ENERGY

Electricity to Reduce CO_2 Emission in Harbours and Coastal Shipping

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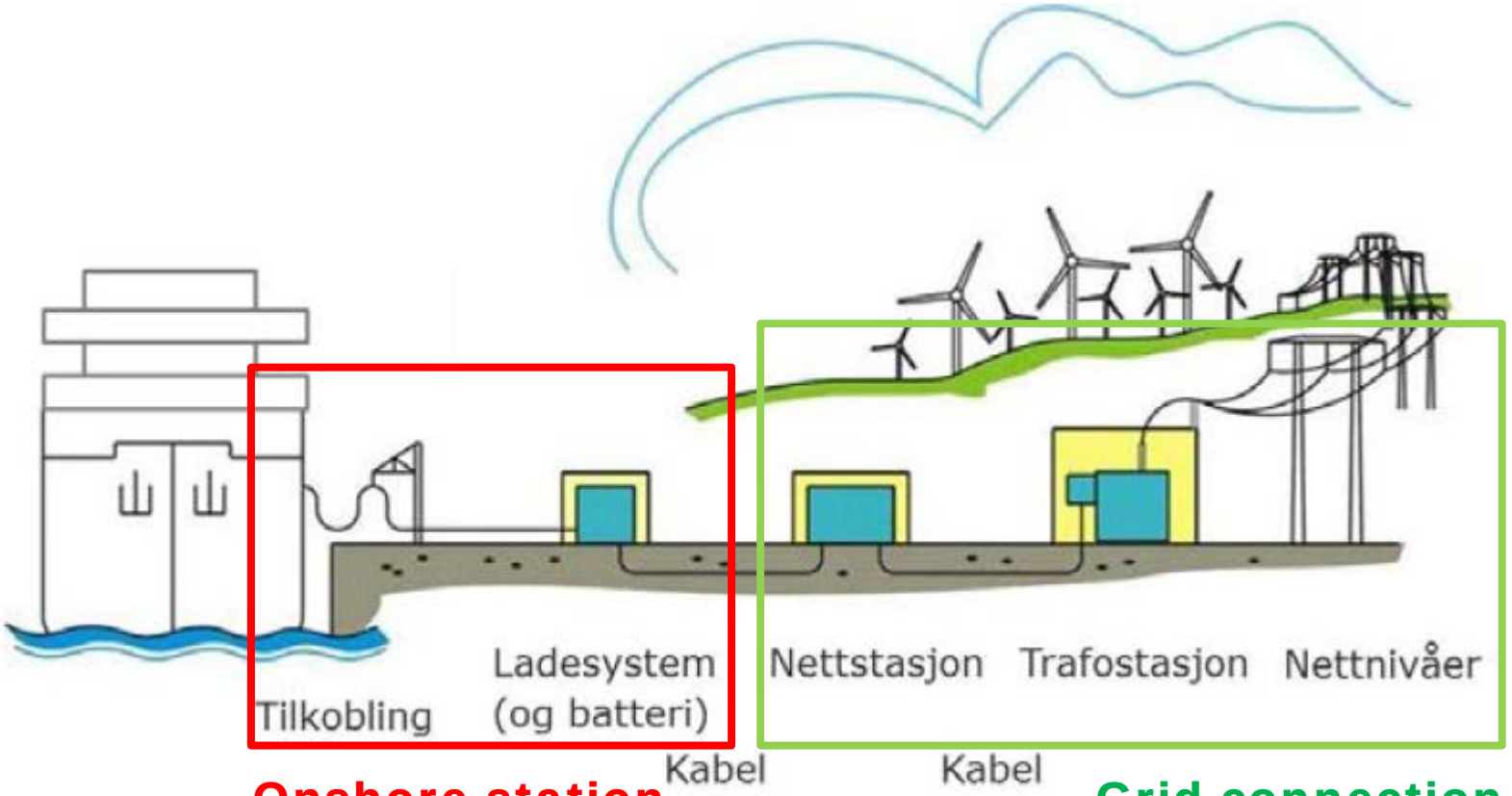
Content

- Grid connection of ships in harbours
  - Requirements and needs from the ships
  - Different conditions for the land based substations
  - Grid connection
  - Safety
  - Who to pay?

