Pentti Itkonen

Developing Wind Power in Finland

ABB's approach from the grid connection perspective

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This thesis was done for ABB OY. It is a snapshot of the Finnish wind power market in 2014. The market is blooming, and the wind power developers are aiming to get the planned wind power parks connected to the national grid in short order. The scope of this thesis includes the electrical balance of the plant (EBoP), but excludes the turbine itself.

The goal was to understand the techno-economic process of the developer in order to achieve optimal grid connection design and to be of better service to the customers. Several wind power professionals were interviewed to gather the study material, and the recurring themes were highlighted for discussion. The premise was that there are "blind spots" in the co-operation with ABB and the customer that need to be acknowledged. When the developer's business environment is mapped out, suggestions can be made to further improve the ABB practices.

Many of the services desired by customers already exist in the ABB portfolio, but unifying the extensive offering seems laborious. A complete wind service concept was created to offer insight on how to start improving the approach to the wind power industry in Finland.

Productised service packages with standardized ABB Wind Products and designated ABB Wind personnel are in the core of this concept. More effort needs to be put to drive these changes as the growing market is demanding for more comprehensive service through the entire life cycle of the wind power park.

Keywords	Wind power, grid connection, market research

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Tämän insinöörityön toimeksiantajana toimi ABB OY ja se on tilannekatsaus Suomen tuulivoimamarkkinoihin vuonna 2014. Markkina kasvaa Suomessa ja tuulivoiman hankekehittäjät pyrkivät liittämään tuulipuistojaan kansalliseen sähköverkkoon kiihtyvällä tahdilla. Tämä työ koskee ainoastaan voimalan verkkoliitäntää, eikä työssä käsitellä itse tuuliturbiineita.

Työn tavoite oli ymmärtää hankekehittäjän teknis-taloudellista prosessia syvemmin. Tämä mahdollistaisi verkkoliitännän suunnittelun optimoinnin sekä paremman palvelun tarjoamisen asiakkaille. Materiaali kerättiin haastattelemalla useita tuulivoima-alan ammattilaisia, jonka jälkeen haastatteluissa toistuvia teemoja nostettiin esiin. Lähtökohta työlle oli, että asiakkaan ja ABB:n välisissä yhteyksissä olisi kehitettävää. ABB:n lähestymistapaa voitiin käsitellä tarkemmin, kun hankekehittäjän liiketoimintaympäristöä oli ensin kartoitettu.

Työ osoitti, että monet asiakkaiden toivomista palveluista löytyvät jo ABB:n portfoliosta. Tarjonnan yhtenäistäminen on kuitenkin työlästä. Yhtenä työn tuloksista syntyi kattava tuulivoiman palvelukonsepti. Konsepti tarjoaa ehdotuksia siitä, kuinka ABB voisi kehittää toimintaansa palvellessaan tuulivoima-asiakkaita Suomessa.

Tuotteistetut palvelupaketit standardoiduilla ABB:n tuulivoimatuotteilla sekä nimetyt tuulivoima-asiakkaiden kontaktihenkilöt ovat konseptin ytimessä. Lisää työtä on tehtävä, jotta muutoksia toimintatapoihin saadaan ajettua läpi. Kasvava liiketoimintaympäristö ja tuulivoiman hankekehittäjät vaativat laajempia ratkaisuja koko tuulivoimapuiston elinkaaren ajalle.

Avainsanat	Tuulivoima, sähköverkkoliitäntä, markkinatutkimus

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Pentti Itkonen

Contents

1 Introduction

Wind power is a domestic, renewable and emission-free source of energy that is connected to the national grid through an electrical substation. The feed-in tariff set for wind power in 2010 (Kuuva, et al., 2009) has activated a wide variety of wind power developers in Finland. This thesis work initiated from the ABB Power Systems –department's need to better understand the wind power developer's technical decision making. The goal for this work is to bring out issues in customer dialogue and develop an approach to the market which suits ABB the best.

The data of the study was obtained in fall of 2014 from the interviews with developers, consultancies, state officials and ABB professionals. The approach was a hands-on qualitative study focused on verbal data rather than measurements. The results from the interviews are summed up in chapter 5, after the literature review of wind power in Finland. Understanding the developer's techno-economic process is vital for ABB to know when to be present and to what extent. This is done in order to be of better service to the customers. (Muhonen and Välimaa, 2014)

A clear development process would help to create suggestions to improve the comprehension between ABB and the clients. The goal was not to map exact technical solutions for the customer. The premise was that "blind spots" exist in the communication between ABB and clients throughout the project dialogue. Acknowledging them would be the first step in improving the practices.

The focus was on the electrical balance of the plant (EBoP) that considers the complete grid connection offering and excludes the turbine itself. The entire life cycle of the EBoP was in the scope. The goal was not to study the authorization process of the wind park, such as zoning, permitting or other preliminary research, but to see the underlying techno-economic process of the developer.

2 ABB

ABB (Asea Brown Boveri) was established when Swedish Asea and Swiss Brown Boveri merged their electro-technical businesses in 1998. The strong presence of ABB in Finland is due to the electric machine company, Oy Strömberg Ab, founded by Gottfrid Strömberg in 1889. The company was transferred to the ownership of Swedish Asea in 1987. (ABB, 2014)

2.1 Organization

Today ABB, based in Zürich, Switzerland, is a global leader in power and automation technologies (Figure 1). The revenue for the multi-national corporation in 2013 was around 32 billion Euros as the revenue for ABB Finland was 2,3 billion Euros. Globally, the company employs approximately 145 000 people and operates in 100 countries. In Finland, ABB is present in over 30 cities and employs around 5400 personnel. ABB factories are located in Helsinki, Vaasa and Porvoo. (ABB, 2014) ABB is one of the largest supplier of industrial motors and drives, one of the largest provider of generators to the wind industry and one of the largest supplier of power grids in the world.

Figure 1: ABB logo and slogan (ABB, 2014).

ABB's business is comprised of five divisions that are in turn organized in relation to the customers and industries they serve. The most relevant divisions for this study are Power Products and Power Systems, which are presented in more detail below:

Power Products (PP)

The product offering across voltage levels includes circuit breakers, switchgear, capacitors, instrument transformers, power distribution and traction transformers, as well as a complete range of medium voltage products.

Power Systems (PS)
Turnkey solutions for traditional and renewable energy based power generation plants, transmission grids and distribution networks. These solutions play a key role in the optimization of electricity generation and the evolution of more flexible, reliable and smarter grids.

A remarkable segment of ABB's total product portfolio was not considered, for example wind generators delivered by the Discrete Automation and Motion (DM) division. Divisions are separated here, but one of the goals of this work is to show possibilities and give suggestions on how the different divisions could be closer to each other and cooperate more.

2.2 Wind Power offering by ABB

Substations and other grid-connection-related products were the main focus of this thesis project. For wind power in Finland, existing grid connection solutions have been offered to the customers. In general, a distribution substation, which have been used in any traditional applications is almost identical to the station used for wind power purposes.

ABB Wind Industry is a team in ABB collecting all the sales units with clients in Finnish wind power under same roof. The goal is to make the total offering of ABB available for the customers in different channels. This is a rather new initiative and one of the triggers for this thesis project In order to efficiently use all the resources ABB has spread out through the organisation, a better understanding of the client's needs is required.

The total offering here refers to all the products, systems and solutions that are related to the wind power grid connection. This also consists of pre-engineering, operation and maintenance (O&M) and any kind of consulting needed in electrification of the wind power plant. Some of these technical offerings are productized packages managed by a Service department which is a matrix organization parallel with the fore-mentioned PS and PP divisions. At the beginning of 2014, the Service division was distributed to the five divisions above (Konttinen, 2014).

The difference between the PP and PS divisions can be explained through the definition of a 'system'. A 'system' here is a 'product' combined with the design engineering and responsibility for the full delivery. Therefore PP is delivering only products, whereas PS is offering also engineering, maintenance and commissioning services related to the product. This might lead to challenging situations where a notable client of then PP division might be completing with PS division or the same project. Common PP products such as MV/LV transformer or switchgear are typically a part of the PS turn-key delivery.

The before-mentioned double role leads to a situation where Eltel and Empower are PP's best customers, but PS's biggest competitors. If PS loses a tender, PP might still win part of the component delivery. Power Systems can also be further separated to PSSS (Power Systems SubStations) and PSNM (Power Systems Network Management), but this subdivision was not considered in the thesis.

