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Analysis of Boost, Cuk, and Zeta Converter in a Hybrid Power system (PV-Grid)

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Abstract: In this paper analysis of DC-DC converters (Boost, Cuk, and Zeta) is done in a Hybrid power system, which is a Solar PV array and a grid-tied system. In the proposed system, the PWM technique is used to synchronize the PV array output with the grid output. The output voltage waveforms of the three converters are analyzed in terms of settling time, Steady-state and transient period etc.
Keywords: PV Array, MPPT, DC-DC converter, IC algorithm.

I. INTRODUCTION

With the increasing use of the Solar PV arrays for power generations in domestic as well as for commercial applications due to its various properties like the ease of installation, minimum maintenance, consumer-friendly, No noise due to no moving parts, environment friendly. Various factors affect the power quality and quantity generated by the SPV array.
The PV arrays while being majorly used for power generation due to their user-friendly properties also suffer from some major drawbacks of their kind, which include their low efficiency etc. Various MPPT techniques have been invented to overcome this drawback like Perturb and Observe, Fractional open-circuit voltage, Incremental conductance, Neural networks, Fuzzy logic. etc
In the proposed system the IC – MPPT technique has been used to enhance the output of the "Hybrid power system".
The output voltage waveforms of the various DC-DC converters are analyzed in the system. The converters used in this system are Cuk converter, Zeta converter, and Boost converter.

II. SYSTEM DESCRIPTION

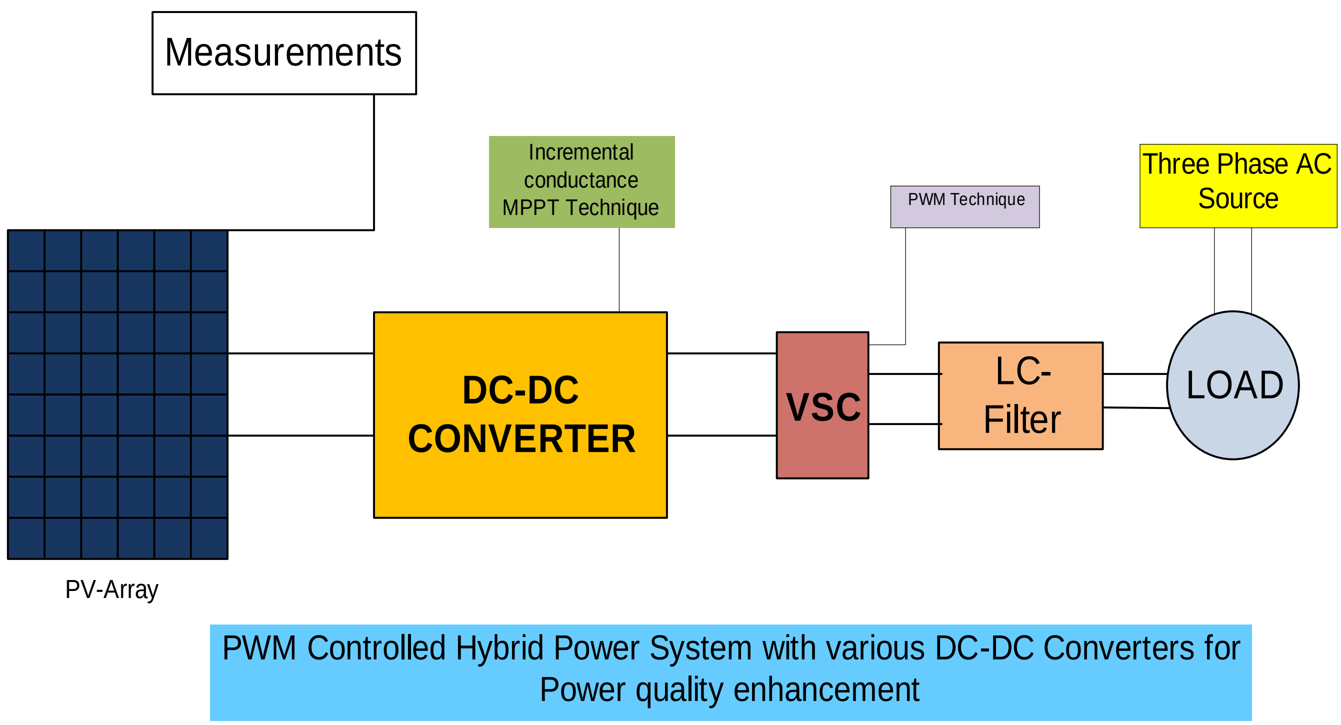

Fig. 1 Block diagram of the system

The proposed system consists of a PV array, A MPPT algorithm for maximum power generation, A DC-DC converter, an LC Filter, and a three-phase source. [1]

