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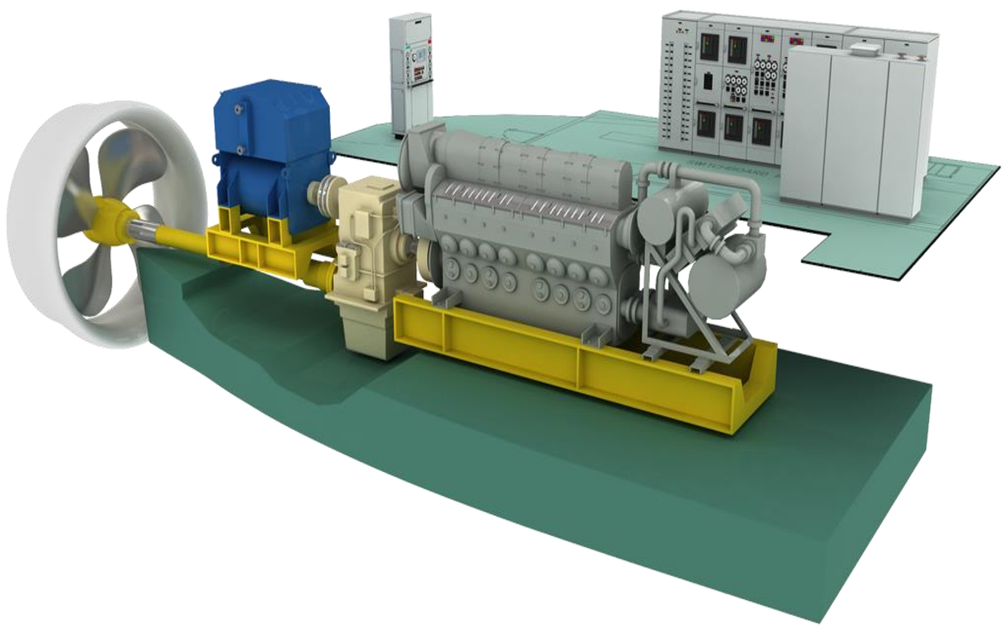
Automation

MORE EFFICIENT DIESEL ELECTRIC POWER PLANT FOR DREDGES



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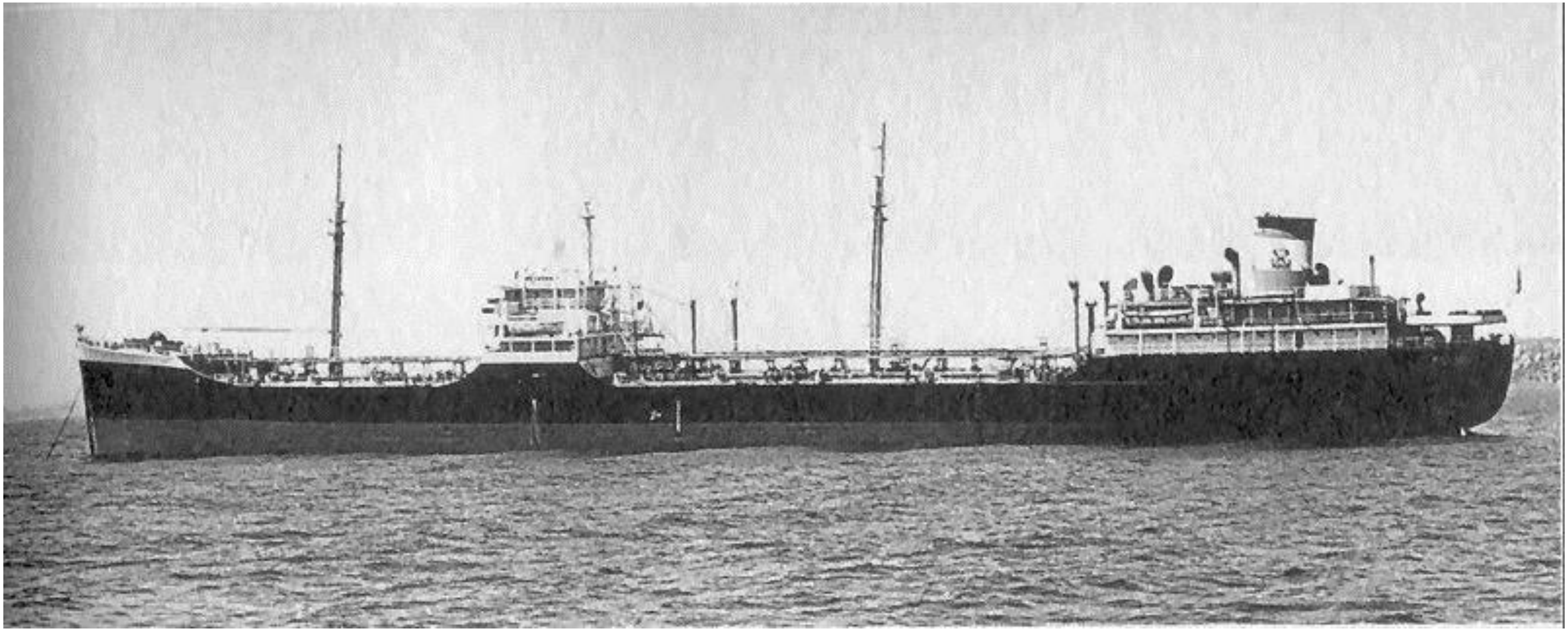
Contents

- History of Electric Power for Marine Propulsion
- Resurgence of Marine Direct Current (DC) Systems
- Comparison of Traditional AC Diesel Electric to New DC Diesel Electric
- Efficiency Improvements
- Operational & Maintenance Improvements
- Cost Considerations
- Summary & Conclusions

