

Transformer less Bidirectional Grid-Connected Single Power Conversion Converter

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Abstract- A transformer less bidirectional grid connected converter is introduced. This bidirectional converter has a bidirectional dc-dc converter and an unfolding bridge, with a single stage power conversion. Advantages of this converter include single stage power conversion and usage of low battery voltage. Bidirectional power conversion is done by the bidirectional dc-dc converter due to its adaptive controlling functions. The grid voltage is obtained from the unfolding bridge as it converts the rectified sine wave into the grid voltage. The grid current is controlled with a feed forward nominal voltage compensator. Therefore the power conversion efficiency increases. By using this non-isolated topology the voltage gain in buck and boost mode can be increased.

Keywords:- Energy storage system (ESS), Non-isolated topology, high efficiency

1 INTRODUCTION

Bidirectional dc-dc converters are important now a days due to the increasing need of bidirectional energy transfer. Apart from the traditional applications the new applications of bidirectional converter include energy storage in interruptible power supplies and renewable energy system. The renewable energy sources like wind, photo-voltaic etc are fluctuating type hence it cannot be use as a single source of power. Energy storage device are commonly used to avoid these fluctuations and it provides a continuous power flow. Batteries are the most economical and commonly used energy storage devices in medium power. For the controlled power flow between batteries and rest of the system a bidirectional converter is used.

In a conventional two-stage bidirectional converter, power is processing in both stages with a high-frequency switching. In a two stage bidirectional converter it has a dc-dc converter for the conversion of the battery voltage to dc link voltage and a dc-ac converter for the dc link voltage to grid voltage. Hence in two stage converters two controllers are required for each stage. Thus the overall efficiency decreases because it is the product of efficiency at each stage. Also the circuit has high switching and conduction losses, due to gate drive circuits. Thus conventional two-stage bidirectional converters are not cost effective and it has very complex circuit and thus it is less efficient [4].

In the single-stage bidirectional converter, there is only a single power-conversion stage with a single high frequency switching for the dc-ac power conversion, resulting in higher efficiency, and cost effective than conventional two-stage converters. Thus, single-stage bidirectional power converters

have enhanced system reliability, improved system efficiency, and a less complex circuit than a two-stage bidirectional converter [1].

This paper presents a modified non isolated single stage power converter with the same control algorithm. The isolated dc-dc converter is replaced with a non-isolated topology. By avoiding the high frequency transformer in the dc-dc converter the high frequency switching can be avoided which means the control circuit is less complicated and the overall efficiency and gain of the circuit is improved. The feed forward control system provides seamless mode transition in charging and discharging modes. Thus size and weight can be reduced. From the above, it can be inferred that this topology can be developed in a cost effective manner.

2 PROPOSED SYSTEM

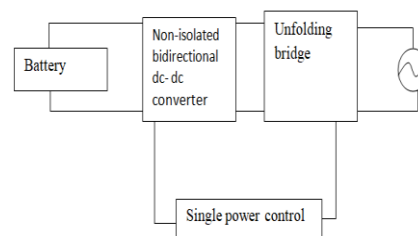


Fig.2. Block diagram of non-isolated system

The block diagram consists of battery source, non isolated dc-dc converter, and an inverter, both are using single power control. The input dc voltage is given to the bidirectional converter by using a battery, where the voltage is stepped up or down to the required voltage level. From the converter circuit, voltage is given to the full bridge inverter. Output ac voltage from the inverter is connected to grid via a filter circuit. A transformer less bidirectional Single-stage dc-ac converter is introduced. The proposed inverter has seven switches and is capable of working in both buck and boost modes of operation.

3 OPERATION OF THE PROPOSED SYSTEM

Fig.3. below represents the proposed system. Here C_3 is the capacitor which links the dc circuit. At the input voltage is provided by battery which is connected to non-isolated dc-dc converter, switch s_1 to s_4 constitutes the unfolding bridge. In the proposed system a transformer-less topology is used. The coupled inductor is used which has the primary inductance L_p and secondary inductance L_s is tightly coupled on the

same ferrite core, which increases the voltage diversity on both buck and boost modes. D_1 corresponds the duty ratio of S_{11} and S_{12} , where D_3 represents the duty ratio of switch S_{13} .

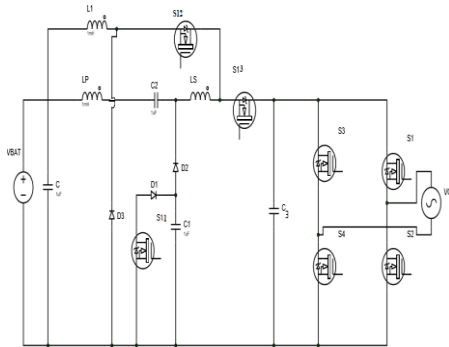


Fig.3. Proposed converter

Both D_1 and D_3 are related to each other by $D_1 = 1 - D_3$. The coupled inductor can be assigned as an ideal transformer with the magnetizing inductor L_m and turns ratio $N (= N_2/N_1)$, where N_1 is the primary number of turns and N_2 is the secondary number of turns of the coupled inductor.

