Contents

• Elenia – Smart Grid Development

• Digitalization of Maintenance Management

• Case Examples of IoT Sensors
## Elenia today

<table>
<thead>
<tr>
<th>The cornerstone of our service is that everyday life runs smoothly.</th>
<th>We produce electricity network services efficiently and reliably.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Society works when electricity is on.</td>
<td>Cables stretch 1.5 times around the world; the underground cabling rate is more than 45%.</td>
</tr>
</tbody>
</table>

| We serve more than 430,000 customers in more than 100 municipalities in the Häme, Pirkanmaa, Central Finland and Ostrobothnia regions. | |

Elenia’s values

COURAGE TO RENEW
The courage to embrace change is what leads to progress. This demands an attitude in which our knowledge, skills and experience see us forging ahead in terms of our own development and that of our entire sector.

CLOSE TO THE CUSTOMER
Customers fire our working community with enthusiasm to seek new ways of providing a service and developing our operations with a bold approach and a focus on results. We keep our promises.

ACHIEVING TOGETHER
We forge lasting relationships with local communities, resulting in trust and acceptance of our operations. We share our professional expertise with the working community at large.

ACCOUNTABLE PARTNER
We demand high levels of responsibility of ourselves and our partners. We actively care about our own and our shared wellbeing and safety at work.
Elenia Oy

Revenue 272.3 M€
Employees 177
Customers 430,000
Market share 12%

Partnerships
- Electricity network services
- Electricity metering
- Data transfer services
- Administrative services
- 700–800 person-years

Quality
- Asset Management Systems ISO 55001 and PAS 55
- Occupational Health and Safety Management System ISO 45001:2018
- Environmental Management System ISO 14001:2015

- 160 metres of network lines per customer
- 72,000 km of network lines 1.5 times around the world
- Underground cabling rate 45%
A key role for a network operator

Network operators play a key role in combating climate change by enabling an efficient electricity market

### Reliability of supply
- Weatherproof network
- Self-rectifying network
- Demand flexibility
- Smart grids

### Energy efficiency and renewable energy sources
- Customer awareness
- Improvement of energy efficiency
- Renewable energy for the market
- Electric motor vehicles

### A functioning electricity market
- Services that enhance market function
- New customer services

### Social requirements

### Using less fossil fuels

### Using resources efficiently
BUSINESS ENVIRONMENT

Requirements stipulated by the Electricity Market Act concerning the reliability of electricity distribution.

Power outages caused by storms or snow loads shall not exceed **6 hours** in zoned areas and **36 hours** in other areas, as follows:

- **50%** of customers by the end of **2019**
- **75%** of customers by the end of **2023**
- **100%** of customers by the end of **2028**
Our electricity networks

- 110 kV lines 1,161 km
- 45 kV lines 342 km
- 110/20 kV substations 128 units
- 45/20 kV substations 9 units
- 20 kV lines 26,037 km (37.6%)
- 0.4 kV lines 44,260 km (50.8%)
- 20/0.4 kV transformer substations 24,226 units
- % of network underground 45%
- Number of customers 430,000

31 Dec 2018

71,800 KM OF NETWORK LINES
1.5 TIMES AROUND THE WORLD
160 METRES PER CUSTOMER
Partnership networks as a strength

Elenia has built partnerships for a couple of decades
- In electricity network services
- In electricity metering
- In data transfer
- In customer service
- On average 700–800 person-years

Partnership as a business strength
- Efficiency and flexibility
- Faster and better service
- Significant impact on employment
An ageing network infrastructure: Elenia Weatherproof faces the challenge

- Public electricity supplies in Finland date back to the 1950-1970s
- Extreme weather causes power grid problems
- Work is ongoing to modernise the ageing power grid
- Long power outages are not acceptable in the businesses and homes of a digital society

Electricity network
72,000 kilometres
160 metres/customer

- Weatherproof solutions developed with universities, hardware manufacturers and contractors in 2006 – 2009
- All network construction since 2009 based on underground cables
- Investment EUR 900 million in 2012 – 2019
- 45% of the Elenia network is now underground cabled

Local work for partners
Elenia Weatherproof

ELENIA WEATHERPROOF

• Our underground-cabled electricity network is safe from winds, thunderstorms and snow loads
• We are modernising the network in cooperation with our partner contractors
• Look at the map to see where we are improving the reliability of electricity distribution

We care.

72,000 km
Elenia has 72,000 kilometres of electricity network – 1.5 times around the world – in Helsinki, Pirkanmaa, Central Finland, and South and North Ostrobothnia. 45% of the network is underground cabled.

3,000 km
We modernise the electricity network by underground cabling 3,000 km per year.

