SUND OG BÆLT

ANALYSES OF NEW ISLAND HARBOUR AT TÅRS

WIND TURBINES – ELECTRICAL INFRASTRUCTURE

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CONTENTS

1 Resumé (dansk)

Dette tekniske notat indeholder en indledende undersøgelse for installation af vindmøller ved Tårs Havn til opladning af elfærger. Det indeholder en vurdering af distributionsnetværket i begge ender af færgeforbindelsen, brugen af produceret vindenergi til opladning af færger, og kravene til tilslutning til det eksisterende 10 kV net.

To scenarier af antal færgeture er analyseret: 18 ture/dag fra hver havn (svarende til time drift) og 36 ture/dag fra hver havn (svarende til halvtimes drift), med de tilsvarende energibehov og forventet produktion fra vindmøllerne. Undersøgelsen overvejer også nødvendigheden af at importere elektricitet fra distributionsnetværket, med antagelse om en given andel.

Fremtidige aktiviteter skal inkludere verifikation af antagelser, engagement i dialog med elforsyningsselskaber (DSO'er), optimering af anlægsstørrelse og sikring af overholdelse af internationale og lokale standarder.

2 Summary

The document provides an initial study report on the installation of wind turbines at Tårs Harbour for charging ferries. It assesses the distribution network at both ends of the ferry link, the use of produced wind energy for ferry charging, and the requirements for connecting to the existing 10 kV grid.

Two scenarios are analysed for ferry trips: 18 trips/day and 36 trips/day, with respective energy needs and expected production from wind turbines. The study also considers the necessity of importing electricity from the distribution network, assuming a certain share.

Future tasks include verifying assumptions, engaging in dialogues with distribution system operators (DSOs), optimizing plant sizing, and ensuring compliance with international and local standards.

3 Definitions and Abbreviations

AEP	Annual Energy Production
BESS	Battery Energy Storage System
HV	High Voltage
HVSC	High-voltage shore connection
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
kV	Kilovolt
MV	Medium Voltage
RMU	Ring Main Unit
SLD	Single Line Diagram
WTG	Wind Turbine Generator

4 Introduction

This initial study report assesses the possibility of placing wind turbines onshore or nearshore close to the proposed new harbour at Tårs, excluding environmental and regulatory considerations.

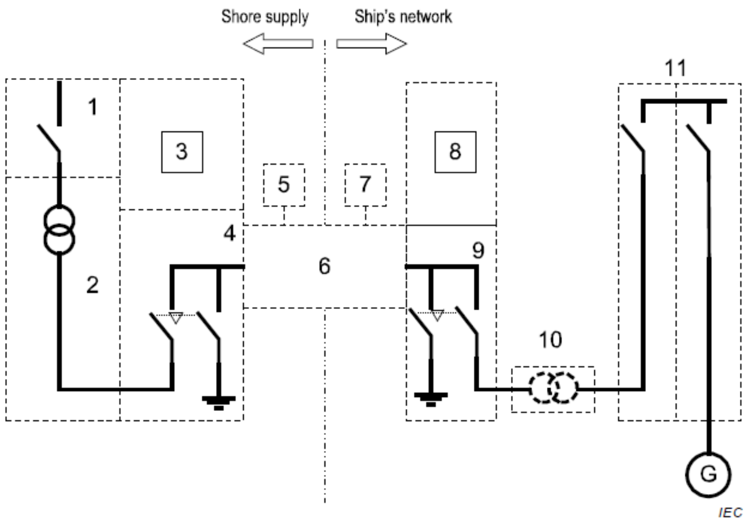
The report also addresses the following key questions:

- Where is the distribution network at both ends of the ferry link?
- Can the wind turbines that are to be installed provide sufficient energy to charge the ferries?
- What will be required at the harbour and for the connection to the existing 10 kV grid etc.?

