

Classification and analysis of a human machine interface (HMI)

Mikael Hudd

Bachelor's Thesis
Electrical Engineering
Vaasa 2014



BACHELOR'S THESIS

Author: Mikael Hudd

Degree Programme: Programme in Electrical Engineering

Specialization: Automation Engineering

Supervisors: Erik Englund, Johanna Björk

Title: Classification of analysis of a human machine interface (HMI)

24.04.2014

32 pages

1 appendix

Summary

This Bachelor's thesis was commissioned by ABB Power Generation, Vaasa. My task has been to investigate the human-machine interface system (HMI), Wärtsilä operator's interface system (WOIS), and whether the system fulfils the requirements for control through the HMI for marine applications. The focus will be on the requirements set by Det Norske Veritas, Bureau Veritas and American Bureau of Shipping.

The task is to first examine the system and then make a list of the needed changes in order to fulfil the requirements of classification societies. Through meetings and discussions a final listing of changes was arrived at. Additionally a list of documentation was created.

Language: English

Key words: HMI, SCADA

EXAMENSARBETE

Författare: Mikael Hudd

Utbildningsprogram och ort: Utbildningsprogrammet för Elektroteknik, Vasa

Inriktningsalternativ/Fördjupning: Automationsteknik

Handledare: Erik Englund, Johanna Björk

Titel: Klassifikation och analys av användargränssnitt. (HMI)

24.04.2014

32 sidor

1 bilaga

Abstrakt

Detta slutarbete är utfört åt ABB Power Generation, Vasa. Min uppgift var att undersöka om ett användargränssnitt, *Wärtsilä operator's interface system (WOIS)*, uppfyller kraven för styrning inom marina tillämpningar. Reglerna som undersöktes är fastställda av Det Norske Veritas, Bureau Veritas samt American Bureau of Shipping. Undersökningen fokuserar först på systemet och sedan på utarbetande av en lista med ändringar som behöver implementeras för att uppfylla kraven från klassificeringsbyråerna. Genom möten och diskussioner har en slutgiltig lista på förändringar. Ytterligare har en dokumentlista utformats.

Språk: Engelska

Nyckelord: HMI, SCADA

Table of Contents

1. Introduction.....	1
1.1 Objectives.....	1
1.2 Control and monitoring system.....	1
1.3 Classification societies.....	9
1.4 Key phrases.....	11
2. Guidelines and user-interface design.....	12
2.1 Intro.....	12
2.2 Guidelines when designing a user-interface.....	14
2.3 The display.....	17
2.4 Interactions.....	19
3. Supervisory Control and Data Acquisition.....	21
3.1 SCADA systems.....	21
3.2 Data acquisition.....	21
3.3 Monitoring and event processing.....	22
3.4 Control functions.....	24
3.5 Data Storage, archiving, and analysis.....	25
4. Hardware.....	26
4.1 Introduction.....	26
4.2 Hardware rules and regulations.....	26
5. Methodology.....	28
6. Results.....	29
6.1 List of solutions.....	29
7. Evaluation, conclusions and recommendations.....	30
8. Bibliography.....	32
8.1 Books & publications.....	32
8.2 Personal Meetings & Discussions.....	32

Appendix A

1. Introduction

1.1 Objectives

Supplying their customers with flexibility and reliability is a high priority for ABB Power Systems. This thesis improves on this by examining the current human-machine interface (HMI) device of marine control systems. The current HMI device is part of the user interface and allows only for monitoring of engines while the control operation is restricted to the soft keys and control panels on the cabinet doors. By taking a closer look at the current HMI system and comparing it to the rules and guidelines stipulated by the classification societies, Det Norske Veritas, American Bureau of Shipping and Bureau Veritas. A plan was created to develop a control and monitoring system that complies with the stricter demands on controlling the engines. The scope of this thesis is that of the HMI computer itself. The HMI computer refers in this thesis to the physical computer and its software.

1.2 Control and monitoring system

The system, installed on a computer consists of databases. There are different programs and functions that allows the very different parts of the system to communicate. Built upon all this information is an HMI system. This system works much like the user interface of any other system. There are buttons that can be pressed, graphs for reading data, counters, overviews, alarms and other important functions. The computer hosting the HMI

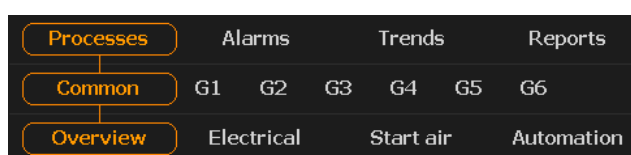


Figure 1. Navigation area. Used for navigating the HMI system.

application is called “a WOIS”. It is an abbreviation that stands for Wärtsilä Operator's Interface System.

Figure 1 shows the navigation

area at the top of the screen.

Navigation is performed by using the mouse to select different topics. In *Figure 2* the operator has selected “Processes” on the top most level, on the middle level “Common” is selected. Common is where all the common processes for a plant are listed, such as Electrical and Start Air. On the bottom level the operator has selected Overview, which displays an overview of the plant.

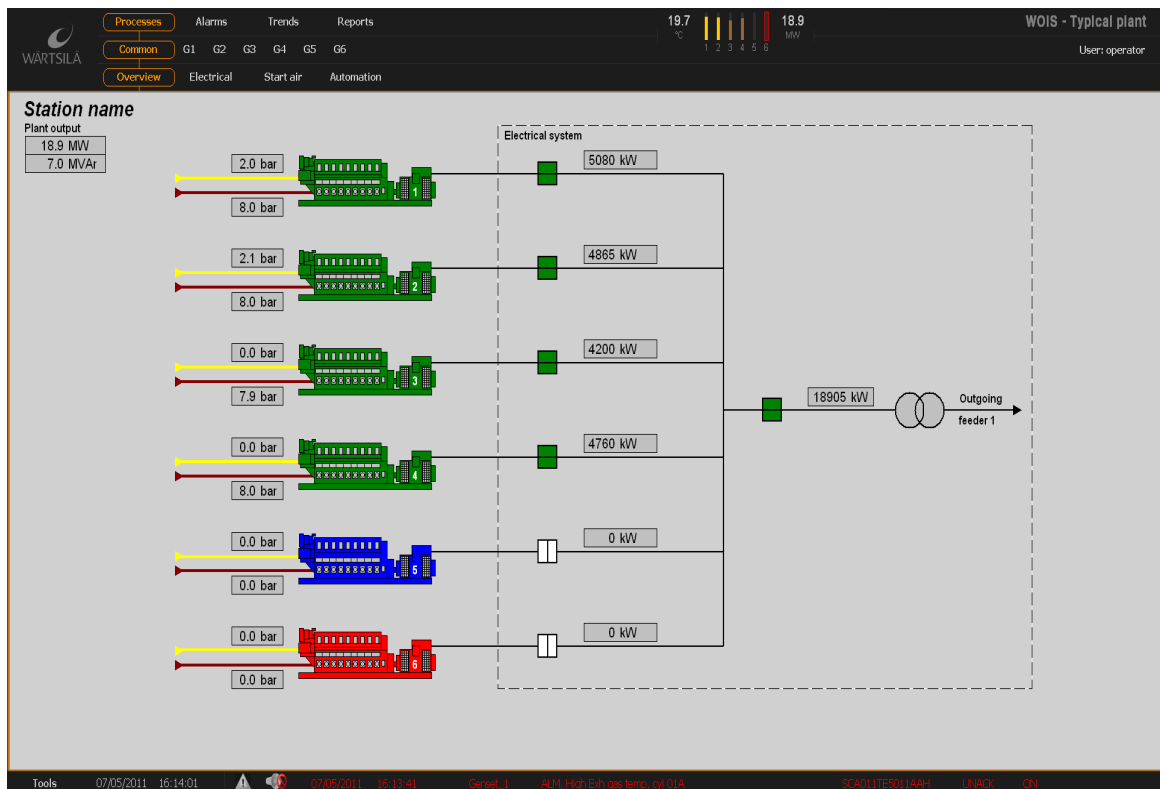


Figure 2. System Overview. Displays an overview over the plant.

