3 Electric Power Station and Azipod® as the Power Train of Propulsion

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1 INTRODUCTION

In the marine industry it takes several years before a new innovation is accepted to enter the market. Therefore systematic development work is required before a product or a system can be released to the commercial vessel market. The Azipod concept was studied for the first time some 13 years ago for an icebreaker and only later came other vessel applications such as tankers, cruise liners and roro-vessels. Certain design steps and early projects were studied and necessary experience was gained for further enhancement of the system. The following are examples of such projects:

The first Azipod unit (1,500 kW/2,040 HP) installation on the waterway service vessel Seili proved the concept and idea to be sound and demonstrated the installation process.

The first high power (11,400 kW/15,500 HP) installation for a commercial vessel, the arctic tanker Uikku, proved the concept’s superior capabilities in maneuvering both in open water and in the most difficult ice conditions. The mechanical construction has also experienced extreme loads and given confidence in the strength and durability of the design.

The first pulling Azipod units were installed onboard the icebreaker Röthelstein in 1995. The comparison to pushing types was made and some very useful conclusions were drawn.

The above projects have been essential to be able to reach today’s level of performance and reliability.

At the same time the tools for dimensioning and simulating the function of the electrical network have been developed. It is possible to use commercially available simulation packages as simulation platform in this kind of development, but quite an amount of own R&D effort is required to build efficient and reliable design tools for daily use.

2 POWER GENERATION AND PROPULSION DRIVE SYSTEM

2.1 Power generation and distribution

Selection power plant concept is made based on total installed power, operating modes, flexibility, redundancy requirements and total cost. Availability of suitable components, e.g. switchboards, generating sets and cables, act as limiting factor.

Number and rating of power generating sets must be optimized to achieve desired flexibility of plant, service factor and fuel economy of prime movers for the selected service profile.

Voltage level of power generation is selected so that load current and short circuit levels are kept within limits of available components. In case total power is not too high, low voltage system is normally the most cost-effective solution. With increasing total power the power generating voltage will increase accordingly. 11 kV is the highest voltage level that has been used so far, but with increase of total installed power even higher voltage become feasible.

Distribution system design has major effect on both material and labor cost of electric distribution system construction. Generally all big consumers, such as
thrusters and compressors, should be connected directly to the power plant main bus. In large cruise vessel distribution system is typically built of separate network sections for each fire zone. In this case also power transmission is normally made at higher voltage level to minimize losses and cabling cost.

2.2 Propulsion Drive

2.2.1 Drive types

Electric propulsion drives have been made by practically all available techniques. In simplest case direct driven synchronous or asynchronous motor combined with a CP-propeller may be used. In modern systems, however, a frequency converter drive is used in high power main propulsion applications.

Electric propulsion systems based on DC-drive have been used over 60 years. About 20 years ago AC-drives came to the market and are used practically in all applications today.

At power range up to four megawatts a low voltage PWM drive is most common solution. With higher powers up to 8 MW medium voltage PWM drive together with asynchronous motor has been more or less standard solution.

Higher power drives are mainly based on two techniques, cycloconverter or LCI. Cycloconverter changes constant frequency input voltage to lower variable speed frequency directly making it ideal for low speed drive such as directly connected main propulsion. Cycloconverter is able to operate at unity motor power factor, which is beneficial for motor design in case of podded propulsion. LCI in turn is based on a DC intermediate circuit and can be used at larger frequency range, but on the other hand low speed operation requires special control methods.

Future development of drives will make possible even higher shafts powers. On the other hand new drive types such as medium voltage DTC (Direct Torque Control) drives together with synchronous motor may replace existing high power drive techniques to some extent.

2.2.2 Electric propulsion drive

All of the drive types described above are widely used in various industrial processes requiring high dynamic capacity. From this point of view propulsion of open water ship is a relatively simple task for any type of frequency converter.

On the other hand a propulsion drive must be able to operate in a week supply network. Propulsion power may be up to 95% of total consumption, which means that it is the only consumer capable of protecting the whole system. Being the major consumer propulsion drive is also the main source of harmonic currents.

Working together with the supplying power plant and distribution system is the most demanding task of an electric propulsion drive control system.

