Control

Power Optimal Thruster Allocation

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WORLD CLASS – through people, technology and dedication

Power Optimal Thruster Allocation

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- Basic optimisation task
- Minimize the total squared thrust used to fulfil the thrust demand

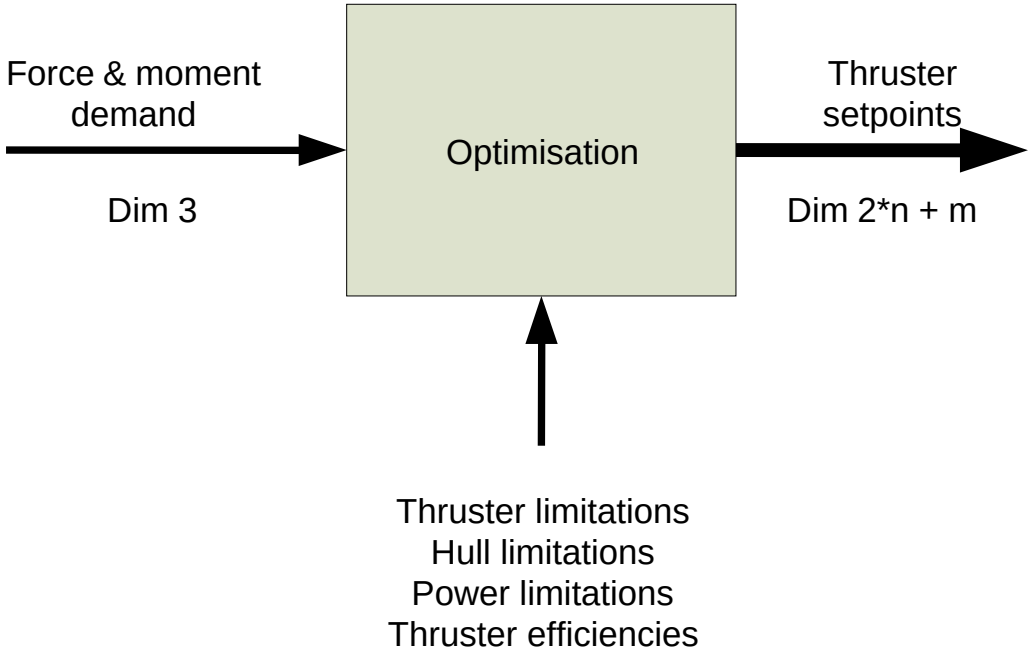
$$g_0(t) = \frac{1}{2} \cdot \left(\sum_j w_j \cdot \left(t_j\right)^2 \right)$$

subject to

$$g_1(t) = \sum_j t_j \cdot \cos(\alpha_j) - d_1 = 0$$

$$g_2(t) = \sum_j t_j \cdot \sin(\alpha_j) - d_2 = 0$$

$$g_3(t) = \sum_j t_j \cdot \left(\sin(\alpha_j) \cdot p_j^y - \cos(\alpha_j) \cdot p_j^x\right) - d_3 = 0$$



Power Optimal Thruster Allocation

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- Thruster constraints

$$T_j^{\min} \leq t_j \leq T_j^{\max}$$

- Power constraints

$$\sum_j p_j \leq P_i^{\max}$$

  - Power phase back (traditional)
  - Power consumption included in the optimisation

Power Phase Back

- Percentage wise distribution of phase back power according to the rated power of each thruster

$$\Delta p_i = \frac{\Delta P \cdot (p_i - p_i^0)}{\sum_j (p_j - p_j^0)}$$

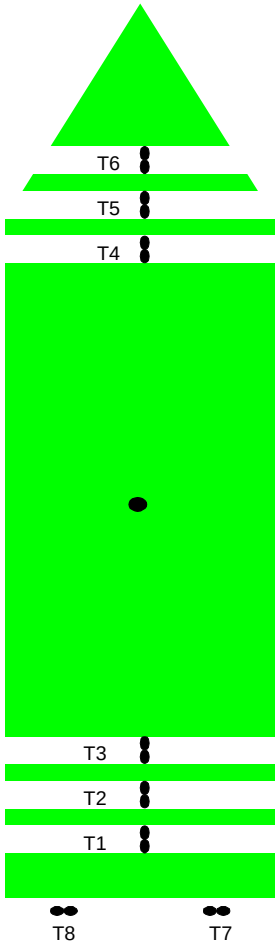
- Sequenced phase back where least efficient thrusters or pair of thrusters are reduced first
  - Sorting according to moment arms $1/|A_i|^m$
  - Sorted according to efficiency r^n
  - Combinations $r^n / |A_i|^m$
- Weighted reduction according to thruster efficiency

$$\Delta p_i = \frac{\Delta P \cdot (p_i - p_i^0)}{\sum_j (p_j - p_j^0)} \cdot \frac{1/|A_i|^m}{\sum_j 1/|A_j|^m}$$

