

SIMULATION OF DOUBLE BOOST DC-DC CONVERTER WITH SOLAR PV SYSTEM FED BLDC MOTOR

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ABSTRACT

The expanded requirement for renewable sources of energy systems in order to generate the power, store energy, and connect the energy storage devices with applications has turned into a major challenge. Energy storage using batteries is in the majority of suitable cases for energy sources like solar, wind, etc. In this paper, double boost converter is designed and simulated for energy storage, interfaced with an output drive. Based on the requirements, the power that is extracted from the solar panel during the daytime is utilized to charge the batteries through the double boost converter. The proposed double boost converter in terms of operating principles and power flow can significantly enhance the system efficiency. To develop the suggested approach's control hardware, and prototype model results are obtained to test the proposed double boost converter control system's efficiency and practicality. Overall, the efficiency of the converter's output has shown an improvement. The success rate is 96.5% when charging an ESS, 98.1% when discharging an ESS, and 95.7% overall.

Key words- BLDC motor; DC-DC converter; MPP tracking; solar PV system; double boost converter (DBC); energy storage device (ESD)

1. INTRODUCTION

Renewable energy is environmentally friendly, but its constant yet variable DC voltage has a disadvantage. For example, solar panels depend on the position of the sun in the sky, as well as the hours of the day, which affects not only the amount of power that is produced but also the current that is transmitted. Since the wind speed is not controllable, the output voltage of the generator is not sufficient to power the inverter directly. Therefore, the DC voltage converter (or other bldc motor load) must be connected to power the output drive.

A non-isolate double boost converter can be built with shared switches. The regenerative energy system is connected to a three port circuit. During the day, the solar panels collect energy and send it to the double boost converter. The three port bidirectional one storage inductor charges the batteries. Multiple port converters have been studied for electric vehicles (EVs), energy storage (ES) and PV (PV). Multi-port converters need only a few conversion stages. The power density and conversion efficiency of these converters are very high when compared with conventional converters. For applications of higher power, isolated DBCs are needed. Non-isolated DBC may offer high efficiency, high power output and low cost in low power applications due to the reduction of transistors in a DBC. Single-switch DBC is a DBC family consisting of dual input/output converters with an additional power flow path. It has a very small size and high integration ratio. The two inductor bidirectional converters and two inductive boost converters combine to form a single DBC family. This DBC allows for the regulation of switching frequency as well as duty cycle. The usefulness and efficiency of the DBC are severely limited by the lack of a separate control approach. A multi-port step-up / step-down converter can be constructed with shared switches and connected to a three-port energy storage system. Different types of multi-port converter have been studied for electric vehicles (EVs), power storage (ES) and DC-to-DC converter circuits. Non-isolation DBCs offer high efficiency, high power output, and low cost in low power applications by decreasing the number of integrated transistors in a circuit. This is due to the high power density and high conversion efficiency of non-isolation bidirectional converters, which do not have isolation, but are inexpensive, easy to construct, and have limited internal components.

This DBC can be further improved and optimized with the help of the proposed magnetic integration technique. High voltage gain non-isolation DBCs are very challenging and complex in design. An important addition to this study is the single stage power conversion that takes place between bldc motor load port and PV or between bldc motor load port depending on the design. Power density can be improved by sharing passive power devices in different power flow modes. Efficiency can be improved by reducing the conversion gain by series connecting the PV in series during the discharge domain and making parallel connection between them during the charging domain. Generally, a PV panel is capable of producing the DC, except for most common household appliances such as fans. It can also use single phase induction motors, so conversion loss may have occurred in the operation of the DC to AC converter. This type of difficulty cannot be eliminated by replacing an AC induction motor by a DC motor.

The disadvantage of a DC motor, however, is its high maintenance cost, low rpm application and high EM (electromagnetic (noise). A BLDC is used as an alternative because it has an improved power to weight ratio over a conservative induction motor. The advantage of a BLDC is that it is openly able to power run of DC, but for speed control of a BLDC drive, it has the advantage of additional current sensors and control.

2. PROPOSED SYSTEM

2.1 CIRCUIT OF PROPOSED SYSTEM

The DC/DC Converter, In commonly used in standalone renewable power systems in order to provide continuous and stable power to the electricity bldc motor loads. Interfaces Renewable Energy Source and Bldc motor load.

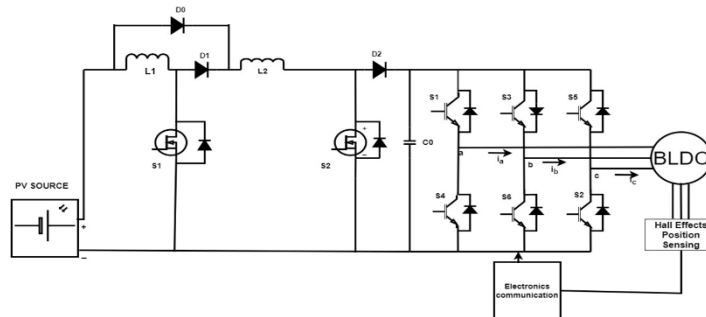


Figure 2.1 Circuit Diagram Of Proposed System

In this figure 2.1 shown the diagram of proposed system that can using the photovoltaic source act as a input and its gives to converter then universal bridge given to motor bldc motor load as BLDC.

2.2 DESIGN OF CONVERTER AND OPERATING PRINCIPLES

The foundation of the converter is established by the voltage extension cell and switching circuit built around an inductor, as illustrated in Figure 2.1.

