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A Study of the Electrical Balance between Plants according to the Arrangement of Generators

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ABSTRACT

The importance of power plants in the Merchant Marine sector is important. Not only are we unable to imagine a merchant vessel sailing without an electrical installation, under no circumstances would it be possible to operate even during their stay in port.

In this article, a study is made of the energy balance of different power plants in vessels, taking as a model two types of extreme plants in the Merchant Marine, such as, liquefied gases and vessels with state-of-the-art high speed, such as a combined trimaran transport similar to that of a fast ferry for both passenger and cargo.

The most characteristic data of their power plants have been taken by comparing them, on the one hand, liquefied gases, which are characterized on a whole as being vessels of great length, with slow speeds, trips with routes longer than 8 days on average and with very few routes throughout the week and on the other hand, fast-ferry vessels of more or less 100 meters in length, very high speed, very short travel paths and many crossings throughout the day.

The distribution of the power plant depends mainly on two factors of operation: the duration of the trip and the number of manoeuvres to be performed per unit time. Due to these factors, not only is the number and power of the electric generators, but also the cost of maintenance, security, etc.

1. Introduction

It is said that in the economic and industrial development of a country, the production and use of electricity play an important role. In order to establish an industry, amongst other things, it is necessary to take into account the networks of electricity distribution, in case that you are not near them, one way to improve energy efficiency, in terms of electricity, would be to install a self-sufficient generator.

At the centre of the merchant marine industry, the installation of generator sets is imperative, due to the fact that a vessel is isolated in the sea and is also in motion. The electrical power systems of ships are subject to load changes, some gradual and others sudden, some by connection of light loads and others as failures in the conduction lines, causing, that the stability of the transmission system of Electrical power is not constant. To all of these factors we have to add, that the performance is dependent on the weight. Of the two power plants chosen on the balance sheet, in the high speed vessels the ratio factor weight / power becomes paramount.

For all of the above the set of electrical generators, protection and manoeuvring devices must be as light as possible. The possibility of suppressing voltage transformers and placing a neutral cable, with the added danger, when a ground fault is produced.

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In general, the name given to a generating station or electrical plant, is the abbreviation of an electrical generating power station. A power plant called a thermal power station is when the electrical energy is produced by means of thermal motors (steam turbines, diesel engines, etc.), we then call it hydraulic power when the power machines are hydraulic turbines (not applicable to vessels). Finally, a nuclear power station is when it harnesses the energy existing in the atomic nuclei of certain elements. (Usually not used in the Merchant Marine).

We can consider the electrical plant of merchant vessels as power plants framed within the so-called thermal plants, which is, the energy produced by means of thermal motors (steam turbines, diesel engines, etc.).

Our study is carried out on a catamaran or trimaran vessels dedicated to the transport of passengers and general cargo. As a reference, we will use a trimaran of 127 meters in length, with an average of 10 sailings daily in and out of port, with an electrical plant of 2160 kW. And a liquefied gas carrier Castillo de Villalba with 285 meters in length with an average of one sailing per week and an electrical plant of 14237 kW.

2. Background

In the early days of navigation with mechanical propulsion, the use of electricity on board was limited to simple lighting installations, their evolution and development in just a century, has been so surprising that at present, it is difficult to find an element or service in which electricity does not play an important role. To the point of becoming the most fundamental energy in all the current merchant ships, whatever its type. The vessels' power plant reaches values that become so important that under the conditions and types of vessels the lowest consumption of electric power consumed ranges from 12 to 30% of the main propulsion power, consumption data referring to merchant vessels themselves, not self-propelled floating devices or vessels with additional electrical installations, such as factory vessels.

The use of electricity on board has become an important, extensive and varied factor, due to the continuous advances in lighting technology; (Lubrication, fuel, start-up, refrigeration) and non-essential systems (fire, inert gas, loading and unloading, sanitation, etc.) from which mechanical energy is obtained by an electric motor;

The aid electricity and electronics have been able to provide to navigation services through the use of radar, sonar, ARPA, GPS, etc..

