PROBLEMS OF PROPULSION ARRANGEMENT CHOICE OF MULTI-MODE SHIP

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Abstract

The propulsion system of multi-mode ships cause many problems of proper the choise of propulsion system elements and theirs arrangement in the design process. This system has to fulfil at least two inverse demands. It ought to make possible efficient ship shift (transit mode) from the port to the offshore work place and return to base, to ensure a ship survive at sea in the worst sea condition possible on that sea area and to fulfil conditions of dynamic positioning accuracy (stationkeeping mode) at specified bad state of the sea - not to stop the ship work for long time. The dynamic positioning systems require multi-element ship propulsion application. The fulfilment, all required possibilities and accuracy of ship positioning by chosen propulsion system specified in the project data, is the most important project problem to obtain the minimum investment costs. The redimensioning of propulsion system, increasing the number of thrusters and theirs possibilities gives the benefits in dynamic positioning accuracy, but increases the investment costs. An expensive project may not be realized because of price. The aim of designer is the choice optimum solution of propulsion system, which is fulfils all expectations of ship owner and crew, and performs all project assumptions.

Keywords: *ships propulsion, propulsion arrangement, multi-mode ships, propulsion choice*

1. Initial remarks

The good choice of propulsion arrangement for dynamic positioning systems (DP systems) is the most important problem during design and it has serious consequences during later exploitation. The cause is that the propulsion system for DP service must generate forces capable of keeping the vessel in position against any number of environmental forces which may attack the vessel at any angle. Also, DP thrusters usually provide the propulsion for transit (cruising) from location to location. The next one is that the major disadvantage of the ship-shaped multi-mode vessel is its higher degree of motion in waves which reduces its operational efficiency during operations in heavier weather. The hull disturbs the inflow of water into the propeller. The radial velocity distribution is not uniform, the axial water velocity is decelerated, and the low pressure field between propeller and hull increases the resistance of the vessel. The interaction between the hull and the propeller is treated by the introduction of certain factors and efficiencies (such as wake fraction, thrust deduction fraction, and various propulsion efficiencies) [4, 9]. They are conducted in a model basin on a routine basis according to the standards of the International Towing Tank Conference (ITTC) [7,8]. Analytical approximations can be applied in the absence of model tests, and, in particular, in order to develop preliminary performance estimates in the early stages of a project. For DP propulsion, the interaction problems of bottom mounted thrusters can be divided into three particular problem areas:

- Interaction of the propeller jet with the hull;
- Intersection of the jet from a thruster mounted on the bottom of a semisubmersible hull with the adjacent hull;
- Interaction between thrusters on multiple thruster installations [9].

The above interaction phenomena occur in situations where several hydrodynamic effects coincide and mutually affect each other. It would be unfeasible to develop accurate and reliable analytical methods which can be applied to any shape of vessel and to a variety of propeller and installation configurations. Only model propulsion tests deliver accurate results. An example of possible propulsion arrangements was shown on Fig. 1.

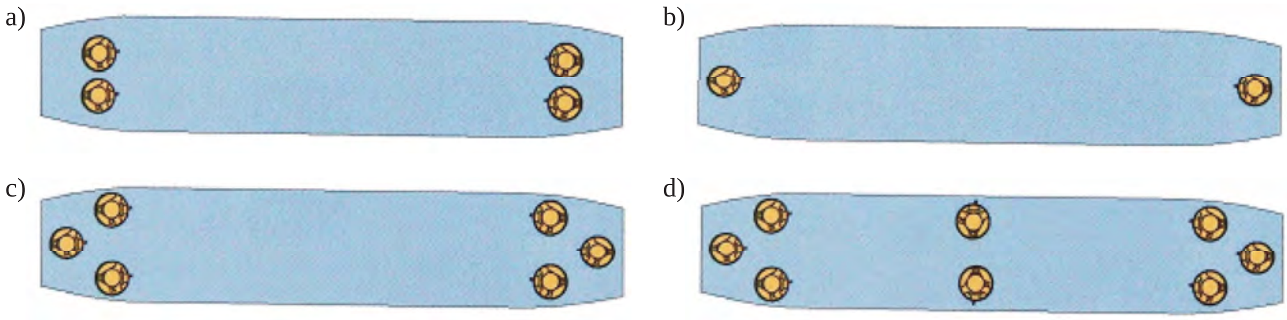

Fig. 1. Possibilities of multi-element propulsion arrangement for DP systems: a) the most popular, b) the minimum, c) good for DP, d) full possibilities

