frequency, thus essentially dominating the switching frequency ripple in the output voltage,[4]. Depending on the switching frequency, inductance and capacitance could be discontinuous [4].

Now,

Vout = Vin* α. (1)

Where,

α= Ton /T

T = Ton + Toff

By assuming that the load ripple current is very small. ΔiL = Δic (2)

Δ Vc = Vin * α *(1- α)/ (8*L*C*f2) (3)

Where, f=1/ T.

Figure 5 shows the power diagram of power converter using a power MOSFET/ IGBT as a switch. As the name implied a step-down (buck) converter produces a lower average output voltage Vout than the d.c. input voltage Vin. By varying the duty-ratio Ton/T of the switch, the average output voltage can be controlled. As switch is on at time t=0, the supply current which rises flows through the inductor and capacitor and load. Therefore the inductor stores the energy during Ton period. During the interval when switch is on, the diode becomes reverse biased and input provides energy to load as well as to the inductor. When switch is off, inductor current flows through L, C, load and freewheeling diode D and hence diode D conducts [7].

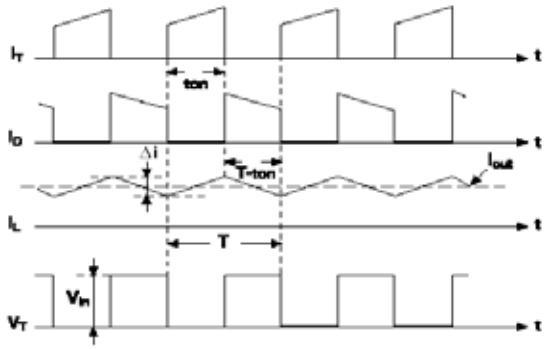


Fig.6 The non isolated 'buck' regulator waveforms

Distortion must be considered in any converter or power supply. How much ripple or other unwanted effects will be present at rectifier output? How pure is the output signal of a dc-dc converter or inverter? Regulation defines how closely a power supply output approaches an ideal source. Power factor helps to address system efficiency rather than just converter efficiency. Unity Power Factor (UPF) is an important term in power electronics [10].

When the total power is equal to the real power and thus, the reactive power is zero, unity power factor is achieved. However unity power factor is also affected by the presence of current harmonics. Unity power factor is achieved when only the fundamental current harmonic is present. The benefit of UPF is the converter will appear as a purely resistive load to the power grid. This means the converter will not return any power to the grid or introduce harmonics into the grid. There are also economic benefits to the electricity supplier due to reduced rms currents. Product of the ratio of the primary current harmonic to the total current multiplied by the displacement power factor (DPF). DPF is the same as PF in a linear circuit.[5]

PF= IS1/IS *DPF (4)

iS (t) =iS1 + ∑ iSn(t) (5)

Where,

n=2, 3, 4, 5… and

iS1 is the fundamental Freq.

Advantages of UPF

- Reduced low frequency voltage and current harmonic to the supply source and regulate DC output voltage.
- High frequency switching harmonics due to chopper may be easily suppressed by the input filter.
- Sensitive to variations of power system impedance.
- Standard regulation can be maintained to meet green power.[8]

A.C. signal is rectified, but before rectification it is pass through EMI filter where the noise or spurious signal is removed and then after it will be passed to the next stage which is power factor correction circuit. The output of the circuit the input power is pulsating (at 100-120 Hz) and, since the power demanded by the load is constant, it is necessary to include an element to store the energy. [11]

III. proposed design criteria for converter
Block diagram

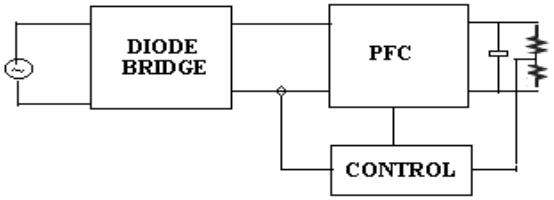


Fig. 7 Proposed Design

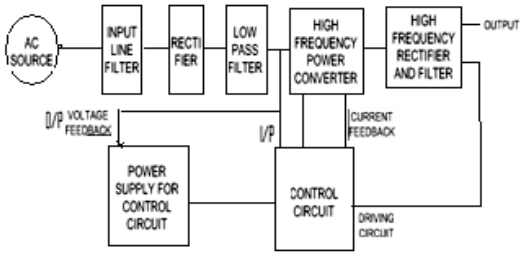


Fig.8 Design blocks

Steps for design converter:-

- The input AC source is applied to line filter and then through rectifier it is converted into DC. By means of the capacitor this DC is smoothened. [14]
- This DC is applied to the high frequency power conversion stage. The control signal to power conversion stage is provided by the control circuitry.
- Output of high frequency power converter is rectified and filtered to obtain DC output. One of the output voltage sources is used as power source to the control circuit under normal working conditions. [12]
- The control circuit also receives peak current and voltage signal as feedback.

