The new pylons are designed to fit into the landscape, with steep mountain slopes straight down into Lysefjorden. (Photo Statnett, Woldcam).

Dec 11, 2017 10:09 GMT

Rock solid anchoring for design pylons at Lysefjorden

One of the most scenic and popular hiking trails in the Norwegian mountains, starts at Øygardstølen and leads to spectacular Kjerag, 1,000 vertical meters above Lysefjorden, east of Stavanger in South-western Norway. Upgrading the country's power grid involves a new 420 kV power line, with pylons that had to be constructed close to the parking at Øygardstølen.

A new type of pylons, or towers, was needed for this location, with a design

that suits the landscape and does not diminish the enjoyment of the many visitors. Statnett decided to hire an industrial designer to come up with a brand new design, which potentially could add to the attraction of the place.

In October 2017, three tall, slim and monumental towers were installed. During the spring of 2018, the power lines will be added.

-This is important infrastructure for the country, and design is only one of many considerations. The safety and stability of the construction is vitally important," says Håvard Bertling, Statnett's project manager.

The pylons must support heavy power lines and withstand the strong forces of nature in the mountains. The purpose of the foundations is to secure the stability of the design throughout their lifespan.

NGI was asked to assist at an early stage in the process. It was quickly decided that solid rock anchors would be the best solution.

Each pylon is secured on an octagonal concrete base which is cast directly on top of the processed rock surface. Each foundation is anchored deep into the bedrock using 12 steel struts, of 12 meters length each. The anchors are installed and cast in the lower end of boreholes, prior to being pretensioned to a permanent force of 75 tons.

Left: The pylon foundation with 12 rock anchors, and cast foot bolts for connection to the tubular towers. Right: Anchor head with load cell, load distribution plate, locking nut and protection lid filled with grease. (Photo: NGI).

Permanent anchors are often used in constructions with heavy horizontal loads and moments, combined with low weight of the structure itself, where the anchors are critically important for the overall stability of the structure.

-Our main task was to design the anchoring and how deep to penetrate into the bedrock to secure required stability," explans Einar John Lande, responsible for soil and rock anchoring at NGI. Together with colleagues, he has worked on the foundation designs for the pylons at Øygardstølen and several other locations along this power line, for more than three years.

Well anchored research project

We have installed elasto-magnetic sensors on some of the rock anchors, at various depths. The purpose of this instrumentation is to monitor how the tension force is distributed down into the anchoring zone. It is the first time that this type of sensors has been used in Norway.

This was conducted as a research project by NGI, in close cooperation with Statnett. A total of 10 sensors have been cast into the rock at three different levels. The tension is monitored and registered at certain intervals by connecting a separate monitoring unit.

-This is done because the tension is not distributed evenly throughout the anchoring zone, unlike what is the basis for the present design method for rock anchors", says Einar John Lande.

-It is also worth noting that the tension will be gradually reduce over time, as a result of relaxation in the steel, and also due to creep effects in the concrete and in the bedrock. Therefore, we want to monitor the distribution of tension over a longer period of time, to check if the conditions for the anchors are altered. Our first report is due in 2019. However, we will follow up on this research project for at least ten years. We use this to gain new knowledge on the design of this type of rock anchors," explains Einar John Lande.

In addition to the sensors cast deep into the bedrock, instrumentation sensors at the locking head where the anchor is fastened to the concrete foundation. This is the traditional method used to monitor the tensional force and condition of this kind of anchoring.

Representing the wildness of the landscape

The specially designed pylons are tall and massive when you get Close (Photo: Statnett_Woldcam).

At an early stage, Statnett held a public hearing in cooperation with the municipality of Forsand and Lysefjorden Development AS. The purpose was to get ideas and input concerning the design of the pylons, that hold a dominating position in the landscape and can be seen from far away. The positioning of the pylons was decided by technical and topographical factors. They are placed close to a sharp bend on the road, and many drivers stop here to admire the view.

Widenoja Design AS was given the assignement to design what is known as

"Statnett's first design pylon".

-With the power lines in both directions these pylons will draw a lot of attention regardless of their shape and design. The challenge was to find an aesthetic solution that can be seen to be in harmony with the wildness of the landscape, and, at the same time, somehow represent the same wildness, explains Eva Widenoja, industrial designer.

-The simple, slanting lines of the pylons are meant to be in harmony with the scenery, and they are inspired by the dramatic, steep mountainsides. The shape of the towering pylons has been designed to give the illusion that they are almost tipping over, but held in place by the power lines. The angles reflect the fjord and the special light, which inspired me to come up with the shapes and colours that were chosen, says Widenoja.

==========

FACTS

- The pylons are part of the new power grid between Lysebotn, Forsand, Rogaland, and Tonstad, Suldal, Vest-Agder. The lines will be operational in 2018.
- The upgrading of the grid from 300 kV to 420 kV between Kristiansand and Sauda will be finished in 2021, resulting in enhanced stability in power supplies and the option to transport more renewable power on cables to England and Germany.
- The pylons are designed by Widenoja Design AS. The pylons, or towers, are shaped as tubes (or pipes), with an outer diameter of 1.8 meters. The heights are 39, 35 and 32 meters from the base to top. The engineering design of the pylons and the concrete foundations has been done by EFLA AS. The pylons are manufactured by Valmont SM, Denmark.
- The construction work was performed by Skanska Norge AS as main contractor, whereas the actual anchoring was made and installed by the subcontractor Berg and Tunnel Anker Systemer AS (B-TAS).
- NGI has been responsible for foundation design and anchoring of the three pylon foundations. Each foundation is anchored deep into the bedrock with 12 steel struts, of 12 meters length each, penetrating at an angle into the rock. The steel struts are 40 mm

diameter with a maximum design capacity of 82 tons. All struts were preloaded up to a tension force of 95 tons to verify required capacity, prior to locking them into position with a pretension load of 75 tons. The pretensioning was performed in September 2017.

- The research project with instrumentation of the rock anchors was a cooperation between Statnet and NGI. The first report will be available by the end of 2019. The overall aim is to gain more knowledge about anchor conditions and capacity over a long period of time. This will establish the basis for improved life span evaluations and design of rock anchors in the future.

The Norwegian Geotechnical Institute (NGI) is a leading international centre for research and consulting within the geosciences. NGI develops optimum solutions for society, and offers expertise on the behaviour of soil, rock and snow and their interaction with the natural and built environment.
NGI works within the markets Offshore energy; Building, construction and transportation; Natural hazards, and Environmental Engineering.
NGI is a private foundation with office and laboratory in Oslo, branch office in Trondheim, and daughter companies in Houston, Texas, USA, and Perth, Western Australia. NGI was established in 1953.

Contacts

Kjell Hauge
Press Contact
Senior Communications Advisor
kjell.hauge@ngi.no
+4793449553