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

# Next-generation Electric Power Equipment for Distribution and Transmission Systems

## Background and Objective

The aging of electric power equipment is progressing, and in the near future, a huge amount of electric equipment will need to be replaced. On the other hand, since safety and low environmental loading will become important, electrical equipment must be able to deal with these changes and new requirements. Therefore, it is desired that next-generation electrical equipment features high performance for disaster prevention and low environmental loading. In this research, we aim to establish fundamental technology for a superconductive fault current limiter to reduce the constraint factors of power distribution and transmission systems by suppressing short-circuit current, along with low environmental-loading transformers for high public acceptance, in order to propose next-generation technology for replacing aged equipment.

## Main results

### 1 Development of a Superconducting Fault Current Limiter for Suppressing Fault Current

Bi2223 superconductive thin coating is used for magnetic shielding-type superconducting fault current limiters (SFCLs), which are suitable for application to high-voltage systems, such as high-voltage transmission lines. We found that the critical current density (Jc) can be increased by increasing the pressure of compression molding between sintering treatments during fabrication (Fig. 1). In case of strip shape samples molded with a pressure of 250 MPa, the obtained maximum Jc was 6,000 A/cm$^2$, which is close to the practical value. $\phi$450-mm large cylinders (Fig. 2), which will be used for 6 kV- and 60 kV-class SFCLs were molded with a pressure of 150 MPa, which is the maximum available pressure for presently used cold isostatic pressing (CIP) machines, and the obtained maximum Jc was 2,400 A/cm$^2$. The Jc was lower than the strip shape sample because of low CIP pressure. Also, we proposed a method to increase threshold energy for the destruction of superconductive coating by Joule heating. In case of strip shape samples, the threshold destruction energy was increased by 2–3 times when compression pressure is 2 MPa (Fig. 3).

### 2 Development of Gas/Solid Hybrid Insulation Bus Technology Without $SF_6$ Gas

Gas insulation electric equipment must be properly managed to suppress gas leakage into the atmosphere, as $SF_6$ gas, which has high global warming potential, is used in gas insulation equipment. CRIEPI proposed a gas/solid hybrid electrical insulation method using natural gas such as $CO_2$ or $N_2$ instead of $SF_6$ and a conductor thickly coated by solid insulation material. In a hybrid gas insulation bus, the joint of coated conductors is the weak point of electrical insulation. Therefore, we proposed a joint structure with an electric field shield as shown in Fig. 4. It is expected that the cross-section of a bus joint can be reduced to 1.1 times that of a conventional $SF_6$ gas-insulated bus, on the basis of experimental results and electric field analysis (H11001). We designed and made a prototype model of a 300 kV-class hybrid gas insulated bus (Fig. 5).

### 3 Development of Elemental Technology for an All-solid Insulated Transformer

The all-solid-insulated transformer is very attractive because of its high safety, compactness, and low environmental loading, owing to its oil-free insulation. So far, CRIEPI made a small outer-layer grounded all-solid-insulated transfer model with an easily detachable, all-solid compact connector, known as the "hyper connector." We are evaluating the performance of this small model to accumulate data regarding insulation and thermal properties, which is necessary for designing a 60 kV-class all-solid transformer.

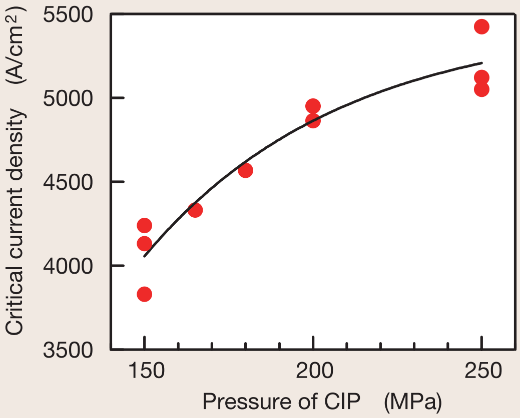



Fig. 1: CIP-pressure dependence of the critical current density

Transition of the critical current density of short samples with increasing CIP pressure between the sintering treatments at the same sintering conditions (temperature and number of sintering treatments)

