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A Novel Multiport Bidirectional dual active bridge DC-DC Converter for Renewable Power Generation Systems

B. Kavya Santhoshi*, K. Mohana Sundaram, M. Sivasubramanian and S. Akila

Department of Electrical and Electronics Engineering, Vel Tech Multi Tech, Chennai - 600062, Tamil Nadu, India; kavyabe2010@gmail.com, kumohanasundaram@gmail.com, shivam.annauniversity@gmail.com, akila@veltechmultitech.org

Abstract

Background/Objectives: Multi Port Converters (MPCs) have gained importance in renewable power generation recently. MPCs can interface and control many power terminals and are generally economical with high power density, efficiency, and compact structure. Bidirectional MPC is proposed in this paper to facilitate power flow between load and source in a two way channel. **Methods/Statistical Analysis:** The proposed model is simulated using MATLAB software. The results confirm that the overall efficiency of the system is increased and the power flow is bidirectional with reduced losses. **Findings:** In the present existing topology, Bidirectional flow of energy is a challenging study in case of MPCs. Power losses will be high due to the use of Diode Bridge. The main motive of this paper lies in proposing a systematic method for deriving MPC topologies from non-isolated BDCs and FBCs. The derived MPCs use four port converters with both buck and boost topologies. Due to the usage of full bridge converter, bidirectional power flow is achieved unlike the traditional method. **Application/Improvements:** The proposed system is capable of being used for the applications of renewable power system, namely, PV-supplied aerospace power systems, fuel cell, battery systems, hybrid energy storage systems, and thermoelectric systems with energy backup. It has reduced power loss and facilitates two way power flow.

Keywords: Bidirectional, MPC, Multiport, Renewable Power Generation

1. Introduction

Renewable sources are spasmodic in nature. In order to supply loads without intervention, storage devices that function as energy buffers, are essential in a stand-alone renewable energy system, where various dc–dc converters are separately employed conventionally[1-6]. These systems have drawbacks such as high cost and low efficiency, the main reason being multi-stage conversion. A Multi Port Converter will interface several renewable energy sources[7]. It can also enable successful execution of Maximum Power extraction through MPPT techniques for each source. This helps in reduction of the impact of mismatch in power amongst sources. Bidirectional power flow becomes necessary to provide a viable solution to interrupted power supply and hence a bidirectional interfacing is done for the MPC.

After a careful observation of related works from the past, a unique dc-dc converter is put forward in this paper. The main objective of this paper is to design a dc-dc converter to meet the requirements for renewable generation systems, such as Bidirectional power flow, integration of various sources into a single converter (MPC), simple technology with reduced number of switches, improved soft switching techniques and galvanic isolation between source and loads

2. Existing System and its Drawbacks

The block diagram of the existing system is shown in Figure 1. The corresponding circuit diagram is shown in Figure 2. It consists of multiple sources such as PV panels

**Author for correspondence*

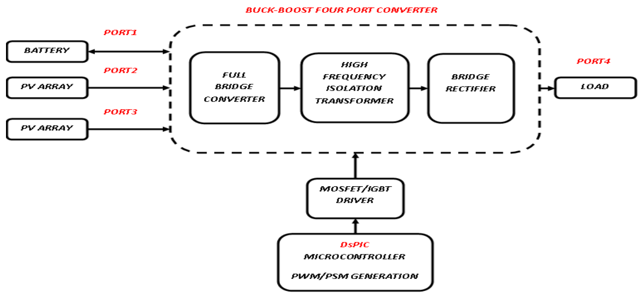

Figure 1. Block diagram of existing topology.

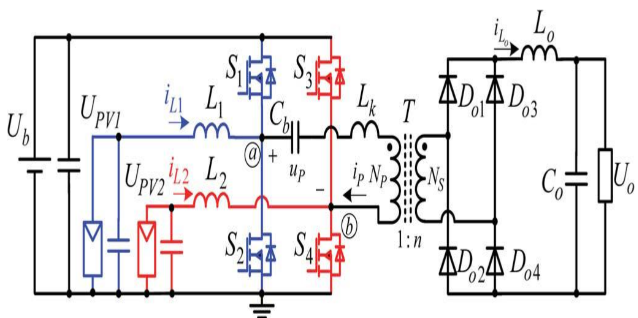

Figure 2. Circuit diagram of existing topology.

and battery storage system, buck-boost 4 port converter and controllers.

