Possibilities for LNG Use in Icebreakers

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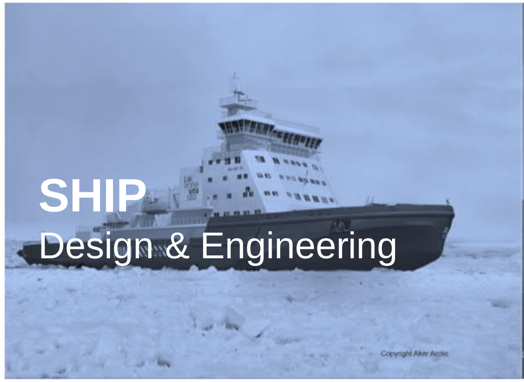
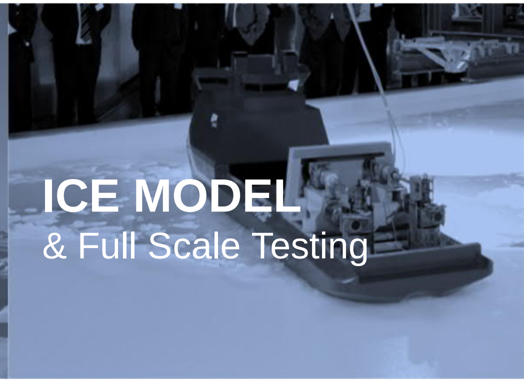
Outline

- Two main topics
  1. LNG storage tank solutions
     - LNG energy density
     - Available tank options
     - Space allocation to the vessel
  2. Functionality of power plant
     - Means to reduce load variation to power plant
     - Means to tolarate load variation of propulsion
- Items not covered
  - Boil of management
  - Availability of LNG
  - Solution details
  - Operational procedure issues
  - Etc...

LNG as a Fuel for Icebreaker

- First LNG fueled icebreaking vessels in operation
  - Icebreaker Polaris
    - Wärtsilä 34DF type engines, power 22 MW
    - Two 400 m^3 LNG storage tank
    - Three ABB Azipod VI1600 (2x6,5MW+1x6,0 MW)
    - Autonomy time with LNG 10 days
  - LNGC Christophe de Margerie -type
    - Wärtsilä 50DF type engines, power 64 MW
    - Membrane type cargo containment system
    - Three ABB Azipod VI2300L (3x15 MW)
    - 10/15 vessels in service
- LNG fuelled icebreaking vessels under construction
  - Le Commandant Charcot – Ponant Icebreaker
    - Under construction at Vard
    - Wärtsilä 31 DF engines, 4x14 cyl + 2x10 cyl
    - Two Mark III membrane tanks by GTT, total volume 4500 m^3
    - Two ABB Azipod VI2300L (2x17 MW)



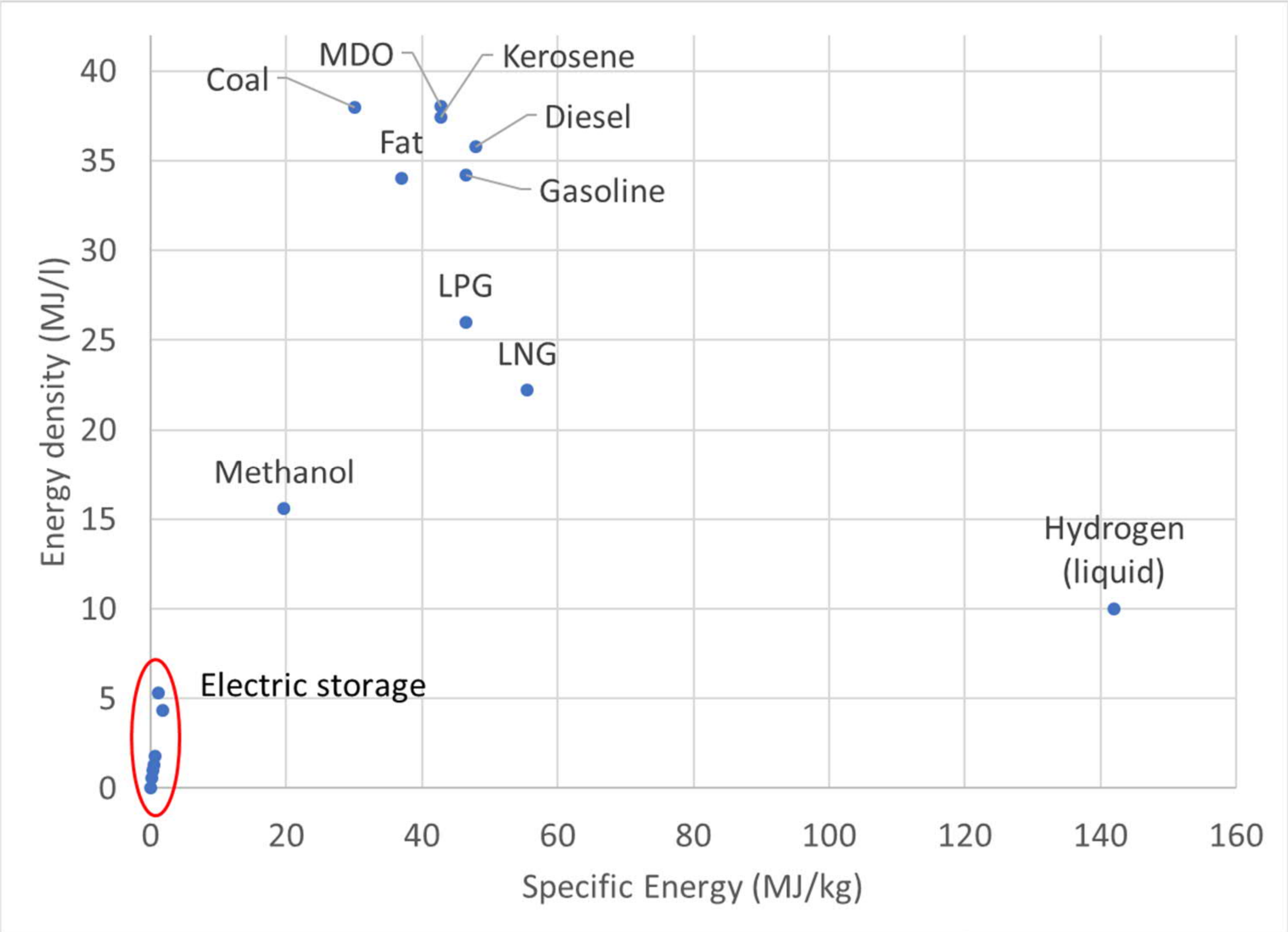


LNG Storage Tank Solutions

Energy density comparison to Diesel fuel

- LNG compared to MDO
  - Higher specific energy +30% (energy in weight)
  - Lower energy density -33% (energy in volume) due to lower liquid density

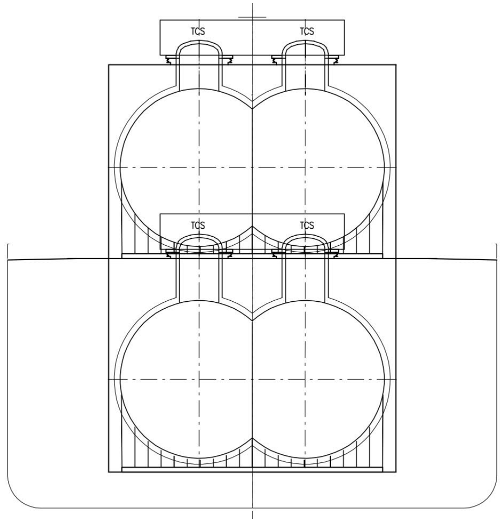
About 50% more liquid volume required for same autonomy time with LNG fuel compared to MDO

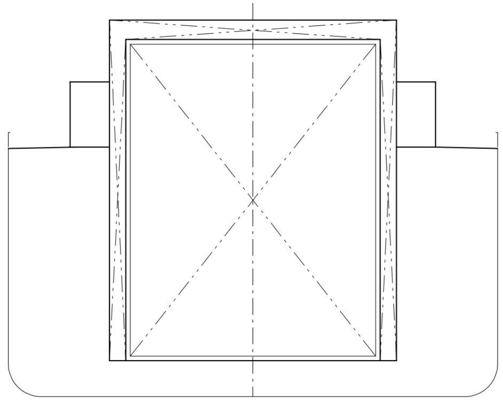


Case study: Icebreaker with 5000 m^3 and 10000 m^3 storage capacity

- Two solution alternatives:
  1. 2 x Bilobe tanks
  2. 1 x Membrane tank
- Theoretical icebreaking vessel, fixed breadth
- Cross section of Bilobe tanks fixed, length variable
  - Lenght of tanks may be different
- Height and length of membrane tank variable, beam fixed
- Comparison of space efficiency

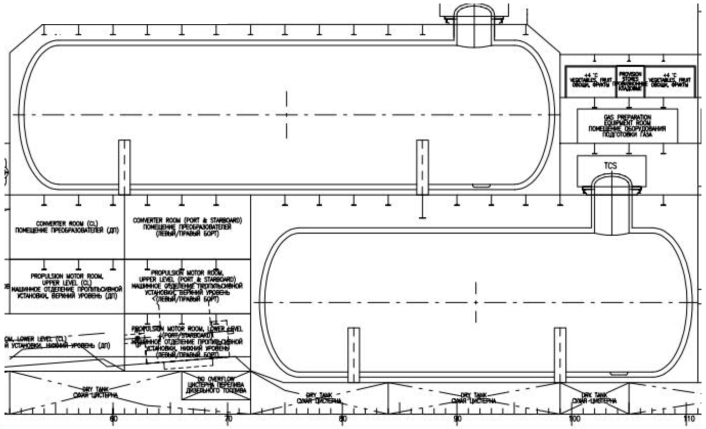
TANK TYPE	MEMBRANE	MEMBRANE	BILOBE	BILOBE
Tank Volume (m^3)	5000	10000	5000	10000
Required space (m^3)	8200	15000	9900	18300
Space efficiency (%)	61 %	67 %	51 %	55 %

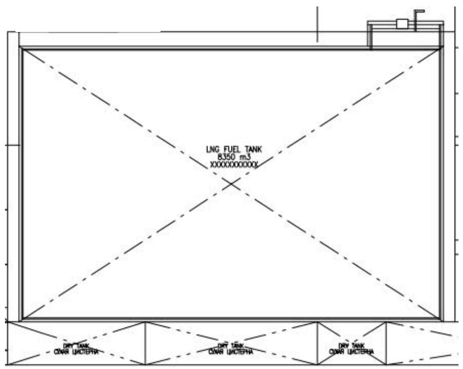




Case study summary

- Membrane tank has better space efficiency, improves in bigger volumes
- Bilobe tank provides some arrangement flexibility
  - Two different length tank possible, storage capacity can be located above main deck
  - Some flexibility in form of space
- Space requirement
  - Energy density leads 50% higher liquid volume
  - Space efficiency leads 30-50% higher volume in vessel
  - Double volume in vessel needed compared to fuel oils to achieve same endurance