To conduct high-level analysis and perform some calculations, battery size and some other electric ferry-related parameters were taken from the document 'Undersøgelse af fremskudt færgehavn ved Tårs - Elfærger', Reference [1]. Assumptions made for preparing the report on wind turbines are listed in Section 6 Assumptions.

International standards are very helpful in designing various systems. For this purpose, 'IEC/IEEE 80005-1 Utility connections in port - Part 1: High voltage shore connection (HVSC) systems - General requirements' can be utilized here. It describes high-voltage shore connection (HVSC) systems, onboard the ship and onshore, to supply the ship with electrical power from shore. This document is applicable to the design, installation and testing of HVSC systems, so it has an important role in the project. The design should be in accordance with this standard and the requirements need to be taken into consideration at all phases of the project.

Figure 1 illustrates a block diagram of a typical HVSC system arrangement, as outlined in IEC/IEEE 80005-1.



Key

1	Shore supply system	7	Control ship
2	Shore-side transformer	8	On-board protection relaying
3	Shore-side protection relaying	9	On-board shore connection switchboard
4	Shore-side circuit-breaker and earth switch	10	On-board transformer (where applicable)
5	Control shore	11	On-board receiving switchboard
6	Shore-to-ship connection and interface equipment		

Figure 1 Block diagram of a typical HVSC system arrangement from IEC/IEEE 80005-1

Similar to the block diagram from the standard, Figure 2 shows another example diagram displaying the connection between different electrical equipment.

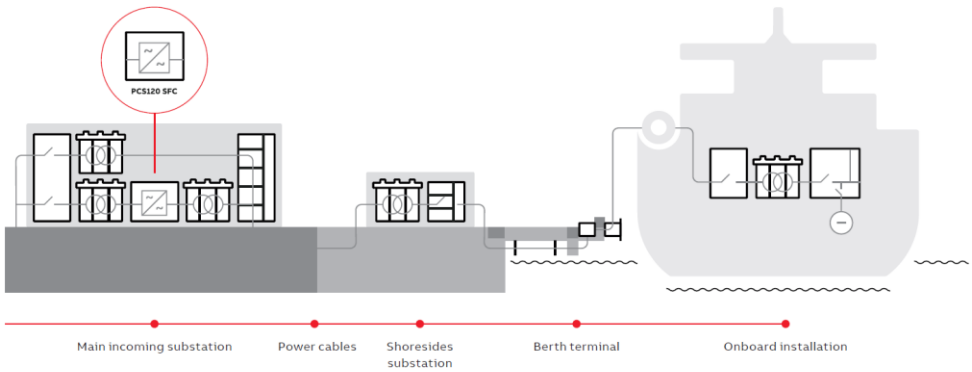


Figure 2 An example connection diagram between electrical equipment [Link]

5 Reference Documents

ID	*Document No*	*Title*
[1]	A258774-HAV-TEK-01	Undersøgelse af fremskudt færgehavn ved Tårs - Elfærger_ver1.0

6 Assumptions

Assumptions made for this report are listed below:

- Ferries will be charged at both ends/harbours.
- An assessment is made of the possibility of placing wind turbines close to the proposed new harbour at Tårs. In principle, a similar solution with wind turbines can be applied in Spodsbjerg.
- Two cases are considered for the number of trips assuming that the ferries are operating in the timeslot from 5:15 to 22:15 every day:
  - Hourly service: 18 trips per day, 365 days/year (this means that 18 ferries will be charged per day at the new harbour in Tårs)
  - ½ hourly service: 36 trips per day, 365 days/year (this means that 36 ferries will be charged per day at the new harbour in Tårs)
- One shore power feeder is considered for charging the ferries per harbour. If another feeder is needed, it can be added by using the same configuration. In case of multiple shore power feeders, it is assumed that only one feeder is energized at a time.
- The connected transformer in the shore power feeder will have a rating of 12 MVA.
- Ferries will operate at a frequency of 60 Hz.
- AC/DC converter is assumed to be on the ferries.
- Ferries are Ro-Ro passenger ships.
- Power for the facilities on site (heating, lighting, HVAC, sockets, etc.) will be provided by local power supply (230/400 V).
- Wind turbine variant V117-3.45 MW is considered as it is the one installed in the neighbouring wind farm, Sandby.
- Wind turbine capacity factor is assumed to be 25%.
- The plant will be grid-connected at the distribution system level.
- Importing electricity from the distribution network is allowed. In case it is not allowed to import any electricity, it might be very challenging to achieve full availability. There might be times when there is not enough wind and stored energy in batteries, and increasing the battery size could significantly impact the cost.

