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DEVELOPING AND EXPANDING THE BUSINESS OPERATIONS OF EXSANE OY IN LINE WITH CURRENT CHANGES IN THE ENERGY AND ELECTRICITY SECTOR

Examiners: Docent, D.Sc. Ahti Jaatinen-Värri
D.Sc. Juha Haakana

ABSTRACT

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The business of distribution grid contractors has fallen into a price crisis. The competition is high, and the development of business operations in the sector has been slow. The upcoming changes in the energy and electricity sector should be utilized to develop and expand the business operations.

The energy system is transitioning to a higher share of renewable energy. Electricity distribution grid owners are investing in smart grid applications to support the requirements of the new structure of the energy system. The next generation of automatic meter reading improves the demand control possibilities of normal households. Preventative maintenance for underground cables is shifting towards measurement-based inspections to improve the security of supply. The electrification of traffic is moving forward at a fast rate. High demand for electric vehicle charging stations is created by statutory requirements and the rising number of electric cars.

Smart grid applications affect the existing business operations of Exsane. Grid automation modernizes fault management. In fault situations, the faulty grid section is automatically separated from the intact grid sections. The demand for manual operations during fault situations is decreasing. The next generation of automatic meter reading creates a significant amount of simple installation work for contractors. Partial discharge measurements are a promising technology for measurement-based inspections for preventative maintenance. Online measurements are a good starting point because of the reasonable prices of measurement devices and easy integration into existing processes.

Electric vehicle charging stations are a good opportunity for a new business area. The future demand for charging stations is ensured because of statutory requirements and natural demand created by the fast rate of traffic electrification. A comprehensive business model including planning, installation, and maintenance services is suitable for the charging station business. The resources of Exsane match the requirements of the charging station business. The starting investment and risks are low, therefore this business area is an excellent possibility to expand the business operations of Exsane.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT
School of Energy Systems
Energiatekniikan koulutusohjelma

Tuukka Mönkkönen

Exsanen liiketoiminnan kehittäminen ja laajentaminen hyödyntäen energia- ja sähköalalla tapahtuvia muutoksia

Diplomityö
2021
91 sivua, 18 kuvaa, 2 taulukkoa
Tarkastajat: Dosentti, TkT Ahti Jaatinen-Värri ja TkT Juha Haakana

Avainsanat: osittaispurkausmittaus, älyverkot, sähköautojen latausasemat, liiketoimintamalli

Sähköverkkourakoitsijoiden liiketoiminta on ajautunut hintakriisiin. Kilpailijoita on paljon ja liiketoimintojen kehittäminen on ollut hidasta. Tulevat muutokset energia- ja sähköalalla tulee huomioida Exsanen liiketoimintojen kehityksessä ja laajentamisessa.

Uusiutuvien energialähteiden osuus Suomen energiajärjestelmässä on kasvamassa. Jakeluverkkoyhtiöt investoivat älyverkkoratkaisuihin vastatakseen energiajärjestelmän tuomiin vaatimuksiin. Uuden sukupolven sähkönmittaus tarjoaa entistä kehittyneempää kulutuksen ohjausta normaaleihin talouksiin. Sähköverkon ennakoiva kunnossapito muuttuu enemmän mittauksiin perustuvaksi, mikä johtuu suurenevasta maakaapeliosuudesta. Tarkoituksena on parantaa toimitusvarmuutta maakaapeliverkossa. Liikenteen sähköistyminen etenee nopeasti. Sähköautojen latausasemien kysyntää kasvattavat lakisääteiset vaatimukset sekä nopeasti kasvava ladattavien autojen määrä.

Älyverkkoratkaisut vaikuttavat Exsanen nykyiseen liiketoimintaan. Jakeluverkon automaatio modernisoi vianhoitoa. Vioittunut verkonosa erotetaan ehjästä verkosta automaattisesti. Perinteiset manuaaliset toimenpiteet vähenevät vianhoidossa. Uuden sukupolven sähkönmittaus synnyttää merkittävän määrän yksinkertaista asennustyötä urakoitsijoille. Osittaispurkausmittaukset ovat lupaava teknologia mittausperusteisiin tarkastuksiin ennakoivassa kunnossapidossa. Online-mittaukset ovat hyvä menetelmä aloittaa mittausten testaaminen. Aloitusinvestointi on kohtuullinen ja mittaukset ovat helposti integroitavissa nykyiseen tarkastusprosessiin.

Sähköautojen latausasemat ovat hyvä mahdollisuus uudeksi liiketoiminta-alueeksi. Latausasemien kysyntä tulevaisuudessa on turvattu lakisääteisten vaatimusten sekä sähköautojen määrän nopean kasvun takia. Sopiva liiketoimintamalli sähköautojen latausasemien toteuttamiselle on kaiken kattava avaimet käteen -ratkaisu. Exsanen olemassa olevat resurssit sopivat sähköautojen latausasemien liiketoimintaan. Aloitusinvestointi on matala ja toiminnan aloittamiseen sisältyvät riskit ovat pienet.

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In Lappeenranta, 10 March 2021

Tuukka Mönkkönen

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LIST OF ABBREVIATIONS

AC	Alternating Current
AMR	Automatic Meter Reading
CCS	Combined Charging System
DAC	Damped Alternating Current
DC	Direct Current
DMS	Distribution Management System
EPBD	Energy Performance of Buildings Directive
EU	The European Union
FLIR	Fault Location Isolation and Restoration
GHG	Greenhouse Gas
HCFT	High Current Frequency Transformer
IoT	Internet of Things
IEC	International Electrotechnical Commission
SCADA	Supervisory Control and Data Acquisition
TEV	Transient Earth Voltage
VLF	Very Low Frequency

1 INTRODUCTION

The structure of the electricity distribution construction and maintenance business has changed completely during the last 20 years. The distribution grid owners have outsourced these businesses to newly founded companies. The start of this new business structure was highly profitable for these new companies. The situation motivated many new companies to join the sector as well. After the fast growth period, there started to be too much competition in the sector and companies started to face problems with profitability. The companies have not made enough effort to improve the business or expertise and there is little that separates the competitors from each other. (Kontu 2019)

Exsane Oy is a company that provides electricity distribution grid construction and maintenance services. Exsane started as a small company and the main business was clearing the distribution grid of trees. The business expanded to distribution grid maintenance and then to construction and planning. Exsane was bought into a Finnish concern Iivari Mononen Oy in 2014. After that, the strategy of Exsane was to grow to be a significant company in the distribution grid construction sector. In 2017, Exsane took a significant leap towards this target, when they got the role of the main contractor in the project worth 21 M€ divided over three years. Now, this project is ending and the next steps towards the target of growth must be taken.

The situation in the distribution grid construction sector currently appears to be at its worst. Now at the latest is the time to start the work for improving the business and find ways to stand out from the competition. When the companies such as Exsane succeeded, the business sector was new, and the companies profited from that. Now the structure of the business sector is not changing, so the change must be found some other ways. When looking at the distribution grid sector and the larger picture around it, there are multiple factors that are changing. The underground cable construction rate in the distribution grid will slowly start to decrease and smart grid applications will get more focus. The new underground cable structure of the distribution grid will require changes in inspection and maintenance methods. Preventative maintenance methods should be updated into measurement-based methods, so the condition inspections would not rely on the senses of the inspector.

At the same time, the whole energy system is slowly transitioning to renewable energy sources. This transition sets requirements for the smart grid applications of the distribution grid. The renewable energy sources are less predictable, so electricity demand should be more predictable instead. Demand control applications will require their own changes from the distribution grid. At the same time, the traffic is transitioning from traditional fossil fuels to electricity. (Lassila et al. 2019)

There is a completely new business area being born around electric car charging stations, which is closely related to distribution grid construction. All these mentioned changes are currently happening, and they can be used to improve the business of Exsane. The changes can be exploited to create completely new business areas for Exsane and to modernize the existing business areas.

The research questions in this thesis are: how the development of the distribution grid affects the business of Exsane, and what possibilities does the energy system's transition to renewable energy sources offer to Exsane. The target of the thesis is to find possible solutions, which can be used to modernize the business of Exsane, and to expand the business area in order to enable future growth of the company in line with the strategy. Exsane only operates in Finland, thus the research and evaluation of the opportunities will be limited to topics that specifically concern Finland. The possibilities will be searched within the areas that support the transition to a sustainable future. Results from the thesis will be estimates of business possibilities that the different technologies offer and designs for possible business models that could be used to implement the opportunities. Exsane have plans to expand the business to electric car charging stations, so the primary business model will relate to electric car charging station business. There will also be suggestions for how to improve the current business areas.

The research includes literature review of the development of the distribution grid and technologies that appear potential for development of Exsane's business. There are a variety of different technologies in different sectors, therefore the extent of research will be kept relatively superficial. Theoretical analysis will be kept on a level which enables the business possibilities to be analysed for different technologies but does not offer deeper comprehension of the subject. Potential technologies are estimated with the help of a survey for electricity distribution grid owners. Representatives from several distribution grid companies are also interviewed for deeper understanding of the plans that the grid owners have for the following decade. The results in the end are a combination of the literature review and the information obtained from the survey and interviews.

2 BACKGROUND

In this chapter, the background of the thesis is introduced. The electricity distribution grid construction business has fallen into an unhealthy state. There is too much competition and there is little that separates the competitors from each other. This has sunken the prices extremely low, and companies are struggling to make profit or even to break even. (Kontu 2019)

The price crisis in the sector is the most important motivation for this thesis. Exsane is struggling to match the targets of growth set in the strategy because of the difficult state that the whole sector is in. Now is the time to start and expand the business over the edges of traditional distribution grid contractor companies. The initial motivation and target for the thesis was set. The problem that needs to be solved is the price crisis and the target is to find possibilities outside of the traditional sector of the company and to improve the existing business areas. The problem, possible solutions that will be studied, and the target of the thesis are presented in Figure 1.

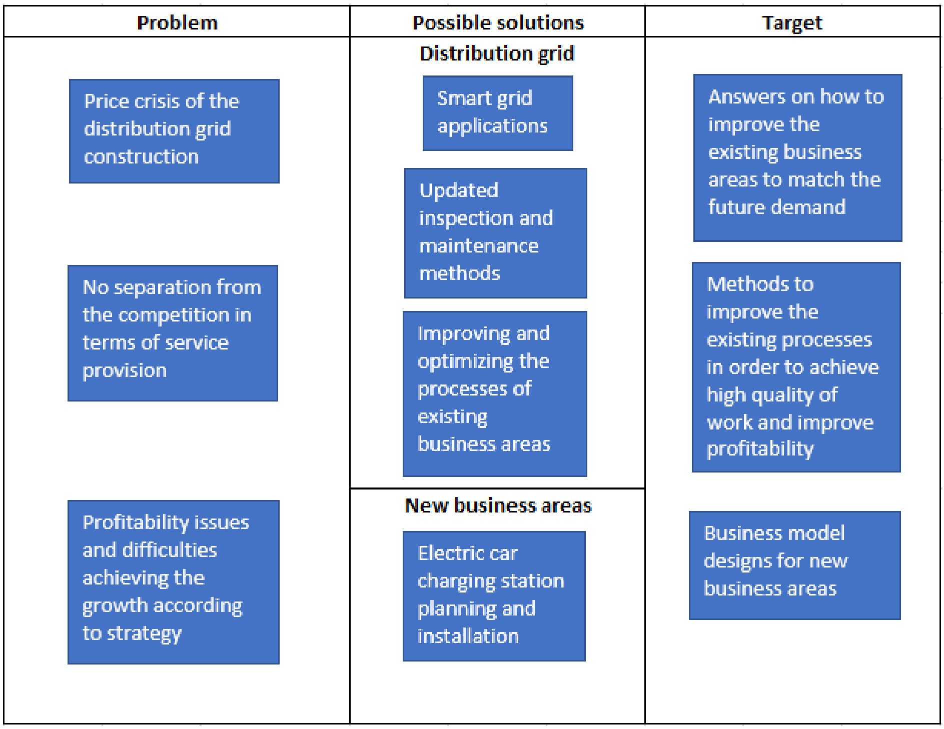

Figure 1. Illustration of the problem, possible solutions and the target on the thesis.

The first step was to evaluate the big picture around the whole business. The share of renewable energy in the energy system is going to increase. The share of renewable energy of the total energy consumption will be over 50% in 2030 (TEM 2016). In 2019 the share of renewable energy of total energy consumption was 39% (Official Statistics of Finland 2019). The increasing share of renewable energy sets requirements for the distribution grid. The share of wind and solar power are increasing, and they are unpredictable, so the electricity demand must be more predictable. The distribution grid must enable demand control possibilities. In the future, the grid owners should invest in flexible smart grid solutions to match the requirements of energy production. (Toivanen et al. 2017)

The next significant change during this decade is the electrification of traffic. In 2030, the CO2 emissions from traffic should be 50% of what they were in 2005 (TEM 2016). A major part of this reduction will be achieved with electric vehicles. Electric vehicle charging will affect the demand for electricity. It will increase the total demand and peak powers of the distribution grid. Peak powers will mainly affect the low-voltage grid. (Lassila et al. 2019)

For this thesis, the more important topic around electric vehicles is the charging station network. The target for the number of electric cars and plug-in hybrids is as high as 670 000 cars by 2030, consequently, there will be a large number of charging stations installed during this decade. The government has also updated the law for charging station requirements based on the EPDB 2018 directive. The law requires charging stations to be installed in certain situations for commercial buildings and apartment buildings. (Eduskunta 2020)

The last change reviewed in this thesis is the change of the electricity distribution grid structure and what the new structure requires from the maintenance point of view. The electricity market act was updated in 2013 and it sets strict limits for customer interruptions. The new limits were 6 h in urban areas and 36 h in rural areas (Sähkömarkkinalaki 9.8.2013/588). Since the update of the electricity market act, the underground cable construction rate has gone up significantly. More detailed numbers will be presented later in the thesis. Recently the distribution grid construction has focused mainly on underground cable construction, but towards the end of the decade, this is most likely going to change. By the end of the decade, underground cable targets are reached, and the distribution grid contractors must be able to answer to the demands of the new structure of the grid. Underground cables could require new inspection and maintenance methods with measurements, instead of sense-based inspections. Old overhead lines will be renewed with new overhead lines and contractors must still have the expertise for that. There must still be enough resources to handle the major faults during storms, even though the overall resource demand could decrease after the underground cable construction has reached the targets.

All these changes in the sector will be reviewed in the thesis in order to find possible solutions to the presented problem, as illustrated in Figure 1. The literature review will be the main research method for the different technologies. The initial research method was a customer survey and interviews. The survey and interviews were used to collect information about the topics and technologies that were chosen to be part of the thesis. The target was to find out which technologies are the most promising as new business opportunities, and which should be focused on the most. Electric car charging stations were chosen to be in a significant role for other reasons than the results of the survey. Other topics were estimated with the survey and interviews.

The survey included questions about the future of the electricity grid business. The target was to gather information from the actual grid owners in Finland, so the subjects of the thesis could be more accurately targeted towards the actual plans of the grid owners. The survey research was made in two phases. The first phase was the email survey in which the participants answered a selection of questions and were asked to take part in an interview about the topics. The interviews were a key part of the research because it was possible to talk about the topic more broadly, bringing forward ideas that were not part of the email survey.

The survey was sent to 82 participants in 36 different distribution grid companies around Finland. 27 participants from 21 different grid companies answered the survey and from those 27 participants, 7 participated in the interviews. There were more possible participants who were interested to be interviewed, but in the selected timeframe, only these seven were possible to be interviewed. In total, the sampling for the answers is good because about 58% of the grid owners who were selected for the survey answered the questions. Also, a sufficient number of interviews were held for more detailed answers. In the interviews, the answers started to repeat themselves at least when it comes to technical solutions and targets. This was expected and the target number of answers was reached. Thus, an overall picture was formed and different approaches to the technical solutions began to take shape. The survey and the interviews reached the selected targets and the research in this thesis will be based on these answers. Also, when reviewing possible new business opportunities, the survey and interviews will be in a key role.

3 ELECTRICITY DISTRIBUTION AND DEMAND CONTROL

This chapter will introduce the current state of the electricity distribution grid as well as the development of the network in recent history. The power balance and demand control will be introduced at the end of the chapter to outline the required future changes in the energy system and electricity distribution.

The last decade was a clear turning point for the structure of the distribution grid because of the massive increase of new underground cables. This has affected the whole electricity distribution grid business quite substantially. The basic structure of the electricity distribution grid had remained relatively unchanged for decades. Densely populated areas were built with underground cables and the vast majority of the distribution grid was built with bare overhead lines. The turning point was the year 2013. Till 2013, the share of underground cables in the network grew slowly. In 2013 the government introduced a new electricity market act. The main update was the strict interruption time limits for the distribution grid. The law requires, that in urban areas, the customer interruption can only last for 6 hours in rural areas the interruption can last a maximum of 36 hours (Sähkömarkkinalaki 9.8.2013/588). The grid owners needed a way to improve the reliability of the distribution network. An obvious way to improve the reliability would be to look at the statistics of the power interruptions and see what the cause for most of the interruption time is and improve that part of the network.