The overview gives a picture of the plant as it is. The current plant has six engines, colour-coded according to their current status: Green for running, red for alarm and blue for not in operation. The plant overview also shows power outputs and pressure readings, and the connection between the engines is also displayed. In this case all engines are connected to a bus bar, the vertical line, which in turn is connected to an outgoing feeder. The breakers and the high voltage transformer are also shown.

As it is a HMI system, assistance in abnormal conditions is important. In order to assist with the variety of situations that can arise, and since it is also based on the same theories that build a SCADA system, handling and displaying alarms is an important aspect of the

WOIS. The following few pictures show the different alarm views.

Alarms can be viewed in different groups, as shown in *Figure 3*, and there are both a summary and a historical view. These pages can further be categorised to show alarms (and events) for the whole plant, the common alarm or only the alarms for a specific generator-engine set (genset). The alarms are colour-coded, red for unacknowledged, purple for acknowledged alarms and blue is for unacknowledged alarms that have returned to normal. Additionally there are green events which can among other things, refer to a change in a state or breaker control and are a part of the event logging, history and archiving function.

Date (yyyy/mm/dd)	Time (hh:mm:ss)	Description	Plant code	Alarm Group	Alarm State	State	Operator
07/05/2011	16:13:41	ALM, High Exh gas temp, cyl 01A	SCA011TE5011AAH	Genset_1	ACK	ON	operator
07/06/2011	12:21:28	SF, Liner temp 2, cyl A01	SCA011TE7012ASF	Genset_1	UNACK_R	OFF	operator
07/06/2011	12:21:38	ALM, Radiator group 1 motor control center fault	VCA011M001MFI	Genset_1	UNACK	ON	operator

Figure 3. Alarm view: Summary. Displays a summary of the alarms in the plant.

Figure 4 shows the trend view. In the trend view the operator can display different signals and then watch the signals both in real time and their historical values.

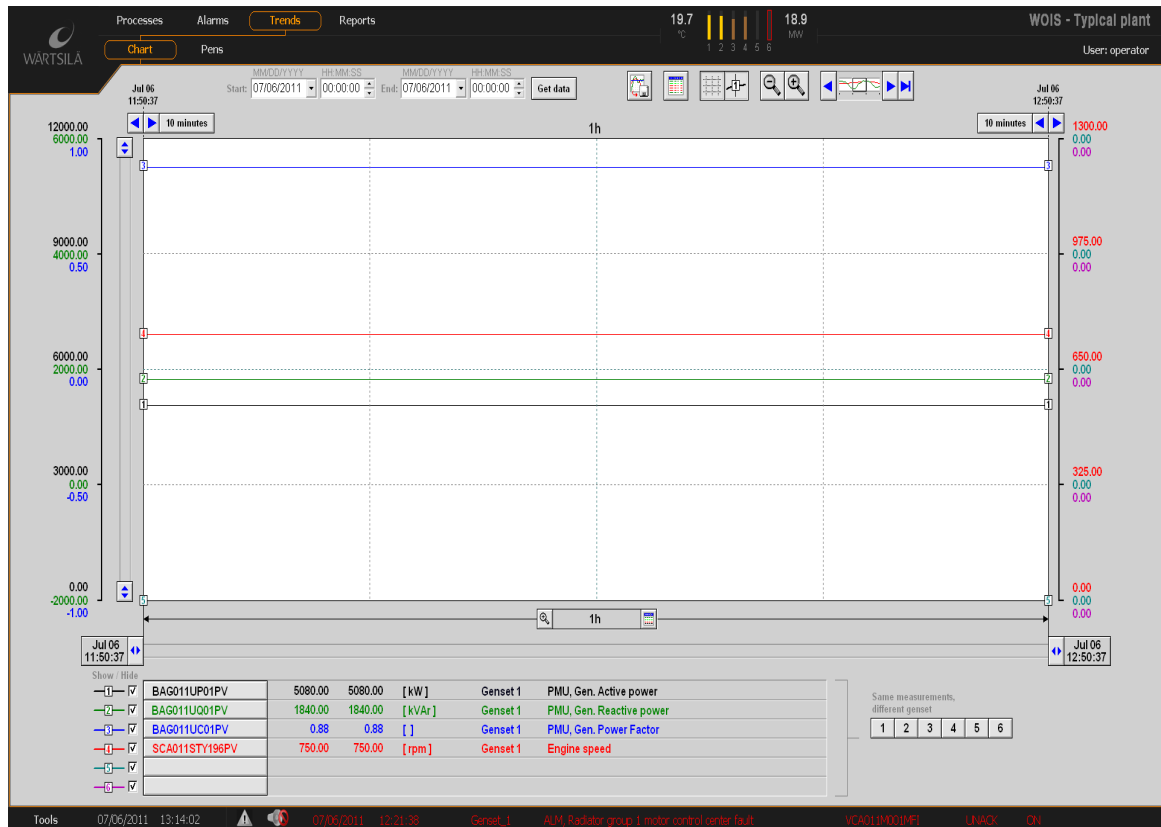


Figure 4. Trend View. Both real time and historical trend views of different analogue variables.

Trend selection and customization can be accomplished in a separate screen, called Pen select. See *Figure 5*.

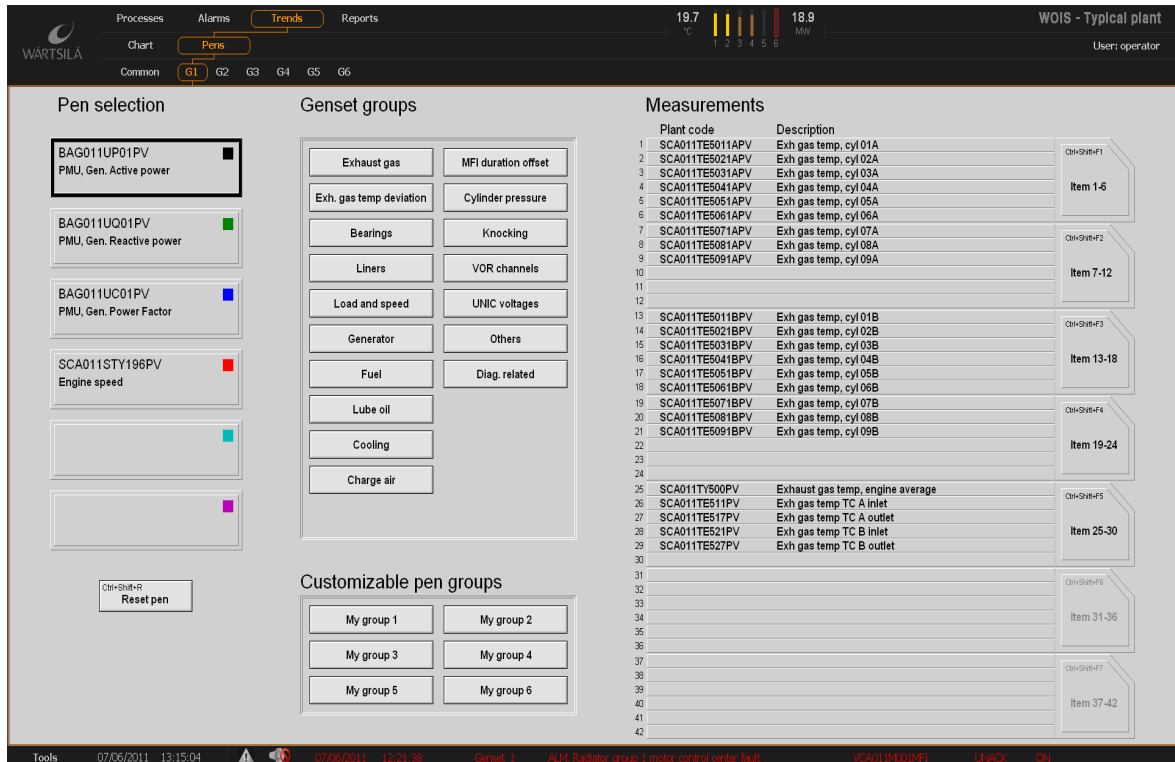


Figure 5. Selection window. Selection window for Trend View.

The operator can select a category from the middle. The group is opened with its associated signals on the right-hand side of the screen. For ease of access the operator can click on the buttons “Item..” or pick and choose which signals to display. The selected signals show up on the left hand side with their associated colours. A selection of signals can be saved for convenience to the “My group..” selections.

