SELECTION PROCESS OF PROPULSION SOLUTIONS

Analytical approach to the selection of suitable navy ship propulsion systems

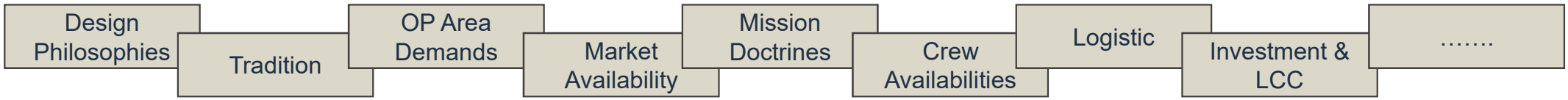
M. Harth, Farnborough, CNE Conference, May 2024

Agenda

1 Motivation for an analytical approach

Different Navies, different decision drivers….

Custom Ship Design Criteria



Generic Ship Design Criteria

- Small to medium-sized ships require drives with **high power density** due to **speed** and **weight** requirements
- **Machinery Deck Space** to little to install numerous Diesel Engines. Generic **weight restrictions**
- **High Electric Power Demand** for high energy hungry weapon systems & availability of high energy peak reserves and emergency system by PT0
- Requirement for **highest redundancy levels**
- Limited market for **powerful Marine Gas Turbines**
- **Multi Purpose operations** requires **flexible propulsion** arrangements
- ……

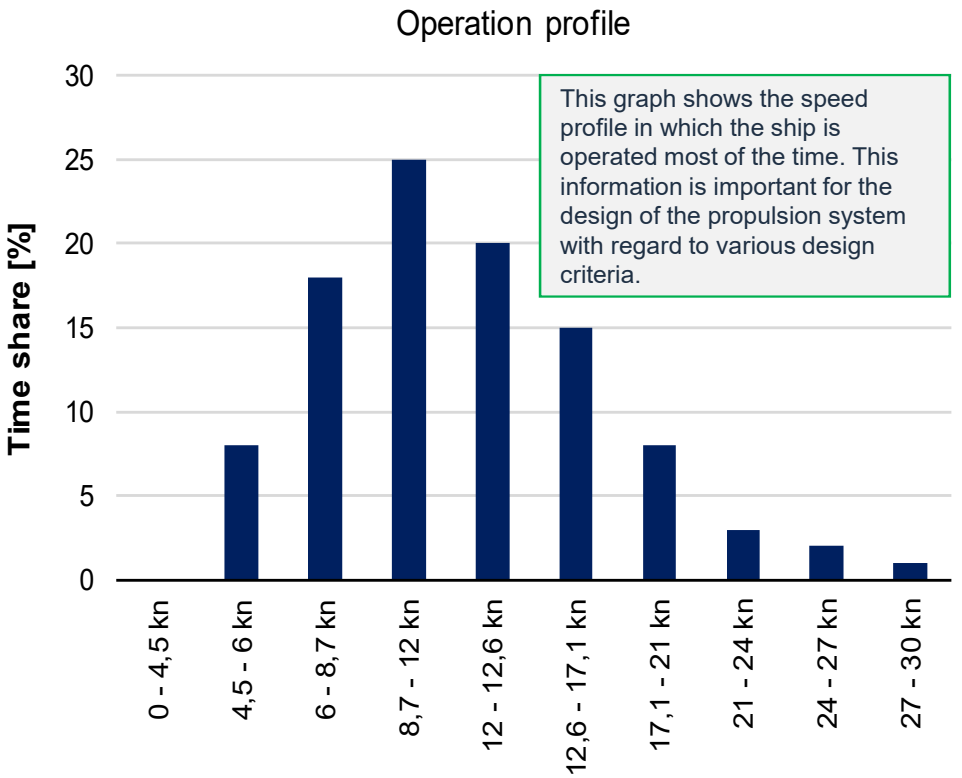
2 Analytic Hierarchy Process

Definition of a typical use case - Vessel Specifics

Based on our experience, we would like to take a closer look at a typical ship with the following specific characteristics.

Displacement:	**< 5000t**
Type:	**Light Frigate / Corvette**
Max Speed:	**~ 28 kts**
Range	**5000 NM**
Hotel Load	**~ 5 MW**
Propulsion Power (max):	**35 MW**
Propulsion Power (12 kts):	**3 MW**

These are typical design criteria for a ship class “light frigate, corvette or larger patrol boat”

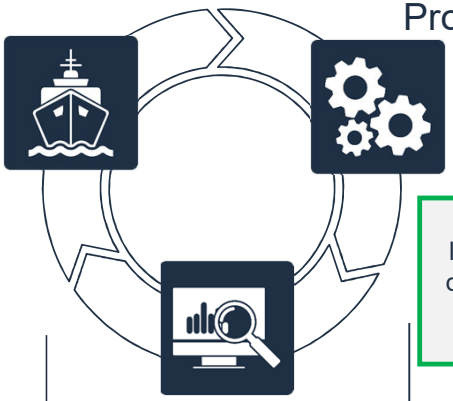


Solutions only as complex as needed, cooping best with functional requirements

The result of each concept can be displayed in a relevance grid with regard to various properties. In the course of this presentation, the attributes shown with arrows will be considered further.

