# 論文 / 著書情報
# Article / Book Information

| | |
|---|---|
| 題目(和文) | |
| Title(English) | Study of Bidirectional Chopper with Single Full-Bridge Auxiliary Converter for Onboard Battery Energy Storage Systems |
| 著者(和文) | NASUTION GHIFFARI ABY MALIK |
| Author(English) | Ghiffari Aby Malik Nasution |
| 出典(和文) | 学位:博士(工学),<br>学位授与機関:東京科学大学,<br>報告番号:甲第349号,<br>授与年月日:2025年3月26日,<br>学位の種別:課程博士,<br>審査員:萩原 誠,藤田 英明,竹内 希,清田 恭平,佐野 憲一朗,小原 秀嶺 |
| Citation(English) | Degree:Doctor (Engineering),<br>Conferring organization: Institute of Science Tokyo,<br>Report number:甲第349号,<br>Conferred date:2025/3/26,<br>Degree Type:Course doctor,<br>Examiner:,,,,, |
| 学位種別(和文) | 博士論文 |
| Category(English) | Doctoral Thesis |
| 種別(和文) | 論文要旨 |
| Type(English) | Summary |

（博士課程）
Doctoral Program

# 論 文 要 旨

THESIS SUMMARY

| | | | |
|---|---|---|---|
| 系・コース：<br>Department of, Graduate major in | 電気電子　系<br>エネルギー　コース | 申請学位（専攻分野）：<br>Academic Degree Requested | 博士 (工学 / Doctor of Engineering) |
| 学生氏名：<br>Student's Name | Ghiffari Aby Malik Nasution | 審査員主査：<br>Chief Examiner | 萩原　誠 |

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）


This dissertation has proposed a bidirectional chopper with a single full-bridge auxiliary converter (BCSAC) for battery energy storage system (BESS) applications in electric vehicles. The BCSAC is a particular case of the bidirectional chopper with an auxiliary converter (BCAC), composed of the conventional bidirectional chopper (CBC) as the main converter, a single-phase full-bridge converter equipped with a floating dc-capacitor as the auxiliary converter, and an inductor. The auxiliary converter functions as an active power filter that cancels the AC voltage produced by the main converter, which reduces the switching-ripple current in the inductor. Meanwhile, the application of a single auxiliary converter of the BCSAC aims to mitigate the significant power loss and cost issues that comes with the usage of an auxiliary converter with multiple cells in the BCAC. To further minimize the produced power loss, the BCSAC operates under the following conditions: 1) The switching frequencies of the main and auxiliary converters are the same, and 2) The dc-capacitor voltage is half of the dc-voltage-source voltage of the high-voltage side.

The BCSAC is able to achieve a reduced switching-ripple current in the inductor, which consequently lowers its volume, while achieving high-efficiency performances. Theoretical analysis conducted on the switching-ripple current has shown that the BCSAC can reduce the switching-ripple current to 4/9 of that the CBC. Additionally, based on the comparison that has been made in this dissertation, focusing on its application in electric railways, the inductor volume can be reduced by 38.4% and 10.5% to those required by the CBC and three-level flying capacitor converter (TLFC). Overall, the BCSAC is smaller in volume than the BCAC and lighter than the CBC and TLFC. The chopper volume analysis considers the volume of the inductor, capacitor, power devices, and cooling systems of the chopper. Further, loss analysis has been conducted, which includes the conduction losses of the insulated-gate bipolar transistor (IGBT) and free-wheeling diode (FWD), switching loss of the IGBT, reverse recovery loss of the FWD, and inductor loss. The results show that although the BCSAC produces slightly higher power losses than the CBC and TLFC, it is significantly lower than those produced by the BCAC with three cells. As such, high efficiency performances can be achieved. Experimental results using a 2 kW down-scaled model have validated the theoretical analysis results of the switching-ripple current, as well as the operations and controls of the BCSAC in the steady states under positive and negative currents, and the transient states during the initial charging procedure and under a step change.

Additionally, the application of phase shift to the carrier waveforms of the main and auxiliary converters in the BCSAC is proposed to further reduce the produced switching-ripple current. Theoretical analysis conducted on the switching-ripple current has shown that the BCSAC with phase shift (BCSAC-PS) can reduce the switching-ripple current to 1/4 of that the CBC, which is significantly lower than that produced by the BCSAC (i.e., 4/9 of the CBC). Consequently, the inductor volume can be reduced by 62.3% compared to the CBC, which is also 38.8% smaller than that of the BCSAC, where the reduction is comparable to that achieved by the TLFC with phase shift with phase shift (TLFC-PS). Overall, the BCSAC-PS is smaller in volume and lighter than the CBC and BCSAC, and comparable to the TLFC-PS. Further, loss analysis has shown that the BCSAC-PS can achieve high efficiency performances that are better than the BCSAC, even though it still produces slightly higher losses than the CBC and TLFC-PS. These results verify the advantage of phase shift application. Experimental results using a 2 kW down-scaled model have verified the theoretical analysis results of the switching-ripple current in the BCSAC-PS.

Finally, a supplementary application of AC component-based control is proposed in the BCSAC-PS to allow the achievement of the DC-capacitor voltage control when there is no power transfer between the voltage sources. Consequently, the stability of the chopper operation would be improved. Experimental results using a 2 kW down-scaled model has verified the operations and controls of the BCSAC-PS during the steady and transient states. In the steady state, the inductor current and DC-capacitor voltage can be regulated to their respective reference values with no steady-state error, where the DC component-based control is used when the DC inductor current is not zero and AC component-based control is used when the DC inductor current is zero. In the transient state, the initial charging of the capacitor voltage can be completed using both the DC component- and AC component-based controls without any overvoltage or overcurrent problem. Additionally, the DC component-based control can stably operate during a step change of the high-voltage-side voltage, while the AC component-based control can stably operate during a ramp change of the capacitor voltage, without any overvoltage and undervoltage problem. Finally, the two control methods can be smoothly operated in coordination during a step change of the inductor current.