Additional overviews of the system and the different measurements can be obtained from the Reports function. The report page, *Figure 6*, shows all the current analogue readings of an engine set or the common side. From the view the operator can also select measurements in order to display them in the trend view.

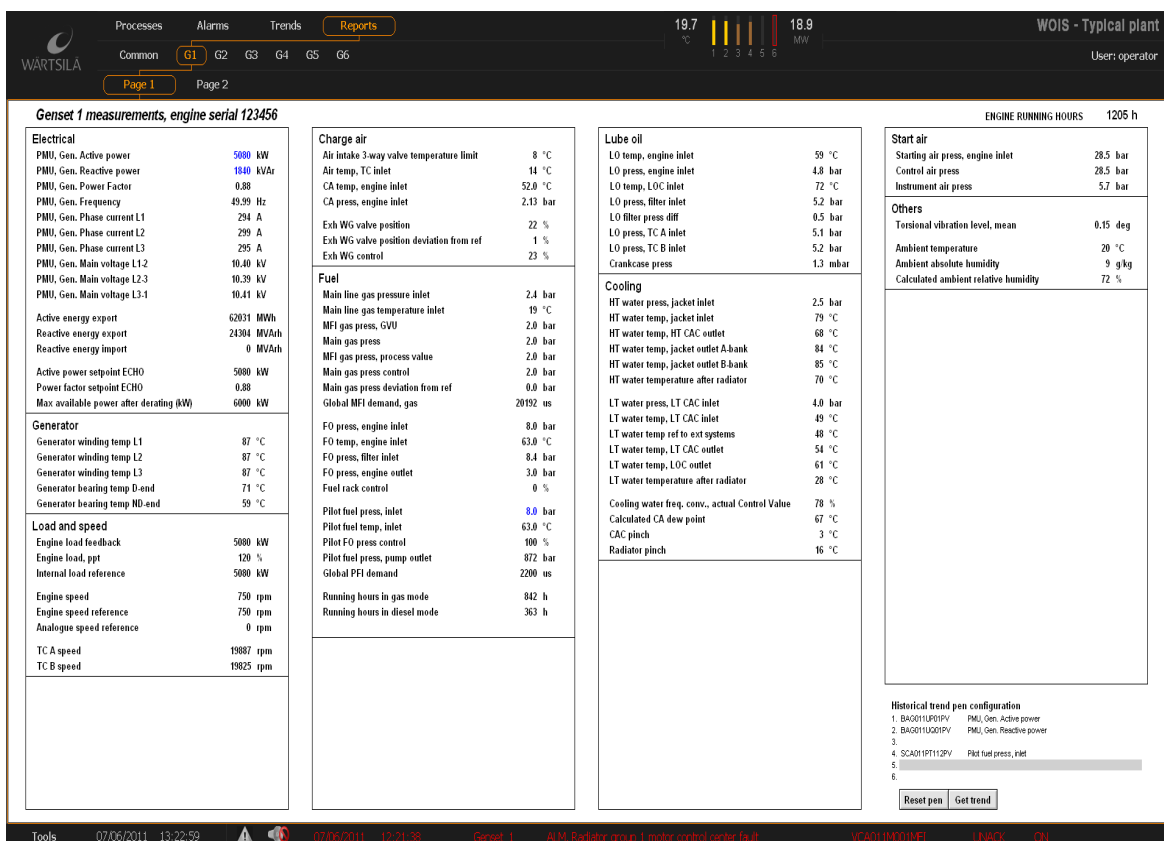


Figure 6. Reports page. Displays all current analogue values per genset.

In addition to all these reporting and archiving tools, the system also allows for operation and control over the plant or ship. *Figure 7*, Electrical, displays a more detailed version of the previously shown *Figure 2*, Overview. In Electrical the auxiliary transformers are displayed. These auxiliary transformers transform part of the output to 400V for the plant's own needs. The AC to DC converter(s) is/are also displayed. Monitoring units, such as VAMP units, with their alarms, are also displayed.

WARTSILA

Processes | Alarms | Trends | Reports

Common | **G1** | G2 | G3 | G4 | G5 | G6

Temp | Control | Fuel | Lube | Cooling | Exh. gas | Exh. gas | Knocking | Cyl press

User: operator

MFI duration ref. 20192 us
Fuel rack control 0 %
Torsional vibration 0.15 deg

Engine speed 570 rpm
Engine phase 5080 kW
Engine load 1205 h

Gen. active power 5080 kW
Gen. reactive power 1840 kVAr
Max available power 6000 kW

TC B

Temp inlet 511 °C		Temp outlet 302 °C		Speed 19825 rpm	
----------------------	--	-----------------------	--	--------------------	--

Exhaust gas temperatures [°C]

B9	B8	B7	B6	B5	B4	B3	B2	B1
519	514	517	519	519	519	517	519	513

Bearing temperatures [°C]

101	97	105	108	104	98	101	99	96
109	104	105	111	105	106	107	98	104

86 89 87 87 87 85 88 89 85 83

1.3 mbar

108 105 103 105 104 105 104 97 104

103 103 98 98 100 104 100 96 104

Exhaust gas temperatures [°C]

519	515	516	508	521	520	519	515	521
A9	A8	A7	A6	A5	A4	A3	A2	A1

TC A

Temp inlet 515 °C		Temp outlet 303 °C		Speed 19887 rpm	
----------------------	--	-----------------------	--	--------------------	--

⑤ ⑤

Liner temperature 2 [°C]
Liner temperature 1 [°C]

Generator

Winding L1 87 °C

Bearing D 71 °C Winding L2 87 °C Bearing ND 59 °C

Winding L3 87 °C

①

Liner temperature 1 [°C]
Liner temperature 2 [°C]

⑤ ⑤

Tools 07/05/2011 16:15:58 07/05/2011 16:15:40 Speed 1 M.M. 1300 Edo cos beam oil OIA SCADA TEST01 MANU 130003 CN

Engine-wise control and start-up display generator measurements and operation mode of the engine. Other useful information and control operations include the start-up and shut-

down process, protection relays and fuel selection.

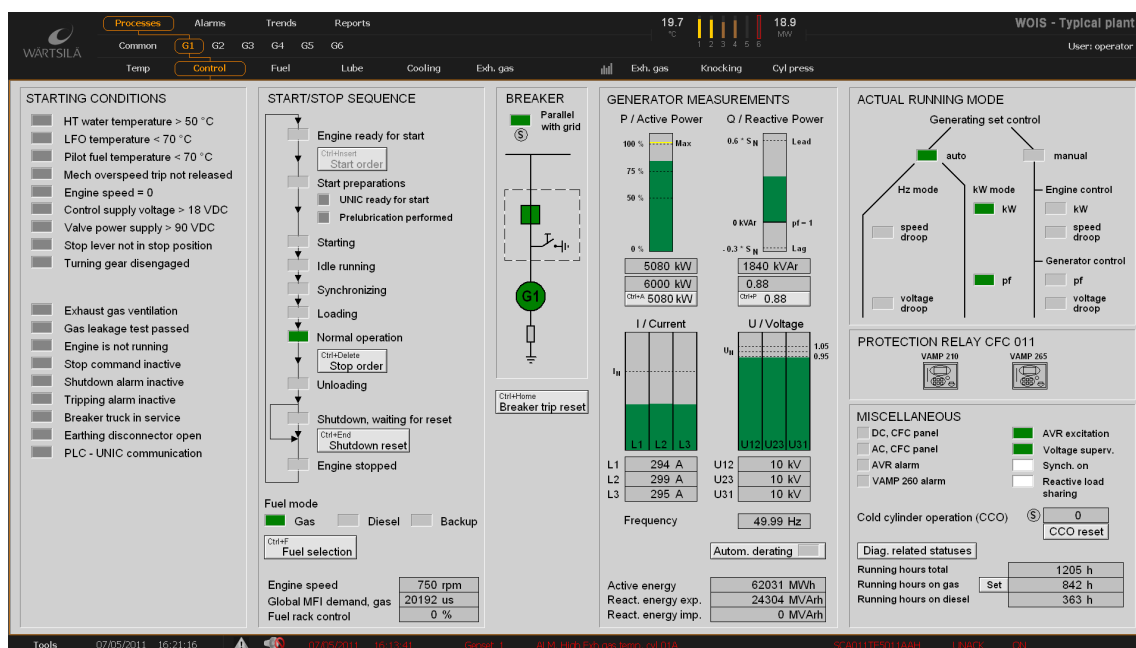


Figure 9: Engine Control. Includes start and stop sequence, generator measurements and run mode.