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A. Solar PV array

The PV array is formed by the connection of various solar cells in series or parallel. A solar cell is formed by the combination of a P-Type and N-Type semiconductor material. The PV cell is shown by an Equivalent model which is a current source in parallel with a diode. An average of 30mA/cm2 current per PV cell at the sun irradiance 1000W/m2 could be obtained. The equivalent model of the PV cell comprises an ideal current source, series, and parallel resistance and diode as shown below in figure 2.

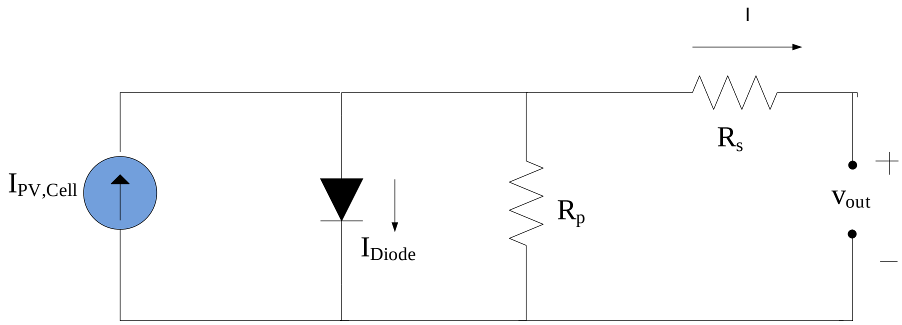

Fig.2 Equivalent model of an SPV cell

The output current of the PV cell is given as

$$I = I_{PV_{cell}} - I_{diode} = I_{pv.cell} - I_{0.CELL}\left[\exp\left(\frac{q*v}{\alpha*K*T}\right)-1\right] \qquad -(1)$$

Where

- $I_{PV,\ the\ cell}$ is the current produced by the irradiation.
- I_{diode} is the Shockley diode equation.
- $I_{0,\ CELL}$ is the reverse saturation current of the diode.
- Q is charge of the electron [1.60217646 * 10e-19 Coulomb].
- K is the Boltzmann constant value [1.3806503 * 10e-23J/K].
- T {K} is the temperature of the PN junction.
- $\propto$ is the diode ideality constant whose value lies from 1 and 2 for monocrystalline silicon.

III. MODELLING AND WORKING OF CONVERTERS

DC-DC Converters are formed by electronic components, these converters have their applications mostly at the places where a change in DC voltage is required. These converters are used for step-Up and step-down applications.

Various types of DC-DC converters exist in literature like-

1) Boost Converter
2) Buck Converter
3) Buck-Boost Converter
4) Cuk Converter
5) Zeta Converter

In the proposed system the analysis of the system is done using Boost, Cuk, and Zeta converter.

A. Boost Converter

A Boost converter is also called a step-up converter which is used to step up the DC voltage. This converter is made up of two Semi-Conductors(diode and transistor) and one energy storage element(Capacitors or an inductor or both in combination). [2]

1) *Working of the Boost Converter:* The main working principle of the boost converter is the property of the inductor to resist any changes of current flowing across it, In the first mode of the Boost converter the current is passed across the inductor and it stores the energy across it. In the second Mode of the Boost converter, The energy stored across the inductor is released and the inductor acts as an energy source. The voltage produced during the discharge phase is a function of the rate of change of current independent of the charging voltage allowing different output and input voltage.

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The operation of the Boost converter can be explained in two modes namely.

