



DEPARTMENT OF ELECTRICAL AND ELECTRONICS  
ENGINEERING

**MANIPAL INSTITUTE OF TECHNOLOGY**

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**Power Electronics Lab ELE 3141**

**Mini Project Report**

**Title: Switch Mode Power Supply**

*Submitted by*

<b>Students Name</b>	<b>Registration No.</b>
Arjun R Pai	230906458

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## ABSTRACT

In the current world, the need to have miniature, effective and dependable power conversion systems has gone up tremendously with the high rate of development of the electronic gadgets and renewable energy technologies. Traditional linear power supplies have high power losses, and large components, thus are not appropriate in current low-power and portable systems. *Switch Mode Power Supplies (SMPS)* have become popular to overcome this dilemma as they are high efficiency, lightweight and can allow versatile adjustments of voltage. The buck-boost converter is a specific type of SMPS topology that is beneficial because it can give an output voltage, which is either lower or higher than the input, which makes it more applicable in devices with battery power, DC microgrids, or renewable energy sources. The primary goal of the work is to design, simulate and analyze a buck-boost converter in MATLAB/Simulink and compare the performances of the converter in the presence of resistive (R) and inductive (RL) loads.

The model suggested was put into practice as a closed-loop controlled SMPS to regulate a controlled output voltage of 26 V out of a 48 V DC input source. The converter circuit comprises of a switching network, inductor, diode, and output capacitor, and is suited to work well at a switching frequency of 50 kHz. Both R and RL loads gave results of simulation and their performance was compared regarding output voltage ripple, current waveform, transient response and efficiency. It was found that the R load had quicker transient response and reduced ripple where the RL load added a phase delay with a small increase of the voltage ripple because of the energy storage effects in the inductor. The findings reveal that the buck-boost converter is effective in delivering regulated DC output under different load conditions, and it is therefore significant in the current power electronic systems that need compact and power-efficient power conversion.

# CHAPTER 1

## INTRODUCTION

Switch Mode Power Supplies (SMPS) have been popular in electronic systems today to effectively transform electrical power in one voltage level into another. The SMPS are efficient and can be much more efficient than linear regulators which dissipate unwanted energy as heat by rapidly switching semiconductor devices and temporarily storing energy in inductors and capacitors. Depending on the need to either step-down, step-up or both the output voltage, different converter topologies are used like buck, boost and buck-boost. Specifically, the buck-boost converter has the benefit of allowing a larger or smaller output voltage than the input, thus being quite flexible in its potential uses in the renewable energy system, battery-operated devices and DC microgrids.

### 1.1 Background & Motivation

As there has been an increasing trend of the demand of portable and energy-efficient electronics, the requirements of compact, reliable, and high-performance power converters have risen considerably. Electric vehicles, solar energy systems, and consumer electronics are among industries that depend on the use of SMPS technology to provide stable power supply with changing loads and supply conditions. Besides, the high rate of development in semiconductor switching devices and digital control methodologies has facilitated better converter efficiency, lesser size and better control precision. Adaptation and study of the operation of SMPS to various types of loads, including just resistive and inductive loads, is, in this regard, a significant field of interest to the optimization of converter design and control.

The growing interest of miniaturization and energy efficiency of power electronics is a good reason to analyze and model the behavior of SMPS in a variety of circumstances. The buck-boost converter is also a very good training ground to appreciate both the steps up and the steps down functions in the same circuit and the effects of the load features on the performance of the system. The study also contributes to the attainment of practical skills in MATLAB/Simulink modeling that is needed in the design, testing, and optimization of real-life power electronic converters.

### 1.2 Significance of the SMPS

High efficiency DC-DC conversion is important in contemporary technologies in which power saving and reliability of the systems are the main concern. A comparative study of SMPS operation with resistive and inductive loads gives useful information on transient characteristics, output voltage regulation, and control stability factors that are important in a

variety of applications, including communication interfaces as well as in renewable energy interfaces. The results of this work also help in improving the knowledge of converter dynamics, which will benefit further improvement in design and application of advanced control measures.

### **1.3 Objectives of the Work**

The primary aims of this mini project are:

- To model and analyze a buck-boost SMPS with a regulated DC output in MATLAB/Simulink.
- To regulate the voltage with a closed-loop operation of a PID controller.
- To compare the performance of the converter when loaded with resistive (R) and inductive (RL) loads.
- To check the efficiency of the converter, ripple of the voltage, and the momentary response of the converter to these two types of loads.

