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DESIGN OF DC-DC BUCK CONVERTER FOR APPLICATION IN SOLAR WATER PUMP

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Abstract - This paper suggests a water pumping system that combines a DC-DC converter with solar photovoltaic (SPV) technology. The DC-DC converter is also employed as a power adjusting device that may adjust the output voltage in accordance with the demands of the load. To harness the sun's full power, this is also coupled with a dual axis sun path tracer. A simple hardware model is also developed, and the suggested mechanism is simulated using the MATLAB software.

***Key Words*:** water pump, SPV, solar, DC-DC converter, MATLAB, dual axis, path tracer

1. INTRODUCTION

More cleaner and renewable energy sources are highly desired due to the rising global energy demand. Solar-generated electricity is now more in demand than electricity from other unconventional sources. Solar energy is a vital renewable resource that may be used most effectively in developing nations like India. The most plentiful source of energy on Earth is solar energy; it continuously bombards the planet with 173,000 terawatts of energy, 10,000 times more energy than the entire globe consumes.

A DC-DC converter is usually used to transfer DC voltage of one variety to another variety where the input voltage is taken by dissimilar voltage source. Occasionally, a DC-DC buck converter is used to generate low output voltage from high input voltage, enabling the construction of smaller devices. To reduce the expense of creating an inverter circuit, a dc pump can be utilised instead of an ac pump.

Usually, the DC-DC buck converters are used for both step up and step down voltage. But the proposed DC-DC buck boost converter will produce negative output voltage with low duty cycle. Due to the low duty cycle it will produces high voltage gain. The proposed DC-DC buck converter builds up using a DC input voltage, LM2596 switching regulator, inductors, diodes and one output capacitor which is used for storing and transferring energy from input to output of the circuit. The proposed DC-DC buck converter will provide superior efficiency.

The dual axis solar tracker used in the proposed solar tracker prototype is managed by an Arduino Uno, an open source prototyping platform built on simple hardware and software.

2. Body of Paper

- **Components required for the proposed system**

Inductors, capacitors, a variable resistance, a solar panel, a DC water pump, an Arduino Uno, connecting and jumper wires, and other essential parts are needed to make this circuit.
Below is a discussion of the ratings.

Table -1: Design Parameters

Sr No.	Design Parameters	Values
1	Input Voltage, V_S	19.25V
2	Output Voltage, V_O	12V
3	Switching Frequency	20Khz
4	Maximum Output Current, I_{Omax}	0.58A
5	Current Ripple, I_{ripple}	1.75A
6	Voltage Ripple, V_{ripple}	0.12V
7	Rating of Dc pump	7W, 12V
8	Rating of Solar Panel	20W, 19.25V

- **Selection of Solar Panel**

The Solar PV system design has been carried out in two main steps:

a. Load estimation
b. Estimation of number of PV panels

Total Power Requirement of the System:

= No. of units * rating of equipment= 1* 7 = 7 Watts.

Total Watt-hours rating of the system:

= Total connected load (watts) * Operating hours

=7 * 8 = 56 Watt hours

Actual power output of PV panel:

= power * operating factor

= 20W* 0.75 = 15Watts

Power used after power losses in the end (80% efficiency)

= 7.5* 0.80 = 12 Watts

Energy Produced by 1 solar panel:

=12 * 5 hours per day (say 9am to 3pm)
= 60 Watt hour

∴ number of PV required= 56/60 =1 panel(approx.)

After considering losses (25%)
Power output= actual power(1-losses)

= 20(1-25%)= 15Watts.

- **Losses in solar panel**

Module temperature loss = 15%
Module soiling loss due to dust = 2%
Module mismatch loss = 2%
Dc cable loss = 2%
Solar radiation loss = 4%

Total PV losses = 25%

- **Selection of Inductor**

The value of inductor is based on the design equation given value below:

$$L = \frac{D(1-D)V_o T}{\Delta I_l}$$

$$L = \frac{0.62 \times (1-0.62) \times 12 \times 5 \times 10^{-5}}{1.75} = 8.077 \times 10^{-5} H = 80 \mu H$$

Where, D is the duty cycle of buck converter which is given by

$$D = \frac{V_o}{V_S} = \frac{12}{19.25} = 0.62$$

T=Operating time of Power Switch

The operating time of power electronic switch,

$$T = \frac{1}{f_{sw}} = \frac{1}{20 \times 10^3} = 5 \times 10^{-5}$$

ΔI_l=Ripple current in percentage (Typically 20 % to 40 % of the load current)

Hence Ripple Current =0.3 * 0.58 = 0.12A

- **Selection of Capacitor**

The value of capacitor can be selected by using equation which is given by

$$C = \frac{D(1-D)V_s T^2}{8L\Delta V_c}$$

$$C = \frac{0.62 \times (1-0.62) \times 19.25 \times (5 \times 10^{-5})^2}{8 \times 80 \times 10^{-6} \times 0.12} = 1.47 \times 10^{-4} F = 147 \mu F$$

- **Selection of Switching Regulator**

For this, we have picked the LM2596 Switching Regulator. A common step-down switching regulator integrated circuit is the LM2596. The adjustable version can source varying voltage from an input voltage range of 4.5 to 40 volts with a continuous current of up to 3 Amperes. Due to its high current capabilities, it is frequently employed in power modules to control or power large loads.

