The E-ferry Ellen: A fully electric regional ferry

Halfdan Abrahamsen
Information Manager, Ærø EnergyLab
Municipality of Ærø, Denmark

Email: hab@aeroekommune.dk
1. The E-ferry is powered by local wind turbines

The E-ferry sails in southern Denmark, from the island of Ærø (Aeroe)

Wind produces 125-140 % of Ærø's electricity usage, electric ferry uses surplus
2. The ferry

- Municipal operator (Ærøfærgerne / Aeroe Ferries)
- Task: Demonstrate a replacement for diesel ferries

- Passengers: 147/196
- Vehicles: 31 cars
- Crew: 3/4 (no engineer)
- Cruise speed: 12.6 knots
3. Batteries and engines

Batteries:
2 x 420 Lithium Graphite/NMC
Total capacity: 4 MW

Engines:
Main engines: 2 x 750 kW (1000 HP)
Bow thrusters: 2 x 250 kW
4. Achieving high frequency service

- Ramp-based charger
- 4 x 1 MW transformers
- 4 MW peak charging (1C)

- Energy efficiency (transformer to propeller): 85%

State-of-charge during the day:
5. Battery life time

Table 26: Calculation of life time battery capacity flow E-ferry prototype battery pack

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Average Depth of Discharge (DoD)</td>
<td>39</td>
<td>%</td>
</tr>
<tr>
<td>Number of cycles down to SOH 80%</td>
<td>24.500</td>
<td>cycles</td>
</tr>
<tr>
<td>Average energy flow per cycle</td>
<td>1.600</td>
<td>kWh</td>
</tr>
<tr>
<td>Life time flow in sailing operation</td>
<td>39.200.000</td>
<td>kWh</td>
</tr>
<tr>
<td>Number of years in sailing schedule</td>
<td>11.74</td>
<td>Years</td>
</tr>
</tbody>
</table>
6. Achieving high frequency service

Special features:

- Specially developed for E-ferry
- DNV-GL type approved
- Scalable design
- Redundancy

10 x

= 20 battery strings
= 840 batteries
7. Battery modules

Pros:
- High energy density
- Fast charge/discharge
- Battery management
- Marine certification
- Commercial viability

Cons:
- Nickel, cobalt and manganese
- Unknown recycling potential

Second life:
- End-of-life: 80 % SoC capacity
- Potential for balancing local grid
- Depends on SoH
8. Evaluation: Emissions

Annual reductions compared to the diesel replaced by the E-ferry:

$$\begin{align*}
\text{CO}_2 &: 2520 \text{ tonnes} \\
\text{NO}_x &: 14.3 \text{ tonnes} \\
\text{SO}_2 &: 1.3 \text{ tonnes} \\
\text{CO} &: 1.8 \text{ tonnes}
\end{align*}$$

The E-ferry also saves the environment from 0.5 tonnes of particulate matter (PM) each year.

Bunker fuel: