

Service and Maintenance

- Lillgrund Offshore Wind Farm

Lillgrund Pilot Project

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PREFACE

Vattenfall's Lillgrund project has been granted financial support from the Swedish Energy Agency and Vattenfall will therefore report and publish experiences and lessons learned from the project. This report is compiled in a series of open reports describing the experiences gained from the different aspects of the Lillgrund Wind Farm project, for example construction, installation, operation as well as environmental, public acceptance and legal issues.

The majority of the report authors have been directly involved in the Lillgrund project implementation. The reports have been reviewed and commented by a reference group consisting of the Vattenfall representatives Sven-Erik Thor (chairman), Ingegerd Bills, Jan Norling, Göran Loman, Jimmy Hansson and Thomas Davy.

The experiences from the Lillgrund project have been presented at two seminars held in Malmö (4th of June 2008 and 3rd of June 2009). In addition to those, Vattenfall has presented various topics from the Lillgrund project at different wind energy conferences in Sweden and throughout Europe.

All reports are available on www.vattenfall.se/lillgrund. In addition to these background reports, a summary book has been published in Swedish in June 2009. An English version of the book is foreseen and is due late 2009. The Lillgrund book can be obtained by contacting Sven-Erik Thor at sven-erik.thor@vattenfall.com.

Although the Lillgrund reports may tend to focus on problems and challenges, one should bear in mind that, as a whole, the planning and execution of the Lillgrund project has been a great success. The project was delivered on time and within budget and has, since December 2007, been providing 60 000 households with their yearly electricity demand.

Sven-Erik Thor,
Project Sponsor, Vattenfall Vindkraft AB
September 2009

DISCLAIMER

Information in this report may be used under the conditions that the following reference is used: "This information was obtained from the Lillgrund Wind Farm, owned and operated by Vattenfall." The views and judgment expressed in this report are those of the author(s) and do not necessarily reflect those of the Swedish Energy Agency or of Vattenfall.

Service and Maintenance

ABSTRACT

This report aims to provide information of, and experiences from, service and maintenance of Lillgrund Offshore Wind Farm.

The report deals with operation and maintenance (O&M) during construction, commissioning and the first three months of operation. Focus has been to describe the O&M organization and cooperation between Vattenfall and Siemens. Experiences have been collected by interviews with representatives from Siemens and Vattenfall.

The O&M strategy defined by Lillgrund's service and maintenance contract are based on a gradual take over of O&M. Siemens will be responsible for maintenance of Lillgrund during the first five years. During this five-year period, Vattenfall will build up its own maintenance organization for Lillgrund. The first three years, Vattenfall's technicians are supposed to form 30 % of the total number of maintenance technicians. The fourth and fifth year, the corresponding amount should be 50 %.

During daytime, Lillgrund is operated locally. During nights and weekends, it is operated remotely by Vattenfall's operating centre in Esbjerg.

The major O&M experience from Lillgrund is the need for good administrative and technical information systems. These systems should be implemented as soon as possible because of the large amounts of documentation that are created during the commissioning phase. The technical information systems must be able to present historic data of measurements in order to see trends and analyse faults.

SAMMANFATTNING

Denna rapport syftar till att ge information om, och erfarenheter från, service och underhåll på Lillgrund.

Föreliggande rapport beskriver drift och underhåll (DoU) under byggnation, driftsättning och de tre första månadernas drift vid vindkraftparken Lillgrund. Fokus för rapporten har legat på att beskriva DoU-organisationen och samarbetet mellan Vattenfall och Siemens. Vidare så redovisas erfarenheter inom DoU vilka insamlats genom intervjuer med representanter för Vattenfall respektive Siemens.

Den DoU-strategi som är beskriven i Lillgrunds underhållskontrakt är baserad på att Vattenfall successivt tar över ansvaret för DoU. Under de första fem åren kommer underhållet att ledas av Siemens och under denna tid så skall Vattenfall bygga upp sin egen DoU-organization. Under de tre första åren skall andelen tekniker anställda av Vattenfall utgöra 30 % av det totala antalet tekniker. Under år fyra och fem så skall motsvarande siffra vara 50 %.

Under dagtid kommer Lillgrund driftövervakas lokalt från Klagshamn och under nätter och helger kommer driftövervakningen att ske vid Vattenfalls driftcentral i Esbjerg.

De främsta erfarenheterna inom DoU från Lillgrund är behovet av väl fungerande administrativa och tekniska informationssystem. Dessa system skall implementeras så snart som möjligt då stora mängder av dokumentation produceras under drifttagningsfasen. De tekniska informationssystemen måste ha förmågan att presentera historiska mätdata för att på så vis se trender och analysera fel.

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LIST OF ABBREVIATIONS

ESA	Elsäkerhetsanvisningar (Electric safety instructions)
DoU	Drift och Underhåll (Eng. Operation and maintenance)
HSE	Occupational Health and Safety and Environment
O&M	Operation (service) and Maintenance
SCADA	Supervisory Control and Data Acquisition
WPS	Wind Power Supervisor
WTC	Wind Turbine Controller
WTG	Wind Turbine Generator
SAP PM	Plant Maintenance module in SAP

GLOSSARY AND DEFINITIONS

Internal electric network: The inter array cables, transformer platform and transmission cable to shore.

