Study Committee B1

Insulated cables

10690_2022

Investigation of Cause of Breakdown and Replacement of 275kV SCOF Cable by XLPE Cable in Japan

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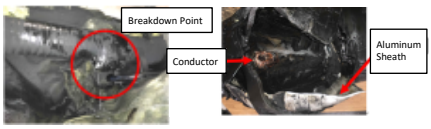
Introduction

- In Japan, about 3000km of SCOF cables are in operation.
- Japanese TSO have managed the state of the SCOF cable joints by dissolved gas analysis (DGA)
- In order to prevent SCOF cable faults and fires, advanced maintenance technology and fire prevention measures are needed

Insulation Breakdown of 275kV SCOF Facilities and Investigation Results

- In 2019, a 34-year-old 275 kV SCOF line (copper 2000 mm^2 with aluminum sheath) broke down
- The insulation breakdown occurred immediately after the restart operation



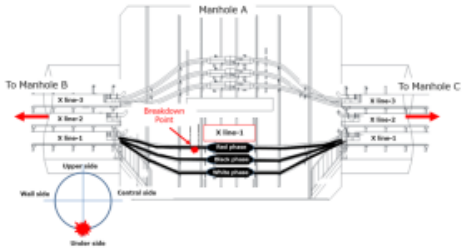


Fig.1 Location of insulation breakdown

- Some deposits were found on the joint in dismantling survey
- Elemental analysis to deposits confirmed the presence of copper, carbon, and sulfur

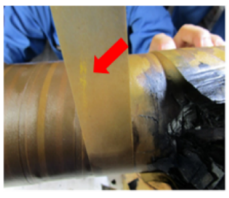


Fig.2 Yellow deposits

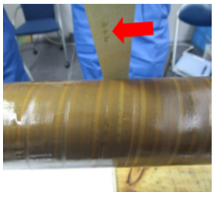


Fig.3 Black deposits

- The insulation performance deteriorates with copper and sulfur deposits.

Discharge start voltage without deposits:40 to 50kV/mm

Discharge start voltage with deposits: 27 to 40kV/mm

Clarification of the process of SCOF Cable deterioration

We had model test, and confirmed the following

- In the electrophoresis model test with dissolved copper and sulfur, the electrophoresis phenomenon occurred
- Higher sulfur content led to higher deposition of the compounds.
- For the first time, we found deposition of copper compounds is promoted by the components of vulcanization accelerators used in rubber products for joints.

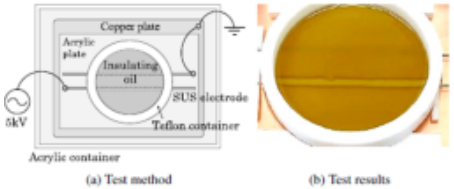


Fig.4 Dielectrophoresis test results

- The PD deterioration process

- ✓ Step1. Copper is dissolved from the conductor and other components into oil as copper compounds
- ✓ Step2. Oil flows and dielectrophoresis make copper compounds concentrate in the paper gap, leading to oxidation sludge and copper sulfide
- ✓ Step3. Minor PD occurs
- ✓ Step4. Copper compounds agglomerate and PD makes wax
- ✓ Step5. Continuous PD occurs and it result in loss of insulation strength
- ✓ Step6. A switching surge causes a dielectric breakdown

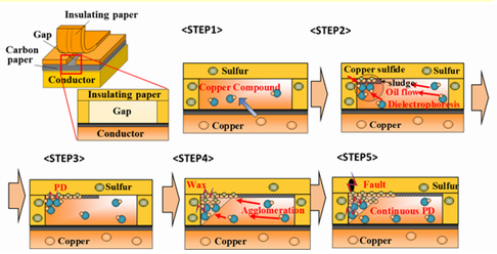


Fig.5 SCOF cable charging degradation mechanism

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We confirmed this process with the model

- The model simulates the electric field gradient of a real cable
- Partial discharges were repeatedly generated, and finally it leads to a breakdown

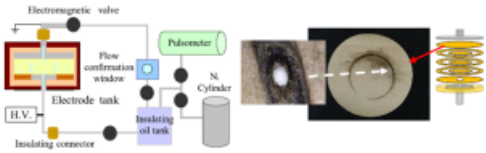

Fig.6 Model test and insulation breakdown

ICP diagnosis method for SCOF cables

We applied a new diagnostic method (ICP imposed deterioration degradation diagnosis)

- ICP diagnosis is a diagnostic method for determining the progress of imposed deterioration based on the amount of dissolved copper and the amount of gas generated.
- The diagnosis results were compared with the results of dismantling surveys and reported to be approximately 96% consistent.

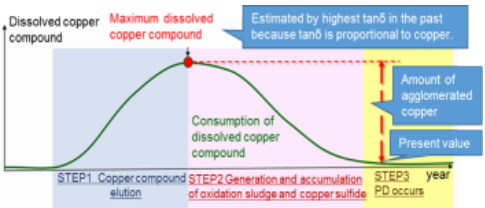

Fig.7 Concept of diagnostic method using ICP measurement

We applied the ICP diagnosis method to the other joints on the same line.

- The result of ICP diagnostic method showed a joint that had the worst abnormal rank by the same manufacturer.
- In dismantling survey, we found similar deposits
- These results demonstrated the validity of the ICP diagnosis results.

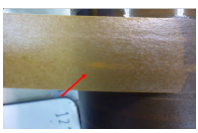

Fig.8 Yellow deposits

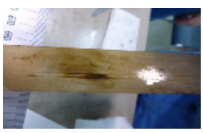

Fig.9 Black deposits

PD measurement

- Adopted a clamp-type high-frequency CT, which does not require line outage and is easy to install.
- we developed an online partial discharge monitoring system that uses PLC(Power Line Communication) as the communication channel and obtains the induced power from other cable lines.

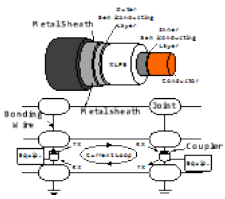

Fig.10 Signal transmission by cable sheath

Replacement work

- The replacement work for the deteriorated line with TJ (Transient joint) was completed
- TJ is a combination of PMJ (Pre-fabricated Mold Joint) and the joint of SCOF cable.

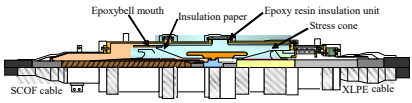

Fig.11 Transient joint structure

- We introduced an automatic fire extinguishing system without a power supply for the first time for TJs.
- Fire can be detected by the melting of the sensor tube owing to the heat generated by the fire

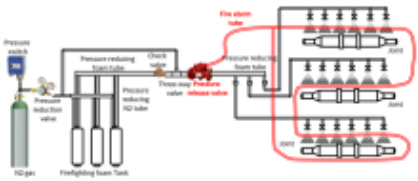

Fig.12 Over all view of a powerless fire extinguishing system

Conclusion

- An insulation breakdown occurred in a highly aged SCOF cable line.
- PD occurs by the oxidation sludge and copper sulfide
- We developed and applied a new diagnostic method (ICP imposed deterioration diagnosis method) focusing on the relationship between the amount of copper and the progress of deterioration..
- We replaced the deteriorated section in line with XLPE cables, Transient joint with fire extinguishing system.