75%
Our goal is to increase the proportion of underground cabling in our distribution network to 75% by 2028. At the same time, we'll bring work to the regions.
Network Maintenance

Each year, 5,000 kilometres of power line clearance
- 250 km of high voltage distribution network corridor clearance and 150 km of adjacent tree felling
- 2,500 km in the medium-voltage network, including adjacent forest areas
- 2,000 km in the low-voltage network

Network aerial inspection with a four-year cycle
- 4,000 km inspected annually
- Also used for clearance inspections

Annual inspections and maintenance
- 3,000 km of low-voltage network inspections
- 10,000 minor tasks
- 300 disconnector maintenance tasks
- 550 substation inspections, 750 relay tests
- Markings, insulator replacements, straightening of link boxes and poles, etc.

The figures are annual averages
Long history of condition-based maintenance
- Network imaging and LIDAR data collection since 2008
Maintenance Management Today

- Inspections are still mainly time-based and maintenance actions are reactive based on the inspection results.
- Maintenance has been quite traditional until very recent years although structure and components of network are evolving.
- Developments in predictive maintenance:
  - Kinetic energy of remote controlled disconnector operations is measured and battery condition remote tested for totally condition based maintenance.
  - Oil analyser for primary substations main transformer has been tested.
- The use of IoT solutions is rapidly becoming more viable.

- A helicopter trims the tops of trees near powerlines in the 110 kV network.
- We manage 20 kV lines by thinning, managing seeding stands and removing hazardous trees.
- We maintain the overhead line network by clearing vegetation on a regular basis.
- We manage adjacent forests in cooperation with landowners.
- The clearing work along the electricity network is performed by forest workers, harvesters and helicopters.
Smart Grid evolution by Elenia

- **2002**: Smart network control and monitoring
- **2006**: 1st and 2nd generation smart meters (AMR & AIM)
- **2008**: Network automation – Overhead lines
- **2010**: Information of power outages
- **2012**: Smart field communication
- **2014**: Low voltage network monitoring
- **2016**: Mobile applications for customers
- **2018**: Mobile DMS for partners
- **2020**: Demand response & flexibility
- **2022**: Mobile DMS for partners

**Evolutionary Stages**:
- **1st and 2nd Generation**
- **3rd Generation**
- **Next Generation**

**Key Technologies**:
- Network automation and fault location – Cable network
- Third generation smart meters
- Decentralized generation
- Smart substations
- New map services on web
- Data analytics
- LVDC technology
- Satellite data
- Sensors in maintenance management
- Storages
- E-mobility

**Additional Features**:
- 3D inspections of the network
- Hourly-based consumption reports to customers
- Smart substations
- Information of power outages
- Network automation – Overhead lines
- Automatic fault location, isolation and power restoration
- Mobile applications for customers
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Digital Disruption in Maintenance

- Strategic target to disrupt maintenance management with rapidly accelerating digitalization development
  - Utilize current data more efficiently with data-analytics and machine learning
  - Introduce new maintenance data from IoT sensors
- Currently available but underutilized data
  - Protection relay pick ups
  - Switching device operation cycles
  - Component type data
  - Open source data, etc.
- Introduce new additional data via measuring indirectly condition of equipment
  - Cost effective solutions already widely available
  - Fast implementation is possible
- Cloud computing and data storage
  - Storage and computing costs are becoming almost negligible
- Decreasing wireless communications costs with NB-IoT over GSM and LoRaWAN networks
  - New technologies are enabling self powered sensors for easy retrofit installation
Information Sources for Advanced Data-Analytics and Machine Learning

CURRENT DATA SOURCES

- Smart substations
- Smart field communication
- 1st and 2nd generation smart meters (AMR & AIM)
- 3D inspections of the network

FUTURE

- Network automation – Cable network
- Sensors in network management
- 3rd generation smart meters
- Next generation smart meters
- LVDC technology
- Next gen field communication
- Satellite data
Concept for Digitalization

- Current Field Communications Network connected to a SCADA System
  - Wireless 2G/3G/4G for disconnectors
  - Dual wireless 3G/4G and satellite connection for primary substations
- Sensor Network connected to a Cloud Based System
  - NB-IoT over GSM and LoRaWAN for cost effective communication
- Data Analytics and Machine Learning
  - State-of-the-art cloud based tools used for data-analytics and machine learning
  - Main users of analytics are Maintenance Engineers and in the future NCC
## Network control and sensor system differences

<table>
<thead>
<tr>
<th></th>
<th>Field Communications network connected to a SCADA system and IED equipment</th>
<th>Sensor network connected to a cloud based system and sensor equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Communication type</strong></td>
<td>Two way</td>
<td>One way</td>
</tr>
<tr>
<td><strong>Cost of installation</strong></td>
<td>Medium</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Cost of operation</strong></td>
<td>Medium</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Reliability criteria</strong></td>
<td>Very high</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Bandwidth and response time criteria</strong></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Commissioning and testing requirements</strong></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Equipment type</strong></td>
<td>Specialised industrial systems</td>
<td>Publicly available IoT sensors</td>
</tr>
<tr>
<td><strong>Changes and development in ICT-systems</strong></td>
<td>Labour intensive</td>
<td>Easy</td>
</tr>
<tr>
<td><strong>Growth potential of information amount</strong></td>
<td>Linear</td>
<td>Exponential</td>
</tr>
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Maintenance IoT Sensors – First implementations