- 5% of total energy needed for ferries is assumed to be the share of the electricity imported from DSO.

- Exporting electricity to the distribution network may be possible, but a prior agreement will have to be made with the DSO about the possibility to export surplus electricity. Otherwise, wind turbines must be curtailed or shut down in case of surplus electricity. Different regulations might apply in different scenarios, so it should be investigated in detail.

7 Distribution Network Connection

Distribution system operators (DSOs) are shown in Figure 3. As can be seen from this figure, the DSO in Langeland is Veksel and the DSO in Lolland is Cerius.

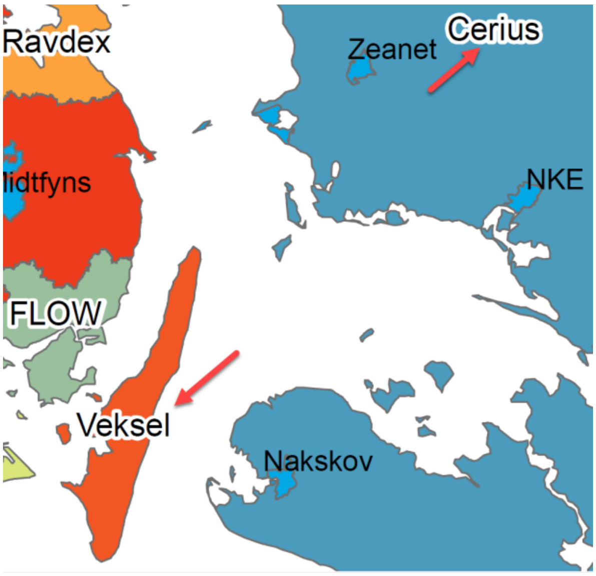


Figure 3 DSOs at both sides [Link]

7.1 Langeland Side

Veksel’s distribution network can be seen in Figure 4 and Figure 5. Considering the harbour location, a 10 kV connection doesn’t seem to be a major concern. However, it’s necessary to have a dialogue with Veksel to discuss the possible connection details, considering their network expansion plan and connection process timeline.

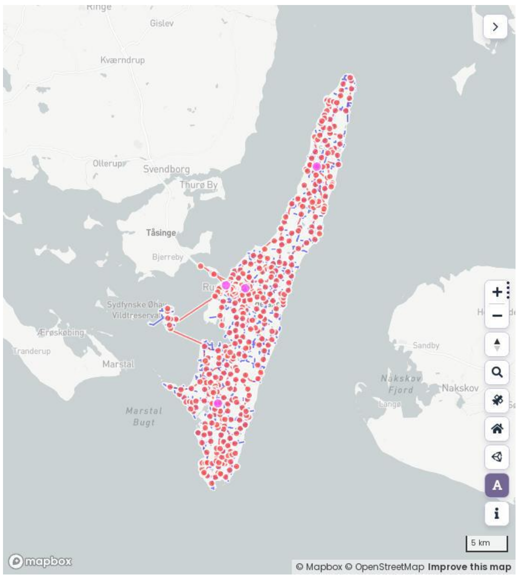


Figure 4 Veksel distribution network [Link]

