CASE STUDY SERIES

EXTREME WEATHER

Storms & Heavy Snow | Finland | 2001 to 2017

This case study is part of an extreme weather impact project, in partnership with Swiss RE Corporate Solutions and Marsh & McLennan Companies, which aims to identify and share best practice within the energy sector to enable a more agile and adaptive response to extreme weather and natural hazard impacts on energy systems and supplies.

CASE STUDY AT GLANCE

WEATHER EVENT
Severe Storms and Heavy Snow

ORGANISATION
Caruna

INDUSTRY SUB-SECTOR
Distribution System Operator (DSO)

RESILIENCE RESPONSE
Physical, R&D, Financial, Collaboration

RESILIENCE COSTS
€3–3.5 billion (2015–2028)

RESILIENCE BENEFITS
Stable electricity supply during severe storms

In Finland, 3.5 million customers are connected to 20/0.4 kV distribution system. The distribution systems of 77 distribution system operators (DSOs) consist of 148 000 km of medium-voltage (MV) distribution lines and 246 000 km of low voltage (LV) lines with a cabling rate of 27 % in the MV grids and 47 % in the LV grids (2017). In rural areas, the distribution lines are mainly located in forest areas.

Over the past 20 years, there has been an increasing trend of severe storms and heavy snow loads on trees leading to large-scale disturbances in distribution grids.

Severe disturbances in electricity distribution systems have occurred in the years 2001, 2003, 2010, 2011, 2012 and 2017. A large number of trees have fallen onto overhead lines as a result of strong summer and winter winds or large amounts of wet snow on trees. In the most severe disturbances, 100 000–400 000 DSO customers have experienced lengthy interruptions at the same time.

The most prolonged interruptions have lasted from 4 to 14 days in winter and from 14 to 30 days in the summertime. This case study considers the preventative, response and recovery processes to address severe storms and heavy snow in Finland, as well as what more is needed for future events and critical lessons learned.

CONTEXT

ORGANISATIONAL PROFILE: CARUNA

- Caruna is an electricity distributor in Finland with 600,000 customers.
- Monitoring the electricity network and improving the resilience of the network

SEVERE STORMS & HEAVY SNOW, 2001- 2017

When a severe storm takes place:

- The first moments of the disturbance, the number of customers without power increases rapidly.
- The highest number of customers without power depends on the type of distribution grid (storm proof or not) and the power of the storm or the magnitude of the snow load as well as the geographical extent of the storm.
- When the storm is over, the number of customers without power decreases as a result of automation on the MV grids (remote-controlled disconnectors) and repair activities.

Fault repair in the MV network significantly decreases the number of customers without power, and after 12–48 hours, most of the customers have regained grid connectivity.

ENERGY IMPACTS

Infrastructure: The damage of transmission lines due to falling trees, high winds and heavy snow.

Losses: 100 000–400 000 customers experiencing lengthy interruptions. Interruptions lasting from 4 to 14 days in winter and from 14 to 30 days in the summertime.

The customer level outage costs are about 100 M€/a. The highest annual value of 400 M€/a was reached in the year 2011.

Compensation for disruption can reach €2,000 per customer

The rest of the power recovery time depends on the structure (storm proof or not) of the LV grid and the repair resources. The repair of the remaining single faults on the MV and LV grids has a low impact on the number of customers without power because of the small number of customers behind a single fault.

The snow load of trees is a different type of severe disturbance. The number of simultaneous faults is typically not large, but new active failures will occur for weeks.

RESILIENCE: PREVENTION AND RESPONSE READINESS

National level

The Electricity Market Act and economic regulation of the DSOs implemented by the Finnish Energy Authority include incentives and sanctions related to the reliability of the distribution networks.

The economic regulation of the DSOs enforced by the Energy Authority includes quality incentives/sanctions based on customer level outage costs. In the regulatory model, the value of non-delivered energy (outage cost) is approx. 13 €/kWh. The quality incentive has been in use since 2008.

After the storms in years 2001 and 2003, customer compensation related to lengthy interruptions (> 12 h) was included in the Electricity Market Act in 2003. In 2013, the impact of very extended outages (> 8 days) was added to the Electricity Market Act. The compensation per interruption varies from 10 % to 200 % of the customer's annual DSO bill. The maximum compensation payment per customer per outage is capped at €2000. Customer compensations are like a sanction to the DSOs and decrease their acceptable return.

After the serious disturbances in 2010 and 2011, the Finnish Parliament accepted in 2013 the amended Electricity Market Act with strict targets to eliminate lengthy customer interruptions based on storms and snow loads (e.g. technical fault or icy rain is an acceptable reason for long interruptions). The most protracted acceptable interruptions are six hours in urban and 36 hours in rural areas. The transition period to reach these targets is by the end of 2028. In the furthest rural areas, the transition period is extended to 2036. By the end of 2019, 50 %, and by the end of 2023, 75 % of the customers must be within the above targets.

