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FINGRID

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FINGRID
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Editorial

80 years in the centre of infrastructure

On 16 January 1929, voltage was connected for the first time to the first 110 kilovolt trunk transmission line in Finland, from the new Imatra hydropower plant to Vyborg in the south and Helsinki and Turku in the west. When the line was completed, some thought that Finland would never consume all the electricity generated by the large power plant in Imatra. That was a wrong notion.

The nation-wide transmission grid has grown with the Finnish society and its needs. It now covers more than 14,000 kilometres of lines and over 100 substations. The grid contains almost 700 connection points, to which the factories, power plants and distribution networks have been connected. The power system covering the whole of Finland constitutes the largest national infrastructure with the most widespread impacts.

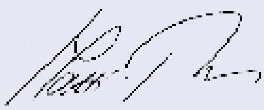
The Finnish transmission grid has always been planned and built in a competitive set-up. From the beginning, private industries aimed to secure electricity supply to their plants irrespective of projects undertaken by the state-owned Imatran Voima. On the other hand, building the energy production and power transmission architecture in a poor country such as Finland in the 1920s also called for the development and use or cost-efficient domestic technology solutions. This was boosted by the rapid growth of heavy industries, required by the war reparations after the war, and harnessing of hydropower in the north to serve the needs of industrialising Finland. Cost efficiency was also highlighted later as the pace of industrialisation grew and as the national economy became even more energy-intensive. The nation-wide grid was expanded especially in the 1970s, when the first large coal and nuclear power plants were connected to the grid.

Reliable availability of electricity is a vital national competitive edge. Finnish system security and cost efficiency in electricity transmission represent top grade globally. These have been achieved by focusing on the problems thoroughly and by applying new technology open-mindedly. Close co-operation between the users, scientific communities and equipment manufacturers has always been characteristic of the Finnish transmission business. This has resulted in the best methods suited for the Finnish conditions. Many pioneering solutions, such as the use of the light guyed tower and a meshed grid which improves system security, have been among the great success factors. Later, automation of substations and power plants together with their centralised operation control added to system security and reduced the costs. A long leap forward in cost efficiency was taken in the early 1990s, when outsourcing and competitive bidding were introduced to the construction and maintenance of the grid.

Finland joining the EU and goals to liberalise the European energy market led to the establishment of Fingrid Oyj (initially Suomen Kantaverkko Oy) in the autumn of 1996. It took over the lines and substations of the network companies of Imatran Voima and Pohjolan Voima and a little later the corresponding parts of the network in the Kemijoki region. These were among the rapid developments towards a Nordic electricity market, where trading in a single exchange guarantees that electricity is produced and transmitted to consumption from power plants with the most inexpensive costs. Thousands of generation units are controlled automatically on the basis of a price determined by demand and supply, without a centralised control system. Some 70 per cent of all Nordic electricity trade takes place through the electricity exchange owned by the Nordic transmission system operators (TSOs). The Nordic market is integrating both with the market around the Baltic Sea and with northern Continental Europe. The volume of electricity exchange trade will grow tenfold while at the same time trading will intensify and the proportion of individual players in electricity trade will decrease.

Finland is now adapting its national economy to the European energy and climate strategy. Fingrid is involved in this by having a crucial role in European TSO co-operation. The new organisation ENTSO-E is a visible indication of this co-operation. ENTSO-E is to create comprehensive binding rules for the development of the European power system regionally so that they correspond to the needs of the electricity market both in terms of the capacity of grids and system security. The climate objectives will not be realised unless the European grids are improved to conform to the changing production architecture and especially to the power regulation needs of the rapidly increasing wind power.

In the next decade, Fingrid will spend almost 2,000 million euros in reinforcing and renovating the Finnish grid. This is roughly half of the replacement value of the present grid. The capital investments contribute to the national energy and climate strategy by creating conditions for the construction of the necessary base load power capacity and renewable energy production. The backbone of Finnish society keeps growing, but more clearly so as part of the European electricity market.



Matti Tähtinen is Fingrid Oyj's Senior Vice President responsible for stakeholder relations.

Weather phenomena are the most common cause for disturbances in the power system.

Minister Jyri Häkämies:

It is necessary to make preparations for threats

Text by Tiina Miettinen ■ **Photographs by** Vastavalo and Erkki Laine

Our society relies on technical systems. Dependence on electricity in particular has increased considerably. This is why a serious disturbance in the electricity infrastructure has been raised as one of the foremost threat scenarios in Finland. "We live in a world of changing threats," says Minister of Defence Jyri Häkämies.

The Council of State supervises contingency planning for various disturbances and extraordinary situations in Finland. A few years ago, the Government accepted a strategy for securing the vital functions of society, used for integrating the contingency plans in the various branches of administration.

The strategy describes those functions that need to be kept running under all circumstances. Electronic communications and data communications as well as energy supply systems are considered especially important issues.

Disturbances in the power system are most commonly caused by bad weather. Sleet, lightning, packed snow or an ice storm are threats arranged by nature on overhead lines. Moreover, terrorism or intrusion into data networks are other threats that require contingency plans for the power system also in Finland.

The Finnish Ministry of Defence carries responsibility for integrating overall national defence and for contingency planning for various situations.

"We live in a world of constantly changing threats, and it is imperative to take these threats into account in emergency supply efforts and other contingency planning. We compiled a work group in our ministry to draw up an analysis of the impacts of a long blackout on vital functions. This work was completed in early summer. I hope that the good practices and recommendations presented in the related report become reality," is how Jyri Häkämies, Minister of Defence and minister responsible for state ownership steering, comments on the contingency planning.

Practical guidelines for authorities

The work group studying contingency planning completed its extensive report at the end of May. The report presents in very practical terms what blackouts would mean to issues such as water supply and waste water services, food supply, transport, health care and monetary transactions, and how authorities can make preparations for disturbances.

Local administrations have a crucial role in the preparations, because they are responsible for arranging many vital functions also during normal circumstances. The report contains several examples and guidelines, also for communications when there is no electricity.

The electricity transmission grid represents critical infrastructure in terms of the functioning of society. The government hence must have a chance to make important decisions concerning it, says Minister of Defence Jyri Häkämies, who is also responsible for state ownership steering.

> **“The principle stated in the climate and energy strategy to increase domestic self-sufficiency in electricity generation is a step in the correct direction.”**

In many cases, a power failure is over even before you notice it. Long blackouts are rare occurrences also in statistical terms, but not impossible.

There have been long power cuts in Europe, also in the Nordic countries. Severe storms have left hundreds of thousands of people without electricity in Finland, too. In extreme cases, heavy storms or other natural phenomena can cause significant damage to the power grid, and it may take days to repair the damage.

Assistance from the Defence Forces?

In serious disturbances, repairs will likely be hampered by scant personnel resources. Fingrid and electricity network operators have outsourced transmission line maintenance and service to service providers. The electricity business may require assistance from the Defence Forces in very serious disturbance situations.

However, Minister Häkämies points out that Finland has not had extensive blackouts, like for example Sweden, and the resource shortage has not been a topical problem yet.

“Power cuts have a fairly short duration in Finland, which is partly due to the stricter statutory damages to be paid to electricity users,” Häkämies says.

The use of the Defence Forces also involves safety risks.

“Repairing power cuts is dangerous work and calls for professional skills. Conscripts cannot be used for such work. On the other hand, it is possible to also use conscripts in support duties relating to the repairs. Special machinery possessed by the Defence Forces could also be of assistance in these situations,” Häkämies states.

Towards self-sufficiency

Increasing the energy self-sufficiency in Finland contributes to contingency planning. The climate and energy strategy of the Government of Finland states that Finland should be self-sufficient in electricity generation also during peak load situations.

At the moment, Finland relies on electricity imported from Russia when the weather is very cold. The competitiveness of Finnish condensing power on the market has deteriorated as a result of emissions trading, and old condensing power plants are under a threat of being decommissioned.

Jyri Häkämies thinks that self-sufficiency should be attained by using a versatile energy mix. He considers that satisfying the power need during a peak load is a special challenge.

“In Finland, old electricity generation capacity has been secured by means of an act so as to ensure supply security during peak load situations. It is still important to replace old generation capacity with new capacity which is available at all times,” Häkämies points out.

“Additional hydropower has its limitations, and the continuous availability of wind power in Finland is not good. Only nuclear power provides a non-emission alternative in a large scale. Overall, it is the versatile electricity generation architecture in Finland that will ensure our emergency supply. The principle stated in the climate and energy strategy to increase domestic self-sufficiency in electricity generation is a step in the correct direction,” Häkämies says.

Positive message to the 80-year-old grid

Vital functions of society have traditionally been secured in Finland in co-operation with businesses. This has involved collaboration within the National Emergency Supply Council together with the National Emergency Supply Agency.

Does market economy and voluntary contingency planning by businesses provide sufficient supply security, or do you think that there is a need for increased governmental control and instruction?

“There are about 2,000 enterprises in Finland which are critical in terms of emergency supply. They have drawn up their contingency plans and participated in various preparedness exercises. This work has taken place under the control of supply security organisations on a voluntary basis and in an excellent spirit of co-operation. Regulation is a commonly accepted procedure in extraordinary circumstances prescribed by emergency powers legislation,” Häkämies says.

The Finnish electricity transmission grid has also been constructed and developed in the name of co-operation and responsibility for 80 years. The objective has been as high system security in electricity transmission as possible, and securing sufficient transmission capacity for the market. We asked the minister to send a message to Fingrid and its employees.

The message is encouraging, because Jyri Häkämies feels that Fingrid has succeeded well in its basic duty.

“The security of supply in Finland represents top grade on an international scale. Imatran Voima and its successor Fingrid have long traditions in emergency supply and contingency planning. I see no reason why this good approach would not continue within Fingrid.”

“Fingrid has been exemplary in the way in which it knows and carries its responsibility for emergency supply efforts. I hope that our internationally original transmission grid system will continue to retain its high system security level. This will call for development work, and I believe that Fingrid has the ability and willingness for it,” Minister Häkämies states. ■

GRID connects now and in the future

"Fingrid updates the scenarios for the operating environment at intervals of a couple of years so that we can keep our antennae up. We aim to come up with a limited number of sufficiently varied scenarios to serve as the basis of long-term grid planning," Jussi Jyrinsalo says.

Fingrid together with the Technical Research Centre of Finland has worked out alternative scenarios concerning the company's operating environment. The scenarios are based on climate change and on the impacts of its control on the power system. The time perspective of the scenarios extends to 2030, and three alternative models for potential trends in electricity consumption and generation are presented.

Text by Tiina Miettinen ■ **Photographs by** Juhani Eskelinen and FutureImageBank

At the beginning of this year, Fingrid launched the drawing up of scenarios for alternative trends that will have an impact on the structure of the electricity transmission grid over the next two decades. The alternative scenarios are needed as a basis of long-term grid planning, among other things. The work was carried out in a work group by creating and defining various alternative scenarios for the future.

In the initial stages, the work group examined the long-term climate and energy strategy published by the Finnish Ministry of Employment and the Economy together with the target track and basic track scenarios described in it. After this, various approaches for the prevention of climate change were worked out from the viewpoint of the power system.

Jussi Jyrinsalo, Senior Vice President responsible for system development at Fingrid, says that the operating environment changes rapidly, and that preparations for these changes were the starting point for the scenario work.

"It is more and more difficult to forecast the trend in electricity generation and consumption and their geographical location. We come up with scenarios involving different types of electricity transmission needs. When we define the grid and reserve power reinforcements required by these various scenarios, we can make advance preparations for reinforcements required by all of the alternative scenarios. We can specify our own plans later in line with developments in the electricity market," Jyrinsalo says.

Wind power to fight climate change

In alternative "Wind produces – grid unites", the focus is on the prevention of climate change and on an increase in renewable energy. Governments both in Europe and elsewhere will endeavour to fight climate change, and the EU countries will be committed to stringent emissions reduction requirements.

The integration of the European electricity market will advance, and more and more decision-making will be shifted to the EU level. The EU will have a single electricity market by 2030, and the market prices of electricity in the various parts of Europe will converge. In Finland, electricity consumption will grow somewhat as a result of electrification which will increase due to higher energy efficiency. Approximately 4,000 megawatts of wind power capacity will be constructed in Finland by 2030.

In this scenario, the market prices of electricity will vary dramatically, the share of wind power will increase, electricity demand peaks will fluctuate rapidly, and there will be more transmission connections to the electricity market in Continental Europe. Both the long-term and intra-day need for power regulation will grow.

"In this scenario, it would be important for Fingrid that the wind power capacity is located in a decentralised manner geographically. This facilitates transmission management and main-

Climate and energy strategy

Target track specified by the Ministry of Employment and the Economy

- Electricity consumption will decrease and will be 95 TWh in 2030
- EU 20-20-20 goals fulfilled
- Self-sufficiency in electricity generation
- Wind power capacity 2,000 MW

Basic track specified by the Ministry of Employment and the Economy

- EU 20-20-20 goals not fulfilled
- Electricity market integration remains unchanged
- Electricity consumption will continue to grow and will be 108 TWh in 2030
- Self-sufficiency in electricity generation
- Condensing power and CHP will increase their shares

Matrix of transmission grid scenarios

Varying electricity generation, inaccurate daily generation forecast

WIND PRODUCES – GRID UNITES
- Focus: control of climate change, increase in renewable energy, solid integration
- No requirement concerning self-sufficiency
- 20% of electricity consumption generated by wind power in the Nordic countries

SISU (NATIONAL ASPECT)
- Focus: energy security, national energy policy, protection of domestic market
- Electricity market integration will slow down
- New generation capacity in domestic renewable energy

National aspect

International co-operation

EVEN GENERATION – LARGE UNITS
- Focus: control of climate change, large units, integration
- Several new nuclear power units will be built in Finland

Even electricity generation, exact daily generation forecast

taining of power balance. There would probably also be a greater need for fast-regulating power production, and the regulation power market should evolve further. Demand elasticity should also be increased. There would probably be a need for additional transmission links from Finland to the neighbouring countries, but the transmission needs would vary greatly between different times," Jussi Jyrinsalo says.