History



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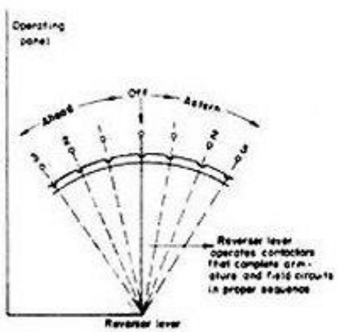
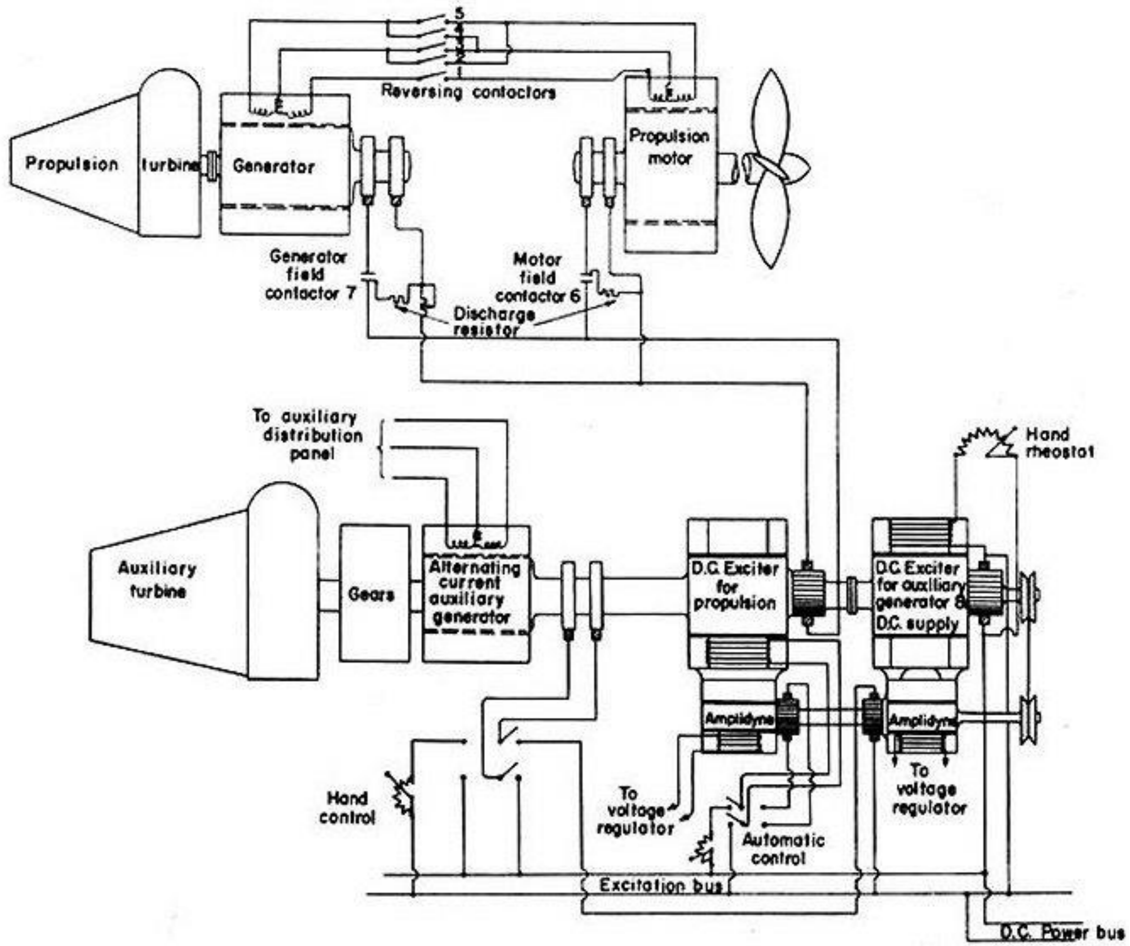


Position		Reversing contactors					Field contactors	
		1	2	3	4	5	Motor 6	Gen. 7
Ahead	Off							
	1	O		O		O		
	2	O		O		O		O
	3	O		O		O	O	O
Astern	Off							
	1	O	O		O			
	2	O	O		O			O
	3	O	O		O		O	O



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Development of Marine Electrical Propulsion

1. *1956 – Thyristor Enable Reliable AC → DC*
2. *1960 – 1980 Many Dredges Used AC Gens with DC Prop & Pump Motors via SCR*
3. *1980 DC Motors Declined for AC Motors via VFD*
4. *2010 AC Gens → DC SWBD → AC Motors*

Resurgence of DC - Why?

Technological Factors For The Resurgence Of Marine DC Propulsion and Distribution Power

