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Input Voltage and Load Voltage Sharing of Series-modular DC-DC converter

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Abstract. This paper comes out with input voltage and load voltage sharing of series-modular DC-DC converter. A detailed analysis is done over input-series and output series connection of modular DC-DC converters. Through the use of MATLAB Simulink tool series-modular DC-DC converter is simulated over fixed load condition. Behavior of converter is analyzed based on the simulation results. From simulation results it is found that converter works smoothly and does not have any problems in operation.

Keywords: DC-DC Converter, Load Voltage Sharing

1. INTRODUCTION

World is transforming towards renewable resources, due to depleting fossil fuels and increasing fuel prices. Renewable energy sources like fuel cell and solar PV cells have low voltage outputs even if connected in stacks (Kong *et al.* 2007). To increase the voltages as to the required level of loads multi modular DC-DC converters are implemented (Chen *et al.* 2009). Depending on the load requirements and source available, multi-modular DC-DC converters can be connected in four topologies,

- If high voltage is available but the load requirement is low voltage and high current. Modules of DC-DC converters can be connected in series at the supply side and shunted at the output load side (Chen *et al.* 2014).
- If source of low voltage is available but the demand of load is high voltage. Multiple modules of DC-DC converter can be shunt connected at supply side and series at the load side (Soomro *et al.* 2013).
- If source of low voltage is available but the load demand is high current and low voltage. Multiple modules of DC-DC converter can be shunt connected both at supply side and load side (Giri *et al.* 2006).
- If a high voltage source is available but load requirement is low current and high voltage. Multiple modules of DC-DC converters can be connected in series both at supply and load side (Sha, *et al.* 2012)

Modular DC-DC converters are widely used in modern power applications because of their high flexibility. When high voltages are feed to the power electronic switches, leakage current increases which may heat switches. Excess heating can trigger switches without gate pulse. Due to high voltage stresses devices may breakdown. Voltage stress on devices are shared, if modules are connected in series both at the input and output. Stress of high voltages on devices are reduced. When voltage stress is reduced then power electronic switches used can be of bantam ratings (Giri *et al.* 2006; Cilio *et al.* 2009). Metal oxide switches can be used, which are cheaper and have very high operating frequency (Yang *et al.* 2014; Guo *et al.* 2014; Soomro *et al.* 2013; Nami *et al.* 2011; Wang, *et al.* 2010)

Voltage at input and output is shared by the modules. Thus voltage stress to the insulation of transformers is reduced (Aboushady, *et al.* 2013). This allows to use transformers of lower voltage ratings. When transformers of lower ratings are chosen than overall size and price of converter is reduces.

Series Input and Series Output (SISO) multi-modular DC-DC converters are used in satellites, data centers and electric traction like applications (Guo *et al.* 2014; Sha, *et al.* 2010). SISO are specially used in applications that require electrical isolation of input and output (Liutanakul *et al.* 2010; Xinbo *et al.* 2009). Impedance of SISO can be easily made equal to the load impedance (Ayyanar, *et al.* 2004; Kim, *et al.* 2002; Heinemann 2002; Panov and Jovanović 2001), so maximum power transfer is possible. Series connection of modules increases overall impedance of converter (Manias and Kostakis 1993). Fault current decreases because of high impedance offered by this converter.

2. BLOCK DIAGRAM TOPOLOGY OF SERIES-MODULAR DC-DC CONVERTER

A general block diagram of series-modular DC-DC converter consisting of three Boost Half Bridge (BHB) DC-DC converters that are connected in series both at input and output is shown in **(Fig.1).**

As can be seen from Fig.1, converter consists an input voltage source V_{in} that is supplied at the input of

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converter. As converters are completely identical so input source voltage V_{in} is internally equally divided into three modules. V_{in} is divided into V_{in1}, V_{in2} and V_{in3} in Module # 1, Module # 2 and Module # 3 respectively.

Every individual module of converter consists of an input inductive coil and half bridge consisting of two MOSFETS and two high value capacitors connected to primary of a high frequency DC transformer. Input inductive coil reduces current ripples and boost the applied voltage, half bridge of switches invert DC voltage. High frequency transformer is used to step up the voltage to required ratio. Output of DC transformer is connected to full bridge of diodes. Diode Bridge convert output voltage of transformer back to DC voltage.