Mission capabilities

Propulsion plant configuration



Operational profile

A design spiral (iterative process) leads successively to a selection of different concepts, which are further examined and analyzed in the following process.

Concept 1

Concept 2

Concept 3

+

Data

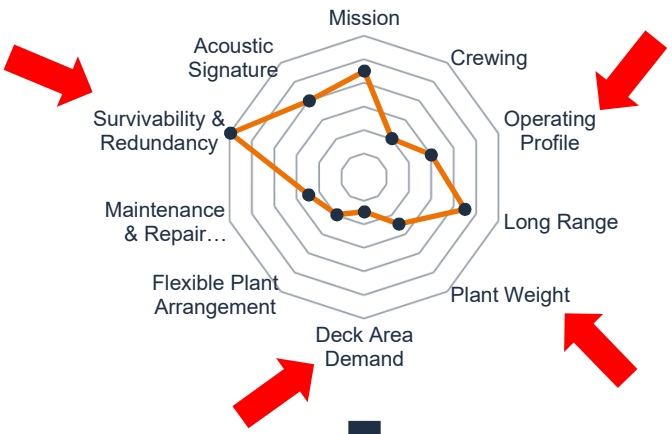
As a result, the correlation of input data and requirements leads to the optimum solution. As a rule, the best compromise is sought and found.

Correlation

Data vs. Criteria

Analytic-Hierarchy-Process

Relevance Grid



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Pre-Selection and Baseline

The concepts shown here illustrate possible combinations of drive machines. For example, the maximum speed to be achieved, the “patrol speed” and the available electrical energy are taken into account.

