# Bringing 5G to power

## Opportunities and challenges with connected power distribution grids

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# Contents

04 Power grids today and tomorrow

05 The need for power grid protection

07 Unveiling the value

11 The future of smart grids

This case study is part of an Ericsson 5G for Industries series, in which we look more closely at the actual business values associated with introducing mobile connectivity.

**Methodology**
In this report we study the opportunities, business values and barriers associated with introducing mobile connectivity in electric distribution networks. The study was conducted between April and November 2019, and its scope covered the Swedish power distribution network market.

The main sources of information were interviews and publicly available reports. Discussions and interviews took place with ABB, the Swedish Energy Agency, the Swedish Energy Markets Inspectorate, Swedenergy, Telia and Tele2, as well as major electricity distribution companies E.ON, Ellevio, Vattenfall and Mälarenergi. The representatives interviewed are all specialists in power distribution networks and power grid digitalization. Reports from Energiforsk, the Council of European Energy Regulators (CEER), the University of Gothenburg and the Swedish Energy Markets Inspectorate were used.

**About Consumer & IndustryLab**
Ericsson Consumer & IndustryLab delivers world-class research and insights for innovation and sustainable business development. We explore the future of consumers, industries and a sustainable society with regards to connectivity by using scientific methods to provide unique insights on markets, industries and consumer trends. Our knowledge is gained in global consumer and industry research programs, including collaborations with renowned industry organizations and world-leading universities. Our research programs cover interviews with over 100,000 individuals each year, in more than 40 countries — statistically representing the views of 1.1 billion people.

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**Ericsson's industry collaborations**
Ericsson is driving 5G for Industries initiatives with multiple partners to ensure we understand the demands and develop the right technology for real-world applications, and to materialize how our technology will accelerate innovation.

It started in March 2015 with the launch of 5G for Sweden, Ericsson's research and development program with leading industry and academic partners. It continued with the creation of a 5G for Europe program, spanning 7 countries and 10 institutions, that same year. 2017 saw a similar program founded in the US, while the latest developments have been expansions in Asia, with a China-focused 5G program in 2018 and the 5G for India program in 2019. In early 2018 Ericsson also established the D15 labs in Santa Clara, whose aim is industry collaboration on specific use cases to achieve innovation using a live 5G platform. In 2019 we also established an Industry 4.0 Center of Excellence at Eurolab in Aachen, Germany.

To date, we have collaborated with more than 50 industry partners globally to define, test and research use cases in the areas of 5G, IoT, Cloud, VR/AR and AI.

**Key findings**

To cater for future demand, improve quality and adhere to environmental policies, power distribution networks need significant investments.
- Investments of EUR 1.5 billion per year are expected for the Swedish market, of which our interviews indicate EUR 150 million is Information and Communication Technology (ICT) related.

Connectivity and automation can deliver higher reliability and better protection of the electric power grid, unleashing high potential values.
- The cost of interruptions to society is high – estimated at around EUR 150 million every year for the Swedish market.
- Interruption durations are expected to be reduced by 50–75 percent with the use of ICT, resulting in an annual revenue increase for a single Swedish distribution system operator of up to EUR 40 million.

Cellular communication is an important enabler to support new power grid architectures and operational models.
- Power grid protection and remote control can be implemented using cellular technologies, which requires 5G in order to handle demanding use cases such as automated protection.

Distribution system operators (DSOs) expect communications service providers to be responsive to the industry's needs and regulations.
- DSOs want to be able to own critical parts of the communication infrastructure to meet performance and regulatory requirements.
- Support for private and hybrid communication networks will be important.

**Renewables demand overhaul of power grids**

Emissions from fossil fuel powered energy generation are a major contributor to global warming. The UN estimates that up to 85 percent of electricity must be renewable by 2050, in order to combat the effects of climate change.[1]

As a consequence, society is investing in renewable energy such as solar and wind. At the same time, consumers are becoming "prosumers", with house owners encouraged to install solar panels and other energy-generating sources.

Electricity is a difficult product to store; therefore, a balance between generation and consumption is vital. Moving towards solar and wind may also lead to increased risk of network disturbances, due to both the way these energy sources work and their inherent lower predictability. More and faster responses to adjust the balance between generation and consumption will thus be needed in the future. Connectivity can play a key role when it comes to enabling this need of fast and accurate power grid balancing. At the same time, with the shift from fossil energy, society will become increasingly dependent on electricity, so reliable power supply is crucial.

