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Maritime technology

Kuituniemi, Santtu

INSTALLATION, COMMISSIONING AND TROUBLE SHOOTING OF VARIABLE FREQUENCY DRIVE

TIIVISTELMÄ

KYMENLAAKSON AMMATTIKORKEAKOULU
Merenkulun koulutusohjelma

Kuituniemi, Santtu	Taajuusmuuttajan asennus, käyttöönotto ja ongelmat
Opinnäytetyö	28 sivua + 2779 liitesivua
Työn ohjaaja	Lehtori Ari Helle
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Avainsanat	taajuusmuuttaja, käyttöönotto, polttoaine-kulutus.

Opinnäytetyössä käydään lyhyesti läpi taajuusmuuttajan (Variable Frequency Drive) asennusta laivakäyttöön.

Kyseessä on jälkikäteen alukselle asennettava laite, minkä vuoksi joudutaan tekemään myös jonkin verran muutostöitä. Nämä muutostyöt tehtiin pää-asiassa telakassa keväällä 2012 ja lyhyellä ylösmakuuajalla alkukesällä 2012. Itse laitteiston testaus ja luokitus tapahtui ylösmakuuajan jälkeisellä koeajolla.

Opinnäytetyössä kerrotaan myös asennuksen aikaisista sekä ajon aikana ilmenneistä ongelmista sekä niiden ratkaisuista.

Opinnäytetyössä on myös pienimuotoinen laskelma asennetun laitteiston tuomasta hyödystä. Toisin sanoen on laskettu, kuinka paljonko kyseinen laite säästää aluksen linjalla polttoainetta ja paljonko siitä sitä kautta kertyy säästöä.

ABSTRACT

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Kuituniemi, Santtu	Installation, Commissioning and Trouble shooting of VFD
Bachelor’s Thesis	28 pages + 2779 pages of appendices
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Key words	variable frequency drive, commissioning, fuel consumption reduction

In this thesis, the installation of variable frequency drive on board a ship is introduced briefly.

In this particular study the variable frequency drive was retro-fitted to the ship and it also required that some alternation work was performed on board. The alternation work was mainly performed as part of dry docking in spring 2012 and was finished in spring-summer 2012, in short lay-up period. The testing and classification procedure of the variable frequency drive was done during this lay-up period and also in sea trial after the lay-up.

Also the problems that occurred during installation, commencing and in operation are elaborated and suggestions to address these problems are presented.

Cost save calculation regarding reduced fuel consumption in the ship’s current route is also included in this thesis.

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1. INTRODUCTION

M/s Bore Sea is one of the latest new buildings for the Bore Ltd fleet consisting in total of 16 vessels.

Before current charterer the Bore Sea has traded mostly between Zeebrügge, Belgium, and Bilbao, Spain. It has had also brief charters from Continent to Russia, Scandinavia to Continent/UK and served for quick replacement of her sister vessel, M/s Bore Song, in Zeebrügge Teesport, UK, route. Now the vessel has a long contract for trade from western France to Mediterranean.

I have worked on board the Bore Sea for approximately one year as a 1st Engineer. I chose this topic for my thesis because I have worked with the equipment, and these kinds of conversions are likely to be performed on other vessels of the company. One of the main reasons is also that lowering fuel consumption in the future will be more common than in near past. This is due to more expensive fuel and tightening emission regulations, for example in the Baltic Sea and in the North Sea and English Channel.

By installing new technology, such as variable frequency drive, on already existing vessels it is possible to expand the service life of the vessel considerably. Variable frequency drive is not the only solution, for example, Stena Line Ab has installed two wind turbines on M/s Stena Jutlandica to reduce auxiliary engine fuel consumption on their Gothenburg- Fredrikshaven- route (Stena Line Group AB). Also, another Swedish company, Wallenius Lines, has developed a prototype of an almost zero emission car carrier (Wallenius Lines AB).

Figure 1. M/S Bore Sea. (Kenneth Karsten)

2. SHIP'S SPECIFICATION

M/s Bore Sea (Figure 1) is a modern Roll on-Roll off (Ro-Ro) - type ship built in Germany, Flensburg. The ship was completed in 2011 and it is built to meet Finnish/Swedish ice class 1A requirements for year-around operation to Scandinavian ports. The ship is 195.4 meters long, 26.2 meters wide and has maximum draft of 7.4 meters. The gross tonnage is 25 586 t, net tonnage is 7 675 t and dead weight is 13 625 t. It has approximately 2863 lane meters and it can load double stack mafis on all of the three decks. The main deck is equipped with two hoistable car decks and lower hold with one hoistable car deck to improve ship's flexibility between different types of cargo.

