Juuso Junila

GUIDELINE FOR WÄRTSILÄ 50DF UNIC UPGRADE

Tekniikka
2024

VAASAN AMMATTIKORKEAKOULU
Sähkötekniikka

TIIVISTELMÄ

Tekijä	Juuso Junila
Opinnäytetyön nimi	GUIDELINE FOR WÄRTSILÄ 50DF UNIC UPGRADE
Vuosi	2024
Kieli	Englanti
Sivumäärä	40 + 4 liitteet
Ohjaaja	Mikko Västi

Tämän opinnäytetyön tarkoituksena on kertoa lukijalle, kuinka moottorinohjausjärjestelmän päivitysprojektin asennus valmistellaan, toteutetaan ja viimeistellään. Kyseessä on Wärtsilä 50DF -moottori, johon on päivitetty uudempi moottorin käyttö- ja ohjausjärjestelmä, UNIC 6-series. Opinnäytetyön liitteenä on myös käytännön ohjeet (Guideline) moottoreiden UNIC-ohjausjärjestelmän rakentamiseen, käyttöönottoon ja testaukseen. Ohjeen kohdekohtaisista tiedoista johtuen sitä ei julkaista.

Opinnäytetyössä käydään läpi, kuinka valmistellaan, esikootaan ja testataan kaikki tarvittavat laitteet ja osat niin, että projektin toteuttaminen on mahdollisimman nopeaa paikan päällä. Siinä käydään läpi myös se, miten työt sekä henkilöstön ja laitteiden organisointi tulee huomioida projektissa.

Avainsanat	Projektihallinta, DF-moottorit, UNIC, Käyttöönotto, Työmaalla työskentely

VAASAN AMMATTIKORKEAKOULU
UNIVERSITY OF APPLIED SCIENCES
Sähkötekniikka

ABSTRACT

Author	Juuso Junila
Title	GUIDELINE FOR WÄRTSILÄ 50DF UNIC UPGRADE
Year	2024
Language	English
Pages	40 + 4 Appendices
Name of Supervisor	Mikko Västi

The purpose of this thesis to describe how an engine control system retrofit project is prepared, implemented, and finished. The project in question is Wärtsilä 50DF engine which is retrofitted with a newer engine operating and controlling system, UNIC 6-series. Part of the thesis was to draw up a practical guideline for building, commissioning, and testing of the UNIC control system. Due to the target-specific information in the guideline, it will not be published.

The thesis depicts how to prepare and preassemble and test all required equipment and parts so that it is as fast as possible on site to execute a project. It also explains how site work and organization of personnel and equipment should be acknowledged when running a project.

Keywords	Project management, DF-engines, UNIC, Commissioning, Sitework

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ABS	American Bureau of Shipping (Classification Organization)
CMOD	WECS Communication Module
CCM	Cylinder Control Module
COM	Communication Module
DF	Dual Fuel (Diesel and Gas)
ECR	Engine Control Room
ER	Engine Room
ESM	Engine Safety Module
FAT	Factory Acceptance Test
HSR	High-availability Seamless Redundancy
HT	Hot Temperature
HMI	Human Machine Interface
HWIO	Hardwire Input/Output
IAS	Integrated Automation System
IOM	Input/Output Module
LDU(LCP)	Local Display Unit (Local Control Panel)
LNG	Liquefied Natural Gas
LO	Lubrication Oil
LT	Low Temperature
MC	Main Cabinet
MCM	Main Control Module
OMC	Optical Media Converter

OMD	Oil Mist Detector
PLC	Programable Logic Controller
PMS	Power Management System
SAT	Site Acceptance Test
sWOIS	server Wärtsilä Operator’s Interface System
TB	Terminal Box
TB-ES	Terminal Box Engine Safety
UCP	Unit Control Panel
UNIC	Wärtsilä Unified Controls
UNITool	Wärtsilä engine software configuration tool
WDCU	Wärtsilä Data Collection Unit
WECS	Wärtsilä Engine Control System
WOIS	Wärtsilä Operator’s Interface System
WTB	Wärtsilä Terminal Box

LIST OF FIGURES

1 INTRODUCTION

Wärtsilä Engine Control System (WECS) has now been in operation for decades. Most system electronic devices in engines have a lifecycle of 10 to 15 years. Because of this end of lifecycle in components, there is a risk of an increase in unexpected shutdowns. The new Wärtsilä UNIC ensures the continuation of efficient operation and global support of the system.

The purpose of UNIC-upgrade is to provide customers better engine efficiency and reduce methane slip during the gas run. 6-series of UNIC engine control system is based of cylinder pressure sensors instead of exhaust gas temperature measurements like it was old WECS system. Customer will also get much more informative data from new HMI panels and sWOIS or WDCU.

The customer also has additional options available example UNITool laptop or expert insight. UNITool laptop will allow customer to live trend engines and gives many tips & tricks for faster troubleshooting. Expert insight will offer preventive maintenance via Wärtsilä remote support. Old engine control system is obsoleted so Wärtsilä don't make or sell any more spare parts for old outdated system.
DF motors are suitable for LNG ships for a few main reasons. DF engines can run on diesel or gas or mixture of both. When operating on a full gas mode some diesel is still used to prime the explosion. LNG ships carry liquified natural gas which is approximately minus 163 degrees Celsius when in the reservoir. It is so cold and there is not so resistant combination of insulation layer and cooling system that can fully keep the temperature above of 163°C. Therefor there is forming some excess gas in top of the containers carrying LNG. This gas would otherwise to be burned into air to get rid of it, but Wärtsilä DF engine can use it as a main fuel, so it is led into the engine instead of burning it in the air.

2 PROCESS

Interviews were conducted to find out the important jobs and targets of the whole project. Based in findings of the interviews in appendices 2, 3 and 4 the following important jobs and targets can be defined.

- Well organized and planned preparations for project.
- Well planned and executed installation and commissioning on site.
- Successful tests at sea and delivery of the system to the customer.

Based on this list of important jobs and targets following flow chart of the project activities was developed. The flowchart is presented in **Figure 1**.

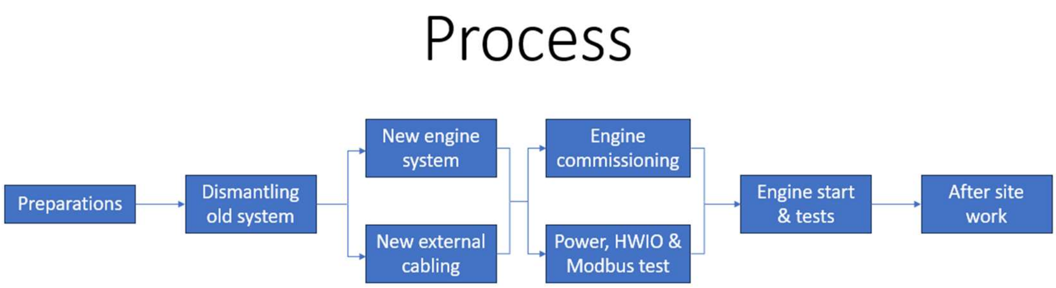

Figure 1. Process flowchart.

The interviews also raised following challenges of the site work phase:

- People and hardware can cause delays in installation. For example, poor time and free time activity choices can cause downgrade in quality and relationships with co-workers.
- On-site it is important to communicate with all teams working in same spaces to make sure that everyone has room and time to do their work.
- A lot of effort has been put into proactive safety at work to keep staff safe on board and the workplace tidy.
- In some countries difficult to obtain supplements which means careful pre-planning and accurate and comprehensive checks on packaging.
- A delay in logistics will cause a delay in the start of the work. Often it is out of our control, but if you know from previous projects that it will be difficult to get the goods to the destination, it is good to anticipate the delay and, for example, send the packages early.