To be effective for yaw maneuvers, the thrusters are often grouped at the bow and stern of the vessel (Fig. 1a,c). In response to certain vector commands, situations can occur in which the thrusters are positioned in such a way that the exit jet of one thruster is directly aimed into a second thruster. The thrust output of the second thruster is greatly reduced if the propeller axis coincides. The trust deduction may reach level of 0.3-0.4 [2, 9]. The second thruster operates in a condition of a higher advance coefficient. Thrust decreases with increased inflow velocity. This applies even if it is possible to maintain the power load on the propeller by increasing the pitch of a controllable pitch propeller or the RPM of a fixed pitch propeller. It is searching other propulsion arrangements to meet required parameters, like dynamic positioning accuracy, minimum thrust deduction (Fig. 2).

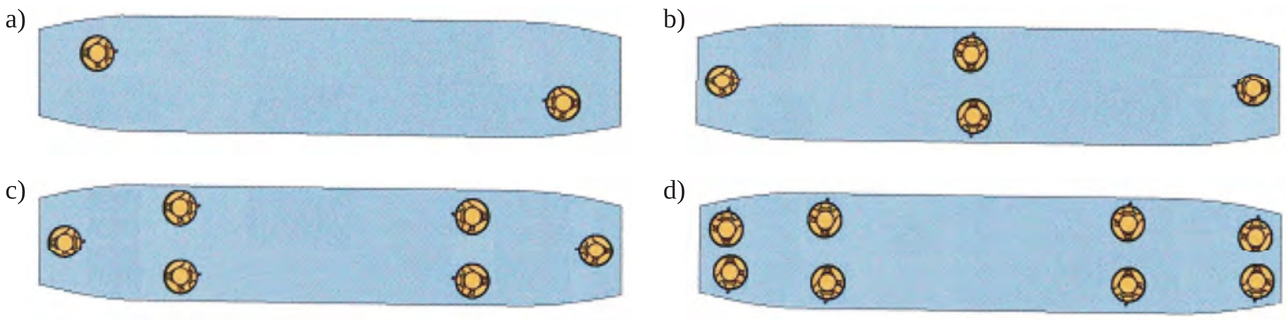

Fig. 2. Propositions of multi-element propulsion arrangement for DP systems: a) the minimum, b) for discussion, c) for analysis, d) for two engine rooms

The next important problem is vertical ship motion forced by sea waves. It makes difficult the proper ship work, for example the co-operation and position between the ship hull and the execution of work of industrial part [10]. It was tried to solve that problem.

2. Ways of restriction limitation in propulsion arrangements

The design of a propulsion system for dynamic positioning (DP) applications varies from that of a conventional propulsion system. For multi-mode ships the propulsion system ought to be design at very small speed near zero and with very good manoeuvring possibilities. Propulsion for DP ships must provide thrust continuously and efficiently in ahead and astern directions of operation.

It must be remembered that the grouped thrusters interact because the distance among them is limited (depends on ship's breadth and length). The rotatable thrusters need the distance "X" between their axis and the distance "L" around them (Fig. 3) from theirs axis of rotation to the end of thrusters body or nozzle.