In this report we look at how ICT and connectivity can enable better performance and protect the power grid. We also examine the possibility of remote control and automation in the event of power failure. This is key in enabling the transition to renewable energy.

85%

The UN estimates that up to 85 percent of electricity must be renewable by 2050.

[1] www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_summary-for-policymakers.pdf

# Power grids today and tomorrow

## Today's power grids will need to evolve in order to handle the new challenges of tomorrow.

**Topology of a power grid**
A power grid is an interconnected network delivering electricity from producers to consumers. Traditional power grids have a clear hierarchical structure: electricity production at the top and end users at the bottom.

At the top of the hierarchy, the power grid voltage is very high, typically between 200 and 400kV. The further down in the network we go, the lower the voltage. Transformation from a high voltage to a lower voltage takes place in substations.

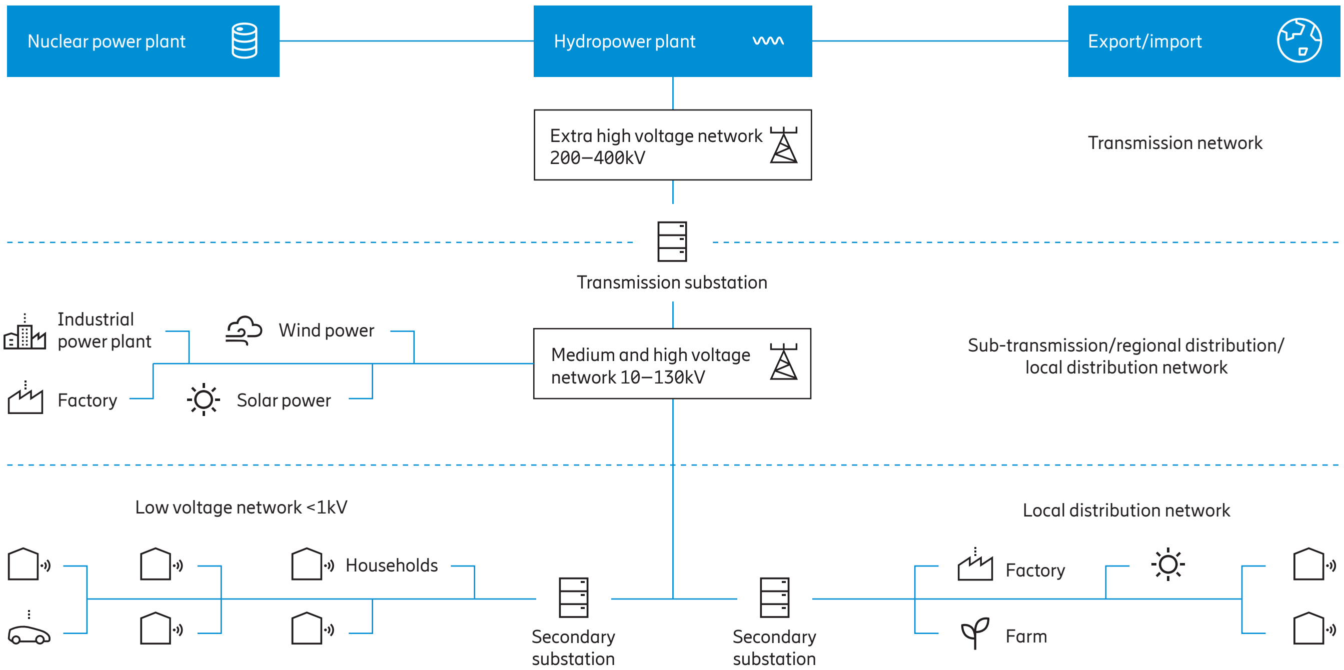
In Sweden, there are approximately 180 power grid operators,[2] so-called distribution system operators (DSOs), which own the power grid and transport electric power from generation facilities to consumers. The three largest network companies, E.ON, Ellevio and Vattenfall, together have over half of all Sweden's power grid customers.

**The challenges with future networks**
While traditional power generation mostly takes place at a limited number of large-scale sites, in many cases renewable generation works better in small-scale installations, such as in wind farms and solar power parks, and even by individual homeowners who add solar panels to their roofs.