- Good to have some kind of workshop after project, to talk about the successes and challenges of the project.
- Project management support should be agile.
- Communication between project and site team.
- Project team competence -> to ensure professional and high-quality installation.

Based on the flow chart, observations and experience and the challenges project management guidelines were developed to solve these challenges, which is shortened in following chapters.

The process of an upgrade project starts with the sale of the project to the customer. The contract states when the project starts and how much personnel the project requests. After the project is sold to the customer, the preparations for the project can start. The project is assigned to a project manager that will start to assemble a team to manage the project.

The site team is assembled starting with the site manager. Then supervisors are requested from departments. If there are new employees to learn different scopes of project, they are also added to the site team, and it is confirmed with the customer that they are happy to pay some expenses of the intern. Also, the site electricians are booked. The electricians will start to prepare the project by assembling all the rails and other components needing prebuild to speed up site work. All permissions and other paperwork are also done before site to make everything as smooth as possible on site.

The first step of site work is to dismantle the old system. The customer may want to keep some components, and old components and wiring are reused so it must be clear for the entire site team what are removed and what is saved. With the components that are reused personnel hast to be especially careful to not brake, because it is costly and time consuming to order new ones from warehouse and may delay the whole project.

Preparations for New Cabling. The new cabling is explored more thoroughly in chapters 5.3 and 5.4. New cabling for the engine and external connections are done simultaneously to reduce time on site. There are two teams: The team to do engine cabling are provided from Wärtsilä because engine cabling requires specially trained electricians. External cabling can be done by shipyard personnel under supervision of Wärtsilä supervisor. New cabling takes most of the time on the upgrade project.

Preparations for Commissioning. Commissioning is explored more thoroughly in chapter 5.5. After all the cabling are connected, can commissioning of the engine start. Commissioning can be done one engine at a time so as soon as the first engine is ready, commissioning of the engine can start. During commissioning engines power supplies, electrical insulation, critical sensors and actuators and safety features are tested. Also, communication bus verification and preliminary safety tests are done in cold commissioning (without electricity). HWIO and Modbus serial communication are tested. They are tested by simulating signals to and from engine. All tests must be carried out before load testing. Engine can perform local idle run (generator braker open) before HWIO and Modbus testing if necessary. This is typically done to monitor engine process pipelines and sensor installation leakages.

Preparations for after site work. After site work is explored more thoroughly in chapter 6. After site work includes updating documents to match actual installation, filling up rest of the commissioning protocols, possible diesel, and gas test at sea, handing over certificate and timesheets.

3 SYSTEM OVERVIEW

3.1 WECS 8000

The old engines what Wärtsilä is retrofitting are usually using the WECS 8000 or older system as the control system. The system is already over 15 years old and has come to the end of its life cycle. Most of these types of engines that are upgrading have been made in Trieste Italy.

The WECS 8000 is a distributed engine control system for monitoring and controlling all engine functions. The system monitors and controls gas, air, ignition, knock, speed, load, diagnostics, and communication with ship control system. The system consists of several hardware modules, interconnected by engine wiring. The modules communicate with each other by two communication buses based on CAN protocol [1].

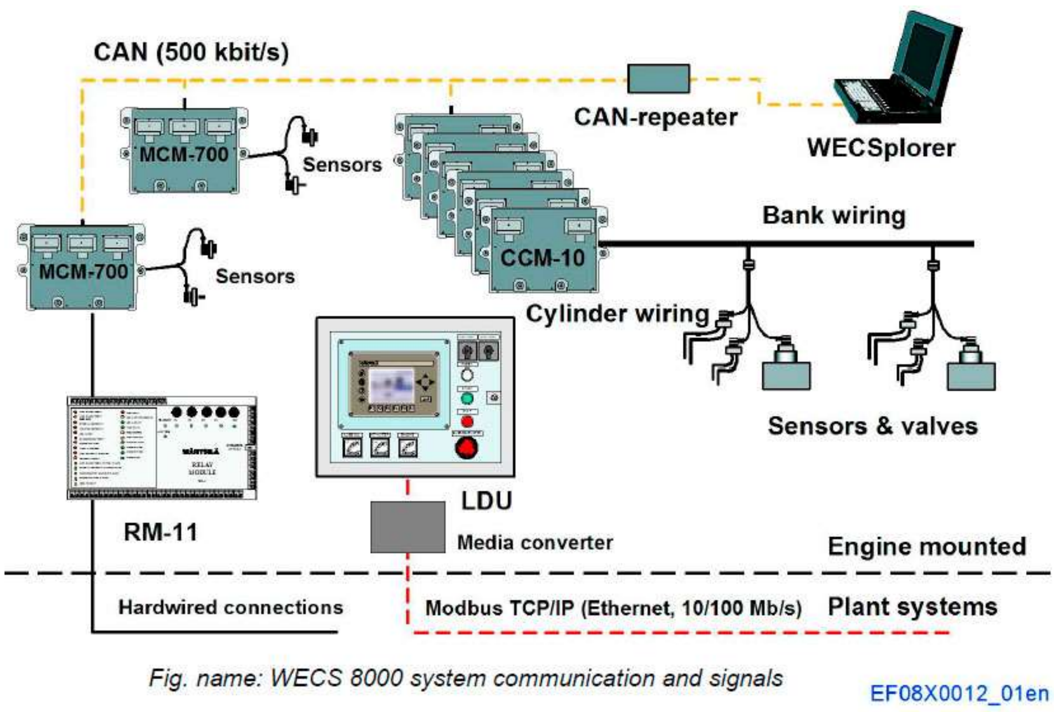

Figure 2. WECS 8000 system architecture

3.2 UNIC 2 GEN (6-series)

UNIC 2 Gen, in comparison with WECS 8000, has improvements in all aspects of the system. Adding peak pressure sensor is the biggest change compared to WECS. The system is modular and can be tailor made for the customer needs and existing systems. Compared to the old system, it provides more reliability that includes redundancy, fault tolerance and diagnostic. These keep customers' engines running longer and giving faster fault information ensures a fast fault fix.

Reliability, safety, and monitoring is accomplished with robust mechanical and electrical design to ensure modular engine that can adapt for example to modules or sensors failing and making replacement easier. Reliable software architecture ensures reliability. Operator interfaces enables standalone engine monitoring via integrated diagnostic and event display that accelerates repairs. Software filters are added to avoid measurement disturbances and noises. Modern system architecture ensures ease of buying spare parts and services, like remote fault and system diagnostics. For more and advanced diagnostics, customer can use UNITool computer software [2].

