Renewing of Unic C3 test rig

Wärtsilä

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BACHELOR'S THESIS

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ABSTRACT

This thesis has been made for Wärtsilä. The department that the thesis has been made for is named WIO/R&D/A&C. WIO stands for Wärtsilä Industrial Operations, R&D stands for Research and Development and A&C stands for Automation and Controls. The task was to renew an old test rig for the system UNIC C3 by updating all of the modules, sensors and cables and finally by testing the system. The target of this work was to build a working test rig that will be used for simulating and measuring different kinds of engine signals and parameters. I the future the test rig will also function as a model for similar equipment. The result of this work was a functioning test rig that will be updated and developed in the future.

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Language: english   Keywords: UNIC C3, test rig, simulation

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EXAMENSARBETE

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ABSTRAKT

Detta ingenjörsarbete har gjorts åt företaget Wärtsilä. Avdelningen som arbetet gjorts åt heter WIO/R&D/A&C. WIO står för Wärtsilä Industrial Operations, R&D står för Research and Development och A&C står för Automation and Controls. Uppgiften bestod av att förnya en gammal testrigg avsedd för systemet UNIC C3 genom att uppdatera samtliga moduler, givare och kablar samt avslutningsvis utföra tester. Målsättningen med arbetet var att bygga en fungerande testrig som används för att simulera och mäta olika motorsignaler och parametrar. Testriggen kommer i framtiden även att fungera som modell för andra liknande utrustningar. Resultatet blev en fungerande utrustning som i framtiden kommer att uppdateras och vidareutvecklas.

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Språk: engelska   Nyckelord: UNIC C3, testrigg, simulering

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TIIVISTELMÄ

Tämä insinöörityö on tehty Wärtsilälle osastolle WIO/R&D/A&C. WIO tarkoittaa Wärtsilä Industrial Operations, R&D tarkoittaa Research and Development ja A&C tarkoittaa Automation and Controls. Työ koostui koepenkin uudistamisesta UNIC C3 -systeemille mikä tapahtui päivittämällä koepenkin kaikki moduulit, anturit ja kaapelit, ja tämän jälkeen laitetta testattiin. Työn tavoitteena oli rakentaa koepenkki, jota käytetään eri moottorisignaalien ja parametrien simulointiin ja mittaukseen. Koepenkin tulee tulevaisuudessa toimia myös mallina samantapaisiin laitteisiin. Lopputulos oli toimiva laite, jota tullaan tulevaisuudessa päivittämään ja kehittämään.

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RENEWING OF A UNIC C3 TEST RIG

1 Introduction

1.1 The company in brief

Wärtsilä is a global leader in complete solutions for the marine and energy markets. By emphasizing technological innovation and total efficiency, Wärtsilä maximizes the environmental and economic performance of the vessels and power plants of its customers.

In 2010, Wärtsilä's net sales reached 4.6 billion € with 17,500 employees. The company has operations in 160 locations in 70 countries around the world. Wärtsilä is listed on the NASDAQ OMX Helsinki, Finland. /7/

1.2 Background

The reason why this work was chosen as my Bachelor's thesis was that I worked at Wärtsilä as a trainee in the summer of 2009 and they had a project that was appropriate for a Bachelor's thesis.

My main task during the summer was to rebuild an old UNIC C3 test rig. However, as other urgent things came up, this work had a lot of breaks and there wasn't that much time to work on the test rig. In the end of the summer, Wärtsilä offered me a part time work in the same department. After a while my supervisor suggested that I could write my Bachelor's thesis about the test rig.

1.3 Target

The target of this work was to renew an old test rig that consisted of old modules and many different kinds of sensors, but also many sensors of the same type. The new version should have updated modules and a smaller amount of sensors. The function of the test rig is to measure and simulate different engine signals and parameters. There are many different types of engines and the tested engine type can easily be changed by downloading the wanted engine software package from the intranet and installing it to the system.

The test rig should be built according to Wärtsilä standards and it was also important that the rig would be good looking and easy to update and modify, because it will function as a model for future rigs as well.

2 UNIC C3

The UNIC C3 automation system is an embedded system for engine management. The system has a lot of functions, but it is specifically designed for the demanding environment on engines and therefore temperature and vibration endurance are the most important properties of the system.

The major parts of the UNIC C3 system are:

LCP (Local Control Panel): This panel is mounted on the side of the main cabinet. It consists of a WIP-11, an LDU-20 and a WCP (Wärtsilä Control Panel) which consists of a switch for mode selection, a start button, an emergency stop button, a stop button and a reset button. By using the mode selector, the engine can be switched between four different modes:

- Local. The starting and stopping can only be controlled locally.
- Remote. Starting and stopping can also be controlled remotely.
- Blocked. Starting is electrically blocked both locally and remotely.
- Blow. By pressing the start button, the engine performs a "blow", which is an engine rotation check with indicator cocks open. The engine won't start, only the starting air valve will be activated in this mode.