Even production in large units

The control of climate change is also in focus in the scenario "Even generation – large units", but the politically chosen means will rest on nuclear power to a great extent. Climate change will primarily be fought by technology, not so much by controlling the demand for energy.

The integration of the pan-European energy market will make progress, and the Nordic market area will have been connected to the transmission grid in Continental Europe. In Finland and the other Nordic countries, products made by the energy-intensive industries will continue to enjoy good demand, and industrial electricity consumption will grow slightly.

Several new nuclear power units will be built in Finland, and a total of 2,000 MW of wind power capacity will be constructed by 2030. Finland will be an electricity exporter, and cross-border transmission connections will be built from Finland to other market areas.

"What is essential for Fingrid in this scenario is the increasing use of nuclear power. The need for disturbance reserves has to be verified as the sizes of production units grow. The construction of several new nuclear power units would require new grid construction projects. Grid planning co-operation within the region of the Baltic Sea would have greater significance when new electricity export opportunities to other parts of Europe would be planned," Jyrinsalo sums up this scenario.

National approach

The third scenario, called "Sisu", suggests that national protectionism will gain a firm foothold. Moreover, no agreement on the emissions reduction goals will be reached. On the other hand, national interests will be highlighted also in energy policy, and the EU's integration developments will not progress as planned. Electricity will be generated from renewable domestic fuels whenever possible, and in other respects generation is based on coal and nuclear power.

Electricity consumption will grow very little in the Nordic countries. The use of biomass fuels in traffic applications will increase as the goal is to boost self-sufficiency. The electricity generation architecture will remain almost unchanged from present. Wind power generation will conform to the climate and energy strategy.

"In this scenario, the grid would be planned from a national basis, but the need for cross-border connections is also influenced by energy solutions in our neighbouring countries," Jussi Jyrinsalo says.

"Antennae up"

The planning work continues on the basis of the alternative scenarios. Now that the scenarios have been defined, modelling of the electricity market and the power system will be used for finding out what types of transmission needs are required by each of the scenarios. The specification of the necessary grid reinforcements, in turn, calls for more precise network planning.

"At this stage, we also have to pay attention to the new technologies and ageing of the grid so that the basic renovation needs and needs for new construction projects can be integrated wherever possible," Jussi Jyrinsalo says.

The scenarios are updated as necessary. Updates may be needed by issues such as new climate policy decisions.

"We will keep our antennae up. We must have up-to-date plans for various developments at all times. Pan-European scenarios are also emerging alongside national scenarios," Jyrinsalo points out.

The work group for the transmission grid scenarios for 2030 consisted of **Ilkka Savolainen, Seppo Hänninen** and **Maija Ruska** of the Technical Research Centre of Finland as well as **Hannu Maula, Kaija Niskala, Pekka Sulamaa** and **Maarit Uusitalo** of Fingrid. ■

Values and values

I was recently asked what the value of the nation-wide transmission grid is. "That's an easy one," I thought to myself. The value of the nation-wide transmission grid in Finland – transmission lines, substations and reserve power plants – is its replacement value, in other words 3,800 million euros, and that's it.

Or...is that it? Maybe we should think about this a bit more, because surely it cannot be that straightforward. First of all, it is difficult to define what the replacement value is. It means the price that would have to be paid if the present transmission lines and substations would have to be procured entirely new. But the grid is not new, it has been used for a length of time.

An alternative answer could be that the value of the grid is its present value. The grid is composed of components of different ages, and an age reduction can be specified for them. Then, all you have to do is to add together the values of the components, which gives a sum of about 2,000 million euros.

Now we have two values, 3,800 million euros and 2,000 million euros. Is either sum the correct answer, or is the truth somewhere in-between?

The difficulty of defining value reminded me of my motor boat, which was 5 years old when its motor was stolen. When the insurance company specified the present value of my motor, its age reduction was tens of per cent. I had to pay this age reduction to get a new motor. On the other hand, I found out that if I had sold my boat with the old motor before the theft, I would have obtained the same price that I had paid when I bought the boat 5 years earlier.

The same certainly applies to the transmission grid. If you examine an individual grid component, its value is determined by age. But when looking at the Finnish transmission grid as a functioning whole, its value is crucially influenced by the way in which it has been developed, operated and maintained.

The grid owned by Fingrid has been kept in a good condition for decades by renewing regularly aged and faulty parts and by servicing it so that in actual fact some parts of the system are as good as new. The new sections of the grid are procured so that they are well compatible with the other sections of the grid. The intelligence of the grid to withstand various extreme situations is also being developed continuously. All this is reflected in a high quality so that the transmission reliability of the grid represents six sigma level.

The value of the grid could also be defined by seeking an answer to the question of what the grid accomplishes: keeping the lights on in Finland, and a functioning electricity market. However, it is a whole different story to find out this value. ■

Kari Kuusela
Fingrid's Executive Vice President, responsible for asset management

This is how a transmission line comes about

The construction of an electricity transmission line begins by digging the foundations and finishes with the final cleaning and clearing of ditches in conjunction with the earthing work for the line. Between these, there are a number of work stages, all of which need to be carried out punctually, sustainably and safely.
This article presents how a solid and reliable transmission line is built using modern technology, traditional expertise and skilled workforce. Our guide presenting the various stages of the work is Fingrid's Project Manager Ritva Laine.

Text by Maria Hallila ■ **Photographs by** Juhani Eskelinen and Jari-Pekka Karhu

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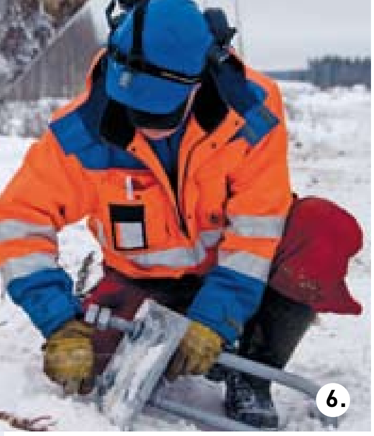

1. A transmission line tower stands firmly when its foundation is rigid and secure. Building the foundation is hence a critical stage. How laborious and demanding this is depends on the ground conditions. Firm moraine is the best soil type in view of the building of a transmission line.

The tower foundation can be made of prefabricated elements, or it can be cast at the site. Prefabricated foundation elements are usually used for guyed towers, i.e. ones equipped with a support wire, while large self-supporting towers require a sturdier cast-in-place foundation.

Fingrid's transmission lines are usually built using guyed steel towers. Self-supporting lattice towers are used in places where the line turns or ends and in areas with a limited right-of-way width, such as urban areas.

In the photograph, the foundation element of a tower leg is being lowered into the foundation pit at Fingrid's Kittilä-Vajukoski line site in the early winter of 2008. The line runs – like in many cases in Lapland – across large bogs, which is why the foundation work needs to be carried out in the winter; it is impossible to use machinery on the bogs when the ground is not frozen.

2. The building of tower foundations on bogs requires more work stages than other types of soil. Soft clay soil can also be problematic for a transmission line project.

The backfilling material used in the foundation pit above the prefabricated element has been brought to the site from elsewhere – the soft boggy soil is not suited for tower foundations. A mould is installed around the foundation element and filled with backfilling material. This prevents the mixing of various soil types.

3. If the soil is very soft, the tower foundations must be piled so deep that a load-bearing soil layer is reached. The piling depth is usually 3 to 12 metres, but it may sometimes be necessary to drive the piles as deep as 40 metres for example when building the foundations in old seabed.

4. The location – distance from the foundation and height – of the guy wire must be measured accurately.

The more difficult the terrain, the more skills and experience are needed in the various work stages. In terms of the reliable operation and safety of the line, it is imperative that the towers have the correct position and that they do not lean.

5. The foundation of a large self-supporting tower is usually cast in place. The area of the foundation may correspond to the building area of a small single-family house. Building of moulds for the columns in progress in the photograph.

6. The guy wire of the tower also needs strong and firm fastening, because it is subject to a heavy tension load in the direction of the wire. The anchor slab of the guy weighs several hundreds of kilos. The slab is embedded in the ground, and the soil layer on top of it must keep the slab reliably in place. The guy is fastened to the concrete anchor slab using a U-bolt.

7.-8. When the foundations are complete, the parts of the transmission line tower are brought to the site. The towers are assembled on the ground, each close to its erection site.

The photograph shows assembly work at Fingrid's site for the Ulvila-Kangasala line in the autumn of 2008.

9. Fingrid's new transmission line towers are made of steel. The tubular towers are made primarily in Finland, but lattice-structured towers are also imported from countries such as China and Turkey.

Before beginning the lifting, it must be ensured that the pin at the head of the foundation element matches the hole in the lower part of the tower leg.

10. Lifting of tower in progress. The steel tower weighing approx. 7 tonnes goes up prompted by a caterpillar, with an auxiliary boom used to assist the erection work.

The erection of a guyed tower represents typical Finnish expertise. In other parts of the world, the transmission lines are built using self-supporting

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towers. At a modern line site, the erection of towers proceeds at a pace of a few towers a day.

11.-12. The tower has been erected. The guys can now be fixed and tightened.

13. The last stage in the building of a transmission line is to install the conductors. Based on their operating principle, the towers can be categorised into suspension towers and tension towers. In suspension towers, the insulator strings hang down from the crossarms, while in tension towers the insulators strings are horizontal.

The conductors are nowadays installed so that they travel in the air throughout the work (tension stringing method). This prevents them from breaking or being damaged.

When the conductors and spacers are in place, the new line is almost ready. In order to secure electrical safety, the towers are provided with additional earthing by installing copper earthing conductors in the ground. The earthing can extend more than 50 metres from the tower.

In conjunction with earthing work, the tower site is levelled and cleaned of construction debris. It is also checked that the nearby ditches and culverts are open. After this, the line can be energised. ■

Progress of a transmission line project

CONSTRUCTION

Preliminary route planning
Preliminary planning of route alternatives
Preliminary alternative environmental impacts
Elimination of alternatives

Selection of final route alternative and decision on launching general design
Competitive bidding for design

General design
Field investigations
Location planning of towers
Prevention and mitigation of drawbacks
Structural engineering
Capital investment decision
Competitive bidding for construction work

Construction stage
Removal of trees
Construction work
Repairing damage caused during construction work

Acceptance inspection

PERMIT PROCESS

EIA procedure
EIA programme
Statement by contact authority
EIA report
Statement by contact authority

Survey permit
State Provincial Office

Construction permit
Determining the necessity for the line
Energy Market Authority

Expropriation procedure
Expropriation permit decision
Council of State
Advance seizure decision
Expropriation committee

Final review
Compensation matters
Expropriation committee

Ongoing transmission line construction projects in the Finnish grid

- 400 kV Keminmaa–Petäjäskoski
- 220 kV Petäjäskoski–Valajaskoski–Isoniemi
- 220 kV Isoniemi–Vajukoski
- 110 kV Inkoo–Karjaa
- 110 kV Hikiä–Vanaja
- 110 kV Nurmijärvi–Ruotsinkylä
- 110 kV Salo–Kemiö

Fingrid's extensive grid investment programme means busy times for Project Manager Ritva Laine. The company has a dozen or so major transmission line projects in progress or about to start soon.

Project Manager Ritva Laine:

"EIA is a GOOD FORUM for the preparation of transmission line projects"

The environmental impact assessment (EIA) procedure goes through the impacts of a transmission line project on the environment even before the final planning of the line begins. According to Fingrid's Project Manager Ritva Laine, the implementation times of projects have been extended by about one year by EIA, but on the other hand the expropriation and construction stages have become easier than before.

Text by Maria Hallila ■ **Photographs by** Juhani Eskelinen

The work of a project manager in a transmission line project begins where the EIA finishes. This is how Ritva Laine outlines her present job description. She is currently responsible for two 220 kilovolt transmission line projects securing electricity supply in Western Lapland: Rovaniemi–Kittilä and Kittilä–Vajukoski, with a total length of 250 line kilometres.

In the early part of this year, she was also assigned the project for the 400 kilovolt line between Vaasa and Seinäjoki in Western Finland. The new line will replace the present 110 kilovolt line in the region.

The boosted voltage level here, like in many other parts of the nation-wide grid, is related to a need to upgrade the transmission capacity of the grid. This is prompted by the ageing of the grid and by the plan of the Government of Finland to increase renewable energy production considerably and to potentially construct additional nuclear power capacity.

It is important to be heard

The EIA process of the 400 kilovolt transmission line project Pori/Tahkoluoto–Kristiinankaupunki was also completed recently, so the actual planning of the line can commence.

Ritva Laine says that she participates in the EIA procedure of her projects whenever possible.

"In this way, I know fairly well what problems can be expected and what critical issues may emerge when the actual project begins," she says.

Ritva Laine considers the EIA procedure as a useful and functioning forum, where matters related to the line project can be subjected to discussion in good time, before actual planning and engineering.

"When people have had an opportunity to express their opinions, fears, wishes and threats, it is easier to process these things in the later stages," she says.

According to her, the benefits of the EIA procedure are reflected in expedited and facilitated expropriation and construction stages.

Knowledge dispels distrust

Ritva Laine is a farmer's daughter and still lives in a countryside environment; her brother continues agriculture at the farm. Due to her background, she can regard and assess the impacts of a transmission line project from a landowner's viewpoint.

Those living and working near a transmission line nowadays tend to have a matter-of-fact attitude towards the projects. "Nobody actually loves the lines and landowners do not wish to have them on their land, but most of them can still see them as necessary and accept them," she says.

