IMOR SURVEY VESSEL DIESEL-ELECTRIC SYSTEM ADVANTAGES

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Abstract

(How diesel-electric system improves reliability, operational flexibility and economy of the survey vessel IMOR)

IMOR was built for Maritime Institute of Gdansk as a multi -purpose shallow water survey and ROV support twin-hull vessel. It is configured and capable of performing a range of tasks, such as: hydrographic and geophysical operations, bottom and pipeline inspection, etc. Its small size, small draught, relatively high power and great flexibility of possible applications makes it ideal for work on shallow waters and offshore projects starting onshore.

It is equipped with diesel-electric propulsion system that consists of: 3 generator sets, 2 dual azipod aft active rudders - propellers, 2 dual waterjet bow thrusters. These units are powered by electric motors controlled by helmsman stand and DP system. First year of service has proven the project success. In contrast to conventional construction, both fuel consumption and pollution discharges have been reduced substantially. Additionally, manoeuvring and maintenance of the vessel has been improved.

A great advantage of such system is the use of sufficient number of auxiliary diesel engines; consequently operation of all engines at a time is avoided. During idle operation or reduced speed of the vessel, it is sufficient to connect only one or two auxiliary generators which, in return, will be operated at an optimum capacity and efficiency. On demand, high speed and operation of all vessel auxiliary generators can be achieved in a few seconds. This flexibility enables substantial energy-savings and exploitation cost advantages. Other benefits may be summarized as follows: high survivability, reduction of noise and vibration, improved operational flexibility and reliability, increased flexibility and adaptability for different kind of survey works, increased space available, reduced manning and logistics.

Keywords: *survey vessel, diesel-electric system, fuel consumption, operational flexibility*

1. Introduction

Diesel – electric system concept is not a new one. It has been successfully applied into vessels including: ferries, dock tugs, supply vessels operating at oil fields, research and seismic vessels, and some types of naval vessels for its special manoeuvre qualities including ability to hold full vessel control during manoeuvring at slow and very slow speed.

These systems were based on direct current diesel generating set and direct current propulsion motors. Control systems, voltage changes and power produced from engines were characterized by great overall dimensions, high price and low efficiency. Significant amount of electric power was converted into heat.

Development of high power semiconductor electronics has enabled implementation of changes in this classic system. Currently, diesel alternating current generating set, semiconductor voltage and frequency converters as well as alternating current propulsion engines i.e. R/V IMOR have been equipped with 2 alternating current engines of 3 x 0-500 V, 0-300 KW, 0-1979 revolutions per minute for main propulsion and 2 alternating current engines of 3 x 0-500 V, 0-75 KW, 0-1979 revolutions per minute for main propulsion. These type of engines are feed from generating units with help of TES converters that convert 3x 400 V, 50 Hz voltage into 0-500 V, 0-60 Hz of 140 do 480 A.

2. How does diesel-electrical system work with merchant vessels?

Units powered by traditional propeller have diesel propulsion engine directly connected to the screw propeller. Usually, there are one or two propulsion engines for one screw. However, diesel engines are less efficient at low direct revolutions when the screw rotates at idle run or little deflection of the blades, meaning at low speed of the vessel. It results in increased fuel consumption in proportion to final result in comparison to standard working conditions, therefore extensive emission of pollutants into the atmosphere and increased engine wear and service cost. One or two main engines of relatively small flexibility are superseded by smaller sets in diesel – electrical systems of generated power equivalent to amount of power supplied in classic system. Replacing one engine with smaller sets allows precise adaptation of generated power to current demand, significantly lessens fuel consumption, as it is not necessary to run all generating sets at the same time. Additionally, it increases propelling system non-standby index, as damage of a main element of a combustion engine results in the vessel's standstill until damage is repaired. A direct effect of a generating set damage can be slower vessel speed, hardly its standstill. Flexibility of this type of power unit is revealed in increased emergency power demand. Further generating sets, which remain at "warm stand-by", can be set working within a short period of time (almost instantly) using automatic or manual mode. Then, joined to power system it allows replenishing power deficit. Having estimated power deficit, they can disconnect automatically from the main power rail and stop on demand. It allows significant power consumption savings, and at the same time optimum load level of generators, that remain in power system. As far as major navigation companies experience is concerned, especially specialist for off-shore unit operators (maintaining rigs at The North Sea, which perform surveying works for petrochemical investments including pipelines, gas pipelines, power cables, etc.) such units, that are equipped with diesel – electrical propulsion system use up to 30% less fuel than equivalent units feed by classic propulsion.