### **1.4 Organization of the Report**

The report will be structured in the following way:

- ✓ In chapter 1, the project, motivation, objectives, and the scope of the work are introduced.
- ✓ Chapter 2 surveys literature on the working principle of SMPS, converter topology and principle of control.
- ✓ Chapter 3 describes the design procedure, selection of components and simulation model implemented using MATLAB/Simulink.
- ✓ The results of the simulation and comparison of R and RL loads are introduced in Chapter 4.
- ✓ Chapter 5 is an overview of the conclusions made in the research and gives potential future work directions.

## **CHAPTER 2**

# **METHODOLOGY**

The chapter explains the approach used in the design and simulation of a Switch Mode Power Supply (SMPS) using a buck-boost converter topology. It is based on the review of the literature that is available related to converter design and control, and the explanation of the circuit design, method of simulation, and the major calculations that were done to obtain the required controlled output voltage. This section is also defined in the comparative analysis of the R Load and R-L load.

### **2.1 Literature Review**

The design and performance tuning of DC–DC converters is a topic that has been very well debated and researched during the past several years. This is because such converters are being used in systems of the nature such as renewable energy, electric vehicles, and consumer electronics. Different scholarly works have prioritized the aspects of efficiency improvement, voltage ripple reduction, and transient response betterment by implementing different control strategies.

Banerjee, G. Praween, O. H. Gupta, S. Kumar and R. Bhushan (2023) introduced the "Design and Simulation of a Buck–Boost Converter for Renewable Applications" in the International Journal of Electrical Engineering and Technology, which was mainly about how the use of closed-loop feedback helps in stabilizing the voltage.

Similarly, by a PID-controlled buck–boost converter for variable load conditions, M. A. Khan and S. Ahmad (2020) in IEEE Transactions on Power Electronics demonstrated performance enhancement.

R. K. Singh and T. Gupta (2021) said in IJEETR that the inductive load changes the the dynamics of the converter significantly because the energy is stored in the magnetic field, hence, the controlling parameters have to be adjusted carefully.

Besides these, the works of D. S. Kumar et al. (2022) point out the benefits of MATLAB/Simulink in modeling the SMPS under various topologies for the efficient prototyping and validation of the hardware phase.

Their research, in a nutshell, is a strong argument for the use of closed-loop simulation, load-based comparison, and converter optimization as the key elements that lead to efficient and reliable power conversion, thus providing the basis for the present research.

## 2.2 Topology Selection

In order to satisfy the requirement of an output voltage which can be lower or higher than the input voltage, a buck–boost converter topology was decided to be used. In fact, the converter is capable of working in two modes (buck – step-down and boost – step-up), essentially depending upon the *duty cycle* of the switching signal only.

The DC input voltage is 48 V, and the target regulated output voltage is approximately 26 V under continuous conduction mode (CCM).