Several objects can be further selected to open a pop-up window that displays additional information and control.

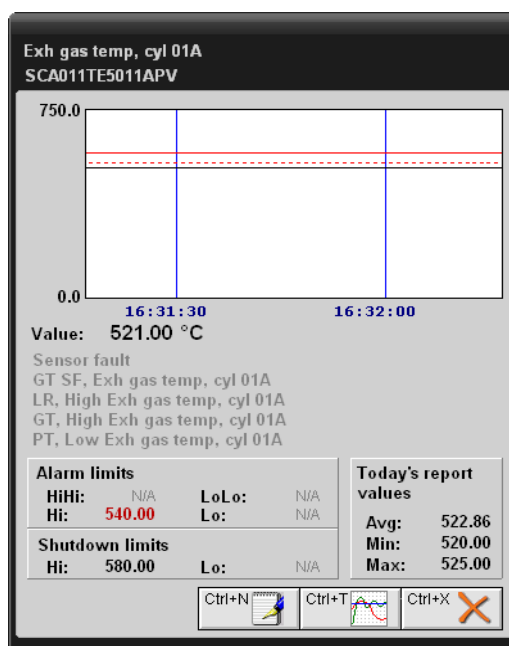


Figure 10: Analogue info. Pop-up window for analogue values.

Note: All values and states in the pictures are simulated. All these images are from a power plant version, and not a marine WOIS. Currently no demo version exists, to my knowledge, for the marine version. The major difference is the screen space. As space on a ship is limited there are no wide screen monitors so the application is more compact and some functions that are displayed in a single view in the power plant version are split between two different views in the marine version. (WOIS demo Rev13. n.d.)

1.3 Classification societies

"A classification society is a non-governmental organization that establishes and maintains technical standards for the construction and operation of ships and offshore structures." (Classification Societies, n.d.)

Classification societies exist in order to ensure that a common ground of standards and safety procedures is available. This common ground created by the societies allows partners in business to have a clear understanding of what one part is selling and the buyer knows, for a fact, what requirements the product or services fulfil. By creating a common ground for trust and mutual understanding, the safety of the workers can be increased and monetary risk calculations in case of failure are made easier.

In this thesis, the main focus among the classification societies has been on Det Norske Veritas (DNV). Det Norske Veritas is an independent assessor of quality, safety and integrity. Their focus areas are the maritime, oil & gas and energy sectors; offering their services both to authorities and the industry. Det Norske Veritas was founded in 1864, by Norwegian insurance companies as a national alternative to foreign classification societies. (Det Norske Veritas, 2011a)

Their purpose, vision and values:

"Our purpose – To safeguard life, property and the environment

Our vision – Global impact for a safe and sustainable future

Our Values – We build trust and confidence, we never compromise on quality or integrity, we are committed to teamwork and innovation, we care for our customers and each other." (Annual Report, Det Norske Veritas, 2011)

DNV has 300 offices across 100 different countries. By the end of 2011 they had 8453

employees. Their offices can be found mainly in coastal areas, with several in Europe.

Maritime services include:

- Classification of ships and mobile offshore units
- Certification of materials and components
- Technical, business risk and environmental
- Advisory services
- Training and competence-related services
- Fuel testing
- Software

Oil & Gas services include:

- Verification
- Safety, health and environmental services
- Asset risk management
- Technology qualification
- Enterprise risk management
- Software and IT risk management

Energy and sustainability services include:

- Accredited climate change services
- Management & operations consulting
- Cleaner energy services
- Transportation systems
- Gas consulting & services
- Electricity transmission & distribution

- Testing, Inspections & Certification
- Sustainable Use Services

Business assurance services include:

- Management system certification
- Product certification
- Supply chain certification and assessment
- Food safety certification
- Training
- Healthcare accreditation and rating services

Other societies that have been studied for this thesis are Bureau Veritas S.A. (BV), an independent classification society based in France. They have about 61,600 employees in 140 countries. They cover several of the business areas that DNV also covers. ABS, American Bureau of Shipping is another competitor in the same fields as DNV and BV. ABS is based in Houston, Texas and their core services are classification services in the form of gathered rules and standards called “ABS Rules”.

1.4 Key phrases

Key phrases used in this work and often found in literature elsewhere, (Det Norske Veritas, 2011b) are:

Alarm is for warning of an abnormal condition and is a combined visual and audible signal, where the audible part calls the attention of the personnel, and the visual part serves to identify the abnormal condition.

An *essential control and monitoring system* (hereafter called essential system) is a system which needs to be in continuous operation for maintaining the vessel’s propulsion and steering.

An *important control and monitoring system* (hereafter called important system) is a system supporting services which need not necessarily be in continuous operation for maintaining the vessel's manoeuvrability, but which are necessary for maintaining the vessel's functions.

Equipment under control (EUC) is the mechanical equipment (machinery, pumps, valves, etc.) or environment (smoke, fire, waves, etc.) monitored and/or controlled by a control and monitoring system.

Genset is the generating set, often consisting of an engine that drives a generator. The engine often runs on some form of fossil fuel. This allows vessels to have energy stored in the form of a combustible fuel that can be converted to electricity as needed.

2. Guidelines and user-interface design

2.1 Intro

A user-interface is the interface which a human uses to act with a piece of machinery. It can be e.g. a few lights and a push button or two. The dashboard in a car is a form of user-interface too. The dashboard allows the driver to read the current speed, the temperature in the engine, the mileage, revolutions per minute etc. The driver controls the car through the driving wheel, pedals and the shift stick. Another user interface many people are in daily contact with are their mobile phones. Phones come in different shapes, sizes and with different operating systems, but they all have a technology that allows the user to interact with the electronic device. Making calls, sending messages, reading mails or browsing the Internet would all be impossible without an interface where the user instructs the software in the phone to request the desired data and/or make connections.

An effective and functional user-interface will greatly improve the experience for the user. For example a touch-screen phone or tablet would not be of much use to a person with reduced sight or even blindness. Older people might prefer phones, TV remotes or other devices to have large buttons, as with age comes reduced mobility in the fingers, where as

a young person living in the fast advancing technological world of today might need the latest model or version of different applications and devices in order to handle daily social contact with friends from near and far.

As these examples illustrate, no one single system is great for everyone, but most systems try their best at serving part of the user base as broadly as possible.



Figure 11: LibreOffice User-Interface

The buttons and fields shown in *Figure 11* probably look familiar to many persons. Versions of this interface have been seen since the early versions of Office suites on computers. These buttons allow the writer in a program to effectively format his/her texts. A user can also pre-define styles for writing. “Text Body” is the default style this text is written in, the font is Times New Roman, the size is 12pt, the text has a “justified” formatting and the line space is 1½ line. From the textbody drop-down menu the user can choose different styles quickly. Often headings have different styles with their bigger font size and maybe bold text. Although this version of a user interface has been around for decades, Microsoft recently (in Office 2010,) changed their user-interface for their office suite so that, instead of having a matrix with buttons and fields, they have categorised functions according to what they do and how. The user first has to select a category among four or so coloured tabs whereafter s/he is presented with buttons from the category. These categories include: *Home, Insert, Page Layout, References, View*. More categories can be added according to the user's desire.

Much like Office suite programs in computers, there are programs that help an operator control and view a ship, a power plant or other energy-producing processes. They come in different shapes and layouts. These interfaces try to improve the experience for the user, by minimizing input errors while increasing productivity. A user interface can often be measured in different tests. These tests range from alpha and beta tests while the product is in development to research tests conducted maybe several years after the product was first introduced. Several aspects of the user-interface can be rated, either by the users themselves or by means of some form of tests and trials. Aspects often tested include: A

positive feeling or sense of satisfaction, few input errors, easy to remember tasks, effective to use, easy to learn. These aspects can be called, with a common name, “Usability”. Usability together with aspects such as cost effectiveness and reliability forms what can be referred to as “System acceptability”. Having a highly acceptable, or effective system improves both the experience for the user performing tasks and for the company.