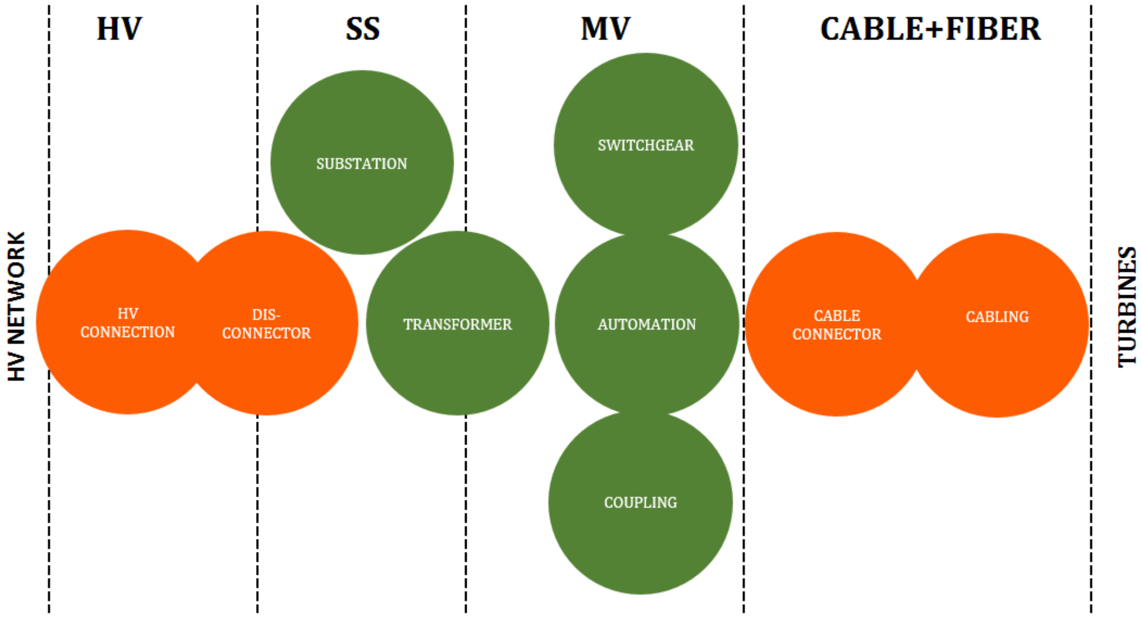

Figure 2: Typical components considered in grid connection of the wind park.

Figure 2 presents the typical components of a substation. The most typical delivery for PS consists of the substation elements (in green): transformer, switchgear, SCADA-automation and coupling. The orange components to complete the grid connection are HV connection, disconnector, cable connectors and cabling which have not been in the scope for the majority of the PS projects. However, there are also cases where ABB has included the orange segments in the scope (Muhonen and Välimaa, 2014). Sub-contracting big shares of the delivery might raise the costs to an uncompetitive level, and it needs to be evaluated carefully.

A technology that could be highlighted from the substation delivery is the transformer. Transformers are electrical devices designed to efficiently change AC voltage level within power networks. In terms of reliability and delivery time, the transformer is the one of the most critical components of the substation delivery.

SCADA (Supervisory Control and Data Acquisition) is an automation system for monitoring the grid state, power production, notifications and alarms. It can be implemented to the turbine’s control system in order to collect all the data for wireless remote control (Muhonen and Välimaa, 2014). All the components of a substation delivery will not be discussed here.

3 Wind Power and Grid connection

Wind power is a clean energy source that has developed rapidly since the end of the 1970s (Wizelius, 2007). Modern wind turbines are designed to catch the kinetic energy in the wind and transform it into electric power. The re-emergence of the wind as a significant source of the world’s energy must rank as one of the significant developments of the late 20th century (Manwell;McGowan;& Rogers, 2009).

Wind power plants do not create greenhouse gases when producing energy. They do not need any potentially harmful fuel transports, they do not create air pollution, and they do not leave any hazardous waste behind. The parts of the wind power plants are recyclable, when the plant comes to the end of its emission-free life cycle (Wizelius, 2007). Technological innovations continue to drive new developments in the application of wind power.

3.1 Wind Energy in Finland

The magnitude of wind energy resources available in the Earth is 20 times larger than the whole world’s energy consumption. The European Union (EU) has obliged Finland, among others, to make use of this resource by increasing the share of renewable energy sources in energy production. This measure is taken in order to prevent the prominent climate change, one of humanity’s greatest challenges. Eighty-percent of the greenhouse gases, speeding up the climate change, are originating from energy production, consumption and traffic (Kuuva, et al., 2009).

On the basis of these facts, Finland has approved the national, long-term climate- and energy strategy stating that the share of renewable energy sources from the final energy consumption should be 38% in 2020. In the strategy, it is estimated that the amount of electricity produced by wind power should be increased to 6 TWh (Kuuva, et al., 2009). As an installed production capacity, this means a total power of 2500 MW, if the peak load time per unit is considered to be 2400 h/a. This power is equal to approximately one thousand 2-3 MW modern wind turbine units. In 2014, out of this 2500 MW –goal, approximately 500 MW were built (STY, 2014). Increasing the share of domestic wind power in energy production would reduce dependency on energy imports in Finland.
The biggest producers of wind power in EU are Germany, Spain, the United Kingdom, Italy and France (EWEA, 2013). When comparing wind power's share of each EU-nations national electricity demand in Figure 3 Denmark is in the lead with 20,3%. (Zervos and Kjaer, 2009). In Finland, only 0,9 % of the electricity was produced by wind power (STY, 2014), which indicates that Finland is well behind the top wind producers in Europe.

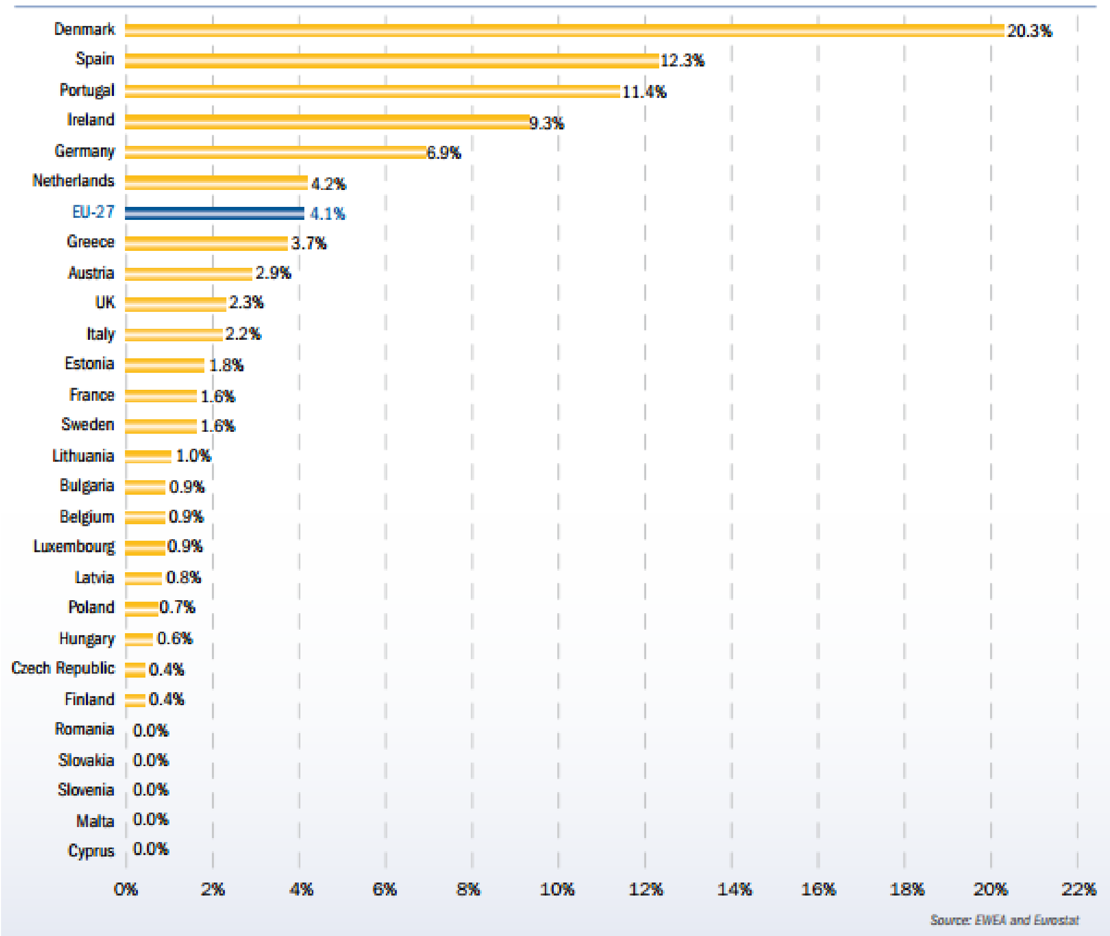

Figure 3: Wind power's share of national electricity demand (Zervos and Kjaer, 2009)

3.2 Wind Power

The wind power potential in Finland is dictated by wind conditions. The wind conditions are affected mostly by Finland's geographical location and the low-pressure areas pulling in from the Atlantic. The best conditions for producing electricity at the turbine height are during the winter months. Practically, the electricity consumption in Finland is also higher then. Summer is typically less windy and therefore less profitable (Tuuliatlas, 2010). The Wind Atlas (figure 4) is an important tool for wind power developers when estimating the production in site selection.