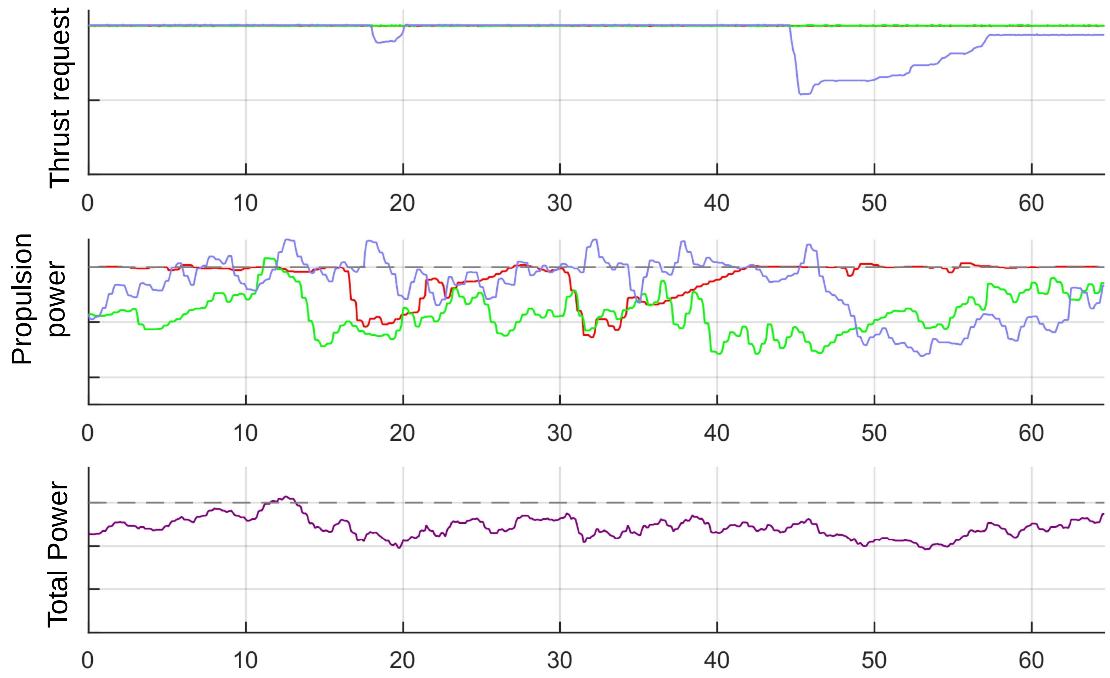




Power plant functionality with gas fuel

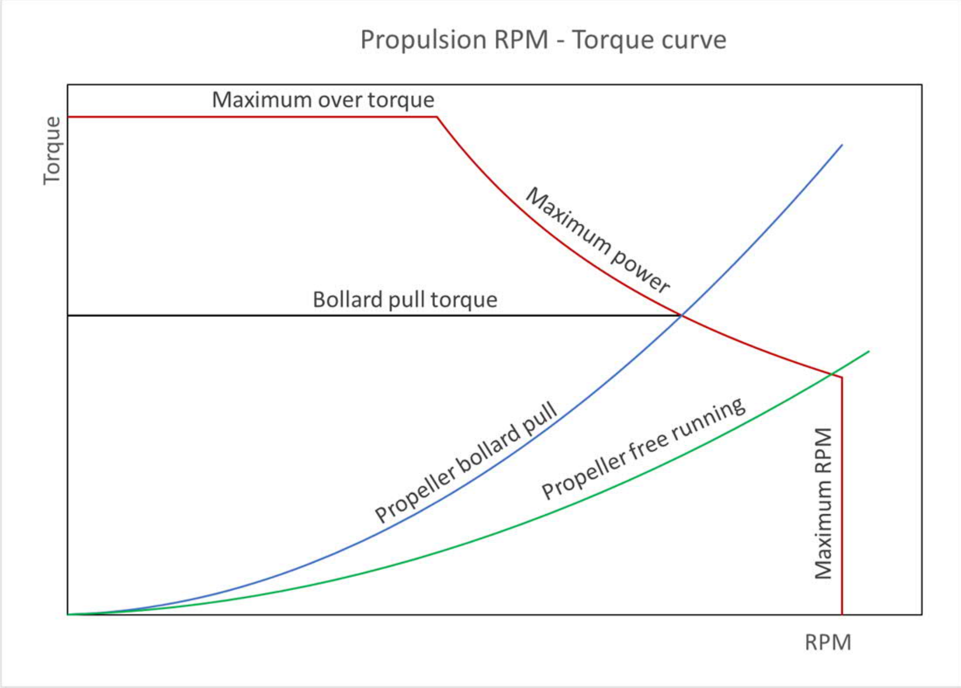
Power plant in icebreaker application – in general

- Icebreaking causes ice-propeller interaction which means either
  - Torque and rpm variation of propeller if constant power is requested
