IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Nitte Conference on Advances in Electrical Engineering NCAEE-2016

NMAM Institute of Technology, Nitte

Vol. 4, Special Issue 2, April 2016

Dual Output DC-DC Converter for DC Micro-Grid Application

Akshatha N.M[1], Prof. K Vasudeva Shettigar[2]

Student, Department of Electrical and Electronics Engineering, NMAM Institute of Technology, Udupi, India[1]

Associate Professor, Department of Electrical and Electronics Engineering, NMAM Institute of Technology, Udupi, India[2]

Abstract: In this paper step up DC-DC converter with different output voltage level for DC micro-grid application is proposed. The wide utilization of renewable sources, have significantly improved the diffusion of distributed generation unit changing the operations of distributed grids from passive networks to micro-grids. This paper analyses step up dc-dc converter with input from the DC source/ photovoltaic array and two DC output at different voltage level. The paper includes operation of proposed converter with different operating modes, the mathematical expression and the simulation results.

Keywords: DC micro-grid, DC-DC converter, distributed generation system, high power DC bus, Low power DC bus.

I. INTRODUCTION

In the present scenario, demand for the electrical energy is rapidly increasing day by day due to the advancement in technology. Renewable energy source can be used as an alternative to generate power with lesser environmental effects. This has led to the development of distributed generation system. Generation of power in small scale at distribution voltage level by using renewable energy source is termed as distributed generation. Renewable energy sources like solar, wind , fuel cell etc produce DC power. Thus DC micro-grid are used in distributed generation system [1]. Most of the electronic devices need DC supply, hence all of these DC devices require conversion of the AC power into DC and this conversion is generally made by rectifiers. The power loss of these multiple conversions could be reduced using DC micro-grids. The prime source of energy in distributed energy system is photo-voltaic energy source. Solar cells convert just 20 percent of sun rays to electricity; however technological developments have led to a considerable improvement of solar efficiency. To overcome the issue of low single cell voltage of photo-voltaic panel a boost converter is used between solar panel and DC bus.[2] In conventional boost converter like switched capacitor converter, switched inductor converter, cascaded boost converter maximum voltage gain is limited due to extreme duty cycle [3]. This results in reverse recovery problem at the switches, high conduction losses, high electromagnetic interference. These problems can be overcome by isolated converter such as flyback converter, push-pull converter, forward converter, bridge converter etc., The isolated converter has the limitation of voltage spike and power loss, due to the presence of transformer or coupled inductor. As a result converter efficiency is degraded and electromagnetic interference problem is severe [4]-[5]. To increase the efficiency and voltage gain modified step up converter topologies have been investigated [6]. The proposed converter has lower number of high voltage capacitors. The voltage gain at two buses depends on single duty cycle as a result the voltage can be maintained within a range at one bus and as desired at another bus. The proposed converter is able to maintain to different voltage level one being high voltage and another being low voltage making it suitable for micro-grid applications.

II. PROPOSED DC-DC STEP UP CONVERTER

The proposed converter consists of two inductors (L_1,L_2), two capacitors (C_1,C_2), three diodes(D_1,D_2,D_3) and three control switches(S_1,S_2,S_3) as shown in Fig 1 .

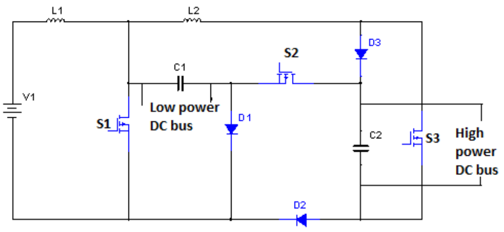

Fig 1 : Proposed converter with two DC bus

DOI 10.17148/IJIREEICE/NCAEE.2016.02

IJIREEICE
ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Nitte Conference on Advances in Electrical Engineering NCAEE-2016
NMAM Institute of Technology, Nitte
Vol. 4, Special Issue 2, April 2016

The proposed converter has only two high voltage capacitors, which accompanies for the reduction of system size. Single control signal is sufficient to control all the three switches. As a result control complexity of the proposed converter is reduced. The loads which need comparatively less input voltage are connected to the low power DC bus, whereas the loads which require high voltage are connected to high power DC bus. The high frequency switches (S_1,S_2,S_3) can be taken as IGBT or MOSFET. Input represents the low voltage PV source. The operation and steady state analysis of the proposed converter are discussed as follows. For easy understanding the DC buses are replaced by resistive loads.

Let,
V_i = Low voltage source
V_{L1} = Voltage across inductor L_1
V_{L2} = Voltage across inductor L_2
V_{C1} = Voltage across capacitor C_1
V_{C2} = Voltage across capacitor C_2
Ts = Switching time period of controlled switches
Ton = Switch ON time period of controlled switches
D = duty cycle of controlled switches (ratio of Ton to Ts)

1) Operation of the converter:
There are two stages of operation
A. Stage 1 - When switches S_1, S_2, S_3 are Turned OFF
During the interval when the switches are off , the diodes D_1, D_2. D_3 in fig becomes forward biased. Thus input V_i and inductors L_1 and L_2 energize the capacitors C_1 and C_2 as well as supply power to the load.

