GE POWER CONVERSION | 2019 MTS Conference

Dynamic Changing of Position from Power to Energy Management

Nick Smith, Technical Director

Back to School

- ***Power*** is rate of change of ***Energy***, in Joules per second, although we often lazily see Power and Energy used interchangeably.
- So: the engine is a 1MW engine, and we are running it at 790kW also means…
- …The engine is producing 790kJ per second, of a maximum possible 1MJ/s (at a terrible efficiency if we go back to the fuel)

Lesson 1: Energy is the Real Enabler

Energy is required to propel a ship, overcome friction, melt a missile in a DEW. Power is simply how fast we can transfer it.

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Back to School, Again

- Fuel is of course energy. Which we should measure in joules.
- But mechanical engineers are more comfortable with gallons or litres, even though to get back to energy we need to multiply by energy density, and a horrendous efficiency.
- Electrical engineers even invent other terms for energy – kWh - as we feel happier multiplying power by time rather than just removing the time divisor. kWh actually has little to do with defining Power, or Hours precisely, it's really energy.
- We could express fuel as kWh, we don't. Because kWh is electrical energy, fuel is mechanical so it's gallons.
- Not to mention gas, which is in cubic feet.

Lesson 2: They Should All Be in Joules, Then We Could See **Relative Efficiencies**

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Converting Energy to Energy for Consumers

If it's not logical for engineers, think about the poor consumers:

From the Web:

Here's how to convert cubic feet (ft3) to kWh from your **gas meter** reading. 482 **unit** used X 2.83 to convert to cubic metres X 1.02264 X 39.2 calorific value divided by 3.6 provides 15,189 kWh. At 2.84p/kWh provides an estimated bill of £431.38.

And that's just to change it to kWh, not joules.

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Power Out = Efficient Power In Generated, Doesn't it?

SPECIMEN A:
Mechanical propulsion designer

"we don't care, we will live with a fuel curve that's poor at many loads, but we win at max power".

i.e. kW demanded from propulsor A always comes from kW of engine A.

SPECIMEN B:
Electrical propulsion designer

"we can help here, we will switch off engines, as we have uncoupled kW demanded from individual engines

we can vary the running peak power available to bring us to a better point of the curve."

SPECIMEN C:
Hybrid propulsion designer

"we can switch off big direct drive engines, as long as we keep the shaft turning on a small motor and small engines.

we can also switch off small engines to push the big engines into a more efficient operating zone, by power take off."
Simple?

Lesson 3: If we equate power to energy for convenience....

...We end up fitting engines based on **peak**, rather than **average load**.

Big, Thick, Heavy and almost guaranteed not to run at their optimum operating point

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Power Out = Power Generated in, Doesn't it?

So all of these solutions are about **Matching** Instantaneous Power **Generation** to Instantaneous **Consumption**…Efficiently

'Holy Grail' is either derating the total running engines to meet instantaneous kW demand, *or* varying kW demand to meet the engine rating

Techniques like stopping engines is actually derating the whole system to match demand. This is Electric Propulsions primary efficiency advantage.

There are other ways to derate the system artificially than stopping engines…

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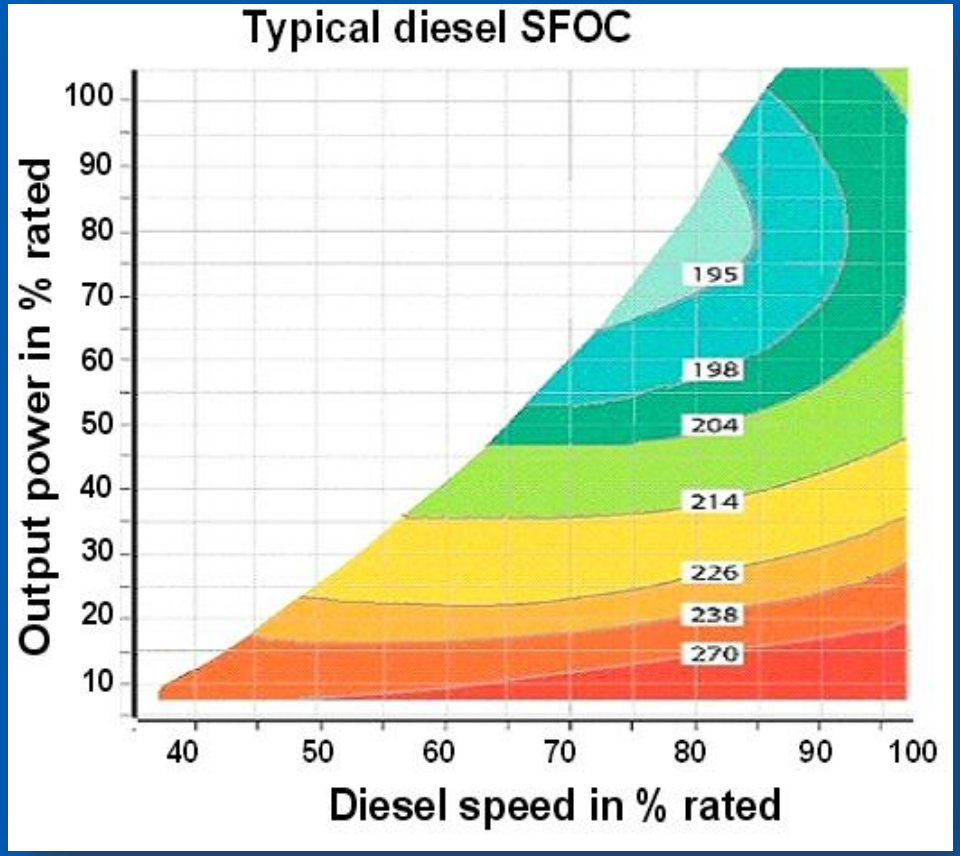
Variable Frequency Generation

1. Drop generator speed to derate engine
2. Lower frequency = lower losses, if you don't need all the engine power
3. Variable frequency generation is not limited to DC.
4. AC can be run 40-60Hz without much modification.
5. Both need a frequency convertor to revert back to 60Hz for Services.