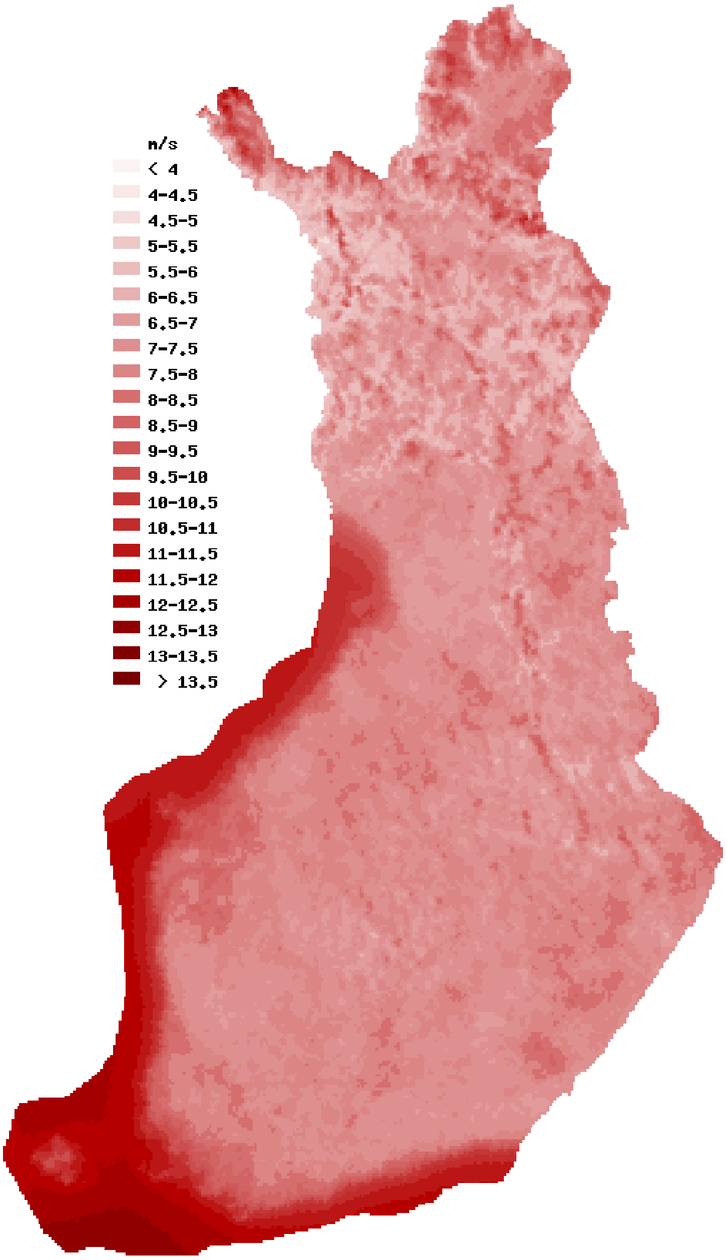

Figure 4: Average wind conditions at 100m height in January (Tuuliatlas, 2010)

3.2.1 Basic wind turbine type

The wind power turbine consists of founding, tower, nacelle and rotor. The kinetic energy in the wind rotates the wind turbine rotor which is subject to lift force and drag. The rotor blades have similar aero-dynamical characteristics as the wings of an aeroplane. Most common types are lift force and horizontal wind turbines as seen in Figure 5. As the winds are stronger in higher altitudes, taller and taller turbines are designed.

Figure 5: Horizontal axis 2,4 MW wind turbines in Honkajoki, Finland. Tower height 120m and the diameter of the rotor 117m. (Taaleritehdas, 2014)

The rotor spins the generator shaft in the nacelle and converts the mechanical energy to electrical energy to be forwarded in the electrical circuit. The power output can be automatically adjusted with pitching of the blades to enhance production or limit the rotating speeds with turning the nacelle (yaw). Too high wind speeds will cause the blades to stop (figure 6). The electric power is reached with a certain wind speed for each turbine model. An example curve can be visualized in Figure 6.

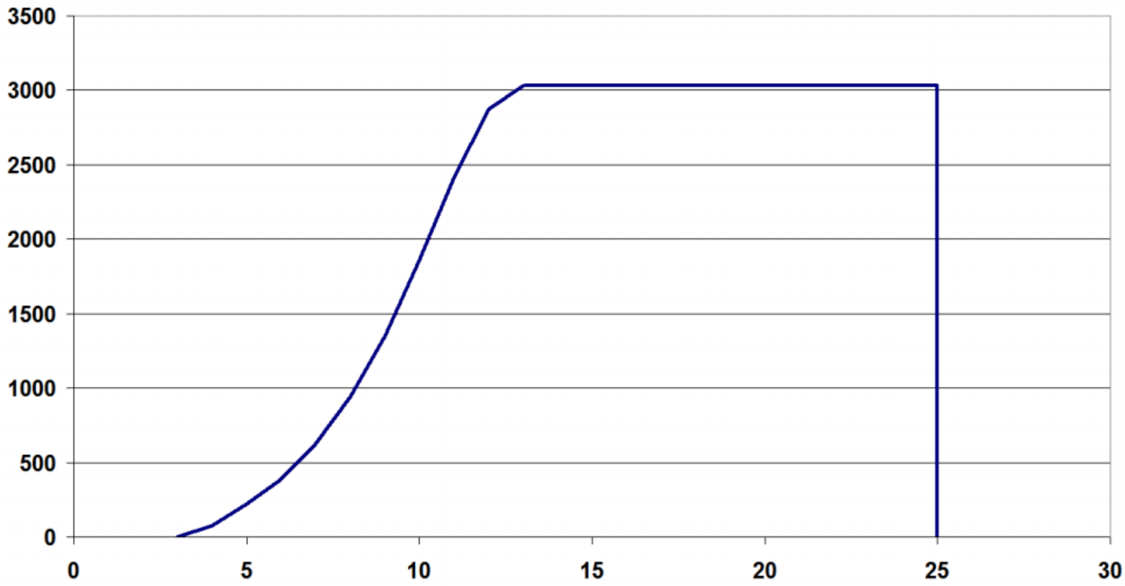

Figure 6: An example power curve of 3 MW plant in kW (horizontal) as a function of wind speed (m/s) (Tuuliatlas, 2010).

3.2.2 Electrical balance of wind power plants

A wind power substation resembles a distribution substation although power flow is in the opposite direction, from many wind turbines up into the transmission grid. Usually the collector system operates around 20-35 kV, and the collector substation steps up voltage to a transmission voltage for the grid. The substation can also provide power factor correction, metering and control of the wind power park.

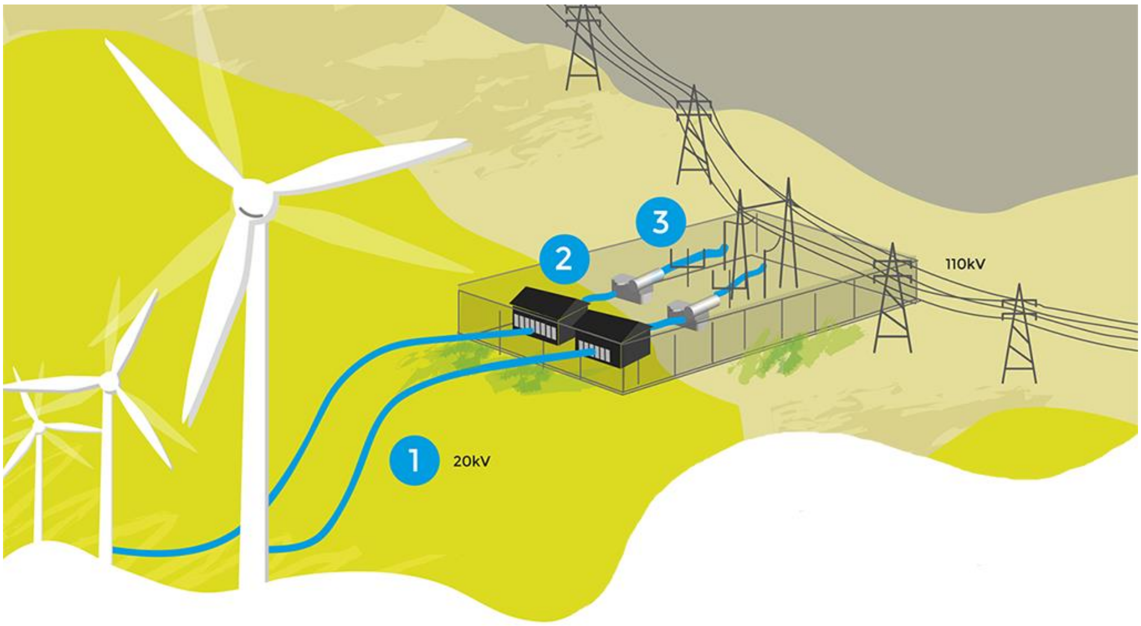

Figure 7: A simplified grid connection illustration with cabling (1), switchgear at substation (2), transformer (3) and transmission grid (EPV, 2014).

In figure 7 the electric current created by the each turbine’s generator moves through the underground cables (1) into the substation (2). In the figure 7, the substation consists of two buildings, transformers and the outdoor switch field. Inside the buildings, the cables are led to switches for each cable. These rows of switches are called the switchgear of the substation (2) and they are a crucial part of ABB delivery. Switchgear is in the core of the electricity distribution and also in a key role in grid management and safety (EPV, 2014). A failure in systems will automatically trigger the protection system and minimize the damage. Generally, substations are unmanned, relying on Supervisory Control And Data Acquisition (SCADA) for remote supervision and control.

The voltage is 20 kV in the medium voltage network managed by the substation. In order to connect it into the transmission grid, the electricity needs to be run through a step-up transformer (3) to meet the higher voltage in HV line, 110kV. From the transformer the electricity is led through switch field into the HV transmission grid. Finally, in order to reach the customer’s outlet socket, the electricity needs to go through a similar substation to step down the voltage with a distribution transformer.

3.2.3 Wind Power Grid Effects

Electricity needs to be produced even when the turbines are not rotating. Wind energy is an intermittent power source, but the end user consumption is constant. Therefore, there needs to be a power generating reserve when wind power is not available. If a larger scale wind power park falls out of the grid, an equivalent power needs to be produced in another way. The de-centralized nature of wind parks helps to even out the fluctuation in production when the different wind sites can compensate each other (Elovaara and Haarla, 2011).