IV. BUCK DESIGN WITH LOSSES

Maximum Output Power (Pomax) = 120W

Nominal Output Voltage (Vonom) = 12V

Nominal Input Voltage(Vinom) = 24V

Switching Frequency (Fs) =250kHz

Minimum Percent CCM :(Iccm) = 10%

Maximum Ripple % :Vopp) = 2%
μ = 1.10-6
m = 1.10-3
Nominal Duty Cycle: D = (V_{onom}/V_{inom})
= 0.5
Critical Inductance: Lc = ((1 – D)*
$(V_{onom2} / I_{ccm} \cdot P_{omax})/2 \cdot Fs$ = 12.000H·μ

Peak Inductor Current: I_{Lopk} = $V_{onom}[(1/(V_{onom}2/P_{omax})$
+ (1 – D)/2·Lo·Fs)]
= 10.06A
Switch Voltage: V_{swmax} = V_{inom} \
= 24V

Switch Current:Id =D*(P_{omax}/V_{onom}) =5A

Choose MOSFET IRF7471 40V 10A R_{dson} 13_{mOhm}
Diode V_{rrm}: V_{rrm}:= V_{inom} = 24V

Capacitance C0 =(1-D)/8*L*Fs2*V_{opp}
= 250*10-3
So Choose 25V 50 Micro Farad Capacitor.[14]
Due to required dead time and slow MOSFET's body diode, a Schottky is connected across the Synchronous MOSFET MOSFET+Schottky=FETKY combo such as IRF7326D2 [12].

V. CONTROL TECHNIQUES

The feedback is employed to maintain voltage regulation regardless of disturbances in input voltage, vg(t), or load current, iload(t), or variations in component values. The duty cycle is varied in the feedback loop to compensate for these variations [13].

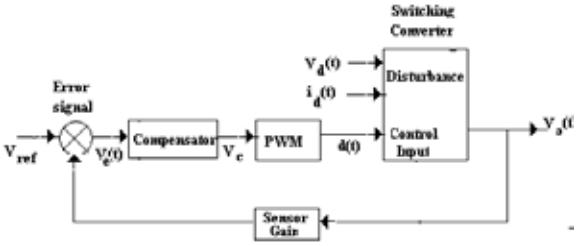


Fig. 9 Block diagram of feedback system

A voltage reference is used to compare with the output voltage. Sensor gain is used to scale down the output to be equal to voltage reference. The error signal thus generated is fed to the compensator which is the key part to be designed to ensure stability of total feedback loop. Compensator design affects the overshoot, steady state error and transient response of the loop. The PWM block compares the compensator output with another ramp signal to give the variation in duty cycle. The source from where the ramp signal is generated leads to different control schemes. The three most common control schemes are voltage mode control, current mode control and V2 control. Other hybrid schemes are derived from combinations of these control schemes .The effect of feedback loop on the small signal transfer function for all the three control schemes and compensation techniques for each control scheme are discussed.

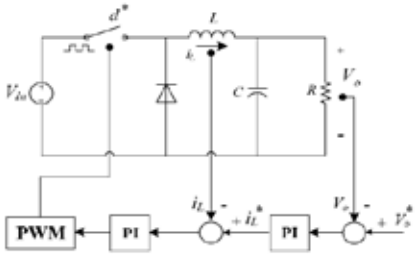


Fig.10 Generalized state-space averaging method (GSSA)

The GSSA method is presented for modeling the controlled buck converter with a resistive load. The GSSA method is used to derive the dynamic model of the considered system as under[6].

V. RESULTS

TABLE 1 THD Result for without Controller and with PID Controller

Without Controller			
%THD	22.3		
With PID/PI Controller			
			THD %
4	35	-	20.98
16	1	-	4.96
34	25	43	14.85
38	20	28	27.98
40	35	43	39.52
48	18	-	19.81

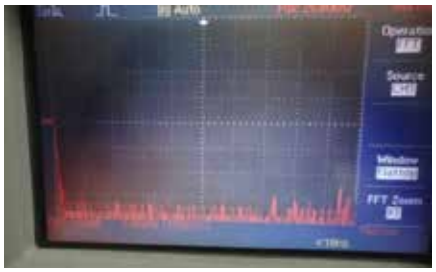


Fig.11 Output voltage with open loop system FFT analysis

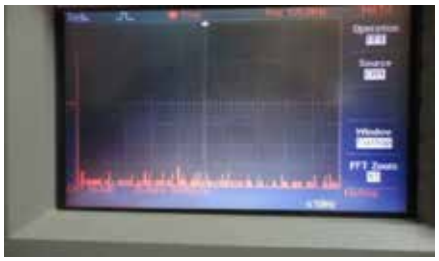


Fig.12 Output voltage with closed loop system FFT Analysis

VII. CONCLUSION

The total harmonic distortion is produced due to variation in line current, load variation and switching frequency change. There are a number of different types of equipment that can have mis-operations or failures due to high harmonic voltage and/or current levels.

This distortion may consist of predominately harmonics, depending on the type of load and system impedances. So we must reduce it. THD is reduced in our practical implementation from 22.3% to 4.6% using PID control algorithm.

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