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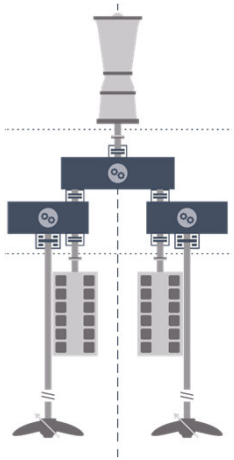
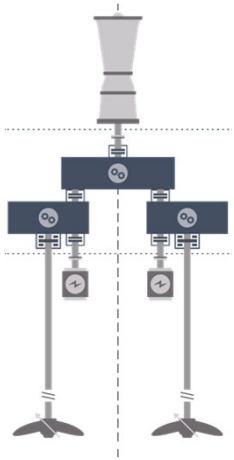
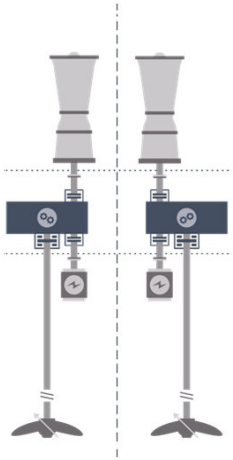
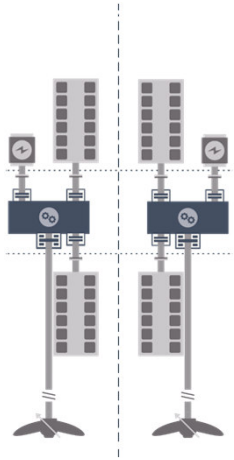
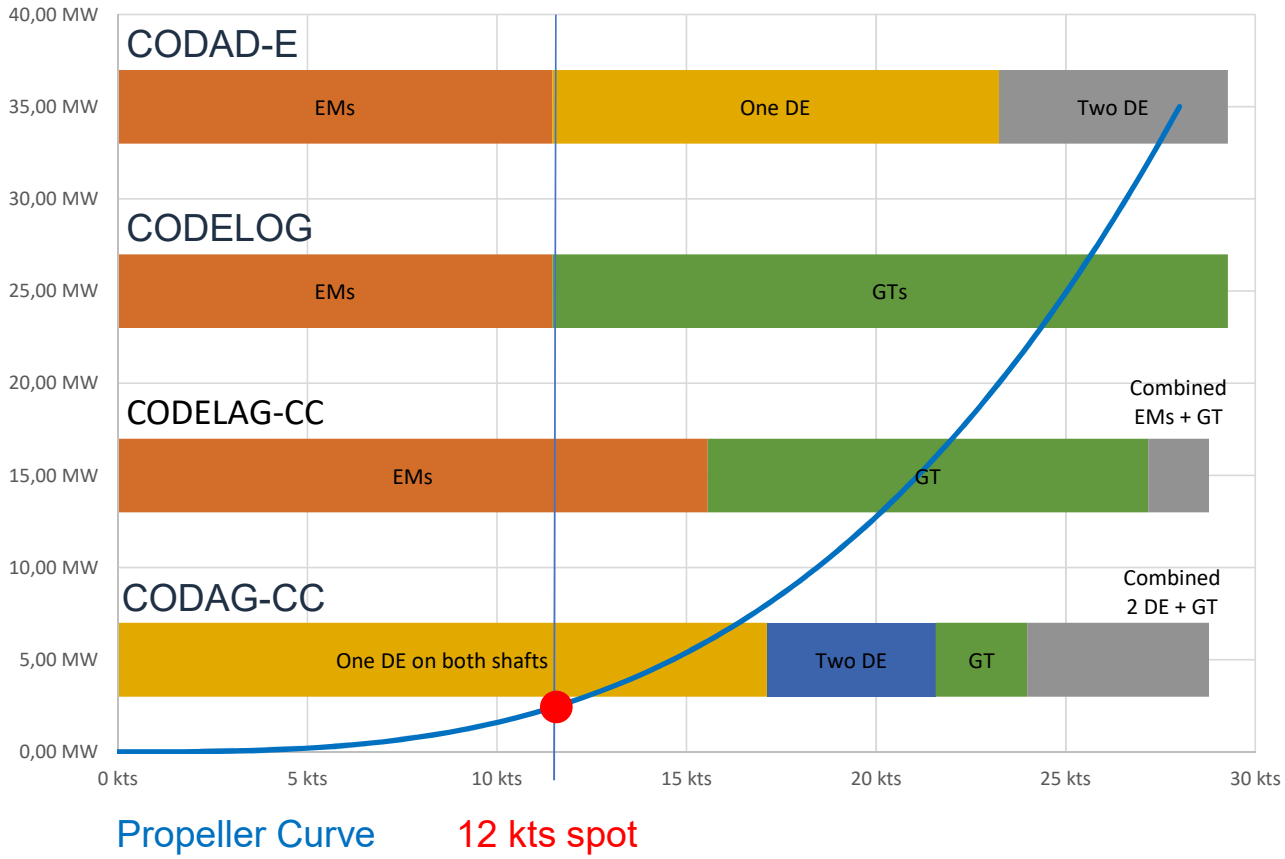
Display				
GT	22 MW	32 MW	2 x 20 MW	-
DE	2 x 8 MW	-	-	4 x 10 MW
PEM	-	2 x 3 MW	2 x 1,5 MW	2 x 1,5 MW
GenSet	~ 5 MW	~ 11 MW	~ 8 MW	~ 8 MW
Prop. Power	38 MW	38 MW	43 MW	43 MW

Power Demand



Propeller Curve 12 kts spot

This diagram shows how the different speeds can be achieved, taking into account the previously selected drive machines and their possible gearbox combinations.

The “12 knots” vertical line shows which drive units are used to achieve this speed.

3 Focus - Operating Profile , Survivability & Redundancy

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Operating Profile

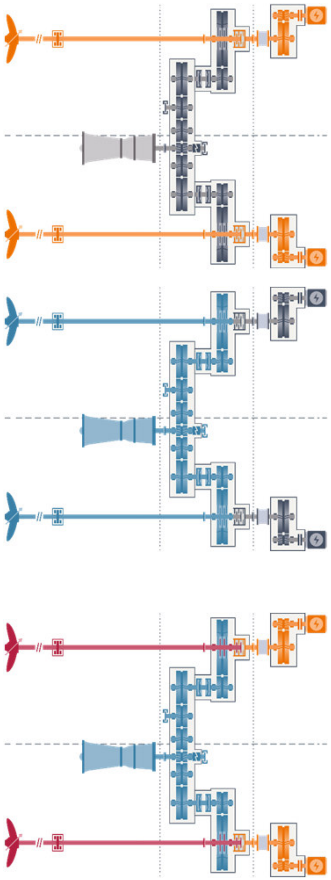
Always enough, never too much!

Today's multi-mission concept combat ships need versatile propulsion systems with intelligent propulsion control systems

Intelligent sailing modes offer the optimum drive option for every mission

Dedicated benefits of this exemplary Cross Connect system under this aspect

- Power Distribution of one (of all) selectable prime mover to both shafts
- Use of the GT in the less efficient low load range can be largely avoided.