Propulsion power is created with one 12 000kW non-reversible four-stroke medium speed main engine, type 12V46 CR made by Wärtsilä. The engine uses a new, revolutionary in marine segment, type of fuel injection system for shipping, the common rail. The engine is coupled to the propeller shaft via gear box manufactured by Siemens, formerly known as Flender. The ship is also equipped with a controllable pitch propeller manufactured by KaMeWa, which is coupled to a relatively slow rotating propeller shaft with only 106 RPM. Low shaft RPM is designed to eliminate vibrations and to improve overall efficiency of the propeller by reducing cavitation in the propeller blades. Also, the twist flow rudder is optimized for low water flow resistance. The rudder is also equipped with costa bulb, as shown in figure 2, to reduce cavitation between the propeller and the rudder and to reduce drag created by the rudder

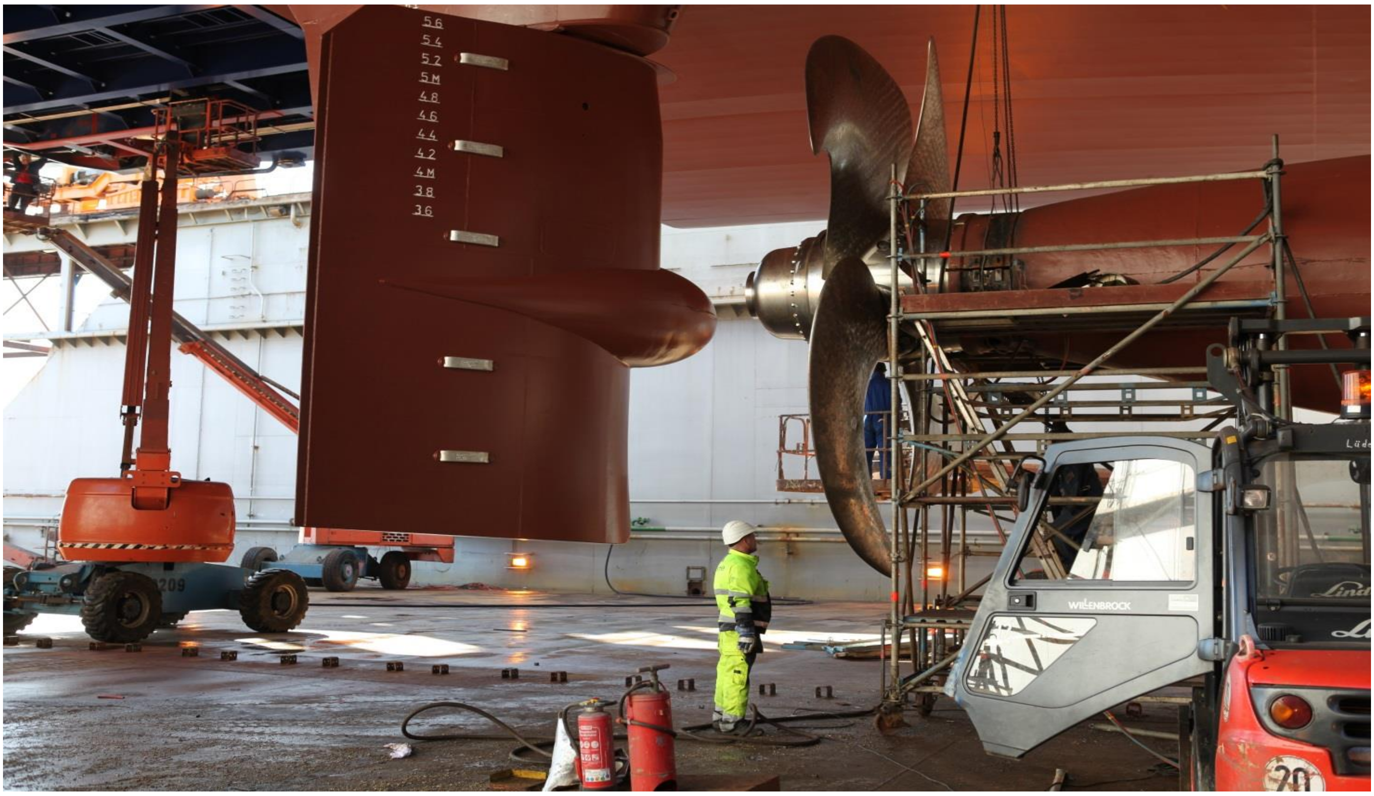

Figure 2. Propeller, propeller hub and rudder. (Kenneth Karsten)

The ship is equipped with two auxiliary engines, made by Mitsubishi, with 1 270kW each coupled to generators with electrical power of 1 500kVA each. The shaft generator of the ship has electrical power of 3 750kVA. For smooth manoeuvrability in ports, the ship is equipped with 1800kW bow thruster and with 900kW aft thruster.