3.1 Faults in the distribution grid

The vast majority of power interruptions for the customer are caused by the bare open overhead lines in the medium voltage grid. Figure 2 shows the distribution of interruption time between different parts of the grid. Between 2017 and 2019 an average of 77% of the customer interruption time was caused by the faults in the bare open overhead lines. (Energiateollisuus 2019)

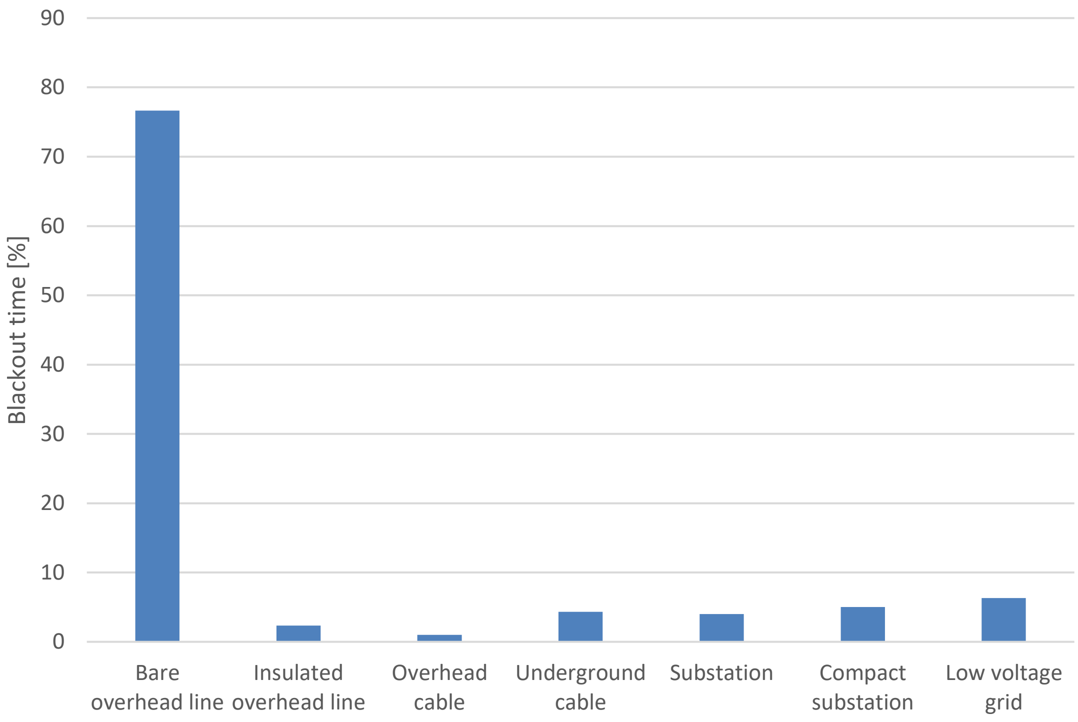

Figure 2. The average interruption times in 2017–2019 caused by different components in the distribution grid. (Energiateollisuus 2019)

The faults in the bare overhead lines are mainly caused by different weather phenomena. Between 2017 and 2019, the average interruption time caused by weather in bare overhead lines was about 80%. After the weather caused reasons, the main cause for interruptions is the planned maintenance interruptions. An obvious way to improve the operational reliability of the distribution grid would be to eliminate the possibility of weather-caused interruptions. (Energiateollisuus 2019)

The main way to improve the reliability of the distribution network, and reach the goals that the government has set, is to change the structure of the distribution grid so that a significant portion of the medium voltage distribution grid is constructed with underground cables. This has clearly been the direction that the distribution network companies have been going during the last years. The bare overhead lines can also be weatherproofed by clearing the trees around the lines to prevent the trees from reaching the lines even if they fall. Some grid owners have used this method to weatherproof the bare overhead lines. (Energiavirasto 2018)

3.2 Development of the distribution grid structure

Figure 3 shows the percentage of the distribution grid that is constructed with underground cables. The red line is the actual development of the low voltage grid and the green line is the future projection of the low voltage grid based on the development plans of the grid owners. The blue line is the actual development of the medium voltage grid and the black line is the projection for the future. In 2013 when the law for the interruption times was introduced, the percentage of underground cables in the medium voltage grid was only a bit over 10%. After that, the distribution grid owners have been investing in new underground cables and the share of underground cables has been increasing at a rate of 3–4 percentage points per year and it reached 35% at the end of 2019. (Energiavirasto 2018)

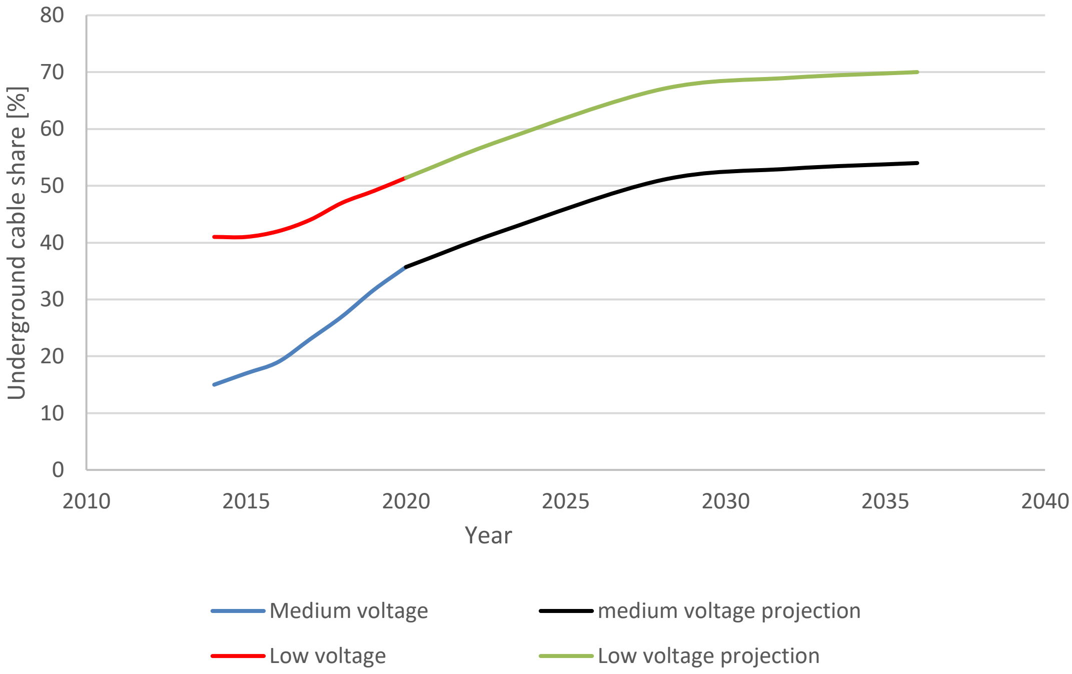

Figure 3. Development of the structure of the electricity distribution network and projection of the future development. (Energiavirasto 2018) (Energiavirasto 2020)

The low voltage grid has been developing on the side of the medium voltage grid although the effect for the reliability is not that significant. The low voltage grid only causes about 7% of the interruption time. The low voltage grid forms the final parts of the distribution grid and connects the customers to the grid. The effect for reliability is not that significant because one low voltage cable is only supplying electricity to a small number of customers. The low voltage section of the whole path from customer to the initial electricity supply is just a fraction, therefore the effect on reliability will also be just a fraction.

Constructing the low voltage grid with underground cables is significantly cheaper than for the medium voltage grid. The cable structure is simpler thus the price of the low voltage cable is only a fraction of the medium voltage cable. When the medium voltage grid is constructed with underground cables, it is natural to do so also with the low voltage grid. The low voltage grid was already more widely constructed with the underground cables because the house connections in the urban area are built with underground cables because of appearance and practicality.

The future projections in Figure 3 have been made according to the development plans that the distribution grid owners have provided. The Finnish energy authority has demanded that the grid owners must provide a development plan for the improvements of the grid and that plan must be updated in two-year intervals. In the development plan, the grid owners introduce their short-term and long-term improvement plans for the distribution grid. The Finnish energy authority follows the development of the distribution grid and that the demanded improvements are made in time. The first significant year is the year 2028. That is the year that the government originally set as the deadline for the new reliability improvements. After that, the government set that the grid owners can apply for additional time for the improvements, but they must fulfil certain criteria in order to be approved for the additional time. The government has also made a proposal as a new law, that the time limit for all grid owners would be extended to 2036 (Eduskunta 2021). If this is approved as a change to the electricity market act, it could affect the development plans that were visualized in Figure 3. (Energiavirasto 2018)

It can be seen from Figure 3 that the current investment pace will stay roughly the same, maybe slowing down a little bit till the year 2028. By then most of the grid owners have made the improvements that are required for the new reliability thresholds. This means that the distribution grid business will face changes at least when it comes to the contractors who build the new underground cable grids.

3.3 Contractors in electricity distribution

Nowadays the grid owners have a compact staff and they usually only do the electrical planning of the network. After the electrical planning, all the work is left for the contractors. The work that the distribution network requires can be divided into three main sectors: construction, inspection, and maintenance.

Construction is the main part of the business for most contractors. During recent years, the construction has mainly been constructing the new underground cable network due to changes in reliability requirements. Construction has developed to be an even more vital part of the contractor’s business because the demand for construction has been so high lately.

Construction projects vary a lot. They can be just small projects that take few months to complete. Or they can be massive projects that consist of hundreds of kilometres of new cable and years of work. Also, the contractors vary a lot. Some are relatively small companies that rely on subcontractors and their own staff basically just handles the management of the project. Then there are companies that handle the planning, managing, and electrical work with their own staff and usually use subcontractors for civil engineering.

Maintenance serves a vital role in the contractor’s business although the turnover from the maintenance is usually not that high. The importance of maintenance comes from its continuity. Maintenance is needed all the time, no matter the economic situation. It is always vital for reliability to keep the distribution network in good operational condition.

Maintenance can be small projects that consist of some area of the distribution network that requires some upkeep. Or it can be longer contracting that applies to a section of the distribution network. Within this contract, the contractor is required to handle all the faults and scheduled maintenance of that section of the distribution network. These kinds of contracts bring reliable cash flow for the company and they are an important part in this kind of high-risk business.

Inspections are also very important when it comes to the reliability of the distribution network. Inspections give data of the current condition of the components in the network and with this data the owner of the grid can evaluate if the wear of the components is in correct state in relation to the age of the component.

Currently, inspections are mainly based on the senses of the inspector. For the overhead lines, the rot inspection is in a significant role. The condition of the pole is inspected and ensured that it is not too rotten, and the observations are recorded for the pole, so in the future, the owner of the network can anticipate the possible repairs that are needed for the network. There is also a general inspection of the condition of the network. This kind of inspection is done for the overhead lines as well as for the underground cable grid. In this inspection, the network is inspected for any kind of visual wear and tear.

Currently, the inspection methods rely almost completely on the senses and experience of the inspector. At the same time, the distribution network is going through a change and the cables are constructed underground. All the time it is getting more difficult to do reliable inspection by just relying on the senses, because the components are not visual anymore. It is impossible to inspect the condition of the underground cable without any sort of measurement device. This is a major change that the inspection of the distribution network must go through. Even in the current state of the network, it is starting to be hard to do the inspections without any measurement devices. In the future when at least 50 % of the medium voltage network is underground, it will be impossible to do reliable inspections without any measurement devices.

3.4 Energy balance and demand control

Currently, the power system requires the perfect balance of the demand and production of electricity. This basically means that the power plants must produce exactly the same amount of electricity that the consumers use at any given second.

Finland is part of the joint Nordic system. Other members are Sweden, Norway, and East Denmark. The frequency control is combined with these members and the obligations for maintaining the reserves are agreed between the Nordic transmission system operators. (Fingrid 2020)

Fingrid is the owner of the main power grid in Finland. It consists of 400, 220, and 110 kV power lines. Fingrid also handles the frequency control for Finland. The frequency of the electricity grid is 50 Hz, and it is adjusted with power reserves. Different power reserves that are used in the Nordic power system can be divided into two different categories: (Fingrid 2020)

- Frequency containment reserves are used in normal operation to constantly adjust the frequency with the variation limits of +- 0.1 Hz. Then there is a frequency containment reserve for disturbances. This system is reserved for the situations like a large power plant suddenly disconnecting from the grid. It makes sure that the frequency does not drop under 49.5 Hz.
- Frequency restoration reserves are used to stabilize the frequency back to 50 Hz after the frequency containment reserves have activated, so they can be released back to being ready for another possible disturbance. (Fingrid 2020)

The concept of frequency control is an important topic to understand when thinking about the energy system of the future. The current frequency control system is usable with the current energy system where the power comes from relatively stable sources. In the future, the renewable energy sources are starting to be the dominating part of the energy system. Renewable energy sources are not that stable or predictable, so in the future, the balancing of the energy system might require some other methods as well. Possible methods are different energy storages and more advanced demand control made possible by the smart grid applications.

Demand control already has some role in the balancing of the energy system. Demand control in Finland is based on the hourly changing price of the electricity. The price of electricity is formed by the demand and supply of electricity. As Figure 4 demonstrates, the price of electricity is the price of the most expensive production method in operation at any given moment. Therefore, when demand is low, the electricity demand can be covered with production methods that have low operation costs such as wind, hydro, solar, and nuclear power. And as the demand increases the production must move to more expensive production methods and this will increase the price of electricity. (Järventausta et al. 2015)

The price formation method introduced in Figure 4 is the core of the demand control currently in use in Finland. Consumers can plan their electricity consumption, so they use it when it is as cheap as possible. This helps the balance of the power system because it divides the supply more evenly across the day. The hourly changing electricity price helps to balance the power system because it is profitable to plan the electricity usage so that the loads that are not tied to a specific time are used when the electricity price is at its lowest. A Perfect example of consumer use for this type of application is the water heater. (Järventausta et al. 2015)

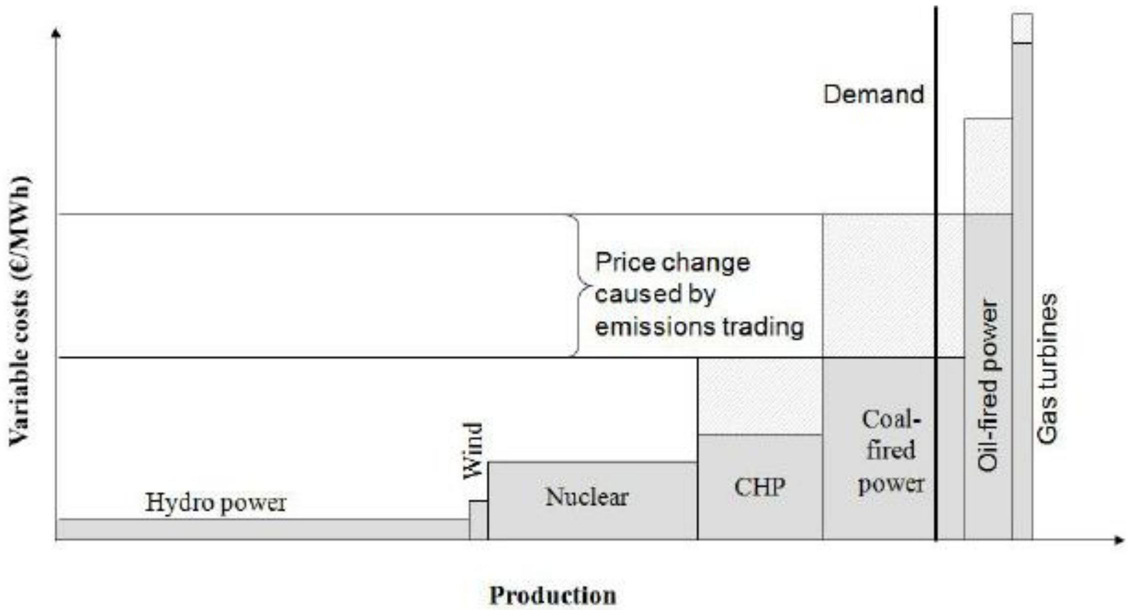

Figure 4. Formation of the electricity price in the market. (Jabłońska-Sabuka et al. 2012)

The amount of nuclear power and the way the nuclear power plants are run in Finland introduces another interesting phenomenon with the price formation method. Nuclear power in Finland is always running on full power. Therefore, the base power in Finland is mostly produced with nuclear power and hydropower, although hydropower is starting to be more important in adjustment power use. When the demand is at its lowest this can create a problem because there can be over supply. This issue will most likely be faced more often in the future because Olkiluoto 3 will provide an additional 1600 MW of nuclear power for Finland's electricity system. Although, the way how nuclear power plants are operated could be changed in the future if this situation becomes an issue. There is no technical reason why the power of nuclear power plants could not be adjusted just like for any other steam power plant. They just have been operated in full power in Finland because of the low operation costs of nuclear power.