Sweet spot at 80% speed, 80% load



Source: adapted from R. Nilsen and I. Sorfonn. Hybrid power generation systems.
In Power Electronics and Applications, 2009. EPE '09. 13th European Conference on, pages 1–9, 2009

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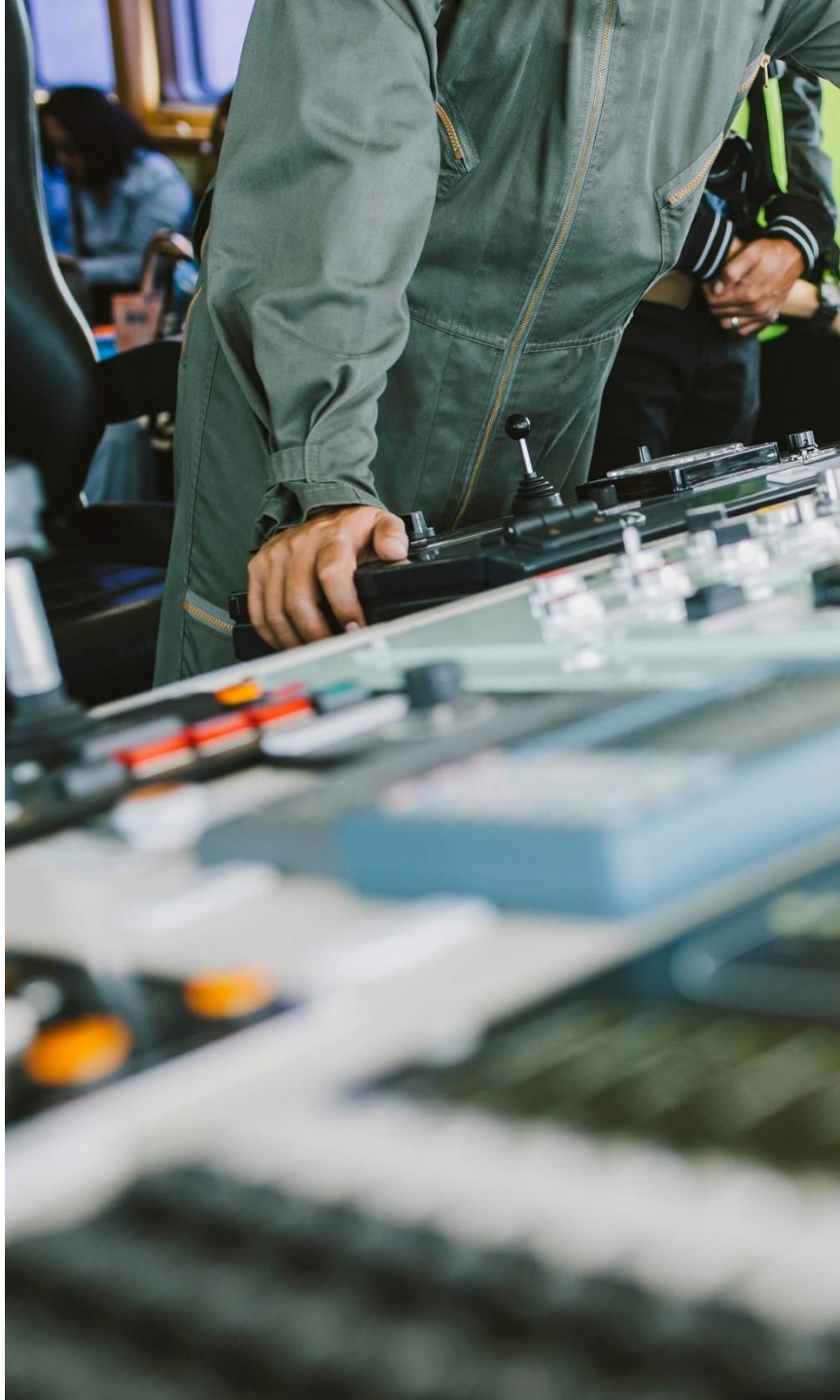
Energy Storage is the Real Game Changer

- Breaks link between “Power Out must equal Power In”
- No longer do you always have to derate the power system to gain efficiency
- “**Energy** Management Systems”, rather than “Power Management Systems” are required
- Allows ‘weaker’ *power* systems like mechanical and hybrid to accept heavy electrical loads, but at a cost
- We truly have to think about “Joules Stored” rather than “Watts Generated” from a generation perspective
- Think of energy stores as “static prime movers” on power systems, which require “reverse power” to fill their limited fuel tanks.



