



DC-DC Converter for Interfacing Energy Storage

Dr. S. W. Mohod¹, Mr. S. D. Deshmukh²

PRMIT Amravati, Maharashtra 444701, INDIA.

Abstract: The proposed circuit integrates different renewable energy sources as well as energy storage. By integrating renewable energy sources with statistical tendency to compensate each other, the effect of the intermittent nature can be greatly reduced. This integration will increase the reliability and utilization of the overall system. Moreover, the integration of energy storage solves the problem of the slow response of renewable energy. It can provide the extra energy required by load or absorb the excessive energy provided by the energy sources, greatly improving the dynamics of overall system.

Index Terms: DC-DC converter, Hybrid distributed generation system (HDGS), Photovoltaic (PV), Maximum Power Point Tracking (MPPT)

I. INTRODUCTION

As interest in renewable energy systems with various sources becomes greater than before, there is a supreme need for integrated power converters that are capable of interfacing, and concurrently, controlling several power terminals with low cost and compact structure. Meanwhile, due to the intermittent nature of renewable sources, a battery backup is normally required when the ac mains is not available.

This paper proposes a new four-port-integrated dc/dc topology, which is suitable for various renewable energy harvesting applications. An application interfacing hybrid photovoltaic (PV) and wind sources, one bidirectional battery port, and an isolated output port is given as a design example. It can achieve maximum power-point tracking (MPPT) for both PV and wind power simultaneously or individually, while maintaining a regulated output voltage.

In this work, a new kind of multi-port DC-DC power converter will be proposed in order to integrate different renewable energy sources and energy storage electively and economically. The proposed circuit will be analyzed, modeled, designed, controlled, and simulated. Certain issues related to practical application will be discussed to verify the usefulness of the proposed circuit. Due to the advantages like low cost and compact structure, multiport converters are reported to be designed for various applications, such as achieving three bus voltages of 14 V/42 V/H.V. (high voltage of around 500 V) in electric vehicles or hybrid electric vehicles [1], [2], interfacing the PV panel and a battery to a regulated 28-V bus in satellite platform power systems [3], PV energy harvesting with ac mains [4] or the battery backup [5], hybrid fuel cell and battery systems [6], and hybrid ultra capacitor and battery systems [7]. From the topology point of view, multi input converters based on buck, boost, and buck-boost topologies have been reported in [8]–[10]. The main limitation of these configurations is the lack of a bidirectional port to interface storage device. Multiport converters are also constructed out of a multi winding transformer based on half-bridge or full bridge topologies [11],[12]. They can meet isolation requirement and also have bidirectional capabilities. However, the major problem is that they use too many active switches, in addition to the bulky transformer, which cannot justify the unique features of low component count and compact structure for the integrated multiport converter.

II. HYBRID DISTRIBUTED GENERATION SYSTEM

Hybrid distributed generation system (HDGS) has gained attention in recent years. This system integrates different kinds of renewable energy sources to increase the overall stability and utilization [13].

A secure supply based on only one renewable energy source requires substantial energy storage. The reason is that the renewable energy is not available during some period of time. For example, the photovoltaic cells produce zero power during the night or little power during the cloudy day. Wind energy may not be available if the wind speed is under certain speed, under which the wind turbine cannot extract energy from the wind. If the system has to provide the power to load during the time when renewable energy source produces little power, the only way is to use the power from the energy storage.

If two or even more different renewable energy sources are integrated, the storage capacity requirement would be greatly reduced, since the fluctuations of these two renewable energy sources may have a statistical tendency to compensate each other. For example, solar power is high during the day, while the wind power is high at night. Combining these two sources will approximately produce a constant power to the load during the entire day.

III. MULTI-PORT CONVERTER

There are two ways to integrate different renewable energy sources and energy storage. The conventional way is to use a common DC bus. Separated DC-DC power converters are used to connect different renewable energy sources to the DC bus. However, there are several disadvantages for this structure. First, there are more power electronic devices, resulting in higher cost. For each renewable energy source, there has to be a DC-DC converter, which connects the renewable energy source to the DC bus. Also, there are more conversion steps. The power is transformed from DC to DC, then from DC to AC if the load is AC load.