DSOs' core mission – of providing a secure electricity supply with a high quality of service, at a reasonable cost – will thus become increasingly challenging. To continue to ensure security of supply and quality of service, DSOs need to evolve and become increasingly active network managers.

As renewable, distributed power generation grows in popularity, power grids will have to evolve, to be able to help handle:
- a large number of power generators
- bi-directional energy distribution; in other words, being able to both sell to and buy from the same prosumer
- greater fluctuation in power production, as renewable generation is less predictable
- a larger number of network issues, causing power quality problems

**Figure 1: Typical topology of a power grid today**




[2] https://www.ei.se/PageFiles/310277/Ei_R2017_06.pdf

# The need for power grid protection

## The cost of faults is driving the increased need for power grid protection.

**Increasing numbers of faults**
General availability of the power network in Sweden is high, at around 99.98 percent.[3] This corresponds to one 100-minute-long power failure for the average end user. These faults result in a substantial cost to society, in the region of EUR 150 million annually for Sweden alone.[3]

The total number of fault events in Sweden's power grids is around 40,000 per year.[4] These power failures have several causes, as shown in Figure 2. They include weather and equipment problems, as well as damage as a result of excavation, for example. However, one-third of faults are caused by unknown reasons. This is due to a lack of information and measurement.

Taking the manufacturing industry as an example, such faults could lead to production failures, destroyed equipment and financial damages due to missed deliveries. They may also affect societal infrastructure, such as transport, healthcare, water and food supply, telecommunications and data communications.

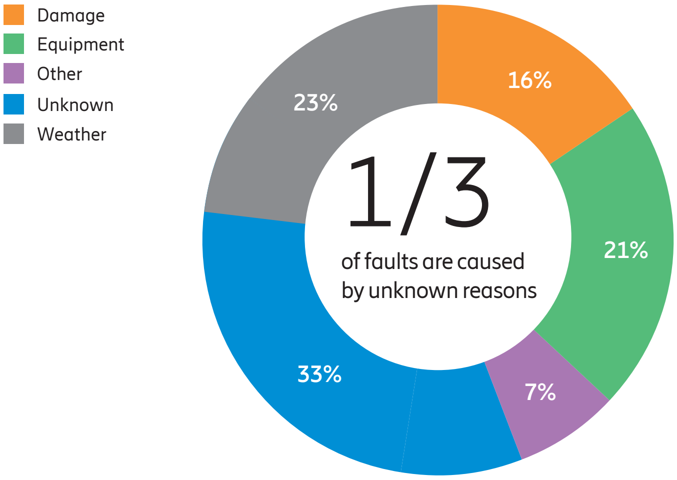
When these faults occur, they may cascade through the system and cause disturbances and widespread outages. Given this, it is of utmost importance to have mechanisms in the network which are able to locate, identify, isolate and fix faults and to switch on electricity in the shortest time and for as many customers as possible.

**The evolution to communicative protection schemes**
Connectivity, sensors and automation can enable greater availability and protection of the power grid. By adding ICT and connectivity, DSOs believe they can gain control of all parts of the network and can better anticipate, prevent, control and even automate power grid protection.

Figure 3 shows how, as a first step, connectivity enables information and measurements about power grid failures to be transmitted. The second step sees communicative mechanisms implemented, which allows DSOs to take control remotely, while in the third step full automation is introduced, allowing better protection and handling of power interruptions. The majority of DSOs interviewed say they want to increase the degree of automation; one DSO mentions that, for more than 50 percent of new secondary station installations, support for remote control is already in-built. However, the challenge is to retrofit installations since the technical and economic life span of power grid equipment is typically in the range of 40 years.