A working system reduces mistakes and allows operators to focus on the actual task, i.e. operating the process, not having to worry about how to use the system for the smallest task. Having a system that is cumbersome, difficult and/or slow might have a severe negative effect on the user, which in turn is negative for the company which might even be bad for the safety of not only the workers but also of the general population and crew. If a system is difficult to use, the first risk is that an operator might need to look through complex manuals, maybe even in an emergency situation, to find out how to operate the desired device. Another risk is that the operator might just say “it's too troublesome”, and that let values maybe go into a so-called “yellow zone” in the hope that the values stabilize so that the operator does not have to do the, in his mind, troublesome operation.

2.2 Guidelines when designing a user-interface

Guidelines often discuss different aspects of user-interface design, colours to choose, type of buttons to pick, form of said buttons and so on. Making the right choice for the right functionality is often more important and complex than at a first glance.

As an example, let us say a designer wants to implement a user-interface for a heating process. There will be warm and cold gases or fluids. Naturally, looking at current systems and maybe thermometers, the user picks blue for the coldest and red for the hottest. In order to allow users, to see at a quick glance the current values of the process, the system designer also makes a dynamic shade, ranging from blue to red. This enables operators to roughly determine the states of the process by a quick glance. In this system, there is a lot of information, every pipe has both a flow meter and temperature measurement leading in and out of pipes. This makes finding faults faster. Coupled with these readings the designer wants to add alarms and statuses. The first problem arises now: what colour to pick for

alarms. Red is the standard, not only through the history of other programs but societies can require red to be for alarms. Yellow is for warnings. In order to implement this, the designer might have to go back to the start, pick a new colour for hot, maybe even for cold too.

Another choice that's often important is shapes: Round, squared, hexagonal, rounded or maybe a star. All of these have different underlying associations and meanings and can change how a user experiences and interprets a button or field. A red square is often seen as a stop button, a green square maybe a start button. But what about red/green colour-blind people? Another way to use shapes can be that a square changes the state of a valve, a circle enters new data. The options and possibilities are endless. And the designer, or a team of designers, has to test, do research and test again how they want to implement different functions. Cultural differences will also have an impact. Some populations or test groups might associate a symbol with a task, while another population might associate it with something totally different. Designers often try to implement into the graphic of a button what the task might look like, or what the effect of the task is. The save button in many programs is still the symbol of a diskette, something that has not been used in a long time, for saving data. But in the past data was often saved onto diskettes, and through that it became a standard.

When discussing user-interface design, different evidence and theories gathered over the years can be classed as follows:

1. Guidelines that outlines good practices and cautions against dangers.
2. Design alternatives compared and analysed through middle-level principles
3. High level theories and models with their included terminology that enable description of objects and actions.

Areas of improvement often include display clutter, difficult procedures, conflicting visual elements and a lack of information. These shortcomings can lead to stress and frustration which in turn can lead to mistakes and errors resulting in negative feelings towards ones work and increasing resistance among consumers. In order to combat these negative results, research and design are now guided by methods for improving pointing, reduced input times, cognitive theories and improved training methods. (Shneiderman & Plaisant 2010)

Going all the way back to the start of computing, guidelines have been written down to

pass along the experience gathered and to further interface design in the coming generations. Guidelines are made to unify language, visual layout and results of actions. These guidelines are produced from studies and experience, including examples and counterexamples. The follow guidelines were developed by U.S. Dept. of Health and Human Services and published in 2006 and they work as good all around goals to aim for. A few examples follow.

- *Standardize Task Sequences* Allow users to perform tasks in the same sequence and manner across similar conditions. By creating a pattern that is standardized across the same type of tasks, the user quickly identifies the pattern and learns that in order to do a type of task the user can apply the same pattern.
- *Reduce User's Workload* Allocate functions to take advantage of the inherent respective strengths of computers and users. By reducing workload on the user, and allowing the computer to assist as much as possible the user will have a more positive experience. E.g. do not make the user remember long numbers, the computer is perfectly suited for this kind of task.
- *Use Unique and Descriptive Headings.* Use headings that are unique and conceptually related to the content they describe. Headings should describe the contents, not only serve as place holders for information. A set of headings with "Column1, Column 2 etc." is not helpful, whereas "File Name, Size, Type, Date Created" is much more helpful and the user immediately sees the differences.
- *Ensure that Embedded Links are Descriptive.* When using embedded links, the link text should accurately describe the link's destination. An embedded link is a type of link that says one thing but has a more complex function underneath. "*Click me!*" is maybe not as descriptive as "*Click here for further data*".
- *Use Radio Buttons for Mutually Exclusive Selections.* Provide radio buttons when users need to choose one response from a list of mutually exclusive options. Radio buttons are a type of buttons listed as different options and the user will only be able to select one. They are often indicated with a coloured mark or tick in a square. Or possibly by dimming out the other options once a choice is made. Example:
 - Choice 1
 - Choice 2

- Choice 3

2.3 The display

The display is often the direct feedback from the machine to the user. The display is an essential part of the relation between user and system, and a designer often faces difficult choices when opting for what to place there, and what not to place there. Putting too much information on a display makes the view feel cluttered. Not putting enough information and there is a risk that user are not receiving enough feedback from the system. Secondary choices are between e.g. lists, drop-down menus and buttons. Using graphical representation can be an option, but maybe numbers are faster. “Does this choice fit well with the design choices picked earlier?” is a question developers have to ask themselves. In addition to functionality examples, aesthetic options exist e.g. light colours, dark colours, rounded buttons/menus, sharp edges etc.

The following lists guidelines in data display choices, design and development:

- Consistency of data display
- Efficient information assimilation by the user
- Minimal memory load on user
- Compatibility of data display with data entry
- Flexibility for user control of data display. (Smith & Mosier 1986 p.88)

These guidelines and ideas have been further worked on by Schneiderman and Plaisant:

Consistency of data display. When choosing terminology, abbreviations, formats, colours and capitalization, standardization should be kept in mind. (Shneiderman & Plaisant 2010)



Figure 12: Consistency

The consistency among the different A's is clear. The user can see from the buttons that they all affect the font. The first one **bolds** the font. The second is *for Italic* while the last one underscores the font.

Efficient information assimilation by the user. Neat columns of data, left justification for alphanumeric data, right justification of integers, lining up of decimal points, proper spacing, use of comprehensible labels and appropriate measurement units and numbers of decimal digits. A common data standard like this serves the user well when interpreting the information at hand. (Shneiderman & Plaisant 2010)

Person	Date	Points
Bob	03/04/2012	5
Jim	03/04/2012	4
Lisa	03/04/2012	3
John	10/04/2012	7

Figure 13: Information Structure.

The user can quickly recognize the headers since they are bold. The interpretation of the data goes fast, there is a name with a date with an amount of points. The eye recognizes the numbers and also notices that the slash between the first set of number indicates dates.

Minimal memory load on user. Remembering data from one input screen to another new screen should not be required by the user. When deciding the order of tasks, they should be sorted in such a manner that the number of actions required is minimized, thus reducing the risk of forgetting a step. (Shneiderman & Plaisant 2010)

When working through different screens or pages, the system should be designed so that the user does not have to remember long strings of texts or long numbers. A computer is perfectly suited for this kind of task.

Compatibility of data display with data entry. The layout of the information should be linked clearly to the layout of the entered information. Output fields can also act as editable input fields, if practical with the given data in the given environment. (Shneiderman & Plaisant 2010)

When entering multiple types of information, the way the data is entered, or expected by the system, should reflect both the way it is displayed and be entered in a logical way. If the system lists something as “Name-Date-Points” the user will enter that data in that order. The system should not wait for points first, name second or any other order that is unclear.

Flexibility for user control of data display. Users should be able to rearrange or otherwise customize the displayed information, if needed; e.g. rearranging rows or columns. (Shneiderman & Plaisant 2010)

Continuing on the example of “Name-Date-Points” the system could allow the user to enter data in any desired order. As the data types in this example are all of different types, the system could be designed to allow the user to enter any of them first, second and last. And the system puts the data into the right columns.