As modules of converters are connected in series both at input and output so under steady state condition of operation DC (average) input current through each modules will be same. Similarly under steady state condition of operation DC current at the output of each module will also be same. The total output voltage will be sum of output voltages of individual converters. Schematic diagram of BHB DC-DC converter module is shown in **(Fig.2).**

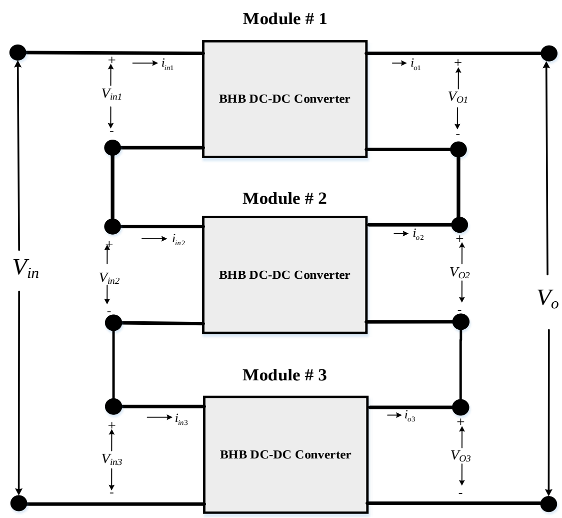

Fig.1: General block diagram of series-modular DC-DC converter.

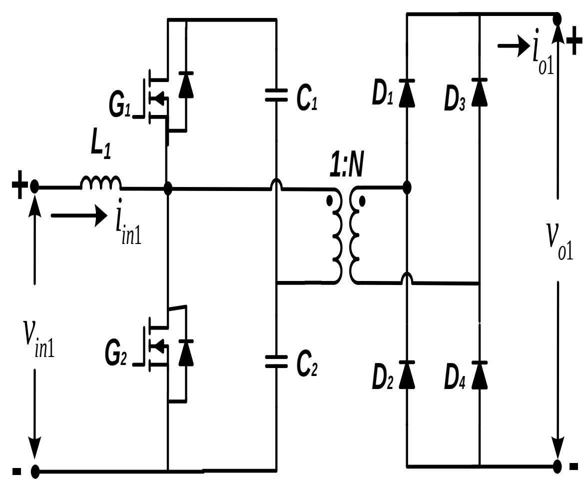

Fig.2: Schematic diagram of BHB DC-DC converter

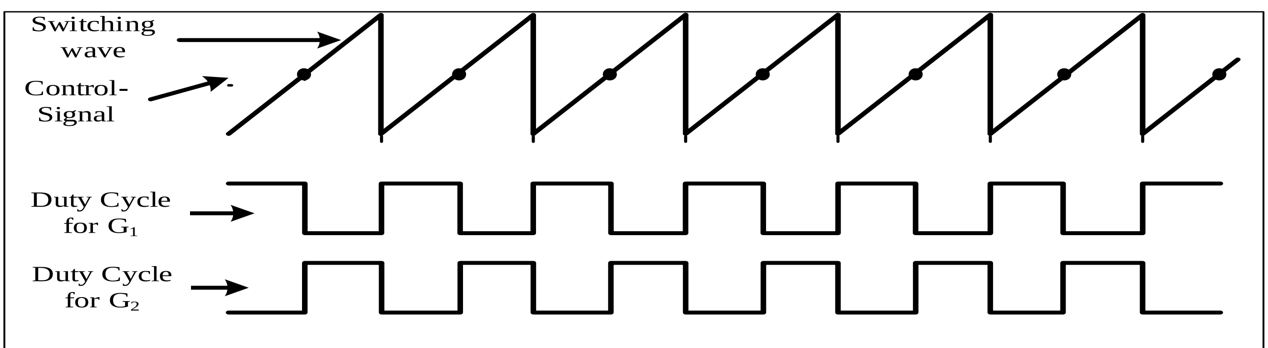

Fig.3: Duty cycle generation for single BHB DC-DC converter module

Duty Cycle Generation For Each Dc-Dc Converter

Controlled duty cycle is required for operation of MOSFETs used in each converter. **(Fig. 3).** shows duty cycle generation for single BHB DC-DC converter module, duty cycles of other modules may be generated in similar way. As can be seen from Fig.3 triangular switching wave is compared with controlled-signal. Switching pulse is generated from points where controlled-signal cuts switching wave. It is obvious for each BHB DC-DC converter module that in each module one switch is operated at a time and other remains closed.

