Comparative Analysis of Dual Input DC-DC Converters for Hybrid Power System

S.Parthasarathy, K.Shanthini, R.Arivuselvi, P.Thenmozhi

Abstract: ***Power electronic converters have become an important component in the hybrid power system. Hence it is essential to identify all the opportunities to reduce the cost or improve the performance of the operation of the hybrid power system. One such possibility is to use dual input DC-DC converter instead of using two separate DC-DC converters for different power supply inputs. Using of such dual-input converters leads to reductions of the filter size, cost and losses. Taking this into consideration, this paper explores an analysis on the performance of different types of dual input DC-DC converters. Comparison is done in terms of better output voltage and less harmonic distortion and the optimal dual input DC-DC converter configuration is suggested for Hybrid power system.***

Key words: Dual input DC-DC converter, Photovoltaic module, DIZETA, Total Harmonic Distortion.

I. INTRODUCTION

In recent years, the energy crisis is the most concern due to the availability of limited natural resources that are used to power industrial society [1,2]. To overcome the energy demand, more new renewable plants preferably solar, wind, biogas should be set up. According to many renewable strength professionals, a small "hybrid" electric powered machine offers numerous blessings over unmarried system. Hybrid systems can provide a constant network-level strength provider. Furthermore, due to their excessive levels of performance, reliability and long term performance, these systems also can be used as an powerful backup approach to the public grid in case of blackouts or vulnerable grids and for expert energy solutions which include telecommunication stations or emergency rooms at hospitals [3]. For the combination of renewable strength resources with application, energy electronic converters are used for efficient conversion of the enter dc-dc/ac electricity. A DC-to-DC converter is typically employed when the requirements for power is high [4].

In older days, for a hybrid system two separate DC-DC converters were used for converting the two power inputs. Employing individual converter with a controller for each source increases the energy cost further. The Unique energy assets can also be related in collection, as a multi-level machine, but it is obvious that the complete gadget's efficiency suffers from the multiple electricity conversion degrees and reliability of this cascaded connection is also questionable [5]. To triumph over the above said draw backs, the common strategy applied is the usage of dual-input DC-to-DC converters instead of multiple converters in parallel and to synchronize them using complex analog control loop. The distinguished gain of the use of dual enter DC – DC converter over single input dc-dc opposite numbers is to provide a fee-powerful answer, improved availability system thru the implementation of modular additives, reliable and flexible [6,7]. In this regard, a detailed survey on available literature is made. [8] gives overview of different power semiconductor switches and converter topologies along with insight into the operation of these converters. [9] Discusses the modeling and manage strategies for fundamental DC-DC converters via three particular case research. It covers both the frequency-domain control techniques and time-area manage methods. [10] describes recent developed power DC-DC converter Topologies in extraordinary packages along with renewable energy, excessive –voltage and medium-voltage DC energy systems, telecommunications and so on. Further the layout and optimization of various parameters are addressed systematically. [11] provides an in depth evaluate of diverse converter topologies inclusive of SEPIC (unmarried-ended number one-inductance converter), increase, greenback-improve and flyback which can be used to reap the desired voltage stage on grid output. The professionals and cons of those converters are mentioned. [12] compares the performance of a non-stop manipulate set version predictive controller with the conventional PI controller for a DC-DC dollar converter used in most power factor tracking (MPPT) of a photovoltaic (PV) module. [13] presents an evaluation and performance of cutting-edge and future fashion of non-isolated DC–DC converters (Such as Buck–enhance, Cuk and Sepic) with various parameters that helps to decide the perfect tool with a specific electricity rating for renewable power based totally packages. [14] explains the theoretical analysis of excessive benefit non-isolated DC-DC converter via combining quadratic boost converter with voltage multiplier mobile. [15] discusses the performances and evaluation of the bidirectional capability and one of a kind storage element placement of multi supply two dc-dc converters. [16]

