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DC-DC converter based power management for go green applications

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ABSTRACT

A non-isolated tri-port converter is a fully compact and functional system by the integration of basic converters. This can be used for renewable energy applications. This converter is capable of achieving different switching patterns of power flow between the source and load, interfaced sources of various voltage and current levels with the dc grid. This tri-port converter has to be used for continuous power distribution of rechargeable battery, photovoltaic panels and load. Due to the implementation of this DC-DC converter some operations like buck, boost and buck-boost operations became easy. Use of this converter helps in easy implementation of the system. The solar PV panel implementation boosts the system to a high level and bidirectional flow became easy from source to load and vice versa.

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1. INTRODUCTION

For the past two decades, the attraction of researchers are renewable energy based power generation to compensate the growing demand of the society; Total capacity of power generation is 177GW with photovoltaic in 2014 [1]. It is very important to note that the unstopped growth of decentralized energy sources affects the quality of the grid voltage. Also the production of circulating energy causes the power quality to diminish. Most importantly, the quality of power is very poor and therefore this results in the disconnection of PV and the inverter from the grid. The situation is created in such a way that the sufficient power is not been able to feed the power to the grid [2, 3]. It is necessary to note that along with the grid quality which results in instability working of PV plant, the high grid voltage also arises the problem. During electrical installations, the high grid voltage may occur due to high injection of power from PV to the grid, during the electrical installations [2, 3]. An emerging portable microelectronic device which includes multiple supply voltage demand from a single miniaturized power-efficient platform use the DC-DC converter based on Single Inductor Multiple Output Switching [1-3]. For SIMO DC-DC boost converter, a load independent current control technique is used for regulating the total current. The zero inductor current instant is monitored instantly [4]. A new control method for a multi output DC-DC converter is DC-DC Converter with Return Current Control. This method simultaneously generates step up/down output to have controlled stability under a wide load variation without a compensation network [4-7].

To choose an optimum multiple input DC-DC converters for a particular application in renewable energy depends upon on the parameters like efficiency, design simplicity, reliability and cost [5]. The suitably designed control loop provides the information about the behaviour of the system for the Bifurcation Analysis of the standalone PV-Battery Hybrid Power System [6-9]. For Uninterrupted Power

Supplies (UPS) application, the charging and discharging of the battery was performed with the Bidirectional Converter which has the high gain zero voltage switching with Reduced Number of Switches. It has the capability to function with the zero voltage switching (ZVS) condition [10-13]. Figure 1 shows the power flow for a PV system with LES and grid support.

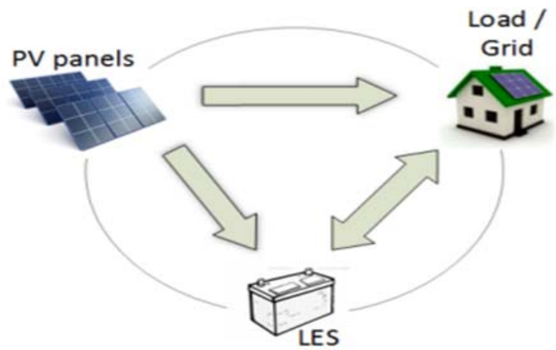


Figure 1. Power flow for a PV system with LES and grid support

The effectiveness of hybrid renewable energy is simulated through MATLAB/SIMULINK [11]. Different Topologies of LLC, LCC, and CLL Resonant Converters have been simulated and compared for the same input voltage. The simulation was done at a very high frequency. The Output Power and the Efficiency of all the three Resonant Converters were calculated. With the results, it has been proved that LCC Resonant Converters were very much suited to give an output voltage of around 62 Kilovolts [12]. The limitations of the existing tri-port converter system are Unidirectional conversion alone is possible; Inductive loss is high due to coupled inductors; Only PV and battery voltages are used to supply to load and to fulfill the requirement and less modes of operations. These drawbacks can be overcome by the application of non-isolated tri-port converter for renewable energy. From the detailed literature survey, it is clearly understood that it is necessary to reduce losses and the bidirectional flow of power is needed to meet the increasing power demands; also with the availability of the components to be used on time sharing basis.