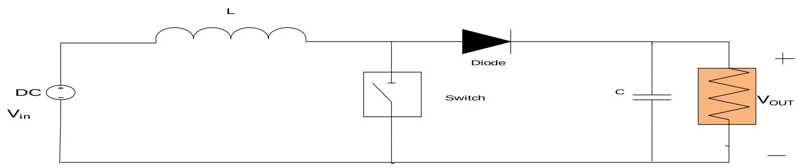

Fig.3 Basic diagram of a boost converter

a) Mode- I

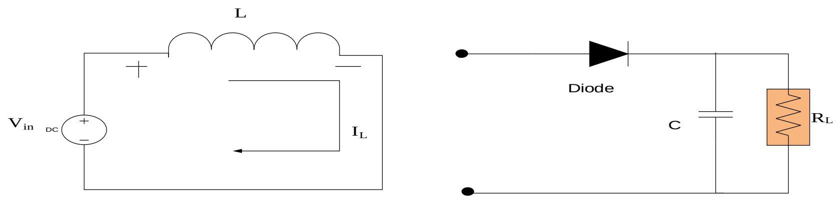

Fig.4 Mode I of the boost converter

In this mode, The current flows across the inductor (L) and the switch (SW) as the switch is in ON state TON. In this mode, the energy is stored across the inductor.

b) Mode-II

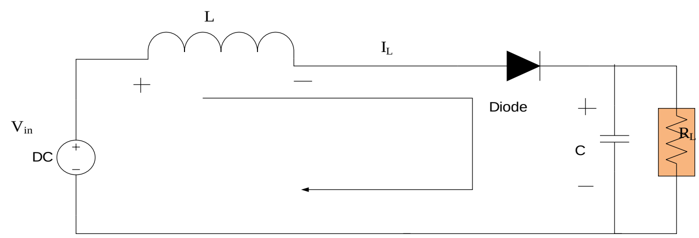

Fig.5 Mode II of the boost converter

In this mode, the current which was earlier flowing across the inductor (L) and switch (SW) starts flowing across the inductor, capacitor, diode, and load R_l as the switch are in TOFF condition. The inductor current falls till the time the switch is turned on again. Energy stored is thus transferred to load.

The output voltage of the boost converter is $\mathbf{V_0} = \frac{1}{1-D}$

B. Cuk Converter

A Cuk converter is a DC-DC converter having properties similar to a Buck-Boost converter, with a special ability to reverse the polarity of the input voltage.

1) Advantages of Cuk Converter

a) Low ripple current

b) Optimum topology does not require two inductors.

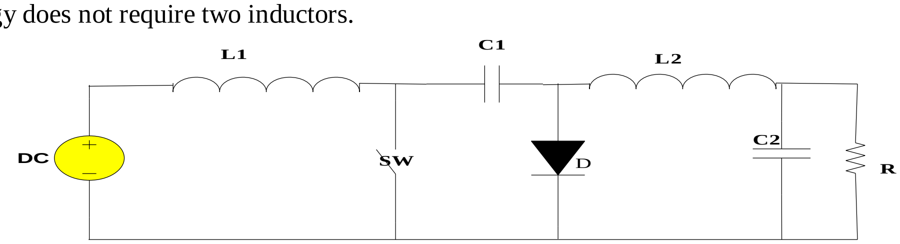

Fig 6 The Cuk converter

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2) *Operating Principle:* The capacitor C is used to transfer energy and connected alternately to the input and the output converters commuting the transistor and diode. The two inductors L1 and L2 are used for converting the voltage sources into the current sources. This conversion is required because if the capacitor is connected directly to the voltage source, The current is limited by the resistance, resulting in high energy sources.

C. Zeta Converter

A Zeta converter is a special type of DC-DC converter which is capable to generate the output DC Voltage of either lower magnitude or higher magnitude than the input DC voltage.

The ideal switch-based diagram of a Zeta converter is shown in Fig.7

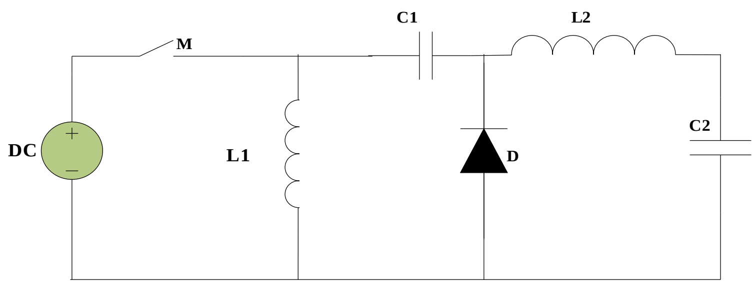

Fig.7. Diagram of a Zeta converter

The Zeta converter operation is explained in two modes. In this system, the continuous inductor current method is adopted with the current $I_{l.}$

The working of this converter is explained in two modes.

