High-megawatt Electric Drive Applications in Oil & Gas

Workshop on Future Large CO2 Compression Systems

March 31, 2009

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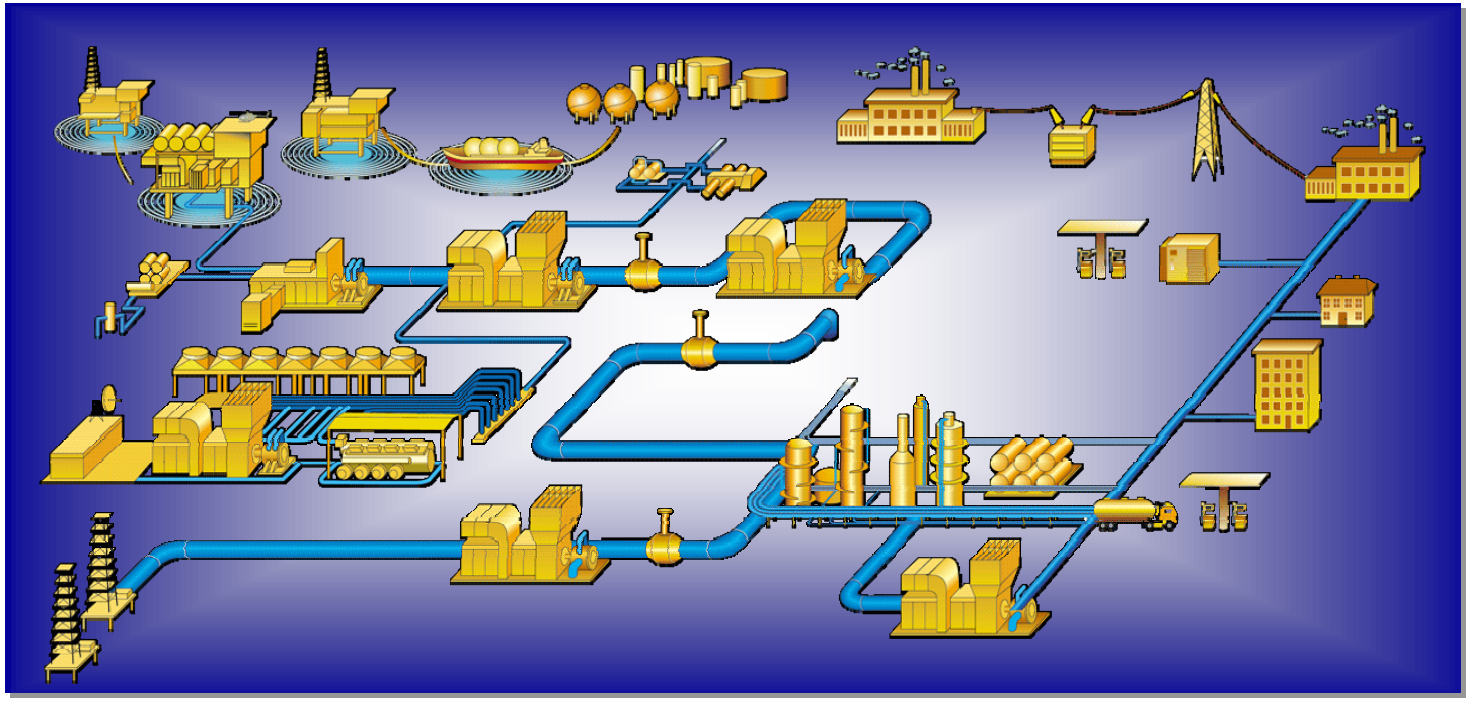
GE Oil & Gas

Oil & Gas Applications for Turbo Machinery



Exploration Production → **Transport** → **Processing**

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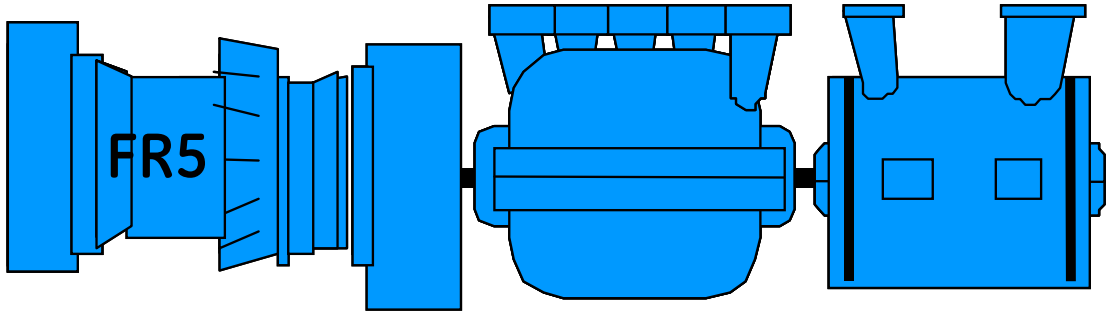
A Typical Conventional Compression Train