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describes a selector based manipulate set of rules in conjunction with a proportional-indispensable controller which is used to trigger the bidirectional converter to provide progressed voltage stability. [17] offers answer for dynamic overall performance requirements underneath charging and discharging operation cycles of the battery using SEPIC-Zeta converter. [18] presents an efficient reduced order based totally solar powered DC-DC SEPIC Converter. The proposed cascade manage method can be able to provide regulated output voltage and 80–ninety nine% of MPPT simultaneously the use of a unmarried stage non-remoted DC-DC SEPIC Converter. [19] employs a brand new manipulate technique based on kind-2 fuzzy neural controller (T2FNC) for you to enhance the dynamic response of an ultra-raise Luo DC–DC converter beneath one-of-a-kind operational situations. [20] proposes a method to derive small sign model of the mentioned 4 quadrant Luo converter using sign flow graph technique. [21] provides a non-ideal model of DC-DC PWM greenback converter thinking about the parasitic elements (or non-idealities) consisting of equal collection resistances (ESRs) of inductors and capacitors, parasitic resistances of semiconductor gadgets (diode, MOSFET) for the duration of conductivity and also the forward fall of the diode. [22] discusses approximately the consistent state and the small signal dynamical behaviors and the comparisons among different quadratic Boost converters are defined and concluded. [23] depicts a greenback–raise Controller designed to care of mode transition automatically based on supply voltage. [24] evolved an adaptive passivity-based totally controller for output voltage law of DC–DC dollar–improve converter with an unknown constant electricity load. [25] gives a new generation in incorporating the renewable source and grid for providing electricity to the villages. This paper also explains the importance of renewable energy sources and the energy electronic converters in effectively changing multi-enter dc-dc/ac power. [26] proposes a excessive voltage advantage dual enter dc–dc strength electronic converter which could draw continuous current from enter resources or a single source constantly which makes it suitable for the programs like sun panels. [27- 29] has reviewed about the operation of diverse Multi-input DC/DC converters. Though various studies articles are available in DC-DC converters, the overall performance analysis of the twin enter DC-DC converters is less available in literature. Taking this into consideration, a entire performance evaluation of different twin enter DC-DC converter topologies is performed and reported in this paper.

II. DUAL INPUT SOURCES

The two types of sources used as input for the DC – DC converters are Photovoltaic (PV) array and Fuel cell.

PV Array

A Photovoltaic cell may be a semiconductor unit that converts physical energy i.e. light energy to power by electrical phenomenon impact. Since the output of a single PV cell is very less to run a utility, they are grouped In series and parallel combination to form an sun array or module. This array develops the electricity directly from the sun power and it will be changes by using relying up on the temperature and sun irradiances. Fig. 1 suggests the simple circuit version of solar PV module [30,31].

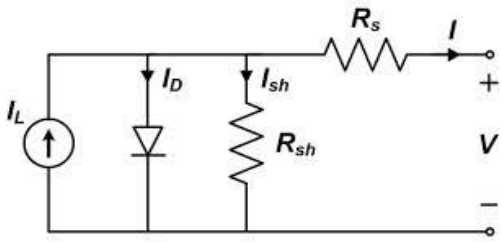

Fig. 1 Basic Circuit model of Solar PV Module

From the equivalent circuit, it is evident that the output current of PV cell (I) will be,

$$I=I_L – I_D - I_{SH} \quad (1)$$

where

I= PV output current (Ampere)

I_L= Photo generated current (Ampere)

I_D= Diode current (Ampere)

I_{SH}= Shunt current (Ampere)

The current through these devices is ruled by the voltage across them

$$Vj = V+ IRs \quad (2)$$

where

Vj = Voltage across each diode (Volt)

V= Voltage across the output terminals (Volt)

I= PV output current (Ampere)

R_S= Series resistance (Ω)

Current diverted through the Shockley diode is:

$$I_D=I_O [exp(qv/nkt)-1] \quad (3)$$

Where

Io= Reverse saturation current (Ampere)

n= Diode ideality factor

q= Elementary charge

k = Boltzmann's constant

T= Absolute temperature

By Ohm's law, the current diverted through the shunt resistor is:

$$I_{SH}= V_j / (R_{SH}) \quad (4)$$

Where

R_{SH}= Shunt resistance(Ω)

Substituting these into equation (1) produces the characteristic equation of a PV cell , which relates PV cell parameters to the output current and voltage;

$$I=I_L –I_0(exp[\frac{q(V+IR_S}{nkT}]-1) – \frac{V+IR_S}{R_{SH}} \quad (5)$$

Fuel Cell

A gasoline mobile works primarily based at the precept that energy can be produced by way of combining hydrogen (H2) and oxygen (O2) in a specific configuration. It own cathode and anode, and they're separated with the aid of a membrane. Hydrogen (H2) is implemented to the anode of the gas cell, wherever it's separated into electrons and high-quality hydrogen (H2) ions by using a catalyst.