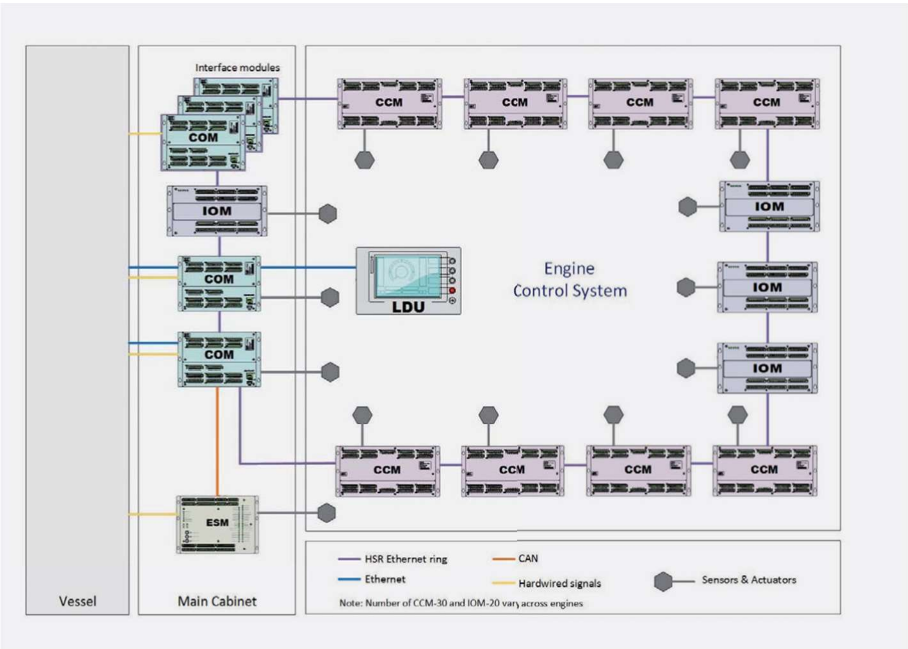

Figure 3. UNIC 6-Series system architecture

4 PREPARING FOR PROJECT

Interviews were conducted to find out the important jobs and targets of the pre-site work phase. Based in findings of the interviews in appendices 2, 3 and 4 the following important jobs and targets can be defined.

- Establishing a timetable for the whole project
- Site audit -> important input to project engineering.
- Initial mapping of the project, kick off with different departments and subcontractors.
- Assembling the project and the site team.
- FAT testing equipment

Based on this list of important jobs and targets following flow chart of the project activities was developed. The flowchart is presented in **Figure 4**.

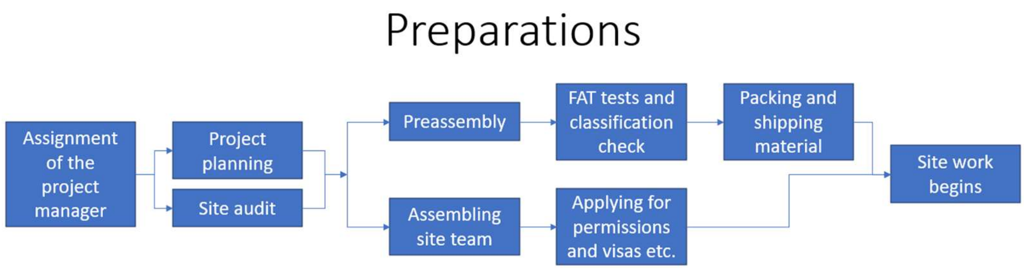

Figure 4. Flowchart of preparations

The interviews also raised following challenges of the site work phase:

- Work permits to country can be a challenge in some countries.
- Right material not arriving on site.
- Material not arriving to site on time.

Based on the flow chart, observations and experience and the challenges project management guidelines were developed to solve these challenges, which is shortened in following chapters.

The assignment of the project to a project manager starts the entire process. Project planning is done for the whole preparation process in the background and the site audit as a supporting element for the planning. The site audit is covered in chapter 4.1. As the project takes shape it's time to preassemble the modules and test them. The preassembly and FAT test, including classification check is covered in chapter 4.2. When modules are ready, they are shipped with the installation material to the site. This is covered in chapter 4.3.

The assembly of the site team is done also in the background as the preparation continues. After the site team is assigned, they apply for all the needed documentation for site country and project. The site team and preparations are covered in chapter 4.5. Preparations for the service engineer are covered in chapter 4.4. When preparation is ready, the site work can start, presented in more detail in chapter 5.

4.1 Site Audit

One of the service engineers does the site audit months in advance before the scheduled time of the upgrade project. The purpose of site audits is to collect useful information related with the installation, for upgrading the engine control system, and for the other automation equipment for obsolescence or other improvements. Useful information includes for example comparing preliminary design drawings, to check that there are not any additional signals. Site audits are important input to the engineering team and to ensure that the project is possible and there are no other obstacles to slow down the upgrade project. Preferably the audit should be conducted before the engineering phase start.

During the site audit, the purpose is also to do on-site design work. This is done to find any possible problem areas for retrofit working scope. These problems can be modification we were not informed and difficult cable routing for new cables. Modules in the preliminary site design include power unit and junction box, which are the biggest add-ons that come to ER. The location of the media converter is

also planned to make sure that it has enough space and reach with the fiber optic cable. New cable routing of the LT and HT valves is also included in the site audit. In ECR new locations to sWOIS or/and WDCU are also decided.

4.2 Preassembling Modules and Rails

The system is preassembled as far as possible to save time on site. Engine siderail / siderails are built in preassembly. When connections between modules is on the same siderail, it is built in preassembly. Connections between modules on different siderails are done on site.

Sensors and actuators and other modules can be named and labelled in prebuild to make on site new material handling easier. Every sensor and actuator part should be checked that they are in operational condition. There are limited amount of spare parts on site. The prebuild process purpose is not to build the whole engine automation but to build most of the module assemblies. It is not sensible to connect cables on power and other external modules even on the other end, which is because the mounting place can change, and the cable routing can also vary.

FAT testing of system is done by the supplier but in case customer wants to do classification check in preassembly usually it is Wärtsilä's service engineer that does that. Fat testing is done by subcontractor assembly test instructions [3] that includes software downloads and checks, safety functions testing and testing the HSR ring of the engine. In the FAT, purpose is also to fix as many software, communication and connection issues as possible. Common problems in communication are a loose connection or bad quality of ferrule crimping or even a broken wire.

When FAT includes classifications check there is classification organization representative (for example ABS) supervising tests. In classifications check, the classification organization representative usually wants to go through test protocol, but

in the preassembly, it is difficult to do all the tests that are included in test protocol because some of the sensors are on site and some sensors and actuators cannot be simulated. Most of the safety tests can be done in preassembly excluding at least OMD and Gas valves because old one is used so there is not one in preassembly. [3]

4.3 Packing and Shipping

Prebuild includes making sure multiple times that all material and parts are included and are sorted in right packing crates. The right material in the right packages ensures that the right material can be found easily on site and in some countries, the customs will check materials and it is crucial that the packing lists are in line with the material in crates, packages, or containers to make the customs check easy and so that material is on site in time.

Packing and shipping should be done months in advance to ensure parts are on time on site. All packages should be made seaworthy. All loose parts must also be fastened to crates to minimize damage in transportation.

4.4 Preparing on Service Engineer Side.

Service engineers make the technical review of the project. In this review, site audits plan for module locations and cabling routes for power, signal, fiber, and control cables are presented. The site audit, as mentioned earlier, also hold the location of other modules, so it brings everyone to speed in their own scope. If improvement needs or additional issues have come up in other projects, they are discussed also in this meeting.

Engine software should be downloaded to a memory stick and computer hard drive. The software is engine specific thus it needs to be requested from "customer installed base" database. Wrong software will cause problems with networking and automation system.

4.5 Site Team

The site team consists of superintendents, service engineers, electricians, and mechanicals. Electricians deal with dismantling the old system, assembling the new system, and upgrading the external cabling. They are mainly responsible for the quality of engine wiring and all the connections. Supervision and final quality control is done by Wärtsilä engineers.

The Wärtsilä representatives are usually site manager, UNIC supervisor, external cabling supervisor and PLC supervisor. The site manager oversees the site work and reports to the customer and the project team how the project is progressing. The site manager is the link between the project team, customer representative and site team.

The UNIC supervisor oversees the engine automation build, commissioning, and testing. He will be in the end responsible for the engine wiring and the quality of the UNIC system Installation. The supervisor can help with the wiring and cabling if there is a shortage of electricians. He handles the engine SAT and preparing engines to a starting condition. The UNIC-supervisor performs the tuning of the UNIC software.