The use of the electric motor as a supplier of mechanical energy provides great advantages over other types which justify the fact that electricity plays such an important role in naval installations, including vessels that their propulsion is through steam turbines for the drive of its auxiliary systems and services. These advantages can be listed in:

- Lack of condensation.
- Better performance and more independent of its use.
- Speed of entry into service.
- Maintenance comfort.
- Lower maintenance cost.
- Better cleaning.
- Simplicity of control.
- Automatism and remote control.

We can also consider the modifications and advances made in the control systems of modular panels which allow changes in similar emergency situations between essential and non-essential equipment with the consequent saving of materials and increase of safety, a sample thereof, can be observed in the images designed by Logstrup, mentioned as Omega Draw-out modular systems of switches.

Figure 1: LogstrupControl panels.

Source: Omega Draw-out panels.

The panels in modular form with all the connections incorporated, are done in such a way that they only need a power input and an exit towards the element of consumption, making it easier for the exchange between them, in case of some having breakage, it can also be emphasized that when done in a modular way, this allows a space saving arrangement in the assembly of the modules.

3. Material and Method

3.1. Material

A high-speed fast-ferry trimaran with a cargo-and-passage distribution is described with a route, with journeys which are approximately two hours long, with a large number of port entries and exits. The hull is made of aluminium, which the whole purpose is to save weight and to make the transport as fast as possible. On the other hand, it is defined as a transport vessel of liquefied gases whose purpose is to transport special loads and their trips have a duration of approximately a week where the speed takes second place and does not produce so many crossings and that the hull is made with conventional materials and has a prioritized loading zone.

Figure 2: Trimaran at the shipyard dam and liquefied gas transporting vessel.

Total Length	**126,7 m**	**284.379 m.**
In line flotation	**116,9 m**	**271. m.**
Width	**30,4 m**	**42.5 m.**
Strut	**8,2 m**	**25.4 m.**
Draft (maximum)	**4,0 m**	**12.3 m**
Dead Weight maximum	**1.076 tons**	**77204 tons**
Crew	**21**	**20**
Speed	**40 knots**	**21 knots**
Load Capacity.	**1.291passengers y 341 cars or 450 m. Cargo lines + 123 cars**	**138000 m³ a – 163 ºC**
Main Engines	**4 x MTV 20 V 8000 9.100 kW/1150 RPM c/u**	**Kawasaki Turbine- UA-400**

Source: Authors.

The Trimaran's electrical plant consists of:
Generator Features:

- Four MTU 12V2000 M40 12 V-cylinder engines at 1500 r.p.m.
- With an output power of 540 kW.

Alternators:

- Output power: 810 KVA 690V. Volts at 50 Hz each one. Revolutions: 1500 r.p.m.

Emergency generator:

- Detroit Motor - MTU 12 V-cylinder engine at 1500 r.p.m.

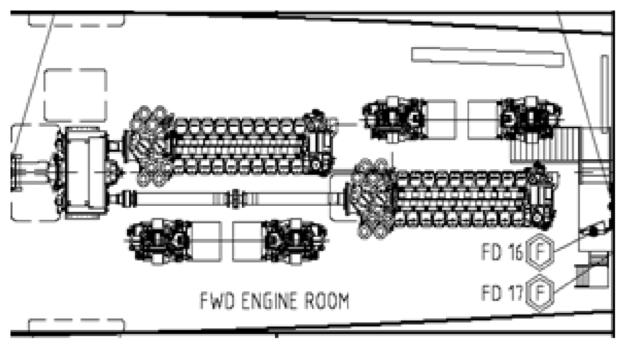
Alternator:

Figure 4: Bow engine room generators.

Source: Authors.

- Output power: 430 KWA 440 volts at 50 Hz. Revolutions 1500 r.p.m.