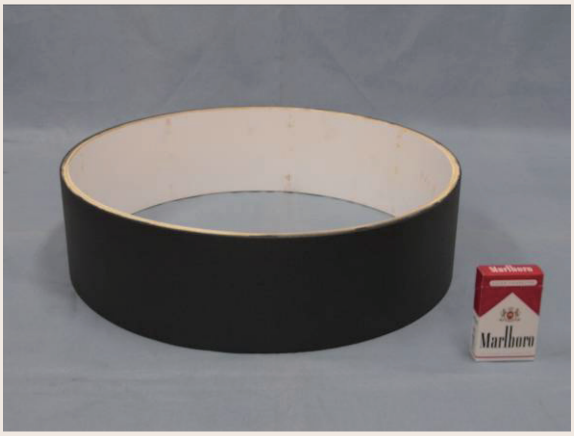



Fig. 2: Prototype large cylinder of $\phi$450 mm in diameter

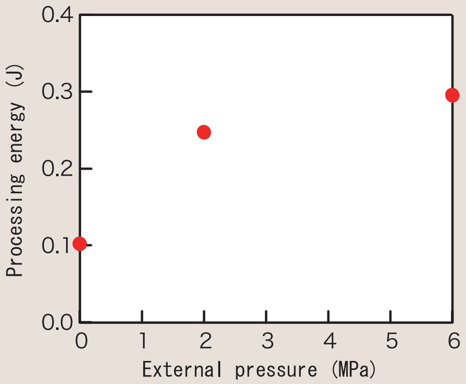



Fig. 3: Damage mitigation effect by the external pressure

We measured the applied energy until when short samples are destroyed by Joule heating during over-current more than the critical current density.

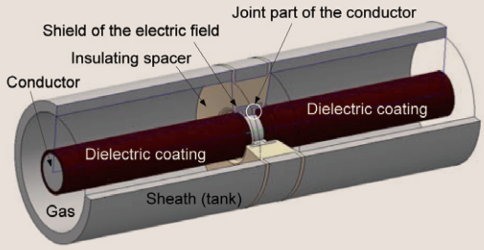
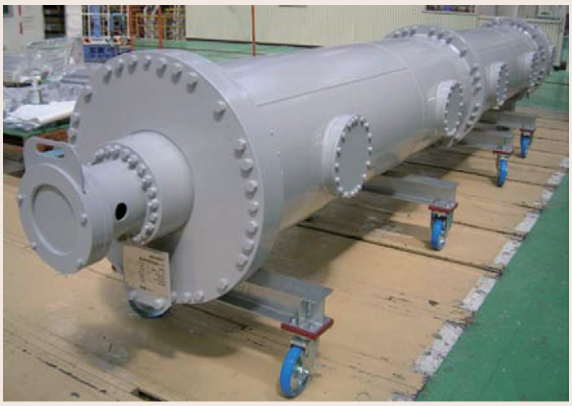



Fig. 4: Hybrid gas-insulated bus and the joint part structure

By coating a high-voltage conductor with a thick solid insulator (up to 10 mm), the maximum electric field in the gas is reduced; therefore, compact equipment is available using natural gas such as $CO_2$. By using electric field shielding inside a supporting spacer, the deterioration of the electric insulation performance of the jointing and supporting part can be reduced.



300 kV/4,000 A
Bus model for single phase

- Cross section: $\phi$140/400 mm coaxial (coating thickness of 10 mm)
- Length (including edge electrode): Up to 3 m (with three conductor-supporting spacers and edges)

Fig. 5: Container including a prototype 300 kV-class gas/solid hybrid insulated bus model

The sizes of a prototype 300 kV-class gas/solid hybrid insulated bus model were derived from electric field design on the basis of insulation breakdown characteristics of the structure of jointing and supporting, and thermal dissipation characteristics of solid insulation coating and gas.