MARCH 26TH 2019

ABB's battery applications and experience

DNV GL's Second Maritime Battery Workshop 2019

Jorulf Nergard – VP Market Development

ABB

Energy Storage System

What is an Energy Storage System (ESS)

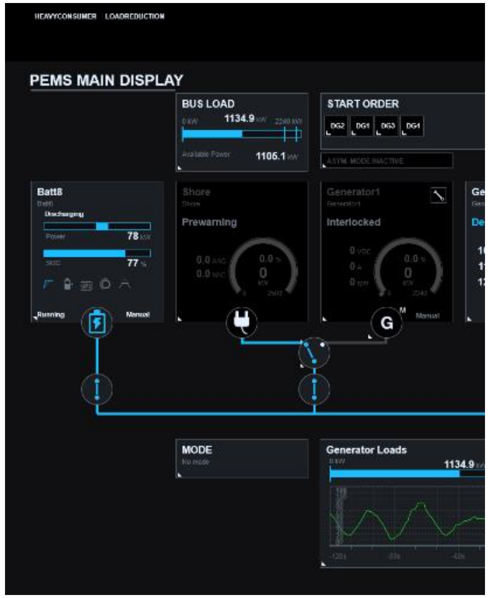
Battery Pack

+

Integration/Converter/ Transformer

+

Control System

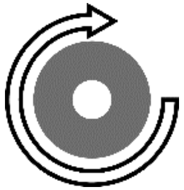


+ HOLISTIC approach to system integration

Energy Storage Solutions

Functionality

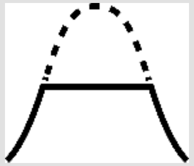
Spinning Reserve



Backup power to running generators.

Benefits include
- Improved safety
- Reduced fuel consumption and engine maintenance

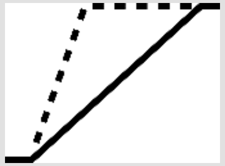
Peak Shaving



Level power seen by engines and offset need to start new engines.

Benefits include
- Reduced fuel consumption and engine maintenance

Enhanced Dynamic Perf.



Instant power in support of running engines.

Benefits include
- Reduced fuel consumption
- Enabler for “slower” sources like LNG and fuel cells

Enhanced Ride Through

Short time backup power to running generators.

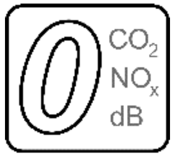
Benefits include
- Improved safety
- Reduced fuel consumption and engine maintenance

Strategic Loading

ESS used to charge or discharge with the aim of optimizing engine operating point.

Benefits include
- Reduced fuel consumption

Zero Emission Operation



Power system is fully powered by ESS.

Benefits include
- Quiet engine room
- Zero emission operation

Energy storage requirements

Different capacity needs

	- High energy density - High charge rates <3C	- Energy range: 1 MWh to 5 MWh - Power range: 1 MW to 10 MW
	- High power density - High discharge rates <5C	- Energy range: 0,3 MWh to 1 MWh - Power range: 1,5 MW to 2,5 MW
	- High power density - High discharge rates <5C	- Energy range: 1 MWh to 2 MWh - Power range: 4 MW to 8 MW
	- High energy and high density - Low discharge rates <0,5C	- Energy range: 2 MWh to 6 MWh - Power range: 2 MW to 5 MW

Drilling Rig

Peak shaving Battery test project

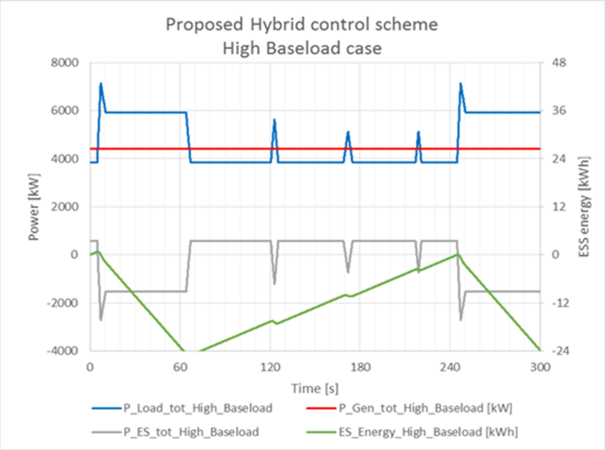
Purpose

Stress testing of 3 types of battery cells, with Drilling rig peak shaving stress profile to establish confidence that the cells can support the high cycle, high power peak shaving load for the required design life. (1.300.000 cycles)

Testing

Testing is performed in our corporate R&D centre's in Sweden and Switzerland, according to a load cycle that corresponds to peak shaving of the draw work on a drillrig. A typical cycle lasts for about 4 minutes with a peak load of 6000 kW and an average load of 3270kW.