These special characteristics of wind energy in grid connection are managed, regulated and developed by Fingrid, the electric grid authority in Finland. The guideline for connecting wind power to the main grid is called ‘Voimalaitosten Järjestelmätekniset Vaatimukset’ (VJV, Engl. transl.: ‘System-Technical Requirements of Power Plants’). The wind power developer needs to meet a number of requirements when connecting the wind power park to the national grid. Such considerations include the power plant model, the point of common coupling (PCC) and the need for reactive power compensation (RPC). The requirements aim to maintain a good state of the national grid in terms of reliability, electricity quality and safety (Fingrid, 2014). These guidelines are more relevant than ever as the intermittent wind power production challenges the electric grid and investments are being done to withstand the growing total of wind power in Finland (Löf and Reilander, 2014).

The reactive power compensation is needed when the energy production suddenly drops due to the variation in wind. Reactive power compensation implies compensating the reactive power consumed by for example generators and transformers (ABB, 2014). It causes frequency to alter in the network and the capacity of the grid is put to test. ABB could provide solutions and expertise for these problems and the need for RPC consulting is growing (Hagqvist, 2014).

3.3 Wind Energy Production

Finnish electricity producers sell their production to the NordPool SPOT markets. Nordpool is the financial energy market for Finland, Norway, Denmark, Sweden, Estonia and Lithuania. SPOT market functions on a day-ahead principle, which means that producers estimate their production and consumers their consumption 12-36 hours beforehand. There is also a possibility to trade electricity during the day in the Elbas market, where trade can still be done until the last hour before the delivery of the electricity (NordPool Spot, 2014).

The cost structure of wind power production differs significantly from the electrical energy produced by fossil fuels. In fossil fuel-based production, 40-70% of the costs are formed from fuel and operation and maintenance (O&M), which causes higher fluctuation in the operational costs, hereby referred as ‘variable costs’. In wind power, the fuel is free, and the production costs can be considered ‘fixed’. This leads to the fossil fuel-based electricity to be sold at a higher price in comparison to electricity produced by wind power.

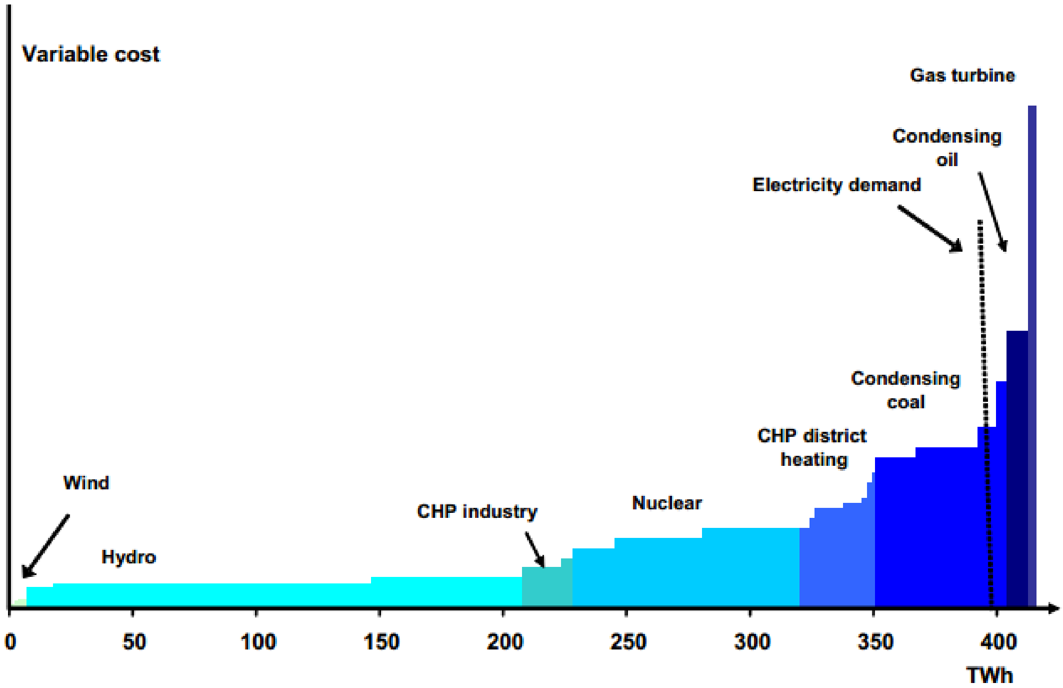

Figure 8:Merit order in the Nordic electricity market (Åhman;Burtraw;and Palmer, 2008)

Different power plants are used in the market starting from the lowest short-term variable costs. This order is often called the ‘merit order’. Figure 8 presents the merit order of electricity in the order of ‘supply and demand’. It can be seen that the variable cost market price (€/MWh) is lowest for wind power, followed by hydro power (cyan) and nuclear power (light blue). However, as the average total consumption of the Nordic countries is around 400 TWh, so also the fossil fuel –based methods are needed, but with higher variable costs. The demand for electricity changes hourly based for example on weather conditions or day-night cycles. The producer providing the last share to the needed amount of electricity is called the ‘marginal producer’. In the Nordic markets this marginal producer has lately been the coal condensing power plant.

Each hour’s marginal producer only gets compensated for the amount of variable costs in the production, whereas other plants which produce electricity with less expenses gets also compensated for their investment costs. Wind power is highly capital-intensive way of producing electricity, where variable costs are relatively small. Therefore, wind power producers get compensated for their investment per hour based on the difference between market price of the electricity and the variable costs of the power plant (Kuuva, et al., 2009) . This section did not consider electricity import and export into the Nordpool.

3.3.1 Feed-in tariff

Finnish government has set a tariff for wind power in the country to meet the EU-requirements. The feed-in tariff set is 85,50€/MWh. The higher feed-in tariff 105,30€/MWh) has also been set for the developers that can start their production before then end of 2015. The feed-in tariff is limited to all the projects finished before the full capacity of wind power in Finland reaches 2500 MW. There are also other requirements and conditions to fulfill. The tariff has caused many developers to pursue the fair compensation. The fast development of the industry has also provoked public discussion. (STY, 2014).

It could be said that the new industry is still finding a balance and best practices when aiming for the renewable and sustainable future. The tariff is an important tool in transition to more wind power and new technologies. In the future, more efficient technologies may yield electricity even from less potential sites.

3.4 Developing wind power projects

Developing a fully permitted and ready-for-construction wind power project can be a decade’s endeavour. Therefore, a comprehensive strategy needs to be elaborated before starting process. Decisions need to be made on location, total power and financing options as well as the involvement of contractors in consulting, manufactory and commissioning. On the first draft version of the project also viability and schedule issues can be considered (Rissanen, 2014).

A typical wind power park in Finland, recurring in the first waves of the finished projects, has been a layout with nine turbines with the total power output of approximately 25 MW. This design is carefully set as more than ten turbines would require a full Environmental Impact Assessment (EIA) to be executed. Also 25 MVA is still possible to connect straight to the 110kV line without first building power line to the nearest switch station with connection to the HV line (Löf and Reilander, 2014). However, a clear trend line in the wind power projects today is the increase in turbine numbers and total output.

4 Methodology

The interviewed professionals were selected to represent a wide variety of wind power experts in Finland. All the participants were interested in the project and many called for more cooperation to be built in the industry (Hietala, 2014).

In order to deliver a statement about the state of the whole business environment a number of interviews were set. ABB wind professionals could provide the status quo and information about the technical possibilities. Several wind power developers of different calibre were chosen, including such companies as Tuuliwatti, Etelä-Pohjanmaan voima (EPV), Taaleritehdas and Prokon. These companies are of different scale, and their project management methods proved to be quite different from another. These differences will be later summed up in the customer profile evaluation.

Pöyry and Ramboll are two biggest companies in Finland offering wind power consultancy. The way the wind developers, often minimally staffed, tend to sub-contract major parts of the project development causes the influence of the consulting companies to gradually increase. Often consultants decide on the majority of the technical details, while the developer itself only acts as an acceptor for the suggested choices (Hietala, 2014). Also Fingrid was considered to be a valuable resource of information on grid connection issues with the developer.

The material for this thesis was collected by confidential interviews that were recorded using an audio recorder. The interviews were carried out in a semi-structural format and the questions were open. This kind of qualitative research method typically ‘seeks to describe the central themes in the subject’s field of work’ (Kvale, 1996). In other words, when interviewing several professionals in the business, it is assumed that certain themes would occur more often and could therefore be considered to be more significant.

5 Understanding the techno-economic life cycle of the project

This chapter sums up all the results from the qualitative research. The aim is to describe the techno-economic life cycle of the project as the wind power developers and other actors in the business see it. The developer’s techno-economic process is opened up in a suggestive process diagram (Appendix 1). All the wind projects in Finland have unique characteristics and the developers in Finland vary in their project management methods.

Figure 9 (also Appendix 1) shows the general process diagram of a wind power project. In this example case, the project is spanned over 4 years and on average that can be considered a smooth execution. The purple colour represents the development phase and orange the construction phase. The two most important milestones in the timeline are the positive wind measurement results at month 17 and the planning permission triggering investment decision at month 24.

