Hot Swapping Capability Analysis of Multi Modular Input-Series Output-series DC-DC Converter

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Abstract

Converters either supplying power to vital loads (communication centers, hospitals, protection devices etc.) or connected with the generation systems especially renewable types, are such sophisticated units that their failure can lead to financial as well as life losses. This paper focus on the capability of the multi-modular DC-DC converter to successfully replace the faulty module of the converter with the healthy one without the load being disturbed (Hot-swap). Using modular converters has been proved a better substitute in terms of cost-efficiency and reliability while improving the overall efficiency of the converter. The proposed model is simulated in Matlab and the results validate the statement during the hot-plug of any module without disturbing voltages at load terminals.

Keywords: DC-DC Modular Converter, Hot Swapping, IVS (Input Voltage Sharing), OVS (Output Voltage Sharing)

1. Introduction

Research has tremendously increased in power electronic converters in quest of enhancing their reliability and efficiency to the optimum level while leaving the load uninterrupted throughout the operation¹. New converter topologies are being investigated to produce high voltage from multiple modules connected in series through various switching techniques of semiconductors. This leads to the applications involving high voltage where availability is of low voltage inputs (fuel cells, PV cells etc.) by altering the switching frequency of the semiconductor switches and number of modules in the converter².

Modules can be connected in four alternative fashions to yield the desired characteristics (high/ low voltage or high/ low current at input/ output side) of the converter^{3,4}. The interconnection types shown in Table 1 are dependent solely on the type of application converter being employed for and the availability of the type of input.

Table 1.	Various module connections with dissimilar
features	

Interconnection Configuration	Desired Characteristics
Input-Series Output-Series (ISOS)	For low current and high voltage output (High voltage input)
Input-Series Output-Parallel (ISOP)	For high current and low voltage output (High voltage input)
Input-Parallel Output-Series (IPOS)	For low current and high voltage output (Low voltage input)
Input-Parallel Output-Parallel (IPOP)	For high current and low voltage output (Low voltage input)

Modular converter is vast area of interest in research these days because of its compatibility to be connected to multiple loads/ sources at a time with advantages of redundancy and hot-plug ability⁵. Some of the key features of modular converters includes:

- (a) Straightforward design and fabrication⁶.
- (b) Reduced conduction losses of semiconductor switches⁷.
- (c) Improved reliability due to inherent redundancy⁸.
- (d) Usage of high frequency semiconductor switches with low voltage rating⁹.

Among four available configurations Input-Series Output-Series (ISOS) modular configuration is proposed to analyze the hot swapping capability of the converter. The proposed configuration has the advantage of voltage sharing on individual modules of the converter, thus low rating less expensive semiconductor switches can be employed rather than high voltage and expensive ones³. ISOS configuration employees' high voltage input and output applications while Input Voltage Sharing (IVS) and



Figure 1. Circuit configuration of BHB Multi Modular DC-DC converter.

Output Voltage Sharing (OVS) remain intact throughout the steady state, transient and fault conditions¹⁰. The proposed configuration has got many applications such as converters getting power through power grids, electric traction/railway system supplied via DC power¹¹.

Hot swapping or hot plugging is capability associated with modular converters which enables converters to be upgraded to higher rating or plugging out faulty module/ component with healthy one without turning off the converter. Hot swapping allows increased up-time with simplified repair and maintenance¹².

2. Circuit Configuration

Modules employed in converter is based on Boost Half Bridge (BHB) configuration having two stages, first stage of inverter and second of rectifier with the transformer of one ratio two as shown in Figure 1.

The supply voltages are shared amongst the series modules which are inverted to Alternating Current (AC) through switching of MOSFETs. MOSFETs are triggered through duty exchange cycle that produces pulses from G1 to G6 as shown in Figure 2.

Output voltages of the individual module are summed up and load receives constant voltages throughout the operation of hot swapping.

3. Results and Discussion

The results of hot swapping are shown in Figure 3. Module# 02 goes out at 0.02 sec and Module # 01 and Module # 03 shares the input and output voltages. As soon as Module



Figure 2. MOSFETs Duty cycle generation through comparing switching wave and control signal.



Figure 3. Input and output voltage of modules before and after hot swap.



Figure 4. Voltage sharing while module# 02 is plugged out and plugged in.

02 is plugged back in, the voltages are again distributed among three modules as they were before the fault.

Multi-modular DC-DC converter while module 2 plugged out and plugged in are shown in Figure 4. The

faulty module is supposed to be out of the converter from simulation time 0.02 sec to 0.08 sec, while the voltages at the output as well as input remain unaltered that are 75V and 150V respectively.

Converter remain in same state before the fault is introduced (at 0.02 sec when module # 02 is plugged out) and after the fault (at 0.08 sec when module # 02 is plugged in).

The successful sharing of the input and output voltages at the input and output side of the converter proves the ISOS modular converter has hot swapping ability. The modules of the converters can be extended to desirable level by introducing suitable control scheme for the switching of MOSFETs employed.

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4. References

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