

Design of Switched-Mode Power Supply Using MATLAB/SIMULINK

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Abstract— The SMPS (switched mode power supply) has been achieved the high performance and high power density by developing the power semiconductor devices such as MOSFET, IGBT, BJT and GTO etc. SMPS have the capacity to handle the variable loads. For the power supply designers the efficiency, weight and size of power supplies are a great area of concern. In this paper the SMPS circuit having power MOSFET for switching operation and by using pi controller based PWM for providing the feedback to the MOSFET for controlling purpose, is simulated in MATLAB. The output of SMPS remains constant irrespective of load and input voltage variation from 140v to 300v. The function of the converter is to provide a reliable and regulated output voltage at varying input voltage.

I. INTRODUCTION

In power electronics various process are used to convert the electrical energy from one form to another in an efficient, compact, clean and robust manner for convenient utilization. The aim of the project is to design and simulate the SMPS (switch mode power supply) circuit by the use of MATLAB for ac voltage to dc voltage conversion, having power MOSFET as a switch and feedback circuit to drive the power switch. This paper explains the operation of PWM control, SMPS (switching mode power supply), rectifier and buck converter. The block diagram shows the operation of the SMPS. This contains the two major circuits, one is power circuit and another one is control circuit which is used to control the power circuit by controlling the pulse which is provided for the power switch.

For some of the DC/DC and AC/DC application such as set top box, laptop adapters and telecom application, instead of low voltage rating power MOSFETs we use high voltage power MOSFETs because it possess high gate charge.

II. BUCK CONVERTER

This converter circuit is use to step down the voltage level from input according to the requirement

The operation is start with a switch that is open, it means no current is flow in the circuit when the switch is closed the current start flowing in the circuit.

Continuous conduction mode: In this mode current through the inductor never falls to zero during the commutation cycle

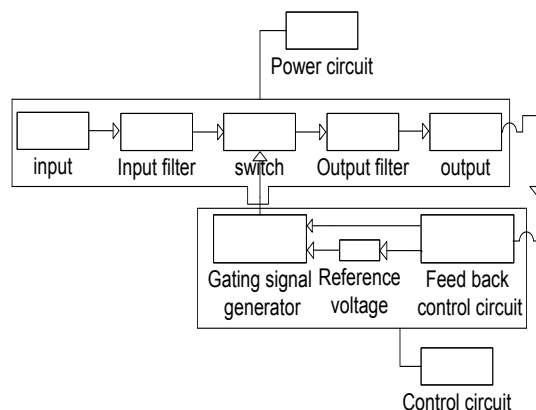


Figure 1: Block Diagram of SMPS

The operating principle is described by the Figures:

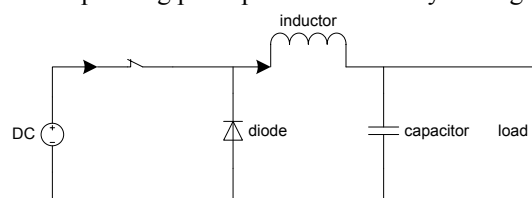


Figure 2: On-state mode

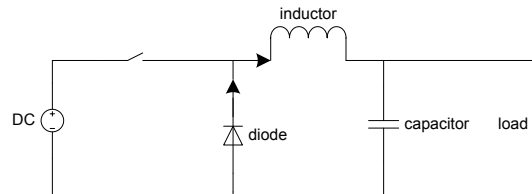


Figure 3: Off-state mode

The two circuit configurations of a buck converter are:

- i) On-state (when the switch is closed)
- ii) Off-state (when the switch is open)

When the switch is in on state, the voltage across the inductor is $V_L = V_i - V_0$. The whole current flow through the inductor and the diode is reverse-biased. This inductor current rise linearly. When the switch is in off state, the diode act as forward biased. Now the voltage across the inductor is $= -V_0$ and the Current I_L decreases. The energy stored in the inductor L is $E = \frac{LI^2}{2}$

Therefore, it can be seen that the stored energy of the inductor (L) increases during On-state and then decreases during the Off-state. Inductor is used to transfer energy from the input to the output of the converter. In on state, the rate of change of inductor current(IL)is calculated from: $V_L = \frac{Ldi_L}{dt}$ with V_L equal to $V_i - V_o$.

$$\Delta I_{L_{on}} = \int_0^{t_{on}} \frac{V_L}{L} dt = \left(\frac{V_i - V_o}{L}\right)t_{on}, \quad t_{\{on\}} = DT$$

