CONSIDERATIONS ON STRUCTURE AND DESIGN OF SHIPBORNE POWER SYSTEMS

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Abstract - Based on an extensive bibliographic synthesis, the present paper presents the state of the art and the characterisitics of the an electric power system onboard shipping vessels and their structure, the criteria to be taken into account during the design phase for the selection of voltage, current and frequency in the bars of the main distribution panel, for the purpose of supplying consumers on-board, and the calculation methods for power requirement analysis to choose the number of on-board synchronous generators and their power. The paper concludes with a case study, which analyzes the functional construction of an electric power system on board an oil tanker, with the presentation of the management system for the synchronous generators and consumers onboard the ship.

Key words: electric power system, ships, design, construction.

1. INTRODUCTION

The ship electric power system (**SEPS**) is defined as a unitary and complex system in which electricity is produced and distributed to the on-board consumers.

The SEPS comprises all sources of electricity, power converters, sections of the main distribution panel, electrical networks and electricity consumers acting together in the generation, transmission, distribution and consumption of electricity on board ships. [1, 2]

The quality of the electricity supplied to consumers is dependent on the way the generators work and the capacity of the power system to cope with the supply requirements of both stationary and transitory consumers.

Electrical installations on board ships are different from the ones on shore, primarily by the conditions in which they will have to operate, and by their specificity, their essential feature being their complexity. SEPS must be more robust and reliable, as, the ship, during operation, becomes an isolated system in which, in case of emergency or failure, it is difficult to intervene from the outside.

From the point of view of the operating principle and the elements of SEPS, they are similar to the ones on shore.

The structural and functioning characteristics of SEPS are also determined by the characteristics of the environment where they are designed to function.

The ambient temperature in which a ship belonging to an unlimited navigation class operates may vary from the temperatures encountered at the equator to those encountered at the polar circles, the equipment mounted on the outer decks facing both the ice on them and the excessive humidity due to ***salt water waves***.[1, 3]

The relative air ***humidity*** is between 70% and 95%, and in the ship compartments, in the separator room, boiler room, the humidity drops to 20%. Humidity in the other compartments in the engine room does not exceed 60%. When the air has a high humidity content on the walls of the ship's compartments where there are variations in temperature even as low as several degrees Celsius, ***condensation water*** is produced. [1, 3, 8]

The negative effect on electrical equipment is amplified by the ***salt*** that the condensation water takes from the air. [1, 3 ,8]

There is a high oil vapor content (3-20 mg/m^3) inside the compartments of the engine room, especially in those where the diesel engines are located. [1, 4]

The admission of hydrocarbon vapours into electrical machines and drive motors leads to lower insulation resistance of electrical windings and damage to electrical equipment and, in the most serious cases, leads to explosion and fire on board the ship.

The contact with seawater has a strong corrosive effect, and it also significantly damages the insulation resistance of electrical equipment and motors with adverse consequences in their operation.

Another characteristic of the electrical equipment on board ships is their operation in sloping position, due to ship oscillations. The majority of classification societies require that electrical equipment and motors operate safely at a 22.5° transverse slope and at 10° longitudinal gradient, provided the pitch and roll have a duration of 7 to 9 seconds. [1, 4]

Under these circumstances, the engine and electrical equipment housings are oversized to cope with the additional shear or torsion forces, and the equipment and engine should be located across the shaft of the ship.

Vibrations are very well propagated in the steel structure of the ship; therefore, the electrical equipment will have to be designed to withstand the stress. Current regulations impose the safe operation of marine engines and equipment, provided that this operation takes place at vibrations ranging from 3 to 50 Hz with an amplitude of 1 mm for frequencies between 5 and 8 Hz and an acceleration of 5 m / s^2 at frequencies between 8 and 30 Hz. [1]

In the case of shakes, the equipment and the electric motors must operate continuously at an acceleration of up to 30 m / s^2 and with frequencies between 40 and 80 strokes per minute. [1, 4]

The rules to be followed in the design and construction of SEPS have been established following the International Convention for the Safety of Life at Sea (SOLAS), which is the final act of the International Conference on the Protection of Life at Sea 1974.[1]

Over time, the Convention has been amended to improve the quality of on-board equipment affecting the quality of seagoing transport in order to increase the safety of goods carried by sea, to ensure a better quality of life on board ships and for a better protection of the marine environment.[1]

2. SEPS STRUCTURE

All equipment on board a seagoing ship is a tribute to the ship's electric power system.

2.1. General Characteristics of SEPS

The structural schemes of SEPS should provide [1, 2, 3]:

- Parallel operation of diesel generators (**DG**);
- The possibility of splitting the main switchboard (**MSwb**);
- The possibility of splitting power supply to bar sections, to the MSwb, if the latter is split;
- The protection of DG and MSwb in case of abnormal working conditions;
- The possibility of supplying the consumers from MSwb by means of “on shore connection”;
- The possibility of MSwb execution using standardized type-dimensional bars, on board
- Manual or automated connection of DG to the MSwb bars;
- Reduction to minimum of MSwb sizes and weight.