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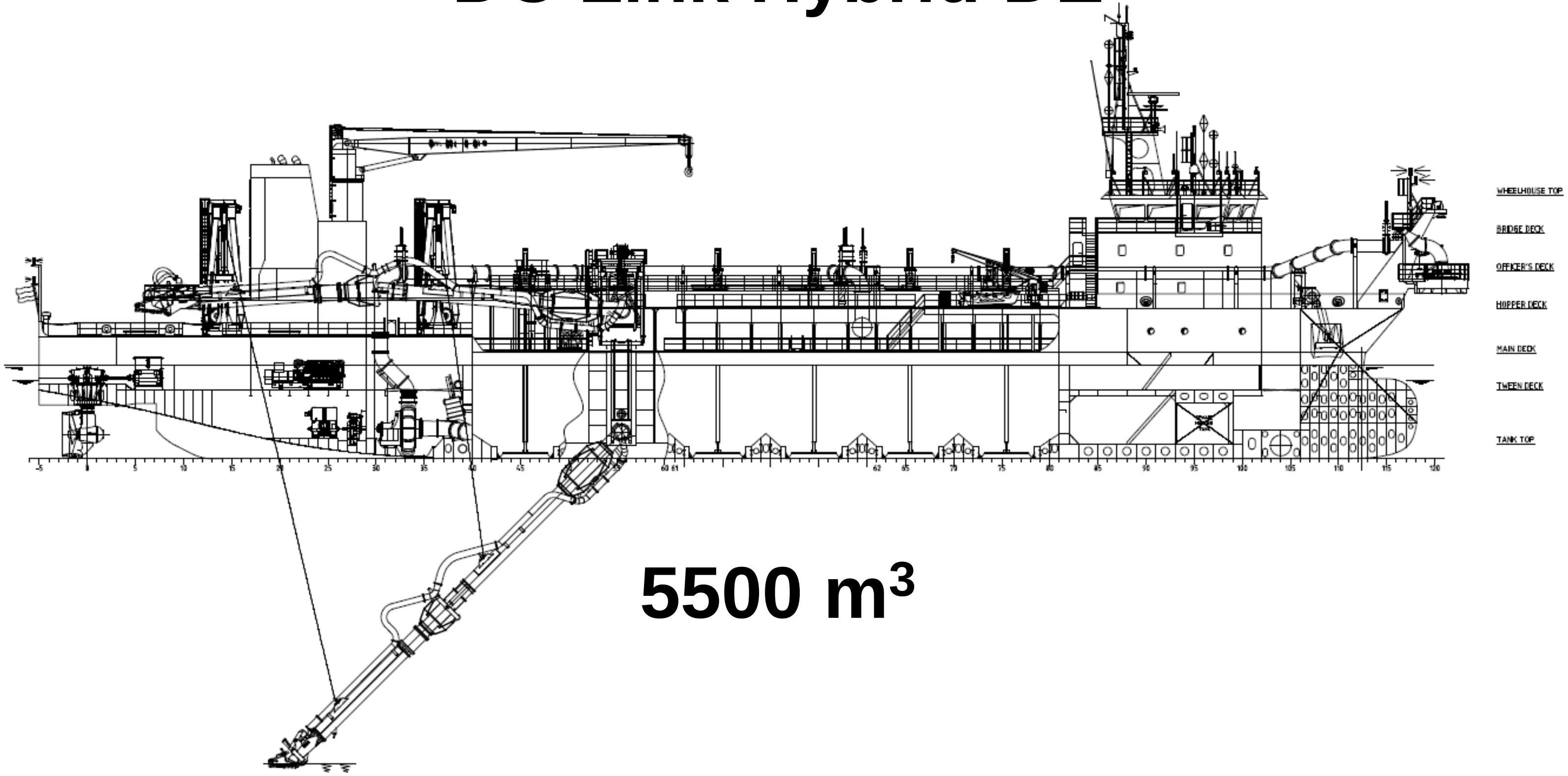
- Development of High Current DC Fault Current Protection

Power Plant Comparison

Traditional AC DE

vs

DC Link Hybrid DE



5500 m^3

Power Plant Comparison

Comparison Objectives

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- Combined potential for 20% in fuel savings

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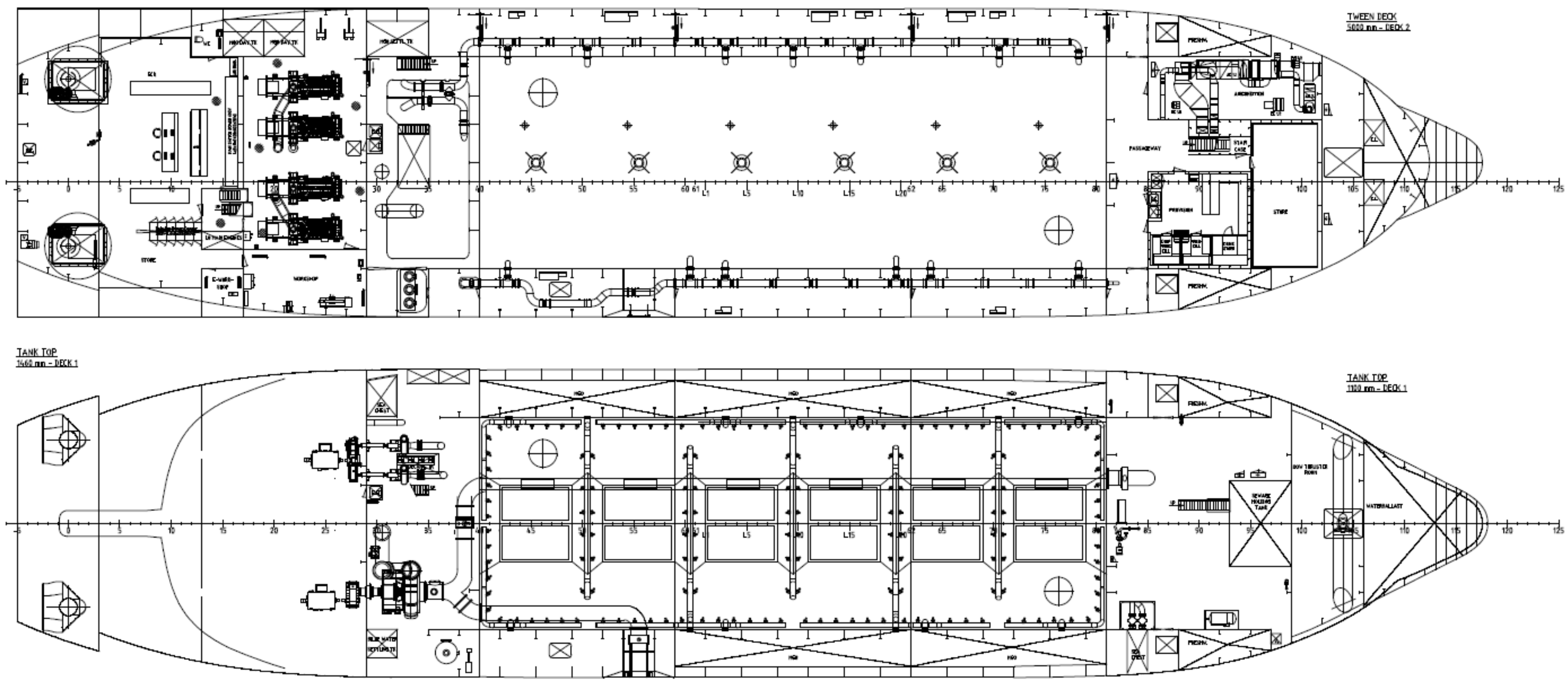
Traditional AC DE Plant

