

A High Performance DC-DC SEPIC Converter for DC Micro Grid

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Abstract—The DC loads are increased drastically and there is a need of renewable energy sources. This paper aims to provide more efficient power supply for DC MICRO GRID from various distributed hybrid energy sources such as solar, wind, fuel cell by using SEPIC (Single-Ended Primary-Inductor Converter) converter. SEPIC converter is much superior to the other converters both in terms of the input current purity and efficiency. The overall efficiency and performance of the proposed system is compared with the existing system. The proposed system has lesser component count, less losses, simple structure with greater efficiency compared to the existing system.

Index Terms— DC-DC SEPIC converter, renewable energy source, micro grid and reliability.

I. INTRODUCTION

Micro grid is a supply system majorly made out of renewable energy sources to provide supply to the remote areas where the electrical transmission and distribution system is absent. It can be modeled in such a way that, it can provide supply independently to the loads or it can be made to operate in combination with the utility grid. It can deal with AC, DC or both AC/DC. It is well known fact that the load demand is rapidly increased and there is a necessity for harnessing clean sources of energy, green energy. Micro grids are shown more interest in the power networks in this regards. It may be made out of multiple renewable energy sources (of similar kind or of dissimilar kinds) such as wind energy, solar cells / PV cells, biomass and storage battery Ref. [6]. Though national grid runs across the nation there are still areas which do not have electricity. On identifying the availability of energy sources most of these remote areas can be powered by micro grid successfully and economically. If micro grid alone acts as supply unit for remote areas then it is called as a stand-alone / islanded mode of operation. If the availability of wind energy and/or solar energy or any other energy sources is abundant then the generated power can be fed to the grid else the load can consume electricity from grid. Based on the characteristics and mode of power flow in the distribution network Micro grids are classified broadly as AC micro grid, DC micro grid, and hybrid micro grids Ref. [9].

In general micro grids are made out of two or more renewable energy sources. In order to extract energy from various available renewable energy sources equal numbers of the power conversion units are needed in earlier case. Here the protection devices are implemented ensuring safety of the system Ref. [5]. Even though the AC micro grids are more beneficial it faces several challenges like synchronization, frequency mismatch and other various issues during implementation. The DERs (Distributed Energy Resources) can also be interfaced with the

micro grid. They either generate AC power by the use of renewable energy sources like biogas, wind or DC power by the use of PV panel. Solar and wind are intermittent energy sources since they mainly dependent on weather condition. In order to obtain the regulated output there is a need of multiple power conversions circuits like rectifiers, inverters, choppers etc. As the circuit increases, the component count also increases and it leads to power losses, generation of harmonics thereby decrease in overall efficiency, reliability and performance of the system. Some of the papers are trying to reduce these undesirable effects by implementing SPWM (sinusoidal pulse width modulation) and by reducing THD (total harmonic distortion) in output voltage Ref. [16]. Next major challenge in micro grids are synchronization of parameters like voltage, frequency and phase of generated power with the utility grid. These greatly affect the quality of power fed into the grid and reliability of the system and if not solved then it will increase the supply-load demand gap Ref. [2]. DC system is advantageous by nature; absence of frequency, skin effect, proximity effect, harmonics, inrush current problem and safer due to reduced electromagnetic field effect as compared to AC systems Ref. [6]. Also DC system has very less losses comparatively. Most of the loads used in modern times are DC in nature. So, DC systems are more focused and multi input multi output converters (MIMO) came into picture but still it is difficult to design the control of MIMO converters of different distributed generators (DGs). This is focused and works done on it, proposing the current control mode which shows better stability characteristics than the conventional voltage control mode Ref. [1, 6]. The power electronic converter circuit with higher efficiency is must for better reliable system and better power management to meet the load demand Ref. [10, 15, 20]. The current value decreases as the boost converter increases the voltage value. Hence we have high gain converters Ref. [14, 17, 18]. For which some papers implemented MPPT (maximum power point tracking) algorithm, soft switching by ZVS (zero voltage switching) concept. We could able to notice that as the voltage gain is increased the efficiency of the conventional converters goes down. These problems are addressed by using fuzzy controller instead of PID controller. But as the load changes in a greater value, the performance of PID controllers is greatly affected. On literature survey we could able to see the many papers working on to achieve regulated output to DC micro grid from fluctuating renewable energy sources Ref. [11, 14]. Also many papers aiming for higher efficiency, reduced size, reduced component count, reduced current stress, lower cost converters and regulated output for wide range of input variations Ref. [13, 14, 15].