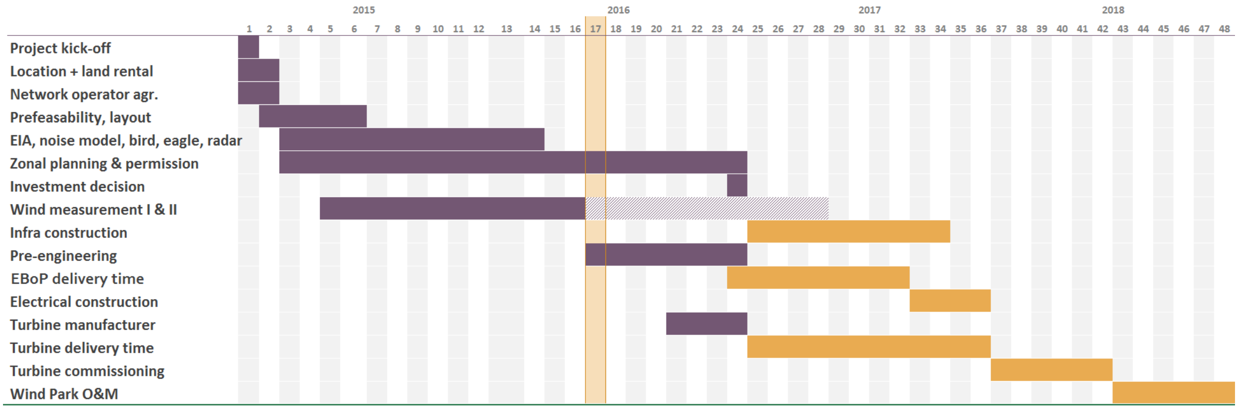

Figure 9: Wind Power Project. Development phase (purple) and construction phase (orange)

5.1 Development process

The fact that moulds the entire industry is that successful permitting of the wind park is uncertain or at least often considerably delayed. Many developers report that they design the park well in advance to avoid unexpected expenses and to raise profits (Alkula, 2014), but the costs need to stay in minimum until the point where investment decision is made. (Hagqvist, 2014). In other words, developing a wind power project is always a risk investment.

The first steps of the project consist mainly of permitting, EIA and preliminary discussion with the network operator about the grid connection. For this discussion, the developer only uses an estimate of the wind park layout, and no exact design is needed. Only the location, estimated total power of the park and layout of turbines and substations are needed in the first phase from now on referred to as Development Phase 1. This approach keeps the project costs as low as possible for the developer. In figure 9 the Phase 1 is considered to end when the first year of wind measurement is finished with good results.

It can effortlessly be stated that none of the first steps of the development process are the core proficiency of ABB and no emphasis should be put on the early phases of the project. The first round of wind measurements are done to ensure the wind conditions, and they typically take 12 months (Heinilä, 2014). If there is no nearby data source to compare the results, even 18-24 months might be required to ensure the wind conditions (Energia-Ekono Oy, 1999b). The developers need to have exact wind data to evaluate the profitability, which then again is the piece of information that might eventually gain the project investors interest. The investors require a minimum of one year to approve the wind conditions (Rissanen, 2014).

After confirming satisfactory wind measurement results the project enters the Development Phase 2. The developer starts now to concentrate on the technical details of the grid connection as the project seems to be closer to succession. The steps taken in the Development Phase 2 all aim to the investment decision and building permission, which would enter the project to the construction phase. These actions contain contracting deals, turbine selection and final economic analyses. Development Phase 2 often takes some months as the Development Phase 1 can take years (Rissanen, 2014).

5.2 Electric pre-engineering

Electric pre-engineering here consists of all the preliminary actions taken when planning the purchase of the complete EBoP-system, including, but not limited to substations, transformers, cabling, SCADA, reactive power compensating, switchgears and all the consulting service required to carry out the needed pre-planning. Some of the developers tend to externalize the whole electrical design (Keisala, 2014).

One of the developers divided their electrical planning in the following four parts:

1. HV Power line routing
2. Reactive power compensation (RPC)
3. Planning of the MV network (Cabling)
4. Substation

The 110kV power line permitting is a tedious task, and it needs to be considered as early as possible. Sometimes the high voltage line has to be connected to the national grid over notable distances and is therefore often required to be included in the EIA. Reactive power requirements are a new challenge for the developers, and the problems intensify when larger wind parks are planned. RPC is something the developer has to consider already on the early phases of the project, because Fingrid requires a clearance on the developer’s plans on dealing with the issue (Löf and Reilander, 2014).

Planning of electric power distribution also includes the MV network done with cabling and the substation design to connect the park to the HV power line (Hagqvist, 2014). The electrical design is also called optimization (Rissanen, 2014). Specifications of the transformer such as size, cooling method and calculated losses are also estimated when planning the electrification (Keisala, 2014).

A good example of electric preplanning being left subordinate to other factors was in Torkkola wind park, Vähäkyrö, where the location of the substation had to be altered due to concerns of EIA- and zoning-caused delay (Heinilä, 2014). This lead to a less optimal electrical design where the distances to the substation grew and losses increased. It cannot be estimated if this was the correct economic decision for the developer in the long term.

Tuuliwatti states that they do not require any assistance in the electric pre-engineering. The frame agreement with their existing external partner, Empower, is covering everything from project management into electric engineering and delivery of the park (Heinilä, 2014).

5.2.1 Optimization of the MV network

Optimizing the voltage level in the medium voltage network is done to minimize the current losses. The medium voltage network typically consists of underground cabling. In general there are two approaches one can take in choosing the voltage of the network. Lower, 20 kV, option is widely used in Finland and the substation design can, in many cases, be considered a standardized solution. The spare components are abundant and the option is considered ‘safe’ (Muhonen and Välimaa, 2014). As the wind parks are increasing in size, the voltage losses in 20kV-network become significant with the total cable mass increasing as well (Hagqvist, 2014). The other option is to raise the voltage level as high as technically possible, approximately 30-40 kV. This would minimize the losses, but needs more detailed engineering and more uncommon components.

The cabling is often designed to save money in minimizing the cable diameter. This solution offers enough current carrying capacity, but a bigger cable would help mitigating the voltage losses. During the preplanning the involved consulting companies might suggest optimised wind park designs including cabling, substation location and number, and other technical details. Many things can be taken into account in the design, but often the simplicity in construction phase practicalities and the lowest investment price are most important aspects for the developer (Rissanen, 2014).

5.3 Planning and consulting services

The developers have different capabilities in carrying out the electrical design for their wind parks. In this project it is assumed that the developer is capable of designing a common wind park with a standardised substation by its own resources. This is the estimate the developer is using for the permitting process. Despite this, there are detailed matters where developers also might need ABB's consulting services.

When the developer is establishing the grid connection agreement with Fingrid, technical challenges may arise from the dialogue. The early phases of VJV-protocol are one of the first measures taken by the developer to study the possibility of establishing a wind power park. A good example of a technical challenge is the reactive power compensation (RPC), which might be needed in the bigger wind parks. The developers are not used to deal with this requirement, since it is not relevant in the smaller wind parks. The developers do not know the technical solutions for the RPC or their costs (Rissanen, 2014).

Some or all of the VJV related calculations and simulations, and later commissioning and operational tests are something that the developer wants to externalise (Muhonen and Välimaa, 2014). The client might also need consultation in the data transmission and fiber-optic communication as well as automation and SCADA solutions throughout the project (Rissanen, 2014). Chapter 3.2 discusses the theory behind RPC in more detail.

5.4 Planning permission and Investment decision

The decisive moment for any developed project is the planning permission. Typically the grid connection agreement and other permitting have already been accepted long before this. The viability of the project has also been extensively evaluated well in advance. The three points that estimate the viability and affect the willingness of investors are as follows:

1. Total investments costs
2. Wind measurements and productivity calculations
3. The amount of feed-in tariff (Hagqvist, 2014)

Planning permission triggers the investment decision and the project is confirmed. It's possible that at this point the project has already been delayed by permitting and investors, if still interested, are eager to continue swiftly. An aspect that could also be addressed here is the bankability of the developer. It was mentioned by some of the interviewees that having ABB, an established company with a strong reputation, as a partner could smoothen the path when in search of investors (Alkula, 2014).

The Development Phase 2 can be considered to end here (Rissanen, 2014) and often the infra construction might start during the same day the permission was obtained (Alkula, 2014). This is also the moment the wind turbine order is confirmed and electrical construction bidding starts. The project has now been sent on to the next phase called Construction Phase.

5.5 Procurement and construction

Construction phase begins with procurement where all the electrical and civil construction needed is acquired. The specifications planned before are now reviewed and then finalised (Rissanen, 2014). In some projects, the tenders are handled by a project management contractor and only confirmed with the developer (Hietala, 2014).

Tender phase is more difficult to enter if the equipment manufacturer has not been involved in any of the technical planning. Also a reactive approach, where the company only reacts to invitations to tender is not preferred by the clients (Hietala, 2014). Before the construction phase was always limited by the delivery time of the wind turbines, but today the competition has been caused some of the turbine manufacturers to promise delivery even in six months. This development adds pressure to the substation delivery as well (Alkula, 2014). It is considered crucial that all the other construction work is finished when the turbines arrive (Hietala, 2014).

In the competitive bidding, delivery time seemed to be the most valued feature; transformer being the most schedule-critical component of the substation delivery. The developers would not mind even a fraction of the wind turbine delivery to be late as long as the transformer is on time. In general, the fastest delivery time wins the bid and a good control of the delivery chain is valued high (Alkula, 2014).

