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THE ARCTIC UNIVERSITY OF NORWAY

Charging technology for small maritime vessels

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Outline

- Charging requirements
- How small maritime vessels are charged today
- Comparison to electrical cars
- International standards for shore connection
- Wireless charging

Charging requirements

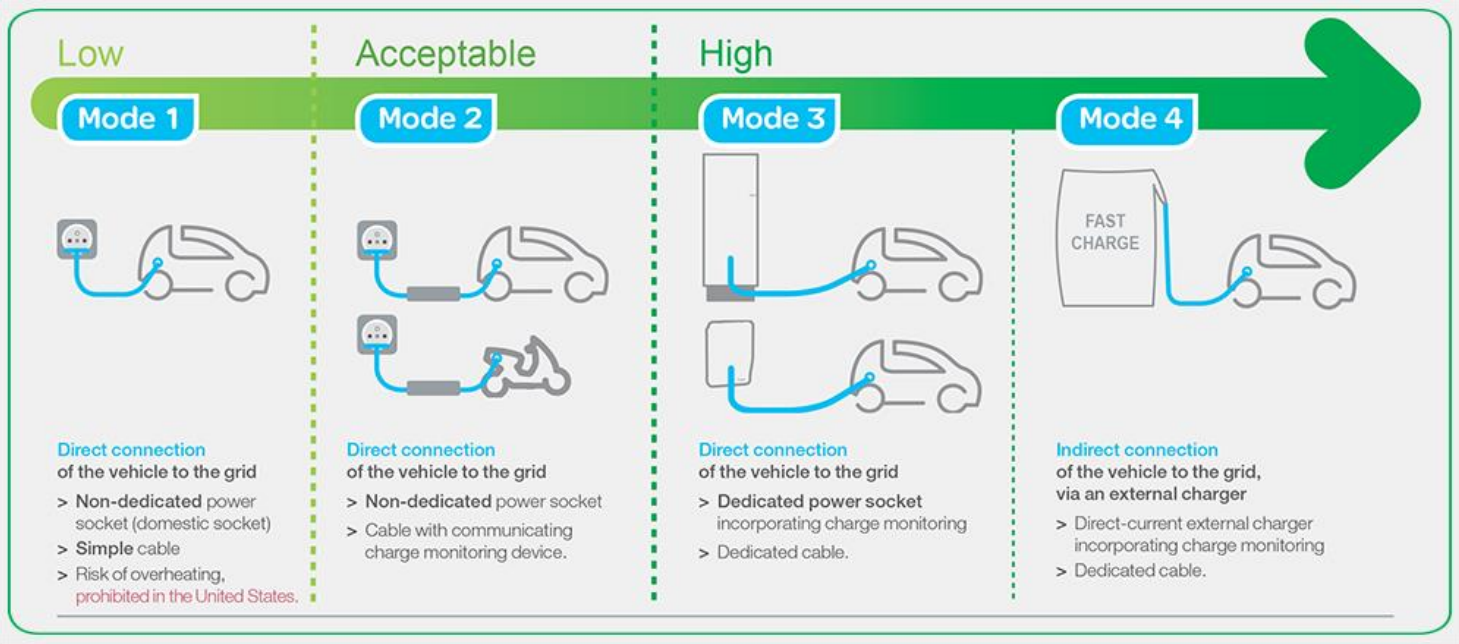
Vessel	Battery capacity	Charging power	Charging solution
Elfrida (Hybrid)	180 kWh		? 400 V
Karoline (Hybrid)	195 kWh	44 kW	63 A plug 400 V
GMV Zero	350 kWh	2 x 87 kW	2 x 125 A plug 400 V
MF Folgefonn (Hybrid)	1000 kWh	1 MW	Inductive + NG3 plug
MF Ampere	1040 kWh	1.2 MW	ST.Pantograf Cavotec plug
MF Future of the Fjords	1800 kWh	2.1 MW	Cavotec plug
Color Hybrid	5000 kWh	7 MW	NG3 plug

