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NEW HYBRID DIESEL ELECTRIC PROPULSION SYSTEM FOR TRAWLERS

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NATIONAL RESEARCH COUNCIL (CNR)
INSTITUTE OF MARINE SCIENCES (ISMAR) ANCONA

Research Project Number: 27/IM/06

"Technical and economical reliability of an hybrid diesel electric propulsion system for fishing vessels"

Partners:

UNIVERSITY OF BOLOGNA – Faculty of Electric Engineering (project leader)

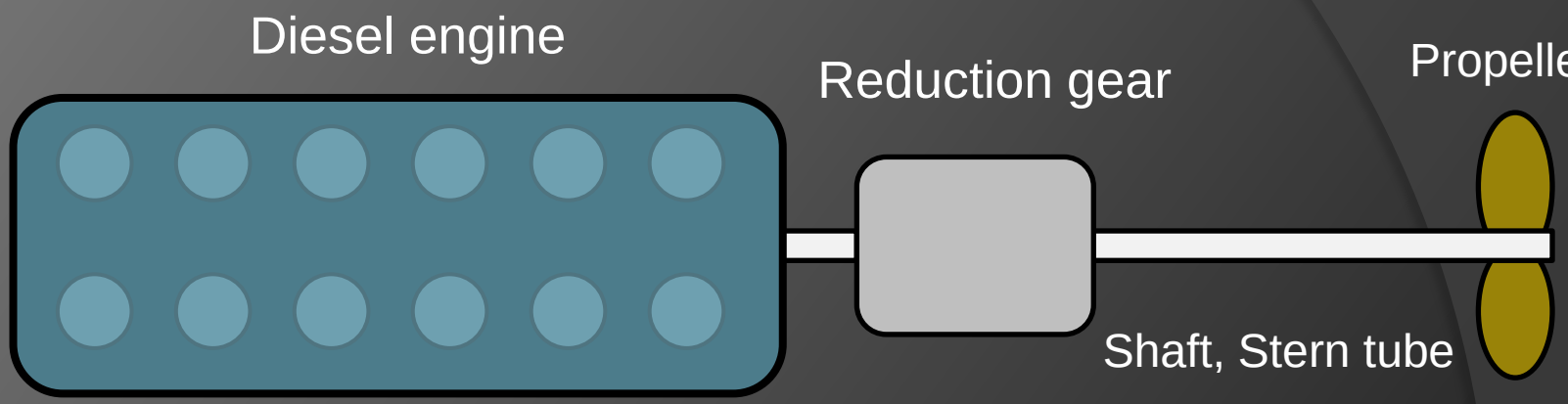
CNR ISMAR – Fisheries Section

R.I.N.A. S.p.A. – Italian Classification Society

FEDERPESCA – National Federation of Fishermen

ASCOMAC – National Union of Marine Engines

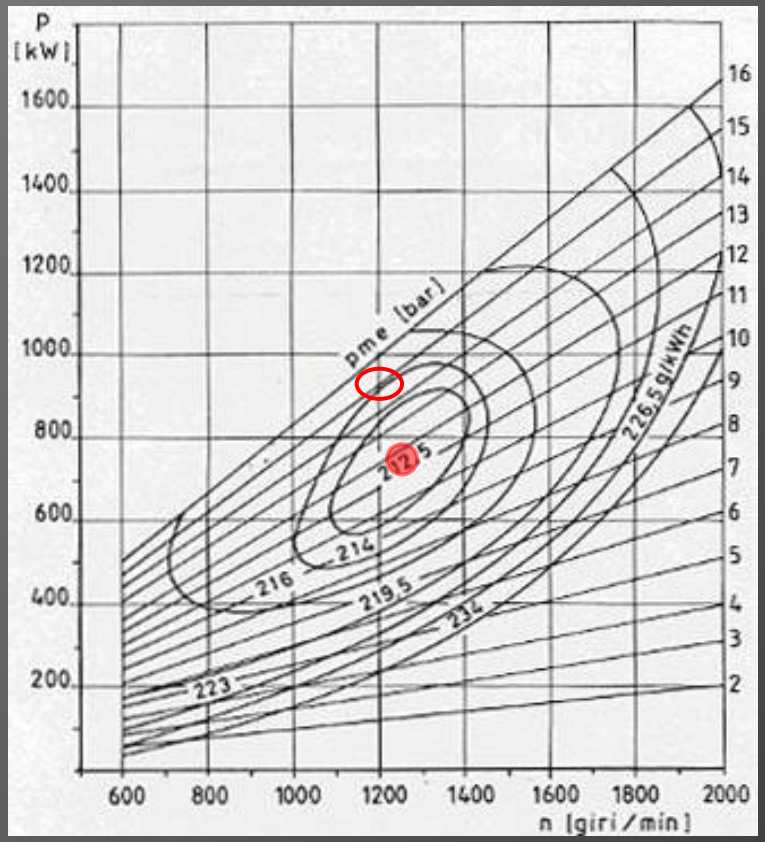
Standard propulsion system layout



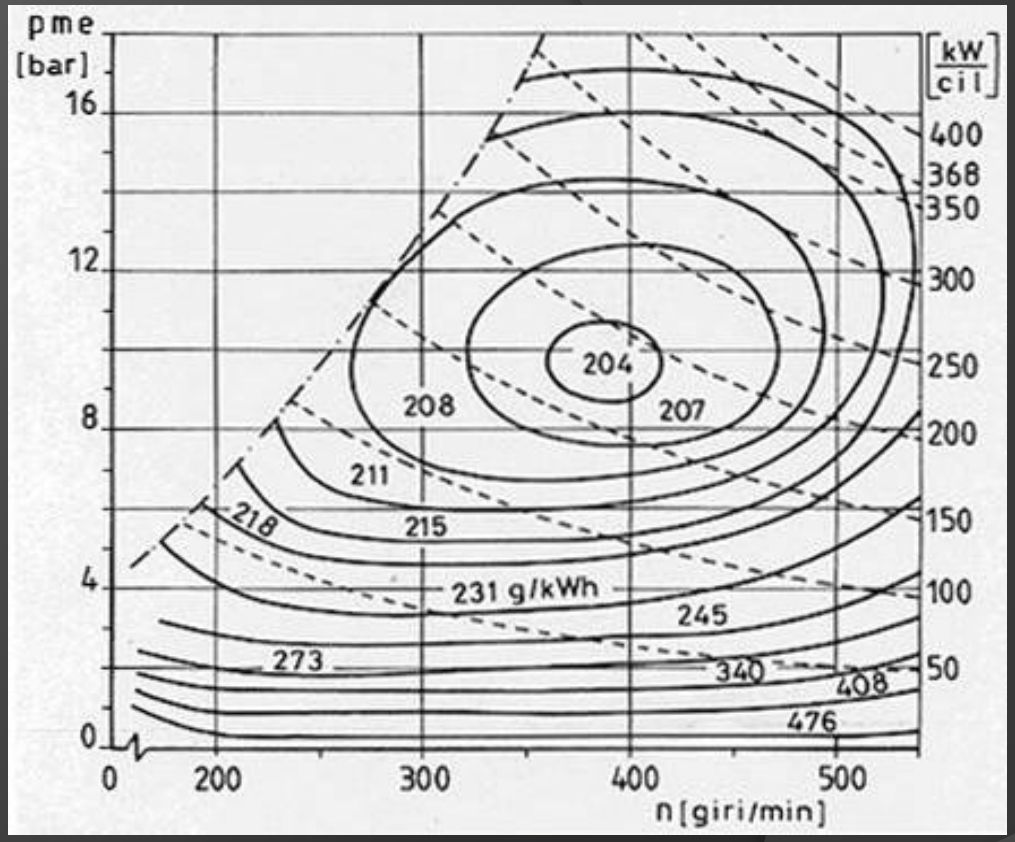
Task of the propulsion system of a fishing vessel:

- Propulsion system must deliver the requested thrust for any fishing phase and condition
- Management of propeller thrust through main engine revolution speed management
- It is difficult that different fishing phases can be carried out in an optimal operating point from the point of view of the fuel consumption

Diesel engine characteristic diagram



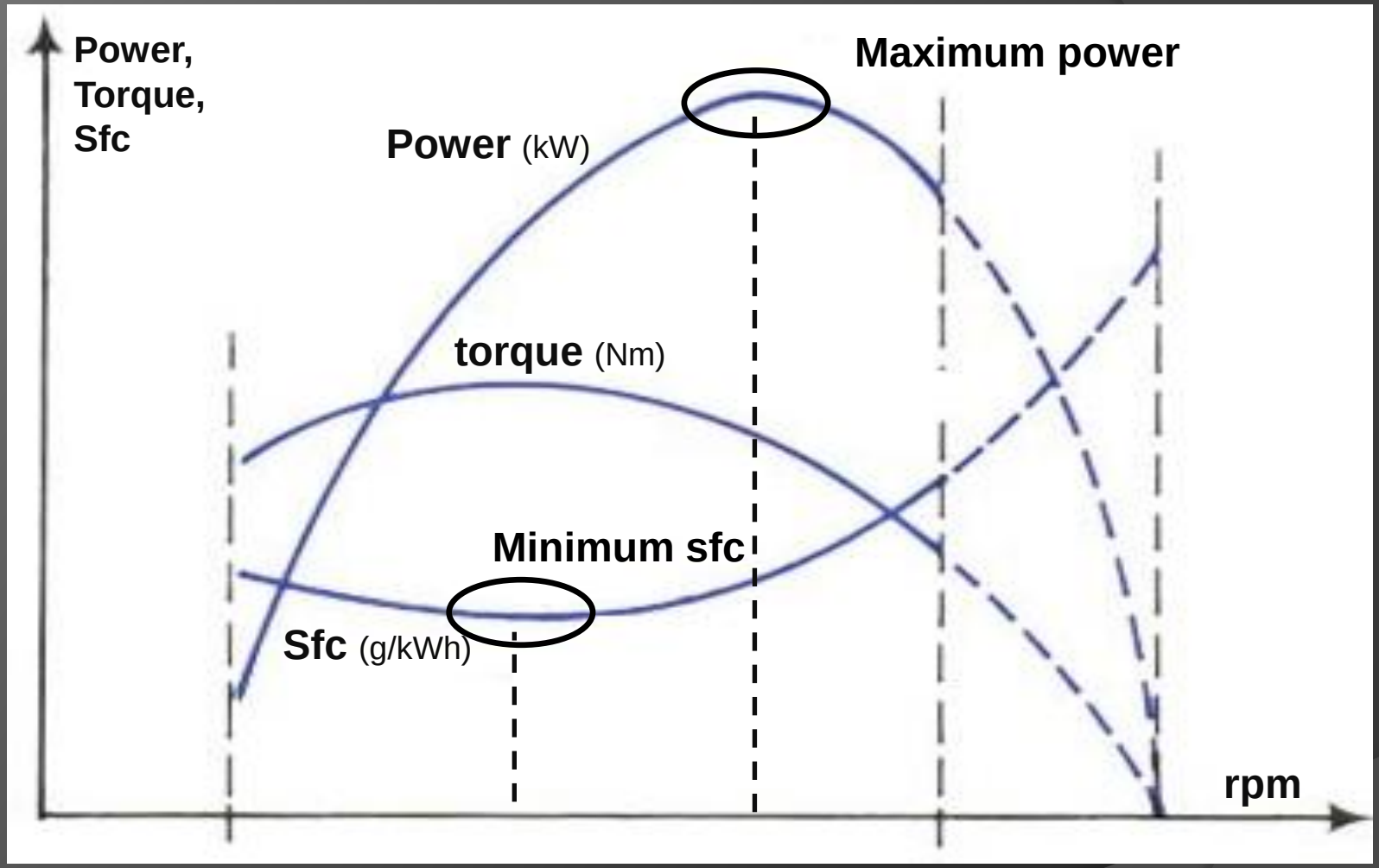
Power delivered at different loads



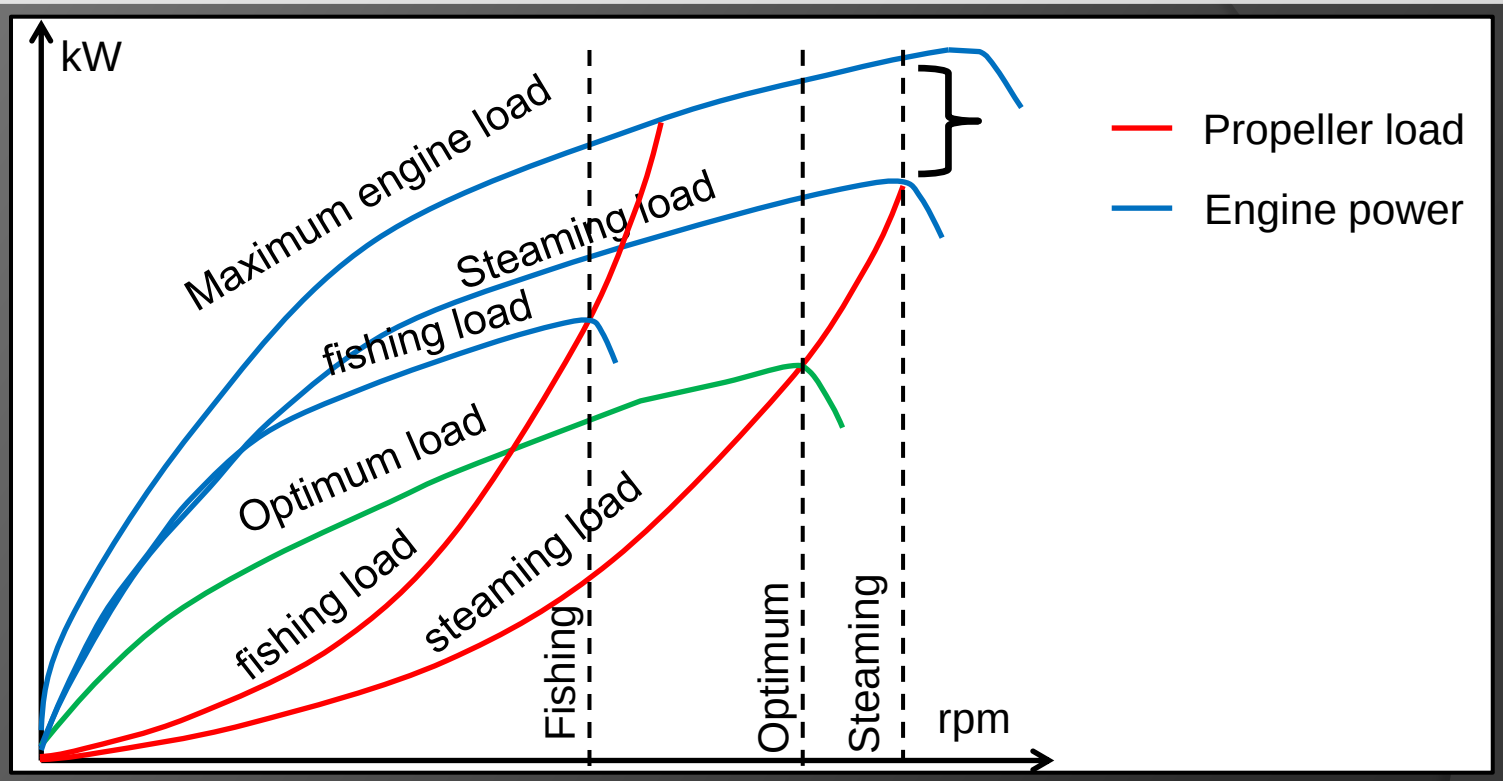
Power delivered per cylinder

- There is only one operating point for each main engine load that minimize fuel consumption (minimum specific fuel consumption)
- There is only one operating point in which the fuel consumption is the lowest