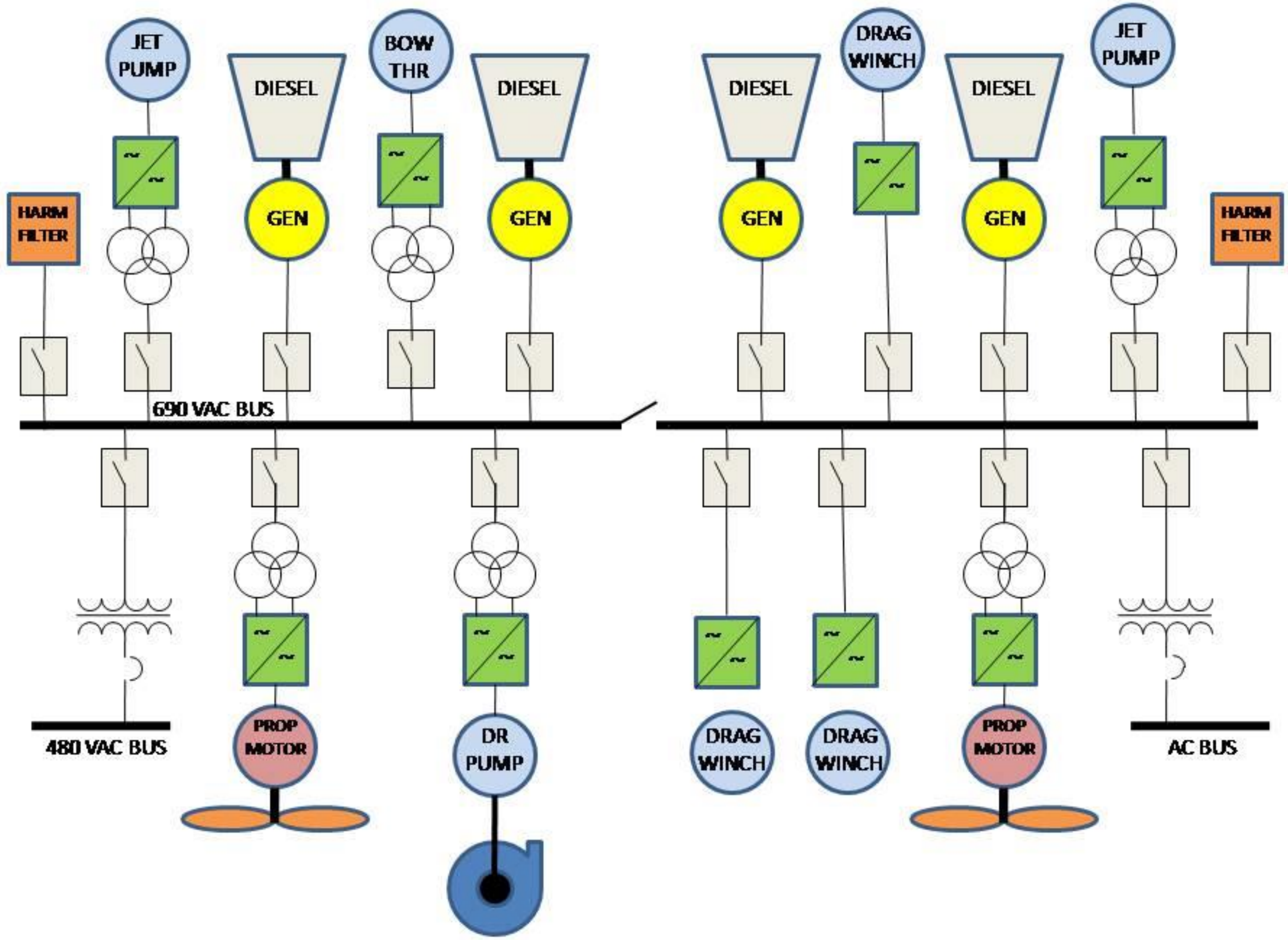


Length Overall	103 m
Breadth	21 m
Hopper Capacity	5500 m^3
Cruising Speed	12.5 kn

Main Generators	4 @ 2250 kw
Propulsion Motors	2 @ 1800 kw
Dredge Pump	1 @ 2000 kw
Jetting Pump	2 @ 1000 kw
Bow Thruster	1 @ 600 kw
Dragarm Winches	3 @ 150 kw