Photo: Karoline, Maritimt Magasin

Photo: GMV Zero, Grovfjord Mekaniske Verksted

Charging solution for small vessels

Charging modes for electric vehicles



- Today's small vessels equals Mode 1 -> Room for development?
- Mode 2 should be a minimum

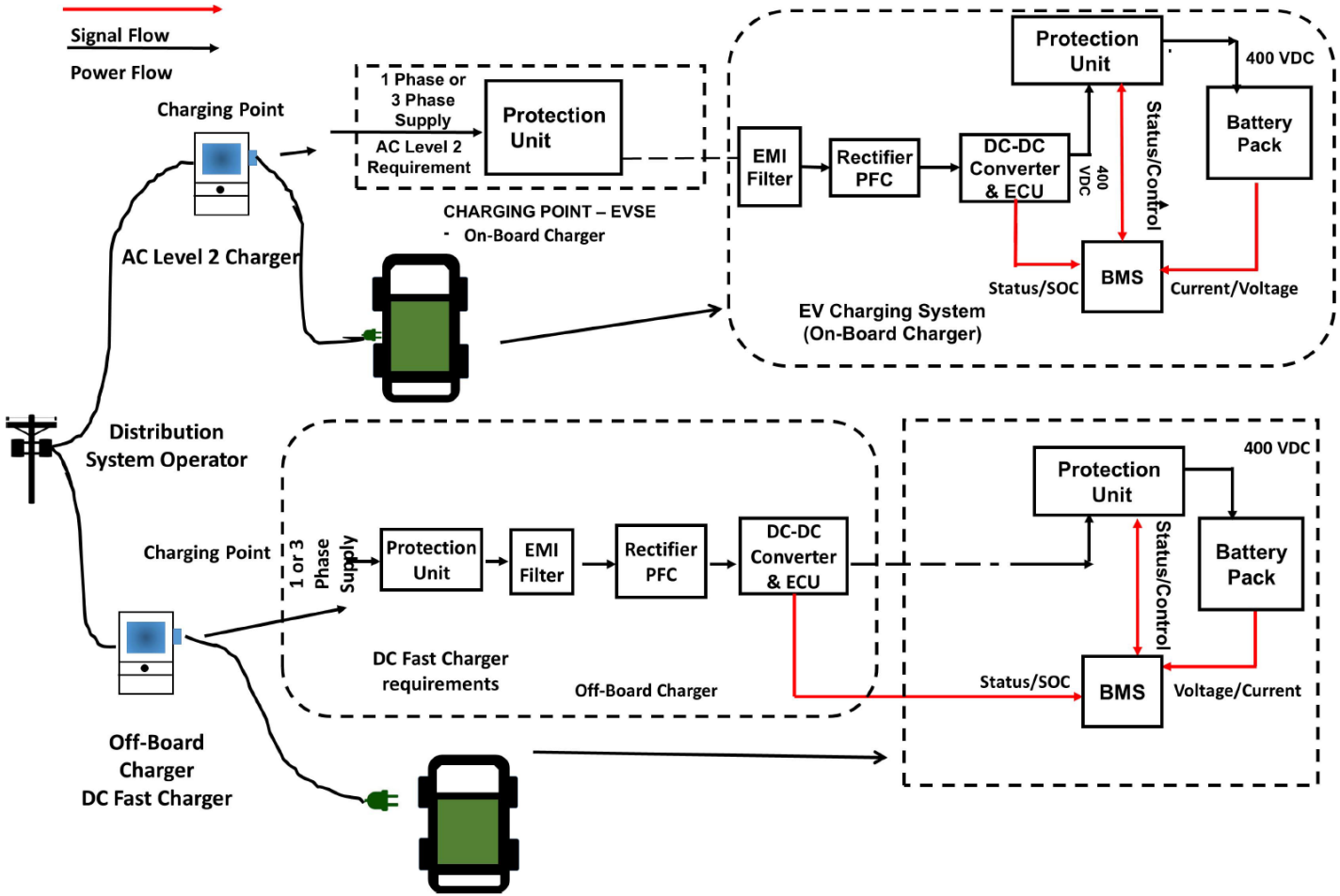
Charging standards for electric vehicles

