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Implementation and Control of Multiple Input Single Converter Battery Charger for DC NANOGRID Applications

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***Abstract*- In this paper a Multi input single converter battery charger is presented. Nowadays due to power failure, there is a great usage of UPS systems in our homes or in industries which leads to a great problem to the consumers. The amount of DC loads used in our buildings such as computers, televisions, mobile phones, induction based appliances and other electronics are increasing day by day. To meet out the concern renewable power and storage have made DC based distribution an attractive alternative solution. By using dc sources it is necessary to use converters. If using multiple sources it need separate converters for each stage. This multi input single converter reduce the system size and cost by reducing the number of components. In addition some other advantages are the system is reliable and its dynamic performance due to centralized control. The system is suitable for applications such as hybrid automobile charging and in residential buildings. The design circuit, performance of different operating modes, simulation results using Proteus software is presented here.**

***Index Terms*- Renewable energy sources, DC-DC converter and PI controller.**

I. INTRODUCTION

Energy is a fundamental aspect to people's life, and is essential not only for individuals but also the fact for various sectors. It can be supplied from various resources which can be divided into two categories; renewable and non-renewable sources**.** Typical examples of non-renewable energy sources are petroleum, coal, and natural gas. As for renewable sources, these include energy generated from wind, solar, wave, fuel cell, geothermal, biomass and hydro. Both renewable and non-renewable energy sources can be used to produce energy sources including electricity and hydrogen. Solar and wind energy which are non-pollution, free in their availability and renewable are considered as a promising power sources. In recent days, the number of applications which require more than one power source is increasing. Distributed generating systems or micro-grid systems normally use more than one power source or more than one kind of energy source. Also, to increase the utilization of renewable energy sources, diversified energy source combination is recommended. The combination of more power sources and diversified power sources make it possible to obtain higher availability in a power system. Nowadays power electronics is covering a wide range of industrial and commercial applications, including computers, mobiles, and telecommunication, aircraft, and transportation, information processing and power utilities. Renewable energy usage has been increasing day by day scenario. And by the parallel connection of converters has been used to integrate more than one input energy source in a power system. However this converter can generally have the following advantages compare to a combination of several individual converters like cost reduction, compactness, more expandability and greater manageability. Consumption of electricity has been rising at fastest rates in the world owing to growing population and economic development. Our economy has been put forth to increasing

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challenges since energy supply is struggling to meet the demand and there are energy shortages almost many places in the country. Therefore the Renewable Energy Sources (RES) such as solar and wind, produce power intermittently according to the weather conditions rather than to the power demanded. Energy Storage Systems may be used to mitigate the intermittent generation from RES and to increase the quality of power supply. This makes it difficult to integrate the power generated from these RES into the electric network. One major benefit with the use of renewable sources is that as it is renewable and so will never run out. Their fuel being obtained from natural and readily available resources reduces the operation cost and maintenance. Even more significantly, renewable energy produces little or no waste products such as carbon dioxide or other chemical pollutants. Human activity is overfilling our atmosphere with carbon dioxide and other global warming emissions, which trap heat, steadily drive up earth's temperature, and create harmful impacts on our health, surroundings and climate. Electricity production is majorly generated by coal-fired power plants which emits global warming gases. The air and water pollutants emitted by coal and natural gas plants are avoided by using RES. Hence, Solar and Wind energy sources are considered as the input sources for this converter. Thus the multi input single converter systems operation can be explained and output can be implemented using Proteus software is presented.