Electric mode

Gas turbine mode

Combined mode

The CODELAG-CC system is used as an example to show which driving modes are possible with a functional arrangement of clutches. The drive machines are operated as efficiently as possible in the most efficient load range.

Survivability & Redundancy

Greater versatility provides security and reserves

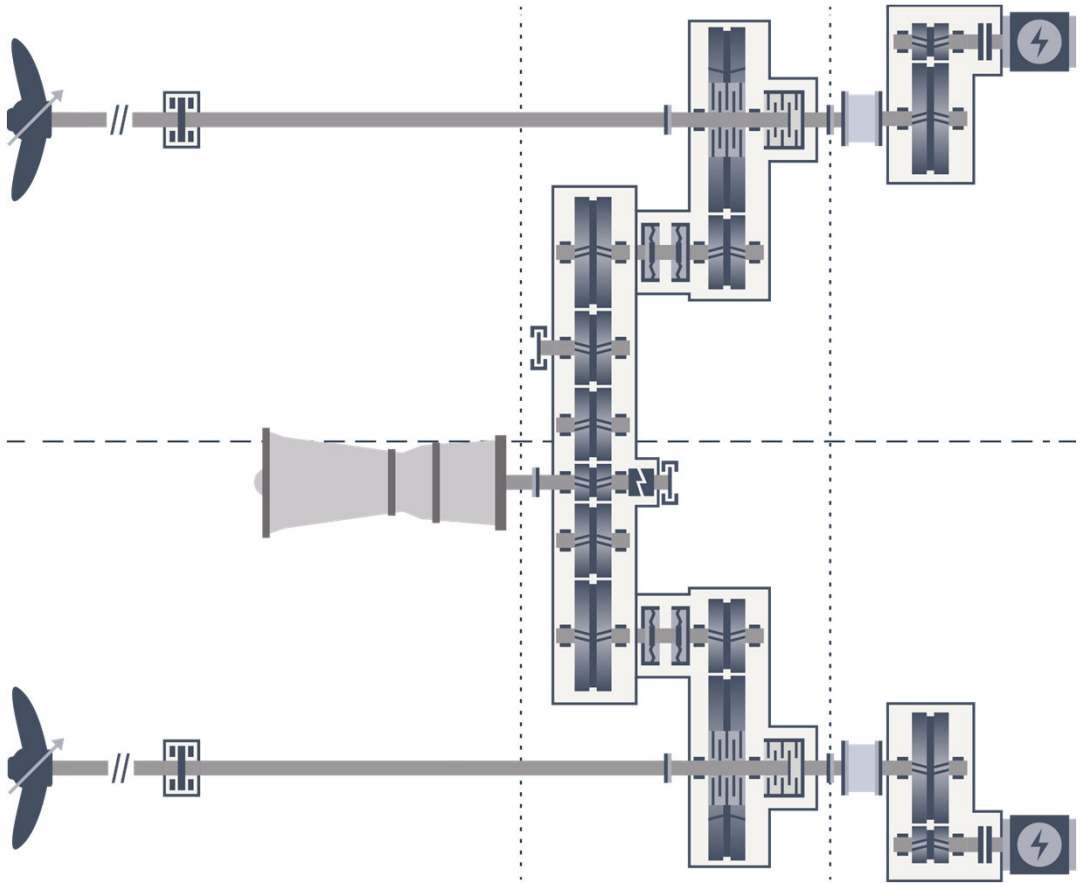
It is **unlikely** that all drive options will fail at the same time. Such a system therefore offers a high level of redundancy and therefore survivability

The **redundancy level** of a Cross Connect system is comparatively higher than with separately controlled shafts, as both shafts can be operated with a higher degree of failure

Power Take Out (PTO)
Emergency supply with electrical energy or peak load coverage by generator operation possible

Dedicated benefits of the Cross Connect system under this aspect

- Both shafts usable with each prime mover



4 Focus - Deck Area Demand & System Weight

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Deck Area Demand

The values shown here (space demand) are based on the manufacturer's specifications for the drive machines selected in the background. A selection of drive units from other manufacturers will lead to different results. Nevertheless, the comparison tends to be meaningful and valid.

Space is valuable….

