LAPPEENRANTA
UNIVERSITY OF TECHNOLOGY

Department of Electrical Engineering

MASTER'S THESIS

Upgrading of the third generation of the Remote Diagnostic Systems for ABB Marine Propulsion Systems

The topic of the Master's Thesis has been approved by the Departmental Council of the Department of Electrical Engineering on the 8th of March 2007.

The supervisor at ABB, Petri O Koskinen
The first examiner, Professor, D.Sc. Juha Pyrhönen
The second examiner, D.Sc. Lasse Laurila

Lappeenranta 06.06.2007

Natalia Sekacheva
Karankokatu 4 C1
53850 Lappeenranta
Finland

ABSTRACT

Author: Natalia Sekacheva

Title: Upgrading of the third generation of the Remote Diagnostic Systems for ABB Marine Propulsion Systems

Department: Electrical Engineering

Year: 2007

Place: Lappeenranta

Thesis for the Degree of Master of Science in Technology.

75 pages, 48 figures, 4 table and 2 appendices.

Examiners: Professor, D.Sc. Juha Pyrhönen, D.Sc. Lasse Laurila

Keywords: Remote diagnostics, propulsion system, Propulsion Condition Management System, PCMS.

Remote diagnostics has become very popular in marine industry. Diagnostic systems are improved all the time and the newest monitoring systems are constantly taken into operation. Most vessels are, however, rigged up by outmoded facilities, which should be updated.

In this work the principles of operating of such a remote diagnostic system as the ABB's third generation remote diagnostic system (RDS) and the newest Propulsion Condition Management System (PCMS) are studied. As a result of the thesis the ways of upgrading the old systems of RDS are presented. Specifically, the work focuses on the establishment of the connection between Advant controller AC-110 from the old system and PCMS server, and in other words how to get Modbus data by OPC server.

ACKNOWLEDGEMENTS

This master's thesis was carried out at ABB Oy, Helsinki. I would like to thank the Vice President in Supports and Services of ABB Marine, Pekko Herola for giving me an opportunity to write my thesis for his company, and my supervisor Petri O Koskinen for his guidance.

Also I want to thank my professors and supervisors from Lappeenranta University of Technology Juha Pyrhönen and Lasse Laurila.

My special thanks to Julia Vauterin for her help during my study.

And of course my deepest gratitude to my parents, relatives and best friends.

Lappeenranta, Finland, June 2007

Natalia Sekacheva

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ABBREVIATIONS AND SYMBOLS

Abbreviations

AC	Alternating Current
AIU	Azipod Interface Unit
AMC	Application and Motor Controller
AVR	Automatic Voltage Regulator
CMC	Converter Marine Computer
DAC	Data Acquisition Computer
DC	Direct Current
DM	Drive Monitor
ECR	Electrical Control Room
EMS	Energy Management System
FMA	Finnish Maritime Administration
FPP	Fixed Pitch Propeller
FP	Fixed Pitch
GOP	Graphical Operator Panel
GUI	Graphical User Interface
IEC	International Electrotechnical Commission
ISA	Industry Standard Architecture
LAN	Local Area Network
LNG	Liquid Natural Gas
MCR	Minimum Cell Rate
OLE	Object Linking and Embedding
OPC	OLE for Process Control
OS	Operating System
PC	Personal Computer
PCI	Peripheral Component Interconnect
PCMS	Propulsion Condition Management System
PCU	Propulsion Control Unit
PIP	Packed Industrial PC

PLC	Programmable Logic Controller
PMS	Power Management System
PWM	Pulse Width Modulation
RDS	Remote Diagnostic System
RTU	Remote Terminal Unit
VLAN	Virtual Local Area Network
VPN	Virtual Private Network
VSI	Voltage Source Inverter
VSP	Virtual Serial Port
WLAN	Wireless Local Area Network
ZMC	Azipod Marine Computer

Symbols

f	frequency [Hz]
p	number of poles
n	rotational speed

1 INTRODUCTION

The development of fault diagnosis and remote control technology for such modern systems as fly-by-wire aircraft, nuclear power plants, and of course marine propulsion systems which are mission-critical and have to be controlled without interruptions, is an unavoidable course. These remote diagnostic systems are usually based on the Internet, as a kind of data transfer medium, and used for the diagnosis of the maintenance of different equipment. In spite of reliability of contemporary systems their components may fail and cause big losses caused by downtimes.

1.1 ABB remote diagnostic systems

ABB offers remote diagnostic systems as a service to provide minimal downtimes of the drive systems. In today's marine drive applications, specialists do not have to fly out to a particular ship to check an engine or its parts, but experts at ABB can guide on-board engineers through the Internet. So, when it is necessary they work as crew members, because they are on-line to the propulsion system. They have an access to the recorded drive historical and also real-time data. An isolated remote diagnostic system is installed in the propulsion system; the data is collected there and then is transferred to ashore in general via global satellite systems. Certainly, most of the data analysis is done on board of the vessel and only selected data is transmitted to ABB.

Remote diagnostic systems are constantly under development to improve the reliability of the propulsion systems, availability at any point of the world and confidentiality of information. By now four generations of remote diagnostic systems and one prototype (used in an icebreaker in USA) have been developed by the specialists of the ABB group. They are utilized at different ships all over the world, but the most widely distributed is the third generation. Also on the credit side off ABB research people there is the absolutely new version of the remote diagnostic systems, which is still under development. However, when it is completed it will be used for the main part of new vessels. [1-7]

Nevertheless, the old systems which already exist on the ships should also be improved and updated. It is, however, not in practice possible to change all their soft- and hardware components and use the totally new version. We can e.g. not change the propulsion controllers (PLC) within this work, but ways to improve the most exploitable third generation system are studied.

The main difference of these two systems, the third generation remote diagnostic system and the new Propulsion Condition Management System (PCMS), is in the way of the data transmitting. In the old system the data is transferring with help of the Modbus protocol and in the new system the Ethernet is utilized.

The new system has modern devices, and thus e.g. the so-called Advant controller is more compact with the same effectiveness. Instead of the data acquisition computer the new system has OLE for Process Control (OPC) server which operates on more modern operational system and utilizes the latest programs. In the new version also the diagnostic and operator networks are separated from each other for safety reasons. As a result an illegal access into the diagnostic network does not affect the operating of the operator's network.

So the main task of the work is upgrading already existing and implementing on many vessels old system to the newest version of remote diagnostic systems. As it is said earlier the replacement of the whole system is not reasonable and in this work the weakest parts of the system are defined and the ways to change them by the parts with similar functions as in the new version are found. After analysing the operation principles of these two systems, the task of upgrading reduces to the establishment of the connections between propulsion controllers from the old system (Advant controller AC-110 and application and motor controller) and the rest parts of the newest system. These controllers are connected only to OPC server from the PCMS system. Therefore, in this work the ways of connecting controllers to the PCMS system or the ways of getting Modbus data by the OPC server are studied.

1.2 Propulsion systems

To prove the importance of the monitoring propulsion systems it is necessary to start the problem consideration directly from what the propulsion systems actually are. The aim of this part is to give a basis for understanding the electro-technical components which are used in the configuration of vessels with electric propulsion.

1.2.1 Motivation for electric propulsion

The idea of electric propulsion is not as new as it might appear to be; its history started more than 100 years ago. However, there were no competitive solutions to control the motors on different speeds with a wide range of power. Only from 1980's the use of propulsion systems began its modern developing. After the first AC propulsion system in 1983, more than 400 ships in a large variety of configurations have been equipped by ABB variable speed propulsion systems.

Nowadays the electric propulsion systems are mainly used in such types of vessels as war ships, cruise vessels, ferries and icebreakers. The main benefits for using electric propulsion are listed below and explain their wide spread occurrence.

- By improving the operational economy with decreased maintenance cost and fuel consumption lifecycle cost is decreased.
- Reduced vulnerability to single failure in the system.
- Low weight of the high or medium speed diesel engines.
- Less on-board space is necessary.
- Increased pay load because of more flexible utilization and location of machinery components.
- Reliability and safety through redundancy and improved manoeuvrability by using e.g. podded propulsion.
- Environmental Advantages due to lower fuel consumption and emissions when the engine operates on a constant speed with optimized loading.
- High efficiency.

- Better comfort because of less propulsion noise and vibrations (rotating shaft lines are remarkably shorter; the prime engine operates on a fixed speed, using special types of propellers). [8]

1.2.2 Historical overview on electric propulsion

After the experiments in Germany and Russia at the end of 19^{th} century the first electrical propulsions were taken into use in the 1920's. Then the high power of propulsions was achieved by using turbo-electric machinery e.g. "S/S Normandie". Electric power for driving 29 MW synchronous electrical motors on each of the four propeller shafts was provided by steam turbine generators.

Then, due to more efficient diesel engines, steam turbines and electric propulsion disappeared from the market until the 1980's. In the 1970's the variable speed electrical drives were improved by the controlled AC/DC thyristor rectifier (Silicon Controlled Rectifier) and in the 1980's by the AC/AC frequency converters. This entailed the creation of the second generation electric propulsion. The power plant with constant frequency and voltage consisted of several generator sets which supplied one network. This power plant supplied the electrical propulsion. For the control of the propulsion force the speed control of fixed pitch propellers (FPP) was used. The second generation propulsion systems were mainly utilized in special ships such as icebreakers and survey ships, but also in cruise ships e.g. in "S/S Queen Elizabeth II" in the mid 1980's.

In early 1990's the ABB's podded propulsion concept was developed. In this construction the propulsion motor is set on the shaft of an FPP. It gave additional benefits for the manoeuvrability and efficiency of the ship propulsion. Since then, podded propulsion became a standard for cruise liners. [8] Fig. 1 illustrates the main parts of an electrically operated ship using two Azipod drives astern and two thrusters in the bow.

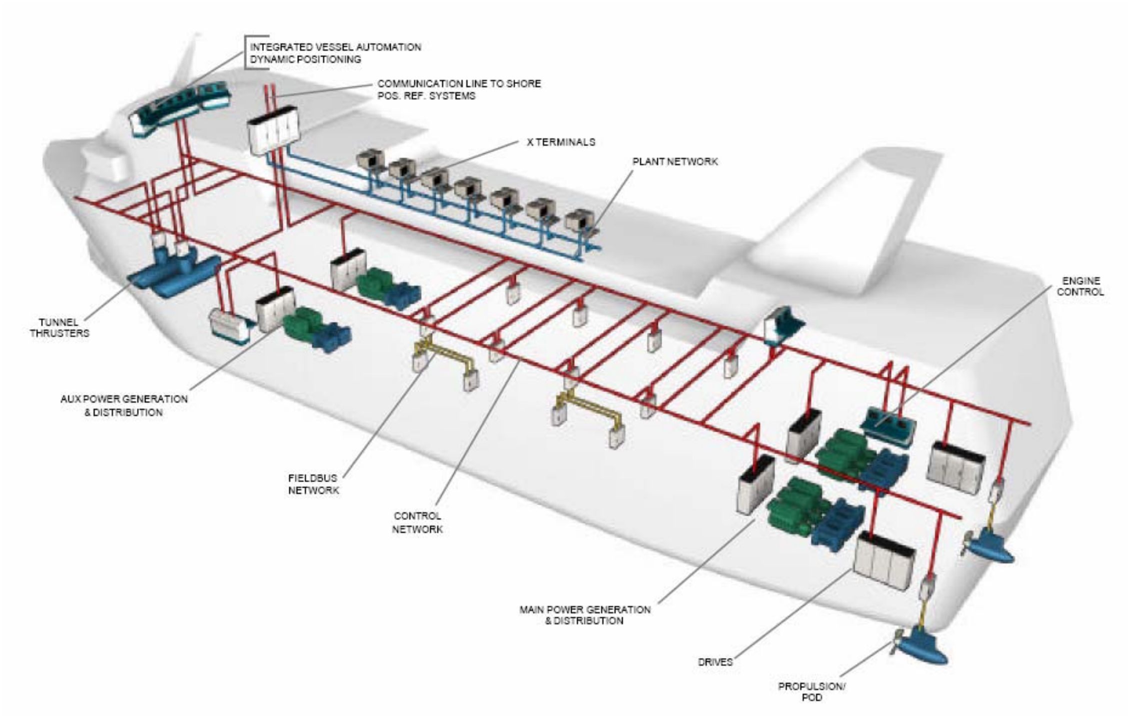

Fig.1. Example of propulsion and control system layout for a cruise vessel [8]

The idea of Azipod dates back to the mid of 80's and started from Finnish Maritime Administration (FMA). One engineer from FMA contacted ABB and gave the idea to construct the shape of propulsion motor so that it would fit into the bottom part of the ship. This entailed the cooperation between such companies as ABB, FMA and Wärtsilä Marine (earlier Kvaerner Masa-Yards). In 1987 a patent for Azipods was given. The Azipod is typically equipped with a large separately excited synchronous motor. The typical rated powers per pod go up to 14 MW. Fig.2 illustrates the construction of the Azipod.

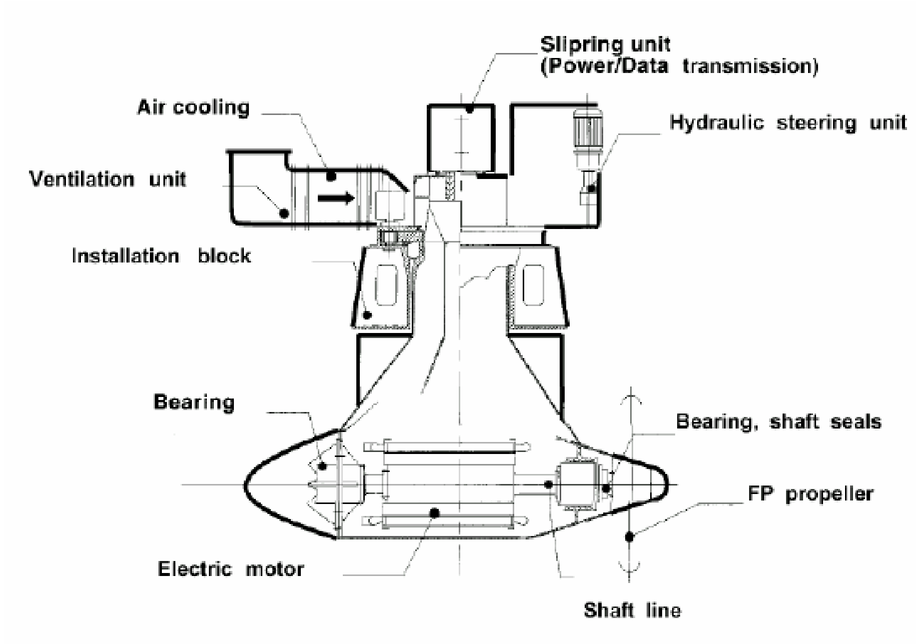

Fig.2. Construction of the Azipod with a fixed pitch (FP) propeller [9]

In 1999 after the field investigation, the decision for creating Compact Azipod, more economical for low power open water units, occurred. During 2000 this problem was solved by using modern permanent magnet low voltage motor technology, and in 2001 the first ship started operation. [9] The next picture shows the simple construction of the Compact Azipod Propulsion.

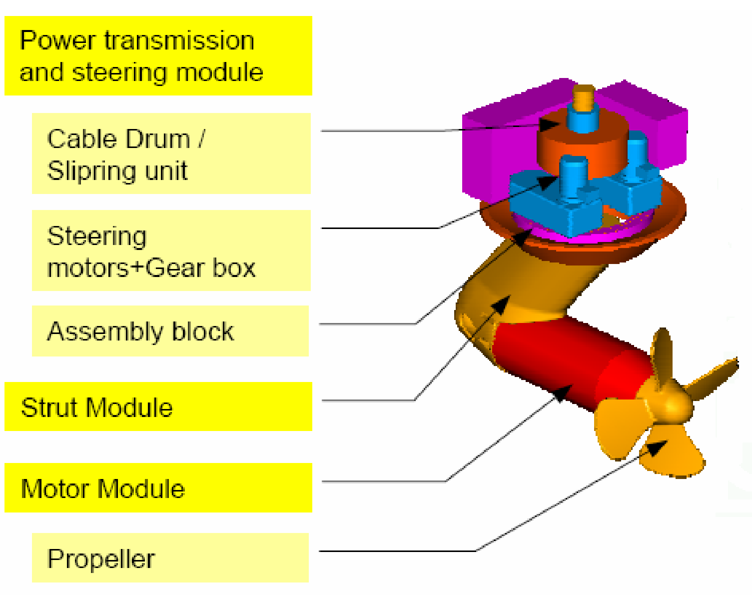

Fig.3. Compact Azipod Propulsion [9]

1.2.3 Electric power generation

1. Prime mover.

The power source is a generator set operated by an internal combustion engine fuelled with heavy fuel oil. Sometimes, especially in LNG transporting ships, natural gas is a cheap alternative, and gas engines or multi-fuel engines are also used. An operational feasibility to power plant is also an important factor for choosing the engine type. Diesel propulsion systems are very reliable due to the redundant network with several diesel engines, which for one's turn are cheaper and more light-weight than others with the same characteristics.