II. RENEWABLE ENERGY SOURCES

A hybrid power system augments the photovoltaic (PV), wind turbine and fuel cell with a reversible energy storage system so that the overall system can cope with the power demands. Solar energy is produced from the sun. The sun forms its energy through thermonuclear reactions that converts hydrogen to helium. The energy storage system can be implemented with a rechargeable battery banks. The system will consists of, (a) PV panels, to convert the sunlight into direct current. (b) Wind turbine, to convert the kinetic energy from the wind to mechanical energy. (c) DC generator, to convert the mechanical energy from the turbine into electrical energy (d) MPPT, to operate the PV at the maximum power point (MPP). (e) Fuel cells, which performs as a backup power source. (f) Battery bank, to supply energy to the system when it is needed. (g) DC/DC converters, to steps-up the voltage to a higher DC voltage. (h) DC/AC inverters, to generate AC waveform from the DC signal. Solar energy is produced from the sun. The sun forms its energy through thermonuclear reactions that converts hydrogen to helium. This process creates electromagnetic radiation and heat. The electromagnetic radiation (ultra-violet radiation) streams out into space in all directions. While the heat remains in the sun, and is instrumental in maintaining the thermonuclear reaction. Solar energy can be applied in different applications such as: heating, and cooling. Heating is the business for which solar energy is best suited. Solar heating has a very high efficiency because it requires no energy transformation. Solar energy can be converted to electricity, besides being used for heating and cooling, so most of our tools can be operated through solar power. The solar collectors that convert radiation into electricity can be either flat-plane collectors or focusing collectors, and the silicon components of these collectors are photovoltaic cells. And then wind has always been an energy source used by several civilizations many years ago. The first use of wind power was to make possible the sailing of ships in the Nile River some 5000 years ago. A wind turbine is a machine that converts the kinetic energy from the wind into mechanical energy; therefore the maximum energy delivered not only depends on the machine limits but also on wind speed. On the other hand, windmills convert the power of the wind into mechanical power.

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III. POWER ELECTRONICS SYSTEM

Power electronics refers to control and conversion of electrical power by semiconductor devices, where in these devices operate as switches. It has applications that extend over the entire field of electrical power systems, with a power range from a few Watts to several Megawatts. In electronic device most power electronics system divided into two stages: i) Power stage ii) Control stage the power stage is responsible to transfer an amount of power from the input to the output, and the control stage is used to control that amount of power. Where the input sources (electrical inputs) are like current, voltage etc., and the output signals are like voltages, currents. Etc. The main function of a power electronic system is to forward the energy to the required load, and the power converter function is to convert the input to the required output energy using switching electronic devices. There are four conversion circuits that are used in the power electronics circuits:

i. Rectification (AC-DC)

ii. Inversion (DC-AC)

iii. Conversion (DC-DC)

iv. AC-AC converter with same or different freq.

A converter that produces an output voltage higher than that of the input voltage is called Boost converter or step-up converter. The fundamental for a boost converter consists of an inductor, diode, capacitor and switch. The input to a boost converter can be from any kind of sources as well as batteries. The DC input voltage is in series with a large inductor acting as a current source. A switch connected in parallel with the current source and the output is turned off periodically, providing energy from the inductor and source to raise the output voltage.

A. The Dc/Dc Converters

To connect a photovoltaic, wind turbine or PEM fuel cell to an external power system (e.g. DC load), it is necessary to boost their voltage or to increase their number. Therefore, a DC averaged switched model converter is needed to regulate the output voltage before being supplied to other electronic devices. There are many DC-to-DC converters including the step-down (buck) converter, the step-up (boost) converter, the buck-boost converter and many others. The following will evaluate the step-up (boost) converter which is shown in Figure1.

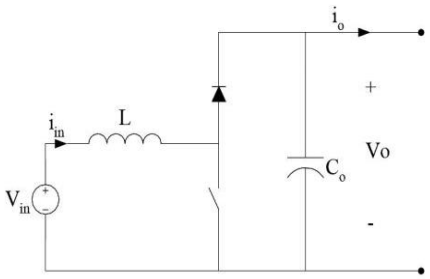

Fig 1. DC-DC Boost Converter

Boost converter is a class of switching mode power supply (SMPS), it contains at least one energy storage element, and at least two Semiconductor devices (MOSFET and diode). This can be works as

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and the switching process be operate as an ideal power switch; OFF when the switch current is very close to zero, and ON when the voltage across is relatively small.