Lillgrund Elnät AB: Electric network company operating the transformer platform, internal 33 kV cable network, and 145 kV cable to E.ON's station in Bunkeflo.

Siemens: In this report, "Siemens" is used for Siemens Wind Power unless other stated.

Vattenfall: In this report, "Vattenfall" is used for Vattenfall Vindkraft AB

SAP: (System Application Products), German software company developing business information systems

1 INTRODUCTION

This chapter aims to give a general introduction to operation, service and maintenance (O&M) of offshore wind farms and to provide background information of the O&M at Lillgrund.

1.1 Lillgrund wind farm



Figure 1 Location of Lillgrund wind farm

Lillgrund wind farm consists of 48 wind turbines with a total capacity of 110 MW. The wind farm is located in Öresund, 7 km from the Swedish shore.

Table 1 Description of wind turbines at Lillgrund

Number of wind turbines:	48
Wind turbine:	SWT 2,3 MW (mk2)
Rotor diameter :	93 meter
Hub height:	68 meter
Type of foundation:	Gravity

Siemens Windpower and Pihl-Hochtief Joint Venture delivered Lillgrund wind farm. Pihl-Hochtief delivered the foundations and Siemens delivered all equipment related to the wind turbines and electric system.

Construction started in 2006 and the wind farm was commissioned in late 2007. The expected energy production is 0,33 TWh electricity per year, which corresponds to the electricity demand of more than 60 000 households.

1.2 Purpose of report

The purpose of this report is to describe the operation and maintenance organization, methods used at Lillgrund wind farm, as well as the experiences gained. Further on, factors that are of special importance for service and maintenance of offshore wind power are discussed.

1.3 Background

Service and maintenance of a wind farm are closely related to how the wind farm is operated. This close relationship makes it difficult to describe service and maintenance without describing the operation of the wind farm. Therefore, description and experiences from operation have been added to this report.

Within Vattenfall, extensive knowledge is found on operation, service and maintenance of offshore wind farms. This has been an advantage that few other companies have. Many companies have knowledge on O&M within thermal-, nuclear- and hydropower production. This knowledge is however not directly applicable to offshore wind farms because of the special circumstances that the O&M is being conducted offshore.

1.4 Previous work and contribution of the report

Previous reports on operation, service and maintenance have mainly focused on costs [1],[2] statistical data [3],[4],[5] and condition monitoring [6],[7]. Practical experiences and organizational issues have not been found in previous work. Therefore, this report contributes to previous reports with practical aspects that are of importance for future O&M contracts and planning of O&M organizations.

1.5 Legislation, standards and guidelines for O&M

Operation and maintenance routines take years to develop. For this reason it is a natural thing that a new industry, such as wind power, has not yet developed its own routines and general guidelines as much as hydro power and nuclear power.

The standardised regulations on operation and maintenance of wind turbines are found in IEC 61400-1 [8] and in DNV-OS-J101 [9]. The IEC-standard regulations pertain to the manufacturer. These demands describe only the manufacturers obligations and don't give any guidance to the operator of WTGs. The DNV-standard lists items that should be covered by inspections and the inspection intervals.

Regarding occupational health and safety, wind turbines are seen as machines and are therefore regulated by the European Council's directive relating to machinery [9]. In addition to this, country specific legislation will apply. In Sweden, the Swedish work environment authority (Arbetsmiljöverket) issues regulations within occupational health and safety.

1.6 Best practice and transfer of knowledge

Vattenfall's O&M organization at Lillgrund wind farm has been created with people with limited offshore wind power experience. This creates a need to acquire knowledge from other wind farms and from other industries.

In order to improve an organization's way of working, or to rapidly build up routines, an assessment of best practice can be useful. Best practice is a management term that implies that with proper processes, a desired outcome can be delivered with fewer problems and fewer unforeseen complications. Best practices can also be defined as the most efficient (least amount of effort) and effective (best results) way of accomplishing a task. How this has been addressed within the Lillgrund project is described in section 3.6.

1.7 Introduction to operation and maintenance at Lillgrund

The operation and maintenance organization at Lillgrund consists of a mixed organization with a site manager from Vattenfall, a site leader from Siemens, a planning engineer from Vattenfall, a stock keeper from Siemens and technicians from both Vattenfall and Siemens.

The O&M strategy for Lillgrund is based on a gradual increase of Vattenfall's O&M organization. The first five years of operation, Siemens is responsible for service and maintenance. During this period, technicians from Siemens and Vattenfall will work together. Gradually, Vattenfall will recruit more technicians and after the first five years, Vattenfall's O&M organization will be fully grown. The organization will then consist of five technicians, the planning engineer and the site manager.

Lillgrund is supposed to be operated locally from Klagshamn during daytime and from Vattenfall's operation centre in Esbjerg during nights and weekends.

1.8 Localisation of the O&M organization

During construction of Lillgrund wind farm, Siemens and Vattenfall had their site offices in Dragör, and respectively, Klagshamn. The temporary site offices will be replaced by an O&M building placed in Klagshamn, which was completed during the summer 2008. Until the O&M building was completed, the service technicians were based in Dragör.