Currently in this situation the electricity would be cheap and that would naturally guide the demand so that all the loads that can be adjusted are in use when the electricity is cheap. In the future, when the demand control will be significantly more advanced, these adjustments in the demand could be done automatically. This way the effects and the efficiency of the demand control would be much higher. (Järventausta et al. 2015)

Finland has been the leading country in demand control technology and demand control products in electricity market. Every consumer has the AMR-meter (Automatic Meter Reading), this allows every consumer to participate in demand control. Electricity sellers offer electricity to be bought with the hourly changing market price, so consumers can plan their electricity usage. If the electricity usage is scheduled when the price is low rather than high this befits the consumer because of the low price and the whole energy system because it divides the electricity consumption more evenly across the day. (Kumpulainen et al. 2016)

4 FUTURE VISIONS

In this chapter, the vision for the future of the distribution network is introduced. First, the development of the whole energy system is introduced briefly because the development of the distribution network is not just for electricity distribution. The distribution network of the future must serve the needs of the whole power system. The amount of renewable energy sources will be bigger and there will also be more changing loads due to increasing amounts of electric vehicles. Also, the micro-production will introduce new challenges for the distribution network because the network must be able to transmit all the excess power from micro-production to the power grid. (VTT 2018)

4.1 Targets and visions for the year 2030

The energy system will face significant changes in the future. The next important year is 2030 (TEM 2016). By then Finland is planning to reach a few significant milestones in the decarbonisation of the energy system. The targets for Finland are based on the targets set by the European Union. The EU sets emission targets for the whole area and guides the environment policies of individual member countries. In September 2020, the European Commission proposed that the greenhouse gas emission reduction target for 2030 would be increased to 55% compared to the emission level in 1990. The currently effective target is 40%. The increase would be significant. The Commission has started making detailed legislative proposals by June 2021. The proposal will include updated targets for different sectors such as share of renewable energy and energy efficiency targets. The targets of Finland are based on the targets of EU, so most likely there will be updates to the targets introduced in this chapter. (European Commission 2021)

Significant milestones that are currently effective for the year 2030 are:

- The amount of renewable energy will be more than 50% of the final energy consumption. Total emissions outside of the emission trade will be 39% lower than in 2005. (TEM 2016)
- 40% of the fuels used in traffic will be renewable. Electricity consumed in traffic will be considered according to the 2009/28/EY directive (TEM 2016). The directive states that the amount of electricity used in traffic can be calculated using the share of renewables of the whole electricity production. The consumption of the of the electric vehicle is assumed to be 2.5 times of the energy content of the electricity produced from renewable sources (Eur-Lex 2009).
- Greenhouse gas emissions from traffic will be 50% of the emission level in 2005.
- Consumption of imported oil consumed in the nation will be decreased by 50%. (TEM 2016)

By 2030 the emissions outside of the emission trade will drop by about 22% when compared to the year 2005 according to the basic scenario. Thus, the measures that are already decided are not nearly enough to reach the required 39%. The traffic sector is one of the main sectors that have significant potential to reduce emissions since traffic causes over one third of the emissions outside of the emission trade. (TEM 2016)

4.2 Targets and visions after 2030

Currently the furthest target that the government has set is in 2050. By then the energy system has gone through some drastic changes in many sectors. Common target in EU is to reduce GHG-emissions by 80% by 2050. Finland’s target is 80–95%. It is estimated that the emissions can be reduced relatively cost efficiently 85–90%, but after 90% the expenses can rise quickly. (Salokoski 2017)

In 2019, the Finnish government set a new target for the year 2035. The new target is to reach carbon neutrality in 2035. Currently the targets that are set in law do not recognise this target and the law for the emissions is planned to be renewed in 2021. Target for the

2050 and 2030 will be updated in the new law and target for the 2040 will be added. (Ministry of the Environment 2020)

4.3 Demand control

The need for the daily power adjustment in the power system is expected to double by the year 2030. One reason for the increasing need for adjustment power is the power system's development towards renewable energy. Renewable energy sources like wind and solar are highly variable and it is hard to plan accurately how much power they will provide at any given moment. Also, the amount of variable load will increase due to the increasing number of electric vehicles and heat pumps. Demand control will also help Finland to reach the national targets in emission reduction because demand control will help to reduce the adjustment power needed in the system. Demand control will also help to divide the load more evenly, so there will be fewer power peaks than currently. This will enable more energy to be produced with renewable energy sources. Providing enough power during the highest power peaks is difficult with unpredictable renewable energy sources, so demand control is in a vital role. (VTT 2018)

Currently, many of the adjustable high-power industry loads are being used in demand control. They enable the system to reduce the electricity demand rapidly in case of some fault in the system that reduces the supply. This way the system has more time to recover from the fault and to increase the supply back to the required level and then the adjustable load can be turned on again. This kind of demand control requires expensive automation and high powers in order to get in the market. It is also not very useful in adjustments during normal operation. In the future, it is important to open the demand control market for smaller operators. (VTT 2018)

In the future, the demand control possibilities for normal households will be significantly better. One part of the smart grid applications that will be implemented to the distribution grid are the next generation of AMR-meters. The new AMR-meters will enable improved demand control possibilities for every house. The meter will be possible to be integrated with house automation. The load of the house can be controlled according to the information that is received through the AMR-meter. This function is open to third parties such as electricity vendors. There will be a whole new way to use normal houses in demand control applications. (Pahkala et al. 2020)

5 POWER DISTRIBUTION IN THE FUTURE

In this chapter, it will be estimated what the future visions from the chapter three will require from the power distribution network. Also, other future developments of the distribution grid will be introduced in a technical point of view. The amount of renewable energy in the power system will be increased during this decade and there will be more variable loads in the system. Maintaining power stability with increasingly variable production and loads will require flexibility from the whole power system. The content of this chapter will also be based on the results of the survey and the interviews. Therefore, the research about advanced electricity distribution will be made based on the theoretical requirements and the actual plans of the grid owners. Researched subjects will be concentrated around the technologies that are important to be considered in companies that construct distribution networks. The focus will be on the hardware installed in the grid and the software behind the automation of the grid will be disregarded.

The distribution network in Finland today can be called a smart grid. In 2004, Andres Carvallo gave a definition for the smart grid and that definition is still valid today. “The smart grid is the integration of an electric grid, a communications network, software, and hardware to monitor, control, and manage the creation, distribution, storage and consumption of energy. The smart grid of the future will be distributed, it will be interactive, it will be self-healing, and it will communicate with every device.” (Carvallo & Cooper 2011) By this definition, the electricity distribution system in Finland qualifies as a smart grid. It has automation, it has remote controlled circuit breakers, it has AMR-meters.

The smart grid concept has many levels to it, so the definition of the term smart grid is complicated and not at all accurately defined. Although there are many definitions for the concept. It does not mean some specific type of technology or devices or anything like that. It is a general name for the more advanced power distribution system or the whole power system. Smart grid is an advanced power system, and it can synchronize all the production, storages, and loads in the system. The core of the smart grid is information that it must gather from all different components in the system. In this thesis the most important smart grid applications are the ones that were highlighted in the survey and in the interviews with the grid owners. (Dileep 2019)

5.1 Advanced AMR-technology

The survey and interviews showed that the next generation of AMR-meters is one of the major investments for distribution grid owners during this decade. Elenia has already started the installations of the new AMR-meters and the mass rollout will end in 2024. Many grid owners are a bit behind on this topic and have not yet started the rollouts or the final development of the next generation AMR-meter.

Pöyry Management Consulting Oy has made a report about the requirements for the next generation AMR-meters. The report summarizes the law-based requirements, and it recognizes the needs of relevant stakeholders and possibilities enabled by the development of technology. The report gives the minimum requirements for the next generation of AMR-meters. The ministry of economic affairs and employment of Finland accepted the minimum requirements suggested by Pöyry. A suggestion for new government regulation was made based on the report from Pöyry. The new regulation is planned to be applied from 1 January 2022 and the requirements must be met by the grid owners by 5 July 2031. (Pahkala et al. 2020)

The suggestions for the next generation AMR-meters made by the smart grid task force:

1. The one-hour tariff will be shortened to 15 minutes by the year 2025. The new AMR-meter must support this feature and there must be a possibility to decrease that time even more in the future.
2. Active and reactive power and energy must be measured and registered by phase.
3. Instantaneous voltage and current values must be measured.
4. The drawn power and the supplied power must be measured separately from each phase.

5. Outages under three minutes must also be registered.
6. The AMR-meter must be able to be updated remotely.
7. Remote disconnection and connection of electricity supply. Not applied for current transformer meters.
8. Local commonly used one-way communication bus. The measured values must be made available for the customer through this communication bus. The update rate is maximum of five seconds.
9. The data security of the new AMR-meters must be ensured.
10. Load control function for the customers who have significant controllable loads. (Pahkala et al. 2020)

These are the minimal requirements that must be met by all grid owners if this will be the final regulation that will come into effect in 1 January 2022. The individual grid owners can set other functions into their AMR-meters if they find them useful as long as they meet these requirements. (Pahkala et al. 2020)

One significant function in the new generation AMR-meter is the load control function, which is available for electricity vendors and other third parties. Through the load control function, the normal electricity users are going to be part of the demand control. There are many electrically heated houses and other controllable loads in normal residential houses, and these are viable loads for demand control uses. (Pahkala et al. 2020)

The load control feature, which is open for third parties, is the interesting part for other companies. The AMR-meters can be connected to house automation system in order to achieve integrated demand control functions. This is also an interesting feature when combined to electric vehicle charging. Charging stations will be a common part of houses in the future and the battery of the electric car will be a significant controllable load in the house’s energy system. The communication bus in the new AMR-meter offers new possibilities for companies in terms of demand control. The demand control possibilities with house automation and new AMR-meters are a complicated subject and it is not directly compatible with Exsane’s strategy. It would require participation in private market, which is not in Exsane’s strategy right now. Also, it would require implementing a completely new area of expertise into Exsane’s business and that is not desirable. For these reasons, the demand control will not be studied any further in this thesis.

The new AMR-meters itself are the second important opportunity. There are a massive number of AMR-meters to be changed during the next ten years. That is something that should not be missed in companies that work in distribution grid construction. This will be the focus for Exsane. It fits into the area of expertise in Exsane and is a good opportunity to exploit.

5.2 Fault control and maintenance

Advanced and intelligent fault control can also be included to be part of the smart grid concept. Faults in the distribution grid were introduced at the beginning of this thesis and it was clear that the main cause for customer interruptions are the different weather-caused faults in the middle voltage bare overhead lines. Currently, the distribution grid owners are doing everything they can to improve the reliability of the distribution grid to meet the new strict interruption time regulations from the government. Grid owners are constructing the distribution grid with underground cables and moving the overhead lines next to the roads and clearing the trees around the bare overhead lines in order to prevent weather-caused faults. The weather-caused faults will significantly decrease during this decade because of these improvements. This development does not remove the need for fault control and maintenance, but it changes it.

In the future, and even today it is increasingly important to change the fault controlling style to a more proactive direction. In Figure 3 it was estimated that the share of underground cables in the distribution grid will be around 52% of the medium voltage cables in 2030. Currently, the share is around 35% and in 2013 it was only a bit over 10%. Considering that most of the medium voltage underground cables are a maximum of 7 years old, it is not expected that there will be many faults in the underground grid in the following years. From the maintenance point of view, now is the time to develop the measurement methods and start to gather data from the distribution grid. This way there will be data from the different components of the distribution grid and the grid owner can anticipate the need for repairs and do them under control.

Automatic measurements and data collection will also be part of the maintenance process in the future. For example, Elenia has already started to form a concept for IoT-sensors (Internet of Things) that gather data from compact substations (Elenia 2020). Measuring the certain components in the distribution grid is important because it gives a real-time indication of possible faults. Manually performed measurements are also important, but they leave certain vulnerabilities in the system. The time interval between measurements cannot economically be so short that it eliminates faults between the measurements. With manual measurements, the risk for unprepared faults decreases, but it does not disappear. Automatic measurements enable the immediate detection of factors that indicate possible fault starting to occur. This way the unprepared faults can be decreased to their minimum.

Automatic measurement is a complex matter. It requires sensors, telecommunications, data storages, and analytics. Sensors gather different data which is found to give indications of possible faults. For example, in compact substations the measured data could be sound, temperature, humidity, vibrations, and oil level. Sound, temperature, and vibrations indicate presence of partial discharges which are harmful for the components. Humidity indicates environmental conditions that the components are in. Oil level indicates oil leaks. All of these can be used to analyse the probability of the failure and estimate the condition of the component and what the actual lifetime could be. Telecommunications are vital for the system, because data must be transferred to data storages from where it can be analysed. Perhaps the main issue of automatic measurement is the analytics of the data. There will be endless amount of data gathered from the various sensors. The data flow must be processed and analysed to find the possible fault indications. (Elenia 2020)

In Exsane’s point of view, the most important part is the hardware related to measurements. Exsane does not have the expertise or resources for the software side of automatic measurement, therefore it is not a significant part of this thesis. Although the manual measurements are the most important part of the maintenance process of the future for Exsane. The resources of Exsane match that side of the inspection and maintenance process better. That is why the automatic measurement will not be studied any further in this thesis and the focus will be on the manual measurements.

5.3 Grid automation

Maintenance should be updated into more preventative way as it was said in the previous chapter. Even with preventative maintenance and intelligent data analysis, there will be faults that cannot be prepared for. For these situations, the automated fault control will come in play.

FLIR (Fault Location, Isolation and Restoration) is an advanced concept for automated fault control. Automated network management and fault control is based on systems like SCADA (Supervisory Control and Data Acquisition) and DMS (Distribution Management System). The first requirement for automated fault management is fault indication, which is based on local measurements. Different measurement methods are used for different fault types. Completely automated fault management would require different measurement methods in compact substations and remote-controlled medium voltage switches. It is not economically viable to retrofit them in all the compact substations. The installations should be optimized based on the cost of the implementation and the benefits that are obtained from it. (Siirto et al. 2014)

FLIR-process is split into two categories, higher level fault management and lower-level fault management. The higher level is based on full automation and lower level utilizes the manual switches as well. The FLIR-process is described in ten different steps: (Siirto et al. 2014)

1. Fault is detected and circuit breaker is opened. DMS gets a signal that there is a faulty feeder.
2. DMS analyses the topology of the network. The result is the state of the network before the fault as well as the topological hierarchy of the compact substations.

3. Information is gathered from fully automated compact substations. DMS collects data from the local measurement devices from the compact substations.
4. Now the fault indicator data is analyzed. The active fault indications are tracked until the fault is located to a specific line section.
5. During this step, the switching sequence is analyzed to isolate the faulty section and get the supply restored in the main feed if possible.
6. After the initial switching sequence is formed, the topology is analyzed to find an automated line section in the faulty section that could be restored using a back feed supply. If there is a line section like this, it is added to the switching sequence.
7. Now the switching is implemented in practice. DMS gives the operation command to the SCADA.
8. Once the automated switching is done, DMS analyses the topology of the faulty sections to find if there are multiple line sections under outage. Now the manually operated line sections are separated into their own sections again to see if supply could be restored in some of those line sections.
9. At this point, the DMS analyses the fault indicators from the rest of the line sections.
10. Last part is the separation of the faulty elementary sections using manual and remote-controlled switches, which are not automated. Now the supply is restored to all the line sections, which are not faulty and can be fed from the back feed supply or the main supply and the faulty sections are repaired. (Siirto et al. 2014)

Based on the survey and the interviews, the distribution grid already has lots of hardware that can be used for more advanced automated fault control. It is still lacking measurement devices and the advanced automation of the hardware. Many grid owners have already applied the use of measurement devices for automation and have some level of FLIR-systems already in operation, but most of the fault management is still done by the operator. The main part of the development on grid automation revolves around the software of the automation, therefore it does not match the resources of Exsane too well.

5.4 Partial discharge measurements

Partial discharge is a phenomenon that is caused by some fault in the insulation of a high voltage system. During the partial discharge, the fault in the insulation causes a bridge to be formed partially over the insulation of the electrodes. There is always a small current leaking through the insulation, but under normal circumstances, the leakage current is indefinitely small. Due to some faults in the insulation, the breakdown strength of the insulation can be decreased in some points of the insulation and then the electric field strength exceeds the breakdown strength, and a partial discharge is formed over that part of the insulation. (Aro et al. 2015)

There are several possible faults in the insulation that can cause partial discharges. Possible faults are for example some cracks, impurities, cavities, or joints of the insulation. The faults can be from the manufacturing process or they can be caused by incorrect installation methods. A sharp edge on the electrode can also create a hotspot to the electric field which can cause a partial discharge. (Aro et al. 2015)

Partial discharge is a sign of wear and weakened insulation and partial discharges are a chain reaction because weakened insulation causes partial discharges, and they wear down the insulation even further. Partial discharges produce heat and chemical reactions that wear down the insulation. They cause these electric trees inside the insulation which eats their way slowly through the insulation. Figure 5 illustrates the insulation wearing process caused by partial discharges. First, there is a circular void in the insulation, then the electric field strength exceeds the breakdown strength of the void and causes a discharge over that void. Due to the heat and chemical reactions, the void starts to grow and form an electric tree. When the electric tree reaches a certain point, the strength of the electric field exceeds the breakdown strength of the whole insulation and causes a complete short circuit which then destroys the high voltage component. (Aro et al. 2015)

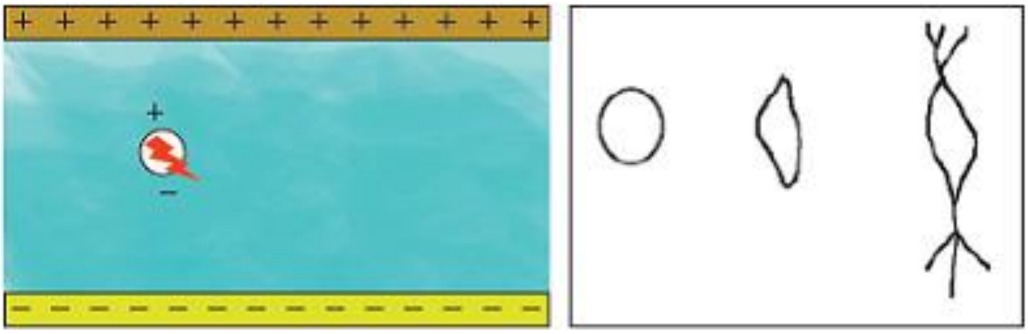

Figure 5. On the left side there is a void inside the insulation and on the right side the formation of the electric tree is illustrated. (Combined Cycle Journal 2020)

There are few different types of partial discharges. In Figure 5 is the internal partial discharge which is the most harmful type because it occurs inside the insulation, thus it deteriorates the insulation material the most. The second type is the surface partial discharge. Surface discharge occurs when the electric field has a particularly strong component in the direction of the surface of the electrode. Surface discharges can be harmful in parts of the high voltage component where there is a surface between two different insulations. The last type of partial discharges is the corona discharge which is generally harmless. Corona discharge occurs on the interface between the electrode and gas; therefore, it does not deteriorate the insulation. Corona discharge can still be harmful because it emits signals that can distract the detection of other more harmful partial discharges. (Aro et al. 2015)

Partial discharge is a measurable phenomenon, and it can be used to analyse the condition of the high voltage components. Partial discharge emits different kinds of signals which can be measured, and the amplitude and frequency of these signals can be used to estimate the condition of the insulation. There are several different ways to measure partial discharges using different kinds of measurement devices. Some of the methods can be done during the normal operation of the high voltage system. Other methods require the normal operation to be stopped for the measurement device to be connected to the component. (Aro et al. 2015)

5.4.1 Acoustic partial discharge measurement

Partial discharge emits electromagnetic signals and soundwaves. The emitted sound signal is at high frequency and it requires purpose build sensors to detect the signal and to separate it from other sound signals that are not related to the partial discharge. The measurement must be done relatively close to the actual place of the partial discharge because the sound signal is absorbed quickly. The signal spreads to all directions and is reflected and absorbed by the surrounding structures which makes the detection and especially the analysis of the signal more difficult. The optimal situation is to have the sensor directly pointed towards the source of the partial discharge without any objects between the sensor and the partial discharge source. (Aro et al. 2015)

Acoustic partial discharge measurements are used for large transformers and SF6 - insulated switchgear in substations. It is a good measurement method for large substations because there are lots of electromagnetic signals that can easily disturb any measurement methods that rely on the electromagnetic signal of the partial discharge.

5.4.2 TEV-measurements

TEV stands for transient earth voltage. Partial discharge changes the electric field which causes a high-frequency voltage to be induced in the grounded metal structures around the high voltage components. This is a relatively easily measurable phenomenon because the signals can be detected from the protective structure of the high voltage component. The signal is a high frequency signal; therefore, it travels on the surface of the metal structure and goes through the seams and bushings of the structure. Figure 6 illustrates behaviour of the signal and how it travels in the structure of the high voltage component. The signals emit from the partial discharge source and travel inside the grounded structure and go through the points where the grounded structure is discontinuous. (Jiangbao et al. 2018)

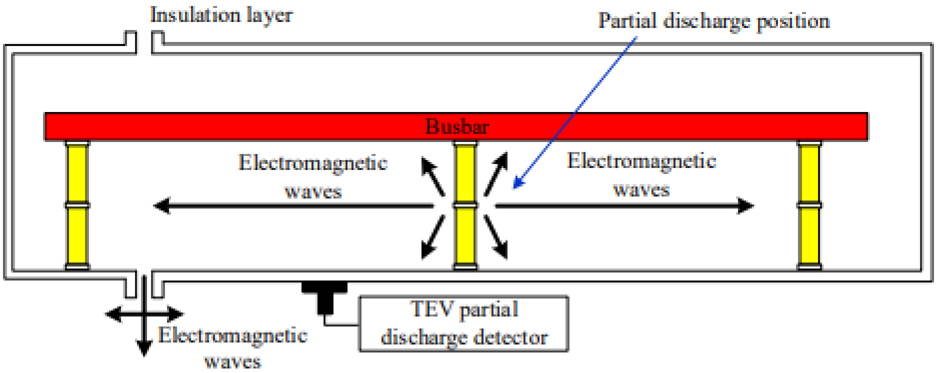

Figure 6. Basic diagram of the TEV-measurement process. (Jiangbao et al. 2018)

In TEV-measurements a capacitive sensor is used to detect the signals on the outer surface of the structure. The sensor must be sensitive because the amplitude of the signal from the partial discharge varies from milli-volts to volts and the duration of the signal is usually just some microseconds. The characteristics of the signal are then used to analyse the partial discharge. There are several parameters of the TEV-signal that are used to evaluate how serious the partial discharge is. (Jiangbao et al. 2018)

The key parameters when evaluating the partial discharge from TEV-signal are the amplitude of the signal and the number of pulses that are emitted. TEV-signal is measured in dBmV and the reading itself does not give a clear answer about the condition of the insulation. The results from the measurements should be compared to measurements that have been done with the same type of components in same kind of operational and environmental conditions. (Davies 2015)

In this thesis the partial discharge measurements are planned to be used for compact substations and for medium voltage underground cables. TEV-measurements have not been used widely for compact substations so there is little reference data available for the comparison. If TEV-measurements are wished to be used for inspections in compact substations, the measurements should be started when the compact substation is new, and the measurements should be continued in roughly five-year intervals. If this same protocol is used for all, or at least a significant portion of the compact sub stations, the database grows and allows the analysis of the component’s condition to be developed based on the TEV-signal. At very least the TEV-measurement will give some idea where the faults will most probably occur during the following years. If one substation starts to give significantly higher readings than other same type of sub stations, it is to be expected that this substation is the most probable one to face some sort of defect during the near future. In this situation, the measurement interval should be decreased and the need for more accurate investigation should be considered. In my opinion the TEV-measurement will not most likely be reliable enough to make decisions for repairs or maintenance on compact substations, but it will be reliable enough to give prediction of which components are most likely to fail before the scheduled replacement of the component.

5.4.3 **HFCT-measurement**

HFCT stands for high frequency current transformer. In HFCT-measurements the high frequency current transformer is used to detect high frequency signals on the grounded part of the cable. The HCFT-sensor is installed around the cable terminal or around the ground wire of the middle voltage cable terminal. An oscilloscope or a purpose build measurement device can be used to analyse the signals. HFCT-measurement is a possible way to get partial discharge data from the cables during normal operation. HFCT-measurement is the only online measurement that can measure the apparent charge of the partial discharge. HFCT is the only online measurement that measures the signals directly from the partial discharge. Other methods measure other signals that are caused by the partial discharge such as sound, induced electrical signals or electromagnetic signals. Because of this, the HFCT-measurement is the most accurate online measurement available, but it is only for measuring cables. The other negative fact is that the HFCT-measurements always require the sensors to be installed around the cable terminals, which is not possible with every type of substation. (Pakonen et al. 2018)

5.4.4 DAC-measurement

DAC stands for damped alternating current. DAC-measurement is an offline partial discharge measurement method. In DAC-measurements the test voltage is the highest in the beginning of the test and from there the amplitude starts to decrease while the frequency stays the same. In DAC-measurements the frequency is much higher that 50 Hz and it depends on the inductance of the test circuit and on the capacitance of the measured cable. Upside for the DAC-measurement is the short time needed for the measurement because of the high frequency. (Pakonen et al. 2018)

5.4.5 VLF-measurement

VLF stands for very low frequency. VLF-measurement is the other offline partial discharge measurement method. In VLF-measurement the test voltage is very low frequency, less than 1 Hz, usually 0.1 Hz. One downside of the VLF-measurement is that the required time for the measurement is long because of the low frequency. Also, the accuracy of the measurement might not be good because the frequency is so much lower than in the electricity grid and the lower frequency changes the partial discharge phenomenon. One upside for partial discharge measurements is that the measurement device is relatively light because the power source only must be able to supply a low frequency, which reduces the power demand. (Pakonen et al. 2018)

5.5 Energy storages

Within the topic of this thesis, the essential energy storages are the batteries that are used in distribution grid for various purposes. There are few different ways to use batteries in distribution grid. First is the private use for customers. A popular reason for a battery to be used in a private house, is a solar power system in co-operation with the battery system. Battery increases the self-utilization rate of the whole system. The study by Lassila et al. found, that the self-utilization rate of a typical private 5 kWp solar power system, could be raised from 53% to 76% with an 8 kWh battery. The same study found out with a customer survey that increasing the self-utilization rate of the solar power system is the main motivation to invest in a battery in a private house. Other motivations are the security of supply for electricity and avoiding the price spikes of electricity. (Lassila et al. 2019)

Another use for batteries is a more centralized type of use, in which the battery system is integrated into the distribution grid. Elenia and Fortum implemented a system like this in co-operation as a pilot project for the technology. In this type of use, the battery is connected to a certain point in the distribution grid with two purposes. The first purpose is to be used as energy storage to balance the supply and demand in the whole energy system. The second use is to be used as a backup supply for a certain part of the distribution grid. In fault situations, the battery system can be used to supply electricity for a small section of the distribution grid, while the main feed is being repaired. This offers few hours of time to repair the faults without customer interruptions. The law is still restricting this type of use. It is illegal for the distribution grid owners to own these batteries. That is why Elenia had a pilot project about this technology in co-operation with Fortum. The system has a battery, which is owned by Fortum and in normal operation, it is used as energy storage to balance the energy system. It is connected to thousands of water heaters to create a virtual battery, which is controlled by the needs of the whole energy system. (Elenia 2021)

6 ELECTRIC VEHICLE CHARGING

Electric and hybrid cars are an important method to decrease the emissions from traffic next to biofuels. The number of electric cars has been increasing rapidly during the past few years and the number is going to go up fast during the following years. Electric cars require a different kind of approach to the usage of a car than a regular combustion engine car. The range of an electric car is not nearly as good as it is in a combustion engine car. According to data from various manufacturers, the range of an electric car varies a lot ranging from about 200 km to up and even over 600 km. The more affordable electric cars have a range of around 200–300 km. Plug-in hybrids usually have an electric range between 30 and 60 km, but some of them reach even 100 km.

On top of the shorter operating range, the electric cars are significantly slower to recharge than combustion engine cars are to refuel. Currently, a standard rapid charger at gas stations etc. has a charging power of 50 kW. The consumption of an electric car is somewhere around 20 kWh/100 km. So even with a rapid charger it still takes almost half an hour to get 100 km of range. Although the rapid chargers are getting more powerful and there are already various chargers from 150 kW to even 350 kW of power in Finland and more to come.

Because of the shorter range and slower refuelling, an electric car is not as practical as its combustion engine rival in long distances. Also, electric cars are still more expensive than their combustion engine rivals mainly because of the high manufacturing costs of batteries. Although after 2010 electric cars have been getting more and more common and because of that the technology and manufacturing processes have improved steadily, and the prices of the batteries have been steadily decreasing.

In 2010 the price of an electric car battery was around 1000 €/kWh and in 2019 it was dropped down to around about 130 €/kWh according to research conducted by BloombergNEF. The price has decreased around 87% in nine years making the electric car economically more viable option than what it was. This development of the battery price is expected to continue and the projected cost in 2024 is under 85 euros. The price development and future projection is presented in Figure 7. (Richter 2020)

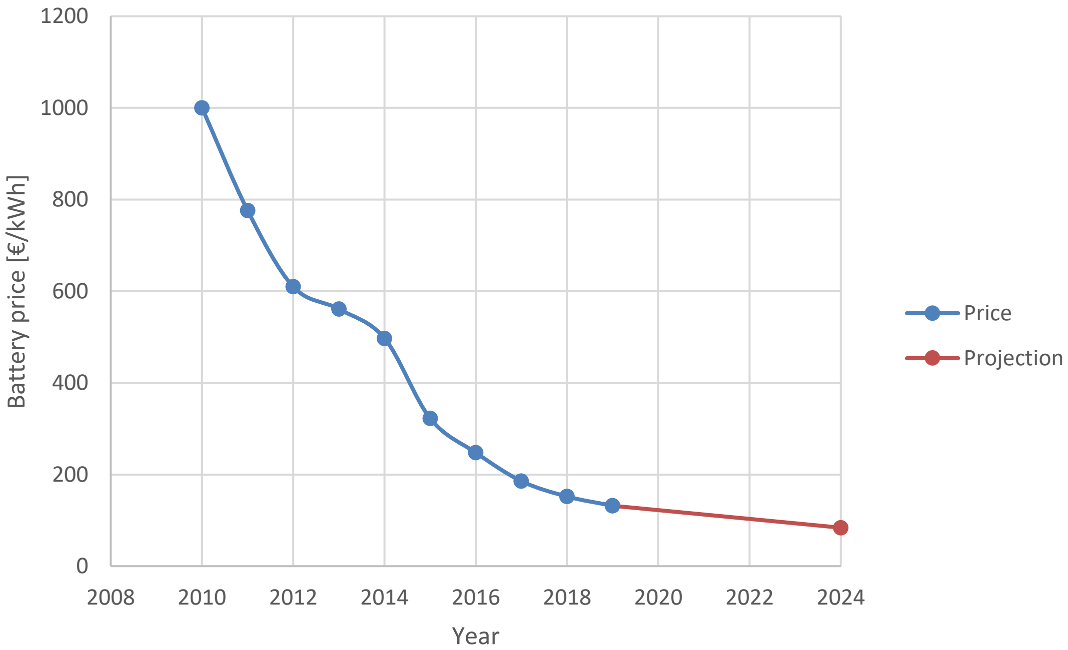

Figure 7. Price development of the electric vehicle battery pack. (Richter 2020)

After the price issue, comes the charging issue of the electric car. Because of the short range, electric cars must be charged more often and even during longer drives. This creates high requirements for the charging network because the cars must be charged fast and in a variety of different locations. Currently, the charging network has kept up with the demand very well, but the fast-increasing number of electric cars is constantly creating pressure to develop the charging network further. There are now regulations that require apartment buildings and commercial buildings to arrange a possibility to charge electric cars. These will be introduced further in chapter 6.4.

6.1 Electric cars in Finland

The number of electric cars and plug-in hybrid cars will drastically increase during the following decade. In 2010 there were only 23 full electric cars in Finland and the increase has been exponential. in 2016 the number was 844 and on 30 June 2020, it was already

6432. Plug-in hybrids entered the scene in 2012 with 128 cars and on 30 June 2020, the number was already 33 883. There are around 40 000 cars already on Finnish roads that require to be charged, or at least require to be charged to function as economically as possible. (Autoalan tilastokeskus, A 2020)

The future targets were introduced in chapter 4.1 and it was said that the target for renewable energy in traffic will be 40% by 2030. In order to reach this target, the amount of electric and low emission hybrid cars must increase significantly. The most recent target for electric and hybrid cars is 670 000 electric cars by 2030 (Jääskeläinen 2019). Before that, the target was 250 000, but the number has been increasing faster than expected so the target was updated according to latest statistics of electric cars. The wildest electric car scenarios even suggest that the number could be over a million electric cars in 2030 (Lassila et al. 2019). Currently there are around 2.7 million passenger cars in Finland (Autoalan tilastokeskus, B 2020). The original target would mean that about 9.3% of all passenger cars would be electric or plug-in hybrid cars. The updated target means that 24.8% of all passenger cars would be electric or hybrid. And in the wildest scenarios the number is suggested to reach even higher percentages.

6.2 Different charging stations and terminology

Electric vehicle charging can be divided into three different categories based on the charging power: slow, fast, and rapid charging. Slow charging is up to 6 kW. Chargers that are capable for only slow charging are the socket chargers provided with the car or low power chargers in residential buildings. Fast charging is from 7 to 22 kW. This type of charger is the most common public charger in Europe. Rapid charging is from 43 kW to 100 kW and after that it is usually called ultra-rapid charging. The most common rapid charger is the 50 kW DC charger. Powers over 100 kW are still rare, but they are getting more common while the electric car numbers are increasing and the demand for rapid charging is increasing. (Lilly 2020)

There are also several different charging connectors for electric cars. The European standard is the type 2 connector. Type 2 connector is used in European electric cars and in European public charging stations. The type 2 connector is showed in Figure 8. It uses AC and most of the common public charging stations in Europe use the type 2 charger with 3x32 A of charging current. This equals to 22 kW of charging power. The type 2 connector can also provide 43 kW of power for rapid charging, but 22 kW chargers are the most common for type 2 connectors. (Lilly 2020)

Figure 8. Type 2 connector is the European standard for electric cars and charging stations. (Plugit 2020)

The other European standard is the CCS (Combined Charging System). CCS is the European standard for rapid charging. With CCS it is possible to get a charging power of up to 350 kW. CCS chargers use DC for charging. The connector for CCS charger is showed in Figure 9. (Lilly 2020)

Figure 9. CCS connector for fast chargers. (Plugit 2020)

The car's onboard charger is the limitation for AC charging. Input for the battery must be DC, thus when using AC to charge, the onboard charger of the car must convert the supplied AC power to DC for it to be supplied for the battery. Electric cars usually have an onboard charger rated from 7.2 kW to 11 kW and hybrids usually have onboard charger capability between 3.6 kW and 7.2 kW. For rapid charging, the DC charging is far the most common charging method. Only the Renault Zoe can utilize the 43 kW AC charging. In DC charging the power is supplied directly from the charging station to the car's battery, thus the onboard charger is not limiting the charging power. Still there are limitations for the maximum power, but the possible powers are considerably higher. (Lilly 2020)

6.3 Electric vehicle charging network in 2020

In Figure 10 is a map of the public charging stations in Finland. As the map shows, the charging stations are quite well spread around the country, but naturally most of the charging stations are located around the highly populated areas around Helsinki, Tampere and Turku.

