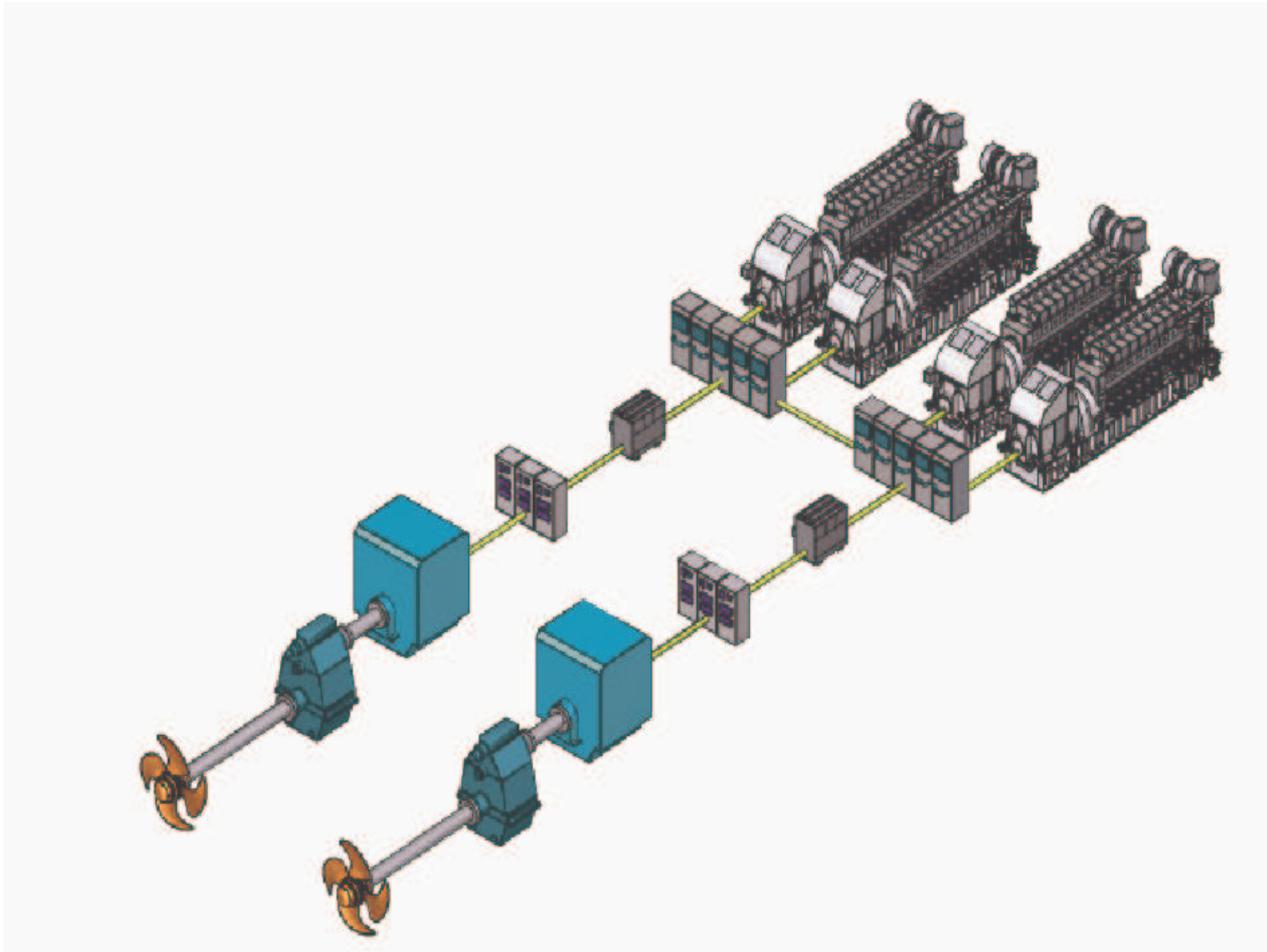# Diesel-electric Drives

Diesel-electric Propulsion Plants

A brief guideline how to engineer a diesel-electric propulsion system

Diesel-electric propulsion plants

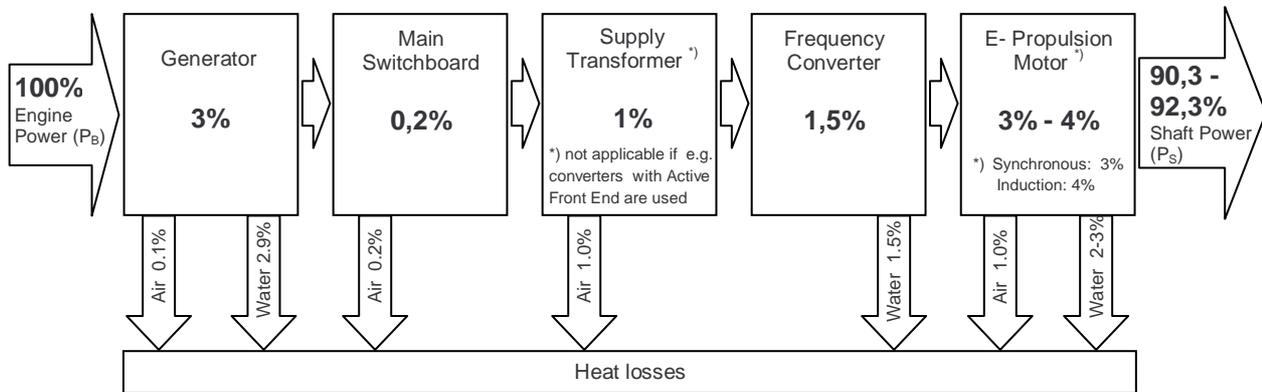## 1.1 Advantages of diesel-electric propulsion

Due to different and individual types, purposes and operational profiles of diesel-electric driven vessels the design of a diesel-electric propulsion plant differs a lot and has to be evaluated case by case. All the following is for information purpose only and without obligation.

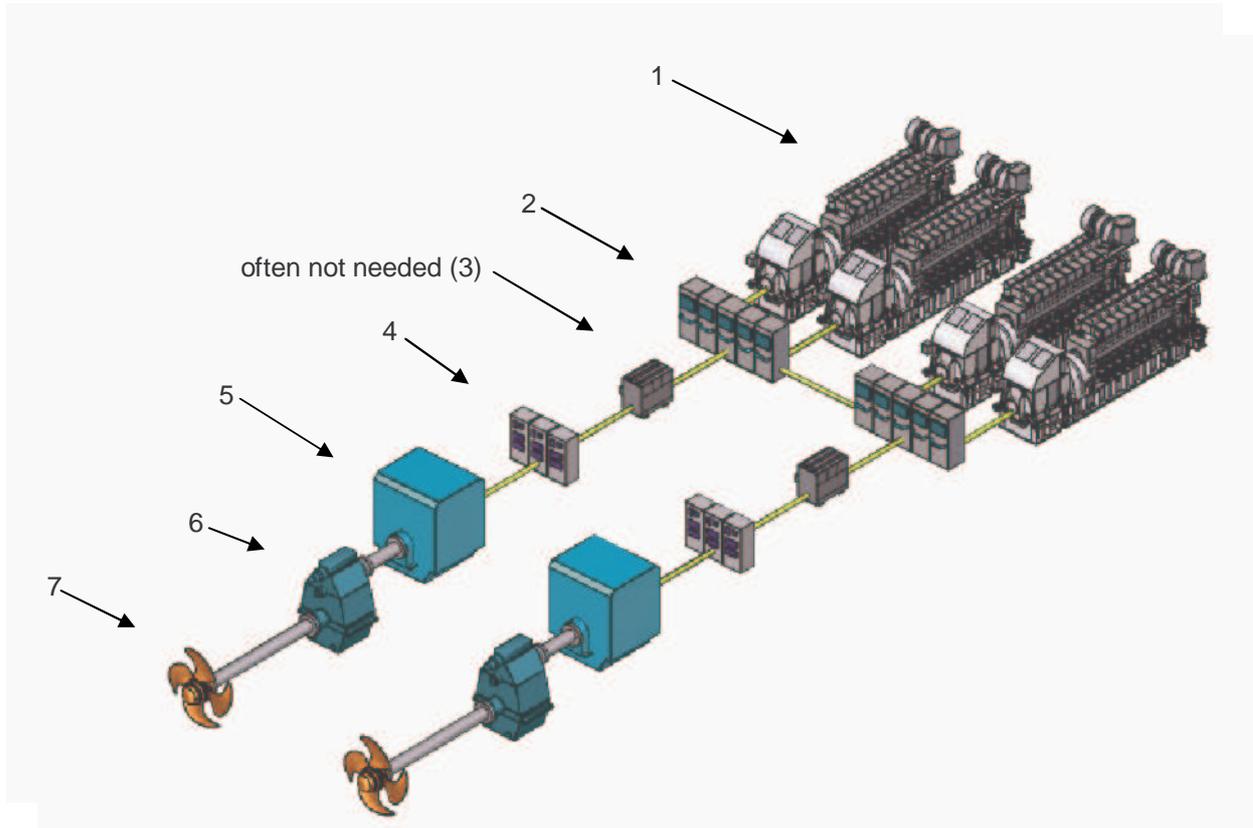In general the advantages of diesel-electric propulsion can be summarized as follows:

