# 論文 / 著書情報
# Article / Book Information

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| 題目(和文) | モジュラー・マルチレベルSSBC変換器の配電系統用無効電力補償装置と 電池電力貯蔵システムへの応用に関する研究 |
| Title(English) | Study of Applications of a Modular Multilevel SSBC Converter to a Distribution STATCOM and a Battery Energy Storage System |
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| 出典(和文) | 学位:博士(工学),<br>学位授与機関:東京工業大学,<br>報告番号:甲第10147号,<br>授与年月日:2016年3月26日,<br>学位の種別:課程博士,<br>審査員:赤木 泰文,安岡 康一,千葉 明,藤田 英明,萩原 誠,吉野 輝雄 |
| Citation(English) | Degree:Doctor (Engineering),<br>Conferring organization: Tokyo Institute of Technology,<br>Report number:甲第10147号,<br>Conferred date:2016/3/26,<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

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| 専攻：<br>Department of | 電気工学専攻　　専攻 | 申請学位（専攻分野）：<br>Academic Degree Requested | 博士　（　工　学　）<br>Doctor of　( Engineering ) |
| 学生氏名：<br>Student's Name | OTA, Joao I. Yutaka | 指導教員（主）：<br>Academic Advisor(main) | 赤木 泰文　教授 |
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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words )


The thesis titled "Study of Applications of a Modular Multilevel SSBC Converter to a Distribution STATCOM and a Battery Energy Storage System" describes the study of applications of a modular multilevel cascade converter based on single-star bridge cells (MMCC-SSBC), or modular multilevel SSBC converter simply, to a Distribution STATCOM (D-STATCOM) and a Battery Energy Storage System (BESS) intended for installation on a 6.6-kV distribution power system.

Depletion of fossil fuels and concerns on environmental issues have brought the attention of governments, power utilities, and industries to power generation based on renewable energy sources. As a result, massive penetration of photovoltaics and wind-power generation has taken place in distribution power systems. Nevertheless, the intermittency of renewable energy sources brings issues related to the stability of distribution power systems, such as the regulation of ac mains voltage and frequency. The D-STATCOM and the BESS are suitable power conversion systems to perform the roles of voltage and frequency regulation in distribution power systems that have a high penetration of renewable energy sources.

The thesis evaluates the modular multilevel SSBC converter as a prospective candidate to D-STATCOM and BESS applications. The SSBC converter consists in three clusters formed by a cascade connection of multiple H-bridge cells. The clusters are characterized by a star-connected common point. The production of voltage waveforms with small low-voltage steps eliminates the need of harmonic filters. An SSBC converter applied to a D-STATCOM brings a transformerless connection to the distribution feeder when a reasonable assessment is made between the blocking voltage of switching devices and the ac mains voltage. The SSBC-based D-STATCOM then becomes a compact and lightweight solution that can be installed on electric poles directly. An SSBC converter applied to a BESS brings the use of multiple low-voltage battery modules because of the cascaded connection of multiple H-bridge cells. The SSBC-based BESS results in a system with increased overall availability and reliability when compared to solutions available in the market presently.

A three-phase downscaled model of an SSBC converter is designed and constructed to verify the operation of a 140-V, 10-kVA, 50-Hz D-STATCOM and a 140-V, 10-kW, 21-kWh, 50-Hz BESS experimentally. The following points are listed as contributions:
i. Modeling and analysis of the current control of the SSBC when applying the phase-shifted-carrier pulse-width modulation (PWM) strategy: two different methods to update the voltage reference of the SSBC, namely "one-cell update method" and "all-cells update method," are compared. Experiments show that the SSBC-based applications produce currents with a Total Harmonic Distortion (THD) lower than 3.0% when the proposed all-cell update method is applied.
ii. Analysis and design of a software-based filter to improve the cluster balancing control of the SSBC-based D-STATCOM: two different filtering methods to suppress a 100-Hz voltage oscillation on the dc capacitors are analyzed and compared. The use of a moving average filter brings an improved dynamic response of the cluster balancing control.
iii. Analysis of the availability and reliability of the SSBC-based BESS: the BESS can maintain its operation even when multiple failures of individual battery modules occur. An analysis shows that the operation availability becomes higher as the number of individual battery modules increases.
iv. Experimental verification of ride-through capability: the ride-through capability is verified extensively by subjecting the D-STATCOM and the BESS to voltage sags, frequency deviations, and phase jumps. Experiments show that both applications are robust against grid disturbances.

The thesis structure is listed below.

Chapter 1 describes the main motivations and the background of the thesis. Considerations on the basic operation of both D-STATCOM and BESS are made. The contents of next chapters are listed.

Chapter 2 presents a literature review on high-power medium-voltage multilevel converter, applications of multilevel converters to D-STATCOMs and BESSs, and grid disturbances. Multilevel converters are considered as prospective candidates for high-power medium-voltage power converters such as D-STATCOM and BESS. In the end, this chapter reviews aspects related to grid disturbances because both D-STATCOM and BESS operate while connected to an actual electrical grid.

Chapter 3 deals with the SSBC converter. The chapter is divided in two parts. In the first part, the SSBC-based D-STATCOM and BESS are explained, then the experimental downscaled model is described in details. In the second part, the modeling and analysis of the current control of the SSBC converter are presented when applying either one-cell update method or the all-cells update method.

Chapter 4 describes the operation of the SSBC-based D-STATCOM. The analysis of the methods for filtering the 100-Hz voltage component on the dc capacitor is carried out. Experimental results are disclosed.

Chapter 5 describes the operation of the SSBC-based BESS. A method to estimate the power flowing in each battery module is described. Considerations on the capability of the BESS to deal with multiple failure of individual battery modules are done.

Chapter 6 deals with the ride-through capability of both D-STATCOM and BESS against grid disturbances. Experimental procedures are explained, then both applications are subject to voltage sags, frequency deviations, and phase jump occurrences.

Chapter 7 summarizes the main contributions of the thesis and limitations of the results.