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HVDC Cable Installation in Freshwater Lake (Suldalsvatnet)

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SUMMARY

The world's longest HVDC cable link between UK and Norway has been developed as a joint project between National Grid and Statnett SF. The main elements of the project consist of 2 x 720 km of 525kV submarine HVDC (MI) cable and two converter stations.

One of the many challenges facing National Grid and Statnett in the North Sea Link project was to find a strong point in the Norwegian HVAC grid that would be suitable to connect the HVDC link, as well as have room for the required converter station. Fulfilling these requirements, the site of Kvilldal was chosen, however, this site is located quite remote and sits on the side of a large freshwater lake. In order to establish the full HVDC link, it was clear that this lake would have to be crossed with HVDC submarine cables.

The lake (Suldalsvatnet) is located in the Ryfylke region in the southwestern part of Norway, with a maximum water depth in the cable route of about 210 m, and the route crossing the lake was approximately 2700 m in length. The lake is typically 70 m above sea level, and no waterway access exists for a vessel. Furthermore, land transport is limited to normal road transport, often limited by the challenging topography in this part of Norway. The two cables were installed separately in separate corridors.

Upon the tendering and contracting phase of the project, the contract to provide the Norwegian part of the NSL cable supply included this challenge. With extensive experience with off-the-normal path projects, the contractor had the required know-how and further developed the ideas, technologies, and methods to install the cables across the deep lake.

A fully self-supported cable laying spread was engineered and mobilized on the lake, consisting of only parts that were fit for road transport in Norway.

The paper focuses on the development of solutions, engineering and planning, and of the actual cable laying operations, including mobilization. The project team developed and executed a cable installation project on the same level (or above) as standard offshore cable installations with regards to specifications, performance and safety – key success factors in any HVDC cable project. The challenges of such cable installation – water depth, only road transport, environmental restrictions, steep seabed, remote location – were duly and safely overcome, even in the circumstances where the COVID-19 pandemic were rapidly developing during the planning and execution stage.

KEYWORDS

Installation – HVDC – Submarine - Cable – Freshwater - Lake – Suldalsvatnet

1. Development of installation philosophy

The cable design is a 525 kV DC 1600 mm Cu core, mass impregnated paper insulated cable with an overall diameter of 126 mm and a mass of 52 kg/m. This cable is usually handled by specially designed cable ships which handles the cable at large bending radii, typically 3 m for untensioned cable and 5 m for cable under tension. The same requirements applied to the lake installation.