The internal combustion engines are constantly under development to get the maximum efficiency and to decrease emissions. Nowadays, the fuel consumption achieves less than 200 g/kWh at the optimum operation point, Fig.4. If we assume that the effective intensity of the heavy fuel oil is 40.6 MJ/kg for the fuel oil and the consumption 190 g/kWh we get an efficiency of about 44.3 % for the diesel motor.

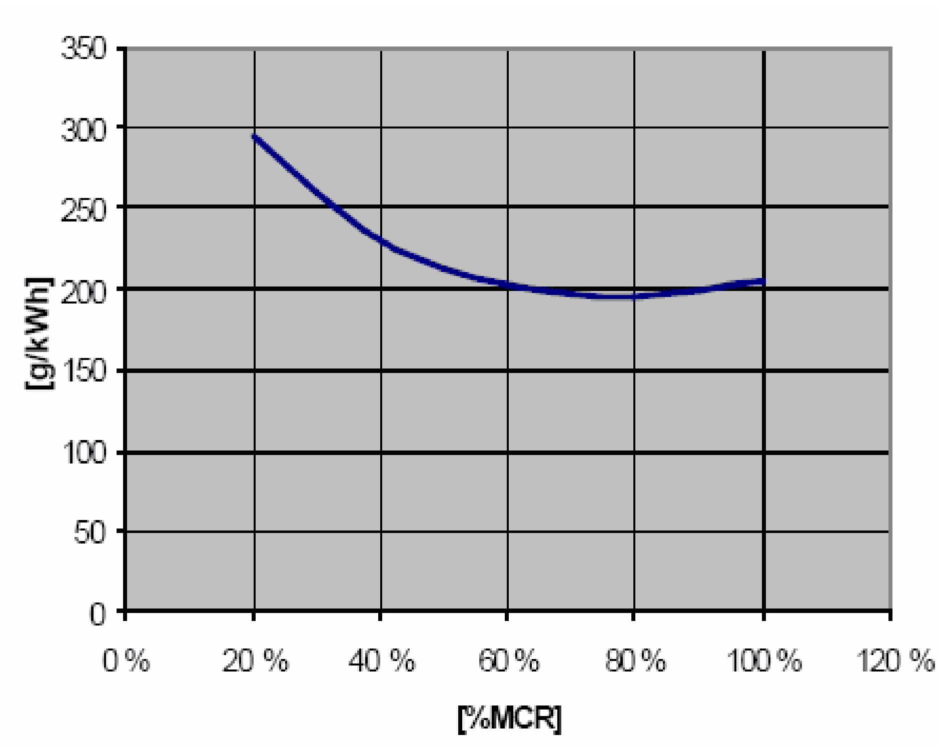

Fig.4. Example fuel consumption for a medium speed diesel engine [8]

Also it is very important for each diesel engine to be loaded at its optimum operating conditions. Hence, generator set's starting and stopping depend on the load. [8] Large electric generators and motors have efficiencies in the range of 98 % or more and the power electronic converters have their efficiencies in the same range. Therefore, it is possible to reach total efficiencies of Fig. 5 for the whole propulsion system.

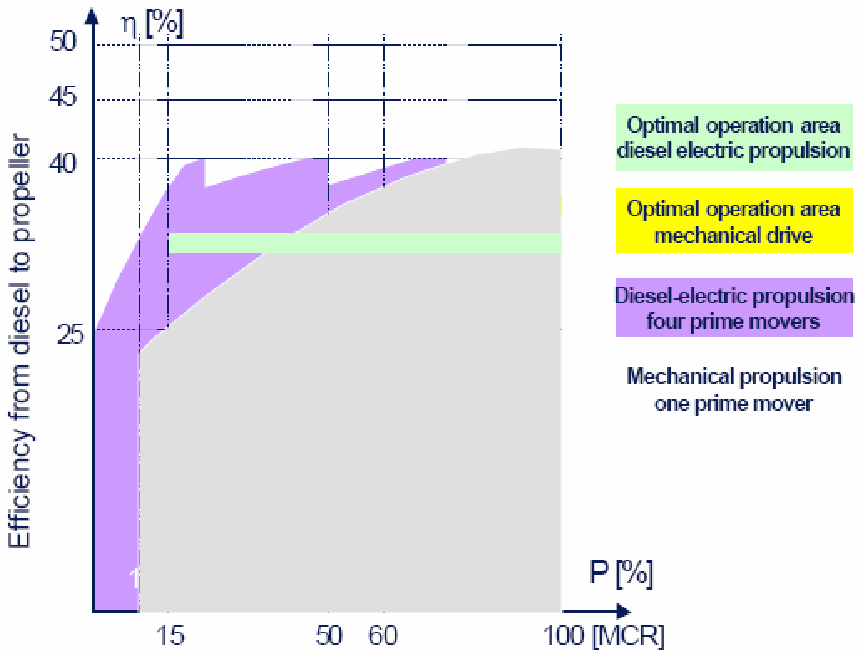

Fig.5. Total efficiency from fuel to engine propeller shaft, in a single machine direct mechanical propulsion system and a four machine diesel electric propulsion system [8]

2. Generators.

Basically, ships have an AC generation plant with AC distribution. The generators are synchronous machines. They have field winding on the rotor with DC current and three-phase winding on the stator. When the rotor rotates, its magnetic field induces a three-phase sinusoidal voltage in the stator winding with the frequency f [Hz] that can be computed from the equation:

$$f = \frac{p}{2} \cdot \frac{n}{60} \qquad (1.1)$$

Where p is the number of poles and n [RPM] is the rotational speed, e.g. a medium speed engine operates in general at 720RPM for 60Hz (10 poles) or 750RPM for 50Hz (8 poles) networks.

Earlier DC current for rotor magnetizing winding was supplied through brushes and slip rings. For decreasing maintenance cost and downtimes, modern generators are performed as brushless excitation machines, which are actually inverse synchronous machines with DC magnetization, rotating three-phase windings and rotating diode bridge rectifiers. Besides magnetizing winding there is also a damper winding in the generator rotor. Its task is to decrease frequency oscillations, transient voltage variations and damp the effects of harmonic distortion in load currents. [8]

1.2.4 Electric power distribution

The high reliability is the main factor for the appropriateness of an electric power plant. Therefore, it is very important to guarantee the required redundancy for the ship, to supply switchboards and motor control centres with strong, reliable strong switchgears and protection devices.

1. Switchboards.

To achieve the required redundancy, the generator switchboards are divided in different parts. One of them should be responsible when the other is failed, e.g. because of short circuit. If the conditions are stricter, one part should also be responsible, when a failure because of fire or flooding forces to isolate the sections.

If we divide our switchboard only in two parts which share the generator load and capacity in equal parts, in the case of failure, 50% of generator load and capacity are lost. To reduce the cost, it is better to divide the generators switchboards on three or four parts.

In propulsion mode, the freedom in the form of power generation plant is provided by the situation, when the switchboards can be connected to each others. The load is shared between all the diesel-generators and the optimal number of parts is connected to the network. Also in some cases it is possible to use independent switchboard sections with some independent networks.

Since the installed power increases, the short circuit and load currents increase, too. So with the restrictions on the mechanical and thermal stress in bus bars and the switching capacity of the switchgear, it is necessary to increase the voltage of the system and as a result to decrease the levels of the current.

Switchboards are made according to IEC standards. Marine main switchboards are mainly medium voltage devices with rated voltages of 3.3kV, 6.6kV or 11kV. Using the IEC levels the following alternatives are most commonly selected for the main distribution system, with application guidelines from NORSOK STANDARDS: [8]

- 11kV: Medium voltage generation and distribution. Should be used when total installed generator capacity exceeds 20MW. Should be used for motors from 400kW and above.
- 6.6kV: Medium voltage generation and distribution. Should be used when total installed generator capacity is between 4-20MW. Should be used for motors from 300kWand above.
- 690V: Low voltage generation and distribution. Should be used when total installed generator capacity is below 4MW. Should be used for consumers below 400kW and as primary voltage for converters for drilling motors.
- For utility distribution lower voltage is used, e.g. 400/230V. [8]

By ANSI standards some other voltage levels are accepted: 120V, 208V, 230V, 240V, 380V, 450V, 480V, 600V, 690V, 2400V, 3300V, 4160V, 6600V, 11000V, 13800V.[8]

If the most significant part of the load contains variable speed drives without contribution to the short circuit level, it is not a problem to use voltage levels for higher generator capacities. The most used voltage level in ship equipment is 440V, because a lot of devices on the ships are available only for 440V.

2. Transformers.

The main task of the transformer is to separate the electric power distribution system into some parts, to get different voltage levels and phase shift. It is done so that to decrease the influence of distorted currents by means of cancelling the dominant harmonics and as a result to decrease voltage distortion.

A lot of transformer types are known, but in general air insulated dry type, resin insulated, oil or other fluid insulated types are used. Basically transformers represent the construction such as a magnetic iron core with the three-phase coils (primary and secondary) around it. The coils may have a Y- or D-connection, which can be different for the sides. In this case, the phase shift between the voltages in primary and secondary sides appears. [8]

1.2.5 Motor drives for propulsion

The main task of the motor is the conversion of electrical power into mechanical. They are used everywhere in the ships devices directly from electric propulsion to fans, pumps, etc. Below are listed the main types of motors used in ship installation:

- DC motors.

  It should be fed from DC supply, but mainly three-phase system is used. As a result DC motors are fed via thyristor rectifiers. It also provides efficient motor speed and torque control.
- Induction motors.

  Principle of operation: AC current flows through the stator windings and induces a rotating magnetic field in the air gap. This magnetic field induces the current in the rotor, which creates its own magnetic field. The torque of the rotor is produced by the interaction of these two fields.

  Induction motors are used in different applications and have a long lifetime with a small number of breakdowns. The efficiencies are somewhat lower than the efficiencies of synchronous machines.
- Synchronous motors.

  Principle of operation: AC current flows through the stator winding and induces a rotating magnetic field. The rotor is fed with a DC current. The strong rotating magnetic field attracts the strong rotor magnetic field induced by DC current. This results in the creation of the torque of the rotor shaft.

Synchronous motors are used only in ships with large propulsion drives >5MW, they are directly connected to propeller shaft, or in some installations at the power range of >8 - 10MW with a gear connection. In other cases asynchronous motors are the best alternative.

- Permanent magnet synchronous motors.

  They are mostly used in the industrial few to few hundred kW drives and direct-on-line applications. But now it can also be used in several MW propulsion drives. Their advantages are in high efficiency and small size. It is necessary for podded propulsion. [8]

1.2.6 Converters

Cycloconverters and Voltage Source Inverter (VSI) types are the most commonly used converters for large motor drives in the ships. They are used in ships with RDS and so they are of interest for us. Cycloconverters are mainly used with synchronous motors. The main operation principle of cycloconverters is shown in Fig.6.

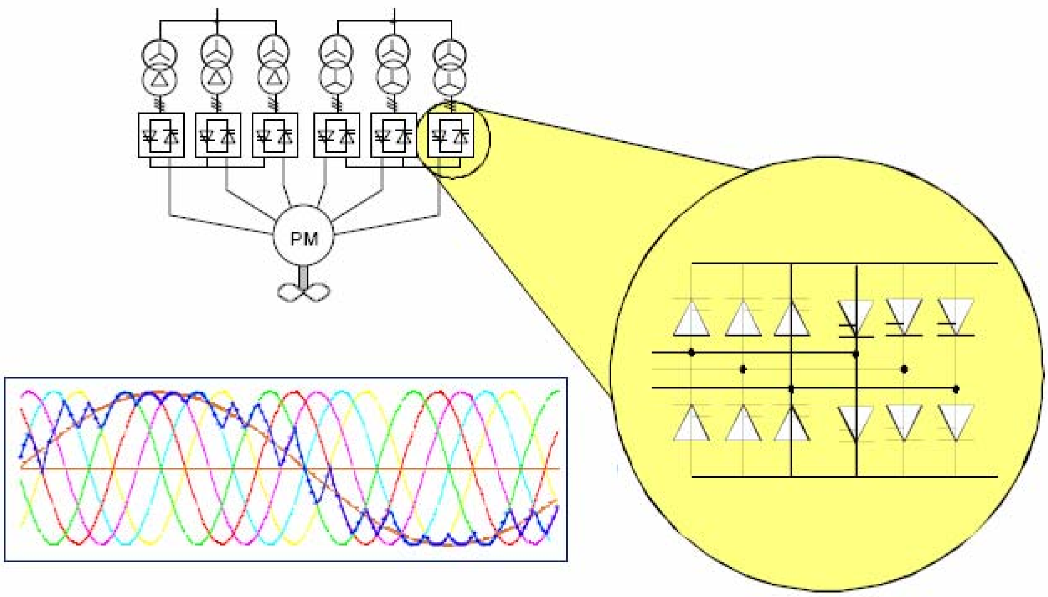

Fig.6. Cycloconverter drive with input and fundamental output waveforms. The output voltage is constructed by selecting phase segments of the supply voltage [8]

Cycloconverter is a direct converter without DC link. The motor's voltage is obtained by choosing the phase parts of the supply voltage, which is controlled by the anti-parallel thyristor bridge. It is mainly realized on frequency approximately 1/3 of supplied, about 20Hz. One of the applications is for propulsion system and even for podded propulsion. There is also an advantage such as low level of harmonics in the output voltage and as a result a high power factor. The cycloconverters are used in a power range of 2-22 MW per drive motor. [8]

The VSI converters are mainly used in AC asynchronous motors and are the most common for industrial utilization. The main advantage of these converters is in high power range. They can be used in the drives with the power more than 30 MW. The typical structure of six-pulse VSI low power converter is illustrated in Fig.7.

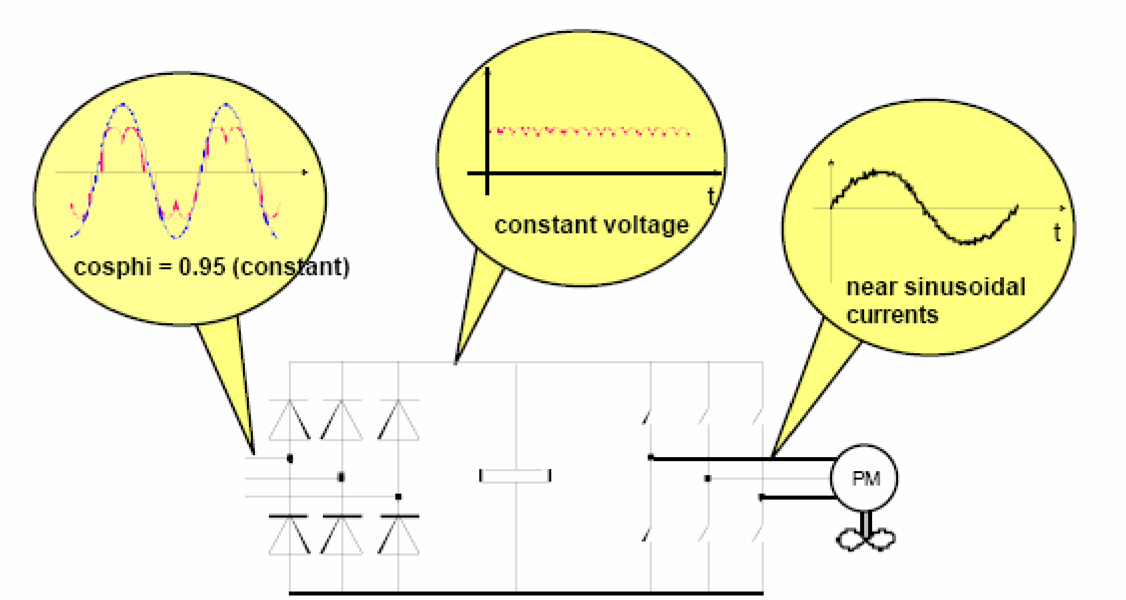

Fig.7. Six-pulse VSI converter [8]

Diode rectifier firstly rectifies the voltage of the network. We get almost constant voltage, as it is depicted in Fig.7. The capacitor in the DC link then smooths the signal. After that, with help of controlling switching elements by different ways, e.g. Pulse Width Modulation (PWM), we get the desired output voltage with necessary amplitude and frequency. Two level converters are used in low voltage (< 1000 V) low power applications up to 5 MW. More complicated medium voltage three level voltage source converters are used in larger applications.