## 2.3 Circuit Diagram

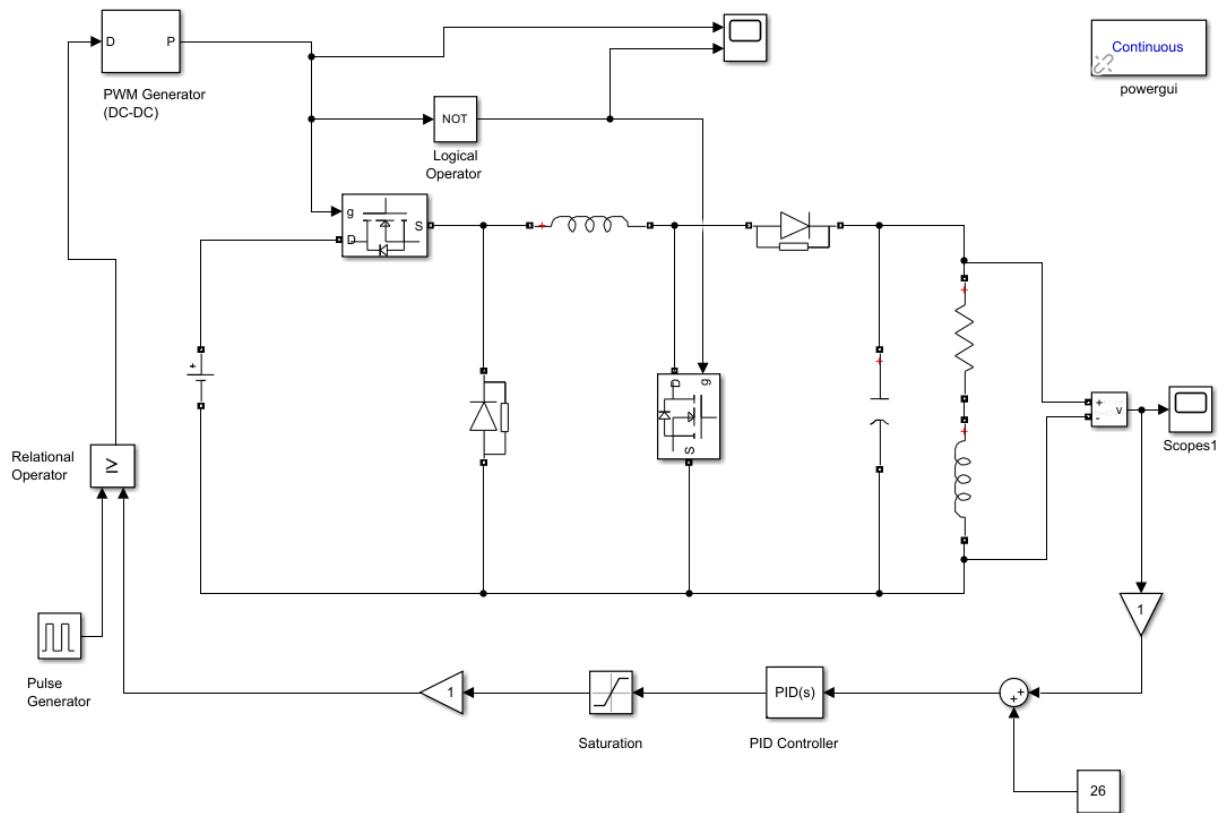


Fig: Switch mode power supply Simulink model

### Function of Components:

- Pulse generator:** It Produces constant square wave signal to act on the MOSFET switch. Determines the frequency and the duty cycle of the buck- boost converter.
- PID Controller:** Compares the reference to the output voltage and reduces the error. For accurate voltage regulation, it adjusts the duty cycle.
- PWM Generator:** Modulates the control signal into pulse-width-modulated signal. Defines the switch ON/OFF time on the voltage control.

- **Saturation:** It limits the controller output over a given range. Prevents too much control signals and provides stability of a system.

## 2.4 Circuit Components and Parameters

- Input Voltage,  $V_{in}=48V$
- Inductance,  $L=0.01mH$
- Capacitance,  $C=2200\mu F$
- Load Resistance,  $R=100 \text{ ohm}$
- Switching Frequency,  $f_s=50\text{kHz}$
- Desired Output Voltage,  $V_o=26V$

## 2.5 Design Calculations For R Load

Output voltage of Buck Boost converter is :  $V_o=V_{in} \cdot D / (1-D)$

Duty cycle,  $D = V_o / (V_o + V_{in}) = 26 / (26 + 48) = 0.351$  or 35.1%

Output Current,  $I_o = V_o / R = 26 / 100 = 0.26A$

$$\begin{aligned}\text{Inductor current ripple : } \Delta I_L &= V_{in} \cdot D / L \cdot f_s \\ &= 48 \cdot 0.351 / 0.01 \cdot (10^{-3}) \cdot 50 \cdot 10^3 \\ &= 33.7A \text{ (peak-peak)}\end{aligned}$$

$$\begin{aligned}\text{Output Voltage Ripple} (\Delta V_o) &= I_o \cdot D / C \cdot f_s \\ &= 0.26 \cdot 0.351 / 2.2 \cdot (10^{-3}) \cdot 50 \cdot 10^3 \\ &= 0.83V \text{ (peak-peak)}\end{aligned}$$