SEPS must ensure the operation of DG, using speed regulators, voltage regulators, to operate properly in the event of overvoltage, overloads, short circuits, drops in nominal voltage or nominal frequency deviation, and overheating in DG windings.

The safe operation of the SEPS is obtained by modifying the power supply scheme for consumers, automatic disconnection of the units not working within the designed technical parameters, automatic disconnection of the damaged units, automatic coupling of spare units and permanent monitoring of SEPS quality parameters.[1, 3]

2.2. SEPS Classifications

SEPS classification is done according to two main criteria: [1, 3, 4, 9]

- Functional relationship with the propulsion system :
  - Autonomous
  - Energy recovery from propulsion systems
  - Joint with propulsion systems
- Type of electric power distribution system of SEPS:
  - Radial
  - Network/main
  - Mixed

2.3. SEPS Structure

SEPS mainly consists of: [1, 3, 4, 9]:

- Synchronous generators;
- Synchronous generators drive motors;
- Synchronous Generators Synchronization Panels
- Speed regulators for generators drive motors;
- Generator Voltage regulators;
- Switchgear and protection devices;
- Measuring devices;
- Main distribution panel/board;
- Auxiliary electrical panels;
- Local switch on/off boards for consumers;
- Cable networks for the transport of electric power to consumers;
- Power convertors;
- Automation systems devices;
- Consumers represented by electrical engines for driving pumps and working devices/machinery.

Depending on the service for which the ship was designed, SEPS may have one or more power generating groups/units.

2.4. SEPS Typical Structure

SEPS structure is diverse depending on the equipment used, ship’s destination and characteristics and other factors.[1, 3, 4, 9]

For example, in figure 1 - 4, you can see typical structures on the basis of block diagram.[1, 3, 4, 9]

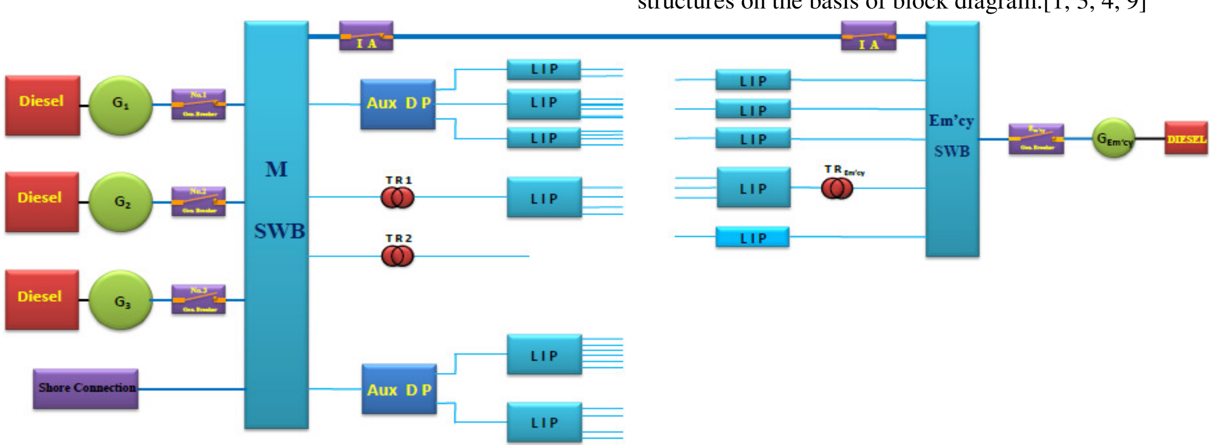

Fig. 1. Block diagram of SEPS with a single main switchboard and an emergency generator

where**:**

Diesel – Synchronous generators drive motors - diesel engine;

$G_{1\text{-}3}$ – Synchronous generator;

MSwb – Main switchboard;

Aux DP – Auxiliary distribution panel

LIP – Local individual panel

TR – Transformer

$G_{Em'cy}$ – Emergency synchronous generator

I A – Bus Bar Tie breaker

The advantage of SEPS with emergency generator is that those consumers considered ***essential*** will be supplied both in normal operation conditions and in case of troubleshooting, from emergency generators.