- Gas Turbine + Compressor
- Fixed low speed operation
- Efficiency/emission limit
- Maintenance cycle

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A Changing World …

Scenario	Challenges
 Demographics & industrialization	Limited resources
 Supply / demand disconnects	Spare capacity
 Elevated cost of energy	Unconventional energy sources
 Increasing environmental regulations	Reduced emissions
 Higher investor / stakeholder expectations	Cost control

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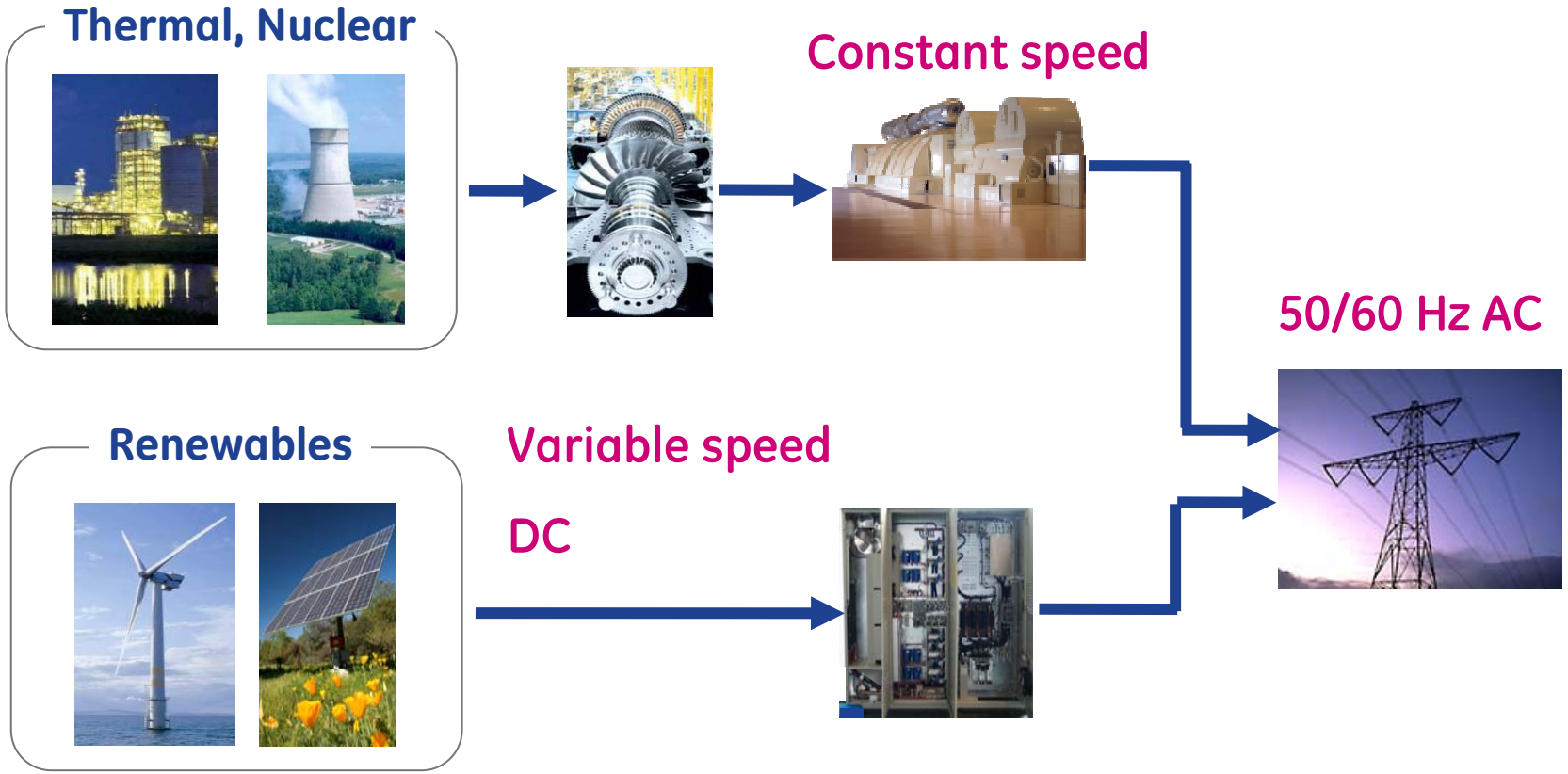
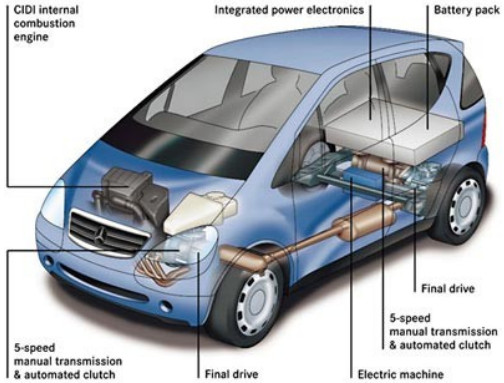
World Is Going More Electric
Power Generation & Distribution