Fig -1: LM2596 Switching Regulator

The LM2596 only requires a small number of components, making it reasonably easy to use. The unregulated voltage is delivered to pin 1 (Vin) via a filter capacitor to decrease input noise. Connect the ON/OFF or enable pin (pin 5) to ground to turn the IC on. In order to stop current leakage, the IC will enter shutdown mode if the value is set too high.
This function will be useful for preserving input power while utilising a battery. Due to the fact that it regulates output voltage, the feedback pin is essential. Based on the output voltage value, it detects the output voltage and modifies the internal switch's switching frequency to provide the appropriate output voltage. The output voltage is then retrieved through pin 2 using an LC filter.
The whole circuit schematic is
shown below; these circuits are commonly found in the LM2596 DC Converter module.

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Fig -2: LM2596 Module

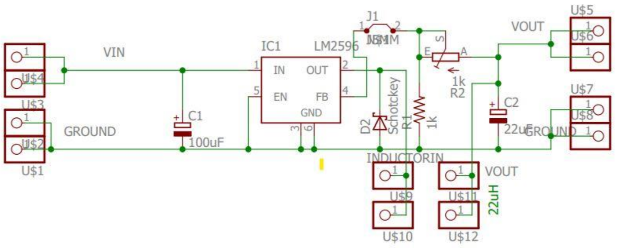
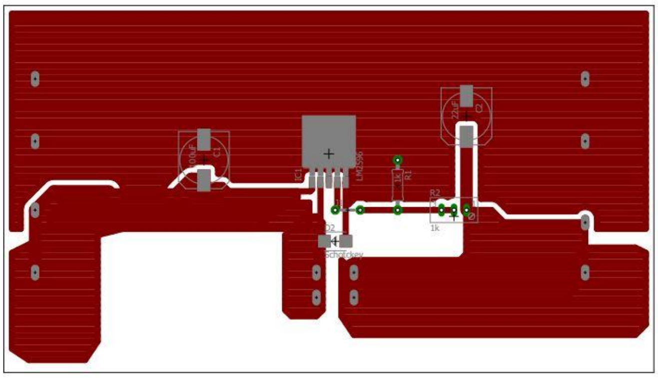


Fig -3: Designed Buck Converter

Fig -4: Circuit Design



- **Dual Axis Solar Tracker**

A stepper motor, which offers higher torque at low speeds and better control for dual axis tracking purposes, is incorporated into the proposed system. This is controlled by an Arduino Uno.
Solar panels are mounted on a moving structure in solar tracking systems to follow the path of the sun throughout the day. Tracking can be done in three different ways: actively, passively, and chronologically.
Then, either single-axis or dual-axis solar trackers can use these techniques.
In active tracking, sensors continuously ascertain where the sun will be during the day. In order for the solar panels to face the sun all day, the sensors will cause the motor or actuator to shift the mounting system.
When there is an imbalance in pressure between two places, a passive tracker will move. The imbalance is caused by gas pressure being created by solar heat on a compressed gas fluid with a low boiling point, which causes the structure to shift as a result. However, the accuracy of this approach of tracking the sun is poor.
A timer-based tracking system is known as a chronological tracker.
All day long, the structure is moved at a set speed.
The actuator or motor is designed to rotate constantly at a rate of 15 degrees per hour, or one revolution, on average, every day.
This method of tracking the sun is quite precise. However, watching the sun on a very gloomy day is useless because the motor rotates continuously, using more power.