B. The DC/AC Inverters

The basic operation of the DC/AC switching inverter is to generate AC waveform from the DC signal, by operating each pair of switches S_1- S_3 and S_2-S_4 alternately with their duty cycle for each switching period.

A DC/AC switching inverter is developed, as shown in figure below

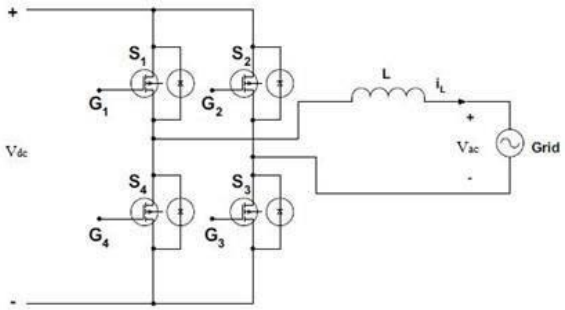

Fig 2. DC/AC Inverter

Most of the power electronic component consists of a converter using a semi-conductor switching device. And as we said before the converters can be classified as rectification (AC-DC), inversion (DC-AC), conversion (DC-DC) and AC-AC converter with same or different frequency. The purpose for using a semi-conductor switching device in the convertor is to increase the efficiency of conversion to the higher value.

IV. MULTI-INPUT DC-DC CONVERTER

Multiple-Input DC-DC converters are the sole key to combine numerous input power sources whose voltage levels are different and to get regulated output voltage for the load from them. In many applications, there is a requirement for multiple power sources to be connected together, providing .The power for a single loads. As in the Source 1 to Source N-1 can be composed of any kind of energy source combinations, such as wind turbines, PV modules, FC, micro turbines and/or electric grid, and Source N could be a storage unit, such as a battery, ultra-capacitor, flywheel or super conducting magnetic energy storage system. All the energy sources are unidirectional where the storage element is bidirectional which can perform both charging and discharging operations.

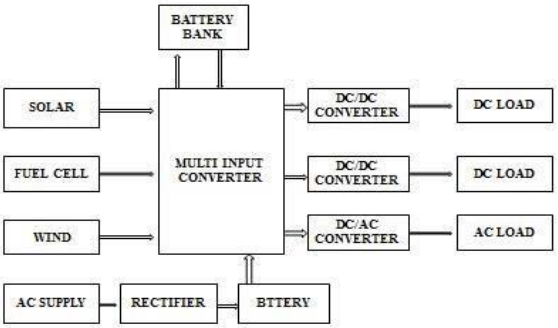

Fig.3.Single Converters for Each Source

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A Multi-Input single output DC-DC Converter replaces several numbers of parallel connected single converters is shown in Fig -3. Fig -4 shows the structure of the four-input DC–DC boost converter. The converter interfaces voltages from four input power sources V1, V2, V3 and V4 and the storage element battery.

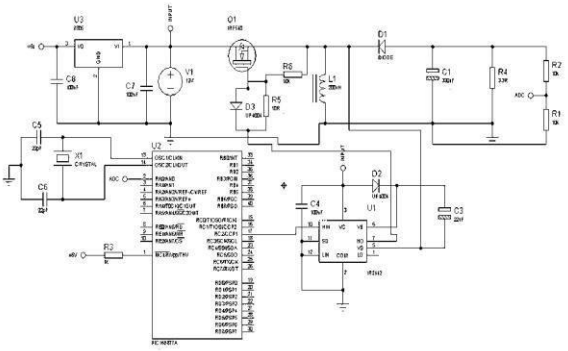

Fig 4. Circuit Diagram of Multi Input Converter

In this circuit diagram it's clearly shown that the switching function of the converter is based on figure above shows the circuit diagram such that the several input source can be used in this circuit a boost converter is used to boost the voltage level.

V. MODES OF OPERATION

The Proposed multi-input DC-DC converter is operated in three different modes based on the performance of the storage element.

- Mode 1

  Supplying the load with sources V1, V2, V3 and V4without battery.

- Mode 2

  Supplying the load with sources V1, V2, V3 andV4 and the battery.