  - Power and torque variation if constant rpm is requested
- Electric propulsion system has been “standard” in icebreakers already decades:
  - Makes constant power mode possible
  - Makes over torque capability possible



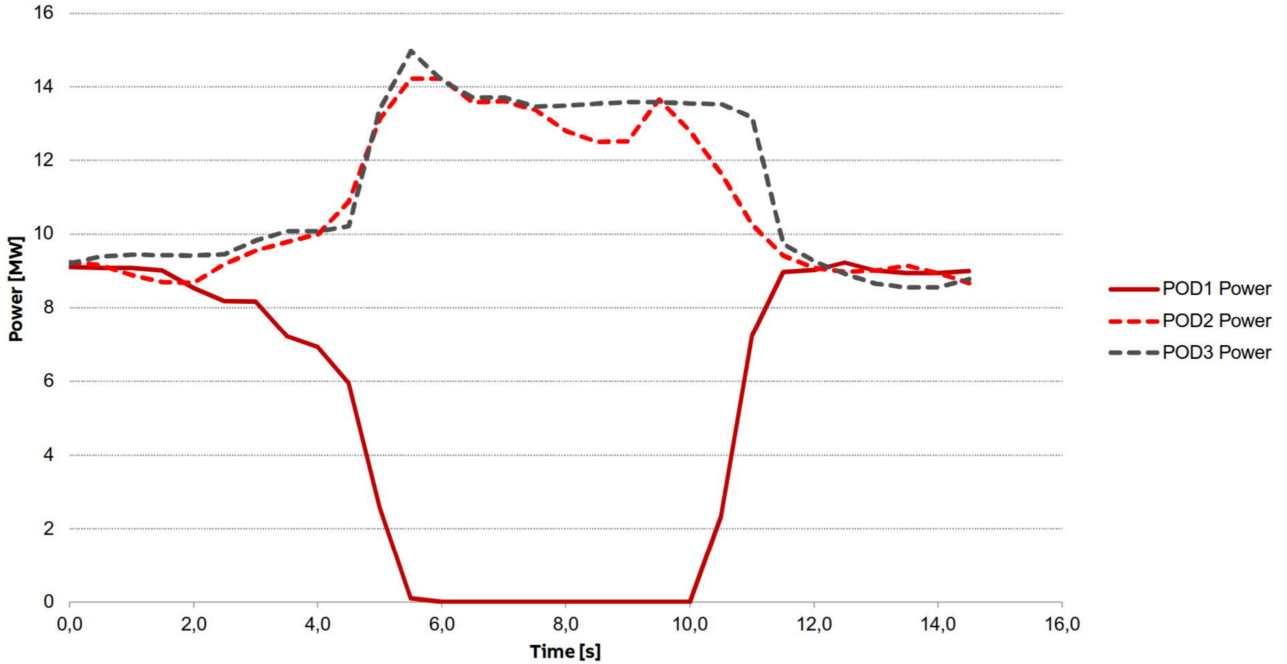
Means to reduce load variation to power plant