To validate the lifetime performance of the selected Li-ion battery technologies for the actual peak shaving application, battery cells will therefore stress tested for approximately 10 months.

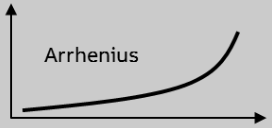
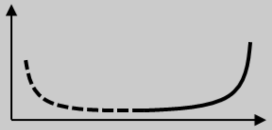
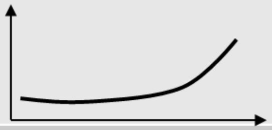
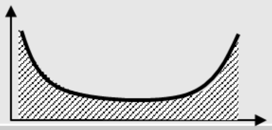
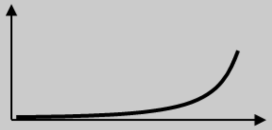
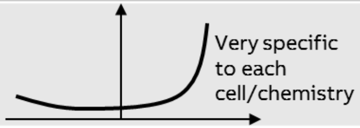


Drillrig peak shaving battery cell test

Background and motivation

Challenge with Li-ion battery lifetime modelling

- Highly non-linear systems
- Many battery aging stress factors
- Cross-dependence between factors
- Many expensive and cell tests required (30-40 for standard range characterization)
- Time-consuming (can only be accelerated to a certain degree)
- State-of-the-Art models are semi-empirical statistical models, only valid within the space they have been characterized

Stress factor	Calendar life impact	Cycle life impact
Temperature		
State-of-Charge (SOC)		
Depth-of-Discharge (DOD)	n/a	
C-rate (current)	n/a	

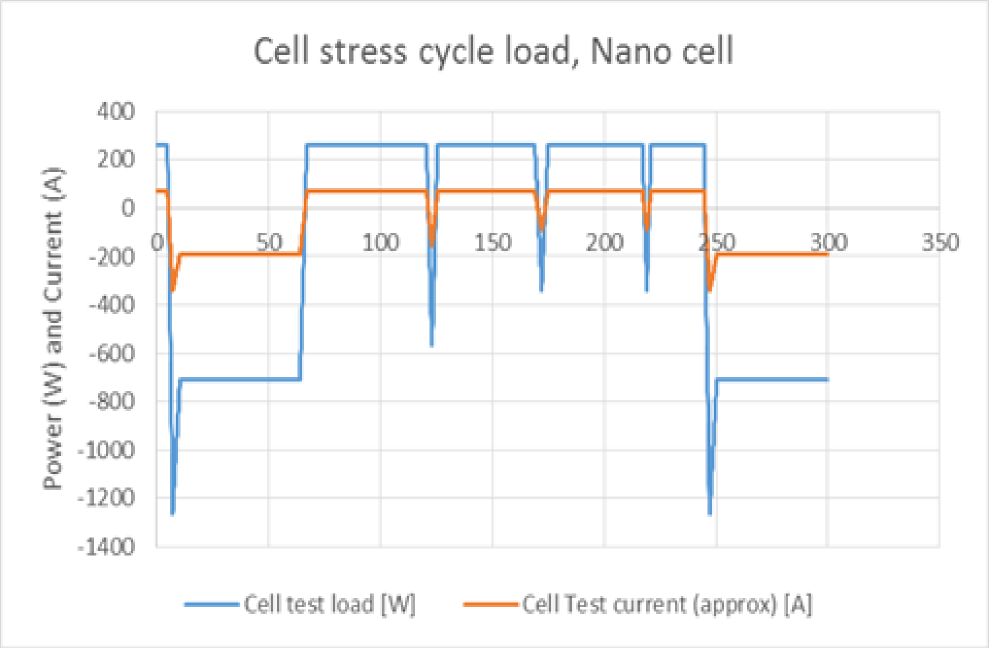
Drillrig peak shaving battery cell test

Background and motivation

As a consequence, aging models are *developed* and *validated* for **typical** use cases, i.e. moderate C-rates, deep to moderate DoD, etc.

