Dielectric and Insulating Technology 2006 : Review & Forecast

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Abstract This article reports the state-of-art of TC-DEI (Technical Committee of Dielectrics and Electrical Insulation of IEEJ) activities. The activities are basically based on the activities of 8-10 investigation committees under TC-DEI. Recent activities were categorized into three functions in this article and remarkable activity or trend for each category is mentioned as was seen in the articles of 2005. Those are activities on asset management (AI application and insulation diagnosis), activities on new insulating and functional materials (Nano composite) and activities on new insulation technology for power transmission (high Tc superconducting cable insulation).

Keywords : insulation diagnosis, insulation design, nanocomposite, thinfilms

1. Overview of the Activities of the Technical Committee on Dielectrics and Electrical Insulation (TC-DEI)

The committee was set up in 1979 succeeding the Permanent Committee on Electrical Insulating Materials upon the reorganization of IEEJ. The activities of the committee have been covering mainly solid and composite dielectric materials and their technologies. The important activity of TC-DEI is the annual Symposium of Electrical and Electronic Insulating Materials and Applications in Systems (SEEMAS), formerly called Symposium on Electrical Insulating Materials.

The TC-DEI organized 36th Symposium (2004 SEEIMAS) held at Shibaura Institute of Technology, Tokyo with General Chair of Dr. T.Okamoto. TC-DEI also organized 2005 International Symposium on Electrical Insulating Materials (ISEIM) in Kitakyusyu-shi, Japan with Honorary Chair of Prof. T.Tanaka and General Chair of Dr. T.Okamoto. The TC-DEI currently runs ten Investigation Committees (IC's) that organize several technical meetings a year. The IC's are categorized into four research areas as followings:

[Macro-view of DEI technology related]

- Environment-friendly materials and systems for electric and electronics application (04/04-03/07, Chairman: Y.Suzuoki (Nagoya University))
- Economical evaluation of insulation diagnosis (04/04-03/07, Chairman: N.Hozumi (Toyohashi University of Technology))

[New materials including nano-materials related]

- Application and improvement of organic molecular films and organic/inorganic composites with controlled nano-structures (04/04-03/07, Chairman: F.Kaneko (Niigata University))
- Dielectric and insulating materials for information communication (01/04-12/06, Chairman: K.Fukunaga (National Institute of Information and communication Technology))
- Development of organic electrical and electronic materials with flexible structure to nanotechnology (07/03-06/06, Chairman: M.Iwamaoto (Tokyo Institute of Technology))
- Application of nano-composite materials to DEI systems (10/02-09/05, Chairman: T.Tanaka (Waseda University))

[Diagnosis of electric and electronic equipment related]

- On-line insulation diagnostic methods of power cable and apparatus (01/03-12/05, Chairman: K. Uchida (Chubu Electric Power Company))
- Insulation ageing and surge endurance of printed circuit boards (04/02-03/05, Chairman: Y.Yamano (Chiba University))

[Basic dielectric and breakdown phenomena related]

- Charge behavior and interface of high electric field insulation(07/02-06/05, Chairman: M. Nagao (Toyohashi University of Technology))
- Discharge evaluation and ageing phenomena on the surface of polymer insulators (04/02-03/05, Chairman: K. Gotoh (Consultant))

2. Activities on Asset Management and Risk Management (AI Application and Insulation Diagnosis)

Recent trends in insulation diagnostic technology for power equipment are strongly affected due to power business liberalization. Through the papers of international conferences certain trends in insulating technology can be conjectured. Large international conference such as CIGRE meeting and ISEIM are some of the best meeting to get the trend information in the engineering research direction. There are many interesting papers concerning insulation technology.

One important trend is introduction and widening of asset management concept to minimize their maintenance cost. In that line, global view of asset management including insulation diagnosis of power equipment or intense environmental stand point of view such as RCM (reliability-centered maintenance) concept are introduced properly as shown in Fig.1.

Along with asset management concept, the failure rate of SF6 circuit-breakers was analyzed and decomposed into characteristic failure rate as shown in Fig.2.