Energy transmission from a power generator to a bldc motor load According to the two operating modes and Kirchhoff's Current Law (KCL), we can obtain the current stress of each device of the proposed converter. In the two operating modes, the capacitor current is represented by I_{Con} and I_{Coff} , and the equation is as follows.

$$I_{con} = -I_o \quad (1)$$

$$I_{coff} = I_{D3} - I_o \quad (2)$$

where I_o represents the output current and I_{D3} represents the current flowing through diode D_3 . By applying ampere-second balance to the capacitor, the following equation can be obtained as

$$I_o \cdot D = (I_{D3} - I_o) \cdot (1 - D) \quad (3)$$

According to Equation (7), the current stress of diode D_3 can be expressed as:

$$I_{D3} = \frac{I_o}{1 - D} \quad (4)$$

Ignoring the loss of the converter, assuming that the input power and the output power are the same, the following equation can be obtained as:

$$V_{in} \cdot I_{in} = U_o \cdot I_o \quad (5)$$

From (4) and (9), the relationship between input current I_{in} and output current I_o can be expressed as follows:

$$I_{in} = \frac{1 + D}{1 - D} \cdot I_o \quad (6)$$

1-D

According to the operating principle of the ON mode, the current stress of the switches S_1 , S_2 and the diode D_1 can be obtained as:

$$I_{S1} = I_{S2} = I_{D1} = \frac{I_{in}}{2} = \frac{1 + D}{2(1 - D)} \cdot I_o \quad (7)$$

where I_{S1} and I_{S2} represent the current flowing through switches S_1 and S_2 , respectively, and I_{D1} represents the current flowing through the diode D_1 .

According to the operating principle of the OFF mode, the current flowing through the diode D_2 is equal to that of diode D_3 , and it can be described as follows:

$$I_{D2} = I_{D3} = \frac{I_o}{1-D} \quad (8)$$

Finally, according to Equations (5) and (6) and the root mean square principle of the capacitor current, the current stress I_{C1} of capacitor C_1 can be obtained as:

$$I_{C1} = \sqrt{\frac{D}{1-D}} \cdot I_o \quad (9)$$

2.2.1 CALCULATION OF INDUCTOR AND CAPACITOR OF CONVERTER

The parameters of the experimental prototype are as follows: the input voltage is 20 V, the rated output voltage is 100 V, the rated bldc motor load is 100 Ω , the output power rating is 100 W, the values of inductors L_1 and L_2 are both 0.35 mH, the value of the capacitor is 47 μ F, the type of switch is IFR640N, the type of diode is DFE10I600PM and the switching frequency is 20 kHz.

According to Equation the inductance value can be calculated as:

$$L_1 = L_2 = \frac{V_{in} \times D}{2 \times \Delta I_L \times f} \quad (10)$$

where ΔI_L is the inductor current ripple; taking 20% of the average current as the inductor current ripple, the inductance value of the two inductors can be calculated to be 0.35 mH.

According to Equation, the capacitance value can be calculated as:

$$-\frac{U_{C1}}{R} = C_1 \cdot \frac{dU_{C1}}{dt} \quad (11)$$

where ΔU is the output voltage fluctuation, taking 1% of the average output voltage as the capacitor voltage fluctuation, and the capacitor value can be calculated as 47 μ H, the output capacitor (C_0) starts discharging to the BLDC Motor bldc motor load.

2.2.1 MODE ON

When switches S_1 and S_2 are turned on, that is, the converter is in the ON operating mode, the inductors L_1 and L_2 are charged by the input power source, and the inductors absorb energy; the capacitor C_1 supplies energy to the bldc motor load. The operating mode of the proposed converter is shown in Figure 2.2.

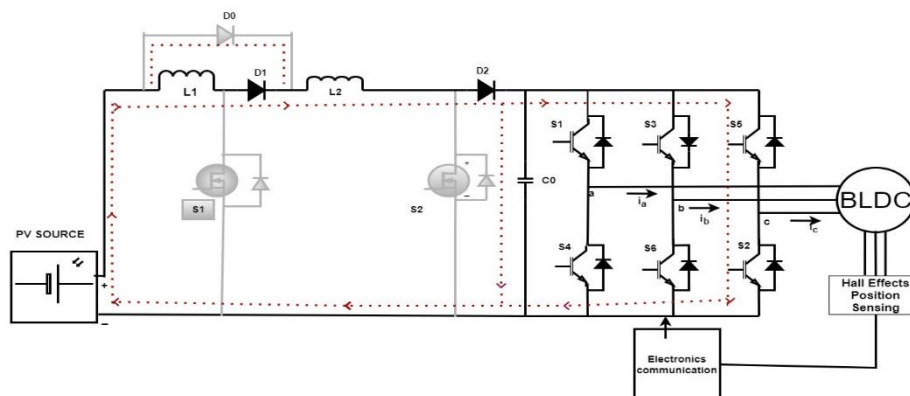


Fig.2.2 mode on circuit diagram

In this mode, diode D_1 is turned on, and diodes D_2 and D_3 are turned off under reverse voltage. During this stage, there are three loops in the equivalent circuit. The input power V_{in} charges the inductor L_1 through the switch S_1 to form the first loop. The input power V_{in} charges the inductor L_2 through the switch S_2 to form the second loop. The output capacitor C_1 provides energy to the bldc motor load to form the third loop. The voltages across the two inductors L_1 and L_2 are the voltages V_{in} of the input voltage power source. then the turn-on time of switches S_1 and S_2 is $D \times T_s$ in one cycle. Suppose that the currents through the inductors L_1 and L_2 are I_{L1} and I_{L2} , respectively. In this stage, the currents of the two inductors are equal, and the energy absorbed by the two inductors in a PWM period is shown in Equation (1).

$$W_L = V_{in} \times I_L \times D \times T_s \quad (12)$$

where W_L represents the energy absorbed by the inductor during the turn-on period of the switch. output capacitor C_0 begins to discharge to bldc motor load.