The external cabling supervisor oversees the modification works in the external cabling. The supervisor should always be from Wärtsilä to ensure the quality of the installation. This way Wärtsilä will also provide the warranty of the external cabling installation.

The PLC supervisor handles upgrading the UCP and commissioning of the PLC system in the retrofit. The UNIC HWIO and Modbus tests are done in cooperation with the UNIC supervisor and the PLC supervisor. The PLC supervisor physical workload is typically light, thus one-member team is sufficient.

After the sales of the project have been completed, it is time to assemble the team that does the work. The project manager and the coordinator that takes the project under their management reserves people to the project. They will contact the field service departments to book personnel. Wärtsilä has local and global departments, and the project management can use either or both. Wärtsilä books their own personnel and subcontractor electricians in advance to ensure enough labour.

The coordinator makes sure that the installation team will complete all the required paperwork, including visas, site permissions and other paperwork to ensure the ease of travel and work. The service engineers can book their flights, trains, and other means of travel themselves. For electricians Wärtsilä coordinator will book all necessary tickets. If hotels and local travel from the hotel to the site are not managed by the customer, installation team will manage it themselves.

The customer assigns a local agent to manage all the practicalities, including hotels and rides, as mentioned before. Also in the local agent's scope are site permissions, pilot vessels, border control points for, for example, sea tests and all other required tasks that affect Wärtsilä's ability to do the work.

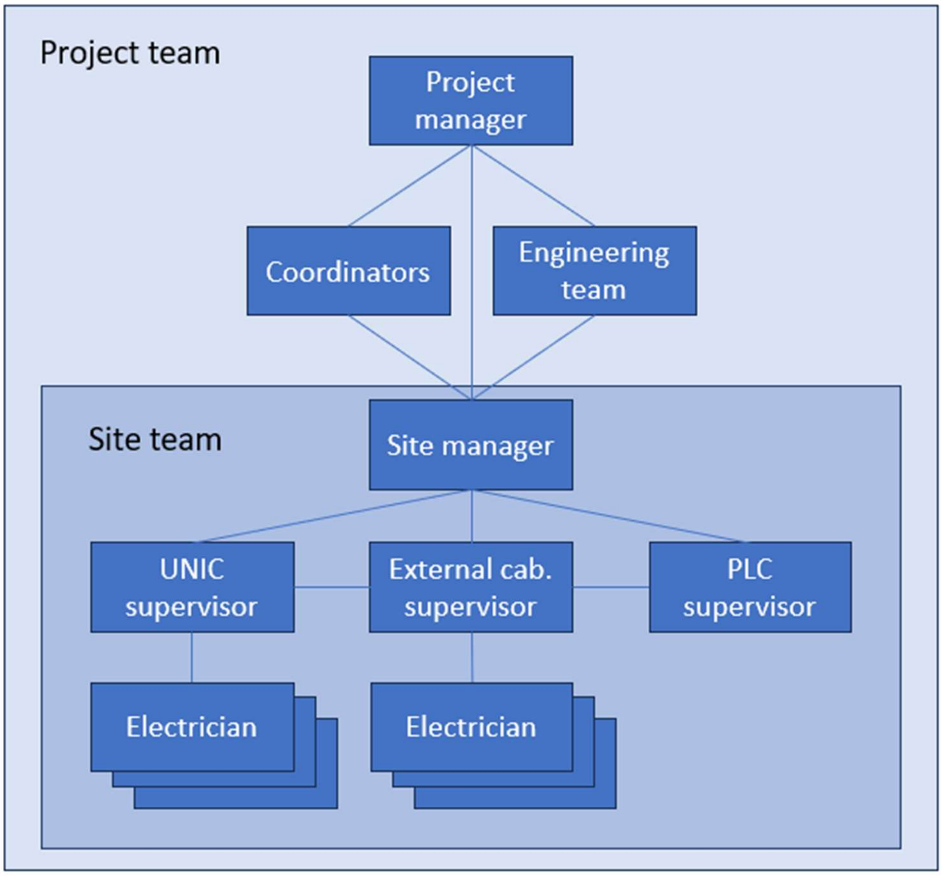

Figure 5. Project team structure

5 SITE WORK

Interviews were conducted to find out the important jobs and targets of the site work phase. Based in findings of the interviews in appendices 2 and 3 the following important jobs and targets can be defined.

- Do a well planned and executed installation and commission on-site and tests on sea afterwards.
- Kick-off meeting to get all the necessary starting information of the engines and surroundings. Engine chief way want a specific order in with the engines are to be worked with. This meeting is also to plan the project in synchronisation with other ongoing projects. Bad planning in this stage can cause problems and extra work in future.

Based on this list of important jobs and targets following flow chart of the project activities was developed. The flowchart is presented in **Figure 6**.

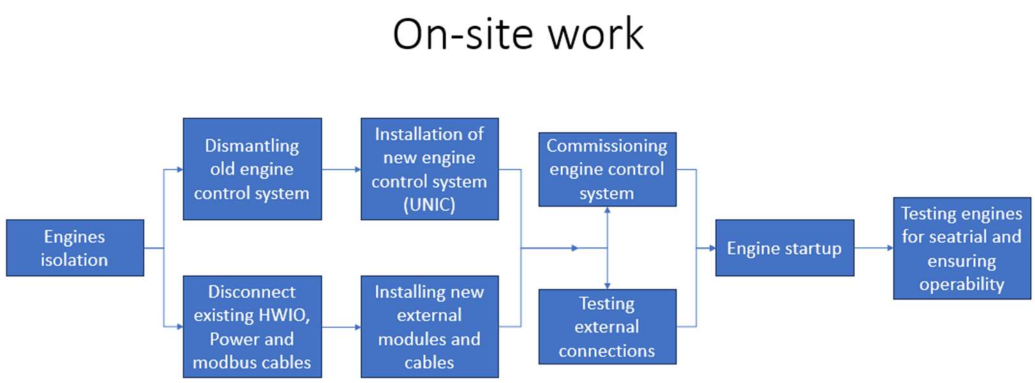

Figure 6. Flowchart of on-site work

The interviews also raised following challenges of the site work phase:

- There can be faults in first drawings of the installation.
- Misunderstandings in instructions can be costly especially when dismantling old system.
- Initial time plans can extend if timetable is not carefully tracked.
- It is impossible to get rid of cable misconnection, but time to fix them is minimal.
- Faults can occur due to people being assigned to unfamiliar roles.
- Cross connections in the external cabling are common but does usually take little time to correct.
- There is not dedicated time for troubleshooting software or signals.

Based on the flow chart, observations and experience and the challenges project management guidelines were developed to solve these challenges, which is shortened in following chapters.

On-site work begins with arriving at the site and getting all the equipment and parts to the engine room or as close to it as possible. Before the work can start, engines must be isolated. After a safe work environment has been created, dismantling and removing of the old parts can begin. This is covered in Chapter 5.2. When engines are stripped of the old cabling, new cabling can be added according to the wiring diagrams. The new cabling to the engine is covered in Chapter 5.3 and the new external cabling is covered in Chapter 5.4. The next parts in flowchart are part of commissioning, testing, and tuning. These parts are covered in chapters 5.5-5.7, but there are more detailed flowcharts in the chapters showing more of the steps needed to complete the on-site work.

5.1 Timetable and Working on Site.

The site team consists of around 10 to 20 people. The site team's roles are mentioned in Chapter 4.5. There are at least a site manager and two to three supervisors, depending on if an external supervisor is ordered. There are around seven to twelve electricians working on site. The number depends mostly on the contract about external cabling. The rest of the team consists of possible interns or people that come to learn a role in the team.