- Lower fuel consumption and emissions due to the possibility to optimize the loading of diesel engines / gensets. The gensets in operation can run on high loads with high engine efficiency. This applies especially to vessels which have a large variation in power demand, for example for an offshore supply vessel, which divides its time between transit and station-keeping (DP) operation.
- Better hydrodynamic efficiency of the propeller. Usually Diesel-electric propulsion plants operate a FP-propeller via a variable speed drive. As the propeller operates always on design pitch, in low speed sailing its efficiency is increased when running at lower revolution compared to a constant speed driven CP-propeller. This also contributes to a lower fuel consumption and less emission for a Diesel-electric propulsion plant.
- High reliability, due to multiple engine redundancy. Even if an engine / genset malfunctions, there will be sufficient power to operate the vessel safely. Reduced vulnerability to single point of failure providing the basis to fulfill high redundancy requirements.
- Reduced life cycle cost, resulting from lower operational and maintenance costs.
- Improved manoeuvrabilty and station-keeping ability, by deploying special propulsors such as azimuth thrusters or pods. Precise control of the electrical propulsion motors controlled by frequency converters enables accurate positioning accuracies.
- Increased payload, as diesel-electric propulsion plants take less space compared to a diesel-mechanical plant. Especially engine rooms can be designed shorter.
- More flexibility in location of diesel engine / gensets and propulsors. The propulsors are supplied with electric power through cables. They do not need to be adjacent to the diesel engines / gensets.
- Lower propulsion noise and reduced vibrations. For example a slow speed E-motor allows to avoid the gearbox and propulsors like pods keep most of the structure bore noise outside of the hull.
- Efficient performance and high motor torques, as the electrical system can provide maximum torque also at low speeds, which gives advantages for example in icy conditions.

1.2 Efficiencies in diesel-electric plants

A diesel-electric propulsion plant consists of standard electrical components. The following losses are typical:

100% Engine Power (P_B)	Generator 3%	Main Switchboard 0,2%	Supply Transformer *) 1% *) not applicable if e.g. converters with Active Front End are used	Frequency Converter 1,5%	E- Propulsion Motor *) 3% - 4% *) Synchronous: 3% Induction: 4%	90,3 - 92,3% Shaft Power (P_S)

Air 0.1% Water 2.9%   Air 0.2%   Air 1.0%   Water 1.5%   Air 1.0% Water 2-3%

Heat losses

1.3   Components of a diesel-electric propulsion plant

Example: Diesel-electric propulsion plant

Legend

1	Gensets: Diesel engines + alternators
2	Main switchboards
(3)	Supply transformers (optional): Dependent on the type of the converter. Not needed in case of the use of frequency converters with 6 pulses, an Active Front End or a Sinusoidal Drive
4	Frequency converters / Variable speed drives
5	Electric propulsion motors
6	Gearboxes (optional): Dependent on the speed of the E-propulsion motor
7	Propellers / propulsors

1.4   Diesel-electric plant design

Generic workflow how to design a diesel-electric propulsion plant:

Start

Ship basic data
- Type of vessel
- Propulsion type: Shaft line driven, thruster, pod, etc
- Propeller type: FPP, CPP
- Operational profile
- Additional class notation: Propulsion redundancy, ice class, etc

Speed – power estimation
- Ship design points
- Propulsion power: At sea, maneuvering, at port, etc
- Sea margin

Electrical load analysis
- Electrical power for consumers: At sea, maneuvering, at port, etc
- Efficiency of DE plant: Consider losses of main components
- Define total engine brake power: Power to be installed

Engine selection
- Number and type of engines / gensets. Number and split of cylinders
- Max. allowed loading of engines: % of MCR
- Maintenance strategy of engines: At sea operation, at port, etc

Switchboard layout
- Frequency choice: 50 / 60 Hz
- Voltage choice: Low voltage, medium voltage
- Number of switchboard sections
- Main alternator parameters: cos φ, xd"

Variable speed drive & propulsion motor layout
- Selection of converter type: PWM, LCI, AFE, Sinusoidal, etc
- Selection of pulse number: 6p, 12p, 24p
- Investigate supply transformer less configuration (i.e. Active Front End)
- Selection of E-propulsion motor: Motor type, over-torque capability
- THD mitigation method

Countercheck DE plant
- Check short circuit currents: Increase voltage, optimize xd", etc
- Check availability of reactive power: Change number/type of alternators, cos φ, …
- Check THD limits: Increase pulse number, add filters, etc

End

The requirements for a dedicated project will be considered in an application specific design, taking into account the technical and economical feasibility and later operation of the vessel. In order to provide you with appropriate system solution, please fill the form *Questionnaire* in the appendix.

1.5 Engine selection

The engines for a diesel-electric propulsion plant have do be selected accordingly to the power demand at all design points. For a concept evaluation the rating, the capability and the loading of engines is basically defined from the operation mode with the highest expected electric load and can be calculated like this:

Example: Offshore Construction Vessel

- Propulsion power demand (at E-motor shaft)   7200 kW (incl. sea margin)
- Max. electrical consumer load   1800 kW

No	Item	unit	
1.1	*Shaft power on propulsion motors*	P_S [kW]	7200
	Electrical transmission efficiency		0,91
1.2	*Engine brake power for propulsion*	P_{B1} [kW]	7912
2.1	*Electric power for ship (E-Load)*	[kW]	1800
	Alternator efficiency		0,96
2.2	*Engine brake power for electric consumers*	P_{B2} [kW]	1875
2.3	*Total engine brake power demand (= 1.2 + 2.2)*	[kW]	9787
3.1	*Diesel engine selection*	type	8L27/38
3.2	Rated power (MCR, running on MDO)	[kW]	2800
3.3	Number of engines		4
3.4	*Total engine brake power installed*	P_B [kW]	11200
4.1	*Loading of engines (= 2.3 / 3.4)*		87,4%
5.1	*Check: Max. allowed loading of engines*	% of MCR	90,0%

For the detailed selection of the type and number of engines the operational profile of the vessel, the maintenance strategy of the engines and the boundary conditions given by the general arrangement have to be considered. Also should be considered that at least one engine / genset should be in stand-by. For the optimal cylinder configuration of the engines between sea and port operation often the load conditions in port are decisive.