1.2.7 Power and propulsion control

The modern controlled system is performed by the separate control, as shown in Fig.8. The whole system is hierarchically divided on some control parts.

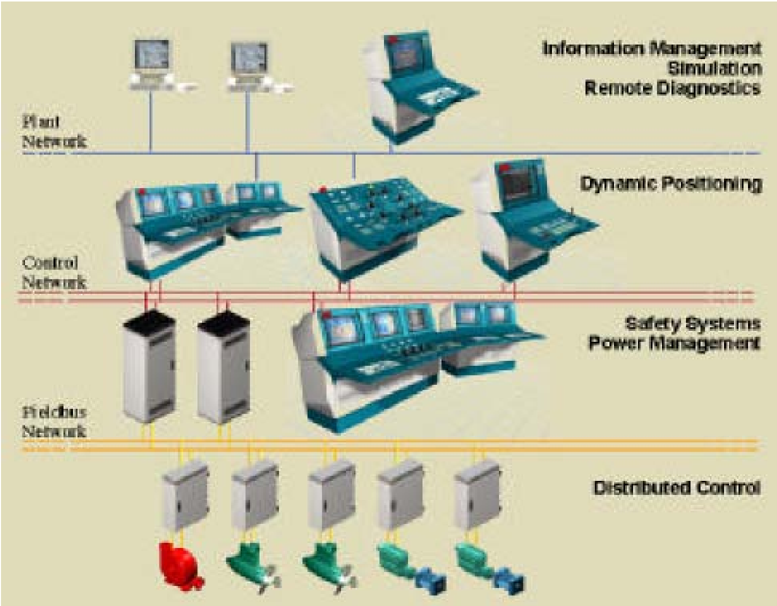

Fig.8. Integrated control system for a vessel [8]

It is better to consider the control system for a power plant in control hierarchy, which is illustrated on the next figure. There are three levels are presented: low level, system level and user interface.

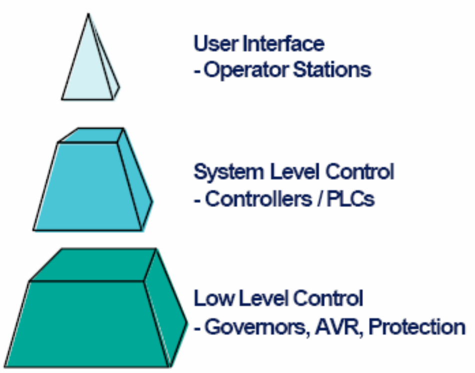

Fig.9. Control Hierarchy for Power Plant [8]

User interface is usually presented by the operator station (bridge consoles with the monitors) with the buttons and light bulbs earlier, and now more common with the Graphical User Interface (GUI), and set in special engine control rooms or on bridge. It is for crew utilizing the control and monitoring of the power and propulsion installation.

System level control is implemented in controllers or Programmable Logic Controllers (PLC). They can have the host or distributed system of computer's location. Here such functions as power management, start-up control, etc., are solved. The main task of the Power Management System (PMS) is to control the sufficient power supply for the actual operating conditions by means of monitoring the load and the status of generator sets. But everything should be done with the optimal fuel efficiency. It is called Energy Management System (EMS).

In **low level control** there are fast control functions and functions for providing safety, such as monitoring and protection of devices. The engine protection defends the engine from overheating, from exceeding of the speed, etc. a governor controls the frequency by means the regulation of the fuel input to the prime mover. The Automatic Voltage Regulator (AVR) controls the voltage by changing the magnetizing current of the generator field winding [8]

It is very important task to understand the necessity of deep control the condition of the propulsion system and especially the necessity of the remote diagnostics. The remote diagnostics is realized with help of the Internet which is opened to general use the way of communication. Because of this fact such kind of monitoring as remote diagnostics has become so popular.

The constant up state of marine propulsion systems are obligatory. In spite of the reliable components of such important system as propulsion system, they can fail and reduce to downtimes and consequently to big explicit costs. So the constant improvement of remote diagnostic systems is necessary, and all systems which are already installed on the ships should be developed to the modern level. This work tries to solve exactly this problem, to upgrade rather old third generation of RDS to the last modern version, so-called PCMS system.

2 REMOTE DIAGNOSTIC SYSTEMS FOR PROPULSION DRIVES

2.1 Benefits of remote diagnostics

For more careful control of the operation of the propulsion systems it is better to collect monitoring data all the time. It gives the possibility to get and observe the whole picture of the faults and to understand the events led to the fault. It is done by analyzing the history before the fault (approximately 80% of the observed data concerning one fault) and just after the fault. This data is available directly on-board on the monitor as well as at any point of the world. This is the main target of the remote diagnostic systems to be available at any time and at any point of the world, in other words to be a global system. This principle is shown in Fig.10.

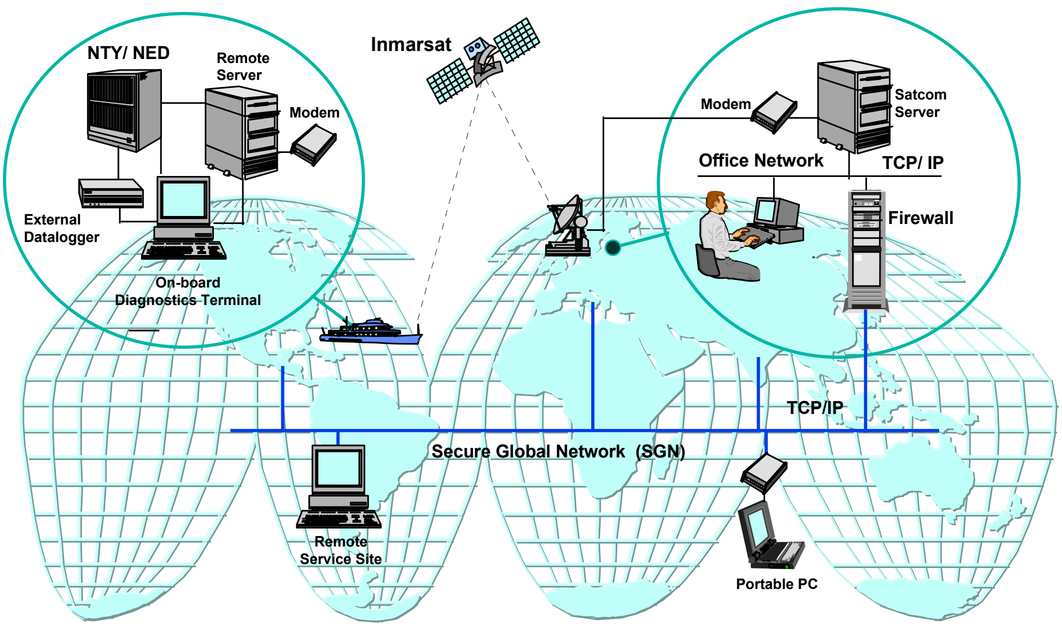

Fig.10. The principle of remote diagnostic [10]

Other, but also very important tasks of the RDS are immediate analysis of the fault, confidential access and interface should be easily used by the personnel. The data of the propulsion system is transmitted through a satellite, to get a global system, for the more detailed analysis in serious cases. For this purpose the Inmarsat system is used with high reliability. So the time for transferring the data is decreased to a minimum. The connection of the ship through the satellite gives the possibility to get help from maintenance specialists rather fast at any time of the day to decrease the downtimes.

Sometimes it is also possible to prevent malfunctions due to the known events leading to the fault.

The data itself is performed by the different characteristics of the current and voltage, statuses, pulses of the thyristor, etc. Data is collected all the time, and stored in a buffer memory.

The security of the information is also achieved by the accurate coding of the data by the encryption technique. These measures are assumed to prevent the system from the hacker fraud or from unpremeditated access. Only authorized users can access the data. Satellite communication server (Satcom server) in the office of ABB in Helsinki provides the connection only with authorized stations. The principle of safe data transmitting is illustrated in Fig.11.

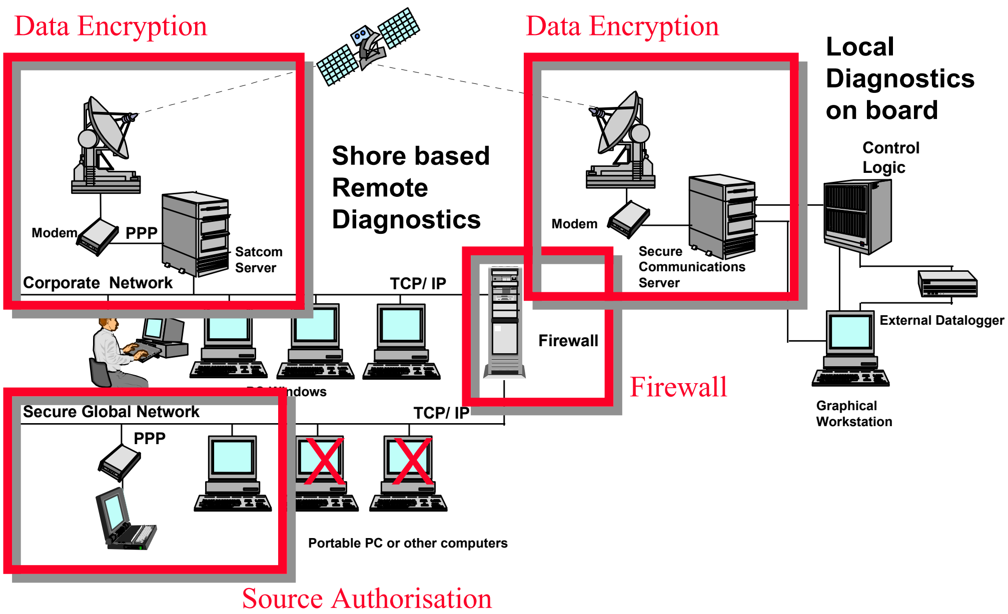

Fig.11. The principle of data security [10]

Moreover, with the satellite connection it is easy to update software, because any data can be transferred through the satellite. But of course all changes or updating can be accepted only with crew members' participation. [10]

2.2 Main features of the third generation of the RDS for propulsion drives

This chapter is devoted to the general description of the hardware and software of the third generation of the remote diagnostic systems by ABB. The main target of RDS is to improve the reliability of the drives systems. The remote diagnostic systems include the following functions: remote control, the search of the faults and the analysis. [10-11]. The system overview of the third generation of RDS is presented in Fig. 12.

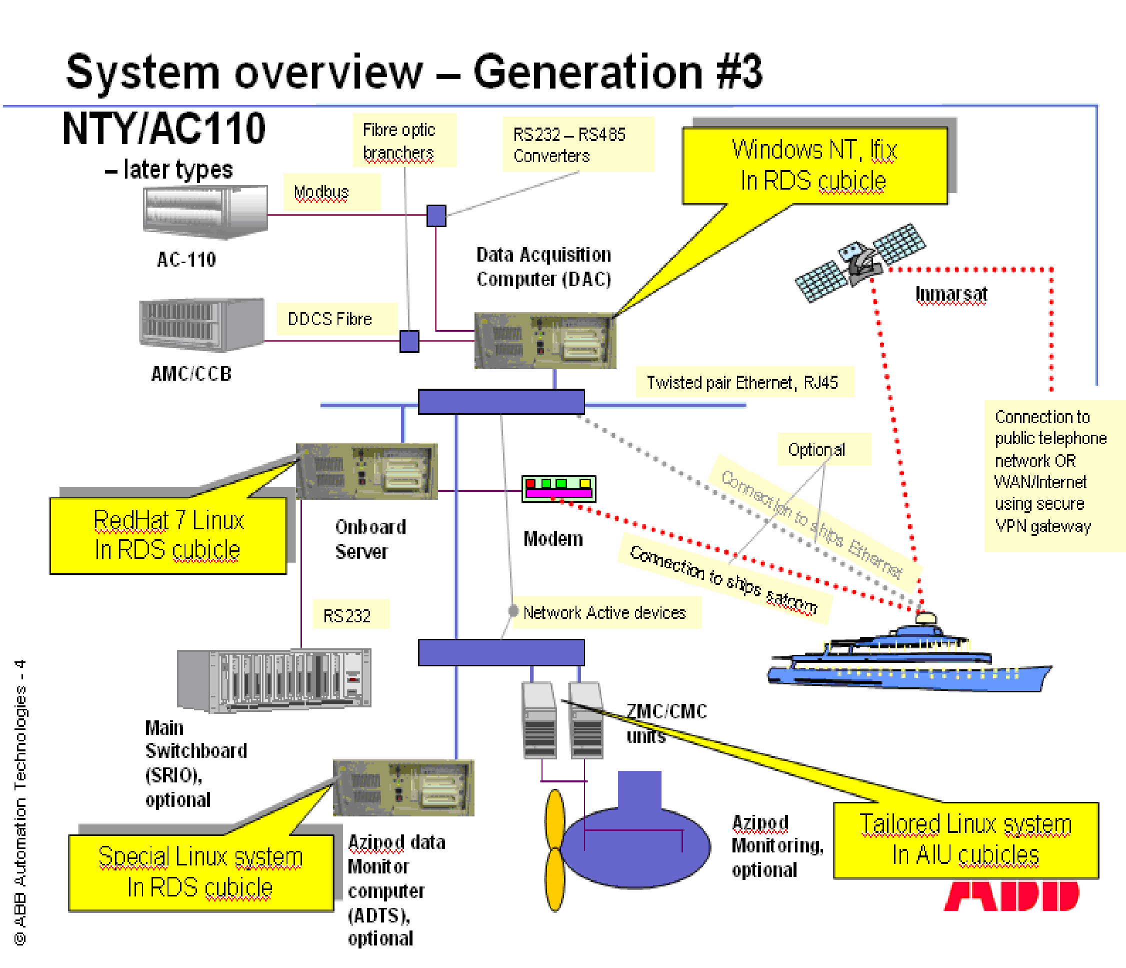

Fig.12. The third generation of the ABB Remote Diagnostic Systems [12]

The information, which is analyzed, are the parameters of propulsion system, alarm list, status information, etc. It can be presented in text form and in graphs. The data is saved all the time to provide the possibility of analyzing the alarm history in case of a fault. The diagnostic system as a rule includes some transient recorders to get the data from the drives such as current and voltage curves, status data, etc. If something is not ordinary in the propulsion system, the data is recorded and then stored in the Data

Acquisition Computer (DAC). This DAC is in turn connected with the communication server. As a result the data can be transmitted through the satellite to the further analysis. For more suitable and faster data exchange, all on-board computers are combined by the Ethernet – the local network. [10-11]

The alarm and event histories are stored during one month and then deleted. Usually only one file of alarms is formed per day. All alarms are represented on the graphical operator panel (GOP.) [13] The Basic components of the RDS are presented on Fig.13.

