CIGRE-479
Root cause analysis of damaged ACSR conductors during construction of a 500 kV transmission line

Presented by: Chen Wang

Senior Transmission Engineer

Manitoba Hydro

Project Background

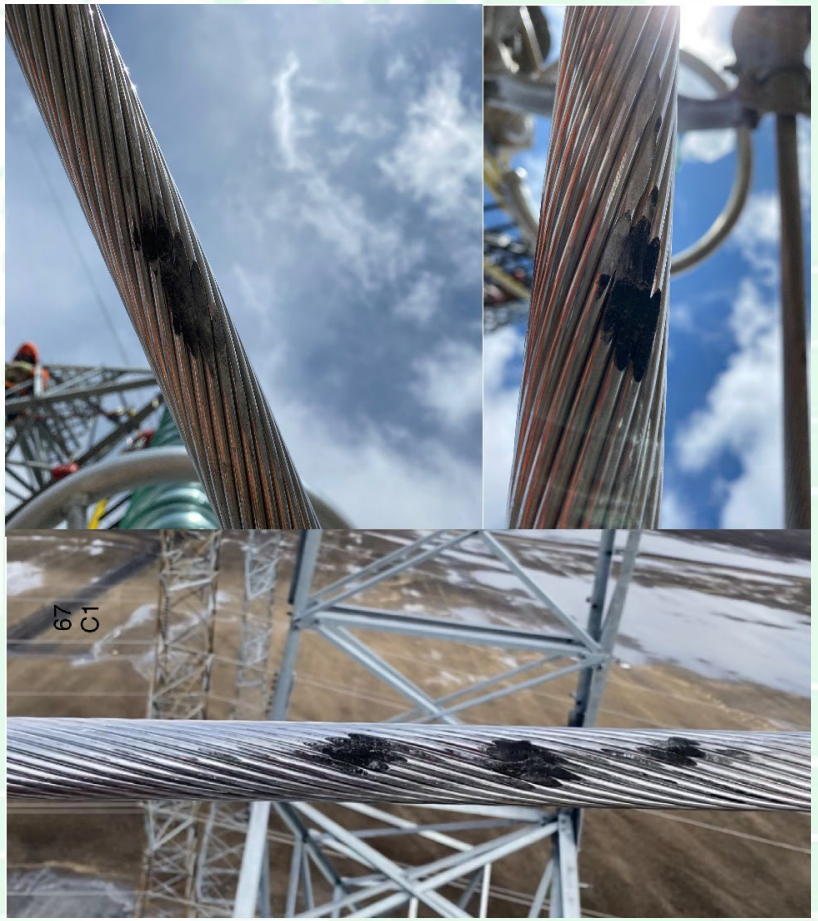
- During a recent 500 kV transmission line projects, a triple bundle configuration with ACSR conductor had been selected as phase conductor, and a 2200 m catenary parameter was adopted for conductor tension criteria.
- Spacer-dampers were required for protection against aeolian vibration and sub-span oscillation.
- During stringing and sagging the conductor, the conductor was loaded for a minimum of one hour to accelerate initial set and creep immediately before sagging. The phase conductor was then tensioned in the travelers to 95% of the sag shown on the sag data sheets.
- After sagging the phase conductor, the conductor shall not remain in traveler for a period exceeding 72 hours before clipping and installing the spacer-damper.

Project Background

- Temporary safe grounding is another requirement during stringing of conductor for this project.
- Several sections of this line are located in a congested area involving exposure to energized parallel lines or the crossing of existing energized lines, the maximum earthing requirements was used following IEEE Standard 524.
- Such maximum earthing requirements include bonding and earthing of equipment, the use of running earths, earth mats at work sites, and stringing block earths.

Unforeseen Damage

- After the conductor stringing, our field line inspectors identified multiple damaged locations and “black marks” along the phase conductor near the suspension clamp.
- Some locations experienced severe damage such as broken strands and some other locations have flattened wires or cut marks.
- These unanticipated damages raised a major concern on the lifespan of the conductor and required a detailed investigation and root cause analysis.