The calculated time for the installation and commissioning of the project is about 4 weeks. In that period the project should be completed quite easily unless there are large complications. Some example complications are the engine requiring other repair work and parts missing or faulty or broken. All these complications have varying time delays. Sometimes it is not in our control if project is late for example when engines can't start because charge air coolers are under maintenance, or the cylinder head needs to be replaced for some reason.

The guideline attached to this thesis is meant to give some insight to new or inexperienced personnel of how the UNIC side, testing and sea tests on the project are managed. It also has information of how the WDCU is installed and commissioned. It goes through the normal processes of how different components and how the entire system is built, commissioned, and tested. There are also some examples of what faults have occurred and how they were fixed.

Working conditions on these projects can be quite extreme especially to people that have no or little experience of working in hot and moist circumstances. It is good to remember to drink a lot of water and take often breaks in cool rooms such as the ECR that is most of the time cooled. Required clothes to be used on site are supplied by the company. It is also advisable to change clothes during the day to stay dry if there is a possibility to do so. The customer usually delivers water to the ECR or other places, but if not, it must be sure that water is always available.

5.2 Dismantling Old System

Before work on the engines can start, the engines must be shut down and isolated. It is necessary to stop the engine a day before the work begins, so that the block has cooled down during that time. The ship crew must isolate the engine from cooling water, fuel, gas, and lubrication oil. All lines must also be emptied, and air let out. The crew must isolate the valves and switches by locks or other means of isolation to prevent an unintentional start-up. All power to UCP, old power unit and old CMOD must be cut off and isolate breakers to prevent an electric shock. Additionally, the turning gear must be turned to on position and stop lever turned to stop position.

Before starting to dismantle the engine automation system, it must be made clear to the team which parts of the old system are saved so that no replacement parts need to be delivered to the site. All old parts removed from the engine must be removed carefully to not damage treads or mounting points. All expensive parts are reused if they are still usable, are hard to replace or located in difficult places

where reaching them requires taking other not necessary parts away, and do not affect the new system in a sense that it would use the same parts in the new system anyway. The old cheap parts are replaced to minimize failure risk if they are easily replaceable.

On the engine side, the saved parts include the following:

- Main gas vales
- Pilot injection valves
- Oil Mist Detector (OMD)
- Turbo speed sensors
- Old rails in free end are mostly reused.
- Degassing valves

In the external cabling, the saved parts include the following:

- Fiber optic cable from UCP to old LDU
- Power cables from UCP to old power unit
- HWIO cables from UCP to old CMOD

When dismantling the old system there is going to be a lot of waste. Especially the old siderails are going to be in the way. They are in one piece in the entire length of the side of the engine. It is easier to transport them away if they are cut in two or three pieces. All other waste material needs also to be collected and transported away from the ER. It is also safer in the ER if there is not waste material lying around; the old rails can be a tripping hazard and should be removed as soon as possible.

One helpful tip is to have big sacks on site. Usually, all new parts are removed out of the crates on the upper deck due to the lack of floor space on the ER, so it is easy to lower all cardboard boxes, parts, and other equipment to the ER with the big sacks. They also work as garbage bags in the ER and could be easily lifted away from the ER and away from ship. Limited floor space is also be kept clean when all waste material goes to the bags.

5.3 Physical Cabling of the New Engine Control System

Engine cabling must withstand a lot of different external disturbances. These include heat in form of radiant and conductive, vibration, oil, and moisture. These cables are marine approved cables. For these reasons, the engine cabling must be done properly and with professionals. The cable armour is connected to the WTB frame according to the wiring diagrams. Other IE and PE protection is done according to the instructions in the wiring diagram.

Wires going inside WTB or Main cabinet are to be installed so that installation is watertight and again the cable armour is connected to the frame. For smaller cables, the inlet can be tightened easily too much. A good rule is that the inlet is tight enough when the rubber is swelling out just barely beside the cable. Inside the box or cabinet cable ties and wire duct are used to fasten and hide wires to that the box or cabinet is clean and it is easy to test or find things if necessary. It is also part of quality when the cabinet is clean, and wires do not lie around ready to make a fault.

Cables outside modules are to be fastened to rails and other fastening points. First with plastic cable ties and lastly when everything is ready with steel cable ties. When wiring the engine automation and you do not get first time all the cables to the rails it is cheaper to cut few of the plastic cable ties rather than the steel cable ties. It is easier to change a broken sensor if there are plastic cable tie. Those are few of the reasons why the steel cable ties are put last when everything is on the place and working. Steel cable ties is used since they withstand heat better and have longer life expectancy than plastic cable ties. Steel cable ties can be fastened tighter than the plastic cable ties so the cable has less room to wiggle around.

Unfixed cables are in risk of rubbing into something sharp and cutting the cable. When cabling avoid sharp turns and edges to ensure that cable still is intact. If sharp edge is not possible to avoid, use rubber mat to protect the cable and prevent effect of sharp edge. Old side rails are replaced with new ones with modules

attached to then in preassembly. Old free and drive end open cable rails can be reused if in good condition, but there are new ones as part of the delivery. Old, closed rails in drive end near old CMOD are good to replace to make cables visible and easier to see if there are problems.

New modules are mostly attached to new rails. There are new brackets to new main cabinet. These are good to assemble after the cables are routed to main cabinet and sensors behind main cabinet has been attached and routed. This is because there is not much room to do those work after main cabinets brackets and main cabinet are in place. Main cabinet and side rails are good to lift in place with the crane in engine rooms. TB-ES module is new to engine control system, so it needs new taps to engine block in free end. Find a suitable location near the sensors for the module.

Inside engines crankcase goes main bearing temperature sensors. These are important to route and bend right way so that the crankshaft do not rip apart the sensor or rub against the cable. Sensor's base must be bended so that it clears the crankshaft. Cable must be attached to the clamps in the crankcase wall so that it is firmly against the wall but does not make sharp turns. Make sure to tighten up the inlet to make sure that no oil escapes from there.

5.4 Physical Cabling of the New External Cabling

External cabling includes all the cabling between ER and ECR, more specifically engines different modules and its unit control panel (UCP). It also includes new cabling to HT and LT water 3-way valves. 3-way vales are in engine rooms somewhere near engines. Every engine has its own HT and LT 3-way valve. New and old cabling is shown in figure 7. Old modules are outlined black, same applies to old cables. New modules and cables are outlined green. Only engine side cabling is renewed for the simple reason that the old cabling will not reach the new termination point in UNIC.