Figure 3: Electrical distribution plant.



Source: Model Ship Manuals.

In the previous chart the distribution of the four motor generators in the bow machine room can be observed, two to the port band and two to the starboard band with two main motors coupled a single central gearbox and distribution boxes of 690 V. on the sides and 400 V front, in which the programmable logic control panels of the auxiliary motors of the port strip and the position of the alternators on both sides of the central gear unit in the battery position are displayed. Mostly saving space.

In the Ilustration 4, we can see the two generators located in the bow engine room on the starboard bow along with their command and control panels in the background marked in the previous graph along with a main engine.

The electrical plant of the Methane Vessel consists of:
Generator Features:
Turbo Alternators:

- Output power: 3150 kW, Revolutions: 10036 r.p.m.

Turbine Alternator:

- Capacity / Features: 3300V, 3 phases, 60Hz, 3940kVA, Cos σ 0.8. Speed: 1800 r.p.m.

Figure 5: Turbo-alternator.

Source: Authors.

Diesel Generator:

- Power: 3330 kW

Diesel Alternator:

- Capacity / Features: 3300V, 3 phases, 60Hz, 3938 KVA, Cos σ 0.8. Speed: 720 r.p.m.

The vessel consists of two turbo alternators and a diesel generator for the production of electric power, to give the same power. It should be noted that the diesel generator was the only generator that could be connected to either of the two 3300 V panels, however, the turbo alternators could only be connected to the designated frame, which can then supply current to the other frame by interconnecting them.

During normal navigation only one of the turbo alternators provides electricity. In port and one day before the setting sail the two turbo alternators would be connected. Only the diesel is connected in situations that could compromise the stability of the plant. It also consists of an emergency diesel alternator only in case plant failure and is used to supply electricity to the emergency lighting and to be able to give power to the boiler operation at the beginning, when connecting the whole electrical plant, this only is coupled to the Supply boards at 440 V.

Emergency Diesel Generator:

- Power: 600 KW. Speed: 1800 r.p.m.

Emergency Alternator:

- Capacity / Features: 450V, 3 phases, 60 Hz, 713kVA; Cos σ 0.8, 4 Poles. Speed: 1800 r.p.m.

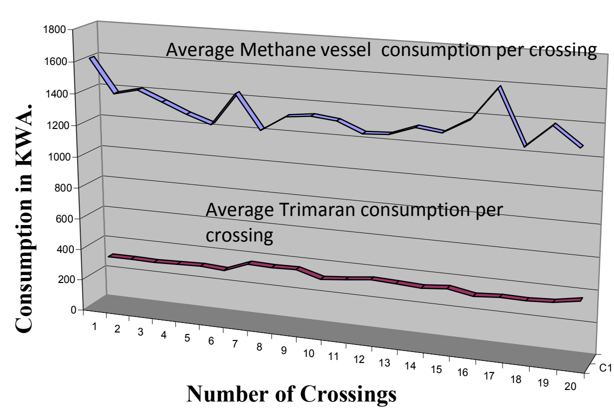
We can also observe that both plants work at different frequencies while the trimaran works at 50 Hz, the Methane vessel works at 60 Hz.

3.2. Method

We will compare the consumption of both plants finding the difference between the two main states, one that occurs during navigation and the other that we have during the maneuvers.

In the graph we can see, on the one hand, we have taken data from twenty trips calculating the average. It can be observed that the fluctuations produced do not go over 10% for the 400 KWA Methane vessel and the trimaran of about 30 KWA.

Figure 6: Average consumption in KWA/trip.



Source: Authors.

In a way that we can see that the total consumption generated from both plants during navigation does not even represent a total of 20As can be observed with only one of the generators, it would be enough to maintain the average consumption of the plant during navigation, since the maximum consumption occurs during the unloading of the product in port, or during the docking maneuver and port exit. During the unloading the methane vessel uses the two turbo-generators in such a way that it is independent of the electrical panels so we can continue the unloading, when any damage occurs in some of them by means of the coupling system of the diesel alternator this also ensures that the unloading can continue.