WIP-11 (Wärtsilä Instrument Panel): This module displays the most important measurements and local information on the engine. The shown parameters on this unit are:

- Lube oil pressure. A bar graph with a scale from 0 to 10 bar.
- HT water temperature. A bar graph with a scale from 30 to 120 °C.
- Engine speed. A circle-shaped curve that goes from 0 to 120 % with a numerical 4-digit rpm display in the centre.
- Turbocharger speed A-bank (TC A). A numerical 3-digit display.
- Turbocharger speed B-bank (TC-B). A numerical 3-digit display used for V engines.

- Running hours. There are two 5-digit displays for counting the running time, one for total hours and one for hour on gas, if the engine uses gas as fuel.

Normal values are shown with a green color while abnormal values are yellow or red depending on how bad the values are, red being the worst case.

LDU-20 (Local Display Unit): The LDU-20 acts as an operator interface for the UNIC automation system and as a communication interface to other networks. It displays all the sensor data from the engine, but also other information such as engine modes, possible failures and an event log.

Figure 1. Local Control Panel consisting of a LDU-20, WIP-11 and a WCP-10.

MCM-11 (Main Control Module): The MCM is a versatile and configurable module. Besides a lot of analogue and digital measuring input channels it also has some analogue and binary outputs.

The main task is to handle the start/stop management and speed/load control of the engine. It can also be used to control a number of devices on the engine.

ESM-20 (Engine Safety Module): The ESM is probably the most important module of the system as it handles the safety of the engine. Besides the safety it also has speed measuring functions and these signals go through the ESM to the instruments. The ESM uses sensors which permanently monitor engine speed, lube oil pressure, cooling water temperature as well as binary inputs for connection of external functions e.g. stops, override of stop functions and reset of stop or override. All of the inputs and the most important outputs are monitored in order to detect wire breaks and yellow LED lights are used for failure indications.

CCM-20 (Cylinder Control Module): The module handles functions related to fuel injection and cylinder specific measurements. The CCM handles the injection of three cylinders and it can also work as a backup controller for three more cylinders. It also handles the limp mode operation in case of MCM or dual CAN failure. The unit's ability to withstand high vibration level, high operation temperatures and chemical environment makes it able to be mounted directly on the engine.

The 24 VDC power supply doesn't give enough power for the handling of fuel injection valves. The CCM provides PWM (Pulse Width Modulation) signals to the valves, which use a driver supply of 110 VDC.

IOM-10 (Input/Output Module): This module is used for collecting data of analogue/binary/frequency signals, but it is also used for control, such as waste-gate control, by-pass control and LT/HT water thermostat valve control.

Like the CCM, the IOM is also very resistant to high vibration levels, operating temperatures and chemical environments, which is very good when mounting happens directly on the engine.

PDM (Power Distribution Module): There are two sizes of PDM; 24 VDC and 110 VDC. The main task of the PDM is to handle the distribution of power to the electronic equipment on the engine, but it also has a few other important tasks, such as short circuit protection, EMC (Electromagnetic Compatibility) filtering, detecting of earth faults and over voltages. The module has one primary supply and one backup. The system is floating

in relation to ground which means that both primary and backup power supplies are isolated.