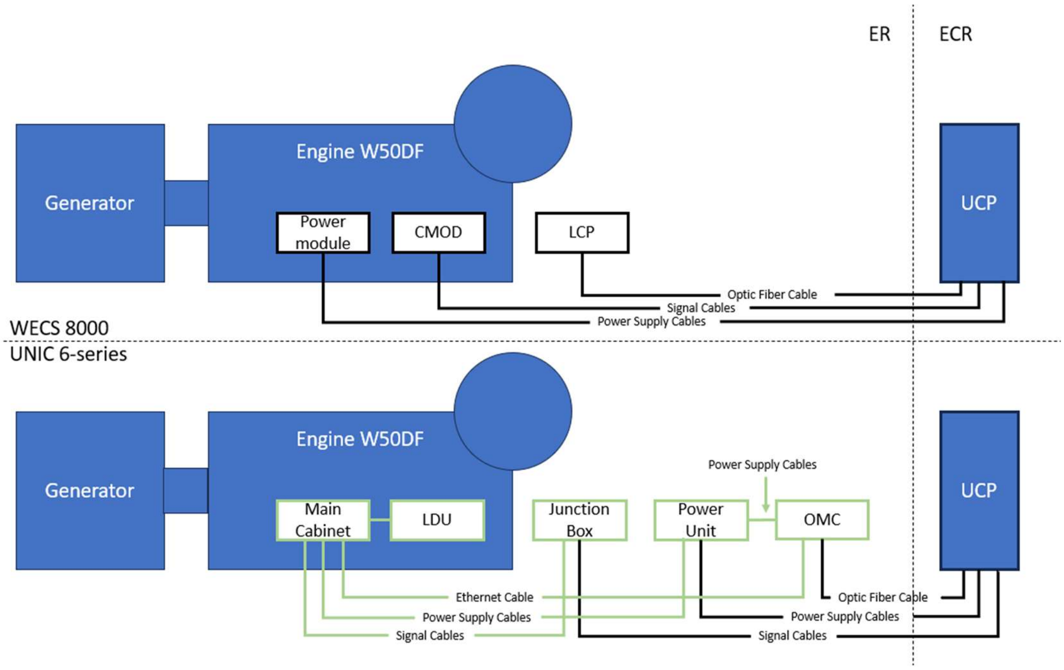

Figure 7. External cabling between WECS/UNIC and UCP

Old cables are reused until new modules. Old signal cables connect to new signal cables inside junction box. Junction box is to be installed somewhere near engine so that old signal cables reach to the box. New cables from junction box routed and box location according to site audits plans or if there are no plans, find a good route to main cabinet and place near engine.

Optic fiber cable must be carefully removed from LCP. While installing cabinets and cables it’s good to protect the fiber optic cable by securing it to some rail and bagging the heads so they stay clean. Optical media converter (OMC) needs to be used since new UNIC system doesn't allow termination of fiber optic cables. Cat cable is installed between OMC and main cabinet. It’s important to be careful when handling fiber optic cable because there is no time to renew cable all the way from ECR and it can cause whole project delaying from agreed time schedule.

Power cables are also reused until new power unit. Power unit is to be installed somewhere near engine so that old power cables can reach new power unit. Location on new power cables and power unit according to site audit. If there are no pre-existing plans, find a suitable location for the power unit that is in reach of old cables. Find good cable routes for the new and old cables. Before turning power on make sure that incoming and outgoing power cables are professionally installed and according to plans so there are no cross connections between phases and polarities.

When routing cables make sure that they do not touch any hot parts like engine block or hot pipes. Also, separate power cables from sensitive signal cables. Make also sure that cables do not touch any moving parts like flywheel, actuators or closing/opening valve handles or wheels. When wiring cables to terminal blocks do not leave to much extra wires because there is not too much extra space.

When crimping ferrules make sure that the wire is stripped down enough to make good contact with ferrule. When ferrule is pressed down partially over the wire insulation it does not have a good connection. Well-marked wires are important not only when connecting but also if there are some earth faults, connection issues or cross connections it is easy to find right wire and to put back in right terminal block.

5.5 Commissioning of Engines

Commissioning of the engine as a process is pictured below as a flowchart. First three phases represented on chart will be covered in the following paragraphs after chart. Machinery safety tests and hardware I/O and signal tests are covered in the chapter 5.5.1. Safety tests are included in the same chapter. Chapter 5.5.2 is handling HWIO testing, and chapter 5.5.3 is handling Modbus testing. Chapter 5.6 goes through rest of safety test and regular test that are performed in shipyard as pre-tests and checks before sea tests. Engine test runs are covered in chapter 5.7. This is performed during sea voyage.

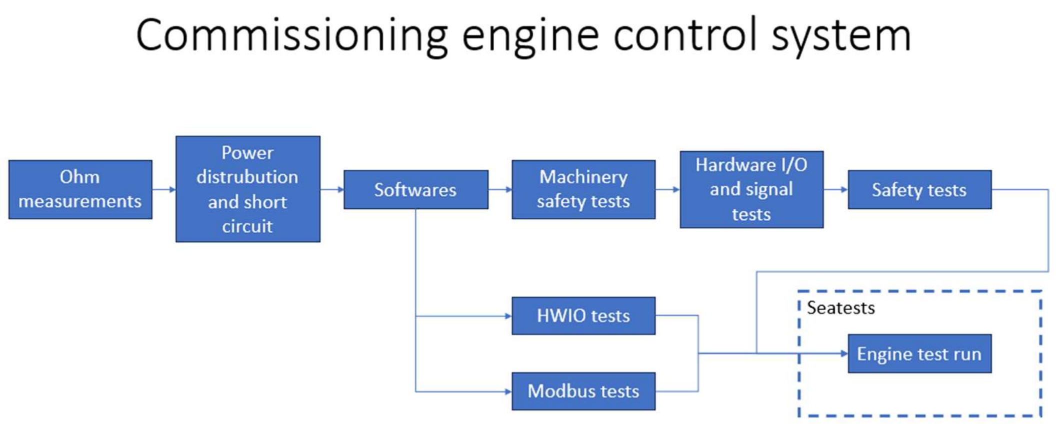

Figure 8. Flowchart of commissioning the engine

Purpose of the commissioning test and inspection is to verify engine control system functionality before project handing over to customer. Commissioning tests are done according UNIC 6-series DF Commissioning Test Protocol [4]. Before turning anything on check that the powers polarities are correct and power terminal blocks are measured with multimeter. Measurements also include HSR and CAN-bus measuring. This is to ensure that there is no short circuits or earth faults.

After measuring and checking polarities power can be turned on to the system. When power is on, check that power polarity is correct. Modules should turn on and LEDs of modules should be fading green or static blue, depending on if there is software inside or not. This is checked on every module on engine including ESM which has two LEDs, one for each power supply. During module checking there might be need to increase main cabinet supply voltage by 0.5 - 1.0 V. This ensures that even the last module in the power distribution has rated voltage [5].

Power supply redundancy is checked by first turning of main supply and checking that all modules' LEDs are still on and checking on LDU in automation page that there are no cross connections in power distribution. After main power supply is cut off and the checks are done, turn main supply back on and wait power to reach all modules. When modules are in both main and secondary power supply, turn secondary off and repeat all checks that was done when main supply was turned off.

When power is on and checked do all short circuit tests according to test protocol [4]. After all power supply related hardware tests are done, can softwares be downloaded to modules and ESM [6]. At this point control and instrument air can be turned on by ship crew to continue testing on UNIC. In next chapters I go through how different commissioning tests are performed to various parts of the system.

5.5.1 Engine Control Systems

Engine control systems commissioning Is done following the UNIC commissioning test protocol [4]. ESM tests are done before and after starting the engine. After starting means that the tests are prosecuted on running engine. There is depending on engine type seven to eight tests done to a running engine. Air compressor needs to be running the whole time, since the engine might need to be started multiple times in a row.

ESM tests include:

- Overspeed, that is simulated by speed simulator.
- Lube oil pressure, which is simulated by handpump.
- HT water sensor, which is simulated by heat.
- Emergency stop
- External shutdown signals
- OMD, that is simulated with glass to bend laser.

Hardware I/O tests include:

- LDU communication and buttons
- Start and stop solenoids.
- Slow turning solenoid
- LT and HT valve control.
- Wastegate
- Knock sensors.
- Main gas valves
- Pilot injections valves
- Degassing valves
- Ensuring all sensors are in right place.

LDU communication is verified by just seeing if all values will appear to LDU. Alarms should also appear to LDU, at least some start blocks. Engine start button is tested so that when pressed start solenoid should be magnetised. When stop button is pressed, there should be stop action in ESM. Reset button activates reset LED on ESM. If solenoids are not tested at same time as buttons them can be simulated in test mode. At least slow turning solenoid needs to be simulated. Degassing valves are simulated from test state and must be checked to see that they open both completely. Be sure to ensure that they are not cross connected when commissioning V engines.