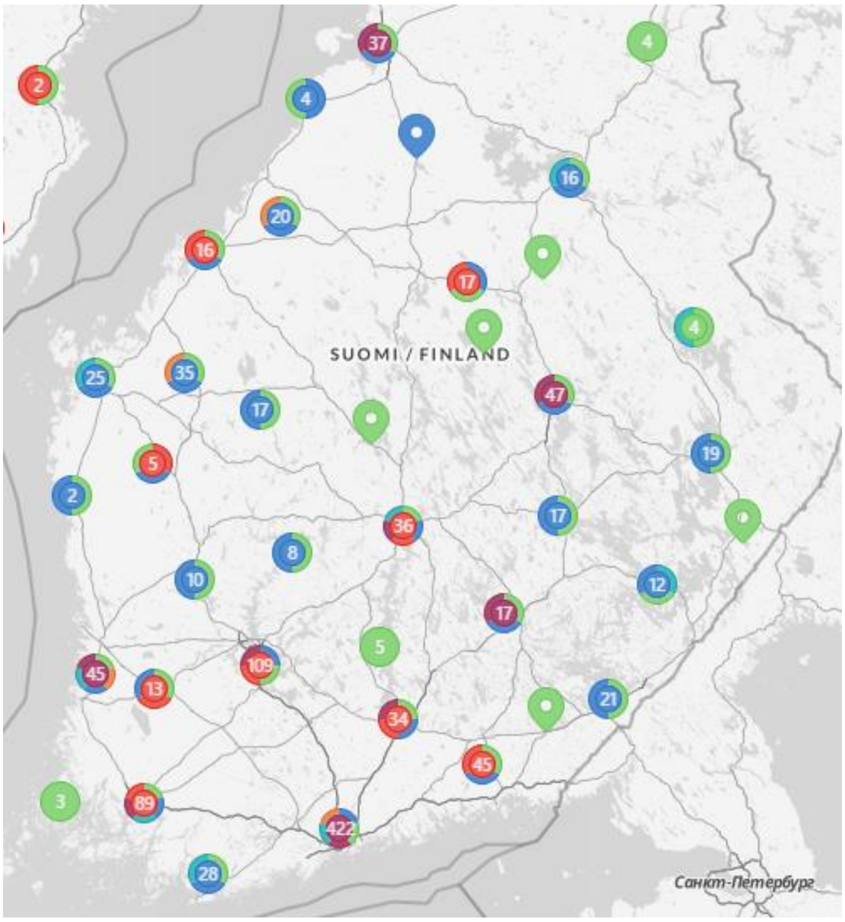

Figure 10. A rough map of the electric car charging network in Finland. (Autoalan tilastokeskus, C 2020)

In the end of 2019, there were almost 1000 public charging locations with 3000 charging spots combined. 220 of those have fast charge capabilities (Autoalan tilastokeskus, C 2020). In halfway of 2020 the number of electric vehicles was a bit under 40 000. Assuming that all electric cars are mainly charged at home, the public charging network serves the existing electric cars quite well since public charging stations are then only used when running errands, eating out or during longer road trips. There is roughly a one charging station for ten electric cars. There might be some local bottlenecks here and there, but the amount of charging stations is sufficient. The recommendation for number of charging stations by the distribution directive is one charger to every ten electric cars

(Jääskeläinen 2020). With the ambitious targets for the number of electric cars set by the government, the need for charging stations in the future will be significant.

6.4 Statutory requirements for the charging network

The European Union has reacted to the increasing need for electric car charging stations. The EPBD 2018 directive sets obligations to install electric vehicle charging stations to apartment building and commercial buildings. Finnish government has estimated that the charging network requirements set by EPBD 2018 directive are not enough to supply a sufficient charging network for all electric cars in Finland during this decade. That is why the Finnish government updated the law to exceed the EPBD 2018 requirements and increased the number of charging stations in different locations. The increase in electric car numbers has been faster than expected and that is why the requirements have been increased as well. (Eduskunta 2020)

The requirements for electric car charging station numbers in different locations are listed in Table 1. The listed requirements are applied in all construction plans after 10.3.2021. These new requirements will have a significant impact on residential buildings. All residential buildings that have over four parking spots must have a possibility to install an electric vehicle charging station. In practice this means that at least there must be installed piping for the parking spots to which the cables can be installed later, when the actual charging station is being installed. (Eduskunta 2020)

For commercial buildings, the new law requires actual charging stations to be installed based on the number of parking spots the building has. After ten parking spots, the building must have at least one charging station and 50% of the spots must have possibility to install the charging station without excavation work. After 30 parking spots the charging station number increases to two and after 100 parking spots the number increases to three. After 30 parking spots, 20% of the spots must have possibility to install the charging station without excavations. (Eduskunta 2020)

Table 1. Required electric car charging stations stated by the law. (Eduskunta 2020)

Type of property	Number of parking spots	Required number of charging stations	Required number of standy installations (share of total parking spots)	Effective date
Commercial buildings				
New and extensively renovated buildings	11-30	At least 1 Type 2 charger or 1 CCS charger	50 %	10 March 2021
	31-50	At least 1 Type 2 charger or 1 CCS charger	20 % or at least 15 spots	10 March 2021
	51-100	At least 2 Type 2 charger or 1 CCS charger	20 % or at least 15 spots	10 March 2021
	>100	At least 3 Type 2 charger or 1 CCS charger	20 %	10 March 2021
Existing buildings without without renovations	>20	At least 1 Type 2 charger or 1 CCS charger	0	Must be installed by 31 December 2024
Residantial buildings and parking buildings related to them				
New and extensively renovated buildings	>4	0	100 %	10 March 2021

6.5 Development of the charging network

The fast development in electric and plug-in hybrid car numbers would require drastic increase in charging stations around the country. Currently the charging station network is reasonably good for the existing number of electric cars, but the need for new charging stations is constant, even outside of the statutory requirements.

There will be 670 000 electric cars and plug-in hybrids in 2030, if the government targets are going to be fulfilled. The recommendation of distribution directive is one public standard charger for 10 electric cars and plug-in hybrids and one fast or rapid charger for 100 full electric cars (Jääskeläinen 2020). If this recommendation is still used in 2030, there will should be 67 000 public charging stations. The share of full electric cars out of the 670 000 cars is not specified, thus the number of rapid chargers is hard to estimate. The number of rapid chargers is not that significant because the recommendation is only one rapid charger for 100 full electric cars. The number of normal charging stations will ensure that there are many public charging stations to be installed before 2030.

Home charging stations are the other significant factor. All the owners of full electric cars must have charging stations at home and most of the plug-in hybrid owners will have one too. In halfway of 2020 there were a bit under 40 000 electric cars and plug-in hybrids in total. In 10 years, this number is anticipated to increase by 15 times. This increase in electric car numbers means a massive increase in home charging stations. The statutory requirements for apartment buildings support this development.

6.6 Planning the new charging system

Charging stations installations must follow the requirements of the SFS 6000 standard. SFS 6000-7-722 gives special requirements for electricity systems that are specifically used for electric vehicle charging. SESKO has given its own suggestions for electric vehicle charging system planning and installations. The suggestions follow the requirements of the SFS 6000 and are also updated according to experience of the previous charging system installations. SESKO is the National Electrotechnical Standardization Organization representing Finland in the electrotechnical engineering field. SESKO is the national committee of the IEC (International Electrotechnical Commission). (SESKO 2021)

The following basics and guideline for the charging station planning and installations will be given based on the suggestions given by SESKO that also follow the requirements of the SFS 6000. Charging station project starts by evaluation of the existing electricity system. The capacity and the condition of the system are evaluated and that is used as a baseline for the charging system possibilities. First part of the report for the customer should be the information of the condition and capacity of the existing system and what kind of charging system it can support. (SESKO 2021)

Evaluation of the existing system should include the following:

- Diameter and condition of the feed cable
- Size of the main fuses
- Condition and nominal current of the main distribution board
- Free available outputs
- Condition and nominal current of the sub distribution boards
- Cable diameters and condition for the vehicle heating systems
- Maximum power of the property.

Next step after the evaluation of the existing electricity system, is planning the charging system that meets the requirements of the customer. Suitable charging stations are selected according to the requirements of the customer or multiple different options are offered for the customer to choose from. Plans for the charging system will be made based on the choice of charging stations. (SESKO 2021)

Following factors must be considered in the planning of the charging system:

- Installation locations for possible new sub distribution boards.
- Sizing should be future proofed so it can withstand probable future installations. Law requires standby installations to be made during major renovations. Sizing of all the cables, distribution boards etc. should be done in a way that the system can support the additional charging stations that may be installed in the future.
- Locations of any existing underground cables, water pipes, telecommunication cables and district heating pipes should be clarified. Then the suitable route for new cables can be planned.

Charging station project for a housing cooperative usually starts with an initial evaluation of the system from which the customer gets a report. Based on that report, the customer decides what kind of charging system will be installed or will it be installed at all. Also, the company that does the installations and the detailed planning will be decided in this point. The initial evaluation should be kept as its own. After the evaluation, customer knows the capacity of the system and different possibilities that are doable with it and the cost evaluations for each option. The report does not include detailed planning of the charging system or detailed dimensioning of the cables and other components. Detailed plan will be made once the customer makes an order for the installation of the charging stations.

6.7 ARA-subsidy

One significant factor in charging station business is the ARA-subsidy that can be granted for charging station installations. ARA is the housing finance and development centre of Finland. ARA grants subsidies for communities that own apartment buildings for renovations that increase the energy-efficiency of the building. There is a special subsidy for installing electric car charging stations to apartment buildings. The subsidy is granted between years 2020 and 2022 for the structural changes to the electrical system of the building that are required for charging stations. (ARA 2020)

The subsidy is 35% of the expenses caused by the renovation or 50% if at least half of the parking spots are equipped with at least 11 kW chargers. Maximum amount for the subsidy is 90 000 €. The de minimis -regulation is applied for this subsidy, meaning that the maximum cumulative sum of the subsidy is 200 000 € within three years. This concerns commercial companies such as rental housing companies. The requirement for the subsidy is that the community must install capacity for at least five charging stations. (ARA 2020)

Accepted expenses for the subsidy are the following:

- Assessment of the current electricity system
- Planning of the project if the project is carried out
- Modifications to the electrical switchboard
- Increasing the size of the electrical connection of the property
- Piping and cabling and the normal excavation work required
- Charging stations only if they are owned by the applier of the subsidy. (ARA 2020)

7 IMPLEMENTATION OF A NEW BUSINESS MODEL IN THEORY

The target of new business models is to introduce a new business concept for the market that is not already used by the competitors (Broekhuizen et al. 2018). In this case, the business model is not something completely new for the market, but it is completely new for Exsane. The target is still to find a new approach or at least a new edge to the existing business models in order to achieve some competitive ground. The business model innovation theory will still follow the theory that is presented in Figure 11.

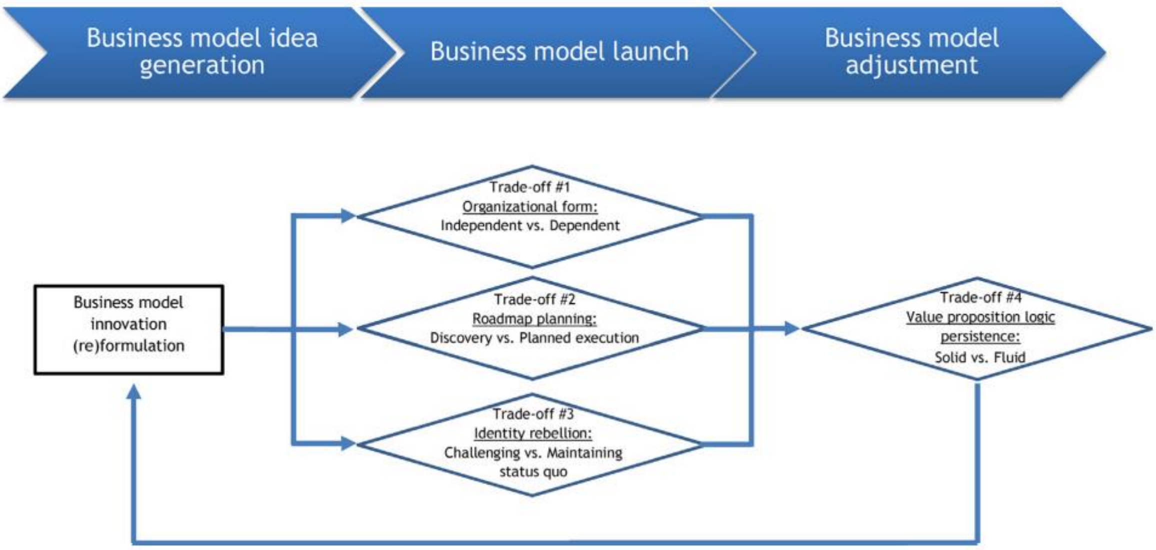

Figure 11. Business model implementation process. (Broekhuizen et al. 2018)

The process of implementing new business models is illustrated in Figure 11. The process starts with an idea of a new business model or motivation to create something new, which then leads to innovation of new business model. The implementation process can be split into three different subjects, organizational form, roadmap planning and identity rebellion. Last part of the process is the value proposition logic persistence. These parts of the process form the general path of the process from business model idea to business model launch and finally the business model adjustment. (Broekhuizen et al. 2018)

Organizational form means how the organization of the company will affect the new business model. It is natural to create and develop business models around the resources and knowledge that the company has. At the same time, it is important to understand that the new business model will need freedom to experiment in order to find the processes and resources to support that specific business model. Many business model innovations will fail if they are restricted to the processes, strategy, and culture of the existing organisation. (Broekhuizen et al. 2018)

Business models and processes that comes with it are designed to be functional for that specific business. The very nature of a business model is that it is designed to not change over time. This means that old business models are not usable for new innovations because they work for what they were designed to work. New business model needs time and experiment to develop independently. (Christensen et al. 2016)

Roadmap planning means forming a path on which the development of the business model is supposed to go. Although the roadmap cannot be too detailed. It must be flexible and open to changes along the way. New business model planning is extremely challenging and business model will face changes during actual projects and customer contacts. The roadmap must be open to changes or the business model will most likely fail. (Broekhuizen et al. 2018)

Identity rebellion means challenging the customers idea of what is valuable service for them. Customers must be aware of the newly shaped service that is provided for them, but that is not enough. Customer must understand the value of the newly shaped business model and how it differs from the competition. When customer understands the difference and added value to the competitors offers, then the business model can be successful. (Broekhuizen et al. 2018)

Last part of the process is the value proposition logic persistence. In this case the value of the planned business model is efficiency and comprehensive service. In the end it is important to stick to the original logic of the new business model. Business model must be altered if needed and the process can go back to the formulation phase. But in order to achieve the goal of the business model, the original logic for the value of the business model must not be forgotten. (Broekhuizen et al. 2018)

8 SURVEY FOR DISTRIBUTION GRID OWNERS

Survey is an efficient method to gather data in statistical form from a large number of people in a short time. The success of the survey is related to few key factors. The chosen questions are very important for the results of the survey. The next important part is the sample of the population for which the survey is sent. Questions must be in a form that they do not lead the respondents to answer in certain fashion. Then the population of the survey must be planned in a way that it represents the desired sampling of the survey. The population of the survey cannot be planned in a way that would make desired results more likely. (McNeill 2006)

One research method in this thesis was a survey and interviews for several grid owners. The questions were about different technologies studied in this thesis and about the investments towards the distribution grid. The questions were sent to 36 largest distribution grid companies in Finland because they represent the normal clientele of Exsane the best. Smaller grid owners were ruled out because the results could have been distorted by them too much. The smallest grid owners are not typical clients for Exsane thus it is not desirable that their result would affect the results of the survey significantly.

The first question was about investments in the distribution grid. The results can be seen in Figure 12 and the question right above it. All 27 participants that answered the survey answered this question and they were able to choose multiple choices. As Figure 12 shows, majority of grid owners are investing mainly in underground cables and in smart grid applications. The investments to underground cables have been going on since 2013. Investments were triggered by the electricity market act renewal and the target year for the new renewed distribution grid has been 2028. Although currently the government is preparing a new electricity market act and grid owners are preparing that the target year will be moved to the year 2036, which may still cause changes to underground cable investment strategies during the following 10 years.