Output Power and Efficiency :

$$\text{Output Power, } P_o = V_o \cdot I_o = 26 \cdot 0.26 = 6.76W$$

Assuming 90% efficiency,

$$P_{in} = P_o / \text{eff.} = 6.76 / 0.9 = 7.51W$$

$$\text{Input Current, } I_{in} = P_{in} / V_{in} = 7.51 / 48 = 0.156A$$

## 2.6 Design Calculation For R-L Load

Output voltage of Buck Boost converter is :  $V_o=V_{in} \cdot D / (1-D)$

Duty cycle,  $D = V_o / (V_o + V_{in}) = 26 / (26 + 48) = 0.351$  or 35.1% (same as it depends only on  $V_{in}$  and  $V_o$ )

Time Constant for RL load =  $L_{load} / R = 100 \cdot 10^{-3} / 100 = 1ms$

$$I_o (\text{avg}) = V_o / R = 26 / 100 = 0.26 \text{ A}$$

$$\begin{aligned}\text{Load Current Ripple, } \Delta I_{\text{load}} &= V * D / L_{\text{load}} * f_s \\ &= 26 * 0.351 / 100 * (10^{-3}) * 50 * 10^3 \\ &= 1.82 \text{ mA}\end{aligned}$$

$$\begin{aligned}\text{Inductor current ripple : } \Delta I_L &= V_{\text{in}} * D / L * f_s \\ &= 48 * 0.351 / 0.01 * (10^{-3}) * 50 * 10^3 \\ &= 33.7 \text{ A (peak-peak)}\end{aligned}$$

Output Voltage Ripple( $\Delta V_o$ )= $I_o * D / C * f_s = 0.26 * 0.351 / 2.2 * (10^{-3}) * 50 * 10^3 \sim 0.9 \text{ V (peak-peak)}$

We know, RL Load maintains energy flow even when the Switch is at OFF position causing a slightly higher during transient state and reduced ripple during steady state condition.

Output Power and Efficiency :

$$\text{Output Power, } P_o = V_o * I_o = 26 * 0.26 = 6.76 \text{ W}$$

Switching loss increase due to stored energy in Inductance so Efficiency will be 88~89%