1.6 E-plant, switchboard and alternator design

The configuration and layout of an electrical propulsion plant, the main switchboard and the alternators follows some basic design principles. For a concept evaluation the following items should be considered:

- A main switchboard which is divided in symmetrical sections is reliable and redundancy requirements are easy to be met
- An even number of gensets / alternators ensures the symmetrical loading of the bus bar sections
- Electrical consumers should be arranged symmetrically on the bus bar sections
- The switchboard design is mainly determined by the level of the short circuit currents which have to be withstand and by the breaking capacity of the circuit breakers (CB)
- The voltage choice for the main switchboard depends on several factors. On board of a vessel it is usually handier to use low voltage. Due to short circuit restrictions the following table can be used for voltage choice as a rule of thumb:

Total installed alternator power	Voltage	Breaking capacity of CB
< 10 – 12 MWe (and: Single propulsion motor < 3,5 MW)	440 V	100 kA
< 13 – 15 MWe (and: Single propulsion motor < 4,5 MW)	690 V	100 kA
< 48 MWe	6600 V	30 kA
< 130 MWe	11000 V	50 kA

- The design of the alternators and the electric plant always has to be balanced between voltage choice, availability of reactive power, short circuit level and allowed total harmonic distortion (THD)
- On the one hand side a small xd" of an alternator increases the short circuit current I_{sc}", which also increases the forces the switchboard has to withstand (F ~ I_{sc}" ^ 2). This may lead to the need of a higher voltage. On the other side a small xd" gives a lower THD but a higher weight and a bigger size of the alternator. As a rule of thumb a xd" = 16% is a good figure for low voltage alternators and a xd" = 14% is good for medium voltage alternators.
- For a rough estimation of the short circuit currents in a switchboard the following formulas can be used:

	Short circuit level [kA] (rough)	Legend
Alternators	$n * P_r / (\sqrt{3} * U_r * xd" * \cos \varphi_{Grid})$	n: No. of alternators connected P_r: Rated power of alternator [kWe] U_r: Rated voltage [V] xd": Subtransient reactance [%] cos φ: Power factor of the network (typically = 0.9 in DE plants)
Motors	$n * 6 * P_r / (\sqrt{3} * U_r * xd" * \cos\varphi_{Motor})$	n : No. of motors (directly) connected P_r: Rated power of motor [kWe] U_r: Rated voltage [V] xd": Subtransient reactance [%] cos φ: Power factor of the motor

		(typically = 0.85 … 0.90 for an induction motor)
Converters	Frequency converters do not contribute to the I_{sc}"	

- The dimensioning of the cubicles in the main switchboard is usually done accordingly to the rated current for each incoming and outgoing panel. For a concept evaluation the following formulas can be used:

Type of switchboard cubicle	Rated current [kA]	Legend
Alternator incoming	$P_r / (\sqrt{3} * U_r * \cos \varphi_{Grid})$	P_r: Rated power of alternator [kWe] U_r: Rated voltage [V] $\cos \varphi$: Power factor of the net-work (typically = 0.9)
Transformer outgoing	$S_r / (\sqrt{3} * U_r)$	S_r: Apparent power of transformer [kVA] U_r: Rated voltage [V]
Motor outgoing (Induction motor controlled by a PWM-converter)	$P_r / (\sqrt{3} * U_r * \cos \varphi_{Converter} * \eta_{Motor} * \eta_{Converter})$	P_r: Rated power of motor [kWe] U_r: Rated voltage [V] $\cos \varphi$: Power factor converter (typically = 0.95) η_{Motor}: typically = 0.96 $\eta_{Converter}$: typically = 0.97
Motor outgoing (Induction motor started: DoL, Y/Δ, Soft-Starter)	$P_r / (\sqrt{3} * U_r * \cos\varphi_{Motor} * \eta_{Motor})$	P_r: Rated power of motor [kWe] U_r: Rated voltage [V] $\cos \varphi$: Power factor motor (typically = 0.85…0.90) η_{Motor}: typically = 0.96

- The choice of the type of the E-motor depends on the application. Usually induction motors are used up to a power of 7-9 MW (η_{Motor}: typically = 0.96). If it comes to applications above this power per E-motor often synchronous machines are used. Also in applications with slow speed E-motors (without a reduction gearbox), for ice going or pod-driven vessels often synchronous E- motors (η_{Motor}: typically = 0.97) are used.
- There is a fix relationship between the network frequency and the speed of the E-motor, if not a frequency converter is used. The formula is:

$$\text{speed}_{E\text{-motor}} \text{ [rpm]} = (2 \times 60 \times \text{frequency [Hz]}) / \text{number of poles}_{E\text{-motor}}$$

- In plants with frequency converters based on VSI-technology (PWM type) the converter itself can deliver reactive power to the E-motor. So often a power factor $\cos \varphi = 0.9$ is a good figure to design the alternator rating. Nevertheless there has to be sufficient reactive power for the ship consumers, so that a lack in reactive power does not lead to unnecessary starts of (standby) alternators.
- The harmonics can be improved by using supply transformers for the frequency converters with a 30° phase shift between the two secondary wi ndings, which cancel the dominant 5th and 7th harmonic currents. Also an increase in the pulse number leads to lower THD. Using a 12-pulse configuration with a PWM type of converter the resulting harmonic distortion will

normally be below the limits defined by the classification societies. When using a transformer less solution with a converter with an Active Front End (Sinusoidal input rectifier) or in a 6-pulse configuration usually THD-filters are necessary to mitigate the THD on the sub-distributions.

The final layout of the electrical plant and the components has always to be based on a detailed analysis and a calculation of the short circuit levels, the load flows and the THD levels as well as on an economical evaluation.

1.7   Over-torque capability

In diesel-electric propulsion plants, which are running with a fix pitch propeller, the dimensioning of the electric propulsion motor has to be done accurately, in order to have sufficient propulsion power available. For dimensioning the electric motor it has to be investigated what amount of over-torque, which directly defines the motor´s cost (amount of copper), weight and space demand, is required to operate the propeller with sufficient power also in situations, where additional power is needed (for example because of heavy weather or icy conditions).

Usually a constant power range of 5-10% is applied on the propulsion (Field weakening range), where constant E-motor power is available.
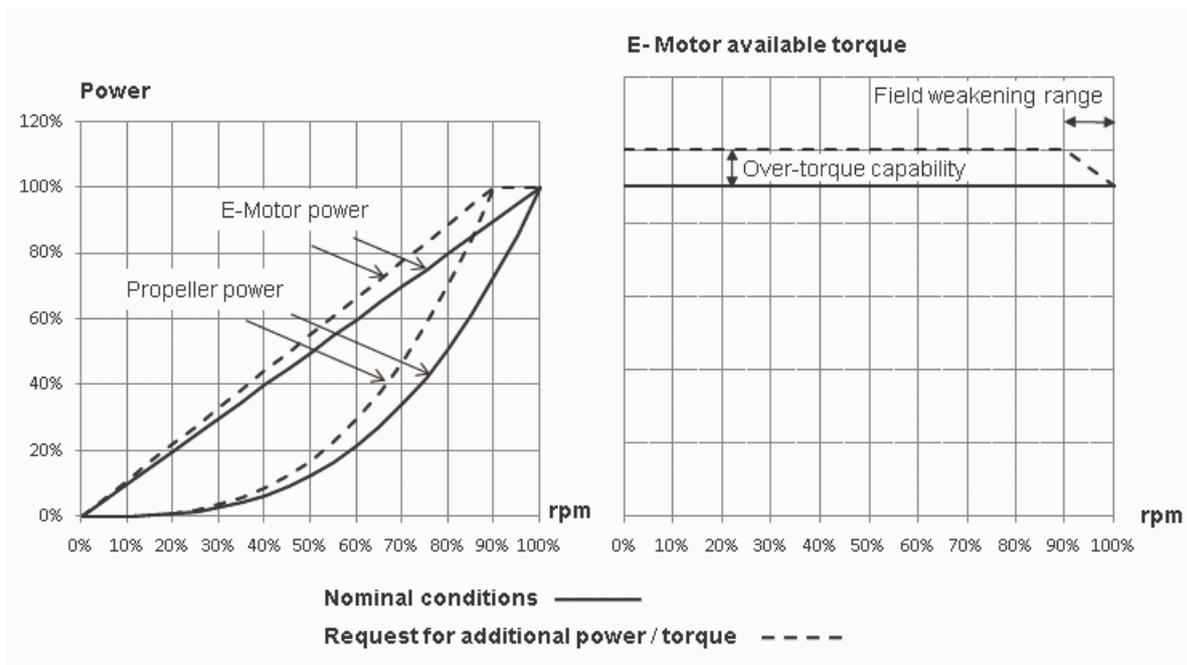
Example: Over-torque capability of a E-propulsion train for a FPP-driven vessel