Another way of integration is by using multi-port power converters. The multi-port power converter will connect all renewable energy sources and energy storage. Some ports are bi-directional if they are connected with energy storage, while some are unidirectional if they are connected with energy source[14]. Fig. 1 shows one of the applications of the multi-port DC-DC power converter. This converter integrates fuel cell, photovoltaic cells, energy storage and the load. If the load is AC, an extra inverter is needed to convert the DC power into the AC power.

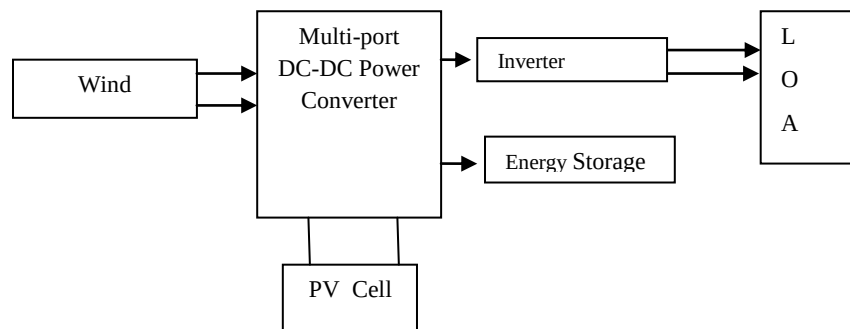


Fig.1 Application of multi-port DC-DC power converter

In this multi-port DC-DC power converter, there will be fewer power devices, which means the cost of the power converter will be lower than that of the conventional one. Also, the conversion steps are minimized, resulting in higher efficiency. Due to the presence of the transformer in some circuits, electric isolation is available, which is important for safety. With the turn ratio of the transformer in certain topologies, it will be more efficient to integrate different renewable energy sources of different voltage levels. Finally, there is a central controller. The controller not only controls the individual switches, but also manages the whole system. the controller can control the switch to perform the "Maximum Power Point (MPP)" tracking for the photovoltaic cell such that the output power is maximum at any operating points The central controller will enhance the overall performance of the system.

IV. BIDIRECTIONAL DC-DC CONVERTERS

Most of the existing bidirectional dc-dc converters fall into the generic circuit structure illustrated in Fig. 2 which is characterized by a current fed or voltage fed on one side [15]-[16]. Based on the placement of the auxiliary energy storage, the bidirectional dc-dc converter can be categorized into buck and boost type. The buck type is to have energy storage placed on the high voltage side, and the boost type is to have it placed on the low voltage side. To realize the double sided power flow in bidirectional dc-dc converters, the switch cell should carry the current on both directions. It is usually implemented with a unidirectional semiconductor power switch such as power

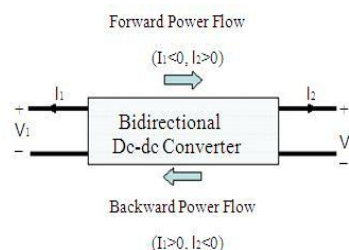


Fig. 2 Illustration of bidirectional power flow

MOSFET (Insulated Gate Bipolar Transistor) in parallel with a diode, because the double sided current flow power switch is not available. For the buck and boost dc-dc type converters, the bidirectional power flow is realized by replacing the switch and diode with the double sided current switch cell shown in Fig 3 [17].

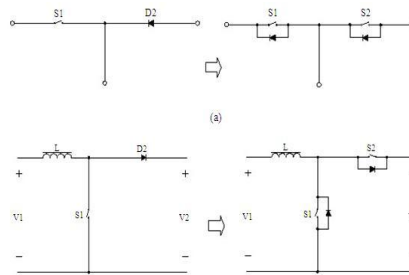


Fig.3 Switch cell in bidirectional dc-dc converter

Numerous topologies for possible implementation as bidirectional dc-dc converters have been reported so far [17-18]. Basically they are divided into two types, non-isolated and isolated converters, meeting different application requirements.