Fig. 1. R/V IMOR during voyage at The Gdańsk Gulf

If we consider one vessel only, it allows savings up to 350 000 EUR annually. Assuming, that average cost of superseding classical propulsion system with diesel-electrical system amounts to

1.3 million EUR, it takes up 4 years of operation to pay off the expense. Assuming, that vessels of that type operate around 30 years and more, actual savings will reach up to 10 million EUR.

3. Factors that influence high efficiency of diesel – electrical system operation at research vessels

Thorough analysis of efficiency of specific propeller systems, that is classic with direct power transmission from the engine to the screw with diesel – electrical one, shows that efficiency of the second on is meaningfully lower, as variable current generator oscillates around 90%. Power conversion efficiency within the converter is also around 90%; moreover conversion of already converted power in the engine can come to 93%. Therefore, from each 1kW of produced power 0,75kW effective power is obtained, and wasted power is dissipated in form of heat in further conversions. However, fuel consumption savings come from flexibility of the whole propelling system. At low speed, which last up to 70% of survey vessel unit's navigation time, classic engine is loaded in a few or even dozen or so per cent. Vessels running diesel – electrical system allows operating as many power sources as needed at a time, at an optimum use. Apart from that fact, there are a number of other significant factors that account for diesel – electrical systems use, including:

- High reliability of the system. It is estimated, that breakdown risk concerning off-shore vessels brought about by a generating set shut-down off duty equals one during 10 years of service. Additionally, other sets can operate as usual,
- Increase in unit safety level and its ability to survive at sea by elimination of transmissions and shaft between the engine and propeller, with flexibility system, which allows arbitrary configuration of assemblies and propellers used (discussed in detail with the example of R/V IMOR),
- Significant noise and vibration limitation through abandonment of manual propulsion system connection with screw propeller; as well as improved conditions for acoustic separation of smaller diesel – electrical sets,
- Improved flexibility of the vessel power system use. Conditions for flexible generated power division among propelling system and other electrical facilities, which maintain every basic life functions of a vessel,
- Improved abilities (output) of power system used, therefore improved certainty that other vessel facilities including AC, freight handling facilities, and measuring electronics are properly supplied with power,
- Extension of space available, as smaller diesel – electrical sets demands less space. Therefore, more space can be used for freight, or in case or R/V IMOR it enables situating units within very narrow power station by lining them up,
- Less human input that operates propelling systems. Module generator systems are highly automated, that controls their performance. These systems can be integrated in groups, which to significant extent limit number of employees the controlling propelling systems in the engine room. IMOR vessel demands one engineer officer who performs 8 hours of work, 4 hours of supervision, and 12 hours of rest,
- Logistic procedures limitation. Application of one or two types of generating engines for complete measuring unit sets greatly reduces quantity of spare parts needed; moreover their modular construction allows quick therefore inexpensive servicing,
- Running costs reduction by modularization and standardisation of whole supplying systems, as well as possibility of application widely accessible electronic parts, that apply to supplying systems and more,
- Significant fuel consumption and supplying systems repairing costs reduction. There is especially significant cost difference concerning vessels that operate at slow speed of

working time and much faster while navigation from one work region to another. Taking into consideration that not all elements of propelling system operating at a time, the sum of working hours all engines may be significantly bigger than for single propelling engine, which is essential for determination of duty run between reparations,

- Reduction of time needed for obtaining operation full readiness from the moment of beginning of an action to unmooring. Standard generating set kept at standby and, what results from its construction, its possible fast duty within short amount of time after putting into motion. It significantly increases unit's ability to take action instantly. In case of IMOR vessel, minimal time needed for getting propelling system ready for action is limited to 3 to 5 minutes, contrary to vessels operated by classic propelling systems which require around 30 minutes and more.

4. Construction of IMOR research vessel powered by diesel – electrical propelling system and economic consequences of its use

IMOR research vessel belongs to steel catamarans and it is used for research within shallow water flooding regions, costal zone area as well as shelf up to 200 Mm from the shore.

Construction of the vessel allows performance of various tasks including: sea floor survey – performed for the need of wind power plant farms, undersea cabling and piping, deep-seated deposits inventory control, dredger winning volume estimation works, depths and sea surface oceanography investigation, near water surface atmosphere layer investigation, human activity effects concerning environment and sea area biocoenosis.

The vessel is easily adaptable to current needs through its ability of meeting multiple requests by the customer concerning all types of underwater investigations. IMOR offers solutions for wide rage of sea research connected problems at an optimum cost. It meets most rigorous prescribed safety standards with its hi-tech systems.

Its extraordinary ability to manoeuvre (thanks to its four widely set propellers, able to perform 360^{o} turn), relatively strong unit power (3kW on every ton mass), variable fixing active system allow action back and forward with the speed up to10 knots, 2 knots shipboard *(*both left and right at the same ship's heading) – simultaneously performing complex manoeuvres, impossible to be performed by a classic vessels..