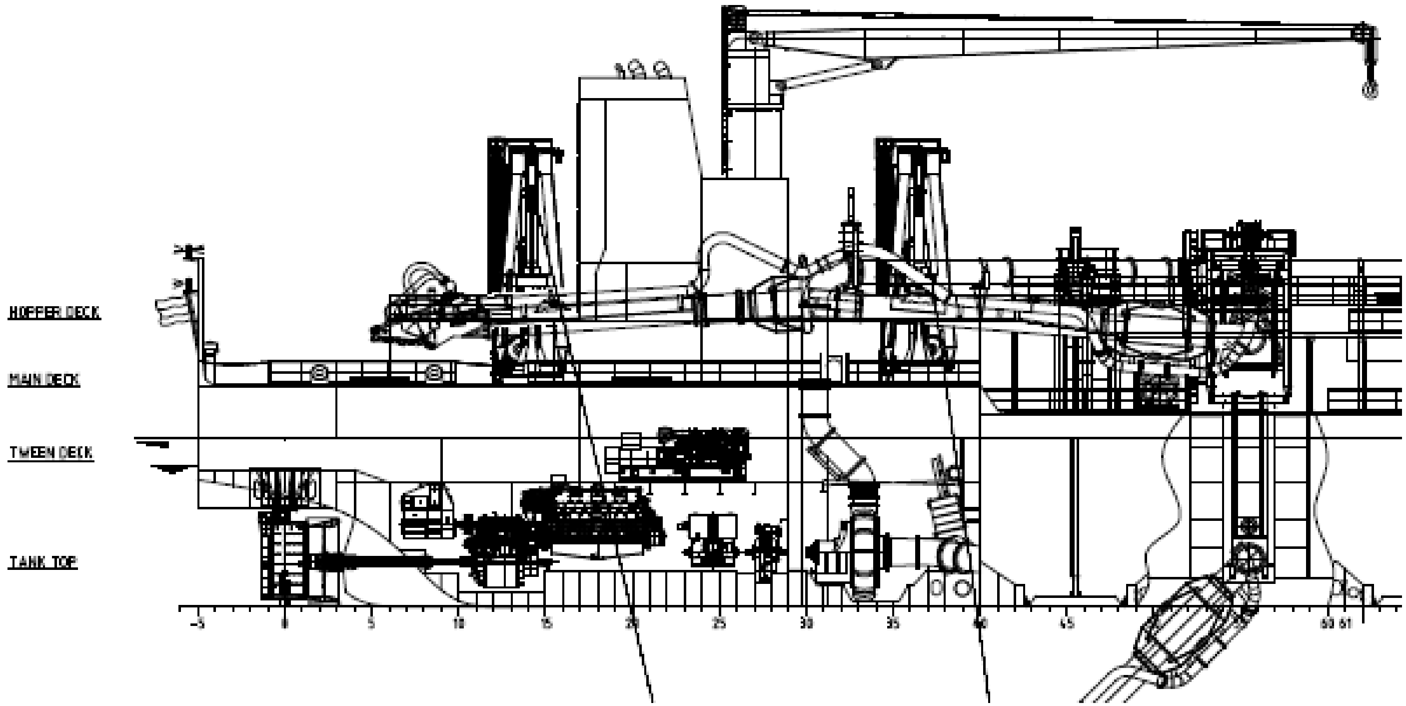
Power Plant Comparison

Traditional AC DE Plant One-Line Diagram



Power Plant Comparison

DC Link Hybrid DE Plant



Length Overall	103 m	Propulsion Diesels w/CPP	2 @ 3000 kw
Breadth	21 m	PTI/PTO Gens	2 @ 1700 kw
Hopper Capacity	5500 m^3	Dredge Pump	1 @ 2000 kw
Cruising Speed	12.5 kn	Jetting Pump	2 @ 1000 kw
Main Generators	2 @ 2000 kw	Bow Thruster	1 @ 600 kw
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Power Plant Comparison

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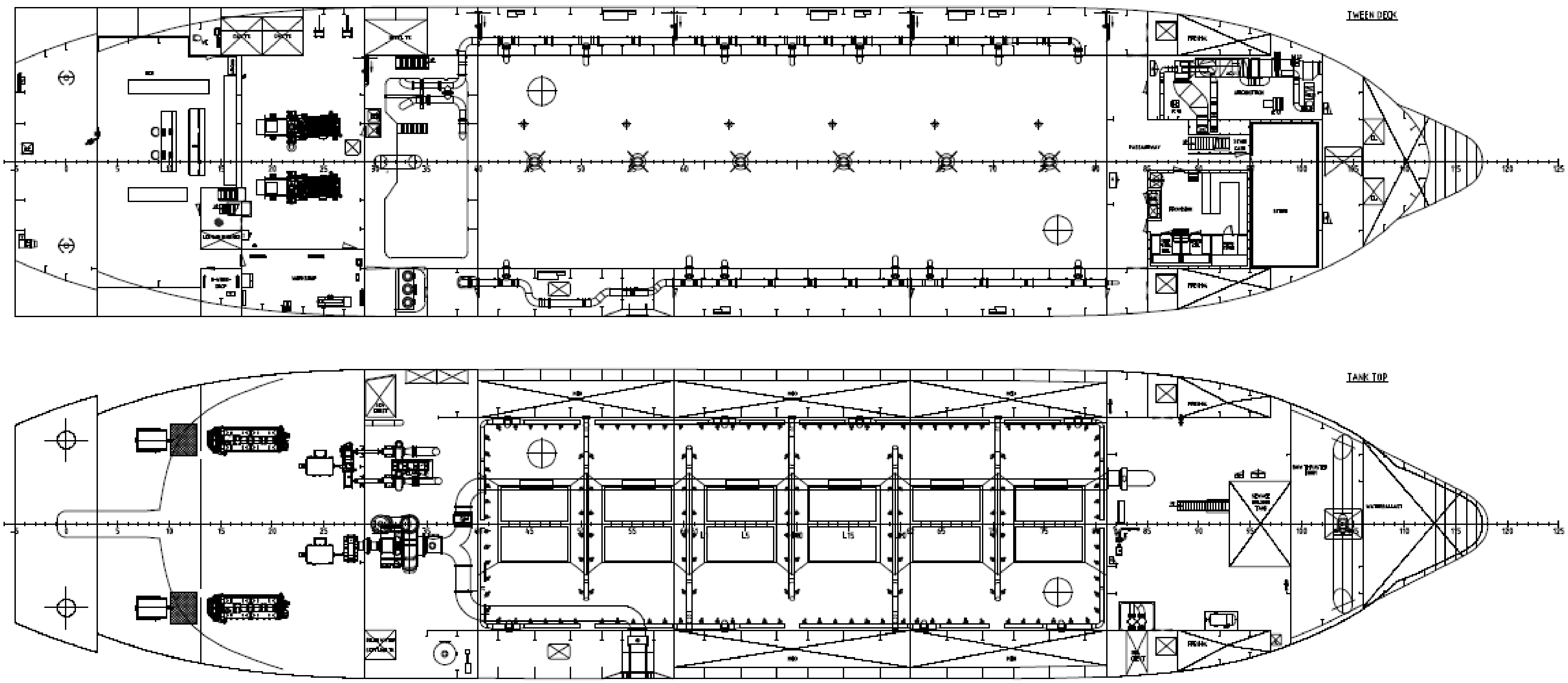

