Project Subjects

Low-loss Compact Inverter Applied Equipment

Background and Objective

Innovation in power electronics technology can play an important role in realizing a low-carbon society through promoting energy saving, electrification of energy usage, and the introduction of renewable energy sources. As a core of the innovation, the development of electric equipment and apparatus which utilize SiC semiconductor devices (SiC devices) can achieve high efficiency, small size and high control performance. For the wide practical use of such high performance equipment, it is important to initiate practical development of SiC devices while placing a high priority on applications where the largest benefit can be gained through their use.

In this project, aiming at the practical use of electric equipment with SiC devices, we intend to develop an SiC device applied equipment after selecting an appropriate application. To establish the simulation and control technologies of power electronics circuit with SiC devices is another important objective of this project.

Main results

1. Development of an SiC Device Applied Transformerless STATCOM for 6.6kV Distribution Systems

We developed a prototype of a 6.6kV transformer-less STATCOM[1)] incorporating an all SiC converter and verified its performance (Fig. 1). Specifically, in terms of efficiency improvement and miniaturization, Y-connection Modular Multilevel Converter[2)] topology (Fig. 2) was applied to the prototype as an optimal circuit configuration for the SiC device applied STATCOM. At the beginning of the development, over current and over voltage capability of 1.2kV SiC-JFET[3)] devices which were applied to the prototype were verified. Then the circuit design was optimized in terms of loss reduction. Experimental verification proves the effects of the design optimization and clarifies the stable operation performance of controls developed for the STATCOM operation.

Moreover, we have designed a power circuit, a control and protection circuit, and a three-dimensional configuration to store a pole-mount container based on a thermo-fluid analysis (Fig. 3) for the practical equipment. Fundamental design technologies for the practical use of the SiC device applied STATCOM were established through these detailed design processes.

The development has been implemented under cooperative research with Toshiba Corporation.

2. Development of Control Schemes for SiC Device Applied Converters

In order to accelerate the practical use of the SiC device applied STATCOM for distribution systems in several years, a control scheme was developed for a hybrid configuration of 1.2kV SiC device which is close to commercialization and high blocking voltage Si-IGBT. Conventional hybrid converters require DC sources in each cell to maintain the DC voltages because the converters consist of several cells with different voltage ratings. The proposed control scheme eliminates the DC sources by enabling energy transfer between cells without output voltage distortion, and realizes highly practical system which achieves the reduction of converter size and cost [R10014]. Moreover, a new control scheme was developed for Y-connection multilevel converters[2)] to compensate unbalanced three-phase voltages which has increasing demand in the STATCOM application to distribution systems [R10022].

Other reports [R10027] [R10039]