1.8   Protection of the electric plant

In an electric propulsion plant protection devices and relays are used to protect human life from injury from faults in the electric system and to avoid / reduce damage of the electric equipment. The protection system and its parameters always depend on the plant configuration and the operational requirements. During the detailed engineering phase calculations like a short circuit and an earth fault calculation and a selectivity and protection device coordination study have to be made, in order to get the correct parameter settings and to decide, which event / fault should alarm only or trip the circuit breaker.

A typical protection scheme may include the following functions (Example):

Main switchboard:

-    Over– and under-voltage
-    Earth fault

Alternator:

-    Short circuit
-    Over-current
-    Stator earth fault
-    Reverse power
-    Phase unbalance, Negative phase sequence
-    Differential protection
-    Over- and under-frequency
-    Over- and under-voltage
-    Alternator windings and bearings over-temperature
-    Alternator cooling air/water temperature
-    Synchronizing check
-    Over- and under-excitation (Loss of excitation)

Bus tie feeder:

-    Short circuit
-    Earth fault
-    Synchronizing check
-    Differential protection (in ring networks)

Transformer feeder:

-    Short circuit
-    Over-current
-    Earth fault
-    Thermal overload/image
-    Under-voltage
-    Differential protection (for large transformers)

Motor feeder:

- Short circuit
- Over-current
- Earth fault
- Under-voltage
- Thermal overload/image
- Motor start: Stalling I2t, number of starts
- Motor windings and bearings over-temperature
- Motor cooling air/water temperature

1.9   Drive control

The drive control system is a computer controlled system for the converters / variable speed drives, providing network stability in case of sudden / dynamical load changes. It ensures safe operation of the converters with constant and stable power supply to the E-propulsion motors and avoids the loss of power under all operational conditions. Usually the propulsion is speed controlled. So the system keeps the reference speed constant as far as possible within the speed and torque limitations and dynamic capability.

The drive control system normally interfaces with the propulsion control system, the power management system, the dynamic position system and several other ship control and automation systems. The functionality of the drive control system depends on the plant configuration and the operational requirements.

The main tasks of the drive control system can be summarized as follows:

- Control of the converters / drives, including the speed reference calculation
- Control of drive / propeller speed according to the alternator capability, including anti-overload prevention
- Control of power and torque. It takes care of the limits
- Control of the converter cooling

For some applications (e.g. for ice going vessels, for rough sea conditions, etc, where load torque varies much and fast) often a power control mode is applied, which reduces the disturbances on the network and smoothens the load application on the diesel engines.

1.10 Power management

Power reservation

The main function of a power management system is to start and stop gensets / alternators according to the current network load and the online alternator capacity. The power management system takes care that the next alternator will be started, if the available power (= Installed power of all connected alternators – current load) becomes lower than a preset limit. This triggers a timer and if the available power stays bellow the limit for a certain time period the next genset / alternator in sequence is started. It also blocks heavy consumers to be started or sheds (unnecessary) consumers, if there is not enough power available, in order to avoid unstable situations.

Class rules require from gensets / alternators 45 seconds for starting, synchronizing and beginning of sharing load. So it is always a challenge for the power management system to anticipate the situation in advance and to start gensets / alternators before consumers draw the network and overload the engines. Overloading an engine will soon decrease the speed / frequency with the danger of motoring the engine, as the flow of power will be altered from network to alternator (Reverse power). The electric protection system must disconnect such alternator from the network. An overload situation is always a critical situation for the vessel and a blackout has to be avoided.

The detailed power management functionality always depends on the plant configuration, the operational requirements but also on general philosophy and preferred solution of the owner. The parameters when to stat or to stop a genset / alternator have always to be evaluated individually. The following figure shows that in principle:
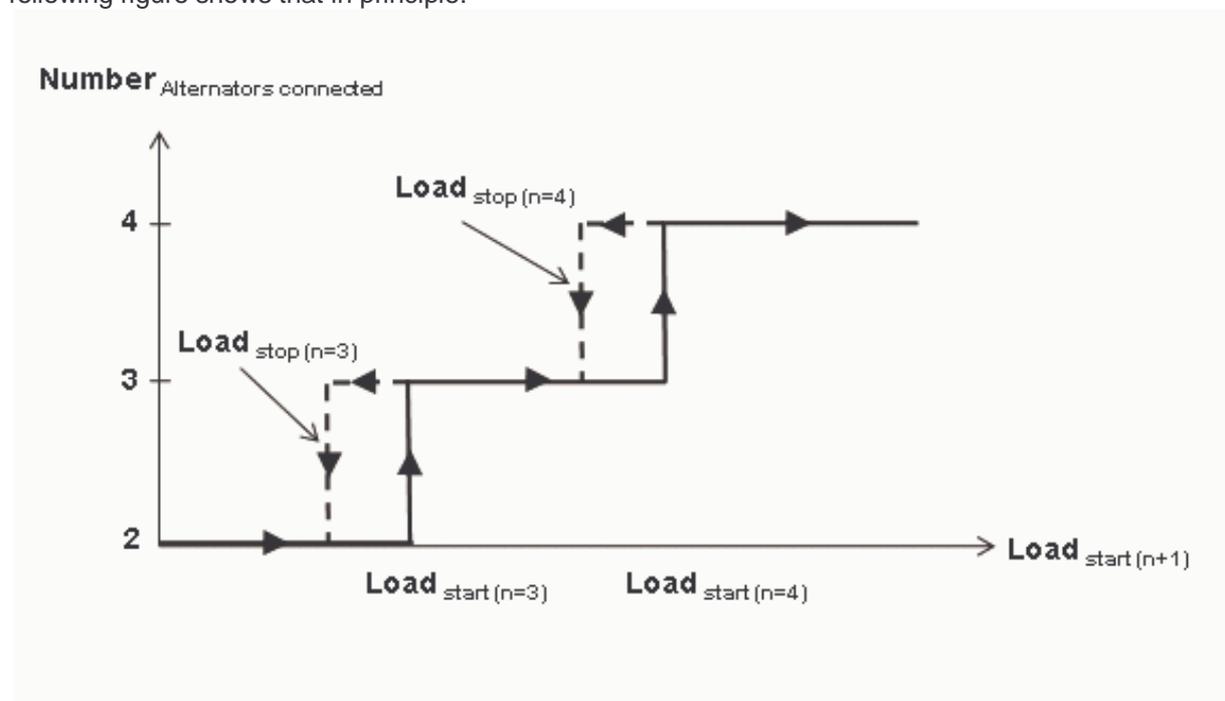
For example the load depending start / stop of gensets / alternators is shown in the next table. It can be seen that the available power depends on the status of the gensets / alternators. As an example a plant with 4 gensets / alternators is shown:

No. of alternators connected	Alternator load	Available power (Power reserve) by load pick-up by the running gensets	Typical time to accept load
2	85%	2 x 15% = 30%	0…10 sec
3	87%	3 x 13% = 39%	0…10 sec
4	90%	4 x 10% = 40%	0…10 sec