2.3 CONTROL OF HERMONICS

The most common solutions for decreasing harmonics have been to use filter circuits tuned to certain harmonic frequencies or to use rotating converters to supply sensitive consumers. Filters need careful design work due to possible network resonances. Rotating converters in turn require extra equipment and cabling for power distribution.

Higher pulse numbers in frequency converter drives will decrease harmonics in the load current, but on the other hand mean the use of extra components and resulting higher costs.

Duplex reactors may be used to build separate propulsion and ship service bus in main power station. This solution will provide very low harmonic content in the ship service network.

By correct dimensioning of power plant generators and propulsion drives it is often possible to maintain harmonics at the desired levels without resorting to any of the above-mentioned additional measures.

All the above solutions have their own benefits and the method to be used shall be decided case by case depending on the application.

2.4 SYSTEM Simulations

Power plant and drive system supplier should have proper knowledge and tools to design the drive and power plant in such a way that specified harmonic...
levels, frequency and voltage variations are not exceeded.

Numerical calculations based on modeling of network components as well as propeller and ship hydrodynamics provide an efficient design and research tool for a system designer. System simulation may be used to study various operations and phenomena, including:
- System efficiency
- Voltage wave form
- Total harmonic distortion
- Starting of large consumers
- Crash stop

3 HISTORY OF THE AZIPOD PROPULSION CONCEPT

The original idea for the Azipod system was developed when the Finnish Maritime Administration began to seek better solutions for the operation of icebreakers in ice channels. An important feature of an icebreaker is that it must be able to break out of an existing ice channel. This is important when the merchant ships that are being assisted, are using the ice channel and the icebreaker has to move around the operational area. To overcome this problem, the idea of a propulsion motor that could direct the thrust to any direction was created. The idea was presented to ABB and the concept of Azipod was drafted and patented.

Kvaerner Masa-Yards and ABB made an agreement in 1992 to develop and market the unit jointly. In 1993 the name Azipod was registered. After the order of the conversion of the M/T Lunni in 1994, the Kvaerner Masa-Azipod unit was founded.

Finally, on October 1, 1997 ABB, Fincantieri and Kvaerner Masa-Yards founded ABB Azipod Oy to market, design and produce Azipod propulsion systems.

3.1 Different installations and experiences of the Azipod systems

M/S Seili
The first joint R&D project was the conversion of Seili, a waterway service vessel owned by the Finnish Maritime Administration, into the first Azipod ship in the world. This took place in 1991. The Seili continues to operate today, and its 1.5 MW unit has operated faultlessly since the conversion.

M/T Uikku and M/T Lunni
The next ship to be equipped with Azipod was a 16,000 DWT product tanker, the M/T Uikku, built in 1978 in Germany. The conversion work of Uikku was done in 1993. The power of Uikku's Azipod unit is 11.4 MW. The ship was built to ice class 1A Super and the Azipod to DnV ice 10 class. In 1995, Uikku's sister ship the M/T Lunni was similarly converted. Both ships have been in heavy commercial use since conversion. Their combined operating hours total well over 40,000. Of these, about 15,000 hours were on ice-infested waters.

In 1997 Uikku became the first western cargo ship to navigate through the North-East Sea route. Uikku started its journey in Murmansk in western Russia in the beginning of September. Twelve days later Uikku arrived in Providenia, located in eastern Siberia south of the Bering Strait. The Uikku and The Lunni demonstrate the soundness of the basic design and construction chosen for the Azipod. The Azipod propulsion is the only way to make North-East Sea route economically viable because the ships can operate very safely without icebreaker assistance.

I/B Röthelstein
The Röthelstein is a small river icebreaker, 560 kW (760 HP), that introduced new ice breaking technology, attacking the ice with pulling propellers. The icebreaker is driven stern first with the Azipod units pulling the vessel.

The icebreaking concept of going astern with pulling Azipod units demonstrates and icebreaking capability that surpasses all other technologies. It has also been tested with the Lunni. The tests showed that although the Lunni was not designed to operate stern first in heavy ice, it was able to operate in the toughest conditions found in Finnish waters without icebreaker assistance. Model and full scale test confirm that only 60% of the power needed when attacking the ice bow first is needed for this mode of icebreaking.