Network mechanisms are important for locating, identifying and fixing faults

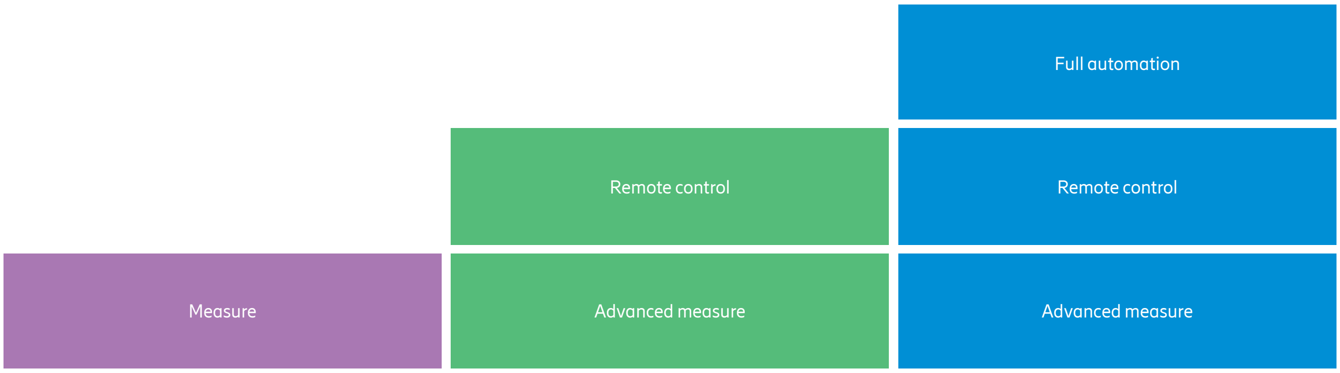
**Figure 2: Reasons for power grid faults**




Source: Swedenergy (2018)

[3] Swedish Energy Agency (2018)
[4] Swedenergy (2017)

**Figure 3: Steps to evolve the distribution network**




**Many different protection mechanisms**
Different power grid protection mechanisms are available today. Which mechanism to use depends on what is economically viable in each situation and the number and type of customers connected. Today, most medium- and low-voltage networks use non-communicative protection mechanisms, such as overcurrent relays and distance relays.

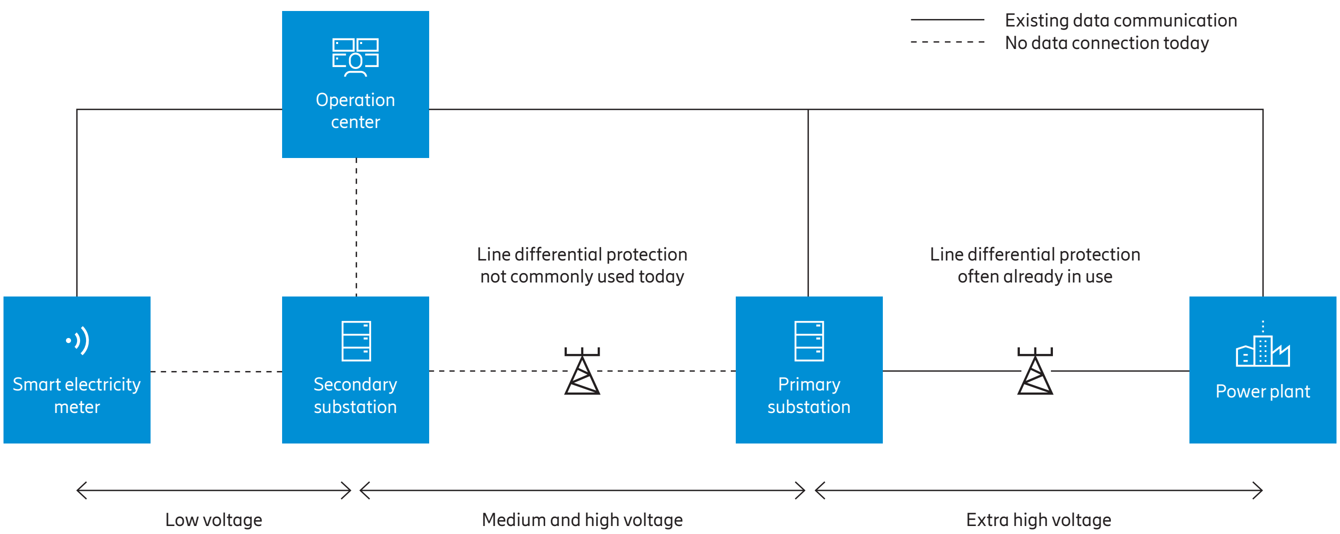
A principle for automated line protection that is becoming more common is line differential protection. The added benefit compared to other protection methods is the increased sensitivity and ability to see the direction of the current. This is growing in importance due to renewables. However, differential protection is more demanding, as it requires a communication channel to transmit momentary values to the other end; in other words, from one remote substation to another, in a fast and reliable way. This requires a communication connection with really low latency, such as fiber or 5G. Generally, the DSOs interviewed are interested in moving to real-time management of the energy system, which in turn requires instant communication between different nodes and the control systems. This way disruptions and outages may be kept to a minimum.