She adds that the change in attitudes has been clearly promoted by Fingrid's active communications and also by the changes in the company's procedures. Among other things, Fingrid is introducing a practice where landowners are also paid harvesting costs in conjunction with the clearing of trees required by a transmission line.

There are still erroneous notions involved in transmission line sites and the builders' performance. According to Ritva Laine, the most common faulty notions are that the ground surface is not restored after the work and that roads, bridges and ditches are damaged.

"Landowners also seem to fear that someone comes to work on their land without them being informed of this in advance."

Ritva Laine says that such neglect cannot happen when the new procedure is followed. She emphasises that Fingrid has made considerable input in instructing the contractors in recent years.

"One of the foremost aspects that we use when assessing the quality of the contractors' work is how well they have maintained contacts with the landowners."

However, the feedback that a project manager obtains from the area of the transmission line is not exclusively negative. Ritva Laine says that she has also received thanks for issues such as repairs of defects or shortcomings. She is delighted by the increased mutual understanding in discussions concerning the location of towers and technical solutions applied.

Strength calculation specialist's background

Ritva Laine, Master of Science in mechanical engineering, is specialised in strength calculations for steel structures. She has spent most of her work career with electricity transmission lines. She worked formerly in engineering and shifted to the position of project manager for transmission line projects in 1994. In the early part of this decade, she worked as Fingrid's environmental manager for a couple of years and then returned to project work.

"Transmission lines have become familiar to me from almost all aspects. The only thing I haven't experience of is maintenance," she says.

The focal areas of her career influence the way in which Ritva Laine regards her environment.

"When I see a transmission line, I nowadays pay attention to the technical solutions applied. Before, I did not notice the lines at all," she states.

She also thinks that the towers and lines adapt mostly well to the Finnish scenery. ■

New transmission line from Kokkola to Muhos

Fingrid is planning a 400 kilovolt transmission line from Ventusneva in Kokkola to the Pyhänselkä substation in Muhos in Ostrobothnia. The environmental impact assessment (EIA) of the project will be launched in the summer of 2009.

The planned transmission line is part of the long-term development plan for the nation-wide transmission grid in Finland. In the next 10 to 20 years, the ageing 220 kilovolt grid in Ostrobothnia in Western Finland will be replaced by a new 400 kilovolt grid, which will conform to the future transmission requirements. Some of the present transmission lines will be utilised later in the 110 kilovolt grid.

Transmission needs in the nation-wide grid in the coastal regions of Ostrobothnia are increasing because of growing electricity consumption and especially because of additional wind power production and large power plant units planned in the region. The planned transmission line from Ventusneva to Pyhänselkä is part of the crucial basic solutions for the development of the grid. These solutions make preparations for connecting new wind power capacity (2,000 MW) and the sixth nuclear power unit to the grid in accordance with the climate and energy strategy of Finland.

The new transmission line will improve not only general electricity supply in Ostrobothnia but also the system security of the entire grid. It will add to the north-to-south transmission capacity, hence responding to the future electricity transmission requirements. The shift-over to a higher voltage level will also reduce losses resulting from electricity transmission.

The transmission line will run in the municipalities of Kokkola (also former Kälviä and Lohtaja), Kannus, Himanka, Kalajoki, Alavieska, Merijärvi, Pyhäjoki, Raahe, Vihanti, Siikajoki, Siikalatva, Liminka, Tyrnävä and Muhos.

From Kokkola to Siikajoki (approx. 130 kilometres), the planned line will be located primarily in the place of the existing 110/220 kV transmission lines or parallel with them. According to preliminary plans, the present right-of-way will become 0 to 10 metres wider than now, depending on the cross-section in question.

Between Siikajoki and Muhos, the transmission line will be located in a new right-of-way over a distance of some 70 kilometres. Two alternative southern routes are also being examined between Siikajoki and Tyrnävä, differing from the main alternative over a distance of about 40 to 50 kilometres. The alternative line routes will also be placed in a new right-of-way. Preliminary plans suggest that the width of the new right-of-way required between Siikajoki and Muhos is approx. 56 metres.

The EIA procedure is expected to be ready in the late winter of 2010. The new transmission line will be commissioned at the end of the 2010s. At Fingrid, the matter is taken care of by **Mika Penttilä.** ■

New video introduces nation-wide grid

Video "Sähkönsiirron selkäranka" produced by Fingrid is a basic presentation providing insight of the principle of the transmission grid to those learning to know the energy industry.

The video using drawing animation introduces the various parts of the grid and related terminology. The presentation is also linked to the everyday life of landowners so that it tells why the transmission lines, the most visible part of the grid, are still constructed and renovated.

There has been a need for a short presentation of Fingrid in its public events arranged in conjunction with construction projects and in meetings with authorities. The video of a few minutes can also be viewed on the company's website. ■

80 years of POWER FOR FINLAND

Crossarm being erected on the first line in the Finnish grid.

The young independent Finland took a long leap forward in its development in January 1929 when electricity was switched on for the first time to the 110 kilovolt electricity transmission line running from the Imatra power plant in South-Eastern Finland to Turku in the west. This is where the nation-wide transmission grid had its origin. Grid construction created the preconditions for industrial growth and development and for consequent rise in the standard of living.
Over the decades, electricity has become an indispensable driving force for society, and as the electricity market is integrating, we are more and more closely linked to pan-European developments.

Text by Maria Hallila ■ **Photographs by** Electricity Museum Elektra and Erkki Laine

Finland was among the pioneers in electrification on a global scale. There are a number of reasons why electricity became so popular here. Because of our Nordic location, cold climate, long dark winters and extensive geographical distances, we need considerably more energy for heating, lighting and transport than countries situated further south and with more dense population. Our industries are also highly energy-intensive, and the high standard of living calls for extensive energy supply.

At around the time when the first line in the nation-wide grid was completed, at the end of the 1920s, electricity had already brought great relief to the life of urban dwellers in particular. Electric lighting had been introduced for the first time in the weaving room of Finlayson's textile mill in Tampere in 1882. Helsinki had started experiments with electricity as the energy source of street lighting in 1910. By 1920, almost all towns and industrial centres had a local electric utility.

Electrification progressed more slowly in the countryside, but by 1929 just over half of the 531 rural municipalities in Finland had at least one electric utility each. When the Second World War began, the electrification rate in the countryside was more than 40 per cent.

Industries as trailblazers

Industries served as the driving force in electrification and electricity transmission in Finland. The first long-distance transmission connections built by private industries had a voltage of 20 kilovolts, but this was soon raised to 70 kilovolts as a result of increased electricity generation volume and greater transmission needs.

The wood-processing industry constructed its first major power plants in the early 1920s, and the first 70 kilovolt transmission lines to south-western and south-eastern Finland were completed at around the same time. Electricity was transmitted from the power plant built in the Äetsä rapids of the river Kokemäenjoki to Rosenlew's wood-processing mills in Pori on the west coast over a distance of 60 kilometres. The route of the other line ran over a distance 38 kilometres from the Inkeroinen power plant constructed by Tampella at Ahvenkoski in south-eastern Finland, from where it branched further to Kyminlinna.

High-voltage networks of dozens of kilometres were also completed in the surroundings of many towns.

State starts to build lines

The building of the Imatra hydropower plant (1921-1929) marked the beginning of the nation-wide electricity transmission grid in Finland. It was a major undertaking for the young republic to extend a transmission line across the country all the way to Turku to transmit the electricity generated by the Imatrankoski rapids to the foremost built-up areas and industrial facilities. At best, over 700 men were working on the line sites, and the costs rose to the same level as the construction costs of the Imatra power plant. The costs of the power plant and transmission network by May 1932 were more than 400 million Finnish markkas (approx. 140 million present euros).

Electricity was switched on to the line for the first time on 16 January 1929. The entire project was carried out in five years. The technical problems involved in the construction work were challenging, because there was no experience of this industry in Finland. Similarly, there were no Finnish security regulations concerning transmission networks until 1930. Mainly German regulations and standards were applied to the construction of the line with almost 2,000 towers.

In 1929, the total length of the transmission lines starting from Imatra was 487 kilometres. The 70 kilovolt lines built by private industries totalled 157 kilometres by that time.

Installers of the first towers presenting the result of their work.

The 400 kilovolt transmission voltage was introduced in 1960.

Parallel and competitive construction

When the Imatra power plant was completed, there were some doubts that Finland would never use as much electricity as is produced by the plant. This soon turned out to be an erroneous notion. Since the commissioning of the Imatra power plant, electricity consumption in Finland has grown continuously apart from the war years and some other exceptional years.

In 1930, electricity consumption in Finland exceeded the milestone of one terawatt hour*. Between the First and Second World Wars, electricity generation per capita in Finland surpassed that in many industrial countries, and was approaching consumption in countries with abundant hydropower production: Norway, Sweden and Switzerland. Industries used a majority of the electricity generated, as much as 90 per cent.

The transmission grid expanded as both private industries and Imatran Voima Oy, established in 1932, constructed their own 110 kilovolt lines in different parts of Finland. The competitive situation between these two electricity producers and transmitters was fairly even at the end of the 1930s: in 1938, Imatran Voima sold about 770 gigawatt hours* of electricity, and industrial transmission systems transmitted some 720 gigawatt hours. The two networks also had about the same size.

As a result of the Second World War, Finland had to cede almost one third of the constructed hydropower plant capacity and capacity under construction as well as the transmission network built in the Karelian Isthmus to the Soviet Union. At the end of the war in 1945, there were 1,680 kilometres of 110 kilovolt transmission lines in Finland.

In the forefront of new technology

One of the most important tasks in post-war reconstruction was to secure electricity supply in Finland. This is why the construction of new hydropower plants was launched in the large rivers in Northern Finland – Oulujoki and Kemijoki – and transmission lines were also built to the consumption areas in Southern and Central Finland. In 1946, there were eight large ongoing power plant projects in Finland.

New solutions were needed so as to transmit electricity to the south. The transmission voltage of 220 kilovolts was introduced in line with the harnessing of the river Oulujoki in the early 1950s, and the level of 400 kilovolts was taken into use ten years later to transmit the power of the river Kemijoki.

Imatran Voima's line ran from Pyhäkoski on the river Oulujoki southward via Central Finland. The line owned by industries, in turn, extended from the Isohaara power plant built by Pohjolan Voima Oy in the river Kemijoki along the coast to Kyminlinna in south-eastern Finland.

In about 20 years (1945–1965), the total power of Finnish hydropower plants and the length of transmission lines (110–400 kV) more than quadrupled. Finland was a pioneer in introducing new high-voltage technology in those days, too.

Borders open for electricity transmission

One of the milestones in electricity transmission in the 1950s and 1960s was the launching of co-operation with Sweden and the Soviet Union. Electricity transmissions between Finland and Sweden could begin after a 220 kilovolt line was built from Petäjäskoski in Finland to Kalix in Sweden.

In the 1960s, electricity purchases from Sweden reached their peak in 1964, when 666 gigawatt hours were imported. An agreement was signed between the countries in 1967 to construct a 400 kilovolt cross-border line.

Purchases of electricity from Svetogorsk in the Soviet Union began in 1961, but it was not until 1975 that an agreement on annual electricity deliveries was signed. This required a new 400 kilovolt transmission link, with the Yllikkälä substation completed near Lappeenranta for the link in 1979.

The transmission connections from the western and eastern neighbouring countries together with the establishment of Nordel, organisation of the Nordic electricity producers, in 1963 improved the security of electricity supply in Finland.

The Fenno-Skan high-voltage direct current link connecting the Finnish and Swedish grids was taken into use in 1989. The nominal voltage of this 200-kilometre submarine cable running in the Gulf of Bothnia is 400 kilovolts and present transmission capacity 572 megawatts.

Electricity from north to south

By the end of the 1960s, most of Finland and by the early 1980s the whole of Finland had been electrified. Household appliances such as freezers, dishwashers and colour televisions became common in Finnish homes in the 1970s.

Industrial production almost doubled in Finland in the 1960s, which also led to a rapid growth in electricity consumption. The need for electricity was also boosted by the rapid electrification of households and agriculture as well as by the increasing popularity of electric heating in single-family houses.

An idea to electrify the railways was first suggested in the early 20th century, and the idea was put into practice when Sähköradat Oy owned by Oy Imatran Voima and Oy Nokia Ab was established in 1964. The first electric train started service between Helsinki and Kirkkonummi in 1969.

What was characteristic of the electricity transmission grid in Finland in the 1960s were the long 220 and 400 kilovolt transmission lines from the hydropower plants in Northern Finland to towns and industrial centres in Southern Finland. The 400 kilovolt grid was meshed, and it was enlarged especially in conjunction with the construction of new coal and nuclear power plants in Southern Finland in the 1970s.

Imatran Voima's extensive project of engineering and building the so-called atomic ring required the work input of 100 engineers, and 1,500 man-years in the construction phase. The atomic ring (Alajärvi–Seinäjoki–Olkiluoto–Inkoo–Hyvinkää–Loviisa–Yllikkälä–Huutokoski–Alajärvi) connects the largest power plants with the consumption centres in Southern and Central Finland.

Era of free electricity market

Finland was one of the first countries in Europe in the 1990s to liberalise its electricity market for free competition. In conjunction with this reform, electricity production and transmission were unbundled from each other. By virtue of the Electricity Market Act which became effective in 1995, industries were able to subject their electricity procurement to competitive bidding, and all electricity consumers have had this opportunity since 1997.

As part of the electricity market reform, the government of Finland, Imatran Voima Oy and Pohjolan Voima Oy made an agreement to establish a separate transmission system operator (TSO). In 1997, the biggest business transaction made in Finland by that date gave Suomen Kantaverkko Oyj (from 1999 Fingrid Oyj) the entire transmission grid business of Imatran Voima Oy and Pohjolan Voima Oy. The core of this business was composed of the transmission grids with a total line length of 14,000 kilometres.