In what area are the investments focused during following 5–10 years?

a) Underground cables
b) Weatherproof overhead lines
c) Smart grid applications
d) Other

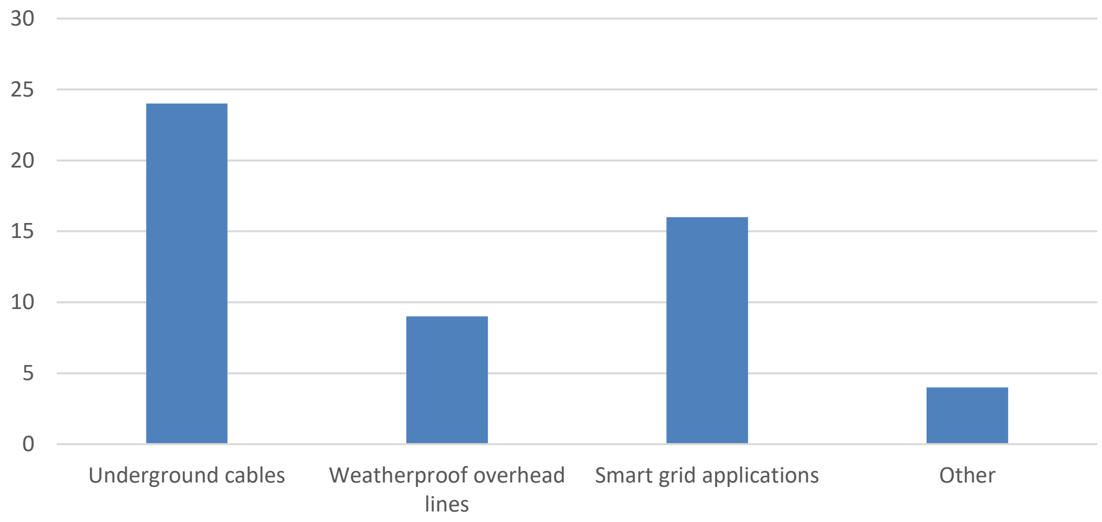

Figure 12. Investments between 2020 and 2030.

The answers for the survey and the interviews confirmed what was already suspected in chapter 3.2. The investments will still mainly focus on the weatherproofing of the electricity grid but increasing part of the investments are starting to go towards smart grid applications and development of the new distribution grid. Although the new electricity market act will alter these strategies in some companies if the new law moves the transition period of the new security of supply requirements to the year 2036.

Next part of the survey was about the inspection and maintenance of the new underground cable distribution grid. The target of this section in the survey was to seek information about the plans that the grid owners have for maintenance. In theory, the inspection and maintenance processes must change to answer the demands of the new underground grid. Although what is economically viable and profitable is another question. Questions were biased towards partial discharge measurements because they are the main part of the inspection and maintenance section of this thesis.

Majority of the grid owners that answered the survey have or are planning to have partial discharge measurements at least in some role in the quality control or inspection process. For this thesis, the most important fact to find out was, what the partial discharge measurements are planned to be used for. The results for this question are shown in Figure 13 and the question is right above it. All 27 participants answered the question, and they were able to choose multiple choices.

For what purposes are the partial discharge measurements planned to be used?

a) Substations
b) Offline commissioning measurements
c) Offline measurements for cables
d) Online measurements for compact substations
e) Other

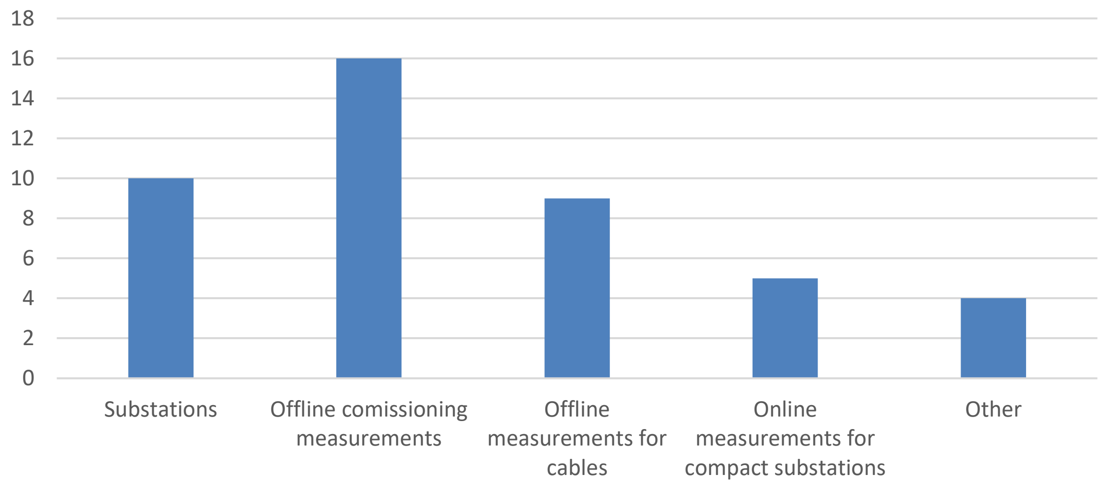

Figure 13. Different applications for which the grid owners are planning to use partial discharge measurements.

Offline measurements for new cables are the dominating purpose that the grid owners are planning. Some grid owners already do offline measurements for new middle voltage cables, but it is still a rare measurement method. Substations are the second largest purpose for partial discharge measurements. Second to last is offline measurements for cables already in use and the last is online measurements for compact substations. In this thesis, the focus of online measurements for compact substations will be higher than what the results of the survey would justify. The reason for this is that the resources of this company are more suited for these lighter and cheaper measurement methods. And there is clear potential in these measurements, although they still require more research and field testing for several reasons.

Last section of the survey was about the smart grid applications that the grid owners are planning to implement during this decade. Clear direction for smart grid applications is the automation of the distribution grid and advanced data collection from the distribution grid. The new AMR-meters are also in development in all the distribution grid companies. Some companies are already starting the mass roll out of the next generation of meters. Majority of companies are currently planning the rollout and the features that the new AMR-meter will get. The government regulations set most of the functions, but grid owners can still have additional functions if needed.

9 NEW BUSINESS OPPORTUNITIES

In this section of the thesis, the different business opportunities will be evaluated. Energy production is facing significant developments during the following decades, which requires more advanced operation from the electricity distribution grid. The amount of renewable power will be significantly increased. The more unpredictable energy production methods require more advanced demand control and energy storages. Also, when the power distribution grid connects the power loads to the energy production in an intelligent way, the efficiency of the whole energy system is increased, and the emissions will be decreased. In energy systems perspective, the smart grid applications are the most important updates that the electricity distribution will face. The effects that the smart grid applications cause to Exsane's current business and what new opportunities they open will be evaluated in this chapter.

There are also other perspectives to be considered in this matter. The development of the structure of the electricity distribution grid changes the type of inspections and maintenance that the grid requires. More proactive approach to maintenance would be beneficial for the underground grid. Inspection and maintenance have heavily been based on the lifetime expectancy of the components and the visual inspection. There are several reasons why maintenance should be more proactive and more based on measurements and data-analysis. The main reason is the stricter security of supply requirement. It encourages the maintenance to be more proactive in order to prevent unexpected failures which can cause long interruptions, which would cause expenses for grid owners.

There was some debate over the maintenance issue in the survey and interviews. Although there definitely was enough interest behind the proactive maintenance approach to evaluate the business opportunities behind it. The arguments against the new maintenance approaches encourage to evaluate the risks very carefully. In our company the main approach for the proactive, measurement-based inspection and maintenance would be the partial discharge measurements. In this chapter, the possible business models around the partial discharge measurements will be evaluated.

Last of the new business areas in this thesis is electric vehicle charging. The emission reduction targets of the government require a significant number of electric cars by the end of this decade. On 10 March 2021, the new law will be applied for number of electric vehicles charging stations in different commercial and residential buildings. These statutory requirements next to the natural demand for electric vehicle charging, creates a business opportunity that must be investigated. The electric vehicle charging business is the main business opportunity in this thesis. The business model that is suggested in this thesis, will be implemented into the business of Exsane after this thesis is completed.

9.1 Partial discharge measurements

It has been under discussion for a couple of years in Exsane, whether the partial discharge measurements should be further investigated. In this thesis, the target was to gather information about the interest that the grid owners have towards the partial discharge measurements. Based on the results obtained from the survey and interviews, the business opportunities around partial discharge measurements will be planned.

The survey and interviews showed that there is interest around offline measurements and online measurements. Online method will be the primary target in this thesis for various reasons. The investment in online measurement device is considerably lower than for offline device. Also, Exsane already does compact substation condition inspection. It would be easy to integrate the online partial discharge measurement process into normal condition inspections.

The reason behind partial discharge measurements is the evolving electricity distribution grid. Constantly growing share of the grid is underground cables and compact substations; thus, the components are hidden from visual inspection. The concept for the improved maintenance was briefly introduced in chapter 5.2. High percentage of the underground cables are relatively new, and it can be expected that the number of faults in following years will be quite low. Now would be the perfect time to test and study new promising measurement methods. The nature of the online measurements is that the single measurement result is not accurate enough to make conclusions about maintenance needs.

Online measurements should be used to collect data from the components preferably from new. The measurement data collection can be used to analyse the results of same components that are the same age. The development of the partial discharge levels can be used to estimate which components are most likely to fail in following years. These components can be moved to a different category which are then measured more often, or more accurate inspection can be made during maintenance interruptions. When planning maintenance investments, the category which is most likely to fail can be prioritized and fault caused interruptions can be avoided. Interviews revealed that some distribution grid owners have already faced problems with certain components in the underground cable grid. These kinds of serial defects in specific components could be avoided with partial discharge measurements.

The measurement process is illustrated in Figure 14. Measurements are started and substations and cables that are in the measurement schedule are put into group A, which is the low-risk group. Group B is the increased risk group. Measurements are repeated every five years for group A and for group B the measurements are repeated every three years. The time interval can be something else as well, these are just for the concept. Group C is the high-risk group. If some component shows significantly higher partial discharge levels in group B, it is then moved to group C for further actions. At this point a maintenance interruption could be scheduled and the components could be thoroughly inspected and replaced or repaired if needed. The components are moved between risk groups like shown in the beginning of the timeline. If a component shows significantly increased partial discharge levels, it is moved to group B. If a component shows significantly increased levels in group B, it is moved to group C for inspection. In group C, the components are physically inspected and repaired or replaced and after that the component is moved back to group B for control measurements. If the partial discharge levels are normal in control measurement, the component is moved back to group A. Components can also be moved back to group A, if the partial discharge levels return to normal. There can be temporarily increased levels due to weather changes or abnormally high load on the components on the particular moment of the measurement.

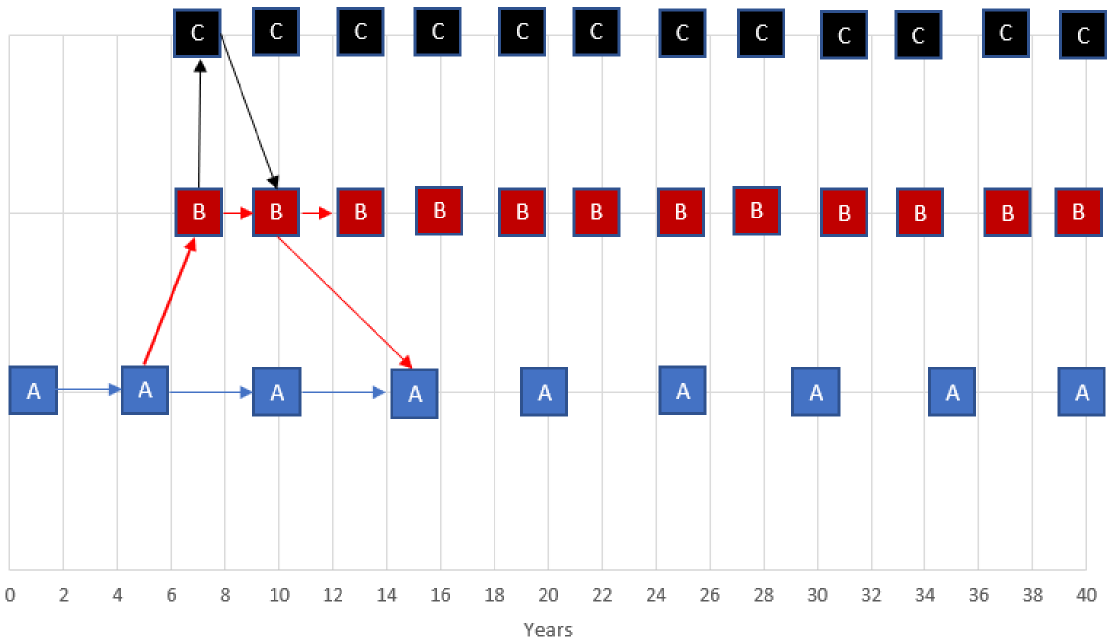

Figure 14. Timeline for the maintenance measurements.

Target is to integrate the partial discharge measurements into the normal condition inspections, so the business model will not change. Current inspection and maintenance process will just get a new addition to it. The primary idea for partial discharge measurements is to invest in a hybrid measurement device that can be used to measure partial discharges by various signals. The partial discharge measurements were introduced earlier in the thesis and the conclusion was that the acoustic, TEV- and HFCT-measurements would be usable for online measurements. There are devices that can use all these signals to detect partial discharges in various places. HFCT can be used for cables, acoustic measurement can be used for visible components, and TEV can be used for components that are not visible in compact substations.

Partial discharge measurements can also be turned into a separate business. The whole subject is still relatively new, at least for smaller scale medium voltage applications. It is still unknown how the measurements are the most sensible or the most profitable to be executed. If they are integrated into the normal inspection process, the changes into the process are simple. The time needed for inspection of one compact substation is adjusted to the new inspection method and price of the inspection is adjusted to the time needed.

This would most likely be the most sensible way for the measurements. It is also possible that experience will change the whole process overall. The proper time interval needed for visual inspections and partial discharge measurements could be so different that it is not sensible to do them with the same time interval all the time. That is why there should be also an option for separate partial discharge measurements and for separate inspection.

When planning the separate partial discharge measurement service, it is important to consider the offline measurement possibility as well. The whole subject is new, thus there is still room for new companies in the field and it could be a good plan to start offering comprehensive partial discharge measurement services early on. There is just one major disadvantage for offline measurements. The prices for offline measurement devices are extreamly high. A capable device would require an investment of about 80 000 €. The survey and interviews showed some interest towards partial discharge measurements and offline measurements were at the top of the list. Still the future market for these measurements is quite uncertain, therefore an investment of 80 000 € for just one measurement device is a substantial risk at this point. There is also a clear possibility with the risk. Some grid owners already demand these measurements for new medium voltage underground cables and some grid owners might start to demand them in the future. There is already clear market for offline measurements, but not too much supply. There is a possibility to make the investment profitable, but with an uncertain future market, it is a major risk.

At this point, the most reasonable approach is to invest in an online measurement device. The functions needed, are the acoustic, HFCT- and TEV-measurement capabilities. This kind of device would require an investment of about 10 000 €. Suitable device would be for example the Megger UHF PDD which is presented in Figure 15. It is a portable and easy to use device for online measurements. It allows multiple signals to be used to detect partial discharges during normal operation of the components. Interviews showed interest towards these measurements and it is quite certain that there would be enough demand to at least cover the investment and get a feel of the field and whether it is worth investing more. If the demand increases, the one device is not going to be enough and further investments are needed.

Figure 15. Megger UHF PDD partial discharge measurement device. (Megger 2021)

The target of this thesis is not to go too deep into the future of this business, but to estimate whether it would be sensible and profitable to invest in it at all. Interviews showed some interest towards the technology, but also some level of scepticism since the technology is quite untested for this application. Still my estimate is that there is enough demand to cover the investment and it is a worthy investment to make. Exsane could be a significant part of starting the partial discharge measurement era in electricity distribution grid inspection. It is an unknown field, and it requires testing and studying, but it could potentially offer stable foothold in the future of the business. Next step would be to contact the grid owners that showed interest in the interviews and invest in a measurement device, like the Megger UHF PDD. Then start a pilot project with some grid owner and do the measurements in real life in order to find the correlation of the results and the actual condition of the components. After some experience of the subject, it is time to estimate the need for further investments. At that point, the offline measurement options should be considered and decided whether it would be a viable option.

9.2 Smart grid Applications

The survey and interviews showed that during this decade, the electricity distribution grid owners are making large upgrades to make the distribution grid more intelligent. Most common upgrades are the more advanced grid automation and sensors in the grid. Every grid owner that took part on the survey are also going to upgrade the AMR-meters to the next generation during this decade.

Grid automation means remote-controlled medium voltage switches and software that controls them automatically. There are already a lot of remote-controlled switches, but they are usually manually controlled by the operator. The major upgrade will be to the software that controls them. This means that a major part of the work will be done by the grid owner and there is not much to do for the contractor. There will be new remote-controlled circuit breakers, which will be installed by the contractor. These installations are usually made during normal distribution grid renewal projects or within the framework contracts. There is not too much there in terms of new business opportunities. It is important to make sure that there are always employees that are capable of doing high-quality installations for the overhead line switches since it is not the simplest installation.

Grid automation is mainly used in different fault scenarios to automatically separate the faulty section of the grid. The target is to restore the electricity supply as quickly as possible in the intact grid sections. Currently these operations are done by the operator of the grid who uses the remote-controlled switches or by the electrician who uses the manual switches by hand. The implementation of automation for these situations changes the handling of major faults. Automation system can separate the faulty sections of the grid automatically during the storm and the DMS system can send notifications to electricians that these sections are faulty and need to be repaired. FLIR will be very common in the future of fault handling and it is important to understand even on contractor level even though it does not offer any major business opportunities. FLIR might just change the current process for major fault situations. It is important to maintain the high quality of that service for the grid owners, thus it is important to adapt while the process changes. It is still unknown how FLIR will affect the contractor's part in fault repairs, but it is good to prepare that there might be some adjustments needed in the future.