The novelty of the proposed system is that, the non-isolated tri-port DC-DC converter is used for go green applications in which the voltage is supplied by altering the photovoltaic voltage, battery voltage and grid voltage. In this converter the bidirectional flow between the load and source can be maintained. This converter is the main component between the source and a load as it is a fly-back converter the output is given to the inverter present near the load. The merits of these systems are that we are using renewable energy as the master piece and which helps us to use this concept for GO GREEN. Renewable energy helps us to have an eco-friendly transmission in our environment and can be very useful for future generation.

2. PROPOSED SYSTEM

The application for which high voltage gain is not mandatory, the buck boost topologies of converters will give the improved performance with good efficiency. The simplicity of the topology and its modelling equations eases the modelling of the power stage. The performance of conventional buck and boost converters for high-power high current applications is poor, since the power is processed by two power devices. This has the disadvantage of increase in the required passive devices which increases the size further. Increase the power rating, obtaining better performance and reduce passive components are performed by enclosing of converters and this is a common practice [13]. Also the challenges found here is the unequal current distribution and increased power stages. Ripple reduction in input current and output voltage [14], reduced EMI filter [15], the phase-shedding that improves the efficiency at light load [16], the coupled magnetic utilization which results in raising the power density [17] helps in reaching higher power levels.

Lately, three port converters are achieving more attention for the applications where the energy stored in the load is integrated with the renewable energy. Single-stage power alteration between the ports is benefit of the purpose of the Tri-port converter (TPC) topologies. This converter is the main component between the source and a load as it is a fly-back converter. Normal tri-port converters (TPCs) have single stage power conversion due to which unidirectional flow of power is maintained. Multiple input multiple output was tried with the development of non-isolated TPC (NITPC). NITPC has the advantages of using less components and hence it is less expensive and compact. These can be derived from basic converters. Also, only one inductor coil is used and hence it reduces the inductive losses in the system.

In our proposed system the fly-back converter is replaced by the non-isolated tri-port converter where the ac grid is linked to the inverter. The output of the converter is linked through the inverter to the grid. The functionality of tri-port converter is to have bidirectional flow and which allows to overcome the limitations of the existing system.

2.1. Block diagram of NITPC

Figure 2 shows the block diagram for the planned system explains the operation of go green applications with non-isolated tri-port converter topology.

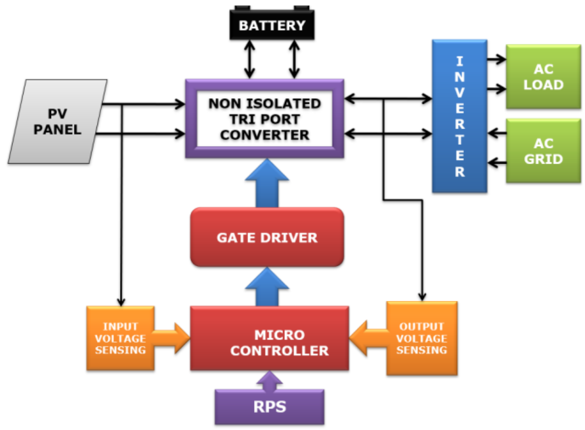


Figure 2. Block diagram of planned system

The NITPC avail three ports for making the connections for PV panel, battery and inverter. The PV panel is linked to the NITPC at one port to collect the renewable energy from sunlight and Battery is connected at second port for storing the energy produced. The inverter is connected to the third port of the NITPC. A micro controller is used to control the system where an LCD display is attached to it. Gate drivers are used to drive the switches of converter as well as the inverter linked to the third port of the NITPC. Inverter is connected in order to convert the dc voltage to ac. RPS units are connected from a transformer in such a way that they drive switches connected to the gate driver unit. Both the input and output voltages of the TPC are computed using voltage sensing units and information is given to the micro controller for further process in the operation. An AC grid is connected at the load side. The AC Grid is added additionally to supply the load in the absence of PV voltage and Battery voltage. A rectifier circuit is used for the conversion of AC supply to DC supply.