Figure 2 shows Dragør and Klagshamn on each side of the Sound separating Denmark and Sweden.



Figure 2 Map showing Klagshamn and Dragør

2 METHOD OF APPROACH

This chapter describes the method used to collect data and information on operation, service and maintenance (O&M) at Lillgrund. The two main sources for information have been documents and interviews with representatives from Vattenfall and Siemens. The most important document has been Lillgrund service and maintenance contract.

2.1 Guidelines for O&M evaluation

To improve the structure of the study, several guidelines for O&M evaluation have been studied. Any guidelines for evaluation of O&M for wind farms have not been found and therefore, O&M guidelines from other power plants have been used [11],[12]. Within nuclear power, several guidelines have been found with a general structure that can be applied to almost all types of O&M. This study has used two guidelines for O&M:

- IEEE Guide for the evaluation human-system performance in nuclear power generating station [13]
- SKI, Inspection handbook – Maintenance [14]

The O&M guidelines are differently useful for different data collection methods. In this report, the use of these guidelines has mainly been used to form interview questions.

2.2 Data sources

Different sources of data provide different type of information. To give a good picture of the O&M organization at Lillgrund, several sources have been used. This report divides information into three categories:

- **Documents**
Documents can be divided into background information and specific Lillgrund information. The two most important documents studied are Lillgrund service and maintenance contract [15] and Lillgrund HSE plan [16].
- **Interviews**
Interviews have been conducted with representatives from Vattenfall and Siemens.
- **Participating observation**

This report uses interviews and documents as primary sources of information.

2.3 Literature review

The literature study has focused on two main topics, O&M in general and O&M at Lillgrund. The general part includes information on general strategies for O&M for offshore wind farms, and to compare with O&M at conventional power plants. Further on, the literature study provided information on reliability centred maintenance (RCM), that have been used when the interview questions have been formulated.

Information regarding O&M at Lillgrund has mainly been based on the service and maintenance contract for Lillgrund [15].

Table 2 Layout of the literature review and connection to interviews

Background information		
<ul style="list-style-type: none"> ○ General review on operation, service and maintenance for offshore wind farms ○ Previous studies ○ General principles, such as reliability centred maintenance and best practice 		
Focus areas – inputs to interviews		
O&M for offshore wind farms: <ul style="list-style-type: none"> ○ Transportations ○ Failures and priorities ○ Methods and strategy 	Best practice: <ul style="list-style-type: none"> ○ Wind power ○ Conventional power plants ○ Other industry 	O&M at Lillgrund: <ul style="list-style-type: none"> ○ Methods ○ Contract ○ Organization ○ HSE
Results from interviews		
<ul style="list-style-type: none"> ○ Organizational structures for O&M for offshore wind farms. ○ Technical- and non-technical experiences. 		

2.4 Interviews

Interviews have been conducted with Jimmy Hansson, Vattenfall's site manager at Lillgrund, and with Leo Jensen, Siemens site leader at Lillgrund. These interviews have been recorded and analysed afterwards. The dates and locations of these interviews were Malmö, conducted February 11, 2008, and Dragör on February 25, 2008. The durations of the two interviews were 3 and 2 hours, respectively.

The two interviews have both been conducted with a fixed set of questions, which were the same for both interviews. In addition to the fixed questions, sets of discussions topics have been selected for each interview.

The set of fixed interview questions have been influenced by the Swedish Nuclear power Inspections (Sw. Statens Kärnkraftsinspektion) manual for operation and maintenance [14]. The inspection manual divides operation and maintenance in to five categories, which have been used to organise the two interviews:

- Personnel
- Material
- Coordination
- Tools
- Information

The discussion topics have mainly focused on specific experiences from Lillgrund. Leo Jensen at Siemens has also provided experiences from other wind farms.

3 PERSONNEL, TRAINING AND TRANSFER OF KNOWLEDGE

This chapter describes the need for education and training for personnel within offshore wind power. Further on, the process of building up competence within the O&M organization is described. Finally, the possibility to transfer knowledge from other wind farms is described.

3.1 Site manager, technicians, planning engineer and stock keeper

Four categories of personnel have been identified as important in order to create an efficient organization for O&M for offshore wind farms. The early planning for O&M for Lillgrund contained only two of these categories. Today, three categories are present within Vattenfall's organization at Lillgrund.

- **Site manager**
This person is responsible for the personnel and the overall operation of the wind farm. This includes issues related to quality- and environmental management as well occupational health, safety and environment.
- **Planning engineer**
This person is responsible for planning and coordination of the technicians work. This person is also the deputy site manager.
- **Stock keeper**
The stock keeper handles the logistics of spare parts and supports the technicians. This function is currently found in Siemens's organization at Lillgrund.
- **Technicians**
At Lillgrund, three two-person teams of technicians are supposed to work with service and maintenance in the wind farm. The teams are rotated so that two of the three teams are working at the same time within the wind farm.

The different categories within Vattenfall's O&M organization at Lillgrund is further described in section 4.1. In addition to the categories described above, several external functions are needed, e.g. sea transportation personnel. It is preferred to contract external companies to fill these functions.