- Synchronous
- Mechanical/Electromagnetic Conversion
- Centralized grid

- Asynchronous
- Electronic Energy Conversion
- Mini and distributed grid

World is Going More Electric – Prime Mover



More Electric or All Electric Prime Movers

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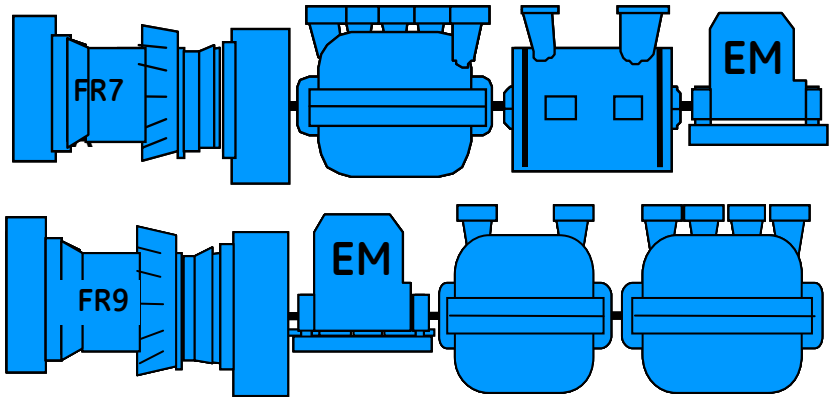
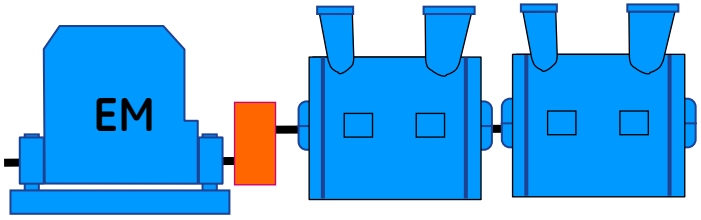
Oil & Gas Electrification

World Largest LNG Train from GE (8 MTPY) tested in Massa, Italy

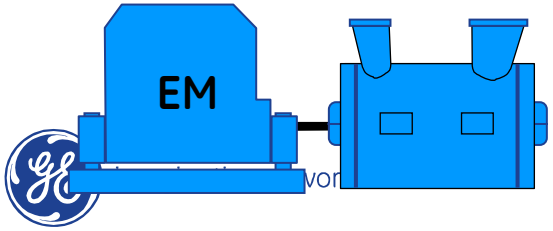
Electric Drives in High Power Compressor Trains



Full electric Trains



HS Electric-driven Trains



Needs & Challenges

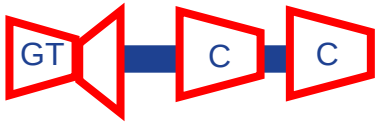
- High power > 10 MW
- High reliability
- High performance
  - low torque ripple
  - low grid harmonics

Very High Power to Ultra-High Power Drives:

LNG/e-LNG example

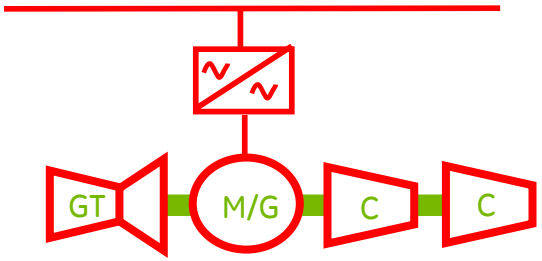
LNG

(Gas Turbine Driven)



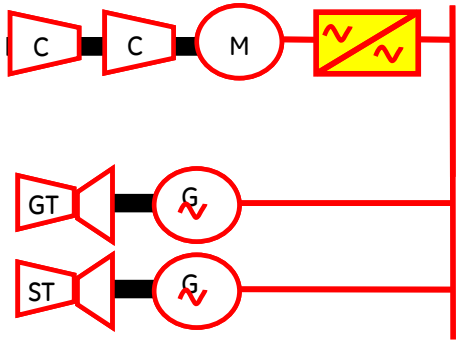
LNG Super Train

(Gas turbine driven w/ electric drive)



e-LNG

(Electric driven)