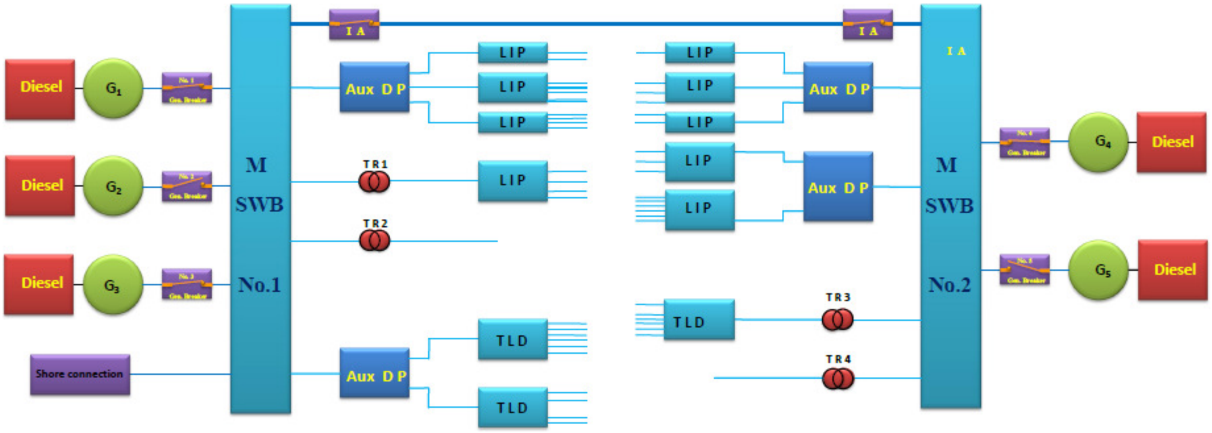

Fig. 2. Block diagram of SEPS with two main switchboard

It is obvious that such an SEPS, fig. 2, is more reliable in case of failure of one of the power units, consumers can be taken over by the unaffected power unit.

There are also ships whose steering gear is represented by a multi-phase steam turbine. After starting the ship and establishing her sailing regime, a shaft generator is coupled to the propeller spindle shaft, it can operate in the SEPS only during the ship's operating regime.

To system presented in fig. 3. in case of accidental stopping of the boilers or changing the ship's operating mode, the shaft generator is disconnected from the propeller shaft and removed from the MSwb bus bars.

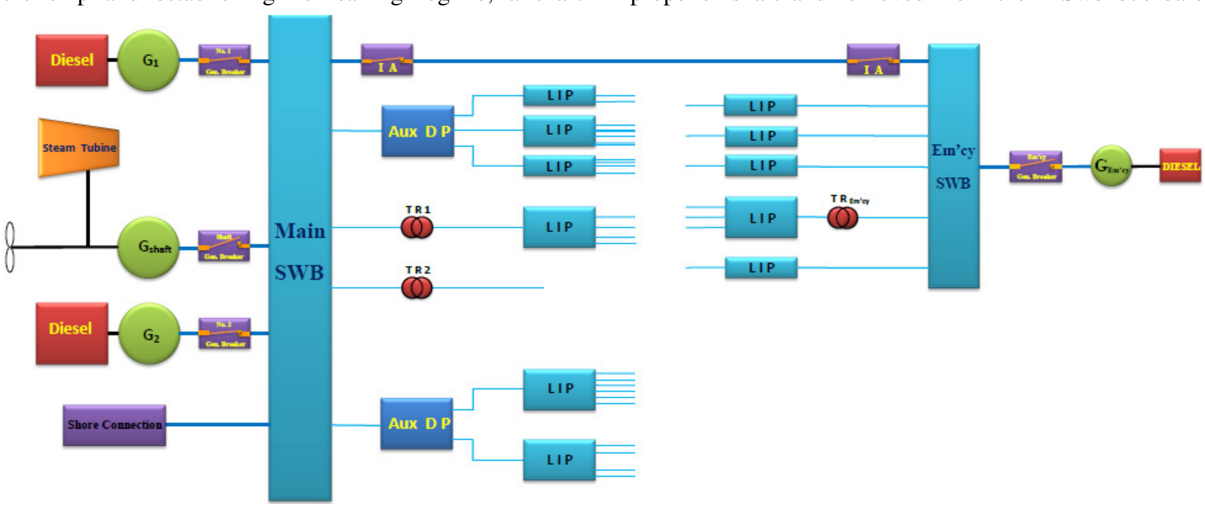

Fig. 3 Block diagram of SEPS with energy retrieval from the propeller plant by shaft generator and exhaust heat/recovery boiler

Generally, the propeller for such vessels is a variable-pitch one, in order to reduce any steam pressure variations from the ship's boiler.

The use of such SEPS configuration is rational for ships being underway for long periods of time where the vessel's speed has not significant variations.

SEPS can have the electrical power distribution system with lines, main lines, radials or a combination of the two systems, mixed, each system having its advantages and disadvantages.

The electrical power distribution system with main lines has as advantage the small number of consumers going out of MSwb, reduced cable consumption, reduced short-circuit currents and as disadvantages, higher voltage drops from the MSwb to consumers.

The electrical power distribution system with radial lines has as advantage the increased safety in supplying the consumers on board, lower voltage drops to consumers than in power distribution through main lines.

As disadvantages, cables consumption is higher, currents have more significant values in case of short-circuits. This system is preferred in case of supplying those consumers considered "essential".

The mixed system of electrical power distribution is the most widely used, where both the main lines system and the radial lines one is present.