Currently, power grids tend to be enabled with data communication at the highest voltage level, and at the customer premises through smart electricity meters (see Figure 4). Line differential protection is also used at the higher levels where data communication is available. For cost reasons, the lower distribution levels (secondary substations) remain unconnected with data. This is related to the high number (more than 170,000) of secondary substations.[5] As a consequence, line differential protection is not commonly used at this lower level.

Power grid protection is one area that benefits from connectivity, but the fully connected power grid would multiply these benefits across all stages. DSOs indicate that as services, such as load balancing and maintenance, become connected the investment decision to digitalize and connect the power grid will be easier to motivate.

**Different needs for network protection**
For parts of the network that are sensitive to interruptions, such as the higher voltage transmission networks and business-critical customers like hospitals and certain industries, there may be reasons to invest in a solution that is resilient to power failures. These solutions may be costly but could still prove necessary due to the high interruption and societal costs, as discussed earlier. In contrast, for lower parts of the network and rural networks with sparse customer density and low sensitivity levels, a simpler protection scheme may be sufficient.

**Figure 4: New communications needed**




[5] Energiforsk (2018)

# Unveiling the value

## Enhancing data connectivity for power grids holds societal, regulatory and economic value.

Connectivity and automation can deliver higher reliability and better protection of the electric power grid, unleashing great potential benefits for DSOs through the following:

1. **Enabling the scaling up of renewable, distributed energy sources**
2. **Raising revenue levels in compliance with regulation**
3. **Lowering compensation fees**
4. **Lowering interruption costs for customers**
5. **Minimizing damages and costs related to power grid equipment**
6. **Lowering service costs and reducing the need for troubleshooting**
7. **Increasing brand value**

The benefits of power grid connectivity are numerous

Growth in the number of small-scale power generators is expected

**1. Enabling the scaling up of renewable, distributed energy sources**
The increase of renewable energy sources such as solar and wind will put new demands on DSOs to be active network managers with total control of the distribution network. Due to inherently increased volatility in renewable sources, there is a need for power grid protection measures which can respond more quickly. Additionally, there is a need to balance production and loads in a more dynamic way, as renewable energy sources have less inertia. Therefore, all DSOs interviewed see digitalization and connectivity as key enablers in the transition to renewable power generation.

**2. Raising revenue levels in compliance with regulation**
National regulators strive to ensure that the delivery of electricity is secure and of good quality. Revenues of power companies are therefore usually adjusted depending on the quality of the electricity delivered by the power grids.[6] One Swedish DSO estimates that it is possible to reduce the duration of interruptions by anywhere between 50 and 75 percent with the use of ICT, resulting in a potential annual increase of revenues accepted by the regulator of up to EUR 40 million.

**3. Lowering compensation fees**
When longer interruptions occur, there is a recompensating guarantee for the affected end users in which the provider makes a reduction on the electricity bill. The daily remuneration is 12.5 percent of the estimated annual cost.[6] The main incentive for improved quality is the potentially high sums in the event of severe interruptions.

**50–75%**

With ICT, it is estimated that interruption times can be reduced by 50 to 75 percent compared with today's levels.

"The main objective of the continuous supply incentives within the regulation of power distribution operators is to reach a quality level that corresponds to the customer's willingness to pay."

Carl Johan Wallnerström,
Analyst/engineer,
Swedish Energy Inspectorate

[6] www.ceer.eu/documents/104400/-/-/27978c4f-4768-39ad-65dd-70625b7ca2e6

**4. Lowering interruption costs for customers**
The economic impact related to faults affects not only utilities companies but also society and industry customers. In Sweden during 2018, customer costs were estimated to be almost EUR 150 million[7] as a result of power interruptions.

According to a study from the University of Gothenburg,[8] increased length of an outage normally leads to rapidly growing costs for consumers and enterprises. One of the DSOs interviewed estimated a cost of EUR 150,000 per minute in Stockholm.

**5. Minimizing damages and costs related to power grid equipment**
Power failures can result in major equipment damages, such as to reclosers, substation transformers, circuit breakers and power line equipment. As an example, a damaged substation may generate costs in the region of EUR 100,000.[9] Additionally, there are high health and safety risks to personnel in relation to potential explosions and fires following an electric arc.

