# Decision of Replacement Time by Executing Insulation Tests to Aged Electric Power Apparatus
## – Estimation of Cumulative Insulation Fault Probability under Different Levels of Voltage Application –

## Background

Lots of electric power equipments which were installed during the period of high economic growth are arriving at their supposed lifetime one after another in Japan. Therefore, an important problem concerns how many pieces of aged electric power equipment are effectively maintained, managed, and replaced. Hence, it is necessary to develop condition diagnosis technique and confirmation method of healthy condition by executing insulation tests for the aged power equipment *[1]. Thus, establishment of a maintenance standard for such aged power equipment is required, which is helpful to making decisions on the possibility of prolonged operation under proper reliability and of the replacement time. If an insulation test is executed for aged power equipment again, it is important to estimate risk (the cumulative insulation fault probability) considering the background (life-stress) of the voltage applications including the insulation test for the second time.

## Objectives

To propose proper specifications of the insulation test for the aged power equipment, the effect of the insulation test on the cumulative insulation fault probability is estimated.

## Principal Results

### 1. Effect of on-site insulation test on cumulative insulation fault probability

By considering the life-stress for a long period (Fig.1), increase of the cumulative insulation fault probability due to the insulation test (Fig.2) was estimated using the life-stress model *[2] based on Weibull distribution and the inverse-power-law. For gas-insulated power equipment (for example gas-insulated switchgear (GIS) and gas blast circuit breaker (GCB)), the applied test voltage at which the cumulative fault probability increased steeply was from 2.5 pu *[3] to 3.2 pu when the presence of metallic foreign object was assumed, and its variation was small even if the applied time was changed from 1 hour to 1 ms as shown in Fig.3(a). On the other hand, for XLPE cable (66kV class, no water tree condition) in which deterioration of insulation was generally accumulated, the applied test voltage at which the cumulative fault probability increased steeply was 5 pu for 1 hour and 13 pu for 1 ms, and its change was large compared with GIS/GCB.

### 2. Specifications of on-site insulation test for aged power equipment

Supposed test voltage and time was shown in Table 1 by estimating the increase of the fault probability under the life-stress (voltage pattern 3 in Fig.1). It was supposed that the test voltage was up to 2pu and 3pu, and the applied test time was up to 1 hour and 1sec for GIS/GCB and XLPE cable, respectively.

## Future Developments

The confirmation method for judging healthy condition of aged power equipment by executing on-site insulation tests will be developed and the maintenance standard will be established.

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***Reference***

H. Goshima, M. Yashima, 2006, "Feasibility of Decision of Replacement Time by Executing Insulation Tests to Aged Power Equipment -Estimation of Cumulative Insulation Fault Probability under Different Levels of Voltage Application," CRIEPI Report H06016 (in Japanese)

*1 : H.Goshima, et al. "Feasibility of Replacement Postponement Based on Insulation Test for Aged Gas-Insulated Power Equipment," IEEJ Trans. PE, Vol.126, No.7, pp.694-700, 2006 (in Japanese)
*2 : H.Hirose: "Theoretical Foundation for Residual Lifetime Estimation," IEEJ Trans. PE, Vol.116, No.7, pp.168-173, 1996.
*3 : 1 pu represents the working voltage.