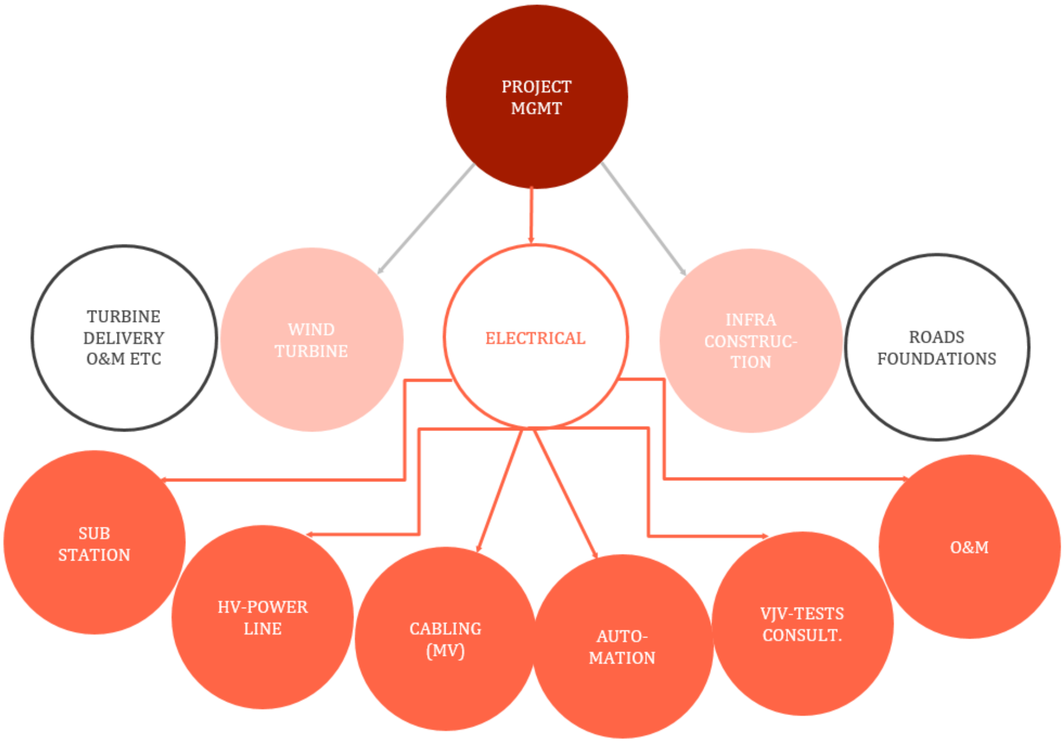

Figure 10: Contracting shares of the wind project. Each project has a unique combination of actors.

Construction phase is carried out according to the companies selected in the procurement. Possible combinations of different actors with varied contracts and subcontracts are endless. Figure 10 represents some of the tasks that the project can be divided into. In principal all the electrical subcontracts could be handled by ABB but for example the VJV tests are often again contracted to another company specialised in the service. In the broadest scope, a project management (figure 10) contractor can be responsible of virtually everything. The main project contractor role is not an approach pursued in the ABB strategy (Välimaa, 2014). The trend seems to be that the developers would like to outsource majority of the tasks.

5.6 Maintenance and operation

After the construction is ready, the VJV-ruled commissioning tests are carried out. Basically, the grid connection is being metered, and it is determined that everything works as planned (Löf & Reilander, 2014).

O&M for the turbines is typically done by the turbine manufacturer. These deals, however, do not include the O&M for the substation, including transformer nor the grid monitoring. The developers would prefer that the O&M would be carried out by the original manufacturer as they have the knowledge and experience about the products (Keisala, 2014). The developers would like to minimise the risks involved in the operation phase of the wind park. In fact many of them would like to agree on the O&M details already as a part of the hardware delivery contract early in the process (Alkula, 2014).

An important aspect when discussing the O&M management is the spare parts policy. Keeping the technical variance in the developer's technical portfolio to minimum enables efficient spare part control. In any kind of malfunction of the electrification, the spare parts service needs to be swift as every production hour lost is economically painful. To sum up, the developers have no interest in handling the O&M of the park. It requires more investments, staff and training. The best way then to handle O&M would be to continue existing partnership (Hietala, 2014).

Many of the developers were interested in "spare part pools" for critical components (Hagqvist, 2014). If a transformer had a malfunction the production would need to be shut down or at least restricted. "A pool" would be an arrangement where, for a certain cost, ABB would store a transformer that could be useable by the members of the "pool". Also other critical components such as switchgears were mentioned in this context. In Joukhaisselkä IMPAX (a wind power developer) was interested in buying a spare transformer for themselves just to minimise the risks of a possible shut down. It could be said that interest for a "transformer pool" is prominent (Alkula, 2014).

Operation and maintenance was one of the most discussed aspects by the developers. A separate chapter, chapter 7, aims to describe in more detail the developer's needs and ABB's potential to meet them.

6 Comprehension between ABB and the client

As the main points from the interviews have been stated as well as the suggestive process diagram, this chapter is about the generated ideas improving the comprehension between ABB and its partners. Comprehension rises from standardised methods and close contacts between the parties. Especially the goal was to find "blind spots" in the communication, where a) ABB does not know, what the customer needs or b) customer does not know what it really needs or ABB could offer. The result of this study can be considered conceptual in a sense that not necessarily all the suggestions are fully applicable in short order. The aim is to point out problematic issues for the business and offer some insight on how to develop the practices to a better direction. The underlying hypothesis is that the comprehensive ABB product portfolio can serve customers better.

Many of the wind power professionals stated a need for discussion and improvement on the field. More co-operation and competition in the business challenges everyone to re-evaluate their methods and point of views. As clear or fixed methods do not exist, every practice in the field can still be affected (Hagqvist, 2014). There are also numerous aspects in the development projects that have not yet been taken into account. These aspects are often left subordinate to other factors or even left out because busy schedule or economic challenges (Alkula, 2014).

6.1 ABB Wind Substation -concept

This section introduces a concept where ABB would be irresistible with its own conditions. ABB's strengths and customer needs would meet. Life cycle thinking cannot be highlighted enough here. This concept seeks to answer the original study questions in a complete manner. It is meant to be a bold attempt to create a new way to look at the ABB wind substation business in Finland. It is possible that some of the ideas in this section are not executable without elaborating further, but the goal is also to stimulate and provoke thoughts. This is an optimal approach to the customer conducted from all the material gathered.

6.1.1 Timing

As stated before, the optimal timing for ABB to activate is when the first positive wind measurement results are completed by the developer. Good results are a strong sign for the developer to proceed with their actions as well as a clear improvement in the certainty of the process. Still, it is possible that some project-specific concern holds the development back. In Eastern Finland, a good example would be the threat of completely shutting down the project due to the radar interference claims of Finnish Defence Forces. Anyway, in general, the optimal time for ABB to step in with the letter of intent is when the project transits from Development Phase 1 to Development Phase 2 (month 17, highlighted in Figure 11).

In figure 11 the ABB letter of intent is sent when there is green light from the wind measurements. The pre-engineering starts immediately, and all the preparations will be certainly finished before the planning permission. It needs to be noted that the zoning and EIA processes may still modify the park layout, but ABB needs to be able to react to these variations. This holds true especially if the customer has signed the letter of intent for the life cycle of the substation. It seems that the need for RPC-consultation is the only exception that appears in the first months of the planning before this suggested timing.

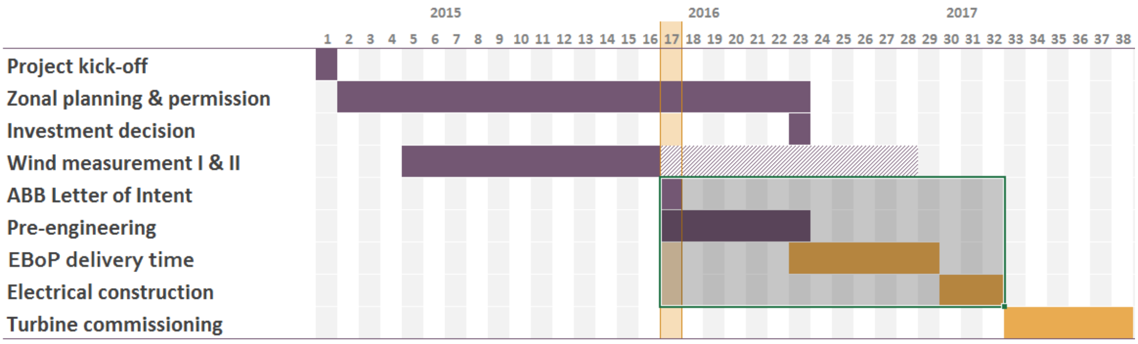

Figure 11: A simplified version of the project process. The highlighted area represents the window where ABB activity needs to be higher.

6.1.2 Letter of Intent

The letter of intent is a document offering the client the exact things they need at this point. In this concept ABB has productised a package which would include the following aspects:

- Pre-engineering
- ABB Wind Products
- Life cycle service (O&M), spares and insurances
- Support of Wind Team

For the customer a solidified, well-thought-out sales approach would in the long term mean certainty in costs and delivery time, simplicity in technical choices and ensured quality. Also if the client has already agreed on the letter of intent, all the engineering and documentation can be done in advance. This way when the long-awaited building permission is accepted, the EBoP manufacturing will start immediately. In the future, the technically most critical part of the wind park can also be the most critical part in terms of delivery time. There is no reason to think that the process does not need improving because at the moment it is usually the turbines that are delaying the commissioning. In the future, it could be EBoP as well.