2.2.2 MODE OFF

When the switches S1 and S2 are turned off, that is, the equivalent circuit is in the OFF mode, the inductors L_1 and L_2 are connected in series with the input power source to provide energy to the bldc motor load and charge the capacitor C_1 ; the operating mode of the converter is shown in Figure2.3.

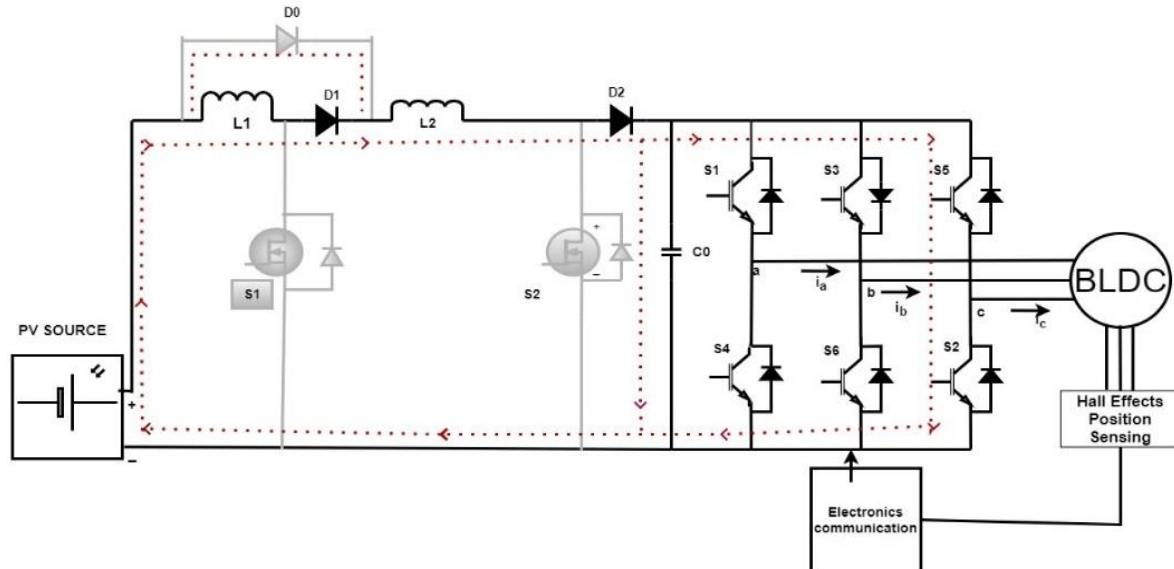


Fig2.3; mode off circuit diagram

In this mode, diodes D_2 and D_3 are turned on, and diode D_1 is turned off under reverse voltage. During this stage, there is only one loop in the equivalent circuit. The input power source V_{in} and inductors L_1 and L_2 are connected in series to provide energy to the bldc motor load and charge the output capacitor C_1 . By ignoring the conduction voltage drop in the diode, the voltage across the two inductors L_1 and L_2 are the voltage V_{in} of the input voltage. The voltage and current reference directions on the inductor are uncorrelated, and the energy released by the two inductors in a PWM period is shown in Equation (13).

$$W_{L'} = (1/2) U_0 - U_{in} \times I_L \times (1 - D) \times T_s \quad (13)$$

where $1 - D$ represents the turn-off period of the switch, and $W_{L'}$ represents the energy released by the inductor during the turn-off period of the switch. Based on the law of the conservation of energy, the following equation can be obtained as Equation (3).

$$W_L = W_{L'} \quad (14)$$

According to Equations (1)–(3), the voltage gain G_D of the proposed converter can be obtained as shown in Equation (14).

$$G_D = \frac{1 + D}{1 - D} \quad (15)$$

By calculating this, the relationship between the voltage gain and the duty cycle D of the proposed double-boost converter can be obtained, as shown in Figure 4

2.3 MATHEMATICAL MODELING OF PROPOSED SYSTEM

2.3.1 PV MODELING

The mathematical representation of a PV module can be derived from the equivalent circuit of a PV solar cell. The photocurrent, denoted as I_c , is determined by the temperature and solar irradiation of the cell, while R_s and R_{sh} represent the series and shunt resistances of the PV cell. The nonlinear voltage-current characteristic of the PV solar cell can be assessed using the Equation.

$$I_{pv} = I_c - I_0 \left[\exp \left(\frac{q(v_{pv} + R_s I_{pv})}{kT} \right) - 1 \right] - \frac{v_{pv} + R_s I_{pv}}{R_{sh}} \quad (4)$$

2.3.2 THE FLOW OF ELECTRICITY IN SOLAR CELL

Electrons, bearing a negative charge, migrate towards the front surface of the solar photovoltaic cell, resulting in an electrical charge imbalance. The electrical conductors on the cell then capture these electrons. Once the conductors are linked in an electrical circuit to an external bldc motor load and electricity is able to pass through the circuit.

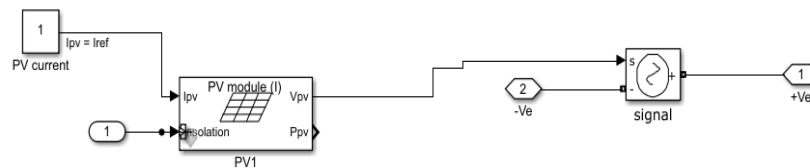


Figure 2.4 Simulation of PV

2.4 CONTROLLERS

This is the mechanism or algorithm responsible for processing the sensor input and producing the control output. It evaluates the measured process variable against the target set point and computes the error signal. Using this error signal, the controller produces the control output for the actuator.