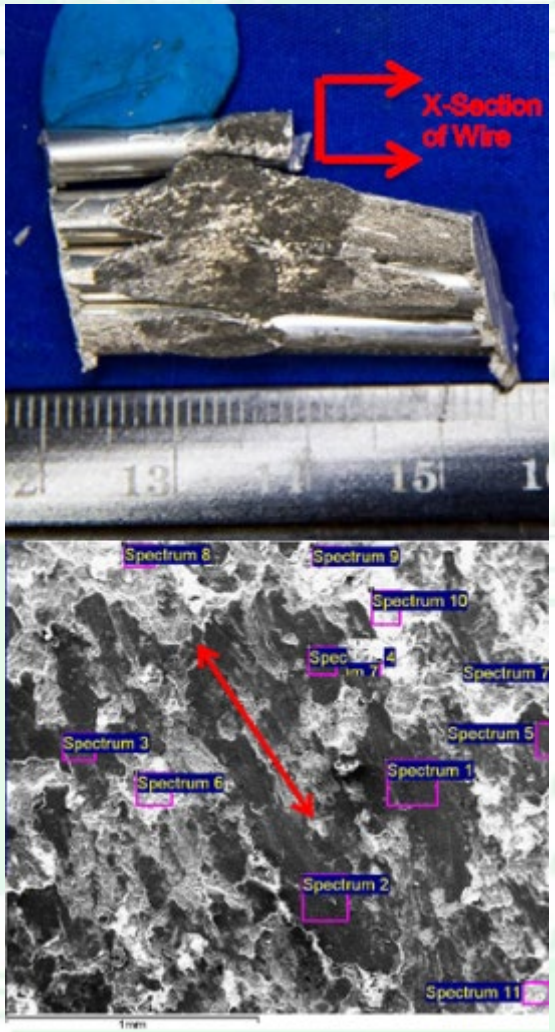


Investigation – Quality of Conductor

- The first possible cause can be due to poor quality of the conductor.
- Sample conductor from on-hand stock was sent to 3rd party laboratory to reconfirm all the technical specifications against CSA/ASTM standard and Manitoba Hydro specifications.
- Sample conductors from different suppliers also went through additional hardness test at 3rd party laboratory.
- The conductor fully confirms all related standards and specifications. So, this possibility was quickly eliminated from the list.

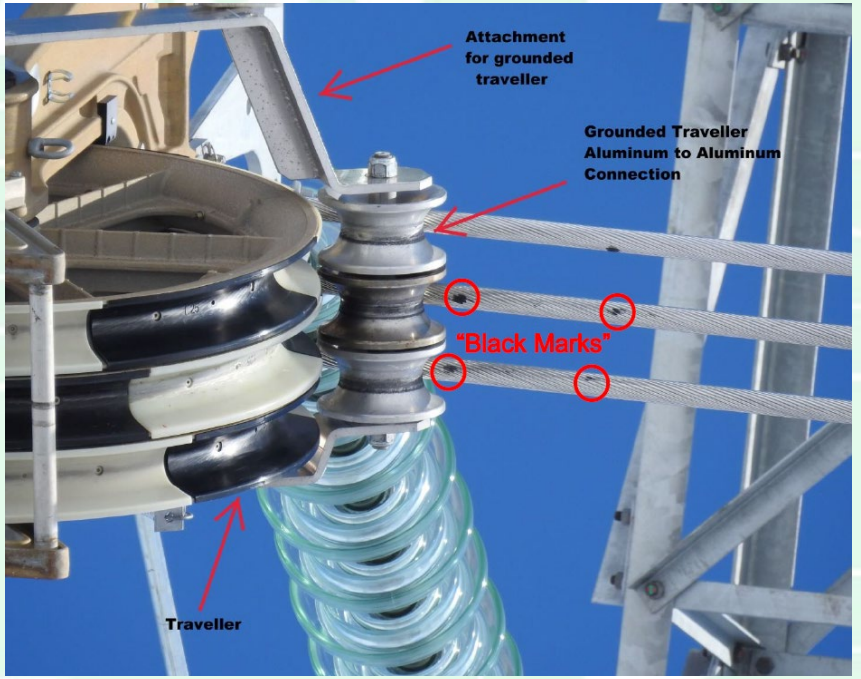
Investigation – Chemical Analysis

- The sample of damaged conductor was also sent to a chemical lab for further analysis.
- A portion of the outer surface of the conductor containing wire strands was cut out for the Scanning Electron Microscope (SEM) examination / Energy Dispersive X-Ray (EDX) Chemical Analysis of the damaged surface of the conductor.
- Based on the chemical analysis, the “black mark” on the phase conductor is aluminum oxide which could be caused by local frictional heating.