In off state, the rate of change of inductor current (IL) is calculated from: $V_L = \frac{Ldi_L}{dt}$ with V_L equal to $-V_o$. The decrease in inductor current is given by:

$$\Delta I_{L_{off}} = \int_{t_{on}}^{t_{off}} \frac{V_L}{L} dt = -\frac{V_o}{L} t_{off}, \quad t_{off} = (1 - D)T,$$

If the convertor operates in steady state, the energy stored in each component at the beginning of the cycle is equal to that at the end of a commutation cycle T. it means that the current IL is the same at $t=T$ and at $t=0$. So from the above equations we can write:

$$\frac{V_i - V_o}{L} t_{on} - \frac{V_o}{L} t_{off} = 0.$$

Here $t_{on} = DT$ and $t_{off} = (1 - D)T$, D is called the *duty cycle* with a value between 0 and 1. This

$$(V_i - V_o)DT - V_o(1 - D)T = 0$$

$$V_o - DV_i = 0$$

$$D = \frac{V_o}{V_i}$$

From above discussion, we can say that for a given input voltage the output voltage of the converter varies linearly with the duty cycle. The duty cycle D is equal to the ratio between T_{on} time and the period T, the value of the D cannot be more than 1, therefore the value of V_o is always less than $V_i (V_o \leq V_i)$. That is why this converter is called as *step-down converter*.

Discontinuous Conduction Mode:

In this case, the energy required by the load is small enough to be transferred in a time lower than the whole commutation period. In that case, the current through the inductor falls to zero during a part of the period. In this case when the converter operates in steady state the energy stored in each component at the beginning of the cycle is equal to that at the end of a commutation cycle T(it is equal to zero). That means the average value of the inductor voltage (VL) is zero; this yields:

$$(V_i - V_o)DT - V_o \delta T = 0$$

So the value of δ is: $\delta = \frac{V_i - V_o}{V_o} D$

The load current (I_o) is constant; when we consider that the output of capacitor is large enough to maintain a constant voltage across its terminals during a commutation cycle. This implies that the current through the capacitor has a zero average value. Therefore, we have: $I_L = I_o$ here I_L is the average inductor current. Therefore, the value of I_L can be calculated as:

$$I_L = \left(\frac{I_{L_{max}}DT}{2} + \frac{I_{L_{max}}\delta T}{2}\right) \frac{1}{T}$$

$$= \frac{I_{L_{max}}(D + \delta)}{2}$$

$$= I_o$$

The inductor current (IL) is zero at the beginning and rises during t_{on} up to $I_{L_{max}}$.

$$I_{L_{max}} = \frac{V_i - V_o}{L} DT$$

Substituting the value of $I_{L_{max}}$ in the previous equation: $I_o = \frac{(V_i - V_o)DT(D + \delta)}{2L}$

And substituting the value of δ :

$$I_o = \frac{(V_i - V_o)DT(D + \frac{V_i - V_o}{V_o} D)}{2L}$$

This expression can be rewritten as: $V_o = \frac{V_i}{\frac{2LI_o}{D^2V_iT} + 1}$

It can be seen that the output voltage of a converter operating in discontinuous mode is much more complicated than the continuous mode.

III. SIMULATION RESULTS

The simulink model of buck converter with PI controller is shown in Figure 4 and simulation is carried out in MATLAB/SIMULINK.

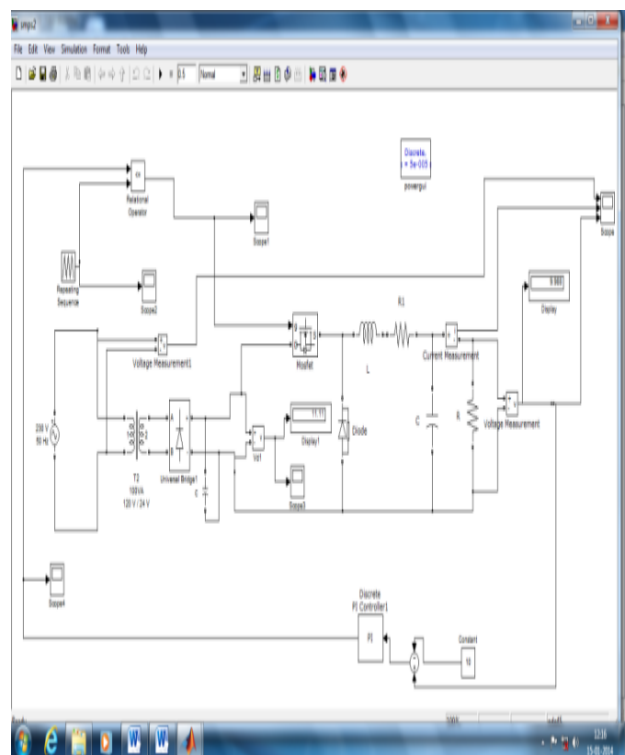


Figure 4 Simulink Model of Buck Converter

Simulation is done with the variation in input voltage from 140 volt to 300 volt at different loads maintaining output voltage constant at 10 volt The simulation results are shown in Figs 5-7 and tabulated in Table 1 & 2.