The membrane keeping apart the cathode and the anode allows the float of the hydrogen ions and rejects glide of electrons. This rejection causes the electrons to require the circuit route to drift to the cathode. Once the electrons attain the cathode, they integrate with oxygen (O2) and hydrogen (H2) ions to make water. The essential belongings of a Fuel cell is that, as soon as natural hydrogen (H2) is employed as the gas, completely water is made because the by means of product. Fuel cells can produce electricity constantly for so long as fuel and oxygen are provided [32]. The electricity era from hydrogen gas is explained through electrochemical reactions which take vicinity on the proton trade membrane/catalyst interface at low temperatures(<eighty°C).The electrochemical reactions are given via:

$$H_2 \rightarrow 2H^+ + 2e^- \quad (6)$$

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O \quad (7)$$

From these equations the equal circuit shown in Fig. 2 may be derived. This equivalent circuit consists of the resistance of the membrane Rm, which is related to the electrolyte resistance. Also the version contains parallel resistor and capacitors particularly RP1-C1 and Rp2-C2.

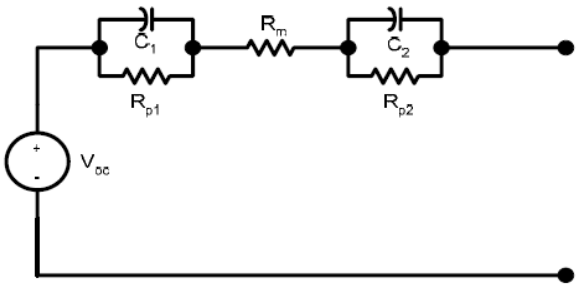

Fig. 2 Equivalent circuit of fuel cell

III. DC-DC CONVERTER TOPOLOGIES

Buck Boost Converter

The dollar increase converter is a DC to DC converter wherein the output voltage of the DC to DC converter is much less than or extra than the input voltage. The output voltage of the significance depends at the obligation cycle. These converters are called the advanced and step down transformers. For the step up mode, the input voltage is much less than the output voltage (Vs < Vout). It shows that the output current is a smaller amount than the input current. Hence the buck booster could be a improve mode. In the step down mode the input voltage is greater than the output voltage (Vs > Vout). It follows that the output current is bigger the enter modern. Hence the greenback enhance tool will be a step down mode. Fig. Three shows the fundamental circuit of Buck–Boost converter.

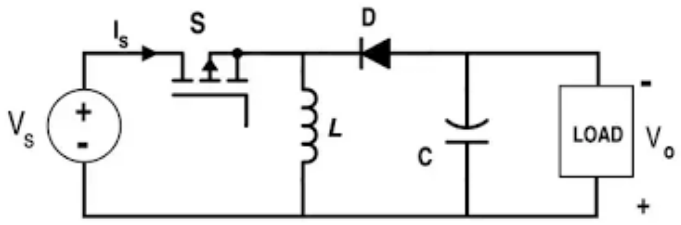

Fig. 3 Buck Boost Converter

CUK Converter

It is much like the Buck–Boost converter with inverting topology, the output voltage of CUK is likewise inverting, and may be lower (Vs < Vout) or higher (Vs > Vout) than the input. It uses a capacitance as its principal power-garage part, not like maximum different forms of converters which use an inductor. Fig. 4 suggests the simple circuit of CUK converter.

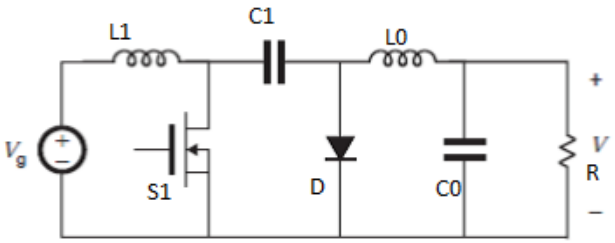

Fig. 4 CUK Converter

SEPIC converter

A SEPIC is basically a lift converter followed by means of a greenback-raise converter, consequently it is similar to buck boost converter, however has benefits of getting non-inverted output. The output voltage is also higher or not up to the input. It's positive output, differentiate CUK from buck boost. SEPIC differ from CUK with the diode connection. Fig. 5 shows the primary circuit of SEPIC converter.