In order to develop the asset management methods, insulation diagnostic methods are key technology such as insulation condition assessment of the stator windings, condition assessment and lifetime extension of power transformers, life assessment of power transformers to prepare a rehabilitation based on a technical-economical analysis, condition based evaluation of net transformers -experience from a new ranking procedure, the impact of economic and reliability considerations on decisions

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Fig. 1. Interpretation of reliability-centered maintenance⁽¹⁾

Fig. 2. Hydraulic drives of SF6 circuit-breakers⁽¹⁾

Fig. 3. Life-cycle costs with different diagnostic parameters⁽²⁾
(failure loss: 100, replacement expense: 1, diagnosis expense: 0.1)

regarding the life management of power transformers, life cycle assessment of substations, asset management in a deregulated environment, development of asset management services.

As an example of asset management consideration, life cycle cost of cable maintenance was estimated in terms of diagnosis interval and replacement criterion as shown in Fig.3. This result indicate there must be the maximum cost effective maintenance procedure for each power equipment depending on its insulation degradation characteristics or risk behavior and therefore to develop proper asset management for each equipment and system becomes one of the most important issues that insulating technology concerns.

In order to construct an effective asset management method, diagnostic methods also play an important role in it. There are proposed several effective diagnostic methods for power equipments. One example is shown in Fig. 4. PD pulses were

Fig. 4. Examples of DAC voltages as applied to a 220kV power cable showing PD activity in a termination; PD activity at 50kV (upper), PD activity at 100kV (middle), PD activity at 150kV (lower)⁽³⁾

Fig. 5. SEM micrograph of XLPE with 5% untreated nanosilica⁽⁴⁾

detected at lower voltage with ocilating wave form in a 220 kV power cable.

3. Activities on New Insulating Materials (Nano Composite)

Recently research activities on nano-composite material developments including organic and inorganic materials have been very intensive. One direction is to modify the conventional polymer with nanomaterials to change their mechanical, electrical and others. As for one example of organic material improvement, polyolefin was modified with silica nano particle to improve mechanical property. The results explore the electrical properties of silicon dioxide nanoparticle/low-density cross-linked polyethylene matrix composites and the effect of the large interface on breakdown strength with both polar and non-polar surface treatments. Figures 5 and 6 show the SEM photograph of the compsite materials and their electrical property. With the nano particle, the electrical property (AC breakdown strength) was

Fig. 6. Weibull plot for the dielectric breakdown strength of XLPE with 5 weight percentage micro- and untreated and surface-treated nanosilica measured at 25°C ⁽⁴⁾

Fig. 7. Surface profiles of the specimens after partial discharge degradation test; (a) without nanofillers, (b) with 3 wt% nanofillers, (c) with 5 wt% nanofillers, (d) with 7 wt% nanofillers ⁽⁵⁾

Fig. 8. LN2 pressure dependence on delay time from heater energization to PD generation ⁽⁶⁾

improved.

Other important materials such as epoxy resins were also improved with nano-composite. Epoxy/alumina nanocomposites were prepared by dispersing 3, 5, and 7 weight % nano-scale boehmite alumina particles in a bisphenol-A epoxy resin. Flexural properties, dynamic viscoelasticity, permittivity, partial discharge (PD) resistance, and electrical breakdown time were investigated

for the nanocomposite specimens in comparison with those of an epoxy resin without nanofillers. Due to dispersion of the nanofillers in the specimens, flexural properties, PD resistance (as shown in Fig. 7), and electrical breakdown time are improved.

4. Activities on New Insulation Technology for Power Transmission (High Tc Super Conducting Cable Insulation)

For the optimization of electrical insulation design for High Temperature Superconducting (HTS) cable, evaluation of electrical insulation characteristics especially for butt gap of LN2 impregnated cold dielectric (CD) plays an important role and steady progress was reported.

For operation of the HTS cable, a quench phenomenon would occur due to over-current operation, degradation of the HTS materials, and so forth. In that case, local heating would occur and local evaporation of liquid nitrogen would occur, which may lead reduction of the electrical insulation capability and generate partial discharge (PD) under operational voltage application. This paper deals PD inception characteristics with local heating simulating local quench of HTS material. As a result, it is revealed that there is a time delay from the start of heating to PD generation, and the delay depends on the pressure of liquid nitrogen as shown in Fig. 8.

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