2.4.1 VOLTAGE CONTROLLER

The DC-DC Voltage Controller block utilizes discrete-time proportional-integral (PI) DC-DC voltage control with feedforward (FF) for optimizing transient response. It can provide either a duty cycle or a current control signal. Additionally, an anti-windup gain is implemented to prevent integral gain saturation.

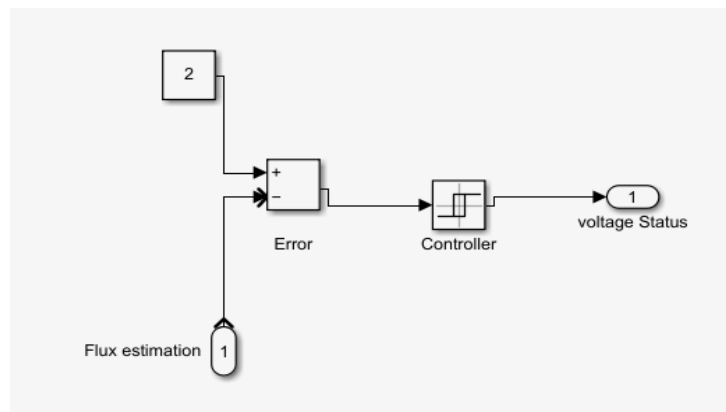


Figure 2.5 Simulation of Voltage Controller

Table 2-controlled voltage source block properties

Source Type	DC
Initialize	On
Amplitude	230

2.4.2 PI CONTROLLER

The PI Proportional and Integral controller is a widely utilized technique in control systems to rectify the discrepancy between the desired setpoint and the actual value, based on feedback. Over the past decade, Permanent Magnet Brushless DC (BLDC) motors have found significant applications in various industries such as E-mobility (Electric vehicles, Electric bicycles), Industrial robots, and CNC machine tools. BLDC motors are crucial components in numerous industrial automation applications due to their exceptional efficiency and high torque-to-power ratios. Unlike traditional motors, Brushless DC motors operate without brushes on the rotor, resulting in minimal maintenance requirements. In the presented approach, the Hall Effect sensors are employed to commutate the BLDC motor. Furthermore, an algorithm is proposed for closed-loop PWM speed control of BLDC motors, where a predetermined value or user control is utilized to regulate the motor speed.

Table 3-Discrete PI Controller block properties

PARAMETER	SYMBOL	VALUE
Proportional gain	k_p	0.1
Integral gain	k_i	1

Sample time	-	50e-6
Output limits	Upper lower	1e6 10e6

2.4.3 PID CONTROLLER

Simultaneously, the PID controller's constant coefficients, namely K_p , K_i , and K_d , are utilized to establish a set of values. By incorporating these values, the modified controller suggested can be adapted to any desired dimension.

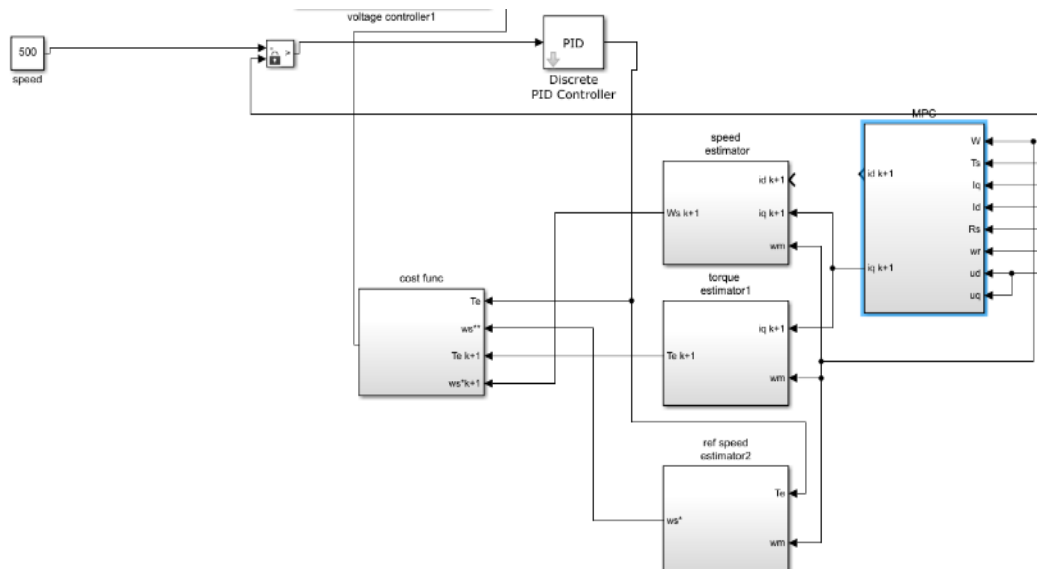


Figure 2.6 Simulation of PID Controller

Table 3-Discrete PID Controller Block Properties

Name	K_p	K_i	K_d	Tc D	Par Limits	Init	Ts
Discrete PID Controller	11.2	90	2.4	1	[100 -100]	0	0.5

3. SIMULATION PARAMETER SPECIFICATIONS

Table 4 : Simulation parameter specification of double boost converter

PARAMETERS	SPECIFICATIONS
Inductor L_1	100 μ H
Inductor L_2	100 μ H
Capacitors C_O	10 μ F
Switch	2Power MOSFET
Diode	3Power Diode
Switching frequency	50kHz
Input supply	1800 W
Cell Temperature	25 $^{\circ}$ C
Irradiance	1000W/m 2

3.1 SIMULATION CIRCUIT

It has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis. Its features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. The figure displays the simulation circuit of the proposed system. The simulation was conducted using MATLAB 2021a version with the ode23tb solver. To execute the simulation and observe the outcomes, the discrete powergui with a time constant of $5e-7$ was employed.