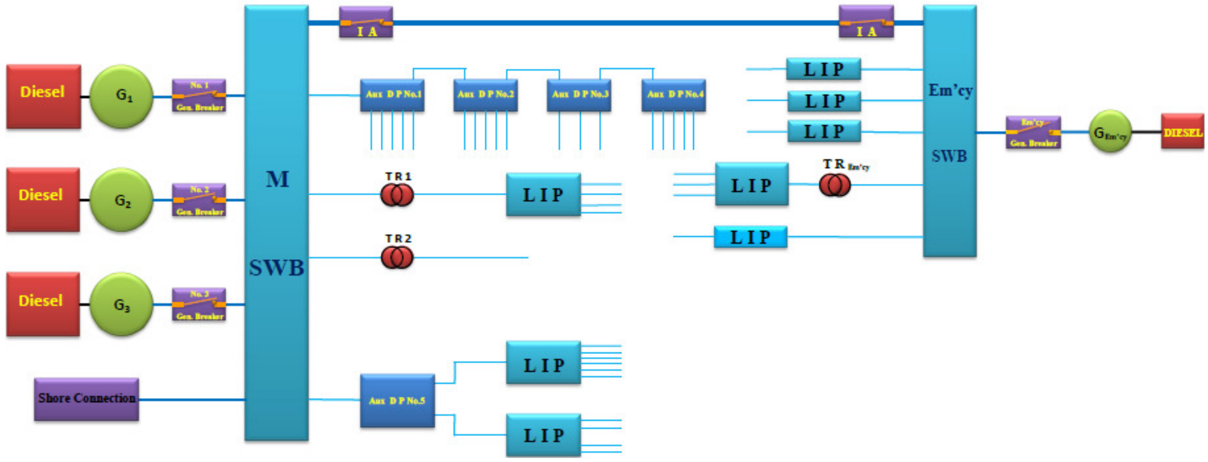

Fig. 4. Block diagram of SEPS where the electrical power distribution is done both by main lines and radial lines.

2.5. SEPS Main Regimes

SEPS has the following three main regimes[2, 5, 11, 12]:

- ➢ The normal stabilized regime characterized by non - variations of its parameters for which the technical and economical characteristics were designed and determined,
- ➢ The transitory regime characterized by modifications in the system parameters over time once with consumers reconfiguration depending on the operation regime of ships, of drilling or special utility equipment.
- ➢ The stabilized post-failure/breakdown regime, characteristic to situations occurring immediately after the failure of one or more elements in the ship's SEPS.

3. SPECIFICATIONS FOR DESIGNING SEPS

When designing and building SEPS, the regulations of classification societies, international conventions regulations and technical and economic conditions set in the design phase by the ship beneficiary must be considered. [3]

There are three phases: [3]

- ➢ ***Preliminary project*** when the block diagram, frequency, current and voltage are chosen, when the preliminary calculations related equipment weight, quality, reliability, price are made depending on the type of the ship and the navigation area, type of propulsion, number and size of consumers, additional requirements from the part of the beneficiary.
- ➢ ***The technical project*** based on the block diagram and when all diagrams are elaborated, all characteristics of electrical equipment are specified for correct dimensioning of all elements. This project must be approved by the Classification Society and the Flag State Administration.
- ➢ ***The execution project*** is the final execution documentation endorsed by the owner and the Classification Society. This documentation is monitored throughout the ship's construction, both by the owner and the Classification Society, and where the technical parameters and economic indicators in the technical project must be complied with.

The following electrical power distribution systems (**EPDS**) are used in the SEPS [3, 9]:

- ➢ *In alternate current up to 1.000 V inclusive*:
  - Three- phase, three conductors, insulated;
  - Three- phase, three conductors, with neutral point grounded;
  - Additional for alternate current up to 500V inclusive:
    - ▪ Three- phase with four conductors with neutral point connected to earth but without using ship's hull as return conductor;
    - ▪ Single- phase with two conductors, insulated;
    - ▪ Single- phase with two conductors, with the conductor grounded.
- ➢ *In direct current*:
  - With two conductors, insulated;
  - With one conductor, using ship's hull as return conductor only for voltages up to 50 V;
  - With two conductors, with an end grounded;
  - With three conductors with zero-voltage current grounded.

When choosing the voltage, the Classification Society recommendations, equipment weight and size, short- circuit currents, electro-shock danger, safety in to exploitation, exploitation and maintenance costs will be considered etc., recommendations being:[3, 9, 13]

- ➢ SEPS with power up to a few kilowatts, voltage of 24 V (small size ships and pleasure ships);
- ➢ SEPS with power of tens of kilowatts, 110/127 V;
- ➢ SEPS with power of hundreds of kilowatts 220 V and with higher powers 380/440 volts.
- ➢ For technical ships 690 V a. c. 3300 V a. c., 6600 V a. c. and 11000V a.c. is used.

