Conceptual Design of 60 kV Class All-solid Insulated Transformer with AlN-filled Epoxy Resin – Design Considering Electrical Insulation Property under High Temperature and Property of Bus Bar Connection –

Background

CRIEPI has proposed the concept of the all-solid insulated substation and has been promoting various elementary technologies for its realization. CRIEPI has already proposed the epoxy resin filled with Aluminum Nitride (AlN) which has good heat dissipation property as an insulating material of the all-solid insulated transformer. Moreover, the concept of the all-solid compact connection system has been also proposed.

Objectives

The purpose of this study is to make a trial design of 20 MVA 60 kV class all-solid insulated transformer, with investigation of thickness dependence of AlN-filled epoxy resin under high temperature and improving method of electrical insulation ability of bus bar connection system of the all-solid compact connection system.

Principal Results

1. Thickness dependence of electrical insulation property of AlN-filled epoxy resin under high temperature

Ac Breakdown strength was measured for AlN-filled epoxy resin with various thicknesses under 155℃ considering enough margins. As a result, it was proportional to insulation thickness to the power of -0.23, as shown in Fig. 1.

2. Proposal of the connection method of all-solid compact connection system to keep high electrical insulation level

CRIEPI has proposed the all-solid connection system having an interface of a mountain-shape cross section, which may have decreased electrical insulation property in connection at atmosphere due to residual air layer at its interface. Thus, it is clarified that the electrical insulation ability can increase more than 30% with connection under vacuum condition using splittable vacuum vessel (see Fig. 2) in order to reject the air layer at the connection interface.

3. Conceptual design of 20 MVA 60 kV class all-solid insulated transformer

Conceptual design of 20 MVA 60 kV class all-solid insulated transformer was executed with ac breakdown strength of AlN-filled epoxy resin under high temperature and modified connection method which relates to realize more compact connection system. The constraint condition under design is shown in Table 1. As a result, it is revealed that the all-solid insulated transformer can be designed with almost the same volume and 80 % in weight compared to the conventional oil-immersed transformer under the design condition to fill the constraint condition and to minimize lifetime CO_2 emissions ($LCCO_2$) at process of manufacture, operation, and disposal considering environmental benignity. The conceptual figure of designed transformer is shown in Fig. 3.

Future Developments

The full-scale model of 60 kV class all-solid insulated transformer will be fabricated to verify its design method and its properties by various verification tests including long-term operation test.

Main Researcher: Toshihiro Takahashi, Ph. D.,
Research Scientist, High-voltage & Insulation Sector, Electric Power Engineering Research Laboratory

Reference

T. Okamoto, M. Shibuya, T. Takahashi, Y. Mizutani and T. Takahashi: “Proposal of All-solid Insulated Substation for Future Substation”, Proc. of 7th Int. Conf. on Properties and Applications of Dielectric Materials, No. S22-4, 2003.
T. Takahashi, and T. Okamoto: “Trial Design of Compact Solid Insulated Connection System and Experimental Investigation on Its Electrical Insulation Performance”, Proc. of 7th Int. Conf. on Properties and Applications of Dielectric Materials, No. P1-15, 2003.
M.Shibuya, et al.,: “Proposition of All-solid Insulated Substation”, CRIEPI Report W00047, 2001.
Y. Hori, Y. Mizutani and T. Okamoto: “Proposal of New Concept Solid Insulated Transformer with Environmental Load Evaluation”, CRIEPI Report W00028, 2001.
T. Takahashi, Y. Mizutani, and S. Furukawa: “Design and Evaluation of All-solid Insulated Transformer (Part 6) – Conceptual design of 60 kV class all-solid insulated transformer considering electrical insulating property under high temperature and bus bar connection –”, CRIEPI Report H08016, 2009.

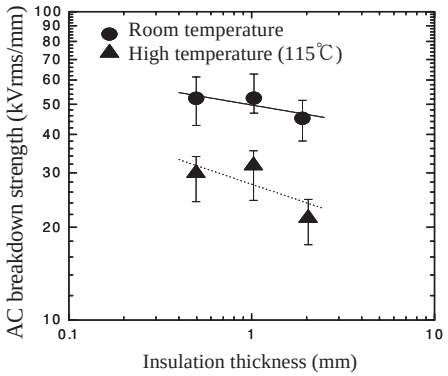

Fig.1 AC breakdown voltages of AlN-filled epoxy resin sheet for different thickness and temperature.

