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"Study of DC-DC Converters in PV Systems using MPPT Algorithm"

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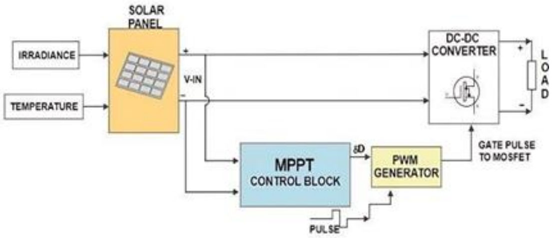
Abstract
In today' s time, conventional methods of energy production based on fossil fuels are not sustainable to full fill the global energy needs since they are the major contributors to global warming. However, irregular solar irradiation and varying ambient temperature are limiting the widespread use of Photovoltaic (PV) systems. DC- DC Converters act as the most suitable option for DC voltage regulation and high efficiency for renewable energy resources to overcome these constraints. A PV system consists of a PV Array connected to a DC - DC Converter. In this paper, a detailed comparative analysis of five popular DC - DC converters - boost, cascaded buck - boost, cuk, Single Ended Primary Inductance Converter(SEPIC) and zeta converter working with the MPPT method has been accomplished.
Keywords: MPPT, DC-DC Converter, PV systems, Cascaded buck-boost, Cuk, SEPIC, Zeta converter.

Introduction

The world is witnessing a significant environmental motivation to shift from fossil fuel - based energy generation to renewable resources such as solar and wind energy. With abundant solar resources, India is at the forefront of encouraging a solar - based economy across the globe. A PV system consists of a PV array connected to a DC - DC converter. A DC - DC converter is employed to overcome such fluctuations in power. The essential role of a DC - DC converter is to operate the PV system at its Maximum Power Point(MPP) in order to extract maximum power from it. Many different DC - DC converter architectures have been developed overtime. In terms of PV application, five primary DC- DC converters are widely used - Boost, Cascaded Buck - Boost, Cuk, SEPIC, and Zeta converter. This paper gives an in - depth comparison of these DC - DC converters forPV applications using control technique for MPPT.

Block Diagram of P V System:



PV ARRAY

A PV array is generally a combination of multiple solar panels connected in a grid - likefashion, with series connected panels called strings and multiple strings are wired in parallel. A PV array showcases non - linear P -V characteristics. The power delivered increases with the output voltage of the PV array, but only up to a particular voltage, and sharply falls after this value is reached, as evident by the single peak in the P - V curve inFig. The PV array module available in MATLAB is used with the electrical parameters as shown in Table I. For clarity, the PV array was designed with single PV module.

Parameter	Variable	Value
Open Circuit	V(OC)	22V

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Voltage		
Short Circuit Current	I(SC)	3A
Voltage at MPP	V(MPP)	17.98V
Current at MPP	I(MPP)	2.77A
Maximum Power at MPP	P(MPP)	49.8W

TABLE I. SPECIFICATIONS OF THE PVMODULE

MAXIMUM POWER POINT TRACKING

It was noted in the preceding section that a PV array's P- V characteristics are non-linear and show a single peak value of power. It is obvious that for maximum power extraction from the PV array and improved efficiency, the PV array must operate at the MPP. The ambient temperature and sun irradiance affect the voltage and power at MPP. DC-DC converters and MPPT algorithms operate together to power the system at the MPP. To alter the input resistance of the converter, the duty cycle can be altered. The MPP algorithm changes the duty as needed.

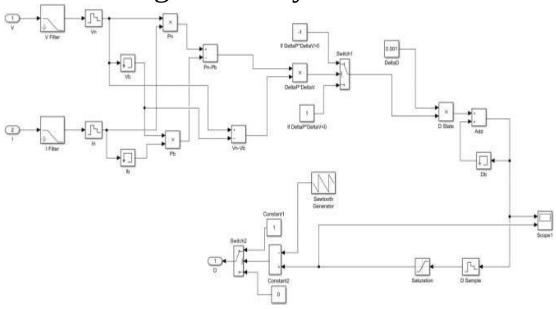

Fig. 1. Simulink subsystem of MPPTcontroller

DC-DC CONVERTERS

Using the even in's theorem, it is shown that a source with internal resistance provides maximum power to the load when the load resistance and internal resistance are equal. In the design of the DC-DC converter, the MOSFET is used as the switching device. This article looks at five different converter topologies: boost,cascaded buck-boost, cuk, SEPIC, and zeta

Boost Converter

DC - DC boost converter is a step - up converter, and the output voltage of the boost converter is always greater than the input voltage. As the duty cycle (D) of the converter is increased, the output voltage also increases, which is evident through. The operation of the boost converter comprises of two stages, when switch is closed and when switch is open. When the switch is on, the diode is reverse biased, and energy is stored in energy storing elements and during off - time of the switch, the diode is in forward biased condition, and the energystoring elements deliver energy.