Knock sensors have their own test state program that can be used to see that they are working [6]. One effortless way to test knock sensors is to find a big bolt and rub the tread parts to the bolt holding the sensor, this should generate enough vibration to cause the sensor to give some values. Other way is just to hammer the cylinder head lightly near the sensor. If tapping beside the sensor does not work just tap lightly on the bolt holding the sensors.

Main gas valves and pilot injector valves have also their own test state program [6]. In there you can set a sequence of clicks. After setting the program go through the vales and listen if they click. Main gas valves will click loudly, and you can hear them easily. Pilot injection valves need a little more silence to hear. You can hear usually fade click when your ear is pressed down on valve covers.

Since new I/P converter was installed to wastegate, it needs to be adjusted [7]. Before any adjusting its good to check that all vibration dampeners are still in one piece, because they have tendency to break down. If adjustment is performed before changing replacement parts to valve it probably must be adjusted again. It may have rotated some degrees to wrong direction because of the broken parts.

Before starting, start blocks are checked. These include external start blocks, lube oil pressure, turning gear engaged, stop lever in stop position, HT water temperatures and control air pressure. Lube oil must be at rated pressure to ensure immediate lubrication. Turning gear must be out of the way and stop lever in upright position. There must be control air in system because air is the first thing that rotates the engine.

5.5.2 HWIO

Physical signal cables deliver most important control and safety signals between engine and UCP. Signal cables must be tested to ensure that every signal works properly and there are no earth faults or cross connections. Testing is done by simulating signals first from engine to PLC. This is done using HWIO tests in UNITool test state [6]. HWIO tests in test state has already programmed simulating modes to every signal, so it is easy to manipulate the signals. The list of signals that must be tested is the same that is on block diagram. Block diagram is the wiring diagram for external cabling. So going through it ensures that every signal works on the signal cables.

There is a better way to testing signals to engine from PLC than going to each one's signals test state value separately [6]. You can collect all the signals to a UNITool trend and see that everyone turns from zero to one or the other way around [6]. You can also easily see if there are any cross connections if the wrong one changes. Analog signals are tested while the engine is running.

When local electricians have wired external cables there has been cases when there has been too much cross connections or otherwise wrong connections. In that case loop testing has been handy to correct the faults in the signal cable wiring [8]. When loop testing is performed, cut all the power to the system. Test with multimeter continuity setting the first pair of cables for example from terminal blocks 1 and 2. For the rest of tests use wire in terminal block 1 for return wire. This is faster than going through every wire and looking up the wire number. You may need to check numbers also but because there are many cables with same number its hard without multimeter. This operation requires two persons to do. Other one is in ER in junction box with jumper and the other one is in main cabinet or ECR on the other end to measure with multimeter.

5.5.3 Modbus

Serial communication delivers bulk data from engine to PLC and from there to IAS. It's tested to ensure that ships own automation and control system gets all the data from engine like temperature and other sensor data, faults in sensors and other faults like shutdown warnings and more. For this test you need to also have the PLC supervisor with you because he can check if the data comes to PLC. Usually there is problem with IAS firewall or some address if data comes to PLC, but not to IAS.

Testing is done in UNITool test state [6]. There is a section called External communication tests. There are all signals that can be tested sorted by name and when opened also by Modbus address. When toggling the switch that appears in the tested signal in question, there should appear warning, value or other signal in IAS depending on what is simulated. Engine is sending over thousand signals to PLC but the ones that are tested are listed in excel in project files.

If signals are not coming through, there can be few problems with ether end of the engine, IAS, or PLC. There can also be a problem with optic fiber cable, it is easily checked from the module in UCP. If light is green, it is working, and data is coming through. In engine side and in IAS side there can be wrong addresses which causes incorrect information to appear to IAS. If IAS doesn't receive information, there can be problems with firewall or serial communication configuration. PLC is a good midway point to check that data is coming there. If it does not come there the problem is in between UNIC and PLC.

5.6 Tests in Shipyard

Tests on shipyard are done to go on sea tests with confidence that all system are still operational. Ship crew usually wants an engine up and running to supply electricity to the ship. This is why usually work is started on one of the smaller inline engines first to get it done faster. Shore power is quite expensive to the ship. After engines are running and brakers have been tested on with every engine, ship can confidently move to sea tests.

5.7 Sea Tests

Interviews were conducted to find out the important jobs and targets of the sea tests phase. Based in findings of the interview in appendix 2 the following important jobs and targets can be defined.

- Commission protocol fully completed.
- Hand over the project to the client and start the warranty, without re-work.
- Make a performance recording and go through it with a designated technical service professional. Corrective conditions for specified applications.

Based on this list of important jobs and targets following flow chart of the project activities was developed. The flowchart is presented in **Figure 6**.

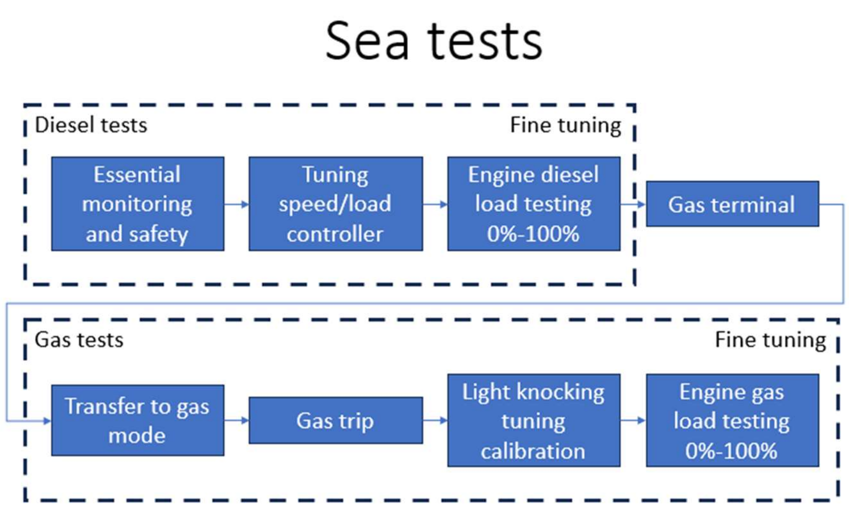

Figure 9. Flowchart of sea tests

The interviews also raised following challenges of the site work phase:

- There can occur gas leaks, and other faults affecting other tests that could slow down tests.
- Long delays in the time gas tests are performed can occur.

Based on the flow chart, observations and experience and the challenges project management guidelines were developed to solve these challenges, which is shortened in following chapters.

Commissioning test protocol has its own part for engines testing while on sea [4]. The part is the last testing phase number 9 and has 7 steps to do. First 3 are done in diesel mode. Usually this is done while sailing to gas terminal. The steps include verifying essential monitoring and safety while running. Tuning speed/load controller and operating loads from 0% to 100%.

After arriving to gas terminal, it takes few days to load gas onboard. After filling up ship cargo can gas tests start from protocol part 9 steps 4-7. These include performing and verifying transfer to gas mode and performing and verifying gas trip, which should make engines jump back to diesel mode. After verifying that gas mode works and it trips correctly, light knock tuning calibration can be performed. It is software-based calibration. Engines can now take load and next and final part is to perform load tests from 0% to 100% on gas mode and tuning parameters.

6 AFTER SITE WORK

Interviews were conducted to find out the targets and challenges of the work phase. These interviews raised the following targets, challenges, and solutions to set challenges.