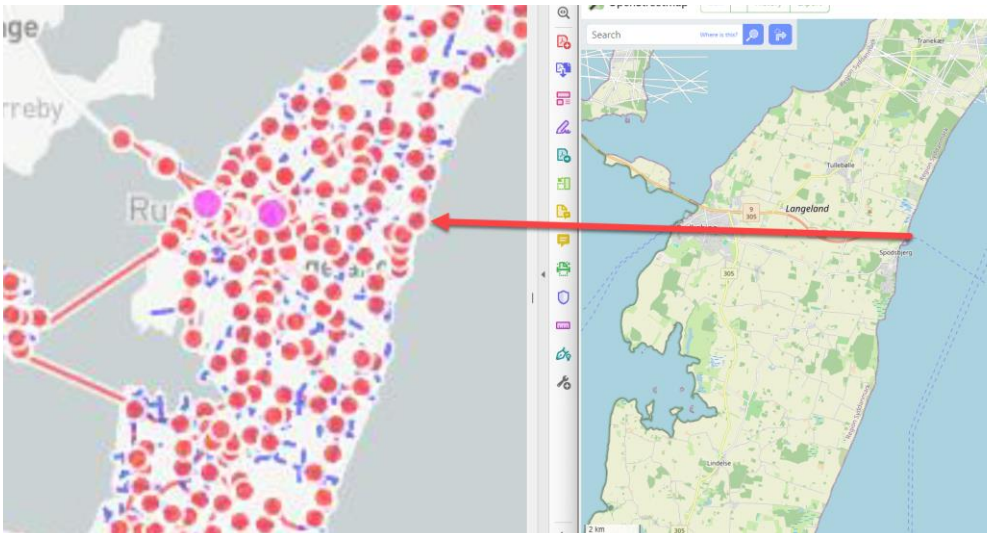


Figure 5 Veksel distribution network - Harbour Location [Link]

The renewable energy generation capacity from wind and solar in Langeland is not available, as can be seen from Figure 6.

Figure 6 Capacity map for the electricity grid of Langeland [Link]

7.2 Lolland Side

Cerius' distribution network details can be accessed through their website. Considering the harbour location, a 10 kV connection doesn't seem to be a major concern. However, it's necessary to have a dialogue with Cerius to discuss the possible connection details, considering their network expansion plan and connection process timeline.

Depending on the power needs and the complexity, the connection time might take many months. The information below is accessible on Cerius' website. It may be related to scenarios involving only customers and may only address straightforward cases. However, its applicability may be limited when equipment such as wind turbine generators (WTGs) and battery energy storage systems (BESS) are involved, as these types of generation and storage equipment might require a different approach, potentially extending the connection time to several months or even years.

Connection to the electricity grid and connection times [Link]:

- *"All citizens, companies and organisations have the right to be connected to the electricity grid. Cerius is responsible for ensuring that the electricity grid in our supply area has the capacity for customers to be connected in a way that matches their needs.*

- *The task of connecting a customer can vary greatly, and therefore the connection time can also be very different. Connections can be divided into three main levels; small, medium and large connections. You can read more about this in the three menus below.*

- *The level of a connection depends on how much capacity you need. The exact level will be clarified in your advisor's/your initial dialogue with us."*

General information about Cerius' distribution area is as follows [Link]:

- *"Our assets include:*

  - *Main stations: 118 – transforming the voltage level in the grid from 30 kV or 50 kV to 10 kV*

  - *Grid stations: 10,000 – transforming from 10 kV to 0.4 kV.*

  - *Cables: 25,000 km. cables and overhead lines (50/30, 10 and 0.4 kV)*

  - *Cable cabinets: 152,000 – which are nodes in the 0.4 kV grid*

  - *Meters: 410,000"*

The local grid station at the current Tårs harbour is shown in Figure 7.