II. DC MICRO GRIDS

A. *Stability Characteristics Of DC-DC Converter Under Input Voltage Fluctuation*

The renewable energy sources are not available continuously and it is highly variable in some time. Since the DC voltage fluctuates even in hybrid energy systems the switching power converters must have high stability. This paper aims to provide stability characteristics for dc-dc converter regarding input voltage fluctuation. There by attempting to improve efficiency of the system.

B. *Decentralized Switched Current Control for DC Micro grids*

In order to obtain droop control dc-dc converters are treated as controlled current sources. The proposed current control is simulated and results are presented in this paper.

C. *Comparison of performance of DC and AC micro grid*

As there is a rapid growth in DC loads in our daily usages, we have to strengthen the low voltage DC supply system. In case of low voltage AC supply system we need to modulate, convert the supply by means of power conversion circuits like converter / chopper as per load nature and demand. Since there is increased DC load demand installation and integration of rooftop photovoltaic system is shown greater interest. As per need the fuel cells are also included in the supply system. It's better to have least number of conversion stages in overall system to have better system performance and efficiency.

D. *A Review on the Overall Control of DC micro grids*

The DC system is more advantageous than AC system. In practice it can be easily operated in combination with various renewable energy sources with or without storage units and also compatible with modern loads / smart appliances. DCMG (Direct Current Micro grid) has become popular in research fields from last few years. The power, control strategies and source-load gap in the DCMG system are the challenges for the researchers. Any micro grid structures basically focus on power and energy management.

III. COMPARISON OF EXISTING AND PROPOSED SYSTEM

A. Existing System

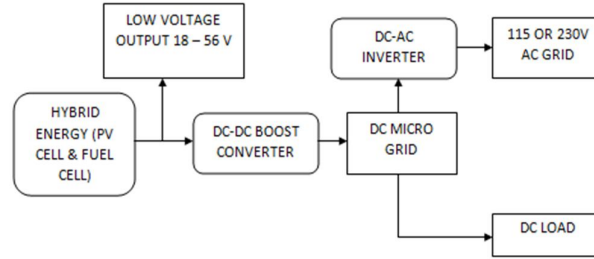


Figure 1. Block diagram of Existing system

Fig.1 shows the basic block diagram of the existing system. Here DC power is generated using PV panels and fuel cells and fed to DC-DC boost converter. This converter increases the amplitude of source and feed the DC micro grid as per requirement. The DC micro grid can directly provide the supply to the DC loads. If AC loads are to be provided supply then inverter can be used and can convert the DC to AC and can be given to AC loads.

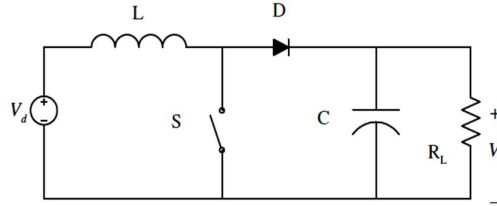


Figure 2. Circuit diagram of Existing system

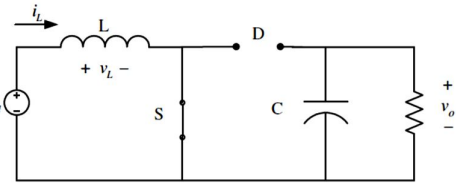


Figure 3. Circuit diagram when switch is closed

Fig.2 shows the circuit diagram of existing system. The DC supply is fed to the DC micro grid. Here load resistor R_L is considered as DC micro grid which has to be fed with DC supply generated by renewable energy sources. The DC has to be boosted for which inductor, diode and switch plays a vital role. Diode gets reverse bias on closing the switch, this separate the load from supply. The input supplies energy to inductor. Generally this inductor value is chosen to be greater value in order to facilitate the boost action. Fig.3 shows the circuit diagram when switch is ON.