Example

- 6 tunnel thrusters each 2,500kW
- Power available 8,000 kW
- Thrust demand
  - 100 tonnes
  - (would require 9,500 kW online power)

Phase back procedure	Lateral force (tonnes)	Moment (tonnes*m)
Percentage phase back	84	835
Armed weighted phase back	83	935
Armed based sequencing	81	832



Power Optimisation

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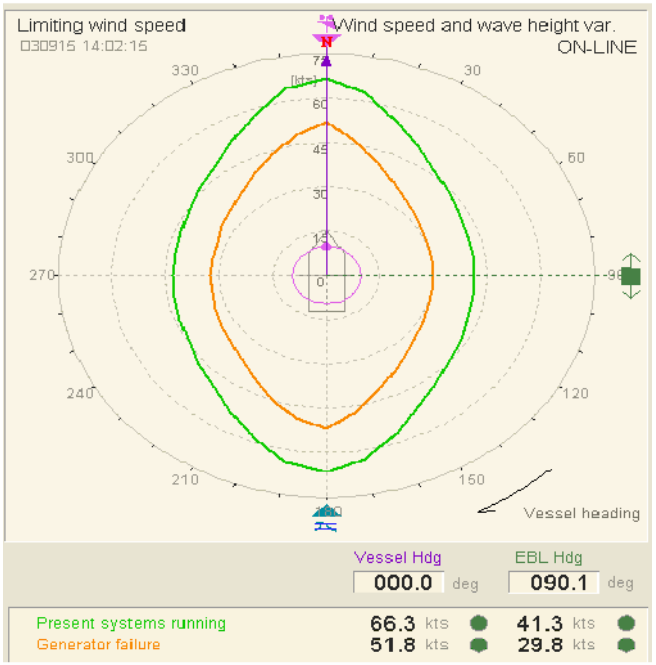
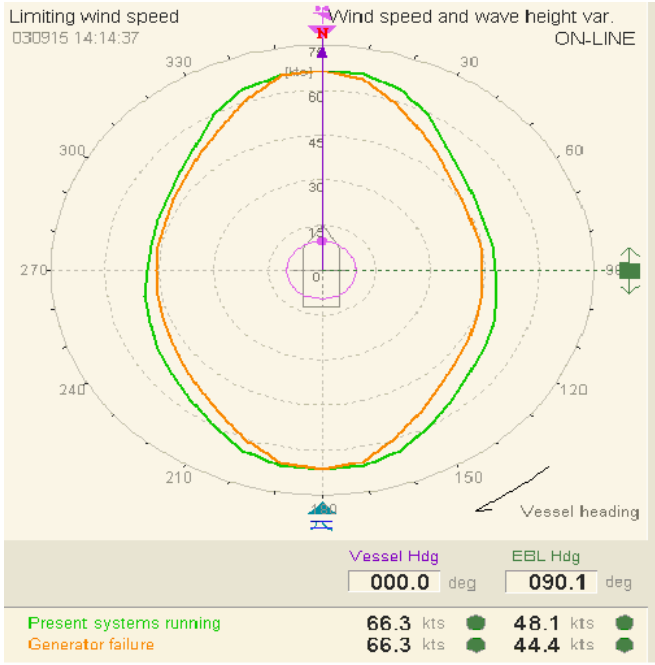
Power phase back