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Centralized Energy Storage Opens Up Many Possibilities:

- **Load Levelling/Dynamic Support/Peak Shaving** including DEW Weapons
- **Faster acceleration** at propulsors, but ramped acceleration on engines
- **Single or reduced generator operation**, as spinning reserve is no longer required, it can now be static.
- **UPS functionality** for the power system, preventing TLFs.
- Avoidance of wasted **fuel** and higher **emissions** during impact loading.
- Ability to run in harbour with no shore supply or harbour engine.
- **Hybrid Boost**, where e-store cyclically charges and discharges to allow an engine to be stopped.
- Real reduction in engine run hours, potentially maintenance.

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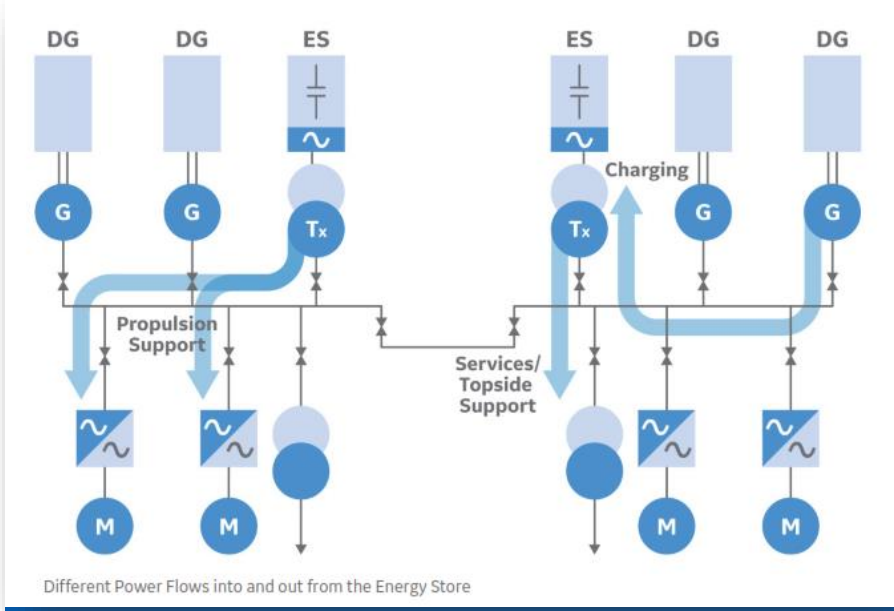
Centralized vs Localized Energy Storage?

Localised Energy Storage:

- Can only practically support local loads, without complexity, in energy management systems.
- Needs local power conversion to do it. Addresses ride through, but not so many other benefits; more difficult to share.
- Local stores per kWh are more expensive.
- May be required for small electrical power systems with limited distribution capability

Centralised Energy Stores

- One per bus is the real growth area
- Function more like static prime movers, than local UPS/load levelling supplies.
- Economy of scale and maximum flexibility to achieve benefits of energy storage, at a lower cost.



Different Power Flows into and out from the Energy Store

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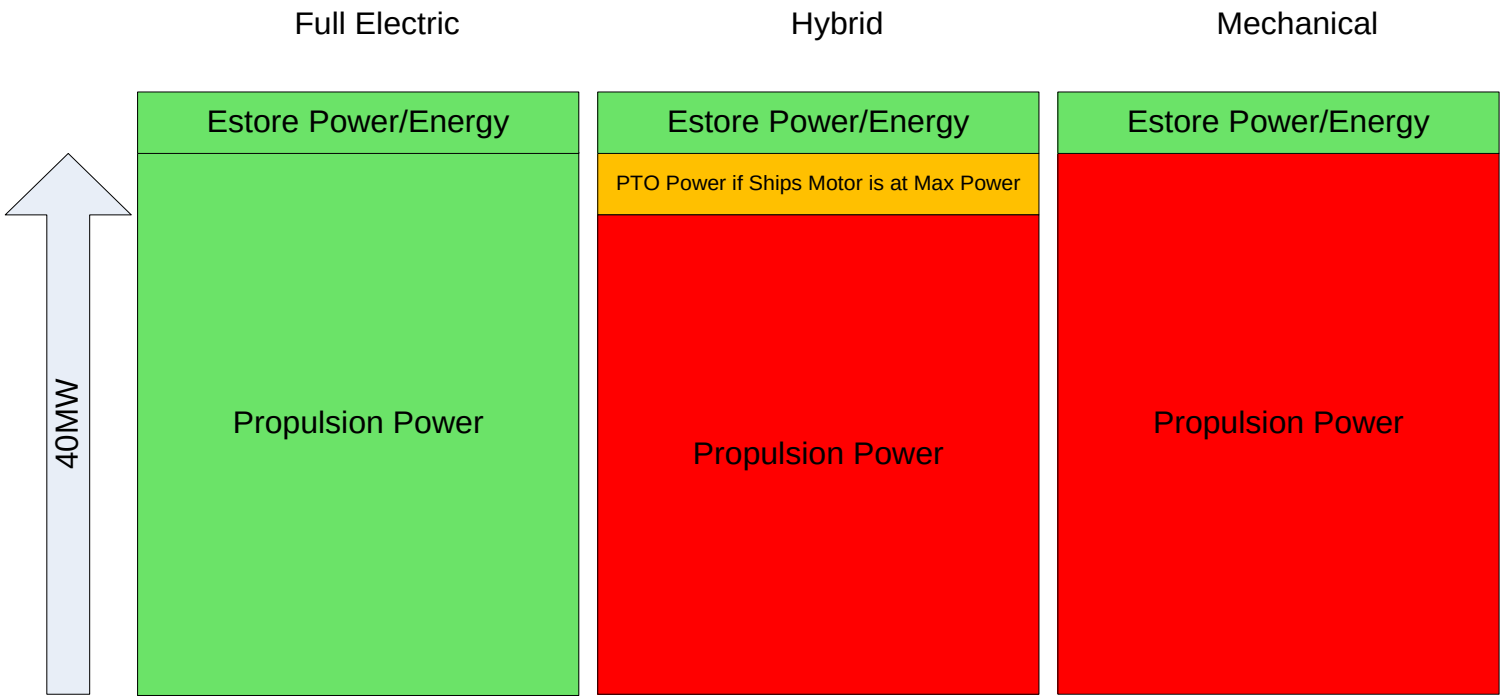
Not All Power Systems are Equal for Impact Loads



