§12. Study on Improvement of Electric Power Quality by Flywheel Energy Storage System

Matsukawa, T.,
Sato, Y. (Dept. of Electrical and Electronic Eng., Daido Inst. of Tech.),
Shimada, R. (Research Laboratory for Nuclear Reactors, Tokyo Inst. of Tech.),
Chikaraishi, H.

Large and unsteady electric power is required to energize magnetic field coil of magnetic confinement type nuclear fusion experimental device. The power supply for the magnetic field coil should output the required electric power, and it may occur that such large and unsteady electric power makes electrical disturbance on the utility power network. To suppress the influence on the utility power network, it is generally adopted that some electric power storage system is equipped with the power supply. As an electric power storage system to be employed to the power supply for magnetic field coil, the flywheel energy storage system has some advantages, which are large capacity of stored energy, high efficiency, rapid control of energy storage and release, etc. In this study, it is aimed that the flywheel energy storage system is operated in high performance. As the result, it is expected that high performance operation of flywheel energy storage system can contribute to leveling the electric power to energize magnetic field coil. And also, the flywheel energy storage system could be used to output power compensation of sustainable power generation system like wind or solar power generation. When the flywheel energy storage system compensates electric power fluctuation, power converter circuit is the important component to connect the flywheel energy storage system to the utility power network and to control the electric power flow between them. Therefore, it is required that power converter circuit should have the performance with high efficiency and high reliability. To achieve power converter circuit with such good performance, the switching element used for power converter circuit is the key issue. Here, it is discussed that some advanced power electronics devices are applied as switching elements to the power converter circuit of the flywheel energy storage system.

Our recent studies on electrical characteristics of advanced power electronics devices have investigated SiC-based one and Si-based super junction type one, which are more excellent than conventional power electronics devices concerning electrical characteristics. SiC-based Schottky barrier diode (SBD) and Si-based super junction type power-MOSFET, which are in the category of unipolar power electronics devices, are typical advanced power electronics devices. Common advantages of electrical characteristics of advanced power electronics devices are high switching speed, high withstanding voltage, low operation loss, wide operational temperature range, etc. Main features of SiC are wider energy band gap, higher breakdown electric field, faster electron velocity, better thermal conductivity and higher vaporizing temperature. Therefore, main electrical characteristics of SiC-based device are high operational temperature, high withstanding voltage, low on-state resistance and fast switching frequency. SiC-based device can allow to minimize the series connected switching devices of power converter circuit. SiC-based SBD has its advantage of lower built-in voltage corresponding to Schottky barrier, and shows lower forward voltage drop. Lower forward voltage drop means good conductive characteristics in on-state which contributes to minimize operational loss. Si-based super junction type power-MOSFET is one of advanced power electronics devices to achieve lower on-state resistance value in higher voltage region, which has excellent electrical characteristics to be applied to high current power converter circuit. The synchronous rectifier is one of power converter circuit, which advantage using Si-based super junction type power-MOSFET is to minimize total on-state resistance of parallel connected devices. In future, as another type advanced unipolar power electronics device, SiC-based power-MOSFET will be developed for lower on-state resistance and higher operational temperature than that of conventional Si-based power-MOSFET.

Considering application of such advanced power electronics devices to power converter circuit of the flywheel energy storage system, the following advantages are expected.

1) The fast switching frequency of advanced power electronics device can realize controllability and responsibility of the power flow corresponding to rapid change of power demand.
2) The improvement of AC side waveforms is achieved by fast switching of advanced power electronics device, and the compensation equipment, which is harmonic filter, etc., is simplified.
3) The switching loss is decreased because of short switching time of advanced power electronics device, and it is desirable for high efficiency of fast switching operation.
4) The conduction loss is minimized as advanced power electronics device has low on-state resistance value. The total operational loss of high current power converter circuit could be lowered.
5) High withstanding voltage of advanced power electronics device allows power converter circuit to minimize the series connected switching devices resulting compact design of converter.
6) SiC-based device can operate in wide temperature range, especially in high temperature, and then the cooling equipment of power converter circuit will be rationalized.

To operate the flywheel energy storage system in high performance, it is proposed that advanced power electronics devices are applied to its power converter circuit. Some advantages of power converter circuit using advanced power electronics devices are discussed qualitatively.