Element Technologies for All-solid Insulated Substation

Background

Electric power equipment which has been introduced in large quantities during period high economic growth must be replaced in the near future, due to exceeding their designed lifetime, 30 years generally. For the power equipment introduced in the future, more exquisite consideration of the environmental aspect than that for the conventional equipment is required. Insulating oils and SF_6 gas are used as an effective insulation medium broadly, but rigorous management is necessary from the aspect of the fire disaster prevention and global warming. In contrast, for a solid insulation medium, there is no environmental load by leakage and no fear of fire accident.

We aim at the development of the next-generation substation which makes the best use of solid insulation medium. We mainly investigate the element technologies in order to realize its maintenance-freeness, intelligence, unitization as well as improvement of environmental influence..

Principal results

(1) Proposal of an all-solid insulated transformer

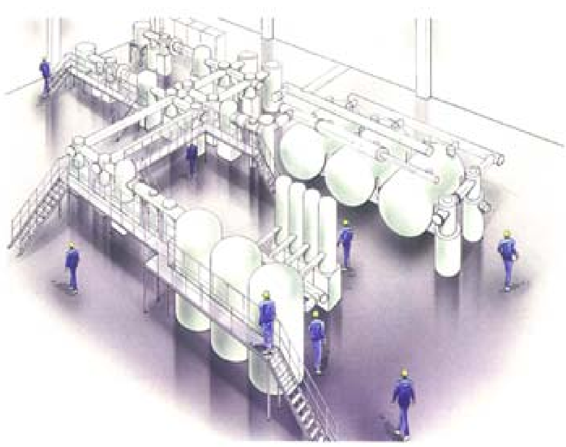
We have proposed the following items for realization prospect of an all-solid insulated transformer with large capacity.

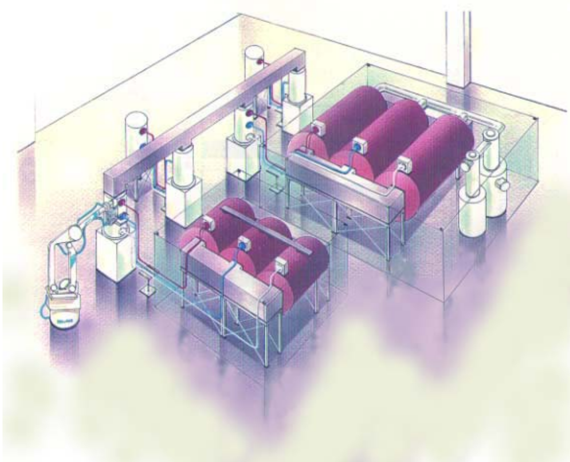
(a) Improvement of heat dispersion radiation characteristics by adoption of the vertical windings.

(b) Adoption of an electrical insulating materials with fillers with high thermal conductivity.

(2) Proposal of a compact all-solid insulated connection system

A flexible connection system is required to connect each power equipment in order to make high flexibility in a layout of power equipment and minimize total setting space. We have proposed a all-solid insulated connection system which has compact connection system, "Hyper Connector" and a cable section with high flexibility.

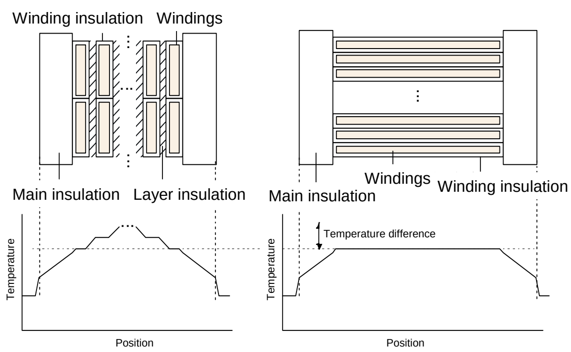




Future Developments

We will improve the design and evaluation methods of the all-solid insulated substation, and promote the investigations in extending the developed designing techniques to the ultra-high-voltage class substation as well as the distribution substation.