R/V IMOR has been equipped with modern diesel – electronic propelling system. The vessel has 3 alternating current generators, which deliver electric power to the main propeller (2 propellers – azipod active rudders- propellers) as well as auxiliary propeller (2 water jet bow thrusters), as well as every other deck facilities including: auxiliary systems, navigational-measuring devices, civil).

The propelling system of the vessel is so flexible, that it successfully enables operation at any configuration: including 2 main propellers (up till 10 knots), including 2 auxiliary propellers (up till 4 knots), operating an arbitrary propeller, or any other configuration of either manual or automatic navigation. Interestingly, it enables navigation using arbitrary number of generators available. During its short operation, navigation powered with one, two, and three generators was tested – also at arbitrary configuration – even at the weakest one. It is possible by automatic system for available Power Management System. In a constant manner, it monitors electric power amount available, which is produced by vessel's power station and gives the propelling systems access to the power needed, consequently it excludes even the smallest generator's overload even at the officer's in charge mistake – i.e. at overload test (after starting sound alarm) the system automatically reduces the propeller's power.

Schottel propellers run by electrical engines operated with TES inverters (3 x 0 - 500 V, 0 - 60 Hz, 0-1979 revolutions per minute), that are monitored from the bridge and dynamic position system. Application of the propelling system enables economical vessel operation, as the officer in charge can adjust current vessel's plant configuration to arbitrary propelling system configuration as well as current power demand at any time. It greatly reduces fuel consumption.

