Using ice monitoring and modelling to increase reliability and optimise OHTL route planning

Boris Adum[1], Øyvind Welgaard[1], Arild Kvamme Berstad[1], Miroslav Radojčić[2]

[1] *Statnett SF, Norway*
[2] *Opp Kraftledningstjenester AS, Norway*

Boris.Adum@statnett.no, Oyvind.Welgaard@Statnett.no, Arild.Berstad@Statnett.no, Miroslav.Radojcic@opp-as.no

Abstract— **The paper presents implementation of an ice load monitoring system on an overhead line operated by Statnett, and on three ice-load monitoring (test) spans. The line was commissioned in December 2013 and shortly after, actual ice loads were found to be considerably higher than design ice loads. After immediate repairs to the OHL were completed, an ice monitoring test span was erected in parallel to the transmission line. In addition to the test-span an ice load cell was installed in one of the transmission lines spans for proactive monitoring. After four seasons of measurement, it was decided to erect two more test spans and investigate possibilities for local line rerouting. A local ice map with higher resolution was made. Three alternative line routes were studied, of which one is under consideration to be used for rerouting a part of the line.**

Keywords— ***in-cloud icing, transmission line, monitoring, design, rerouting***

I. Introduction

Sima-Samnanger transmission line is, since commissioning 9.12.2013, been exposed to a breadth of damages and outages caused by icing or wind, or a combination of the two. One of the biggest events was breakage of the shield wire 24.12.2013, right after commissioning. During a field trip to the line icing of 69 kg/m was measured, the design ice load for the line was 25 kg/m.

Fig. 1 - Icing on the broken OPGW shield wire

The event triggered the establishing of an ice monitoring span parallel to the power line in November 2014 [1], development of ice monitoring sensors that were installed in the power line to monitor icing on the phase conductors, and the subsequent installation of two additional ice monitoring spans in November of 2020. Ice monitoring equipment was installed on other lines as well [2].

Two ice measuring projects were started in the aftermath of the collapse. The first project – Frontlines, had a main aim of developing a toolbox with numerical methods and algorithms for accessing maximum design icing for transmission lines, it was initiated by Statnett and Kjeller Vindteknikk in 2014 by an application to the Norwegian Research Council Energy program [1]. The second project Icebox [3], was initiated by Statnett, project partners and supported by the Research council of Norway.

One of the activities in the Icebox projects was to create a national icing map to be used as input for transmission line design. Parts of this icing map, measurements on the test spans, and influence on the line route are presented.

II. Corrective actions and reviewed alternatives

From commissioning and up until today, the transmission line has seen a number of flashovers and subsequent outages. Approximately 90% of these can most likely be attributed to ice, wind, combination of the two, or galloping. The remaining 10% can be attributed to lightning.

A. Immediate corrective actions

The shield wires were completely removed from the OHL section most affected by icing.

Fig. 2 - Area where shield wires were removed

Additional measures were done in summer 2014 and autumn 2015:

- Shield wires were removed, OPGW secured to the ground.
- Insulation level was increased.
- In areas with high icing damper loops were moved outside suspension towers.
- In all spans where galloping was suspected interphase spacers were installed and support strings for all loops in tension towers were installed
- An ice monitoring span with a weather station as well as icing sensors in the power line were installed to collect data on icing for the specific location and improve icing models