1) *Mode-I:* In the First mode. The switch is taken to be in OFF condition. In this Mode, the current flows through inductors L_1 and L_2. This mode is considered to be the charging mode.

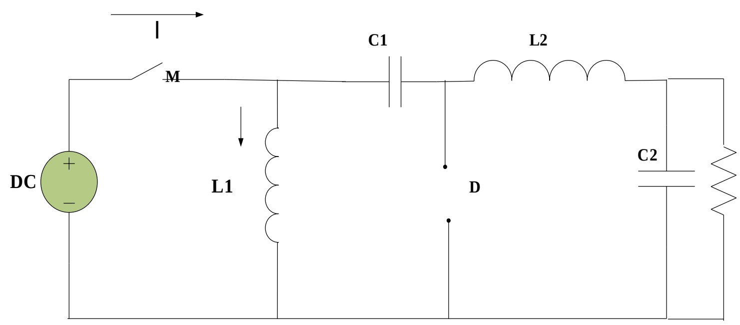

Fig. 8 Mode-I of Zeta converter

2) *Mode-II:* In the second mode the switch is taken to be in OFF state and the diode to be in ON state which is just the opposite case to the first Mode. This mode of operation could also be considered as the discharging mode. Since the energy stored in the inductor L_2 is released across the load resistance.