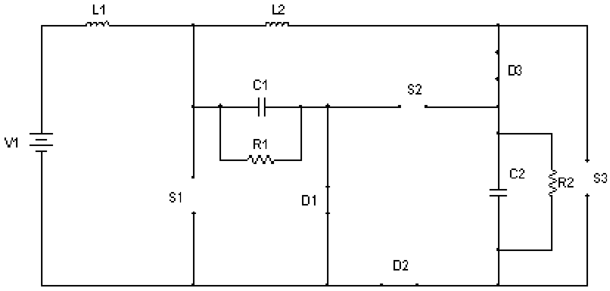

Fig 2: Equivalent circuit when switches are turned OFF

By applying kirchhoff's voltage law to the Fig : 2 , voltage across inductors L_1 and L_2 are found to be as:

$$V_{L2} = V_{C1} - V_{C2} \quad (1)$$
$$V_{L1} = V_i - V_{C1} \quad (2)$$

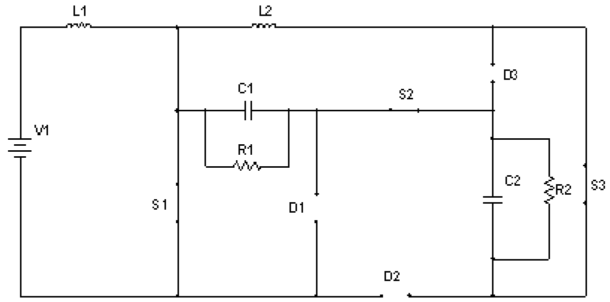

Fig 3:Equivalent circuit when switches turned ON

III.STAGE 2 - WHEN SWITCHES S_1, S_2, S_3 ARE TURNED ON

During the interval when the switch is turned ON, the diodes(D_1, D_2. D_3) becomes reverse biased. The capacitors along with input Vi energize the inductors and supply power to loads.
By applying Kirchhoff's voltage law, voltage across inductor are

$$V_{L1}=V_i \quad (3)$$
$$V_{L1}=V_{C1} + V_{C2} \quad (4)$$

Since in steady state the time integral of the inductor voltage over one time period must be zero, using equation (1) and equation (3),

IJIREEICE
ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
Nitte Conference on Advances in Electrical Engineering NCAEE-2016
NMAM Institute of Technology, Nitte
Vol. 4, Special Issue 2, April 2016

$$(V_i - V_{C1})(1-D)T_S + V_i D T_S = 0 \quad (5)$$

or

$$V_{C1} = \frac{V_i}{(1-D)} \quad (6)$$

Similarly, Applying Volt-second balance across inductor L_2 , using equation (2) and equation (4),

$$(V_{C1} - V_{C2})(1-D)T_S + (V_{C1} + V_{C2})D T_S = 0 \quad (7)$$

or

$$V_{C2} = \frac{V_{C1}}{(1-2D)} \quad (8)$$

Substituting V_{C1} from equation (6) in equation (8),

$$V_{C2} = \frac{V_i}{(1-D)(1-2D)} \quad (9)$$

From equation (9), it is found that voltage gain at capacitor C_2 is significantly higher compared to capacitor C_1.

IV. SIMULATION RESULTS

The proposed converter is designed and simulated using MATLAB simulink as in Fig. 4 . The circuit parameter taken for simulation is shown in table 1. Using equation (6) and (9), mathematically the high power and low power DC bus voltage is found to be V_{C2} = 72 Volts, V_{C1} = 19 Volts respectively. From the simulation result it is found that the voltage at high power DC bus is 72 V and at low power DC bus is nearly 19 V with negligible ripple content as shown in Fig 6 and 7respectively.

Table 1 : Simulink model parameters

Sl. No	Parameters	Value
1	Switching Frequency	25kHz
2	Duty ratio	0.368
3	Inductor L_1 , L_2	350μH, 600μH
4	Capacitors C_1 , C_2	470e-6 F
5	Resistors R_1, R_2	180Ω, 170Ω