3.2 Site manager / service leader

The positions responsible for the O&M work are the site manager and service leader. Vattenfall uses the term "site manager" and Siemens uses the term "site leader". The responsibility of coordination of the O&M lies with Vattenfall.

3.3 Planning engineer

The planning engineer is responsible for operation surveillance of the wind farm. This includes prioritisation of alarms and the issuance of work orders. In addition to planning, the planning engineer will support the technicians with technical matters.

The planning engineer is trained together with the technicians and has been working closely with the technicians during the commissioning phase.

3.4 Stock keeper

The stock keeper for Lillgrund is a position used currently in Siemens' organization. This person is responsible for the logistics of spare parts, special tools and material used by the technicians. He is also supporting Siemens' service manager at Lillgrund.

Using the list of next days planned work; the stock keeper prepares a container with necessary spare parts and tools. The following morning, the container is complemented with tools and material needed to serve and restart wind turbines that have been stopped during the night. After that, the container is loaded to the service boat Lillgrund and the technicians have all the parts and tools they will need during the day.

Experiences gained:

Having one person that is responsible for preparing the spare parts and special tools is important in order to maximise the technicians time within the wind farm. Thus far, the stock keeper has been working approximately 50 % of the time with logistics and 50 % of the time supporting the service manager.

3.5 Technicians

3.5.1 Technicians – suitable background

The technicians selected for working at the offshore wind farms must be used to working individually or in small teams without the support commonly available in conventional power plants. Further more, they have to be skilled in problem solving.

Technicians best fit to fulfil these requirements have for example a background as travelling service and installation technicians. This group is used to work remotely and to solve problems that arise on their own.

Technicians who have been working with maintenance in the manufacturing industry or at conventional power plants tend to have been working in large maintenance departments. In these large scale departments, it is common to be specialised within a certain area of competence. For offshore wind power, it is advantageous to have a broader knowledge and experience than a specialised knowledge, since each team of technicians are built up of one mechanic and one electrician. Therefore, both technicians must have a good understanding of the other technician's area of responsibility.

3.5.2 Technicians employed at Lillgrund

All three technicians employed at Lillgrund have been very well qualified, with two having a higher education background. On one hand, this creates a need to provide them with interesting work in order to keep them at Lillgrund. On the other hand it provides a strong basis from which the organization's competence can be built up. In the future, technicians from one of the two-year courses, held in Varberg and Strömsund can hopefully be recruited.

3.6 Transfer of competence from other wind farms

The idea of Lillgrund's technicians being able to acquire knowledge from other wind farms may be possible by allowing the technicians at Lillgrund to work at these other offshore wind farms. Technicians from Lillgrund have been able to work at the Horns Rev, Utgrunden and Yttre Stengrund wind farms.

The possibility to let technicians from other wind farms to work at Lillgrund is much more difficult. Because Siemens has the responsibility for service and maintenance at Lillgrund, all the technicians working at Lillgrund must fulfil Vattenfall's, as well as Siemens' demands for training. Siemens demands that all technicians working at Lillgrund pass Siemens's own training program for technicians.

3.7 General training for technicians

The training can be separated into two categories. The first category is general training needed for work offshore. This category includes; first aid, sea survival training, fire fighting, climbing and rescue. Sea survival training and climbing training is compulsory to be allowed work in any of Vattenfall's offshore wind farms.

The second category includes specific training for each wind farm. This includes training on the specific type of turbine, site introduction and lift training. A summary of requirements for work at Lillgrund is listed in Table 3. This table lists the training required by the HSE-plan for Lillgrund.

Table 3 Training requirements for work at Lillgrund wind farm

Type of work:	Site Introduction	First aid course	Sea survival and transfer training	Fire course	Climbing and rescue training	Tower lift training
Site access:	X					
Access foundation:	X	X	X			
Transfer vessel:	X	X	X			
Access foundation, switch gear energized:	X	X	X	X		
Access tower, nacelle and hub:	X	X	X	X	X	X
Any hot work:				X		
Course validity:		3 years	3 years	3 years	3 years	

Experiences gained:

In order to ensure that all personnel have sufficient training, the wind turbine supplier may not accept training given by other suppliers. For this reason, it is important to come to an agreement with a list of courses that are acceptable by both the purchaser and the supplier.

3.8 Specific training – wind turbines

The training that Vattenfall’s technicians are given for the specific type of wind turbine found at Lillgrund consists of both theory and practice. The theoretical parts are given at Siemens’s central training centre. The first portion of the theoretical training is two weeks long and provides basic knowledge about wind turbine. At completion of the first theory course, Vattenfall’s technician trainees’ work closely with experienced technicians from Siemens. The second theory portion of the training focuses on the specific type of wind turbine used at Lillgrund.

Experiences gained:

All suppliers of wind turbines are growing rapidly. This implies a risk that the supplier’s courses will be fully booked. Therefore, it is important to define (in contract) the number of technicians that should be provided training each year.