The other upgrade that the distribution grid is going to face, is the more advanced measuring. This means that there will be different kinds of sensors and measuring devices in the substations and compact substations. This does not offer any major business opportunities for contractors, but it is another factor that must be considered in the future. There might be intelligent measuring components in compact substation in the future and it is possible that electricians must have access to then via computers in order to make adjustments or updates of some sort. It is important to maintain some level of IT skills for the electricians as well. Grid owners appreciate modern contractors with comprehensive service, and this is one factor that affects the quality of the service.

Battery systems in the distribution grid are one factor to be considered as well. There will undoubtedly be more battery systems like the one from Elenia and Fortum mentioned in the chapter 5.5. The existence of these systems is important to consider, although I do not think they offer any significant business opportunities for Exsane. It is important to study the subject and evaluate the requirements and possibilities of this area at the time when these projects are starting to be more common. Currently these are not something that are made often and there is little Exsane can do to affect that situation. It is not profitable to start to prepare and obtain suitable resources for this, while it is still unknown when there will by any significant demand for these systems. Other possibility in battery systems is the private owned batteries that are mostly used with solar power systems. This will be left out of the consideration at this point. Simply because it mostly revolves around private market. Private market is not something that fits into the Exsane's strategy right now. Other reason is that the battery systems are commonly used with solar power systems. Solar power system market for private customers seems to be quite saturated because there have been steady demand and supply for them in years already. For these reasons, the energy storages are left out of the consideration for new business model for now. If the situation changes, they will be reconsidered.

The most important business opportunity in smart grid technologies is the new generation of AMR-meters. The technology of the new AMR-meters is not really the important part for Exsane. Important part is the number of new meters that are going to be installed during the following decade. Changing the AMR-meter is an extremely simple job, but it is a good business opportunity because there is an AMR-meter in every house. Large grid owners have too much of them and Exsane's resources probably are not suitable to handle that kind of volume. There are many smaller grid owners as well, that still have thousands and tens of thousands of AMR-meters. Getting a project like that would be good for Exsane. Changing AMR-meters is highly predictable work. It is easy to calculate the needed time and there is little variation to that. Project like that would have low risk and it would be stable income over the length of the project. These projects are something that Exsane should really concentrate on getting. There are many of these starting during the following five years and more after that. These could be done with normal distribution grid electricians without any special training. The project requires very little planning or managing compared to normal distribution grid construction project. Exsane has the possibility to start a project like that right away.

9.3 Electric vehicle Charging

The main new business area in this thesis is the electric vehicle charging. Exsane has experience and vast knowledge about electricity distribution network planning, construction, and maintenance. All these skills are directly applicable for electric vehicle charging station business. The initial idea is to design a business model around planning, construction, and maintenance of the electric vehicle charging stations. Also, other options will be included for example own charging stations. Focus is on the business model that provides comprehensive service around the installation and maintenance of charging stations.

The idea for constructing electric vehicle charging stations originated from the idea to apply the skills of this company to wider variety of different business areas. Electric vehicle charging stations are an excellent possibility for this. The focus is on the commercial charging stations and on the ones for apartment buildings. These charging stations require more power because of the higher power of one charger or a high number of low power chargers. They are also usually located around parking lots; thus, underground cables are required. The higher power demand requires changes to the electrical connection of the property or usually at least the main fuses must be changed to bigger ones. These are the main reasons why the best business opportunity for Exsane is most likely around commercial and apartment building charging stations.

Private customers have also been under debate whether to include them in the business model or not. For private customers, the electric car charging usually has a maximum power of 11 kW. The charging station is usually installed on the wall of the house or sometimes on a pole next to the parking spot of the car. For private customers, the market is around private houses and summer cottages. In apartment buildings, the housing company is in charge for most of the work around charging stations, therefore the private market is quite limited to private houses and summer cottages.

For private customers, the installation and planning are simple because there is usually only one charging station. Capacity of the building’s electricity system can almost definitely handle a charging station with 11 kW or at least 7.4 kW of power. Installation only requires the cables to be routed to the charging station from the power center of the building and the actual installation of the charging station. Planning is as simple as to dimension the cable and circuit protection accordingly. The electricity supply for the house can remain unchanged. Rule of thumb is that, if the house has an electric sauna stove, it can handle an electric car charging station with some relay control to prevent the simultaneous connection of sauna stove, charging station and electric heating.

Because of the simple planning process and installation, the market for charging station installations for private customers is already quite saturated. Basically, every electrician can install them without any special resources. For that reason, the competition level is extremely high. The possible profit from one installation is small and in private market, there is always a risk for unpaid invoices. For these reasons, the decision is to leave out the private market from the business model and this thesis.

9.3.1 Competition

Now that the first vision for the business model has been formed, the competition situation should be evaluated more accurately. There has been market for electric vehicle charging station for some years already, therefore there is some competition on the market. The number of charging stations is increasing fast because of the statutory requirements and the increase of overall demand. There should be room for new companies as well.

In Table 2 are some of the companies that are providing electric vehicle charging station services. Many companies on the charging business offer comprehensive service consisting initial planning, project planning, installation, and maintenance. Some companies have their own electricians and workers, and some use their own staff only for initial planning, but the actual project is executed in co-operation with a contractor.

Table 2. Overview of the various supplier for charging stations.

Company	**Business model type**	**Charging station supplier**	**Region**	**Target group**
Caverion	Turnkey	Virta	Whole Finland	Companies
Plugit	Turnkey	Various suppliers	South/West	Private, companies
Kymenlaakson Sähkö	Turnkey	Satmatic	Kymenlaakso	Private, companies
Parkkisähkö	Turnkey	Fibox, Alfen	Capital area	Companies
Helen	Turnkey	Virta	Capital area	Private, companies
Defa	Turnkey	Own devices	Capital area	Private, companies
SLA	Turnkey	Unknown	Oulu	Private, companies

Several different business models can be recognized from the market. Caverion and Helen offers services in partnership with Virta. Virta supplies charging stations and software behind the charging station operations. Smart charging, payment, remote control, access, and other smart features are possible with software that Virta supplies with its charging stations. In this business model, the company does the initial planning, executes the project, and handles the maintenance. Virta handles the technical support for customers, software preinstallations, software updates and maintenance notifications for the company that provides the service for the customer. This is an easy business model in the contractor's perspective because the software upkeep is handled by the partner as well as the payment transactions of the charging. Contractors' role is to do the planning, installations and maintenance if needed. Companies that are using this business model are the direct competition for Exsane in this field.

Then there are completely different business models compared to the previously introduced one. Plugit and Parkkisähkö have a similar business model. They both have their own software that handles payment transactions, smart charging, remote control access and other smart features. Their business around charging stations is much more comprehensive and it is the main business for both. For Helen, Caverion, and Kymenlaakson Sähkö, the charging station business is just a small fraction of their business. For SLA, the charging station business is the main business. Their business model is a turnkey service for charging station installations and maintenance. Partners supply the charging station, and the software and SLA handles the planning, installation, and maintenance.

Defa is primarily a supplier of charging stations with their own software services as well. They also offer planning for charging stations and installations through partners. Their business mainly consists of hardware sales and software services for charging stations. Planning and installation is just an extra service for customers.

There are lots of different companies in the charging station business already with several different business models. Some of them are direct competitors for Exsane with similar business models to what Exsane is planning. Some of them are major companies with comprehensive service around all areas of electric vehicle charging. Exsane cannot realistically compete with these companies in their field, but Exsane could seek partnership with them as a contractor. The business model for Exsane must be carefully planned so it fits between the competition with an own approach for charging station business. Or Exsane must use the major companies in the charging station business as partners and seek projects as a contractor for these major companies in this field. Both options can also be combined, and the business model could be built around multiple solutions in order to find sustainable cash flow around charging business.

9.3.2 The primary business model

The primary business model will be planned according to available resources, investment possibilities and competition situation. The initial idea was to seek partnership as a contractor with large companies in electric vehicle charging business. After that the idea expanded to having an own service for customers in charging station installations and seeking partnership for charging station hardware and software supplies. There are already multiple different services on the market for charging stations, therefore there will be competition no matter what the business model is. At this point the target is to plan a business model that fits between the competition.

Two options were the strongest, thus the combination of these two will be chosen to be introduced as primary business model. First is the partnership as contractor for large companies in charging stations business and the other is having an own turnkey service for charging station systems. The existing resources support both options and neither of them require any major investments in the beginning, therefore the risk is relatively low. Exsane has multiple electrical engineers working in distribution network planning, multiple electricians working in distribution network installations, and large contact network for civil engineering companies.

The planning of own charging station installation service started with finding a suitable partner. The first choice for a partner was Virta for several reasons. Virta supplies the hardware and software for the charging stations and handles the technical support, software updates, payment transactions and so on. In that matter, Virta is the perfect partner for this business model because Exsane lacks the resources for the software side of charging business. The draft for the business model was planned in co-operation with Virta. Few meetings were held with the sales manager of Virta and we discussed of what Exsane plans to achieve in charging business and what kind of resources we can invest in this. The resources and abilities of Exsane were combined with what Virta has to offer and a business model draft was created. The draft is illustrated in Figure 16.

In the business model, Exsane owns the process and handles the marketing and sales process. Customer orders the full electric vehicle charging station planning and installation service from Exsane. Exsane handles the survey of the customers electricity system. The condition and capacity of the system is examined. Different upgrades are suggested for the customer and customer chooses the one that will be carried out. Exsane handles the project planning, management and all the improvements to electricity system and all the charging station installations and excavation work. Virta supplies the charging stations with the operating system preinstalled. Virta also handles all the updates and other software management operations and service notifications for Exsane.

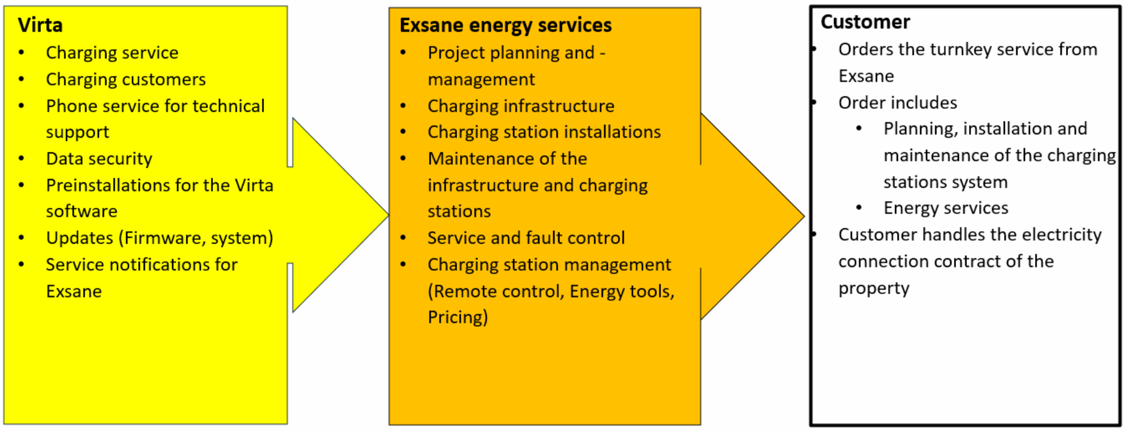

Figure 16. Business model draft of Exsane’s charging station business in partnership with Virta.

In Figure 17 is the alternative version of the business model, which contains some modifications to the first one, but the general idea is the same. In this version, Exsane is in contractor role for another company that provides charging station services. There are companies that provide nationwide services, but do not necessarily have own personnel around the country. This could be a good opportunity for Exsane to provide contractor services. Basically, the service is the same, but just the customer changes. In the first model, Exsane’s customer is the party that have demand for charging stations. In the second version, Exsane provides services for the final customer through another company that handles the orders, pricing, energy services, charging station hardware and software supply and other matters related to charging services. Exsane only provides planning, installation, and maintenance services. This business model can also be altered so that Exsane for example only provides installation and maintenance and the partner company handles the planning.

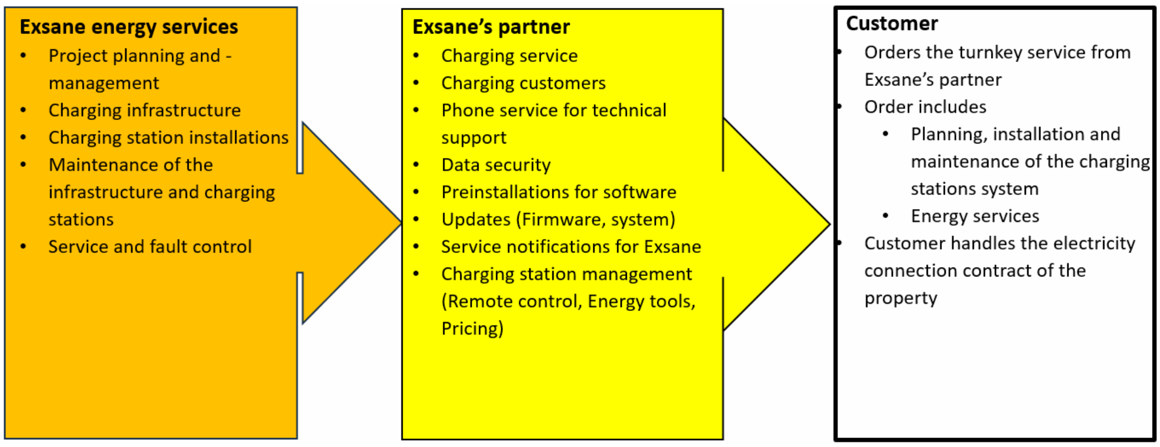

Figure 17. Business model draft of Exsane's contractor role in charging business.

After the business model drafts, the organisation requirements were planned. Charging station business requires the following organization structure around the business:

- Business manager (owner of the process)
- Sales manager
- Partners (charging station and software suppliers)
- Project team
    - Project manager
    - Planners
    - Electricians
    - Subcontractors for excavation work.

The organization structure varies according to the size of the business. The business manager can also be the project manager if there are only few projects at the same time. Separate planners might not be needed as well if there are only few simple projects. Although as the business grows and there are several projects at the same time and the size of the individual project grows as well, there will be need for separate project manager and planners for the projects.

Next step is the evaluation of the investments that are required at the beginning of the new business area. In this case the resource requirements of the electric vehicle charging business matches the requirements of Exsane's current business so well that the required investments are minimal. Only hardware investment that is required is a measurement device for mandatory safety measurements. There are adapters available that enable the charging station to be connected to the installation tester. With an adapter like this, the mandatory installation measurements can be measured with normal installation testers as long as they are compatible with each other. With this setup the investment cost would only be roughly 500 euros. Then there are more advanced measurement devices for charging stations that can simulate the charging process. If this is needed, the investment would rise to about 2500 euros in total. This is the starting point, but as the business grows, the requirements grow as well. In the future there might be need for larger investments such as new vehicles for electricians and need to hire or train more electricians.

Other investments are towards workforce around charging station business. It cannot be expected that the business is profitable or even breaks even in the beginning. Exsane is in a position that hiring new employees just for charging station business is not required. The start of the business will be handled by current employees that have suitable experience towards it. There are already multiple electrical engineers in the company that are fully qualified to plan the charging stations. Also, there are multiple electricians that are qualified to install them. The only direct investment will be the installation tester that is required for the charging station. Other than that, there will be labour costs while the current employees learn to be efficient in the charging station planning and installation process.

Then the risks of the new business must be evaluated and considered. In this case the hardware investments are low and current employees can handle the projects, at least in the beginning. The risks around investments are low. Main risks are around the projects in this new business area. New types of projects always include high risk because the area of business is somewhat unknown. In this thesis, the most important part of the risk analysis is the evaluation of the risks that are included in the new business area implementation. It is easy to say that the risks of starting this new business area are low easily acceptable.

Electric car charging station planning, and installation business revolves around separate projects. Project work always includes its own risks that must be considered. First part of the new business would be seeking a pilot project. The target of the pilot project is to learn the different real-life aspects of the new business area and gather knowledge about the subject. The pilot project is a crucial part in the implementation of the new business area. Pilot project is an advertisement for new customers. The pilot project is what can make or break the new business area. It is extremely important to choose the first project wisely. If the new project is too big and too complicated and the plans are too optimistic, the project can fail massively. There is no existing experience about the topic and crucial factors might be ignored in the planning phase. The first project should be something relatively simple and transparent and the risk analysis of the project must be done extremely carefully. (Bissonette 2016)

In this thesis, the important part was to consider the risks of starting the new business. As said, the risks of starting the business are low and the main risks are around the projects. Exsane has always done project work and managing the risks around them is generally a familiar subject so it is not necessary to go deeper into that in this thesis. It is just important to understand that the first project is the crucial part of the new business area and when the first project comes, the risks must be evaluated carefully.

9.3.3 The secondary business model

For secondary business model around electric vehicle charging, the possibility to invest in Exsane’s own public charging stations was considered. The idea would be to invest in own charging stations and charge customers who use them. This would be something completely different than what Exsane is used to. Also, the risks are significantly higher due to the higher investment costs. This type of business model would require investing in charging station hardware and for decent turnover, the number of charging stations should be more than just few. It was quickly decided that this type of business model is not suitable for this situation. It is still not completely abandoned, and this business model might be something that will be reconsidered in a few years.

