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# Redundant Capability Analysis of input-series output-series Multi-modular DC-DC converter

S. M. JISKANI, A. M. SOOMRO++*, S. TALPUR**, S. D. KALHORO***, A. R. CHACHAR*

Department of Electrical Engineering, Mehran University of Engineering and Technology, Jamshoro

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**Abstract:** This paper analyzes input and output voltage behavior for multi-modular DC-DC converter when due to fault conditions, any module is totally bypassed and its output and input voltages are shared by other healthy modules (Redundancy). Modularization is better substitute to eliminate high cost, low voltage capabilities of converter by employing module replicas to build different power converters or even enhance the efficiency of converter due to inherent redundancy and hot-swap characteristics. The model is built through the use of Matlab Simulink tool and the model validates the above statement as the load voltage remain unaltered before and after fault.

**Keywords:** Input-series-output-series DC-DC converter, Redundancy, input voltage sharing, output voltage sharing

## 1. INTRODUCTION

DC-DC converter is one of the mostly used power electronic circuits, and it has applications in various areas ranging from portable devices to aircraft power system. Various topologies of dc-dc converters are suitable for different applications. Regardless of the topology used for this application, the reliability of the converter can be greatly enhanced by introducing redundancy of some degree into the system. Using redundancy, uninterrupted operation of the circuit may be ensured when a fault has occurred(Khan, 2007).

To gain any particular input-output specification, the building block (modules) can be connected in four possible configurations with the following particular features mentioned in Table 1(Giri *et al.,* 2006); (Chen and Lai, 2010); (KHATRI *et al.,* 2015).

**Table 1. Modules connection configurations with their specific characteristics**

| Connection Configuration | Particular Specifications |
|---|---|
| Input-Series Output-Series (ISOS) | High voltage input and high voltage, low current outputs |
| Input-Series Output-Parallel (ISOP) | High voltage input and low voltage, high current outputs |
| Input-Parallel Output-Series (IPOS) | Low voltage input and high voltage, low current outputs |
| Input-Parallel Output-Parallel (IPOP) | Low voltage input and low voltage, high current outputs |

The modularity in power electronic circuits is becoming a very important issue in power electronics research (Khan and Tolbert, 2009).Using the modularity, it is possible to localize any fault in the system, and the affected module can be bypassed and another good module activated, and thus, a continuity of operation can be maintained (Song and Huang, 2010) overall modularity has following features:

a) It simplifies design and manufacturing(Pan and Bkayrat, 2010).
b) Components' standardization leads to reduction in production cost & time(Giri *et al.,* 2004)
c) Significant improvement in reliability by introducing desired level of redundancy (Pan and Bkayrat, 2010); (Giri *et al.,* 2004).

Input-series output-series (ISOS) is proposed configuration for the redundancy analysis of the converter. The series connection has many advantages such as it provides reduced voltage rating of the semiconductor switches at input as well as output side of the modules (Fernandez *et al.,* 2013) and it provides galvanic isolation (Sha *et al.,* 2012). ISOS configuration has got many applications such as converters fed from the power grid, the dc voltage supply in an electric railway system or dc voltage supply aftera power factor correction (PFC) pre-regulator(Bo and CHENG Lu Lu, 2006); (Kong and Khambadkone, 2007).

The converter outage is unbearable if the system connected with converter is protecting life or producing revenue (White and Miles, 1996), thus the paper focuses on the redundant capability of (ISOS) modular converter as one of the most considered characteristic of modular schemes is redundancy which enables the model to be available even though any fault takes place at the input or output side of the module.Redundant system is vital because it enables the system to successfully bypass the faulty module of converter without modifying power or control sections(Konstantinou *et al.,* 2013), to achieve the extra performance (Siri *et al.,* 2007) and to be feasible for uninterrupted energy transfer (Liu *et al.,* 2015).

++Corresponding Author: aamir.m.soomro@gmail.com
*Department of Electrical Engineering, Mehran University of Engineering,& Technology, Jamshoro.
**Department of Computer Systems Engineering, Mehran University of Engineering,. & Technology, Jamshoro.
***Institute of Business Administration, Community College NosheroFeroze.

