Qun-wei XU, Jin-xiang ZHAN, Long XIAO, Guo-zhu CHEN, 2018. A multi-modular shunt active power filter system and its novel fault-tolerant strategy based on split-phase control and real-time bus communication. *Frontiers of Information Technology & Electronic Engineering*, 19(9):1166-1179.
https://doi.org/10.1631/FITEE.1601296

A multi-modular shunt active power filter system and its novel fault-tolerant strategy based on split-phase control and real-time bus communication

Key words: Shunt active power filter; Fault-tolerant topology; Split-phase control; Bus communication

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Motivations

1. Shunt active power filter (SAPF) is a preferred solution for harmonic compensation. However, the capacity problem restricts its development. Multi-modular SAPF has been paid attention to realize the large-capacity compensation.

2. Continuous operation of SAPF is important and must be ensured in some applications. But the traditional method has not particularly considered the fault-tolerant scheme of SAPF at present.

3. The advantages of structural consistency and functional compatibility of multi-modular SAPF system are not fully exploited.

Main ideas

1. By introducing the multi-modular SAPF system, optimized system configuration and mechanism of compensation capacity allocation are studied.

2. The advantages of structural consistency and functional compatibility among modules are fully considered. It is a goal of this study to contribute to the systematic analysis of multi-modular SAPF system and extend the redundancy from internal fault-tolerance to novel mutual fault-tolerance.

Methods

1. The whole system consists a centralized monitoring unit and N identical modules. Each module's reference signal is obtained by multiplying the total reference signal by the respective distribution coefficient k_j.

2. Decouple the three-phase compensation capacity allocation into three independent single-phase allocation.

3. Instead of halting the whole faulted module, we isolate the faulted bridge arm, recalculate the distribution coefficients, and transfer the compensation capacity to the same phases of the other normal modules, resulting in a continuous operation of the faulted module.