The inputs and outputs of all modules are highly protected from connection errors and the software can in most cases recognize hardware failures. /6/
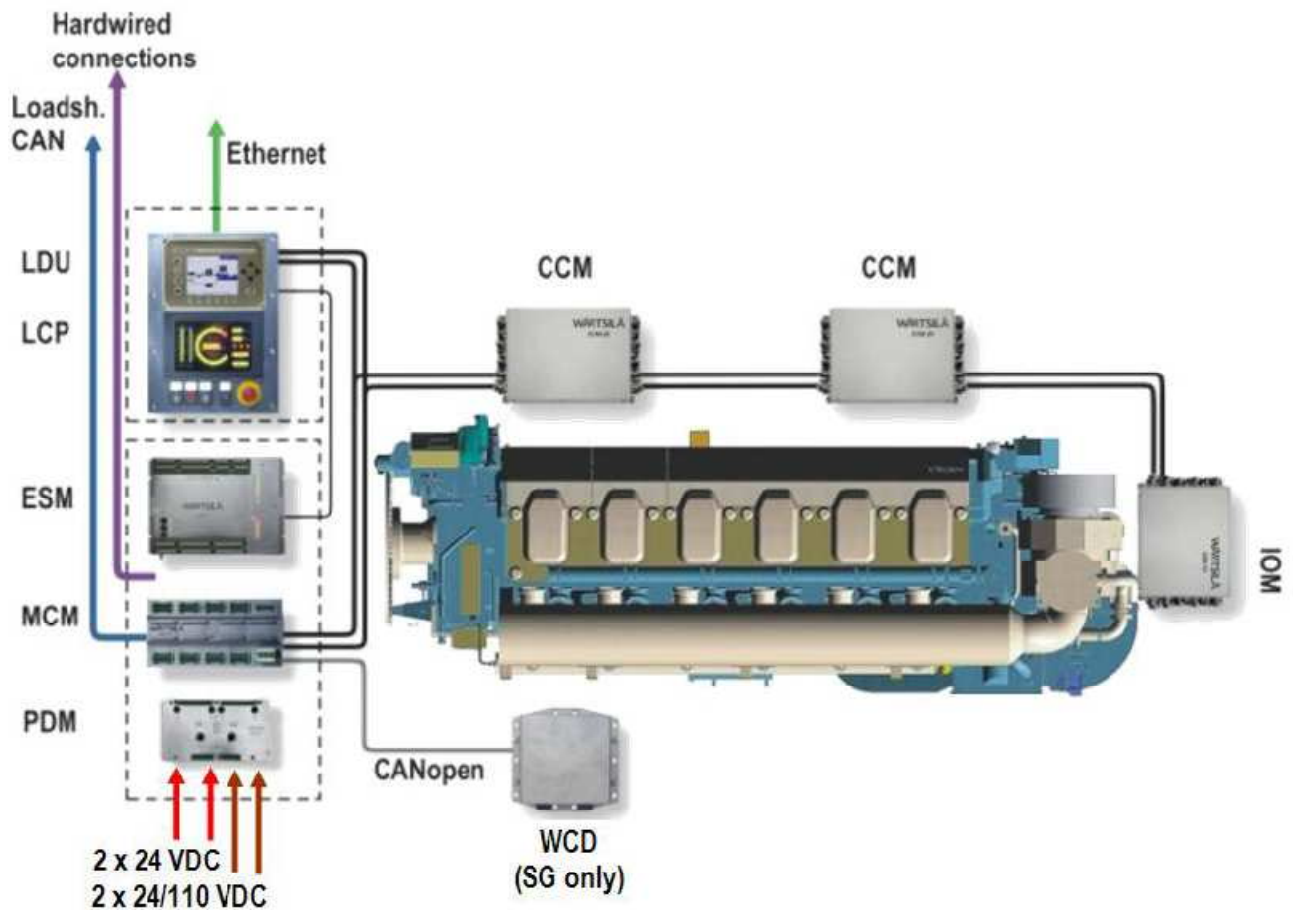

Figure 2. Construction of a UNIC C3 system /6/

3 The test rig

3.1 Construction

The test rig can be split into three major parts:

- Main Cabinet
- 110V Cabinet
- The engine

3.1.1 Main cabinet

The main cabinet is the heart of the whole system. It consists of two MCM:s, one ESM, one PDM-24V and the LCP.

The main cabinet also works as an access point for the wiring and besides the modules it also contains terminal blocks, fuses, switches and opto relays. Most of the wires belonging to the 24V system are linked to terminal blocks in the main cabinet and from there they go on to their final point. The main cabinet also has an ethernet output, which is very much needed when using computers for testing and software installations.

Chapters 3.3, 3.4 and 3.4.1 will give further descriptions of the planning and wiring in the main cabinet.

Figure 3. Main cabinet

3.1.2 110V cabinet

The PDM-110V module handles the 110V signals and is located in its own cabinet, so that the 24V system won't be mixed with the 110V system which could be hazardous. Keeping the 110V and 24V systems separated from each other also reduces the risk of EMC disturbances. The cabinet contains only the PDM-110V, a power switch and a few terminal blocks.

Figure 4. 110V cabinet

3.1.3 The engine

"The engine" part consists of four modules, sensors, sensor simulations and cabling. Two CCM:s and two IOM:s are mounted into their own WTB:s. Each module has its own sensor simulator box and the physical sensors are connected to the modules or the main cabinet.

Figure 5. The engine

3.2 Purpose and function

As already mentioned the purpose of the work was to rebuild the old test rig by renewing all the components and wires. The test rig itself looks pretty much the same as before, but the modules are updated, and the amount of sensors has been reduced.

The function of the test rig is to simulate different kinds of signals and measure a lot of engine parameters. All the sensor signals, temperatures and pressures can be monitored using a computer program named WECSplorer. The computer is connected to the system using CAN bus and/or ethernet connection.

3.3 Planning and structuring

There was not that much to plan on the rack that the test rig was built on, since the old one was still good enough. Some planning still had to be done because the structure of the new test rig was a bit different compared to the old one, due to new and different components.

The main cabinet was a bit torn and a bit too small so a new bigger one was ordered, but the 110V cabinet was good enough and didn't need to be exchanged.