Here, four port converter consists of a full bridge converter, high frequency transformer and a bridge rectifier. This four port converter is used to perform dc-dc conversion between various sources such as PV panels and battery to dc loads. Micro controller and driver circuits are used to perform phase shift PWM for four port converter. Bidirectional power flow isn't possible between source and load due to the presence of bridge rectifier in the secondary side of four port converter. Power losses will be high due to Diode Bridge[8,9]. EMI will be produced. Overall efficiency will be reduced.

3. Proposed System and its Merits over Existing System

The block diagram representation of the proposed topology is shown in Figure 3. and the corresponding circuit diagram is shown in Figure 4.

It consists of multiple sources such as PV panels and battery storage system, bidirectional buck-boost four port converter and controllers. Here bidirectional four port converters consist of full bridge converter-1, high frequency transformer and full bridge converter-2.

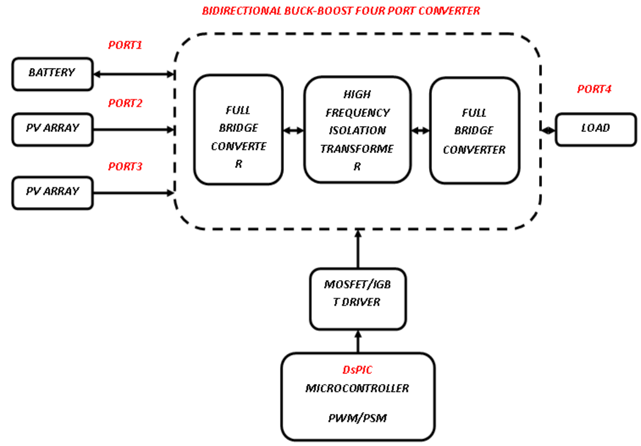

Figure 3. Block diagram of proposed topology.

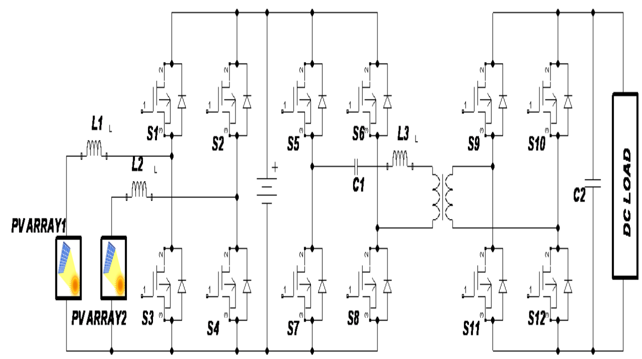

Figure 4. Circuit diagram of proposed topology.

Due to buck and boost topology, the output voltage can be either more or less than the input voltage. This four port converter is used to perform dc-dc conversion between various sources such as PV panels and battery to dc loads and also used to perform bidirectional operation[10,11]. Micro controller and driver circuits are used to perform phase shift PWM for four port converter.

4. Modes of Operation

Table (1) shows the modes of operation in a consolidated manner. It can be observed that there can be charging and discharging while using MPPT[12]. During constant current and constant voltage operation, MPPT is not achieved. The modes of operation are explained briefly in the following segment.

In the above table, Table (1), the terms CC and CV indicate the following,

$CC \rightarrow Continuous\ current$
$CV \rightarrow Continuous\ voltage$

IV. (A) Mode 1

Figure 5. shows the power flow during mode I indicated with red lines. During mode 1, electrical energy produced from PV array energizes the battery as well as supplies power to the load. Boost converter increases the voltage obtained from PV array and energizes the battery[13]. In this mode, bidirectional dc to dc DAB converter acts as inverter-rectifier combination from source side. Finally the rectifier output is given to the dc load.

IV. (B) Mode 2:

This mode represents night time operation. Sunlight is absent so charged battery supplies power to the load. DAB converter operation is same as mode 1. Figure 6 indicates the power flow during this mode of operation represented by red lines.

IV. (C) Mode 3:

This mode represents regenerative braking and is shown in Figure 7. Bidirectional dc to dc DAB converter helps to replace the braking energy into useful energy. During this mode DAB converter acts as inverter-rectifier combination from load side and it charges the battery.

