SIMULATION OF DC-DC CONVERTER TOPOLOGY FOR SOLAR PV SYSTEM UNDER VARYING CLIMATIC CONDITIONS WITH MPPT CONTROLLER

P. Selvabharathi¹ S. Veerakumar¹ V. Kamatchi Kannan²
¹Assistant Professor, EEE Department, Bannari Amman Institute of Technology
²Associate Professor, EEE Department, Bannari Amman Institute of Technology
selvabharathip@bitsathy.ac.in

Abstract- Nowadays Renewable energy is more important because of growing power demands, lowering of carbon emission and depletion of fossil fuels. From all renewable categories, Solar energy is multiplied because of sun power to be had for lots hours. The performance of sun energy may be very low; the usage of energy electronics converter may be very critical for maximizes the moving of energy from renewable power resources. Since many converter topologies are layout and implemented, out of which appropriate converter need to be taken out for the unique layout of applications. This challenge goals to layout and simulated of diverse converters topology like Boost, CUK and SEPIC converters with MPPT algorithm. The converter layout is completed and theoretical layout is proven with simulations for comparing the nice topologies for PV primarily based totally software the use of PSIM tool.

Keywords- Boost Converter, Cuk converter, MPPT Controller, P&O algorithm

1. INTRODUCTION

Electricity consumptions is improved day via way of means of day. The traditional electricity reasserts including oil, coal and petrol creates pollutants due the manufacturing of greenhouse gases like CO₂, N₂, etc., and walking down of those reasserts improved. Because of walking down of reasserts make the researchers to discover trade electricity reasserts which must have longer life, absence of noise, absence of pollutants, much less time of set up like photovoltaic device. In current days, primarily based totally grid linked sun PV structures and standalone device are speedy rising everywhere in the world. The hazards of PV device are low electricity conversion performance that makes it highly-priced for excessive electricity requirements. Various electricity converters are designed to enhance electricity harvest. In PV device most electricity factor monitoring algorithms are helped to extract excessive green electricity from sun PV device which ends up boom in performance. Other benefits of this approach is it does now no longer require separate converter circuit to implement. With assist of all DC-DC Converters MPPT may be carried out and can also step up/step down the voltage ranges with appreciate to every application.

2. DC-DC CONVERTER

Generally, Power Electronics converters are labelled into classes that’s isolated and non-isolated power converters. Boost, Buck-Boost, CUK, SEPIC converter are non-isolated converters which is easy in shape and excessive performance for small voltage conversions. These converters don’t provide safety towards excessive enter voltage and transient’s voltage. Boost converter is kind of DC to DC energy converter that step-up implemented enter voltages to required output voltage. Boost converter shown in figure 1. The operation of the circuit is primarily based totally upon the conduction time of the MOSFET transfer. To function the boost converter in continuous conduction mode, high switching frequency is used. MOSFET has excessive conduction loss and to less conduction loss, switching frequency need to boom and voltage pressure throughout the transfer to be reduced. The output voltage has received has DC ripples, output capacitor is inserted to make ripple loose output voltage.
The buck boost converter is a DC to DC converter which generates output voltage less than or greater than applied voltage magnitude. Figure 2 shows circuit diagram of buck boost converter. Buck-boost converter generates range of output voltage, from much greater than applied voltage and down to nearly zero.

![Figure 1 Boost Converter](image)

![Figure 2 Buck-Boost Converter](image)

CUK converter is combination of boost converter which is in input part followed by output part has buck converter circuit with capacitor is connected in between to couple the energy. CUK is similar one like buck–boost converter circuit with inverting topologies. Cuk converter is shown in figure 3.

![Figure 3 CUK Converter](image)

The SEPIC converter is one of the DC-DC converter which step up/step down the input voltage based on the duty cycle which is applied to power converter switch. Figure 4 shows the circuit diagram of SEPIC converter.

![Figure 4 SEPIC Converter](image)
3. Solar PV with MPPT Controller

Solar panel with MPPT controller as shown in figure 5. The output of the solar panel varies from time to time due to the intensity of light (irradiance). The maximum power can be delivered when the irradiance is maximum. The voltage and current will be an input to the MPPT algorithm block. Solar panel consists of photovoltaic cells which is used to absorb sunlight and convert it into electrical energy.