Fig -5: Dual Axis Tracer

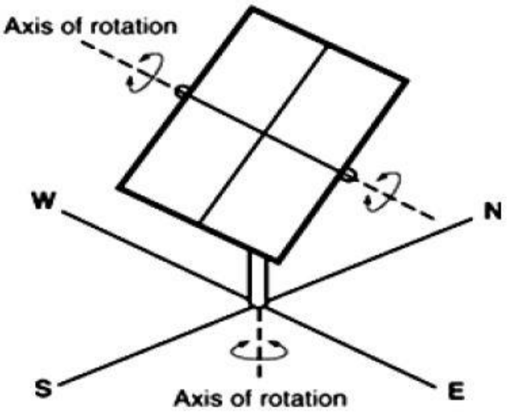


Fig -6: Stepper motor setup

- **Simulation Results**

Fig -6: Input Voltage vs Time

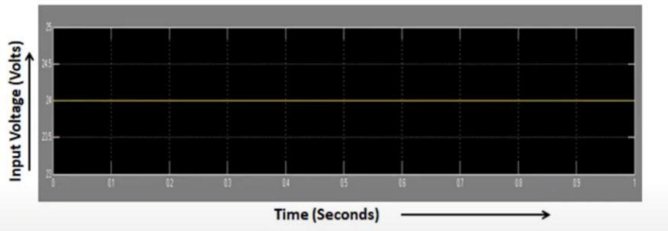
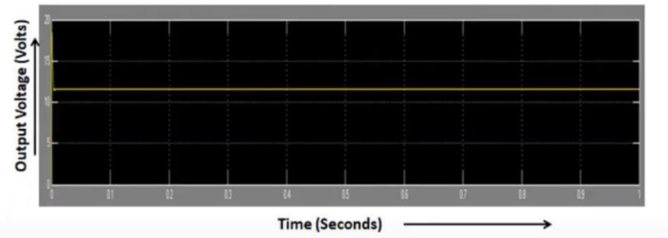
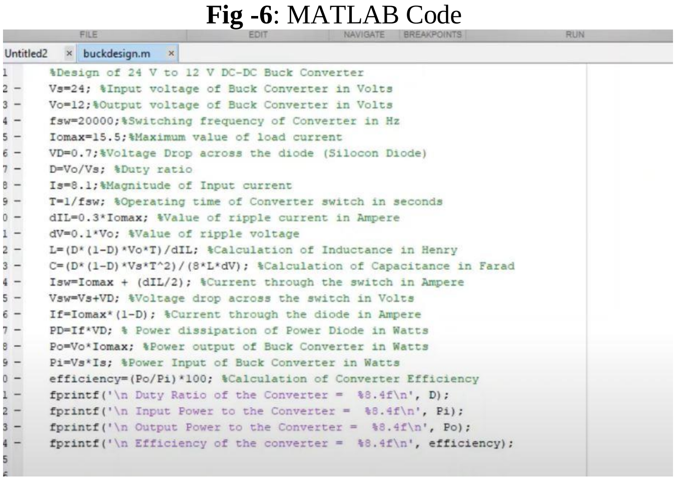


Fig -7: Input Voltage vs Time



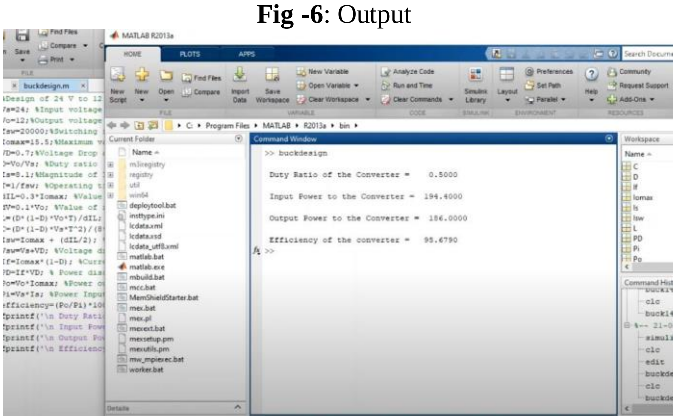
- **MATLAB Code and Output**

Fig -6: MATLAB Code



```
%Design of 24 V to 12 V DC-DC Buck Converter
Vs=24; %Input voltage of Buck Converter in Volts
Vo=12;%Output voltage of Buck Converter in Volts
fsw=20000;%Switching frequency of Converter in Hz
Iomax=15.5;%Maximum value of load current
VD=0.7;%Voltage Drop across the diode (Silocon Diode)
D=Vo/Vs; %Duty ratio
Is=8.1;%Magnitude of Input current
T=1/fsw; %Operating time of Converter switch in seconds
dIL=0.3*Iomax; %Value of ripple current in Ampere
dV=0.1*Vo; %Value of ripple voltage
L=(D*(1-D)*Vo*T)/dIL; %Calculation of Inductance in Henry
C=(D*(1-D)*Vs*T^2)/(8*L*dV); %Calculation of Capacitance in Farad
Isw=Iomax + (dIL/2); %Current through the switch in Ampere
Vsw=Vs+VD; %Voltage drop across the switch in Volts
If=Iomax*(1-D); %Current through the diode in Ampere
PD=If*VD; % Power dissipation of Power Diode in Watts
Po=Vo*Iomax; %Power output of Buck Converter in Watts
Pi=Vs*Is; %Power Input of Buck Converter in Watts
efficiency=(Po/Pi)*100; %Calculation of Converter Efficiency
fprintf('\n Duty Ratio of the Converter = %8.4f\n', D);
fprintf('\n Input Power to the Converter = %8.4f\n', Pi);
fprintf('\n Output Power to the Converter = %8.4f\n', Po);
fprintf('\n Efficiency of the converter = %8.4f\n', efficiency);
```

Fig -6: Output



3. CONCLUSIONS

An experimentally confirmed DC-DC buck converter has been modeled, simulated in MATLAB, and interfaced with a solar path tracer water pumping system. Different input power levels have been supplied, and outcomes have been reported. The suggested water pumping system stands out for its significant characteristics, which include solar tracing for increased efficiency and variable output voltage depending to the connected load. The performance of a dual axis tracker has greatly improved since it properly aligns with the direction of the sun and records its movement. The proposed system is also economically advantageous due to a minor change made to the single axis tracker that significantly increased the system's power.

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