The wiring diagrams had already been made as this project started, which saved a lot of time. But since they were made for a specific "real" project, some components and wires on the drawings could be left out, because every measurement point on the real engine wasn´t necessary on the test rig. Most of the planning time of the wiring was spent figuring out how to route the cables in order to save space, achieve a good looking result, and meet Wärtsilä's requirements in the electrical installation. The requirements will be explained more in the following chapter.

Due to long delivery time for the main cabinet, it took a long time before it arrived. When it finally arrived, it turned out that it was not made correctly. The screw holes for some of the modules were completely misplaced, which meant that either a new cabinet had to be ordered or that it had to be modified so that the screw holes would fit. Since the holes that were misplaced would become completely covered by the modules and that it would probably take a very long time for a new cabinet to be delivered, the decision was to modify the cabinet.

3.4 Electrical installation

A lot of equipment on the test rig is sensitive to interferences. Therefore it is very important to avoid EMI (electromagnetic interference). There are a few different ways to avoid these unwanted disturbances. When mounting modules directly on the engine, WTB:s (wiring terminal box) are required. The boxes meet high demands of ingress

protection, and all outgoing cables use 360° cable glands. When installing cables to a module in a WTB, it is very important to use the cable gland properly. By grounding the cable shield in the cable gland as in the picture below, 360° EMC shielding is achieved. EMC shielding is also maintained by foil wrapped around sensitive wires in a cable. This foil should not be completely removed, only a few centimeters should be removed so that cable connection can be made, and a little piece of shrinking tube should be used in the end of the foil to keep it as tight as possible.

Figure 6. Proper usage of a cable gland in a WTB

Low current cables should be separated from high current cables and the installation of these two, if too close to each other, may cause disturbances. Soldering the cables on the engine is not an accepted method, because it is not strong enough and it easily causes corrosion in high humidity areas.

Wire ends must be terminated using end sleeves fastened with a crimping tool. The reasons why end sleeves must be used are:

- The end sleeves make the wire more resistant to vibrations.
- The end sleeves keep the wires together and thereby short circuits are prevented.
- The end sleeve supports the wire, which is needed especially at the point where the insulation ends.

Since the WTB:s are mounted directly on the engine, they are very exposed to vibrations. To ensure that the cables inside the box endure the vibrations and stay in good condition they need to be fastened very tightly. This is done by using tie wrap holders very close to each other (max. 2cm in WTB:s) and tightly fastened. The vibrations may also damage the cables due to sharp angles in the cable glands. Therefore it is important to use shrinking tube for extra protection in these places. /1/

3.4.1 Cable marking

The markings of the cables used on the real engines are printed on a small piece of tape. This is a very simple, quick and nice way to do it. When the wiring and marking were scheduled to start in this project, it was noticed that there was no marking tape. Since the ordering of the marking tape would have been a pretty long process and the marking should be done at the same time as the wiring, it was decided that the marking would be done in another way. The markings that were used instead were small plastic pieces marked with a number, a letter or another symbol. The pieces were slipped on the ends of cables one by one and then linked together. This method was slow compared to the other method and it made the markings quite big and clumsy due to long names which needed a lot of marking pieces.

On top of all, the cabinets, especially the main cabinet, were quite tight which made it hard for me to get a good-looking result. In tight places the tape markings could have been bent and still good-looking. The markings that were used were thicker and stiffer, which made them unbendable.

3.5 Main components

Figure 2 shows the modules that are required in a UNIC C3 system. This project didn´t have the WCD (Wärtsilä Coil Driver) component because it is only needed for the SG system (gas engines). The CCM:s and IOM:s are located on the engine while the rest of the modules are in the main cabinet, except the PDM-110V which has its own small cabinet. Of course, both of the cabinets contain other important components besides the modules, such as fuses, circuit breakers and terminal blocks. However, these components won't be mentioned very much in this text.

In addition to all the modules, the test rig has a few different types of physical sensors. This project used 4 x pressure sensors (2 x 0-6 bar and 2 x 0-10 bar), 4 x mA sensors, 4 x thermocouple sensors, 2 x speed sensors (primary and secondary), 2 x phase sensors (primary and secondary) and one stop solenoid. This provides the possibility to easily measure a wide variety of signals, e.g. a pressure sensor can measure a variety of measuring points, including oil pressure, HT water and LT water. The type of signal measured can easily be changed in a few minutes by switching two or three wires, depending on what kind of sensor it is.

Besides all the physical sensors a lot of sensors had to be simulated, too. This method saved a lot of space and money. The total amount of simulated sensors reached 70 pcs. (30 pcs. thermocouple, 8 pcs. ratiometric, 22 pcs. pt100 and 10 pcs. of mA) and they were split up on two CCM modules and two IOM modules. Even though the simulation saved a lot of space compared to 70 real sensors, they also required some space and became quite visible, which also meant that it had to be good looking. This was solved by casing them into four 153x83x50.5 mm aluminum enclosures with printed markings under the potentiometers for each sensor.