The drillrig peak shaving application uses the battery in a **non-typical** way, i.e:

- Very high peak discharge rate
- Shallow Depth of Discharge (DoD)
- Very high cycle life demand



Hence, ABB Marine have conducted application-specific validation tests to ensure the performance meet requirement and expectation

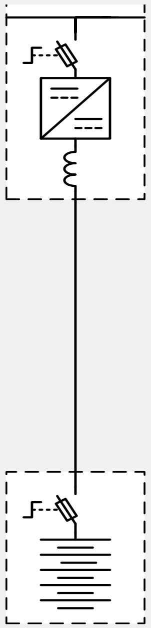
Energy storage system solutions

Product scope: 4 solutions available

Integrated ESS DC

Onboard Grid or Drive DC Link, i.e. Drilling or Thruster

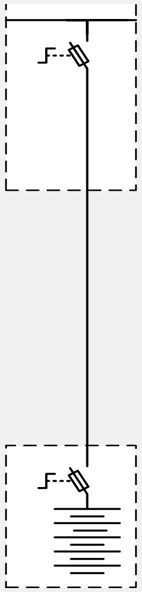
- Through DC/DC Converter
- ACS 880
- HESS 880
- Main Driver: Control



BMS | Monitoring | Control, ESCS

Direct online (DOL) DC

- Higher efficiency
- Less control of energy flow
- Limitations in peaks having
- Main Driver: Efficiency