We will define a series of power plants distributed according to their consumption.

1. Generators coupled directly to a motor with a defined power.

2. Generators coupled by an external power take-off of them either being mechanical or the hydraulic type.

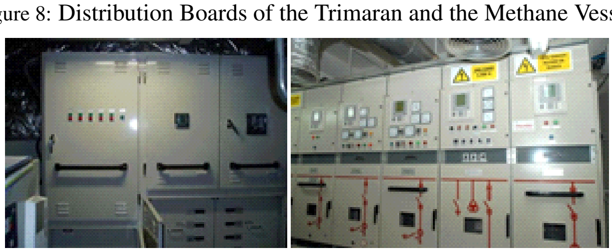
The former are based on a stable calculation of the plant's power consumption, but also depends on how many of them we should place according to the needs. For example, in a plant which has a calculation of 1000 KW. How many generators do we choose? One generator, two generators or three generators, that have a voltage to use 380V, 440V, 690V, 3300V. We will also use three phases and earth, or three phases, a neutral and earth.

Figure 7: Transformer. 690/440 V.

Source: Authors.

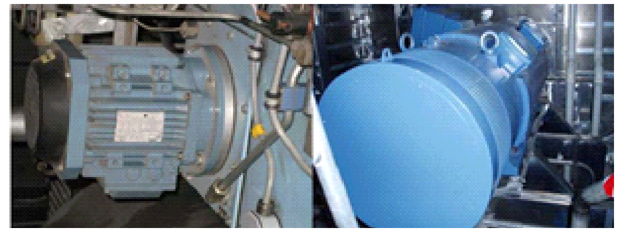
At higher voltage, it means saving weight in alternator size and saving wiring, stacking alternators in batteries and control systems that have programmable logic control. The question is. Do I need a higher voltage? Yes, we are dealing with a vessel where weight is a fundamental premise.

Figure 8: Distribution Boards of the Trimaran and the Methane Vessel.



Source: Authors.

Figure 9: 690V engine: hydraulic system and bow propeller motor coupling.

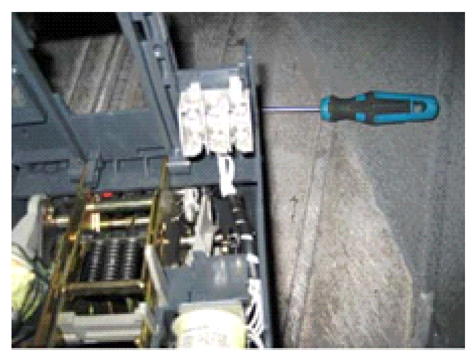


Source: Authors.

Having a neutral wire or not, that does mean that the reduction in voltage is done without having to use a transformer.

For example: If we use 440 we will have 240 v. By means of a phase and neutral, this leads us to have a system with a very important weight reduction, but, saving of transformers, we must be very careful with earthing, to which the effect is very important. In a conventional vessel we do not need to save on transformers (weight saving) we could have different current transformations if there is a need to use a neutral wire. In the Methane vessel we use a current to 3300 V. that soon gets transformed into 440 V and through a transformer also generates 220 V. to use board movements, etc.

Figure 10: Motorised circuit breaker. 440 V.



Source: Authors.

High voltages of electric motors, reduces their size. If there is a need to reduce the voltage we would have to place a series of transformers to reduce the voltage from 690 to 440 V or 3300 to 440 V to have the circuits combined with two different voltages, an emergency generator with less voltage is placed in such a way that it is only used for emergency lighting. Placing transformers to obtain a reduction in voltage or in turn introduce neutral to obtain 220 V. In the case of assigning neutral, with the trimaran, the wiring has to be of higher quality and cost because the vessel itself, is a closed circuit whereby any short circuit or grounding, means an immediate plant failure. Care must be taken to give the vessel energy to the external facilities on land, because of the danger that the ground lines are not sufficiently isolated or in good condition. This case, usually occurs on fast vessels when, for any reason, the electrical power to the vessel must be supplied by port facilities for the movement of ramps or ladders during loading or unloading.