**6. Lowering service costs and reducing the need for troubleshooting**
Today, most stations at the edge of the power distribution network are "in the blind"; in other words, they lack communication capabilities. This means DSOs work in more of a reactive way and typically need to have personnel in standby mode, which generates high costs. Staff are also needed for maintenance and inspection rounds. In the event of a failure, service personnel are normally required to move out and locate faulty systems by patrolling a line and manually sectioning it away. With communication capabilities, the DSOs interviewed estimate they could reduce the labor required by as much as 50 percent, since they would no longer need to manually locate faults or carry out inspection rounds. Video surveillance of power lines and substations would add extra value to this process.

"We have an ongoing procurement arrangement for remote control equipment for secondary substations where robust and fast communication is an enabler for future implementation."

Ellevio

**7. Increasing brand value**
Electricity companies must consider how the quality of electricity delivered and end-user trust in renewable energy sources affect their brand. The perception of high-availability power supply systems based on renewables leads to greater societal trust and may also attract major new customers, such as the process and electronics industries, as well as the establishment of various kinds of server rooms with extreme reliability requirements.

[7] Swedish Energy Markets Inspectorate
[8] https://gupea.ub.gu.se/bitstream/2077/59639/1/gupea_2077_59639_1.pdf
[9] ABB estimates

DSOs' choice of connectivity technology will depend on the particular circumstances

**The role of 5G and cellular**

Connectivity solutions in general and cellular communication in particular are seen by the respondents interviewed as important enablers for new power grid architectures and operational models. Today, DSOs use a mix of connectivity technologies, such as very high frequency (VHF) and ultra high frequency (UHF) radio, Wi-Fi, optical fibers, and 3G and 4G cellular networks. The cost-effectiveness and preference for a specific technology will ultimately depend on the type of power grid and regulation, as well as the customer situation and density.

The DSOs interviewed see clear opportunities but also challenges in using cellular technology. They recognize that cellular connectivity can offer a reduced maintenance and lower capex investment in grid communication infrastructure due to the lesser need for extensive cabling. Cellular wireless technologies available today, such as 4G-LTE, are also perceived by DSOs to offer a viable business case for retrofitting existing substations where no wired connectivity exists.

As outlined earlier, when it comes to more demanding use cases, such as line differential protection, connectivity with ultra-low latency will be needed to meet the performance requirements. This can only be fulfilled with fiber connectivity or by using 5G. However, as many lower parts of the power grid (secondary substations) are in remote locations, fiber is seen by DSOs as more costly and less flexible than cellular.

**Wireless challenges**

Needless to say, DSOs expect mobile service providers to be responsive to the needs and regulation of this industry.

A common concern among DSOs is over the cellular technology in general and the use of public networks in particular. Several DSOs in Sweden express trust and security concerns around intrusion and unauthorized access to information as well as the risk of malicious connection disruption attempts. Other major concerns are the ability of communications service providers to meet DSOs' needs, as well as the availability of the communication network if there is a power outage. There are hard requirements for uninterrupted power supply (UPS) systems to support at least 12 hours in a total outage situation.

The DSOs interviewed perceive a difference between the utility and ICT sectors in terms of life spans and depreciation of equipment; this can be in the region of 40 years in the utility sector. Meanwhile, the ICT industry is seen to have a much shorter lifecycle; maintenance over time and future support of legacy systems could become potential hurdles.

Regulation of both the energy and telecom sectors is another important point, as communications service providers may become economically accountable for power failures related to connectivity issues.

**Defining the deployment model**

Today, the DSOs interviewed want to be able to own critical parts of the communication infrastructure, and typically do so, mainly due to performance and to better meet regulatory requirements. They have therefore been reluctant to place critical communication services over a public telecom network. The revenue-related regulatory frameworks have also tended to favor investments in own infrastructure.

While owning communication infrastructure makes it easier to have control, in the long run it is likely to be less cost-efficient than using a service from, for example, a communications service provider, which makes it possible to share the infrastructure cost with others. Interviews indicate emerging models of DSOs combining owned connectivity infrastructure for their most critical parts with commercial services. Support for private and hybrid communication networks will therefore be important.