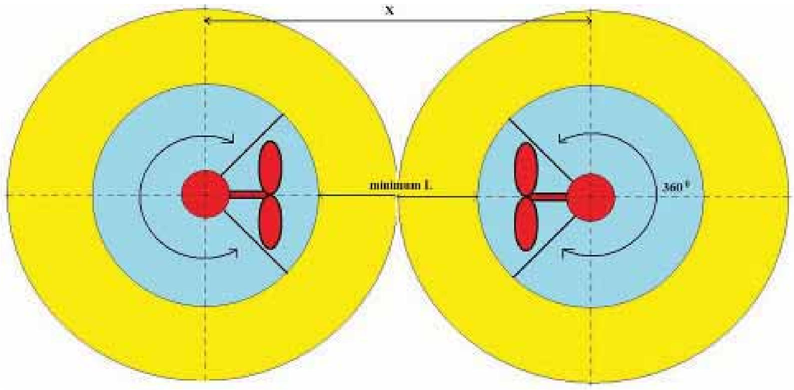

Fig. 3. Minimum distance "L" between nozzled thrusters

The interacting distance depends on many parameters, one of them is the thruster power. Often the distance "L" is smaller down to about 1 m. It is better if the distance among thrusters is the best possible (minimum L). It must be remembered that in the position presented on Fig. 3 the thrusters may overload theirs engines or electrical motors. The load may be over 150% of nominal power. If the distance "L" is smaller than the overload will increase. The preferable position of zero thrust of two thrusters is presented on Fig. 4.

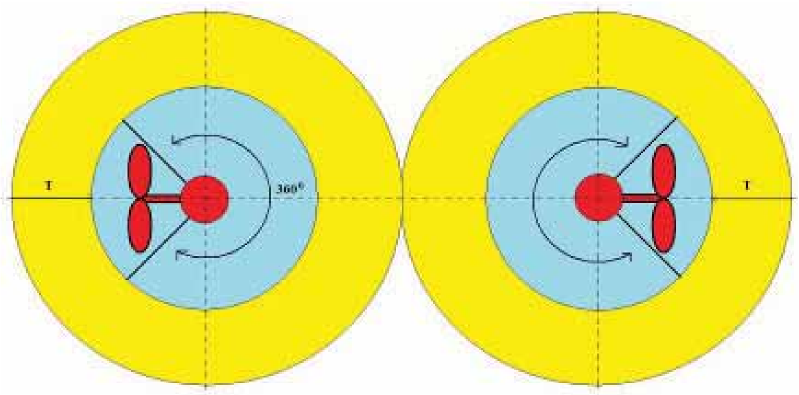

Fig. 4. Zero thrust position – the thrusters work at the same conditions and parameters

For dynamic positioning manoeuvres this is good position of thrusters because they are ready for change of total load. We may change the thrust one of them – in result total thrust is different from zero. The rotation one of them makes the same but additionally the direction of total thrust is change too. This is the best way of ship positioning. When the environmental forces are increased the availability for DP accuracy needs to work all thrusters on increased loads because in that case the time for obtaining the needed force and direction of thrust is decreasing for the correction of vessel position where the correction signal has worked out by DP system. Generally, the DP system needs the thrusters work on bigger loads when the needed DP accuracy is increased. It wastes much power for it and it costs. It's very important that the ship hull ought to be symmetrical and the thruster foundations ought to be symmetrical in respect of ship longitudinal axis. This is simplified and decreased problems of DP systems [2, 4].

Although a DP vessel most often is designed to operate in and survive extreme sea environmental conditions, although statistically these conditions occur very rarely.

Every vessel needs the electricity in all operational conditions. When the power plants equipped with main generators (diesel-electric or gas-electric type) it may be told that the power plant is still in work or ready for work. The demand for electric energy of ship industrial part is large, more often than for the propulsion part. In those circumstances the electrical driven thrusters are good possibility of application. There are some advantages: the possibility of compound electrical propulsion system, simple construction of electrical propulsion system, high reliability of electrical motors and possibility of theirs overloading [5].

