Project Research — Development of a Supply/Demand Infrastructure for Next-generation Electric Power

Low-loss Compact Inverter Applied Equipment

Background and Objective

Innovation in the power electronics technology can play an important role in realizing a low-carbon society and stable electric power supply, including the introduction of renewable energy sources. As a core of such innovation, the development of electric equipment that utilize SiC semiconductor devices (SiC devices) can achieve low power loss, small size, and high control performance.

Another possible innovation is the improvement of the stability of the electric power supply system by developing and applying a novel high-voltage DC transmission system for enforcing grid interconnection and for the increase of renewable energy sources, which have recently gained prominent attention.

In this project, we establish the simulation and control technologies of power electronics systems. Based on the technologies, we develop SiC device-applied equipment and novel high-voltage DC transmission systems, which can meet recent needs.

Main results

1 Development of an Existing-SiC-device-applied STATCOM for Distribution Systems

We have developed a prototype for a 6.6-kV transformerless STATCOM*1 by combining existing SiC devices and Si devices (Fig. 1). The prototype is based on the multi-voltage cascade converter*2 and realizes direct high-voltage output of 6.6 kV. Development of a novel pulse control method realizes a small AC filter and small power loss. A series of basic performance verification tests were executed by the prototype. Reactive power control and DC voltage balancing control among the cells were verified to have enough performance for actual use in steady-state operations. The development has been implemented under the cooperative research with Toshiba Corporation.

This result can be applicable to develop demonstrative equipment implemented in a small container for pole-top mounting by verifying the control performance during faults and by optimizing its design with utilizing the simulation models developed in our laboratory (R11028).

2 Proposal of a Novel High-voltage DC Transmission System

DC line faults are usually cleared using AC circuit breakers in conventional voltage source converters based high voltage DC transmission (HVDC) systems because the fault current continues to flow after halting the converter. As a result, it takes time to resume power transmission, and such interval is a problem when realizing quick recovery from a lightning failure in an HVDC system having overhead transmission lines. We propose two methods to solve this problem. One method is to use a full-bridge cell MMC*3 and suppress the DC fault current using the converter's control (R11021). The other method is to remove the fault section by using high-speed solid-state DC circuit breakers*4 (R11018) (Fig. 2). These methods can realize the quick recovery of the power transmission in a DC line fault. The first method can be quickly put into practical use by utilizing existing control and protection technology for line-commutated current-source converters. The second method is effective for future multi-terminal DC grids because it can remove only the fault section.

*1 STATic synchronous COMpensator: Reactive power compensation equipment using a voltage source converter
*2 A circuit configuration for a multilevel converter: It has multiple single-phase inverter modules of which the DC voltage is different. They are connected in series and operate as a high-power converter.
*3 A modular multilevel converter (MMC) is a converter consisting of cells (modules) having identical voltage rating among them. A full bridge cell MMC consists of series-connected several single-phase inverter modules.
*4 Includes not only pure solid-state breakers, but also hybrid breakers of high-speed mechanical switches and solid-state switches.

Other reports: (R11027)