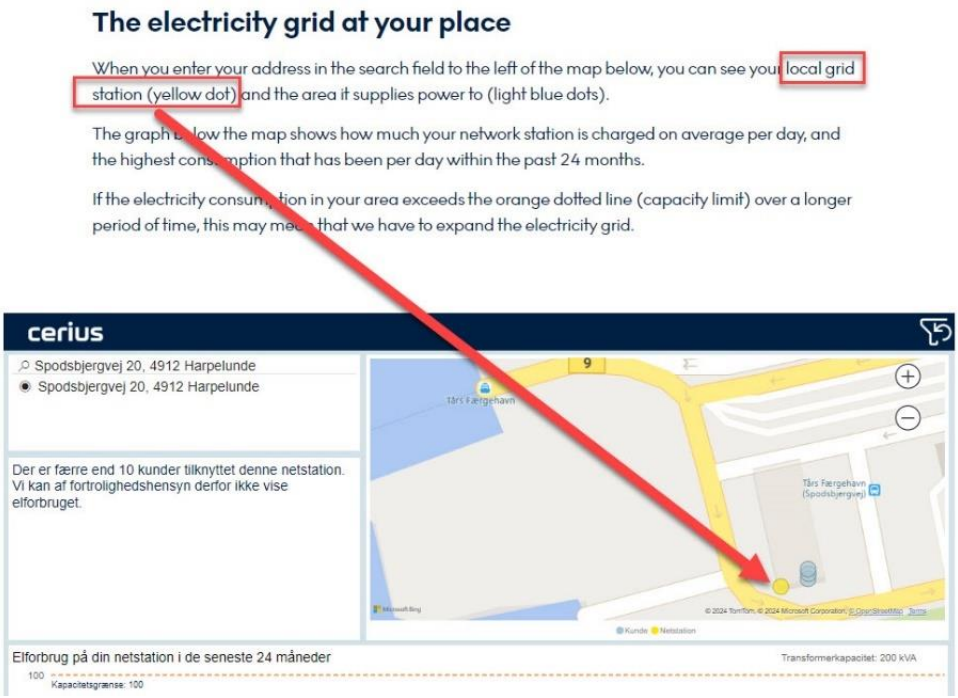


Figure 7 Local grid station at the current Tårs harbour [Link]

Some other local grid stations in the area can be seen in Figure 8.

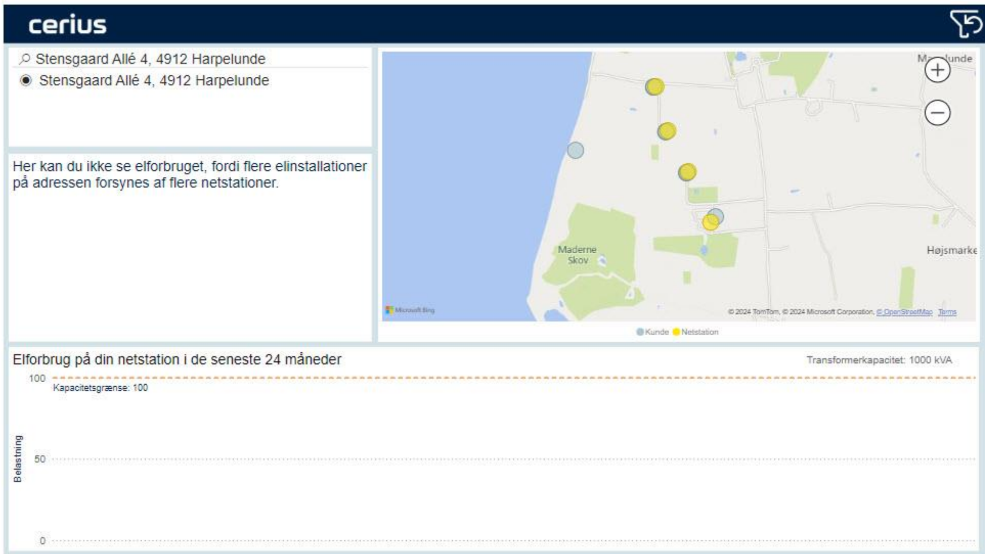


Figure 8 Other local grid stations in the area [Link]

Figure 9 and Figure 10 show the location of Sandby wind farm in the area close to the proposed location of the new harbour. This provides an idea of the possible wind turbine model that can be used for this project and also shows the existing connection to the distribution network.