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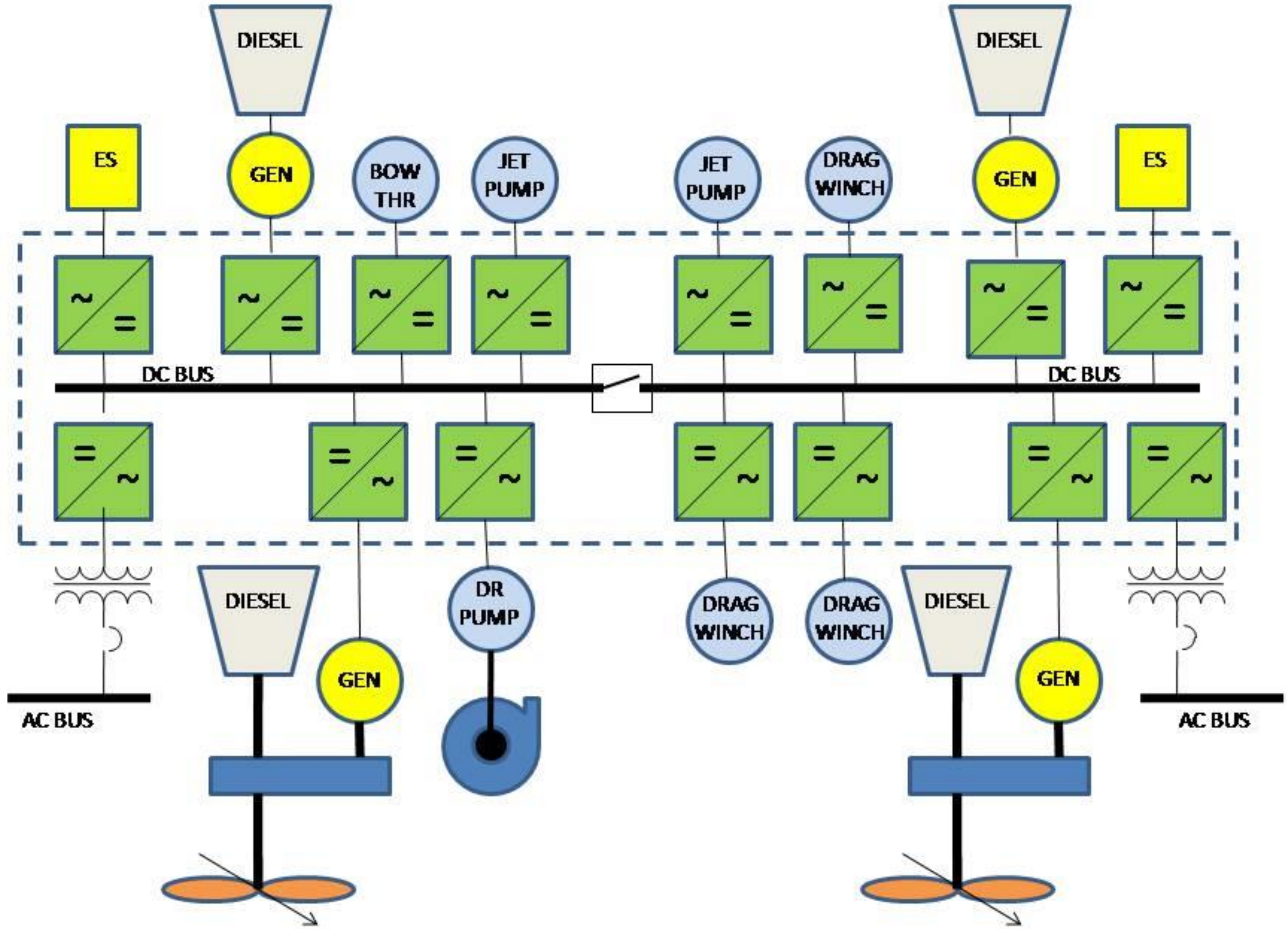

Operational Improvements

Differences Between AC and DC Link w/ ESS

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- Combines synergies not available in traditional AC propulsion systems.
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  - Energy Storage System (ESS)

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  - Dynamic response of an AC System is characteristically slow

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- AC Systems are inefficient with regards to maintenance, energy consumption, and emissions
  - Conventional AC systems engines operate isochronous with enough reserve capacity online to absorb load steps
  - Dynamic response of an AC System is characteristically slow
- A DC link with ESS & EMS:
  - Enhances the overall availability of the system
  - Adapts to quickly changing operational requirements
  - Reduces energy consumption and emissions

Efficiency Improvements

How Does a Dredge Measure Efficiency?