No. of alternators connected	Alternator load	Available power (Power reserve) by starting a standby[*)] genset	Typical time to accept load
2	70%	2 x 30% = 60%	< 1 min
3	75%	3 x 25% = 75%	< 1 min
4	80%	4 x 20% = 80%	< 1 min

*) preheated, prelubricated, etc. Starting conditions see belonging MAN Diesel & Turbo Engine Project Guide

The available power for this example could look like this:
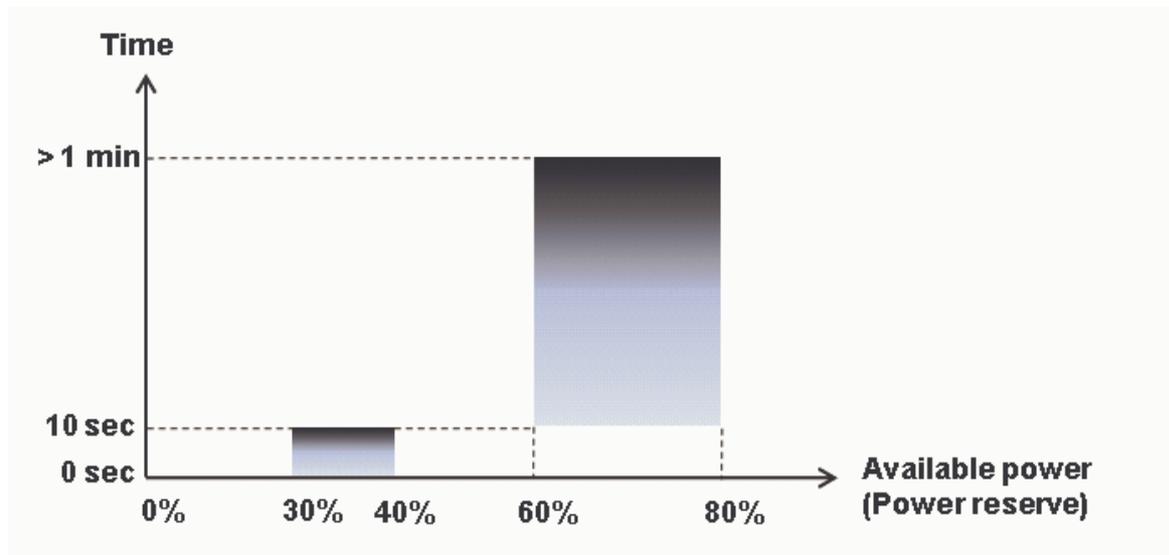
Power management system

Derived from the above mentioned main tasks of a power management system the following functions are typical:

- Automatic load dependent start / stop of gensets / alternators
- Manual starting / stopping of gensets / alternators
- Fault dependent start /stop of standby gensets / alternators in cases of under-frequency and/or under-voltage.
- Start of gensets / alternators in case of a blackout (Black-start capability)
- Determining and selection of the starting / stopping sequence of gensets / alternators
- Start and supervise the automatic synchronization of alternators and bus tie breakers
- Balanced and unbalanced load application and sharing between gensets / alternators. Often an emergency program for quickest possible load acceptance is necessary.
- Regulation of the network frequency (with static droop or constant frequency)
- Distribution of active load between alternators
- Distribution of reactive load between alternators
- Handling and blocking of heavy consumers
- Automatic load shedding
- Tripping of non-essential consumers
- Bus tie and breaker monitoring and control

All questions regarding the functionality of the power management system have to be clarified with MAN Diesel & Turbo at an early project stage.

1.11 Example configurations of diesel-electric propulsion plants

Offshore Support Vessels

The term "Offshore Service & Supply Vessel" includes a large class of vessel types, such as Platform Supply Vessels (PSV), Anchor Handling/Tug/Supply (AHTS), Offshore Construction Vessel (OCV), Diving Support Vessel (DSV), Multipurpose Vessel, etc.

Electric propulsion is the norm in ships which frequently require dynamic positioning and station keeping capability. Initially these vessels mainly used variable speed motor drives and fixed pitch propellers. Now they mostly deploy variable speed thrusters and they are increasingly being equipped with hybrid diesel-mechanical and diesel-electric propulsion.
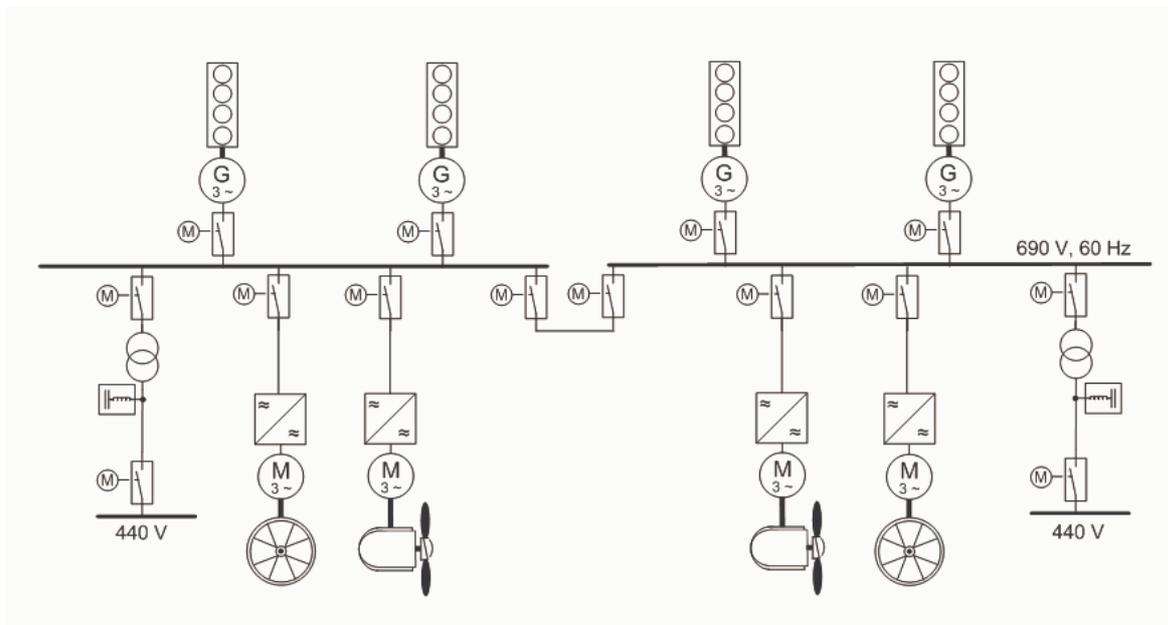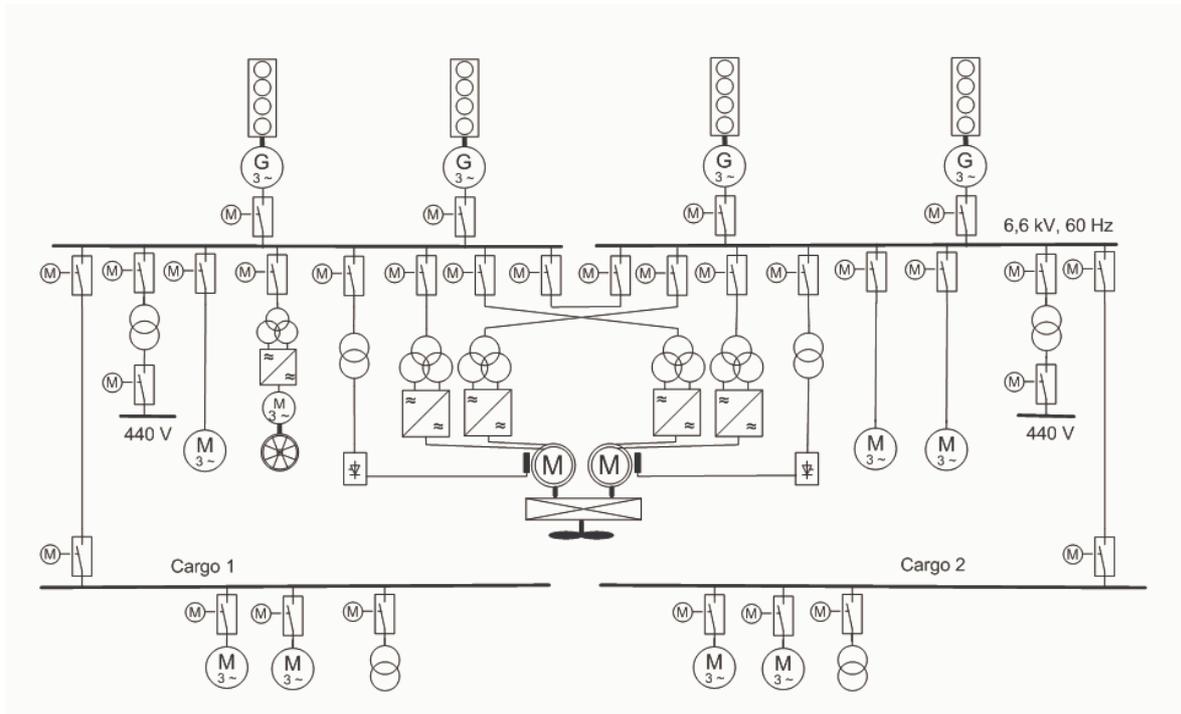