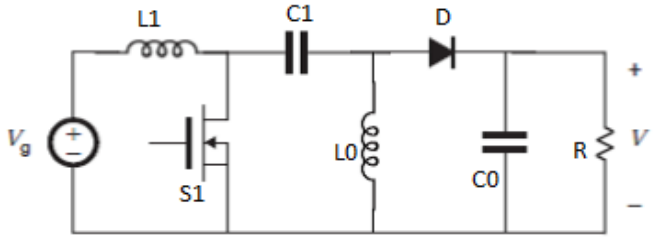

Fig. 5 SEPIC converter

ZETA Converter

ZETA also known as 'inverse SEPIC', is another one of those dc-dc converters. A ZETA converter is a fourth-order DC-DC converter made from two inductors and capacitors and able to operating in either boost or buck mode. Similar to the SEPIC converter, The ZETA also presents a high-quality output voltage from an input voltage that varies above and beneath the enter voltage.

The zeta converter is a fourth-order converter having real and complicated poles and zeroes. Fig. 6 shows the simple circuit of ZETA converter.

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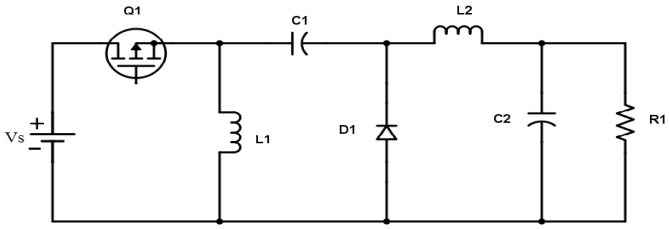

Fig. 6 Zeta Converter

LUO Converter

LUO converter is one of DC-DC converter which step up the input voltage in limited range. It can provide positive output as well as negative in different circuit. Fig.7. Indicates the tremendous output LUO converter. One of the gain of LUO converter is it overcomes the parasitic problems gift within the classical DC-DC converter.

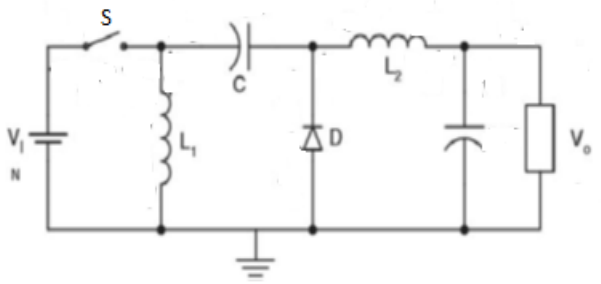

Fig. 7 Luo Converter

IV. DI CONVENTIONAL CONVERTER

The goal of a DI(dual-input) power supply is to provide power to a single load from two input power sources either simultaneously or alternately. This objective can be met using simple diodes or paralleled low dropout regulators with some control logic. As shown in Fig. 8, a dual-input power supply has two inputs or power sources and a single output also called a load. The output typically has a regulated voltage set by the power supply itself and current is supplied to the load on demand. The inputs are typically a loosely fixed voltage and may or may not be the same as the output voltage; current drawn from these inputs is determined by the power supply itself. In a dual-input power supply, the current or power drawn from the inputs is drawn from both sources either simultaneously or alternately [33]. Using of two inputs reduces the input voltage interruption when one input unavailable, so the other source can be utilized. It reduces the size of filter as well as losses, accordingly increasing the efficiency.