Fingrid is now responsible for the nation-wide grid and entire power system in Finland. The company sells grid services to all electricity market parties and contributes to the functioning of the market.

The set-up of two different parties had prevailed in the construction of the Finnish grid almost throughout the 20th century: private industries and their

* 1 terawatt hour (TWh) = 1,000 gigawatt hours (GWh) = 1,000,000 megawatt hours (MWh) = 1,000,000,000 kilowatt hours (kWh)

partners on one hand and the government-owned power companies on the other hand carried out their projects side by side and in competition with each other. A transmission grid was a major competitive edge for both.

"The set-up was quite controversial at times. However, the construction of overlapping grids was considered to be uneconomical, and Finns have been able to develop the system as a whole through responsible co-operation," is how **Timo Toivonen**, who headed the Finnish transmission system operator for 15 years, characterises the history of the Finnish grid.

According to him, accomplishing a uniform transmission grid has created a good foundation for the electricity market and its development. On PVO's side, grid co-operation was developed by **Ilmari Leskinen**.

Towards a European electricity market

Electricity consumption in Finland went over 80 terawatt hours in 2001. The Nordic electricity market came about, and Fingrid made considerable investments in increasing the transmission options on the cross-border connections.

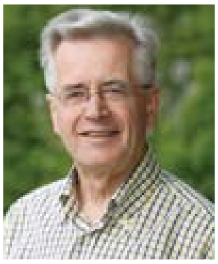
The commissioning of the third 400 kilovolt connection between Finland and Russia was celebrated at the Vyborg converter station in February 2003.

The system security of the nation-wide grid has remained at an excellent level for a length of time, and Fingrid has repeatedly been among the best performers in international benchmarking studies concerning the operational quality and costs of transmission system operators.

The development of the Finnish grid is currently guided to an increasing extend by pan-European and even global trends and aspirations. Fingrid, like all European TSOs, is facing major challenges by the fighting of climate change while at the same time the goal is to maintain a reasonable price of electricity and its secured supply.

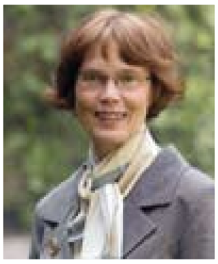
In order to intensify the functioning of the electricity market and so as to re-

Comments on the Finnish grid



"For industries, the most crucial turning point in the development of the Finnish grid was the establishment of Fingrid. It revolutionised everything, and there was no way of forecasting the scope of the change at that time. Fingrid has become a true win-win story. Everything now works as it should, and we are satisfied with the market that has been created through Fingrid. The grid is now used for promoting competition, and this is the great change that came about in line with Fingrid."

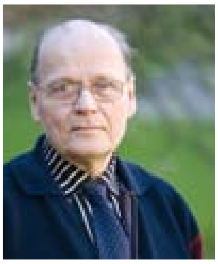
Magnus Buchert, M.Sc. (Eng.), served in senior duties in industrial energy use and production from 1970 to 2003



"The system security of the grid is becoming an increasingly important consideration. People are less and less tolerant of power cuts, and if one was to occur in the nation-wide grid, it would concern a large area. There would certainly be much criticism as a result of something like that. On the other hand, people are against almost all types of construction: 'There's no need for new power lines, we get electricity from the socket anyway!'

It must be difficult for a transmission system operator to live with this discrepancy. People should understand that if we wish to have a reliable supply of electricity, the towers must be there. The discussion concerning these things is not always intellectually honest."

Liisa Haarla, Professor, Power Systems and High Voltage Engineering, Helsinki University of Technology



"What comes to my mind first of the Finnish grid is its reliability. We have had very few power cuts in the nation-wide grid. This must be among the best results globally, maybe even the best. The grid also works very economically. The grid is reliable despite the fact that being a sparsely populated country, Finland has long lines and severe winter conditions. Engineering skills are one explanation to this."

Tapani Jokinen, Professor emeritus, Electrical Engineering, Helsinki University of Technology

"Development work was given much emphasis after the Second World War: there were electricity laboratories, and tower tests and vibration measurements were carried out. There has also been significant co-operation with Finnish industries such as Strömberg, Suomen Kaapelitehdas and Vuoksenniska Oy.

Personally, I consider it very important that responsibility for the engineering, construction and maintenance of transmission lines belonged to a single organisation. In this way, total responsibility was in the same hands, and feedback was obtained from maintenance both to engineering and construction. Above all, we built the grid for ourselves.

I am not saying this to criticise the present approach where the client orders the work from separate suppliers through competitive bidding. It's just that in the earlier stages of the Finnish grid this procedure would have been completely wrong. In the present situation, Fingrid has great retain the high level of system security, Fingrid has launched its most extensive capital expenditure programme to date. The objective is to use grid reinforcement projects to make preparations for a considerable increase in the share of renewable energy in electricity production, as defined in the energy strategy of the European Union.

Of Fingrid's present capital investment projects, the biggest is Fenno-Skan 2, the submarine cable connection between Finland and Sweden due to be ready in 2011. The company is also prepared to build Estlink 2, a second high-voltage direct current link between Finland and Estonia, in the near future.

"From the Finnish viewpoint, future grid development will mean the development of the grid in the area of the Baltic Sea rather than the Nordic grid," says Fingrid's President and CEO **Jukka Ruusunen**.

According to him, the Nordic countries are too small an area when regional grid plans conforming to the EU's objectives are being drawn up and when developing the international electricity market.

ENTSO-E, organisation of the European TSOs launched in April 2009, coordinates and promotes grid development in all 34 signatory countries in the spirit of the EU's energy strategy on the way towards a single European electricity market.

This article is based on the following publications describing the history of the Finnish transmission grid:

- Vaiheikas verkko, 1999
- Sähkön valtavirta (multimedia CD), 2004
- Yhteisillä linjoilla, 2004
- The other sources comprise Fingrid Magazine issues from 1998 to 2009 as well as Imatran Voima Oy's jubilee book "Puoli vuosisataa Imatran Voimaa", 1982. ■

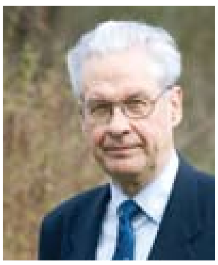
sponsibility for it having sufficient expertise and knowledge of the suppliers."

Jaakko J. Laine, M.Sc. (Eng.), served in expert and management duties in transmission line engineering and construction at IVO from 1961 to 1998

"In view of the system security of the nation-wide grid, the basic structure of the grid is one of the foremost issues. It must be as good and unambiguous as possible. We have suitably few transmission voltages: 110, 220 and 400 kilovolts, with the share of 220 kilovolts decreasing further.

Selectivity of relay protection is also important. This means that in the event of a fault, only the damaged equipment is separated from the grid. And of course it is also essential to know the entire grid and its transmission capacity. Our transmission distances are long, and we need to be able to set such limits on the transmissions that they are not exceeded so that the transmission capacity can be kept good."

Lauri Mäkelä, M.Sc. (Eng.), served in key duties in grid engineering and joint operation at IVO from 1958 to 1997



"Competition in electricity transmission and production has kept Finns on their toes. With an engineering background, I tend to say that we Finns had very competent engineers to build the nation-wide grid. One example of this is the portal support type designed in Finland, now also used elsewhere in the world.

We have also engineered vibration dampers which prevent the lines from swaying too much by wind. These dampers are also referred to in Cigré's reports. Many still remember Doctor of Technology hc **Antti J. Pesonen**, who was a top expert in the thunder protection of lines. The Finnish transmission grid relies on solid engineering expertise."

Kalervo Nurmimäki, Last President of Imatran Voima Oy

"When Fingrid's operations were launched, it was set certain financial objectives: the transmission prices had to come down by 15 per cent. This was achieved fairly quickly. There was a bit of good luck involved, with the price of money being quite low, but what was decisive was the operating model whereby everything possible was obtained from the market through competitive bidding. Construction projects and maintenance as well as loss energy purchases were obtained through skilful competitive tendering. The transmission system operator had the strength to understand these things: it retained a sufficiently solid personnel so that it could know what it wants.

The company personnel were – and certainly still are – highly motivated. The organisation was put together from a clean slate. There was no burden that easily accumulates in old organisations. Fairly soon there was a feeling that people like to work in Fingrid, and we were able to attract good people in this way."

Timo Toivonen, M.Sc. (Eng.), Fingrid's President from 1997 to 2006

The quotations are based on interviews made in May and June 2009.

Design and colour in the landscape

– History of the Finnish landscape tower

Text by Maarit Kauniskangas ■ **Photographs by** Juhani Eskelinen and Sami Kuitunen

Landscape towers stand out from other transmission line structures due to their special shapes and colours. They are often also landmarks, and can even be regarded as environmental art in some cases. The landscape towers show that technical solutions can also pay attention to aesthetical considerations.

Finland has more landscape towers designed specifically for a certain location than any other country in the world. Moreover, Finland was the first country in the world to design and build them.

How it all started

The impetus for special-design electricity transmission line towers was provided by a seminar in the early 1990s organised by the then transmission system operator IVO Voimansiirto Oy (IVS). The seminar discussed the appearance of transmission line towers.

One of the participants was architect **Simo Järvinen**, who had said that the towers look ugly. **Erkki Partanen**, Environmental Manager of IVS, suggested that whenever an overhead line structure cannot be "hidden", a structure suited to the particular scenery could be built. Simo Järvinen agreed and recommended that the matter be developed further with Professor **Antti Nurmesniemi**, interior designer and "grand old man" in Finnish design.

Since IVS's President **Timo Toivonen** and the Board of Directors of the company warmed up to the idea right away, Partanen contacted Antti Nurmesniemi. However, the transmission line engineers were less enthusiastic – they feared that the towers would be considerably expensive and that people would soon demand that such towers be built everywhere.

First landscape towers

Studio Nurmesniemi Ky commenced the design of landscape towers in 1993. At that time, the studio employed Antti Nurmesniemi and two other interior designers: **Jorma Valkama** and **Björn Selenius**. At first, the designers learned about the technical requirements of transmission line towers.

The first tower suggestions by Studio Nurmesniemi were reviewed by IVS, with an internal vote arranged on them there. This was won by a great majority by a tower repeating the shape of a bird's beak in the crossarm structure. However, this tower type never suspended IVS's own transmission lines but was introduced by Turku Energia at Hirvensalo in Turku. On the other hand, the shape of the bird beak is used in Fingrid's emblem introduced in 1997.

IVS's first landscape tower was completed in Laukaa in Central Finland in 1995 soon after "Keltanokat" (Yellow beaks) at Hirvensalo in Turku. The same year, "Sinikurjet" (Blue cranes) were erected at a multi-level junction at the crossing of Turuntie Road and Ring Road III in Espoo. The towers were named a work of environmental art even before they were erected. They were awarded the Finnish Steel Structure Award in 1995 and in the annual Good Design competition by the Chicago Athenaeum in 1999.

From idea to implementation

Since the "Yellow beaks" and "Blue cranes", many different landscape towers have been installed in various

"It takes time to hone the ideas – this work is no instant design," says Jorma Valkama.

parts of Finland. Antti Nurmesniemi's last assignment was a series of towers called "Antin askeleet" (Antti's steps) at Meilahti in Helsinki.

Jorma Valkama, who has been involved in the design of the landscape towers from the very first one, has designed the four most recent erected towers. Where does a designer get the ideas for landscape tower design?

"The ideas certainly do not come about by just drawing, but by thinking. I need a lot of photographs from the location of the tower. I visit the site often and let the ideas mature in the subconscious. It takes time to hone the ideas – this work is no instant design."

According to Valkama, the design process has changed in line with devel-

This year, Fingrid celebrates the 80th anniversary of the Finnish electricity transmission grid by publishing the book "Form and colour in the landscape – History of the Finnish landscape tower". The book is distributed in Fingrid's events. The book containing many photographs compiles not only the history of landscape towers but also information on the work processes and technical details of the towers.

Transmission lines through the eyes of local people

Text by Katriina Soini, Eija Pouta, Maija Salmiovirta, Tapani Kivinen, Marja Uusitalo, MTT/Taloustutkimus

Beauty is in the eye of the beholder, they say. This is true, because notions of a good landscape reflect people's values and attitudes, age, profession, interests, but also knowledge of various scenic elements and their impacts on the environment. Transmission line landscapes can be viewed from a number of aspects: visual, ecological, economic, social and cultural. When local residents assess the significance of a transmission line landscape, these various aspects are present, with various emphases in the residents' views.

The attitudes of local people to transmission lines are usually studied when a new right-of-way is being planned or when an existing line is repaired. Instead, it is rarer on an international scale to study how the local people experience transmission lines and rights-of-ways as part of the landscape in their residential environment. Researchers of MTT Agrifood Research Finland have studied this in a survey among the residents of the villages of Lepsämä, Nummenpää and Perttula in Nurmijärvi.

According to the results, local people usually regard both existing and potential future transmission lines and rights-of-ways as a scenic drawback because of appearance, sound inconveniences and potential health impacts. However, 1 out 10 respondents had a positive attitude towards transmission lines. They thought that electricity is needed, which is why pow-

Design and colour in the landscape (continues from previous pages)

opments in information technology. At Studio Nurmesniemi, the plans were drawn by hand, and scale models were built of them. The suitability of a tower to its surrounding landscape was tested by photographing the scale model using suitable optics.

"Nowadays the entire design of a landscape tower takes place by means of computer. The sketch can be inserted in its correct environment in an image made by computer, and the sketch tower can be given various colours and studied from different angles in different times of the day and year."