Here input dc voltage is given to the boost circuit where it is stepped up to a required voltage level. From the boost circuit the stepped up dc voltage is given to the full bridge inverter and dc to ac conversion take place. This ac voltage is given to the load via the filter. In boost mode, the non isolated converter boosts up the low input voltage to high dc-link voltage and the switch S_2 remains OFF during this mode. The proposed system has four modes of operation. The four operating modes are:

- A. MODE 1:** During mode1, switch S_{11} was ON, whereas switch S_{13} was OFF. Low-battery bank voltage is applied to the circuit. Capacitor C_2 remains charged before mode1 and i_{LM} increases linearly.
- B. MODE 2:** Switch S_{11} turns OFF in mode 2. The capacitance across switch S_{11} is charged by primary current i_{LP} , capacitance across switch S_{13} and is discharged by the secondary current i_{LS} . This mode completes when the voltage across switch S_{11} is equal to the capacitor voltage V_{C1} .
- C. MODE 3:** Since switch S_{11} is OFF, due to leakage inductance the primary current i_{LP} start decreasing while the secondary current i_{LS} goes down. Hence, the body diode of switch S_{13} turns ON. Through diode D_1 Capacitor C_1 starts charging because the voltage across capacitor C_1 is get lower than the voltage across switch S_1 . Hence the voltage stress across switch S_1 is decreased.
- D. MODE 4:** During the ZVS Switch S_{13} turns ON. For the transfer of energy to the inverter side of the circuit the two windings of the coupled inductor and C_2 capacitor are all now connected in series. i_{LS} goes up until it reaches i_{LP} , then it follows i_{LP} until the end of mode 4. Thus, the energy stored in both windings are dissipates across the

inverter side of the circuit. In this mode D_1 and D_2 are in off condition.

- E. MODE 5:** In this mode, switch S_{13} turns OFF. The parasitic capacitance of switch S_{13} is charged by the current i_{LS} . Capacitor C_1 starts discharging across capacitor C_2 , through diode D_2 .

$$G_{boost} = V_H/V_L$$

Switch	S_{11}	S_{12}	S_{13}
MODE1	1	0	0
MODE2	0	0	0
MODE3	0	0	0
MODE4	0	0	1
MODE5	0	0	0
MODE6	1	0	0

Table.1. Switching states of the proposed system in boost mode

- F. MODE 6:** During Mode6, switch S_{11} is turns ON due to the ZVS. Hence S_{11} is not accepting any current from the clamped circuit, the switching losses becomes decrease due to ZVC, and gets an improved efficiency. The next switching cycle starts when $V_{C1} = V_{C2}$, and repeats the cycle.

3 CONTROL SECTION

In this converter the grid current i_o is controlled in the power processing stage. The primary switch duty D can be re-expressed as the sum of two duty terms as follows: $D = (D_p + \Delta D)$. D_p is the steady-state duty and ΔD is the control duty. The sign of the reference current I_g determines the direction of the power flow for the selected mode. The control block diagram of the proposed transformerless bidirectional converter is shown in Fig. 4. D_p is shared in both charge and discharge modes by using a fed forward voltage compensator so that an easy control environment is obtained by presetting an operating point. Seamless mode transition can be obtained due to these features. The power flow direction and power value are calculated only by the reference grid current I_g . In a steady-state condition ΔD is not sufficient to achieve precise tracking because it results in periodic errors.

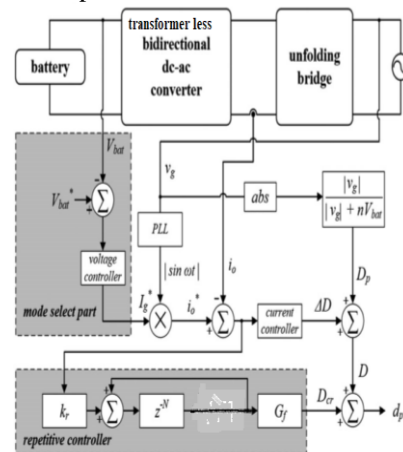


Fig.4. Control system block diagram

So that, a repetitive control duty ΔD_{rc} should provide better control input responses for the grid current and the zero steady state error tracking. Therefore the control system is a developed one and is very suitable for reference current tracking and seamless mode transition.

4 SIMULATION RESULTS

The proposed system is simulated in MATLAB/SIMULINK. The simulation model is shown in Fig.5.a and 5.b. Figure 5a shows the simulink model view from battery side and 5.b shows the simulink model view from grid side.