Instantaneous Power Available for DEW on a Destroyer Sized Vessel, or high impact loads on an Offshore vessel with different P&P fits.

Must be able to Distribute Energy

- Instantaneously, or using more expensive energy storage
- Only electronic converters are fast enough to move power
  - Away from propulsion
  - Out of Energy Storage
- At max speed, an Electrically propelled destroyer could electronically switch e.g. 40MW to weapons and back without impacting prime movers , and without energy storage.
- Stationary DP electrical vessels with spinning reserve can also pick up impact loads, but lightly loaded engines are less effective, and DP Thruster loads are harder to divert, so Estore is Helpful

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SeaGreen Plug and Play Energy Storage

Commercial marine is embracing **plug-and-play, deck-mounted storage** for current platforms - ISO containers on deck

Typically 1-3MW

Centralised energy storage

Could be a mission/charter specific fit?

Fitted in days, with no hull cuts

Provide rapid, or even emergency additional prime mover capacity/DEW/Efficiency

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SeaGreen Battery Energy Storage System

Features

Applications in all vessel types requiring cycling operations

CONTINUITY OF OPERATIONS

Mitigating Black Out Concerns, Static “Spinning” Reserve
Instantaneous Discharge Upon Loss of Diesel Generators
Contributing Power On Demand to Ride Through Generator Overload

INCREASED RESILIENCE & EFFICIENCY

Dynamic Load Levelling
Reducing Stress on Prime Movers
Active Heave Compensation and Crane Load Balancing
Optimizing Operating Profile of Prime Movers

REDUCED EMISSIONS

Reducing Combustion Emissions and Noise in Port
Battery Power Manoeuvring for Port Entry and Egress
Short stay in harbour with no use of engines.

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SeaGreen Battery Energy Storage System

Operating modes

UPS	POWER RESERVE	DYNAMIC SUPPORT	ENERGY STORE ONLY	HYBRID BOOST
5 - 20 MINUTES	**5 - 20 MINUTES**	**1 MINUTE**	**30 MINUTES**	**>30 MINUTES**
UPS mode enables continuity of operations, increases availability, improves resilience.	Continuity of operations through blackout avoidance, improves efficiency, reduces opex (fuel & maintenance), reduces emissions.	Improves responsiveness, improves efficiency, reduces opex (fuel & maintenance), reduces emissions.	Improves efficiency, reduces opex (fuel & maintenance), eliminates emissions, reduces noise.	Improves efficiency, reduces opex (fuel), reduces emissions.

Table above depicts standard modes and duration only.

- SeaGreen ESS can be configured to operate in any or all of the above five operating modes.
- Many modes can be selected in parallel - such as dynamic support and UPS.
- Energy storage options tailored to suit the level and duration of power required.

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SeaGreen Battery Energy Storage System

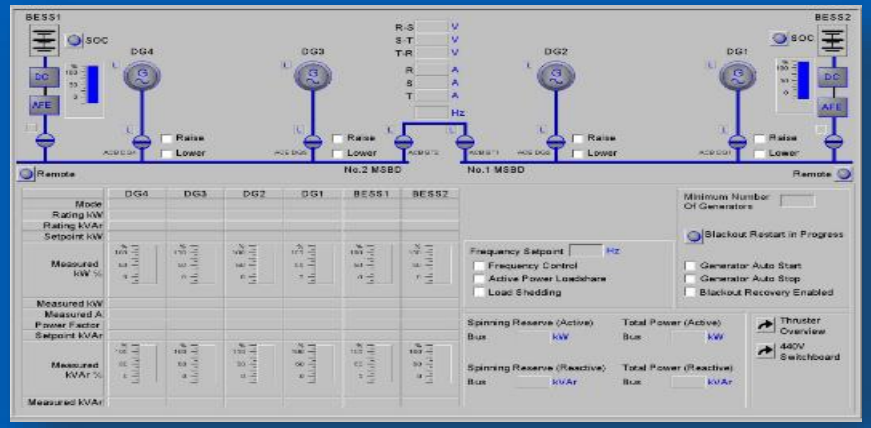
Integration With Ships Automation & Dynamic Positioning (DP)