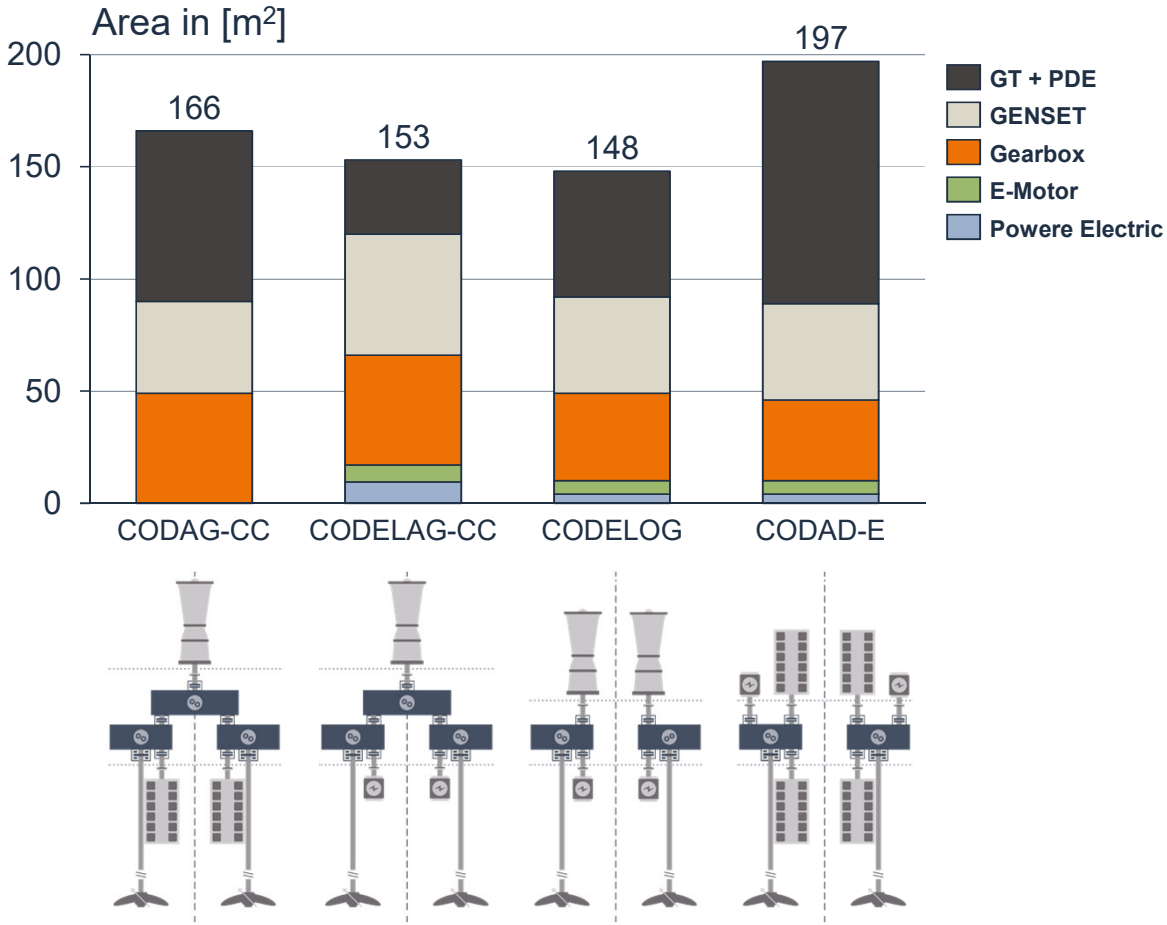
Modern combat ships are packed with sensors and multi-mission equipment. Space is therefore valuable and is considered an important design criterion

The power density of a gas turbine is significantly higher than that of a diesel engine. The specific space requirement per power unit is therefore always lower.

Power demand for E-propulsion
An increased need for GenSets in systems with e-propulsion must be taken into account. However, the placement of GENSETs on board is more flexible.