Table 2 .proposed system parameters

Parameters	Values
C	10 μ F
C ₁	4.4 μ F
C ₂	4.4Nf
L ₁	80 μ H
L _m	24 μ H
N	2.5
C _F	800 nF
L _F	400 μ H

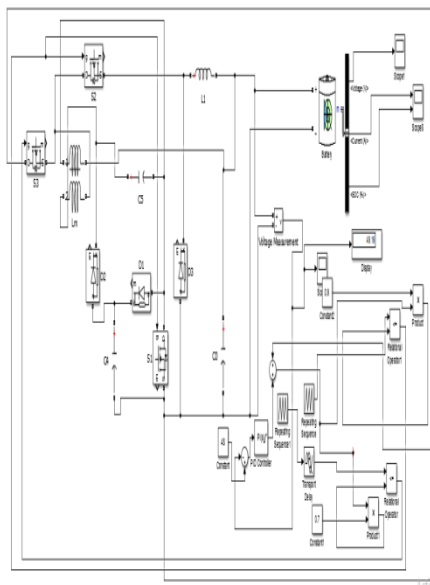


Fig5.a, Simulink model of the proposed system at battery side

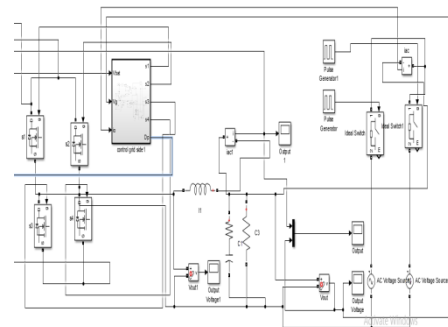


Fig.5.b. Simulink model of the proposed system at grid side

Here 48V dc is provided at the input side. This dc voltage is then given to the boost circuit. From the boost circuit stepped up voltage is given to the full bridge inverter. When simulated output ac voltage from the full bridge inverter is 230 V_{rms} is obtained. Fig.8.and Fig.9 shows the input and output waveform of the proposed system.

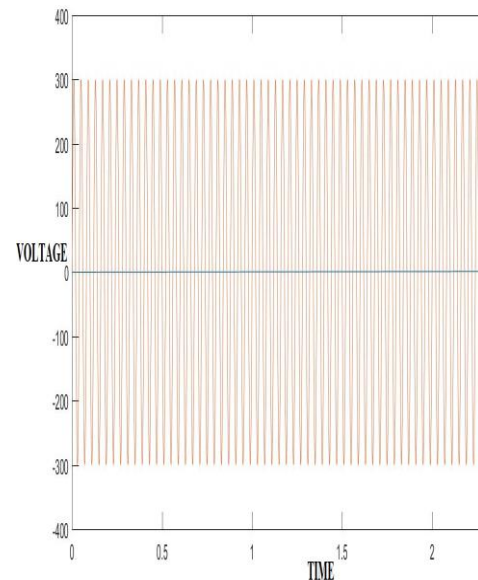


Fig.9. Output ac voltage

There is a voltage perturbation is applied on the grid at 1 second and the perturbation is lasts for 1 second. After 1 s the system regains its original state. Another advantage of proposed system is improved gain. On calculating the gain the existing system has voltage gain 10 and the proposed system has an improved voltage gain which is equal to 12.

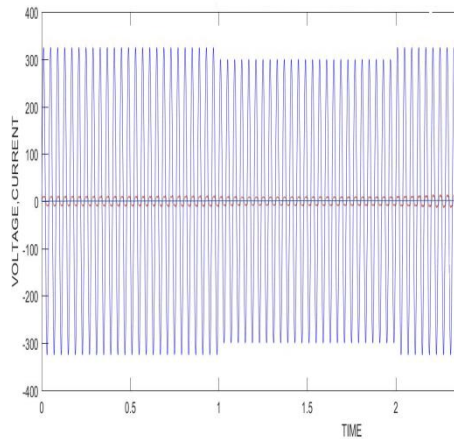


Fig.8. Output ac voltage and current waveform of the proposed system with grid voltage perturbation

Table;3 comparison of existing and proposed system

Parameters	Existing system	Proposed System
Input voltage	48V	24V
Output voltage	230V _{rms}	230V _{rms}
Voltage gain	8	10
Size and weight	Bulky	Small

6 CONCLUSION

A single stage transformerless dc–ac converter is proposed. It can be used for photo voltaic grid connected systems and low input battery voltage applications. In the existing system, transformer used for isolation purpose increases core losses in the system. It also makes the system bulkier and costlier. Increase in core losses reduces efficiency of the system. To overcome this problem transformer less topology is adopted. This configuration has higher efficiency. Since transformer is avoided it reduces the size and weight of the system, making the system efficient and cost effective. Large voltage diversity is obtained in all modes of operation due to the ZVS operation. This helps the circuit to boost up the low-input voltage to high dc-link voltage, and vice versa. The control algorithm consists of a feed-forward nominal voltage compensator and a repetitive control scheme. The feed-forward nominal voltage compensator provides an easier current control.

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