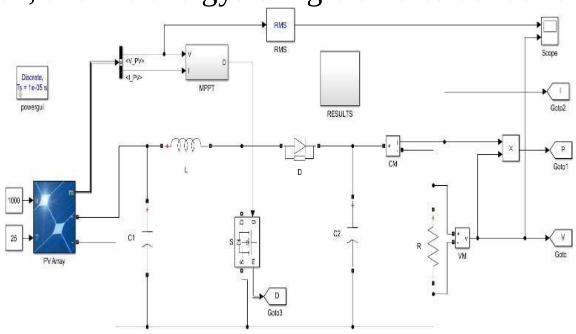

Fig. 2. Simulink model of DC-DC Boostconverter

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Cascaded Buck-Boost Converter

The cascaded buck - boost converter can step - up and step - down the input voltage. This converter covers the whole I - V curve in continuous conduction mode henceovercoming the major disadvantage of the boost converter. As the converters can step - up and step - downthe voltage, it is highly effective in tracking the MPP.

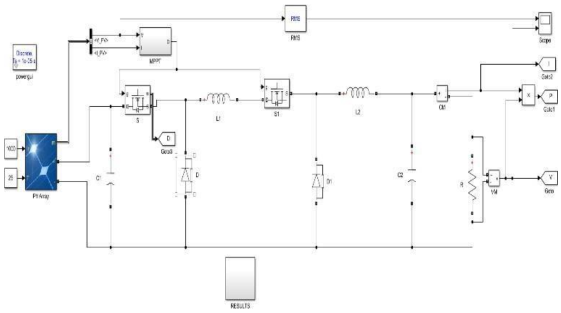

Fig. 3. Simulink Model of DC-DC CascadedBuck-Boost Converter

Cuk Converter

The cuk converter is again a combination of buck and boost converters and hence, the output voltage can either be greater or smaller than the input voltage. As opposed to other topologies, cuk converter features a capacitor for energy storage and an inductor on the output stage, givingbetter output current characteristics. During the off – time of switch, current from the inductors flows through the diode, which charges capacitor.

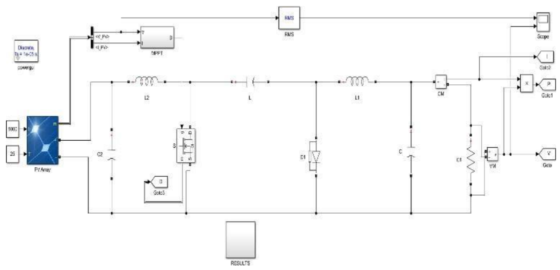

Fig. 4. Simulink Model of DC-DC CukConverter

SEPIC Converter

SEPIC (Single Ended Primary Inductance Converter) is a non - inverting converter. The similarity between SEPIC and cascaded buck - boost converter in terms of their input to output voltage relation is visible. When the switch is on, current flows from the switch to L1 and from the capacitor to L2, charging the two inductors. When theswitch is turned off, both the inductors supply energy, and the current is delivered to the load sidecapacitor throughthe diode.

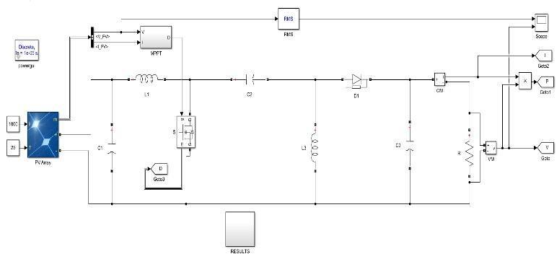

Fig. 5. Simulink Model of SEPIC DC-DCConverter

Zeta Converter

The zeta converter utilizes a two inductor topology, similar to the SEPIC converter. Depending on the duty cycle, it can also work asboth a step - up and step - down converter. The output

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voltage equation is similar to the Cascaded buck - boost converter. The energy stored in the inductor (L1) is transferred to capacitor (C1) during the on - time of the switchas the diode is forward biased.

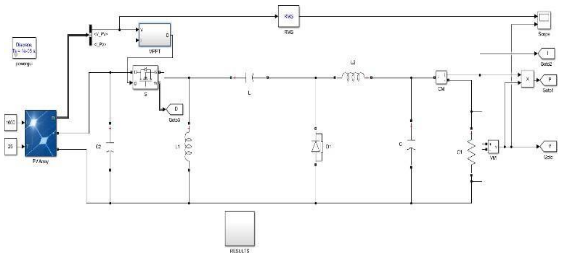

Fig. 6. Simulink Model of Zeta Converter

SIMULATION RESULTS

The analysis of the discussed DC - DC converters was carried out through simulation in the MATLAB/ Simulink environment. The PV system was designed using one PV module in all the simulations. According to the equations described for each converter, we have designed the circuit parameters as depicted in Table II. The value of this capacitor is fixed at 50μ F, and similarly a capacitor is connected across the load, fixed at 470μ F.11 to 15 show the output graphs for each converter.