In order to reduce the consumption during start-up (starting torque) of the different cicuits, it would be carried out by means of a frequency inverter, which, by decreasing the speed of rotation while the different circuits being put into place we reduce the consumption.

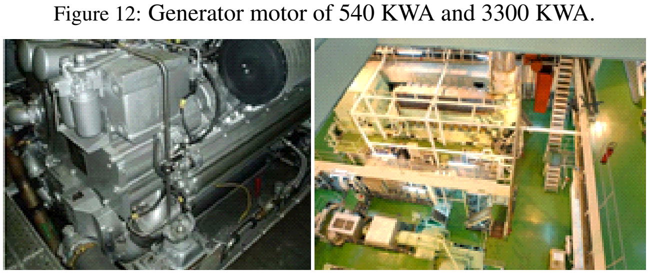
Figure 11: Motorised cicuit breaker with an electronic control of 690V.

Source: Authors.

The generation systems of the electrical plant can be seen from the several distribution points of view of:

1. That the generator is drawn by a motor proper and this depends on the number of r.p.m. Approximately 1500 to 1800, the cost would be the same as the supply that is needed plus the overall performance loss.

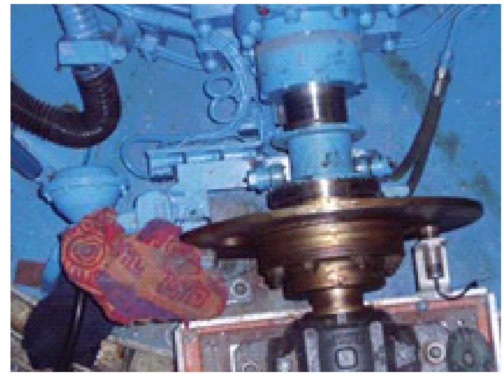
Figure 12: Generator motor of 540 KWA and 3300 KWA.



Source: Authors.

2. That the generator is drawn by a power intake as well as a gearbox which supplies output reduction to the tail axis, directly or indirectly, either by means of an axis or by means of hydraulic fluid coupled to a system of pumps.

Figure 13: External power take-off system.



Source: Authors.

The first system we always have a power supply while we have fuel so that the engine turns. The second depends, in addition to the rotation of the main engine, being as the force output depends on the rotation of the engine too.

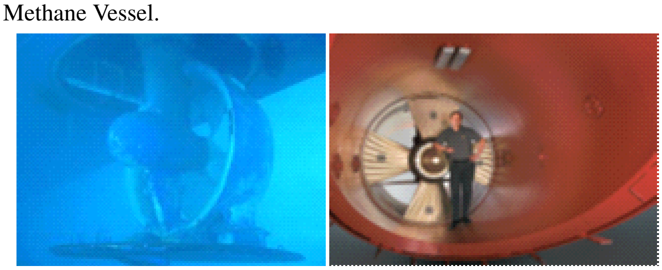
For example: A reducer that is in relation does 3 turns of input for 1 of output. The power intake that is connected to the generator depends on the rotation of the engine, therefore, it can not be used when we are in motion or when we have constant fluctuations of rotation in the main engine. When the power intake moves by a hydraulic pump and the hydraulic fluid, to have space, we have to move it by means of hoses or pipes so that it is connected to another hydraulic pump that acts on the generator, the increased fluctuations or decrease of rotation can be absorbed by means of controlling the flow, but also does not serve while doing port docking and undocking maneuvers where the flow fluctuations in this case are very high.