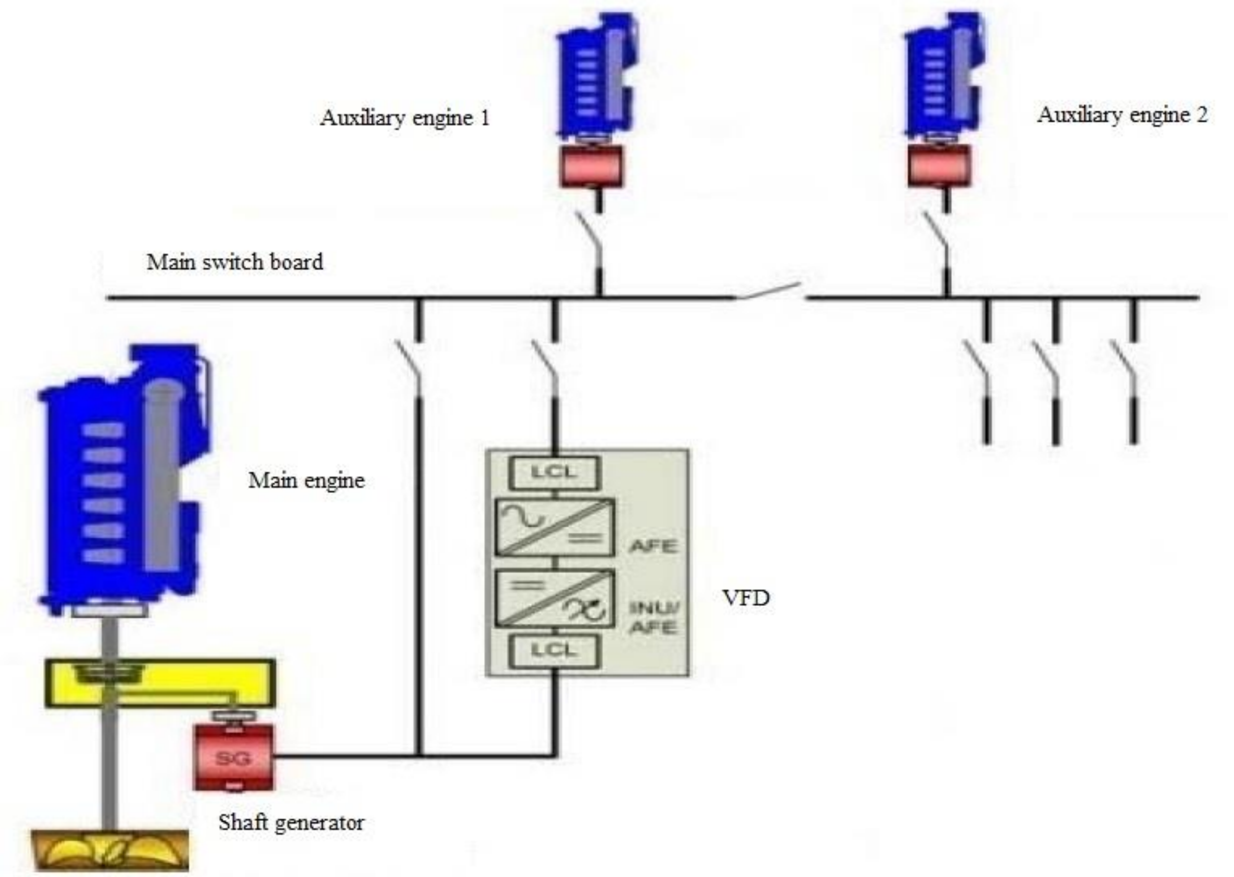

Figure 3. Ship's power distribution principle chart (Juha Niskanen)

The Lloyd's Register has granted the ship with "Green passport" as environmentally friendly ship. This means that the ship is also equipped with the most advanced ballast water treatment system.

The ship can also accommodate 12 drivers or special persons as passengers along with the crew itself.

3. BACKGROUND

Installing the variable frequency drive (VFD) on board became topic when the vessel was starting with new charterer on a totally different kind of route than the vessel was designed for. The vessel is designed for voyages with average speed of 17-19 knots with high cargo average and quick turnaround time in ports. The new voyages are designed for average speed of 11-16 knots in almost full ballast water conditions.

The VFD was planned to save large quantities of fuel due to lower consumption in the new charterer’s routes, thus saving large sums of money, and lowering the sailing pace even more. Also, it protects the equipment on board due to lower vibration level caused by the main engine (ME) and propeller enabling larger pitch angle to the propeller and lower revolutions to the ME. Due lower revolutions, the ME can run more effectively.

The vibration in constant revolutions is mainly caused by ME running in constant revolutions combined with small angle of propeller. In small angles, the propeller does not deliver the whole thrust created by the ME to aft wards, instead it delivers it also upwards to the hull, making it shake and vibrate. The reason not to deliver all the thrust aftward is that the power request is so low that the propeller has to mislay the unrequired thrust elsewhere so the ship would not consume more power than requested. In VFD equipped ships the thrust is constantly directed aftward courtesy by variable revolutions in the ME. Principally, at constant revolutions the power is pending to propeller angle and at variable revolutions the power is pending to ME revolutions.

4. VFD

In this chapter, the operation and the function of the VFD are briefly introduced and shown in figure 4.