When choosing frequency, the tendency is to use the 60 Hz frequency more and more and for the special ships, where the engines have high synchronic speeds (hydrofoils, hovercrafts, submarines, ships with electric propulsion) frequency of 400 Hz is preferred. [3]

When designing SEPS, we must consider the active power absorbed by:[3]

- Consumers for electrical circuits dimensioning;
- Groups of consumers and equipment, for distribution boards dimensioning;
- Supply units for various categories of equipment to dimension the transformers and the main distribution panel.

The technical characteristics of receivers are the following :[3]

- Active power P_n and apparent power S_n;
- Voltage U_n;
- Phases connections;
- Current I_n;
- Efficiency $ή_n$;
- Power factor cos φ_n;
- Ratio between the starting current I_p (connecting) and rated current I_n.

The main methods to determine the necessary installed power in the design phase are:[3, 7, 9, 25]

- Demand factors method, applicable to large groups of receivers;
- Binominal formula method, recommended for calculating the power values required in the distribution boards;
- Direct analysis method, when the operation and loading diagrams of all receivers are known;
- Methods based on specific consumption;
- Methods based on average power and load curves indicators;

Further, we are describing the two methods frequently used:

3.1. Calculation of power needed in SEPS using the statistic method

For the statistical approach method, in order to establish the power needed in the bars of the main distribution board the following statistical parameters are used [1, 3]:

M - The average power required

σ - Distribution and average square deviation (dispersion)

$$P_{ct}=\frac{1}{\sigma\sqrt{2\pi}}\, e^{-\frac{(P-M)^2}{\sigma\sqrt{2\pi}}} \qquad (1)$$

where:

P_{ct} - total power required

P - active power required (momentary)

Depending on the operation regime of ship, consumers are divided into constant load consumers, variable load consumers or intermittent load consumers.

Constant load consumers can operate continuously or intermittently.

The likelihood of continuous and constant load consumers working/running will be considered equal to the unit. The power of these consumers is added to the final calculation of power needed.

The likelihood of intermittent consumers working/running with constant load P_{ci} is calculated according to the formula:[1,3]

$$p=\frac{t_f}{T_b} \qquad (2)$$

where:

t_f - duration of consumer operation/working/running with load P_{ci} during operation cycle;

T_b - regime total duration.

If the operation duration of intermittent consumers is cyclic, then the working likelihood is calculated according to the formula:[xxxx]

$$p=\frac{t_f}{T_c} \qquad (3)$$

where :

t_f - total consumer working duration during the cycle

T_c - cycle total duration

If the consumer has a short duration regime, with constant power, but with breaks and uneven connection times, the likelihood of working is calculated according to the formula:

$$p=\frac{\sum_{k=1}^{1} T_{fk}}{T_b} \qquad (4)$$

where:

T_{fk} - working duration in k period

l - total number of connections

T_b - regime total duration

If the power need varies according to a complex graphic, this graphic is approximated in accordance with some of load levels and then the occurrence probability of each of them is estimated.

For consumers having an intermittent cyclic running the likelihood of working under load $P_i > P_{im}$ is:

$$P_{im}=\frac{1}{T_b\sum_{k=1}^{1} T_{ik}} \qquad (5)$$

where:

P_{im} - consumer power „i" for level „m"

T_{ik} - „k"period duration for consumer working under a load $P_i > P_{im}$

T_b - total duration of the considered regime

l - total number of working periods under load $P_i > P_{im}$

For continuous working consumers:

$$P_{im}=\frac{1}{T_c\sum_{k=1}^{1} T_{ik}} \qquad (6)$$

where:

P_{im} - power of consumer „i" for level „m"

T_{ik} - „k"period duration for consumer working under a load $P_i > P_{im}$

T_c - cyclic duration of the considered regime

Consumers "i" and „i+1" have constant load and consumers „i+2" have variable load divided on „m" levels.

For consumer „i" the statistic average is calculated according to the formula:

$$M(P_i)=\sum_{m=1}^{m_{max}} P_{im}\,[p_{im}-p_i(m+1)] \qquad (7)$$

where:

P_{im} - the likelihood that the receptor operates under a load $P_i > P_{im}$

$$P_i(m_{max}+1)=0 \qquad (8)$$

Dispersion of electric power of the consumer is calculated using the formula:

$$D(P_i)=\sum_{m=1}^{m_{max}}[P_{im}-M(P_i)]^2[p_{im}-p_i(m+1)] \qquad (9)$$

The sum of statistic averages of powers required by each consumer is calculated according to the formula:

$$M(P) = \sum_{j=1}^{n} M(P_i) \quad (10)$$

The dispersion of total power required, the sum of dispersion for each individual consumers is calculated according to the formula:

$$D(P) = \sum_{i=1}^{n} D(P_i) = \sigma^2 \quad (11)$$

According to this calculation model, the required power at the MS bars is never higher than M(P) + 2σ

3.2 The calculation of power needed in SEPS using the experimentally determined formula method

In the design phase empirical methods are often used, based on the experiments results and observations performed on various types of ships. The results obtained by this method will be adapted using other more precise calculation methods during the technical project phase [1, 3].