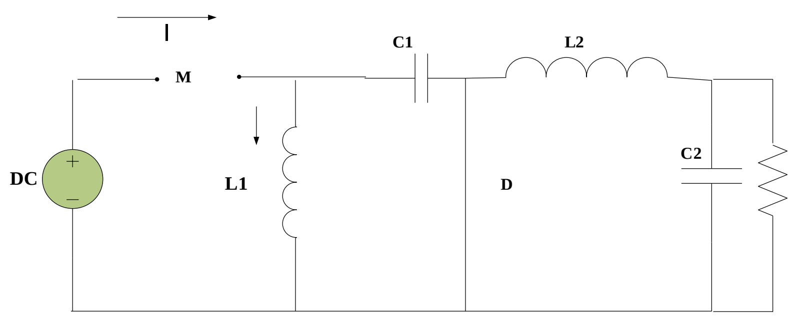

Fig.9 Mode-II of Zeta converter

IV. SIMULATION RESULTS

A. Simulation Results Of The Boost Converter

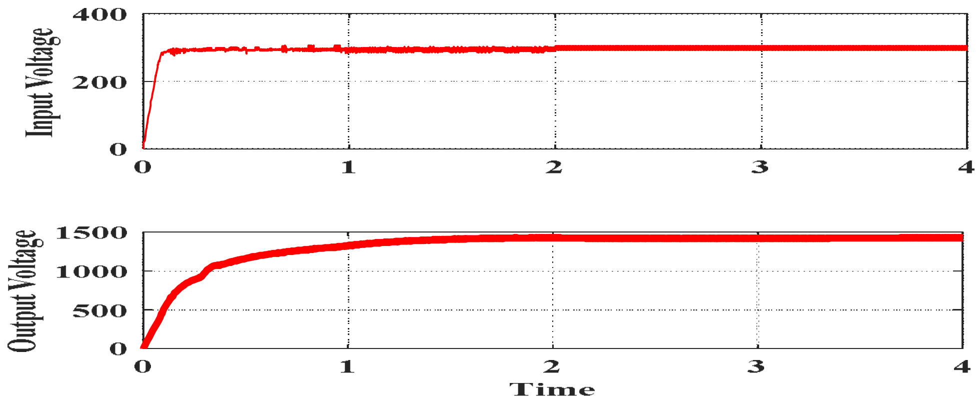

Fig 10 Simulation results of the Boost converter

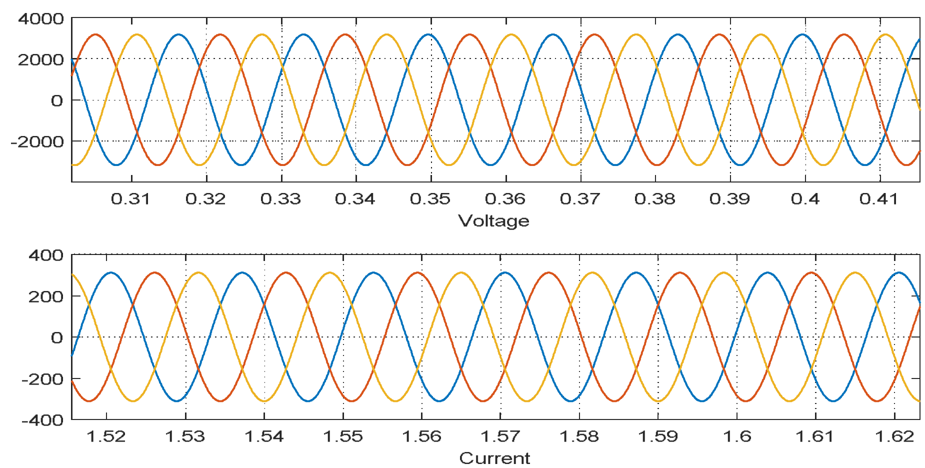

Fig 11 The output of the Inverter across the load

B. Simulation Model of the Boost Converter

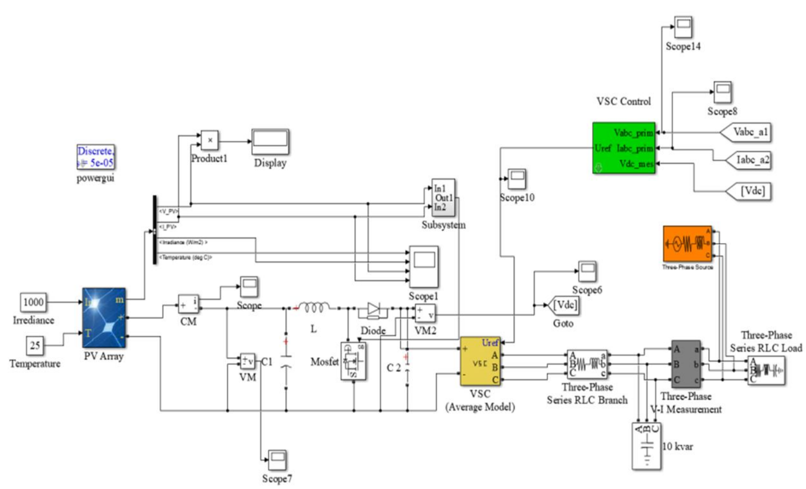

Fig 12 Simulation model of the Boost converter

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C. Simulation Results of Cuk Converter