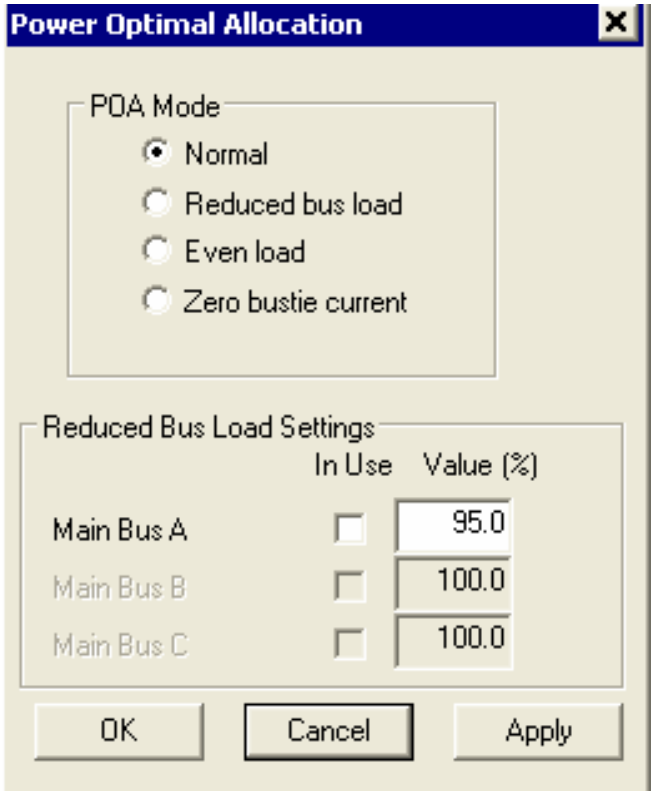


Power optimisation



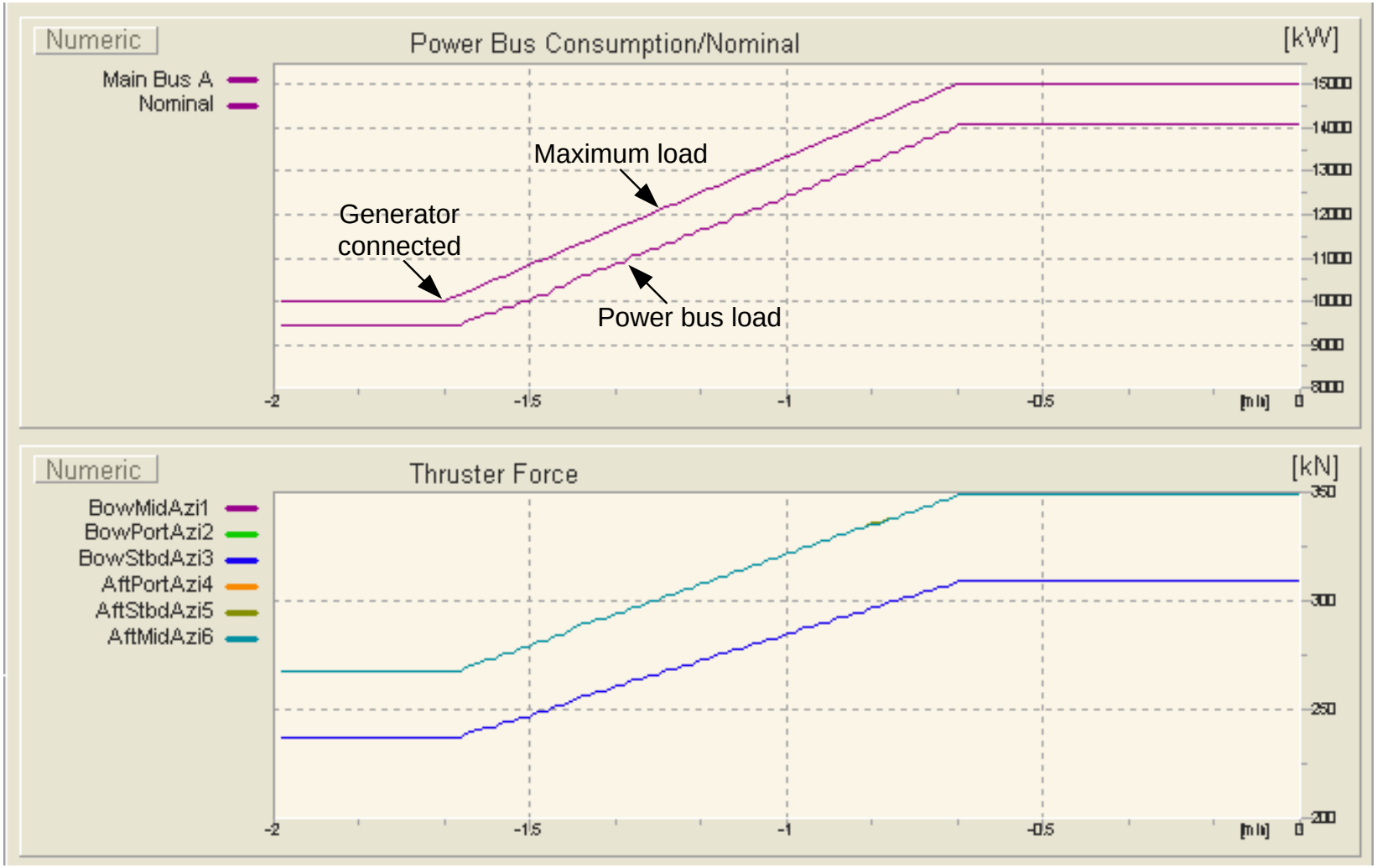
Additional Features

- Equal percentage load on each switchboard (*Even Lode* mode)
- Operator specified max load on one switchboard (*Reduced Bus Load* mode)
- Minimum bus tie current with connected switchboards (*Zero Bus Tie Current* mode)