2.2. Modes of operation of NITPC

Figure 3 shows the proposed grid-connected PV plant with energy storage system (EES).

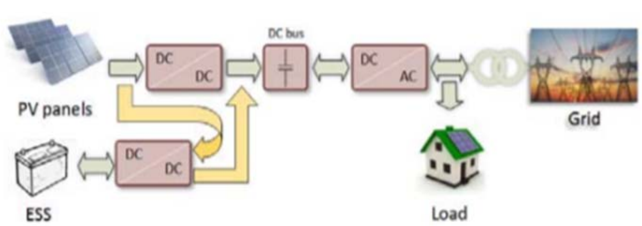


Figure 3. Block diagram of the proposed grid-connected PV plant with energy storage system (ESS)

In the proposed system Solar/PV voltage, Battery voltage along with AC Grid voltage is used for the operation. NITPC is used which has a single inductor that reduces the inductive loss. The bidirectional flow of the energy in the system is possible since the use of NITPC. Based on the direction of energy flow, the system operates in six modes.

- Photo-voltaic (PV) to the battery
- Photo-voltaic (PV) to the load
- Photo-voltaic (PV) to the battery and the load
- Photo-voltaic (PV) and the battery to the load
- Grid to the Battery
- Battery to the load

Single inverter is proposed to boost the voltage. These modifications made the system an effective system and also raise the efficiency of the system. The NITPC has low inductive loss, Bidirectional flow of energy, continuous load supply by altering the sources. Also all types of renewable energy sources can be connected to the system. This system can be used in home and industrial applications.

3. SOFTWARE SIMULATION

Figure 4 shows the Proposed TPC topology with interleaved stages. The circuit diagram of the Triport converter is shown in Figure 5. Figure 6 to 10 shows the steady state waveform obtained at various operating modes of the proposed system.

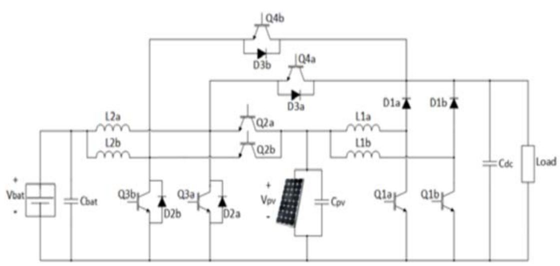


Figure 4. Proposed TPC topology with interleaved stages

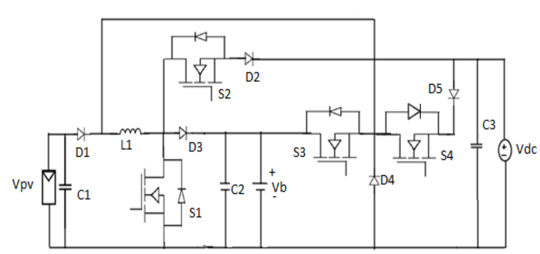


Figure 5. Tri port converter

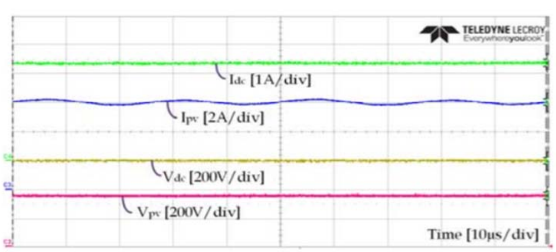


Figure 6. Steady-state waveforms in PV to DC bus operating mode

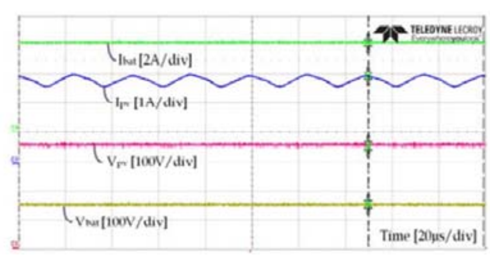
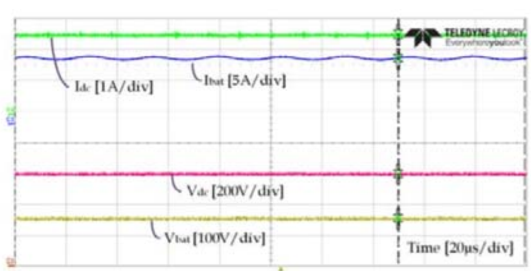