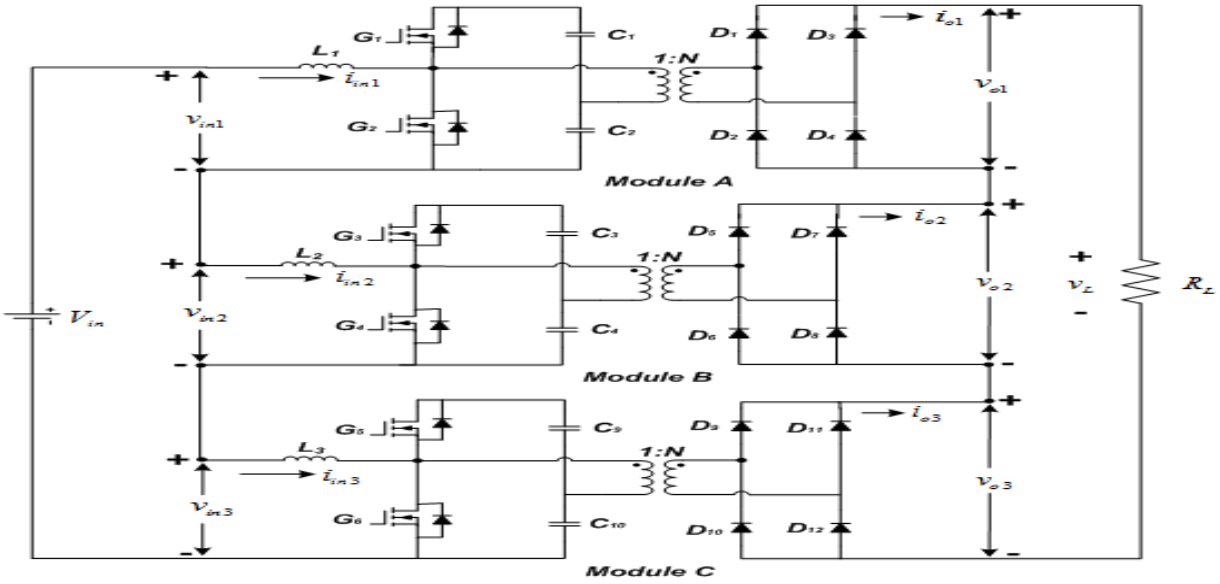
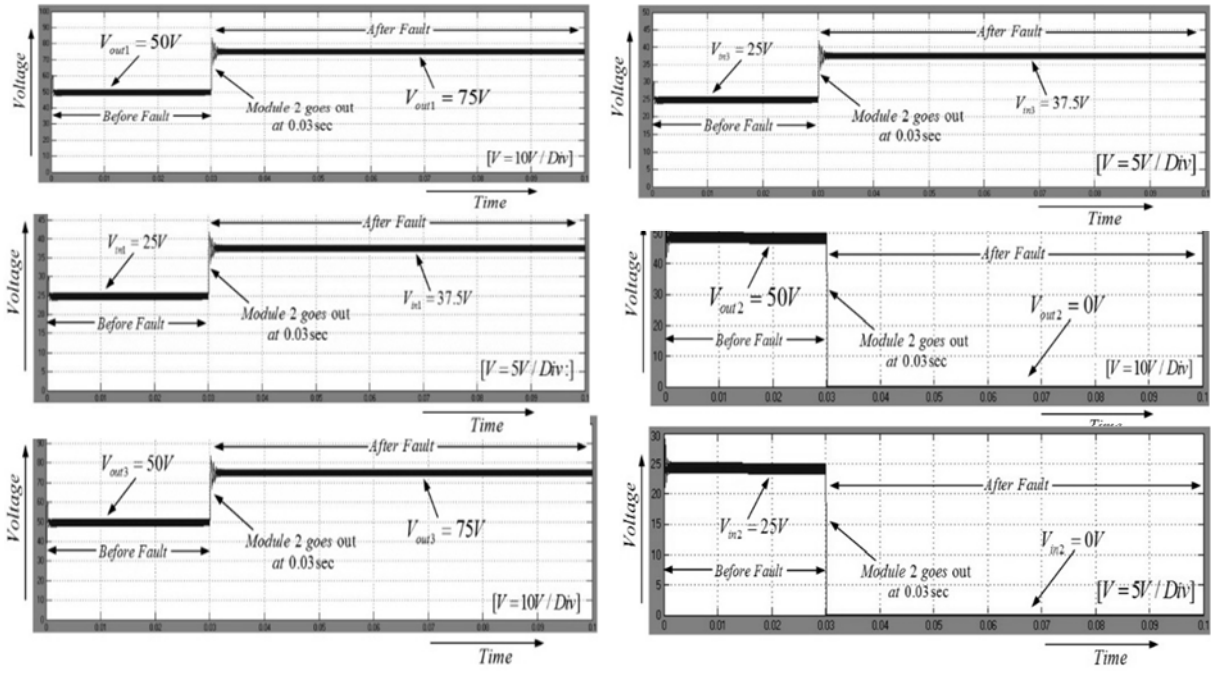



**Fig 1. Shows schematic circuit diagram of ISOS multi-modular DC-DC converter** Every module in modular converter is identical having half bridge inverter at input side which converts DC voltages to AC through MOSFETs. At intermittent state AC voltages are stepped up through transformer connected in every module and finally increased voltages are rectified through uncontrolled full bridge rectifier.




