

Distributed Generation onboard Cruise Ships

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Context and Motivations

- Cruise vessels are experiencing an **intense innovation trend** of their shipboard power systems, driven by the International Maritime Organization regulations intended to increase the ships efficiency and to reduce polluting emissions.
- The traditional shipboard power systems layout consists of **large diesel generators** (gensets), usually located in a couple of engine rooms in the afterward part of the ship, and of a distribution system which delivers the power from the main switchboard, through cables, to all final users scattered all along the ship.
- The presence of **highly dynamic large loads**, such as propulsion loads and other power converter interfaced loads and resources, cause severe power quality and reliability issues.

Context and Motivations

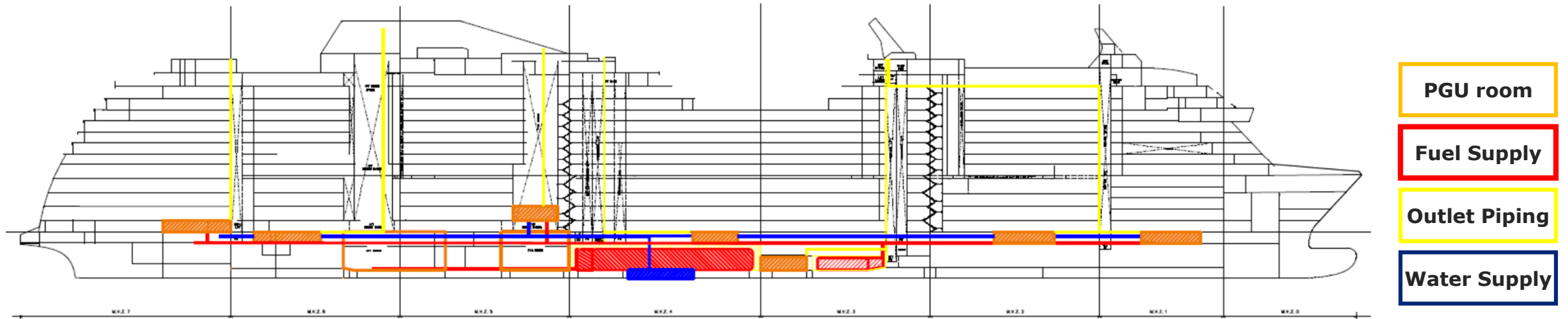
- **Lithium-based Battery Energy Storage Systems** are today of major interest in new building and retrofitting projects to improve performance and efficiency.
- One of the most promising approach to improve efficiency and reliability while integrating novel energy resources is the adoption of the **Distributed Generation**.
- The purpose is to overcome the traditional concept of power generation with the installation of a greater number of **small generating elements properly distributed** on board and integrated each other through an appropriate electrical distribution grid.
- The most interesting technologies for the distributed power generation are the **micro-Gas Turbines (mGTs) and fuel cells**.

Distributed Power Generation System

- **Gas Turbines** are characterized by a small size, reduced weight and limited emissions. They can be fed with Natural Gas.
- **Fuel cells** have good efficiency, modularity and almost zero emissions in terms of noise, vibration and air pollutants. They can be fed with pure Hydrogen (H₂) or Natural Gas (NG) properly processed.
- The power production units can be located in each of the ship **Main Vertical Zone (MVZ)** already identified on board to comply with fire safety rules and very useful for the purpose of DER concept.

