Project Research — **Further Improvement of Facility Operations and Maintenance Technologies**

Operation and Diagnosis of Aged Power Apparatuses for Substations and Underground Power Transmission Lines

Background and Objective

Recently, the management and maintenance of aged power apparatuses have become an urgent issue for the electric power industry, and cost reduction including running cost, repair cost, and renewal cost is also an important issue. Within these last several years, huge numbers of power apparatuses, which were manufactured and installed during the rapid economic growth periods in Japan, seem to be reaching the end of their expected life. Based on such a situation, this research project aims mainly at two items. One is to develop on-site diagnosis methods of aged power apparatuses, while the other is to provide a user-friendly decision support tool for maintain aged power apparatuses. For these objectives, the research project aims at the development and practical utilization of on-site deterioration diagnosis techniques for the main apparatuses of power transmission and distribution systems. As the main apparatuses, power transformers of 66 kV to 275 kV class, XLPE cables of 22 kV to 66 kV class, and GIS (gas-insulated switchgears) are selected. On the other hand, the research project aims to establish optimal criteria to determine renewal time as well as to develop rational and reliable maintenance decision support programs for aged equipment based on the actual maintenance cost data of such apparatuses. In addition to those main apparatuses stated above, the project also aims to develop an evaluation method of coating layer degradation as a common issue of power apparatuses.

Main results

1 Development of On-site Insulation Degradation Diagnostic Methods for Power Apparatuses in Substations and Underground Transmission Lines

A diagnostic method for the thermal deterioration of the insulation paper of transformers has been proposed. The method utilizes basically only the load history of the transformer, and the method has been applied to distribution transformers (66-kV class) up to extra-high voltage transformers (275-kV class). The estimation error of the degree of polymerization of the insulation paper based on this method was found to be practically acceptable (±10%) as shown in Fig. 1 (H11026). As for the abnormality diagnostic method of a transformer winding, a transfer function obtained by a frequency response analysis (FRA) is utilized, and an abnormal part of an actual transformer winding structure can be estimated as shown in Fig. 2 (H11027). In addition, a partial discharge recognition technique has been improved to detect minute water tree degradation in removed XLPE power cables in order to establish a XLPE power cable degradation database for future use, and a new on-site diagnosis method for aged XLPE power cables has been proposed based on a dumped oscillating wave voltage source (H11031). Furthermore, a new diagnosis method to detect the abnormality of gas-insulated switch gears (GIS) has been proposed based on an analysis of absorbed by-product gases from partial discharge.

2 Development of Decision Support Programs for the Maintenance and Renewal of Power Apparatuses

In order to develop decision support tools for making rational renewal and update plans for aged power apparatuses, a support program for a single apparatus such as a transformer and a gas-insulated breaker (GCB) has been proposed by minimizing the average annual maintenance cost for such apparatuses based on the actual maintenance costs. Through the experience of developing those programs, more complicated programs for multi-component apparatuses such as gas-insulated switch gears (GIS) and overhead transmission lines have been developed. On the other hand, an estimation program has been proposed in order to compare the difference of the averaged annual maintenance cost based on the different maintenance strategies and to estimate the effect of life estimation accuracy of a given diagnostic method as shown in Fig. 3 (H11032).

3 Development of an Estimation Method for Coating Layer Deterioration

In order to develop an estimation method for coating layer deterioration for power equipment such as transmission towers, a long term accelerating aging test has been carried out using typical coated steel plates with a molten zinc primary coat and an epoxy resin secondary coat. The plates were set in three different inclinations, namely, horizontal, a 45° inclination, and vertical. The test continued for 55 months, and the results showed that the horizontal setting has the fastest degradation and that the coating impedance can detect a faint difference of degradation with higher sensitivity than surface observation by human eyes.

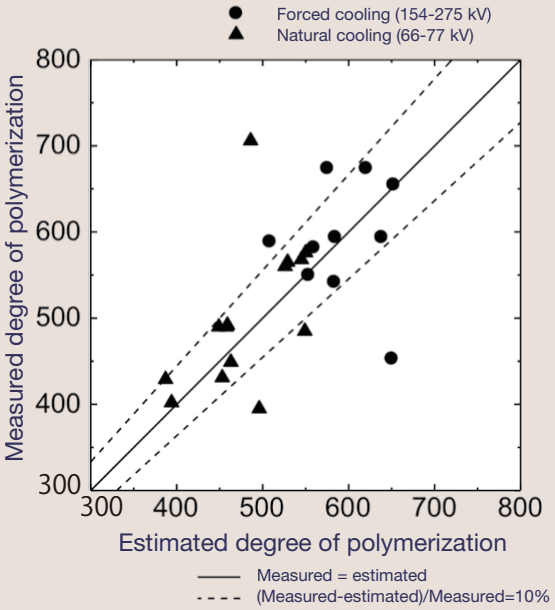

Fig. 1: Comparison between the measured and estimated averaged degree-of-polymerization of oil-impregnated insulation papers in 66–275 kV power transformers

We found good agreement between the estimated averaged degree of polymerization and that measured for 24 66–275 kV power transformers. The average error of the estimation was found to be less than 10%.