DSO Level

The economic regulation of the DSOs and the requirements defined by the Electricity Market Act have had significant impacts on the DSOs' operational and investment strategies.

The main actions and functionalities of the DSOs are the following:

- The DSOs must prepare their operational and investment development plans to meet the security of supply requirements within the transition periods. The DSOs must deliver their updated projects to the Energy Authority once in two years. Furthermore, the DSOs must report the number of customers within the requirements.

- The DSOs have improved their capability to prevent and repair faults. This includes activities such as:

   1. On-line readiness to change over from the usual daily organisation to a significant disturbance organisation (management, staff maintenance in 24/7 operation, customer information, media communications, etc.)
   2. Long-term contracts with local and national service providers
   3. Daily proactive preparation with service providers
   4. Constant follow up of weather forecasts and active readiness of resources (repair staff and equipment, helicopters, spare parts, communications, foresters, etc.)
   5. Proactive preparation of line routes and adjacent forests; removal of risk trees
   6. Use of extra extensive line routes for existing overhead lines (40 m instead of 10 m) to ensure storm proof lines for at least the next 20 years

Updated network investment strategies

   1. Replacement of overhead lines by underground cables
   2. Moving overhead lines from forests to roadsides (almost storm proof and fast to repair in the case of a fault) or to open areas (fields)
   3. No new overhead lines in forests

RESILIENCE: TIMELY RECOVERY AND ABILITY TO BOUNCE BACK

Storm-proof network

The requirement of a "storm-proof" electricity distribution grid has required numerous development activities of the DSOs. In addition to operational improvements, DSOs have had to make significant investments in storm proof systems (cabling, moving overhead lines to roadsides) in an accelerated schedule.

Distribution tariffs

Investment costs of cabling in MV systems are more expensive than overhead lines. In LV systems, on the other hand, the investment costs of overhead lines and cables are similar. The total extra investments in storm-free distribution systems will be about 3–3.5 billion euros in 2015–2028 /Ministry of Economic Affairs and Employment in Finland/, which is about a 50 % addition to "normal" replacement investments in components with a maximum age of 40–60 a. For several DSOs, the investments account for more than 50 % of their annual turnover. As a result, the DSOs operating mainly in rural areas are facing significant challenges with distribution tariffs. Consequently, they must raise their distribution tariffs (by 30–50 % in the long term) because of massive investments.

Reliability of supply

The reliability of supply has improved based on the above-described requirements and associated organisational improvements and investments. Figure 3 shows a significant decrease in customer outage costs and customer compensations in the time period of 2011–2017. At present, the customer level outage costs are about 100 M€/a. The highest annual value of 400 M€/a was reached in the year 2011. At the same time, compensations paid to customers because of long interruptions have significantly decreased. It is expected that the outage costs and customer compensations will be very low after 2028.

The experiences from winter 2019 were also positive. Although the snow loads on trees were massive and there were significant damages in forests, the number of long interruptions was low. For example, a rural DSO having about 100 000 customers operated with four helicopters continuously for one month in order to observe trees that posed a risk to the distribution system. Based on the information obtained, they removed the risk trees before they caused damages to the distribution lines.

BARRIERS

Working cross-sector: It can be a challenge to break people out of silos, but complicated issues like this need communication across response groups, technical experts, government and industry to develop frameworks jointly.

Cost and balancing priorities: Some actions can be in opposition to one another. Spending quickly on a solution does not always address long-term challenges.

Financial/environmental/technical performance tradeoffs: Considering the balance of tradeoffs through risk and risk mitigation lenses helps. There needs to be a comprehensive way of vetting different approaches.

Scale: Reduction of utility ignitions is complicated due to the extent of infrastructure in Finland.

ENABLERS

Technical innovation: Weather analytics, forecasting, satellites, Artificial Intelligence (AI), and machine learning will all improve information quality and understanding.

ANTICIPATION OF FUTURE EVENTS

In general, there has been a continuous collaboration between different stakeholders (Parliament, Ministries, Energy Authority, Association of Energy Industries, DSOs, service providers, research institutes, universities, etc.) in order to find cost-efficient solutions now and in the long term.

LESSONS LEARNT FOR DYNAMIC RESILIENCE

- It is extremely important to have a clear overview of the event, including thousands of single events in a large geographical area. Helicopters are an excellent tool if the weather does not prevent their use.
- Network automation significantly facilitates the management of operational work, yet it does not reduce the number of faults.
- Large-scale disturbances as such cannot be managed without long power outages to customers. The readiness to maintain (by the control room staff) and repair thousands of simultaneous faults requires "unlimited" resources. In addition to the improvement in operational actions, there is a clear need to update the network development/investment strategies.