# CHAPTER 3

## RESULT ANALYSIS

### 3.1 Simulation Results for R Load

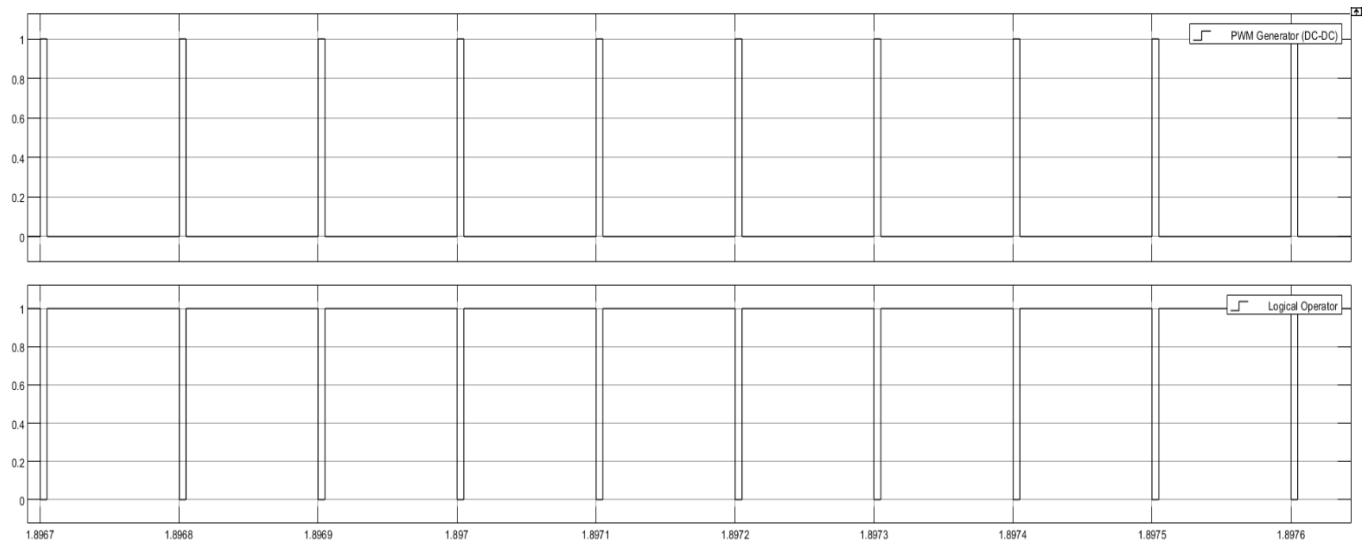


Figure 2. (a) PWM output Logical (b)Operator Output

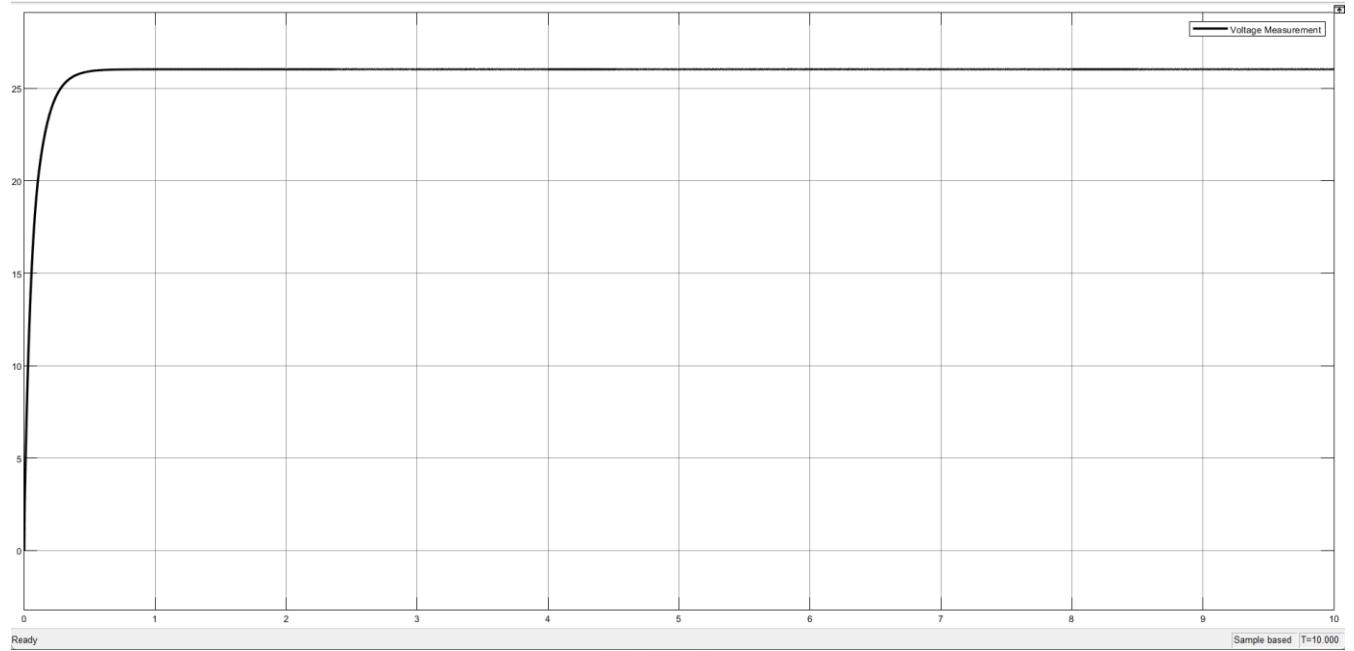
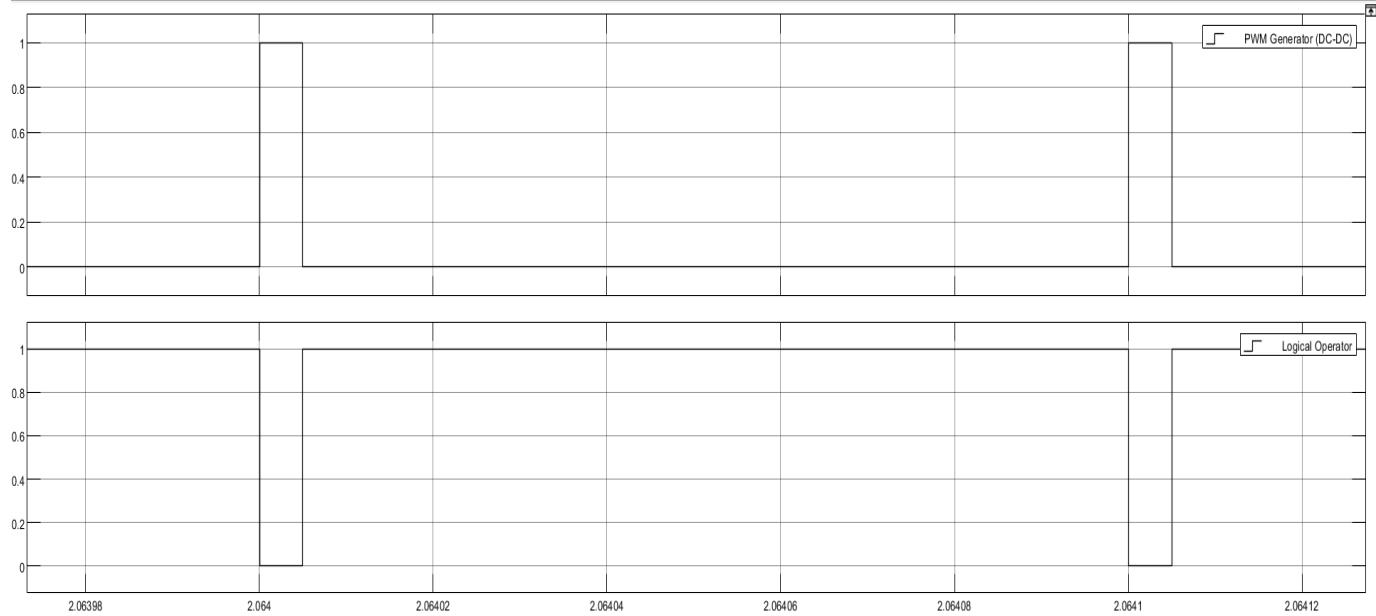