M/S Elation and Paradise
The good results and reliable operation of the Uikku and the Lunni enables CLL (Carnival Cruise Lines) to choose Azipod for the Elation and the Paradise in the autumn of 1995. The power of each of the two units is 14 MW. This order actually set off the change of propulsor type for big cruise ships. The CCL Fantasy series actually started the electrical propulsion era for cruise ships. When Elation and Paradise belongs to that series we can say that no other series of passenger ships has affected so much the propulsion concept of cruise ships.
The VOYAGER Class

The next Azipod system order came over a year later. It was placed for RCI (Royal Caribbean International). The biggest cruise ships ever ordered will be equipped with two 14 MW (19,000 HP) Azipod units and one 14 MW Fixipod, a non-rotating Azipod unit. The first ship will sail in the autumn of 2000. It is also one of the first cruise ships equipped with a DP-system. With the Azipod propulsion system and 3 × 4 MW (5,440 HP) bow thrusters, this system will be so powerful that the giant ship will be able to stay on its designated place in winds, from any direction, of up to 18 m/second.

The MSV Botonica

In February 1997 Finnyards Oy ordered two 5,000 kW (6,800 HP) Azipod units for the multipurpose icebreaker Botonica it had on order for The Finnish Maritime Administration. The ship will operate in the Gulf of Finland in winter and in the North Sea oil fields for the rest of the year. To accomplish its offshore duties, the ship is equipped with a DnV Autro dp-class. The ship entered service at the North Sea in the summer of 1998. Excellent sea-trial experiences proved the system to make the ship very well suitable for the offshore work.

The Botonica is the first ship equipped with Azipod units and used in the offshore market and will provide a good reference for future applications.

Supply ships Arcticaborg and Antarcticaborg

In November 1997 Kvaerner Masa-Yards received an order for two small icebreaking supply ships powered by two 1,620 kW (2,200 HP) Azipod units. The ship's operation pattern in the Caspian Sea is made possible by the use of Azipod propulsion units. The ice conditions in the northern Caspian Sea are very severe, so the Azipod units will operate as ice lathes.

Other Azipod propulsion concepts

As the Poddoped propulsion has become an standard solution on cruise ships ABB has secured orders in power classes from 6,6 to 19,5 MW. The total number of built or on order or Azipod units are to-day, 30.5.2000 55 units.

The concept has been used also on separate project such as product tankers, RoPax ships but not by us.

The first cost of the diesel electric propulsion compared to direct diesel driven shaft line prevents the use of electric propulsion in normal merchant ships. The last part of this paper describes a concept, CRP; that can change the situation.

3.2 Design Aspects of the Azipod Propulsion System for ELATION and PARADISE

In the following the different aspects are described. I use the Elation and Paradise conversion as an example because the different with normal shaft line is quite clearly seen.

Several aspects have to be taken into consideration when applying the Azipod concept: hull form, Azipod location, motor design parameters, propeller design and strength, hydrodynamic details, structural strength, vibration design and tuning, steering logic and operation modes, ship characteristics like course stability and heeling, behavior in black-out situation and redundancy.

The Azipod turning shaft is located in the place of the old rudder vertical shaft. This allows full azimuthing angles and enough clearance to the baseline as well as sideways. The Azipod attachment to the ship hull is carefully designed according to the model scale tests and full scale experience. The synchronous electric propulsion motor design values, power and torque curves were kept identical to the sister vessels although savings in propulsion efficiency were expected.

3.2.1 Propellers

The fixed-pitch propeller diameter is 5.2 meters, as on the sister vessels. There propellers are the most powerful pulling propellers ever built. New operation modes created new challenges for the design. The task was successfully performed by making detailed hydrodynamic and FEM-calculations and by model scale tests.

The hydrodynamic optimization procedure resulted in inward rotating propellers. The Azipod was slightly inclined (six degrees) downwards in order to give a good inflow for the propeller. The results based on model scale tests estimated a several percentage improvement in propulsion efficiency.