3.9 Training to fulfil legislations and regulations

Even if legislation and regulations are similar in several countries, differences can lie in the industries’ own practices to meet the requirements. At Lillgrund, this conflict has been an

issue in regards to the electrical equipment. In Sweden, Vattenfall's production units are working according to a system called ESA. ESA provides a method for working with electrical equipment that is in accordance to Swedish legislations and regulations. In Denmark, the corresponding system is called LAUS.

Because Vattenfall demand that ESA should be used at all power production units, Siemens has to give their personnel training in ESA. Similarly, Siemens demands that all technicians working under their management should practice LAUS. This creates a situation where both systems must be practiced.

3.10 Level of competencies

Siemens have defined a system where the technicians are divided into competence levels. Similarly, the wind turbines are divided into zones. A new technician is assigned to work in a specific zone within the wind turbine. As the technician becomes more experienced he will be allowed to work more freely within the wind turbines. The two most important levels are:

- **Level 7**
A technician allowed to work freely within the wind turbine.
- **Lead technician**
A technician with long experience of O&M of the specific type of wind turbine and who is able to lead the work.

4 ORGANIZATIONAL STRUCTURE AND RESPONSIBILITIES

When the contract for Lillgrund wind farm was settled between Siemens and Vattenfall, a strategic decision was made to have a gradual take over of service and maintenance. During a period of five year, technicians from Siemens and Vattenfall are working together. This affects how the organization is built up and defines the responsibilities of Vattenfall and Siemens.

4.1 Vattenfall's organization at Lillgrund

Vattenfall's O&M organization at Lillgrund has a gradual expansion plan. In the beginning, five people were employed by Vattenfall at Lillgrund. Of these five, there were three technicians, one site manager and one planning engineer. When the responsibility for service and maintenance is transferred from Siemens to Vattenfall, a total of seven technicians are planned. Despite the fact that the turbines and the electrical grid have different owners, the O&M will be done by the same technicians.

4.1.1 Site manager

The role as site manager is to lead the work conducted within the wind farm. This has since been revised and the role as site manager is now more administrative. The site manager is responsible for creating routines for the work including standardised work orders and checklists for inspection rounds. The site manager is also responsible for the HSE at Lillgrund.

4.1.2 Planning engineer

The planning engineer position was not included in the early plans for O&M at Lillgrund. In early 2007, the need for a planning engineer arose. The planning engineer is responsible for the plant supervision and receives alarms and error messages from the control system. Based on the character of the alarms, he prioritises the work and coordinates the technicians accordingly.

The planning engineer was employed at the same time as the technicians were and has had the same training as the technicians. Because of this, the planning engineer can work within the technician's role, if necessary. Further more, the planning engineer acts as the deputy site manager, if the site manager is absent.

During the time Siemens is responsible for the service and maintenance, the planning engineer will also be coordinating external contractors for larger projects within the wind farm.

4.1.3 Technicians

The three technicians that were employed in 2007 will be working together with technicians from Siemens during the first five years. Because these three technicians will build up a very good working knowledge of the wind farm, it is the hope that they will move on to work as team leaders in the future, when more technicians are taken on in Vattenfall's O&M organization.

4.2 Development of the operation, service and maintenance organization

The development of the operation, service and maintenance (O&M) organization at Lillgrund has been based on experiences from other wind farms. The setup has been adjusted as new experiences are gained. Table 4 shows the organizational structure for Lillgrund and how it could have been organized according to today's experiences.

Table 4 Vattenfall's operation, service and maintenance (O&M) organization at Lillgrund and preferred O&M organization according to today's experiences, technicians from Siemens not included

Lillgrund project/operation phase:	Vattenfall's O&M organization at Lillgrund:	Preferred O&M organization based on today's experiences:
Procurement / contracting	0-1 person (appointed)	1 person
Installation	0-1 persons	1 person (site manager)
Commissioning	5 persons	5 persons (site manager, operation engineer, and 3 technicians*)
Take-over	5 persons	5 persons*
Operation first 5 years	5-9 persons	5-9 persons*
Operation	9 persons	9-11** persons (site manager, operation engineer, and 7 technicians)
Decommissioning	Unknown	unknown

* Based on a set-up with technicians from the wind turbine supplier.

** Siemens's representative suggests the higher number.

4.3 Recruitment of O&M personnel

Both Vattenfall and Siemens have been recruiting personnel for operation, service and maintenance to Lillgrund. Vattenfall was first to start the recruitment process in late 2006 by recruiting the site manager. Technicians and a planning engineer were employed during late summer 2007, after starting the recruitment process in spring 2007.

When Vattenfall recruited technicians for Lillgrund, job advertisements were circulated through several newspapers. These advertisements for technicians were general in what prerequisites were required of the applicant for the job, but did explain the work itself and work environment in detail.

Siemens started their recruitment process for technicians a few months after Vattenfall. When Siemens advertised the openings, they had very similar requirements as Vattenfall. It resulted in several applicants applying to both the Vattenfall and Siemens postings.

4.4 Responsibilities

The responsibilities and obligations of Vattenfall and Siemens are defined by the service and maintenance contract [15].

5 ELECTRIC SYSTEM

The service and maintenance organization is affected by the legislative demands related to the electrical system. This section describes how this affects the service and maintenance organization at Lillgrund wind farm.