Dedicated benefits of the Cross Connect system under this aspect

- Installation space for one (1) GT only



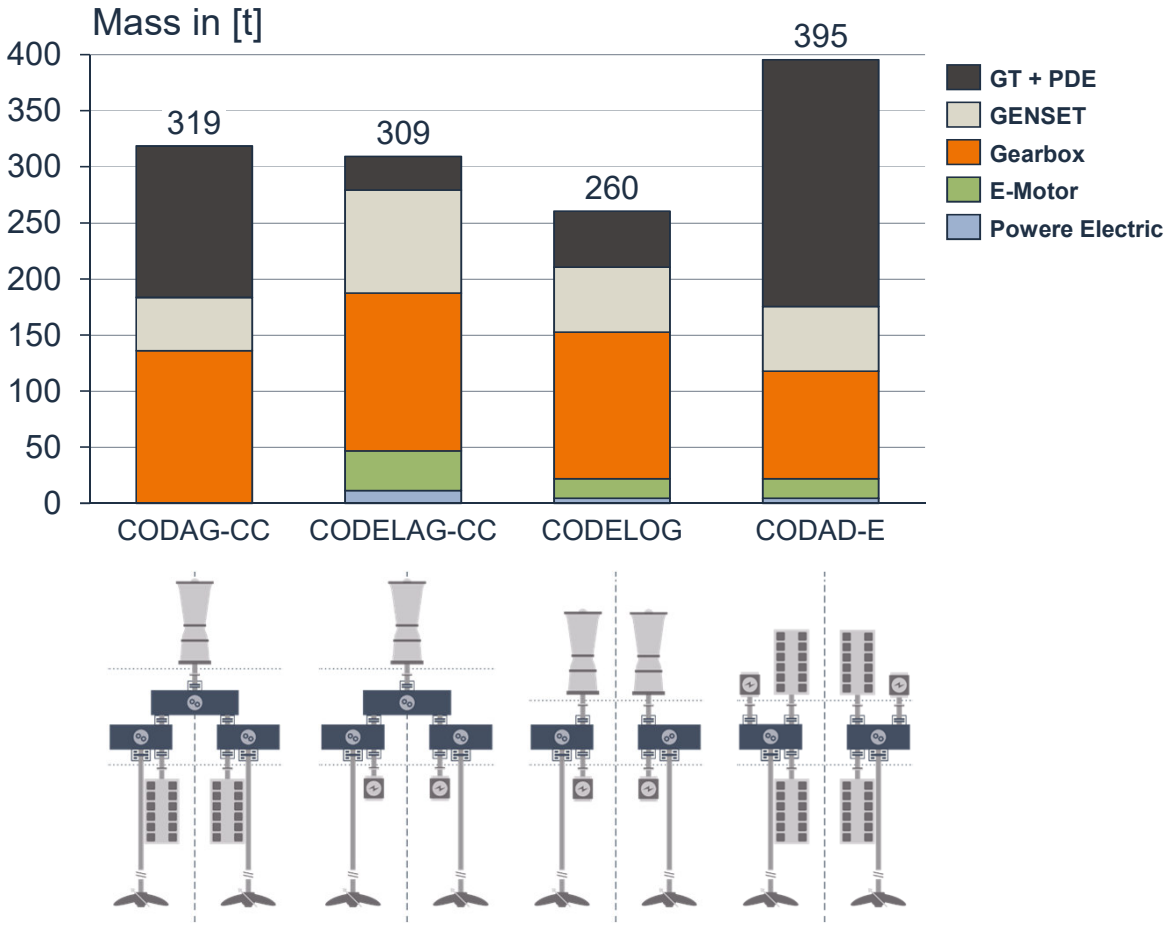
Machinery Weight

Payload instead of Equipment weight

The weight of the machines is an important aspect in the design of ships. Furthermore, the placement of the components is subject to shipbuilding restrictions

All solutions show individually large differences in the equipment weights. However, the comparatively high weight of the diesel engines in the overall system is striking.

But what if we include efficiency aspects, specific fuel oil consumption and bunker requirements to achieve the set range of 5.000 NM?