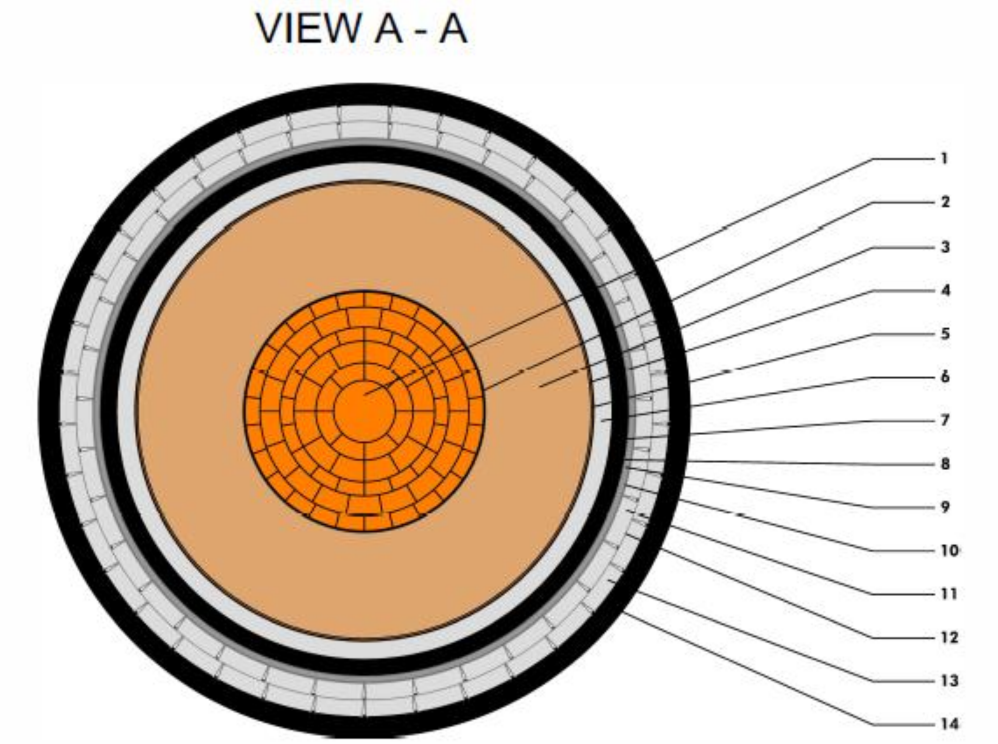

Figure 1 Cable section NSL cable

Several designs for installation philosophy were evaluated, among them the possibility of floating each cable using inflatable floats and lowering the cable with a small barge. However, due to the considerable water depth and the risk of an uncontrolled sinking of the cable, this was discarded.

The procedure chosen involved spooling of the whole cable length of 2700 m onboard a work platform, and then towing the platform across the lake along the planned route while installing the cable. While this has been done in many projects before, some challenges were more demanding in the NSL project.

- The cable weight in the lake was 142 metric tons total
- The maximum calculated top tension in the cable was approx. 100 kN ([2] Worzyk, 2009) ([1] Mousselli, 1981)
- The accuracy of positioning was required to meet North Sea offshore standards
- Full ROV touchdown monitoring and as-laid documentation was required
- The laying process was to be reversible, in case the cable at some point had to be recovered
- Access to the lake for the equipment would be via public roads, through tunnels with typical maximum cargo width of 4 m width x 3,6 m height.

- Inclination of the service tunnel was 70 m in 2300 m, ie. 1,7 degrees
- Max gradient of the seabed was approximately 25 degrees.
- Friction factor between cable and soil in gradients was conservatively estimated to 0.5 (static) / 0.3 (dynamic) ([1] Mousselli, 1981)
- The lay spread was designed for a Dynamic Amplification Factor of 1.1, ie. a wave height of app 0.5 m. ([1] Mousselli, 1981)
- The cables were protected by a concrete conduit at the west landfall (Djupevika), and by water jetting into the seabed to 1 m cover at the east landfall (Kvilldalsvika). Both areas were protected to the maximum ice interaction level.

2. Design of Cable work platform

To overcome these challenges, a suitable modular platform was sourced. A full cable laying equipment and positioning spread had to be designed to equip the modular platform as a self-contained cable laying system. The complete system was designated the Cable Work Platform (CWP). For the mobilization of the CWP, a temporary mobilization base had been established only a kilometer from the landfall Djupevika (West). The base had office facilities, outdoor storage space, mobile crane and a forklift.