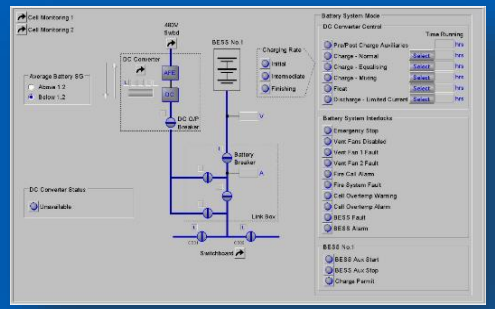
Battery System could run stand alone for most operating modes

- Reactive by sensing bus conditions
- Would confuse Current System Blackout Recovery, Spinning Reserve and Consequence Analysis

To get maximum benefit out of the system need to add Energy Management Modules to Power Management and DP Systems

- Proactive by integration with PMS
- Dynamic Positioning (DP) Estore features updates
- Automation system Estore features updates
- Functionality and mimic updates for Estore
- DP Consequence Analysis Updates
- Add 2 static Prime Movers to System with Energy Limits as well as power limits





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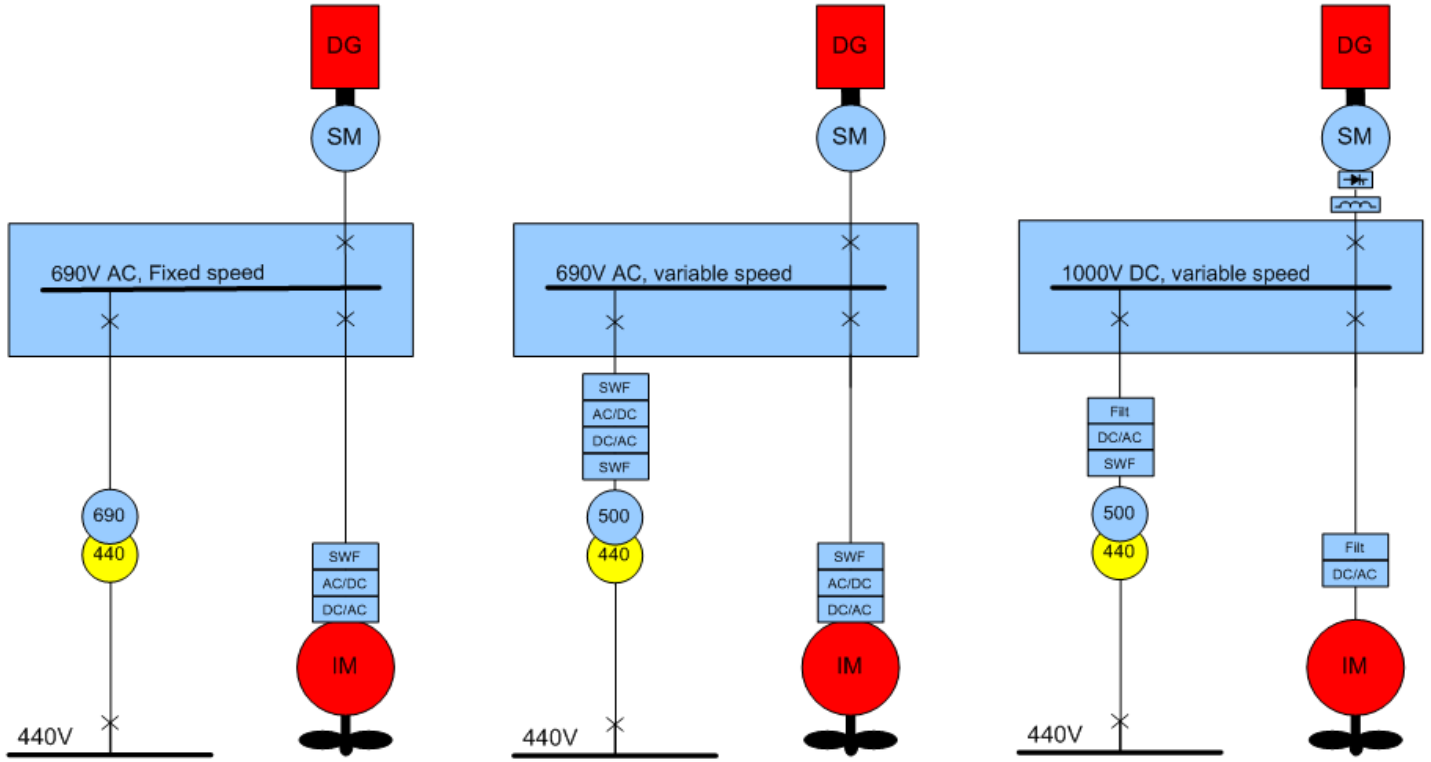
Architectures for Energy Optimization



Fixed Frequency AC

The benchmark

Variable Frequency AC

DC Architecture (Simple DC)