3. Possibility choice of electric driven propulsion application

The ship power plants consist of following main parts:

- power generation system with main engines and generators;
- power distribution system consisting of medium voltage (3-11 kV) switchboard and tie breakers, usually split into two, four or more sections (drilling ships);
- transformers for feeding of alternate voltage levels;
- low voltage (0.38-0.69 kV) switchboards and motor control centres;
- frequency drives for propulsion motors and other users;
- filters for reducing the harmonic currents;
- rotating converters for clean power supply;
- uninterruptible power supply (UPS) of sensitive equipment and automation system;
- medium and low voltage motors for various services (propulsion, fans, compressors, thrusters).

An example of power system configuration for drilling vessel was presented on Fig. 5.

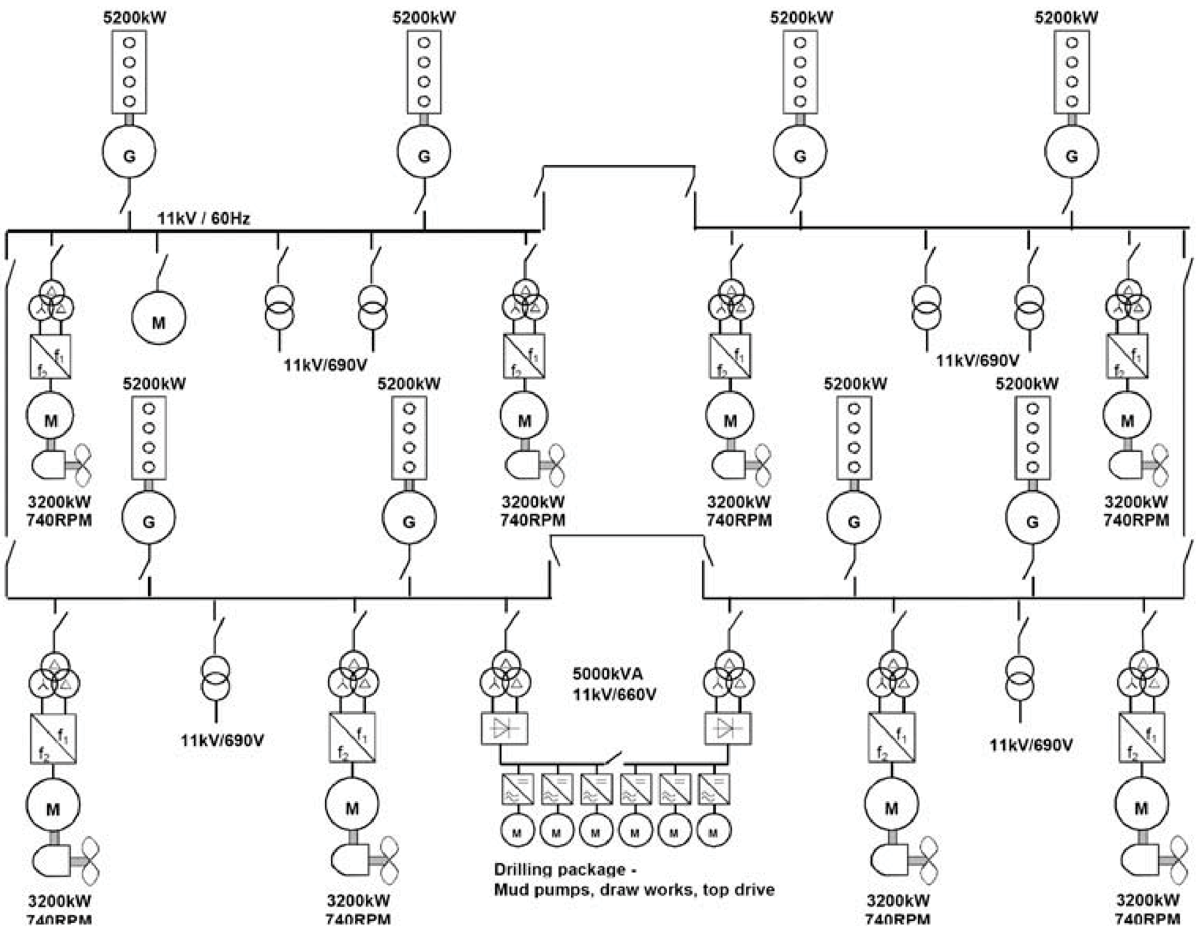

Fig. 5. Power system configuration for drilling vessel [1]. Single line diagram for a DP Class 3 drill rig with a four-split power system - ring network