Diesel engine characteristic diagram (maximum load)

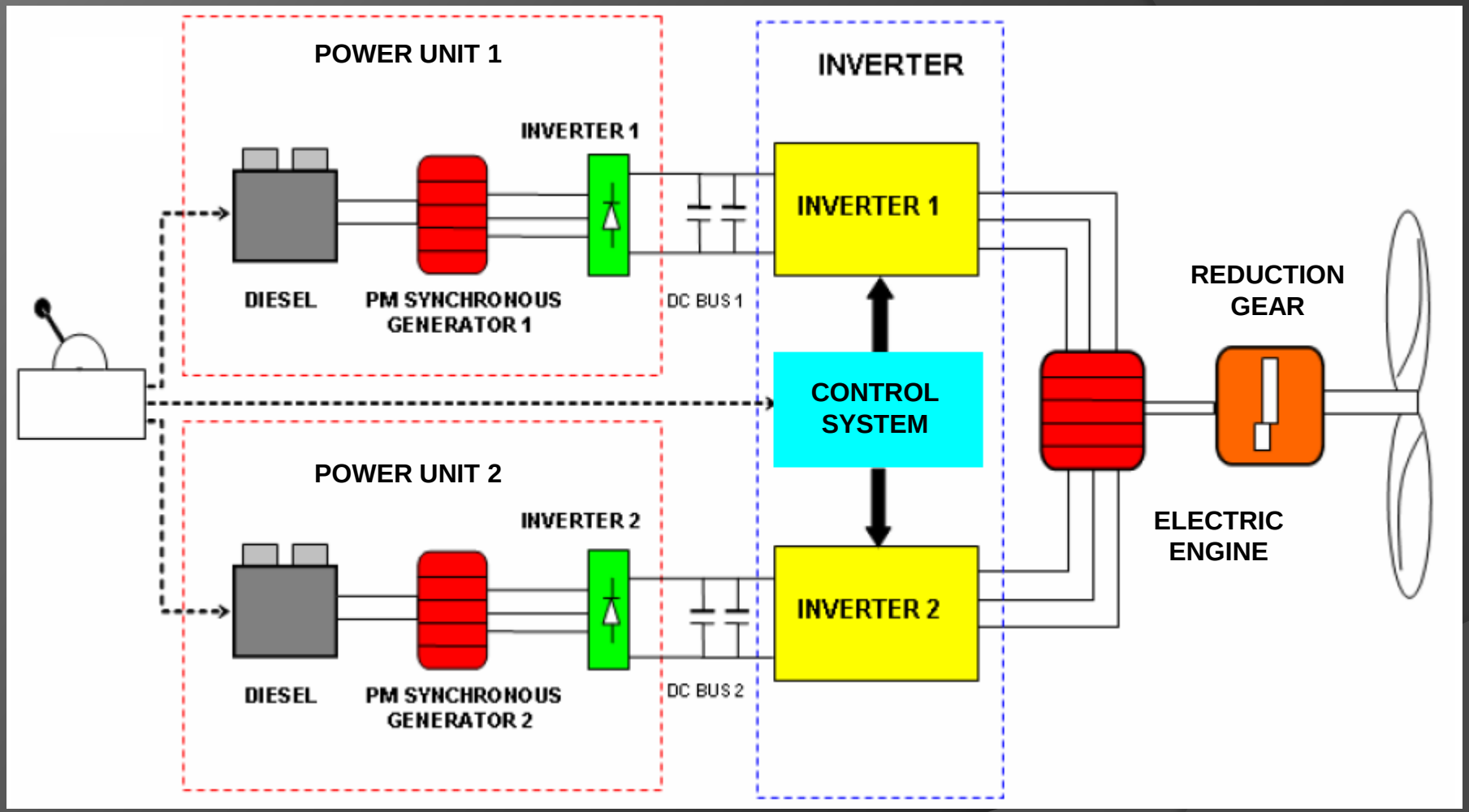


Matching of propeller and main engine



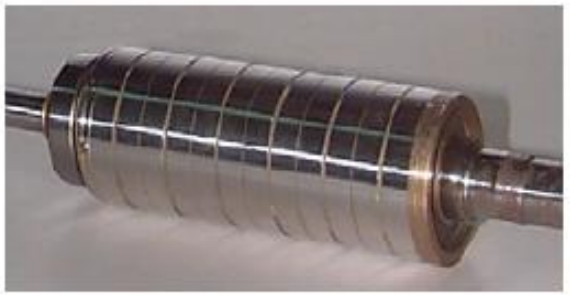
- Over sizing of main engine is needed due to increasing in propeller load
- The engine load is controlled by adjusting throttle
- Setting load at optimum, specific fuel consumption could be minimized.
- Fishing load curve is more steepish than steaming curve

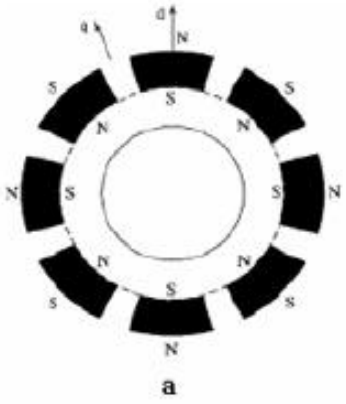
Hybrid propulsion system layout

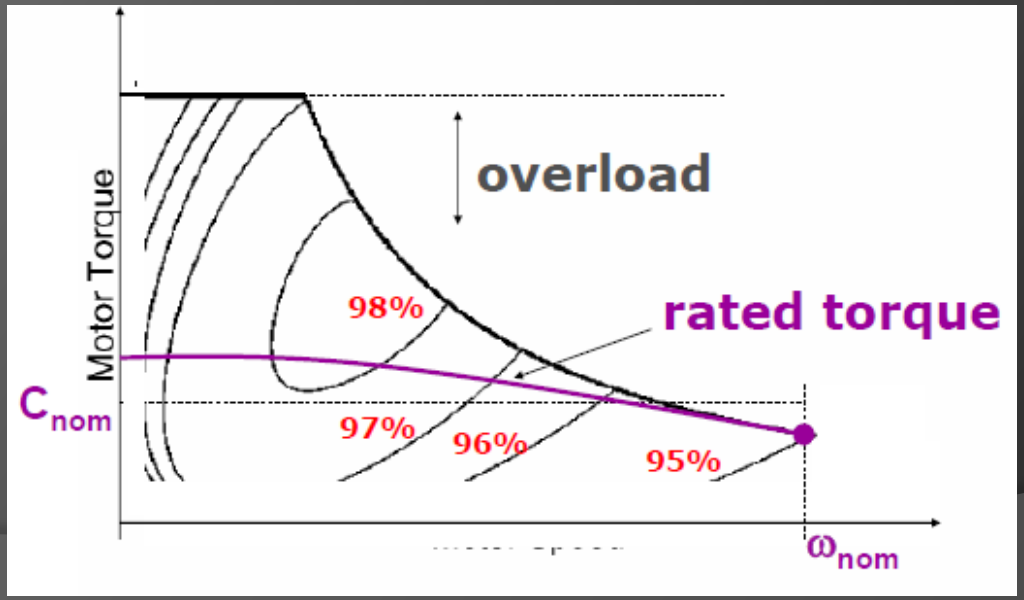


Main components: Synchronous electric engines and generators

Brushless synchronous electric engines and generators:



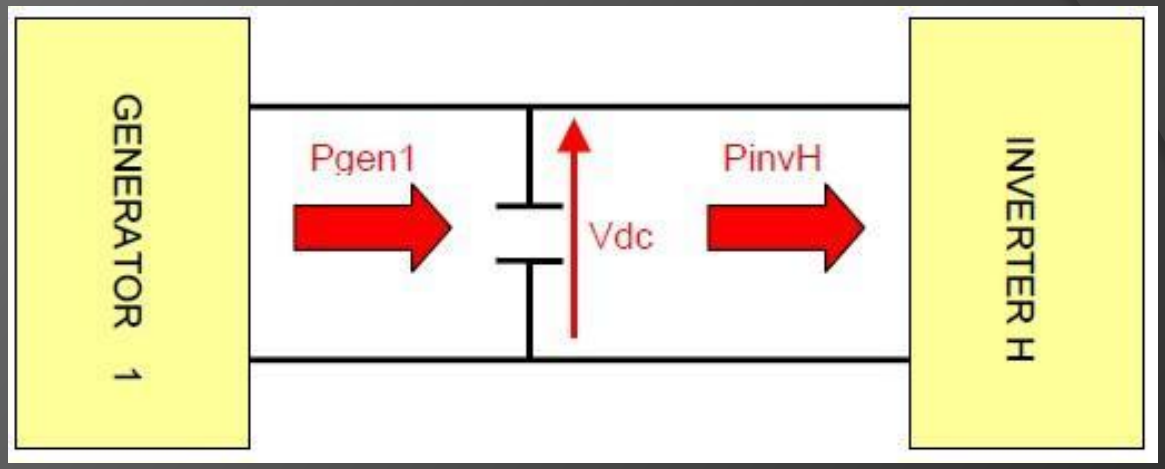




Main properties:

- Complexity in the rotor (permanent magnet)
- 3 ÷ 4 C_{nom} power overload
- Low passivity at reduced power
- High ration Nm/k
- High ratio Nm/A
- High efficiency
- Variable speed and torque (torque and speed control through voltage control)

Main components: Bus DC



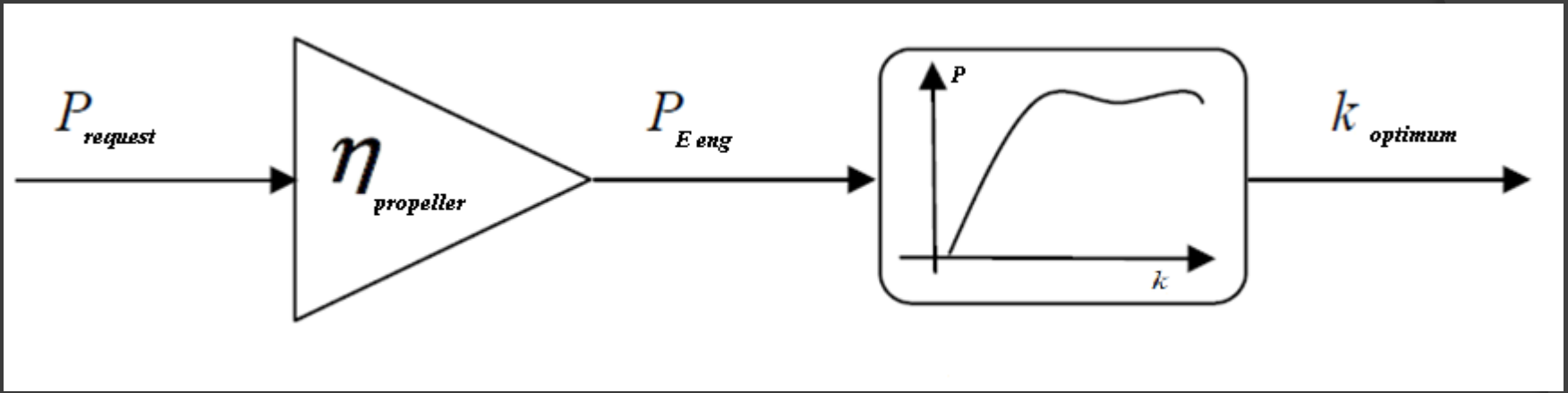
Role of Bus DC:

- Interface between power units and propeller drive system
- Management of balance between power required and power delivered from each power unit through V_{dc} control

$$E = \int (P_{gen1} - P_{invH})dt$$

E	Energy stored by the capacitor
P_{gen1}	Power generated by power unit
P_{invH}	Power absorbed because requested by the electric motor

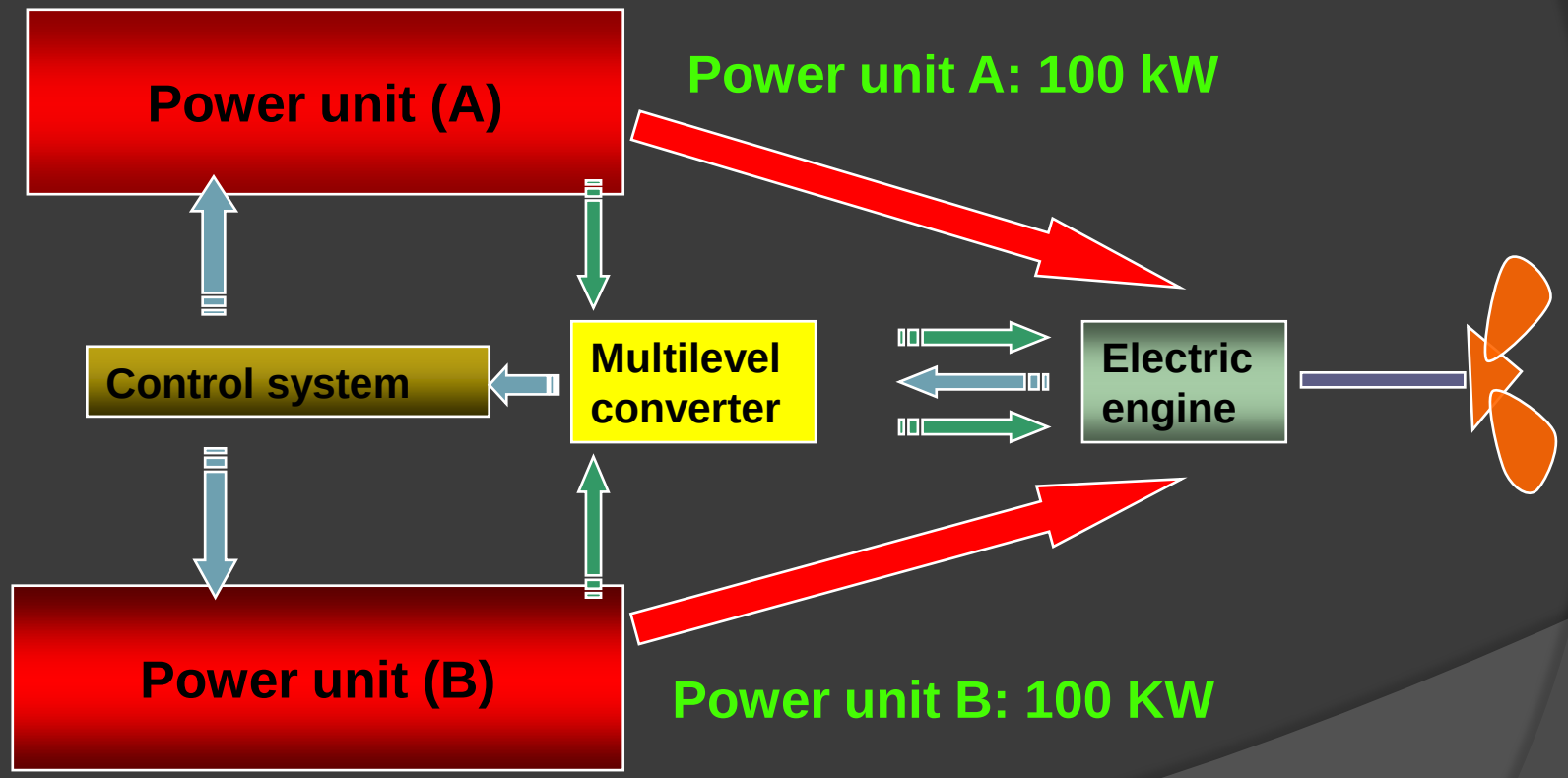
Control System architecture



- $P_{requested}$ is the power requested by the propeller
- $P_{E\ eng}$ is the power requested by the electric motor
- K is the power sharing coefficient, that manage the distribution of power generation among power units
- $K_{optimum}$ is the value of the coefficient that minimize overall specific fuel consumption