- Electric ferry boats – Different projects in Sweden
  - Small ferry boats for short distances – Picking the low-hanging fruits…

- Electric ferry boats – A big project in Norway
- Charging and weak networks – Batteries also in the land station

Grid Connection – Overview



Onshore station

- The harbour

Grid connection

- The grid owner

Present technology for grid connection of ships in harbour

- Available in larger harbours where ships stays for longer time
  - Supply of the electric power to the ship, when in the harbour
- Not available in smaller harbours and for smaller ships

- Present installations :

Port	Country	Connection voltage	Frequency
Port of Göteborg	Sweden	400 V / 6.6 kV / 10 kV	50 Hz
Port of Stockholm	Sweden	400 V / 690 V	50 Hz
Port of Helsingborg	Sweden	400 V / 440 V	50 Hz
Port of Piteå	Sweden	6 kV	50 Hz
Port of Antwerp	Belgium	6.6 kV	50 Hz / 60 Hz
Port of Zeebrugge	Belgium	6.6 kV	50 Hz
Port of Lübeck	Germany	6 kV	50 Hz

Ship electricity systems – flexibility for connection?

- The ship electricity system and connection possibilities put requirements on the onshore system
- DC, 50 Hz eller 60 Hz?

	380 V	400 V	440 V	450 V	460 V	6.6 kV	10 kV	11 kV
Container vessels (< 140 m)	42 %	16 %	42 %	-	-	-	-	-
Container vessels (> 140 m)	6 %	79 %	-	3 %	-	12 %	-	-
Container vessels (total)	19 %	6 %	64 %	2 %		9 %		
Ro/Ro- and Vehicle vessels	-	30 %	20 %	43 %	7 %	-	-	-
Oil- and Product tankers	13 %	-	40 %	47 %	-	-	-	-
Cruise ships (< 200 m)	14 %	18 %	59 %	9 %	-	-	-	-
Cruise ships (> 200 m)	-	-	12 %	-	-	48 %	4 %	36 %
Cruise ships (total)	6 %	9 %	34 %	4 %	-	26 %	2 %	19 %

Next step of using electricity?

- Electric main engine for propulsion of the ship?

  - The power need & the distance -> Energy requirements [kWh]
  - Time at shore & Energy need -> Charging requirements [MW]

The power need and the distance -> Energy requirements

- Most demanding crusing conditions (wind, waves, currents, etc.)
- Longest distance between charging + reserves
- Electricity needs for other purposes, lighting, heating, control, etc.

- Where is the limit for beneficial electrification?

speed [knot]	distance [nau mil]	Energy need [kWh]	Shore connect. [min]	Onshore staion power requirement [MW]
5,5	4,5	100	10	0,6
8,5	6,5	400	10	2,4
18,2	4,5	200	3	4
13	3,2	280	3	5,6
20,2	23,5	1500	5	18

Time shore connected – Energy need – Charging requirement

- Time for loading and unloading of people, cargo, vehicles, etc.
- Keep the time table ….
- Time requirement for charging – to cover the energy need at max charing speed
- Possibility to charge more than one ship at a time?
- ---- Put requirement on the grid……
- ---- Perhaps onshore battery banks are needed …..

Speed [knot]	Distance [nau mil]	Energy need [kWh]	Shore connect. [min]	Onshore station power requirement [MW]
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Onshore conditions for charging

- Charging of ship / ferry boat batteries for propulsion might need significantly higher power than the present grid can handle
  - very often weak grids close to the coastline
  - not dimensioned for this type of battery charging

- Onshore stations for short ferry boat tours, e.g. the Swedish ”Trafikverket” or the Norwegian ”Statens Vegvesen”, use similar types of ships
  - The same frequency (50 Hz) for all ships
  - The same voltage levels

- Harbours for cargo ships must be more flexible
  - Different frequencies 50 Hz or 60 Hz
  - Different voltage levels
  - > Higher costs