- **110 kV pole**
  - Pole tilt angle
  - Temperature
  - Humidity
  - Acceleration

- **Primary substation**
  - Main transformer
  - Basin water level

- **Secondary substation**
  - Temperature
  - Sound (partial discharges)
  - Humidity
  - Light (are the doors closed)
  - Acceleration (door)
Secondary substation sensor

- The pilot has been concentrated on a cost effective solution for cabinet mounted secondary transformers
- Challenging weather conditions in Finland: temperatures from -30 °C to +30 °C, rain, snow, icing, condensation, etc. are putting stress on especially air isolated switchgears
- With the future network structure identifying any problems before they cause defects on the equipment or outages is vital in providing customers with the service expected
- Study for defining what added value for life cycle management can be achieved with monitoring ambient conditions inside secondary transformers has been started
Secondary substation sensor – Ambient conditions monitoring

- LoRaWAN sensors
  - 12 pcs at the moment located at 4 secondary substations

- Long operating period
  - Battery powered
  - Approximately six years operation period
  - Update interval of 2 times per day

- Quantities monitored inside the substation
  - Illuminance
  - Temperature
  - Humidity
  - Acceleration

- Easy installation
  - Two sided tape or screws
  - Installed inside the cabinet
  - At the moment battery must be installed on site

- Sensor identification number documented to network information system (NIS)
Secondary substation sensor – Ambient conditions monitoring

- Substation temperature and humidity have a correlation to partial discharges on surfaces in air isolated secondary substation switchgear parts

- Enhanced life cycle management and more accurate forecasting of remaining operational service time

- Illuminance measurement is used to notice any unintentional open cabinet doors in a cost effective way. In new software revision push notifications will be included
Secondary substation sensor – Ambient conditions monitoring

- Case example of two very close by (distance = 300 m) secondary transformer stations
- Clear differences in service conditions in both temperature and humidity
- Substation 1: SF6 isolated switchgear and transformer nominal power 200 kVA
- Substation 2: air isolated switchgear and transformer nominal power 630 kVA
Cost Effective Partial Discharge Monitoring

- Monitoring of partial discharges (PD) in secondary substation has been studied with industry partner UnSeen Technologies Oy
  - https://www.unseen.fi/

- Sound analysis of a secondary substation with PD problems has been made to verify the possibility of monitoring PD via sound signal
  - Positive results with a clear noise peak at about 8 kHz

- A pilot sensor has been manufactured by UnSeen to further test PD monitoring with sound
  - Battery powered
  - 4G/LTE connection

- Installation of pilot sensor in May 2019

- Other possibilities for sound monitoring are also being studied
110 kV pole sensor

- The pilot has been concentrating on cost effective solution for 110 kV power line pole monitoring especially for the parts that can not be visually inspected
- Most of the 110 kV poles in Finland are anchored with stay wires for necessary structural strength
- Chemical and electrical corrosion can affect the underground stay anchors
- Current methods for inspecting underground stay anchors are inefficient and costly
- IoT solution is being tested to monitor even the slightest movements in pole tilt angle
- 180 pcs of sensors are installed in summer 2019 for all corner poles in the northern area of Elenia’s network
110 kV pole sensor

- LoRaWAN sensors
  - 10 pcs at the moment installed

- Long operating period
  - Battery powered
  - Approximately six years operation period

- Quantities monitored from poles
  - Three dimensional pole tilt angle change

- Easy installation
  - Magnetic fixing or screws
  - Installed on a pole structure
  - At the moment battery must be installed on site

- Sensor identification number documented to network information system (NIS)
Next steps in digitalization

Publications
• Master of Science Thesis: Utilizing Internet of Things sensors in distribution network maintenance, Pekko Niemi, 2019
• CIRED 2019 paper n. 1080: Defining a Digitalization Concept for Electricity Distribution Network Maintenance, Turo Ihonen, Henri Niemi, Pauliina Salovaara, 2019

Practical steps
• 180 pcs of IoT tilt angle sensors for 110 kV poles installed in summer 2019
• Piloting of IoT sound monitoring for cost effective partial discharge sensor
• Piloting main transformer basin water level monitoring with IoT ultrasound sensor
• Several data-analytics implementation studies ongoing
• Testing machine learning for predicting maintenance needs
• Ongoing discussions for comprehensive IoT sensor solution for primary substations
The digital transformation is not something to wait for

It is already here!
Thank you!

Questions?

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