6.1.3 Pre-engineering

For ABB being part of the engineering process would mean that it can be made sure that the EBoP-design is optimal. Also closer partnership with the client could lead to an ABB delivery when the equipment is purchased (Muhonen and Välimaa, 2014). The negative side of this kind of approach for the developer could be that, if ABB cannot, for whatever reason, deliver the equipment according to its own specification. In this case the developer would be left with an “ABB-specification” that could be more difficult to be met by other manufacturers (Hietala, 2014).

ABB has studied carefully the best wind park layouts. When orientating with the case-specific layout and plans, ABB designers can from experience suggest the best possible choices. It needs to be remembered that the developer has reached this point with a crude estimate. Some developers may have a more through-out plan, but some may need some drastic changes to their original designs. It is possible that some of these more drastic design improvements cannot be applied, but either way ABB will find the optimal electric design for the customer.

On a later stage of this thesis project it turned out that there already is a designated optimization package for substations (Välimaa, 2014). This was surprising because the existence of this service was not mentioned in any of many interviews with ABB personnel or the customers. Such a modular service would fit perfectly in to the ABB WIND concept.

This example shows how important the ‘Wind Industry’ gatherings are inside ABB. To truly serve the customer the best possible way, ABB divisions need to still work on improving the cooperation. It would help ABB a great deal to have standardised methods how to carry out the optimization. The standard products would be a great start to clarify the ABB portfolio. ABB Wind Substations would be optimised for wind power distribution use taking into account the transformers, voltage levels, maintenance, automation, spare parts, required consulting (VJV) and most importantly, the full responsibility of the life cycle of the park electrification.

6.1.4 ABB Wind Products

The wind substation can be considered a complicated piece of technology, and this is true in terms of how many different optional components and customer requirements there can be. On the other hand, the basic design of a wind substation is highly standardised (Muhonen and Välimaa, 2014). The voltage inside the wind park has been 20kV in most designs. Now, when the wind power parks have been growing in output and turbine numbers, the distances in the MV-network start to increase, and cable losses start to show a significance. A 33kV MV network would mitigate the losses, and it sets no technical hurdle for ABB.

When evaluating the whole park optimization, the number and location of substations as well as power directed through each substation starts playing a role. In a 9*3MW (~27MW) wind park, a single ~25MVA substation is sufficient, but bigger wind parks require further thinking. Considering a big wind park with a total power of 120MW consisting of forty 3MW turbines, the way how to design the MV network needs to be carefully evaluated. The factors to vary are the number of substations and how many transformers (25 MVA or 40 MVA) are installed in each substation. The 40 MVA transformers are manufactured in ABB Turkey instead of Finland, but this should not affect how the product is offered in the Finnish market.

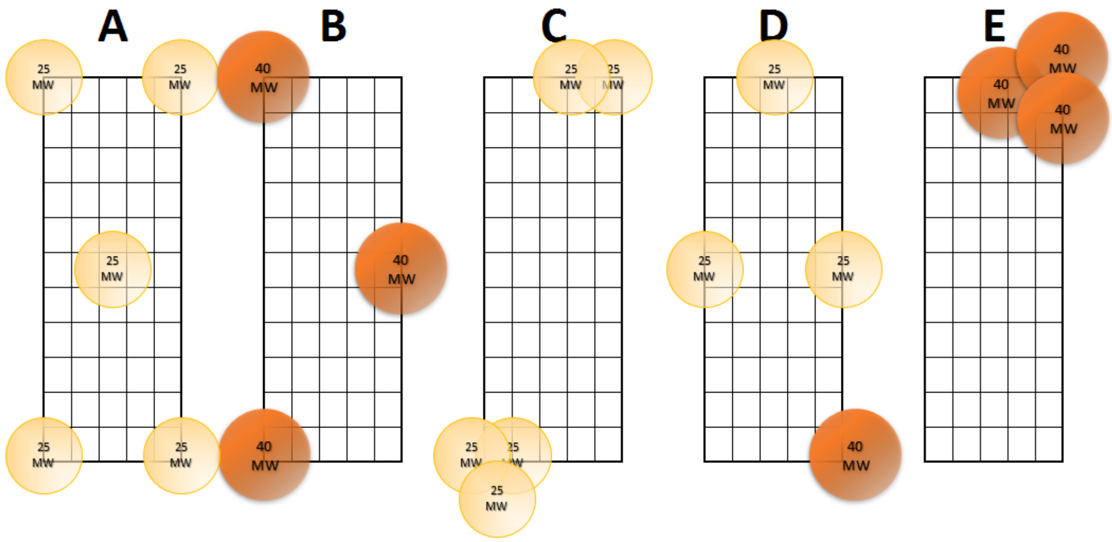

Figure 12: An example of possible optimization scenarios.

In figure 12 each square represents a wind turbine and the round shapes represent substations. In theory the question is simple: how to connect the turbines to the nearest possible substation (either 25 or 40 MW capacity). From all the substations, there then needs to be 110kV line connected to the HV grid. Option A would have the shortest total distances from turbines to substations, but HW power line would need to be built across the development area. The 110kV line is something that needs to be considered in EIA. Then again options C or E would be easiest to construct, but they also have the longest distances in cabling and therefore greater losses. Optimization is a hard task highly affected by the local characteristics.

Additionally Figure 12 is a highly simplified presentation of the issue. In reality the turbines have to be commissioned for example on elongated sites and it is possible that the number of sub stations constructed is also limited. The limiting factor in number of substations is typically the HV line (110kV) that can be tedious to permit and construct. Also, the capacities of the HV transmission lines for PCC are starting to be limited and in the future more planning could be needed to figure out the network design (Hietala, 2014)

	Voltage (kV)	
Apparent power (MVA)	20kV, 25 MVA	33kV, 25 MVA
	20kV, 40 MVA	33kV, 40 MVA

Table 1: Suggestion for a simplified ABB Wind Substation portfolio.

The point here is not to estimate which one of the options presented in Figure 12 would be the best one. The idea here is that ABB would foresee the need for these standard solutions and have prepared solutions for the customer when the need occurs. Engineering has already been done to standardise the solutions. With the products introduced in the Table 1, ABB could have an answer to all the Finnish wind parks designed in the future.

Locking few modular options down has also benefits in terms of maintenance unity and spare part control. It is already being said that if the customer does not have special requirements for the EBoP, the delivery will be highly similar (Muhonen and Välimaa, 2014). Tailoring products for each project has always had a place in ABB business, but tailoring for unnecessary requirements or non-optimal design is something that is happening in the field of wind power more than other industries. This statement is based on the number of private equity funds or small developers with thin engineering resources and organizations that do not necessarily have the best knowledge in the options available.

ABB should be the expert here and always have the latest information to offer the customer. The possibility to serial-produce the substation components and transformers has been considered before to utilise replicability and maximise the profits. The Wind Substation thinking would just take the same idea even further.

Another aspect with the productised substations is the technical brilliance developed with highly specialised offering and practices. The ABB power solutions are already described as 'ingenious' and 'of best quality' (Alkula, 2014) so with some further elaboration ABB could be simply the only sensible choice when picking up the partner for the electrification of the wind park.

6.1.5 Scope

Basically two roles suitable for ABB could be found. The first, broader one is making a subcontract deal on the grid connection of the wind park. In figure 14 the typical substation delivery is colour-coded with green, and the rest of the needed equipment for grid connection is indicated with orange colour. In this concept, it is advised to include the 'orange' segments to the letter of intent as well. This would require a deeper involvement in the project, but reference cases of this role already exist (Muhonen and Välimaa, 2014). Arrangements would need to be made to handle the VJV requirements and especially cabling, but this is clearly a more desirable setup for the client (Hagqvist, 2014).

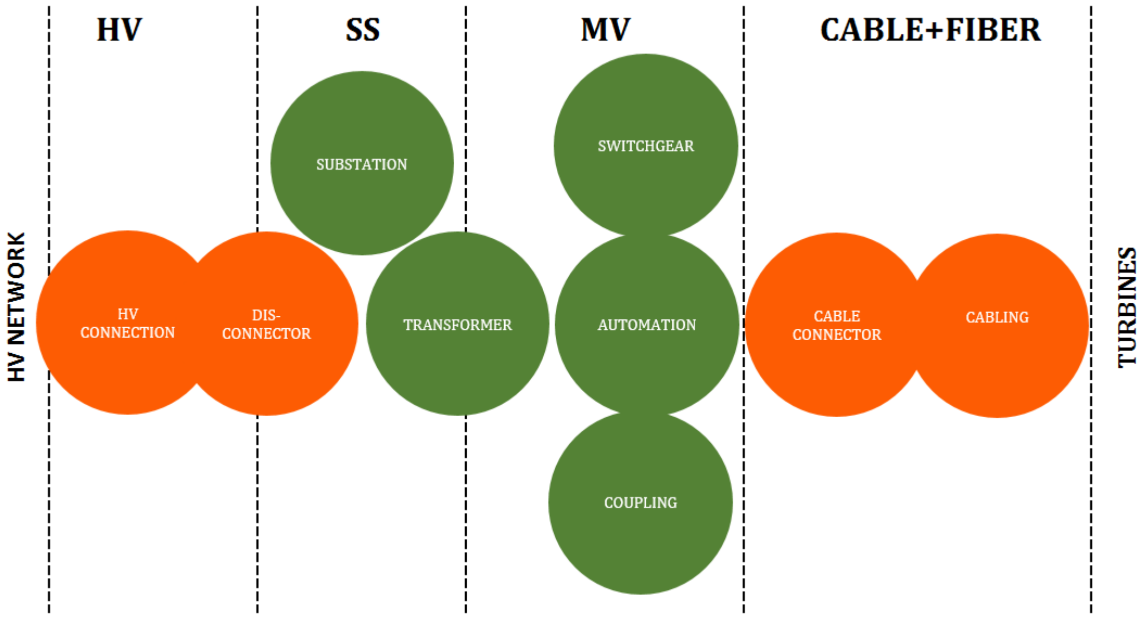

Figure 13: Typical components considered in grid connection of the wind park.