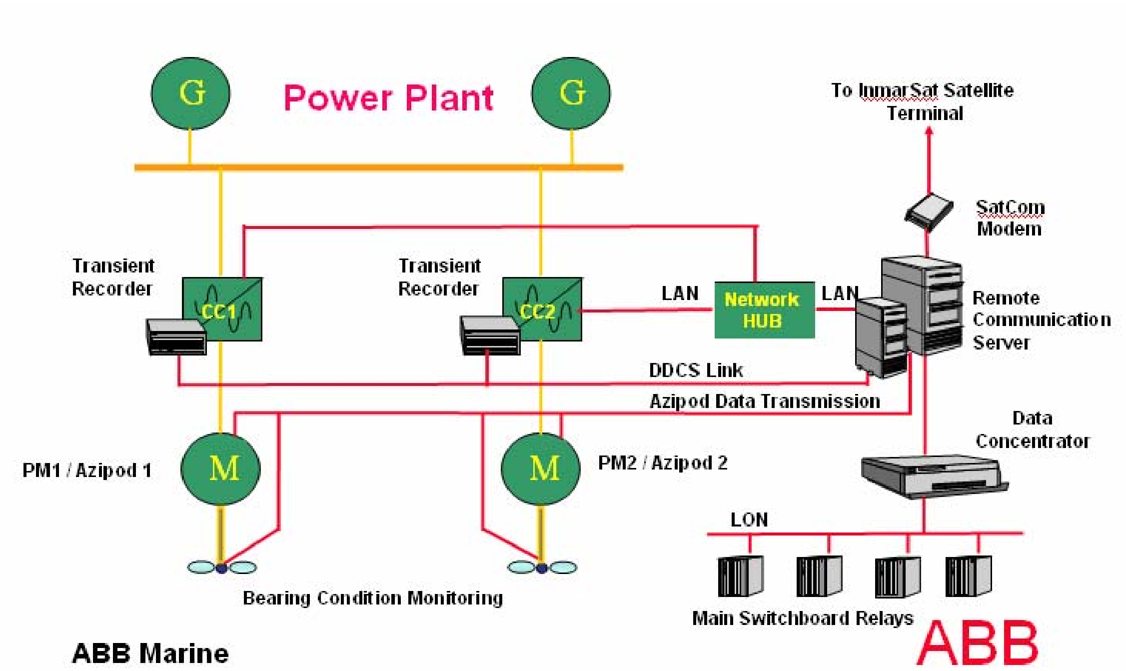

Fig.13. Remote diagnostic system by ABB [13]

Data acquisition computers collect the data from the Application and Motor Controller (AMC) – inner controller and from the upper controller AC-110. The computer is connected with the AC-110 through Modbus and with the AMC through the fibre optical line – DDCS Fibre (ABB standard link). The computer is also connected to the Ethernet – local network. The software of DAC is running in Windows NT. Ifix is the control software. For establishing the connection between Ifix and AC-110 the Modbus Driver is used and between Ifix and AMC an A/B Data Highway is used. There are also some programs for data collection; Trend Datalogger, ABB Indus Datalogger and Fuse Lifetime counter (ABB proprietary).

On-board communication server is based on the Linux Operating System (OS) and placed in the RDS cubicle. The aims of choice of Linux OS are reliability, due to uninterruptible operation, and security.

Satcom Server is used for centralized access to all diagnostic systems. It also should provide the security of the data, and communication via Internet or Intranet. Intranet is ABB internal network whereas Internet is a common unsafe network. The management of Satcom is realized via Intranet, because it has no own keyboard or display. Computer is set up in a special server room. The operation of Satcom is similar to the operation of usual Web server. It can receive or send all kind of information. It also uses Linux OS. [10-11]

The collected data contains all kinds of information about the propulsion system such as temperatures of winding and bearings, valve and pump control, the signals from the camera, which is located in the pod, oil levels, etc. It is the information about the components inside the pod. [13] Fig.14 shows the principle of Azipod data transfer system.

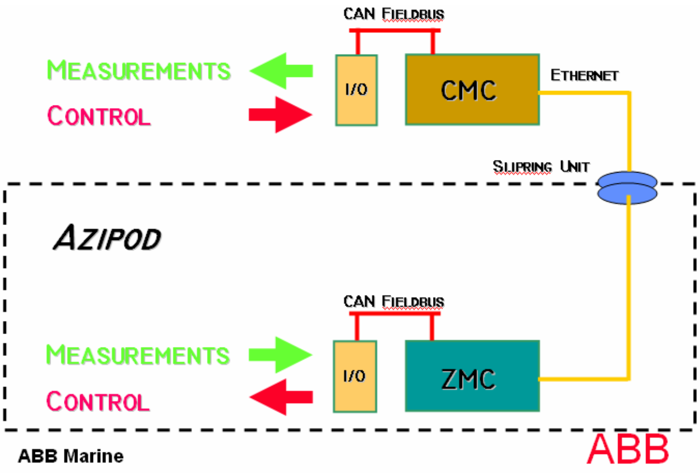

Fig.14. Azipod data transfer system [14] CMC is the converter marine computer and ZMC is the azipod marine computer.

The data is transferred from the pod to the Azipod room with the help of this system. This connection between two rooms is realized through the Ethernet. There are two ends transmitting and receiving. The measurement equipment consists of Azipod Marine Computer (ZMC) which is placed in the Azipod and Converter Marine

Computer (CMC) located in the Azipod room. They are connected via the Ethernet. The data about the condition of the Azipod gets via I/O ports to ZMC then transfer to the CMC via Ethernet and after that goes to the upper control levels. The data from the Azipod can also be shown on the Azipod data monitor computer – local computer. [13]

2.3 New version of ABB RDS

The main target of Propulsion Condition Management System (PCMS) is the collection of all possible information about the whole propulsion system. All the measurements are collected in the Propulsion Control Unit (PCU), which in turn has its own common network with I/O ports. The possibility of data transfer between control and diagnostic systems is provided by the using of OLE for Process Control (OPC) standard, where OLE is Object Linking and Embedding.[15] OPC is a client and server technology. The first uses the data and the second provides it. This principal is depicted in Fig.15.

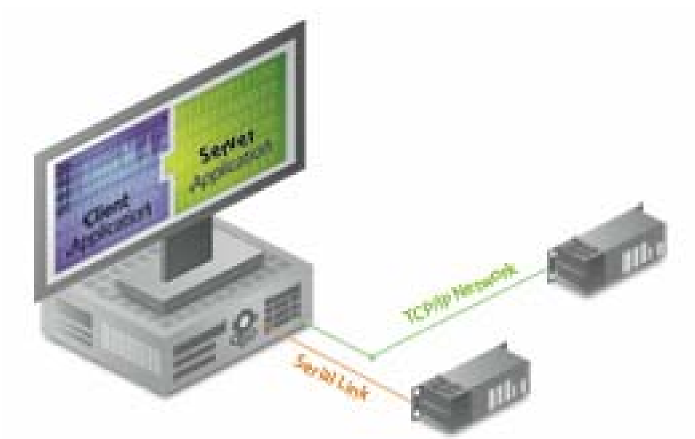

Fig.15 Principle of acting OPC's applications [16]

OPC is a standard for transmitting data between Programmable Logic Controller (PLC), Remote Terminal Unit (RTU) and software on the PC in electrical control room in our case. The configuration of the PCMS is presented in Fig. 16.

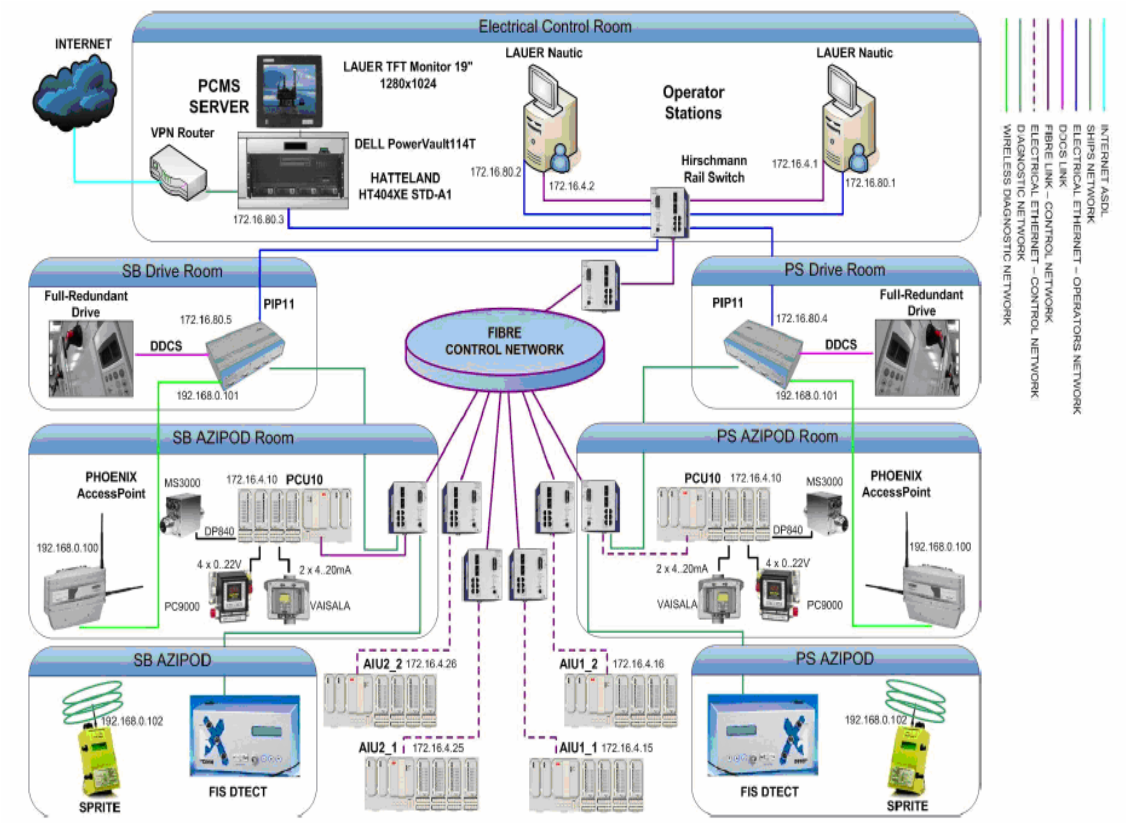

Fig.16. The new version of the Remote diagnostic Systems – PCMS system [15]

To access the OPC server, there should be a connection between PCMS and operators network, the higher level of the propulsion control. It is the connection between the control and the operator networks, which gets the signals from the controllers and transforms them into OPC tags.

There are physically three industrial computers that build the entire PCMS system. Two local so-called Packed Industrial PCs (PIP) one for each side of the ship. Each PIP11 computer is mainly responsible for data logging and performing calculations. Exactly here all data calculations are made. They collect the data from the Azipod and the control system, make calculations and estimate the condition of the Azipod.

And there is another desktop in the Electrical Control Room (ECR) for collecting all the data from starboard and port side pods, but it does not make any calculation or transfer the data; it is just like a common database. This so-called PCMS server can show trends, statuses, calculation results, etc from both PIP's.

On all of those PC's there is a software installed, called Drive Monitor (DM), that is pretty generic and can be customized for marine purposes. The detailed description of the very important for propulsion system's diagnostics software DM is discussed later.

DM reads data from full redundant drive; propulsion control system, Azipod interface unit (AIU) and main switchboards – all of that via AC800M controller and the OPC server that reads from the controller; 3rd party condition monitoring units for bearing vibration monitoring and oil treatment – these are also connected to AC800M and exposed as OPC items. [15]

Communication between PCMS and AZIPOD system is physically based on the Ethernet. The next picture represents more detailed construction of PIP computer and connections existing in PCMS.

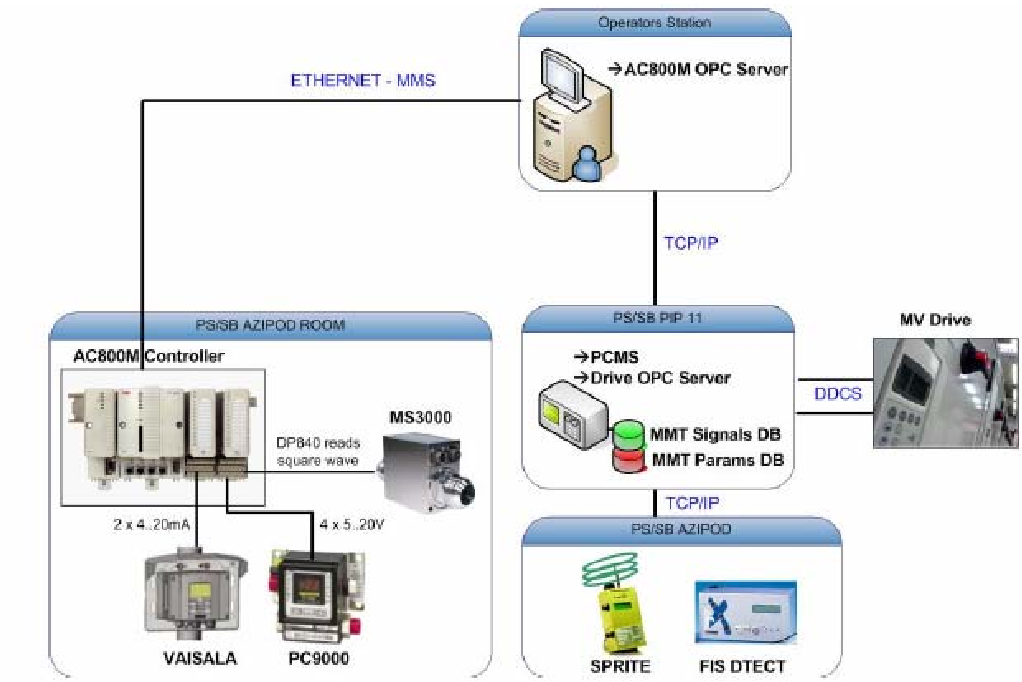

Fig.17. Connections between different parts of PCMS [15]

The PIP PC has its own local PCMS with the DriveOPC installed on it. DriveOPC is software for connection Windows system with the drives of ABB for monitoring on the industrial PC its condition. It is connected with the drive control boards through DDCS. DriveOPC shows the data and fault loggers and monitor software reads them. PIP PC has two network cards, one for the connection with the operator station and one for the connection with the access point which has wireless connection with the SPRITE – data acquisition unit for the measurements of vibration. DriveOPC permits remote connection in the local network using its IP address.

The main PCMS has also two network cards, one also for the connection with the operator station and one for the connection with the ship's network so that to get a connection through Internet with the service office. For the safety of the system the network should be divided in two parts: operator's network and diagnostic network. Toward this end the Ethernet adaptor in the PC's located in electrical control room and PIP PC's should have two IP addresses, one for the operator's network and OPC servers of the control system and one for internal data transfer. So there should be TCP/IP addressing. Physical division of the operator's network and wireless network guarantees that unauthorized access to the wireless network will not violate operator's network. There should be a separate Virtual Local Area Network (VLAN) for the wireless components. Also it is better to use the connection between PIP PC's and access point PHOENIX directly through Ethernet.[15]

2.3.1 Components of the PCMS

Metalscan MS3000, which is presented in Fig.18, is the monitor used for definition the presence of ferrous or non-ferrous metal particles. It is a highly reliable and low-price devise for preventing damage of different components, e.g. gear damage, and for monitoring damage progression.[15]

Fig.18. Metalscan MS3000 [15]

A Vaisala sensor is used for monitoring the humidity and the temperature of the oil. It is a very reliable control device, which also gives signals for beginning of operating the separators and oil driers only when it is necessary. The Vaisala sensor is shown in Fig.19.

Fig.19. Vaisala humidity sensor [15]

Particle Counter PC9000 is used for the detecting and monitoring the impurity levels of the fluid power and lubricating system. This device is illustrated in Fig. 20.

Fig.20. Particle CounterPC9000 [15]

FIS DTECT X1, shown in Fig. 21, is used for different types of measurements for vibration pickups: acceleration, velocity, displacement and for calculation RMS, peak, peak to peak values, steady components, crest factor. It also gives the bearing diagnostic value.

Fig.21.FIS DTECT X1[15]

SPRITE is a data acquisition unit for the measurements of vibration. It is utilized for acquisition the vibration data and presented in Fig. 22.

Fig.22. SPRITE [15]

ACCESS POINT represented on Fig.23 provides wireless connection with the SPRITE. It is one of the newest parts of the PCMS system, because wireless connections have become so popular not too much time ago.