We will consider the different maneuvers of the two vessels with respect to the consumption of their propellers located in the bow, which are used in maneuvering, but the trimaran can also use them as a push in navigation in case of a governing emergency which provides azimuthals:

- Two azimuthal bow propellers, each of which is 500 KWA. (Trimaran.)

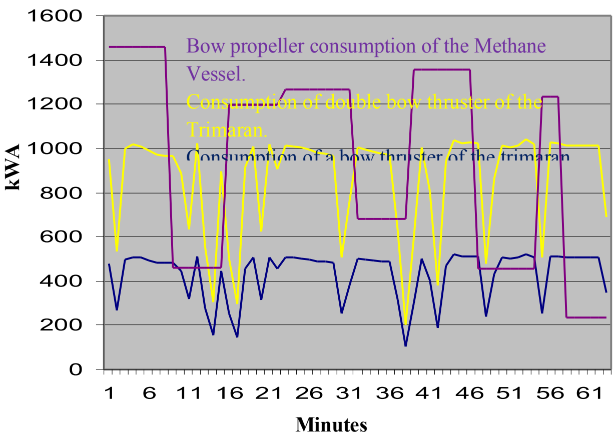
- An 1830 KWA variable pitch bow thruster. (Methane vessel.)

Figure 14: Azimuth propeller of the trimaran and lateral propeller of the Methane Vessel.



Source: Authors and `www.eximtec.cl`.

Figure 15: Consumption of bow propellers during maneuvers.



Source: Authors.

In the chart above, larger consumers, such as bow thrusters, on one side, the bow thruster of the Methane Vessel, where those maneuvers lasts for about an hour, while the trimaran usually lasts in the order of 10 minutes. In the chart we consider an approximate hour, which is the duration of the maneuver of the Methane Vessel, and in the trimaran we have taken into consideration an hour of operation of the propellers (approximately 6 maneuvers).

In the trimaran we have contemplated two consumptions one with a single propeller and another with the two propellers in operation, we can also consider that the tanker vessels dock with tugboat support, while the trimaran docks by its own means.

4. Conclusions

Both vessels need their maximum electrical power during maneuvers. The Methane vessel needs during loading and unloading 75% of the energy, whereas during the navigation it drops to 20%.

The trimaran needs during loading and unloading due to its ballast system for trimming and heeling of 30% loading and 20% during navigation.

The conclusions were obtained based on the following considerations:

a. If we consider that the motors have their pumps coupled and depend on themselves for the operation, they only have a small pre-lubricated pump and some resistance heaters for maintaining fresh water circulation within a certain temperature that takes the power supply from the outside.

b. That the main engines have external power outlets placed at the exit or entrance of the reducers depending on the system we want to use.

c. That during the maneuver, due to the fluctuation that occurs in the propulsion engines, these cannot be used for the electrical energy supply, therefore, the plant needs a series of auxiliary engines that are used as a power supply.

In this way, depending on the **type of maneuvers**, we can conclude:

1. If the vessel performs many maneuvers, the generator systems would be more profitable with independent engines coupled to the electric system when there is a demand for maneuvers.

2. If the vessel performs few maneuvers during navigation alternators coupled to the power intakes of the main propulsion engines.

3. If the vessel performs an intermediate number of maneuvers it should have a mixed system between independent motors coupled to the electric system during the maneuver. And alternators coupled to the main propulsion plant.

Depending on the **number of generators**:

1. If the vessel performs many maneuvers it will have to have a number of raised auxiliary engines so that in case of an emergency it can perform the maneuver safely, in case some of the generator engines being out of service or they become unusable in the maneuver for any circumstance.

2. If the vessel does not carry out many maneuvers simply having a generator engine of sufficient power for the accomplishment of the maneuvers it would be enough.

3. If the ship performs a number of average maneuvers, in this case between the two would be taken into account.

4. We always take into account the time we have that day, since, it depends on the height of waves and the wind that can affect the maneuver of entry or exit, or the type of port that we enter.

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