Supply is short circuited once when the switched is turned on result in zero resistance for the current flow in the path. So the supply current gets looped in the inductor and switch path thereby increasing the inductor voltage. In this stage inductor builds the voltage across it. Let the switch be in ON state for a time T_{ON} and OFF state for a time T_{OFF} . Then total time period is the sum of T_{ON} and T_{OFF} . When switch is opened, the output section or load or DC micro grid receives energy from the supply as well as from the stored energy in the inductor. Hence output is large. Thereby boosting action is achieved. A higher value of capacitor C can be implemented across the load to obtain constant output voltage. Fig.4 shows the circuit diagram when switch is open.

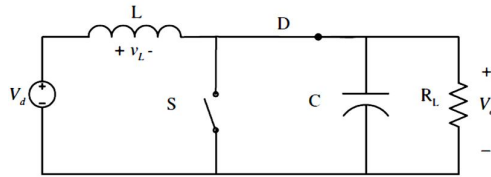


Figure 4. Circuit diagram when switch is open

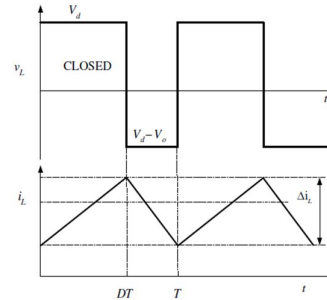


Figure 5. Output voltage and current waveforms

Once when the switch is open, the inductor is reverse its polarity and starts to dissipate its stored energy to the load resistor. In this instant the load will receive the inductor voltage in addition to the supply voltage. The current through the load will be maintained in the same direction while the output voltage gets boosted up. Fig.5 shows output voltage and current waveforms.

In overall, the fluctuating variable DC energy from DER is boosted as per load demand and wide range of stable dc output power is provided to DC micro grid of 2.5kW capacity. Here the current is regulated and controlled for better load sharing. Instantaneous value of energy demand at DC bus gives the value of power flow from the DC bus. The existing system achieves the simulation results of 400V DC output with ripple content less than one percentage for the input voltages of 350V and 250V from two different parallel supply units, battery operated as optional as per load demand. The demerits of existing system are power supply boosting is less compare with the SEPIC converter, Output has inverted, Output voltage is highly sensitive to changes in duty cycle, large value of inductor and capacitor are required to produce ripple free output.

B. Proposed System

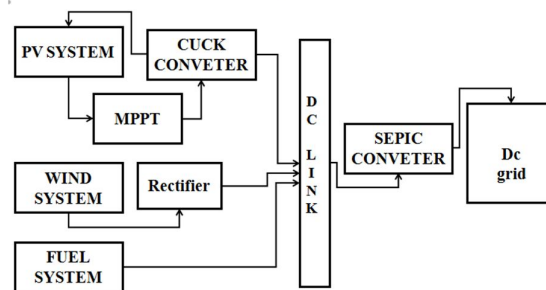


Figure 6. Block diagram of Proposed system

The various available Disturbed Energy Resources such as wind, solar, fuel cell are integrated and hybrid energy source system is formed. Fig.6 shows the basic block diagram of the proposed system. In case of energy extraction from wind the rectifier is used to convert the generated ac power to dc power and to meet the dc load demand. To obtain better results from PV system, it is implemented with a CUK converter and MPPT (Maximum Power Point Tracking) concept. Then all the generated DC is integrated by means of DC link and then given to SEPIC converter. The converter boosts the supply and gives to the DC micro grid then the output given to DC load. Inverter can be used and the output dc is converted to ac and fed to ac loads.

A PV (photovoltaic) system is an arrangement of components designed which could be able to convert the solar energy to electrical energy.

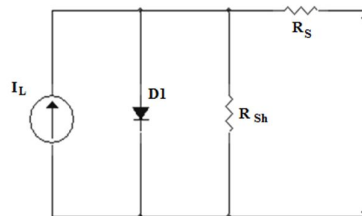


Figure 7. Circuit equivalent of PV cell

Undoubtedly Solar Energy sources are the present and future energy supply units due to its inherent advantageous nature like unlimited potential, green energy and better alternate to face energy crises. In economic point of view it is better decision to go with Solar Energy system. Electricity bills can be reduced to greater extent when solar energy is used.

