2차측 하프브리지를 갖는 3상 및 단상 겸용 1단 OBC

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Three- and single-phase compatible single-stage OBC with Half-Bridge secondary

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ABSTRACT

This paper introduces a three- and single-phase compatible single-stage OBC featuring a half-bridge secondary configuration. The topology ensures a constant DC output current for a three-phase grid and incorporates a module for split power decoupling in a single-phase grid scenario. Furthermore, the proposed topology is designed to improve efficiency at low battery voltage and light load. An 11kW for 3-phase and 7.4kW prototype for 1-phase is constructed to validate the proposed topology with a wide battery voltage range (460V~800V) and long-time operation.

1. Introduction

In recent times, the single-stage topology, which integrates AC/DC and DC/DC converters, has emerged as a prominent trend in EV chargers [1][3]. However, during single-phase operation, the output current often contains the second harmonic, leading to significant ripple output current. This high ripple current can potentially reduce battery lifetimes.

To address this challenge, recent research has focused on active power decoupling circuits aimed at mitigating output current ripple and absorbing second harmonics [1-2]. Unfortunately, many previously proposed converters have required additional switches and passive components, resulting in increased component count and compromised reliability of the converter. This paper introduces three- and single-phase compatible single-stage OBC with three half-bridges secondary side.

This topology has some advantages as below:

- Compatible three-phase and single-phase.
- Improve efficiency under light load at low battery voltage.
- Mitigate adding external semiconductors and passive components for the APD circuit in 1-phase operation.

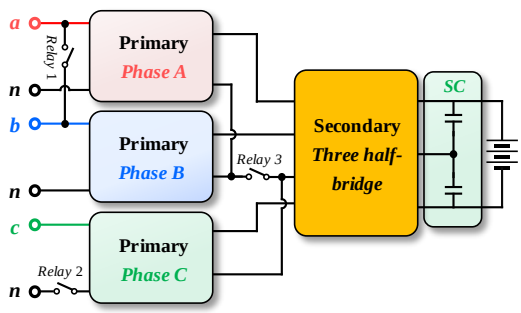

Fig 1. Concept structure of the proposed single-stage OBC.

2. Proposed 3-phase and 1-phase compatible single-stage OBC with half-bridge secondary

The proposed single-stage OBC with three-phase operation is illustrated in Fig. 1. Three relays are employed to facilitate operation in both single-phase and three-phase modes as Fig 2. On the primary side, each interleaved Totem-Pole PFC 3.7kW module is connected to the three-phase four-wire grid [1]. On the secondary side, only one 11kW module with three half-bridge legs is used instead of three full-bridge

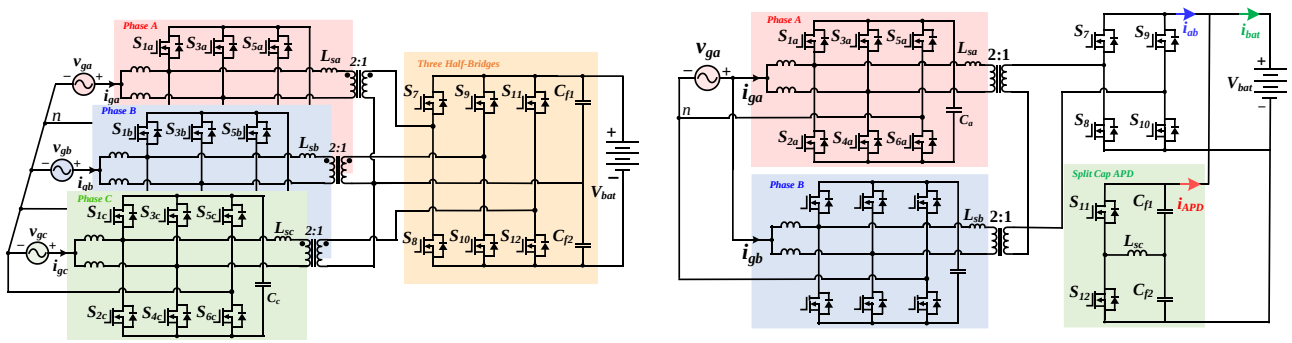

Fig 2. Proposed three- and single-phase compatible single-stage OBC with three half-bridge secondary
a) The 3-phase operation, b) 1-phase operation with a split capacitor APD circuit