Fig.23. ACCESS POINT [15]

A PC in the electrical control room operates as a database server. For the local utilization there is also the monitor for control the data by the ship's crew. Also the data can be transferred through the internet to the ABB office in Helsinki. Two PC's PIP 11 on both sides of the ship are used for storage on-line data from the Azipod. [15]

2.3.2 Drive Monitor

With the good diagnostics and maintenance, the active period of the devices essentially grows. And for the control effectiveness of the drive's life time it needs constant monitoring of its conditions. It gives the possibility of preventive inspection. It considerably reduces the risk of fault and service expenses. In this connection the Drive

Monitor (DM) – software was developed. It gives the possibility for the operator of the remote monitoring to change the characteristics of the drives and to collect the data.

The main structure of the operating of the Drive Monitor installed on the PC for the collection the data and then transferring it to the remote experts through the Internet with the help of the technology Virtual Private Network (VPN) is illustrated in Fig.24.

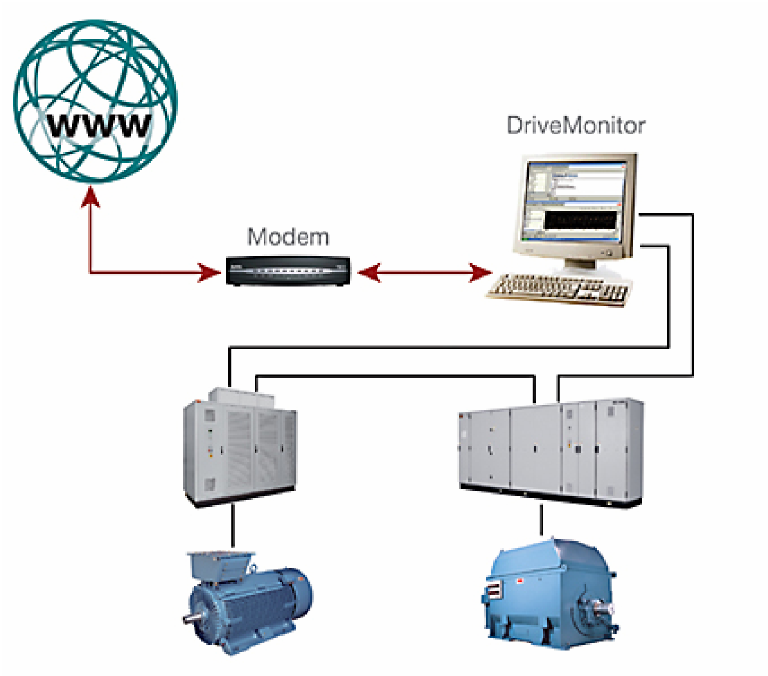

Fig.24 Typical structure of using Drive Monitor software [17]

The system Drive Monitor provides continuous monitoring and analysis of its condition and operation. In the core of the system there is an industrial PC with the Drive Monitor installed on it. On the programming level all desired data is automatically collected and analyzed. The PC is also necessary for remote access to the data about propulsion system. Remote Access is realized through the technology VPN with the high level of security.

The system Drive Monitor proves taking the report with the intervals in milliseconds with programming a year in advance. The main function of the DM is to constantly control the condition of the propulsion system and to react in a case of changes in the drive condition. The reaction should be the next: firstly save the current status and after that perform a more detailed investigation of the failed subsystems. It is necessary for the revelation of the source of the trouble. It gives the possibility of fast troubleshooting that leads to decreasing downtimes. [17-18]

3 POSSIBILITY OF USING DEFINITE PARTS OF THE NEW VERSION OF RDS FOR UPGRADING THE THIRD GENERATION.

3.1 Comparison of the third generation RDS and the new one

Let us try to compare two remote diagnostic systems – the third generation and the new one PCMS. In the third generation system AC-110 is used as an Advant controller. Advant is the "family" name for several automation and control products in -90's. This is illustrated in Fig.25. In the new version AC-800M is used instead, which is illustrated in Fig.26, with the same effectiveness, but more compact realization.

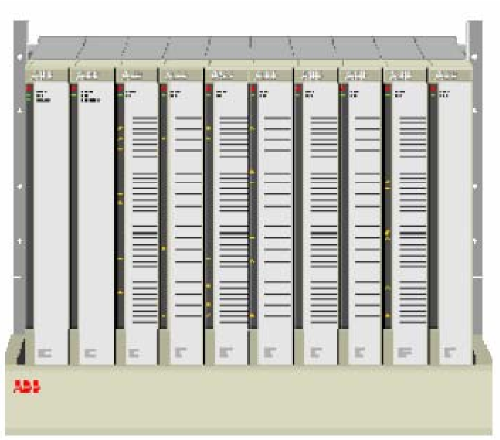

Fig.25 Advant Controller AC-110 [19]

Fig.26 Advant Controller AC-800M [20]

Also there is a difference in the way of data communication. In the old system the data transfer from the AC-110 to the Data Acquisition Computer (DAC) is fulfilled with the

Modbus – serial communication protocol which is utilized in controllers with programmable logic. For the data transmitting it uses serial ports RS-232 and RS-485.

In the new system the data transfer between the Advant controller AC and PCMS is realized through the Ethernet. A connection between the inner Application and the Motor Controller (AMC) and Packed Industrial PC PIP11 in both cases is realized through fibre optical link DDCS – a standard ABB link.

In the new version also the diagnostic and operator networks are separated for safety reasons. PIP11 should have two IP addresses one for access the operator's network and one for wireless connection with the Access Point in the Azipod room. So in the case of interference in the wireless network it does not affect the functioning of the operator's network.

The data acquisition computer is the vulnerable part of the old remote diagnostic system. It does not satisfy new requirements of constantly improved technologies. This data acquisition computer even operates on Windows NT, which was released in 1993 and now became out of date.

In the new version a rather powerful industrial rack computer Hatteland HT 404XE STD-A1 is used. It operates on Windows Server 2003 and has its own monitor for controlling the data by on-board crew. Windows Server 2003 is a server operating system produced by Microsoft. Introduced on April 24, 2003 as the successor to Windows 2000. It also has two network cards for connection with the operator's network and PIP and for connection with the ship's network. In PCMS the most connections are realized via the Ethernet. More data about conditions of the Azipod is collected, e.g. in PCMS there is bearing condition monitoring.

And of course everybody knows about the increasing interest of using wireless technologies in condition monitoring. Condition monitoring itself is very important in question concerned with the decreasing extra cost because of unplanned shutdowns. To find quickly the fault we have to collect and save data, such as vibration, temperature, torque and other, all the time. The data from the sensors is transmitting to higher levels and exactly in this process the wireless technologies should participate. The main advantage of using wireless technologies is a low price.

Especially, during the recent years the wireless technologies have become very popular and it is not amazing that the new version of RDS has such a technology for transferring the vibration data from the data vibration acquisition unit SPRITE to the Access Point. These devices use a radio interface IEEE 802.11. Wireless Local Area Network (WLAN) technologies such as IEEE 802.11 are not suitable for low power networks. Despite of the rather strict requirements for microprocessors and complex protocols the cost of such technologies is comparatively low and it is possible to connect them directly to the Ethernet.

In conclusion a summary of all the main differences between the two systems, the third generation of RDS and PCMS system, are shown in a table 1. We have to improve in this work all the details in the third generation RDS except of the Advant controller AC-110 and AMC.

Table 1 Differences between the third generation of RDS and PCMS system

The main differences	**The third generation RDS**	**PCMS system**
Exploitable Advant Controller	AC-110 is used as an Advant controller. It is rather old development with not the best characteristics in its size.	As an Advant controller in PCMS system AC-800M is utilized. It has the same effectiveness as AC-110 but more compact realization.
The way of data communication between the Advant Controller and Data Acquisition Computer	In these systems the serial communication protocol – Modbus is utilized. And the data transmitting is realized with help of serial ports RS-232/485.	In PCMS systems TCP/IP protocol is used. Data transfer is realized through the Ethernet.
A connection between	The standard ABB fibre optical link DDCS is used in	

the inner Application and the Motor Controller and PIP11	both cases.	
Present Networks	In old system there is utilized just one control network for data acquisition and transmitting.	In the new version the diagnostic and operator networks are separated for safety reasons.
Wireless connection	In these systems all the devices are rather old because of their development in 1990's. So wireless connection is not utilized.	There is wireless connection between PIP and Access Point via Wi-Fi diagnostic network. Also there is a wireless connection for transferring the vibration data from the data vibration acquisition unit SPRITE to the Access Point. They use a radio interface IEEE 802.11.
Data Acquisition Computer	It is the weak point of the system. Such technologies are improved all the time and new, several generations later versions are available now.	There is utilized one of the newest variants of the industrials computers Hatteland HT 404XE STD-A1.
Operating systems of data acquisition computers	Windows NT	Windows Server 2003

Bearing Condition Monitoring	In these systems such kind of monitoring is not available.	In the new version of RDS more data about conditions of the Azipod are collected, the most important of them is the bearing condition monitoring.

3.2 Possibility of the replacement of the old system by the new one

The main question of this part is about porting the third generation of RDS to PCMS or what should be done to have PCMS system working in already operating vessels where the third generation diagnostic system has been used. It is possible to change all the parts of the RDS, but we can not change the propulsion controllers AC-110 and AMC. So the main task is to find a solution how to establish a reliable connection from AC-110 and AMC to the new PCMS.

Concerning cycloconverters; they can work with DriveOPC and as a result we can read Azipod data with the PCMS server. The AMC is connected with the Data Acquisition Computer via the DDCS link and the Full-Redundant Drive in the new version as well. Physically, PIP11 has a PCMCIA-card that on one side can be connected via DDCS link to the drive's branching unit, on the other side can load the data to the DriveOPC server installed on PIP as well. To be connected with this card we need an adapter PCI/PCMCIA, which is depicted in Fig.27, to provide the desktop-PC with one PCMCIA-slot.

Fig.27 PCI/PCMCIA Adapter [21]

This card provides a DDCS-connection to the desktop PC. It can work with operating systems Windows 2000/2003/XP. As a result we can draw a conclusion that the new system can read the data from the AMC and our task comes to establishment of the connection between Advant controller AC-110 from the old system and PCMS server or how to get Modbus data from AC-110 to PCMS server. [21-22]

3.3 Establishment of the connection between AC-110 and PCMS server

In the remote diagnostic system of the third generation Advant controller AC-110 uses the Modbus protocol, when in the new version the data is transmitting via the Ethernet. So we have to get Modbus data by OPC. To work with this task firstly we have to investigate what is the Modbus protocol, Ethernet and OPC server.

3.3.1 Modbus protocol

In marine industry it is very important to have access to reliable data about the condition of the Azipod all the time. It helps to control and sometimes even predict possible failures of the propulsion system. Because of such importance of the distance control AC-110 collects the information about the Azipod condition and transfers the data to the PC via a communication channel using a serial port.

Modbus is a communication protocol, the base of which is client-server structure. Controllers are connected using the principle head/subordinate. The head can make request and subordinates can just transfer the data required. In our case the role of the head device is playing data acquisition computer and subordinate device is the Advant controller AC-110. So only DAC can initiate the data exchange. DAC asks for information from AC-110, saves it in a file and then makes a report. There are four types of messages in the communication mode between client and server: request, indication, response, confirmation. Request is the message sent by a client, indication is a reaction of server on request message. Response is the message sent by a server, confirmation is a reaction of client on response message. The principle of communication mode is presented in Fig.28.

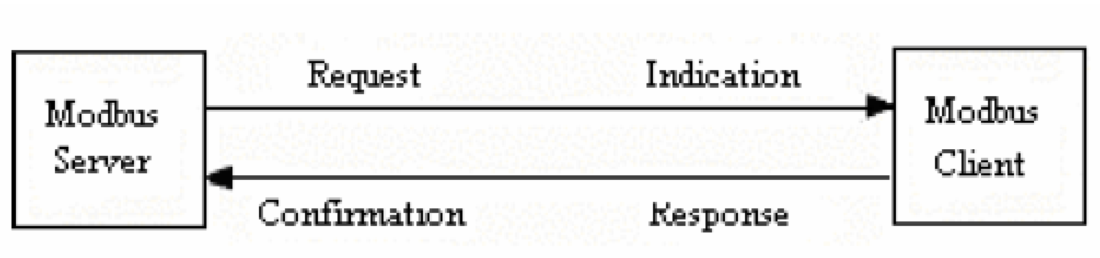

Fig.28 Client/server mode [23]

Modbus protocol is developed by the company Modicon for using in programmable logic controllers and has become the standard communication protocol. For transferring the data they typically used serial communication ports RS-232 or RS-485.

In the new version of Remote Diagnostic System serial communication ports are replaced by the connections through the Ethernet. Now communication via the Ethernet becomes the most popular. And in the whole system we can have the same types of the network protocols. It is very convenient to realize long-distance data exchange between central PC and programmable logic controllers via the Ethernet.

The frame of the Modbus message has four fields: device address, function code, data itself and error check. Let us consider so-called Master/Slave Query/Response cycle, which is depicted in Fig. 29.

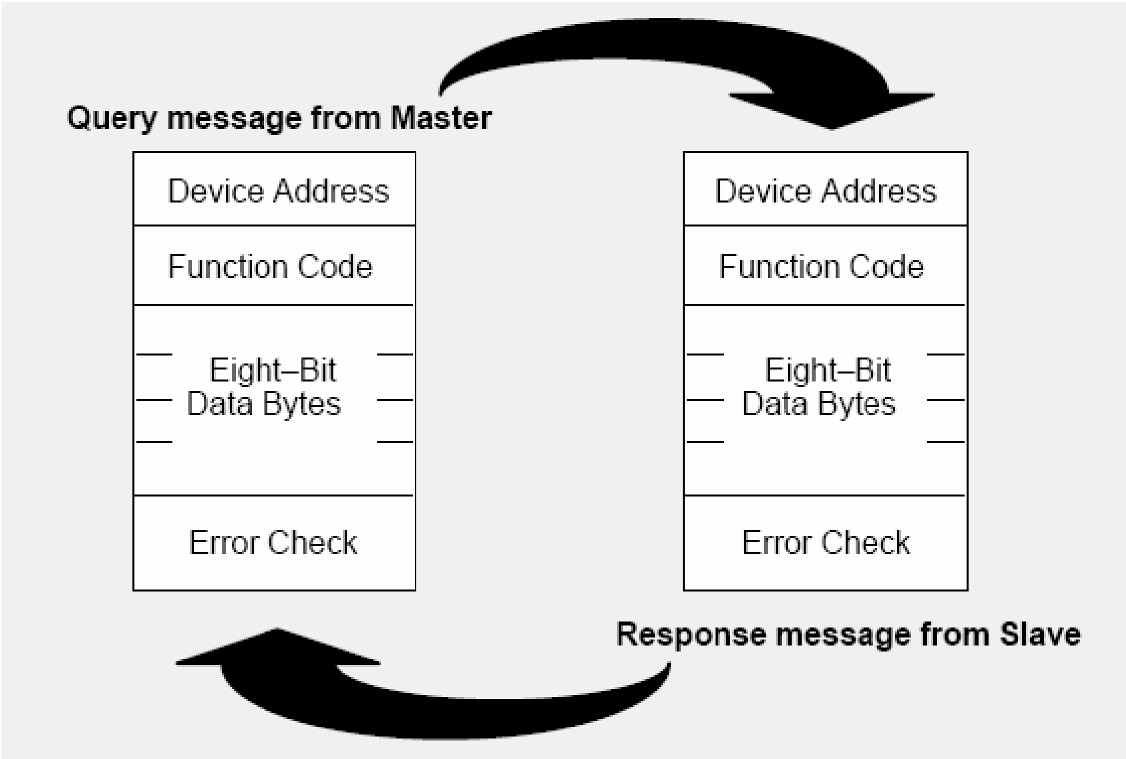

Fig.29 Master/Slave Query/Response cycle [24]

Device address is the first one byte field that specifies address of necessary device; function code is the next one byte field, which defines what kind of action should be performed, data bytes contain the necessary data and error check (two bytes field) provides verification algorithm. During the data exchange two types of errors can appear: logical errors and distortion of the data. [23-25]

3.3.2 Ethernet

As it was mentioned earlier, the Ethernet forces out the Modbus communication between DAC and the Advant controller in the new system. Because of the fast developing it becomes more and more popular to realize the communication via the Ethernet and to have the same types of protocols in each parts of the system. Also it gives simplification of the network maintenance, decrease of the price of such solutions and possibility to connect devices of the different producers. Usually Ethernet is utilized for the connection of programmable controllers.