The purpose of the VFD is to convert incoming alternating current (AC) from shaft generator at first is to a direct current (DC) and then again to alternating current, which will correspond to the desired frequency of main switch board, in this case 60Hz.

The conversion from AC to DC is done by AC rectifier. This is done by diodes. One diode is letting through currency in positive half period and second one in negative half period. Therefore, to rectify one phase there have to be at least two diodes, so called diode bridge. For the rectification of threephase electricity there have to be at least six diode bridges, pending on the installation there can be 12, 18 or 24 diode bridges.

AC rectifier is followed by intermediate circuit. Current from the AC rectifier is stored to large condensator, which act slightly similar to accumulators. The condensators also stabilize the DC voltage. DC voltage is fed from the condensators to DC inverters. There are also restrictors in the intermediate circuit. The purpose of the intermediate circuit is to create capacitance to the circuit and maintain steady DC voltage in the system.

DC inverters converts DC voltage fed from the intermediate circuit back to AC voltage. This is done by insulated gate bipolar transistors (IGBT). The IGBT is used because it has many advisable qualities. It with stands high currency and voltage and it has relatively small voltage and power loss, which aids to keep the IGBT cooler. This transistor is also easy to control and it can be opened and closed thousands of times in seconds, which assists to create AC voltage and sine wave. The sine wave that the VFD unit produces is not harmonic sine wave, it has little bit coarse edges that normal sine wave. It is impossible to create harmonic sine wave with VFD unit. Most of the electrical equipment can use to sine wave and voltage created by DC inverters.

Control circuit super vices, controls and communicates between different units. The most important task is to up keep the amount of energy fed from the intermediate circuit when generator speed and load changes. By performing this, the voltage and frequency will be constant. It also measures and relays all essential information.

Compared to conventional system, where the electricity is made with shaft generator (SG), the SG must have same constant revolutions to generate desired frequency. Hypothetically, for example, to produce 50Hz electricity to main switch board, the main engine having to have 500rpm, so the SG could develop 1275rpm from gear box secondary power take out shaft. In VFD installation, the ME and SG rpm can be variable for the reason that the VFD converts the incoming frequency to 50Hz.

With VFD, the largest saves are made when the ship is steaming slowly, VFD affects the full speed consumption only slightly.

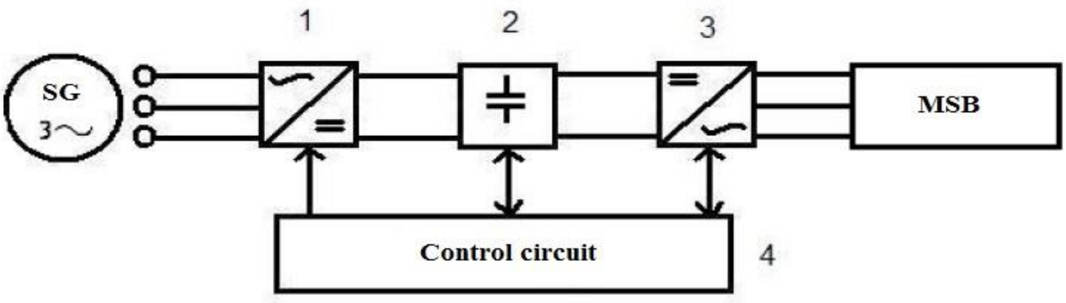

Figure 4. VFD principle chart (Juha Niskanen)

1. AC rectifier 2. Intermediate circuit 3. DC inverter 4. Control circuit

5. INSTALLATION

5.1. Planning the conversion

In this project, the electrical power consumption was measured and evaluated on board the ship as well as at the offices. The normal power consumption on board is approximately 385kW during normal sailing, summer time, without reefer container sockets which has the maximum power consumption of 50 x 11kW. This has been planned for the cargo hold fire extinguishing systems main pumps, drencher pumps, 2 x 190kW, and the reefer container sockets will be blocked for operation when the VFD is producing the electrical power. This means that if the ship is carrying cargo of reefer containers or if there is fire in the cargo holds, the VFD has to be disconnected first. The VFD-mode does not affect the conventional fire pump, emergency fire pump, water mist fire extinguishing pump for engine room or CO2 extinguishing systems.

In this ship, it is possible to drive the bow tunnel thruster with electrical power produced by the SG or by the ships auxiliary engines. When the VFD is installed the operation of bow tunnel thruster is blocked together with operation of stern tunnel thruster. This is caused by the VFD’s smaller capacity compared with SG or auxiliary engines. The auxiliary engine generators produce 1200kW each, the SG 3000kW and the VFD unit produces only 648kW, so the possibility to overload the VFD is eliminated to protect the electrical equipment on board. Use of the ballast water pumps at sea is also restricted, in normal conditions, to one pump only, to avoid overloading the VFD unit.

Figure 5. Dry dock at Bremerhaven. (Kenneth Karsten)

5.2. Spring 2012

The installation was started 14 March 2012 in Lloyd Weft dry dock in Bremerhaven, Germany. It was planned to last for 12 days and in this time frame it was planned to install the VFD cabinet, do all the cabling works, carry out the test drive and adjust the VFD-unit.

