HIGH GAIN MULTIPLE-INPUT DC-DC CONVERTER FOR HYBRID ENERGY SYSTEMS

1VIJAYA BHASKAR REDDY G, 2JAMUNA K

12Scholl of Electrical Engineering, VIT University
E-mail: 1vijaybhaskarreddy2a9@gmail.com, 2jamuna.k@vit.ac.in

Abstract— Hybrid power systems means connection of more than one source at the input of system. To continuously deliver the power from source to load, the use of single output with single input non-isolated dc-dc converter is not that much efficient, then for this type of systems, single output with multiple input converter proposed. It can regulate the voltage levels above or below the input voltage by adjusting switching signals. In this, pulsating voltage and current source cell configurations presented and used. These are useful for energy diversification from renewable energy like solar, fuel cells and stored energy systems through individually or simultaneously. By connecting voltage multiplier cells (VMCs) obtain high output voltage for small input voltage on the required gain factor. In renewable energy sources, now solar systems (PVs) are present trending in the power generation. In this paper, solar cell used as one of the input source of multiple-inputs. In the described different types of control schemes, intermediate synchronization of switching signals is used. The simulation results are verified by using MATLAB/SIMULINK software.

Index Terms— High Gain Converter, Hybrid Energy System, Multiple-Input Non-Isolated Converter, Voltage Multiplier Cells.

I. INTRODUCTION

In general conventional dc-dc converters like buck, boost and buck-boost are used to change input dc voltage to required output regulated voltage for each source individually, that means connection of more than one source to regulated voltage system separate dc-dc conventional converters require. This increases the complexity of system, for reducing complexity of interconnection of different energy sources multiple input (MIC) dc-dc converter proposed. The Inter connection of more than one source is called hybrid energy system. The dc input sources has different magnitudes and these are connected to converter through a series connected active switch. Depending upon the activation of switch, these multiple sources deliver power to the load at a time from one sources or from multiple sources. In this work the proposed multiple input converters (MICs) has two inputs and single output with operating above or below voltage levels of input voltage by adjusting the switching signals. From the input source to load Energy transfers individually or simultaneously on depending upon switching signals.

The connections of MICs are different when the different source cells are used as inputs like voltage source cells and current source cells used to only non-isolated converters. The isolated converters like fly back converters configuration can be used for the MIC but the problems associated with the isolated converters are more compared to non-isolated converters. In the isolated converters use transformers for isolation purpose and this increases the complexity and the cost of the circuit.

The objective of this work is to introduce the MICs for hybrid energy systems. It can capable of operating above or below voltage levels of input sources, the basic structure and synthesis of MICs are introduced, the configuration of pulsating source cells like PVSCs and PCSCs, proposed two level MIC working principle and operations are explained in section II. The control strategies of any MICs are given in section III. The design considerations and ratings of parameters are presented and explained in section IV. The simulation results using MATLAB/SIMULINK are shown in section V. Finally, the proposed topology concluded in section VI.

II. MULTIPLE INPUT CONVERTERS

A. Structure

The systematic design of multiple input dc-dc converter (MIC) is shown in Fig.1. To make Input source the pulsating source cells (PSCs) are used, these are connected to the converter as PVSCs and PCSCs depending upon the requirement. The configuration of these two approaches are same to each other but only difference is the arrangement of used components like active switch and diodes. The combination of the pulsating voltage source in parallel with the diode which is named as PVSC. It can’t be connected in parallel with any branch of PWM converter because due to this the voltage across the connected PWM branch is equal to the connected PVSC. Hence PVSC connected only in series. The parallel diode in PVSC is used to circulating current of difference between PVSC and connected branch of PWM converter. Similarly, the pulsating current source as well as series diode combined is formed as PCSC. It can’t be connected in series with any branch of PWM converter otherwise, the current in the connected PWM branch is equal to the connected PCSC. Hence PCSC connected only in parallel.
B. Input Sources
The input sources of multiple input converter is more than one, renewable energy sources are very attractive input sources for any system. Interconnection of more than one source is called hybrid energy system. In general conventional dc-dc converters like buck, boost and buck-boost are used to change input dc voltage to required output regulated voltage for each source individually, that means connection of more than one source to regulated voltage system separate dc-dc conventional converters require. This increases the complexity of system, for reducing complexity of interconnection of different energy sources multiple input (MIC) dc-dc converter proposed.

Input sources of MIC are configured by PVSCs and PCSCs. In this paper two input sources used in that one is photo voltaic (PV) cells and other one is direct DC voltage or battery voltage but designed converter is not bidirectional for recharge the battery so it is better to use direct DC voltage from supply instead of charge the battery. Fig. 3. Shows the equivalent circuit model of one PV cell.

C. Operation
The all working voltages and switches, and inductor charging discharging status for different states of operation in the MIC topology are presented in the Table.1.

<table>
<thead>
<tr>
<th>State</th>
<th>Supplying source</th>
<th>ON state switch</th>
<th>Inductor status</th>
</tr>
</thead>
<tbody>
<tr>
<td>state-1</td>
<td>V2</td>
<td>S1</td>
<td>charging</td>
</tr>
<tr>
<td>state-2</td>
<td>V1 and V2</td>
<td>S2, S2</td>
<td>charging</td>
</tr>
<tr>
<td>state-3</td>
<td>V2</td>
<td>S2</td>
<td>charging</td>
</tr>
<tr>
<td>state-4</td>
<td>None</td>
<td>D1, D2</td>
<td>discharging</td>
</tr>
</tbody>
</table>
D. High Gain Multiple Input Converter

By applying the voltage multiplier cells gain factor will increase by factor of two, these are apply based on the requirement of gain or power to load. Here, two only stages of multiplier cells explained as shown in Fig.6. For every first stage of converter small resonant converter used, it is to reduce negative effects of reverse recovery current characteristics of all diodes.