V. TYPES OF DC-DC CONVERTER

There are number of dc-dc converters are available such as Buck, Boost, Buck-boost, Flyback etc. For the proposed circuit we are using Cuk converter as a MPPT source. CuK converter is actually the cascade combination of a boost and a buck converter as shown in fig. 4.

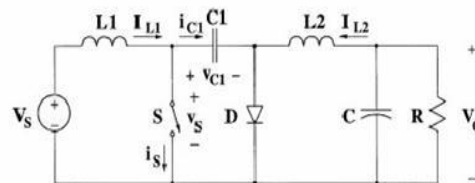


Fig. 4 Cuk converter Circuit

It consists of dc input voltage source V_S , input inductor L_1 , controllable switch S , energy transfer capacitor C_1 , diode D , filter inductor L_2 , filter capacitor C , and load resistance R . An important advantage of this topology is a continuous current at both the input and the output of the converter. Disadvantages of the Cuk converter are a high number of reactive components and high current stresses on the switch, the diode, and the capacitor C_1 . The main waveforms in the converter are presented in Fig. 2. When the switch is on, the diode is off and the capacitor C_1 is discharged by the inductor L_2 current. With the switch in the off state, the diode conducts currents of the inductors L_1 and L_2 , whereas capacitor C_1 is charged by the inductor L_1 current [19].

Implementation of Cuk Converter Using MPPT Technique

A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load [20,21]. A dc/dc converter (step up/ step down) serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between the load and the module. By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power [21]. Therefore MPPT techniques are needed to maintain the PV array's operating at its MPPT [22]. Many MPPT techniques have been proposed in the literature; example are the Perturb and Observe (P&O) methods [20, 22], Incremental Conductance (IC) methods [23], Fuzzy Logic Method [20], etc.

The MPPT techniques is to automatically find the voltage V_{MPP} or current I_{MPP} at which a PV array should operate to obtain the maximum power output PMPP under

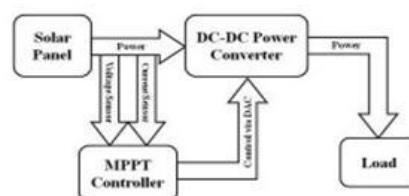


Fig.5 DC – DC converter for operation at the MPP

a given temperature and irradiance. It is noted that under partial shading conditions, in some cases it is possible to have multiple local maxima, but overall there is still only one true MPP. Most techniques respond to changes in both irradiance and temperature, but some are specifically more useful if temperature is approximately constant. Most techniques would automatically respond to changes in the array due to aging, though some are open-loop and would require periodic fine tuning. In our context, the array will typically be connected to a

power converter that can vary the current coming from the PV array as shown in Fig. 5.

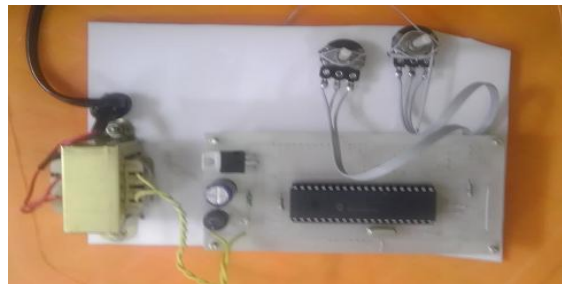


Fig 6. Cuk converter as MPPT.

Fig. 6 shows the implementation of cuk converter with IncCond algorithm using PIC controller.