Figure 7. Steady-state waveforms in PV to battery operating mode



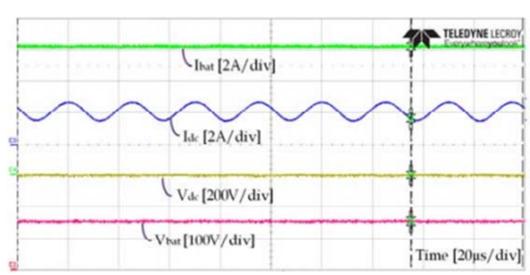
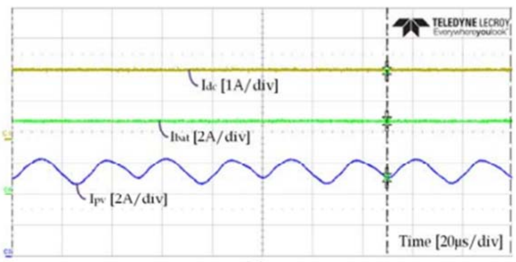
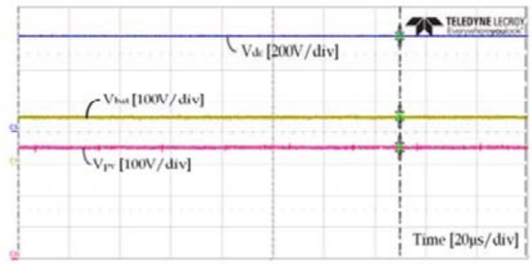


Figure 8. Steady-state waveforms in batteryto DC bus operating mode

Figure 9. Steady-state waveforms in DC bus to battery operating mode



(a)



(b)

Figure 10. Steady state waveform under PV to battery and DC bus operating (a) Voltage (b) Current

4. HARDWARE

In this system, the solar panel is connected to the Non Isolated Tri-port Converter (NITPC) which is in turn connected to the Capacitive Battery system. The NITPC is connected to the inverter and relay as well as the micro controller. The switches of both converter and inverter are connected to the gate drivers which are given supply form the RPS units. The RPS units are given supply through the step-down transformer. The micro controller gives the instructions to the system depending upon the conditions. A voltage sensing unit is connected to check the input voltages at the converter side and output voltages at micro controller side. A LCD display is connected to the micro controller for displaying the mode of operations. We assume a load of 12V LED light which is connected at the output side. A DC grid is arranged in the form of a transformer to supply the voltage in the absence of solar panel & battery voltages.

A solar cell or photo voltaic cell are such type of electrical devices that convert light energy directly into physical and chemical phenomenon. Photoelectric cell possess characteristics such as current, voltage and resistance. The multiple photo voltaic cells get integrated in one plane which constitutes of solar photo voltaic panel or module. The PV system or solar power system is designed to supply solar power through photovoltaic. The proposed system hardware is shown in Figure 11.

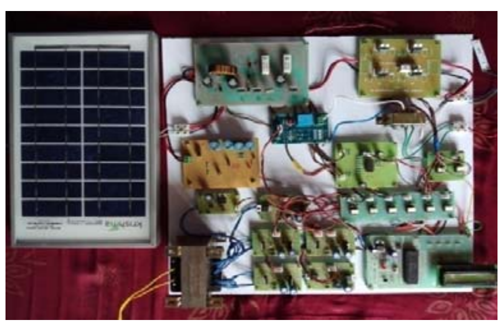


Figure 11. Hardware setup of proposed system

A tri-port converter is used to perform buck, boost & buck-boost operations depending upon the voltage differences.When the voltage is under the threshold value, it boosts the voltage to the required level. When the voltage is above the required value, it bucks the voltage to the required level. Similarly when the voltage varies the converter will buck-boost the voltage to the required limit. It has a simple construction with 5 diodes, 3 capacitors, and 1 inductor. This tri-port converter is controlled using 4 MOSFET switches.