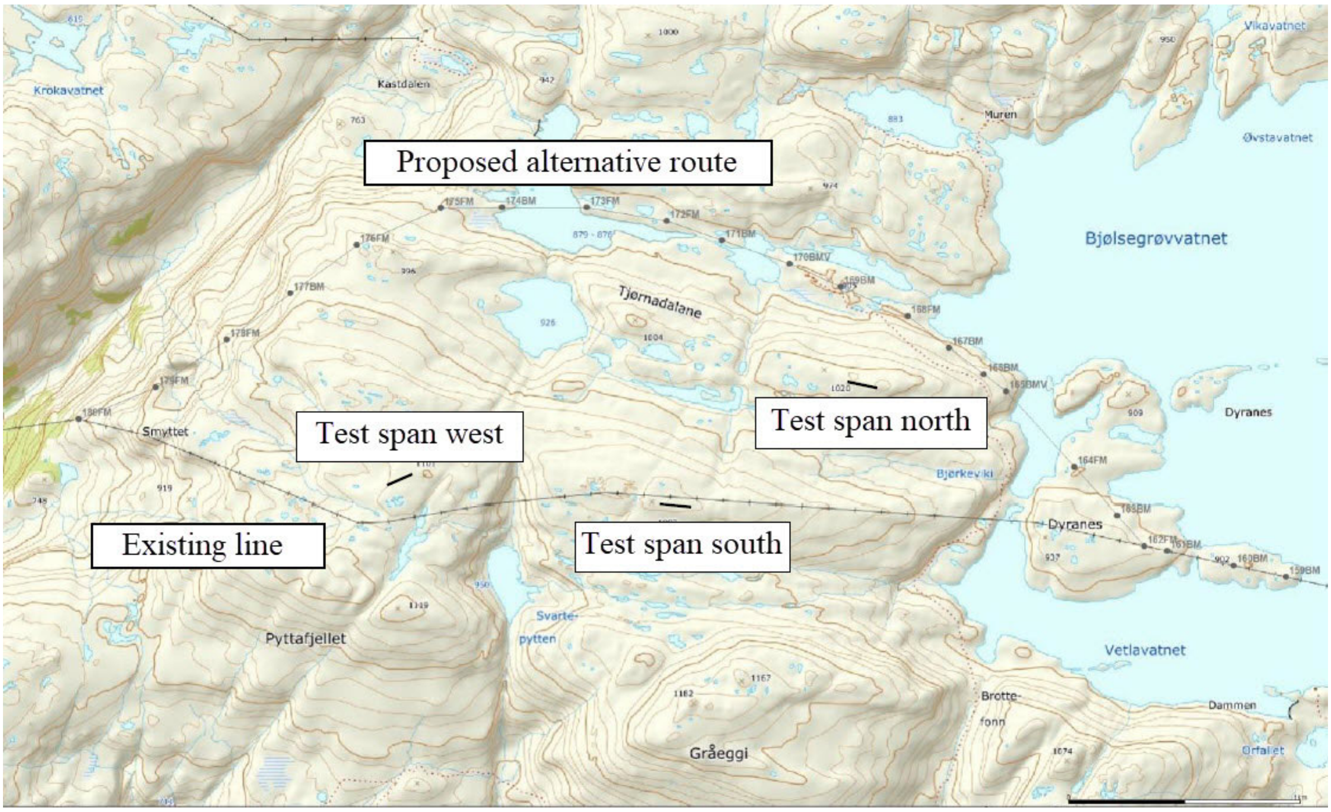

Fig. 3 - Proposed alternative line route and installed icing measurement test-spans

The corrective actions significantly reduced significantly of the number of phase-to-earth and phase-to-phase flashovers on the line. The number of flashovers per year was reduced by a factor of approximately 2,5.

B. Establishing the ice monitoring system and revied alternatives

In total three test spans for ice-load monitoring were installed. The South test span was installed in November 2014, and tests spans West, and North were installed in November 2020. In total there is data for seven icing seasons for test pan South, two seasons of data for test spans North and West. Test spans North and West were installed to better estimate climatic loads, primarily ice-loads, for alternative transmission lines considered.

During first couple of measurement seasons, on test span South and on the transmission line itself, it was established that the maximum ice load on the existing line is considerably higher than the design ice load. Maximum ice load, on the Ålvikfjellet plateau, with a 150-year return time was revised to 145 kg/m, almost six times higher than the original design ice-load of 25 kg/. This had consequences not just for the utilization of the conductors/shield wires as well as towers and foundations, but also the minimum electrical clearances required. Even though the shield wires were removed some towers and foundations were in danger of being overloaded.

Additional factor that needed to be considered is the need for continuous earthing, for correct functioning of the protection systems in the substation, and the need to keep the optical communication possibilities (i.e., optical fiber connection).

There were two critical sections of the line that needed attention, they have different maximum ice-loads so different corrective actions were considered.

Corrective actions proposed for the Langevatnet section:

- Using a stronger phase conductor;
- Removing both shield wires;
- Establishing optical communication by burying and submerging the optical cable along the section;
- Establishing continuous earth with a copper conductor;
- Reinforcing selected towers;
- Reinforcing foundations if needed.

For the section over the Ålvikfjellet plateau it was decided to ask for a permit to change the transmission line route to reduce loads, the permit process is ongoing. Three different rerouting options were considered, one was chosen as the most viable alternative. Prior to applying for a rerouting permit, different corrective actions were considered to keep the line in the existing corridor over Ålvikfjellet.

Options considered for Ålvikfjellet:

- Using a stronger phase conductor;
- Removing both shield wires;
- Establishing optical communication by stringing the OPGW on steel monopole towers parallel to the existing transmission line route;
- Reinforcing towers;
- Reinforcing foundations

It was decided that economically and technically the best solution for the corridor over Ålvikfjellet is to change the line route, if permitted.