Some advantages of using Ethernet are: increase of the speed which has reached 1 GB per second, increase distance and overall performance, and of course the possibility of using access points, optical fibres and other connections instead more expensive serial ports.

The firsthand benefits of the Ethernet in data acquisition systems are the wide choice of technologies in this area and freedom in choice of program language, because almost all of them are matched for the programming of the network.[26] The typical data acquisition system based on the Ethernet is illustrated in Fig.30.

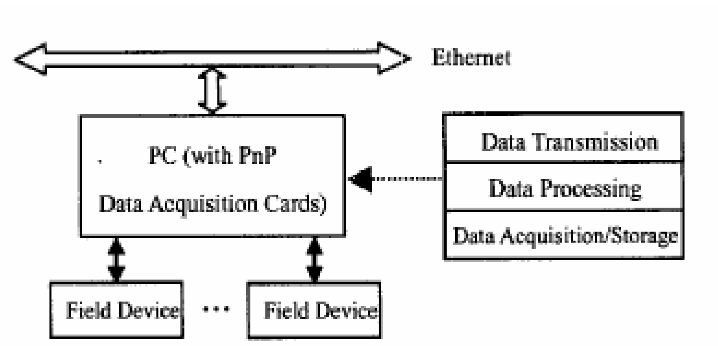

Fig.30 Data acquisition system based on the Ethernet [26]

PC in this case is data server for storage the data, data processing and network communication. Network communication is realized by utilizing network card.

3.3.3 OPC server

OLE for Process Control (OPC) is the standard for the communication between devices in the process control systems. OPC constitutes a typical client/server structure of technology. Client ask server for the data and the server provides it. OPC was developed as a standard for transferring the data between different types of devices in industry. It even does not dependent on the programming language and operates as a software gateway. OPC server gets data from different devices and then transforms it into appropriate OPC data for unification devices in one whole system and for creation distributed control system. Data exchange between client and server is realized via OPC interfaces. The typical structure of OPC server is presented in Fig.31.

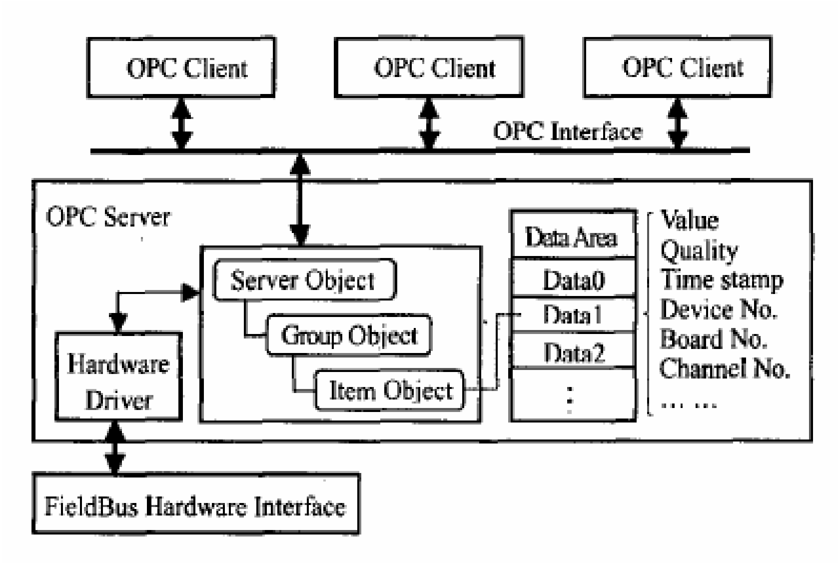

Fig.31 Typical structure of OPC server [26]

OPC object mainly includes three parts: server object, group object and item object. Server object has information about server and includes OPC group objects; also it can operate over group objects, e.g. delete or create them. Group objects in turn contain information about group and collect OPC item objects. Also they control the connection of item objects with the data storage area of the OPC server. To simplify the structure of OPC server let us redraw it to the next figure without external connections and only with main blocks.

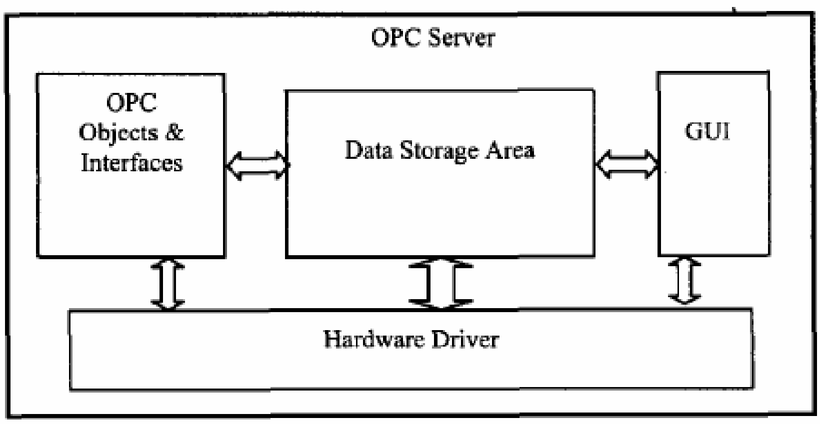

Fig.32 Simplified version op the structure of OPC server [27]

OPC server mainly consists of four parts: OPC objects and interfaces, data storage area, hardware driver and Graphical User Interface (GUI) which has a tree structure for simple utilizing by the crew members. Server is contacting with the client with help of

OPC objects which should interact with the data area or hardware driver to get the required data or find necessary devices.

Data storage area is very important part of OPC server. All the information is stored here. And when the server gets a request from the client, the data is taken from this area. As a conclusion we can say that the systems with OPC server are very popular now thanks to openness, price and reliability. [26-27]

4 TECHNICAL VARIANTS OF GETTING THE MODBUS DATA BY OPC SERVER

The next step is to find real technical solutions to connect the Advant controller AC-110, which uses the Modbus protocol as a way of data transmitting, and OPC server from the new version of RDS, which gets the data with help of the Ethernet. In this chapter some possible solutions are suggested.

4.1 Modbus converter

One of the solutions is to convert the signal from the Modbus form into the Ethernet form so that the Advant controller AC-110 and the OPC server can operate in customary regime or, in other words, the Advant controller can send a signal in the Modbus form and the OPC server can get the data from the Ethernet. So in this case we do not need any special devices for getting the signal.

4.1.1 Converter DL-MES1A

The company Data Link Communication offers different Interface and Control solutions. One of them is a Modbus-to-Ethernet converter DL-MES1A, which is shown in Fig.33.

Fig.33 Modbus to Ethernet converter DL-MES1A [28]

This converter can be used for connection Modbus serial controllers to TCP/IP network, what we exactly need for the communication with our OPC server. This converter transforms the Modbus serial protocol into TCP/IP protocol. It has also an RS-232 port and can solve different cases of network configurations. The first is such as slaves with the Modbus protocol, as in our case the AC-110, can communicate via TCP/IP network with masters with TCP/IP protocol (OPC server in our case). Second type of configuration is masters with Modbus protocol have a possibility to communicate via TCP/IP network with slaves using TCP/IP protocol. And the last variant is that the slaves with the Modbus protocol can communicate with masters with the Modbus protocol via TCP/IP network in case when the TCP/IP network tunnel is required between these devices.

Detailed description of technical parameters of DL-MES1A:

- Its terminals are mobile and it can be fed with 10-30 VDC.
- DL-MES1A has auto detecting 10/100 Mbps Ethernet via RJ-45 port.
- Light Emitting Diode (LED) indicates the operation.
- Extra security is provided by an installed password.
- The real temperature in which this converter operates at is from -20 to 80°C.
- The dimensions of the converter are 3.2 × 11.3 × 12.2 cm.
- The retail price is 272.60 euro. [28]

The main advantages of this device:

- The high security to prevent illegal access.
- Mobile terminals that simplifies the utilization of the converter DL-MES1A.
- Wide temperature range. Maybe it is not so important for the operation in normal conditions, because this converter should be installed in Electrical Control Room normally with the room temperature, but it has a side benefit in extraordinary cases.
- The high data transferring speed – 10/100 Mbps to the Ethernet.
- It has not so big size for the ship and can be installed on any space, what is very important in marine industry.

- For the system we need just one converter so the cost of the implementation of this device is not big.

4.1.2 NetBiter Modbus – TCP/IP Gateway

The company IntelliCom has a solution to convert Modbus data into TCP/IP transferring with the help of a NetBiter Gateway. Such a solution has some advantages in the cost and in the flexibility of the connections. And of course, during the latest times the utilization of the Ethernet in automation systems has become very popular.

To establish a connection between a Modbus network and an Ethernet network we can use NetBiter Gateway as a connecting-link. This gateway has an embedded web server, serial port RS-485 for connection from Modbus side and the Ethernet port with the speed 10/100 Mbps. An example of an automation network created on the basis of using this Gateway is illustrated in the Fig.34.

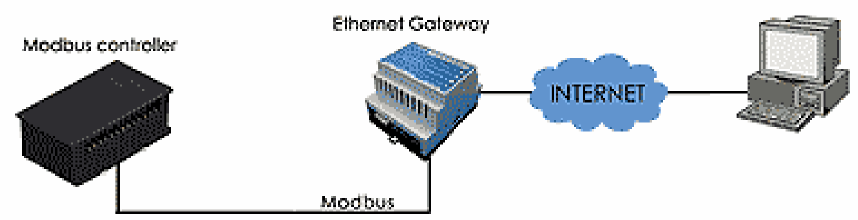

Fig.34 An automation network built with using Ethernet Gateway [29]

So the task of NetBiter Gateway is to connect all Modbus devices to the Ethernet. As in typical client/server structure or master/slave, as actually the same, the gateway plays the role of the master from the serial Modbus side and the role of the slave on the Ethernet side. This principal of Master/Slave modes is described in Fig.35.

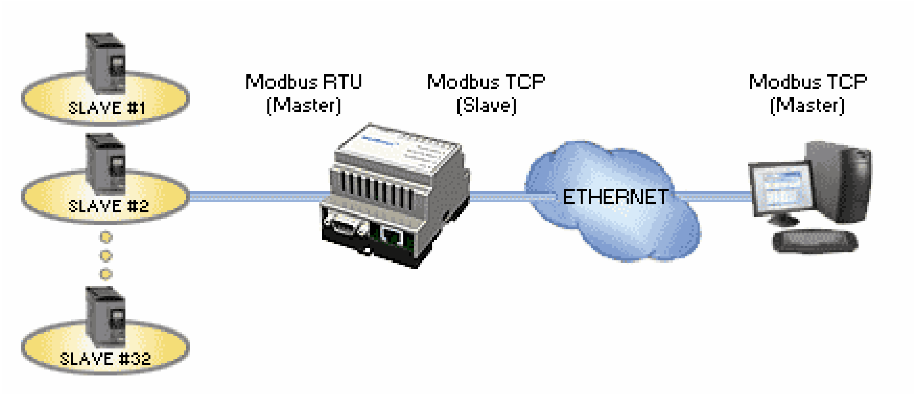

Fig.35 The Master/Slave principal in a network with NetBiter Gateway [29]

It has rather simple a structure and anyway from the serial Modbus side can support 32 slaves. Detailed description of technical parameters of NetBiter Gateway:

- Power supply of the NetBiter Gateway is 9 – 32V AC/DC.
- The consumption of current is 50mA at 24V.
- It has Ethernet transferring speed 10/100 Mbps via RJ-45 port.
- Serial network transferring speed 57.6 kbps.
- The temperature which this converter operates at is from 0 to 60°C.
- The dimensions of the converter are 9 × 7 × 5.8 cm. [29]

The main advantages of this device:

- Flexibility of the connection. Many variants of connections are realizable with help of the Net Biter Gateway.
- Sufficient temperature range.
- The high data transferring speed – 10/100 Mbps to the Ethernet.
- Very compact realization.
- Low cost.

As disadvantages it is significant:

- Absence of additional protection.
- Very low data transferring speed from the serial side - 57.6 kbps that slows down data exchange between Advant controller and OPC server.

4.1.3 Communication Gateway NPort 6110

Industrial communication gateway NPort 6110 is used for connection devices with Modbus protocol to the Ethernet network. This variant of converter is offered by the company Moxa Technologies.

NPort 6110 Gateway, which is illustrated in Fig.36, contains one Ethernet port with the transferring speed 10/100 Mbps and one serial port RS232/422/485 which is software selected, in other words the right required port is chosen automatically. To this port all types of Modbus devices can be connected.

Fig.36 NPort 6110 Gateway [30]

This device is suitable for different operational modes and network configurations. For transformation the Modbus protocol, firstly, we have to determine master and slave devices as we know in our case the master device is the OPC server and the slave device is AC-110 (generally PLCs use usually Modbus protocol as communication standard). And in contrast to other auxiliary devices NPort 6110 Gateway gives a possibility to set independently the master and slave devices on both sides either on Modbus or on Ethernet. It is a very powerful device and very simple to use.

The typical applications of NPort 6110 are considered below. Data exchange between serial master devices and serial slave devices can be realized through the Ethernet. The traditional serial Modbus devices can transfer the data via the network on basis RS-232 or RS-485, but utilizing these ports restricts the number of Modbus devices to 32 and the distance to 1.2km. This type of an automation network is shown in the Fig.37.

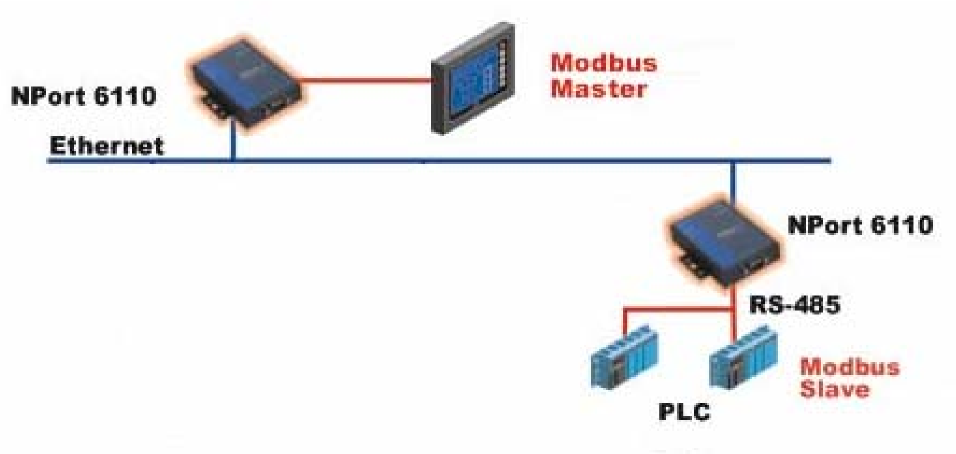

Fig.37 Connection between Modbus Master and Modbus Slave with help of NPort 6110 [30]

The data communication between the Ethernet master device and the Modbus slaves can be realized also with the help of an NPort 6110 Gateway. Exactly this case is very interesting for us, because the OPC server gets data from the Ethernet and the AC-110 uses the Modbus protocol. A typical connection between a master and a slave in this case is depicted in Fig.38.

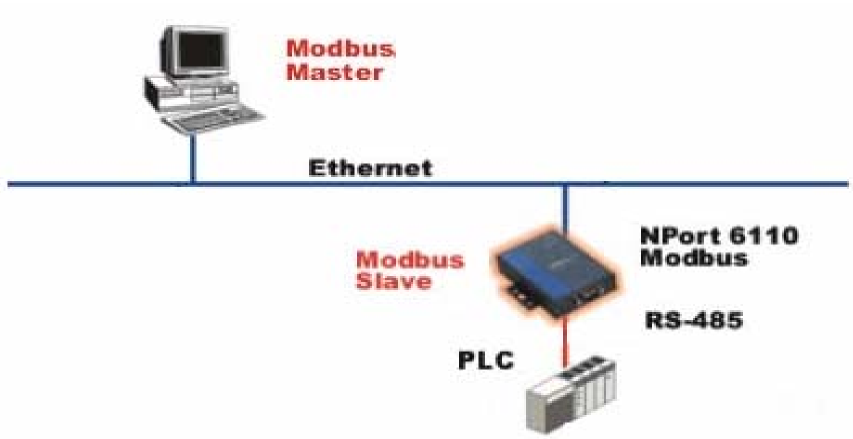

Fig.38 Using NPort 6110 for connection Ethernet Master and Modbus Slave [30]

And the last case is when the serial Master devices can communicate with Ethernet slaves. The number of Slave devices in this case is limited to 4. The graphical representation of the connection system is presented in the Fig.39.