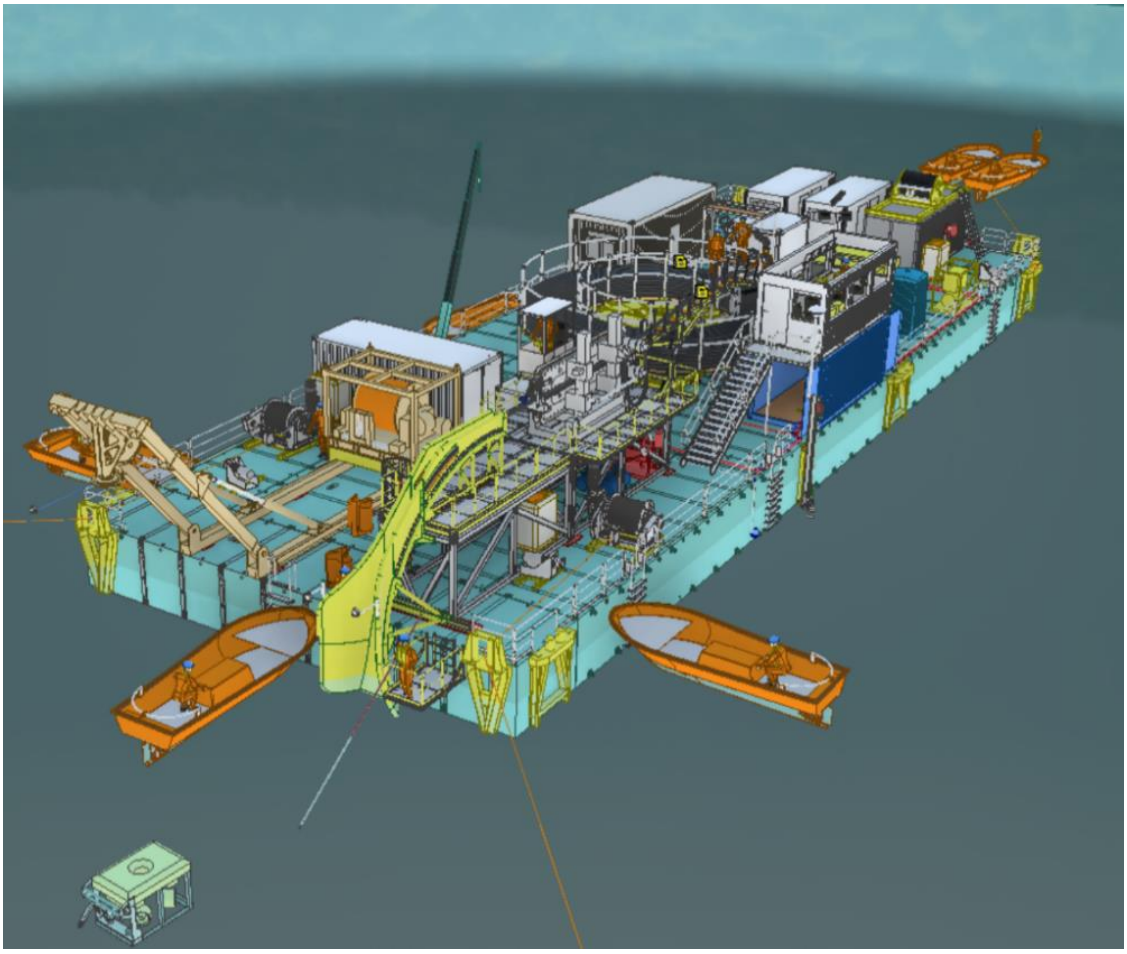

Figure 2: Inventor model of the Cable Work Platform (CWP) developed during engineering

The platform itself was assembled from 25 individually certified pontoon segments of varying size, interlocked to a stable platform of 15 x 43 m. The largest of these were 12 m x 3,1 m x

2,1 m (l x w x h). The platform itself was rented as a package from a Dutch specialist company, utilizing standard reusable elements. The maximum draft was 1,0 m.

Figure 3: Cable Work Platform (CWP) during cable laying across Suldal Lake

A turntable of 10 m overall diameter / 150 ton capacity was installed on the platform. This turntable had to be specially designed and built for road transport, i.e. no part could exceed 4 m in width when loaded to a truck. A full ROV spread, control room, and an electrical distribution central was installed on board. In all, almost 1 MW of ultra-silent generator power was installed, with 100% redundancy and 5 days endurance from an onboard fuel tank. All equipment was sea-fastened to the steel deck according to a dynamic amplification factor of 1.1.

A lot of engineering was focused on the means of propulsion and positioning. Positioning by warping, thrusters, or similar means was considered, but the project landed on using a triangular mooring pattern, combined with a fleet of 5 small work boat/tugs of 2 ton pulling capacity. The main mooring lines were two high capacity 16 mm fibre-lines, each with a length of 1,5 km and a braking load of 28 tons. These lines were held by electric drum winches of 5 ton capacity, remote controlled from the navigation room. For extra mooring (during stops), capstan winches, all of 2 ton capacity were fitted at each corner.

In normal movement, the main moorings were held tight by the work boats pulling the CWP in the desired direction. To move the platform along track, the mooring lines were paid out simultaneously, sideways position controlled by independent operation of the winches. Rock anchors were installed on shore at 12 positions along the route. The geometric pattern of the mooring lines was analyzed in all positions along the route.

To store the cable, a turntable turret was designed and built especially for the project. This turntable was designed to be packed for road transport and was assembled to a full 10 m diameter / 150 ton capacity at the mobilization site. To control the cable tension, a linear cable tensioner / caterpillar of 15 t pulling/braking capacity was put atop a specially designed lay spread tower. The lay speed was finely adjustable between 0 and 20 m/min. The system was fully capable of recovering any section of laid cable product, at any position along the lakebed. In the event of a contingency, the complete cable could be recovered and stored in the turntable on board. This is in line with sound installation practice. The cable went over a specially designed and built chute at the stern with a full 5 m radius.

A 15 ton abandonment and recovery winch was installed in line with the lay equipment, to be able to lay down the cable end in any point of the route, in the unlikely event of an unresolvable mechanical fault.

