

Failure Investigation of the Flashover of an 11 Kv Oil Link Unit

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The Oil Link Unit (OLU) at Substation A experienced a flashover on 21 July 2007 at approximately 10.35 a.m. The incident occurred during the opening operation of the OLU, which was manufactured in 1977. The Failure Analysis Group of TNB Research Sdn Bhd (TNBR) was commissioned by the Utility Asset Manager to conduct a failure analysis on the OLU at P/E Hwa Hong to determine if there was any inadequacy in the equipment. The findings and report of the investigation is as presented.

The maintenance records showed that the OLU was being maintained according to procedure. The oil samples taken from the busbar and switching compartment showed low BDV value and a high moisture content. The switching compartment was filled with black soot and sludge. All the parts were still intact in the switching compartment except for the Yph. The dismantled parts of the three phases moving and fixed switching contacts had arcing marks. However, there was no damage to the busbar compartment. Most of the gaskets had deteriorated.

The flashover could have occurred due to prolonged arcing during the switching open of the OLU (between the Yph moving and fixed contacts) primarily due to a degradation of the insulation oil in the switching compartment. When this occurred, other secondary arcing had then ensued.

It is recommended that the condition of the gasket and rubber seal of the OLU should be changed when its condition have deteriorated. An oil analysis should be carried out whenever there is a change in colour or when the oil volume had gone below the minimum required level.

BACKGROUND

The OLU at Substation A experienced a flashover which caused the tripping of the Vacuum Circuit Breaker (VCB) at the adjacent station.

TECHNICAL SPECIFICATIONS

The technical specification and nameplate information are as follows:

- Type: OLU Oil Switch
- Service Voltage: 6.6 or 11kV
- Normal Current: 400A
- Breaking Current: 400A
- Making Capacity: 33.4 peak kA
- Short Time Current: 13.1kA. 3 seconds
- Frequency: 50Hz

The OLU consists of three main parts, namely, the busbar compartment, the switching compartment and the incoming cable box. The whole compartment is mounted on a steel support frame.

After the unit failed, oil was taken out from the busbar and breaker compartments and sent to the Transformer Oil Lab (TOL) of TNBR for insulation testing. The oil was tested on 28 July 2007. The test result is as shown:

Note:

- Sample A: Busbar compartment (tested at TOL)
- Sample B*: Busbar compartment (tested at site and TOL)
- Sample C: Switching compartment (tested at TOL)
- Sample D: Switching compartment (tested at site and TOL)

Some oil samples from the busbar and switching compartments were tested at site, and the test results for BDV was 11kV and 14kV respectively. Oil samples A and B were taken from the busbar compartment. Sample A was tested at TOL while sample B was tested both at site and TOL using the same oil sample.

However, the volume for sample B was insufficient to carry out the BDV and density test respectively. Oil samples C and D were taken from the switching compartment. Sample C was tested at TOL

Table 1: Summary of oil analysis on hyrax oil used in the damaged OLU

Samples/Tests	A	B*	C	D	Reference
Moisture (H ₂ O), ppm	58	65	46	59	15 (30-Max)
Density, g/cm ³	0.8879	NA*	0.8889	0.8889	0.8893
Flash Point (FP) °C (Class 1)	146	144	144	142	145
Dielectric Breakdown (BDV), kV	28	NA*	31	6	44 (30-Min)

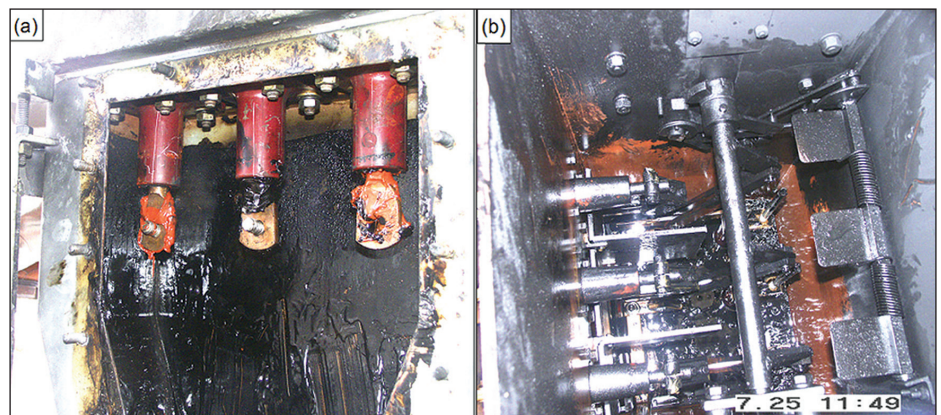


Figure 1: Switching and incoming cable compartment

while sample D was tested both at site and TOL using the same oil sample.

