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Forensic Analysis of Automatic Splices Leads to Change

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During the early 1980s, BC Hydro began using automatic sleeves for splicing aluminum distribuion conductors. These sleeves became popular with many utilities because of their ease in installation without the need for dies and crimping tools. Now, 20 years later, BC Hydro (Burnaby, British Columbia, Canada) is reverting to compression sleeves for splicing Aluminum Conductor Steel Reinforced (ACSR) and Aluminum Stranded Conductor (ASC).

Failures of the Splices

In 1998, in the coastal city of Prince Rupert, several automatic splice failures occurred, resulting in energized primary conductors falling to the ground. Investigation of the failures disclosed corrosion of the splices, probably due to the salty seacoast environment. For an entire installed population of automatic splices in excess of 100,000, the failure rate over the next several years continued at a low but relatively steady rate. However, with the possibility of more energized conductors falling to the ground, public safety was a concern.

Investigating the Failures

An initial random sampling of in-service automatic splices in a few service areas indicated that 45% were in poor to fair condition and were at risk of premature failure as a result of corrosion. Samples from wet-weather geographic regions were more at risk than those from dry areas.

Forensic analysis by Powertech Labs Inc. (Surrey, British Columbia) showed that splices found to be in an advanced stage of deterioration were corroded on all interior surfaces, including the inside of the outer tube, all jaw surfaces and the spring (Fig. 1). Also, corroded splices tended to fail under high current loading and during faults. Fig. 2 shows typical debris from such failures.

To develop a condition assessment of sample splices removed from service, a numerical ranking scale was constructed for three significant attributes of interest:

1. **Corrosion Condition**

   Rank 1: Very heavy buildup of corrosion around conductor and both jaws

   Rank 2: Generally corroded around conductor jaws, or heavily corroded around one side of conductor and jaws

   Rank 3: Corrosion in spots between conductor and jaws

   Rank 4: Little corrosion

   Rank 5: No corrosion

2. **Arcing/Heating Condition**

   Rank 1: Heavy arcing/heating damage

Rank 2: Significant arcing in two or more locations and significant heating

Rank 3: Signs of heating and a small amount of arcing in one location

Rank 4: Signs of moderate heating but no arcing

Rank 5: No arcing or heating

3. **General Condition**

   Rank 1: Very poor condition with failure imminent under normal load current or immediately under fault current

   Rank 2: Poor condition with failure likely in near future under normal load current or immediately under fault current

   Rank 3: Marginal condition with a risk for failure onset under normal load current and under fault current

   Rank 4: Aged but in generally good condition with failure unlikely in the near future under normal load or fault current

   Rank 5: Very clean inside and in near perfect condition

Using this ranking system, the laboratory analyses of 24 automatic splice samples taken from a distribution circuit located on Vancouver Island were summarized. Included in the summary were the year of manufacture, the condition of each splice end identified as being either north (N) or south (S) and the lubricant type being either grease or wax. The average ratings were 2.83 for corrosion, 3.79 for arcing/heating and 3.00 for overall condition. The proportion of 24 splices potentially at risk for future failures during normal load or fault conditions was estimated to be 46%. Out of 48 splice halves, 17% exhibited a heavy buildup of corrosion and 13% had heavy arcing damage.

Remedial Action

The experience with the failed splices resulted in a revision of purchase specifications. This included a provision for accelerated aging tests, whereby splices are simultaneously subjected to salt fog, mechanical tension and controlled electrical currents as well as short duration burst of high current following blocks of salt fog exposure. The new type test specifications were developed for automatics sleeves to better model actual in-service conditions as follows:

- The splice is installed on lengths of conductor with crimped and welded current equalizers, which are held in a jig for applying tension to the splice and simultaneously passing a controlled current through the splice (Fig. 3).
- A bare wire is similarly installed as a control conductor.
- The splices are tensioned to a specified level above the manufacturer's minimum recommended service tension.
- The tensioned splices are subjected to three blocks of 500 hours of salt fog corrosion testing for a total of 1500 hours, during which time alternating cycles of clear rain, acidic salt fog and current heating are applied.
- During each 500-hour corrosion test, periodic dc current resistance measurements are made to determine changes in resistance that would indicate a deterioration of the connection.
- After each 500-hour corrosion test, splices are subjected to five short duration bursts of high current.
- Splices pass these tests if the dc resistance, at the conclusion of the testing, is no greater than that of the control wire subjected to the same testing.

It was expected that suppliers would undertake these tests to come up with a redesigned splice that would offer greater reliability. Because this expectation was never realized, BC Hydro initiated a risk assessment program to determine how to manage the maintenance of the existing splices still in service. The program involved removing statistically significant quantities of splices from various environments, noting parameters involving climate, sources of pollution and thermographic readings. With this information, the data can be analyzed to develop event trees to determine the least-cost risk-based maintenance solutions by geographic service areas.

Conclusion

From an asset management point of view, it was decided to revert to compression-type splices for all new work and for maintenance replacements of automatic splices. A primary consideration in making this decision was the wide discrepancy between the useful life of the automatic splice compared with the life of the conductor. At BC Hydro, the useful life of the automatic splice is about 20 years, whereas the conductor is expected to last at least 40 years. The change to compression splices has involved major tasks for retooling, revising work methods and finding adequate supplies of approved compression connectors. This transition process is proceeding deliberately and smoothly as a result of the efforts of technical staff, researchers, line staff and purchasing agents.

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