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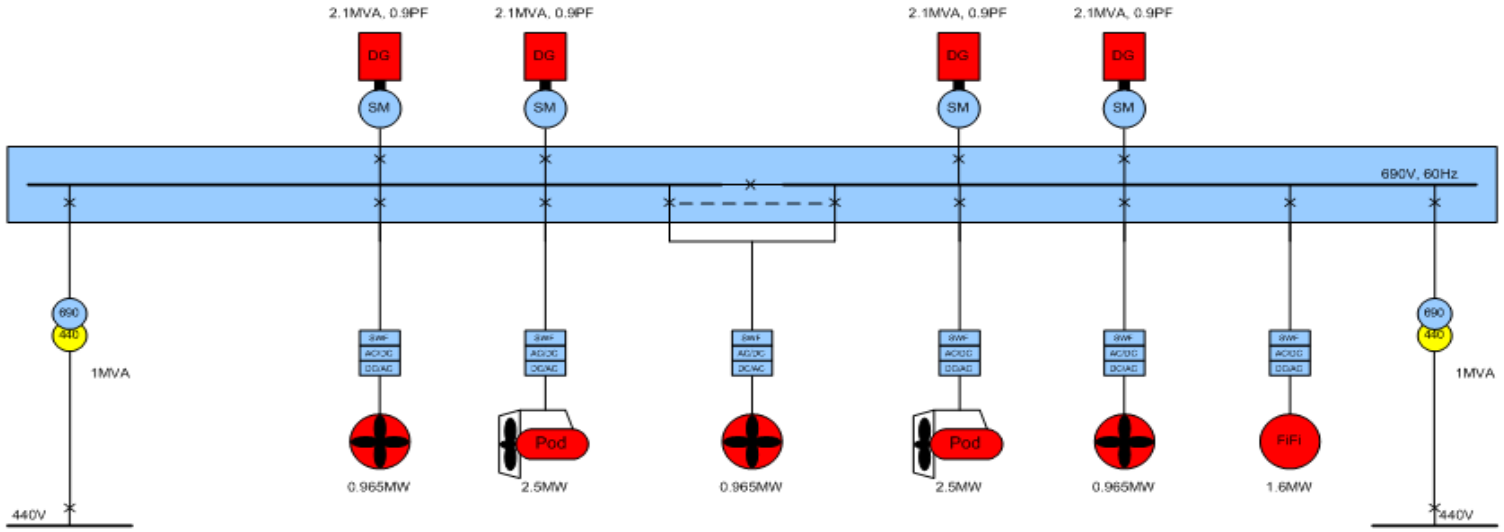
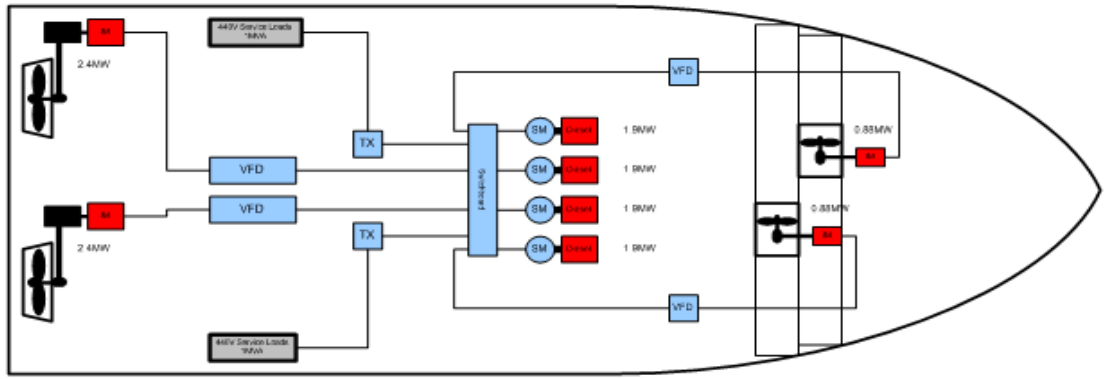
Fixed Frequency AC





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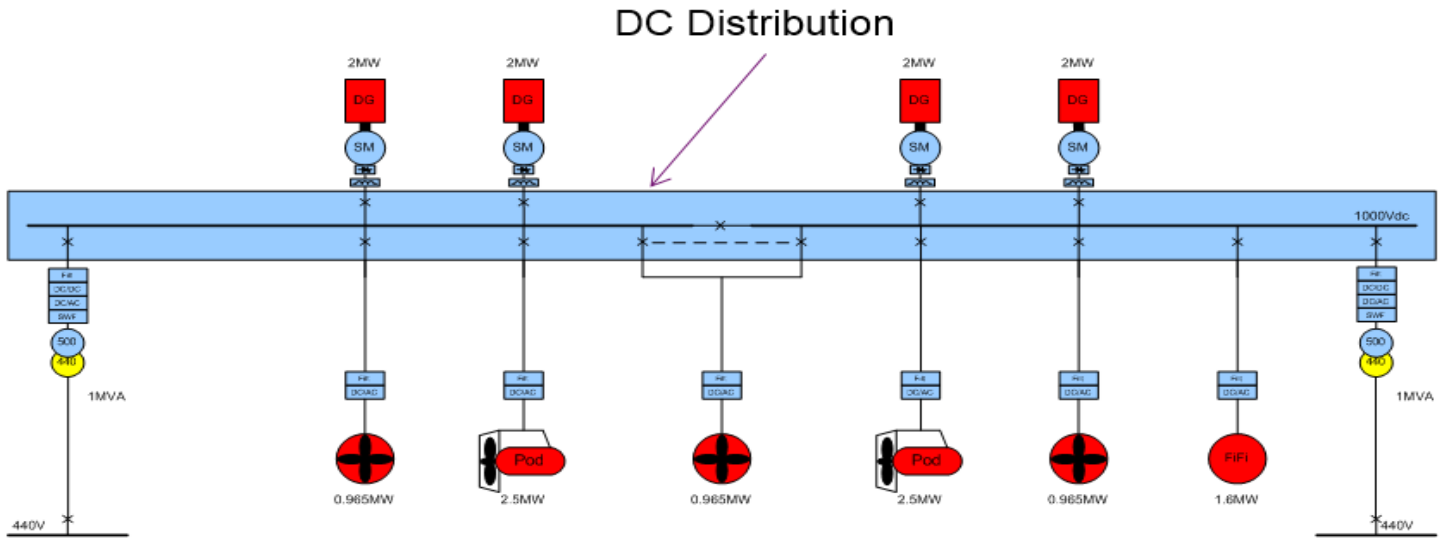
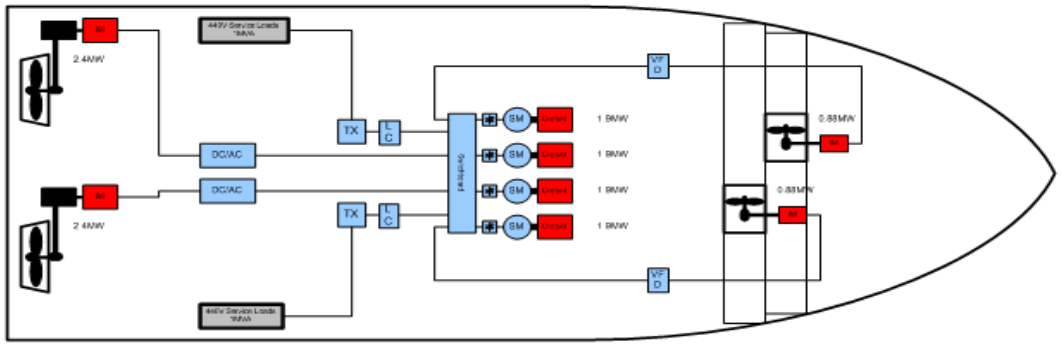
DC System