In recent years, it has also been possible to change and control the lighting of landscape towers by means of computer. According to Jorma Valkama, it is presently standard procedure that a landscape tower is illuminated. This affects the choice of surface materials and colours during the design stage.

Team work and innovations

However, the designers of landscape towers do not plan the towers on their own, but tower design is team work. Even the first ideas are reviewed carefully by a group consisting of experts in various fields. The team comprises the designer, representative of the client, structural engineer, representative of the engineering works building the tower, and lighting designer.

"Landscape towers involve a multitude of knowledge, which no single person can master," Jorma Valkama points out.

The landscape towers have also given an opportunity to experiment with new technical solutions. As an example, the mosaic-patterned landscape tower erected at Nummela in Vihti is clad with steel cassettes specifically designed for the tower, giving a very smooth surface. It is also easy to service the surface of the tower one steel cassette at a time.

Landscape towers attract interest

The initiative for the design of new landscape towers has often come from Fingrid's stakeholders. Local decision-makers have also been involved in the design process.

The publicity gained by the landscape towers has been invariably positive. Moreover, the towers have also been noted in cultural news – much thanks to Antti Nurmesniemi.

Interest towards landscape towers has not faded; on the contrary. Fingrid receives frequent inquiries about landscape towers. Several foreign experts in the electricity transmission business have also visited Finland specifically to see the Finnish landscape towers. ■

Transmission lines through the eyes of local people (continues from previous pages)

Photograph by Tapani Kivinen

Transmission lines traversing a countryside scenery in Nurmijärvi.

er lines are necessary. They also assessed transmission lines and rights-of-ways from the viewpoint of recreational uses.

The survey also revealed that especially those who lived close to the lines had a positive notion of them. This can reflect becoming accustomed to transmission lines, but also an ambition to accept all scenic elements in one's own immediate environment. New residents in particular tend to have a positive attitude towards transmission lines and to accept them.

Many research studies have shown that transmission lines offer a favourable habitat for several increasingly rare and even endangered species. From an ecological viewpoint, electricity transmission lines constitute an interesting and even conflicting environment, because they have both positive and negative impacts in terms of the natural environment. The survey indicated that people are not yet very well aware of the positive impacts of transmission lines, since most people interested in environmental issues had a very critical attitude towards the lines. All in all, it appears that people's attitudes towards transmission lines are guided by beliefs rather than relevant research results. The more information a respondent possessed, the more positive the attitude.

The survey also examined landowners' views of transmission lines. Forest owners had a more negative attitude than farmers. It would be worth while to communicate and market the multiple uses of transmission line areas to forest owners.

The results of the survey will be advanced in landscape workshops in the same research area, also involving the transmission line topic. ■

According to Leena Korpinen, work and other activities under a transmission line are limited by factors primarily related to electrical safety, not so much ones pertaining to electric and magnetic fields. The forbidden issues include flying a kite, spraying of water on the conductors (for example irrigation), and walking under a line with a long, conducting fishing rod (for example made of carbon fibre) on the shoulder. It is also forbidden to operate the crane of a truck under a line. Moreover, some medical devices inserted in the body may operate erroneously under a transmission line.

Health impacts studied continuously

Electric and magnetic fields of transmisson lines pose no threat to people

Is it safe to buy a plot close to an electricity transmission line? Should I build a house next to a power line? Leena Korpinen, Professor of Environmental Health at the Tampere University of Technology, is accustomed to answering questions like these. However, she points out that you must ultimately make the decision yourself.

Text by Suvi Artti ■ **Photograph by** Teemu Launis

The impacts of the electric and magnetic fields of electricity transmission lines preoccupy people's minds especially when a transmission line is being planned in the neighbourhood or when people are moving close to one. This concern is understandable but undue: the recommended values set on the exposure of population on the basis of research results are not exceeded in the vicinity of transmission lines.

No risk of electric and magnetic fields in the transmission line area

The power system causes electric and magnetic fields in its surroundings, and the potential health impacts of these fields have been studied extensively. Based on the research findings, the Finnish Ministry of Social Affairs and Health has issued a decree which confirms the recommended maximum values for low-frequency electric and magnetic fields.

According to the decree, the recommended value for the exposure of population to the electric field of a transmission line (50 Hz) is 5 kilovolts per metre (kV/m) and to the magnetic field 100 microteslas (μT), when the exposure lasts for a considerable period of time. If the exposure does not last for a considerable period of time, the values are 15 kV/m and 500 μT respectively.

In terms of the magnetic fields, the values measured at transmission line areas are clearly below the recommended values: the highest measured values under a 400 kilovolt line at a height of 1 metre from the ground are 12 μT, in other words clearly below the upper limit of 100 μT of the recommended value.

Similarly, the recommended values for the electric field are not exceeded on 110 and 220 kilovolt overhead lines, but according to measurements by the Tampere University of Technology, the value of 5 kV/m is exceeded on 30 per cent of the measured 400 kilovolt line sections. Considering that people do not spend significant periods of time

beneath the lines, the recommended values for the electric and magnetic fields are not exceeded in the transmission line area or outside it.

Cancer risk in the same range as that of coffee

Some research studies have suggested that there could be impacts at clearly lower exposure levels than what the values recommended in the decree of the Ministry of Social Affairs and Health are. IARC (International Agency for Research on Cancer) working under the World Health Organization WHO has stated that long-term housing in a magnetic field of over 0.4 µT may cause leukemia in children. IARC has categorised low-frequency magnetic fields in Group 2B, possibly carcinogenic to humans.

However, according to Fingrid's Chief Specialist, Professor **Jarmo Elovaara**, the increase in the risk has not been indicated in a scientifically valid manner. "Even after 30 years of research, we do not know a single mechanism that could explain the potential ability of magnetic fields to cause cancer," Elovaara says.

Leena Korpinen points out that other substances in Group 2B include coffee and exhaust gas. This group means that it has not been possible to indicate conclusively the causal relationship between the substance studied and cancer. The group does not mean that there would be a significant growth in the occurrence of cancer as a result of the substance.

"The controversial risk of leukemia was known in 2002 when the decree of the Ministry of Social Affairs and Health was drawn up," Korpinen states. "In 2007, WHO adopted the same view as IARC earlier, and SCENIHR, the independent scientific committee of the Commission of the EU, did so this year. In other words, it appears that there would be no changes to the recommendations."

Living close to a line raises questions

Leena Korpinen, doctor in both medicine and technology, has studied electric and magnetic fields for 20 years. Her job description also includes answering related questions. She says that she receives a telephone call on this topic on average about every second week.

"Most often, people have questions about the buying of a house or plot: the caller is considering buying one near a transmission line and wants to know what risks are involved in this."

She says that the telephone calls have left her with an impression of Finns as "quite level-headed people".

"People do not usually call me in distress, but they have usually thought about the matter and found out things on their own before they contact me. They may want to have a confirmation to their own notion and ask what I would do in a similar situation; would I build the house or buy the plot."

"The callers may be disappointed at first when I cannot specify a certain safe distance in metres for buildings from a transmission line," Leena Korpinen says. "However, after we talk for a while, people usually understand that they ultimately have to make the decision themselves."

Leena Korpinen says that her "standard answer" consists of three parts. First of all, she gives the facts concerning the recommended maximum values, and also mentions IARC's leukemia view "so that people would not feel that some information is concealed".

"Secondly, I encourage people to reflect on their own worrying: are they usually troubled by various things, and what would it be like to live somewhere if you had to worry constantly. It is good to contemplate these things in advance, because you may even develop physical symptoms if you are concerned over something on a continuous basis."

Thirdly, according to Leena Korpinen, you should also remember that close-by transmission lines may influence the price of a real estate if the matter becomes topical at some point in the future.

Health concerns should be considered in zoning

Leena Korpinen says that there are no official building regulations relating to electric and magnetic fields in Finland, but the regulations are based on electrical safety – there must be a certain distance to substations and transmission lines because of the risk of electric shock. However, the guideline* drawn up as support of the decree of the Ministry of Social Affairs and Health recommends that health concerns should be taken into account both when zoning areas close to transmission lines and when planning new lines. The group of experts formulated this as follows:

"The decree does not require that a protective area outside the transmission line area be specified in the zoning process. However, in the zoning of residential areas it would be good to consider electric and magnetic fields because of the health impact concerns people may have. Moreover, it is desirable that no extra activities are zoned in transmission line areas. ---

There are no official instructions for the placing of transmission lines in Finland, but the goal in the planning of lines is usually that they are not built close to housing, day care centres, playgrounds or schools, for example. One reason for this is that notions discussed in public, concerning the poten-

*Korpinen, Leena 2003. "Yleisön altistuminen pientaajuisille sähkö- ja magneettikentille Suomessa." Sosiaali- ja terveysministeriön oppaita 2003:12

tial health impacts of overhead lines, may cause anxiety in people."

Sami Kuitunen, who is responsible for zoning matters at Fingrid, says that Fingrid cannot control building outside the transmission line area. Even though the adverse impacts of the electric and magnetic fields of transmission lines have not been proven scientifically, Fingrid urges, for example in conjunction with its statements to zoning plans, that people's concerns related to electric and magnetic fields should be taken into account.

New research on 110 kilovolt lines and substations

The most recent research project concerning the electric and magnetic fields of transmission lines, funded by the Ministry of Employment and the Economy, will come to an end in September 2009. According to Leena Korpinen, this project primarily focusing on 110 kilovolt lines and substations does not aim at new research findings related to the health impacts of the fields, but it was launched so as to increase general awareness of exposure to electric and magnetic fields.

"The earlier research studies have concentrated on 400 kilovolt lines and substations, while there is no measurement data on 110 kilovolt lines," she says.

As could be expected, the electric and magnetic fields under 110 kilovolt lines were clearly below the recommended values: the highest measured electric field value was 2.3 kV/m and the next highest 1.7 kV/m. The highest value was measured at a location where a 400 kilovolt line is situated parallel with a 110 kilovolt line.

There is also an ongoing project which studies comprehensively the exposure related to working at 110 kilovolt substations. Earlier studies of the exposure of workers have also concerned primarily 400 kilovolt lines and substations. ■

KNOW THE TERMS

This column presents and defines terminology in the electricity transmission business.

Quantities used in conjunction with electromagnetic fields

An electrically charged conductor creates an electric field around it. It can also be said that the conductor is energised in this case. If there is a voltage difference between the ends of the conductor, the electric charges begin to move towards the ends of the conductor. This movement is referred to as current, and it creates a magnetic field around the conductor. At low frequencies, for example at the frequencies applied to electricity transmission and distribution, the electric and magnetic fields are in practice independent of each other. This is necessarily not the case for instance with radio frequencies.

Describing physical phenomena calls for the use of certain quantities and their units of measurement, such as time/second, distance/metre, weight/gramme etc. Life is easier if the same units of measurement are used everywhere. There is an almost universal convention on this. In 1960, the General Conference on Weights and Measures (CGPM) reached an agreement on the introduction of the so-called SI system (SI = Système International d'Unités).

In the SI system, the magnitude of the electric field strength is expressed by a quantity where the dimension is volts per metre (V/m). Correspondingly, the intensity of the magnetic field strength is expressed by a quantity where the dimension is amperes per metre (A/m), and the intensity of the magnetic flux density is expressed by tesla (T or Vs/m^2). Physically, one tesla is defined as the field intensity generating one newton of force per ampere of current per metre of conductor. In practice, the electric fields of man-made systems are so much greater than the basic unit that it is justified to use the quantity of 1,000 V/m, i.e. 1 kilovolt per metre (= 1 kV/m). On the other hand, the magnetic flux densities are most often so low in relation to the basic unit that it is practical to express their magnitude by a fraction of the basic unit. An ordinary quantity is 1 microtesla (1 μT), which is one millionth of 1 T.

Even if there were no man-made electromagnetic fields, the surface of the Earth is influenced constantly by an electric field caused by various natural phenomena. In areas of beautiful weather, its intensity is approx. 0.1 kV/m and under a thunder cloud up to a few kilovolts per metre. Correspondingly, at the latitudes of Finland, the Earth's own magnetism causes a magnetic flux density in the range of 40 μT close to the ground. However, the rate of change of these fields is so small that they can be regarded similar to the fields created by direct current. Experience has shown that they pose no danger to people, animals or other organisms. All electric and magnetic fields having a considerable duration and a frequency other than zero are man-made fields.

The quantities describing the intensity of an electric field strength and of a magnetic flux density together with the related dimensions are very vague to laymen, because in normal conditions people do not notice an electric or magnetic field in the environment. It is difficult to have a concrete point of reference to these quantities.

I will illustrate the matter with an example calculation. Let us assume that there is an electricity conductor with a radius of 1 mm suspended at a height of 1 metre above even ground, and a voltage of 7.6 V is led to the conductor. In this case the intensity of the electric field strength on the surface of the conductor is 1 kV/m. Correspondingly, if there is a current of 6.3 A in a single conductor in the air, the intensity of the magnetic field at a distance of 1 metre from the conductor is 1 A/m. In this case, the magnetic flux density at this point is 1.26 μT. If you wanted to reach a flux density of 100 μT at a distance of 1 metre from the conductor, the current should be 500 A, in other words quite high, because 500 A corresponds to a power of 110 kW in a 220 V single-wire system! ■

Text by Jarmo Elovaara

Birds seldom collide with transmission lines

In this decade, Fingrid has commissioned several research studies of the risk of collision between birds and transmission lines. Based on the research findings, transmission lines in the nation-wide grid seldom pose a significant threat to birds, let alone to entire populations and their favourable conservation status.

Text and photographs by Pertti Koskimies

Potential disadvantages caused by transmission lines at places where birds tend to gather have been studied recently at Fingrid's initiative. The risk of birds to collide with a transmission line or have an electric shock from one has earlier been studied in several countries such as the United States and Spain, where transmission line towers offer nesting places and lookout spots for birds of prey and other large birds favouring open areas. These results cannot be adapted to Finland as such, because the species, their habitats and living habits differ from each other.