2.4 Interactions

Interactions can be defined as the user performing actions with, or influencing, a piece of equipment, machine or process. These interactions can be acknowledging alarms, changing set points, manipulating variables, accessing other pieces of information currently not visible, or making calculations.

When interacting with different elements, the primary interaction styles can be classed as follows (Shneiderman and Plaisant 2010):

- Direct manipulation
- Menu selection
- Form fill-in
- Command language
- Natural language. (Shneiderman & Plaisant 2010)

The different ways of interactions all describe different ways for the user to interact with a system. They all have their own pros and cons. Some of these can be hard to program, such as direct manipulations. Others might take up excess screen real-estate like the form fill-in. Command language supports user initiative and flexibility but requires experience and training. Menu selection reduces required input, organizes the functions but can slow down frequently used functions and risks using an excessive amount of screen space for displaying the menus. Each one of these five styles has its own place and time where it can

be used as the most effective one.

Table 1: "Advantages and disadvantages of the five primary interaction styles."

Interaction Style	Advantages	Disadvantages
Direct Manipulation	Visually presents task concepts Allows easy learning Allows easy retention Allows errors to be avoided Encourages exploration Affords high subjective satisfaction	May be hard to program May require graphics display and pointing device
Menu Selection	Reduces keystrokes Structures decision making Permits use of dialogue-management tools Allows easy support of error handling	Presents danger of many menus May slow frequent users Consumes screen space Requires rapid display rates
Form fill-in	Simplifies data entry Requires modest training Gives convenient assistance Permits use of form-management tools	Consumes screen space
Command language	Flexible Appeals to "power" users Supports user initiative Allows convenient creation of user-defined macros	Poor error handling Requires substantial training and memorization
Natural Language	Relieves burden of learning syntax	Requires clarification dialogue May not show context May require more keystrokes Unpredictable

(Shneiderman and Plaisant, 2010, p. 85)

3. Supervisory Control and Data Acquisition

3.1 SCADA systems

The WOIS system has a lot in common with a SCADA system. For example both gather data, both monitor, and both can be used to control a process. Since the systems are close to each other, it is important to understand the structures and philosophies of a SCADA system.

Supervisory Control and Data Acquisition systems are also known as SCADA. A SCADA system is the basis of any real-time control system. The system collects data from multiple sources and pre-processes and stores the data. The data is transferred to a data base where it's available for various users and applications. The following six items are the basis for modern SCADA systems:

- Data acquisition
- Monitoring and event processing
- Control
- Data storage archiving and analysis
- Application-specific decision support
- Reporting. (Northcote-Green & Wilson, 2007)

3.2 Data acquisition

As the focus lies more on a power distribution and electrical system, the theory and examples reflect that industry. Note that system designers, operators, planners and other personnel all have an influence on how, when and what type of data is gathered. As the power distribution for a marine vessel can be seen as a miniature power grid, the same

theories often apply.

Throughout various processes the SCADA system automatically gathers basic data about the state of the process. The information also includes calculated data and manually input data of crews working on non-automated processes. The gathered data is categorised as follows (Northcote-Green and Wilson 2007):

- Status indications
- Measured values
- Energy values

Status indications represents the different statuses switches and alarms can be in. These are digital input signals from one or many remote terminals, also referred to as RTUs. Switches often have a double indication to enable detection of false values, intermediate states and improved error handling.

3.3 Monitoring and event processing

The stored data in itself does not contribute new insight. Therefore data comparison against normal values and limits is an important part of the SCADA system. The main goal of the SCADA system (and WOIS system,) is to reshape and present raw data into something understandable for humans. Data is often presented in real-time and the system has a response time that depends both on the hardware and the software. If reading a node takes 5ms and there are 100 nodes, a full sweep of the nodes will take 0.5 seconds. Thus real-time will always be a modified truth. And the term real-time is used when the system is near real-time and within a system-specific threshold. This threshold is unique to every process, if a process requires a new input every second in order to be called real-time, the system has to be able to supply this input faster than every second.

Each indication in status monitoring requires the value to be compared to its previous state. A change notifies the operator. Limit-value monitoring is applied on each measured value. When the status changes past a set limit value, an event is generated. Different limits can each have their own dead-band, which allows small fluctuations in the value around a limit not to trigger multiple alarms every second. A value can have multiple limits depending on the severity of the value. E.g. a notification event can be triggered at 90%, alarm at 100%

and finally a shut-down at 110%. (Northcote-Green and Wilson, 2007)

To enable correct analysis of e.g. a complicated power system, precise time-stamping is important. This is done by synchronising all RTUs, which can be accurate down to the millisecond level, with the SCADA master. This forms the basis of the “sequence of events” list.

Process variables that change too quickly in a given time frame are also monitored. This is called trend monitoring. Trend monitoring also triggers an alarm if a given value changes in the “wrong” direction.

All events generated are processed. This includes actions by an operator and functions by the monitoring system. By processing each event, they are grouped and classed according to their origin and/or type of information. The processed information in turn, is sent to various parts of the human machine interface where the operator can read the information. Especially during alarm bursts, event processing influences the real time performance. Event processing results in a list of all the events in a chronological order which is further categorised as e.g. unacknowledged and persistent alarms, and priority events. (Northcote-Green and Wilson, 2007)

Improved operator accuracy and response time are the result of this automated process. By sorting the events and putting emphasis on more important events, the operator is able to make the correct choices in times of multiple events.

3.4 Control functions

Control functions can be automatically initialised or started by an operator and have direct impact on the operation of the system. They may be grouped as:

- Individual device control. This is direct open/close operation of a device.
- Control messages to regulating equipment that requires the operation to automatically be conducted by local logic.
- Sequential control. Can for example be described as a set of steps automatically performed in order to restore power through a preconfigured set of actions.
- Automatic control is triggered at a predefined time or by an event and involves automatic response according to a set of rules. (Northcote-Green and Wilson 2007)

When performing control tasks, it is of utmost importance that the system confirms both the command and that the task has been completed. This can be realised for example in such a way that every given command gets logged in an even list. And every performed task gets logged. Together with timestamps of these events the operator receives a visual confirmation that the desired tasks have been performed. This type of logging is also important when reporting past data. Tasks that fail to complete also need to be shown, maybe even more clearly so that the operator notices that something tried to perform what he ordered the system to do but failed. Error messages will often be in a different colour and the system might even alert the operator that a desired operation failed to complete.

Manual and automatic operation often plays by different sets of rules. The rules vary both in response time and type of task. Manual tasks often have a certain pattern to them. The operator picks an object or part of the process, then picks a task, selects to do the task and further confirms the whole operation. In response the operator expects the system to confirm that it received the command and a status of the current state, if the process is of a slow type, finally followed by a confirmation message when the task is completed. (Northcote-Green and Wilson 2007). Automatic tasks often act faster and are mainly used in:

- Safety features

- Operations that require too quick an input for humans
- Automatic updates of a running process. (Northcote-Green and Wilson 2007)

These three are not the only categories for automatic operation, but they are three that often are made automatic.

Safety features, such as the stop function such as in the event of a too high pressure or fire-fighting systems, need to be made automatic in order to protect human lives, the environment, the machinery and the surroundings.

Sometimes the decision process might need an input within the next second or the next few seconds. Choices at this speed are not optimised for human operation. A computer can much more quickly go through a check list of states and perform the desired operation.

Automatically updating variables or reading from one node and copying them into the database where another node can request the data and change its own output accordingly are tasks that are easily automatised and would not be suited to a human as they are repetitive and not engaging.

3.5 Data Storage, archiving, and analysis

Data is stored in the SCADA system server in chronological order to give an accurate picture of the system and the current process. By using the sequence of events list, statistics can be created for the customer and the regulators. These figures show e.g. the quality of the power in different electrical network segments or in the work as a whole. The requirements on data and databases are increasing and nowadays fully redundant systems are an integral part of any data management system. Data bases allow staff to go back in time and examine what happened at given times. The demand for even more flexible ways is steadily increasing.

Different types of data can have different types of storage time. Data can have time, and information (data that has been analysed and processed) can have a totally different storage time. Open and close functions or start and stop function can be processed in order to

create graphs of uptime, downtime and also a number of control actions within different time frames. All of this depends on the type of process, and even the same type of process can have very different policies regarding storage of data, all depending on the owner, operator, manufacturer and other factors.