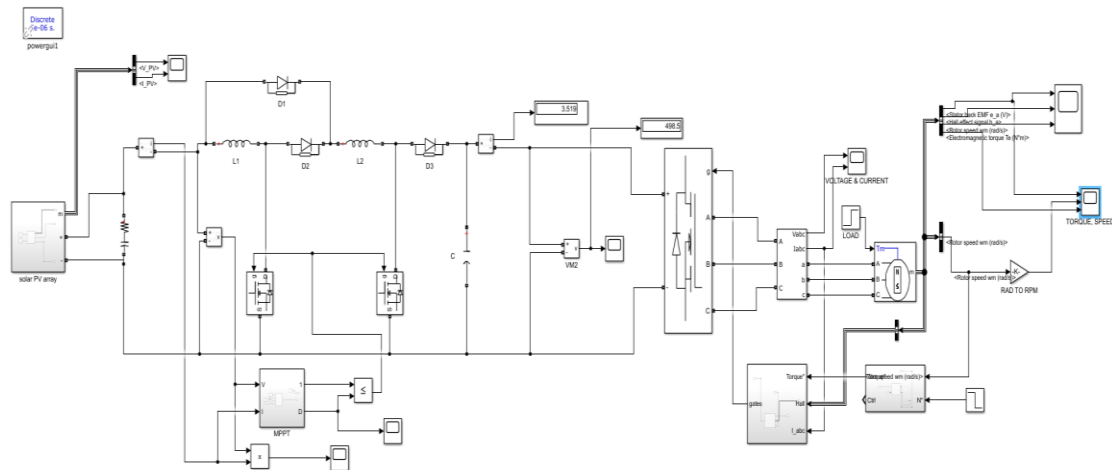


Figure 3.1 Simulation of DBC Circuit.

3.2 SIMULATION RESULT

The system simulation was created utilizing MATLAB/Simulink. A prototype of the DC-DC Converter under consideration has been constructed and examined. In order to attain the target output voltage, the simulation circuit was formulated in MATLAB, incorporating the necessary components available in MATLAB/Simulink.

3.2.1 PANEL VOLTAGE

The voltage obtained from the panel is depicted in Figure 3.1. The Simulink model utilizes a user-defined panel. By increasing the series and parallel strings, the desired voltage has been achieved.

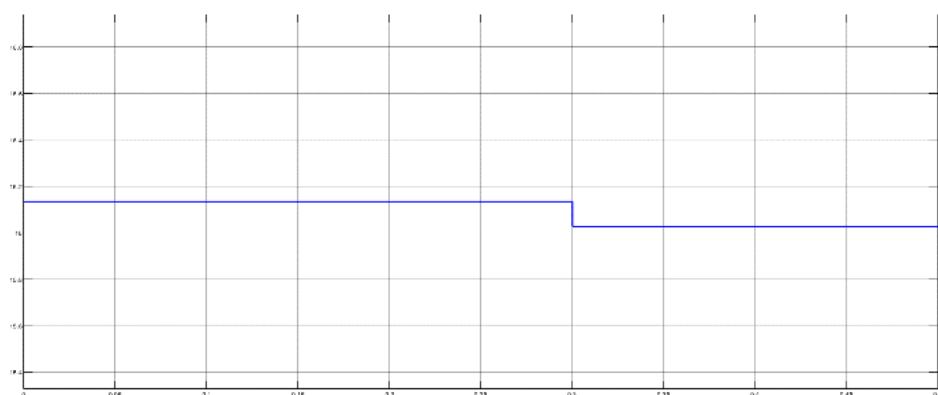


Figure 3.1 Waveform of PV

3.2.2 CONVERTER VOLTAGE

The output voltage obtained from the Double boost converter converter for the designed duty cycle is illustrated in Figure 3.2. By utilizing the double boost converter, the voltage of the PV panel is effectively increased.

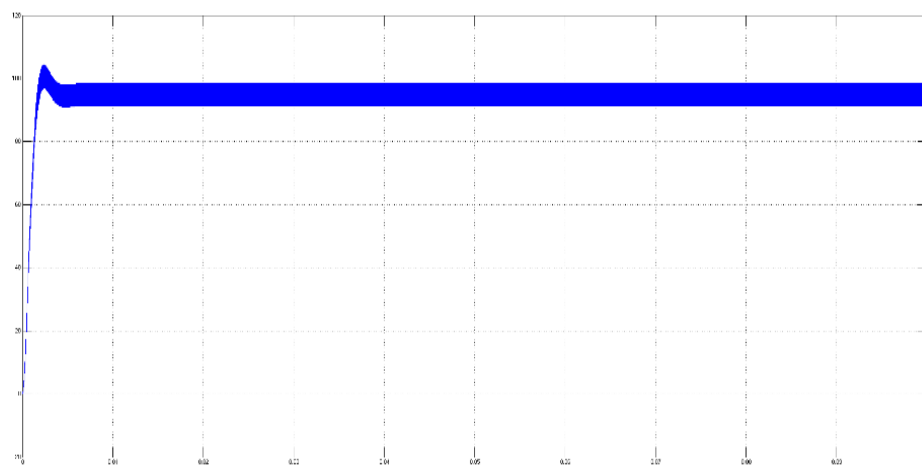


Figure 3.2 Waveform of double boost Converter Voltage

3.2.3 UNIVERSAL BRIDGE

In Figures 3.3 and 3.4 depict the universal bridge with and without a filter. The plot was obtained prior to the filter being utilized in the circuit, showing ripples in the waveform.