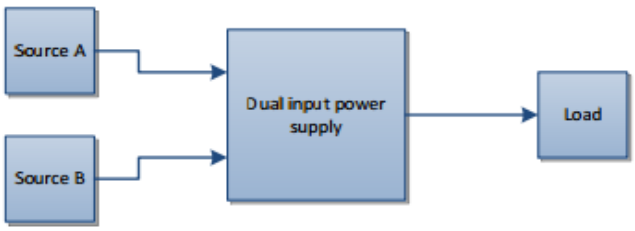

Fig. 8 DI Conventional Converter

The widespread operation of DI (twin enter) DC-DC converter is defined in three modes of operation as Mode 1, Mode 2 and Mode 3 [34, 35]. In Mode 1, Switches S1 and S2 are in ON country. Although both the switches are in ON nation, switch S2 does no longer conduct due to the fact it is opposite biased. The voltage throughout the capacitor C1 is extra than C2 which means that source one output is better than source. Inductors L1 and L2 are energized from input resources Vin1 and Vin2 respectively. In this situation, the burden is drived by way of the capacitors voltage. Freewheeling diode D does not behavior any current thru it at this mode, due to the fact it is reverse biased. In Mode 2, switch S1 is in became OFF nation and Switch S2 stays in ON state. Current through L1 and L2 is extended constantly and the load is drived by way of the capacitors voltage. Up to this country Freewheeling diode D may be in reverse biased situation, so it does not behavior any present day through it. In Mode 3, switches S1 and S2 are in OFF country. Freewheeling Diode D is made forward biased, the stored electricity in the inductors L1 and L2 drives the burden thru the freewheeling Diode D. The simple circuit of various Dual Input DC-DC Converter topologies taken into consideration for analysis in this paper is shown in Fig. 9 to Fig. 13.