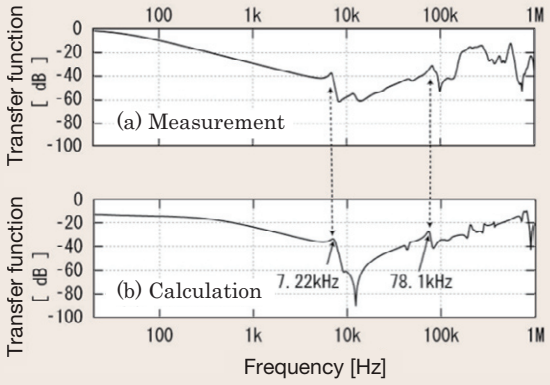

Fig. 2: Measured and calculated transfer functions

We tried to develop an equivalent circuit to obtain a theoretical transfer function based on the structure and actual sizes of each part of a 66-kV power transformer. As shown in the above figures, the peak positions of the measured and calculated transfer functions are similar to one another. With this result, there seems to be clear possibility to develop a method to correlate the peak frequency change of a transfer function and the coil abnormality. For example, the peak frequency of a transfer function at about 7.22 kHz in the figure is found to be shifted according to the distance change between the primary winding and the secondary winding.

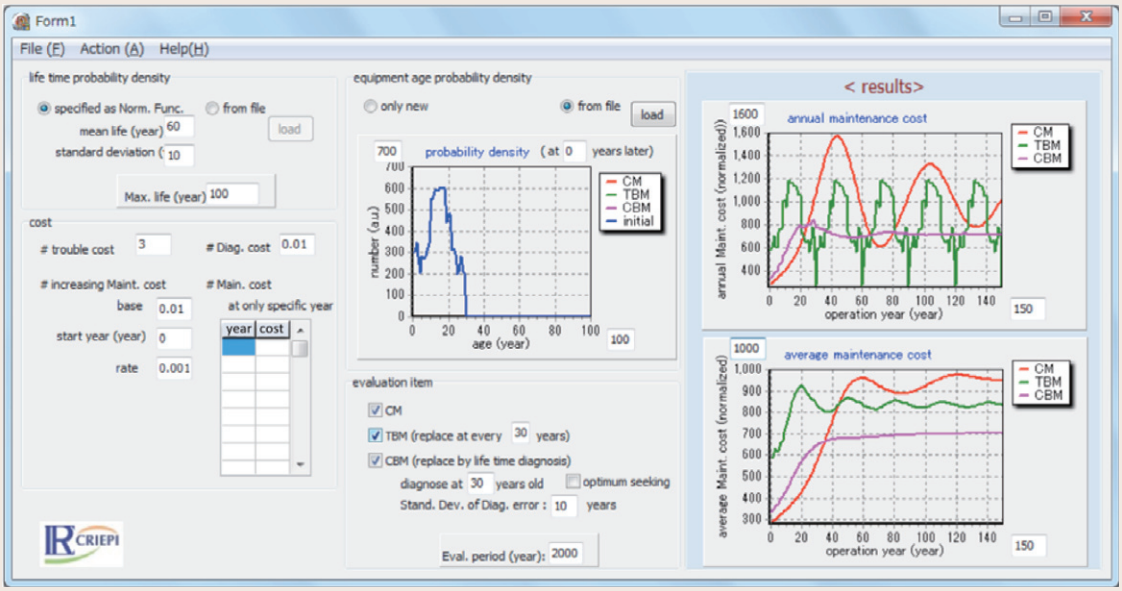

Fig. 3: Sample display of a program to compare long-term effect under different maintenance strategies

This program can compare the long-term effect of different maintenance methods on the average maintenance cost. The methods to be compared are CM (corrective maintenance), TBM (time-based maintenance), and CBM (condition-based maintenance) based on several types of input information, such as equipment age distribution and expected life time probability. It can evaluate the annual and average maintenance cost during the operation period of the equipment. This program uses a graphical user interface and is designed to be easy in utilization for staff responsible for devising maintenance strategies and developing diagnosis techniques. The sample calculation in the sub-figure at the lower right corner shows that TBM and CBM are more expensive than CM before 40 years of operation, but after that, CBM has the lowest maintenance cost among those methods.