The cabling works included pulling two sets of cables between main switch board (MSB) and the VFD unit. The first set of cables is for VFD unit incoming frequency and the second set is for frequency treated by the VFD unit to MSB. Also modification in MSB to place in dry dock, it needed to fit one extra retractable breaker only for VFD. Also a breaker control panel was fitted to MSB, as shown in figure 6. The new cables utilize the existing cable trays and also lead-in opening of the ship. The pulling of the cables underneath engine control room was made easier by leading them through an existing manhole in side of the engine control room. This made access to the middle space definitely easier and helped greatly the process.

Figure 6. Retractable breaker and breaker control panel

The cabinet, with all electronic equipment inside, found a way to the engine room from extra opening made to the main deck. The initial plan was to slip the unit to engine room trough the existing engine room hatch, but it turned out to be slightly too small to fit the cabinet. The cabinet was placed at aft end of engine room top level, as shown in figure 7. It is the only place where it could be fitted due to the cabinet size, approximately 2.1m x 2.8m x 0.6m.

Due to some mishaps, the testing, adjusting and commissioning of the VFD-unit was not finished in the dry dock period.

Figure 7. VFD unit cabinet.

5.3. Late spring 2012

During lay-up time in Nantes, France, in late spring 2012, the rest of the work was carried out. At first, a soft starter was installed for general service pump (GS-pump) which can act as a back-up fire pump or as a bilge pump. The initial plan was that electrical power would be also blocked to the GS-pump when sailing with VFD-mode. In worst case scenario calculations, when using the maximum power produced by the VFD-unit, a start current needed by GS-pump could be enough to make the VFD-unit to trip, causing a black out to the ship. Soft starter reduces the current used by GS-pump electrical motor by starting the motor at first in “star”- type electrical connection and shifting to a “triangle”- type connection after approximately 10 seconds. If the motor was started immediately in “triangle”- connection, the starting current would be noticeable higher. The soft starter cabinet needed also a place to be and it was designed to be fitted on the wall next to the original starter cabinet. Due wrong size cable delivered by unit providing company, the ship crew had to make a place for the cabinet next to the GS-pump so that the old cables could be reused to connect the new starter and electrical motor.

Figure 7. GS pump and soft starter

When all the paper work was approved by the ship's classification society Lloyd's Register (LR) the new cables between VFD-unit and MSB could be connected. This work required that the MSB be separated on two independent sides. One side would provide electricity to the consumers and the other would be out of power so the cables could be connected. It is a safety measure to always connect all cables with power switched off. This partial blackout lasted in total 19 hours in two different periods in two days. The crew of the ship had to be flexible during this period of time, for example the galley and the sauna was out of electrical power.

After the cables were connected, it was time for system test. The first test was to test the function of the GS-pump and the new soft starter. There was no problem commissioning the soft starter, it worked as planned. In the test the GS-pump starting current was measured with clamp ampere meter and it did not exceed the limit value.

The second phase was to produce electricity with the VFD-unit when ME is running at constant RPM. The VFD-unit stayed connected to the MSB and produced electricity and this was succeeded only after five blackouts. There were multiple communication errors in the connection between VFD-unit and the alarm and supervising system SAM and also some synchronizing problems in SAM itself. It took two days to establish the communication working between SAM and the VFD-unit before we could produce electricity with VFD-unit with reduced RPM in ME. It was not only the communication errors, there were also some internal troubles in the VFD-unit itself caused by the design of the unit. It is not designed for maritime use but it can be converted to work on board a ship. Therefore configuration took some time and it was not always clear what is causing the upcoming problems, SAM or the VFD-unit. Due that, the commissioning of the VFD-unit took quite a long time.

One specific item that needed special adjustment was automatic synchronizing. The first step was to adjust the system, that synchronizing of the VFD to the MSB is only possible when SG is producing electricity. This means that it is not possible to synchronize VFD on when the auxiliary engines are connected to the MSB. For the VFD a special synchronization button block was created on the alarm system. At first it was possible to synchronize from VFD back to SG when the ME was running at constant RPM. This kind of act will cause synchronization fail alarm because the SG frequency is so low, or black out. This matter was corrected by pulling a signal cable from

KaMeWa-cabinet to indicate the alarm system when the ME is running in constant RPM. The system blocks every attempt to synchronize VFD back to SG if there is no constant RPM signal.

Figure 8. Main engine room. (Kenneth Karsten)

One of the crucial tests was to simulate blackout and load reduction on main propulsion machinery. The main propulsion machinery consists of all related machinery, main engine, gear box and the controllable pitch propeller and the machinery related for it.

One of the last tests was to make sure that the power distribution blackouts work. It is a simple test, only try to start the equipment from local control cabinets and see if it starts or not. The test was carried out for both drencher pumps and the reefer sockets and it was passed, in the end.