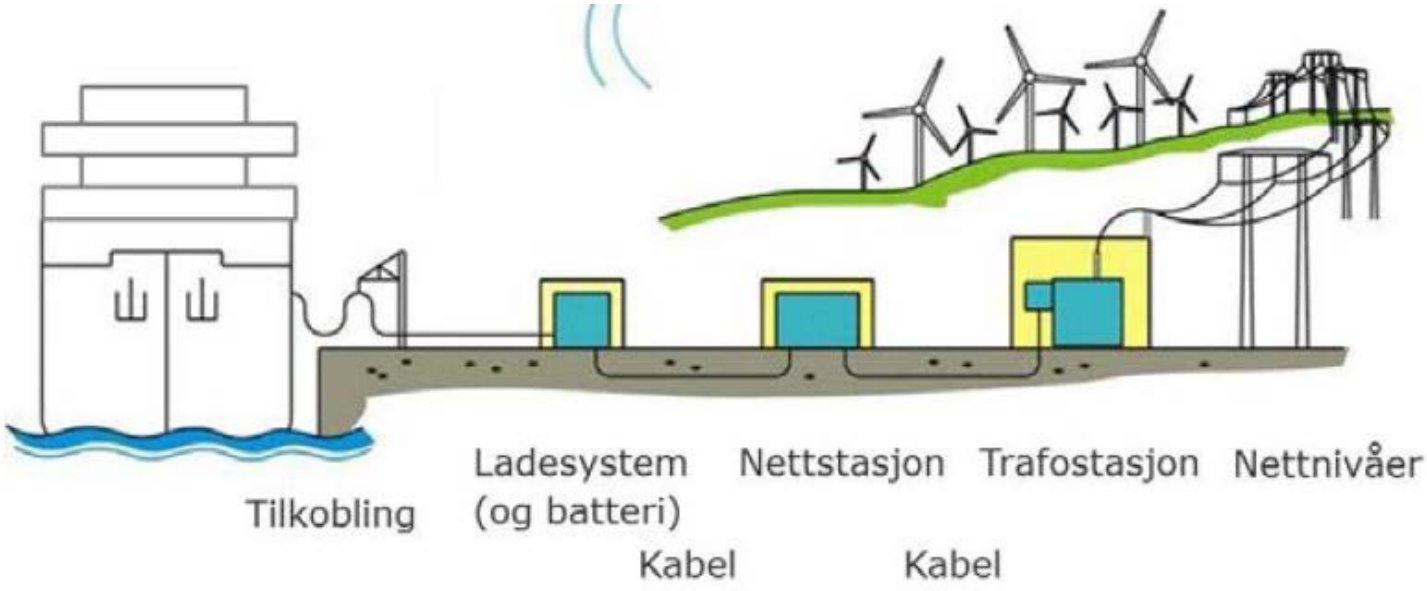
Grid capacity in the point of connection

Energy need [kWh]	Shore connect. [min]	Onshore station power requirement [MW]
100	10	0,6
400	10	2,4
200	3	4
280	3	5,6
1500	5	18

- Often weak networks ……
- Short charging times require high charging power - > might require grid reinforcements
- Examples on reinforcements
  - Voltage level increase, e.g. from 11 kV to 33 kV or 66 kV
  - Parallel feeders
  - Reactive power compensation
  - Battery storage also at the onshore substation (which is charged with a constant low power – and supplying the ship with a higher power)
- A great possibility for the grid owner to reinvest, upgrade, improve, and approach a new market segment …

Safety

- Galvanic separation between the ship power system and the grid is often required (transformer -> ”magnetic” connection)



- Arcs are not accepted, at connection or disconnection
- The cobination of salt seawater and electricity might also put requirements on the connection.

Who pays?

- Investments are needed:
  - On the ships
  - In the harbours
  - In the grid

- In Sweden – Grid owners are obliged to connect any load, but may charge the specific grid user

- Crusing costs for ships may be reduced over time – but investments are needed

- Government subsidies to reduce CO_2 emission, etc.

The 4th electricity driven cable ferry boat in Sweden (source NT)

- Kornhallsleden:
  - 200 m
  - 730 000 cars annually
  - 2 el. motors
  - 2 converters for speed control
  - Transformer on board for galvanic separation
  - Diesel engine as backup

- Other ferries in a similar way: Hamburgersund, Malö, Kastellet
- Hamburgersund: 2 first years – 107 tons of CO_2 emission saved!!
- Plans for more installations!!
- Also Scandlines are converting two ships to electricity – with batteries

Today – Commuters between Nacka and Solna goes by electric ferry

”E/S Sjövägen”

- 7 knots
- 15 minutes travel
- 150 passengers
- 2 asynchronous motors
- Total power 320 kW
- Lithium-Ion battery:
  - 5 tons
  - 750 V
  - 500 kWh
  - 5 hour operation
  - 10 years life time
- Dieselbackup

Norway

- ”Statens vegvesen” is responsible for the operation of the national road ferries
- Private operators operates the ferry boats on cotracts
- 130 ferry lines; 200 ferry boats

- Parlament instruction to the government:

«Stortinget ber regjeringen sørge for at alle kommende fergeanbud har krav til nullutslippsteknologi (og lavutslippsteknologi) når teknologien tilsier dette»

Ampere – The world's first electrically-powered car ferry

- Entered into service early 2015 in Sognefjord between Larvik and Oppedal
- 120 passengers
- 360 cars
- 34 fjord-crosses /day
- 6 km / 20 minutes
- 2 electric motors
- Each motor 450 kW
- Lithium-ion batteries
- Total 1 MWh
- Onshore batteries of 260 kWh at each end
- Savings:
  - 2680 tons of CO_2
  - 37 tons of NO_X

Summary

- Speed, distance, size and margins set the energy requirements
- Energy and time for shore connection set the power requirements for charging
- The electricity system on-board set the requirements on the flexibility of the onshore substation
- Safety is always a major concern and must be sufficient
- Who will pay for what……..?

Thank you for the attention

- Questions?
- Comments?
- Welcome to contact me in any electrical issue

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