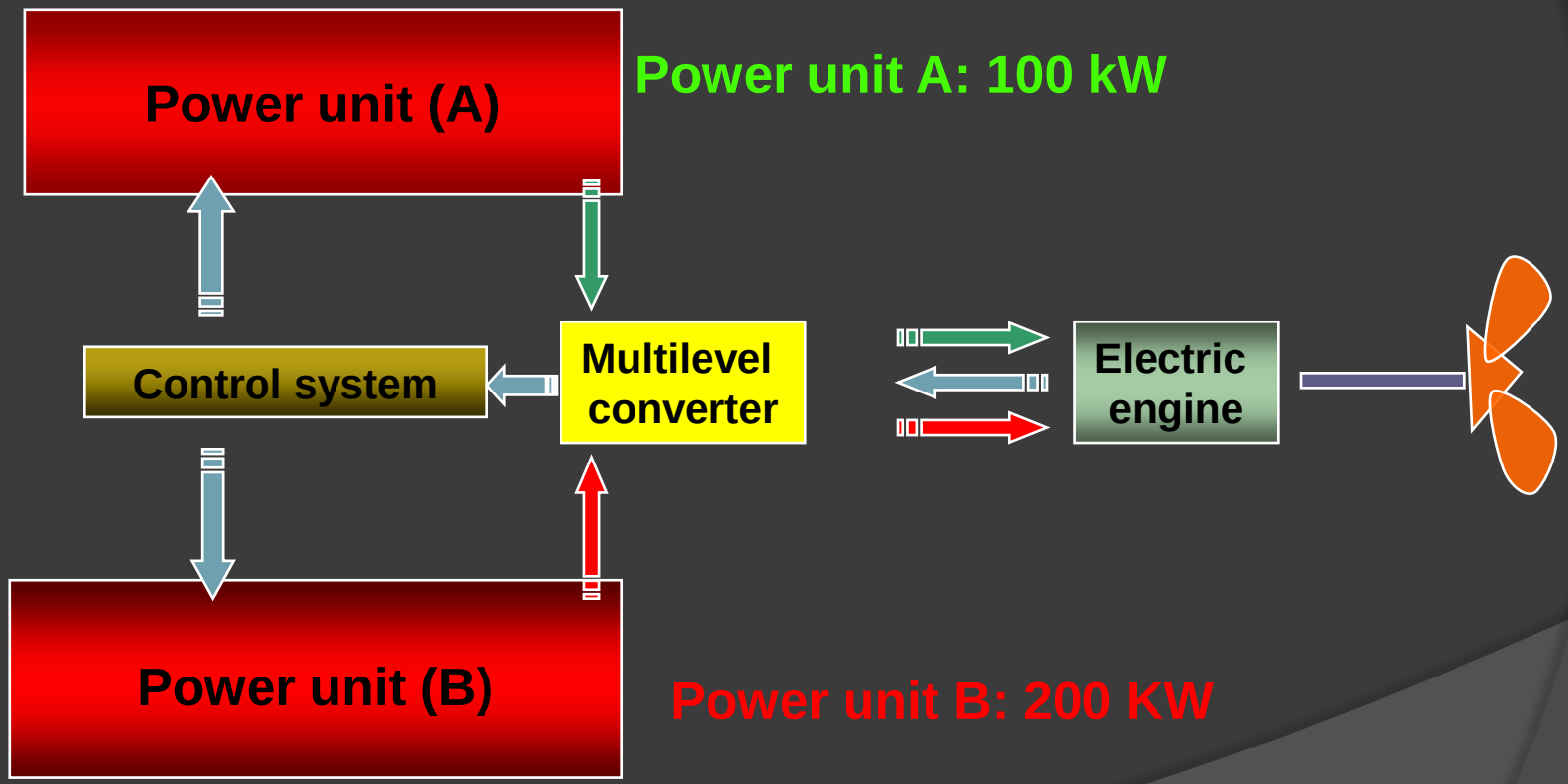
Hybrid propulsion system layout

P_{Max} = 2x260 kW P_{Opt} = 100 kW $P_{request}$ = 200 kW

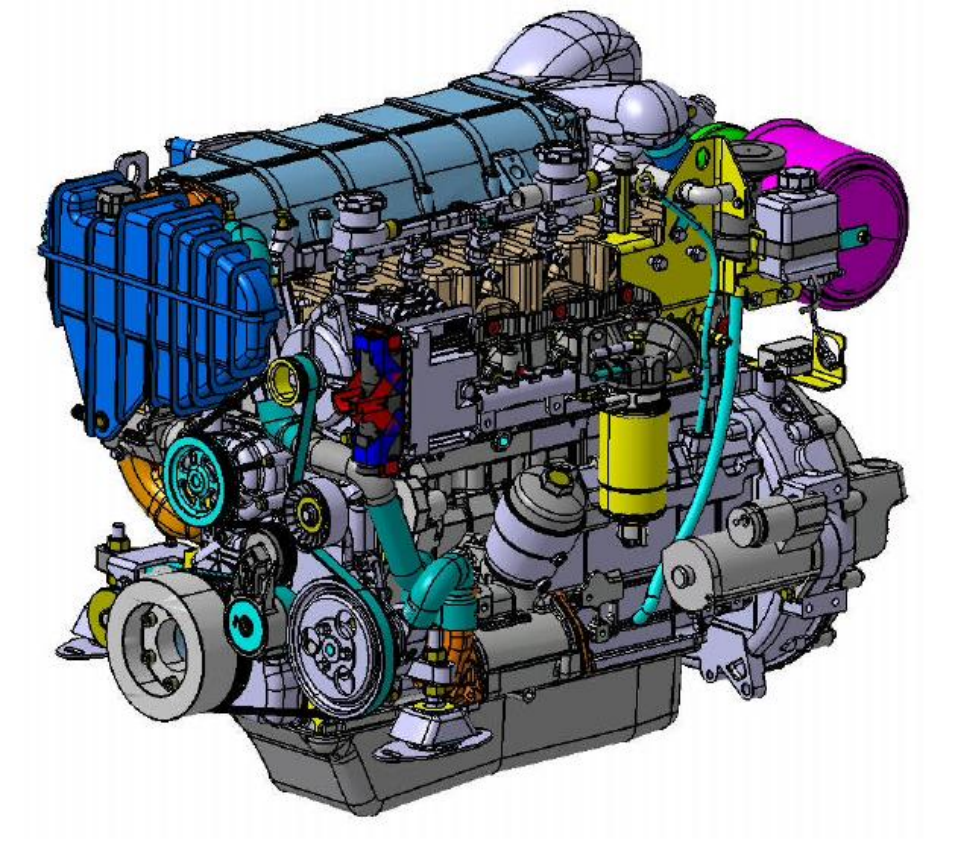


Hybrid propulsion system layout

P_{Max} = 2x260 kW P_{Opt} = 100 kW $P_{request}$ = 300 kW



Bench test of diesel engine