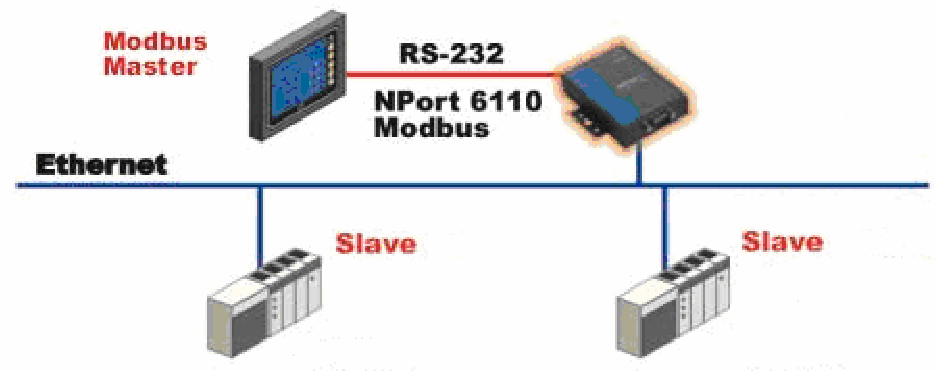

Fig.39 Using NPort 6110 for connection Modbus Master and Ethernet Slaves [30]

This gateway helps to solve the existent problem and the diagnostic of Modbus connection is realized easily and instantly.

Detailed description of the technical parameters of NPort 6110 Gateway:

- Integration of Modbus serial and Ethernet devices.
- Ethernet master device supports up to 31 Modbus slaves.
- Modbus master device supports up to 4 Ethernet slaves.
- It has Ethernet transferring speed 10/100 Mbps via RJ-45 port with automatic distribution of IP addresses.
- NPort 6110 Gateway has a software selectable serial port RS-232/422/485 with the data transferring speed 230.4 kbps.
- The real temperature which this converter operates at is from 0 to 55 °C and which it is stored is from – 20 to 80 °C.
- The relative humidity which this converter operates at is from 5 to 95% RH.
- The power input of NPort 6110 Gateway is from 9 to 30 VDC.
- The power consumption is 300mA at 9 VDC.
- The dimensions of the converter are 9 × 10.04 × 2.2 cm. [30]

The main advantages of this device:

- Easy accessibility of this device.
- Wide temperature range that gives the possibility of operating in extra cases.
- The high data transferring speed – 10/100 Mbps to the Ethernet.
- The high data transferring speed from the serial side - 230.4 kbps.
- Automatically software selection of the serial port RS-232/422/485.
- This device is suitable for different operational modes and network configurations.
- NPort 6110 Gateway gives a possibility to set independently the master and slave devices on both sides either on Modbus or on Ethernet.
- Very powerful device but easy to use.
- Ethernet master device supports up to 31 Modbus slaves.
- Very compact realization.

4.1.4 PortBox

PortBox is a RS-232/485 to Ethernet converter developed by the company HW-group. The typical use is for connection devices with serial ports to Ethernet network. So two devices, one of each has the serial port and other has Ethernet connection, can be linked with each other.

The other possibility of using this device is a remote access to the RS-232/485 technology because of the built-in virtual serial port. The outward appearance of the PortBox is presented in the Fig.40.

Fig.40 An appearance of PortBox [31]

This device can operate in TCP/IP client/server TCP/IP server mode. The Fig.41 explains the typical connections of the devices via PortBox and its protocols.

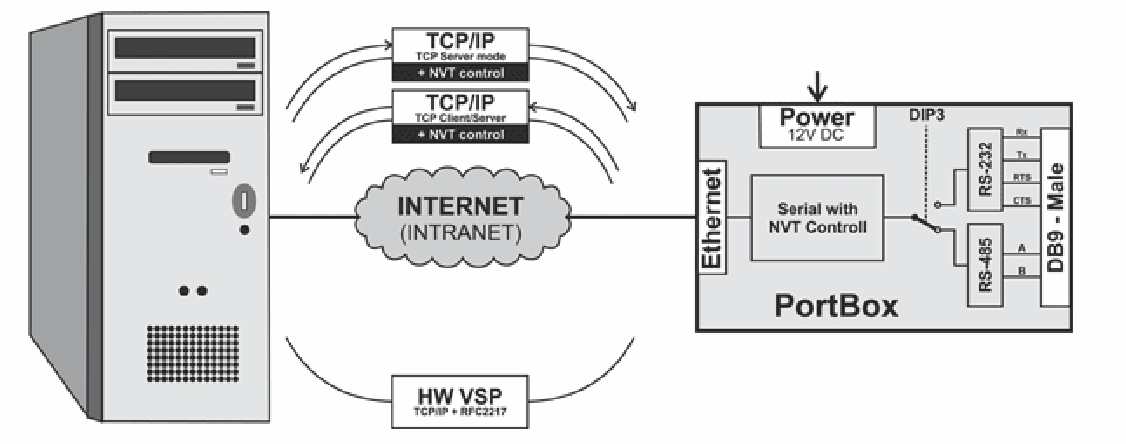

Fig.41 Typical connections through PortBox and network protocols [31]

On the picture three modes are presented. Server mode is used when the PortBox, in case of opened TCP connection from the side of the server or PC, sends the buffered data and than works as a terminal server. Client/Server mode: PortBox gets a data from the side of serial port into its buffer, then establishes connection with required address and resends the data to it. Virtual Serial Port (VSP) connection: it has special VSP software which creates virtual port and the connection of the device is realized as direct connection to the PC.

Detailed description of technical parameters of PortBox:

- Integration of Modbus serial and Ethernet devices.
- It has Ethernet transferring speed 10/100Mbps via RJ-45 port.
- PortBox has one serial port RS-232/485.
- PortBox has Virtual Serial Port HW VSP available for operational systems like Windows 98/2000/XP/NT 4.0.
- The real temperature which this converter operates at is from 5 to 50 °C and which it is stored is from – 10 to 85 °C.
- The relative humidity which this converter operates at is from 5 to 95% RH.
- The power input of PortBox is from 8 to 15 VDC.
- The maximum power consumption is 200mA.
- The dimensions of the converter are 2.8 × 10.5 × 13.5 cm. [31]

The main advantages of this device:

- Remote access to the RS-232/485 technology thanks to the built-in virtual serial port.
- The high data transferring speed – 10/100 Mbps to the Ethernet.
- Rather compact realization.

As disadvantages it is significant:

- Absence of additional protection.
- Rather small temperature range in which this device can operate.

4.1.5 EtherPole EPL-1

EtherPole is a Supervisory for Control and Data Acquisition (SCADA) communication server. It is developed by the company Arselect for conversion of the Modbus protocol into Ethernet signal. EtherPole connects different serial devices via Local Area Network (LAN) and suites for converting Modbus protocol into IP protocol. The front and back view of EtherPole EPL-1 are depicted in Fig.42.

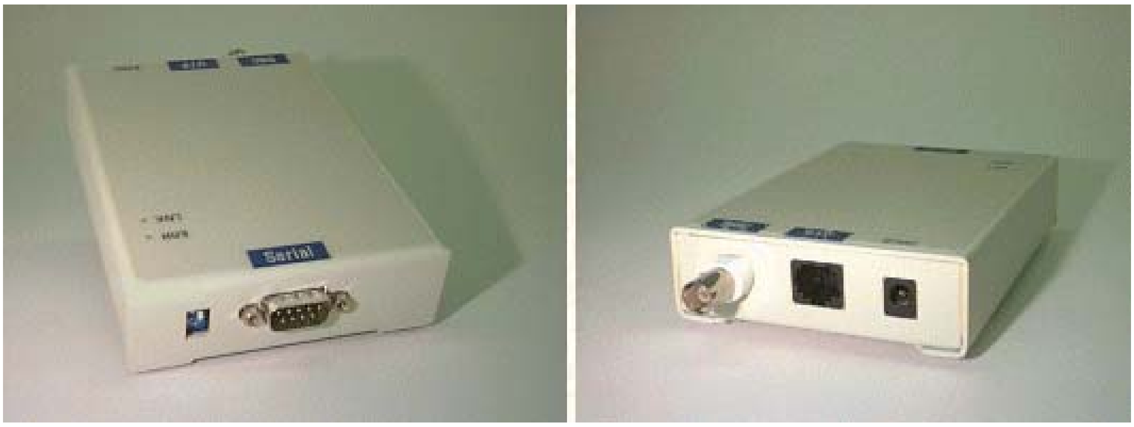

Fig.42 Front and back views of EtherPole EPL-1 [32]

It has one serial port RS-232, which is shown from the left side, with the data transferring speed till 230kbps and one RJ-45 port for Ethernet connection. Detailed description of technical parameters of EtherPole EPL-1:

- Integration of Modbus serial and Ethernet devices.
- It has one RJ-45 port for Ethernet connection.
- EtherPole EPL-1 has one serial port RS-232 with the speed up to 230kbps.
- The power input of PortBox is 9 VDC.
- The maximum power consumption is 500mA at 9 V.
- The dimensions of the converter are 3 1/2" × 4 3/4" × 1 1/4". [32]

As advantages we can notice:

- The high data transferring speed from the serial side – 230kbps.
- The high data transferring speed – 10/100 Mbps to the Ethernet.
- Rather compact realization.

As disadvantages it is significant:

- Absence of additional protection.
- Absence of the possibility to use serial port RS232/485 for choice.

4.1.6 EtherPath SS-1R

EtherPath SS-1R is developed by the company Data Comm for Business. It is rather similar in operation to the EtherPole EPL-1 converter described above. The front and back view of the EtherPath SS-1R is presented in Fig.43.

Fig.43 Front and back views of EtherPath SS-1R [33]

The main task of the device is to connect serial port RS-232 over Ethernet Local Area Network (LAN). EtherPath uses TCP/IP protocol for transferring the data. The speed of the data transferring through the serial port is up to 230kbps.

There are many configurations of the connection system can be presented realized with help of EtherPath SS-1R, but we are interested in the simple connection of serial port with the PC. This configuration is illustrated in the Fig 44.

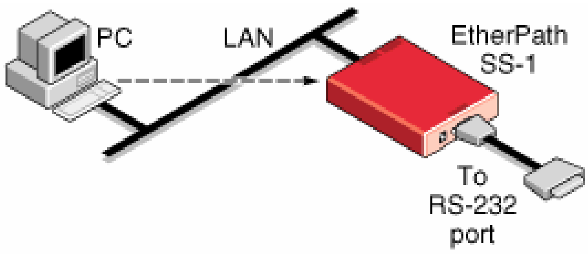

Fig.44 Connection of the PC to RS-232 port with help of EtherPath SS-1R [33]

Detailed description of technical parameters of EtherPath SS-1R:

- Integration of Modbus serial and Ethernet devices.
- It has Ethernet transferring speed 10/100Mbps via RJ-45 port, autoselected.
- EtherPath SS-1R has one serial port RS-232/485 with the transferring speed up to 230kbps.
- The data transmitting is realized over TCP/IP protocol.

- The real temperature which this converter operates at is from – 40 to 70 °C.
- The power input of EtherPath SS-1R is from 5 to 30 VDC.
- The maximum power consumption is 350mA at 5V and 200mA at 12V.
- The dimensions of the converter are 5 × 7.8 × 2.8 cm. [33]

As advantages we can notice:

- The high data transferring speed from the serial side – 230kbps.
- The high data transferring speed – 10/100 Mbps to the Ethernet.
- Very compact realization.
- Very big temperature diapason.

4.2 RS-232 – PCI cards

The other way to connect Advant controller AC-110 and OPC server is not to convert the Modbus signal into Ethernet signal, but to find a solution how it is possible to link up them directly. Firstly let us consider how AC-110 is connected to the data acquisition computer in the third generation of remote systems. There are ISA slots in the PC and built-in RS-232 – ISA cards. So Modbus is connected to the serial ports RS-232. In new version of RDS there are not ISA slots, but there are more modern slots – four PCI-slots. And one way is to find RS-232 – PCI cards to connect AC-110 and OPC server and consequently to get Modbus signal by OPC. Such RS-232 – PCI cards are offered by many companies with different solutions, but below just the most famous solutions are listed.

4.2.1 Quatech RS-232 – PCI board

The company Quatech offers many different RS-232 – PCI cards. There are cards with 2/4/8 independent RS-232 ports. So the main advantage of such a type of cards is that we need just one PCI slot for some RS-232 ports. The appearance of such card is presented in Fig.45.

Fig.45 Quatech RS-232 – PCI board [34]

Detailed description of technical parameters of Quatech RS-232 – PCI board:

- The number of serial ports that can be provided by one card is 4, 8, or 2.
- Data transferring speed via serial port is up to 921.6 kbps.
- It can be supported by Windows 98/NT/2000/XP and Linux.
- The Quatech Company offers 5 years warranty.
- The real price is from 109 euro for the 2-ports card to 429 euro for 8-ports card. [34]

4.2.2 Startech RS-232 – PCI card

Two variants of RS-232 – PCI cards are presented by the company StarTech, with one and two serial ports. It is rather easy way to add serial devices to the PC. The appearance of such a kind of cards is presented in Fig.46.

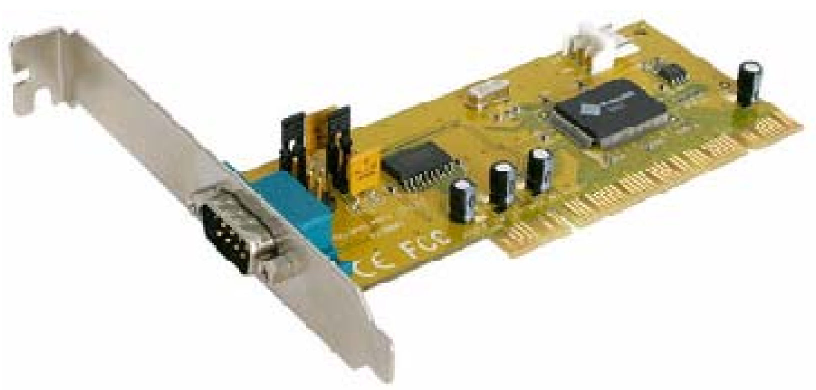

Fig.46 StarTech RS-232 – PCI card [35]

Detailed description of technical parameters of StarTech RS-232 – PCI board:

- The number of serial ports that can be provided by one card is 1 or 2.
- Maximum data transferring speed via serial port is up to 920 kbps.
- It can be supported by Windows 98/NT/2000/XP, Linux and also DOS/Windows 3.1.
- The StarTech RS-232 – PCI board height and length are 5 × 12 cm.
- Operating temperature is 0 – 57 C.
- The real price is from 25 to 55 euro. [35]

4.2.3 Advantech RS-232 – PCI card

The company AdvanTech has developed the 8 serial ports RS-232 – PCI board. It was developed for communication PC with serial devices. This card is presented in Fig.47.

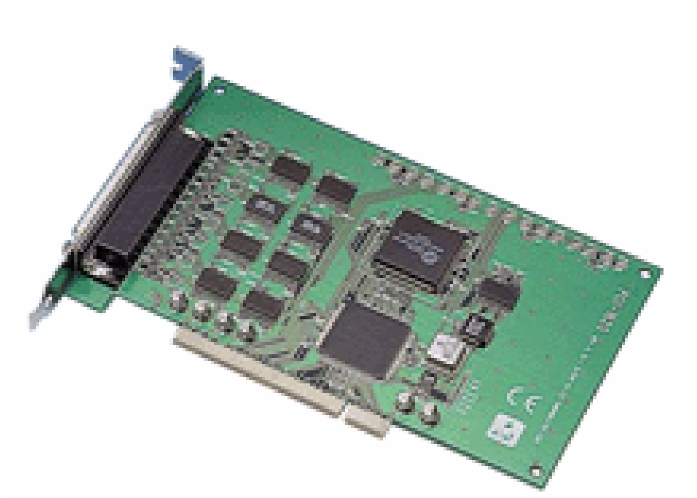

Fig.47 AdvanTech RS-232 – PCI card [36]

Detailed description of technical parameters of AdvanTech RS-232 – PCI board:

- The number of serial ports that can be provided by one card is 8.
- Maximum data transferring speed via serial port is up to 921.6 kbps.
- The real price is up to 392euro. [36]

4.3 PCI – ISA converters

Another possible solution for connecting Advant controller to OPC server is to find a converter from PCI to ISA buses. A bus is the instrument for establishing of connection between PC and other devices. Industry Standard Architecture (ISA) is a 16-bit standard interface by which the data transferring speed is 8MHz. It is utilized in old boards. The newest standard Peripheral Component Interconnect (PCI) can transfer the data of 32 or 64 bits at transferring speed 33MHz. Bus adapters depends on the protocol and type of connection.