40 years

The utility sector has a very long equipment lifespan – in the region of 40 years – compared to that of the ICT industry.

# The future of smart grids

## To enable the transition to renewable sources, investment in the smart grids of tomorrow is necessary.

**High investments in the future**
To cater for future demand, improve quality and adhere to environmental policies, the power distribution networks in Sweden need significant investments. Annual investments in the Swedish power sector alone are estimated to reach EUR 1.5 billion.[10] The ICT proportion of this figure is estimated to be 5 to 10 percent by DSOs interviewed, meaning an annual investment level of up to EUR 150 million in the power sector.

DSOs are already now investing in communication infrastructure with dedicated organizations and operation centers. Investments in connectivity will become increasingly important and will play a key role in enabling cost-efficient deployment of renewable energy sources.

**Power systems going digital**
Power systems all over the world are on the cusp of a transition from being highly centralized to supporting more distributed electricity generation and storage.

More connected sensors and smart meters will enable real-time network monitoring, including data about power quality, broken wires and consumption spikes. As a great amount of data is generated from electricity customers at the edge of the network, AI-powered predictive analysis and edge computing can be introduced to reduce costs and increase revenues.

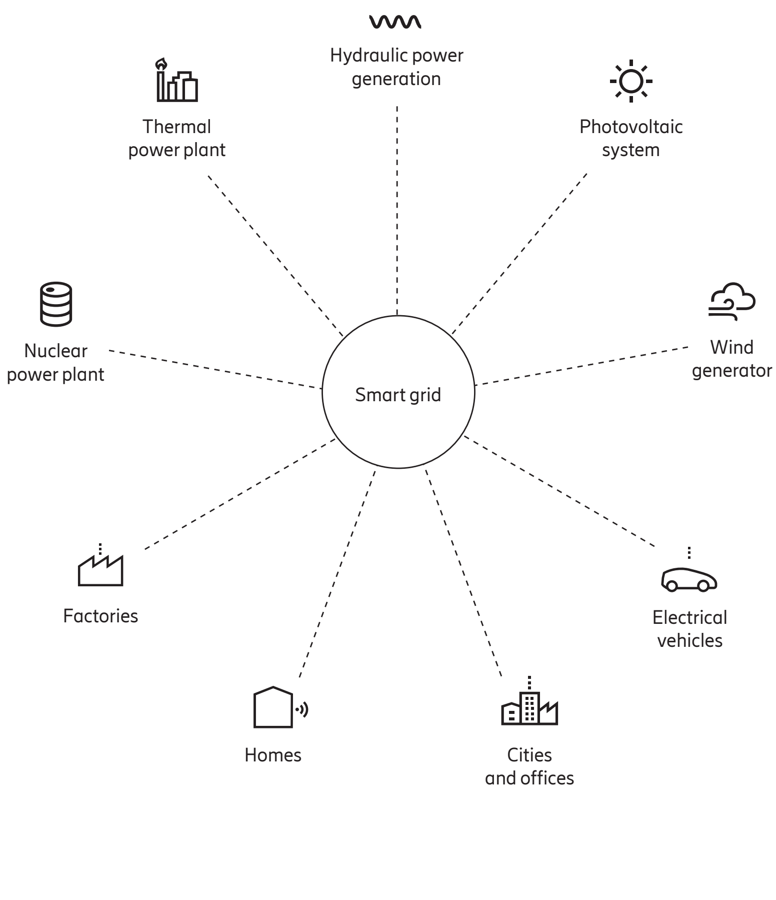
Predictive maintenance based on machine learning and AI may also reduce power outages and improve investment decisions. This predictive analysis can include rapid detection and response to spikes in demand. One example is the mass charging of electric vehicles (EVs) that can be both a challenge and part of the solution.

Another application area, as mentioned earlier, is that of production compensation between many small-scale installations, where it would be possible to achieve an optimal production balance between distributed energy sources. This is done by measuring and compensating for imbalances in the grid.

The need to introduce smart ways to monitor, balance and predict power consumption and generation will thus continue to grow. The power grids of tomorrow will be digital infrastructures, meaning they will be highly connected and automated.

**EUR 150m/year**
Swedish power distribution network investments in ICT are expected to reach up to EUR 150 million per year.

**Figure 5: The smart grid of tomorrow**




[10] Swedish Energy Markets Inspectorate

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