3. Transport of cable to site

The two cables combined weight, including the cable length through the tunnel was approx. 600 tons, so road transport was not feasible. The cables were transported on a cable transport barge to an adjacent fjord. As part of the main cable route, and to bring the cable from the fjord arm to the lake, a cable tunnel was built by the project through the mountain between the lake and the fjord. The 2,3 km tunnel has a cross section of approx. 25 m^2 with the cables installed in a trough on the side. The tunnel was built with a gravel road for inspections and maintenance, which was also necessary during the mobilization and installation works for the cables.

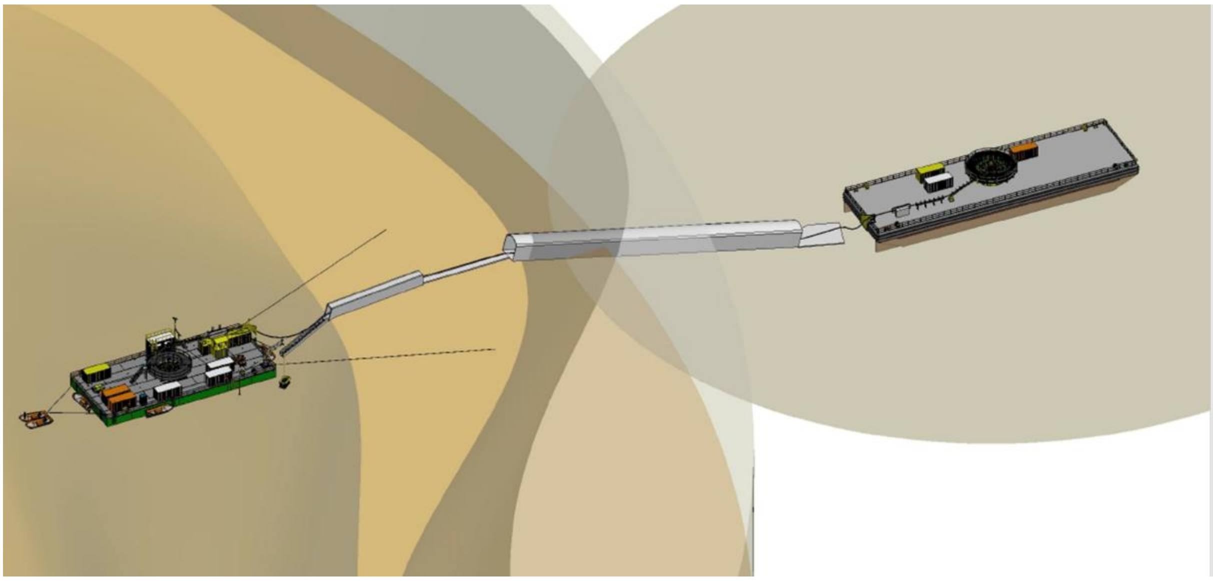

Figure 4 Cable pulled through tunnel - principle sketch

The cables were spooled to the cable transport barge at the cable factory at Halden and towed to the saltwater exit of the tunnel and securely moored. Each cable was pulled up the tunnel, by using 40 pre-installed pulling machines along the cable route inside the tunnel. It was then further loaded onto the work platform as a continuous operation. Each cable was cut to length during production, about 5,7 km in total per length.

Figure 5 Service tunnel with open conduit during cable pulling

The tunnel was organized as a completely separate entity. The cable pulling was performed with a large number of synchronized cable tensioners.