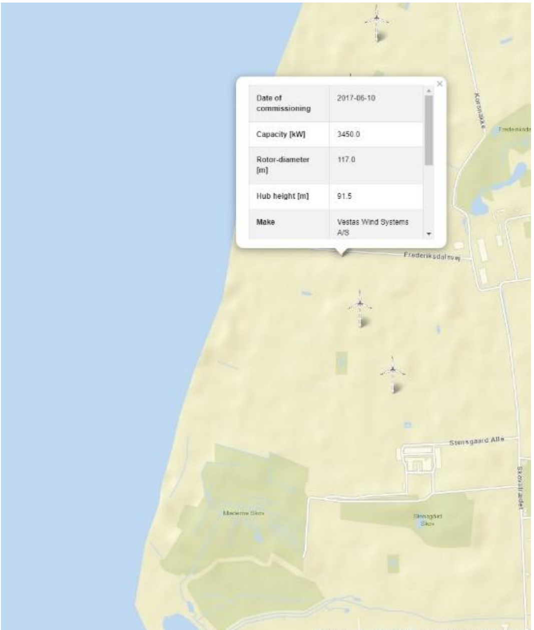


Figure 9 Sandby wind farm [Link]

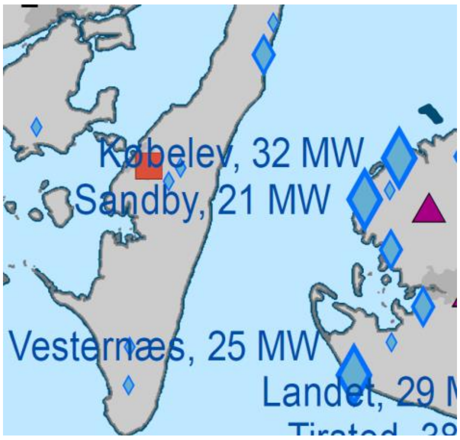


Figure 10 Power production and transmission in Denmark – Sandby wind farm [Link]

Figure 11 shows the approximate distance from the Sandby wind farm to the sea.

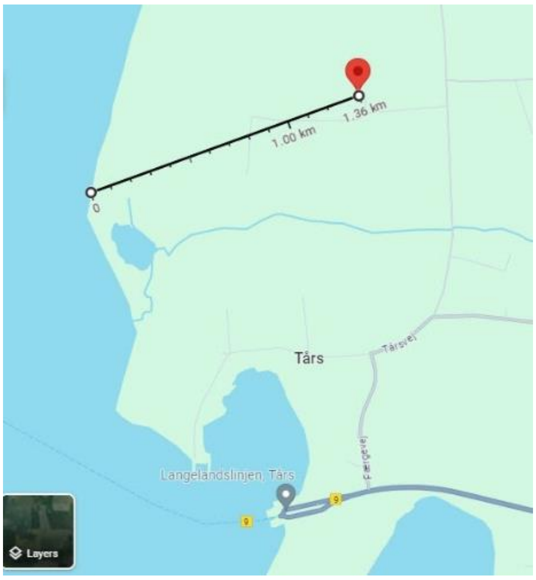


Figure 11 Approximate distance from Sandby wind farm to the sea

According to Figure 12, Lolland has a high renewable energy generation capacity from wind and solar. This indicates that in case of electricity import from the grid, it's very likely that the renewable energy share in the mix would be high.

Figure 12 Capacity map for the electricity grid of Lolland [Link]

8 Wind Turbines in Tårs

The high-level preliminary single line diagram (SLD) in Figure 13 shows the MV switchgear panels connected to different feeders. The SLD is also include in Appendix A.