There are eight main generating sets each 5200 kW electrical power, in total is 41600 kW. There is a four-split power system creating ring network. The propulsion system have eight thrusters each of 3200 kW power. The drilling package is supplied of 5000 kW power. Other auxiliaries are supplied low voltage by transformers 11kV/690V. The industrial part of power system requires more and more electrical energy and the demand is increasing.

Nowadays as main propulsion of multi-mode ships dominate the propulsion solutions with unconventional thrusters driven by electrical motors. It is seemed to be reasonable to consider more complicated propulsion solutions, like presented on Fig. 5. The redimensioning of propulsion system, increasing the number of thrusters and theirs possibilities gives the benefits in dynamic positioning accuracy, but increases the investment costs. An expensive project may not be realized because of price.

The independent ship power plants may decrease needed total power of multi-mode ship. An analysis was shown on Fig. 6 where presented four propositions of power system configuration for drilling vessel needed 35 MW. By reason of redundancy in case of two engine rooms the total power plant ought to be 70 MW. In the event of three independent engine rooms the total power is enough 52.5 MW, for four engines rooms 46.4 MW and for six engine rooms enough total installed power is 42 MW. Only in case of four power rooms there are eight generating sets in others that are enough six.

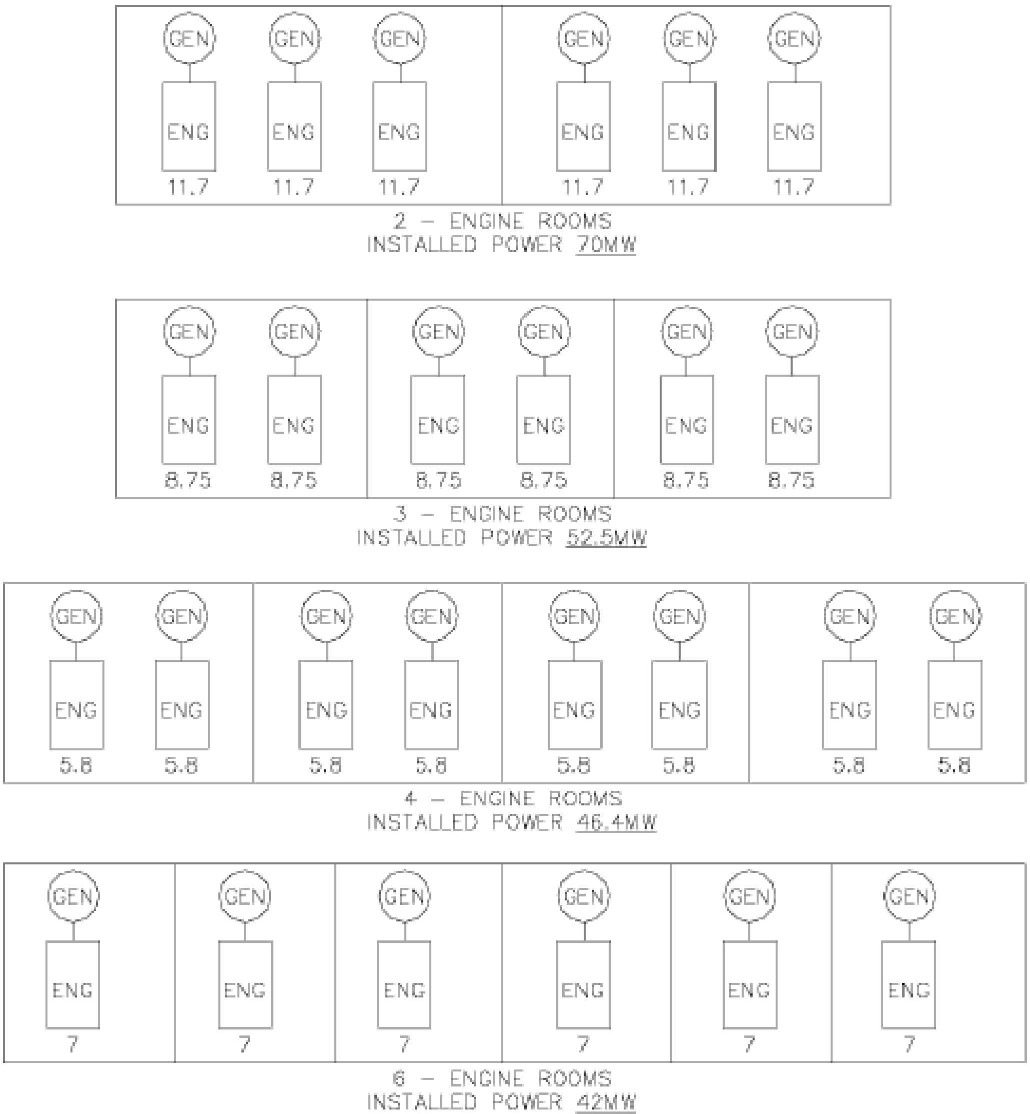

Fig. 6. Power system configuration for drilling vessel [3]

4. Requirements of energy management systems

Power management system (PMS) has become an integrated element of totally integrated power, automation and positioning system. That is one of the new challenges for PMS. Traditionally, power management system has been analyzing only current situation on the network and has been considering limited number of consumers and their control systems. In recent years, advanced functions have been added to power management system to be able to control the power generation and consumption by optimizing the instantaneous power flow and use. That is the reason for calling the same control system the Energy Management System (EMS) [1, 3]. Usually, different terminology has been used for the same control system so there is not big difference whether we call it energy management system or power management