III. CONTROL STRATEGIES

In MIC topology, the control strategy is very essential for better utilization of energy sources. The working sequence of proposed topology is changed by adopting the following gate pulse generation schemes.

a) Intermediate synchronization
b) Rising edge synchronization,
c) Falling edge synchronization.

In Fig. 3.1 the time duration of working states can be defined in terms of duty cycle as,

\[ t_1 = (d_1 - d_{12})T_s \]
\[ t_2 = (d_{12})T_s \]
\[ t_3 = (d_2 - d_{12})T_s \]
\[ t_4 = (1 - d_1 - d_2 + d_{12})T_s \]

Where, \(d_1\) and \(d_2\) are the duty ratios of the pulses and \(d_{12}\) is the common duty ratio of two pulses. In this work, intermediate synchronization of gate pulses has been taken for analysis of proposed converter. However, other schemes are also equally applicable and produce similar results.
IV. DESIGN CONSIDERATIONS OF HGMIC

The main equations to design the single phase high gain multiple input converter are given with values and specifications are as follows for single stage voltage multiplier cell

Output Power: 200 W.  
Input Voltages: 12 V and 18 V.  
Output Voltage: 180 V.  
Switching Frequency: 50 kHz.  
Number of multiplier stages: M=1

1) **Static Gain**: The multiple input converter gain will increase by increasing number of voltage multiplier cells in the design circuit. The multiplier cell capacitors are charged with output voltage, its charging voltage is equal to output voltage of conventional multiple input converter and the output voltage of high gain multiple input converter is summation of multiplier capacitor voltage and conventional converter output voltage that means the output voltage is multiplied by two of conventional converter.

\[ V_{CM2} = V_{CM1} \frac{V_1 d_1 + V_2 d_2}{(1-d_1)} \]  (2)

\[ V_o = V_{CM2} + V_1 d_1 + V_2 d_2 \frac{1}{(1-d_1)} \]  (3)

For one multiplier cell, the output voltage is increased two times then the gain is two but it varies according of multiplier cells applied to converter, for this the consideration equation of High gain multiple input converter is

\[ q = \frac{V_o}{V_{in}} = (M+1)d_1 \frac{1}{(1-d_1)} \]  (4)

\[ M \rightarrow \text{Number of multiplier cell stages} \]
\[ D \rightarrow \text{Duty cycle of switches} \]
\[ q \rightarrow \text{Representation gain} \]

2) **Input Inductance**: The design of inductor is main important for smooth out the ripple content in input current, it designed by considering ripple current 45% of nominal input current, and the input voltage is combination of two sources has to be take, then the input inductor as follows

\[ A_L = \frac{P_o}{V_{in}} \times 0.45 = 3 \text{ A} \]  (5)

\[ L_{in} = \frac{V_o d_1}{A_L \times f} = 30 \times 0.8 \times \frac{3}{50} = 160 \mu H \]  (6)

3) **Voltage Multiplier Capacitor CM**: The design of minimum capacitor value depends upon the maximum power of specified design converter, the taken value of maximum power more than the design output power of converter for example 250 W taken for a nominal output power equal to 200 W.

\[ C_{CM1} \geq \frac{P_{max}}{V_{CM1} \times f} = \frac{250}{45 \times 50} = 2.5 \mu F \]  (7)

\[ P_{max} \rightarrow \text{Maximum output power} \]
\[ f \rightarrow \text{Switching frequency} \]
\[ V_{CM1} \rightarrow \text{Voltage of the CM1 multiplier capacitor} \]

4) **Resonant Inductor Lr**: The resonant inductor can be defined by the maximum current variation at the turn-on commutation, in order to minimize the commutation losses, it also minimize the negative effects of reverse recovery currents of all diodes and for high switching frequency.

\[ \frac{dI}{dt} = \frac{V_o - V_{CM2}}{L_r} \]  (8)

The variation of current maximum at the turn-on commutation is equal to 25 A/µs, then the resonant inductance is as follows

\[ \frac{dI}{dt} = \frac{V_o - V_{CM2}}{L_r} \]  (9)

V. RESULTS AND DISCUSSIONS

The proposed converter results presented using MATLAB/SIMULINK software. By operating different switching signals the proposed converter operate in step up and step down modes on required gain factor without applying voltage multiplier cells. The duty cycles of three switches are 0.6, 0.6 and 0.8 respectively and are shown in Fig.8.

The inputs of two sources PV cell and DC supply are 12 V and 18 V respectively. The inputs of all stages of proposed converter means, with and without applying voltage multiplier cells are constant. The output voltage, current and power are 90 V, 1.11 A, and 100 W with gain factor of three without applying voltage multiplier cells and are shown in Fig.9.

By applying one stage voltage multiplier cells, the gain of converter increase by factor two, then for single stage VMC the output voltage is 180 V and for power 200 W the output current is 1.11 A. shown in Fig.10. For second stage of VMC the gain factor is 9, then the output voltage of converter is 270 V and for power 400 W the output current is 1.48 A. shown in Fig.11.
CONCLUSION

The proposed MIC operates above or below voltage levels with different energy sources as input with
adjusting the switching signals, for the continuous supply of power to the load individually or simultaneously. The synthesis of the MIC using the concept of PSCs as input sources and different control strategies are discussed in detail. The proposed converter is proficient for energy diversification from different energy sources. It is observed that the steady state performance of proposed converter is satisfactory. The achieving gain factors by applying voltage multiplier cells has been discussed. The static behavior of the converter is interested in the fields of distributed generation applications where hybridization of energy systems are essential.

REFERENCES