SAE J1772 IEC Type 2
- AC charging
- 44 kW
- 63 A, 400 V

CHAdeMO
- DC fast charging
- 400 kW (version 2)
- 350-400 A, 1 kV

CCS
- DC fast charging
- 350 kW (version 2)
- 500 A, 1 kV

Photo: Paul Sladen



A. Ahmad, M. S. Alam and R. Chabaan, "A Comprehensive Review of Wireless Charging Technologies for Electric Vehicles," in *IEEE Transactions on Transportation Electrification*, vol. 4, no. 1, pp. 38-63, March 2018.

Example of charging using CHAdeMO

RAICHO-I

- Built by Tokyo University of Marine Science and Technology
- Charged to 80% within 30 minutes using CHAdeMO
- Contains a 18 kWh battery and a 25 kW motor

T. Takamasa, T. Oode, H. Kifune, E. Shimizu and T. Hazuku, "Quick charging plug-in electric boat “RAICHO-I”," *2011 IEEE Electric Ship Technologies Symposium*, Alexandria, VA, 2011, pp. 9-11.

Shore connection standards

NEK IEC/ISO/IEEE 80005-1:2018 - High voltage

- For supply over 1 MVA with a voltage of 6,6 kV or 111 kV AC

NEK IEC PAS 80005-3:2014 - Low voltage

- For supply up to 1 MVA with 400 V AC three-phase. The system uses a 350 A plug, where several plugs are paralleled for higher current levels.

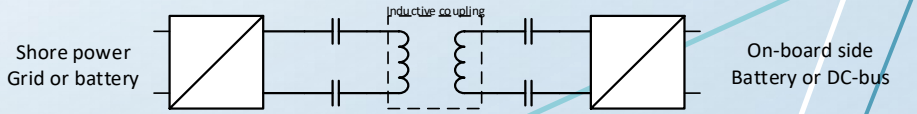
NEK IEC/IEEE 8005-2:2016 - Communication

- Ethernet based on MODBUS TCP and optical fiber.

Inductive (wireless charging)

- Already demonstrated at 1 MW for ferries
- What about simplified solutions for lower power levels?

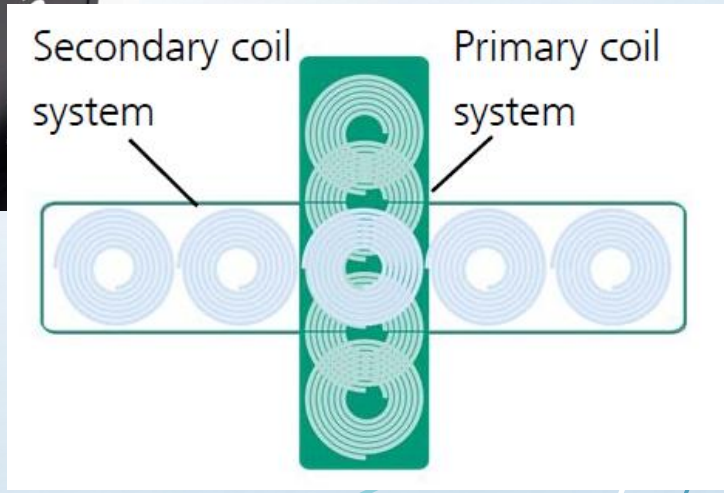
G. Guidi, J. A. Suul, F. Jenset and I. Sorfonn, "Wireless Charging for Ships: High-Power Inductive Charging for Battery Electric and Plug-In Hybrid Vessels," in *IEEE Electrification Magazine*, vol. 5, no. 3, pp. 22-32, Sept. 2017.