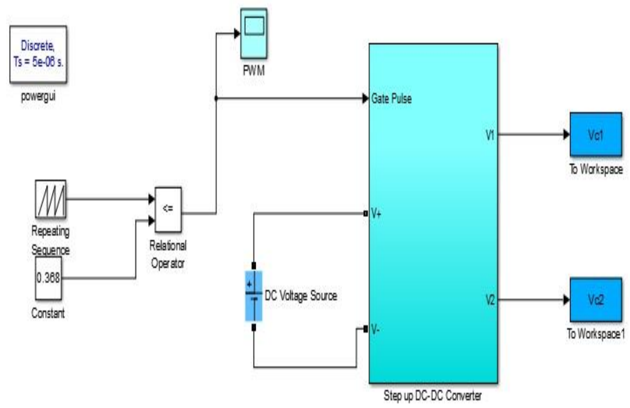

Fig 4 : Simulink Model of the Proposed Converter

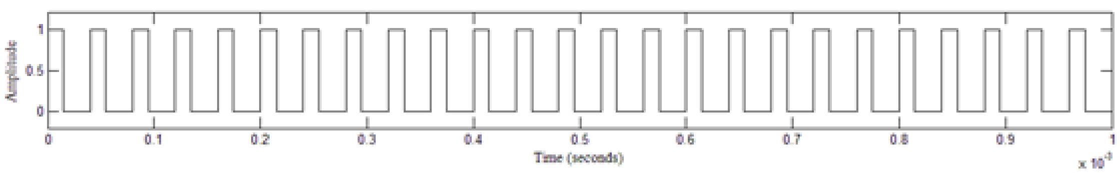

Fig 5: Gate pulses at duty ratio 0.369

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

IJIREEICE

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Nitte Conference on Advances in Electrical Engineering NCAEE-2016

NMAM Institute of Technology, Nitte

Vol. 4, Special Issue 2, April 2016

Fig 6: Voltage at high power DC bus

Fig 7: Voltage at low power DC bus

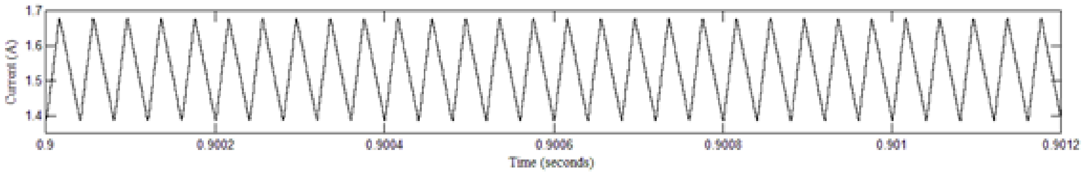

Fig 8: Inductor Current I_{L1}

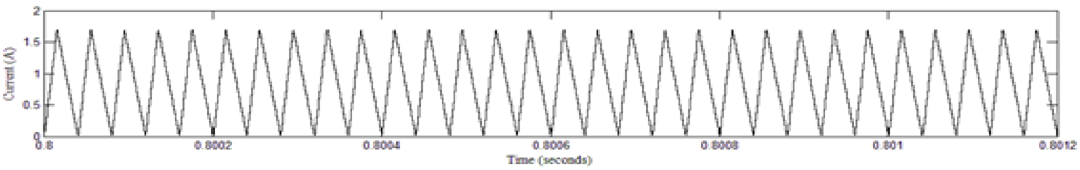

Fig 9: Current across inductor L_2

V. CONCLUSION

The proposed step up DC – DC converter is able to maintain high voltage with smaller duty cycle (0.368). It overcomes the drawback of extreme duty cycle for getting high voltage gain as in case of conventional boost converter. The converter has lower number of passive components. The converter is able to maintain two different output voltage level i.e, one for high power application and another for low power application. These merits makes the proposed converter suitable for DC micro – grid application. The control complexity is reduced since signal control signal is sufficient. The efficiency of the converter is found to be 93%. The converter operation is analyzed and verified by simulation using Matlab/simulink.

REFERENCES

[1]. [1]H. Kakigano, Y. Miura, T. Ise, and R. Uchida, “DC Micro-grid for Super High Quality Distribution- System Configuration and Control of Distributed Generations and Energy Storage Devices, 37th Annual IEEE Power Electronics Specialists Conference, Korea, 2006, pp. 3148-3154.
[2]. [2] P. Biczel, Power electronic converters in dc microgrid, in Proc. IEEE Compat. Power Electron. Conf. (CPE), 2007, pp. 16.
[3]. [3] B. Axelrod, Y. Berkovich, and A. Ioinovici, Transformer less DCDC converters with a very high DC line-to-load voltage ratio, in Proc. IEEE Int. Symp. Circuits Syst. (ISCAS), 2003, pp. III435III438.
[4]. [4] Ray-Lee Lin; Chi-Rung Pan; Kuang-Hua Liu, ”Family of single-inductor multi-output DC-DC converters,” Power Electronics and Drive Systems, 2009. PEDS 2009. International Conference on, vol., no., pp.1216, 1221, 2-5 Nov. 2009.
[5]. [5] R. J. Wai and R. Y. Duan, High-efficiency DC/DC converter with high voltage gain, IEE Proc. Inst. Elect. Eng.-Electr. Power Appl., vol. 152, no. 4, pp. 793802, Jul. 2005.
[6]. [6] Ray-Lee Lin; Chi-Rung Pan; Kuang-Hua Liu, ”Family of single-inductor multi-output DC-DC converters,” Power Electronics and Drive Systems, 2009. PEDS 2009. International Conference on, vol., no., pp.1216, 1221, 2-5 Nov. 2009.

ACKNOWLEDGEMENT

I express my gratitude to Visvesvaraya Technological University, Belagavi for providing me an opportunity. I extend my sincere thanks to our esteemed institution NMAM Institute of Technology, Nitte for supporting me in all the ways possible.

DOI 10.17148/IJIREEICE/NCAEE.2016.02