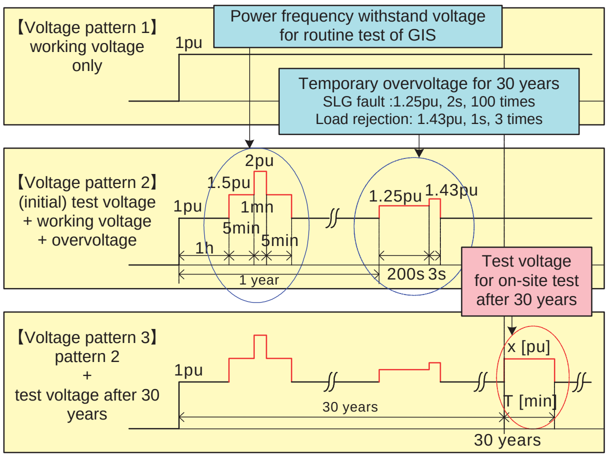



**Fig.1** Voltage pattern based on the insulation test for aged gas-insulated power equipment.

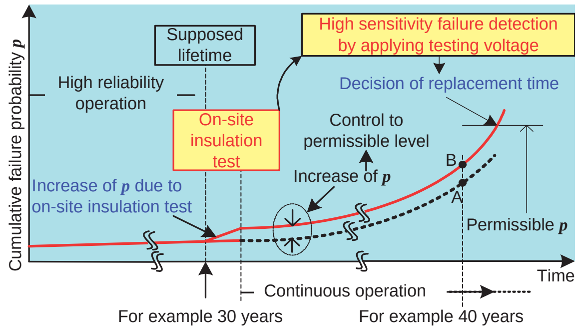
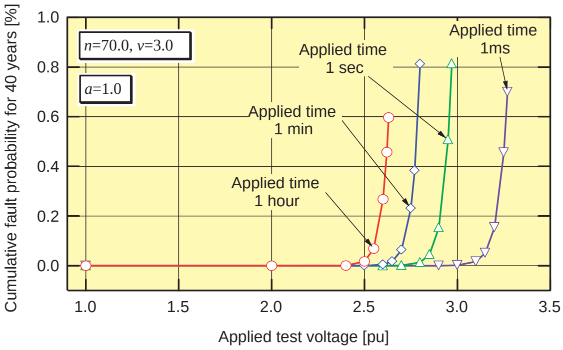
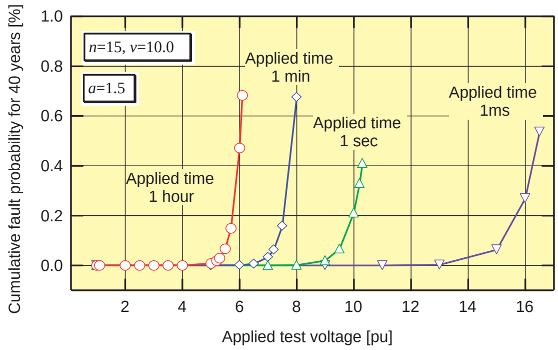



**Fig.2** Schematic illustration of influence of the insulation test for aged power equipment on cumulative insulation failure probability.




(a) GIS/GCB




(b) XLPE cable (66kV class, No water tree)

**Fig.3** Cumulative fault probability after 40 years as a function of voltage value of the insulation test.

**Table 1** Summary of arrangement of the insulation test for aged electric power equipment.

| Object | Influence on cumulative fault probability | Insulation test from viewpoint of insulation performance | Supposed test voltage and time | Notes |
|---|---|---|---|---|
| GIS/GCB | # Higher voltage values cannot be set for insulation test even if applied time is set to be short.<br># Long-duration voltage application is effective. | # Partial discharge will not always occur for short-time voltage application, depending on the situation of metallic particle. | up to 1hour<br><br>up to 2.0pu | # Object is gas in the presence of metallic particles.<br># Influence (degradation) of insulation test on insulating spacer is supposed to be small. |
| XLPE cable | # The shorter the applied time, the smaller is influence on cumulative fault probability even if selecting higher voltage value of insulation test.<br># Short-duration voltage application is effective. | # It may be possible to detect partial discharge for even short-duration voltage application because defect is fixed in solid.<br># It is important to produce further degradation by insulation test. | up to 1sec<br><br>up to 3.0pu | # Object is 66kV class, no water tree cable. |

Note: adopted parameters of GIS/GCB: $n$=70.0, $v$=3.0, $a$=0.5-1.0, and XLPE cable: $n$=15.0, $v$=10.0, $a$=0.5-2.0