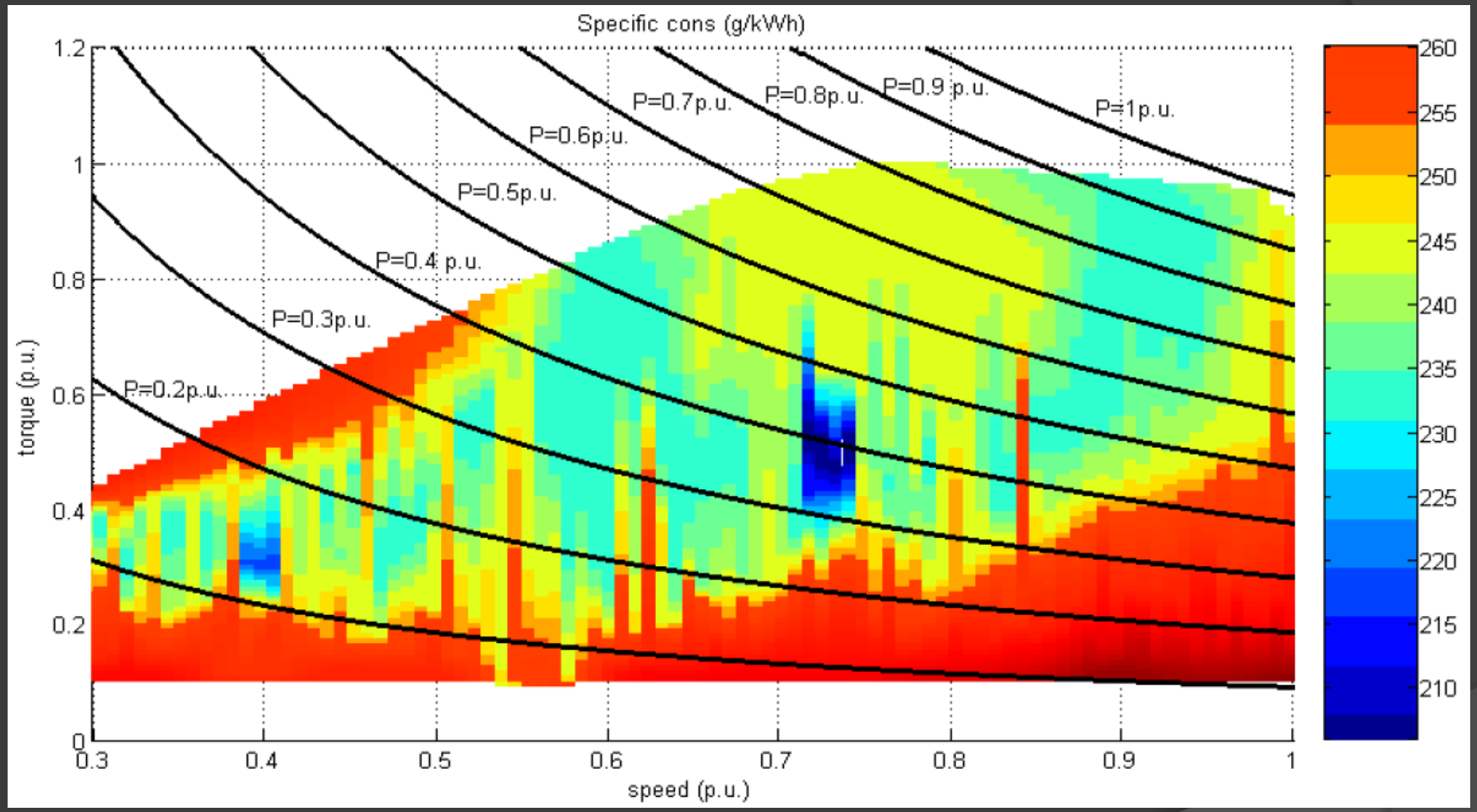


CUMMINS MERCRUISER MR706LH

Main characteristics:

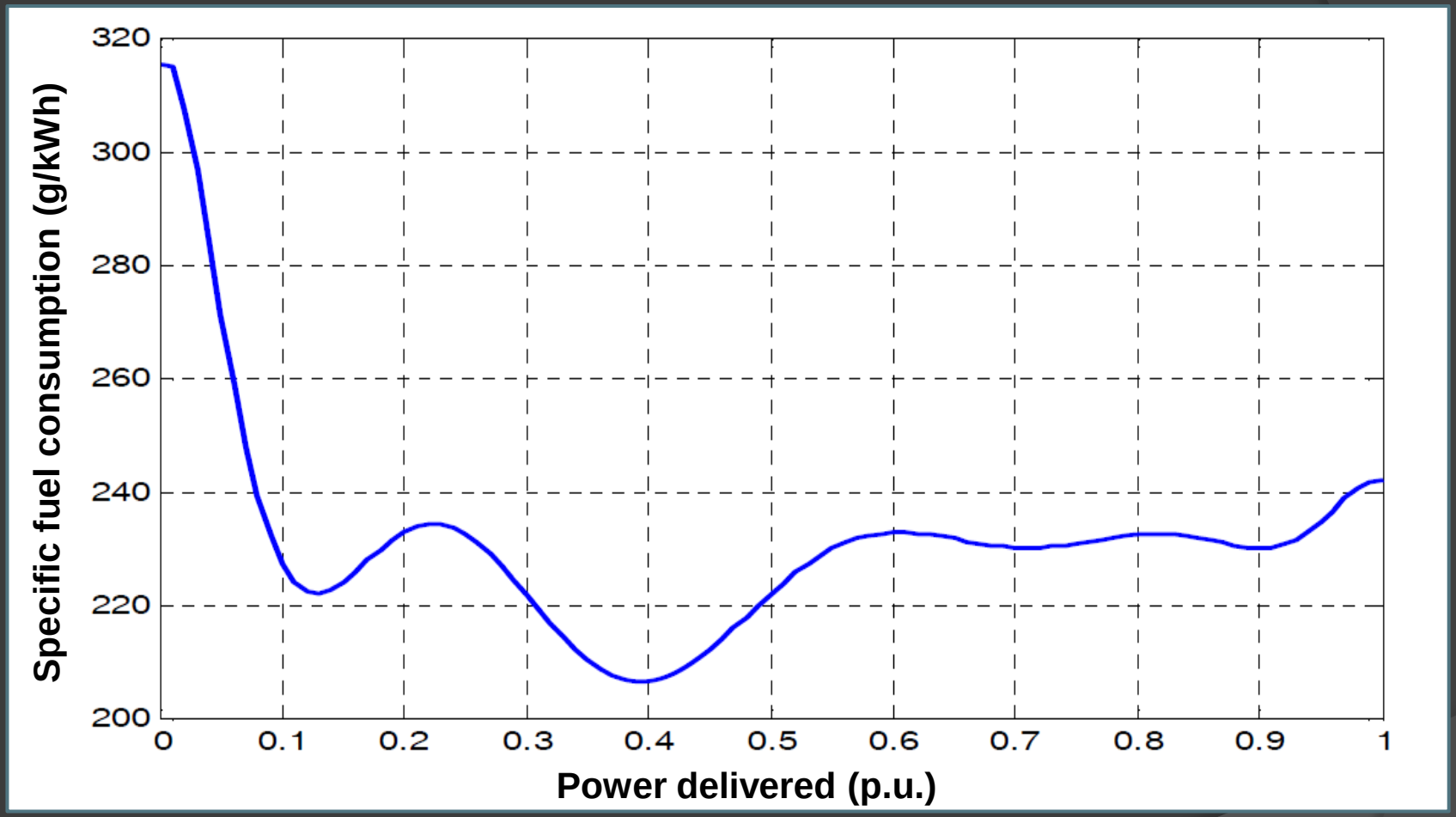
- Combustion cycle Four stroke
- 6 cylinder in line
- 2 valve per cylinder
- 257 kW total power @ 3800 rpm
- Cooling medium Water - Water
- Turbocharged with Intercooler
- Common Rail