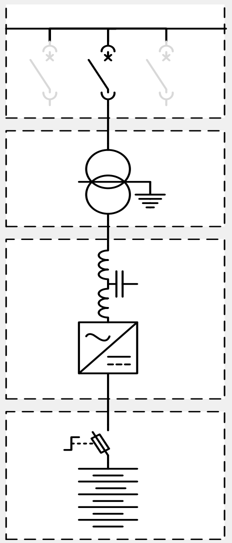


BMS | Monitoring | Control, ESCS

Integrated ESS AC

In AC solutions

- MV or LV Systems
- ACS 880
- HESS880
- Main Driver: AC System or MV



BMS | Monitoring | Control, ESCS

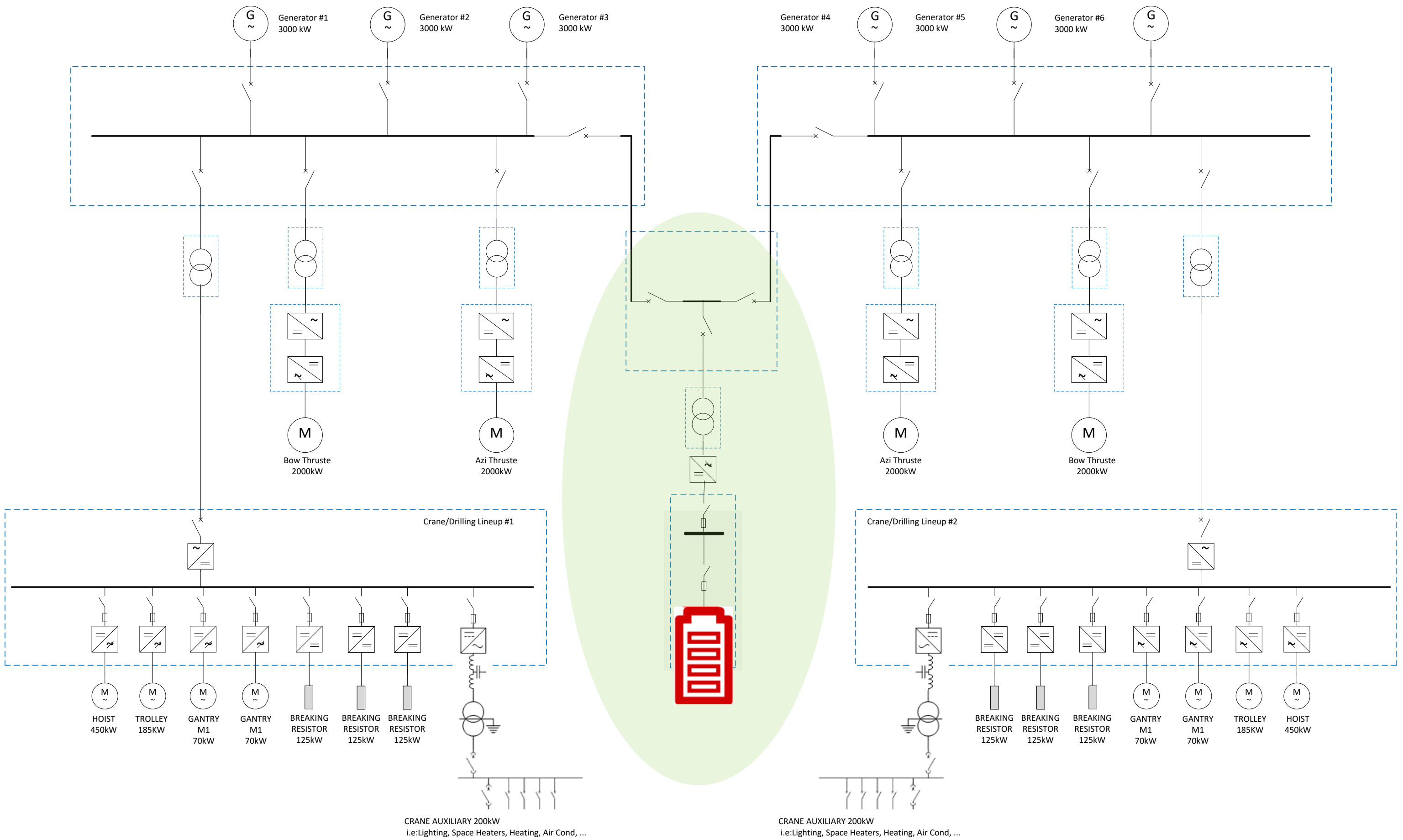
Containerized solutions

- 20” high cube container
- Weight (incl. all equipment): 13 000kg
- Cable and piping connection from one side
- Commissioned and tested.
- Backup & spinning reserve for up to 1,5MW
- Shore connection up to 570kVA
- Remote diagnostic connection

BMS | Monitoring | Control, ESCS

Battery integration in power systems

Retrofit AC – OCV – 1750kW@ESS@DG



Containerized solution

Container layout and size

- **20” high cube container** (6050x2862x3100 mm)
- **20” high cube ISO container** (6050x2430x3100mm)
- Total weight (including all equipment): 23000kg
- All cable and piping connection from one side
- Commissioned and tested.
- Backup & spinning reserve for up to **1,75MW**
- Energy reserve 350kWh (621kWh)
- Shore connection up to **570kVA**
- Remote diagnostic connection for battery life time monitoring and for converter
- Instrument hookup
  - Smoke/fire detector
  - Manual Alarm call point
  - PA/GA speaker
- Water mist hookup, Material Aisi316, Ø50 mm