- Electric propulsion system is must
  - Propulsion control with constant power mode
    - Filters most of ice loads compared to constant RPM mode
  - Adequate over torque capacity
    - Provides range for constant power mode
- Other electric means
  - Load sharing between propellers
    - Power boost function of ABB
  - Load balancing by resistors
    - Rapid load variation can be slowed down to comply loading ramps of power plant
  - Energy storage system
    - Not sufficient to day for rapid – high power – low energy applications



Means to reduce load variation to power plant

Power Boost Function



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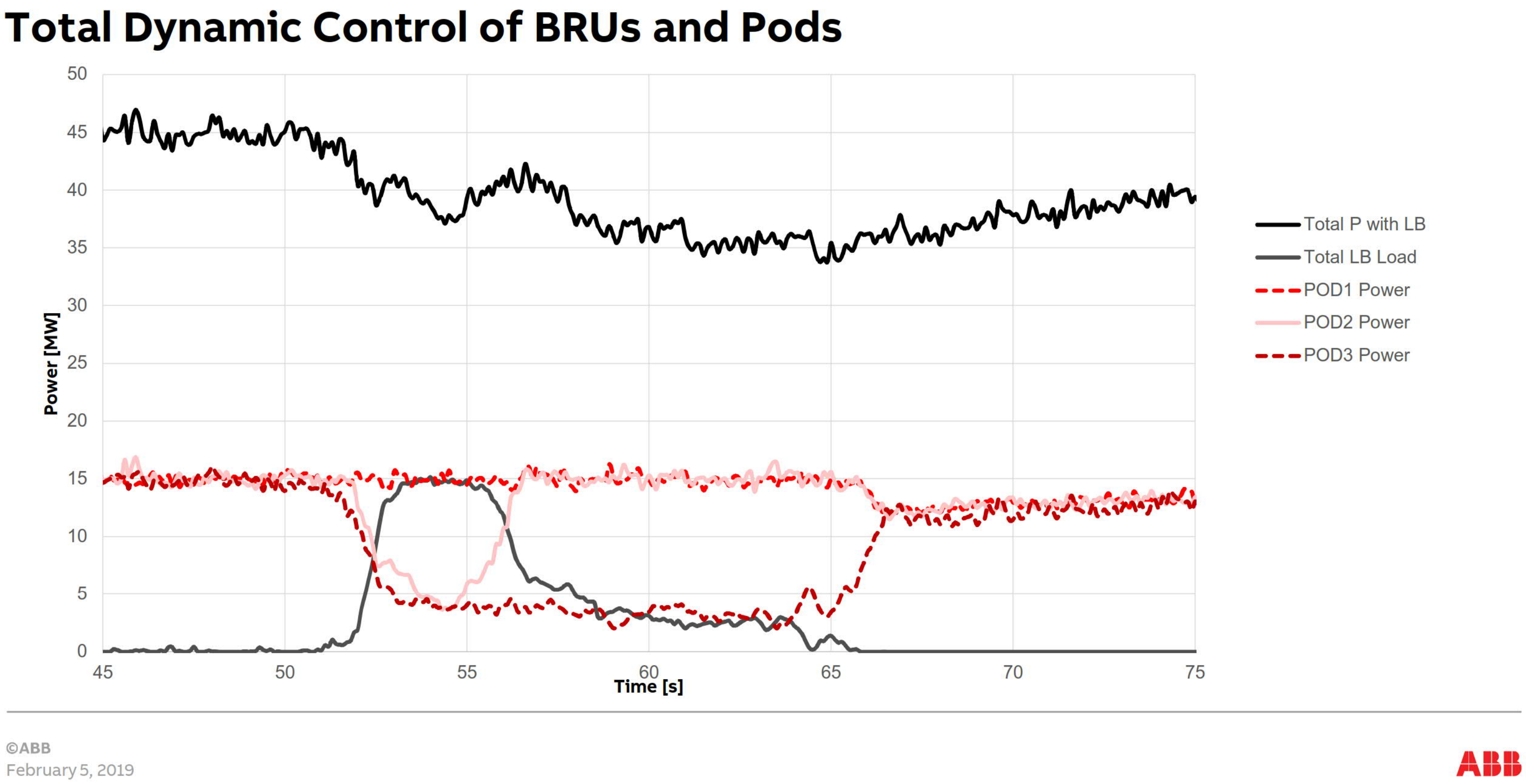
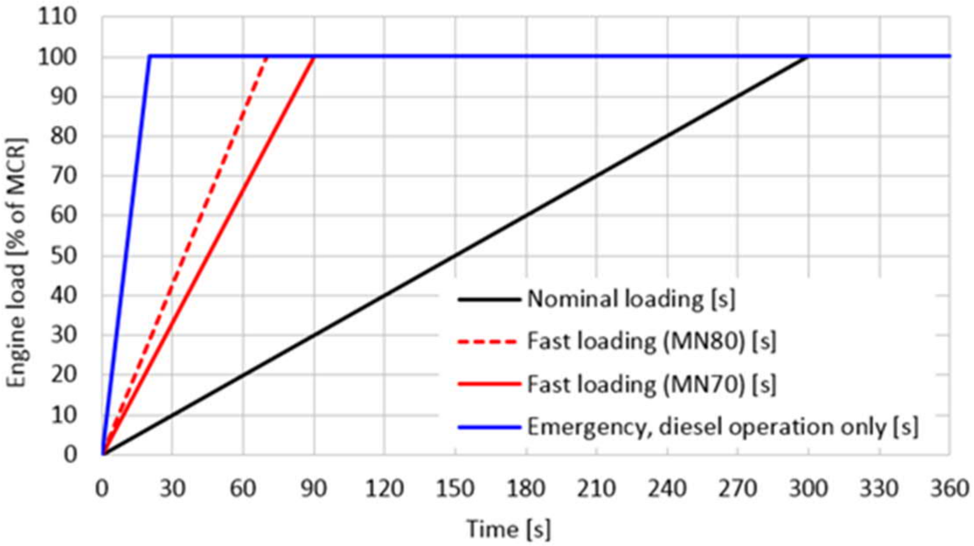
Means to reduce load variation to power plant



Means to tolarate load variation of propulsion

- DF engines has slower loading ramps in gas mode compared to diesel mode
  - Tend to changes automatically to diesel mode if quicker loading is requested
  - Manual actions needed to change back to gas mode
- Means to secure maximum operation with gas fuel
  - DF engines under heavy development
    - Typical load variation can be maintained by gas fuel with modern technology
    - Pilot boost as a very interesting alternative
      - If extreme loading in gas mode is required, special pilot boost feature can be used, temporarily increasing the share of pilot fuel and void changing to diesel fuel



Loading rates Constant speed 31DF engines (DE / Aux / CPP)
Normal loading rate, constant speed engines, 720/750 rpm (DE / Aux / CPP)
Source: Wärtsilä

Conclutions

- Currently 11 vessels operating in very difficult ice condition with LNG fuel
- Main technical challenges in ship design point of view
  - How to achieve required autonomy time for remote operations
  - How to get power plant working properly under propeller ice interaction
- LNG tank alternatives exists – requires more space from vessel compared to diesel fuel
- Means to secure LNG as a “only” fuel exists
  - Electric propulsion plant
  - Electric load balancing with resistors
  - Development of DF engines with pilot fuel boost alternative
    - Temporary increasement of pilot fuel in most extreme loading cases and maintain still gas as a primary fuel

Thank you!