Efficiency Improvements

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Least Cost vs. Maximum Production

$\$ / YD^3$

Efficiency Improvements

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- Least First Cost
- Least Maintenance Cost
- Most Efficient Hull
- Most Efficient Propulsion System
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- Crew Size Matched to Automation

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- Largest Hopper
- Most Maneuverable
- Highest Density Excavation
- Most Efficient Hopper Loading (least overflow losses)
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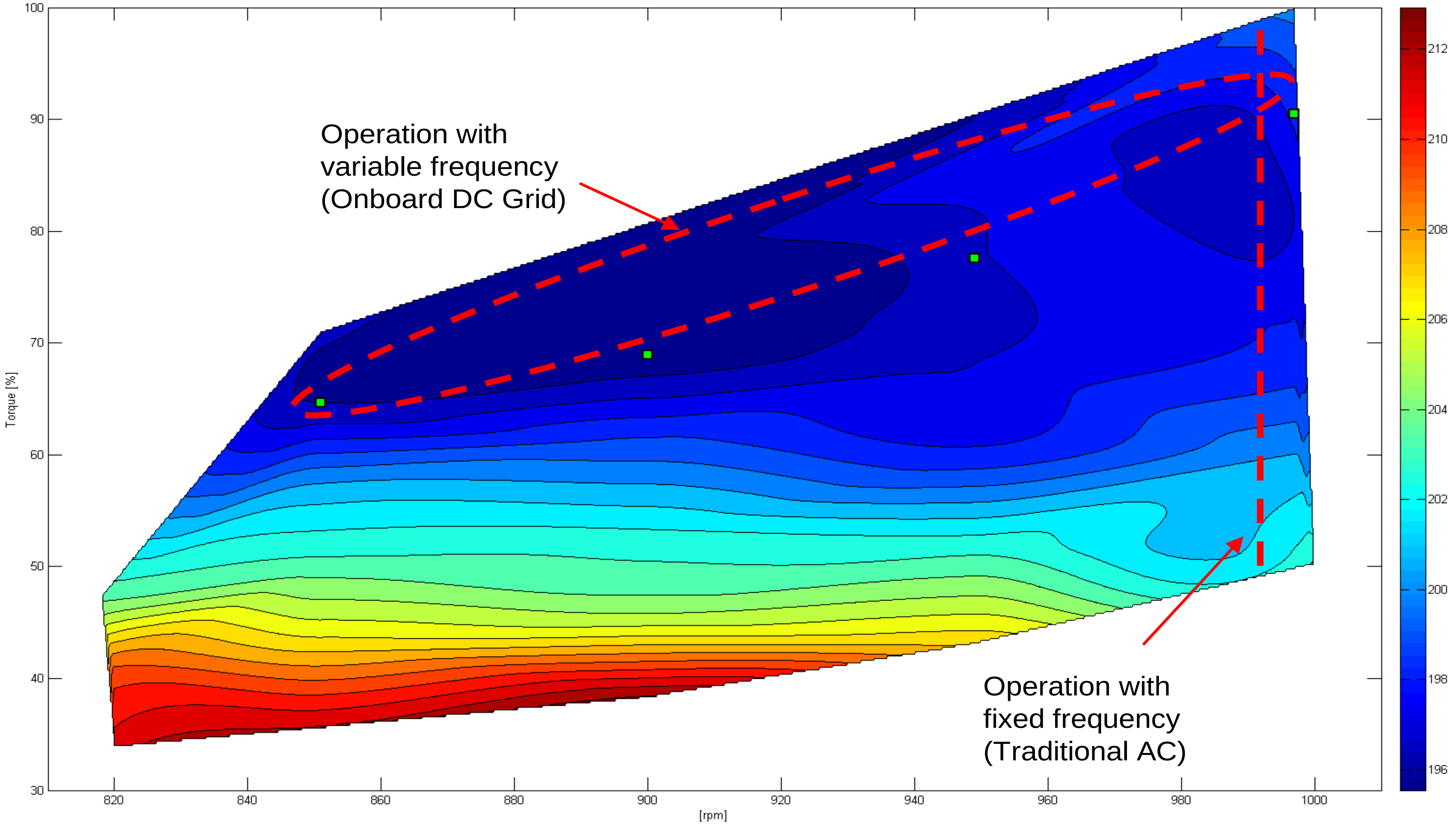
Fuel Savings for Variable Speed Generators