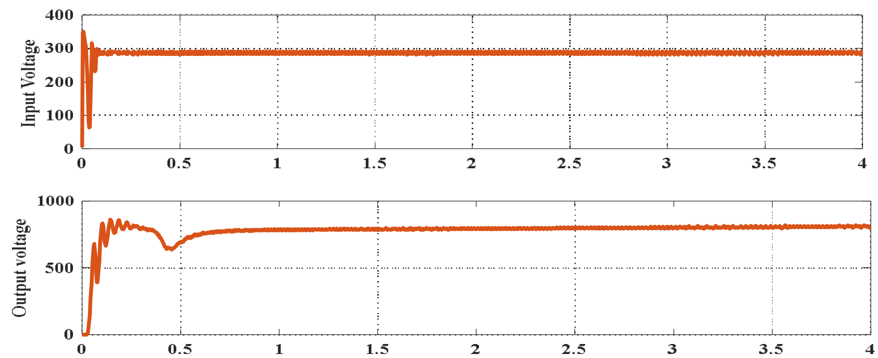

Fig 13 Simulation results of Cuk converter

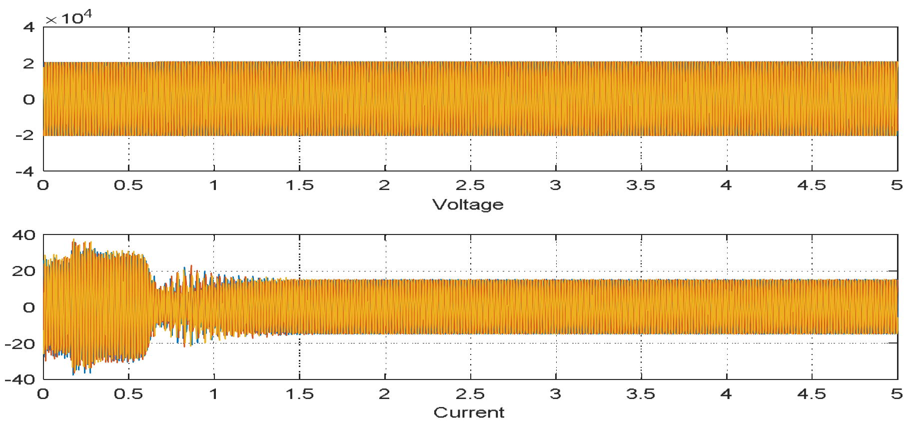

Fig 14 The output of the Inverter across the load

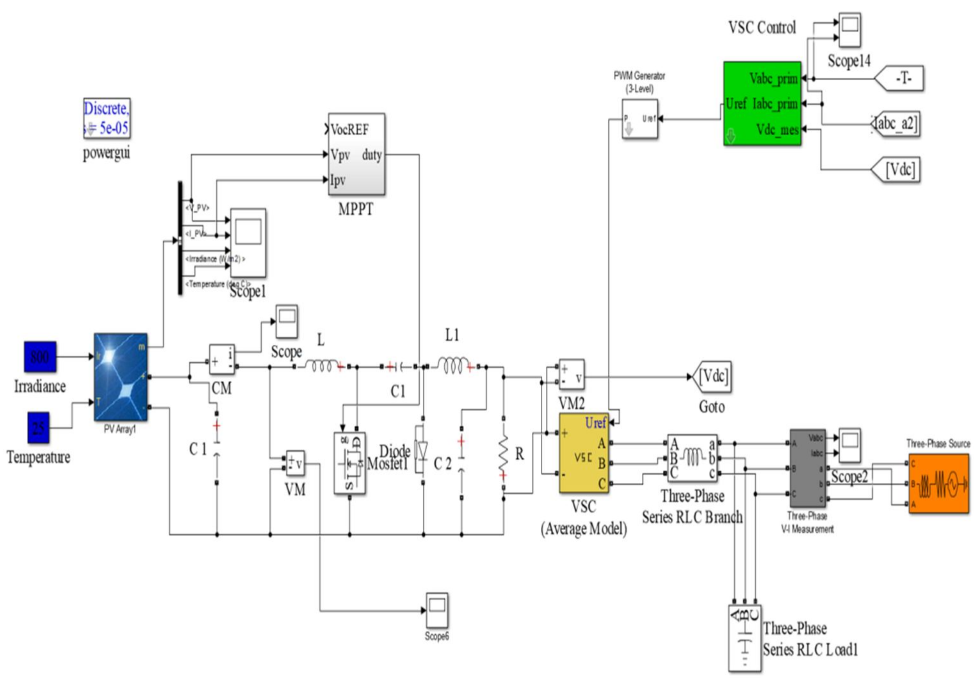

Fig 15 Simulation model of Cuk converter

D. Simulation Results of Zeta Converter

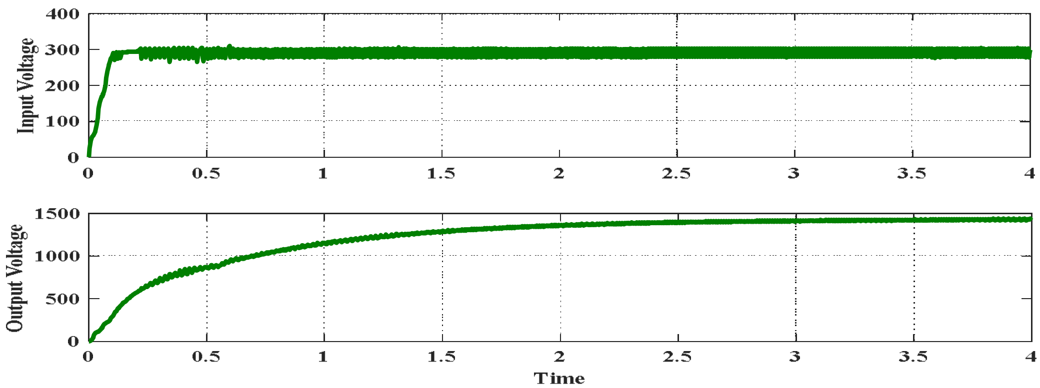

Fig 16 Simulation results of Zeta converter

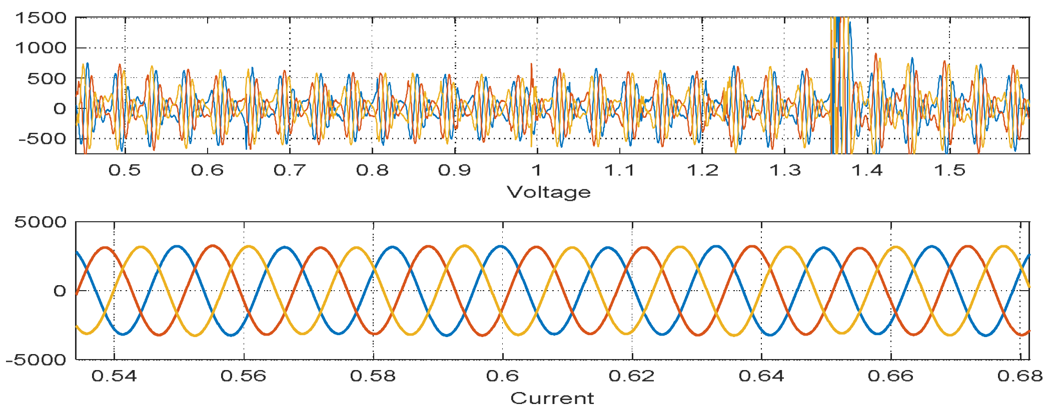

Fig 17 The output of the Inverter across the load

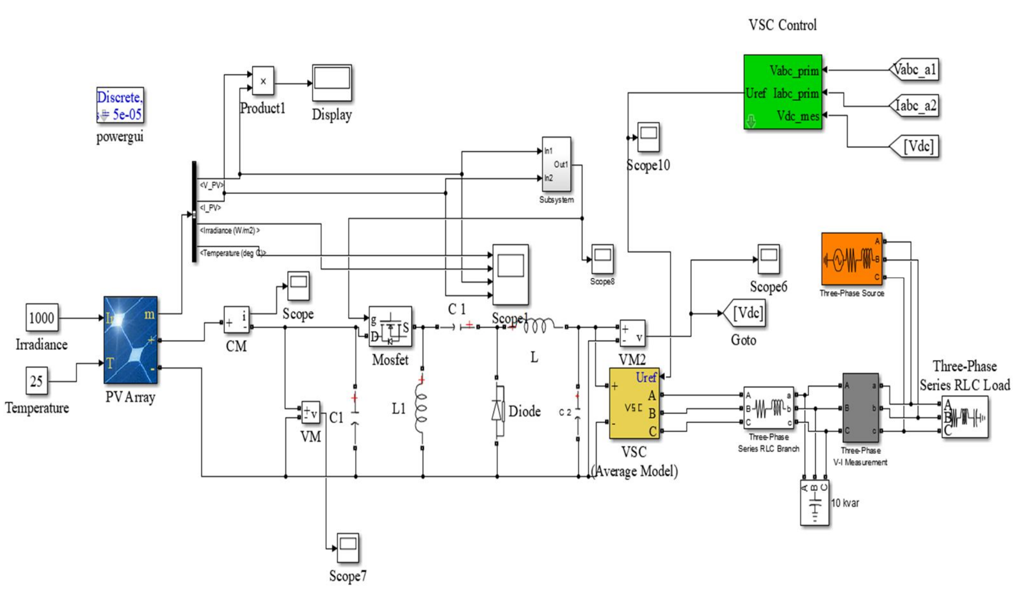

Fig 15 Simulation model of Zeta converterr

V. CONCLUSION

The following are the major contribution of this work-

This work provides a deep study of the most used DC-DC converters. The analysis of the output AC voltage waveform is done in this proposed system. The selection of the converter is dependent on the type of application. In this system, a Solar PV array is used as the main source of power which makes the system environment friendly as well as cost-efficient. Among the three converters, the performance of the Zeta converter is found to be the most efficient, and reliable as it has very minimal ripple content as compared to the output of the other two converters.

