A NON ISOLATED THREE PORT DC-DC CONVERTER FOR LOW POWER APPLICATION

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Abstract: This paper focuses on interfacing PV panel, battery bank, and Load for sufficient power flow. The design consist of one PV port, one bidirectional battery port and one load port of PV-Battery DC power system, a novel non-isolated three-port DC/DC converter named Boost Bidirectional Buck Converter (BBC) and its control method based on three domain control is proposed. This converter system features high integration and single-stage power conversion from both photovoltaic and battery, leading to high efficiency. The current of all the three-port is continuous so that the electromagnetic noise is minimized.

Furthermore, the control and modulation method for BBC is discussed using the Maximum Power Point Tracking (MPPT) algorithm, battery management, and bus voltage regulation. The study further highlights a detailed report on Power flow management where PV system, Battery and load are interconnected and controlled using PWM technique. A three-port DC-DC converter topology is preferred due to its high efficiency, more flexibility, and low operating cost. Finally, the system is simulated using MATLAB /SIMULINK tool to estimate the feasibility of the system.

Keywords: Photovoltaic system (PV), Three Port Converter topology, Battery, Maximum Powerpoint Tracking (MPPT), Boost Bidirectional Buck Converter (BBC), Pulse width modulation (PWM).

1. INTRODUCTION

Except for Direct Energy Transfer (DET) power systems [1]-[4], pulse width modulation switching DC/DC converter controlled by MPPT algorithm has been used to extract the maximum power from PV in PV-Battery power systems. A Three port converter network is depicted in Fig.1.

The Fig.1 shows a three-port converter, interfacing one PV port, one bidirectional battery port and one load port of PV-Battery DC power system, are a right candidate...
for such a renewable power system, especially for spacecraft power supply system. Because of the high power density and high-efficiency merit of the three-port converters, it has attracted research interest towards various applications [5]-[8].

Three port converters structure is classified into non-isolated, partially isolated (two power ports that shares a common ground are isolated from the remaining port) and fully isolated (each power port has its reference ground).

![Three Port Converter network](image)

The Partially-isolated and fully-isolated converters originated from half or full bridge topologies, featuring flexible voltage levels, high power levels, and soft-switching [9]-[12]. Non-isolated three-port converters usually derived from the buck, boost, buck-boost feature, a more compact design, higher power density, and higher efficiency compared with isolated three-port converters.

2. LITERATURE SURVEY

Young-Joo Lee et al. formulated a novel integrated bidirectional ac/dc charger and dc/dc converter (henceforth, the integrated converter) for PHEVs and hybrid/plug-in-hybrid conversions are proposed. The integrated converter can function as an ac/dc battery charger and transfer electrical energy between the battery pack and the high-voltage bus of the electric traction system.

2.2. Bidirectional dc-dc converter for a small electric vehicle

João Silvestre designed a bidirectional DC-DC converter for a small electric vehicle. The DC-DC converter designed and tested is capable of raising the voltage from the battery pack (96V nominal) to 600V necessary to feed the Variable Frequency Drive that controls the induction motor, This converter is also capable of working in the opposite direction (600V to 96V) in order to capture energy from regenerative braking and downhill driving.

2.3. The bidirectional isolated dc-dc converter

Zhe Zhang et al. designed a bidirectional isolated DC-DC converter controlled by phase-shift and duty cycle for the fuel cell hybrid energy system is analyzed and designed. The proposed topology minimizes the number of switches and their associated gate driver components by using two high-frequency transformers which combine a half-bridge circuit and a full-bridge circuit on the primary side.
2.4. Magnetic transformer
A magnetic transformer usually performs both galvanic isolation and voltage matching in power electronic systems, which call for an ac link for proper energy transfer.

2.5. The non-isolated bidirectional dc-dc converter
In the transformer-less non-isolated power conversion systems, the boost type and buck type dc-dc converter are chosen usually. The high-frequency transformer-based system is an attractive one to obtain isolation between the source and load sides. However, from the viewpoint of improving the efficiency, size, weight, and cost, the transformer-less type is much more attractive.

Thus, in the high power or spacecraft power system applications, where weight or size is the primary concern, the transformer-less type is more attractive in high power applications. Non-isolated BDCs (NBDC) are more straightforward than isolated BDCs (IBDC) and can achieve better efficiency; the transformer-less type is more attractive in high power applications.

3. PROPOSED MODULE

3.1 Proposed topology
The block diagram of the proposed three-port converter is illustrated in Fig. 3.1. The proposed system consists of a PV array, Closed-loop control, DC-DC Converter, PWM for Converter Control and Battery. The DC-DC Converters are those devices which can change one level of direct voltage/direct current to another level which are suitable for Standalone Green energy applications.

Multi-port converters are bringing into existence by introducing a bidirectional converter into Boost converter.