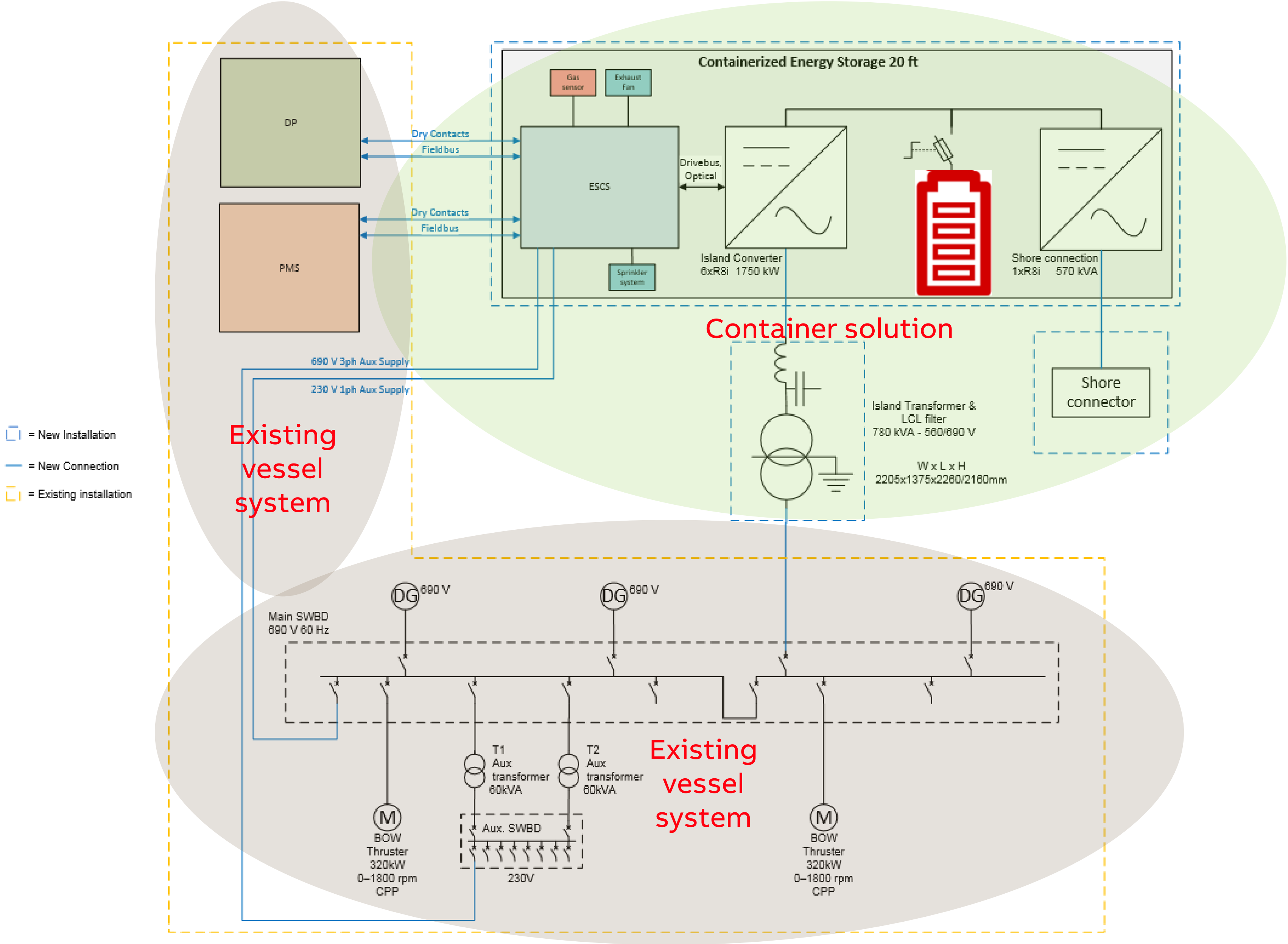
Containerized solution

Power integration to vessel

The containerized energy storage unit is connected to the Main distribution SWBD via the step down transformer with inbtegrated LCL filter.

ESCS (Energy Storage Control System) located in the container with accessed through a process panel, is integrated to DP and PMS system.

Water based extinguishing system (flexi fog, hi-fog and others) or heavy foam. Connected to existing system onboard if sufficient capacity.



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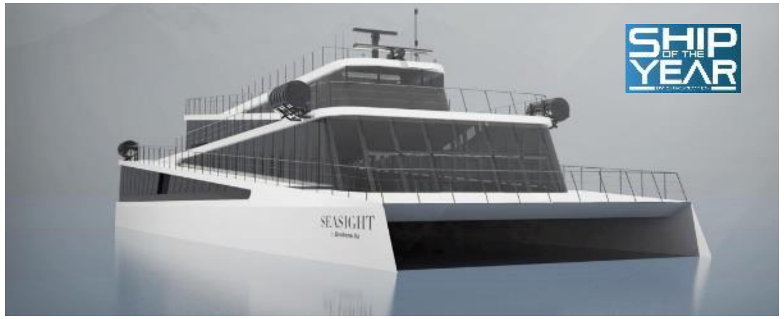
Hybrid references

Some important references

NKT Cable Layer

Vision of the Fjords



Icelandic Ferry

Exploration Cruise

Tycho Brahe & Aurora

MS Heilhorn, MS Hornstind

Onboard DC Grid and Energy Storage

Tycho Brahe & Aurora Car Ferry

Co-financed by the European Union
Trans-European Transport Network (TEN-T)

Vessel information

Vessel name:	Tycho Brahe & Aurora
Vessel Type:	Car Ferry
Design:	Knud E. hansen
•Yard:	Landskrona
Year of delivery:	2017Q2
Class/Notation:	Lloyds Register
Owner:	ForSea

Solution and scope: Onboard DC Grid

Generators:	4 x 2480kW (remain as back-up)
Energy Storage:	4 x 1040kWh
Propulsion:	4 x 1,5MW Azimuth thruster - Drives
Automation:	PEMS with integrated VMS
Advisory:	Remote Diagnostic, Energy Story Control System

Other information

Retrofit of existing system and install energy storage to enable full battery based operation with Diesel backup with 4x containers on top deck.

Ferry operating between Helsingor (DK) - Helsingborg (SWE)

Shore side infrastructure for Battery charging, with automatic shore connection.

Energy Storage onboard including transformers, rectifiers, DC/DC converters for battery connections, Power management upgrade and Energy Storage control

INEA, the EU's executive agency for innovation and network, support the project with approximately SEK 120 million (~$15M)

This project has received funding from the Innovation and Networks Executive Agency (INEA), Connecting Europe Facility, under grant agreement No. INEA/CEF/TRAN/M2014/1040935."