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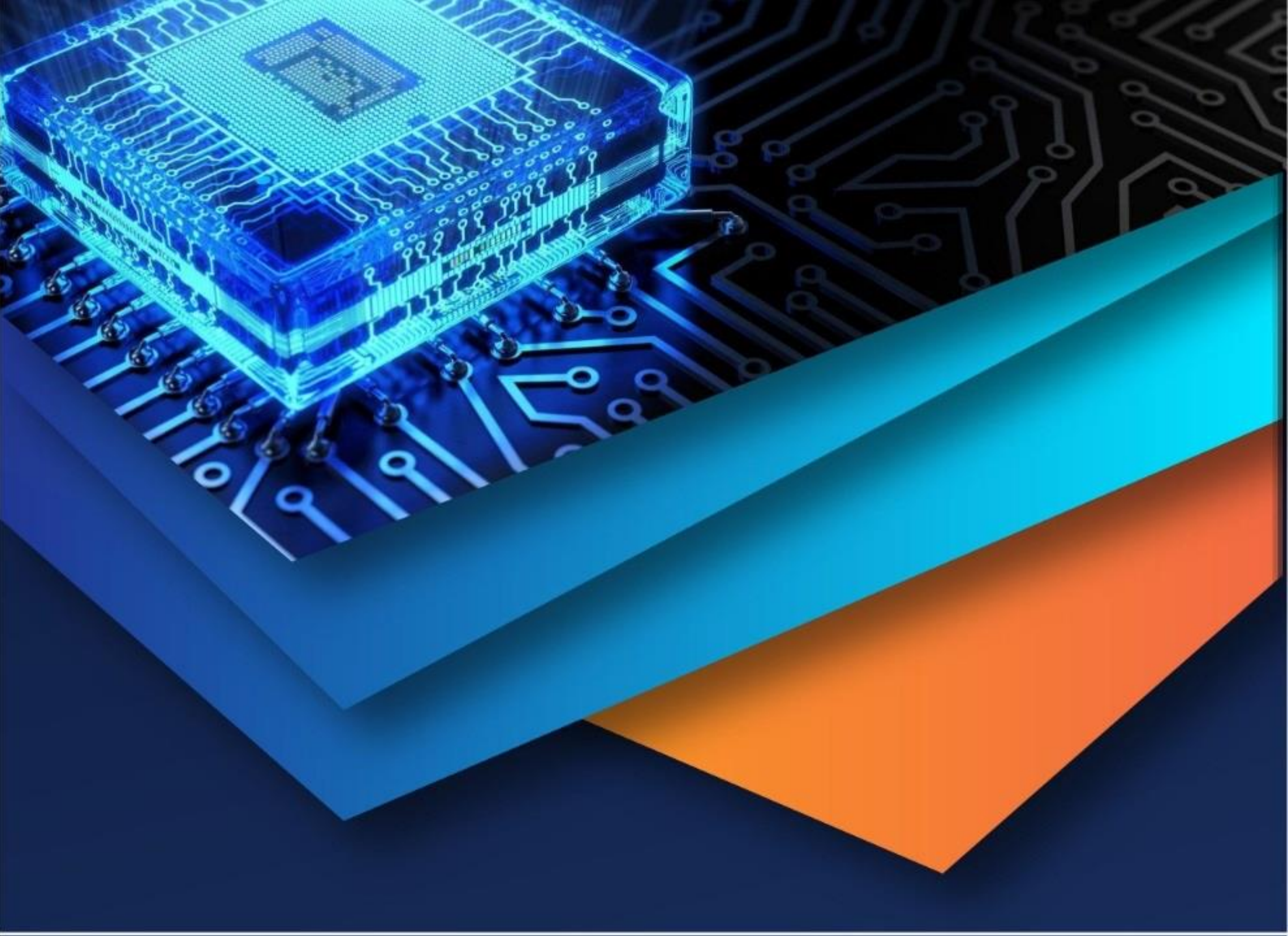

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