Figure 3.1 Boost TPC with bidirectional converter
3.2 Working principle of the proposed converter

Non-isolated Three-Port (DC/DC) converters that are NI-TPC interposing PV array, the battery, and the load. Non-isolated converters contain an inductor instead of a transformer (isolated). The power efficiency of all three ports power flow paths in the Boost (DC/DC) TPCs is high. As long as the solar radiation is high, the PV array generates maximum power to meet the load demand and also charges the battery. When the irradiation of sun is low, the battery discharges the power to the load because the PV panel doesn't have sufficient power to meet the load demand, thereby keeping the system in operating condition.

To maintain a constant and smooth power flow, MPPT control technique is implemented. The controller used in this MPPT is an electronic tracking system. The PWM controller adopted for this system senses the output from the PV system and keeps the system in active power flow condition. The Bidirectional converter is preferred due to its simplicity and high efficiency.

3.3. Different modes of operation

The proposed system operates under three modes:
- Dual Output Mode (DOM)
- Dual Input Mode (DIM)
- Single Input Single Output (SISO) mode.

When the input power is higher than the load demand, the battery will be charged. The charging is controlled by the switch s2, called a power switch. As the charging
takes place, there occurs a reversal of current from the battery to the PV panel, so to block the reverse flow of current diode D2 is placed in the circuit. The boost converter, which is present on the output side helps in boosting the voltage.

3.3.1. Dual output mode (DOM)
The PV system provides power to the load and involves in stocking the energy in the battery resulting in charging of the battery. This mode of operation takes place when the output power goes low compared to the input power. Since the battery and the input source (PV) works as output, it is called Dual output mode.

3.3.2. Dual input mode (DIM)
Because of the change in climatic conditions, the solar irradiation varies, resulting in less power flow at the output of the PV panel. At this stage, the battery discharges and delivers power to the load. Since the PV and battery act as an input source, it is called Dual Input Mode.

3.3.3. SISO mode
This mode is also called night mode where the output from the PV panel is zero. Since the power to the load is delivered only by the battery source, it is called Single Input Single output mode of operation.

3.4. Conventional controller (pi)
In general, the controllers are used to deliver a steady-state and harmonic free output. The PI controller eliminates forced oscillations and steady-state error resulting in the smooth operation of the system. However, introducing primary mode harms the speed of the response and overall stability of the system. Thus, the PI controller does not increase the speed of response. This problem can be solved by choosing derivative mode were the errors can be identified in a less time interval. The PI controller is very often used in industry, specifically where speed control is not a constraint.

The system can be operated without Derivative controller when the:

a) Settling time of the system is not required
b) Maximum disturbances and yelling of the machine are present during operation.
c) The system has any one of the passive components involved for energy storage.
d) A massive transit delay in the system.

The PI controller compares the equal quantity with an integer value, which is the input to the controller, whereas the derivative controller does not take the derivative value for evaluating the signal. The Fig.3.3 depicts the PI controller.
The controller (PI) play a vital role in the proposed system. The stability of the system is controlled by the P controller, and the steady-state response, error elimination, and control is done by the Integral control which serves as an input to various ports. In recent years the Mechanical controllers are replaced by Electronic controllers involving solid-state devices in addition to the passive components to eliminate the errors and to keep the system active.

4. SIMULATION RESULTS

The proposed model is simulated with the MatLab/ Simulink tool, which is user-friendly for monitoring the system stability. In the proposed three-port converter, a photovoltaic array with a DC-DC converter is connected with a battery function, and this combination is connected to the load. The simulated model for the proposed system is illustrated in Fig. 4.1.

![Figure 3.3 PI Controller](image-url)
Figure 4.1 Simulation Diagram of Three Port Converter

Figure 4.2 Simulation Diagram of PI Controller

Figure 4.3 Simulation Diagram of PV Source
Three-port DC/DC converters connection is connected with PV, Battery, and the Load. Power is obtained in all the three modes of operation, thereby allowing a continuous supply to the load. Also, whenever solar power is not available, especially in the night time, the system automatically senses, and the battery discharges the power using the MPPT algorithm for optimal power flow to the load.

Figure 4.4. Simulation Output of PV Panel Input Voltage

Figure 4.5. Simulation Output of PV Panel Input Current
Figure 4.6. Simulation Output of PV Panel Voltage & Current

Figure 4.7. Simulation Output of Battery Charging and Discharging
5 CONCLUSION

This research work highlights the advantage of using a non-isolated three ports DC/DC topology. The control methods have been proposed for interfacing a PV port, a battery port, and a load port. The working principle of the proposed converter and the DC voltage relationship between the three ports is analyzed. Also, the proposed converter’s single module and paralleling control methods are highlighted. According to
the PV generation power, load power demand, battery management command, and efficiency of the power system can work in both MPPT and conductance mode, and the transition between these two modes is autonomous. It has been demonstrated that the improved MPPT is more reliable and efficient during weather changes in the presence of many power converters operated simultaneously. The conventional controller plays out the improvement in precision, acting time, and waveform aggravations. Finally, a 30V/2A and 60W LED Lamp load simulation results are validated, and this proposed converter exhibited a high dynamic response, low output impedance, and a high phase stability margin. PWM converter design paves a way to be used in aerospace and Standalone renewable energy system for sufficient power flow.
REFERENCES