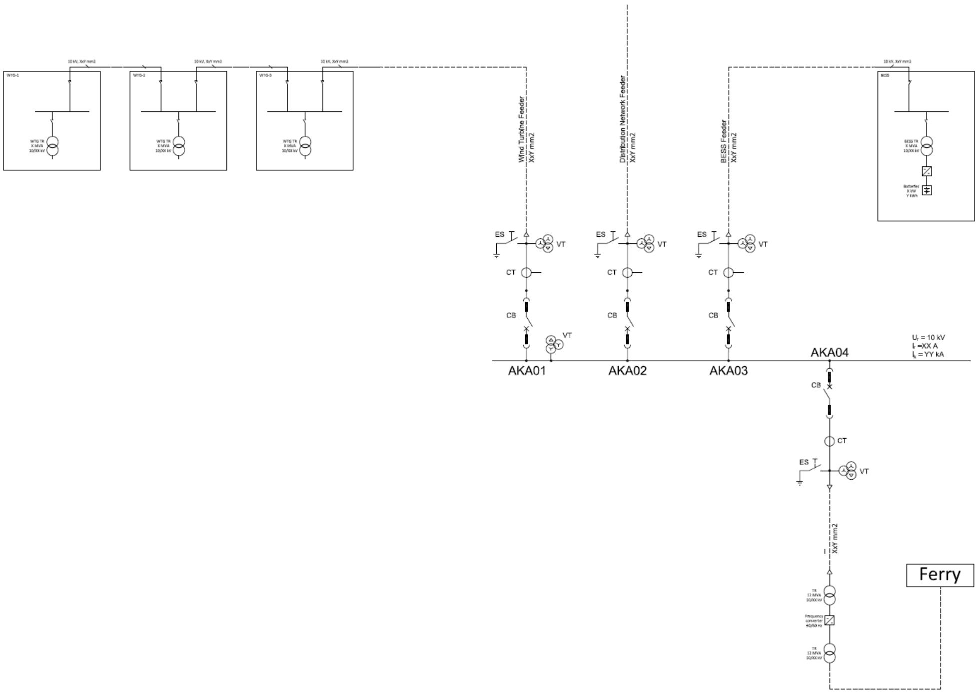


Figure 13 Preliminary single line diagram (SLD)

According to this SLD, the feeders will be as follows:

- Wind turbine feeder (AKA01)
  - Several wind turbines can be connected to each other via RMUs, and then the whole feeder can be connected to the MV busbar through a dedicated MV switchgear panel.
- Distribution network feeder (AKA02)
  - A dedicated MV switchgear panel can connect the facility to the distribution network.
- BESS feeder (AKA03)
  - Battery Energy Storage System (BESS) equipment can be connected to the MV busbar through a dedicated MV switchgear panel. If there are several BESS containers, similar to wind turbine feeders, they can be connected to each other via RMUs, and then the whole feeder can be connected to the MV busbar through a dedicated MV switchgear panel.

- Shore power feeder (AKA04)
  - The shore power feeder can be connected to the MV busbar through a dedicated MV switchgear panel. As the distribution grid operates at 50 Hz, a frequency converter will be utilized ashore to convert 50 Hz to 60 Hz to comply with the frequency of the electric ferries.
  - If another shore power feeder is needed, it can be added by using the same configuration. In case of multiple shore power feeders, it is assumed that only one feeder is energized at a time.
- There may be more feeders depending on the final design. For example, if it is decided to provide power for the auxiliary load, a separate feeder will be needed for auxiliary service transformer connection.
- Additional equipment may also be needed depending on the final design. As this is not the detailed design, not all the equipment is shown on the SLD. For example, it may be necessary to add a neutral earthing resistor.
- Not all details are shown at this stage, and even some mentioned details are subject to change in the next phases.