Figure 3. Output Voltage( $V_o$ ) with R Load

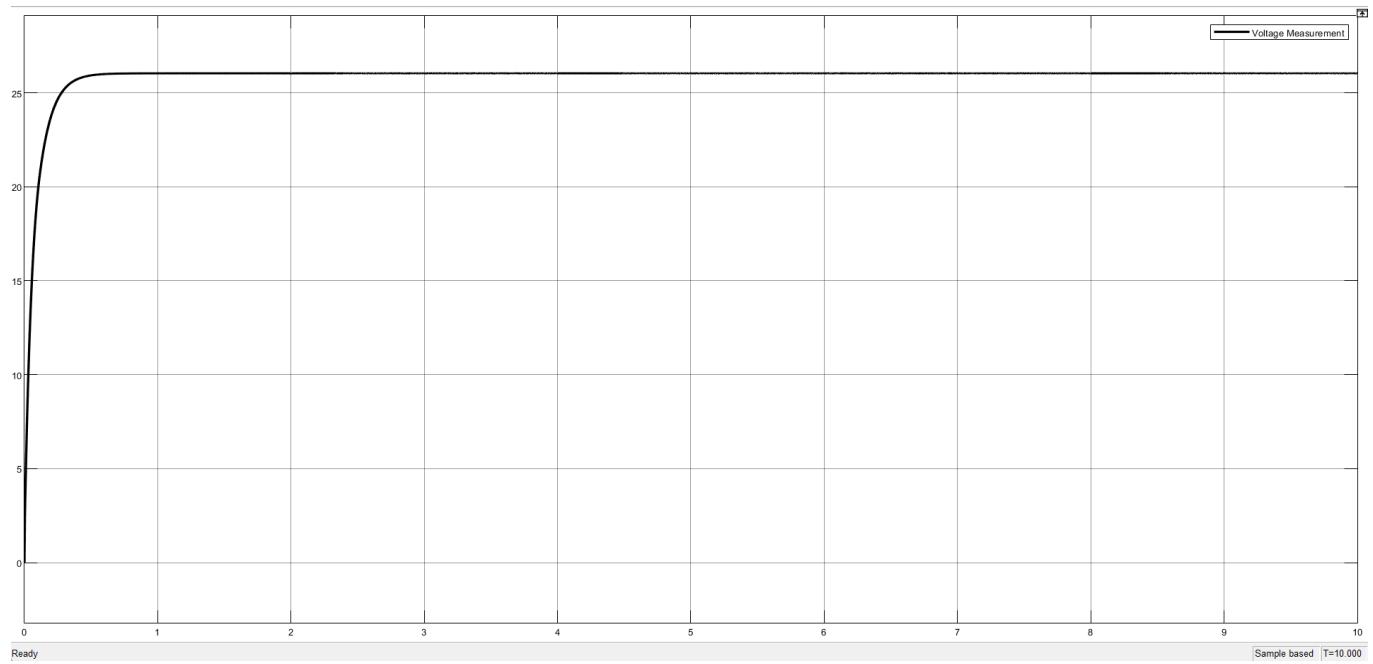
The Simulink model of the Switch Mode Power Supply with a 100 ohm resistive load. The input voltage of 48V (DC) was applied, and the closed-loop system controlled the output voltage with a PID controller and PWM-based switching. The simulation time was 10sec, and the switching frequency was 50 kHz. By the use of a logical gate, the PWM generator (DC–DC) signal shown in Figure 2. and the output of the corresponding switch controlling the MOSFET are displayed. The PWM signal is operational with a duty cycle of about 35%, which matches the theoretical value. With this duty ratio, the converter can output a voltage lower than the input voltage (buck–boost mode). Each waveform shows proper rectangular pulses that confirm the correct performance of the switching logic and PWM generation subsystem.