3.2.3 Steel structure

The structural dimensioning was based on two basic load conditions: max. continuous loading in normal service and extreme loading (abnormal operation, e.g. if the control of the Azipod fails). The key design point was to adjust the dynamic behavior. The excitation forces and moments were known from earlier projects. Excitation level is low due to the good wake field. The steel structure of the Azipod and ship hull was dimensioned so that the resonance were avoided in critical areas and in full powers. A special emphasis was placed on the Azipod attachment to the hull.
3.2.3 Steering system
The steering of the Azipod units is done by an electro-hydraulic steering system. A total of two to four hydraulic motors give the pod sufficient turning speed and redundancy. Steering logic had to be rethought e.g. the stability of the Azipod units, steering angles versus ship speed, power limitations and crash stop characteristics. Ship behavior calculations during extreme maneuvering were done. The black-out situation was analyzed: Azipod system behavior, dimensioning of the emergency network and starting sequence of the steering motors.

Also the redundancy was studied in order to prevent any failure in one pod to stop the order. The Azipod units are mechanically, electrically and hydraulically independent.

3.2.4 Layout Modifications Onboard the Elation
Changes in the layout were kept to a minimum, except for the Azipod itself. The propeller motor room, no longer needed, actually offers new design possibilities because it makes available an additional 1,200 m$^2$ of space. This space is as wide as the ship (32 m), 20 m in length, and two decks high, the height of the propeller motors. In the case of the Elation, the room was excellent for additional waste handling equipment:

An incinerator and a gray water treatment plant were installed in the propeller motor rooms of the original design and the old shaft tunnels were converted into fresh water tanks. Changes in the lay-out of the machinery space were minimal compared to the sister vessels. This was an advantage to the shipyard and the owner.

3.3 Verification of design data in full scale
Propulsion efficiency
The following results were recorded during the sea trial in December 1997 in the Gulf of Finland. The increase in propulsion efficiency compared with the existing Fantasy class ships was 8%. The hull lines are the same on the Elation as on the previous ships in the Fantasy-series. The only changes were the local modification around the Azipod units and the closing of the stern holes for the thrusters.

Later the owner has found out that the real fuel savings on a rate that has been operated early with a sister ship are over 10% on week’s cruise.

3.3.1 Maneuverability
The maneuverability of a ship is best demonstrated by its full speed turning circle. The diameter of the turning circle of the Elation was about 30% smaller compared with the previous Fantasy-class vessels. The ability to turn the ship fast gives the master a better margin for maneuvering in tight situations and increases the safety of the ship.

The other important feature in a ship is its crash stop performance. The test was performed by reversing the propellers. An additional safety feature of a ship with Azipod units during a crash stop, is that the ship can be steered towards the desired stopping point.

3.3.2 Passenger comfort-vibrations
Reduction in noise and vibrations were also observed during the sea trails. This is mainly due to the very good wake field of the pulling propeller and resulting reduction in pressure pulses from the propeller to the hull. The passenger will observe the biggest difference in the confined area operations and during harbor maneuvers. The absence of the stern thrusters and the rudders makes a big difference in passenger comfort.

4 THE CONTRA ROTATING PROPELLER (CRP)CONCEPT
The Contra Rotating Propeller (CRP) concept has been widely studied and used in a variety of vessels. The idea of applying the CRP concept and an electric podded driver or azimuthing thruster in place of a rudder is not new although it has never gained popularity. The development of the electric podded propulsion systems and experience of pods at higher vessel speeds give new possibilities in utilizing the concept in a wide range of vessel applications.

The main benefits of the concept are:

- Fuel economy
- Propulsion redundancy
- Maximum propulsion power capacity of a conventional single shaft hull form
- Maneuverability
- General arrangement of the machinery areas
- First cost
- Life cycle cost

The popularity and acceptance of electric propulsion systems for ships has been accelerated by the introduction and success of the podded propulsion concept. First installations of the electric podded propulsion systems took place in the early 1990’s. In ten years the operating experience has proven the concept to be ideal for a vari-
ety of vessels. Some of the challenging issues when introducing electric podded propulsion systems to new types of vessels are:

- First cost of equipment compared to conventional solutions
- Building costs with the podded propulsion concept
- Reliability and maintainability
- Operating costs.