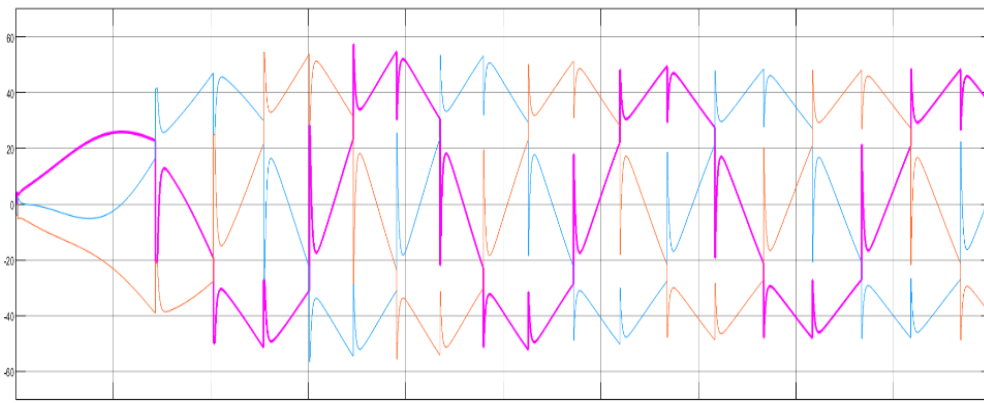


Figure 3.3 Waveform UB Without Filter

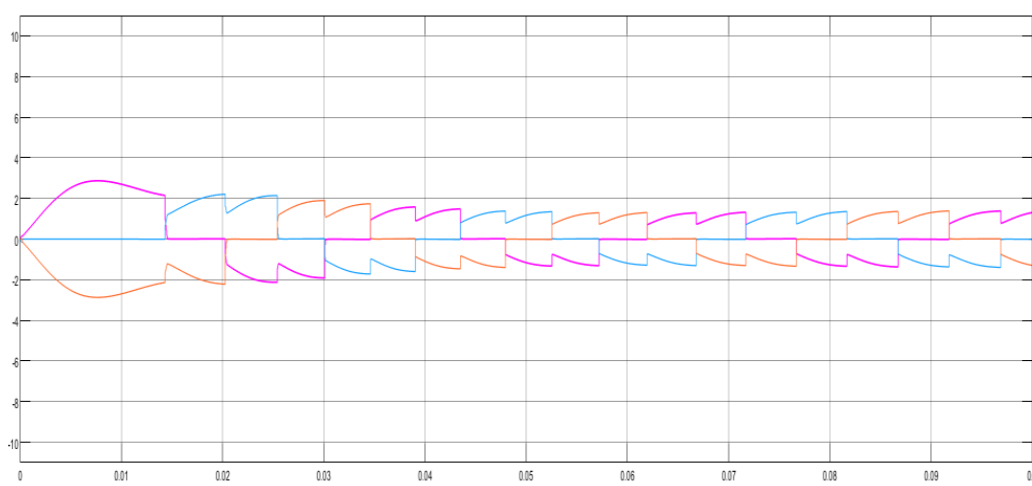


Figure 3.4 Waveform UB With Filter

3.2.4 SWITCHING PWM GENERATOR

The figure 3.5 shows the switching pulse width modulation given to the double boost converter.

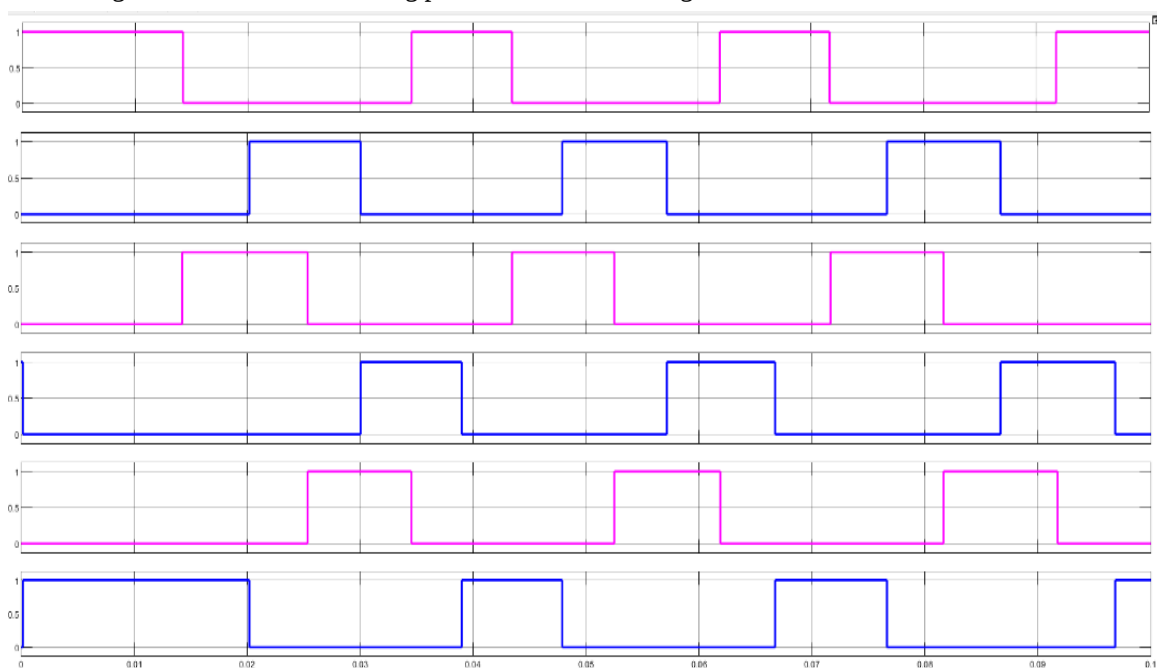


Figure 3.5 Waveform of Switching PWM Generator

3.2.3 BUS SELECTOR OF HALL SIGNAL

In this figure shown the hall signal that from bus selector of bldc. Time (sec)

