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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	Electrical and Electronic Engineering 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （Engineering）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This dissertation contains extensive theoretical analysis and experimental results from the study of back-to-back (BTB) system using modular multilevel cascade converter based on double-star chopper-cells (MMCC-DSCC) for power distribution systems. Basic design concepts of DSCC-based BTB system, with and without a line-frequency transformer, have been presented for the 6.6 kV power distribution systems.

The dissertation contributed to the improvement of DSCC-based BTB systems with three innovative ideas as follows:

■Experimental Verification of DSCC-based BTB System Without Common DC-Link Capacitor This dissertation has provided an intensive discussion on analysis, simulation, and experiment of the BTB system. Low voltage steps bring significant reductions in harmonic voltage and current to the BTB system. Neither dc-link capacitor nor voltage sensor is required for regulating the dc-link voltage and controlling the dc-link current. Modeling and analysis have been done for the single power conversion system unifying the two DSCCs that take the equal responsibility for regulating the dc-link voltage and controlling the dc-link current. Analytical, simulated, and experimental results were conducted to confirm the validity of the proposed method in which all results agree well with each other in steady and transient states.

■Experimental Verification of Transformerless DSCC-based BTB system for Power Distribution Systems This dissertation has discussed on the transformerless DSCC-based BTB system application to the power distribution system with many distributed power generators. Equivalent circuits for zero-voltage and current have been proposed to verify the validity of zero-sequence current circulating between the two feeders in the three-phase three-wire ungrounded distribution system under normal voltage conditions. The experimental results have confirmed that the transformerless DSCC-based BTB system has the capability of mitigating the power-flow imbalance between the two feeders.

■**Experimental Verification of Zero-Voltage Ride-Through Capability of Transformerless DSCC-based BTB system** This dissertation continued to verify the effectiveness of the transformerless BTB system under voltage sag conditions. The control method has been proposed to suppress both overvoltage and overcurrent of the BTB system during the sags. The results obtained from experiments and simulations show that the transformerless DSCC-based BTB system is equipped with zero-voltage ride-through (ZVRT) capability even under the most severe voltage sags.

This dissertation is divided into seven chapters and is organized as follows:

■ **Chapter 1 (Current Chapter)** contains the introduction and briefly describes the global energy scenario and impact to the global warming. The chapter explains the operation paradigms of power systems. It also talks about the modern scenario of the electrical grid using VSC-based FACTS devices and BTB systems, especially the BTB application for distribution systems working as a loop power flow controller. Following that, this chapter states the aims of the research and also provides an outline for this dissertation.

■ **Chapter 2** discusses a literature review on modular multilevel cascade converters (MMCCs) family with focus on the MCCC-DSSC topology. Afterwards, it presents the modulation techniques, control methods, modeling, design, operation, and various applications. Fault-ride-through capability of the DSCC is also present in this chapter.

■ **Chapter 3** provides a detailed analysis of DSCC circuit and basic equations. This chapter also presents the DSCC control systems consisting of the power control and the capacitor voltage balancing control based on the phase-shifted-PWM technique.

■ **Chapter 4** presents the experimental setup of three-phase 200-V, 10-kW, 50-Hz downscaled DSCC-based BTB system. It provides the design considerations for distribution and transmission systems. Modeling and analysis are presented for the single power conversion system unifying the two DSCCs that have equal responsibility for regulating the dc-link voltage and controlling the dc-link current. The experimental and simulation results are presented to verify the effectiveness of the presented control methods.

■ **Chapter 5** presents the application of the transformerless DSCC-based BTB system working as a loop-power-flow controller. It is intended for installation on the 6.6-kV Japanese power distribution systems. It provides the details of design, implementation, and test on a 200-V, 40-kW power distribution simulator consisting of two radial feeders. The equivalent circuits for zero-sequence voltage and current are revealed to confirm the effective of the zero-sequence control and common-mode choke in suppression the zero-sequence components. This chapter

also discusses the experimental results on the performance of the system operating in the power-flow imbalance between the two feeders. Following that, the zero-sequence current circulating between the two feeders can be suppressed as small as 10 mA in rms by the combination of achieving current feedback control and connecting a common-mode choke to the common dc link.

■ **Chapter 6** provides an experimental discussion on the transformerless DSCC-based BTB system under voltage sags by using a 200-V, 10-kW downscaled system focusing on the zero-voltage ride-through (ZVRT) capability of the system. This chapter also discusses the experimental and simulation results showing that the BTB system is equipped with ZVRT capability without inducing any overvoltage and/or overcurrent even under the most severe voltage sags.

■ **Chapter 7** summarizes the contribution of this research, discusses the limitations of the implemented DSCC-based BTB systems, and suggests further work that can be carried out.