3.5.1 Thermocouple sensors

Thermocouple sensors are used for measuring high temperatures. They consist of two different types of metal connected in one end. There is always an emf (electromotive force) in an interface between two types of metal. The size and polarity of this emf vary between different types of metal, and the size is also temperature dependent.

If two wires that are of different types of metal, type A and type B, are put together as in the picture below, the total emf (E) will be zero if both of the interfaces have the same temperatures, i.e. $T_1 = T_2$. If $T_1 \neq T_2$, E becomes proportional to $T_1 - T_2$. T_1 will be the measured temperature. /5/
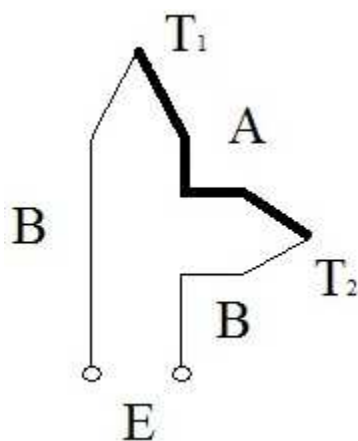

Figure 7. Thermocouple function description

A thermocouple sensor simulation circuit is built of one 7805 voltage regulator, one potentiometer (1kΩ) and one resistor (120kΩ). The circuit uses +24V DC as supply voltage and the 7805 regulator reduces the voltage to 5V. The output signal is measured over the potentiometer acting as a voltage divider and it is varied between 0 and 40 mV. The output signal of a thermocouple simulation circuit is the input signal to a CCM

module's TC (thermocouple) input, which converts the voltage to a simulated temperature (-50°C…+750°C). The temperature is shown on the screen of the LDU and it can also be seen in WECSplorer. /3/
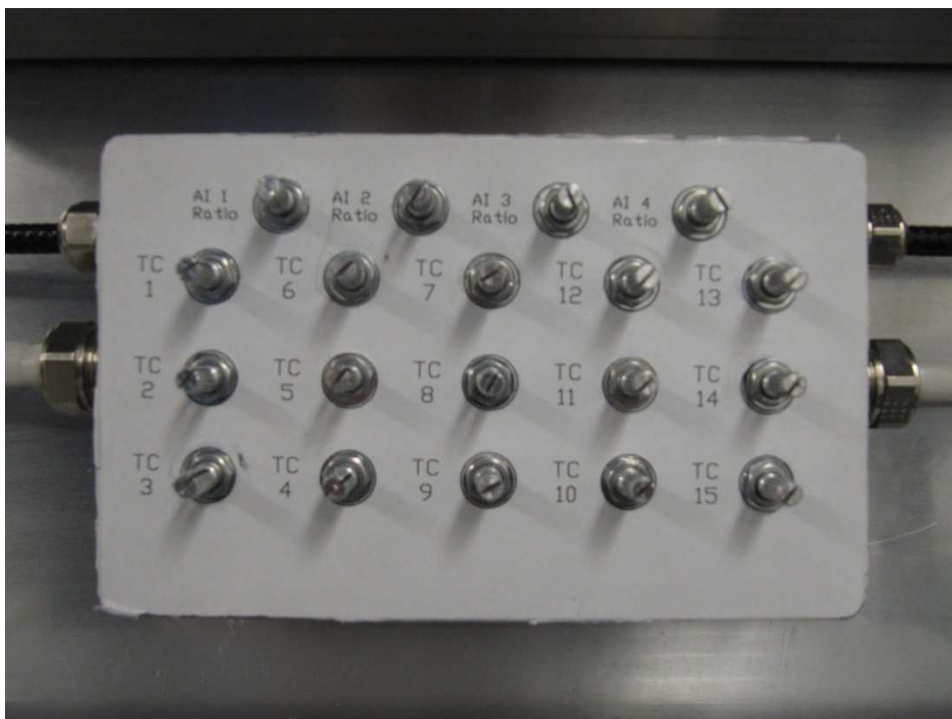

Figure 8. Box with potentiometers for thermocouple and ratiometric sensor simulations.

3.5.2 mA sensors

The mA sensors are used for e.g. pressure measuring. Two different types of pressure sensors were used in this project, one with a pressure range from 0 to 6 bars and another one with a pressure range from 0 to 10 bars. The good thing with mA sensors is that because they operate with current instead of voltage, they become less sensitive to voltage drops and EMC disturbances compared to the ratiometric sensors, which makes mA sensors very useful especially when using long cables. The sensors had an output signal between 4mA and 20mA.

The mA simulations for these sensors were made of a 1.1kΩ resistor and a 10kΩ potentiometer, which gave a current range between 2mA and 22mA since the power supply was 24V.

3.5.3 Ratiometric sensors.

The ratiometric system is a voltage based system for pressure measuring. As already mentioned, ratiometric measuring has two disadvantages. It is inappropriate for systems using long cables, because long cables may cause high voltage drops resulting in high inaccuracy in the measurements and it is very sensitive to EMC disturbances.