Simulation Results For Fixed Load Condition

Series-modular BHB DC-DC converter consisting of three boost half bridge DC-DC converter modules is simulated with Input and output parameters given in **(Table 1 and Table 2)** respectively. Load on series-modular BHB DC-DC converter is kept fix during the complete simulation time. **(Fig. 4.1)** shows equal input voltage sharing and input current sharing at fixed load on different modules. **(Fig 4.2)** shows equal load voltage sharing and load current sharing at fixed load on modules.

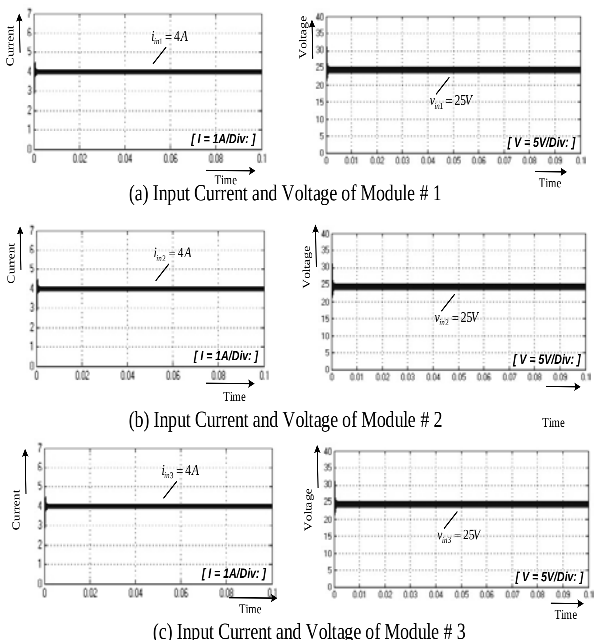

Fig. 4. 1 Shows equal input voltage sharing and input current at fixed load.

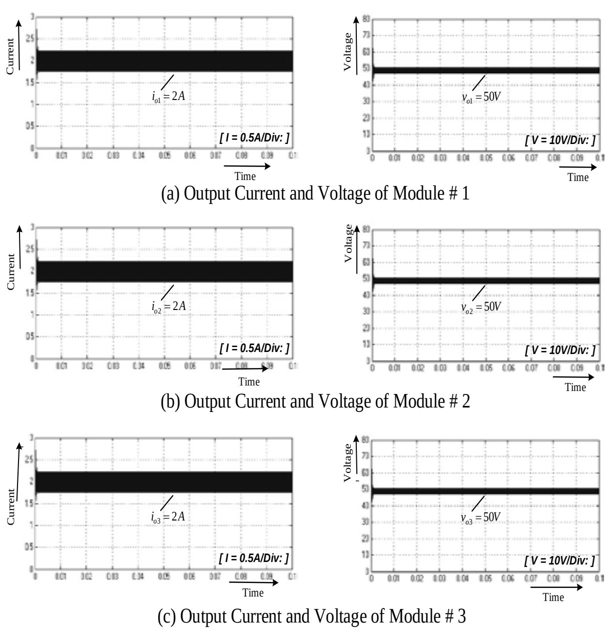

Fig.4.2 Shows equal load voltage sharing and load current at fixed load.

Table-1 Input parameters of simulated converter.

INPUT PARAMETERS	VALUE
Voltage	75V
Inductance	300μH
Capacitance	15μF
Switching Frequency	20 KHz

Table-2 Output parameters of simulated converter.

OUTPUT PARAMETERS	VALUE
Voltage	150V
Capacitance	9μF
Load	75

3. CONCLUSION

The simulation results for series-modular DC-DC converter show that input voltage are equally divided to three BHB modules of the converter. The output voltage of converter is sum of output voltages of individual BHB converters. The current at input of each converter remains same because of series connection of converters. Current at output of each converter is also same as the modules of converter are also connected in series at output. Power is balanced both at inputs and outputs of the converters which satisfies stable operation of the converter.

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