One problem was spotted already at the start of the testing when the voltage regulator on SG could not sustain with descending voltage. The voltage droop is caused by reduced RPM in the SG. The current regulator was not designed for VFD use, therefore a new different type voltage regulator for the SG had to be purchase. It was installed successfully in March 2013.

6. TEST DRIVE

After six days of work, it was time to go for sea trials. Mostly, this was a functional test of the equipment installed. Also minor adjustments were made during the test drive, such as fine tuning the synchronizing time. Almost every test that was performed in port was tested again to see that the equipment will work as should also in practice under normal sea going circumstances. The only exception was that blackout test was not performed during the test drive. The reason for this was that it is always a great risk testing blackout at sea and it may damage applications not related to the test. The classification society attended the test drive and in the end approved the system for normal use.

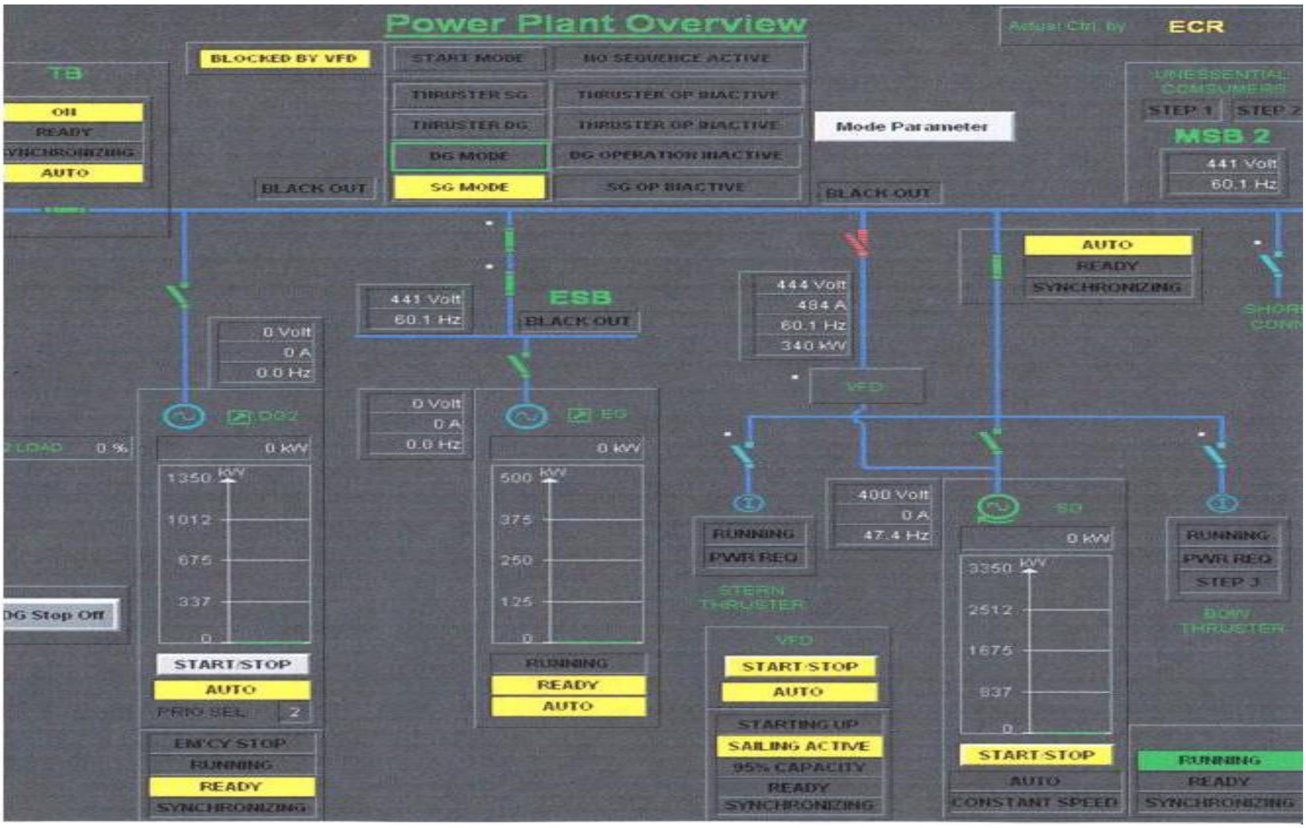

Figure 9. Power management system.

7. CLASSIFICATION

All plans have to be examined to meet Control and Electrical Engineering Requirements rules as stated in Part 6, Chapters 1 and 2 of classification society rules. Chapter 1 gives rules for essential features of control, alarm and safety systems as well for unattended machinery spaces, integrated computer control and centralised control station for machinery operation. Chapter 2 defines requirements for electrical side of the installation.

The cabling and wiring needs to be arranged so that they will comply with LR rules Part 6, Chapter 7.15 and 10. This means that all wiring needs to be insulated, flame resistant and also all required national standards have to be met. Chapter 10 defines requirements for electric cable type and performance capabilities of the cables, for example operating temperature, current ratings in normal operation and in short-circuit, cable current rating correction factors and installation guidelines, such as bending radiuses and mechanical protection and attachment of the cable.