Special Features

Reduced bus load – Start generator



Special Features

Zero bus tie current

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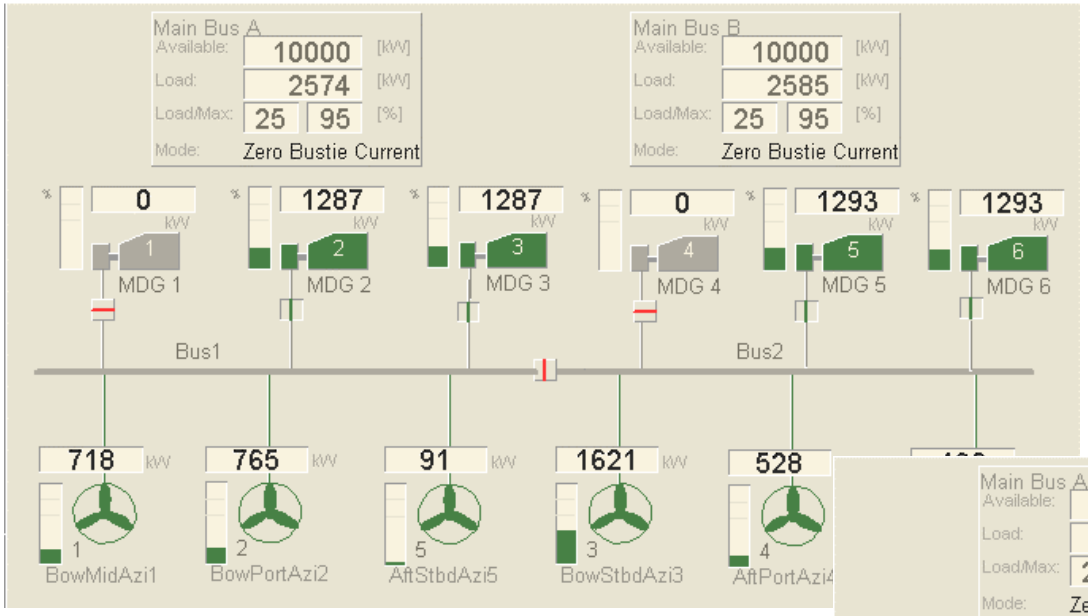
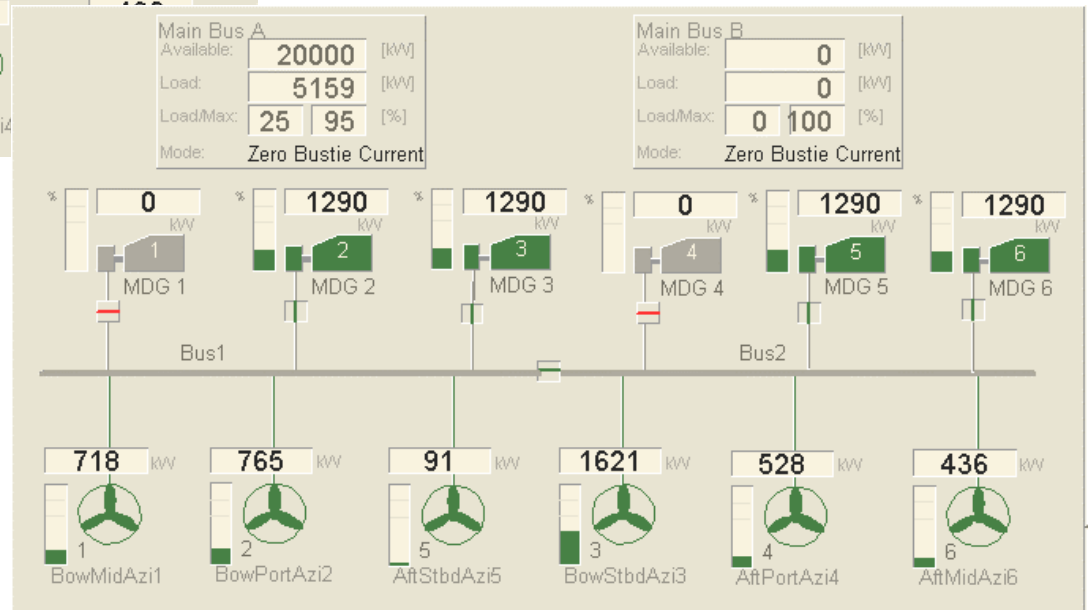


Closed bus tie

Open bus tie



Special Features

Zero bus tie current - scenario

- Redistribution of power among the generators when the bus tie is
  - closed
  - and reopened
- The bus tie operation has no effect on the thrusters (lowest part of graph)
- When the *Zero Bus Tie Current* is selected necessary redistribution to minimize the bus tie current if the two halves should be connected
- At closing the bus tie there is no change in neither power distribution (generators and thrusters)