Ratiometric simulation can also be made easily by only two components, a resistor and a potentiometer. The voltage is adjustable between 0 and 5 volts, which was made by using a 10kΩ potentiometer and a 56kΩ resistor.

3.5.4 Pt100 sensors

Pt100 sensors are used for temperature measuring. The temperature varies with the resistance as the figure below shows. The nominal resistance at 0°C is 100Ω. /4/

°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90
-200	18,49	14,45	10,49	6,99	4,26	2,51				
-100	60,26	56,19	52,11	48,00	43,88	39,72	35,54	31,34	27,10	22,83
0	100,00	96,09	92,16	88,22	84,27	80,31	76,33	72,33	68,33	64,30

°C	0	+10	+20	+30	+40	+50	+60	+70	+80	+90
+0	100,00	103,90	107,79	111,67	115,54	119,40	123,24	127,08	130,90	134,71
+100	138,51	142,29	146,07	149,83	153,58	157,33	161,05	164,77	168,48	172,17
+200	175,86	179,53	183,19	186,84	190,47	194,10	197,71	201,31	204,90	208,48
+300	212,05	215,61	219,15	222,68	226,21	229,72	233,21	236,70	240,18	243,64
+400	247,09	250,53	253,96	257,38	260,78	264,18	267,56	270,93	274,29	277,64
+500	280,98	284,30	287,62	290,92	294,21	297,49	300,75	304,01	307,25	310,49
+600	313,71	316,92	320,12	323,30	326,48	329,64	332,79	335,93	339,06	342,18
+700	345,28	348,38	351,46	354,53	357,59	360,64	363,67	366,70	369,71	372,71
+800	375,70	378,68	381,65	384,60	387,55	390,48	800			

Figure 9. Table of how the temperature varies with the resistance in pt100 systems.

A pt100 simulator circuit was made with a resistor and a potentiometer. In this project the simulated temperature range should be between -50°C and +200°C. The resistance was thereby varied from 80Ω to 180Ω. .

Figure 10. Box with potentiometers for pt100 and mA sensor simulations.

3.5.5 Engine speed measurement.

The measured engine speed is very important information and it is used for speed control, which also means that it is used for controlling the fuel demand in order to have an engine speed that is as stable as possible. In engines with electronic fuel injection it is also important to know the position in the working cycle so that the injection timing can be calculated. The engine position is measured by a phase sensor and the calculation of the injection timing, which is done by the CCM, needs information from both the speed sensor and the phase sensor. For redundancy reasons the system uses two speed sensors and two phase sensors, one primary and one backup.

The speed sensors are placed close to the flywheel. The flywheel has a certain amount of holes or teeth. By dividing the flywheel holes or teeth into equal areas on a length, the engine speed can be measured. The sensor measures the rotational time for every area and since the rotational angle is known, the time can be transformed to engine speed by calculating.

UNIC needs to know the exact angular position of the engine. Therefore one hole is missing on the flywheel for both primary and secondary speed measuring, which in the pulse train will result in one missing pulse for each engine revolution. The signal is sent to all CCM:s and to the MCM. /6/

3.6 Testing

When all components were connected and everything on the hardware side was ready, it was time for the testing of the system. The first thing to test was the function of all the most critical parts by using a multimeter and to make sure that it was safe to turn on the power to the whole system. The next step was to install an engine software package for the system. Since none was created specifically for this project only, a software package from a "real" project was used instead. When a suitable one was found for testing purposes, it was time to install it in the system. The installation was done via a computer program named WECSplorer, which could be downloaded from the intranet. Using WECSplorer needed privileges that not everyone has. An application for these privileges needed to be made and it took a while to get them granted. As the application got granted and the installing of the engine software package was to be started, WECSplorer didn't allow the installation because the user level didn't have the privileges for that. There are four different user levels; viewer, operator, expert and developer. Developer is the highest in rank, and this level was needed for the maximum usage of WECSplorer.

When starting up WECSplorer, a login menu is shown where the choice of engine package also happens. After logging in and choosing the wanted engine package, a basic parameter list for the engine type shows up, but it is also possible to add more functions, e.g. sensors to the system. The basic parameter lists are of course different from one engine type to another, due to different equipment on the engines. Before downloading the engine package from the computer to the rig it is important to activate the used modules in WECSplorer.