system. However, it is important to recognize the difference between conventional power management functions and modern advanced functions that open possibilities for further improvements in blackout prevention, overall safety and fuel consumption. In case of main generating sets working on heavy fuels the minimum load must be over 60% of nominal. It allows for long-lasting work and guarantee minimum specific fuel oil consumption (SFOC). It means that the efficiency is near nominal and is acceptable and gets a saving. It requires multi-element power systems and needs to choose the number of working generating sets to fulfil the actual total power demand. The PMS or EMS systems must be field-programming according to power system arrangement [6]. The power reserve of energy system is very important problem to solve. An example of analysis was shown on Fig. 7.

Number of generators connected	Generator load	Available power (power reserve)	Time delay to initiate the starting sequence
2	70%	2x 30% = 60%	10 min.
3	75%	3x 25% = 75%	10 min.
4	80%	4x 20% = 80%	10 min.
5	84%	5x 16% = 80%	10 min.

Number of generators connected	Generator load	Available power (power reserve)	Time delay to initiate the starting sequence
2	85%	2x 15% = 30%	10 sec.
3	87%	3x 13% = 39%	10 sec.
4	89%	4x 11% = 44%	10 sec.
5	91%	5x 9% = 45%	10 sec.

Number of generators connected	Generator load	Available power (power reserve)	Time delay to initiate the starting sequence
2	105%	0%	immediately
3	105%	0%	immediately
4	105%	0%	immediately
5	105%	0%	immediately

Fig. 7. Proposition of time delay to initiate the starting sequence in relationship of available power [3]

The setting of time delay to initiate the starting sequence must be incorporated into the EMS system.

5. Final remarks

The fulfilment, all required possibilities and accuracy of ship positioning by chosen propulsion system specified in the project data, is the most important project problem to obtain the minimum investment costs. The aim of designer is the choice optimum solution of propulsion system, which is fulfils all expectations of ship owner and crew, and performs all project assumptions. The proper choice of propulsion arrangement and power system configuration for multi-mode ships is the most important problem during design and has results in the whole time of ship exploitation. The proper EMS may cause further improvements in blackout prevention and ship safety.

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