Distributed Power Generation System

Study Case: 14000+ gross register tonnage, integration of Fuel Cells



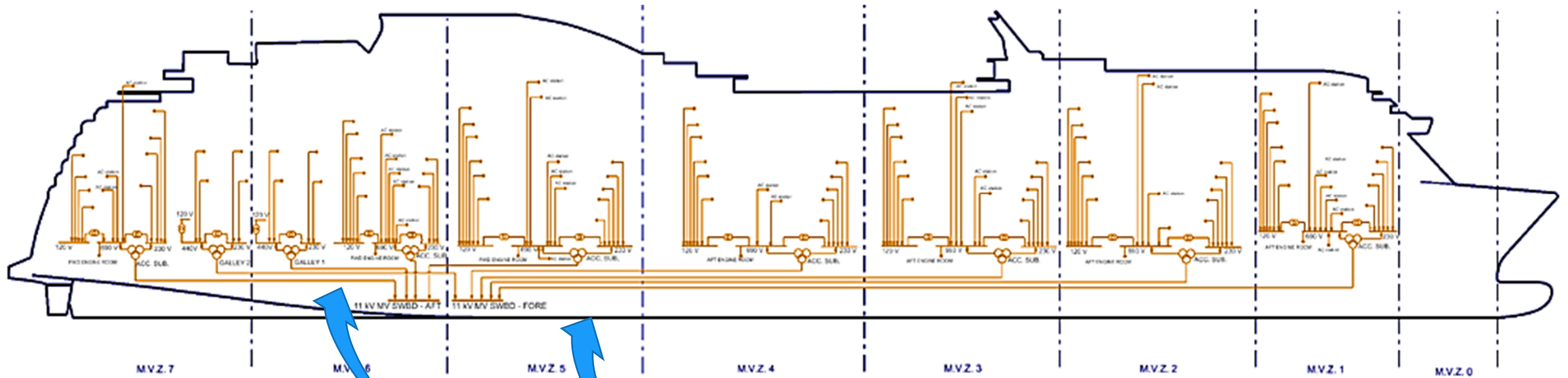
RIPRODUZIONE RISERVATA

GRT	140000+
Design Speed	22 knots
Propellers	2 x fixed pitch
Passengers	5600
Total power demand	~50 MW

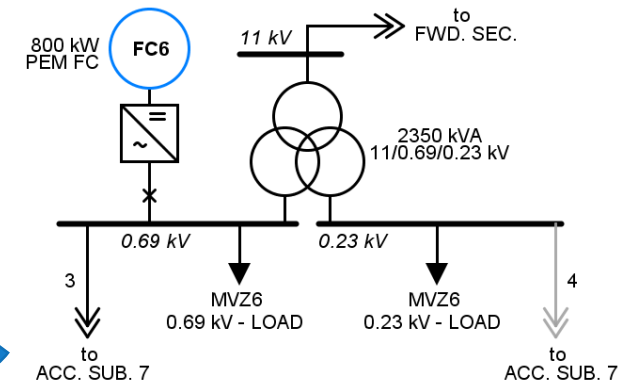
Distributed Generation	9 x PEM FC units
FC Units Power	9 x 800 kW (7.2 MW)
Power Station (AFT, FWD)	1 x Type-1, 2 x Type-2
Type-1 DG Nominal Power	13.74 MVA
Type-2 DG Nominal Power	7.34 MVA

A Study Case

Study Case: Distribution System Layout



RIPRODUZIONE RISERVATA



Remarks

- The distributed generation regards not only the possibility to drastically enhance the **energy performance**, but also the reduction of the **environmental footprint** of ships.
- One of the most promising approach is to redesign the shipboard power system with a **different power generation technologies** such as FCs, mGT and BESS.
- The **most challenging issues** for the integration of distributed generation on board of a cruise ship are related also to space, volume and normative requirements.

Further readings:

1. F. D'Agostino, G. A. Di Mare, G. Flore, P. Gualeni, L. Magistri, F. Silvestro, "Generazione Distribuita a Bordo delle Navi da Crociera", *AEIT* - Volume 105 - Numero 5/6 maggio/giugno 2019
2. F. D'Agostino, P. Gualeni, G. P. Schiapparelli and F. Silvestro, "Control Strategy and Architecture for Integrating Distributed Fuel Cells on board Large Cruise Ships," *2020 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM)*, Sorrento, Italy, 2020

Thank you for your attention.

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