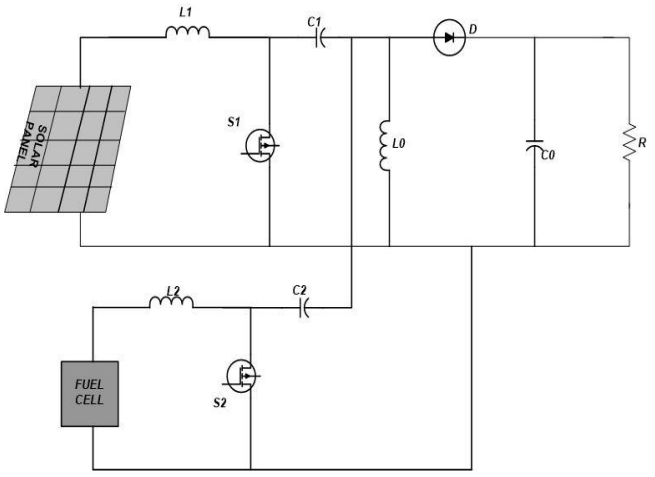

Fig. 9 DISEPIC Converter

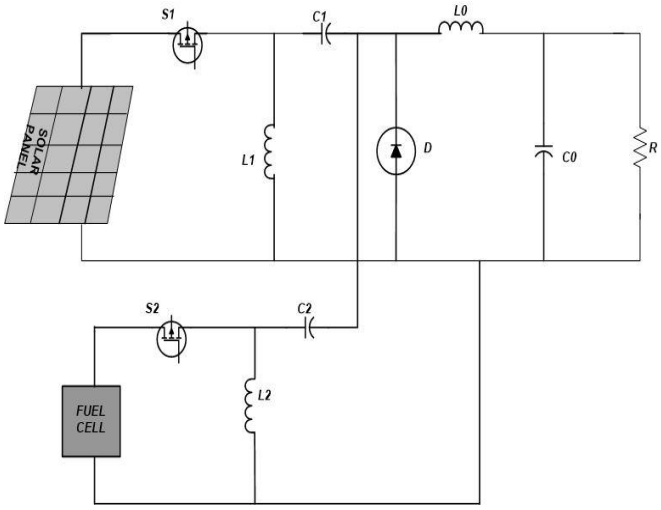

Fig. 10 DIZETA Converter

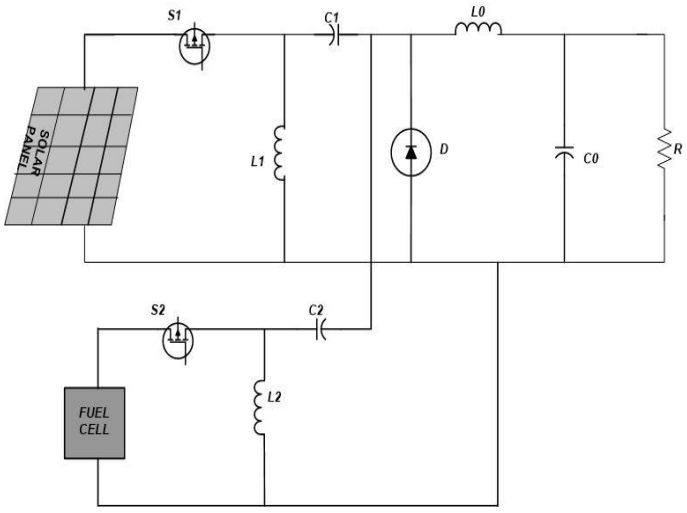

Fig. 11 DILUO Converter

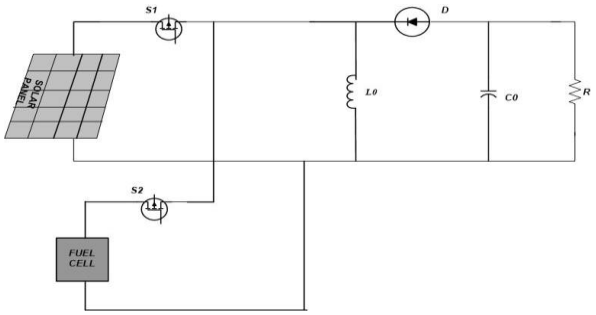

Fig. 12 DIBUCK BOOST Converter

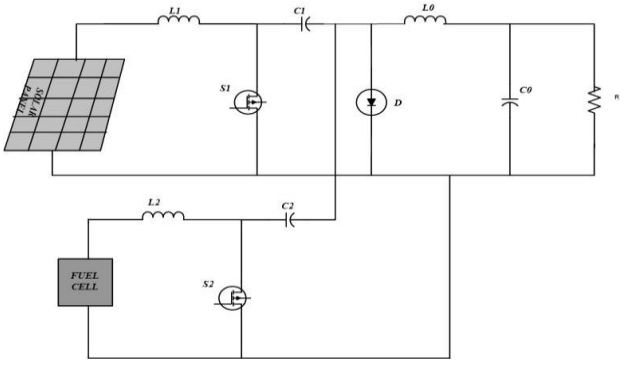

Fig. 13 DICUK Converter

V. RESULTS AND DISCUSSION

The DI Conventional converter topologies described in Fig. 9 to Fig.13 were incorporated in Matlab Simulink. Almost the design parameters for all the converters were fixed as same values to do fair comparison. The output voltage of PV module is eighteen V and the output voltage of Fuel cell is 17 V. The values of the inductors and capacitors used in the circuit of all of the converters are constant as equally L1 = zero.Nine mH, L2 = zero.Nine mH, C1 = 0.185 mF, C2 = zero.185 mF, Lo = 0.64 mH and Co= 8.Sixty six mF. For assessment, important parameters specifically the output voltage and the Total harmonic distortion (THD) was considered and the outcomes are shown in Fig. 14 and Fig. 15.