Breakdown strength decreased in proportion to the insulation thickness to the power of -0.23.

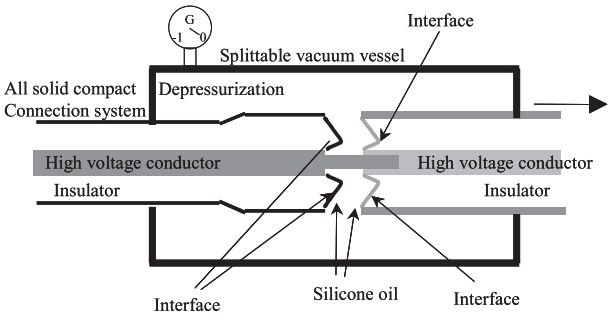

Fig.2 Connection method of the all-solid compact Connection system.

Connection under vacuum atmosphere rejects air layer at the interface to keep the higher insulation ability.

Table 1 Constraint conditions and results of conceptual design of 60 kV class all-solid insulated transformer.

Item	Target value (20MVA)	Result of conceptual design (20MVA)	Spec. of conventional oil-immersed transformer (15MVA)
Volume	Less than 10 m^3	10.0 m^3	10.3 m^3
Weight	Less than 35 t	28.1 t	34.2 t
Efficiency	More than 99.56 %	99.71 %	99.49 %
Height	Less than 2.2 m	2.1 m	2.5 m
$LCCO_2$ evaluation		3303 t-CO_2	4770 t-CO_2

※Except heat radiator

Target specifications are those that overcome the conventional oil-immersed transformer with similar capacity.

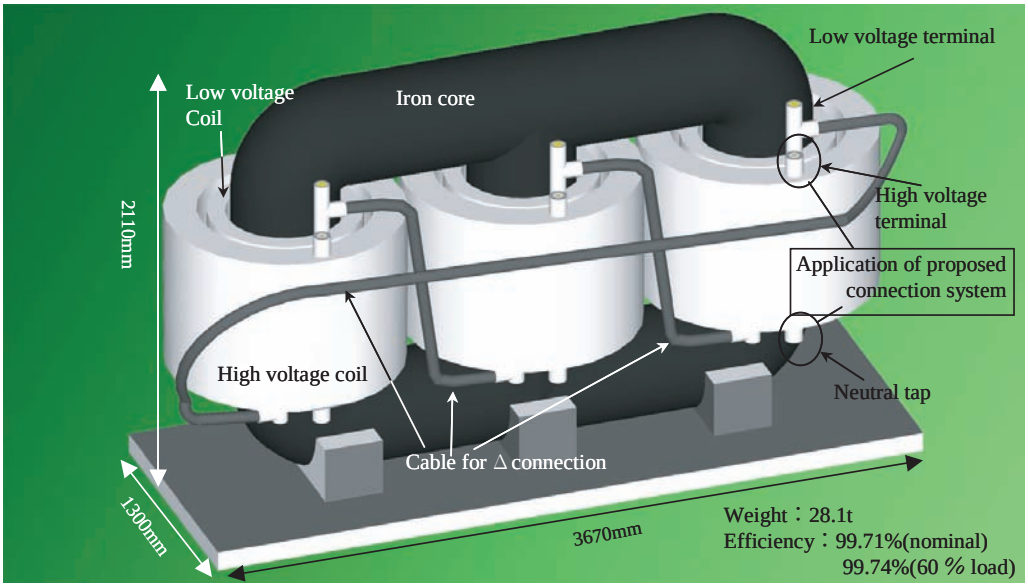

Fig. 3 Schematic figure of designed 60 kV 20 MVA class all-solid insulated transformer. (In the case of the minimum CO_2 emission)

Designed transformer has almost similar volume and 80 % weight compared to the conventional transformer with similar capacity.