Table 1. Modes of operation of the proposed MPC

MODE	PV ARRAY1	PV ARRAY2	BATTERY
1	-	-	DISCHARGE
2	MPPT	MPPT	DISCHARGE
3	MPPT	MPPT	CHARGE
4	NOT MPPT	NOT MPPT	CC,CV CHARGING

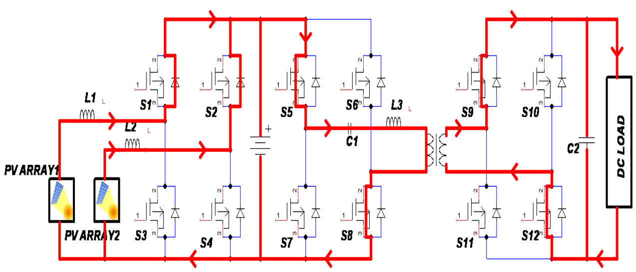

Figure 5. Mode I.

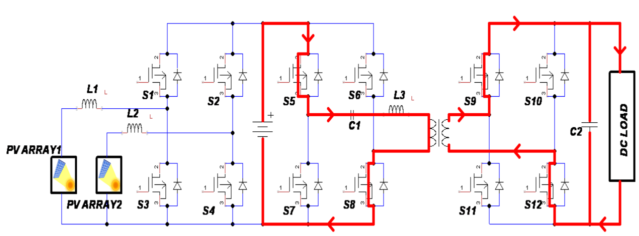

Figure 6. Mode II.

5. Results and Discussion

It can be observed from figure that the Electric torque builds and attains a constant level at 24 Nm and the speed of the motor also builds correspondingly and is shown in Figure 8, Figure 9. shows the output voltage that is about 70 volts.

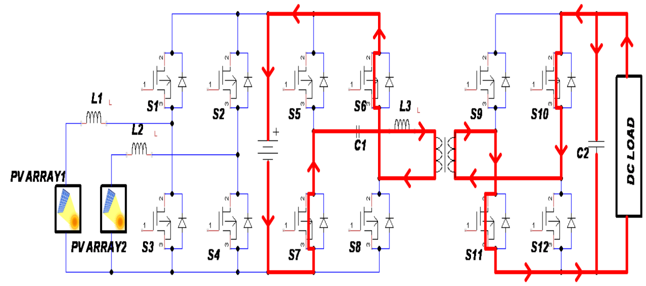

Figure 7. Mode III.

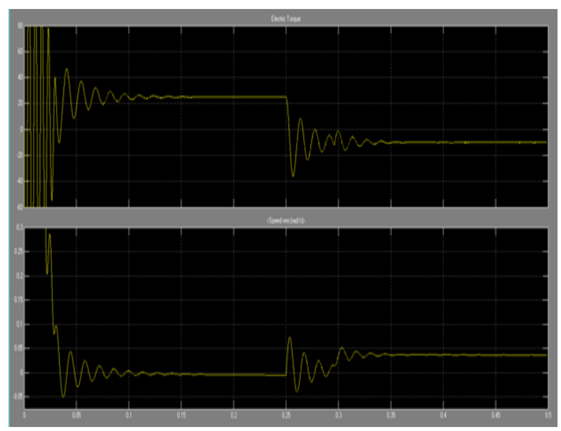

Figure 8. Electric torque.

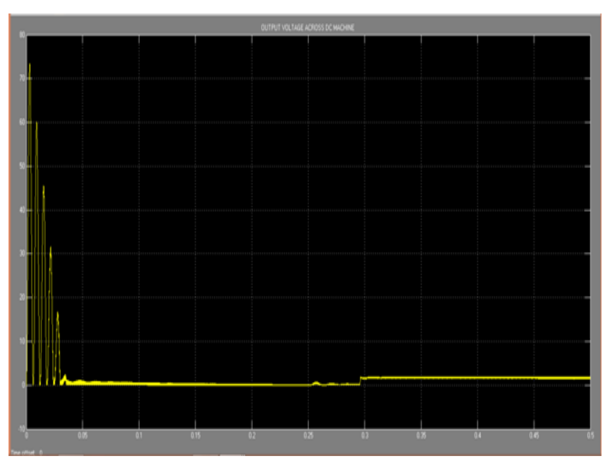

Figure 9. Output voltage.

6. Conclusion

The results confirm that bidirectional power flow is possible due to presence of two active full bridges. The losses due to switching are reduced. Inherent zero voltage switching and galvanic isolation property is present and the EMI will be reduced due to absence of diode rectifier. The proposed system has an improved overall efficiency and can be used for industrial applications.

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