Example: DE-configuration of a PSV

In modern applications often frequency converters with a 6-pulse configuration or with an Active Front End are used, which give specific benefits in the space consumption of the electric plant, as it is possible to get rid of the heavy and bulky supply transformers.

Type of converter / drive	Supply transformer	Type of E-motor	Pros & cons
6-pulse Drive or Active Front End	-	Induction	+ Transformer less solution + Less space and weight - THD filter required

A propulsion configuration with two high speed E-motors (e.g. 600 RPM or 720 RPM) and a reduction gearbox (Twin-in-single-out) is a typical configuration, which is used at LNG carriers where the installed alternator power is in the range of about 40 MW. The electrical plant fulfils high redundancy requirements. Due to the high propulsion power which is required and higher efficiencies synchronous E-motors are used.

Example: DE-configuration (redundant) of a LNG carrier with geared transmission, single screw and FP propeller
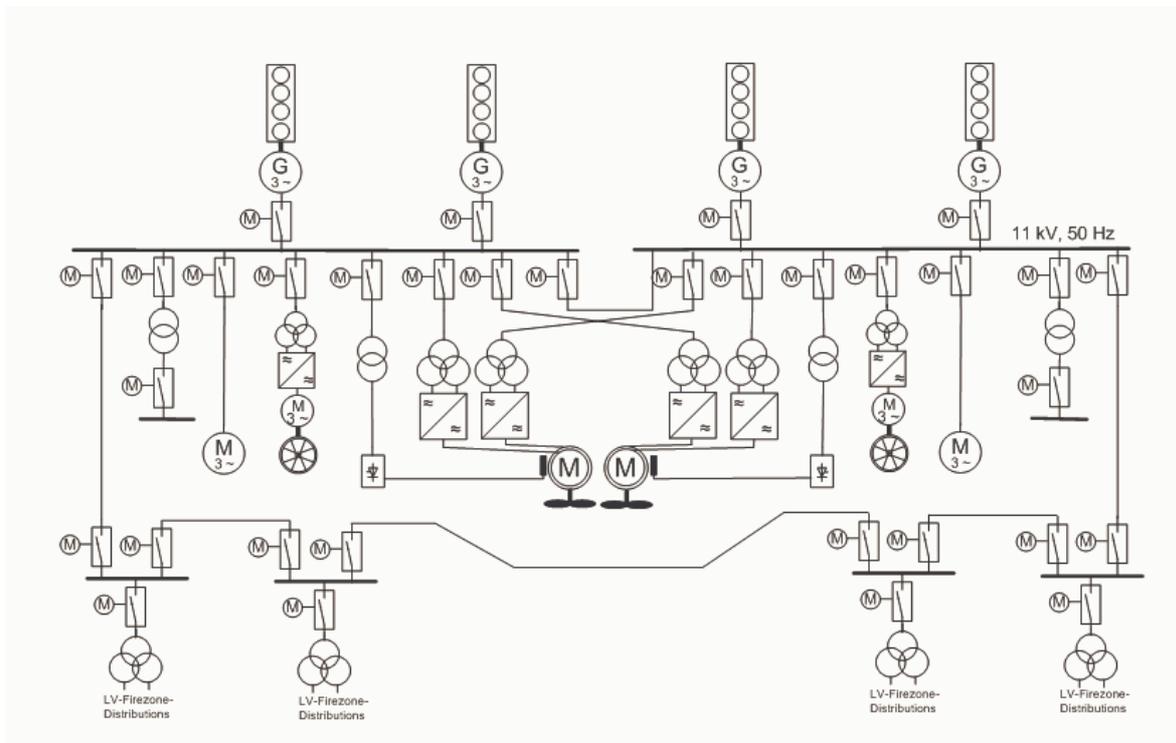
Type of converter / drive	Supply transformer	Type of E-motor	Pros & cons
VSI with PWM	24pulse	Synchronous	+ High propulsion power + High drive & motor efficiency + Low harmonics - Heavy E-plant configuration

For ice going carriers and tankers also podded propulsion is a robust solution, which has been applied in several vessels.

Cruise and ferries

Passenger vessels – cruise ships and ferries – are an important application field for diesel-electric propulsion. Safety and comfort are paramount. New regulations, as "Safe Return to Port", require a high reliable and redundant electric propulsion plant and also onboard comfort is a high priority, allowing only low levels of noise and vibration from the ship´s machinery.

A typical electric propulsion plant is shown in the example below.

Example: DE-configuration (redundant) of a cruise liner, twin screw, gear less

Type of converter / drive	Supply transformer	Type of E-motor	Pros & cons
VSI with PWM	24pulse	Synchronous (slow speed 150 RPM)	+ Highly redundant & reliable + High drive & motor efficiency + Low noise & vibration - Complex E-plant configuration

For cruise liners often also geared transmission is applied as well as pods.

For a RoPax ferry almost the same requirements are valid as for a cruise liner.