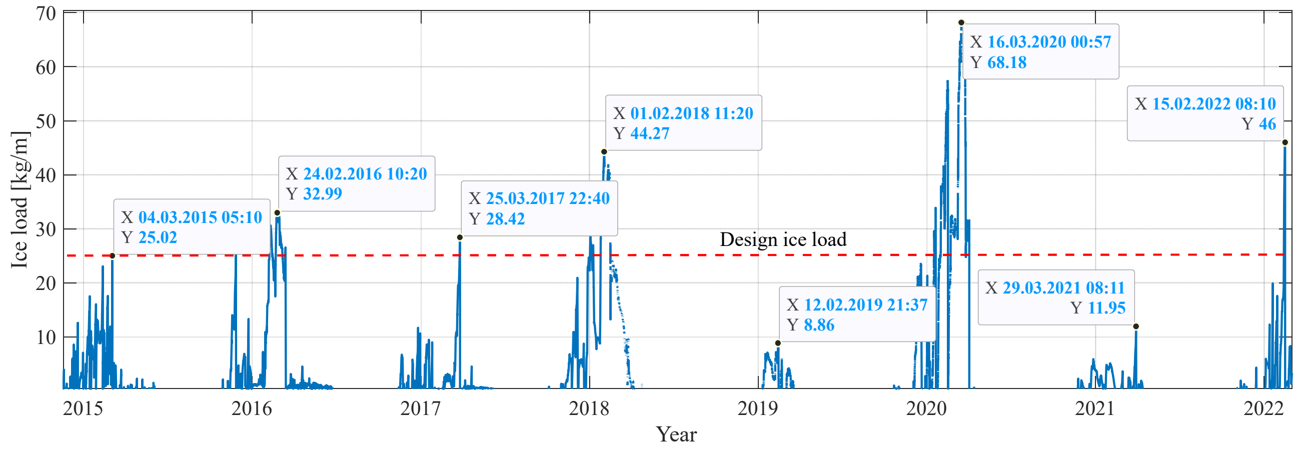

Fig. 4 - Measurements on the South test span with seasonal maximums

III. Measured Icing

South test span was installed first. To verify numerically calculated ice-loads two additional test spans were installed in 2020. One further to the north of the existing test span but still in parallel with the OHL ("North test span"). The second test span was installed north-west of the existing test span and also oriented in the most occurring wind direction ("West test span"). The purpose of the North test span was to verify the assumption that the ice loads will be significantly reduced if it took longer for the moist air to reach the line, and if the span was situated lower in the terrain.

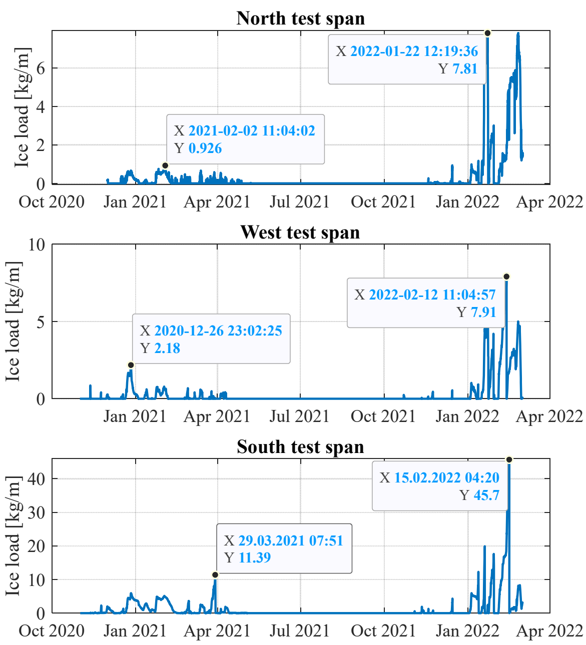

Fig. 5 - 2020-2022 measurements on all three test spans

With test span west, the goal was to verify the assumption of lower ice accumulation if the line was oriented in the same direction as the wind, compared to if the wind was perpendicular to the line, (i.e., the current situation).

If we compare measurements for all three spans, we can see that both assumptions were confirmed. What we also see are significant seasonal variations, as measured values in the same location can vary with a factor of 8 from year to year.

For the new proposed route, the maximum calculated ice load with a 150-year return time is 22 kg/m, which is 6.7 times lower than the calculated 145 kg/m of the existing route.

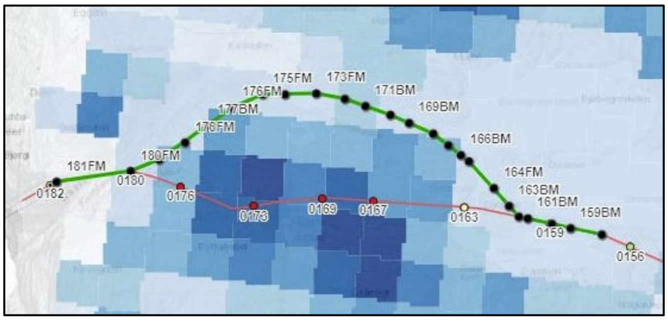

Fig. 6 - Proposed and existing route on an icing chart

IV. Conclusions

Detailed ice mapping, measuring, and modelling proved to be a crucial design tool in areas with extreme icing. Using a design ice for a region is not recommended. In areas with extreme icing longer measurements are advised as well as safety coefficients. On the new proposed route, the line was dimensioned to tolerate 50% higher ice-loads than calculated.

Acknowledgment

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