Wireless charging for electric vehicles

- 3,6 kW
- 97 % efficiency

- Multiple coils increases tolerance in positioning



Source: Fraunhofer Institute for Integrated Systems and Device Technology

Wireless charging for electric vehicles

Plugless (third party):

- 7.2 kW

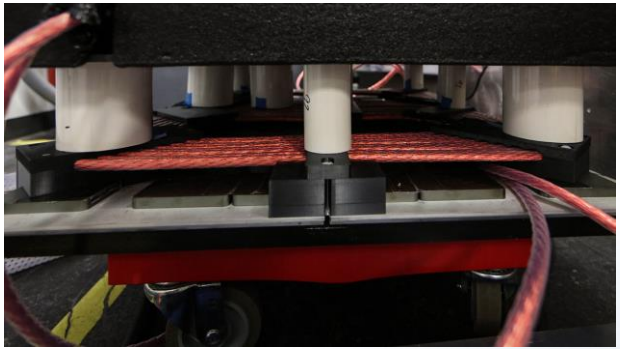
Wireless charging by BMW:

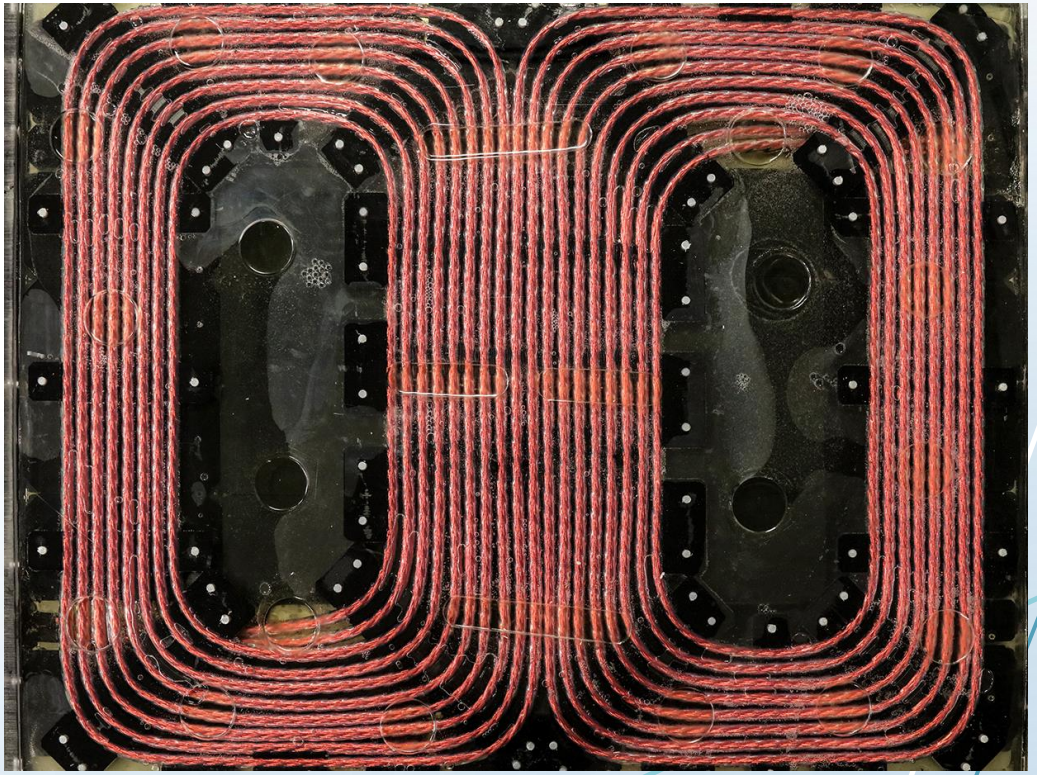
- 3.2 kW

Wireless fast charging for electric vehicles

Oak Ridge National Laboratory

- 120 kW fast charging
- 97% efficiency

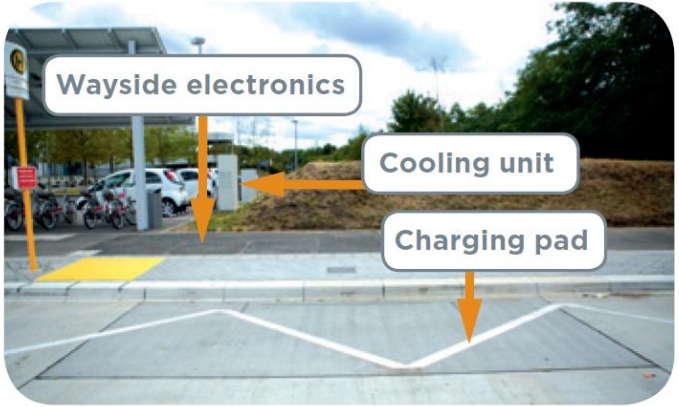




Source: Mark Anderson, «Oak Ridge Inches Closer to 15-Minute Wireless EV Charging," IEEE spectrum, 2018.

Wireless chargers for electric busses

Wayside grid connection:



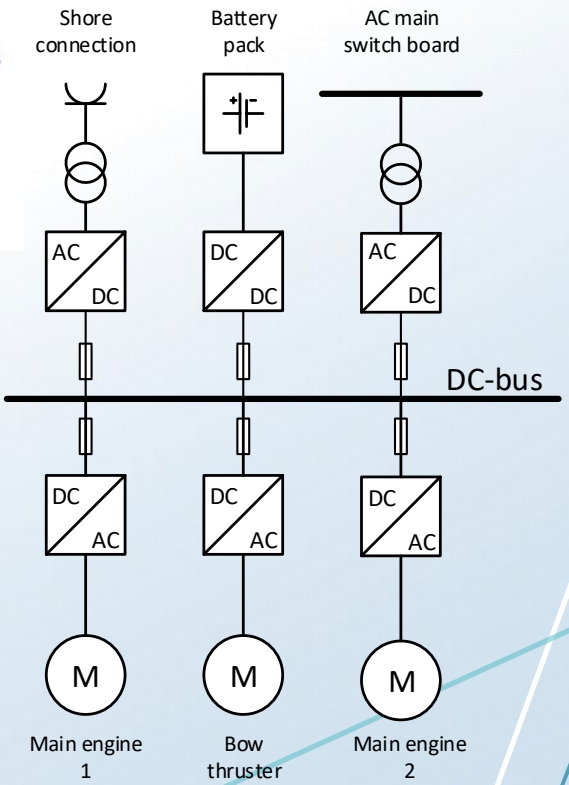
Onboard equipment:

Bombardier Primove charging 200

- 200 kW
- 280 A
- 530 – 750 V DC

Possible charging solutions and improvements?

- Conductive (cable) or inductive (wireless)?
- On-board charger in the boat or on-shore?
  - Will a fast charging station survive the salty water?
  - Fast and slow charging options like EV's?
- Grid monitoring and fault detection
- Charge with DC instead of AC?
- Galvanic isolation?
- Replace the big and heavy 50 Hz transformer with more modern compact solutions?
  - High frequency transformers
  - Solid state transformers
  - Integrate with the charger as an converter with galvanic isolation?



On-going project about charging technology for electric boats and aircrafts

Ladeteknologi
for elektrifisert framdrift av
maritime fartøy og luftfart

- One year project financed by ARC – Arctic Center for Sustainable Energy
- Main goal: Identify future research topics

- Visit the project website for more information (in Norwegian): https://site.uit.no/ladeteknologi/

Master theses at UiT in Narvik

Application of electric vehicle charging solutions
on small maritime vessels

Wireless charging for small electric vessels

Thank you for your attention