Clarification and evaluation of these issues require both extensive studies and experience. A vessel will benefit from electric propulsion when one or more of the following conditions exist:

- A variable operating and power requirement profile
- A need to maximize the cargo or passenger volumes within given measurements of the ship
- A requirement for low vibration levels
- A requirement for reduced exhaust emission levels
- Propulsion redundancy and safety requirements

There is a growing demand for building environmentally friendly ships, which produce less exhaust gases, are equipped with redundant propulsion systems and are capable of maneuvering safely in narrow passages and difficult weather conditions.

This paper will present the Contra Rotating Propeller concept applying a podded drive in place of a rudder of a conventional propulsion system. The concept is an alternative to e.g. conventional mechanical propulsion systems where a twin shaftline design is chosen to achieve propulsion redundancy and/or reduce propeller loading in high power applications. A case study of applying the podded CRP concept to a fast RoPax vessel is also presented to specify costs and performance differences in more detail.

### 4.1 Introducing The podded Contra Rotating Propeller (CRP) concept

A typical way to achieve propulsion redundancy is to double the existing single propulsion plant and design the systems to be independent of each other. Thus a single fault will not result into a total loss of propulsion power. This solution is widely used and is in many types of vessels a standard (cruise vessels, offshore supply vessels). Duplicating the propulsion plant is in many ways a compromise where the following sacrifices are made:

- Machinery space is increased at the expense of cargo space
- The aft hull from is more complicated and expensive to build

- Machinery operation at low speeds can be uneconomic, because of low load of the main engines
- Machinery weight increases significantly

Fig. 2 presents the podded CRP concept principle:

- The rudder is replaced by a pulling type podded propulsion unit.
- The main propeller is typically driven by a diesel engine, 2-stroke without a reduction gear or 4-stroke with a reduction gear. Naturally the main propeller can be driven by an electric motor to implement full electric propulsion.
- Aft thruster is removed.

The vessel's electric generating capacity is upgraded to meet the electrical power demand.

### 4.2 Benefits of the podded CRP concept

Several areas are affected when the podded CRP concept is applied compared to standard mechanical propulsion solutions.

- Fuel economy
- Propulsion redundancy
- Maximum propulsion power capacity of a conventional single shaft hull form
- Maneuverability
- General arrangement of the machinery areas
- First cost
- Life cycle cost

The benefits are discussed below and more specific data can be found from the case study included in this paper.

#### 4.2.1 Fuel economy

Fuel economy is improved with the contra rotating propeller principle. Depending on the vessel type and
speed of the vessel the propulsion power demand can be reduced by approximately 5 to 15%. The total fuel economy depends also on the amount of maneuvering time and slow speed sailing of the vessel and therefore the improvement is not necessarily the direct impact from the reduced power requirement. In addition the possibility to use only the podded propulsion unit during slow-speed sailing improves fuel economy and decreases maintenance requirements of the main shaft line engines. The losses in the electrical power system from the generator to the propulsion motor are typically 8...10% and they will therefore be more than compensated with the total efficiency and flexibility of the system.

4.2.2 Propulsion redundancy
Propulsion redundancy is achieved with two independently operating propellers and a single failure in the propulsion power systems will not result in loss of maneuverability or operability. The required power of the podded propulsion unit can be set by a minimum speed achievable with only the pod in use. The power of the pod unit then gives sufficient speed for the vessel also in a “take-me-home” mode.

4.2.3 Maximum propulsion power capacity of a conventional single shaft hull form
A single shaft hull design can accommodate more propulsion power than with only a single propeller when the power can be divided to 2 propellers. This will be especially interesting for fast cargo vessels e.g. large container ships with more than 5,000 TEU. The limit of power produced by a single 2-stroke engine is forcing designers to apply twin shaft line ships and to change the single propeller hull form.

4.2.4 Maneuverability and dynamic positioning
Maneuverability of the vessel in naturally improved as the podded propulsion unit is free to rotate at maneuvering speeds around its vertical axis. Propeller thrust can directed to the desired direction and the power to achieve the required thrust is lower than what must be supplied to a tunnel thruster to achieve the same thrust. This is due to the larger propeller diameter of the pod and reduced hydrodynamic losses when comparing to the propeller in the aft thruster tunnel.