In recent years, Fingrid has ordered from ornithologists several studies concerning the collision risk. The most extensive studies have been carried out in conjunction with line renovation projects at Pernajanlahti in Southern Finland in 2001 to 2002 and at Ritassaarensuo beside the Ridasjärvi lake in Hyvinkää in Southern Finland in 2008. This year, the collision risk is studied at Isoneva in Pomarkku, where nesting birds and birds resting there during the migration period will also be counted.

The methods and results of the research studies conducted in these nature protection areas are comparable both mutually and with research studies obtained in other countries. Based on the results to date, the risk of birds colliding with transmission lines has been overstated in the environmental impact assessments of most transmission line projects.

One swan collided at Pernajanlahti

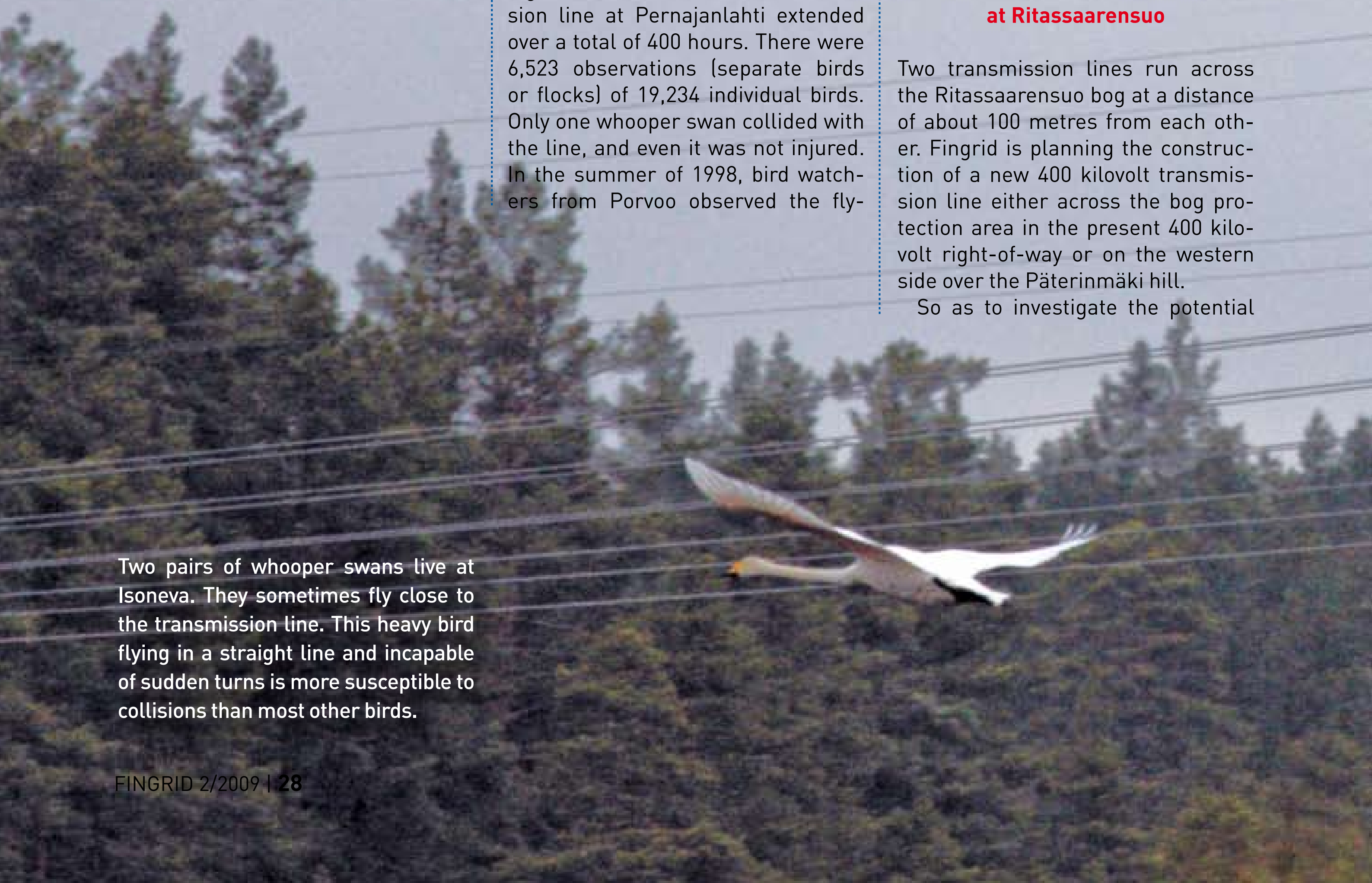
The observation period for the flying routes of birds near the transmission line at Pernajanlahti extended over a total of 400 hours. There were 6,523 observations (separate birds or flocks) of 19,234 individual birds. Only one whooper swan collided with the line, and even it was not injured. In the summer of 1998, bird watchers from Porvoo observed the flying routes for 67 hours, with 994 observations of 3,014 individual birds. When these materials are combined, the colliding birds only accounted for 0.004 per cent of all individuals which flew near the transmission lines (1 out of 22,248).

Since nocturnal migrators fly at an altitude of at least hundreds of metres and since, according to radar observations, they ascend to and descend from the migration flight in a rather vertical pattern, the transmission lines probably do not cause a significant threat to them, either. The research findings suggest that the Pernajanlahti transmission line does not cause significant negative impacts on the population of any species, protection value of bird life in the area, or favourable conservation status.

Rare near miss situations at Ritassaarensuo

Two transmission lines run across the Ritassaarensuo bog at a distance of about 100 metres from each other. Fingrid is planning the construction of a new 400 kilovolt transmission line either across the bog protection area in the present 400 kilovolt right-of-way or on the western side over the Päterinmäki hill.

So as to investigate the potential



Two pairs of whooper swans live at Isoneva. They sometimes fly close to the transmission line. This heavy bird flying in a straight line and incapable of sudden turns is more susceptible to collisions than most other birds.

impacts on birds, Fingrid ordered a study from Apus, the association of bird watchers in Central and Northern Uusimaa, concerning bird life in the area during the nesting and migration season as well as migration routes of birds from the spring to autumn of 2008.

The Ritassaarensuo protection area was a nesting place for at least 28 bird species and 85 pairs of birds. Almost all species represent basic species inhabiting wooded bogs. Species included in Annex I of the EU's directive on the conservation of wild birds, requiring special conservation measures, are the osprey, black grouse and crane. The area of influence of the alternative planned across the Päterinmäki hill is a nesting place for 36 bird species and 120 pairs of birds. The species with high conservation value by virtue of the bird directive in this area are the black grouse, grey-headed woodpecker, black woodpecker and red-backed shrike.

Monitoring of flying birds in the area close to the transmission lines covered a period from 6 April to 23 October 2008 (137 hours), during which period 85 different bird species were seen. There were 3,561 separate observations, and a total of 9,984 different individual birds were seen. No collisions with the lines were observed during the monitoring period. Birds which evaded a collision at the last moment were the black grouse (2 individuals), woodcock (1), wood pigeon (1) and crane (1), so the individuals with an imminent risk of collision represented 0.05 per cent of all birds. 95.8 per cent of the birds flew over the lines, 1.9 per cent flew between the current conductors and ground wire, and 2.3 per cent flew under the lines. Only 11.7 per cent of the individuals flew at a distance of no more than 10 metres from the conductors (0–10 metres under or over the lines or between the lines).

With the exception of black-headed gulls, very few aquatic birds and waterfront birds staying at Ridasjärvi flew over the Ritassaarensuo bog, because the rugged bog does not attract them. The black-headed gulls flew considerably higher than the transmission lines.

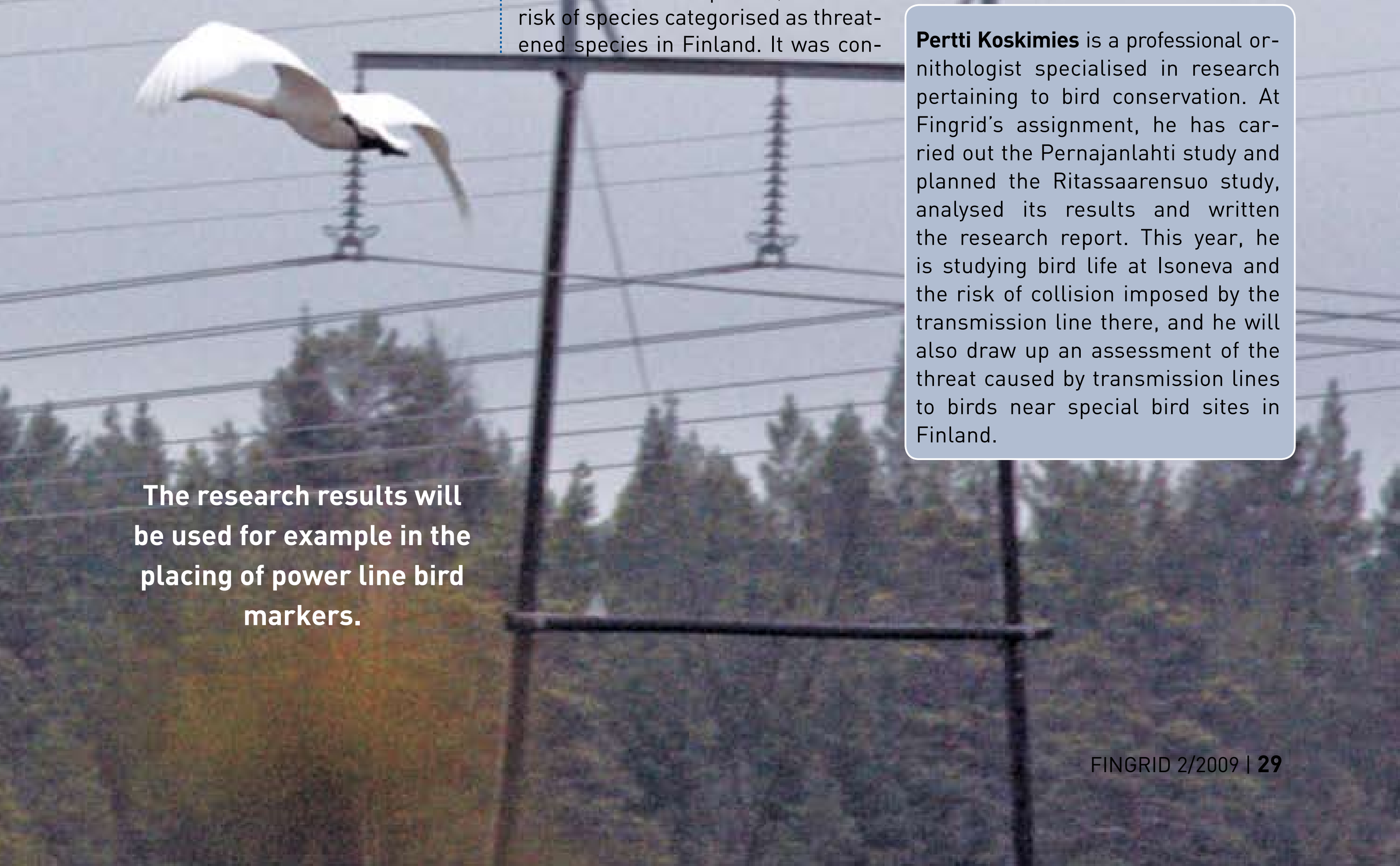
Only the risk of the black grouse to collide with the transmission lines in this area can be assessed to be fairly high. Of the species referred to in the directive, the risk of collision is small with the whooper swan, barnacle goose, smew, red-throated diver, crane, ruff, grey-headed woodpecker and black woodpecker, as is the risk of species categorised as threatened species in Finland. It was concluded that the safest route for the new transmission line in view of the birds is the alternative running parallel with the existing line on the bog.

No bird accumulations at Isoneva

The study at Isoneva commenced in mid-April 2009. The bird density on the rugged bog is small, but the species comprise ones which are theoretically most susceptible to collisions. Such species living in flocks and flying fast and in a straight line include the whooper swan, crane, red-throated diver and many waders. On the other hand, not many birds fly across the transmission line, because there is nothing in the nearby area that would attract flocks of birds nor terrain contours which would direct their flying routes.

An overall assessment will also be drawn up this year of the collision risk imposed by a nearby transmission line in the gathering areas of birds during nesting and migration in all valuable bird sites in the whole of Finland. The assessment will be used for example in the planning and placing of power line bird markers and other structures preventing collisions of birds. ■

Pertti Koskimies is a professional ornithologist specialised in research pertaining to bird conservation. At Fingrid's assignment, he has carried out the Pernajanlahti study and planned the Ritassaarensuo study, analysed its results and written the research report. This year, he is studying bird life at Isoneva and the risk of collision imposed by the transmission line there, and he will also draw up an assessment of the threat caused by transmission lines to birds near special bird sites in Finland.



The research results will be used for example in the placing of power line bird markers.

The inspectors are more than happy to answer any questions that landowners may have, or they can refer the landowner to Fingrid's adviser responsible for the issue in question. Juhani Kantola inspecting a line in the photograph.

Inspectors take care of the lines

In the summer, you may see a person walking on a transmission line area, gazing around the open area and stopping every now and then to shake and knock on the tower structures. Even though he also uses binoculars occasionally, he is not necessarily a bird watcher but most likely a transmission line inspector surveying the lines.