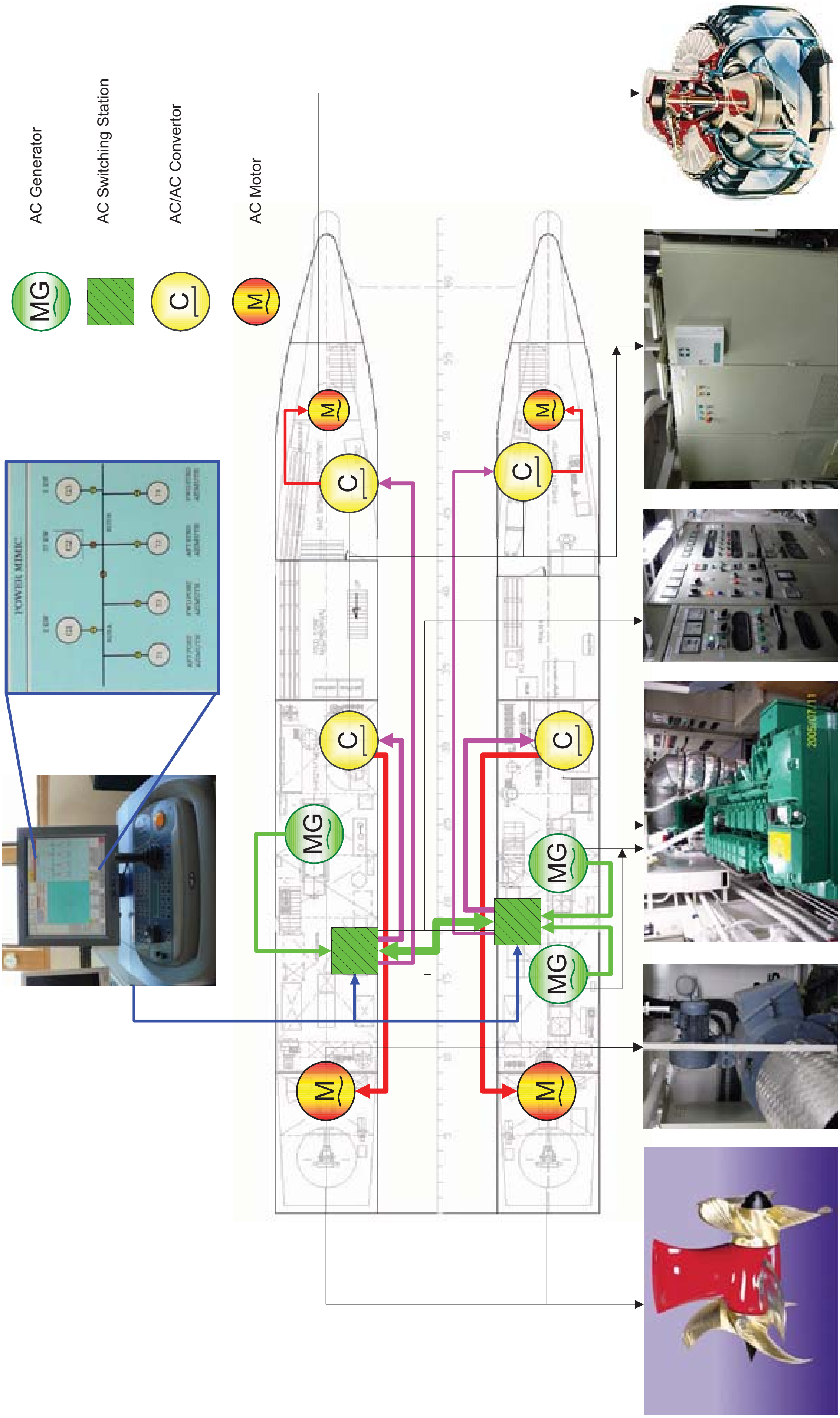

Fig. 2. Power Management System on R/V IMOR

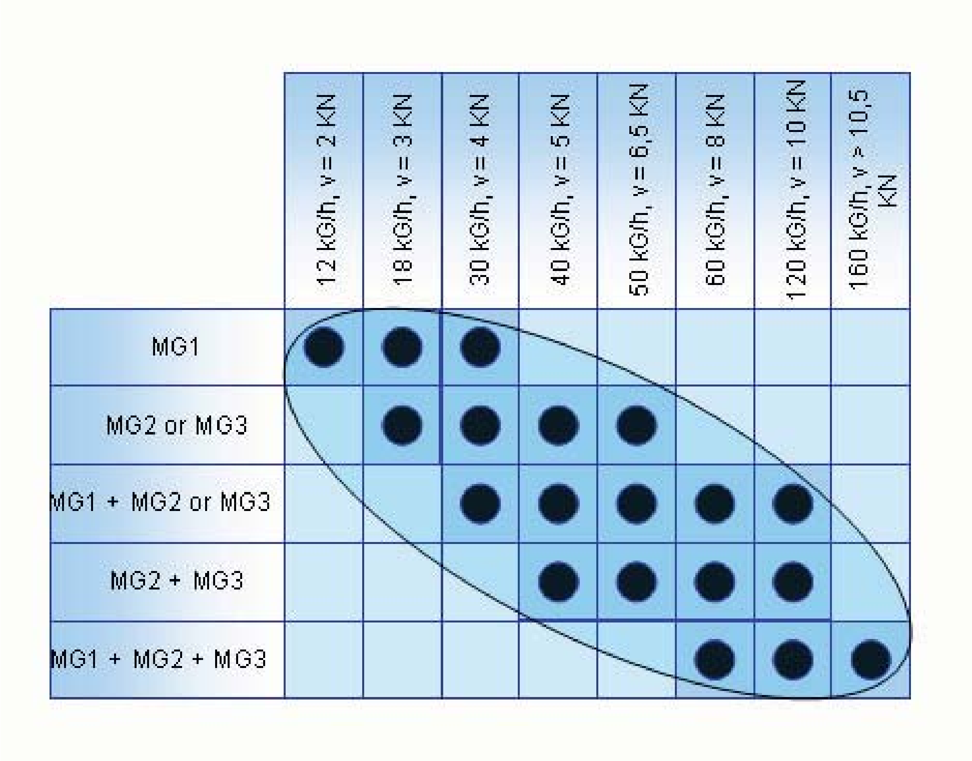

Fig. 3. Fuel consumption in various conditions

Having performed first tests it is possible to run a vessel at even 12 kg of fuel an hour; average fuel consumption during investigation works oscillates between 20 and 25 kg/h of activity; during navigation at around 8 knots it does not exceed 60kg. Only during extreme conditions - maximum speed 10.5 knots it may reach 125kg.

Power station elements split was achieved by situating two generators on the right side and one on the left side of the engine room, possibility of operating one arbitrary propeller of four as the propeller that keeps the vessel in motion improves safety level of the vessel and the crew during states of emergency, i.e. flooding one of the engine rooms or other room where the propellers were situated.

R/V IMOR Electrical power system involves three aggregates:

1 Volvo - Penta 415 kVA, (332 KW),

1 Volvo - Penta 401 kVA, (321 KW),

1 Volvo - Penta 180 kVA, (144 KW.

Propelling system of the vessel consists of:

2 dual azipod aft active rudder-propellers type SCHOTTEL STP 200 propelled by 2 alternating electrical current engines 3 x 0-500 kW, 0-1979 revolutions per minute,

2 two –water jet bow thrusters - SCHOTTEL SPJ 22 – propelled by 2 alternating current engines 3 x 0-500 V, 0-75 KW, 0-1979 revolutions per minute.

All SCHOTTEL engines and propellers are maintained from helmsman station and DP system situated at the navigation bridge.