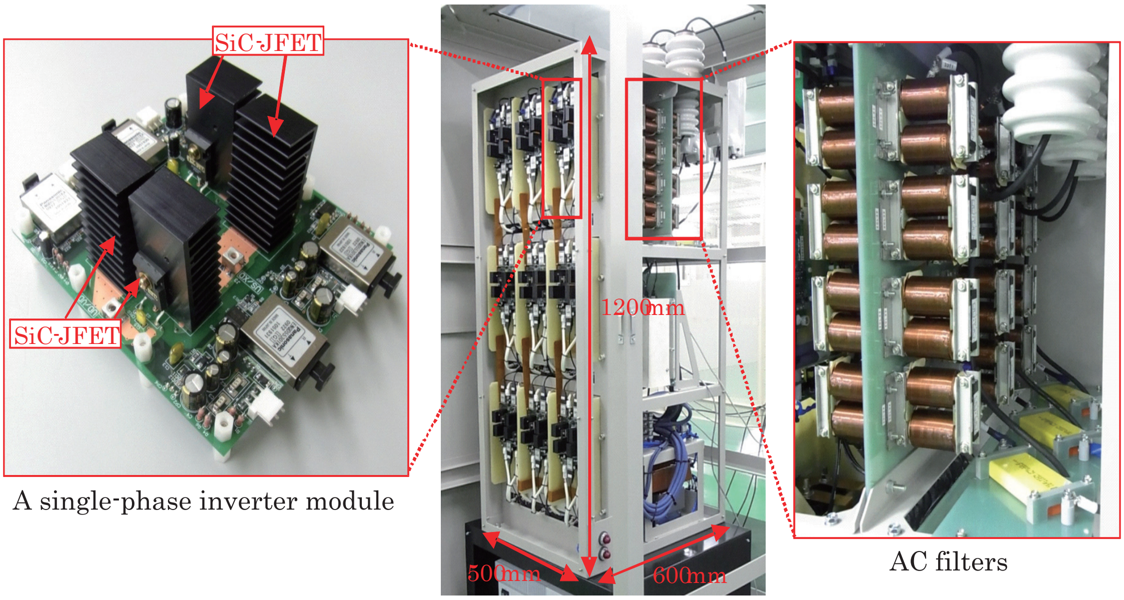

Fig. 1　Prototype of the all SiC STATCOM (rated at 2.2kV, 33.5kVA)

Circuit design and control system design technologies were established through manufacturing and testing an all SiC converter prototype applying 1.2kV SiC-JFET devices.

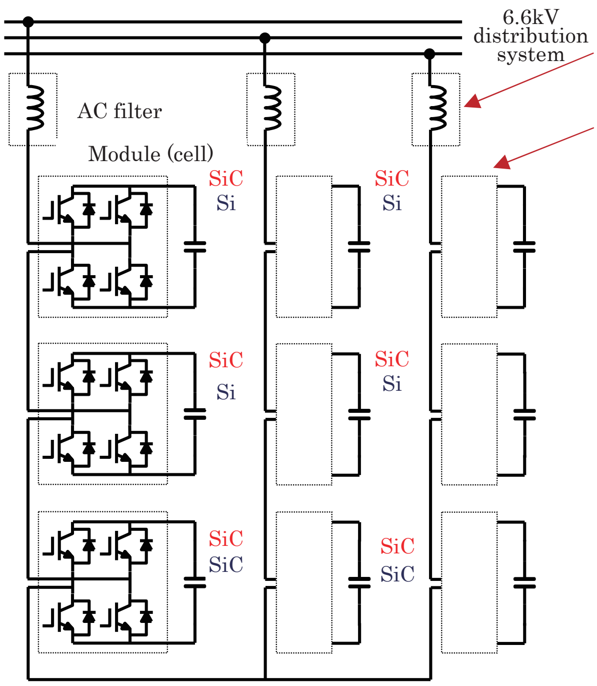

Fig. 2　Configuration of the Y-connection multilevel converter[1), 2)]

All SiC converter and hybrid converter have the identical circuit configuration (topology).

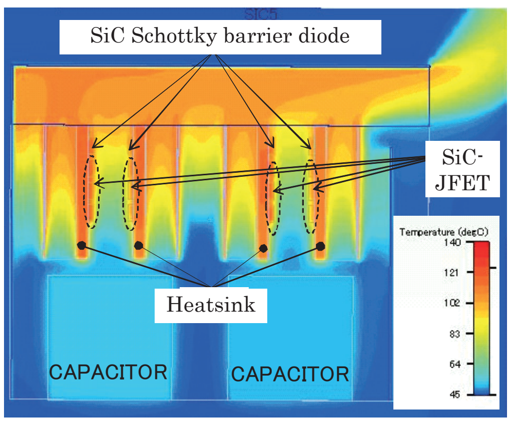

Fig. 3　Thermo-fluid analysis of the inverter module

The thermo-fluid analysis verified that highest temperature (119℃) in the module is within the acceptable level (125℃).

1) STATCOM (STATic synchronous COMpensator) : Reactive power compensation equipment using Voltage Source Converter
2) Multilevel converters consist of series connected several single phase inverter modules (cells). Modular multilevel converter is the converter consisting of modules having the identical voltage rating among them. There are Y-connection type and Δ-connection type converters.
3) Among SiC switching devices, SiC-JFET and SiC-MOSFET are now under intensive development. At present, SiC-JFET is the most promising device close to commercialization.
4) A converter consisting of SiC devices and Si devices is called a hybrid converter in this article. Its configuration is a multilevel converter, which consists of several cells with different rated voltages using 1.2kV SiC-JFETs and high blocking voltage Si-IGBTs.