System Weight plus bunker

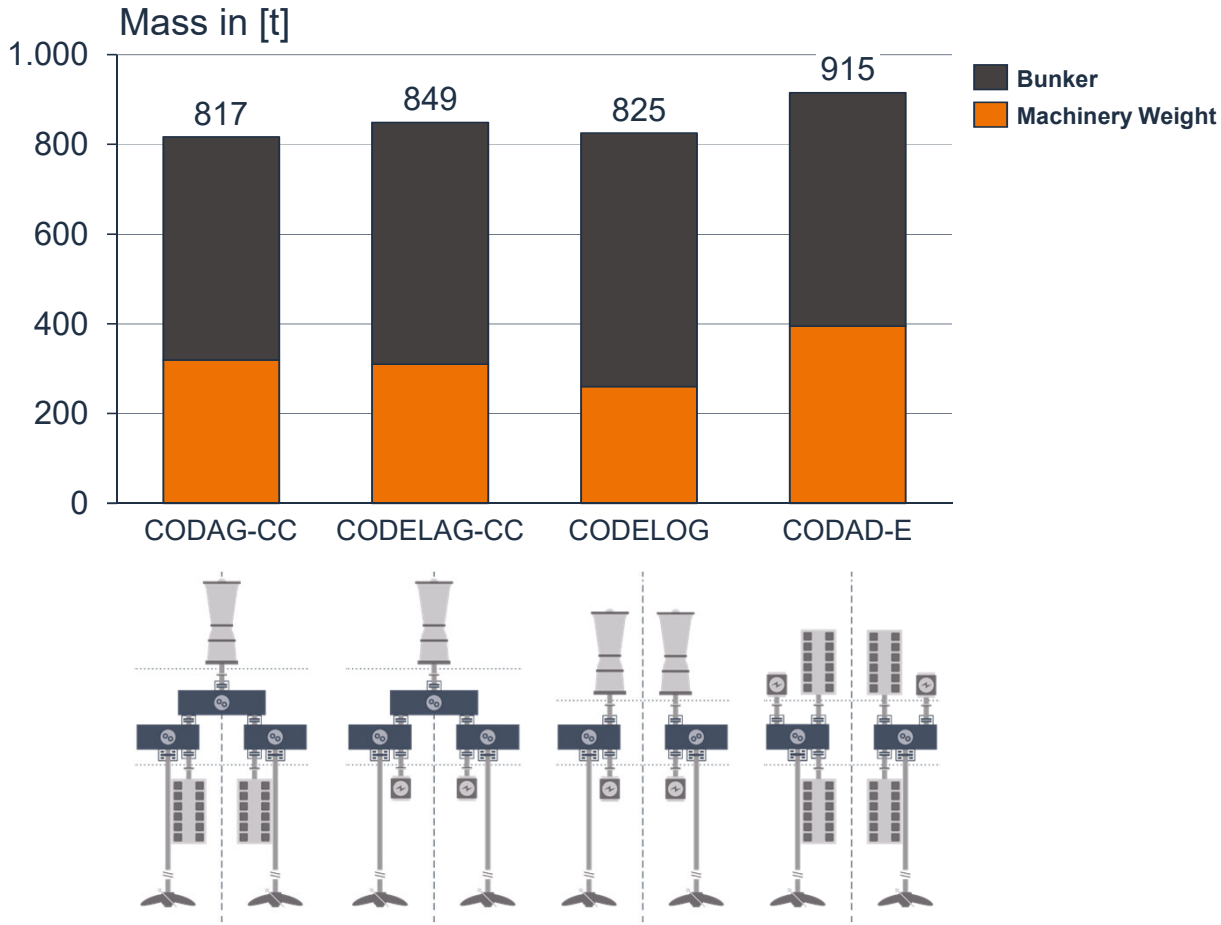
The fuel consumption assumed here is based on the known efficiencies of the drive machines, taking into account the load spectra. In the case of diesel-electric drives, the consumption of the generator sets was included in the analysis.

Payload instead of Equipment weight

Assuming a range of 5.000 NM the total weight on board comprising of machinery weight and bunker does not differ much.

However, this is only another aspects within the total selection process. The results of further comparisons and aspects will in the end make the difference, such as:

- Even distribution of prime mover operating times…
- Use of "hot machines" always in the optimum load range…
- Maintenance work during operation...



5 Application Examples

APPLICATION EXAMPLES

Thaon-di Revel-Class & Baden Württemberg Class

Thaon-di Revel-Class (PPA)