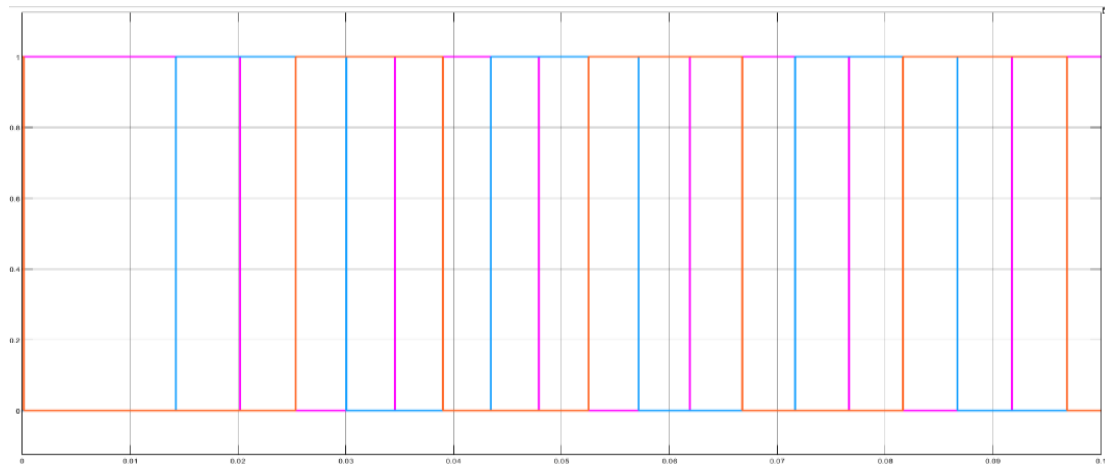
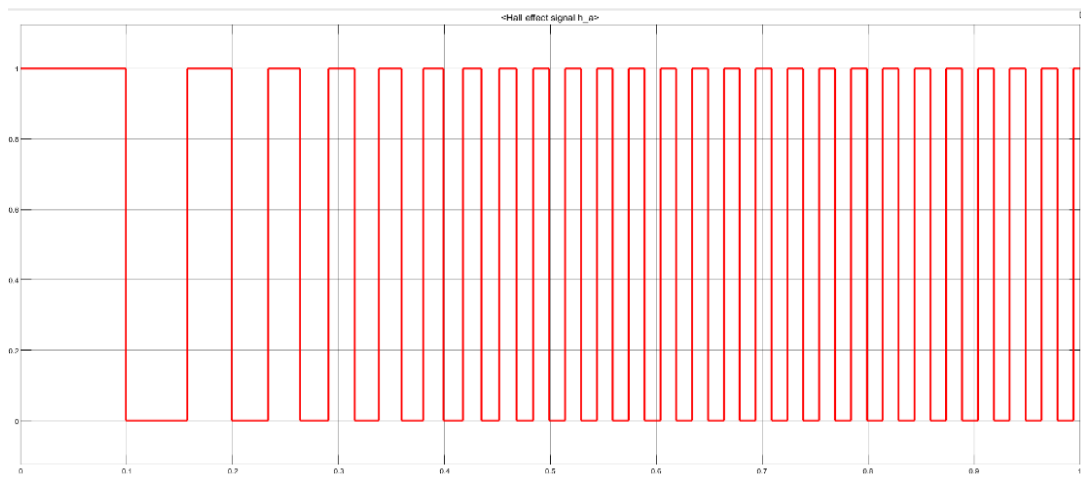


Figure 3.6 Waveform of Hall Signal

3.2.4 HALL SENSOR PWM MODULE

In figure 3.7 this shows using hall sensor for bldc motor with pulse with modulation

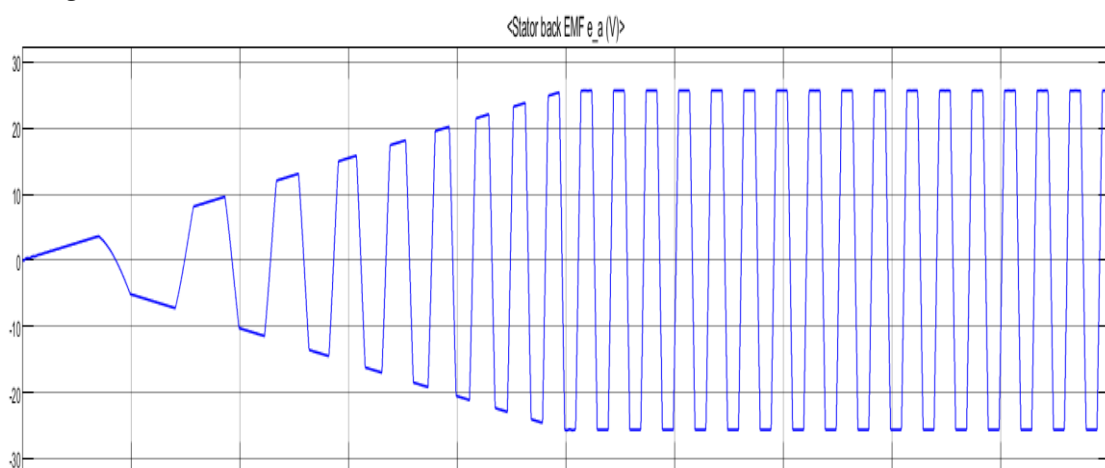


Time (sec)

Figure 3.7 Waveform Hall Sensor PWM Module

3.2.3 STATOR CURRENT

The simulation output waveform of the stator current is displayed in Figure 3.8. The time is represented on the X-axis, while the magnitude of current for the stator waveforms is shown on the Y-axis.