- Mode 3

  Supplying the load with sources V1, V2, V3 andV4 and the battery charging performance.

a) Mode 1

The first operation mode is shown in Fig -5. In this operation mode, four input power sources V1, V2, V3 and V4are in charge for supplying voltage to the load, and battery charging or discharging is not done. This operation mode is considered as the basic operation mode of the converter. As clearly seen from the converter structure, there are two options to conduct input power sources currents iL1, iL2, iL3and iL4 without passing through the battery; path 1:S4-D3 andS8-D7, path 2:S3-D4 and S7-D8. In this operation mode, the first path is chosen; therefore, switch S3 and S7 are turned OFF while switch

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S4 and S8 are turned ON entirely in the switching period. Switches S1, S2, S5 and S6 are turned ON and inductors L1, L2, L3 and L4 are charged with voltages across V1, V2, V3 and V4 respectively. In this mode, voltage from the input sources is directly fed to the load and the battery remains unused. Therefore, the charging state of the battery should be provided in this operation mode. Referring to the converter topology. Thus the mode 1 operation can be show in below figure 5. Mode 1 Operation

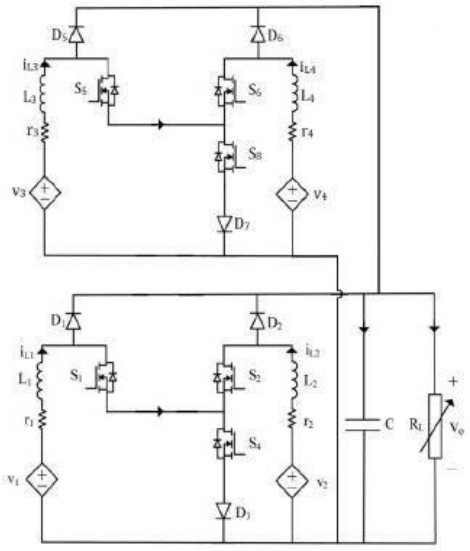

Fig 5. Mode 1 of Multi-Input DC-DC converter

b) Mode 2

Second operation mode is shown in Fig -6. In this operation mode, four input power sources V1, V2, V3 and V4 along with the battery are accountable for supplying the load voltage. Therefore, discharging operation of the battery is performed in this operation mode. Referring to the converter topology, when switches S3, S4, S7 and S8 are turned ON simultaneously, currents iL1, iL2, iL3 and iL4 are conducted through the path of switch S4 and S8, the battery, and switchS3 and S7 which results in battery discharging. However, discharging operations of the battery can last until switches S1, S5 and S2, S6 are on.

As a result, the maximum discharge power of the battery depends on inductor currents iL1, iL2, iL3 and iL4. Therefore, in order to acquire a maximum charge power of the battery, the input power sources should be designed in proper current and voltage values. On the other hand, regulate the discharging power of the battery below the maximum discharging power. Maximum charge power of the battery, the input power sources should be designed in proper current and voltage values. On the other hand, regulate the discharging power of the battery below the maximum discharging power.

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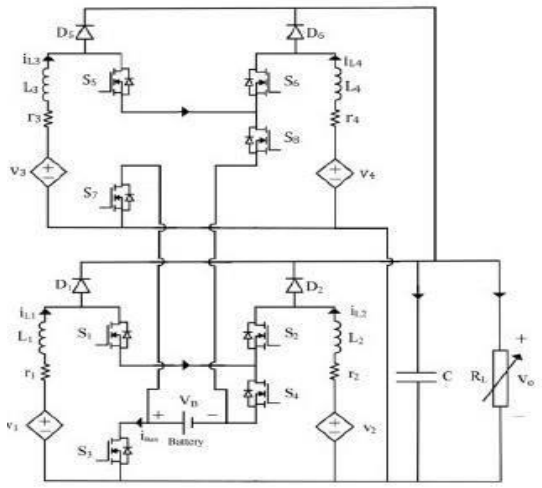

Fig 6. Mode 2 Operation

c) Mode 3

In this operation mode, four input power sources V1, V2, V3 and V4 are responsible for supplying the load while the battery charging action is accomplished. Therefore, the charging state of the battery should be provided in this operation mode. Referring to the converter topology, battery can only last until switches S1, S5 and/or S2, S6 are conducting. when switches S 3, S4, S7 and S8are turned OFF, therefore, the condition of battery charging is provided. However, the charging operation of the battery can only last until switches S1, S5 and/or S2, S6 are conducting.