Bench test of diesel engine



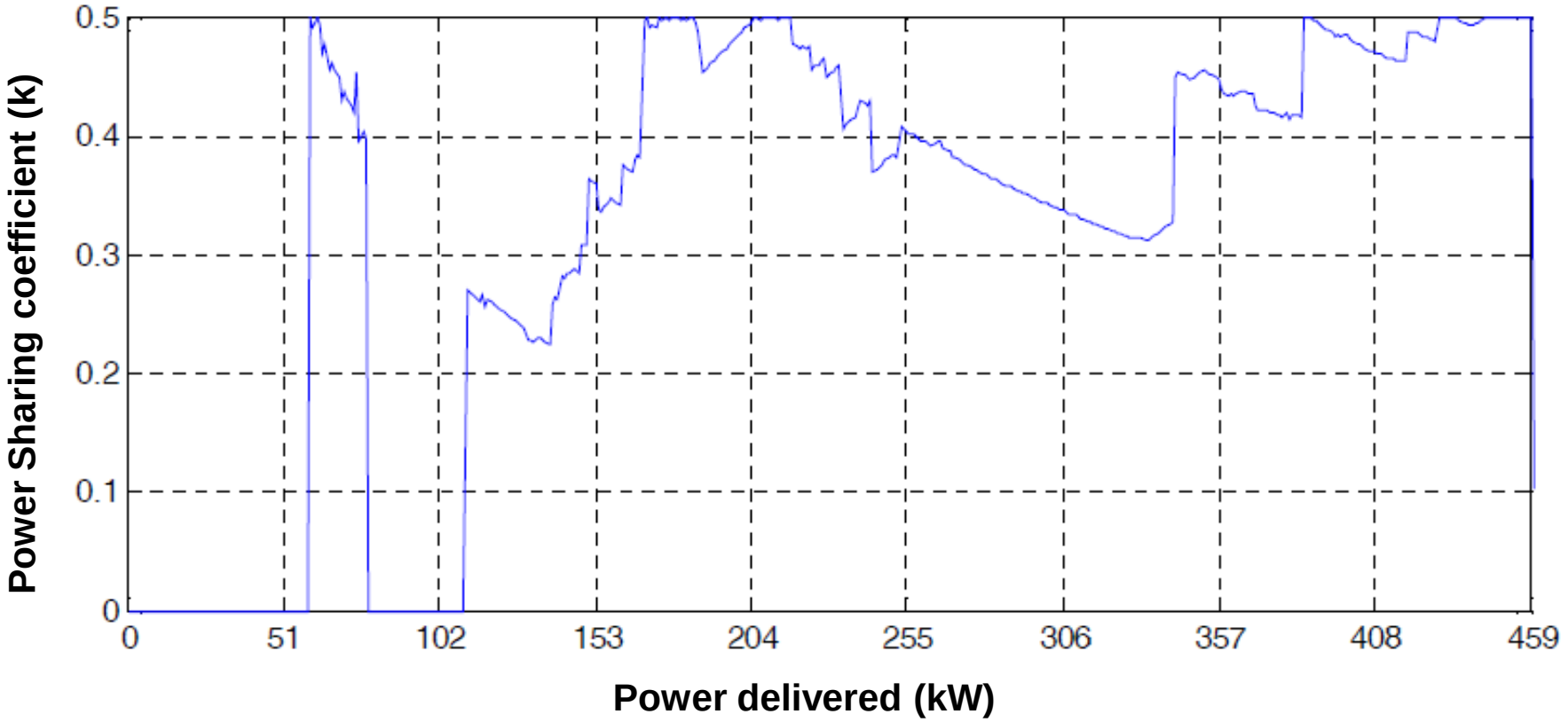
Bench Test for specific fuel consumption evaluation against torque, rpm and power delivered.

Trend of minimum specific fuel consumption



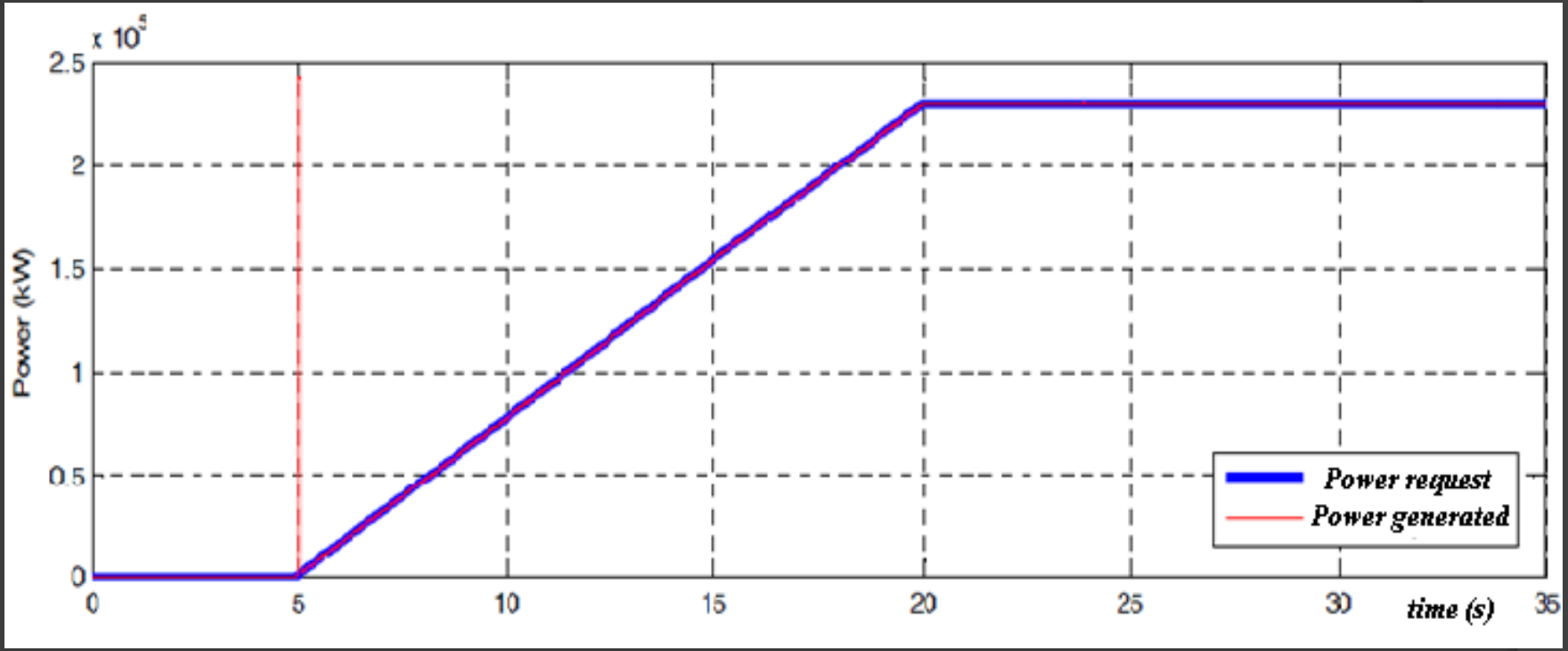
Through bench test, the minimum specific fuel consumption trend is obtained, against power delivered

Trend of Power sharing coefficient (k)