5.1 Description of Lillgrund electric network

Lillgrund wind farms are built up of 48 wind turbines connected to a transformer platform using five 33 kV radial cables. The transformer platform consists of a 33/145 kV transformer, switchgear and control equipment. The transformer platform is connected to E.ON's substation in Bunkeflo by a 7 km long sea cable and a 2 km long land cable.

The layout of the electric network at Lillgrund is seen in Figure 3. The different colours indicate areas of responsibilities for E.ON (red), Lillgrund elnät AB (blue) and Vattenfall Vindkraft AB (green).

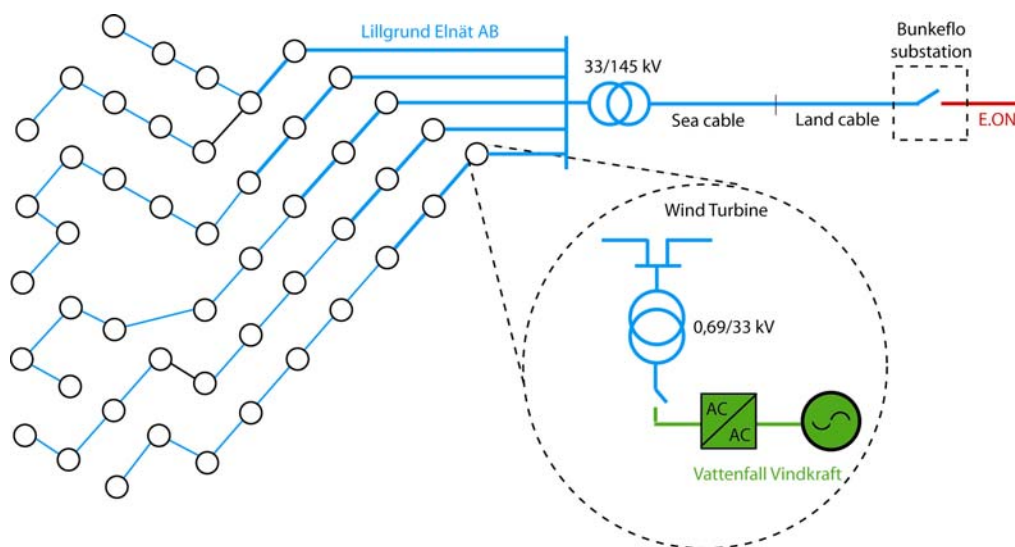


Figure 3 Lillgrund electric network

5.2 Ownership within Lillgrund

The Swedish electricity law [17] prohibits (Swedish electricity law (1997:857), 3rd Chapter, § 1a) production and transmission of electric power within the same company. In order to comply with the regulative demands, the electric network at Lillgrund is organized into:

- Vattenfall Vindkraft AB, Owner and operator of the wind turbine generators.
- Lillgrund Elnät AB, A subsidiary company to Vattenfall Vindkraft AB. Owner and operator the electric network and transformer platform.

The areas of responsibility for each company are marked with different colours in Figure 3. However, technicians working at Lillgrund are working with both the electrical system owned by Lillgrund Elnät AB and the wind turbines owned by Vattenfall Vindkraft AB.

The dividing line for equipment owned by Lillgrund Elnät AB and Vattenfall Vindkraft AB are the breakers on the low voltage side (0,69 kV) within the wind turbines. In Bunkeflo substation, the 145 kV breaker is the dividing line against E.ON.

5.3 Senior authorised person (Eldriftsansvarig)

The Swedish legislation demands that a senior authorised person should be appointed for the operation of electric networks. Vattenfall's legal advisors define the term "senior authorised person" as "a qualified individual for the purpose of being nominated as a senior authorised person for the operation and monitoring of the network facilities".

During commissioning, a senior authorised person was appointed by Vattenfall to work under Siemens's management. The need to have the senior authorised person working on site is mainly during construction and commissioning. Thereafter, the senior authorised person can be outsourced to an external company. For example, Vattenfall's offshore wind farms Utgrunden and Yttre Stengrund have outsourced the responsibility of operation of their electrical networks to Elektro Sandberg.

6 TRANSPORTATION

This chapter aims to describe the need for transportation and special equipment at Lillgrund including experiences gained so far. Focus is not only on operation and maintenance alone, but the general use of boats and special equipment.

6.1 Need for sea transportation

The need for sea transportations changes during construction, commissioning and operation. During construction and commissioning the need for sea transportation is bigger than under operation. Table 5 shows the need for personnel transportation boats at Lillgrund.

Table 5 List of personnel transportation boats during construction, commissioning and operation

Number of personnel transportation boats:	Siemens:	Vattenfall:
Construction:	3	1
Commissioning:	2	1
Operation:	1	

Experiences gained:

The O&M personnel transportation boats planned to be used during operation should be ordered early in order to be used under construction and commissioning.

6.2 Boats

The choice of boat type and design is affected by the sea conditions and how the boat will be used. Boats suitable for personnel transportation within offshore wind farms are usually designed to carry 12 or 24 persons. At Lillgrund, Siemens has chosen to use the 12 person boats.