4. Carry out various experiments based on the proposed strategy.

Major results

1. Good steady-state compensation performance for balanced loads is achieved.

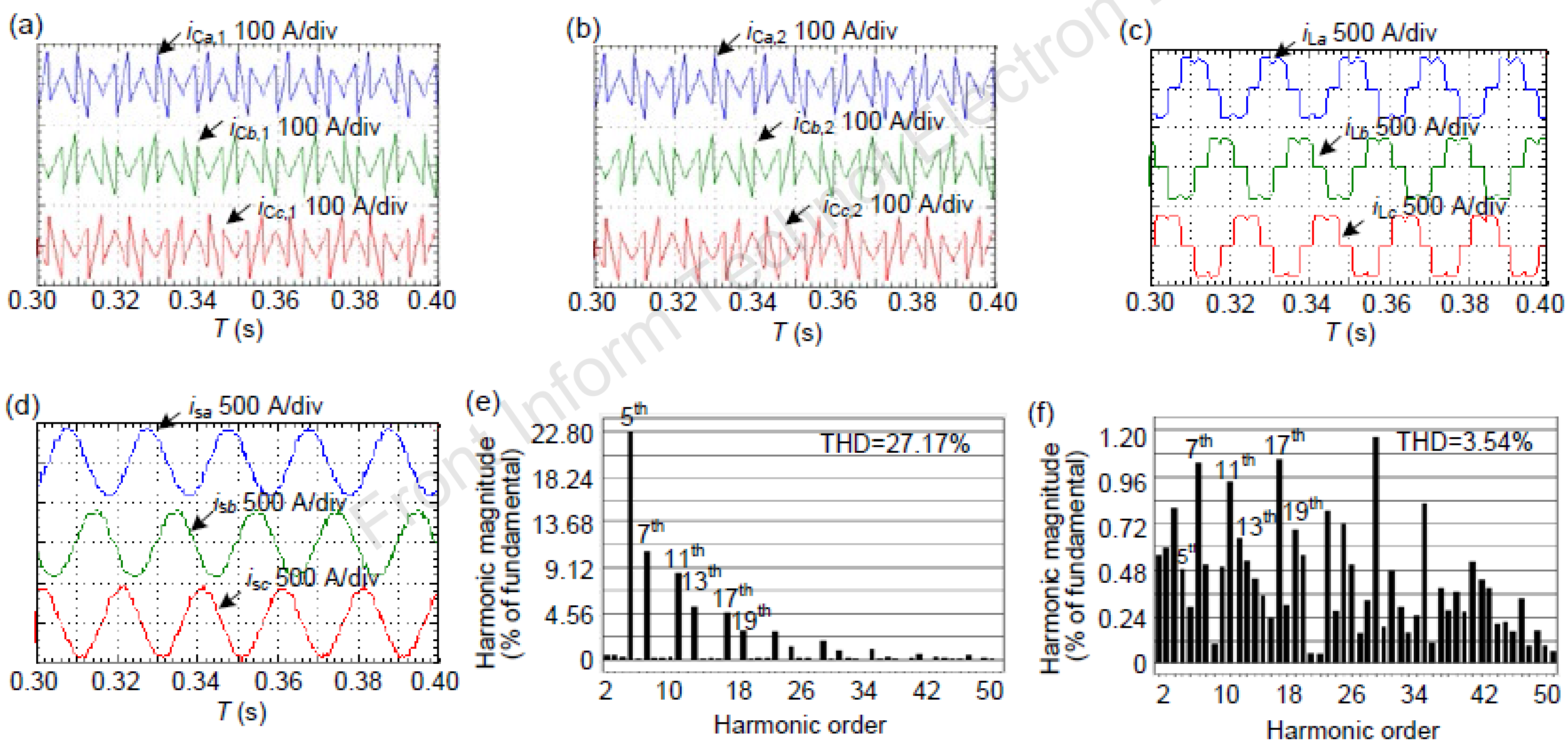

Fig. 14 Compensation waveforms with balanced loads: (a) module 1 output currents $i_{Ca,1}$, $i_{Cb,1}$, and $i_{Cc,1}$; (b) module 2 output currents $i_{Ca,2}$, $i_{Cb,2}$, and $i_{Cc,2}$; (c) load currents i_{La}, i_{Lb}, and i_{Lc}; (d) grid currents i_{sa}, i_{sb}, and i_{sc} after compensation; (e) frequency spectrum of load current i_{La}; (f) frequency spectrum of grid current i_{sa}

Major results

1. Good steady-state compensation performance for unbalanced loads is achieved.

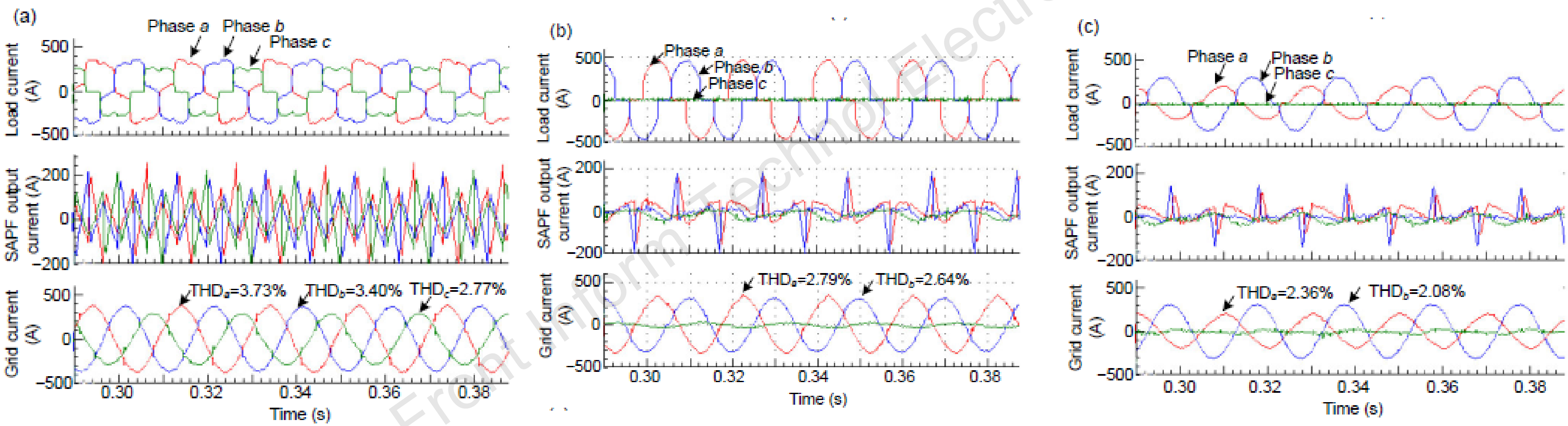

Fig. 15 Compensation waveforms with unbalanced loads: (a) a 20-Ω resistor between phases *a* and *b*; (b) an open circuit of phase *c*; (c) an open circuit of phase *c* and a 4-Ω resistor in series in phase *a*