These are connected in such a way that they can operate as tri-port converter. The modes of operation of this system are purely based on this tri-port converter and its operation. It is an automatic device which works and takes decision on its own depending up on the condition. These are highly used as they are easy to construct and operate as well as cheap and efficient. The model concentrates on DC to AC power inverters, which aim to alter the DC power source to a high voltage AC source. Inverters are used for many applications to balance with the situations of having low voltage DC sources such as batteries, solar panels must be converted. The low voltage DC power is inverted with 2 steps. In the first step the low voltage DC is converted to DC to a high voltage DC. As the second step, this DC is converted to high voltage AC. A novel single inductor NITPC is planned for a PV-Battery to the DC micro grid. As two of the three ports are able to handle reversible currents, this method ensures more flexible power flow. The proposed NITPC can transmit the power smoothly between DC-grid and AC grid. The flexible operation of the converter is verified with the experimental results.

5. OPERATION

The 6 modes of operation of the proposed system is explained as below. The circuit operation each mode are shown in shown in Figure 12 to 16.

5.1. Photo-voltaic (PV) to the battery

In the operation, PV voltage is given to the battery where the voltage has to be stored using capacitors from which the load gets the supply. This mode is designed for grid-connected mode. In this mode, the DC bus is controlled by the AC grid. And the PV has adequate power to charge the battery. Therefore the converter works like a conventional SISO boost converter. When S1 turns on, the energy in inductor L1 is stored from PV. When S1 turns off, D3 conducts and both PV and L1 deliver their energy to battery.

5.2. Photo-voltaic (PV) to the load

In this operation, the PV voltage which is produced with the solar energy is fed to the load. When the battery is fully charged and PV power is obtainable, the converter operates. The energy is sent from the PV panel to the AC bus. Now the converter operates as Single Input Single Output (SISO) boost converter. S1 and D2 are working in a balanced manner and the switching losses reduced with S2 is turned on for the whole operation. As diode of S4 is reverse biased, D5 will not conduct. Figure 12 shows the circuit diagram for PV to load

5.3. Photo-voltaic (PV) to the battery and the load

In this operation, the voltage from the PV panel is transferred to the battery and the load. The energy can be stored using the battery. When the PV current is advanced than the rated charging current of the battery, this mode becomes active. Therefore this configuration works as a Single input Double Output (SIDO) boost converter. The battery power and the AC power is supplied by the PV power. When S1 is turned on, L1 is charged, and is shown in Figure 13.

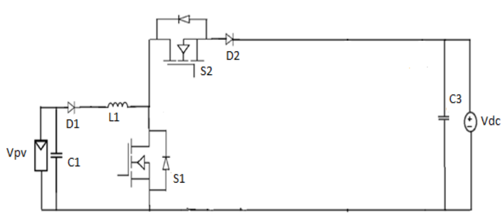


Figure 12. Circuit diagram of PV to load

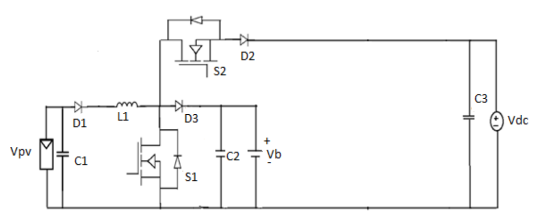


Figure 13. Circuit diagram of PV to battery and load

When S1 becomes off the power is dispatched to the battery and the AC bus through the S2, D2 and D3. The load demand determines the current ratio of the two outputs in which D2 is regulated by S2. The remaining current flows to the battery and it's stored in it. If the battery approaches full SOC the amount of charging current produced needs to be limited. As D5 is unregulated, the control of this current can be observed by regulating S2 using the currents relationship.