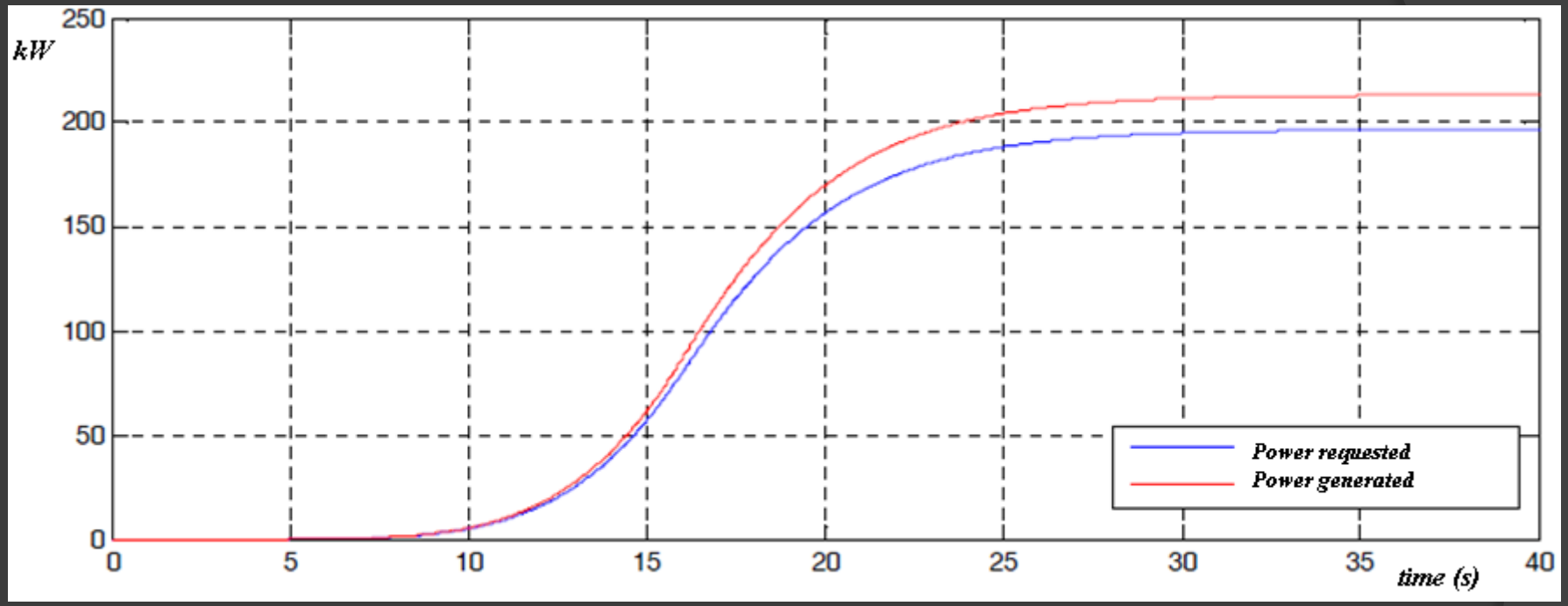
From the minimum specific fuel consumption trend, the Power Sharing Coefficient (k) is obtained for any power request

Results: Test of power delivered



Power request by the propeller (in blue) is followed by power generated by the electric motor (in red)

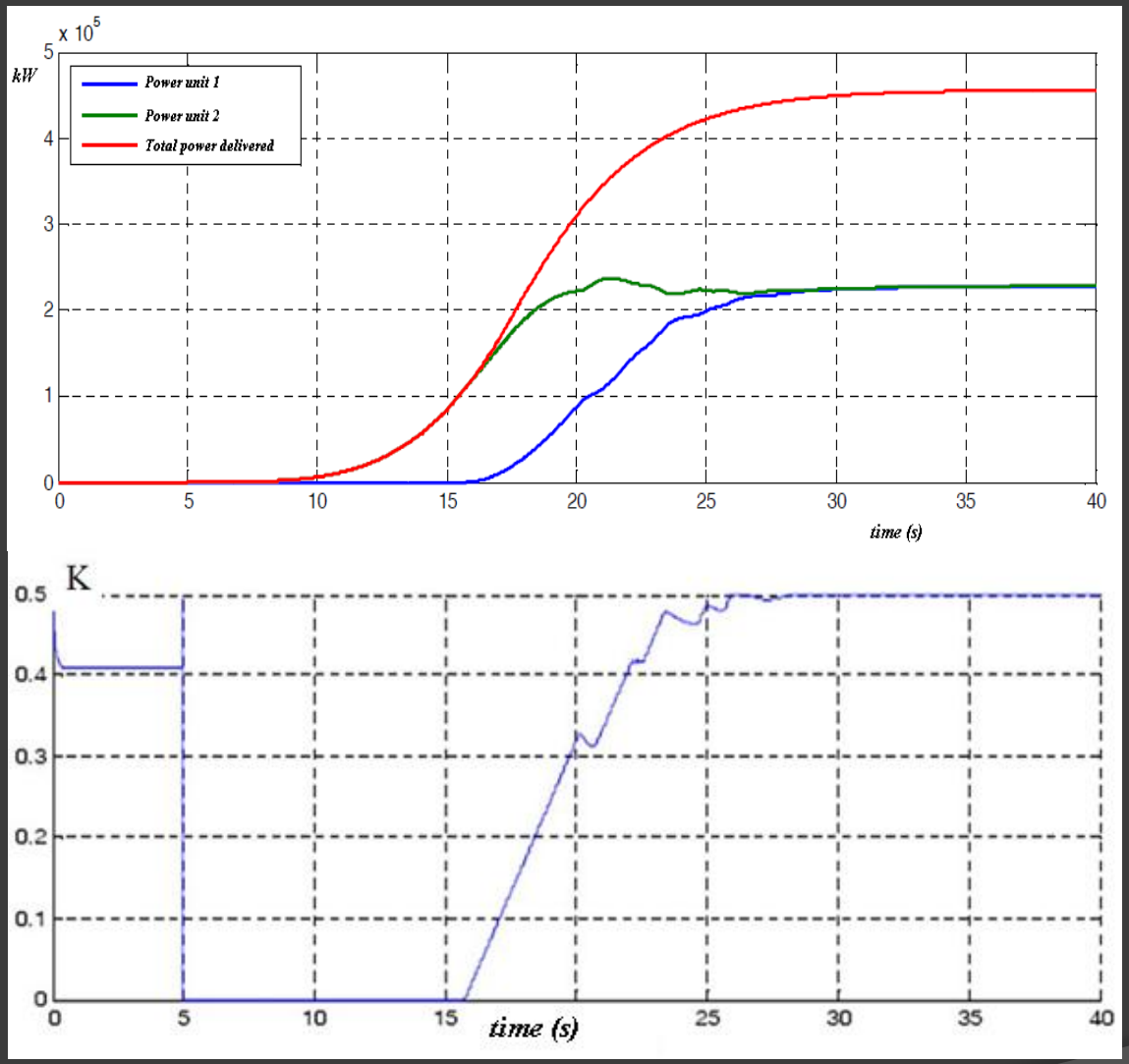
Results: Test of power delivered



Power request by the electric motor (in blue) is followed by power generated by the power units (in red)

Taking into account losses, power generated by power units is greater than the power requested by the electric motor

Results: Startup of the system



- Optimal operating point when a power of 100 kW is delivered.
- At t = 16 s first power generation is delivering 100 kW; the second power generation unit starts.
- Around t = 20 s, delivering 300 kW, the control system sets power unit 1 to 100 kW (optimum) and the power unit 2 at 200 kW.
- When maximum power is required, the sharing coefficient is 0.5, so that both power units develop their maximum power

Conclusion

- Test results demonstrated technical reliability
- From the results obtained, for the diesel engine monitored a 15% fuel saving has been obtained during trawling simulation
- It is possible to include auxiliary power generally used for electric machineries
- It is possible to change propeller configuration maintaining a good matching of the propulsion system
- It is possible a retrofitting of existing propulsion systems; the architecture proposed could works also with one power generation unit
- Engineering tests at sea are requested

ICEEF PROJECT

“Information collection in energy efficiency for fisheries”

IPSC/2011/04/01/NC (ICEEF)

Why

This is an initiative by the European Commission to facilitate the exchange of ideas and best practices on how to improve the energy efficiency of fishing and reduce energy costs

What

The pilot website includes reference documents and studies related to energy savings in fisheries, general information on research and funding opportunities and links to relevant EU projects, legislation and events.

How you can help

Please disseminate this information and if you wish to suggest items for inclusion in the website, please send your contribution to the contact address given below

ICEEF PROJECT

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https://energyefficiency-fisheries.jrc.ec.europa.eu

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- energyefficiency-fisheries@jrc.ec.europa.eu
- a.sala@ismar.cnr.it
- e.notti@an.ismar.cnr.it


“…the most efficient and precious energy is the energy that you do not use…”
Thank you for the attention!