Major results

2. Fault-tolerance among modules is well realized based on the proposed method.

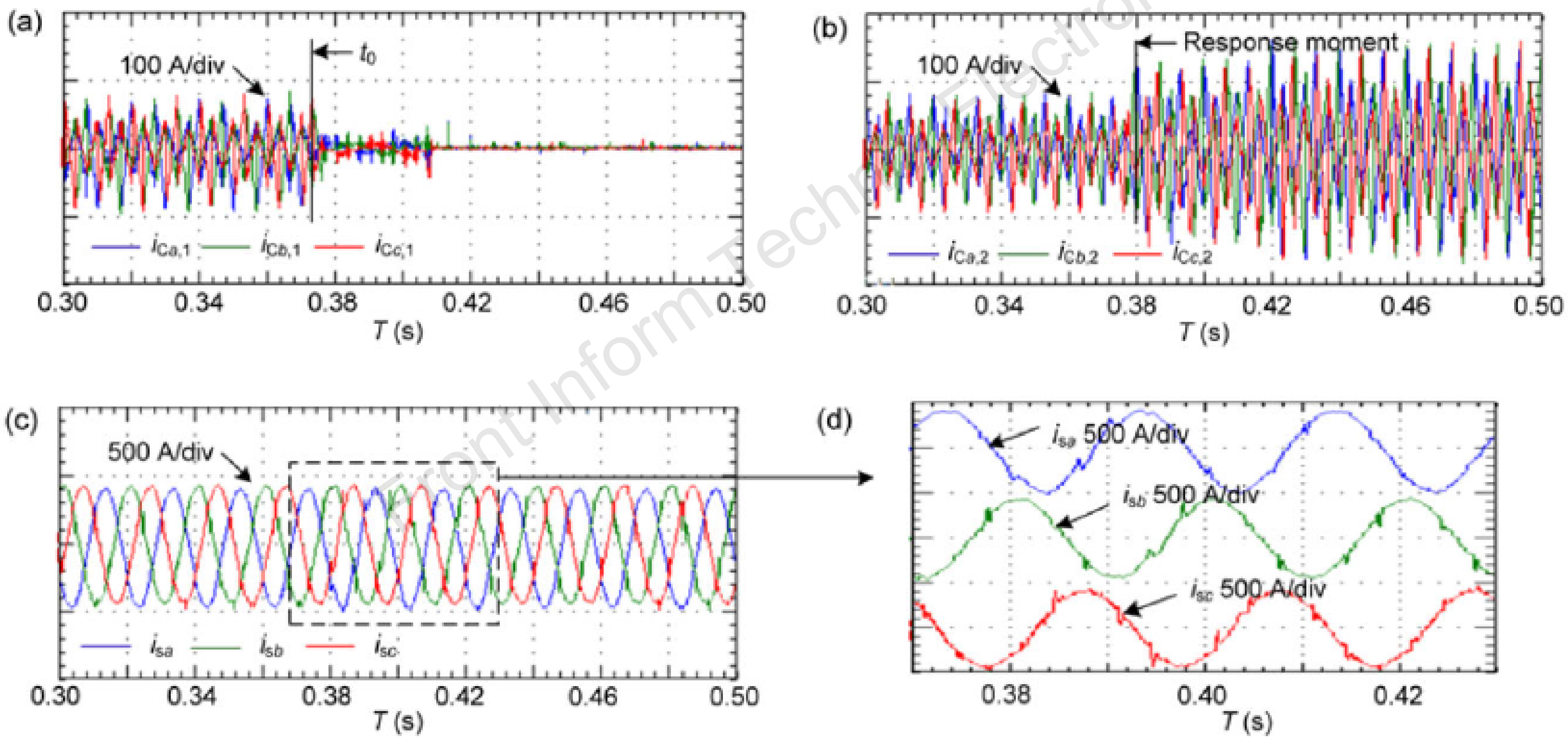

Fig. 17 Waveforms based on the conventional fault-tolerant strategy: (a) module 1 output currents $i_{Ca,1}$, $i_{Cb,1}$, and $i_{Cc,1}$; (b) module 2 output currents $i_{Ca,2}$, $i_{Cb,2}$, and $i_{Cc,2}$; (c) grid currents i_{sa}, i_{sb}, and i_{sc}; (d) zoomed grid currents during the strategy activation (References to color refer to the online version of this figure)

Conclusions

1. Due to the structural consistency and functional compatibility, each module's reference signal can be obtained by multiplying the total reference signal by the distribution coefficient.

2. Control system is decoupled into three independent phases in the *a*-*b*-*c* frame and split-phase control is implemented, which creates a condition for realizing the fault-tolerance among modules.

3. When a fault occurs, the proposed method just isolates the faulted phase and transfers the compensation capacity to the same phases of the other normal modules through real-time bus communication, resulting in the optimized operation of remaining usable power devices.