The PV technology is one of the booming technologies in electrical and electronic field. The PV cell is made up of silicon material which can liberate the electrons when sun light falls on it and by means of lead the output voltage can be obtained. The PV system electrical output increases as the illumination increases but reduces the overall efficiency if the temperature of the panel increases. The PV cells are the basic building blocks of the solar energy supply systems. The cells can be grouped to form module. Modules can be integrated to form panel. These panels can be arranged in series or in parallel to form the array as per the voltage and current requirements thereby providing electricity to power entire towns. Fig.7 shows the circuit equivalent of PV cell.

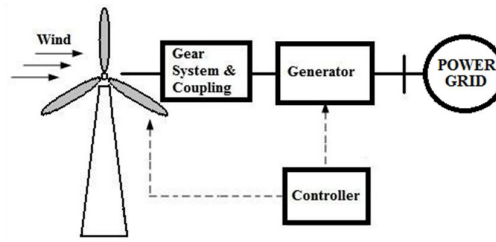


Figure 8. Energy extraction from wind energy

Electricity can be even obtained from wind energy. There was a rapid development in the wind power generation in the world because of its advantageous nature like pollution free, good results in terms of efficiency and performance, etc. Fig.8 shows the model of energy extraction from wind energy.

It is cost effective compared to other electrical sources. Another great advantage to go for wind energy generation is it is basically a renewable energy source and pollution free and less running cost. Installation challenges are present like logistics, transportation, wind availability, wind speed; other climatic conditions and greater initial cost, once done it will yield good results.

The chemical energy of a fuel, usually hydrogen can be converted to electrical energy by means of fuel cell. In which oxygen acts as an oxidizing agent provides electricity through a pair of redox reactions. Continuous electricity can be obtained by providing continuous input to the fuel cell. It is ideally suitable as indoor supply units mainly in hospitals. Hydrogen and oxygen is passed through the anode and cathode of a fuel cell respectively. Electrons and protons are liberated at anode side on splitting of hydrogen molecules thereby producing electrical energy. Compared to diesel or gas engines, fuel cell has greater efficiency. It is noise free; most fuel cells operate silently compared to internal combustion engines. In case of fuel cell the nitrogen oxide emissions is much lesser than the thermal power plants. It is quieter in operation since the moving parts are absent in fuel cell. The only drawback with fuel cell is they are expensive to manufacture due to the high cost of platinum catalysts and lack of sufficient infrastructure to support the distribution of hydrogen.

C. SEPIC Converter

A SEPIC (single-ended primary-inductor converter) converter is essentially a boost converter. The output voltage can be obtained with same polarity as in case of the supply voltage. It includes DC input supply voltage in V_{in} , capacitors C_1 and C_2 , inductors L_1 and L_2 , switch S (MOSFET), diode D_1 and the load resistance R . Fig.9 shows the circuit diagram of SEPIC converter.

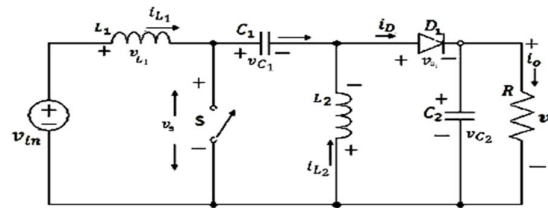


Figure 9. Circuit diagram of SEPIC converter

Mostly the DC-DC converters are operated with higher switching frequency. Mostly MOSFET switch is opted considering switching frequency. The SEPIC converter is superior in this case. Table I shows the comparison of Boost converter and SEPIC converter.