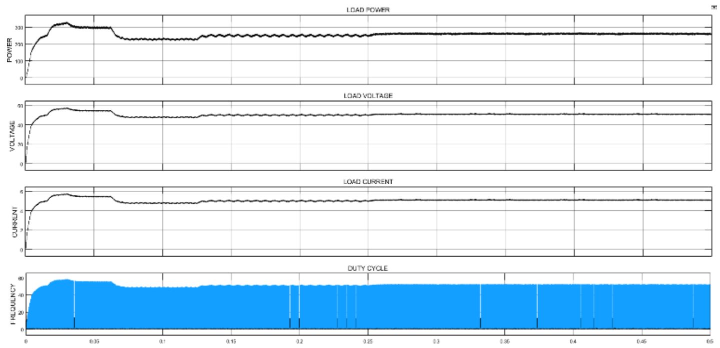

Fig. 7. Input and Output Voltage of the Boost Converter

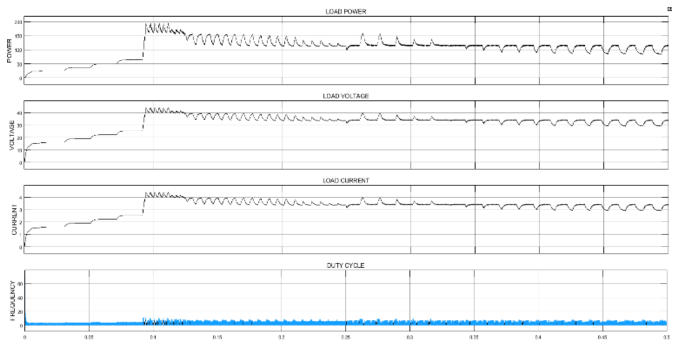

Fig. 8. Input and output voltage of theCascadedconverter

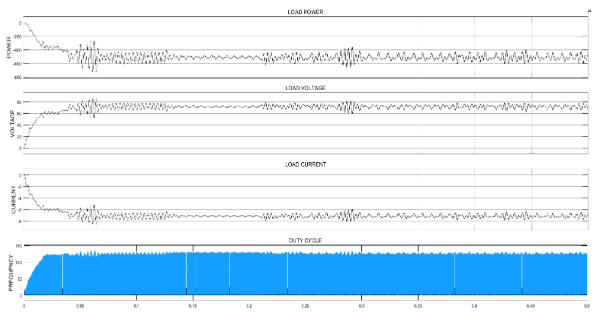

Fig. 9. Input and output voltage of the Cukconverter

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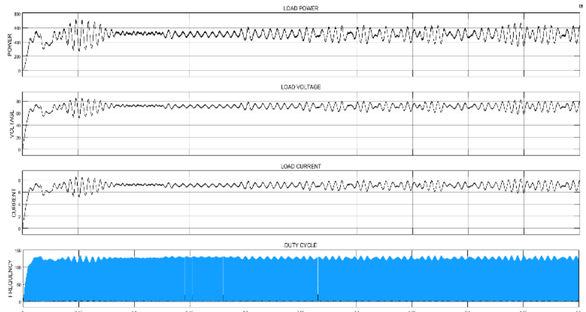

Fig. 10. Input and output voltage of theSEPIC converter

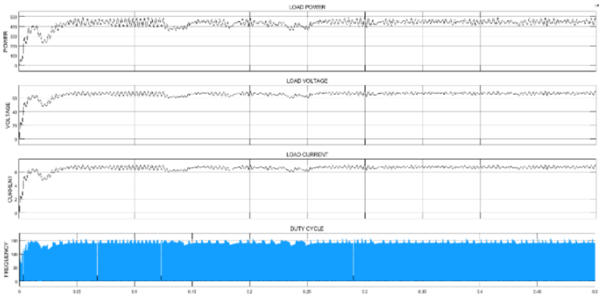

Fig. 11. Input and output voltage of the Zetaconverter

CONCLUSION

Input and output voltage of the Zeta converter aPV system. Five popular DC - DC converters have been explored in - depth and have been designed and simulated in MATLAB/ Simulink.A comparative study is then carried out to find the best converter topology. A detailed analysis was carried out for eachconverter and it is observed thatthe boost converter has the highest efficiency of 91% while the zeta converter has the lowest efficiency of 76. 16%. The boost converter lacksthe ability to step - down the input voltage, which can be accomplished by other converters. Hence,in regions where the sunlight is low, the boost converter can be implemented for PV applications, but in regions where the irradiation has ahigh variance, the boost converter cannot be used as the need to reduce the voltage to a lower value for continuity and stability may arise. Out of the rest 4 converters, it is observed that cascaded buck - boost, cuk and SEPIC have comparable efficiencies, andtherefore, a choice here can be made on the basis of cost and need for an inverting output.

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