Voltage output waveform of Switch Mode Power Supply is depicted in Figure 3 using resistive load. On the very first moment, a small transient can be seen that is caused by the charging of the output capacitor and inductor current buildup of buck-boost converter. The voltage goes up smoothly thereafter and stabilizes around 25.8 V, which is almost the same as the designed output of 26 V. At steady state, the voltage ripple is very low. Such a waveform demonstrates a rapid transient response, steady state is reached within the first 1.5 seconds. Voltage regulation is maintained without large overshoot and PID tuning.

### 3.2 Simulation Results for RL Load



*Figure 4. (a) PWM output Logical (b)Operator Output*



**Figure 5. Output voltage ( $V_o$ ) with RL Load**

### 3.3 Comparative analysis

Parameters	R Load	RL Load
Duty Cycle	<b>0.351</b>	<b>0.351</b>
Output Voltage	<b>26 V</b>	<b>26</b>
Output Current	<b>0.26 A</b>	<b>0.26A</b>
Inductor Ripple Current	<b>33.7A</b>	<b>33.7</b>
Load Current Ripple	-	<b>1.82mA</b>
Output Voltage Ripple	<b>0.83</b>	<b>0.9</b>
Efficiency	<b>~90%</b>	<b>~88-89%</b>
Transient Response	<b>Fast</b>	<b>Slow (due to Inductance)</b>

## CHAPTER 4

### SUMMARY AND CONCLUSION

#### **4.1 Summary**

The project was targeted towards the design and simulation of a Switch Mode Power Supply (SMPS) with MATLAB/Simulink on the buck-boost converter topology. The converter was constructed such that a 26 V DC output would be controlled by a 48 V DC input on a closed loop basis. To examine how the nature of loads influences the converter performance, comparison has been taken place with two kinds of loads, resistive (R) and inductive (RL). Theoretical and simulation results were used to calculate design parameters like inductance, capacitance, switching frequency, and duty cycle.

The findings showed that the buck-boost converter was effective in keeping the required voltage at the desired level, which proved that it could be used in both step-up and step-down configurations. It was demonstrated by the comparative analysis that the R load offered a stable and fast transient response at lower voltage ripple whereas the RL load offered a phase lag and a little more ripple because of the energy storage in the inductor. The system had been found to have better voltage regulation and the efficiency which validated the efficacy of the chosen system design and control strategy.

#### **4.2 Conclusion and Future Scope**

To conclude, the simulation study was able to confirm the principle of working and performance of the buck-boost converter based SMPS under varying load conditions. The converter demonstrated effective DC voltage regulation with reasonable voltage ripple and transient characteristics, which also demonstrate its applicability in battery charging systems, DC micro grids, and renewable energy interfaces.

To do more work, in the future, it is possible to extend the project with the implementation of hardware prototype to check the simulated results in the conditions of real time. This can be further enhanced using more sophisticated digital control methods (e.g. fuzzy logic, PID-fuzzy or microcontroller-based control) to develop better dynamic response and efficiency. Also, the converter can be incorporated with other renewable energy such as solar photovoltaic systems to enhance its use in the sustainable and energy-effective system of power.

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