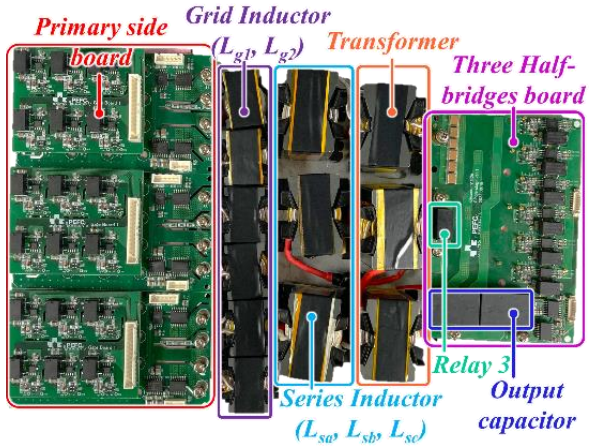

Fig.3. Prototype of the proposed 11kW single-stage OBC with three half-bridges secondary

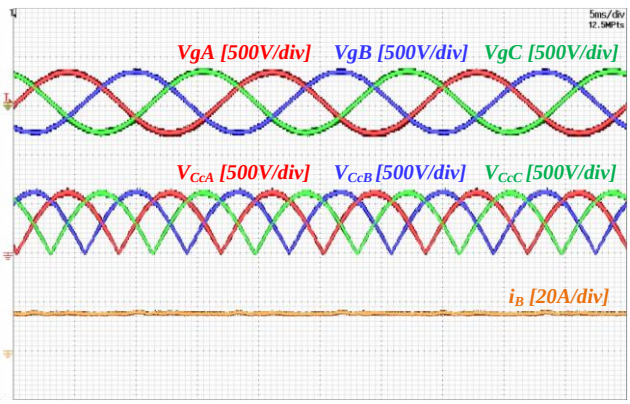

Fig.4. Experimental waveform in three-phase operation

Table 1 Prototype specifications of the proposed OBC

Items	Symbol	Value
Rated power	P	11kW/ 3φ
		7.4kW/ 1φ
Grid voltage (RMS)	V_g	220V 1φ / 380V 3φ
Battery voltage	V_{bat}	460V – 800V

3.7kW modules. The common points of the output transformers are connected to the center point of the series output capacitor.

In the 3-phase operation, each secondary leg operates independently, and the modulation signals for each leg are determined by the phase angles of each grid voltage respectively. In the 1-phase operation, the primary side of phase C and S_{11}-S_{12} of the secondary side are configured as a split capacitor power decoupling circuit. The primary side of phases A & B are connected parallel for grid current sharing.

3. Experiment results

To verify the performance of the proposed single-stage OBC, an 11kW prototype was built in Fig 3 with the following specifications as Table 1:

Fig. 4 depicts the experimental waveforms of the proposed single-stage OBC during three-phase operation at a battery voltage of 600V. With a low battery voltage of 460V and a light load of 1kW per phase, the efficiency exceeds 93%. This represents a 5% improvement compared to conventional 3-phase single-stage chargers [1]. Fig. 5 illustrates the experimental waveforms for single-phase operation with the power decoupling circuit, ensuring consistent DC charging current. Additionally, the temperature profiles of the series inductor and transformer after 30 minutes of operation at a high battery voltage of 800V are only 72°C and 76°C respectively.

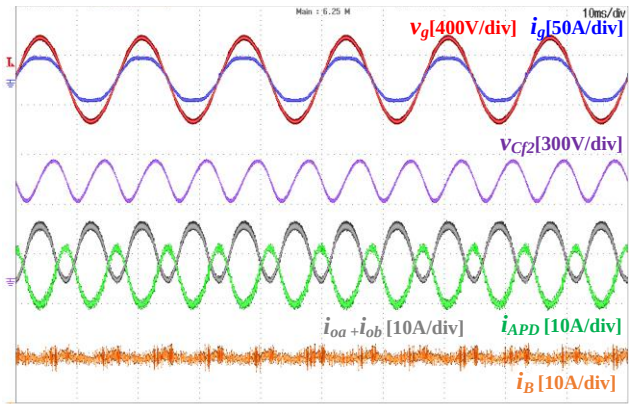

Fig.5. Experimental waveform in single-phase operation

4. Conclusion

This paper introduces a 3-phase and 1-phase compatible single-stage OBC. It reduces the number of secondary switches by half in three-phase mode and incorporates an active power decoupling circuit to absorb second harmonic currents in single-phase mode. Furthermore, the proposed topology can increase efficiency at low battery voltage under light load. An 11kW for 3-phase and 7.4kW for 1-phase prototype is built to verify the proposed topology.

References

[1] H. Kim, J. Park, S. Kim, R. M. Hakim, H. Belkamel and S. Choi, "*A Single-Stage Electrolytic Capacitor-Less EV Charger With Single- and Three-Phase Compatibility*," in IEEE Transactions on Power Electronics, vol. 37, no. 6, pp. 6780-6791, June 2022, doi: 10.1109/TPEL.2021.3127010.

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