

All Electric Cruise Liners: Evolution of Electrical Systems in the Last Decade

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First experience (1995):

- One 6.6kV switchboard with SF6 circuit breakers and analogue single function protection relays.
- Radial network with 440V low voltage and two winding cast resin transformers.
- 1000V Cyclo drive with 4 propulsion transformers (and electromechanical harmonic filtering on bigger units).
- Inboard synchronous propulsion motors with controllable pitch propellers.
- Low power factor (0.7) synchronous generators.

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Power Distribution

- Rated voltage is now 11kV
- Digital multifunction protection relays are exclusively used, and their communication features exploited
- Vacuum contactors and circuit breakers have been used with success.
- High voltage switchboards are usually two, interconnected with an medium voltage line. A more fault tolerant structure.

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Network architecture.

- Some examples of radial 11kV distribution lines have been seen (Queen Mary 2, Aida Project).
- Multiple winding (11/0.69/.23 kV) transformers are becoming more and more common.
- Low voltage have been raised to 690V from 440V. 440/690V transformers are installed to enable power from shore in locations not embracing 690V standard

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Propulsion.

- Cyclo-converter has almost completely disappeared, with exception of some pod based projects (only one manufacturer offers this solution, in conjunction with pods).
- Load Commutated Inverter is the preferred solution because of its reduced complexity, better power quality (harmonics have fixed frequencies, therefore can be easily filtered) and higher voltage to motor.

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Propulsion Motor.

- Still inboard for larger ships (propulsion power > 17.5MW), but pods have gained merits, despite their critical maintenance-ability (dry-docking necessary to perform many tasks, such as changing bearings).
- Motor voltage with LCI is in the range of 2kV or more now.
- Controllable pitch propeller systems have been abandoned in favour of frequency controlling through the drive.

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Generators.

- Use of LCI permitted a power factor of 0.8
- There are projects with 0.9 pf generators and static harmonic filtering (harmonic filters are designed to offer power compensation as well)

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Evolution guidelines:

- Weight and complexity reduction
 - Fuel efficiency increase
 - Comfort increase
- Cost reduction & more comfort to the customer

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The Future:

- P. W. M.?

Evens:	Odds:
More comfort in virtue of reduced torque harmonics	More critical motor construction (insulation)/filtering
Better power quality	More expensive components (solid state devices, cooling, and so forth)
Better dynamic performances	More money to buy and then longer payback time
Lighter generator design (better power factor)	

Do we need these?

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The Future:

- Pods?

Evans:	Odds:
Better space allocation	Critical maintenance. Risk
Better comfort (less vibrations)	Not available in the range of power usually required
Fuel economy (?)	Interfaces and quality/integration management
Improved manoeuvrability	Transmission of power through a slip-ring

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The future:

- Co-generation?

Evans	Odds
Fuel efficiency	Space lost in the stack
Control of smoke emissions	Complexity
	Difficult restart after black out if no diesel engines are used

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The future:

- No dramatic changes in present power generation architecture. Diesel engines are retained as the best trade-off. 11KV and separable power plants are regarded as the most valuable combination.
- Maybe pods will penetrate the market more, when high power output are available

The future is optimising what we have already, with great attention to environment and energy saving (cruising is fuel intensive)

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Areas for optimisation:

- System Integration, with particular attention to controls. Controls in these days are designed by subcontractors lacking the knowledge of the big pictures. Chances to achieve fuel economy are lost. Awareness of rotating machinery control is lacking in the marine field (to say the least, for example not many ships are equipped with over-excitation protection; some others have reactive power metres without the indication of sign, ...). Very often propulsion contractor implement protective functions not coordinated with power plant.
- Automation is only a higher level control. It does not perform machine control, but process control.

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Attention to the environment.

Main objective: reduce smoke emissions, both in port and at sea.

- High Voltage Shore Connection. Enables to shut engines when in port. Good integration with appropriate controls shipboard can avoid passing through a blackout
- Proper load management. Avoiding starting engines without real necessity (feeding reactive load) and reducing load impacts.
- Scrubbers.