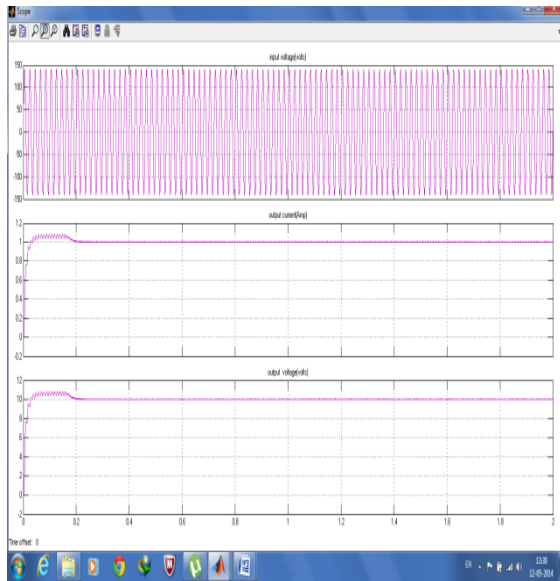


Figure 5. Output Voltage and current with 140 V input voltage at load resistance 10Ω

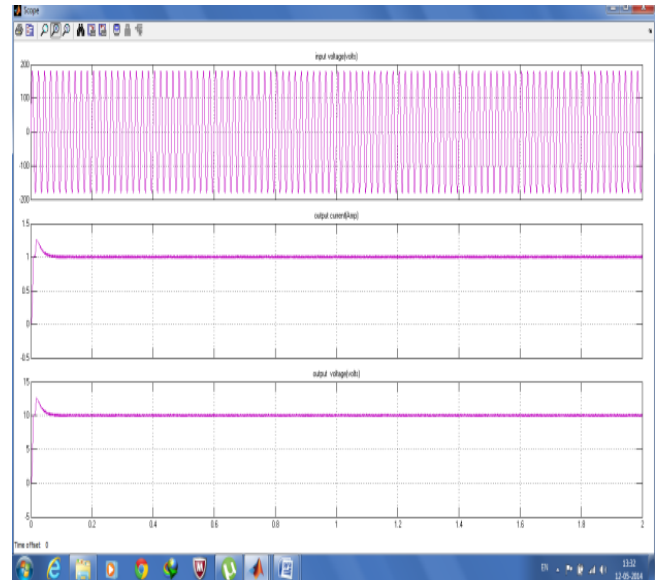


Figure 7. Output Voltage and current with 180 V input voltage at load resistance 10Ω

The output of SMPS remains constant irrespective of load and input voltage variations from 10Ω to 40Ω and 140v to 300 v respectively



Figure 6. Output Voltage and current with 140 V input voltage at load resistance 40Ω

Table 1: With load variation

	Input voltage (v)	Load resistance (Ω)	Output voltage (v)	Output current (mA)
1	140	10	9.988	998.8
2	140	15	9.979	665.3
3	140	20	9.956	497.8
4	140	25	9.948	392.9
5	140	30	9.962	332.1
6	140	35	9.970	284.9
7	140	40	10.02	250.6

Table 2: With input voltage variation

	Input voltage (v)	Load resistance (Ω)	Output voltage (v)	Output current (mA)
1	140	10	9.988	0.9988
2	180	10	10.11	1.011
3	260	10	10.01	1.001
4	300	10	9.822	0.9822

IV. CONCLUSION

SMPS operating in a Buck converter is an efficient step down DC-DC converter used in numerous electronics devices. The same is designed and simulated by Using the MATLAB and an output voltage of 10V was obtained with an input voltage range of 140V-300V DC supply. Also the waveforms across various test points were obtained, studied and compared with the theoretical waveforms. The waveforms were found to be in precise proximity of theoretical waveforms.

REFERENCES

- [1] Bimal K.Bose: Modern Power Electronics and Ac Drives
- [2] Mohan, N. (2007): First Course on Power Electronics.
- [3] Rashid, M H. (2004): Power Electronics: Circuits, Devices and Applications.