- **Higher Availability**
- **Higher Power**
- **High Power Quality**
- **Lower Emission**
- **Higher Efficiency**

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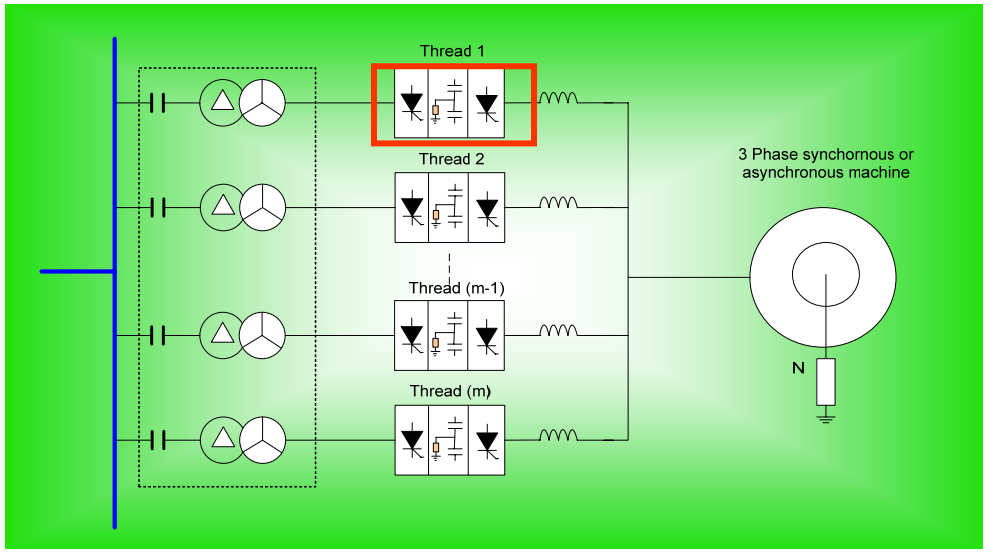
High Power High Performance Drive Example

Challenges		*Solutions*
• High power 35MW @ 100Hz	>	Multi-thread parallel
• Low torque ripple	>	Interleaving control
• High reliability	>	Less parts-count & proven building block



High Reliability - High Quality Waveform

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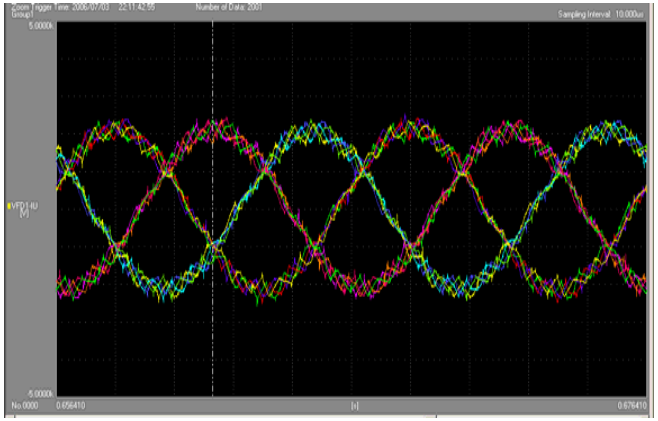
35 MW Drive System Test Results at GE Oil & Gas

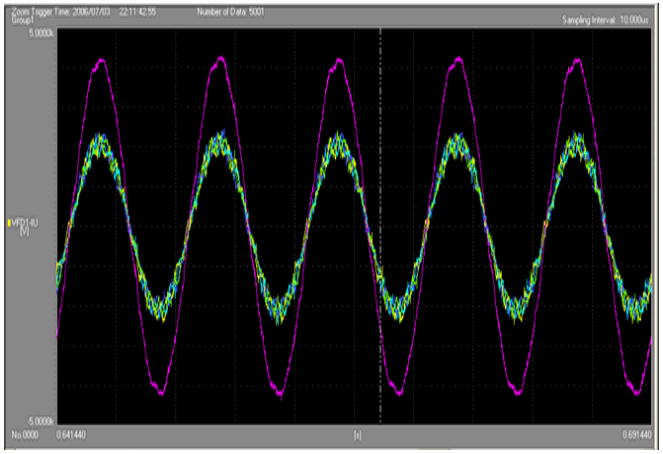
Massa Testbed, Italy

35 MW, 110 Hz capability

Inverter Currents



Motor Current



High waveform quality and less complexity

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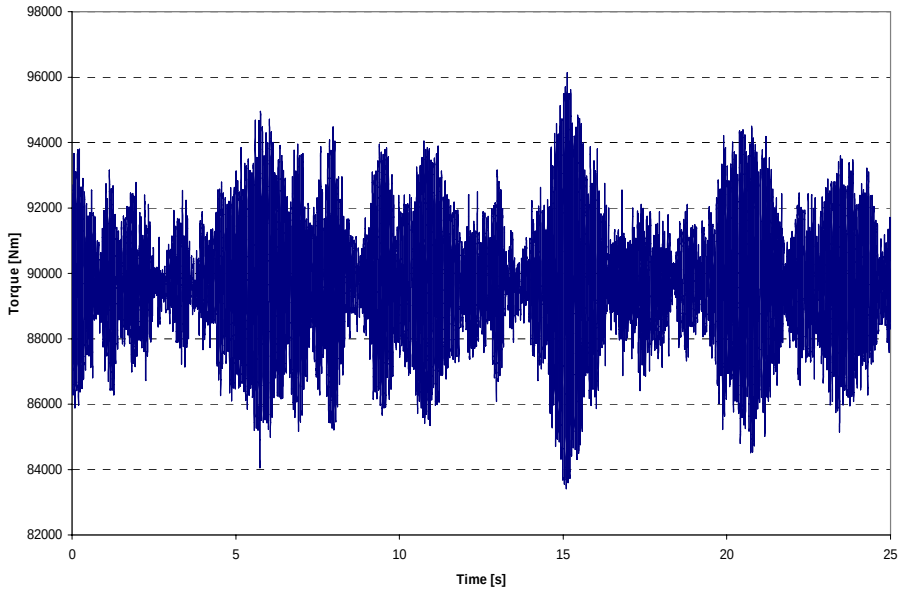
Performance Comparison with LCI

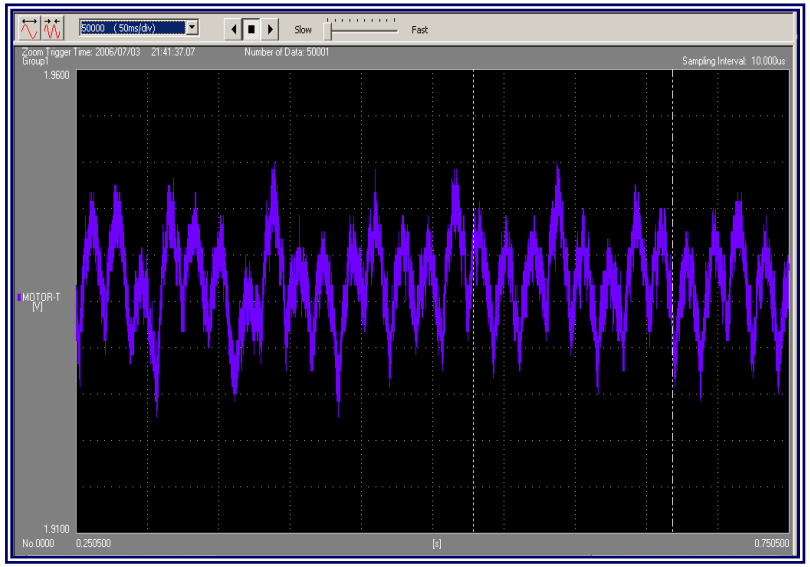
Motor Mechanical Torque Ripple (steady state)

LCI



Torque Ripple: 14.8% @ 31MW 3400rpm

IGCT Drive System



Torque Ripple: 3,7% @ 30MW 3300rpm

Torque Ripple reduced by more than 3x

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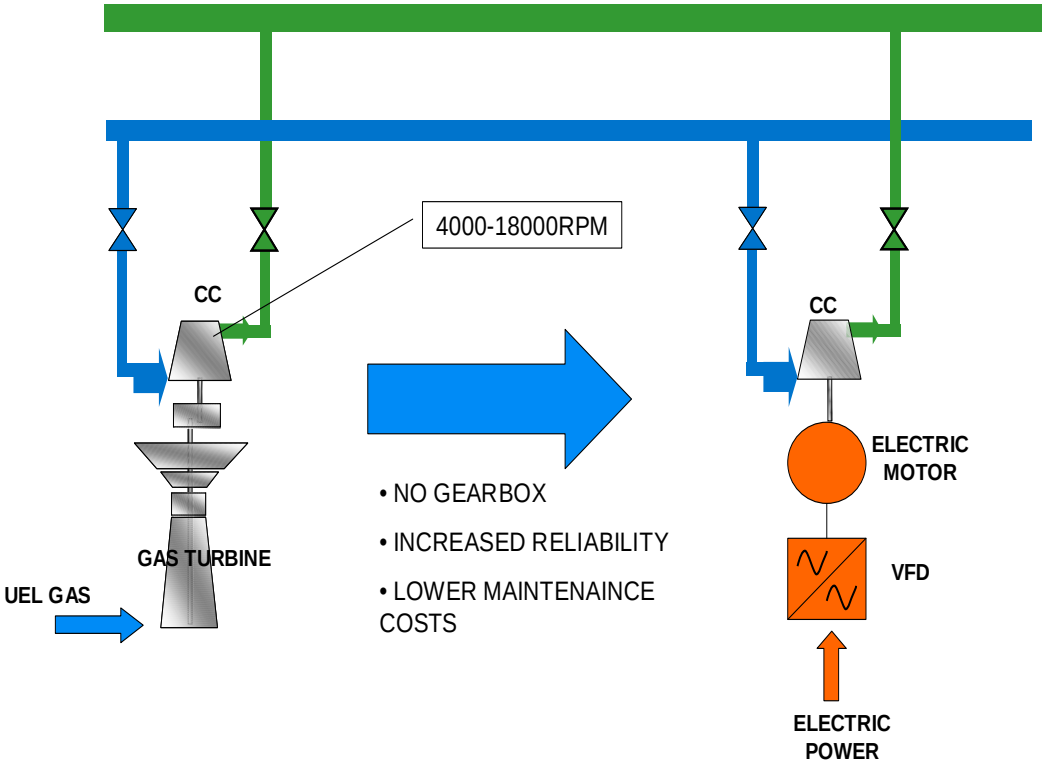
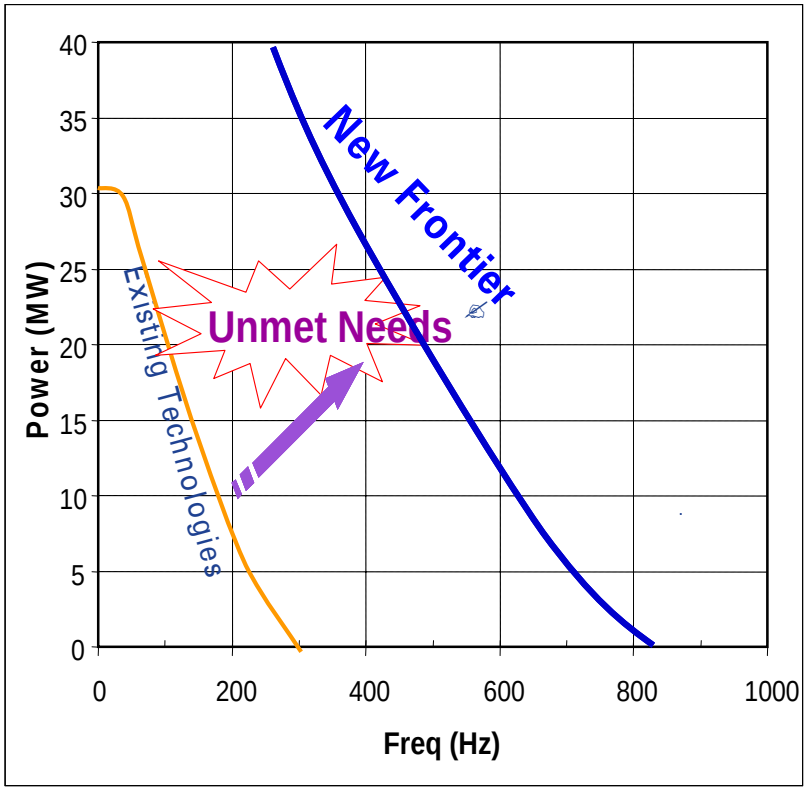
High Speed High Power Direct Drive Compression





High Power High Speed/Freq. Reliable Solutions

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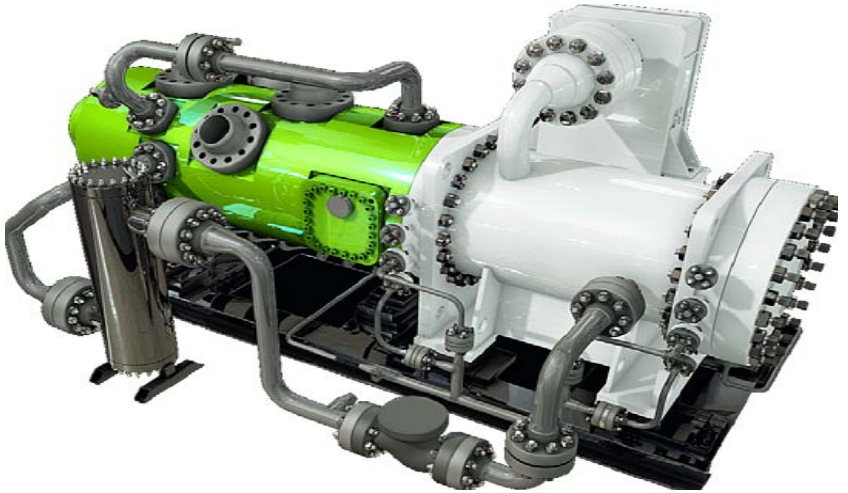
Applications

- **Transportation**
  - Pipeliners
  - Storage
- **Natural Gas**
  - Sales Gas
  - Export
  - Dry Clean Gas Services
- **Downstream**
  - Feed Gas
  - Fuel Gas Boosters

- **Integrated high speed motor-compressor**
- **Serve the O&G segments up to 15 MW**



Integrated Compressor Line :

Simple to install

Easy to operate

Environmentally friendly

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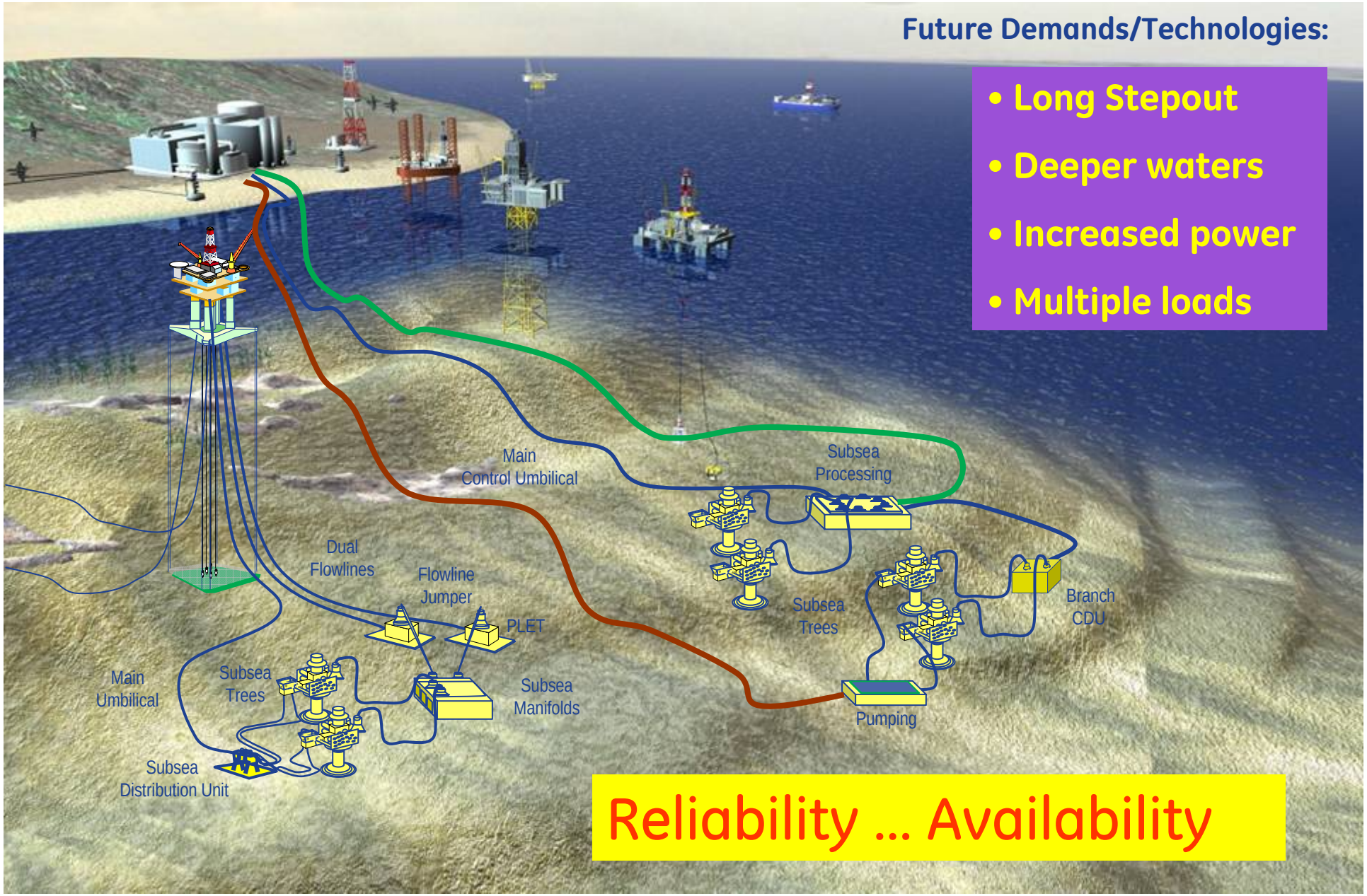
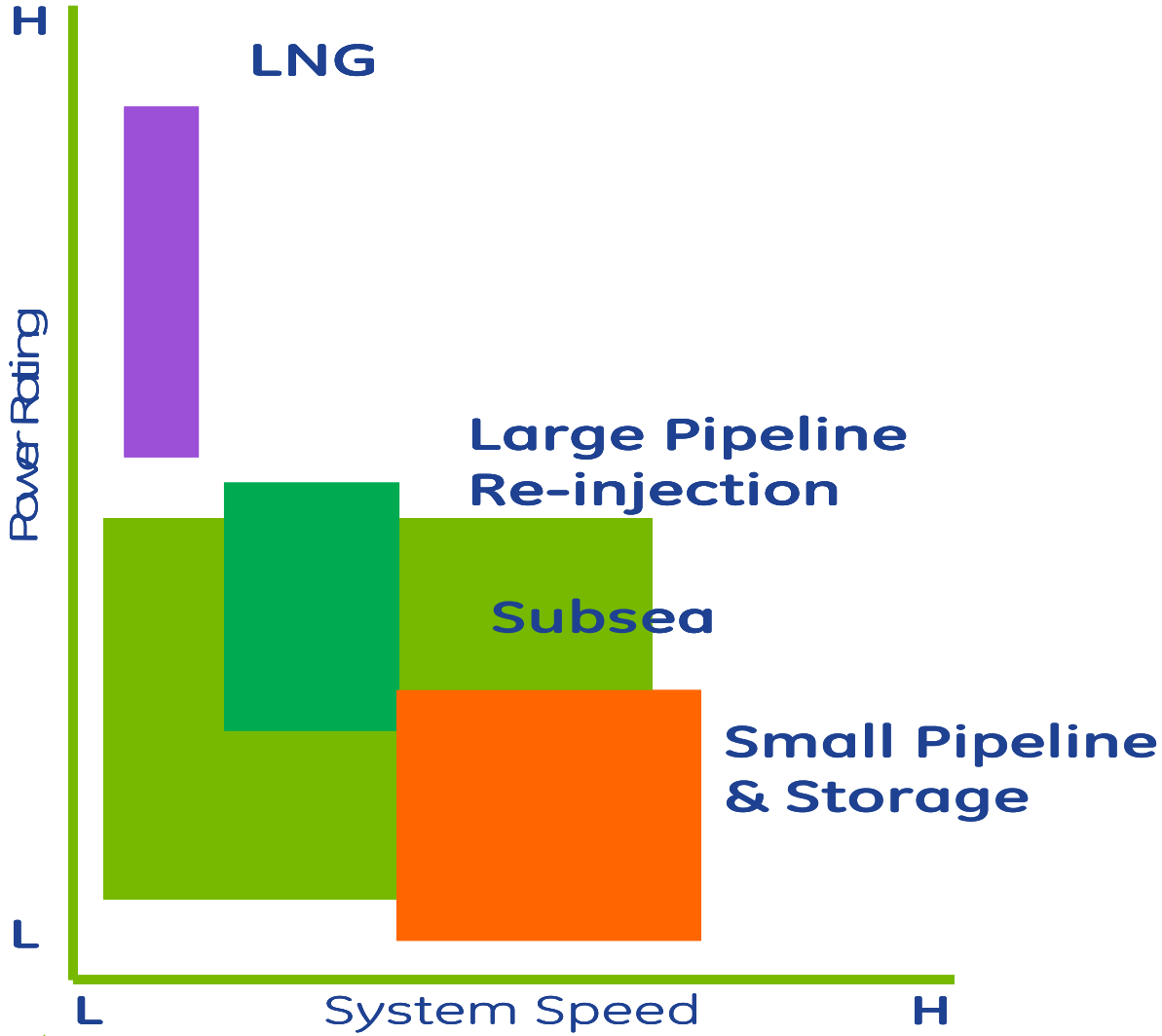
Subsea … Next Frontier



High Power Electric Drives for Oil & Gas Applications



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Conclusions

- World is going More Electric … happening in Oil & Gas industry too
- Diverse range of applications for high power electric drives started to emerge
- Many new applications call for new technologies
  - High reliability/availability/maintainability
  - High power
  - High voltage
  - High speed
  - Harsh environment
  - …

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Questions?

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