Investigation – Installation Procedure

- After identifying a possible cause (local frictional heating), Manitoba Hydro has reviewed the installation procedure and construction records.
- Multiple spans were identified as violating the maximum of 72 hours requirement between sagging and clipping/installation of spacer-damper.
- The ground traveler was also identified as contributing to the conductor damage.
- The documented delays during stringing allowed the conductors to sit on the ground traveler for a long period is one of the major causes of conductor damage.

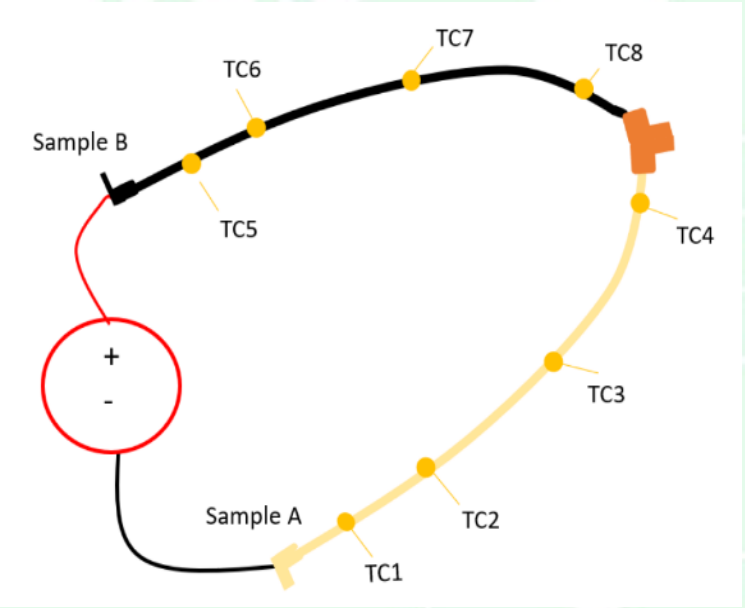


Investigation – Field Inspection and Testing

- To confirm the severity of damage on phase conductor, both non-destructive robotic tool and mobile X-ray were used.
- The non-destructive robotic tool was used to inspect the steel core.
- Mobile X-ray was used to examine all aluminum layers near the suspension clamp to confirm the condition of the aluminum strands.

Investigation – Thermal Profile and Electrical Testing

- In addition to mechanical strength loss, a degradation in electrical/thermal performance was also a concern and was investigated in a 3rd party lab.
- The expected operating temperature for this conductor under test condition should be 94°C; Some damage areas resulted in localized heating that exceeded the design temperature and may cause annealing of the conductor. (maximum temperature is 103.2°C)



Mitigation and Repair Plan

Damaged Component	Severity of Damage	Mitigation Method
Wire / Individual Strand	Up to 10% of strand depth; “intact”	Smooth or polish strand
	10% - 50% of strand depth; “damaged”	Armor/repair rods required to restore conductor strength; refer to criteria for damaged conductor (below)
	>50% of strand depth; “broken”	Armor/repair rods required to restore conductor strength; refer to criteria for damaged conductor (below)
Conductor	≤5 damaged/broken strands on outer layer	Armor/repair rods required to restore conductor strength
	>5 damaged/broken outer aluminum strands on outer layer, or any damage to inner layers	Full tension splice required to restore full conductor strength

Conclusion

- A root cause analysis of the visibly damaged on outer strands of ACSR conductor identified extended undesirable contact between the conductor and Ground Traveler as major cause of the damage.
- The stringing procedure including the ground traveler application has been revised at Manitoba Hydro to minimize the possible conductor damage in future project.
- Manitoba Hydro’s experience has been also shared within CIGRe and IEEE committee for consideration in future updates to their standards and technical brochures.