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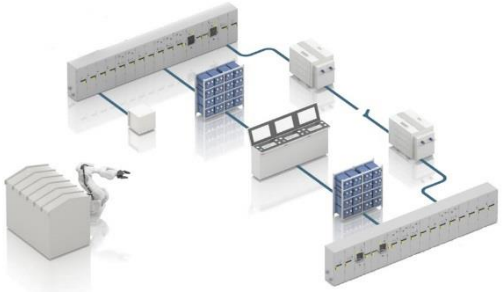
Trans-European Transport Network (TEN-T)

Battery System retrofitting

From Diesel to Fully Electric

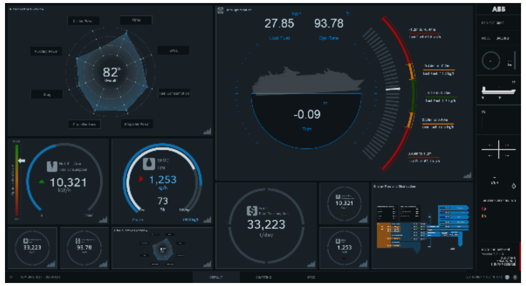
Charging Robot

Onboard DC Grid



Batteries

Control System



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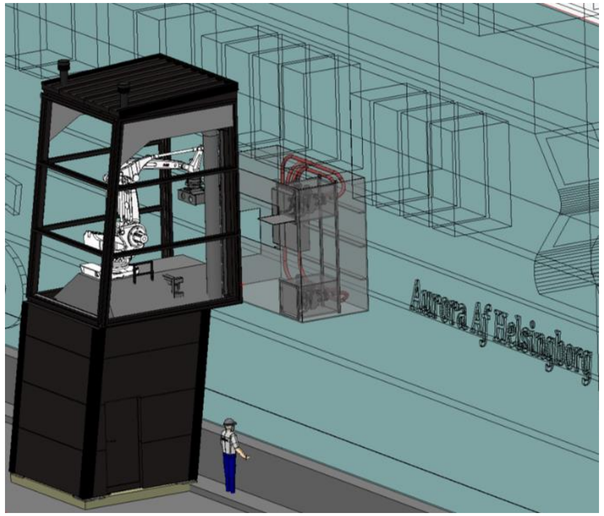
Battery System retrofitting

Battery and converters in containers on top of the vessel



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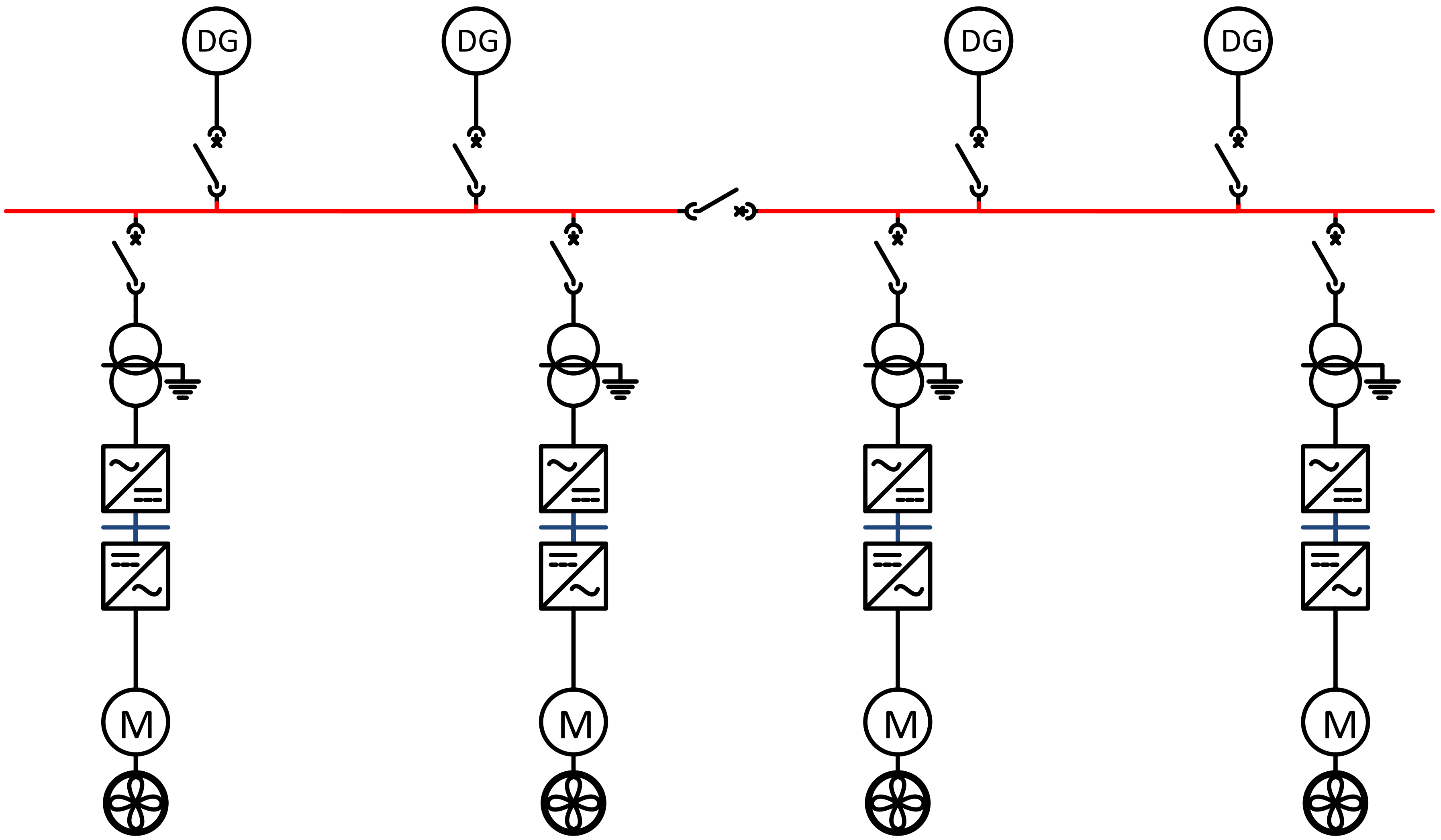
Starting Point