8.1 Scenario 1

The following scenario is considered for the number of trips in Scenario 1:

- Hourly service: 18 trips per day, 365 days/year (this means that 18 ferries will be charged per day at the new harbour in Tårs)

For 18 trips/day, the annual energy need is 9,000 MWh, with two wind turbines expected to produce 15,000 MWh, leaving a surplus. Table 1 shows the energy needed for the ferry.

Table 1 Energy need for the ferry for Scenario 1

Energy needed per trip including transmission losses on the ferry	1,352	kWh
Number of charging per day on one site	18	
Total energy needed per day on one site	24,336	kWh
Total energy needed per year on one site	≈ 9,000	MWh

Table 2 displays the expected energy production from wind turbines and the surplus energy, considering the total need for the ferries.

Table 2 Wind turbine data and energy production for Scenario 1

WTG rated power	3.45	MW
Number of WTGs	2	
AEP at rated power (full)	60,444	MWh
WTG capacity factor	25%	
AEP (expected)	≈ 15,000	MWh
Need for ferries	≈ 9,000	MWh
Production surplus	≈ 6,000	MWh

It is expected that at times there might not be enough wind and stored energy in batteries, and in that case, electricity needs to be imported from the distribution network. For simplicity, 5% is assumed to be the share of the electricity imported from the DSO as shown in Table 3. If a more accurate figure is needed, a detailed analysis should be conducted, considering important factors such as wind profile, BESS capacity, charging/discharging cycles, and ferry charging profile.

Table 3 Imported electricity from the DSO for Scenario 1

Share of electricity imported from the DSO	5%	
Total electricity imported from the DSO	445	MWh

8.2 Scenario 2

The following scenario is considered for the number of trips in Scenario 2:

- ½ hourly service: 36 trips per day, 365 days/year (this means that 36 ferries will be charged per day at the new harbour in Tårs)

For 36 trips/day, the energy need is 17,750 MWh, with three turbines producing 22,500 MWh, leaving a surplus. Table 4 shows the energy needed for the ferry.

Table 4 Energy need for the ferry for Scenario 2

Energy needed per trip including transmission losses on the ferry	1,352	kWh
Number of charging per day on one site	36	
Total energy needed per day on one site	48,672	kWh
Total energy needed per year on one site	17,750	MWh

Table 5 displays the expected energy production from wind turbines and the surplus energy, considering the total need for the ferries.

Table 5 Wind turbine data and energy production for Scenario 2

WTG rated power	3.45	MW
Number of WTGs	3	
AEP at rated power (full)	90,666	MWh
WTG capacity factor	25%	
AEP (expected)	22,500	MWh
Need for ferries	17,750	MWh
Production surplus	4,750	MWh

It is expected that at times there might not be enough wind and stored energy in batteries, and in that case, electricity needs to be imported from the distribution network. For simplicity, 5% is assumed to be the share of the electricity imported from the DSO as shown in Table 6. If a more accurate figure is needed, a detailed analysis should be conducted, considering important factors such as wind profile, BESS capacity, charging/discharging cycles, and ferry charging profile.

Table 6 Imported electricity from the DSO for Scenario 2

Share of electricity imported from the DSO	5%	
Total electricity imported from the DSO	890	MWh

9 Tasks For Future Phases

- All assumptions should be checked, verified, or updated as needed.

- Dialogues should be initiated with the DSOs to discuss the possible connection details, along with their network expansion plan and connection process timeline. The dialogue can be extended to also include the possibility to export surplus electricity.

- Optimized plant sizing needs to be conducted to choose the correct ratings for WTG, BESS, and any other required equipment.

- A detailed analysis can be performed, considering important factors such as wind profile (e.g. time series data), BESS capacity, charging/discharging cycles, and ferry charging profile.

- In addition to the international standards, local standards, norms, and codes should be thoroughly reviewed and complied with.

Appendix A Preliminary Single Line Diagram (SLD)