The use of dynamic positioning systems is common in the offshore industry in e.g. shuttle tankers during buoy loading operations. The use of a podded propulsion unit reduces both fuel consumption and maintenance costs of the main shaft line engines, which would be operating most of the time at very low loads.

4.2.5 General arrangement of the machinery areas
The minimum of additional machinery components required onboard with the podded CRP concept are a frequency converter and the podded propulsion unit with auxiliaries. Other components (generators, main switchboard, and transformers) already exist onboard, although upgrading is usually necessary to meet the requirements of the higher total installed electrical power.

The general arrangement of the vessel is not drastically changed when applying the podded CRP concept to a single shaft line vessel. Additional space is required for the machinery components mentioned above, however changes are small when comparing converting a single shaft line installation to a twin shaft line installation. The case study presented later will present an example of the space requirements.

4.2.6 First cost and installation cost
The first cost of the propulsion machinery is the major factor when shipyards make decisions on which propulsion alternative to choose. Another factor, which is more difficult to calculate accurately, is the installation cost and especially comparison of the installation cost of different concepts, such as electric vs. mechanical of shaft line vs. podded propulsion. The items, which a shipyard has to study in addition to the purchase cost, are costs resulting from the purchasing, designing and manufacturing processes. Also the total building time of the vessel will affect the full cost to the shipyard.

4.2.7 Life cycle cost
The decision criteria of ship owners evaluating new building alternatives are increasingly shifting from first cost evaluation to life cycle cost (LCC) evaluation. The LCC consists of the capital cost, operating cost and resale or scrapping value of the vessel.

Capital costs are directly proportional to first cost. Fuel, maintenance, manning and tug costs are other operating costs of which fuel and tug costs are the most potential sources for savings in the podded CRP concept. Tug assistance requirements vary from port to port and are therefore difficult to estimate. The maneuverability of the podded CRP vessel makes tug assistance from the maneuvering performance point of view unnecessary in almost all conditions. Tug costs can be a major cost and should be included in the LCC.
4.3 Hydrodynamic aspects
Design criteria for optimizing the propellers of the podded propulsion unit can be:

- Booster power at high speeds
- Maximum power available also when main propeller is not in operation
- Dynamic positioning mode

Design of the fixed pitch propeller is optimized according to the set requirements. The characteristics of the electric variable speed drive give good dynamic response to propeller speed commands at all ship speeds even when the propeller is optimized for higher speeds.

The detail design of the propellers and the pod are optimized in model tests to assure best performance and also to avoid harmful cavitation.

4.4 Upgrading the auxiliary power plant
The additional required power of the auxiliary power plant will be small in vessels with an existing high auxiliary load when not using propulsion (shuttle tankers, chemical and product tankers). A larger power increase is required in vessels with a small auxiliary power requirement or a simultaneous high auxiliary power and propulsion power requirement (reefers). The required power can be achieved by installing larger generators sets and/or applying an additional primary shaft generator to the main engine. A shaft generator can be used increase the load on the main engine when the vessel is slow steaming and the maximum power is not used in the main propeller.

4.5 Environmental requirements
In certain geographical areas (e.g. U.S West Coast and Alaska, Baltic Sea, port areas) strict limits for exhaust gas emission levels are already implemented or can be expected in the near future. Meeting the strictest requirements requires either the use of special measures in diesel engine plants using HFO e.g. SCR (Selective Catalytic Converter) systems or using a higher grade fuel and even gas turbines.

4.6 Safety of navigation
Safety of navigation is a result of the performance of the vessel's crew and functioning of the technical systems. The machinery systems are to be designed for reliable operation minimizing the risk of operator failures. Redundancy is often required to tolerate failures and maintain the capability of safe operations.

4.7 Flexibility in the building process
When a shipyard is studying the podded propulsion system alternative, all processes affected by the new building method should be studied. There are multiple areas where the benefits of the podded propulsion concept, flexibility and modularity, can be maximized. One of the challenges is to estimate how much effect the modified building method has on other than direct purchase and installation cost.

Some of these indirect costs are:

- Cost of the total purchasing process of shaft lines and related equipment, including factory acceptance tests and negotiations.
- Cost of design of the propulsion machinery
- Cost of logistics, storage and handling of the equipment at the shipyard

After analyzing the whole chain of the shipyard processes related to delivering the vessel to the owner the real cost comparisons can be made. Naturally a reliable calculation can be made by the shipyard itself.

