Cascaded Connection of Fault Tolerant Dual-Input LLC Resonant DC/DC Converter with PWM & PFM Hybrid Control for HVDC Interconnection

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Introduction

In recent years, cascaded DC/DC converter connections have gained wide adoption in HVDC systems due to their advantages of voltage scalability, modularity, and high efficiency. However, faults in primary-side semiconductor switches can cause not only the complete failure of the affected module but also affect through the cascaded structure, leading to severe power loss and even total system shutdown. To address this issue, this paper proposes a cost-effective cascaded fault-tolerant dual-input LLC resonant converter topology. The proposed design enables each faulted module to sustain nearly 90% of its nominal output even under fault conditions, thus also ensuring that primary fault switch in a single-module failure does not compromise the operation of the entire system.

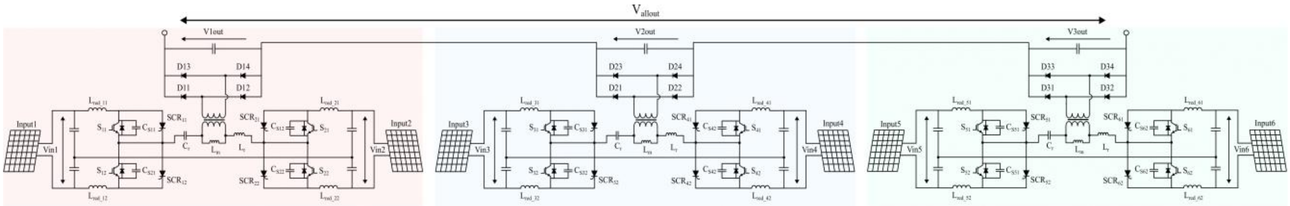

Figure 1: Cascaded connection configuration of fault tolerant dual-input LLC resonant converter

Proposed Cascaded Connection Configuration

The proposed cascaded connection is shown in Fig. 1. Dual-input structure is based on [1]. Key novelty of the proposed structure is that each converter module in cascaded connection is integrated with series connection of redundant inductors (L_{red}) to reconfigure converter into Boost-like operation during short-circuit faults (SCFs). Moreover, redundant one-time triggering silicon-controlled thyristors (SCRs) are connected in parallel to create an alternative current conduction path in case of open-circuit fault (OCFs). Finally, three converter modules are connected in series at the output side to form cascaded connection.

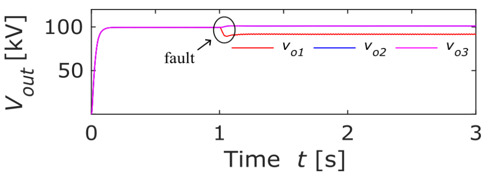

Figure 4: Output voltage of each module

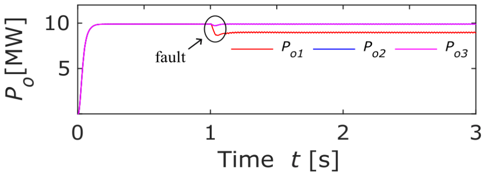

Figure 3: Output power of each module

Results and Discussion

In this study, OCF and SCF are simultaneously applied to upper leg switches of converter module 1 (S_{11} & S_{21}), respectively at t=1s. The output voltage and power of each converter module are shown in Figs. 2 and 3, demonstrating that the faulted module can still deliver power up to 9MW (initially 10MW), without affecting the operation of the remaining cascaded modules. The overall system output voltage and power are shown in Figs. 4 and 5, where the results indicate that the system continues to supply 295kV (initially 300kV) and 29MW (initially 30MW). Furthermore, the dual-input topology effectively doubles the converter's power-capacity, thus reducing system cost compared with conventional designs that would otherwise require two separate converters to achieve the same output. Therefore, it is highly expected that the converter can be implemented as a cost-effective and reliable solution for future HVDC transmission systems integrating renewable energy sources.

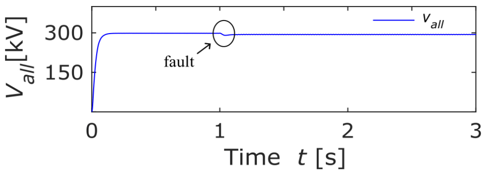

Figure 5: Overall output voltage of the system

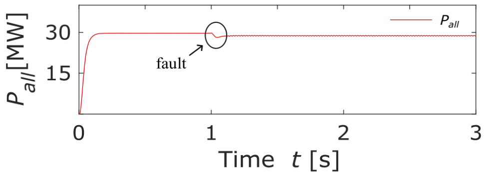

Figure 6: Overall output power of the system

References

[1] Seyed Milad Tayebi, Haibing Hu, Sam Abdel-Rahman, and Issa Batarseh, "Dual-input single-resonant tank LLC converter with phase shift control for PV applications," IEEE Transactions on Industry Applications, vol. 55, no. 2, pp. 1729–1739, March 2019.