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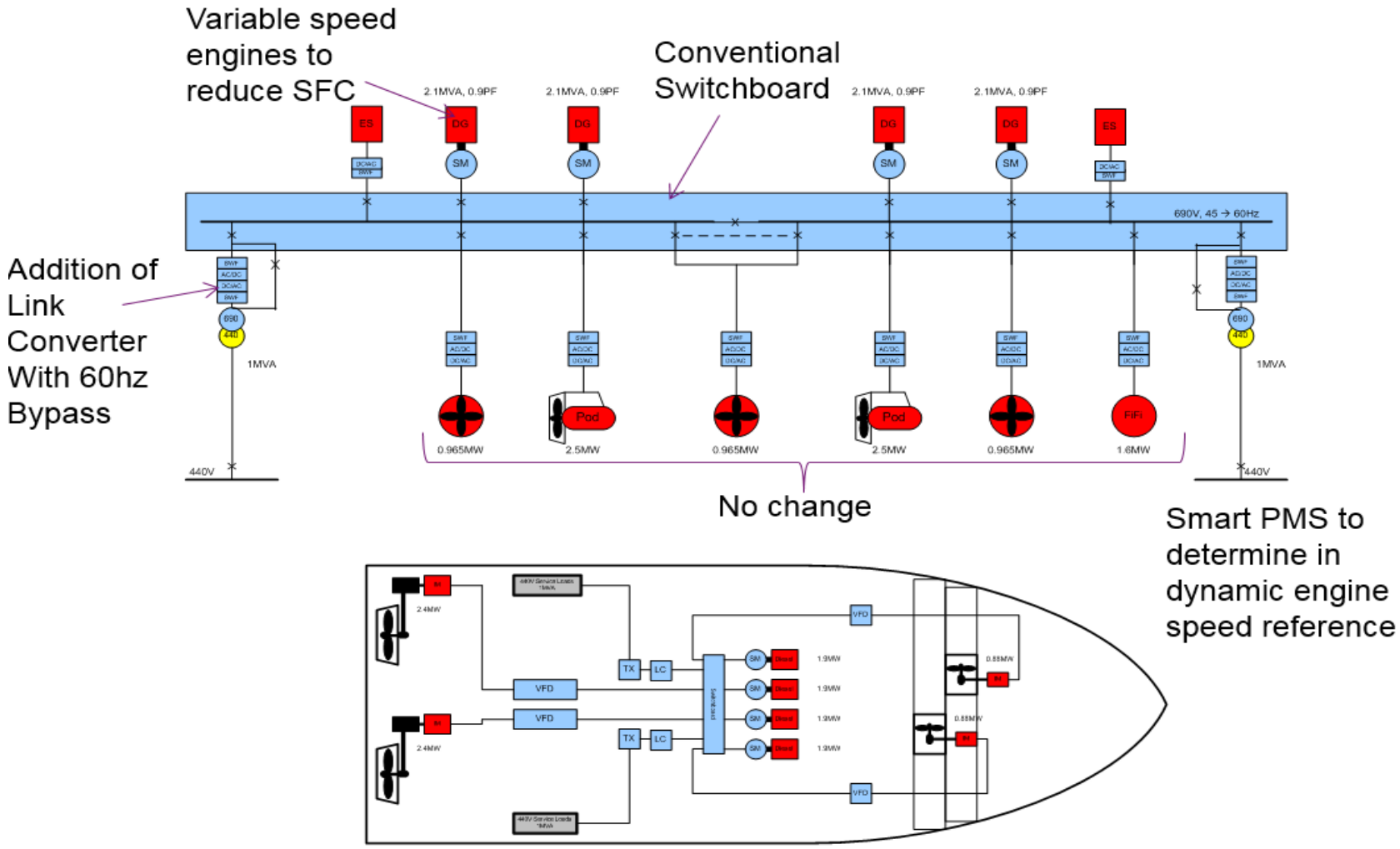
Advanced AC including Centralized Energy Storage