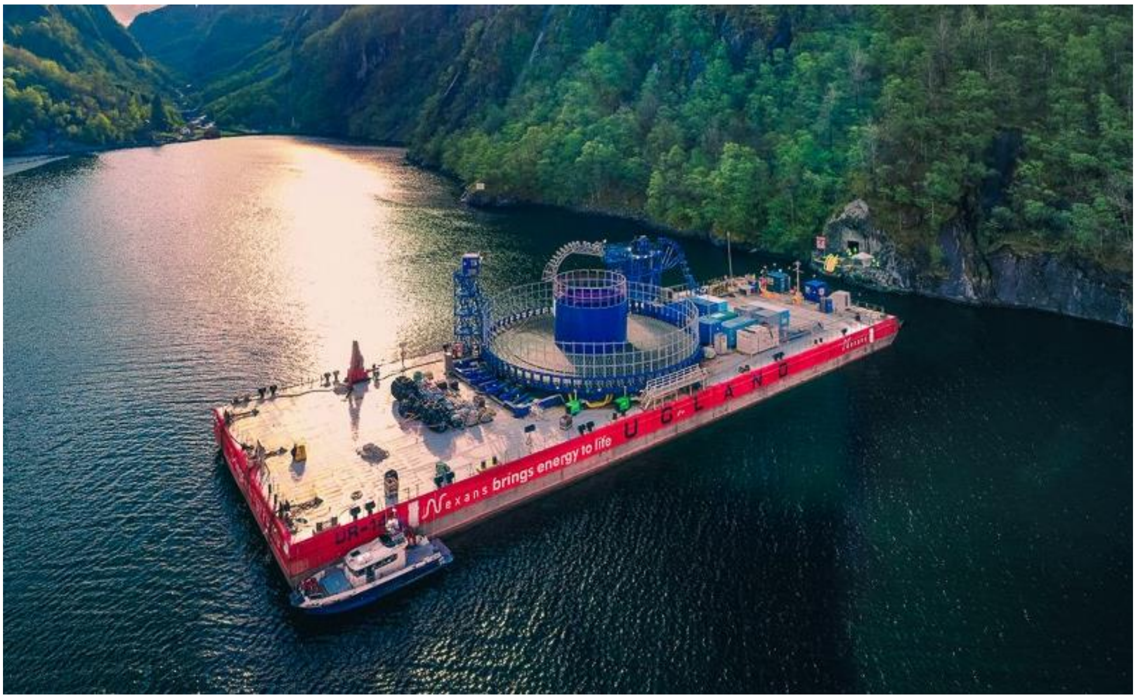

Figure 6 Outside the tunnel, the transport barge was moored.

4. Installation

After mobilization and trials of the CWP (Cable Laying Platform), it was moored in position at the west landfall (Djupevika) for loadout. The first day of operation was focused on transferring the required length of cable from the transport barge to the CWP. When this was complete, the CWP was left in standby position over night.