Classification society also defines a short circuit ampere level for the installation. This calculation is defined in classification society rules Part 6, Chapter 2, Section 6.2. The currency is defined when full rated load currency is multiplied by ten.

Arranging alarms to current alarm system is done as presented in Part 6, Chapter 1, Sections 2.3.8. and 2.3.4. This means that common alarm will be shown in alarm system and an audible and visual alarm must be activated when a fault occurs, in this case in VFD. Section 2.3.8. also defines that when an alarm has been acknowledged and a second fault occurs before the first one is corrected, an audible and visual alarm must be activated again.

8. PROBLEMS DURING OPERATION

As it often is, at first several problems occurred. The first problem occurred in the galley. The modern high tech oven did not withstand the electricity produced by VFD and every time the chief cook wanted to use the oven, the electricity had to be produce conventionally by using constant RPM in the ME and in SG. After several weeks of e-mail conversation with the manufacturer of the oven, the fault was pin pointed to the oven’s fan that needed to be changed to new type which would withstand a slightly lower voltage and unharmonic sine wave produced by the VFD.

Second, almost a similar problem occurred in the ship’s sewage treatment unit. There is a three-stage sewage treatment plant with two vacuum pumps and three transfer pumps. The third transfer pump delivery is controlled also by VFD, but in this case the unit works in reverse order compared to the VFD unit that was recently installed on board. The function of this VFD is to reduce the production of the pump and control pump rotating speed by controlling the pump’s RPM. The fault was corrected by purchasing a new, slightly different type of VFD for the transfer pump which would not be so sensitive concerning the quality of the electricity.

Another, slightly more serious problem occurred with the VFD. The unit itself started to increase internal temperature when sailing under normal conditions. Filters were removed at first from the cabinet doors to divert more fresh air to internal cooling fans. This failed to give the desired cooling power to the unit, so the second solution, not the safest, was only to open the VFD unit’s doors so that air could flow through the unit without any obstructions. This action cooled down the unit as much as needed for normal operation, enabling to produce the electricity with VFD again at sea. The supplier of the unit was contacted regarding the heat issue and they suggested that the roof of the unit should be raised by 10 centimetres from only one end to allow better air flow out of the unit. The requested improvement was carried out, without any significant improvement in the air flow. This implicated that we had to continue operation of the VFD with open unit doors, as shown in figure 10.

Figure 10. Temporary air flow aid to the VFD- unit.

The next solution was to change the roof to another type which would be higher than the present one. The new roof is approximately 10 centimetres higher than the old roof. The new roof is also fitted with larger ventilation openings, than the old roof type. After three weeks of driving with VDF unit doors open, the new roof arrived on board. It was installed immediately and at the same time the supplier installed a few heat deflection shields inside the VFD unit to divert hot air to flow more efficiently out from the cabinet. The application failed to direct the air flow through the unit as desired and the unit heated up as before the modification.

At the same time, the ship had some issues with salt entering the engine room and a solution for the unit ventilation had to be created quickly. At first the crew constructed a suction filter stands and platforms for every three main engine room fans. The construction of the filters was not so straight forward. The suction side of the fan situated approximately 2.5 meters above floor level. This meant that crew had to construct also ladders and platform to the fan ducts to make safe environment for fan filter changing. This action reduced the amount of salt entering main engine room considerably, almost to zero.

The next step was to install an air duct branch leading from one of main engine room fan ducts and lead air through an independent fine filter to the VFD unit. The new duct entered the VFD unit cabinet underneath it. This meant that a specific fan has to be constantly running when producing electricity with the VFD. The air duct required holes with the diameter of 160 millimetres underneath every section of the cabinet, totalling four holes. These holes were made by a subcontractor of the supplier during ordinary port stay in St.Nazaire in July 2012. At the same time, the heat deflection shields were also changed to a thicker type, which should not bend so easily in hot environment.

Making those penetrations was somewhat troublesome. Machining through the ship's floor structure was the first piece of work followed by machining through the unit floor. The unit is constructed out of four different cabinets. Two out of four cabinets has an electronic component only approximately 2 centimetres above the cabinet floor, which made the work slightly difficult. The subcontractor borrowed ship's magnetic stand drill to speed up the work and to reduce the risk of damaging the electronic components. The duct itself was built by the ship's own crew during voyage

Figure 11. New cooling air filter.

Figure 12. New cooling air duct lines.

The solution has proven functional and there has been no cooling trouble with the unit since the air duct was installed. The duct is also approved and classified by LR.