4.7.1 Challenges to the shipyard and shipowner
The challenges the shipyard and the ship operator are facing when using the CRP podded concept are same as with electric propulsion systems in general. New tasks for the ship owner are training of the staff and crew to the new systems as well as familiarizing them with the maintenance and day to day operations. The shipyard must adapt the current design and building processes to the new concept to be able to utilize the advantages in full.

4.8 Case study of a fast RoPax vessel
A case study was made to evaluate the economical and technical effect of applying the podded CRP concept. As the base case a vessel with the following characteristics was selected:

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4.8.1 RoPax vessel machinery arrangement with a twin shaftline
The base case has a machinery consisting of two shaft
lines, with two medium speed diesel engines each, driving CP-propellers through a reduction gear. A shaft generator is connected to each gearbox.

The auxiliary machinery consists of three medium speed diesel generator sets.

The vessel is also equipped with two forward bow thrusters and one stern thruster.

The machinery concept with power levels is shown in Fig. 3.

4.8.2 RoPax vessel with the podded CRP concept

The base case is compared with a vessel having the same main dimensions and the following machinery:

Two medium speed diesel engines drive one CP-propeller through reduction gear. Auxiliary power is generated by three medium speed diesel generator sets. This power is also used to drive the single Azipod unit located behind the main propeller. Due to the pod, the stern thruster has been removed. The bow thrusters are the same as in the base case.

The machinery concept with power levels is shown in Fig. 4.

The comparison was made for a vessel operating in the Baltic on the route between Helsinki and Rostock, a route that includes both full speed operation in the open sea as well as maneuvering in narrow channels and in the harbors. The selected service speed gave the ship a roundtrip time of 48 hours.

The study focused on determining the required passenger ticket rate, when the freight rates were considered the same for each alternative.

Experience from earlier CRP tests and theoretical studies conclude that the single shaftline CRP Azipod arrangement requires 10-15% less power to achieve the same speed as the fully mechanical twin shaftline CP-propeller configuration. On this specific route, the annual fuel saving, taking into account the different power transmission efficiencies is 12%, giving an annual fuel cost saving of $1 million in favor of the CRP Azipod alternative.

When comparing the shipyard construction costs of the two alternatives, it could be seen that the CRP Azipod option is 2% (2 MUSD) more expensive which converts into an annual additional cost of approximately $150,000. This comparison takes into account the cost of procuring the individual components as well as the installation costs of the whole system.
The final outcome of this study was that the CRP Azipod alternative required a 4.5% lower ticket rate that the mechanical twin shaftline alternative.

In addition to this clear economical advantage, the study identified the following advantages:

- The machinery weight was reduced by 6.5%.
- Nitrogen oxide (NOx) emissions were reduced by 12%.
- Sulfur oxide (SOx) emissions were also reduced by 12%.
- CO₂ emissions were 12% less than conventional ship.
- The maneuverability of the vessel was improved.

5 CONCLUSIONS

Recent experiences with the diesel-electric power plant concept combined with the Azipod propulsion system have proven the concept to be an attractive solution for various types of vessels. The improved total efficiency, enhanced maneuverability, redundancy, simplicity and proven reliability of the design, can be utilized in various ship projects. The suitability of the concept for cruise ships is obvious, which the successful sea-trials of the M/S Elation prove. Other ship types such as RO-RO vessels and offshore supply and support vessels are a potential market as well as all other typically dynamic positioning ships.

The feasibility analysis for a new project should always be carried out together with the shipbuilder. The Azipod propulsion concept changes not only the way ships can be designed and operated but also how they are built.

The above summarized concept study clearly showed that the Contra Rotating Azipod concept was the most feasible solution, providing a more capable vessel at a lower total cost. The concept clearly shows high potential for a variety of vessels and operation profiles. The success of the concept naturally requires experience of different installations and thorough studies and testing of areas such as hydrodynamics, electrical network configuration and development of building processes from the shipyard point of view. As in all new technical concepts and innovations in the shipbuilding market, shipowners and shipyards must accept and see the benefits to be ready to implement them.

References