Transformer

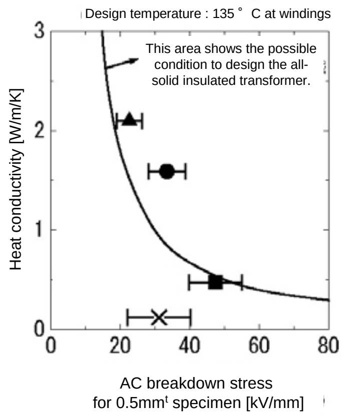


(a) Conventional coil windings

(b) Vertical type coil windings
Having no electrical insulation layer between windings

Shape effect of coil windings (conventional and proposing vertical type)

Compared to the conventional windings (left side), the vertical windings (right side), which we have been proposing, have a flat inner thermal gradient due to elimination of the electrical insulation layer between windings that would be a large heat resistance. This lowers the maximum inner temperature.



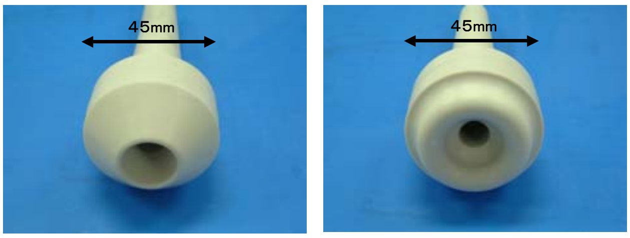
	Filling material in a epoxy resin	
	Kind	Filling rate (vol. %)
×	No filler (Epoxy resin itself)	0
▲	fructured particle (Commercial base)	42.5
■	Spheroidized particle (Commercial base)	35
●	Composite particles	40

Note: Plots show each estimated values at 135 ℃.

Effect of filler

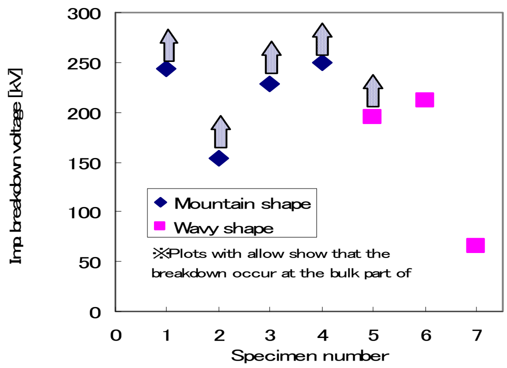
We confirmed that adequate filling materials with high thermal conductivity such as Aluminum Nitride (AlN) improves the heat dispersion characteristics of an epoxy resin. We confirmed that obtained results fulfill the required specification for the all-solid insulated transformer.

Connection system (Hyper Connector)



(a) Mountain shape (b) Wavy shape

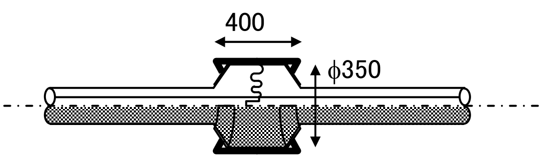
Outer view of the Hyper Connector (prototype)



Impulse breakdown voltage of the prototype Hyper Connector

Connection interface shape of Hyper Connector

We made prototype Hyper Connectors having two interface shapes, (a) mountain shape and (b) wavy shape, which were subjected to impulse breakdown test. As a result, mountain shape could withstand higher voltage which was confirmed from the electric field calculation along the interface which showed that the maximum stress of the mountain shape was lower than that of the wavy shape.



Trial design of 275 kV class Hyper Connector

Trial design of the Hyper Connector

The Hyper Connector has following features;

(a) Shrinkage of longitudinal length by bent interface.

(b) Prevention of local stress enhancement by rounding bent interface.

We carried out the trial design of 275 kV class Hyper Connector, and we confirmed that it could be realized with a size of 135 mm in electrical insulation thickness, 400 mm in length, and $0.04 m^3$ in volume.