4. Hardware

4.1 Introduction

Hardware rules often have as their main goal to increase the safety of the user, the vessel and the whole crew. For example cranes, or other heavy machinery, are often required to either stop or go into a default state in case of an emergency.

Computers are required, when possible, to not have forced ventilation. Computers are also required to monitor their own temperature and have an appropriate alarm if safe values are exceeded. As the focus is on a ship, the computers have to be built in such a manner that they can withstand the vibrations of a ship. Power supplies are required to have redundancy in the form of the independent supplies. This is often solved by connecting the normal 230VAC and the 24VDC to the computer.

4.2 Hardware rules and regulations

As the other parts of the control system, the PLC, the control panels etc. are all classed according to desired standards. The scope is focused on the WOIS (hardware+software).

For the purpose of this thesis, the term hardware includes the following parts:

- A computer. Similar to a personal computer or a laptop but of a stronger quality.

- A display unit. Often called monitor or just display. Abbreviated as VDU, visual display unit.
- Input devices, mouse and keyboard.

The different classification societies have their own hardware requirements; they are similar in requirements, if not identical, in most points. Some of the more important things to take note of that might differ from standard desktop computer specifications are: Emphasis is being put on longevity, reliability and accessibility to the system, even during partial loss of power. For example temperature monitoring and environmental rules are strict.

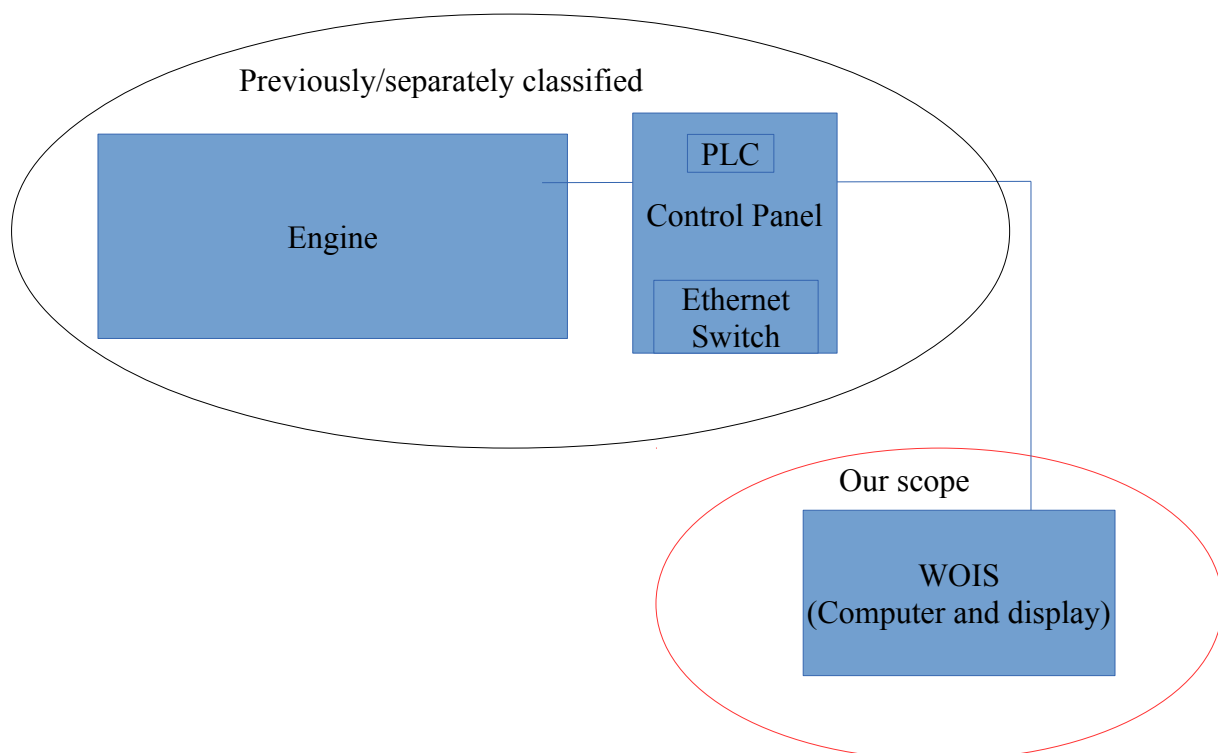
Some examples include: “When required, the cooling system is to be monitored, and an alarm activated when the normal temperature is exceeded”. (Det Norske Veritas 2011b) There are also rules regarding vibrations e.g. “The mechanical construction is to be designed to withstand the vibration levels defined in...” (Det Norske Veritas 2011b). Cooling is another aspect, “Whenever possible, computers shall not have forced ventilation. For systems where cooling or forced ventilation is required for keeping the temperature at an acceptable level, alarm for higher temperature or maloperation of the temperature control function, shall be provided.” (Det Norske Veritas 2011b) For power supply, it can generally be said that a workstation will be supplied by two sources i.e. “Essential control and monitoring systems shall be provided with two independent power supplies. This applies to both single and redundant control and monitoring systems.” (Det Norske Veritas 2011b)

The most practical way of acquiring hardware that fulfils these requirements is to buy the hardware from select vendors that have pre-built solutions according to different standards. Manufacturers have put a lot of time and effort into their products to ensure that they meet the high standards. When browsing computers, lists are often clearly visible that presents which standards they currently fulfil and which they have applied for.

5. Methodology

This task has been a study in classification of workstations and the demanding conditions of the marine environment. Due to lack of previous research in this field the main methods for establishing the current state and cross-referencing the guide lines provided by the different classification societies have been discussions and meetings. We talked through the rules in RULES FOR CLASSIFICATION OF Ships / High speed, Light Craft and Naval Surface Craft Part 4 Chapter 9. We listed any rule we were unsure about or if we needed further clarification from the classification society. Using a colour scheme we marked the rules according to actions needed. Green for okay, yellow for “needs to be implemented”, blue for “needing additional information either from Wärtsilä or the classification society”. Red was used for any rule that would be more difficult to implement so extra attention could be given to it. When compared to other classification societies this document was the strictest and most demanding one, therefore we chose to use it as a baseline. As the work progressed we kept cross referencing both with DNV, BV and ABS.

A graphical view to illustrate the scope of the thesis:



6. Results

The result which ABB was interested in was a two-part question:

- Does the current hardware and software configuration fulfil the rules?
- If not, which changes are needed?

The answer to the first question is yes, but some changes will be needed. Working our way through the document (DNV) we started out with the colour codes as mentioned earlier:

- Green for OK.
- Yellow for changes filed as “needs to be implemented”.
- Blue for “needing additional information” - either from Wärtsilä or the Society”.
- Red was for any rule that would be more difficult to implement.

Starting out with roughly 30 pages we worked our way down, page by page, line by line. Whenever something was unclear, we marked it, and held discussions. The meeting with our local DNV contact (Arto Virtanen) gave us more insight into the different problems and possible solutions at hand. A meeting (21st August 2013) with Krzysztof Aleksander Jankowski, Senior Approval Engineer from the Approval Centre Ship and Offshore, DNV Norway, resulted in the final list presented below.

6.1 List of solutions

Upon further discussions and a meeting between ABB OY and representatives from DNV on 21st August 2013, the previously mentioned issues were solved and full lists of implementations, results from meetings and documents exist internally at ABB.

7. Evaluation, conclusions and recommendations

My personal recommendation for anyone working with classifications, in general, is to keep a dialogue with your local representative from whatever society or rule set you are trying to get your process or equipment approved by. They are (often) experts within their fields, and have valuable knowledge to share. They also work as a direct link to their own head offices for checking up on more difficult/tricky questions.

The most difficult part has been the terminology, both the advanced terms in the documentation but also in the system, as it was all new to me. But as the project has been proceeding at a steady rate, so has my knowledge of the vocabulary of the WOIS system, and the technical solutions behind the WOIS.

We opted for prefabricated computers and monitors already classed by a 3rd party manufacturer. It's not central to our needs to assemble the hardware itself, we tailor software suites to the needs of our customer. Our volume of needed units of hardware is big enough for bulk orders. Ordering parts and classifying the hardware separately is not an option that would have suited us. But, do read up on the hardware specifications and limitations. As you will be buying at a premium, knowing what you pay for can come in handy.