MAINTENANCE HISTORY AT SUBSTATION A

The substation's maintenance record was investigated. From available records, maintenance of the substation was last carried out on 5 October 2005. The substation's preventive maintenance included general inspection on the busbar and busbar chamber, operating mechanism, test plug inspection and cable box inspection. According to the records, the test results were satisfactory. The scheduled inspection checklist was also found to be satisfactory.

SITE VISIT TO SUBSTATION A ON 25 JULY 2007

The Failure Analysis Group, together with the Asset Manager, Asset Maintenance unit and the manufacturer, went to the site for further investigation of the damaged OLU. All of the parts on the damaged OLU were intact after the incident. However, the switching and incoming cable compartment was filled with black soot as in Figure 1.

The oil level was approximately 2 inches lower than the minimum required level. The low oil level was most probably the result of splashing of oil from the switching compartment during the flashover. The damaged drain cap had contributed very little to the low oil level. However, scheduled maintenance conducted three months prior to the incident did not detect any oil leak. The leak, if any, could have been very minimal.

The busbar compartment's mineral oil was still clear even after the incident. However, the oil level was also below the minimum required level. There was no history of scheduled maintenance conducted three months prior to the incident on the busbar compartment and no damage was detected there. The top cover of the switching compartment had become dented and the middle part was slightly opened after the incident.

The rubber seal on the top cover of the switching compartment had damage marks with uneven thickness. The Yph earth switch fixed contact and moving contact were dismantled at site and brought back to TNBR. The OLU's insulation oil in the switching and busbar compartments was drained out at site and

the testing was done there. Some of the samples were taken back to TNBR for oil analysis at TOL.

VISUAL/PHYSICAL EXAMINATION General Methodology

The OLU was first examined in the as-received condition. The moving and fixed (switching and earth switch) contacts for the Rph, Yph and Bph were removed from the switching compartment. The busbar and switching compartment were cleaned of soot and oil. The OLU contained no oil when received at the Failure Analysis lab at TNBR. The Yph earthing switch fixed contact was still intact in the switching compartment when the OLU was sent to TNBR. The Rph and Bph fixed and moving switching contacts together with the earth fixed contacts were intact when the OLU was delivered. The switching compartment was filled with black soot and sludge. The mineral insulating oil was very sticky and sludgy. There were signs of dents on the top cover of the switching compartment due to the outward force.

The most effected part is the Yph cable test plug. Pitted and arcing marks were observed along the cable test plug. The busbar compartment parts were all still intact when examined at TNBR. There was no sign of damage on the copper busbar, bushings and also the steel wall compartment.

However, the gasket on the busbar connection plate was observed to have deteriorated (Figure 2).

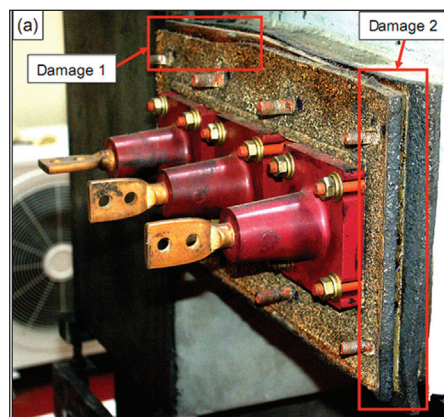


Figure 2: Busbar connection plate

DISCUSSION

The initial flashover had probably started from the Yph moving switching contact to the fixed switching contact during the opening of the OLU from the CLOSE

to OPEN position. This is supported by the arcing marks found only on the Yph moving switching contact. This is possible because the moving switching contact was still carrying current and had a flashover during the opening from high potential (moving switching contact) to zero potential (fixed switching contact) under a degraded insulation medium.

The arcing generated during the opening should have been quenched by the insulating oil in the switching compartment. However, due to poor and degraded insulation oil, it was incapable of quenching the arc swiftly and this, consequently, created a highly conductive plasma and other contaminants, e.g. carbon, hot gases, metal pieces, etc, within the insulating medium.

The contaminants generated in the switching compartment thus created other possible arcing path such as arcing between phases and phases to earth as shown by available evidence. These damages are categorised as secondary damage.

The root cause of the failure was possibly due to a degradation of oil in the switching compartment. This is further supported by the low breakdown voltage from the oil analysis.

CONCLUSION

The flashover could have happened due to prolonged arcing during the switching open of the OLU (between the Yph moving and fixed contacts) primarily due to a degradation of the insulation oil in the switching compartment. When this occurred, other secondary arcing had thus ensued. ■

RECOMMENDATIONS

Based on the experience gained during the investigation of the failure of the OLU, the Failure Analysis Group would like to recommend the following measures:

- The condition of the gasket and rubber seal of the OLU should be changed when its condition have deteriorated.
- An oil analysis should be carried out whenever there is a change in colour or when the oil volume had gone below the minimum required level.
- All new OLU's to be purchased should have sight glass to show the level of oil in the switching and busbar compartments.
- The person who handles switching must always wear PPE to avoid any injury.