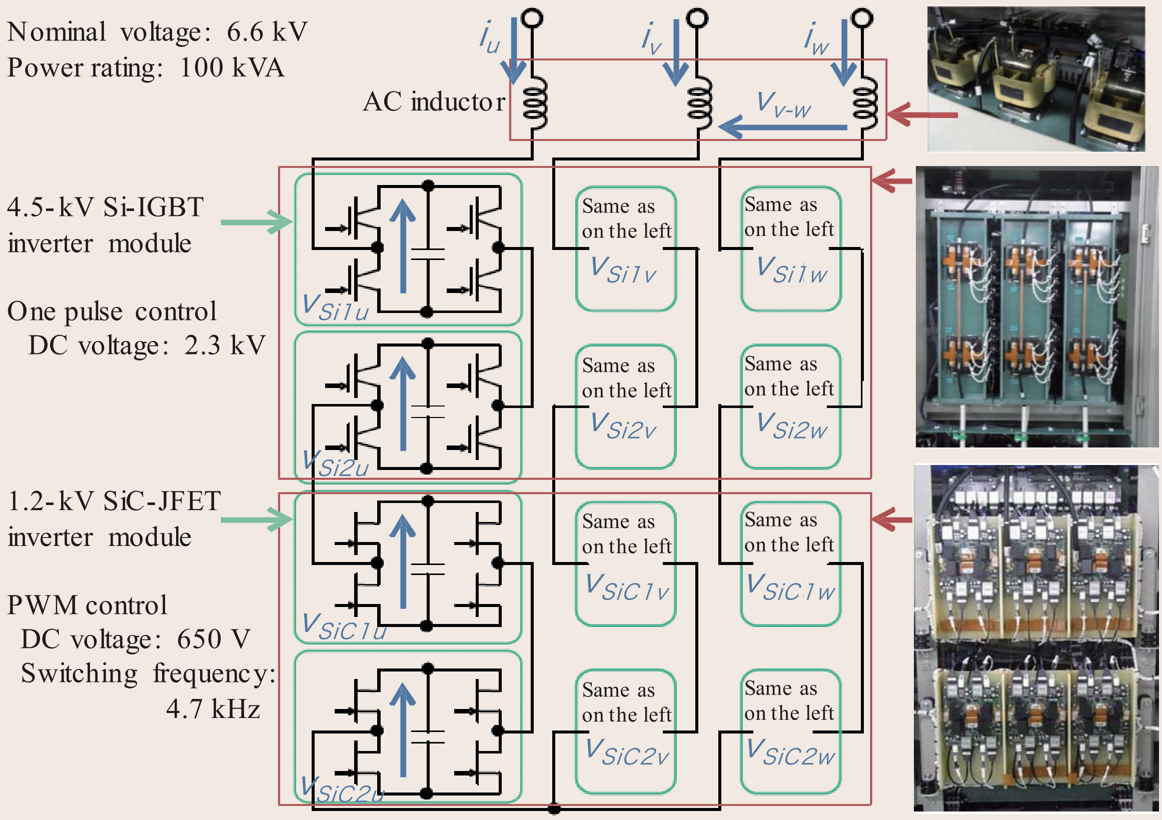

Fig. 1: Prototype of the transformerless STATCOM consisting of existing SiC devices and Si devices (rated at 6.6 kV in voltage and 100 kVA in power)

A full scale STATCOM prototype was developed. It consists of 1.2 kV SiC-JFET devices that have excellent switching performance and 4.5 kV Si-IGBT devices that feature low conduction loss. The operation of the prototype was confirmed by a series of verification tests on basic performance.

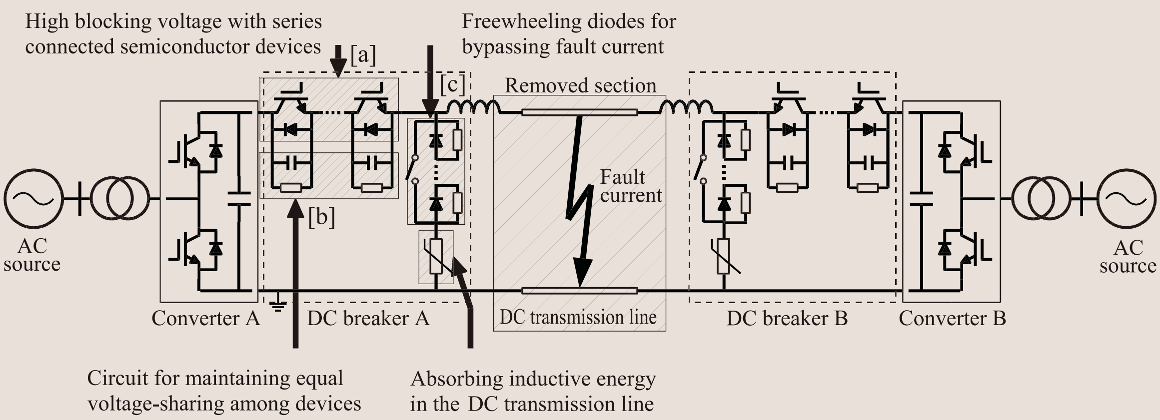

Fig. 2: A circuit configuration of the proposed voltage source converter-based high-voltage DC transmission systems using DC circuit breakers.

Several switching devices are able to be connected in series by paralleling a circuit for maintaining equal voltage-sharing among the devices [b] to the semiconductor devices [a] to realize the high blocking voltage of the DC circuit breakers. A freewheeling diode [c] can bypass the fault current and slowly reduce the fault current to suppress the surge voltage arising from the current blocking.