The figure below shows an electric propulsion plant with a "classical" configuration, consisting of high speed E-motors (900 RPM or 1200 RPM), geared transmission, frequency converters and supply transformers.
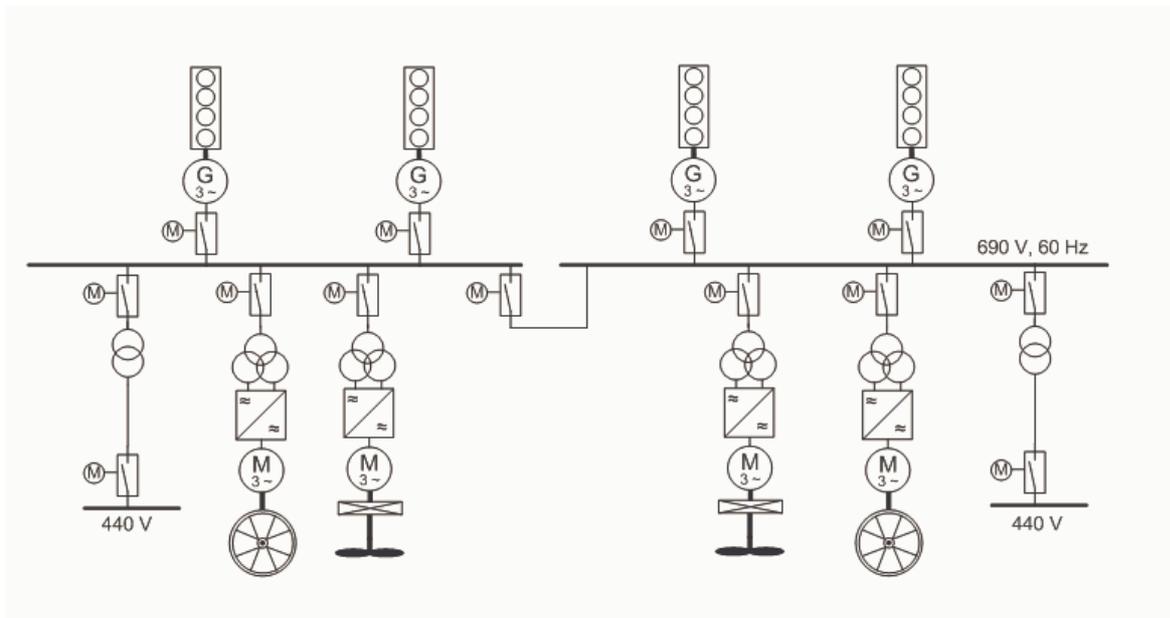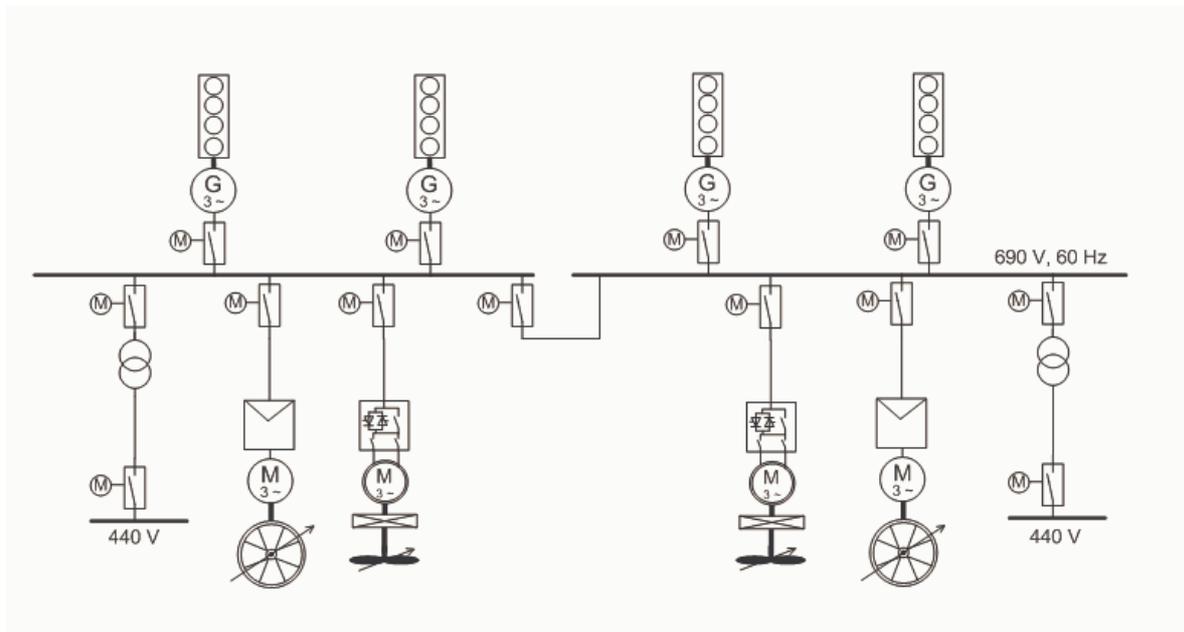

Example: DE-configuration (redundant) of a RoPax ferry, twin screw, geared transmission

Type of converter / drive	Supply transformer	Type of E-motor	Pros & cons
VSI-type (with PWM technology)	12 pulse, two secondary windings, 30° phase shift	Induction	+ Robust & reliable technology + No separate THD filters - More space & weight (compared to transformer less solution)

Low loss applications

As MAN Diesel & Turbo works together with different suppliers for diesel-electric propulsion plants an optimal matched solution can be designed for each application, using the most efficient components from the market. The following example shows a smart solution, patented by STADT AS (Norway).

In many cases a combination of an E-propulsion motor, running on two constants speeds (Medium, high) and a pitch controllable propeller (CPP) gives a high reliable and compact solution with very low electrical plant losses.

Example: DE-configuration (redundant) of a RoRo, twin screw, geared transmission

| Type of converter / drive	Supply transformer	Type of E-motor	Pros & cons
Sinusoidal drive (Patented by STADT AS)	-	Induction (Two speeds)	+ Highly reliable & compact + Very low losses + Transformer less solution + Low THD (No THD filters needed) - Only applicable with a CP propeller

Energy-saving electric propulsion systems

Recent developments in Diesel-electric propulsion plants show electrical systems, where the Diesel engine can operate on variable speed, which gives a huge potential in fuel saving.

The system uses Gensets operating in variable speed mode, where the rpm can be adjusted for minimum fuel oil consumption according to the system load. The electrical system is based on a common DC distribution, frequency controlled propulsion drives and normal AC sub-distributions. The DC distribution allows a decoupled operation of the Gensets and the consumers. It also allows the integration of energy storage sources like batteries.

The energy storage sources reduce the transient loads on the Diesel engines and give much better dynamic response times of the propulsion system. Fast load acceptance is taken away from the Diesel engines and peaks are shaved. Also emission free propulsion can be realized when running on batteries. In addition to that the energy storage sources will have a positive effect on engine maintenance.

The footprint of such a propulsion plant is up to 30% smaller compared with a classical Diesel-electric propulsion plant described before.
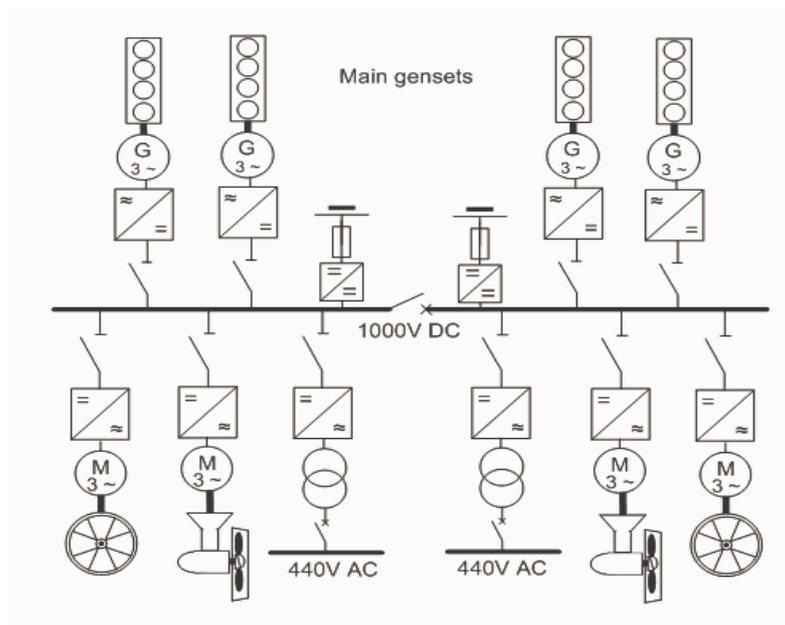
Example: DE-configuration (redundant) of a PSV, with an energy-saving electric propulsion system with variable speed Gensets and energy storage sources

Questionnaire: Diesel-electric propulsion plants

In order to provide you with appropriate project material and to carry out proposals promptly and accurately, we would kindly request you to fill in as many of the following details as possible and return it with a complete set of arrangement drawings to your sales representative.