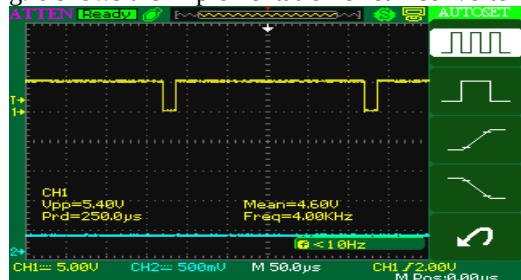


Fig. 6.a MPPT Output

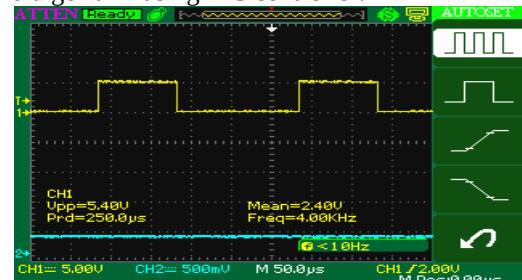


Fig. 6.b MPPT Output

Fig 6 a & 6 b shows change in MPPT output duty cycle with respect to change in input voltage & current.

VI. HARDWARE IMPLEMENTATION.

In the design of PWM inverter, single or three phase, the entire process of design is made into small modules. The functionality of each section are tested separately. The following section gives the details of each module of the project and explains each module in the design. The PWM approach is used for switching of inverter through the PIC microcontroller.

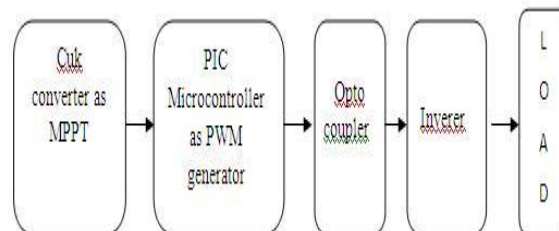


Fig. 7 Hardware Implementation

Fig. 7 is the block diagram that describes the hardware development for controller circuit. The PWM signal generated from PIC16F877A microcontroller is fed opto-coupler and gate drives the inverter. The switching frequency used in this project is 50Hz. The software development includes facility for suitable switching pulses with the use of the variable frequency and variable duty cycle. It is desired to control the inverter with proper switching purposes. The digital implementation usually achieved with a timer based card inside microcontroller. Modulation technique that is used in this project.

PIC generates the PWM pulses for MOSFET Bridge which drives the gate of MOSFET. These pulses are generated by microcontroller with respect to the changes in duty cycle of MPPT. These pulses are then fed to optoisolator. For single phase inverter four PWM pulses and three phase inverter Six pulse are required to drive the bridge of MOSFET. These pulses then drive the MOSFET Bridge. By varying the TON and TOFF, the RMS output voltage can be varied. Thus by varying duty cycle, modulation index is varied.