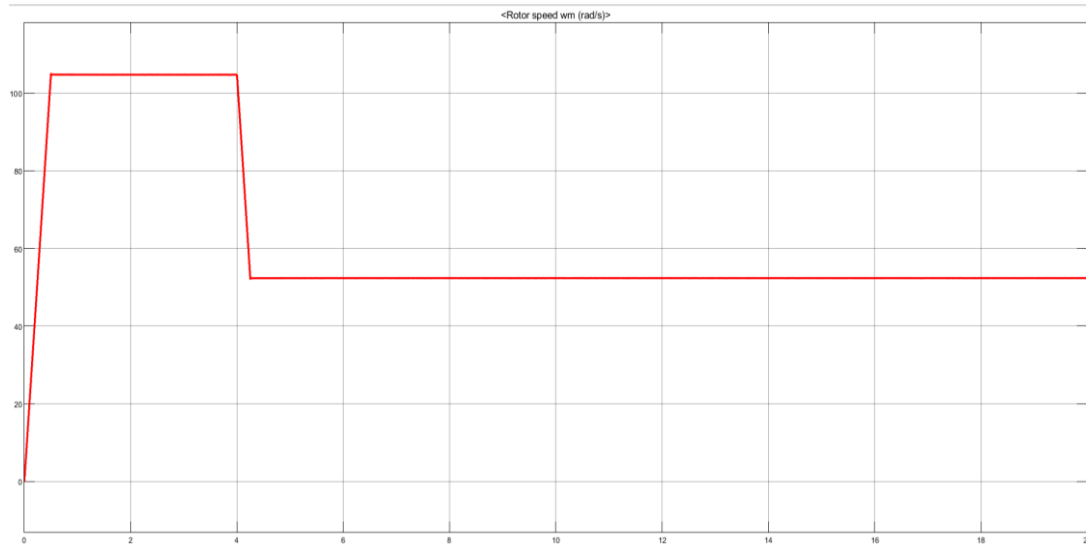


Time (sec)

Figure 3.8 Waveform of Stator

3.2.5 ROTOR SPEED

In figure 3.10 shows output waveform of speed in BLDC motor ,to calculate speed by x axis is represents speed and y axis is represents time.

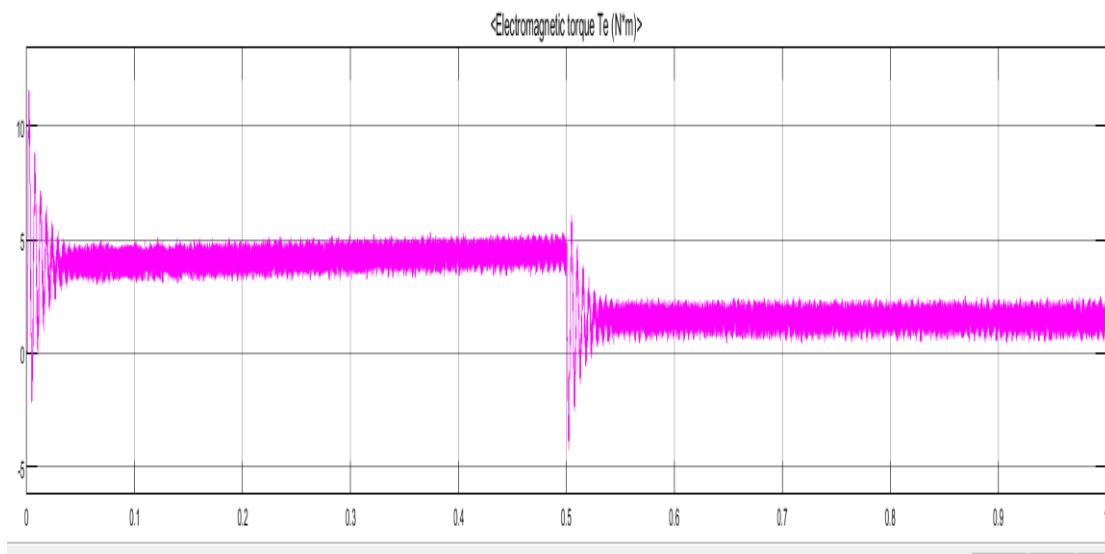


Time (sec)

Figure 3.10 Waveform of Speed

3.2.6 TORQUE

In figure 3.11 output waveform in torque from BLDC Shows, X axis represents Torque and Y axis represents time.



Time (sec)

Figure 3.11 Waveform of Torque

4. CONCLUSION

In this study, we have introduced a novel DC-DC converter that combines solar PV and a battery to power a BLDC motor. This converter has been designed to efficiently manage power simultaneously. Unlike traditional converters, the power generation sources directly charge the battery, regardless of the bldc motor load power. As a result, the overall output efficiency of the converter is significantly improved.

The results clearly demonstrate that the converter is capable of maximizing power generation from solar PV during radiation and effectively controlling the battery to maintain a constant output value during irradiation. The proposed design exhibits an impressive efficiency of 96.5% while charging an ESS, 98.3% during discharge, and 95.76% when not charging an ESS.

In the future, this innovative system can be implemented with a hysteresis comparator approach for automotive fuel pump applications.

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