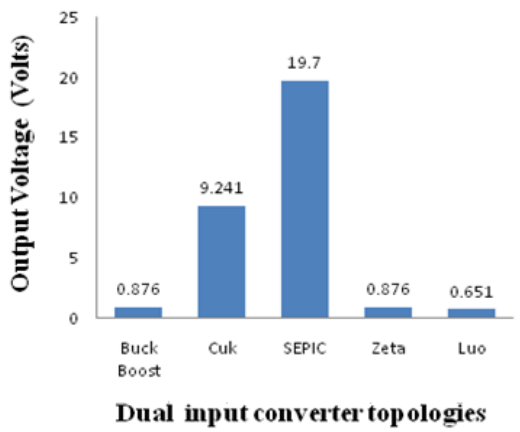

Fig. 14 Output voltage results

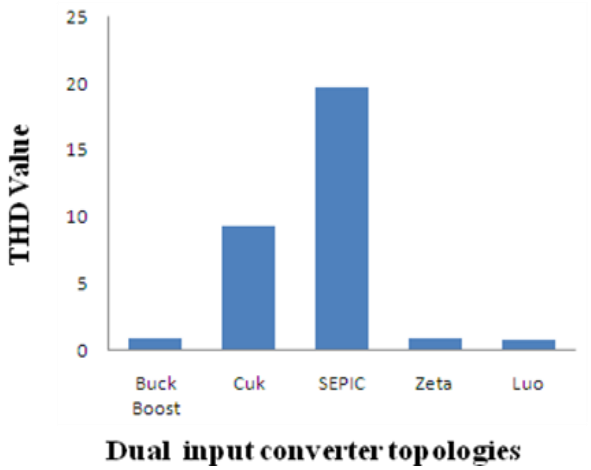

Fig. 15 THD analysis results

From the comparison we could find that both DIBUCK BOOST and DICUK Converter configuration provides negative output voltage. DISEPIC converter configuration has high output voltage but its THD value is also high. DILUO converter configuration has better THD value but while seeing the output voltage, it seems to be less. While checking the values of DIZETA converter configuration, we could say that it has better output voltage and THD value. The Matlab – Simulink diagram of DIZETA converter configuration is shown in Fig. 16 and the simulated output is shown in Fig. 17 and Fig. 18. From the simulated output it is evident that DIZETA converter configuration has continuous output current and less ripple to the load.

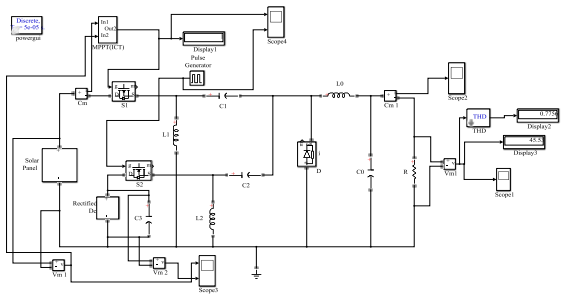

Fig. 16 Matlab – Simulink diagram of DIZETA converter

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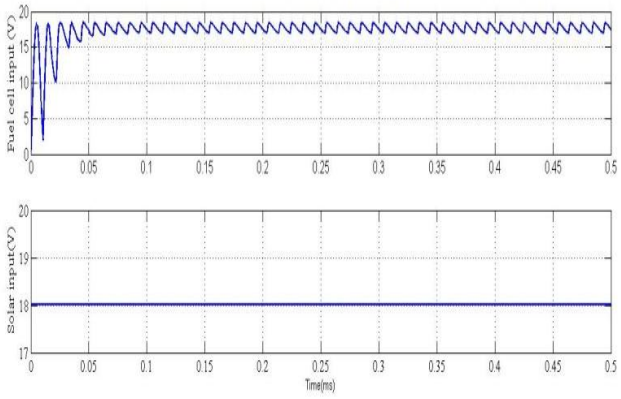

Fig. 17 Dual Input Voltages of DIZETA

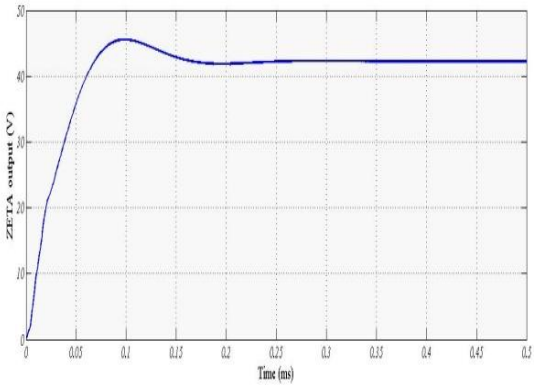

Fig. 18 Output Votage of DIZETA

VI. CONCLUSION

Implementation of DI conventional converters In preference to the usage of separate DC-DC converters for one of a kind electricity substances inputs for Hybrid power system is advantageous in terms of reductions of filter size, cost and losses. Taking this into consideration, this paper explores an analysis and performance of different types of dual input DC-DC converter configuration such as DISEPIC, DIZETA, DILUO, DIBUCK BOOST and DICUK Converter configuration. Comparison is done in terms of better output voltage and less harmonic distortion. From the comparison we could find that both DIBUCK BOOST and DICUK Converter configuration provides negative output voltage. DISEPIC converter configuration has high output voltage but its THD value is also high. DILUO converter configuration has better THD value but while seeing the output voltage, it seems to be less. While checking the values of DIZETA converter configuration, we could say that it has better output voltage and THD value. From the detailed simulated result it is evident that DIZETA converter configuration has continuous output current and less ripple to the load. Thus it is concluded that DIZETA converter configuration is optimal for use in hybrid power system.

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