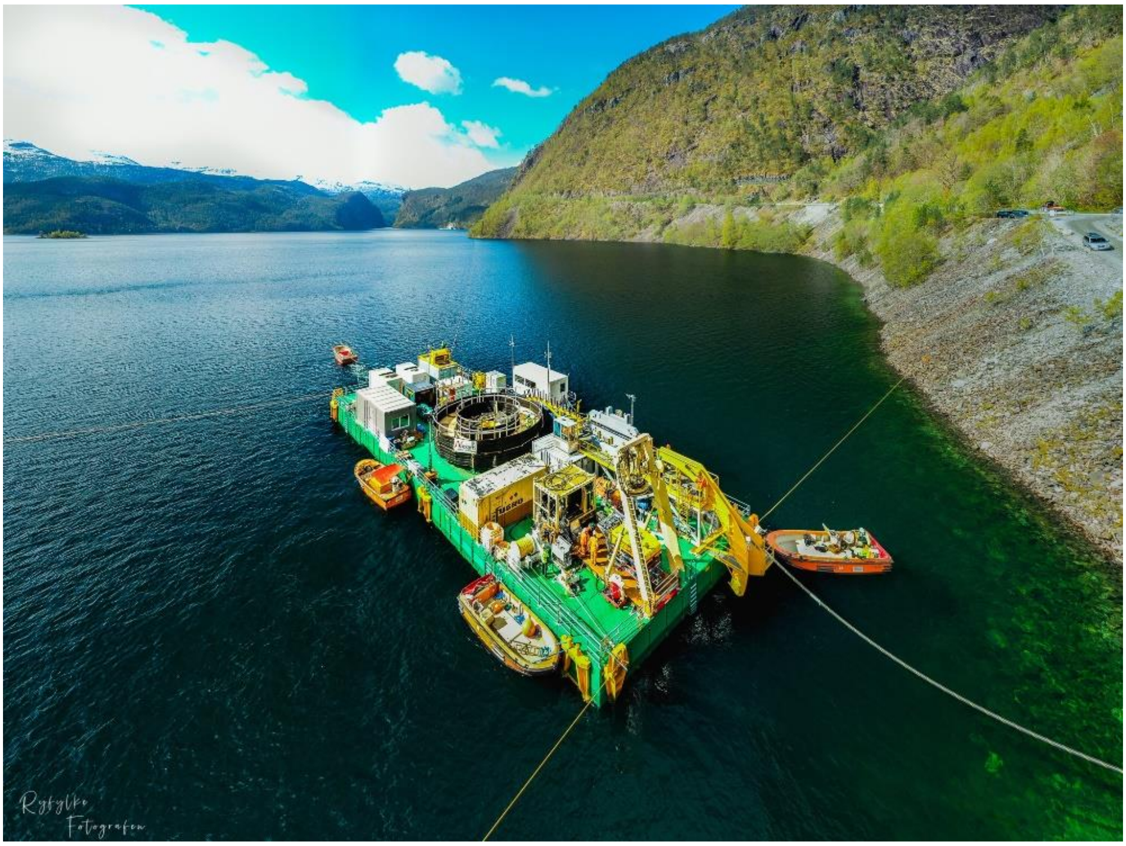

Figure 7 The CWP moored at Djupevika, loading cable via the tunnel.

On day two, work boats were hooked up to hold the CWP: The temporary forward moorings were released. Position relied on pull from the work boats, against the tension of the mooring lines pulled from the stern and fastened to rock anchors at shore. The ROV was deployed, but as expected, visibility in the lake was very soon reduced to zero. Using acoustic cameras and other electronic equipment, position of the cable catenary was monitored as the cable was laid to the seabed.

As the CWP moved along track, mooring points were shifted to maintain a favorable geometry. This was done by establishing a temporary line to the next applicable point, releasing the main line and reconnecting it to the next point. This was made as efficient as possible by selection of fast electric mooring winches.

The work was planned as a daytime operation, and only one shift of 22 persons was allocated to man the CWP. After approx. 75 % of the route had been installed, the mandated working time had been expended, so the CWP was moored overnight in a favorable spot with regards to mooring line geometry. Selection of “safe harbors” along the route was a part of contingency planning. Night watchmen ensured that the CWP was not at risk while on standby.