This type of business model would require a relatively large investment in the beginning, but it would bring stable income for the company once the charging stations are installed. There would be many factors to be investigated in this field and it is not in line with the target of this thesis. Here is a compact list of the advantages and disadvantages of this business model.

Advantages of the model:

- Steady income
- Low workforce required once installed
- Advertisement for Exsane’s charging service
- Dividing the business of the company in different area for stability.

Disadvantages of the model:

- Large investment in the beginning
- Unknown business area
- Competition from large charging station suppliers
- Reliance on the charging station hardware and software suppliers.

9.4 Improving the current business areas

One important subject of this thesis is the development of current business areas. There has been an extreme competition situation going on in the electricity distribution construction field for years now. This has sunk the prices to minimum and contractors are struggling to make ends meet. Because of this high level of competition, it is important to update the current processes to match the situation of the business sector. This topic was also mentioned in the interviews of the grid owners. It has been under discussion in their companies that they also need contractors to modernize their businesses and redesign the business models.

First thing is to define the processes of the company clearly. Exsane has ISO 9001 and ISO 14001 certificates for standardized quality and environment management system. ISO 9001 standard requires the processes to be defined and described and everyone must know the company’s operation models. These processes are defined for the current operation models, but these models must be updated and redefined. First step is to redefine the process descriptions. The issues of the current processes must be detected and fixed. There are own descriptions for processes of different business areas of the company. Internal auditing must be organized separately for different business areas so the issues can be detected. Auditing starts with the management of the business area, but it is also extreamly important to include the planners, electricians, and other members of the business area into the auditing process. The process must be clear for everyone. Project management will be significantly easier, and projects will be significantly more efficient when everyone knows the proper process how the project should go forward. This way the whole project team knows what to do and what to expect in certain phases of the project. Project manager can focus more on the big picture of the project and maintain the control of the project without too much daily guidance of the project team.

Other important factor that must be included into the process descriptions is the telecommunications network construction. Construction of fibre optic networks is now usually integrated into the electricity distribution grid constructions. This is the efficient way because both cables can be installed during same excavation work. Many grid owners said in the interviews that this has caused some issues with contractors. The reason is that the management of the construction for these individual technologies falls into different people or at least the expertise of the subject does. For the project to be efficient, the construction of fibre optic network and electricity distribution network must be well integrated. It is extremely important to carefully describe the construction process in integrated projects. This way the needs of both technologies can reliably be taken into consideration in different parts of the project. Other important thing is that the project manager should have knowledge of both technologies in the project. It is risky if the success of the project relies on two people who manage the different parts of the project, but still the whole project must move forward in complete harmony. The project managers in Exsane have already gotten some level of training for fibre optic networks. It must be made sure that all the project managers, who work in projects like these, get the training. There still should be someone with more comprehensive knowledge of the fibre optics network as well, but the project manager should be able to make necessary decisions to ensure the success of the project for both technologies.

After the existing processes are optimized and company is operating in its full potential, it is time to increase that potential. Profitable business around electricity distribution grid construction must be regenerated somehow. Now is the time to consider new approaches to the business. Currently, the underground cable construction rates are high, therefore there is plenty of workforce in this sector which also ensures the needed workforce for storms and other situations that causes major faults in the grid. This is most likely going to change during this decade. The underground cable construction rates are going to decrease, and the needed workforce is going to decrease with it. Still there will be plenty of bare overhead lines and faults that must be repaired at even shorter times due to the electricity market act. There will be demand for resources in fault repairs, but there necessarily will not be enough work in normal grid construction to employ them. Now is the time to think of the ways that the fault repair resources can be ensured and employ them at the meantime as well. One solution to this is to expand the area of expertise for the whole company.

A business model for electric car charging station business was planned in the previous chapter. That business area requires project managers, planners, and electricians. There is lots of demand for electricians in fault repairs during storms and crown snowload situations for example. The more modern approach to this demand and supply balance problem could be to obtain work outside of the distribution grid constructions for electricians. At the same time maintain the expertise they have in distribution grid construction and use those electricians in fault repairs when needed. This way the resources are not tied to the demand levels of distribution grid construction. This might be the future of distribution grid construction companies. Expand the business over several business areas that are not tied to each other and create workforce that have wide area of expertise. This way Exsane could create extreamly comprehensive service models in certain areas in Finland. The same resources could handle the framework agreement work for the distribution grid owners and the fault repairs during storms and meanwhile work outside of distribution grid business to ensure the full employment for all the workers. It should be considered how the charging station business can support the whole company. Finding a way to employ electricians, who have skills to repair storm damages in distribution grid, might yield significant competitive edge on this highly competitive sector in the future.

10 CONCLUSIONS

The target of the thesis was to carry out a literature review of the technologies and topics that were highlighted in the customer survey and interviews. The studied topics were analysed to find answers to the initial problem, which were the profitability issues and difficulties of growing in line with the strategy. The research questions in this thesis were: how the development of the distribution grid affects the business of Exsane, and what possibilities the energy system’s transition to renewable energy sources offer to Exsane. In this chapter, the concluded answer for the research question will be presented. The answer includes improvements to Exsane’s existing business operations and a completely new business area that could be implemented into Exsane’s business.

Electric vehicle charging stations were chosen to be the completely new business area that would be studied in this thesis. It was chosen because the resources of Exsane match the requirements of charging station planning and installations. The other reason was that there will be considerable demand for charging station installations during this decade. The Finnish government updated the law based on the EPBD 2018 directive. The new law requires charging stations to be installed in certain situations for commercial buildings and apartment buildings. The conclusion about the charging station business is that it is a promising business area and something that is worth exploiting. There are already many companies that are providing charging station installations, but the business area is still new and thus there are no established customer and supplier relationships formed yet. The business area still has room for new companies, and it is suitable for Exsane.

The recommended business model for the charging station business is a comprehensive planning and installation service. The starting investment is low, and the risks are tolerable. It is extreamly important to start working on the charging station business right now. The new law is effective from 10 March 2021 and it will raise the rate of charging station installations. The plan for the business model was designed in this thesis, but there is still plenty to do before the business area is properly implemented into the business of

Exsane. The following list introduces the next steps that should be taken in order the charging station business to succeed.

The next steps for the charging station business are:

- To set a financial target for the business area
- To define the marketing plan
- To find the needed charging station supplier
- To appoint suitable persons into the organization of the business area
- To define processes and process descriptions
- To define the provided services with competitive prices.

The electric vehicle charging station business could also support the distribution grid business with shared resources. It is expected that there will be shortage of resources for major fault repairs towards the end of the decade. The construction rate of the distribution grid will decrease because the targeted underground cable percentages will be reached. Consequently, the normal distribution grid construction does not employ as many electricians as it does today. At the same time, there will still be a significant demand for fault repair resources in many companies. Exsane could use electric car charging station business to employ the electricians and at the same time maintain their expertise for fault repairs so that they can be used as fault repair resources when needed. This could offer significant competitive edge in the future.

The survey and interviews showed that the investments are shifting from underground cable construction to smart grid applications during this decade. Contractors such as Exsane must react to this change in order to provide services that are demanded. There were also indications that the inspection and maintenance methods are going to change, even though some grid owners were sceptical of this. The major opinion was that the methods are going to change at least to some extent. Exsane is planning to answer to this change in demand and be on the ground floor of the new era in distribution grid maintenance.

Exsane has been planning to implement partial discharge measurements into the maintenance process for medium voltage distribution grid. The survey showed that there is and will be demand for that, although the amount of demand is still unknown. The grid owners are still quite reserved about this technology because there is not very much experience about the technology in this application. Some grid owners were already interested in online measurements and they recognized some faults in their grid, which could have been avoided with these measurements. Offline measurements were the more familiar subject, and it is a tested technology and there is more secure demand for it when compared to online measurements. Still the online measurements got more attention in the thesis for various reasons. The business opportunities around partial discharge measurements were planned for online measurements because this is a better match with Exsane’s strategy. The investment is smaller, and the measurements can be integrated into the inspection and maintenance process which already exists. Online measurements are a promising business opportunity considering the size of the investment this method requires. They can be started with a relatively small investment and after that the size of the business is easily scalable to the demand level. Offline measurements require a substantially larger investment in the beginning, and this method does not fit directly into the existing inspection process. The offline measurements will still be kept as an option and they will be reconsidered later. If some investments are made now towards partial discharge measurements, they will be into the online measurements.

The next reviewed subject was the smart grid applications. The survey and interviews showed that the grid owners are investing towards smart grid applications. The main technologies are the grid automation and new generation of AMR-meters. The different aspects of grid automation were introduced earlier in the thesis. when it comes to grid automation, it does not seem to offer any significant business opportunities for Exsane. It is still important to consider as it affects the normal work that Exsane does, but it does not offer significant new opportunities. The effects of grid automation must be considered in the process descriptions of the current processes. This way the processes are up to date and everyone are familiar with the new technologies and the service maintains the quality standards set for it.

The significant opportunity in smart grid applications is the next generation of AMR-meters. It is work that is already familiar to Exsane and the nature of these projects suits the current needs of Exsane perfectly. The new AMR-meters are changed in mass rollouts. Grid owners change all their meters in a period of a few years. Interviews showed that these projects are starting in some companies in just a few years and Elenia already started the mass rollout. The new government regulation, regarding the next generation AMR-meters, is going to set the time limit for the new meters to 5 July 2031. It is certain that there will be a considerable number of AMR-meters to be changed during the next ten years and this is an opportunity that Exsane should seize. Changing AMR-meters is a simple job and it is easily predictable, therefore the cost of the project can be accurately evaluated. Risk in these projects is low because of that. There are few unexpected factors that could cause unpredicted expenses or delays.

As regards smart grid applications and the opportunities brought by them, the conclusion would be to focus on the rollout of new AMR-meters. A mass rollout project of new AMR-meters in suitable size would bring stable, predictable, and low risk turnover for the company. Other topics in smart grid applications that were introduced earlier in the thesis, should be taken into consideration and they should be included into the process descriptions. Also, proper preparations should be made so that when grid automation, different automatic measurement methods and battery systems are starting to be more common, the service provision of the company would already have adapted to the new requirements.

As regards the distribution grid, it is also important to improve the existing business areas and processes. The next step in improving the existing business should be updating the process descriptions of different business areas in the company. Accurate and up to date process descriptions help to improve the quality of work because the whole personnel know the correct methods in each part of the project. The interviews also raised the issue of integrating fibre optic construction with distribution grid construction. This subject must be accurately described in the process descriptions in order to prevent any avoidable issues from occurring.

The next steps to be taken for improving the service around the distribution grid include the following:

- A decision has to be made whether to invest in partial discharge measurements.
    - After the investment, a partner for a pilot project must be searched for.
    - The financial target for the business area must be defined, including the targeted volume of the measurements.
- A plan for the AMR-meter projects has to be defined.
    - Which grid owners are the priority.
    - In which volume the AMR-meter projects are planned to be implemented.
- Processes and process descriptions should be updated.
    - Fiber optic construction should be described in the distribution grid construction process.
    - The effects of grid automation should be included in the processes when the automation technology is starting to be common.

Figure 18 presents visually the measures taken to fulfil the required targets. The possible solutions, as presented in Figure 1, were studied in the thesis and the answers for the research questions were found. The answers resulted in the improvements suggested for the existing business areas and in the design of a completely new business area. The result of the thesis fulfils the targets set for it, but the work does not end here. This thesis was a first step into the process of modernizing the business of Exsane and taking the next step in the strategy of growing. Now the measures designed and suggested in this thesis must be implemented.

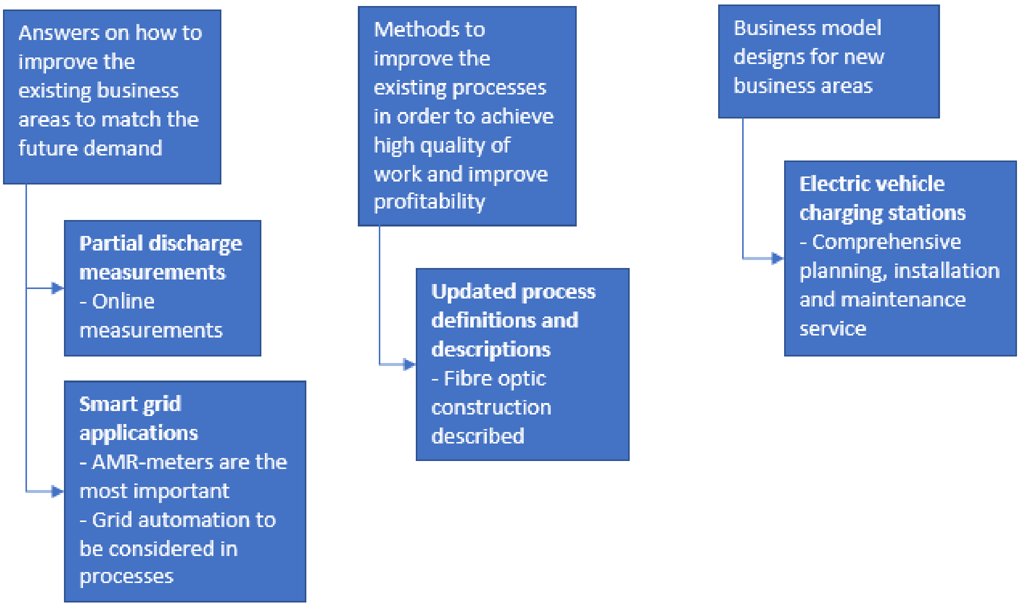

Figure 18. The results of the thesis and how they correspond to the target of the thesis.

11 SUMMARY

The electricity distribution grid construction sector has fallen into a profitability crisis because of high competition. The service provisions of different companies in the sector are very similar and there are few separating factors other than price. The target for this thesis was to find a way to improve the business of Exsane by exploiting the changes that are happening in the electricity distribution sector and around it.

Potential technologies were evaluated with the help of a customer survey and interviews. Then a literature review was carried out to study the technologies. In the end, all the material was used to form suggestions on how to improve the business and what type of business model could be used to expand the business.

The energy sector and the electricity distribution sector are going to face changes during this decade for various reasons. The Government has set emission targets for 2030 and the energy system must change in order to meet those targets. The electricity distribution grid must adapt to the changes in the energy system in order for the whole system to operate in harmony. Grid owners also face regulations for customer interruption times and the next generation of AMR-meters.

Grid owners are investing in smart grid applications in order to create demand control possibilities for the energy system and to improve fault management. The next generation of AMR-meters are going to enable better demand control possibilities for normal households and the one-hour tariff is going to be decreased to 15 minutes. Grid automation is going to modernize the fault management. In fault situations, the DMS analyses the faulty grid sections and separates them automatically from the grid, and the electricity supply is quickly restored back to the intact grid sections.

The structure of the distribution grid has changed significantly after the update of the electricity market act in 2013. The underground cable share of the medium voltage grid has increased from just over 10% to about 35% and the target for 2030 is 52%. The inspection and maintenance needs for the underground grid are different than for overhead lines. The sense-based inspection is not that effective because the components are mostly not visible. Preventive maintenance needs measurement-based inspections. Partial discharge measurements are a promising technology for preventive maintenance. Harmful partial discharges in compact substations and even cables can be measured during normal operation with online measurement devices. Offline measurement can be used for more accurate and reliable measurement. Online measurements are a suitable option for Exsane because of the reasonable starting investment. Interviews showed that there are mixed opinions about partial discharge measurements. Some grid owners are sceptical and some think that the technology is very promising. The overall attitude seems to be open for this technology and a pilot project should be implemented to further study and field test the online measurement technology.

One significant change around the energy and electricity sector is the electrification of traffic. The target is 670 000 electric and plug-in hybrid cars in 2030. The law requires charging stations to be installed in commercial and apartment buildings in certain situations. The number of charging stations will increase remarkably during this decade because of these reasons. Public charging stations are usually fast chargers with 22 kW of power in AC chargers and from 50 kW to even 350 kW in DC chargers. Charging stations in apartment buildings usually have power from 3.7 kW to 11 kW. Charging stations add a significant amount of power to the electricity system of the building and to the low voltage distribution grid. Some modifications to the electricity system are often needed and in some cases to the low voltage distribution grid as well.

The changes around the energy and electricity sector offer different ways to develop the business operations of Exsane. Smart grid applications must be considered in the existing construction, maintenance, and fault repair processes. The next generation of AMR-meters will bring a significant amount of simple installation work for the distribution grid contractors. This opportunity should not be missed. The new structure of the distribution grid with a high share of underground cable requires new maintenance methods. Partial discharge measurements are a promising technology, and it is a good opportunity for

Exsane. The starting investment is relatively low and there is little supply on the market for these measurements.

Electric vehicle charging stations are a promising opportunity for a completely new business area. The existing resources of Exsane match the needs of the business area, thus the starting investment is low. Statutory requirements force charging stations to be installed and there is also natural demand because of the fast rate of traffic electrification. The demand for charging stations is guaranteed. A comprehensive business model including planning, installation, and maintenance services is a good way to move forward in this sector. The next steps would be to create a marketing plan and find the proper charging station suppliers as partners.

Solutions for improving and expanding the business operations of Exsane were found and the target of the thesis was reached. Even though the thesis reached its targets, the work of improving and expanding the business of Exsane is not completed. The thesis was just a research into possible solutions and business model concepts. Now the actual work for improving and expanding the business operations of Exsane must start.

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