Twelve-person boats minimise the time for transportations. It takes approximately 35 minutes to sail from Dragör to Lillgrund and another 10-15 minutes between each wind turbine. If a 12-person boat is used to transport 6 teams of technicians to the wind farm, it will take approximately 1 hour to leave the teams at different wind turbine locations once arriving to the wind farm. Using a 24-person boat would be twice as much and thereby decrease the time that each technician will be able to work with O&M during the day. During normal operation, only two teams will be working within the wind farm. However, this can be an issue during commissioning and major retrofits.

Further on, the choice of boat design is depending on the sea characteristics of the site. The amplitude and length of the sea waves are important factors for the design of boats. To decrease the boats motions caused by waves, the length of the boat should be longer than the wavelength of sea waves. Therefore, boats used in the north sea will be longer than boats used in the Baltic sea where the wave length are shorter.

Experiences gained:

The capability to operate in high wind and waves are very important to be able to maximise the amount of hours of work each week.

6.2.1 m/s Thjalfe

The inspection boat used by Vattenfall during construction and commissioning was the boat m/s Thjalfe. Thjalfe is of conventional monohull construction and was planned to be used until December 2007. However, the contract was extended until June 2008 because of the increased need to transport people between the Siemens site office in Dragör and Vattenfall's site office in Klagshamn.



Figure 4 Vattenfall's inspection boat m/s Thjalfe

6.2.2 m/s Lillgrund

The boat m/s Lillgrund is specially designed for Lillgrund wind farm. The chosen design is a catamaran for 12 persons with a capacity to carry one container onboard. Figure 5 shows m/s Lillgrund from side. The crane seen on deck is used to lift equipment onto wind turbine foundations. Between the superstructure and the crane, a container can be placed. The possibility to carry a container allows an easy administration of parts and material used by the technicians. The container can be loaded and unloaded using m/s Lillgrund's crane.

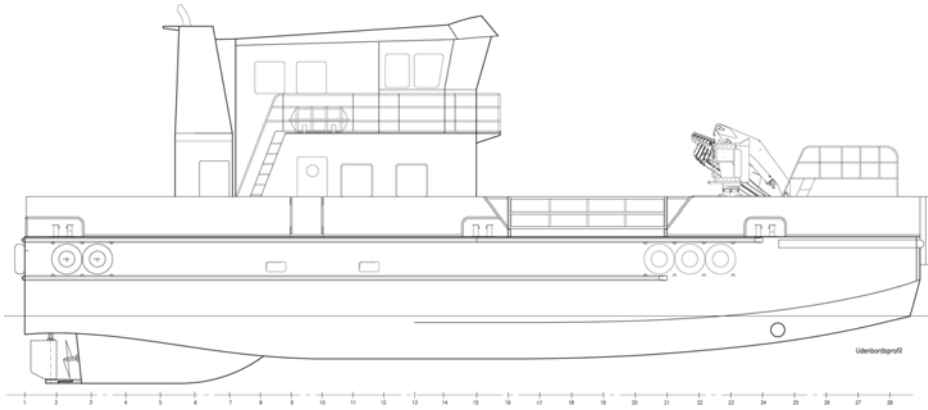


Figure 5 m/s Lillgrund from starboard side

The advantage of using a catamaran instead of a one-hull boat is the increased stability. This is an important factor when boarding a wind turbine or loading and unloading of equipment. The two-hull design increases the possibilities to form the bow to fit the form of the wind turbine foundations. Figure 6 shows the specially designed bow of m/s Lillgrund.



Figure 6 Photos showing m/s Lillgrund's specially designed bow

The crane onboard m/s Lillgrund facilitates an easy loading and unloading of equipment to the wind turbines. Figure 7 shows the crane from the superstructure during loading/unloading of equipment to a wind turbine.



Figure 7 Unloading of equipment from m/s Lillgrund

M/s Lillgrund has shown very good seaworthiness and can be used for all wind and wave conditions for which it is allowed to enter wind turbines.

Lessons learned:

Compared to the one-hull boats used at Lillgrund during construction and commissioning, m/s Lillgrund's design and features are much more stable in high waves.

7 OCCUPATIONAL HEALTH-, SAFETY AND ENVIRONMENT (HSE)

This chapter describes how occupational health, safety, and environment (HSE) is managed at Lillgrund. A large framework of regulations and legislation regulates HSE in general. These requirements have been the base for which the HSE plan for Lillgrund has been developed.

7.1 HSE management in general

The area of health-, safety-, and environmental management are constantly developing because of the increasing knowledge and awareness of HSE aspects. This demands a HSE management plan that constantly adapts the way in which the work is conducted.

7.2 Lillgrund HSE plan

The HSE plan for Lillgrund has been prepared by Siemens and approved by Vattenfall. The HSE plan describes the specific requirements for work conducted within Lillgrund wind farm. The different sections of Lillgrund's HSE are shortly described below.