The formula accepted in this calculation method are different for each operation regime of the ship. During the underway regime it was ascertained that the loads determined by the consumers on board are relatively constant loads, the load diagrams are in general the same for each sailing day, the variations being considered non-significant. (they are random and less than 15%).

During this operation regime of the ship, a correlation between the power required by the SEPS consumers and the propelling plant power, irrespective of the type and size of the ship was observed.

The maximum and minimum power required by consumers at MSwb bars is calculated using the formulas:[1, 3, 4]

$$P_{c\,max} = 120 + 0.023\, P_{MP}$$
$$P_{c\,min} = 65 + 0.0175\, P_{MP} + P_{supl} \quad (12)$$
$$P_{supl} = P_{pe} + P_{vent} + P_{cond}$$

where:

P_{MP} - main engine power (C.P)
$P_{c\,max}$ - maximum power required by consumers
$P_{c\,min}$ - minimum power required by consumers
P_{supl} - additional power required at the tropics during summer
P_{pe} - total power of electric cookers in the galley for the entire year
P_{vent} - total power of fans in the accommodation, taken with a Cs between (0.4 – 0.8). If the air conditioning is on $P_{vent} = 0$
P_{cond} - the power of air conditioning considered with a coefficient of simultaneity Cs = 0.7.

During the stationary regime without loading and discharging operations, the load diagram is stable enough and its value is directly connected to the ship displacement.

For displacements ≤ 30,000 dwt, the calculation formula is as follows:

$$P_{c\,min} = 43 + 0.003D + P_{supl}$$
$$P_{c\,max} = 104 + 0.0066\, D \quad (13)$$

where:
D – is the ship displacement [dwt].

For the stationary regime with loading – unloading operations characterized by sudden variations of the power required.

$$P_{med} = \left(\frac{0.53+1.05}{n}\right)\sum_{i=1}^{n}(0{,}15 G_k V_k) \quad (14)$$

where:

n - number of mechanisms,
G_k - rated load for each windlass or crane in [t],
V_k - total load lifting speed [m/min].

For manoeuvring regimes (mooring, entry and leaving port, anchoring, etc.), the load diagram depends on the type and particularities of the manoeuvre performed and presents an unsteady feature.

$$P_{c\,max} = P_{mars} + 0.8(P_{anc} + P_{compr}) \quad (15)$$

where:

P_{mars} - power required underway;
P_{anc} - power required by the anchor windlass;
P_{compr} - power required by the starting air compressor.

4. CASE STUDY. SEPS TYPICAL CONFIGURATION FOR AN OIL TANKER WITH DISPLACEMENT OF 300,000 DWT

For oil tankers of 300,000 dwt, the SEPS consists of three identical synchronous DG and an emergency generator ensuring the minimum electrical power needed in those cases when temporarily, at least one of DG cannot be started or coupled to the MSwb bars.

The typical diagram of the SEPS shown in fig. 5.[17, 18, 19]

DG can be connected to any of the two sections of the MSwb and can operated both in parallel and by themselves depending on the energy balance characteristic to each situation in the ship.

DG selection to the MSwb bars, is done by means of automatic bar couplings, both remotely and locally controlled in automatic and manual mode.

Each of the DG driving motors will be provided with an autonomous revolution control system at the nominal operating value of the DG and each DG will be provided with its own electronic unit for voltage regulation.

The revolution and voltage control units have the purpose to maintain the values of frequency and voltage in DG terminals and implicitly in the SEPS bars complying with the quality parameters imposed for continuous operation of consumers on board.

Technical data obtained from DG for such ships are found in table 1.[26]

The data in „Italic" are calculated from [27] and [28]

The main consumers supplied by the ship SEPS for a oil tankers having a displacement of 300,000 DWT are found in table 2.

where:

P_n - nominal power of electromotor
η - efficiency
$\frac{P_{GEN}}{P_n}$ - rate between sincronous generator and electomotor