![Diagram of Solar PV with MPPT Controller](image)

Figure 5 Solar PV with MPPT Controller

It always produces direct current (DC). In this paper, five solar panels of 100W are connected in parallel to give 500W. The solar panels can be connected in three different ways. They are series or parallel or the combination of both. When the solar panels are connected parallel, the voltage of the circuit remains same and current will be additive. The specifications of solar panel used in this paper is listed in Table 1.

| Parameters                  | Values  |
|-----------------------------|---------|
| Maximum Power ($P_{\text{max}}$) | 500 W   |
| Open circuit Voltage ($V_{\text{oc}}$) | 18 V    |
| Short circuit Current ($I_{\text{sc}}$) | 6.06 A  |
| Maximum Voltage ($V_{\text{max}}$) | 12 V    |
| Maximum Current ($I_{\text{max}}$) | 5.56 A  |

4. CALCULATION OF PARAMETERS

The design parameters of DC-DC converters are derived and equations for Duty cycle, Inductance and Capacitance are listed in Table 2. All the converters are assumed to be worked in continuous conduction mode such that inductor is designed above the critical value. The values for inductor and capacitor of each converter are calculated using the equation derived and listed in Table 3.
Table II. Design of dc to dc modulators

| Parameters | Boost converter | Buck-Boost converter | CUK converter | SEPIC converter |
|------------|-----------------|----------------------|--------------|-----------------|
| Duty Cycle | \( D = \frac{V_m}{V_{\text{out}}} \) | \( D = \frac{V_{\text{out}}}{V_{\text{out}} - V_m} \) | \( D = \frac{V_{\text{out}}}{V_{\text{out}} + V_m} \) | \( D = \frac{V_{\text{out}}}{V_{\text{out}} + V_m} \) |
| Inductance | \( L_1 = \frac{V_{\text{out}}}{\frac{\Delta L_1}{f}} \) | \( L = \frac{V_{\text{out}}}{\frac{\Delta L_1}{f}} \) | \( L_1 = \frac{V_{\text{out}}}{\frac{\Delta L_1}{f}} \) | \( L_1 = \frac{V_{\text{out}}}{\frac{\Delta L_1}{f}} \) |
| Capacitance | \( C_0 = \frac{D}{R(\Delta V_{\text{out}}/V_m)f} \) | \( C_0 = \frac{D}{R(\Delta V_{\text{out}}/V_m)f} \) | \( C_0 = \frac{D}{R(\Delta V_{\text{out}}/V_m)f} \) | \( C_0 = \frac{D}{R(\Delta V_{\text{out}}/V_m)f} \) |

Table III. Design Specifications

| Parameters | Boost converter | Buck-Boost converter | CUK converter | SEPIC converter |
|------------|-----------------|----------------------|--------------|-----------------|
| Input voltage (\( V_{\text{in}} \)) | 12 V | 12 V | 12 V | 12 V |
| Duty Cycle (D) | 0.5 | 0.67 | 0.67 | 0.67 |
| L₁ | 12 mH | 16.8 mH | 28.8 mH | 32.16 mH |
| L₂ | 28.8 mH | | 32.16 mH | |
| C₁ | 25 mF | | | 28 mF |
| C₀ | 41.6 mF | 67.9 mF | 12.5 mF | 14 mF |
| Load Resistor (R) | 1.153 \( \Omega \) | 1.153 \( \Omega \) | 1.153 \( \Omega \) | 1.153 \( \Omega \) |

5. MAXIMUM POWER POINT TRACKING (MPPT)

A solar panel can provide 15% to 20% efficiency because of its bad conversion price of the Incident sun irradiation into electric energy. To extract most feasible electricity from the sun panel and boom the performance of the sun panel, the Maximum electricity factor monitoring set of rules should be used. According to the Maximum Power Transfer theorem, most electricity may be introduced to the burden whilst the supply impedance is same to the load impedance. Tracking the most electricity factor turns into easy if we match the load with the supply. In this simulation, the boost converter is used with the solar panel to step up the output voltage to run a DC motor.