Text by Reija Kuronen ■ **Photograph by** Juhani Eskelinen

Transmission lines are inspected at intervals of 2 to 3 years, and the crucial sections are inspected more frequently. The inspectors cover more than 5,000 kilometres of Fingrid's transmission lines annually, making observations of the condition of line structures and transmission line area and of events in the line area.

"About 10,000 new observations are made each year. These observations constitute the foundation of transmission line maintenance. They are used as the basis of plans for maintenance work carried out on the lines and for comprehensive renovations, and even rebuilding of a line," says Fingrid's senior grid management adviser **Mikko Jalonen**.

Line inspectors with great responsibility

Unlike in many other countries, the line men inspecting Fingrid's lines carry much responsibility, because maintenance is based to a great extent on an inspector's assessment of the need for repairs and their urgency. In many other countries, this responsibility has been shifted to foremen, who inspect and, if necessary, classify the observations made by the inspectors. "At Fingrid, the

Work of inspector

An excursion to learn about the work of transmission line inspectors begins on a beautiful morning in late spring in Hikiä. We start off near the old Hikiä substation and continue across a field and over a hillock, following the line route.

The transmission line inspectors work in pairs. One of the inspectors walks a certain distance along the line to the next change point, usually a crossing forest road. Meanwhile, the other inspector drives to the same point, where the inspectors change places. Depending on the terrain, lines and other conditions, they can cover about 6 to 7 kilometres of line areas per day.

Today, the inspectors are Eltel Networks' authorised transmission line inspectors **Juhani Kantola** and **Mikko Suoranta**. Juhani Kantola has an experience of 34 years in the industry, and Mikko Suoranta has been in the business for about 20 years. There is hence plenty of knowledge and experience, and the inspections take place reliably and in an expert fashion.

The inspectors prepare themselves carefully by taking with them the necessary equipment, high-visibility clothing, and footwear suited for the environment. They also take along the most important tools: data logger, binoculars, axe, and telephone with camera.

The data logger is used for recording all observations made on the lines. These are then compared to earlier data to see whether there have been any changes. The conditions of the inspection day, such as temperature, are also recorded.

According to Kantola and Suoranta, spring is the best time for making observations – there is not yet vegetation to disturb monitoring or moving. This quality of inspections has been at a high level for years, and we have solid confidence in the professional skills of the inspectors. The quality of inspections is monitored using statistical methods, by making field surveys and by auditing the inspection work regularly," Mikko Jalonen says.

Transmission line inspections are included in the contract for basic maintenance, subjected to competitive bidding every 3 years. The newest contract period covers the years 2009–2011.

Training gives solid basis for the work

According to Mikko Jalonen, systematic training of inspectors constitutes a crucial component of the quality assurance of the inspection work and condition observations made. Before a line man can make field inspections, he must possess sufficient work experience and pass an inspection licence examination.

The training arranged by Fingrid aims at obtaining the licence. The training covers general inspection work and issues such as transmission line structures and their numbering, condition classification, recording of observations, and equipment needed in the inspections. Other things reviewed are moving under transmission lines, and guidelines for meeting with landowners and for supplying information.

"In this year's training, the licence examination was arranged in the field. The trainee had to carry out a field inspection on a selected part of the line and record all nonconformities detected, such as loose guys, rotten tower wood, and erroneous information on the identification plates of towers," Mikko Jalonen says. A total of 29 new line men aspiring the licence required in inspection work participated in the training sessions in 2009.

"The participants also included line men with years of experience of transmission line work but no prior inspection experience or licence. There were delightfully many new line men who have just started in this industry."

Service providers have crucial role in quality assurance

In the coming inspection period, 17 new inspectors can practice inspections with a fresh licence in their pocket. Initially, the new inspectors work with experienced professionals, and gradually they can also do inspections on their own.

Mikko Jalonen says that the large and presumably growing number of new line men in the training poses greater challenges on the future training sessions.

"The candidates do not have experience of transmission line structures acquired for example on line construction sites, like the earlier inspectors. It is not possible or even purposeful to fill in such an information gap during two days of training. The service providers must focus on the basic training of new line men in the future," he points out.

"When a line man has the basic knowledge of transmission lines, licence training can be used for giving sufficient facilities for the actual inspection work," Mikko Jalonen says.

According to him, the service providers should be more actively involved in surveying the training needs and developing the training. ■

The guidelines and requirements of inspection work have been compiled into a transmission line inspector's manual. A new edition of the manual was published in early 2009. It was used as material in the three training sessions for inspection licence arranged in the spring.

is why the annual inspections begin in April and continue until the end of September.

Juhani Kantola says that in 30 years, the inspections have become more comprehensive by nature. They now cover everything in the transmission line area: vegetation, towers, earthing, foundations and other conditions at the tower site. Even though the inspection of for example insulators and other equipment is an essential part of the work, it is currently only one section to be inspected. The entire line is inspected in all respects during the same inspection.

The axe serves as a tool for clearing thickets and also for knocking on the tower materials. Observations concerning the other environment include whether for example the circumstances at crossings have changed from the previous inspection. The inspectors also knock on and shake the towers and guys in order to get a feel of their condition and mounting. The conductors, insulators and other overhead parts are reviewed in detail using binoculars and the naked eye. Each part of the line must be in place and in a good condition, and even small deviations are recorded and assessed on site. A good mobile phone camera is a good aid in documentation: the photograph can be sent to the office for review right away.

Kantola and Suoranta characterise their work as independent, responsible, comprehensive, and one that calls for attentiveness. Each part of the line must be reviewed no matter how difficult the terrain is, and sometimes the inspectors have to go long distances around waterways. Auditory perception is also applied: woodpeckers building a nest in a tower do not go unnoticed.

The morning inspection finishes at a crossing road, in a transmission line area yellow with blooming flowers. Juhani Kantola has recorded issues such as minor erosion in a foundation, which had not been noted earlier, and a faded tower number requiring further action. The circumstances and changes have been recorded carefully in the system. Nothing escapes the eyes of the inspectors. ■

Reija Kuronen

Regular management of trees guarantees SECURITY OF TRANSMISSION LINES

A transmission line and tall trees make bad neighbours. The taller the tree, the greater the safety risk. However, this risk is well under the control of Fingrid: on transmission lines maintained by Fingrid, trees only cause 0.05 disturbances per 1,000 kilometres annually.

Text by Suvi Artti ■ **Photographs by** Juhani Eskelinen and Rodeo

There are approx. 33,000 hectares of areas under Fingrid's transmission lines requiring regular clearing. Since the clearing interval is 5 to 8 years, the area cleared annually is 5,500 to 6,000 hectares.

The transmission line areas are cleared mechanically; either by heavy machinery or hand-held machines. Fingrid's Maintenance Management Manager **Marcus Stenstrand** says that herbicides, which are still used in some parts of the world, have not been applied in Finland for decades.

The clearing work is procured from specialised enterprises on the basis of competitive bidding, where the selection criterion is overall economy. In 2009, Fingrid has a clearing contract with 20 enterprises.

Landowners notified by letter

Fingrid does not own the land areas under the transmission lines or the trees located within these areas. These are property of the landowner. Through expropriation, the company has acquired a permanent right to use the transmission line area, and the owner of the transmission line has an obligation to keep the trees in a condition conforming to relevant regulations.

This spring, Fingrid mailed letters for the first time to inform landowners of clearing work. All in all, some 10,000 letters were sent to landowners with land under various transmission lines. The letters contained information on upcoming clearing, its location, and the width of the transmission line area in question.

"The parcels of forest in Finland are small: there can be as many as 500 landowners on a stretch of land 100 kilometres long," Marcus Stenstrand says in explaining the large number of letters.

Earlier, clearing work was communicated through newspaper advertisements and on Fingrid's website, but the information did not always reach all landowners.

Never drive machinery between the tower legs or closer than 3 metres from the tower structures!

Trees close to a transmission line should always be felled by professionals. Fingrid offers advice in matters concerning yard trees, and free felling assistance.

Trees are property of the landowner

The trees felled in the transmission line areas frequently rouse the interest of passers-by. "We receive hundreds of telephone calls and e-mail messages every year from people who ask for a permission to fetch firewood from a newly-cleared transmission line area. The answer is always the same: 'the trees belong to the landowners, so you'd better ask them'. The closer the cleared area is to a large town, the more firewood inquiries we receive," Marcus Stenstrand says.

People would also like to fetch Christmas trees from a transmission line area, but the same reply concerns them, too.

For safety reasons, timber or energy wood must not be stored under a transmission line or closer than 10 metres from the closest current conductor of the line in the lateral direction.

Trees in border zone managed at intervals of 10 to 25 years

The goal is to manage the edges of transmission line areas so that if a tree falls there, it must not reach the conductors. Excessively tall trees are felled, or their tops are cut by 2 to 4 metres using sawing from a helicopter. Decay in a tree with a cut top progresses so slowly that a landowner does not need to fell the trees right away. Instead, they can be harvested in conjunction with the next logging if one is planned to take place within the next 4 to 8 years.

If a transmission line is damaged and the current conductor is on the ground or close to the ground, it is dangerous to life to go near it.

If there is a need to fell the edge trees, Fingrid endeavours to arrange joint felling and sales, with the trees felled by professionals. However, as the owner of the trees, the landowner has a right to decide how to arrange the harvesting and sales of border zone trees, which need to be felled because of transmission line maintenance. Trees in the border zone are managed

Remember that the "fuse" never blows in a transmission line, but it is always dangerous!

over a distance of 400 to 800 kilometres per year.

Guideline for forest management recommendations for border zones

A forest owner should always take the border zone of a transmission line into account when managing forest areas bordered by a power line. Tall trees in the border zone are felled in conjunction with intermediate felling. The border zone trees are also felled in conjunction with regeneration felling, because the maturity of the border zone trees is determined by their prescribed maximum length, not the age of the trees.

In order to improve forest management in the border zones of transmission line areas, Fingrid has drawn up new forest management recommendations for the border zones together with Forestry Development Centre Tapio. This guideline in Finnish can be downloaded from Fingrid's website. ■

Grid ABC

This article series deals with the main operating principles, equipment units and components in the main grid. The articles published in the series previously can be viewed on our website at www.fingrid.fi.

Static Var Compensator in Kangasala

Text by Matti Lahtinen ■ **Photograph by** Hannu Heikkinen

Fingrid has introduced new intelligent technology at the Kangasala substation, intended to improve the stability of the power system. The compensator taken into use for the first time in the Finnish electricity transmission grid will make the nation-wide grid more "intelligent" by improving its system security.

The Static Var Compensator (SVC) connected at the Kangasala 400 kilovolt substation primarily intends to dampen inter-area mechanical power oscillations in the power system, i.e. improve its stability and hence system security. The damping effect of the SVC can also be utilised in restricting the impact of line outages occurring in the transmission grid on the transmission capacity of the system.

The SVC can improve the damping of low-frequency power oscillations, because the reactive power generated by it can be regulated very quickly and steplessly, which also enables supporting the voltage of the transmission grid. The Kangasala SVC is dimensioned so that it can feed a maximum reactive power of 240 Mvar to the 400 kilovolt network and take a maximum reactive power of 200 Mvar from it.

Structure of the facility

The Kangasala SVC consists of four controllable components and one harmonic filter group connected stationarily to the grid (Figure 1). The reactors and capacitors are located outdoors, but the thyristor valves are situated indoors in the same facility as the control and protection system of the SVC, and batteries.

The thyristor-controlled capacitors consist of antiparallel thyristor valves and a capacitor battery of 132 Mvar, which is connected to and from the grid by means of the thyristor valves. The thyristor-controlled reactors consist of antiparallel thyristor valves and a reactor of 92 Mvar. The reactive power generated by the reactor can be controlled steplessly and very quickly by means of the thyristor valves.

By co-ordinating the switching of the thyristor-controlled reactors and capacitors, the reactive power generated by the SVC can be varied freely within the capacity of the SVC. The SVC can implement a change of 440 Mvar in reactive power in as little as just over 100 milliseconds.

The thyristor control causes harmonic waves which are filtered by means of harmonic filters so that only an acceptable amount of them can access the transmission grid. The thyristors are cooled by water and glycol in outdoor heat exchangers. The cooling system keeps the thyristors at almost constant temperature irrespective of the loading.

The nominal voltage of the capacitor is optimised to be 20 kV, but it influences the voltage of the 400 kV network via a 410/20 kV transformer.

The total costs of the investment, encompassing the 400 kV duplex field, transformer and the SVC facility, were approx. 12 million euros.

Principles of operation

SVC operation is controlled by a duplicated numerical control system, and the SVC works fully automatically in local control. Only measures related to changing and setting the SVC's control function

SVC facility at the Kangasala substation.

are carried out in remote control from Fingrid's Power System Control Centre or Network Control Centre. Depending on the SVC's respective use, the control system generates a control signal to the thyristors on the basis of a measurement carried out in the 400 kV network. The SVC has a specific control function for each of the three uses of the SVC, and each control function operates using a different measured variable.

1. Damping of inter-area power oscillations

Damping control is the primary control method of the Kangasala SVC, used for controlling reactive power on the basis of the local frequency measurement to dampen power oscillations taking place in the grid. In practice, damping control activates the SVC when frequency measurement detects oscillations with an amplitude exceeding the threshold value set for the control. Such situations can be expected primarily when there are transmissions from Finland to Sweden.

2. Constant reactive power control

Constant reactive power control is the secondary mode of control of the Kangasala SVC, which, as the name suggests, aims to keep the reactive power generated by the SVC at a constant level. Constant reactive power control can be used to support normal 400 kV network voltage control, for example during a small load in the middle of summer.

3. Constant voltage control

Constant voltage control is also a secondary control method, aiming to keep the voltage of the 400 kV busbar at the set value on the basis of the 400 kV voltage measurement. This control method can be used to support 400 kV network voltage control in extraordinary operating situations.