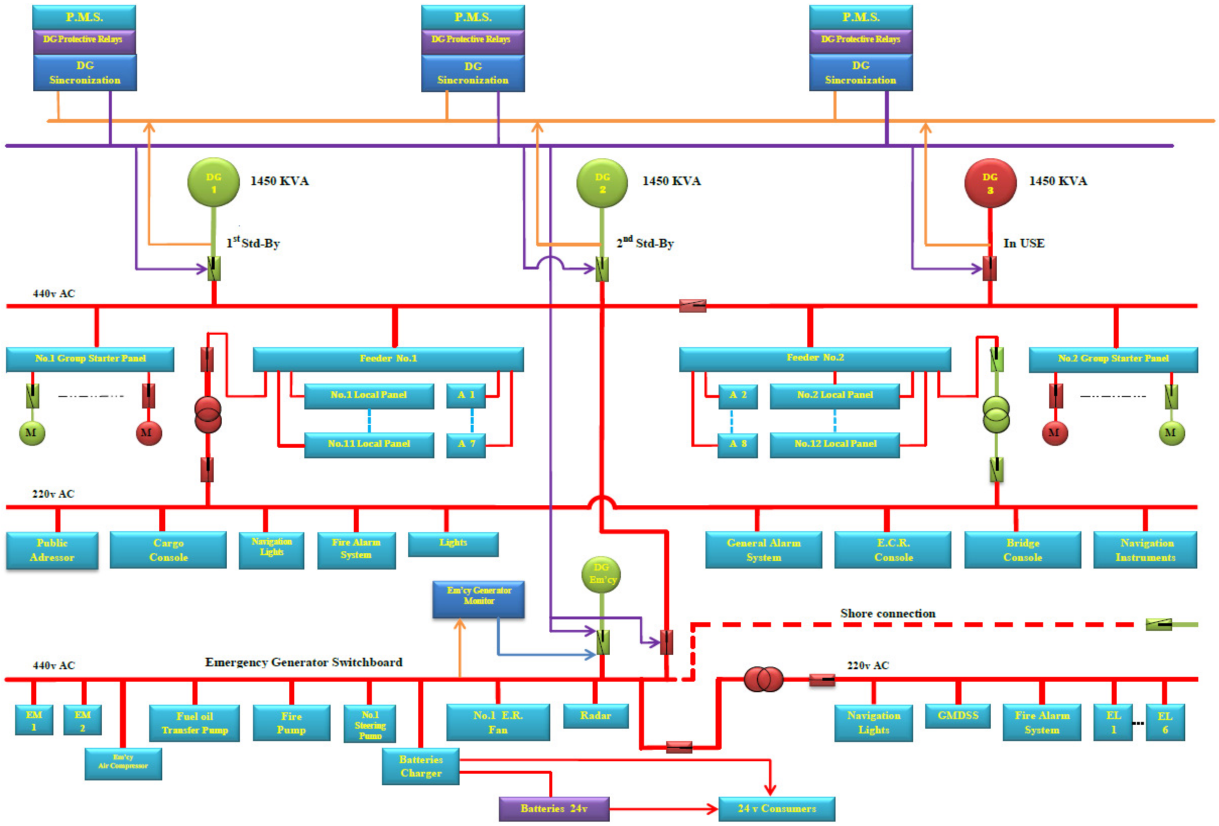

Fig. 5. **The typical diagram of the SEPS' s**

Table 1.

Specification	Quantity Description	Unit of measurement
Nominal apparent power	1437.5	KVA
Active nominal power	1150	KW
Windings connection	3Φ, 3W, Y, damping windings	-
Line voltage	450	$V_{L\text{-}L}$
Nominal current	1844	A
Nominal excitation current	14.2	A
Frequency	60	Hz
Power factor	0.8	-
Number of poles	10	-
Moment of inertia GD^2	644	$kg{\cdot}m^2$
Speed	720	Rpm
Unsaturated reactance X_d	240.9	%
Transient reactance X'_d	19.5	%
Sub transient reactance X''_d	10.9	%
Transient short-circuit time constant T'_d	0.082	s
Sub transient short-circuit time constant T''_d	0.0033	s
Transient time constant T'_{d0}	*7.5*	*s*
Subtransient time constant T''_{d0}	*0.07*	*s*
Stator resistance	0.004	Ω
Rotor resistance	0.908	Ω

Table 2.

Consumers	No	Details			$\frac{P_{GEN}}{P_n}$
		P_n Kw	η %	P_c Kw	%
Ballast Pump	2	400	95	380	33.04
Fire & General Service Pump	1	234	94	220	19.12
Cooling SW & VAC. Cond. Pp.	1	234	94	220	19.12
Main SW Pump	1	234	93	217.6	18.92
Steering Gear Pump	2	160	92	146.8	12.76
Aux. Boiler Feed Water Pump	2	142	92	130.5	11.35
General Service & Fire Pump	2	118	93	110	9.56
Main Engine Lub.Oil Pump	2	118	93	110	9.56
Aux. Boiler Blower	2	118	93	110	9.56
Inert Gas System Fan	3	107	93	99.05	8.61
Anchor Winch	2	103	93	95.98	8.34
Mooring Winch	6	103	93	95.98	8.34
Emergency Fire Pump	1	97	93	90.02	7.82
Low Temp. Fresh Water Pump	2	97	93	90.02	7.82
Scrubber Pump	1	82	92	74.98	6.52
Main Air Compressor	3	82	92	74.98	6.52
Air Condition Compressor	2	60	91	54.96	4.77
Main Engine Blower	2	60	91	54.96	4.77

$$P_c = \frac{P_n}{100}\,\eta \tag{16}$$

Interconnection with MSwb of the main SEPS equipment is realized by means of electric power management system (**PMS**), fig. 6 [16, 20, 21].