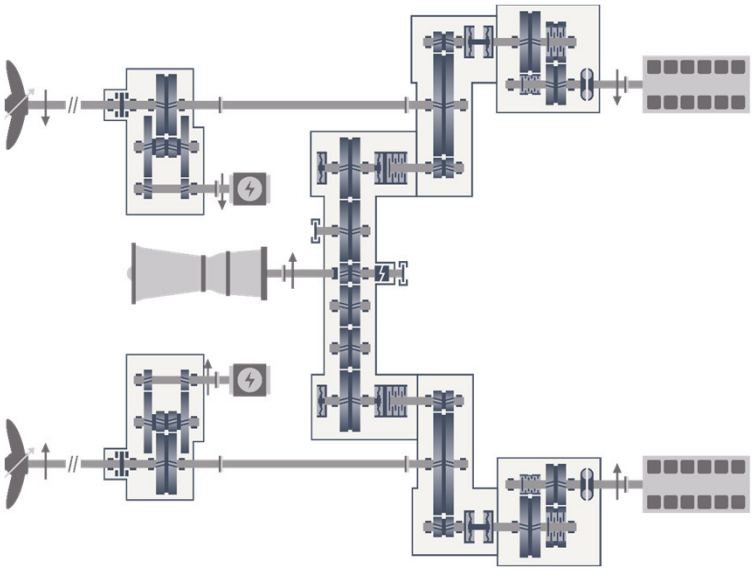
CODAG-CC-E

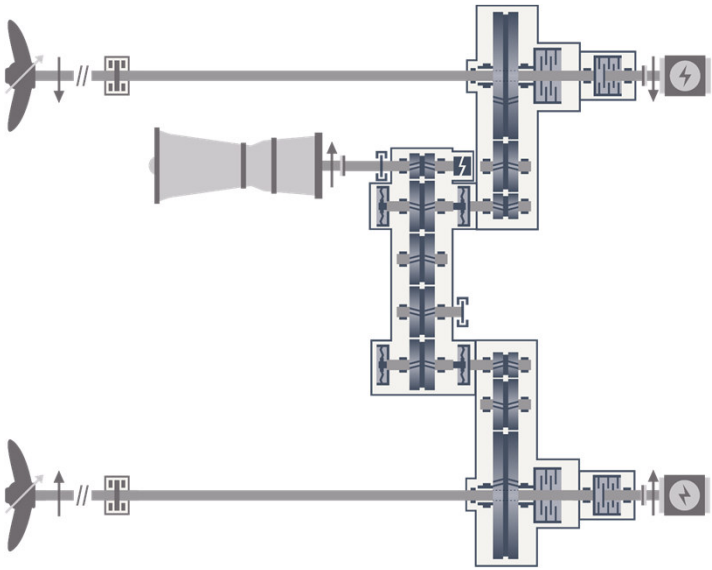
Propulsion plant with highest focus on efficiency in any operation point

F125

CODELAG-CC

Propulsion plant with highest focus on silent operation in electric mode





APPLICATION EXAMPLES

Pohjanmaa Class & Incheon Class

Pohjanmaa-Class

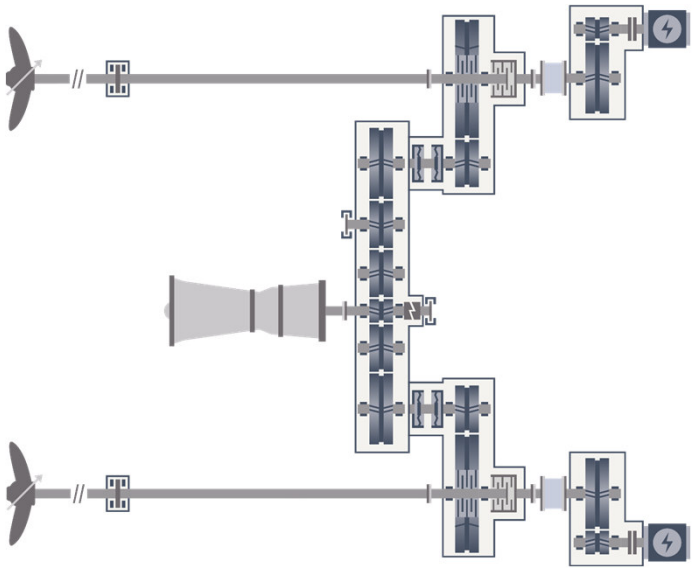
CODELAG-CC

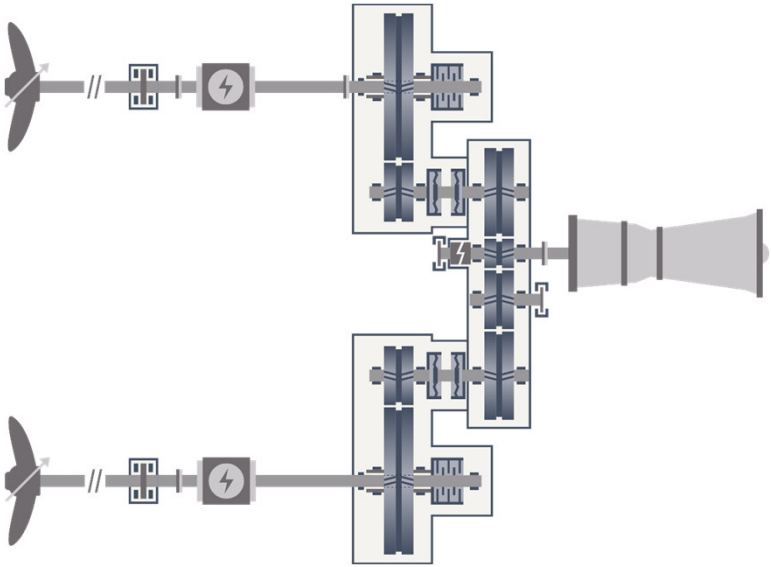
Application of RENK “Advanced Electric Drive” AED© to achieve super-silent ASW capabilities incl. optimized VFDs

Incheon Class Batch III

CODELOG-CC

RENK cross connect reduction gear with 40 MW total power installed





6 Conclusion

(Our) Conclusion

- **There is not „the one“ propulsion arrangement that outnumbers all others**
- **Combined systems and in particular hybrid systems are more sensible propulsion variants**
- **Among the combined systems, Cross Connect systems offer several advantages in the areas of redundancy, survivability, flexibility and deck space demand**

Please note

The results presented here are not at all based on a complete or specific project analysis, but are intended to describe generic properties. The results of more in-depth analyses may reinforce or mitigate the statements made.

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