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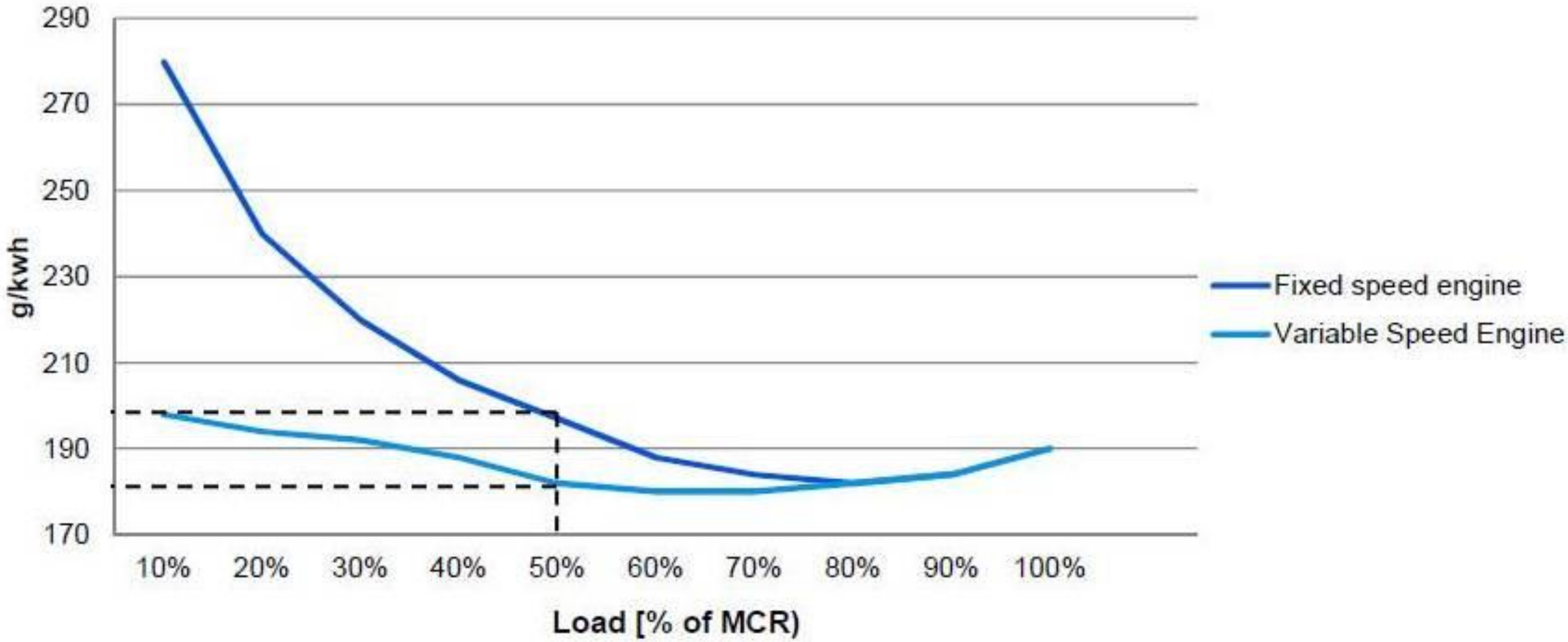

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- Reduced GHG emissions
- Potential for reduced noise pollution (~5 dB)
- Reduction in maintenance costs (up to 30%)

Efficiency Improvements

Space Savings for DC Link Hybrid Systems

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- Renewable energy sources such as hydro, solar and wind can be easily integrated with shore side ESS for fast charge.

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Energy Storage Systems (ESS)

ES Systems take several forms:

- Battery banks
- Capacitor banks
- Flywheel

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Why Add ESS:

- Agile
- Instantaneous Power
- Cost

Efficiency Improvements

ESS with an Energy Management System (EMS)

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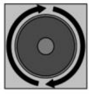
– ***Spinning reserve*** - Provides backup for running engines when a loss of propulsion could be a major risk to the vessel.



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ESS with an Energy Management System (EMS)

– ***Spinning reserve*** - Provides backup for running engines when a loss of propulsion could be a major risk to the vessel.

– ***Bridging or UPS*** – Similar to “spinning reserve” but the ESS is utilized to “bridge” and provide enough peak torque instantaneously as a ride-through function until enough generator power is available.

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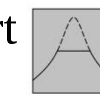
– ***Peak Shaving or Load Leveling*** – Load leveling offsets the need to start additional engines for high transitional loads.



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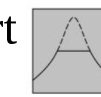
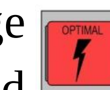


- ***Strategic Loading Control of ESS*** – Automatically control ESS charge and discharge cycles so diesels are optimally loaded. Energy is produced at the lowest cost.



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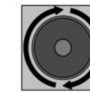

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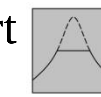

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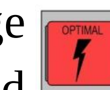
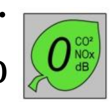


- ***Zero Emissions operation*** – Propulsion plant runs entirely on ESS. Vessel operates with low noise emissions, zero fuel consumption, zero Co2 and zero NOx emissions.



Operation & Maintenance Improvements

O&M Savings for DC Link Hybrid Systems

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O&M Savings for DC Link Hybrid Systems

- Less Downtime
- All Rotating Machines are AC
- Variable Speed Generators
- Less Repairs of Power Electronic Building Blocks (PEBB)
  - All loads use multiples of same IGBT Bridges
  - Crew becomes adept at troubleshooting
  - Inventories are less
  - Human error is reduced in accomplishing repairs
  - Life cycle of PEBB are increased from 12 years to 16-20 yrs

Operation & Maintenance Improvements

Fault Current Protection for DC Link Hybrid Systems

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- Until Recently Fault Current Coordination for High Amperage was Difficult in DC Systems
- Siemens, Alstom, and ABB have developed Regulatory Approved DC Circuit Interrupters for High Voltage, High Current DC Circuits
- Solid-state converter components and topology will manage and clear serious fault conditions quickly and predictably.

Cost Considerations

Capital Expenditure

AC Diesel-Electric	Hybrid DC Diesel-Electric
AC Distribution with VFDs	DC Distribution with multi-drives
Electric driven Azimuthing Z-Drive Propulsion	Med Speed Propulsion Diesel, CPP, Flapped Rudders, & PTO Gen
Fixed Speed 1800 RPM Generators	Variable Speed Generators (2 shaft gen, 2 high speed)
Strong Potential for Harmonic Filters	Potential for ES and Regenerative Load Reduction

Cap Ex for both designs are practically equivalent

Cost Considerations

Operating Costs

- No Direct Comparison
  - Several Siemens and ABB DC Installations Overseas
  - Less than 6 in North America
- Fuel Savings 10 – 20%
- Reliability Up, Downtime Less
- Less Maintenance
- Improved efficiency of power due to EMS and ESS
- Better quality power

Intangible Operating Cost Savings

- Less space and weight
- Less machinery noise and vibration

Summary & Conclusions

- Excellent Functional & Operational Benefits for DC Link Hybrid Applied to Dredges
- Several Similar Plants Built to Date
  - Many Designs Commissioned Now
- Cap Ex Equivalent to AC DE
- Op Ex Significant Savings Compared to AC DE

DISCUSSION/QUESTIONS?

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