After the cooling problem had been sorted out successfully, the VFD produced electricity, for some four months, all the time at sea without any troubles. The only nuisance since the installation of the VFD has been that SAM is giving a breaker alarm almost every time when synchronizing the VFD. The alarm does not cause any real danger, as the circuit breaker itself has its own internal protection system against fault situations. It is only that alarm system does not relay any alarms to alarm system from the VFD breaker during voyages because there is already alarm activated in the alarm system. It is really frustrating to have always one alarm in the alarm panel. The fault has been pinpointed to the alarm system and it will be corrected next time when a serviceman from SAM comes on board.

At the beginning of 2013, the KaMeWa system software was updated. This meant that the new software needed to be tested. When the testing was engaged, it was noticed that the alarm system automation did not start and synchronize AE to produce electricity to MSB, when having a load reduction alarm from the gear box. This even eventually led to a black out. This matter is still under investigation, so no further details can be given regarding the fault.

An internal cooling fan failure was also suffered in late spring 2013. The cooling fan was situated in one of the control unit and was changed by manufacturers service engineer. Second cooling fan suffered also a break down in mid-summer 2013, this time the fan could be changed by the ship's crew.

9. BENEFIT CALCULATION

This is only a rough calculation of the saves in the use of heavy fuel oil that the VFD creates.

This consumption test was conducted in summer in 2012. Sailing with SG- mode in calm sea condition with speed of approximately 12 knots the ME consumed approximately 0.885 m³ per hour. By doing the same sailing with VFD in same sea conditions the consumption of the ME reduced to roughly 0.725m³ per hour with average speed of 12.1 knots. The amount of fuel that is saved by the VFD compared to SG-mode is calculated by following formula.

$$SF_{vol} = (24 * C_{SG}) - (24 * C_{VFD})$$

SF_{vol}= amount of fuel saved in volume

C_{SG}= hourly consumption in SG- mode

C_{VFD}= hourly consumption in VFD- mode

$$SF_{vol} = (24 * 0.885\text{m}^3/\text{hour}) - (24 * 0.725\text{m}^3/\text{hour}) = 3.84\text{m}^3/24 \text{ hour}$$

The determination of the heavy fuel oil (HFO) price is done by weight. In order to determine cost saves created by VFD, the volume of saved fuel has to be converted to weight. The density of the HFO at 15ºC is 0.991, so one cubic meter of HFO weights 0.991 ton.

$$SF_{ton} = SF_{vol} * D_{HFO}$$

SF_{ton}= amount of fuel saved in tons

D_{HFO}= density of HFO at 15ºC

SF_{ton}=3.84m³/24hour*0.991ton/cubic=3.80544ton/24hour

The IFO380 HFO price 21 May 2013 was 586.5€/ton in Rotterdam (Petromedia Group Ltd).

$$SM_D = SF_{ton} * P_{HFO}$$

SM_D= saved money in 24 hours

P_{HFO}= price of HFO

SM_D=3.80544ton/24hour *586.5€/ton=2 231.89056€/24hour

Saves in one year.

$$SM_Y = SM_D * 365day$$

SM_Y= saved money in one year

SM_D =2 231.89056€/24hour *365=814 640.0544€/year

These saves can be only achieved when the ship is sailing around the year, which is of course impossible. Also, the price of the HFO can alternate greatly effecting to the final profit calculation. Another approach to this subject is to calculate the time that it takes to pay back the investment for the equipment. In this calculation the assumed cost of the equipment would be approximately 375 000€.

$$PB = I/SM_D$$

PB= payback time of the investment

I= assumed cost of the equipment

PB=375 000€/2 231.89056€/day=168days

It is safe to say that the VFD begins to make profit after eight months of sailing at the speed of 12 knots with the VFD.

CONCLUSION

Despite the problems that occurred, this retrofit has improved the ship's fuel efficiency significantly in current route. All upcoming problems cannot be predict, but for future conversions, it would be good to focus more in planning of the conversion and not to believe everything that salesman promises. Especially the ventilation of the VFD unit requires more attention in the future, if the unit is to be installed in the engine room and has an internal air cooling. Also, when commissioning the equipment in test drive it would be advisable to have all parties present at all time to solve problems that may occur. Every ship will have different problems after the test run, pending on the installation, ship's age and construction type. It is almost impossible to anticipate all difficulties that VFD- unit could cause. One way to prevent electrical difficulties is simply to ask, if possible, the ship's electrician to check equipment on board for VFD compatibility.

SOURCES

Lloyd’s Register Group Limited. 2010. General information for the rules and regulations for the classification of ships.

Niskanen, Juha, Electrician, M/S Bore Sea.

Petromedia Group Ltd. http://www.bunkerworld.com/prices/ [referred 21 May 2013].

Stena Line Group AB. http://www.stenaline.com/en/stena-line/corporate/media/press-releases/wind-power-onboard-a-ferry/ [referred 24 April 2013].

Wallenius Lines AB. http://www.walleniuslines.com/Environment/Strategy/ZERO---Zero-Emission-Roro/The-background---ES-ORCELLE/ [referred 24 April 2013].

APPENDICES

Lloyd’s Register Group Limited. 2010. General information for the rules and regulations for the classification of ships.