The picture below shows UNIC C3 CR (common rail) engine package. The "scalar" window shows the most important engine parameters, such as symbol name, current value, the unit of the measured signal, minimum value and maximum value. The same window also shows that the MCM-11 tab is chosen which means that the green values shown in the window are all values handled by the MCM-11.
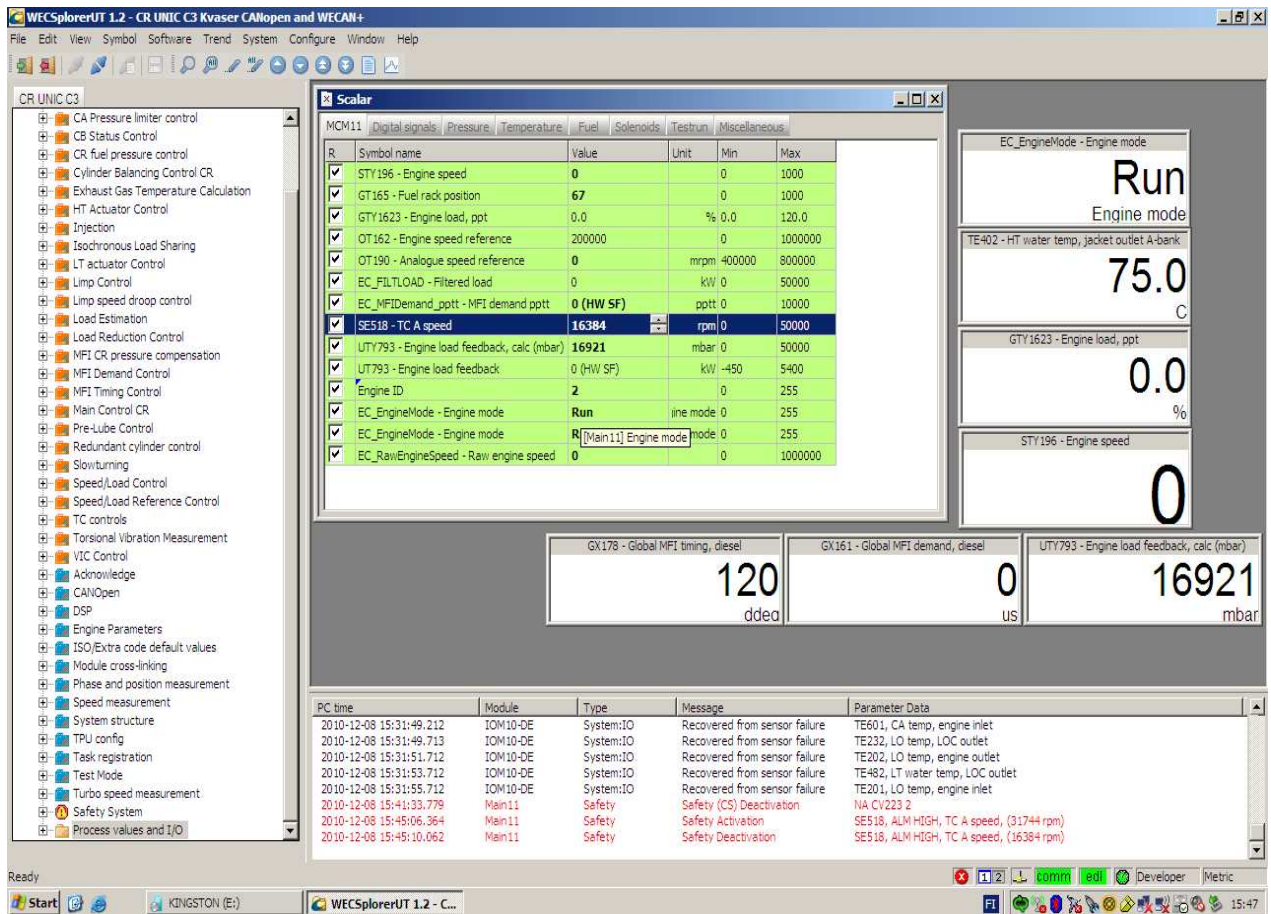
Figure 11. Screenshot from MCM-11 values in WECSplorer