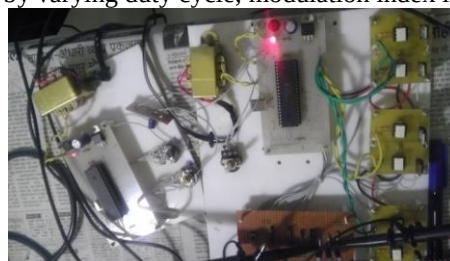


Fig. 8 Hardware setup

VII. RESULTS AT EACH STAGE

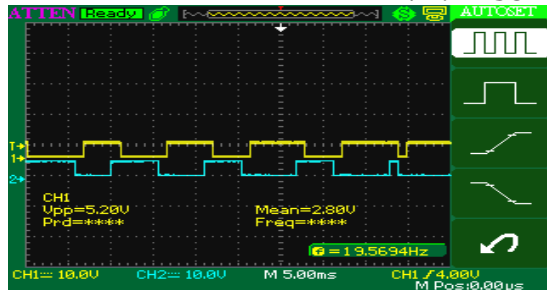


Fig. 9 (a) PIC Output

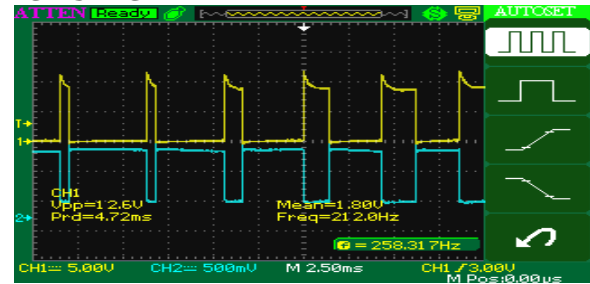


Fig. 9 (b) Inverter output

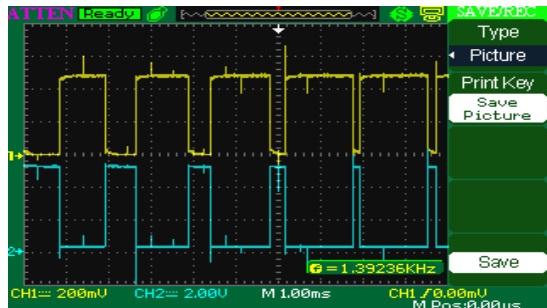


Fig. 9 (b) Optocoupler output

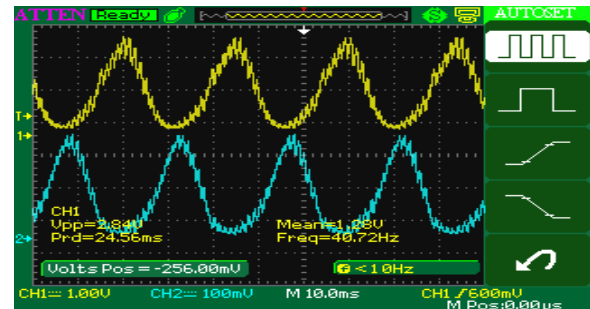


Fig. 9 (d) Output at Load

VII. CONCLUSION

The Paper present implementation of dc-dc converter capable of four dc ports; two input source ports, a bidirectional storage port, and a isolated loading port. This four port converter is suitable for renewable energy systems, where the energy storage is required while allowing tight load regulation. For the Hybrid PV and wind system, the structure is able to achieve maximum power harvesting, meanwhile maintaining a regulated output voltage. The circuit operation of this converter & its control system is experimentally verified. In this paper a fixed size MPPT with control was employed with the help of PIC controller. From the result acquired during the hardware experiments, it was confirmed that, the implementation of MPPT achieve an acceptable efficiency level of the PV modules & track the maximum power.