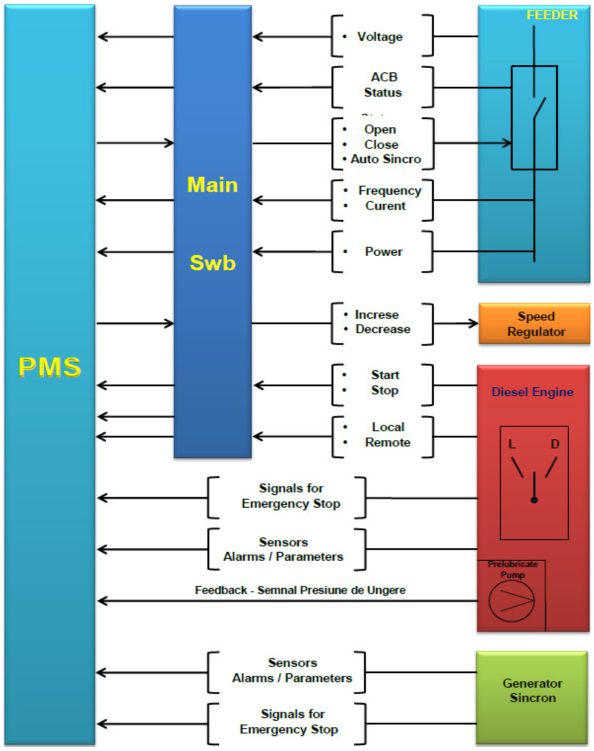

Fig. 6.

PMS allows load distribution between generators in the following ways: symmetrical, asymmetrical, manual.

In the case of symmetrical load distribution between generators, PMS will distribute the load equally between the generators situated in the MSwb bars.

For the case when the load is asymmetrically distributed, the first generator that will be coupled to the bars will be considered "Master" and the others with which it will operate in parallel will be considered "Slave".

In the beginning the two generators will distribute the load so that the "Slave" generator will not be loaded more than 30% of the rated power and the rest of the load will be transferred to the "Master" generator.

When the load on the "Master" generator reaches 80% of the rated power, the PMS will begin to transfer the load to the "Slave" generator, too.

When the "Master" and the "Slave" generators will be loaded 80% of their rated power, then the PMS will distribute the load equally to the two generators.

When the load in MSwb bars begins to decrease, the PMS will distribute load equally in the two generators until the load in the "Master" generator will be 80% of its rated power. From this moment the load on the "Master" generator will remain at 80% until the load on the "Slave" generator will reach 30% of the rated power.[16, 21]

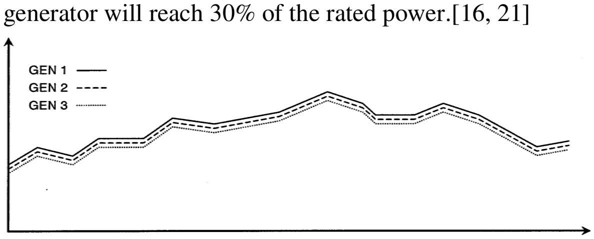

Fig. 7. Diagram of symmetrical load distribution between generators

If the load on the "Slave" generator reached 30% of the rated power then the PMS will order the unload the "Master" generator.[16, 21]

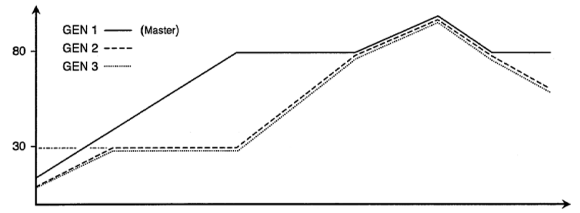

Fig. 8. Diagram of asymmetrical load distribution between generators

To adjust the voltage in the MSwb bars, the PMS will decrease or increase the speed of the generator drive machine in the bars. Deviations up to 0.1 Hz are allowed.

5. CONCLUSIONS

The development of oil transport industry imposes the identification of new solutions to ensure the supply with electrical power and the reliable operation of consumers on board ships for the safe carriage of goods.

The automatic systems monitoring the DG and consumers operation on board ships allow DG power management, entire SEPS monitoring, automatic warning in case the technological operation parameters exceed their limits, insulation or adjustment of certain elements of SEPS, maximising the safety of consumers supply under real structural conditions of the SEPS.

Both the DG and MSwb of the SEPS are fundamental sub-systems of the latter; their reliability playing an essential part on availability for the consumers.

It is necessary to use monitoring systems for DG operation and protection within designed parameters, following the quality indicators of electric power supplied in the MSwb bars.

When dimensioning the SEPS, both the electric power necessary for various situations and the ship working regimes (energy balance) as well as the potential situations the ship may encounter will be taken into account.

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