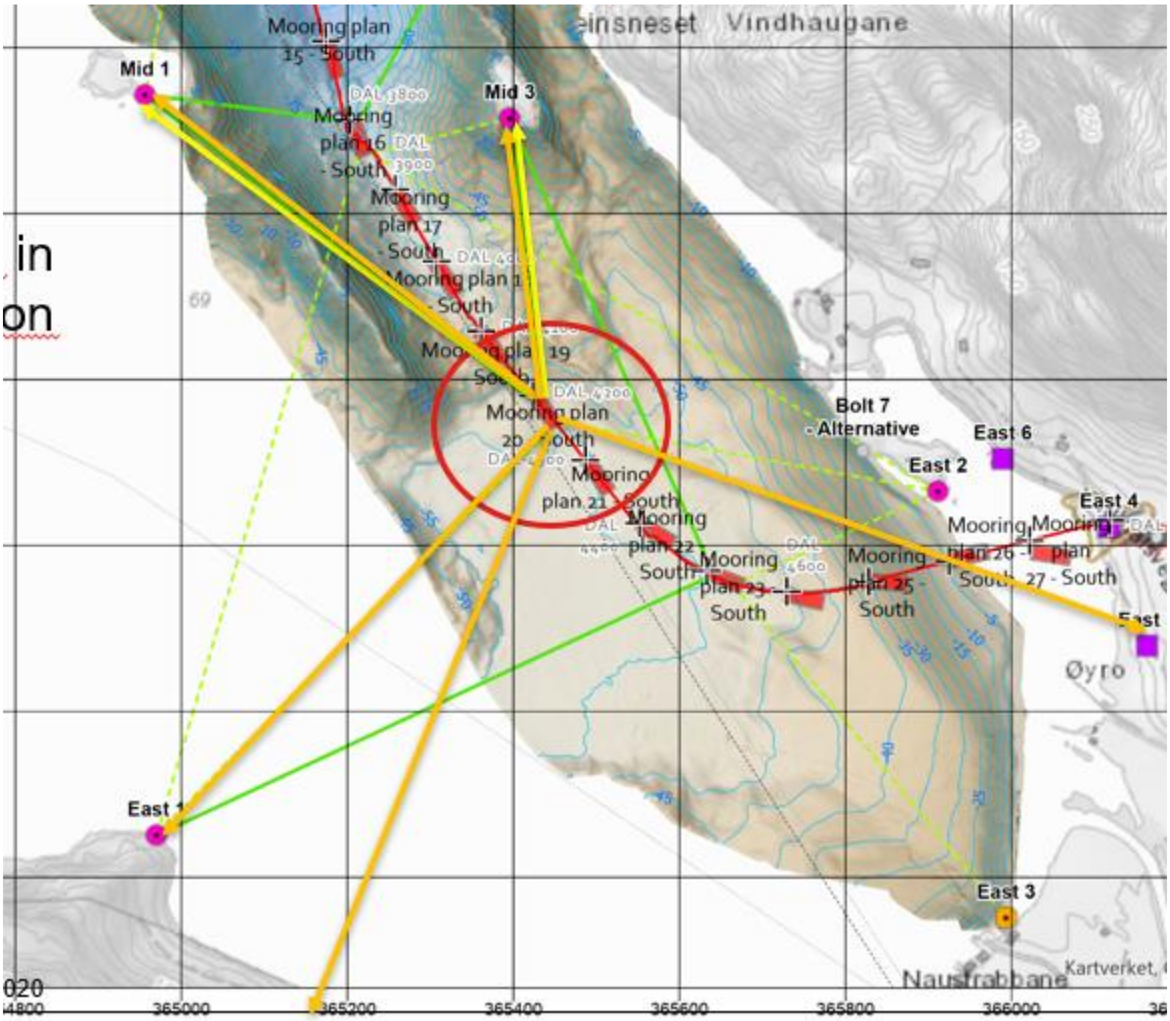

Figure 8 The CWP was moored by 7 points during standby overnight

The lower temperature limit of handling the HVDC cable is 0°C, and due to unusually low temperatures for the season, the cable coil needed to be heated during the standby periods. Insulation mats were installed on the turntable and along the cable, and diesel heaters used to maintain temperature. The weather was generally favorable, but sudden gusts of fall winds from the tall mountains occurred frequently. Temperatures ranged from typically -2 °C at night to +10 °C at day. Winds occurred with up to 12 m/s in short squalls daily.

On day three of the operation, the cable laying continued. The CWP was moored close to the eastern landfall (Kvilldalsvika), and the remaining cable was floated to shore. After completion of cable no 1, the CWP was refueled at the shore base.
Days 4-6 turned out to be a repeat of the first lay campaign, with little changes in time schedule.

Upon completed landing of the second cable, the following day was spent to run a complete ROV survey of the cables. Some "hard points" had occurred close to land on the west landfall, which were corrected by post lay intervention by divers. Otherwise, the cable route proved well suited to cable laying.

After the completed survey, the CWP was demobilized at the base.

5. Lessons Learned

Due to intensive planning, the installation was completed exactly in the allotted time. No HMS incidents were reported, and there was no waiting on weather. The project was executed during the first wave of the Covid-19 pandemic. National and local restrictions were enforced throughout the campaign, but all in all the work on site was not very affected by the pandemic. All workers had to submit tests and self-declaration at the beginning of the mobilization. No cases of Covid-19 were recorded.

The design of the platform worked according to requirements, and the number of changes compared to the original plans were almost nil. Keeping the position stable, even in quite rough wind conditions was never a problem. The handling of the cable was kept to a minimum, with few and large bends all along the cable path of the CWP. The as built survey proved that an accuracy better than required, and mostly better than 1 m, was attained.

As expected, due to the nature of freshwater lakebeds, visibility from the ROV during large parts of the laying was practically zero. The movement of the cable close to the seabed caused sediments to stir up, and the absence of current prevented them to be transported away, as is normal when working in open sea conditions. Anticipating this problem, an acoustic sonar was attached to the ROV, and it helped considerably in navigating the cable between obstacles on the seabed. An as-laid survey could only be performed after the cables had been laid. The seabed was very suited to cable laying, and the cable was only touching three hard points / sharp rocks in total. These were all remedied in post lay intervention.

The positioning relied on towing of the platform against two or more mooring lines, each secured to landfall points. An adaptation of the plan was implemented, in the placement of a third work boat at the stern, to act as a pusher. It seemed that this was even more effective than towing.

Otherwise, the arrangement met and exceeded expectations.

Bibliography

[1] Mousselli, A. H. (1981). *Offshore Pipeline Design, Analysis, and Methods.* Tulsa, Oklahoma: Penwell.

[2] Worzyk, T. (2009). *Submarine Power Cables - Design, Installation, Repair, Environmental aspects.* Heidelberg, D: Springer.