ABB has to carefully evaluate the risks involved in subcontracting too many aspects of the scope. A high level of ABB content in the delivery ensures higher success rate as the project is in in-house control and the external factors do not risk ABB's business (Kärnä, 2014).

The other role would be the hardware supplier for the sub-contractor responsible of the wind park grid connection. This a reactive approach to the business and would need less effort from ABB. Some of the tenders would be still won, but this method is closer to passive supplier than a pro-active business partner. When involved with the developer long, prosperous partnerships might occur.

6.1.6 Life cycle service (O&M)

The ABB WIND concept is a comprehensive service: starting from the pre-engineering to the operation-phase component maintenance. The strong message from the developers was that they want a strong partner for the full life cycle. The limited effort to pick up parts of the grid connection can be questioned, when the deal is there to be taken as a complete turn-key delivery.

A crucial advantage for ABB in selecting a certain approach for the business is the efficient management of the full life cycle of the substation. Spare parts pools, especially for transformers and switchgears, were mentioned by many as service they would be eager to pay for. Basically, a single extended black-out of the park already causes higher expenses than taking part of ABB spare parts pool for the full life cycle. ABB transformers are already installed everywhere in Finland; thus the market already exists for “spare part pools”.

Another input from the customers was an interest in throughout maintenance insurance for the components. Again, the developers are willing to pay in advance to avoid future hassle with malfunctioning technology. The critical main parts are the most interesting prospects for this insurance arrangement, i.e. transformers and switchgears.

6.1.7 Wind Team

ABB professionals connected with wind projects should be appointed to a Wind Team to further develop the approach to the wind business. The “Wind Industry” mentioned in chapter 2.2 differs from this because “Industry” team members are representing the front end sales only. The new “Wind Team” would be a concept where there is full customer support throughout the wind power project, not just until the deal terms are negotiated.

Some of these responsibilities do exist already (mainly in sales), but the suggestion is to take this thinking further. The clients repeatedly mentioned the need for designated wind professionals from ABB (Alkula, 2014). This arrangement would provide the customer a partner that could always be reached and consulted. To have a designated person to contact, for example, in transformer manufacturing was valued high. The same thinking should also be applied to the preplanning and maintenance phases. The idea is not to re-organise and –locate all the people involved in the wind power projects, but to ensure that when there are wind related experts needed, they would be the same people every time. Trust based professional relationships cannot be underestimated.

In the end, the whole ABB WIND concept breaks down to the people working for it or with it. All the reasons why the developer would want to go with the ABB partnership is eventually up to the fact if the “wind” personnel have been excelling in their jobs or not. This is why an emphasis should be put to clearly state the personnel involved in wind projects. It could be said that the wind solutions have been drifting in the “no-mans-land” in ABB and this should be looked into as soon as possible.

6.1.8 Marketing

After conducting the ABB Wind offering into a productised package it is absolutely vital to market this concept to all the developers in Finland. The customer must also now about the new, suggested ABB products (20kV/33kV and 25 MVA/40MVA). In the best scenario, the customer would plan their first draft of the park according to the transcendent ABB products. At the same time, information of ABB's RPC solutions could be distributed as it is a new challenge in the business and ABB has solutions for it.

6.2 Partnership agreements

Long term partnerships were suggested at least by one of the interviewees (Hagqvist, 2014). This would practically mean an agreement that extends over a number of projects were ABB would provide electrical design consultancy and in return get a clear vantage point when making choices in procurement. This is very understandable from the developer's point of view as a way to share the risks involved in the business (Alkula, 2014). It would not even increase the risk involvement of ABB necessarily as electric planning would be needed in all the tenders anyway, even done one at a time (Kärnä, 2014).

6.3 Customer profiles

The field of wind power development is extremely fragmented, and one of the starting points of this thesis was to make some conclusions about the wind market. Roughly three different customer profiles could be extracted from the visited companies:

1. *The established developers* – experience on a number of completed projects, clear processes and strong expertise, no need for consulting, frame agreements on electrification exist. ABB can tender power products.
2. *Private equity funds* – still expanding business, also investors outside of Finland, thin organizations, less staff and expertise, need for technical consultancy, possibility for frame agreements. Warranties for the unproblematic O&M and the partnerships for whole life cycle in high value. Main competencies desired from ABB: SS, grid and HV line construction (Hagqvist, 2014). ABB could provide power systems, frame agreements and deeper partnership to the companies.
3. *Small developers* – many small projects, evident need of technical consultancy, clear trouble with the long and expensive permitting, and heightened risk of never

entering the construction phase. ABB should not get too heavily involved in all the smaller “risky” projects.

It is good to recognise the potential of different clients, and this sampling suggests that the private equity funds would have the most potential. The established developers are the ones with greatest revenues and biggest wind parks, so actions should be taken to market ABB’s rethought approach again. The small developers will have massive set-backs throughout the tedious permitting process, and only a negligible fraction of these endeavours will succeed in building few turbines here and there. Of course, ABB can offer products when the developer reaches construction phase, but extensive involvement before can be considered a waste of time. This statement is also based on the relatively small scale of the projects carried out by “small developers”

7 Life cycle service

The clearest conclusion that could be made from this study is the unwanted distance between service offering and the PS substation products. Even though greatly valued by the customer, ABB has not been able to include the life cycle service in their everyday actions. Section 6.7 listed some of the situations were ABB could have won a stronger position with already existing services. This is something that has been suggested in discussions for some time already (Kärnä, 2014), but more work is needed to bring closer the separated ABB units.

Spare part transformer already exists in the service department, the information has just not reached the customers. This is something that the thesis suggests to look into as clear interest already exists from the clients. Obviously the practicalities and business method have to be considered first and the technical compatibility of the transformers needs to be confirmed. The transformer is a component that regularly needs maintenance so the transformer maintenance department will always have the spare component. To have uniform ABB Wind Power products would strongly compliment with this idea. This development area is also recognised by ABB, and it seems that the reason why the implementation has delayed is that the transformer maintenance is a service provided by ABB PP (Muhonen and Välimaa, 2014).

It was repeated in customer comments that the taking care of the maintenance of the ABB substation should not be the customer’s problem (Hagqvist, 2014). The developers also stated that they would prefer to sign the maintenance for the park when the contract for the delivery is signed. The wind turbine manufacturers always offer 12-15 years of O&M with insurance, and the developers are eager to include this part in the deal. It seems that the transition from construction phase to the O&M phase does not work optimally in ABB PS (Alkula, 2014).

Another aspect that would need a closer look is that ABB also does have similar services in pre-engineering and maintenance offered by PS Consulting outside of Finland. This function is not utilised at the moment (Kärnä, 2014). Also the wireless control solutions should be included in the discussion more often. This is a segment that has not been fully utilised until this point (Konttinen, 2014).

The ABB strategic decisions and marketing material have a clear focus on life cycle services (Kärnä, 2014), but it seems that these intentions are not transferred to the negotiation table with the developer. All the services already exists and some of them are already even productised, but the distance between different divisions seems still prominent and the “One ABB” thinking still needs actions to be fully in practice. These challenges are also recognised by the PS department (Muhonen and Välimaa, 2014).

8 Conclusion

This thesis was set to discover and describe the possible “blind spots” in the communication between ABB and the customer. Mapping out the wind developer’s techno-economic process was an efficient way to find out issues where the customer saw room for improvement on ABB’s behalf. There are aspects where ABB could meet customer’s needs better especially in maintenance and pre-engineering through deeper involvement and use of already existing resources.

The most occurring theme in the material gathered was the clear separation of the well-defined substation delivery and other wind power offering, such as maintenance or optimization packages. The customers state that an approach taking the full responsibility of the complete life cycle of the grid connection would be ideal. The most demonstrative “blind spot” found was when several customers suggested a spare transformer pool that they would be highly interested in participating. It was found out later that such service already exists.

One of the goals was also to provide an optimal approach to the market from ABB’s perspective. For this purpose, a thought-provoking ABB WIND Substation concept was designed. It comments many of the original questions as well as brings new ideas to the discussion. Productised service packages with standardised ABB Wind Products and designated ABB Wind personnel are in the core of the model. More resources would need to be allocated to drive these changes as there is clear demand for a more complete ABB offering.

This eye-opening exploration has shown what a great potential ABB has in the wind market genuinely within its reach. Wind power will keep on growing in Finland, and with more co-operation, urge to improve and efficient use of all resources ABB could provide the truly comprehensive life cycle solutions for the blooming market.

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10 Appendix 1