Low-frequency power oscillations in the transmission grid

Power oscillations occur in the power system after various types of changes. Such changes include line faults, sudden tripping of power plants from the grid, and major load changes. These cause an imbalance in the static state of the power system, and as a result of the change the system remains oscillating around the new state of balance.

The lowest oscillation frequencies related to the purpose of use of the Kangasala SVC are created when large machinery groups in the power system oscillate against each other. The greater the (electric) distance of the machinery from each other and the larger the machinery groups involved in the oscillation, the lower the frequency of the oscillation between them.

The most typical inter-area oscillation frequency is approx. 0.3 Hz. This is the specific frequency while machinery in Southern Finland and Southern Sweden/Southern Norway oscillates against each other. The corresponding natural oscillation frequency of machinery between Northern Finland and Southern Finland is approx. 1.1 Hz.

The damping of oscillations is influenced by a number of factors, but to put it simply, damping reduces as electricity transmissions between the regions increase. In other words, the deterioration of oscillation damping generally reflects the fact that the power transmitted between two regions is approaching the maximum transmission capacity between the regions.

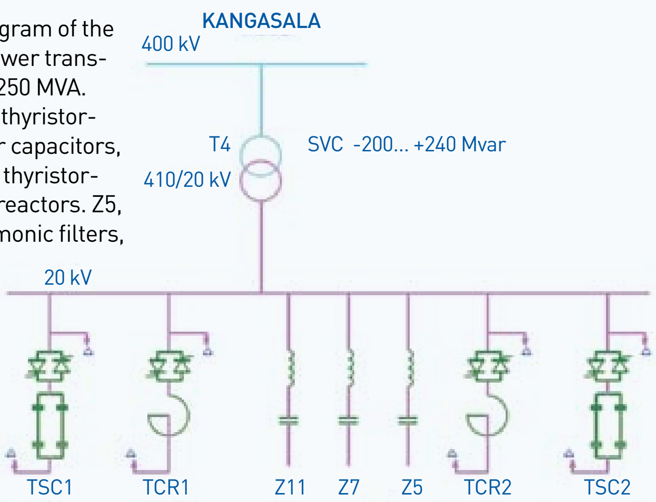
With system-frequency oscillations, the significance of the oscillations depends on the transmission situation in the power system, in other words on how much power is being transmitted between Finland and Sweden. The more power transmitted, the smaller the change situation in the grid that causes significant oscillations. As an example, the tripping of a line in a situation where no power is transmitted between the countries causes oscillations, but they are dampened very quickly and their magnitude remains small. On the other hand, if much power is transmitted between the countries, the magnitude of the oscillations in a corresponding change situation is significant, and damping is correspondingly poorer.

Transformer requirements

The necessary capacity of the transformer is always determined by the current going through the transformer. In other words, the nominal power of the transformer is determined by the maximum reactive power of the SVC, in this case 240 Mvar of capacitive reactive power. The structure of the transformer is ordinary, but the feeding of a large reactive power volume to the grid has been taken into account in its design values.

This is so because capacitive reactive power raises the secondary voltage by the relative short-circuit impedance of the transformer, and the iron core must be dimensioned to be slightly larger. The design values for the transformer core also take into account the direct component caused by the small asymmetry in thyristor control. ■

Simplified main diagram of the SVC facility. T4 is power transformer, 410/20 kV, 250 MVA. TSC1 and TSC2 are thyristor-connected 132 Mvar capacitors, TCR1 and TCR2 are thyristor-controlled 92 Mvar reactors. Z5, Z7 and Z11 are harmonic filters, usually 34 Mvar.



Night birds

Heikki Willamo, the new columnist of the Fingrid magazine, is a photographer, author and journalist from Karjalohja. He has published several nature books for both children and adults; most recently "Hirven klaani" (Otava 2005), "Pyhät kuvat kalliossa" (together with Timo Miettinen, Otava 2007) and "Huuhkajavuorella" (together with Leo Vuorinen, Maahenki 2008). Heikki Willamo's special objects of interest include forest nature in Southern Finland, Northern rock art, and myths related to animals.

The setting sun turns the rugged steep red, but it is already a bit dark further down under the spruce trees. A young Northern eagle owl glides along the cliff and descends on a boulder. It starts to preen its feathers, scratches its ear and stretches its long wings. Then it hisses in a hoarse voice. Hunger! The fasting of a long day is behind, now it is time to get some food.

It is late summer, but the events at the steep commenced in the winter. The hollow courtship song of the male Northern eagle owl echoed in the frosty February nights, and the courtship rituals reached their peak in early March. Then the female laid three round eggs in a sheltered cavity, hatched them for about six weeks, and stayed in the nest even after this to keep the nestlings warm. The nestlings grew rapidly, and when summer came, they were already like small trolls with fiery eyes, leaping from the nest ledge and climbing on the cliff in the dusk of the night. In the daytime, they kept strictly to the cavities of the crag.

During the summer, the fluffy nestlings evolved into handsome Northern eagle owls, and it was difficult to tell them apart from their parents. They fly suspended by their large wings, and their hungry hisses resound in the dark in all parts of the large rocky hill. The male owl takes care of his family throughout the long nesting period, and his work continues until early October. He carries to his offspring mostly moles but also young raccoon dogs and rabbits, ducks and gulls. The feathers of a young buzzard on a stump show how versatile the menu is.

I have had an opportunity to monitor the everyday life of the family of Northern eagle owls, follow how the nestlings grow, and how the male works hard. A couple of times I have been scared off by the large female when I have inadvertently approached a nestling which has been in hiding. The mother owl looks lazy while perched on a branch, but her gloomy warnings are backed by a body weighing three kilos, and sharp hook claws. A fox stays away from owl nestlings, and people should do so, too.

Even in the daytime, Northern eagle owls are magnificent and fascinating birds, but nocturnal dusk renders them even more interesting. The shiftover beyond the border, to the world of night creatures, makes them "hyypiäs" again. That name, which is at least 5,000 years old, belongs to the bird which was greatly respected by the forefathers of Finns. The bird supposedly had a close relationship with the underworld where the spirits of the dead lived. "Hyypiäs" were soul escorts and assistants of shamans, in whose figure they travelled to the underworld.

The world gone by comes to life when you listen to the courtship shrieks, gaze a young owl striding in the dusk of the summer night, or admire the horned silhouette of the head of an adult owl.

The world gone by comes to life when you listen to the courtship shrieks, gaze a young owl striding in the dusk of the summer night, or admire the horned silhouette of the head of an adult owl. The curtain opens slightly, and you get to peek beyond times, to see the dance of the mountain goblins and experience the magic of nature. In those moments, I commend myself for my career choice, because it gives me an opportunity to be part of something which is concealed from most. I get to enjoy a connection to nature, advance it, and sometimes embark on the vortex of imagination. Both the biologist and lover of ancient ages in me are satisfied.

The young Northern eagle owl still sits in place, hisses every now and then, and stares down to the valley. Then it sees the male, which flies to the boulder with a mole in its beak. The young one becomes excited, hisses wildly, and attacks the comer. The owls collide together and merge into one, seeking balance by spreading their large wings.

The moment is soon over. The male takes to its wings and disappears behind the trees. The sun is slowly setting. I lay down on the soft moss. The night takes over, and the owls disappear into the darkness. Once more, I see the magnificent silhouette against the glowing sky, and then my world relies on my ears. It's quiet, only the occasional begging sound every now and then. Finally, the much-awaited signal blow further down. Agitated hissing, and then beaks clanging together. The night birds do not sleep, it is turn for the next hungry one. ■

Heikki Willamo

Fingrid has expanded its web service

Fingrid expanded its web services in the early part of this year by launching a new Extranet service for the invoicing measurement and balance settlement system, referred to as LTJ Extranet.

The web service now consists of three sections: Fingrid's external website, Extranet, and LTJ Extranet.

LTJ Extranet is divided into the network service and balance service. The balance service section provides the electricity market parties with an opportunity to view their own balance settlement information and that of parties included in their balance responsibility. The network service section contains information on issues such as grid invoicing, cross-border transmission invoicing and electricity tax invoicing as well as time series data related to the monitoring of reactive power use. The system can also provide measurement appendices to the grid contract, invoice specifications, and various reports.

"If a customer wishes, he can have a real-time connection to Fingrid's system for managing invoicing and follow-up related to various contracts. This improves transparency and operational quality," says **Antti Vesanen**, developer of the new LTJ Extranet from Fingrid's energy settlement unit.

"The new service gives our clients a swift and easy way to follow measurement information as almost real-time hourly data," he adds.

The balance service section contains general balance settlement information shared by all as well as customer-specific energy settlement and invoicing data. Balance settlement data is presented as hourly information so that it is possible to use the Extranet service to verify a party's balance settlement information conforming to the balance model applied as of 2009. The service also serves as an interactive channel for the reporting of fixed deliveries and production plan information. The reporting section of the balance service is primarily intended for presenting customer-specific invoicing data.

Fingrid will finish the sending of reactive power reports by mail from the beginning of May.

"We have opened a reactive power user profile in the LTJ Extranet for all those to whom we have sent a reactive power report on paper," Antti Vesanen says.

New users can report their information to Fingrid's customer service. LTJ Extranet can be accessed either via the LTJ Extranet link on our website or directly from address https://energiaselvitys.fingrid.fi. ■

Municipalities and network companies as partners in the landscape management of rural areas

ProAgria Pirkanmaa has launched a project for developing the landscape management of rural areas. In addition to municipalities, the partners include Fingrid and energy company Vattenfall.

The purpose of the project is to experiment with landscape management contracting in areas owned by the municipalities of Nokia, Sastamala, Urjala, Vesilahti and Virrat. The foremost areas managed include natural green areas such as meadows, fields, transmission line areas, and lakeside and riverside areas.

The project involves seven partners. Transmission system operator Fingrid and energy company Vattenfall will manage meadow-like line areas.

The project will survey fields and meadows in built-up areas, draw up area-specific landscape and nature management plans, and study the management of the areas by local agricultural entrepreneurs. The management methods can include mowing, pasturing, clearing, or growing of landscape plants. The project also studies the interest of entrepreneurs to produce landscape management services, and arranges training in the field. ■

Source: ProAgria Pirkanmaa

Fingrid's power system control takes care of the state of the system continuously.

Dimensioning fault in Finnish power system back to 865 megawatts

Protection changes were carried out at the Olkiluoto nuclear power plant during the annual service in May. As a result of this work, the behaviour of the plant in faults in the nearby region was restored to the former state.

After the change, the dimensioning fault in the Finnish power system is again at a level of 865 MW, which corresponds to the power of one unit at Olkiluoto. The plants no longer reduce their power in voltage dips caused by short circuits in the adjacent area unless the fault concerns the plant unit itself.

As a result of the change, the limited import capacity has also been restored to the level of 2,050 MW in a normal operating situation. There were no hours with price area differences during the import restriction. ■

Grid Quiz

Competition to the readers of Fingrid Magazine

Answer the below questions and send your reply by fax (number +358 (0)30 395 5196) or mail to Fingrid no later than 18 September 2009. Address: Fingrid Oyj, PL 530, 00101 HELSINKI, FINLAND. Mark the envelope with "Verkkovisa".

Among all those who have given right answers, we give 5 books "Intohimona sienet" by Antonio Carluccio by drawing lots. The book contains more than 100 recipes for delicious mushroom dishes from the various parts of the world, from salads and soups to main courses. We will inform the winners in person. The answers to the questions can be found in the articles of this magazine.

1. Fingrid's transmission lines are nowadays built mostly using
- ◯ guyed wooden towers
- ◯ guyed steel towers
- ◯ self-supporting steel towers.

2. Fingrid's "Sinikurjet" (Blue cranes) landscape towers can be admired in
- ◯ Espoo at the junction of Turuntie Road and Ring Road III
- ◯ beside the Helsinki-Tampere motorway
- ◯ in Meilahti in Helsinki.

3. After the war, one of the foremost tasks in reconstruction in Finland was to secure electricity supply. How many ongoing large power plant projects were there in Finland in 1946?
- ◯ 4
- ◯ 8
- ◯ 12.

4. The first electric train in Finland was introduced in 1969 on the service between
- ◯ Helsinki and Riihimäki
- ◯ Riihimäki and Lahti
- ◯ Helsinki and Kirkkonummi.

5. IARC (International Agency for Research on Cancer) has categorised low-frequency magnetic fields in Group 2B in terms of their carcinogenic nature. The same group also includes substances such as
- ◯ tobacco
- ◯ UV radiation
- ◯ coffee.

6. Fingrid's transmission line areas are cleared using
- ◯ chemical clearing
- ◯ mechanical clearing (= by heavy machinery or hand-held machines)
- ◯ both chemical and mechanical clearing.

7. The wood material piled up beside Fingrid's transmission line areas after the clearing of trees is
- ◯ property of the landowner
- ◯ property of Fingrid
- ◯ available to anyone based on everyman's right.

Name ______________________________

Address ______________________________

Post office ______________________________

E-mail address ______________________________

Telephone number ______________________________

Winners of prizes of the Grid Quiz in the previous Fingrid magazine (1/2009): Petteri Helisten, Kuopio; Tuomo Jokinen, Helsinki; Juha Kangasmäki, Jyväskylä; Ella Käck, Helsinki and Reijo Lehtonen, Valkeakoski.

Taking care of the lines.

Fingrid is responsible for the nation-wide electricity transmission grid in Finland. We make sure that Finland obtains electricity without disturbance. The total length of our transmission lines is approx. 14,000 kilometres.

As the owner of the transmission lines, we take care of our duty and keep the lines reliable and in a condition conforming to the safety regulations. It is safe to move and pick berries and mushrooms under our transmission lines.

Our line areas are also utilised as growing areas for plants, trees and berries, and as butterfly habitats.

FINGRID OYJ

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