PCI – ISA converters are not so propagated, because there are many problems with their utilization and not so many such solutions are presented by different companies. They are not so effective for example than other devices for connection serial devices to a PC.

The company Costronic for example offers in the market PCI to ISA bridge kits. But if you are not a professional it is a big trouble for you to utilize this card, because you have to write a special program by yourself. They sell these cards but do not provide any support. [37]

4.4 Summary analysis of the introduced devices

So we have considered above all the possible ways to get Modbus data by OPC server or in other words to connect Advant controller AC-110 to OPC server utilized in the new version of ABB's RDS systems. AC-110 as we know uses the Modbus protocol for data transmitting and the OPC server gets the data with help of the Ethernet. There are three variants found:

- Modbus converters. They are utilized for the conversion of the Modbus protocol into the TCP/IP protocol. They should be installed somewhere between the Advant controller AC-110 and the OPC server, in Electrical Control Room. This way of connecting AC-110 and OPC server gives us the possibility not to change the form of signals, that are sent by the controller (Modbus) and that are got by the PC (via Ethernet). So the controller and the PC can, in principle, operate in their normal conditions without any special transformation devices for getting or sending the data on them.

- RS-232 – PCI cards. The second technical solution of this problem is the realization of the connection with help of special adapter cards (RS-232 – PCI cards). So, with these devices we are able to link the controller and the OPC server directly. As an example we can consider the already existing system installed on many ships – the third generation RDS. There is a straight connection of the Modbus signal to the serial ports RS-232/485 on the data acquisition computer. These ports are available on the computer thanks to built-in RS-232/485 – ISA cards. So just one difference exists in our case, as we have the newest development of the industrial computer there are not outdated ISA slots and instead of them there are four PCI slots. So for providing vacant ports RS-232/485 we need to build RS-232/485 – PCI cards in the computer.
- PCI – ISA converters. It is the last technical solution for connecting AC-110 and OPC server. PCI – ISA card is a kind of bus adapters. They provide data connection for the peripheral devices to the computer without the possibility of original support for the interface, exploitable by the peripheral devices. Such adapters are not so often used because of the complexity of their utilization and of course such converters may distort the signal.

The terminal decision about utilization the concrete device of course should be taken by the designer relied on its own experience. But let us try to compare the devices, considered above, in groups, based on the better functionality and price.

The first question that can appear is: Which way of connection is the best to choose. To find the answer on this question we have to evaluate firstly the availability of the devices, their price and simplicity in use.

The most evident are the drawbacks of the utilization PCI - ISA cards. As noticed above a bus adapter – PCI – ISA converter – is the most complicated device. It can not be used for example by the people without additional deep knowledge in programming, because the company which sells these cards does not provide any help in the utilization of their product for their clients. Besides it, such bus adapters sufficiently slow down the data transmitting and may distort the data that is not permitted in our system. For the Modbus converters let us compare introduced variants and summarize it in Table 2.

Table 2 Comparison of the Modbus converters

Parameters	**Converter DL-MES1A**	**NetBiter Gateway**	**NPort 6110 Gateway**	**PortBox**	**EtherPole EPL-1**	**EtherPath SS-1R**
Power supply, VDC	10-30	9-32	9-30	8-15	9	5-30
Current consumption	Not found	50mA at 24V	300mA at 9 V	Maximum 200mA	500mA at 9 V	350mA at 5V
Temperature range, °C	-20 to 80	0 to 60	0 to 55	5 to 50	Not found	– 40 to 70
Transferring speed from the Ethernet side, Mbps	10/100	10/100	10/100	10/100	10/100	10/100
Transferring speed from the serial side, kbps	Not found	57.6	230.4	Not found	230	230
Dimensions	3.2 × 11.3 × 12.2 cm	9 × 7 × 5.8 cm	9 × 10.04 × 2.2 cm	2.8 × 10.5 × 13.5 cm	3 1/2" × 4 3/4" × 1 1/4"	5 × 7.8 × 2.8 cm
Exact price	272.60 euro	Not found	Not found	Not found	Not found	Not found

Additional benefits	-High security; -High flexibility, thanks to the mobile terminals	- High flexibility of the connection	- Easy accessibility; - Automatically software selection of the serial port RS-232/422/485	- Built-in virtual serial port	No special benefits	No special benefits

We have to consider the solutions presented from the point of view of our application. About power supply it does not play a big role in our case of marine application, all the presented powers are not so big. Temperature ranges in which these devices can operate are also not so important in our application, because of their location in electrical control room with the normal room temperature. It is maybe important only in case of emergency. About their sizes, all of them are rather small, especially, in comparison with the dimensions of the devices utilized in the marine industry. So power consumption does not play a significant role in the choice of the utilizing device.

The main task of this device is to deliver the right form of the data to the OPC server. And of course the key aspect is the transfer rate of the data. Transferring speed from the side of the Ethernet connection is the same for all the solutions. So the main aspect is the speed from the serial part, from the part of the serial ports RS-232/485. Transfer rates of three devices have approximately one high level (230 kbps). It is NPort 6110 Gateway, EtherPole EPL-1 and EtherPath SS-1R.

To choose from these three variants we have to take into account their additional advantages. The most attractive variant from this side is NPort 6110 Gateway. As for the other devices the main task is to connect controllers with the Modbus protocols through the Ethernet to the PC. It can also operate in different operational modes and network configurations. NPort 6110 has a serial port which can be selected by the software according to the request. Another benefit is when we use this device as converter of Modbus data in our case we can connect from the serial side up to 31 Modbus slave devices. And of course the most important argument to NPort 6110 is the company which offers it. Moxa Technologies is very famous and reliable partner. Now let us compare different RS-232 – PCI cards. Their comparison is presented in table 3.

Table 3 Comparison of RS-232 – PCI cards

Parameters	**Quatech RS-232 – PCI card**	**Startech RS-232 – PCI card**	**Advantech RS-232 – PCI card**
Possible number of serial ports	2,4,8	1,2	8
Data transferring speed via serial port, kbps	921.6	920	921.6
Price	from 109 euro for the 2-ports card to 429 euro for 8-ports card	from 25 to 55 euro	up to 392euro

So in case of using RS-232 – PCI cards the key aspect is the number of possible serial ports. The widest choice of numbers of the serial ports is offered by the company Quatech. The transferring speed is the same for all cards and price is significantly lower on card offered by company Startech. But as we need more than one or two ports it is better to use one multiport card instead of some 1 or 2 port cards so that to leave free some PCI slots.

4.5 Suggested solution for the problem

As a result of the work we have found three possibilities of getting Modbus data by OPC server: Modbus converters, RS-232 – PCI cards and PCI – ISA cards. From the analysis of found examples we can conclude that the third group (PCI – ISA cards) is not suitable for the solving of our task. From the first two groups (Modbus converters and RS-232 – PCI cards) we have picked out one best device for each group.

For the Modbus converters it is NPort 6110 Gateway and for RS-232 – PCI cards it is Quatech card with four serial ports, because excessive superfluity of ports overloads the computer. The price of this four ports card is 229 euro. It has one Ethernet RJ-45 port and provides four serial ports RS-232.

As it is said earlier the key aspect in selection of the device in our case is data transferring speed. Let us compare now the price and transferring speed of these two devices. The results are presented in table 4.

Table 4 Comparison of NPort 6110 Gateway and Quatech RS-232 – PCI card

Parameters	**NPort 6110 Gateway**	**Quatech RS-232 – PCI card**
Data transferring speed, kbps	230.4	921.6
Price, euro	Not found	229

The data transferring speed of the Quatech RS-232 – PCI card is four time higher than the transferring speed of the NPort 6110 Gateway. About the price, in spite of the fact that the exact price of NPort 6110 Gateway was not found we can say that the price on the devices of such types (Modbus converters) are of one level, approximately up to 500 euro.

As a conclusion, the simplest and the most effective way to connect Advant controller AC-110 to OPC server and consequently to whole PCMS system is to build in the computer RS-232 – PCI card with four serial RS-232 ports. Quatech is very experienced company in this direction. It has dealt with producing of such boards more than 20 years and can guarantee the quality of its production. The schematic connection of AC-110 and PCMS server is shown in Fig.48. The card is built in the computer.

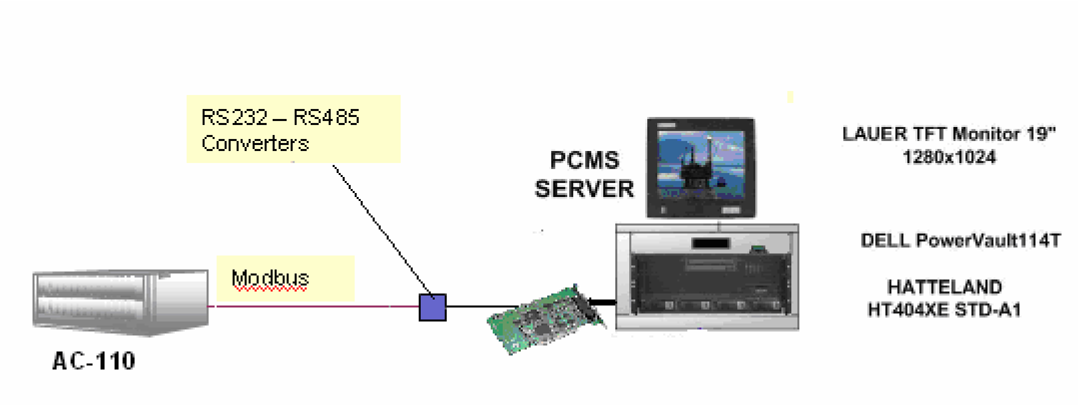

Fig.48 Schematic connection of AC-110 and PCMS server with help of RS-232 – PCI card

5 CONCLUSION

Nowadays such monitoring systems as remote diagnostics are commonly used in marine industry, due to downtimes that can cause big losses or even danger of life which are not permissible for the modern shipbuilding. As a result the development of the remote control technology has become a challenging task for marine designers.

The company ABB improves all the time its control systems and offers just the newest technologies for its clients. The reliability of operating the propulsion system of the vessels is the most important task for the monitoring. Now the most ships manufactured with help of ABB designers are equipped with the third generation remote diagnostic systems for the propulsion system. This RDS was issued at the end of 1990's but its devices date back to the beginning of the 1990's.

In recent times the newest ABB remote diagnostic system, PCMS system, was developed by the group of designers in the Polish department of ABB Marine. After absolute completion and testing this system is planned to be installed in new ships. However, the old already existing systems are also in need for revision to the modern level adjusted by the new system. However, it is not reasonable to change the whole system by the new one. The old propulsion controller – the Advant controller AC-110 and and the original propulsion motor converter – should remain.

As a result of this work the ways of upgrading the old remote diagnostic systems were studied. Firstly, the operating principles of these two diagnostic systems were thoroughly investigated and analyzed. Then, based on the analysis, the decisions about the parts which should be changed were suggested. The task of improvement was reduced to the establishment of the connections between invariable parts of the system (propulsion controllers) and the rest parts of the newest version of RDS.

For solving this problem, different types of the data transferring protocols were considered and many technical solutions for getting Modbus data by the OPC server were suggested (Modbus converters, RS-232 – PCI cards and PCI – ISA cards). As a consequence of the analysis the most suitable device in effectiveness and price appears to be the RS-232 – PCI card. However, the final solution of the use of the concrete devices should be made by the main designer based on his own experience.

The remote diagnostic systems are constantly in need of upgrading and this work can be a good base for additional investigation of the problem. Especially, since this work contains mainly just the hardware side of the improvement.

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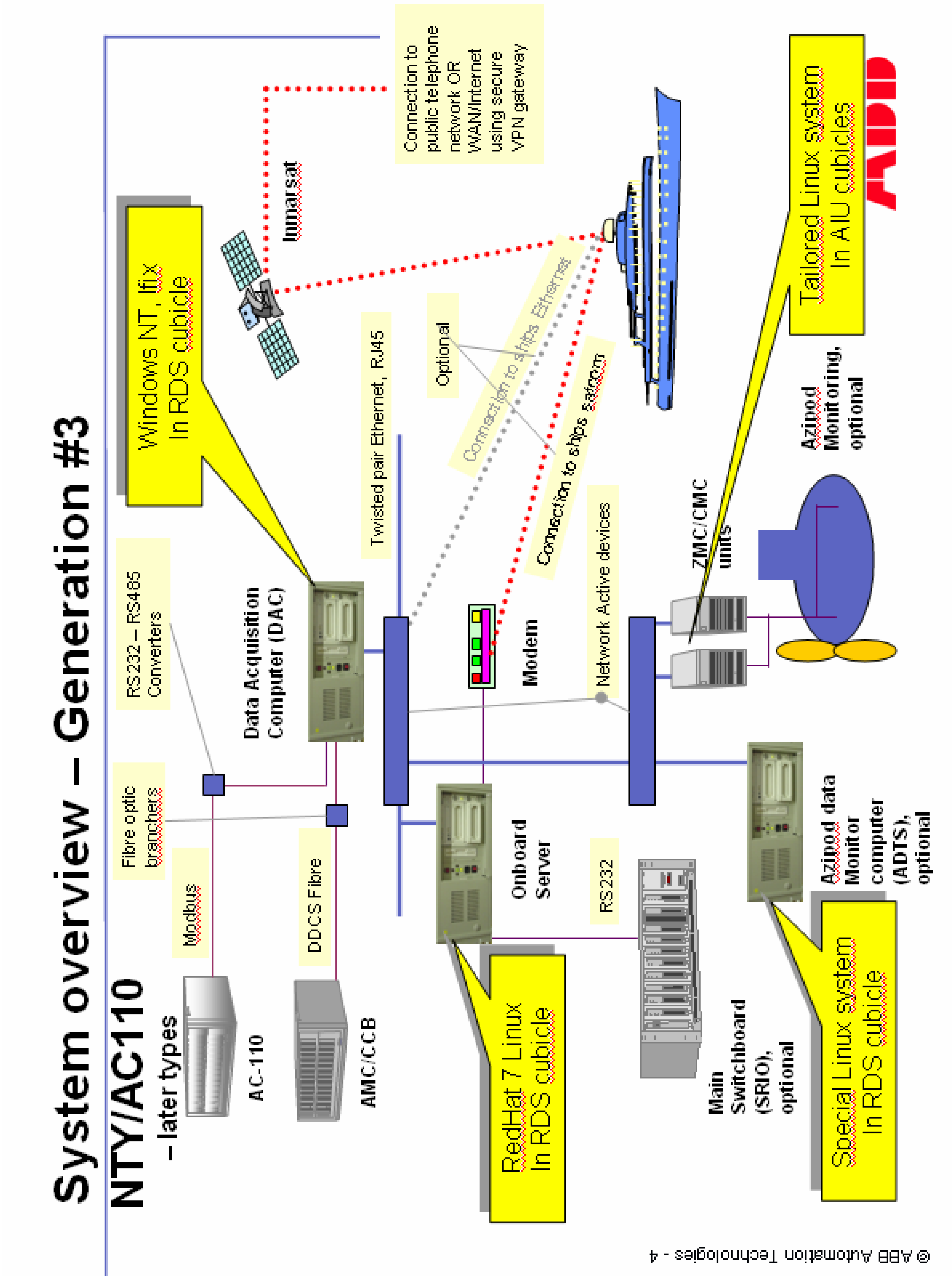
APPENDIX

A. THE THIRD GENERATION OF THE REMOTE DIAGNOSTIC SYSTEMS.



B. THE NEW VERSION OF THE REMOTE DIAGNOSTIC SYSTEMS – PCMS SYSTEM.