**(a) Input and output voltage of Module # 01**
**(b) Input and output voltage of Module # 02**
**(c) Input and output voltage of Module # 03**
**Fig 2. Shows input and output voltages of individual modules**

At the output side every modules voltages are summed up and appear across the load. Load voltages appeared to be increased all the time as compared to input because secondary turns (N) at the output side are greater than the primary turns of the transformer.

It is worth noting that proposed model is employed with three modules ISOS system. This is due to the fact that in two module system if one module is faulty its current compensator output is saturated (Sha *et al.,* 2014).

**Multi-modular Boost Half Bridge (BHB) DC-DC converter.**

Schematic circuit diagram of modular BHB DC-DC converter having three modules connected in series at input as well as output is shown in **(Fig.1).**

## 2. RESULTS AND DISCUSSION

**Simulation results of redundancy for DC-DC Modular converter.**

The simulation result for the redundant modular converter is shown in **(Fig. 2)** for module # 01 to module # 03 where two modules remain healthy throughout the operation and module # 02 is bypassed due to fault at 0.03 sec time of simulation.

The simulation result shows that at time 0.03 sec when module # 02 gets faulty, its total input (25V) and output (50V) voltages are successfully shared between other two modules. Thus the result shows that ISOS multi-modular DC-DC converter is true redundant system under the fault conditions.

## 3. DISCUSSIONS

Block diagram of series modular DC-DC converter with the proposed input and output voltages before and after fault are shown in **(Fig. 3 and Fig. 4)**, where all modules share equal voltages at input and output side of the converter.

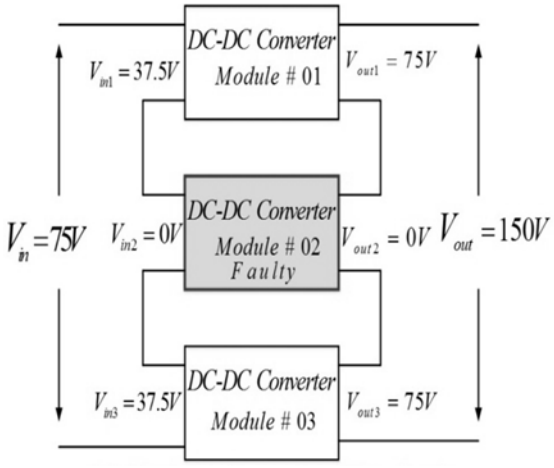



**Fig 3. Shows block diagram of series modular converter before fault.**

Fault is introduced at the input side of the module # 2 through a parallel ideal switch that short circuits the module as shown in **(Fig. 4)**. The short circuited voltage of module # 2 (25 volt at input side) are shared successfully by remaining two healthy modules through proposed control scheme for gate drive circuit of MOSFETs.

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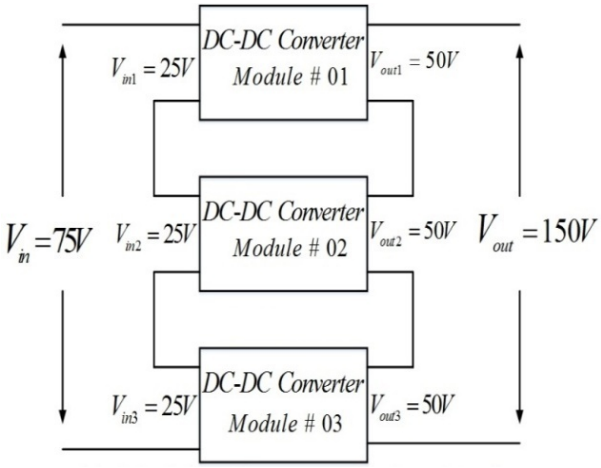



**Fig 4. Shows block diagram of series modular converter after fault.**

## 4. CONCLUSION

The simulation results conclude that the modular DC-DC converter proposed in this research work is capable to deliver constant load voltage during the redundancy. The faulty voltage of module # 02 are shared among other healthy modules of the converter resulting same output voltage for the load throughout the operation. Load voltages remain unaltered before and after fault because healthy modules share the voltages and the system remain intact and thus the input and output power also remain unhindered.

## 5. ACKNOWLEDGEMENT

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