General data

Name: _____

Address: _____

Phone: _____

E-mail: _____

Project: _____

Type of vessel: _____

Propulsion principle:

☐ Diesel-electric   ☐ CODLAD   ☐ CODLAG   ☐ _____

Main particulars:

Length, overall [m]: _____

Length, pp [m]: _____

Breadth, moulded [m]: _____

Depth, moulded [m]: _____

Draught, design [m]: _____

Draught, scantling [m]: _____

DWT, at sct draught [t]: _____

Gross tonnage [GRT]: _____

Crew + Passengers: _____ + _____

Classification society: _____ Class notation: _____

Additional class notations: _____ Redundancy: _____

Ice class: _____

Ambient conditions:

Max. machinery room temperature [°C]: _____

Max. sea water temperature [°C]: _____

Max. fresh water temperature [°C]: _____

Speed and margins

Speed:

Ship design speed [kn] : _____ (at maximum propulsion shaft power)

Sea margin [%] : _____

Max. allowed load of engines [%] : _____ % MCR

Propulsion system and power demand

Main Propulsion:

☐ Shaft propulsion: ☐ Single Screw: ☐ Single in – single out

☐ Tandem

☐ Twin in – single out

☐ Twin Screw: ☐ Two shaft lines

☐ 2x Twin in – single out

☐ Steerable rudder propellers (= Azimuth thrusters)

☐ Pods

☐ _____

Data for main propulsion:

☐ FPP: Number: _____

Max. shaft power on propulsion E-motor (per propeller; including sea margin) [kW]: _____

Propeller revolution [RPM]: _____

Input speed (= E-motor RPM): _____

Reduction gearbox: ☐ yes   ☐ no

☐ CPP: Number: _____

Max. shaft power on propulsion E-motor (per propeller; including sea margin) [kW]: _____

Propeller revolution [RPM]: _____

Input speed (= E-motor RPM): _____

Reduction gearbox: ☐ yes   ☐ no

☐ Azi. thruster: Number: _____

Max. shaft power on propulsion E-motor (per thruster; including sea margin) [kW]: _____

Input speed (= E-motor RPM): _____

Propeller type: ☐ FPP   ☐ CPP

☐ Pod: Number: _____

Max. shaft power on propulsion E-motor (per pod; including sea margin) [kW]: _____

E-motor speed [RPM]: _____

☐ _____   Number: _____

Max. shaft power on propulsion E-motor (each; including sea margin) [kW]: _____

Propeller revolution [RPM]: _____

Input speed (= E-motor RPM): _____

Reduction gearbox: ☐ yes   ☐ no

Data for manoeuvering propulsors:

☐ Bow thruster: Number: _____

Max. shaft power on propulsion E-motor (each; <u>including</u> sea margin) [kW]: _____

Input speed (= E-motor RPM): _____

Propeller type: ☐ FPP ☐ CPP

☐ Stern thruster: Number: _____

Max. shaft power on prolusion E-motor (each; <u>including</u> sea margin) [kW]: _____

Input speed (= E-motor RPM): _____

Propeller type: ☐ FPP ☐ CPP

☐ _____ Number: _____

Max. shaft power on propulsion E-motor (each; <u>including</u> sea margin) [kW]: _____

Input speed (= E-motor RPM): _____

Propeller revolution [RPM]: _____

Propeller type: ☐ FPP ☐ CPP

Electrical load balance

Max. total electrical power demand at sea:

for main propulsion [kW_{el}]: _____

for vessel´s consumers [kW_{el}]: _____

Max. total electrical power demand at manoeuvering:

for main propulsion [kW_{el}]: _____

for manoeuvering propulsors [kW_{el}]: _____

for vessel´s consumers [kW_{el}]: _____

Max. total electrical power demand at port:

     for vessel´s consumers [kW_{el}]: _____

The five biggest electrical consumers of the vessel
(apart from main propulsion and maneuvering propulsors):

     Name: _____ ; kW_{el}: _____

     Name: _____ ; kW_{el}: _____

     Name: _____ ; kW_{el}: _____

     Name: _____ ; kW_{el}: _____

     Name: _____ ; kW_{el}: _____

Please provide us with a complete E-Load-Balance of the vessel.

Electrical system and motors

Number of generators: _____

Power per generator [kW_{el}]: _____

Power factor: _____

Revolution of generators [RPM]: _____

Frequency [Hz]: _____

Voltage level of generator and MSB [V]: _____

Voltage levels of sub-switchboards [V]: _____

System grounding of MSB: ☐ 3-phase, 3-wire, isolated from hull

                             ☐ 3-phase, 3-wire, isolated via high-resistive resistor

                             ☐ _____

Main propulsion E-motors:

     Number of winding systems: ☐ 1   ☐ 2

     Speed control: ☐ variable speed via frequency converter

                                 ☐ _____

Manoeuvering E-motors (i.e. bow thrusters):

☐ variable speed via frequency converter

☐ constant speed (Start via Y/Δ-unit)

☐ constant speed (Start via Softstarter)

☐ _____

Dimensioning of the propulsion E-motor

For the design of the torque capability of the propulsion E-motor usually a constant power range of 5% …10% is applied (for a FPP-driven vessel). In case of additional load, like bollard pull or icy conditions, this range has to be extended.

Open water propeller power [%] ▬

Request for additional torque [%] ••••
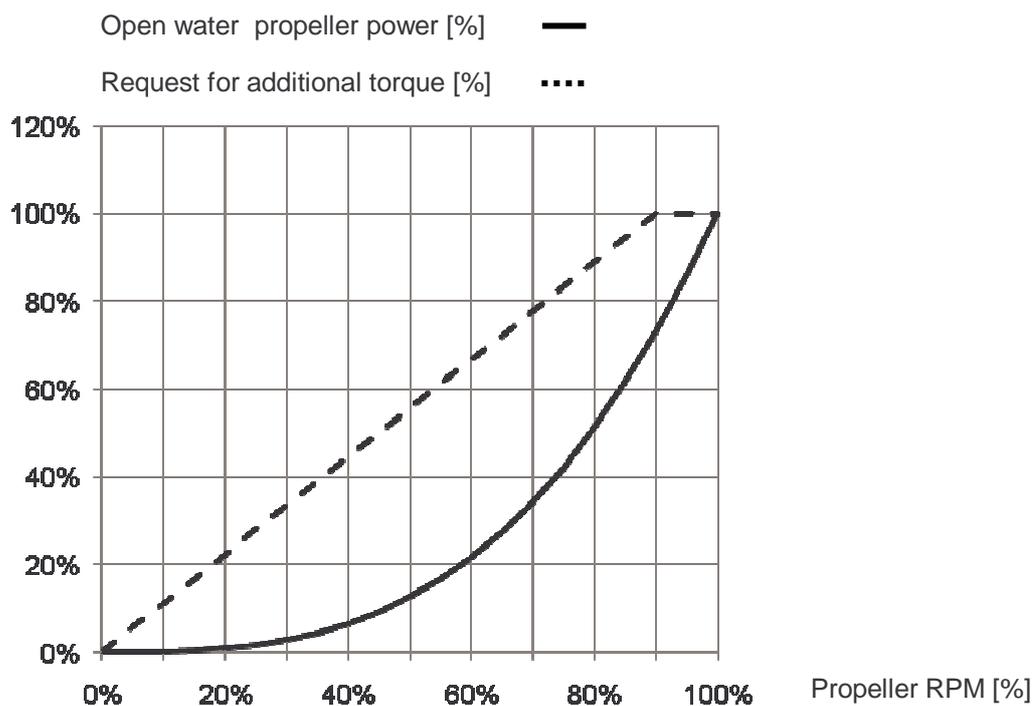
Torque capability: ☐ Constant power from _____ % to 100% of propeller RPM

☐ Max. over-torque capability of the E-motor: _____ %

Single line diagram

Please provide us with a complete single line diagram of the vessel, if available.