Check what your system will be defined as. We could have saved time if we would have checked the definitions with an expert at the start of this project. In our case, several functions resides in the PLC and are only extended to the software in the computer. The functionality itself is in the PLC, thus, several restrictions that we thought would apply to the hardware in our scope only apply to the PLC. The PLC is previously and separately approved.

When starting this type of work, work from a “What is the safest way to do this?” perspective. The rules exist to ensure the safety of the crew, the vessel and other parties involved. When designing, if you keep safety and usability as high priorities, you will end up close to the rules set by the different classification societies.

This work has been a journey into the more academic and theoretical fields of engineering. Upon starting, my personal system knowledge was next to none. Now I have a better understanding of these systems and can even work with them and in them. I have learned a

lot, probably the most about my self, my capabilities, limits and abilities. As a project it has had its up and downs but I am happy with the end results, especially since we came to a positive and workable solution. A major upside is also that this kind of methodology is not something that there are lessons for in school. In school, most lectures are either practical or theoretical about engineering, but not in the sense this thesis has been theoretical for me. Evaluating my own work, the timetable has been overshoot, both due to controllable and uncontrollable circumstances, but the end results are satisfying. We have evaluated our hardware and software system, learning the different definitions of the system parts and which rule sets apply to which parts. Support has been great from all parties involved, from the start until the end.

8. Bibliography

8.1 Books & publications

Det Norske Veritas AS 2011a, *Annual Report 2011* [Online], http://www.dnv.com/binaries/DNV_annual_report_2011_tcm4-517127.pdf [Retrieved 2012]

Det Norske Veritas AS 2011b, *Ships / High Speed, Light Craft and Naval Surface Craft*. [Online] <https://exchange.dnv.com/publishing/RulesShip/RulesShip.asp> [Retrieved 2012]

Northcote-Green J. & Wilson R. 2007: *Control and Automation of Electrical Power Distribution Systems*. Boca Raton, FL: Taylor & Francis Group LLC.

Shneiderman B. & Plaisant C., 2010: *Designing the User Interface*, Boston, MA: Pearson Higher Education.

Smith S. & Mosier J. 1986: *Guidelines for designing user Interface software*. [Online] www.dfki.de/~jameson/hcida/papers/smith-mosier.pdf [Retrieved: 2013] Bedford, MA: The MITRE Corporation.

U.S. Dept. of Health and Human Services, 2006. *The Research-Based Web Design & Usability Guidelines, Enlarged/Expanded edition*. Washington DC: U.S. Government Printing Office.

Wärtsilä, *WOIS demo Rev13*. n.d.

Classification Societies, n.d. [Online] http://en.wikipedia.org/wiki/Classification_society [Retrieved: 8th April 2014]

8.2 Personal Meetings & Discussions

Krzysztof Aleksander Jankowski, DNV, *meeting 21st August 2013* Vaasa, Finland

Johanna Björk, ABB, *regular meetings Spring 2013*, Vaasa, Finland

Arto Virtanen, DNV, *meetings Spring 2013*, Vaasa, Finland

Table C1 Documentation required submitted prior to commencing approval work (typically submitted by yard based upon their detailed specification, applicable for ships with integrated systems installed)			
<i>Documentation type</i>	<i>Information element</i>	<i>Purpose</i>	<i>Where to</i>
System philosophy (I010) (T)	—the tasks allocated to each sub-system, divided between system tasks and manual tasks, including emergency recovery tasks —principles that will be used in the technical implementation of each system	Information	Approval centre
General arrangement for the ship	General ship information	Information	Approval centre
General arrangement for the main engine room	Main equipment layout	Information	Approval centre
Specification of main electro/mechanical equipment	Electric power generation. Main propulsion line(s) with machinery and essential auxiliaries. Miscellaneous machinery or equipment (where control and monitoring systems are specified by other sections of the rules). The following shall be specified: —manufacturer and type —rating —number of —purpose	Information	Approval centre

Table C2 Documentation required for assessment (project specific documentation typically submitted by manufacturers)		
<i>Documentation type</i>	<i>Information element</i>	<i>Purpose</i>
Functional description (system requirement specification) (I020) (T) <i>See Guidance Note 1</i>	—clear text description of the system configuration —clear text description of scope of supply and what is controlled and monitored and how —clear text description of safe state(s) for each function implemented —clear text description of switching mechanisms for systems designed with redundancy R0 —P&I/hydraulic/pneumatic diagrams if relevant.	Approval
System block diagrams (I030) (T)	—a diagram showing connections between all main components (units, modules) of the system and interfaces with other systems.	Approval
User interface documentation (I040)	—a description of the functions allocated to each work and operator station —a description of transfer of responsibility between work and operator stations.	Approval
Power supply arrangement (I050) (T)	—electrical supply: diagram showing connection to distribution board(s), batteries, converters or UPS.	Approval
Functional failure analysis (Z070) (T) Only where specifically requested by the DNV rules, or in special cases	The purpose of this functional failure analysis is to document that for single failures, essential systems will fail to safety and that systems in operation will not be lost or degraded beyond acceptable performance criteria when specified by the rules. The following aspects shall be covered: —a description of the boundaries of the system including power supply preferably by a block diagram —a list of items which are subject to assessment with a specification of probable failure modes for each item, with references to the system documentation —a description of the system response to each of the above failure modes identified —a comment to the consequence of each of these failures.	Approval

Table C2 Documentation required for assessment (Continued) (project specific documentation typically submitted by manufacturers)		
<i>Documentation type</i>	<i>Information element</i>	<i>Purpose</i>
Failure mode and effect analysis (FMEA) (Z071) (T) where specifically required by DNV Rules <i>See Guidance Note 2</i>	<p>A failure modes and effect analysis (FMEA) shall be carried out for the entire system. The FMEA shall be sufficiently detailed to cover all the systems' major components and shall include but not be limited to the following information:</p> <ul style="list-style-type: none"> —a description of all the systems' major components and a functional block diagram showing their interaction with each other —all significant failure modes —the most predictable cause associated with each failure mode —the transient effect of each failure on the vessels position —the method of detecting that the failure has occurred —the effect of the failure upon the rest of the system's ability to maintain station —an analysis of possible common failure mode. <p>Where parts of the system are identified as non-redundant and where redundancy is not possible, these parts shall be further studied with consideration given to their reliability and mechanical protection. The results of this further study shall be submitted for review.</p>	Approval
List of control & monitored points (I110) (T)	<p>A list and or index identifying all input and output signals to the system as required in the rules, containing at least the following information:</p> <ul style="list-style-type: none"> —service description —instrument tag-number —system (control, safety, alarm, indication) —type of signal (digital / analogue input / output). 	Approval
Circuit diagrams (I150)	—for essential hardwired circuits (for emergency stop, shutdown, interlocking, etc.) details of input and output devices and power source for each circuit.	Approval
Test program for testing at the manufacturer (Z120) (T)	<p>Description of test configuration and test simulation methods. Based upon the functional description, each test shall be described specifying:</p> <ul style="list-style-type: none"> —initial condition —how to perform the test —what to observe during the test and acceptance criteria for each test. <p>The tests shall cover all normal modes as well as failure modes identified in the functional failure analysis, including power and communication failures.</p>	Approval
Data sheets with environmental specifications (I080)	—environmental conditions stipulated in Sec.5 for temperature, vibration, humidity, enclosure and EMC.	Information
<p>Guidance note 1: If the control system is simple, does not contain programmable components and the functionality and failure mechanisms can be easily understood from submitted drawings, the textual part of the functional description may upon agreement be omitted.</p> <p style="text-align: center;">---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---</p>		
<p>Guidance note 2: Where an overall ship FMEA is requested in the application rules, this FMEA is normally supplied by the yard, and often made by an independent FMEA supplier. The manufacturers of control systems related to the application (e.g. propulsion, steering, power management,) normally provide an FMEA covering their scope of delivery. Then these FMEAs from the control system manufacturers are supposed to be evaluated by the overall FMEA supplier with respect to the overall design intention, and the conclusions shall be incorporated into the overall FMEA.</p> <p style="text-align: center;">---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---</p>		