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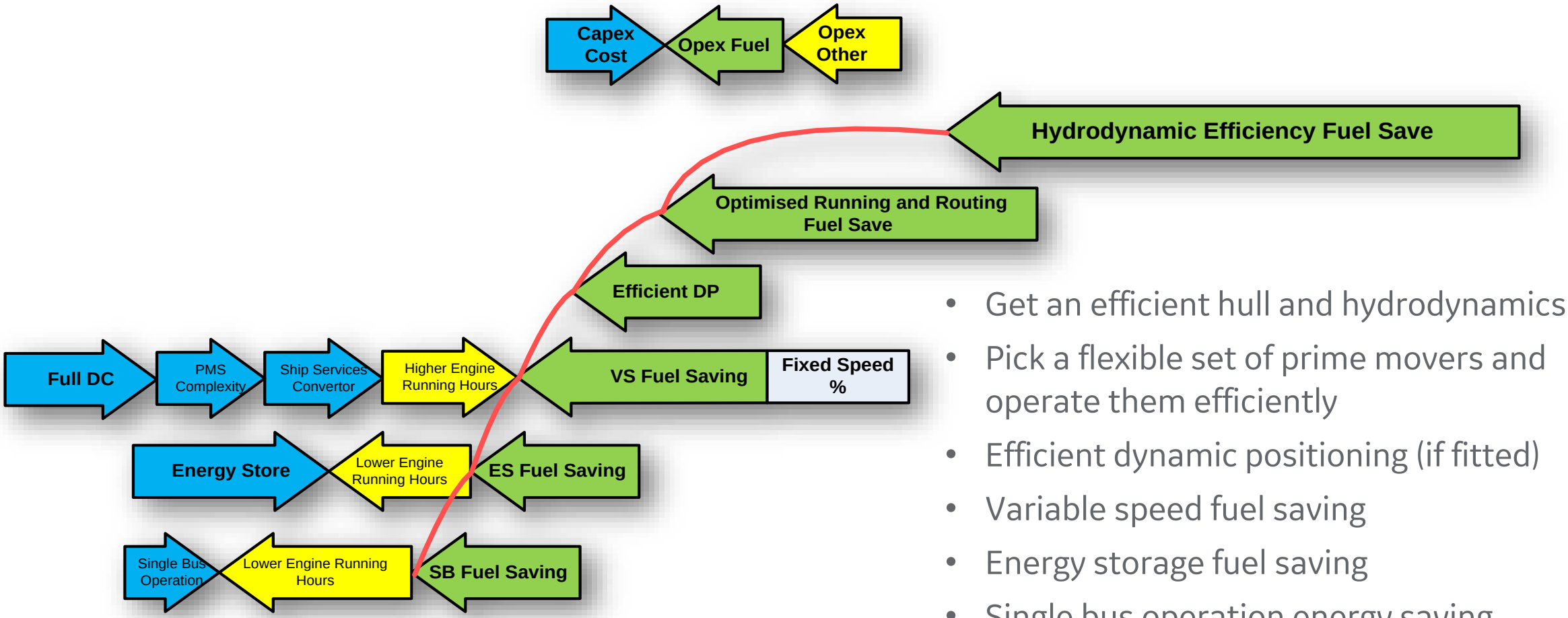
The Fuel Line, OPEX vs CAPEX



- Get an efficient hull and hydrodynamics
- Pick a flexible set of prime movers and operate them efficiently
- Efficient dynamic positioning (if fitted)
- Variable speed fuel saving
- Energy storage fuel saving
- Single bus operation energy saving

Don’t pick them all, you don’t get 100%

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Increasing Commercial World Resilience

Commercial ‘peacetime’ and missions overlap

Safety, availability, cost… consequences of loss can be dire – lives, high $B liabilities

Has to manage high-impact loads, like drilling

Single bus for high integrity operations is common

Rethink.. splitting switchboards into more sections, and better redundancy groups

Don’t group more equipment into fewer switchboards, harming resilience (like some DC offerings)

Resilience can be significantly enhanced with **energy storage**

Increasing rapidly for efficiency, emissions and availability

Retrofittable, temporary or permanent

Immediate, solid state prime movers, with 1ms start up time, no wear, and no dips in Hz

Only power electronics really has response time for directing energy storage power, or diverting propulsion power, or responding to sudden engine loss.

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Conclusions

Architecture type (DC, AC) is actually less important to efficiency than the **techniques** that can be applied to either

Pick a **flexible set of prime movers** and operate them efficiently

Single bus operation is simple, and just requires enhanced generator protection for resilience , so is low cost

Energy storage, more cost effective when centralised

- Most benefit, lowest PU cost (load levelling, UPS, harbour, boost)

Power Management Systems need to be changed to **Energy Management Systems**

Lesson : Only Power Electronics and Pivoting to an Energy rather than a power management system can maximise resilience and get the most out of Ship Systems with Estore

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