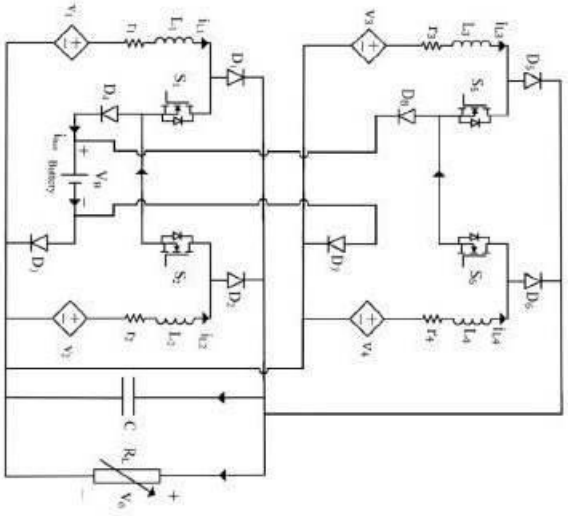

Fig 7. Mode 3 Operation

As a result, the maximum charge power of the battery depends on inductor currents iL1, iL2, iL3 and iL4.

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VI. SIMULATION RESULTS

PROTEUS (Professional Text for Easy Use) is a digital high-performance language for technical computing. It integrates computation, visualization, and programming in an easy to use environment. PROTEUS is an excellent tool for teaching and research. In this, the PROTEUS design suite model for Multi-Input DC-DC Converter is modeled and simulated with PI controller. The results are studied based on the performance of DC-DC converter and battery in obtaining a continuous regulated output voltage. The below figure shows the Proteus simulation circuit in which that the operation can be done with three dc sources such as solar, wind and fuel cell from which that the simulation can be done through Proteus Software with taking voltage reference as 12V. And the solar panel range is 12V as master source from which that maximum power can be extracted through MPPT (Maximum power point). This MPPT can be increasing current into higher level to extracting maximum power from the solar. Thus the simulation results can be verified using Proteus software.

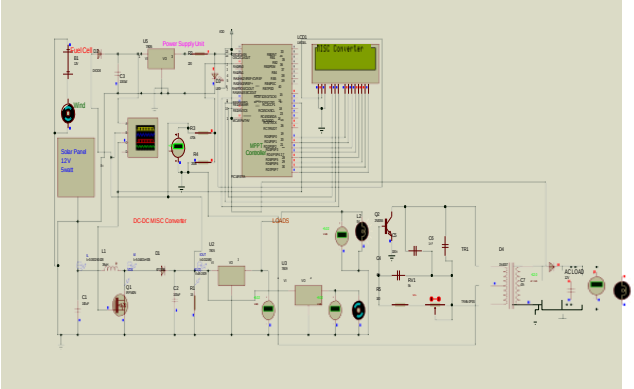

Fig 8. Simulation of the proposed method

VII. CONCLUSION

The Proposed Multi-Input DC-DC converter produces regulated output voltage to the load from the different input sources. This supplies power to the load either individually or simultaneously from the input sources. As the power delivered by the renewable energy sources like solar and wind which are discontinuous due to change in weather conditions, a storage element battery is provided. Battery starts discharging, when the power delivered by the input sources is not as much of to the load voltage to provide a continuous supply to the load. Instead of using individual converter for each source in hybrid system. This Multi input single converter battery charger can be proposed which improves the system performance and reduces the size and cost of the renewable energy system to make convenient for the domestic users.

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