5.4. Photo-voltaic (PV) and the battery to the load

The inadequate radiation of the solar to supply only the AC bus results in the activation of this mode. Therefore the battery also becomes active to supply for the AC bus instantaneously. Hence this mode requires a Dual Input Single Output (DISO) converter structure. Depending on the amount of PV power accessibility, there are two switching sequences available in this mode. As first level the PV charges inductor L1. When S1 turns off, L1 is discharged with both battery and PV. The PV power drops and the system intend to switch as battery alone supply for the AC bus. However, there is a small amount of PV power, the converter turns on S3 so that the battery charges L1 and powers AC bus. After S3 is turned off, PV turns up to energise L1 for AC bus. Figure 14 shows tha circuit diagram of PV and battery to load.

5.5. Grid to the battery

The protection of battery form over discharging is performed with this mode. Also some energy is stored as the backup to supply at the time of absence of the PV power. Therefore the Grid helps in charging the battery. The same SISO boost converter in Mode 1 is used but with extra switch S4 and diode D5 are added in the operation. S4 fully turns on to allow bus to distribute power and to minimize switching losses. First Switch S1 turns on to charge L1. When S1 is off, the power from both AC bus and L1 will be released through diode D3 to the battery. D1 is reverse biased, hence, no power will flow to PV. Figure 15 shows the circuit diagram of grid to battery mode.

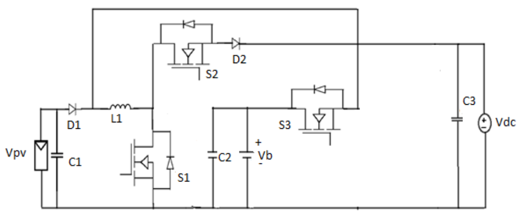


Figure 14. Circuit diagram of PV and battery to load

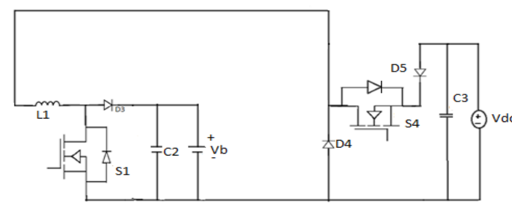


Figure 15. Circuit diagram of grid to battery mode

5.6. Battery to the load

In the absence of PV power and when the AC grid needs the power, this mode is activated. Therefore the battery is active and it supplies the power to the load. The converter works as a SISO buck converter. When S3 turns on, L1 is charged. The freewheeling diode D4 conducts when switch S3 is off. Switch S2 is always turned on in this mode. Similar to PV and Battery to Load, D3 is responsible for controlling the AC bus voltage. Figure 16 shows the circuit diagram of battery to load.

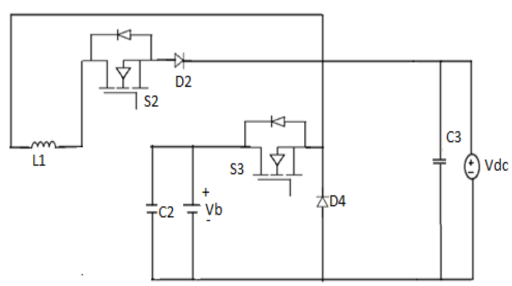


Figure 16. Circuit diagram of battery to load

6. CONCLUSION

In this paper, a three port DC-DC converter for PV systems with battery storage was obtained. The operating modes and the design procedures are explained in detail. From the simulation and the experimental results the efficiency, wide operating range and operating modes of the topology. The TPC converter presented is based on the well-known conventional buck and boost converter topologies, thereby enabling the design and modelling. Furthermore, converter modularity to raise power rating is achieved by means of including without adding high complexity to the design, as shown in the experimental prototype. Therefore, the proposed converter is suitable for high efficiency PV systems with battery storage where no galvanic isolation is essential.

The scope of our project is to build a perfect system for non-stop supply of power to the load without any disruption using hybrid energy sources. The power is stored in battery and can be used as backup power in the absence of renewable energy. At the time of draining of the battery completely a grid is attached to the system which supplies the power to the load.

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