REFERENCES

- [1] G. Su and L. Tang, "A reduced-part, triple-voltage DC-DC converter for EV/HEV power management," IEEE Trans. Power Electron., vol. 24, no. 10, pp. 2406–2410, Oct. 2009.
- [2] F. Z. Peng, H. Li, G. J. Su, and J. S. Lawler, "A new ZVS bidirectional DC-DC converter for fuel cell and battery applications," IEEE Trans. Power Electron., vol. 19, no. 1, pp. 54–65, Jan. 2004.
- [3] Z. Qian, O. Abdel-Rahman, J. Reese, H. Al-Atrash, and I. Batarseh, "Dynamic analysis of three-port DC/DC converter for space applications," in Proc. IEEE Appl. Power Electron. Conf., 2009, pp. 28–34.
- [4] H. Matsuo, W. Lin, F. Kurokawa, T. Shigemizu, and N. Watanabe, "Characteristics of the multiple-input DC-DC converter," IEEE Trans. Ind. Appl., vol. 51, no. 3, pp. 625–631, Jun. 2004.
- [5] Y. M. Chen, Y. C. Liu, and F. Y. Wu, "Multi-input DC/DC converter based on the multiwinding transformer for renewable energy applications," IEEE Trans. Ind. Appl., vol. 38, no. 4, pp. 1096–1104, Aug. 2002.
- [6] W. Jiang and B. Fahimi, "Multi-port power electric interface for renewable energy sources," in Proc. IEEE Appl. Power Electron. Conf., 2009, pp. 347–352.
- [7] D. Liu and H. Li, "A ZVS bi-directional DC-DC converter for multiple energy storage elements," IEEE Trans. Power Electron., vol. 21, no. 5, pp. 1513–1517, Sep. 2006.
- [8] Y. Liu and Y. M. Chen, "A systematic approach to synthesizing multiinput DC-DC converters," IEEE Trans. Power Electron., vol. 24, no. 2, pp. 116–127, Jan. 2009.
- [9] B. G. Dobbs and P. L. Chapman, "A multiple-input DC-DC converter topology," in Proc. IEEE Power Electron. Lett., Mar, 2003, vol. 1, pp. 6–9.
- [10] N. D. Benavides and P. L. Chapman, "Power budgeting of a multiple input buck-boost converter," IEEE Trans. Power Electron., vol. 20, no. 6, pp. 1303–1309, Nov. 2005.
- [11] H. Al-Atrash and I. Batarseh, "Boost-integrated phase-shift full-bridge converters for three-port interface," in Proc. IEEE Power Electron. Spec. Conf., 2007, pp. 2313–2321.
- [12] H. Tao, A. Kotsopoulos, J. L. Duarte, and M. A. M. Hendrix, "Family of multiport bidirectional DC-DC converters," in Proc. IEEE Power Electron. Spec. Conf., 2008, pp. 796–801.
- [13] S. Jain; V. Agarwal, "An integrated hybrid power supply for distributed generation applications fed by nonconventional energy sources," IEEE Trans. Energy Conversion, vol. 23, no. 2, pp. 622–631, June 2008.
- [14] A. Kwasinski, "Identification of feasible topologies for multiple-input DC-DC converters," IEEE Trans. Power Electron., vol. 24, no. 3, pp. 856–861, Mar. 2009.
- [15] H. Matsuo and F. Kurokawa, "New solar cell power supply system using a Boost type bidirectional dc-dc converter," IEEE Trans. Ind. Electron., Volume IE-31, Issue 1, Feb. 1984, pp. 51 – 55.
- [16] G. Chen, D. Xu, Y. Wang, Y.-S. Lee, "A new family of soft-switching phase-shift bidirectional dc-dc converters," in Proc. IEEE

- PESC, Vancouver, British Columbia, Canada, Volume 2, June 2001, pp. 859 – 865
- [17] G. Chen, D. Xu, and Y.-S. Lee, "A family of soft-switching phase-shift bidirectional dc dc converter synthesis, analysis & experiment" in Proc. the Power Conversion Conference, Osaka, Japan, Volume 1, 2-5 April 2002, pp. 122 – 127.
 - [18] J. Zhang, J.-S. Lai, R.-Y. Kim and W. Yu, [18]"High-power density design of a soft- switching high-power bidirectional dc–dc converter," IEEE Trans. Power Electron., Volume 22, Issue 4, July 2007, pp. 1145 – 1153.
 - [19] Neeraj Tiwari, D. Bhagwan Das, "MPPT Controller For Photo Voltaic Systems Using Cuk Dc/Dc Convertor" International Journal of Advanced Technology & Engineering Research (IJATER)
 - [20] M.E.Ahmad and S.Mekhilef, "Design and Implementation of a Multi Level Three-Phase Inverter with Less Switches and Low Output Voltage Distortion," Journal of Power Electronics, vol. 9,pp. 594-604, 2009.
 - [21] S. Chin, J. Gadson, and K. Nordstrom, "Maximum Power Point Tracker," Tufts University Department of Electrical Engineering and Computer Science, 2003, pp.1-66.
 - [22] R. Faranda and S. Leva, "Energy Comparison of MPPT techniques for PV Systems," WSES Transaction on Power Systems, vol. 3, pp. 446-455, 2008.
 - [23] C. S. Lee, "A Residential DC Distribution System with Photovoltaic Array Integration.," vol. Degree of Honors Baccalaureate of Science in Electrical and Electronics Engineering, 2008, pp. 38.