- 2-split AC Power plant



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Starting Point

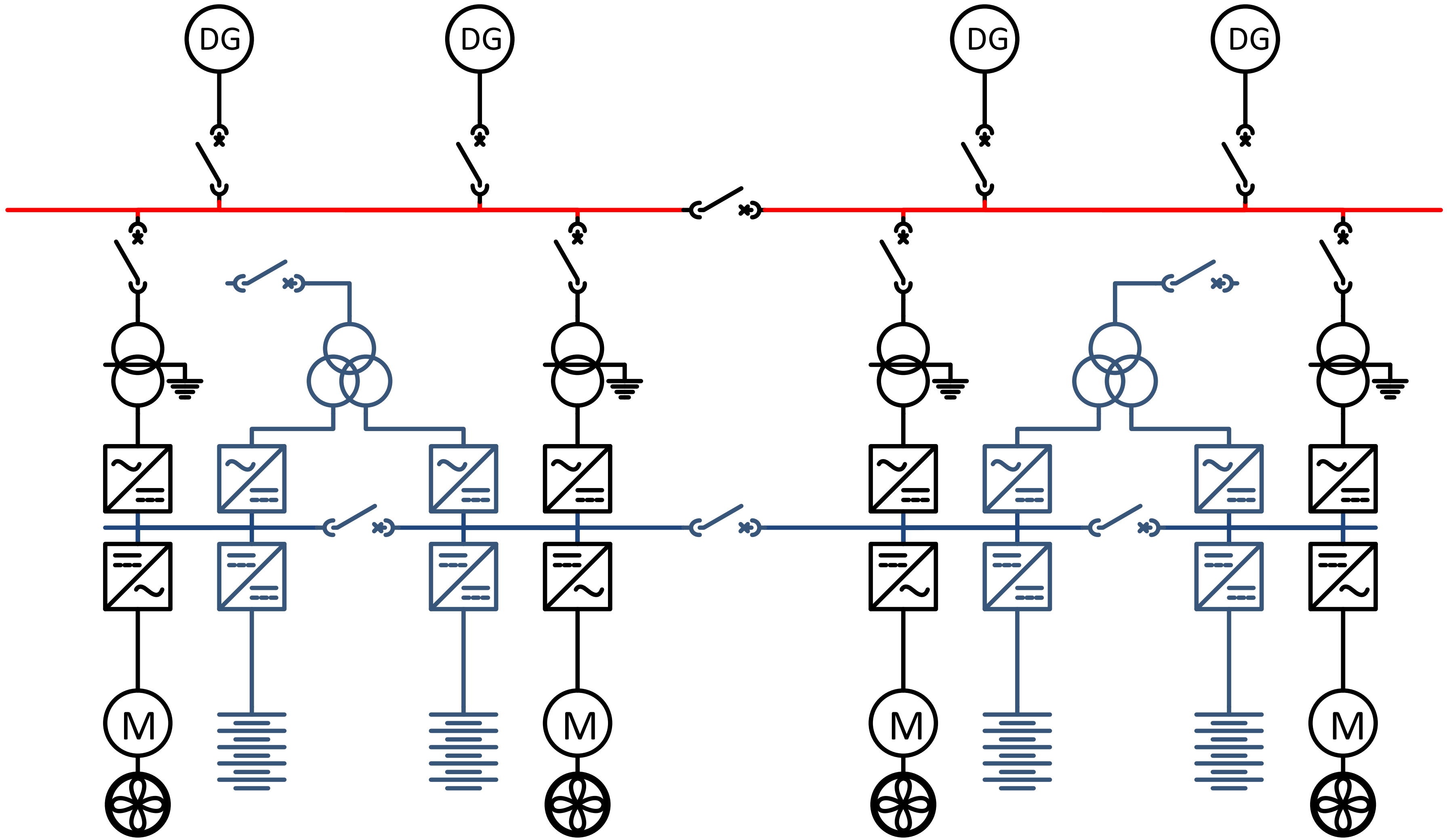
- 2-split AC Power plant

Modification

- Connecting DC links together
- Attaching battery banks to all 4 sections
- Fitting charging feeders
- Automating the charging

Result

- Transformation from AC to DC Power Plant



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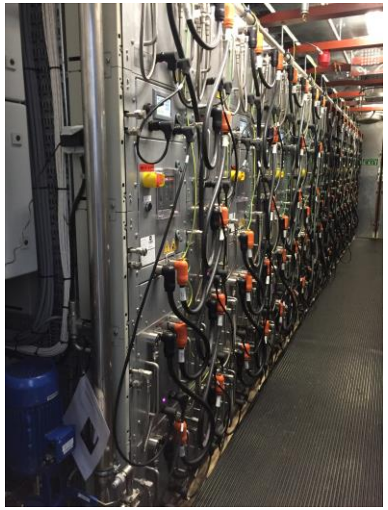
Battery System retrofitting – equipment



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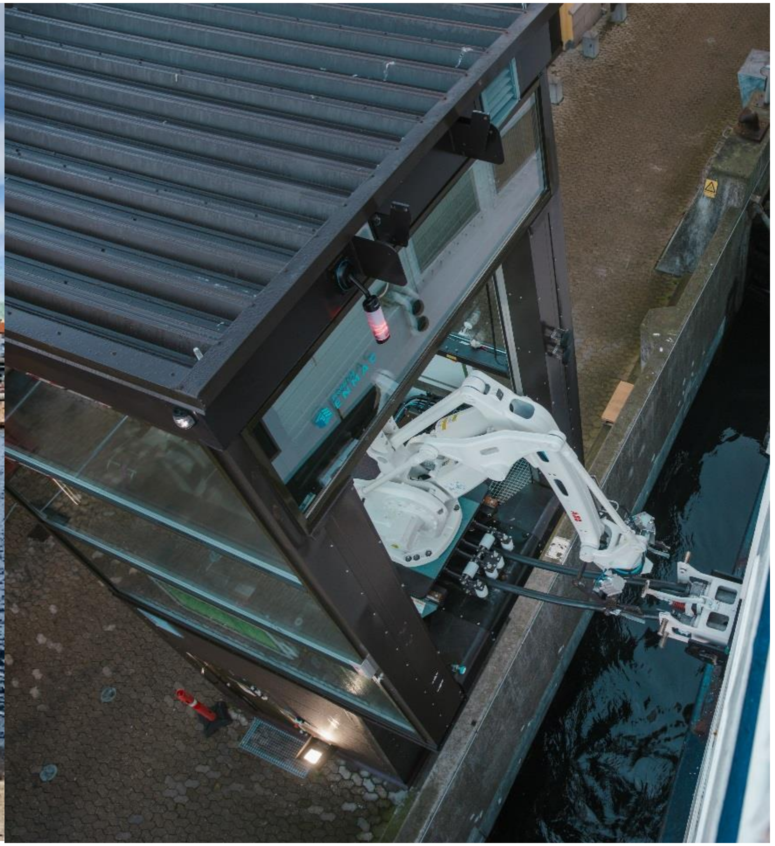
Automated Charging System

Helsingor pier



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Automated Charging System

Integration challenges in general

- Complete system integration with the several existing vendors

- Mechanical integration
  - Structural design changes, Chiller/Water system changes, Heat balancing, New stability booklet
- Existing pier design
  - fenders, car ramps, traffic control, emergency escape routes, automooring system, building infrastructure

- Requirements from the local authorities Danish Maritime Authority, Swedish Transportation Authority, Building Approval process.

- Novel technology, No Rule books from Lloyd's Register
  - -> Pre-HAZID, HAZID studies, Design Team processes according to the IMO 1455 guideline process.

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