TABLE I. COMPARISON OF BOOST CONVERTER AND SEPIC CONVERTER

S.NO	PARAMETERS	BOOST CONVERTER	SEPIC CONVETER
1	EFFICIENCY	LOW	HIGH
2	POLARITY	OUTPUT POLARITY CHANGING SOMETIME	OUTPUT POLARITY NEVER CHANGE
3	OUTPUT CURRENT	MEDIUM	HIGH
4	TOTAL HARMONIC DISTORTION	LOW (THD-8.52 in 48V)	HIGH (THD-1.14 in 48v)
5	SWITCHING LOSSES	HIGH	LOW
6.	CONVERTER USING BOOSTING	2	1

Fig.10 shows the operation of SEPIC converter when switch (MOSFET) is closed. This makes the supply to flow inductor forming the loop of supply V_{in} , Inductor L_1 and switch S . Thereby increasing the voltage across inductor L_1 . The supply flows further to the capacitor C_1 and charges it and this capacitor will charge the inductor L_2 . Once the switch is turned on due to the supply voltage the diode will be reverse biased. This makes the capacitor C_2 to provide the output voltage when switch is in closed position. Fig.11 shows the operation of SEPIC converter when switch is open. The inductor L_1 which was already with increased voltage will now discharge it to load via capacitor and diode. Thus the overall output is obtained by stepping up the DC input voltage. As long as the inductor is getting charged the output voltage can be obtained in a boosted manner. But still it is better to avoid large pulses for smooth charging operation of the capacitors 1 & 2.

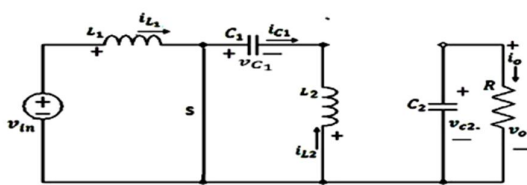


Figure 10. SEPIC converter when switch is ON

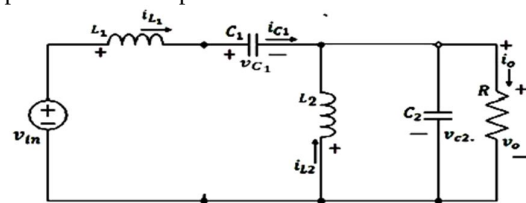


Figure 11. SEPIC converter when switch is OFF

IV. SIMULATION RESULTS OF PROPOSED SYSTEM

The DC-DC SEPIC Converter has been modeled. The converter circuit is analyzed by means of MATLAB software. Fig.12 shows the schematic of the modeled DC-DC SEPIC converter. The output voltage of 91V is obtained and the output voltage is regulated much better. The converter has a voltage output of 91V and current output of 15A. The different parameters of the output voltage are shown graphically. Fig.13 shows the output voltage of solar energy system which is of 24V dc. Fig.14 shows the output voltage of wind energy system which is of 24V dc obtained after rectification. Fig.15 shows the output voltage of fuel cell which is of 12V dc. The simulation analysis and results shows better current sharing among different input energy sources.

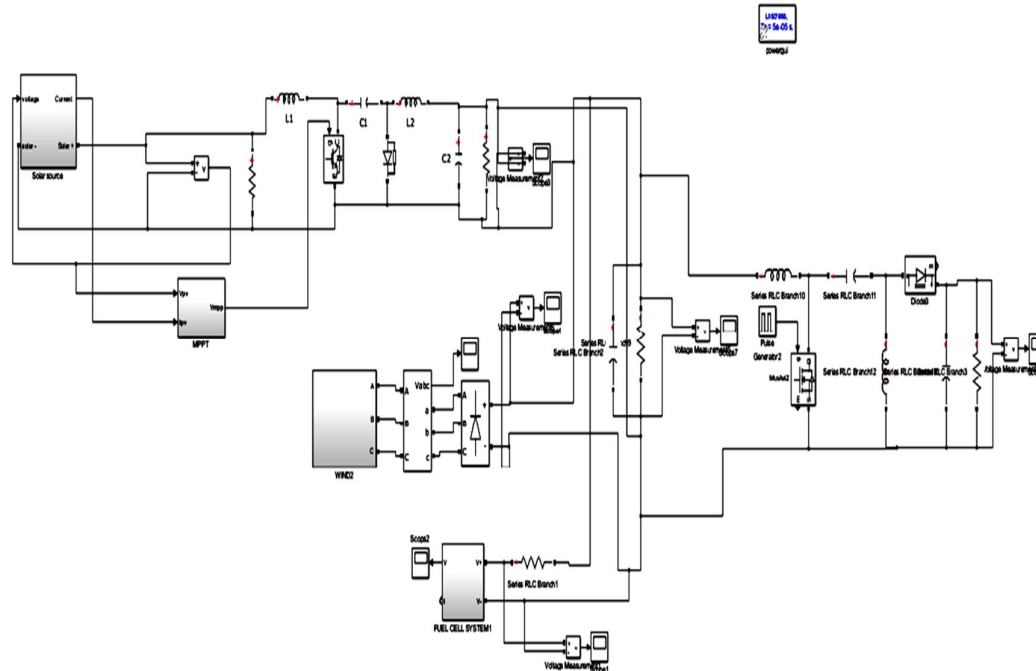


Figure 12. Schematic of the modeled DC-DC SEPIC Converter

The gate pulse to the switches in converter circuit is provided by means of pulse width modulation to obtain better results. The solar panels are implemented with maximum power point tracking algorithm to have better performance of the system. Fig. 16 shows the pulse width modulation technique for generating gate pulse to switches.

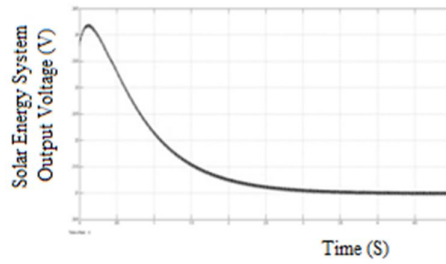


Figure 13. The output voltage of solar energy system

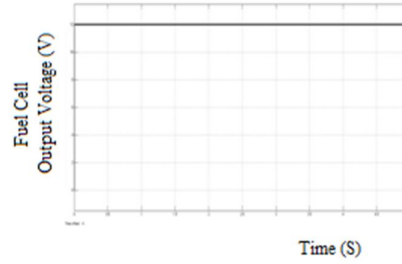


Figure 15. The output voltage of Fuel cell

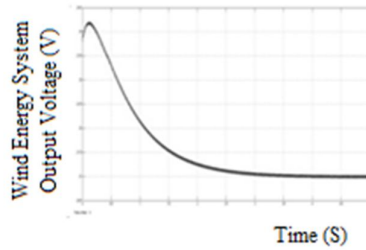


Figure 14. The output voltage of wind energy system

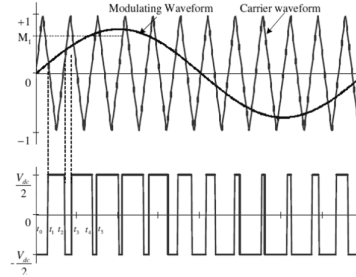


Figure 16. The pulse width modulation technique

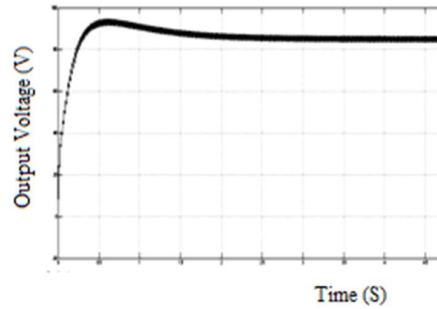


Fig. 17. Output voltage of SEPIC converter

On analyzing we could able to generate a voltage up to 91V from various distributed hybrid energy sources such as PV panel, wind energy and fuel cell by using SEPIC converter. Fig.17 shows the output voltage of SEPIC converter. We getting an output with non-inverted as well as more boosting output voltage compare to traditional boost converter and the switching losses also reduce in proposed system.

V. CONCLUSIONS

The various factors like boosting power supply, load increasing and synchronization in a dc micro grid are mitigated in hybrid micro grid. DC-DC converters play an important role in energy harvest from various hybrid energy sources and in increasing the overall efficiency of a hybrid micro grid. The various parameters of the output voltage like output voltage and current of PV system, wind energy and fuel cell are given and the regulation is done for a wide range of load demand values thereby ensuring better current sharing among different input energy sources. Hence overall increase in system performance is achieved by implementation of SEPIC converter. The major focus of this paper is to study and analyze the better load sharing, boosting the power, regulation of output and system stability.

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