- **Legal requirements**
This section describes legislations and regulations that have been considered.
- **Service organization and responsibilities**
This section describes the service organization and responsibilities of Vattenfall and Siemens.
- **Education and training**
There is no official industrial standard for the technical education and training of wind turbine technicians. To achieve a minimum level of competence, the HSE plan defines a number of training requirements that must be fulfilled. See Table 3 on page 11.
- **Risk assessment and work procedures**
Before the work can be undertaken, a risk assessment must be performed. All work instructions and safety methods are based on the risk assessment. This section also describes the system of written permits to work. Permits to work are used to control potentially dangerous operations.
- **Inspections and audits**
This section describes inspections and audits conducted by Siemens.
- **Environmental impact**
This section is formed as a guideline for environmental issues. The guideline provides the preventive measures to be followed in case of accidents and disposal of waste.
- **Health and safety rules**
This is the most extensive section. Instructions are given regarding marine activities and work activities combined with risk and risk limitations.

- **Emergency preparedness plan**
The purpose of the emergency preparedness plan is to ensure that swift and correct actions are taken following an emergency to help minimize personal injury and environmental damage. Special concerns are evacuation, helicopter rescue and sick leave.

7.3 Reporting of HSE information at Lillgrund

The reporting of HSE information at Lillgrund is regulated in the HSE plan for Lillgrund. Reporting is done both to Siemens and to Vattenfall. The reported information flow is illustrated in Figure 8.

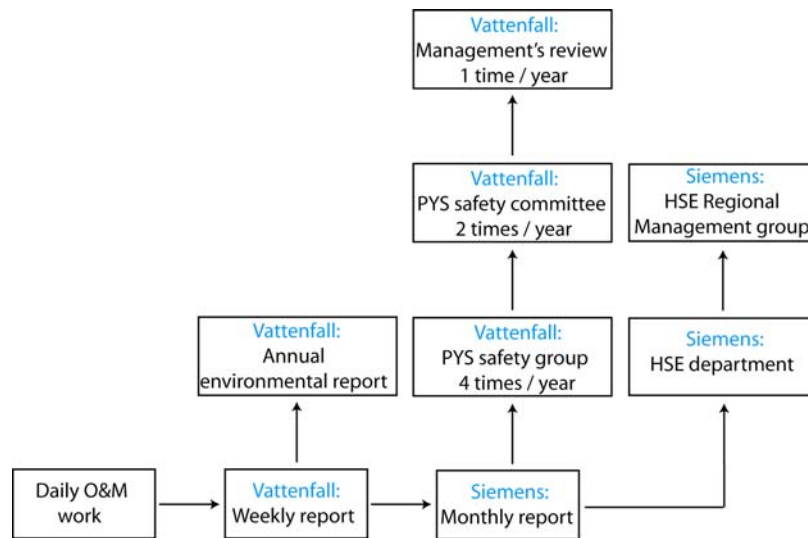


Figure 8 Reporting of HSE information

8 SUMMARY

This chapter provides a summary of the report and experiences gained.

This report has described the O&M organization at Lillgrund wind farm. Focus has been on organizational setup and cooperation between Siemens and Vattenfall.

The literature has been reviewed to identify O&M issues addressed in the interviews. These interviews were conducted individually with representatives from Vattenfall and Siemens. The documents that have been studied are mainly the service and maintenance contract for Lillgrund and the health, safety and environmental plan prepared for Lillgrund.

The service and maintenance organization at Lillgrund is a blend of personnel from both Vattenfall and Siemens. Vattenfall's O&M organization at Lillgrund consists of a site manager, a planning engineer and three technicians. Siemens's O&M organization at Lillgrund consists of a service leader, a stock keeper and technicians. The service and

maintenance work is conducted under Siemens's management and Vattenfall conducts the operation independent from Siemens.

The recruitment of O&M personnel started during the construction of Lillgrund. Vattenfall and Siemens started their recruitment of O&M personnel almost at the same time. The employed technicians have been given training for work offshore, as well as specialised training on the specific wind turbine technology used at Lillgrund.

The separate responsibilities of Vattenfall and Siemens are described by Lillgrund's service and maintenance contract. Siemens's service organization is responsible for the service during the first five years. During these years, Vattenfall's technicians are working under Siemens's management. Vattenfall manages the operation of Lillgrund from the beginning. During day-time, Lillgrund is operated from a local control centre and during nights and weekends, Lillgrund operates remotely from Vattenfall's operation centre in Esbjerg.

The information systems that are used at Lillgrund consists of technical and administrative information systems. The technical information systems are the wind farm SCADA and the electric network SCADA. No administrative information system is in place at Lillgrund. In the future, SAP r3 will be used in combination with a system of handheld PDAs.

The Swedish electricity law requires separate companies to run the production and transmission of electric energy. For this reason, a new company has been created to operate and own the cables and transformer platform. Another legislative demand is to have a senior authorised person responsible for the operation of the electric system.

The need for sea transportation within the wind farm varies between the construction, commissioning and operation phases. During the construction and commissioning phases, traditional monohull boats were used. The boat that has been appointed for personnel transportation during the operation is a specially designed catamaran.

The occupational health, safety, and environment plan (HSE plan) for Lillgrund has been created by Siemens and approved by Vattenfall. The HSE plan describes requirements that must be met to work within the wind farm. Examples of such requirements are the required training for different types of works.

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