Figure 11 shows a screenshot from the same system and engine package but the chosen tab is now "Miscellaneous". The parameters in the green window are mixed and they have been manually added to the basic package. It is very easy to add parameters that don't exist in the basic package. The column to the left shows a lot of engine parameters that can be added for monitoring simply by using the drag and drop method. The "Process and I/O" folder contains a lot of input and output signals (e.g. sensor signals) that have been very useful for testing purposes in this project. When expanding the folder, seven subfolders numbered from 100 to 700 show up. The sensors are named with two or three letters followed by a number, which can be seen in the green field in the figures. If a wanted parameter is e.g. "TE601" (charge air temperature, engine inlet), it will be easy to find just by searching in subfolder "600".
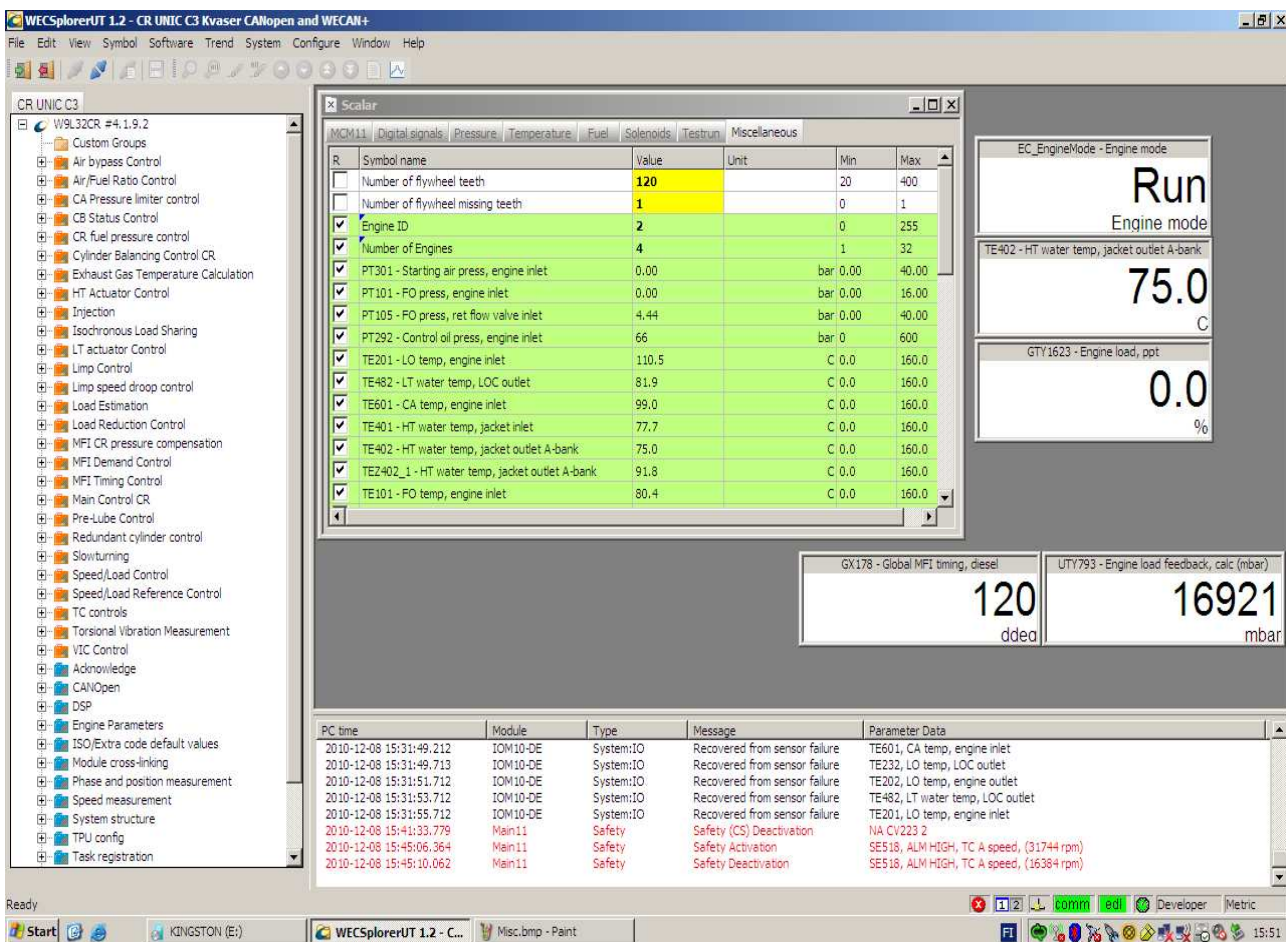
Figure 12. Screenshot from miscellaneous values in WECSplorer

4 Results

The final result was a functioning test rig for the UNIC C3 system. Tests have been made with different kinds of engine software packages and most of the tests have shown good results, but since there were a lot of signals and parameters to be measured and adjusted, some deviations from the wanted measurement values occurred, which was expected.

Some components, especially potentiometers have already been exchanged due to too bad quality and inaccuracy. The test rig will still be continuously updated and modified.

5 Discussion

This work has been very interesting and challenging, especially the beginning was challenging because I didn't have that much knowledge about Wärtsilä's equipment, systems or standards. After reading documents about the company and UNIC I understood a bit more and it helped me with this project, but I have to say that the biggest and most valuable help came from my colleagues.

It took me quite a long time to build the test rig. The most time-demanding work wasn't the most difficult work, but the wiring and marking of the wires in the main cabinet. Other works that took a long time were the planning and making of the sensor simulations.

This work has given me a lot of knowledge about Wärtsilä, which can be very useful in the future. On top of it all the Bachelor's thesis work has given me a better insight into the working life of an engineer in a big company.

I want to thank Novia and Wärtsilä for giving me the task and topic for my my Bachelor's thesis, my supervisor, and last but not least, my very helpful colleagues for their help and support. Without all these this work would not have been completed.

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