MPPT set of rules is used with a boost converter to change the frequency so that supply impedance can be matched with load impedance. The perturb & observe (P&O) technique is extensively used due to easy implementation. In this technique, the cutting-edge and voltage output from the panel is measured. From the measured cutting-edge and voltage, electricity is calculated. The Perturb and look at set of rules is likewise called the hill-mountain climbing technique due to its iterative procedure in set of rules.
This technique is simple to put into effect and less expensive however it has oscillations with inside the output throughout hastily various irradiance and temperature.

6. SIMULATION OF DC TO DC CONVERTER TOPOLOGIES

The following figures shows the current - voltage and power- voltage curves of constant temperature and varying irradiance conditions.
Figure 9. I-V characteristics of solar panel for changing irradiation conditions

Figure 10. P-V Characteristics of solar panel for changing irradiation conditions

Figure 11. I-V Characteristics of solar panel for changing temperature conditions

Figure 12. P-V Characteristics of solar panel for changing temperature conditions
Table IV. Simulation results of Boost and Cuk Converter

| Converter | Rise Time (µs) | Settling Time (µs) | Overshoot (%) | Undershoot (%) |
|-----------|----------------|--------------------|---------------|----------------|
| Boost     | 558.6          | 800                | 0.424         | 2.246          |
| Cuk       | 452.4          | 725.4              | 0.426         | 1.997          |

Table IV shows that Artificial neural network based MPPT controller provides better results under uniform and non-uniform atmospheric conditions. Cuk convertor provides higher performance for variable atmospheric conditions than Boost convertor.

7. RESULTS AND DISCUSSION

Figure 13-16 represents the output waveforms of voltage and current of boost, buck-boost, CUK converter. The output parameters of each converter includes output voltage, output current, power delivered and Efficiency are listed in Table 4. For the application of 500W, loss occur in CUK converter is minimum around 2%. Among all the converters, CUK has the maximum output voltage, current and power. The Efficiency of CUK converter is around 97.85%. The settling time of CUK converter is around 0.22 sec and having peak overshoot of 8%(26 volts’ peak magnitude).

Figure 13. Output of boost converter

Figure 14. Output of buck-boost converter
### Figure 15. Output of CUK converter

![Figure 15](image1.png)

### Figure 16. Output of SEPIC converter

![Figure 16](image2.png)

### Table VI. Output parameters comparison.

| Parameters       | Boost converter | Buck-Boost | CUK      | SEPIC   |
|------------------|-----------------|------------|----------|---------|
| Output Voltage   | 23.85 V         | 23.76 V    | 24 V     | 23.5 V  |
| Output Current   | 20.32 A         | 20.15 A    | 20.4 A   | 20.1 A  |
| Output Power     | 480 W           | 474 W      | 489.5 W  | 488 W   |
| Efficiency       | 96%             | 94.70%     | 97.85%   | 93.65%  |

### 8. CONCLUSION

DC to DC converter includes Boost, Buck-boost, CUK and SEPIC are designed and simulated using PSIM simulation tool for Solar PV based applications having load of 500 W output power. The performance analysis of each converter are done with help of simulated output waveforms. The efficiency of each converter are calculated among them CUK Converter having maximum Efficiency of 97.85%. Time response analysis of CUK output waveforms are quite good. For 500W PV based application, CUK converter with MPPT Algorithm of perturb and observe method is preferable.

### REFERENCES

[1]. K. Kavitha, Dr. Ebenezer Jeyakumar “A Synchronous CUK Converter Based Photovoltaic Energy System Design and Simulation,” International Journal of Scientific and Research Development, 2019.

[2]. Subramani Saravaram, Neelakandan Rameshbabu, “A modified high step up non isolated DC-DC converter for PV applications,” Journal of Applied Research and Technology, in press.
[3]. Ned Mohan, Tore M. Undeland and William P. Robbins, Power Electronics: Converters, Applications, and Design, Wiley, 2016.

[4]. Alagu, M, Ponnusamy, P, Pandarinathan, S, Mohamed Ali, JS. Performance improvement of solar PV power conversion system through low duty cycle DC-DC converter. Int J Circ Theor Appl. 2020; 1–16. https://doi.org/10.1002/cta.2918.

[5]. L.Umanand, Power Electronics Essentials and Applications, Wiley, 2016.