- Completing the project and bringing all documentation up to date.
- Communicating with customer with technical topics until handing over.
- Can be much to do in punch list after handing over has been done that causes costs.

Based on these observations and experience, the following flowchart and project management guidelines were developed.

After successful tests at sea with diesel and gas operation, the project handing over certificate can be signed. This document contains for example the beginning time of warranty and possible punch list steps that needs to be done. All performed and signed documents including commissioning protocols are added as attachments. The punch list is a list of things that need to be done to consider the system completed. These are usually matters requiring parts or software that needs to be prepared but does not affect the operability of the ship.

After the documentation is signed and copied onto their own files, project personnel can disembark the ship and start the homebound journey. The site manager must write a final report on the project, and it helps if he collects every day what has been done. It is also worthwhile to do the daily reports because the project manager and the customer may want it daily.

When the project is coming to the completion, faulty modules on site must be transported to the laboratory to do fault research. One of the Wärtsilä's onsite representatives can do this. Red pens are also to be delivered to the project engineer to correct and add to customers as built files.

7 CONCLUSIONS

The aim of the thesis was to make a guideline and to describe how UNIC retrofit projects to 50DF engines are done from start to finish, firstly to future service engineers and secondly to electricians. Its purpose is to help new personnel to get on track on projects and to give an insight how the project has before been done. This guideline should be helpful for those people, who have little to zero practical experience of UNIC or other control systems. It can also work as support for engineers that do not know some part of the project.

A test time of the guideline would have been a good add-on to the thesis but because of the tight timetable, unfortunately it was not possible to do in this time frame. The development of the guideline then continues to be an inside company effort and done beside working. Currently, I have only relied on coworkers' feedback and experience of the correctness of the guideline.

It is hard to compress months' work in one paper but as a little glimpse of what is about to happen in this kind of project, I think this gives useful information. Most of the experience still can only be taught on field and just doing the things can get you good at it. I see that these documents are also a reliver of tension before the project because of the normal uncertainty especially in personnel that just came out of school and start travelling work.

REFERENCES

[1] Wärtsilä, "WECS 8000 manual 20V34SG," 2007.

[2] Wärtsilä, "Wärtsilä UNIC for gas engines," 2020.

[3] Strand, Greger, "Test instructions for 6-series DF engines subcontractor assembly," 2020.

[4] Strand, Greger, "UNIC 6-series DF commissioning test protocol," 2023.

[5] R. Childers, "How to Measure Voltage," 13 January 2024. [Online]. Available: https://www.wikihow.com/Measure-Voltage.

[6] K. Alajärvi, "UNITool User's Manual (Internal version)," 2018.

[7] J. Vertanen, "Tuning instruction - wastegate system," 2007.

[8] R. M. a. E. McClure, "How to test continuity with a multimeter," 10 October 2023. [Online]. Available: https://www.wikihow.com/Test-Continuity-with-a-Multimeter.

APPENDICES

Appendix 1 (Will not be published fully)

Wärtsilä 50DF UNIC-upgrade guideline, Juuso Junila, 2024

Appendix 2

Service Engineer Interview

Appendix 3

Project Manager Interview

Appendix 4

Project Engineer Interview

Juuso Junila

GUIDELINE FOR WÄRTSILÄ 50DF UNIC UPGRADE

Wärtsilä Finland Oy, Field Service E&A
Vaasa University of applied science, Electrical Engineering
2024

ABSTRACT

Author	Juuso Junila
Title	GUIDELINE FOR WÄRTSILÄ 50DF UNIC UPGRADE
Year	2024
Language	English
Pages	
Name of Supervisor	Klaus Rajala, Mikko Västi (Vamk)

This guideline is intended to service engineers, electricians and service engineer trainees as a guideline for how to complete 50DF UNIC upgrade on site in vessels. This guideline is meant to personnel that has no, or very little experience of UNIC upgrades.

The guideline consists of the following topics,

- Overview of the system and what the upgrade consists in the bigger picture.
- Physical cabling both engine and external cabling from UCP to engine
- Commissioning UNIC, HWIO and Modbus
- WDCU installing and commissioning.
- Running on load and sea trials

Table of contents

Service Engineer Interview

I interviewed a service engineer about the target, problems, and solutions of pre-site, on-site and sea tests. The interview had 3 main questions:

- What important jobs and targets are there is this phase of the project
- What are the most typical mistakes and problems in this phase of the project
- How could these be prevented

The following topics were discussed.

Pre-site

- The purpose of FAT testing is to search and solve as much as possible of the problems that occurs with the system. During FAT there is not too much to test with the sensors but the communication between modules is possible to test.
- Good checks with packing to ensure that all material is travelling to site.

On-site

- Moving the boxes close to the engine room and inspecting the material and searching for defects inspecting critical sensors. This ensures that customs have not mixed-up crates and to do second check after packing ex.
- Review of the layout material and accuracy -> installers always have an up-to-date electrical diagram. Red pens on the first few days of all the faults.
- Kick-off meeting to get all the necessary starting information of the engines and surroundings. Engine chief way want a specific order in with the engines are to be worked with. This meeting is also to plan the project in synchronisation with other ongoing projects. Bad planning in this stage can cause problems and extra work in future.
- Clear instructions prevent misunderstanding. This is important especially when going through the dismantling of old system because some parts are reused.
- An introduction for all. Assigning responsibilities to different people.
- It is impossible to eradicate misconnection, but we strive for the highest possible quality of installation.
- Monitoring and tracking the timetable daily.
- Dedicated time in project timetable for troubleshooting and updating softwares.
- Cross connections in the external cabling are common but does usually take little time to correct.

Sea tests

- Commission protocol fully completed
- Hand over the project to the client and start the warranty, without rework.
- Make a performance recording and go through it with a designated technical service professional. Corrective conditions for specified applications.
- There can occur gas leaks, and other faults affecting other tests that could slow down tests.
- Problems with gas tests delaying can occur. Witch is not in our hands.

Project Manager Interview

I interviewed a project manager about the target, problems, and solutions of the whole project. The interview had 3 main questions:

- What important jobs and targets are there is this phase of the project
- What are the most typical mistakes and problems in this phase of the project
- How could these be prevented

The following topics were discussed.

Project

- Agreement with the customer of the project
- Establishing a timetable for the whole project
- Installation survey in the contract. There must be a deadline by which the place and time are known. Always a big challenge to know where and when the installation is prosecuted.
- Work permits to country can be a challenge in some countries (China, Malaysia, and Dubai to name few)
- People and hardware can cause delays in installation. For example, poor time and free time activity choices can cause downgrade in quality and relationships with co-workers.
- On-site it is important to communicate with all teams working in same spaces to make sure that everyone has room and time to do their work.
- A lot of effort has been put into proactive safety at work to keep staff safe on board and the workplace tidy.
- Comprehensive daily and final reports are important for both the project team and the client.
- Important to discuss the practical arrangements for the ship.
- In some countries difficult to obtain supplements which means careful pre-planning and accurate and comprehensive checks on packaging.
- A delay in logistics will cause a delay in the start of the work. Often it is out of our control, but if you know from previous projects that it will be difficult to get the goods to the destination, it is good to anticipate the delay and, for example, send the packages early.
- Good to have some kind of workshop after project, to talk about the successes and challenges of the project.
- Project management support should be agile.
- Communication between project and site team.
- Project team competence -> to ensure professional and high-quality installation.
- Scheduling of gas tests -> Technical risk when not tuned.
- If there is a punch list that will cause significant economic things.
- Delivery and quality of external cabling -> Sales should promote customer to buy this service for us, at least a supervisor.
- Competence of the Site Manager -> Too technical can be a bad thing to leading people.
- Site kick-off meeting as a big part of preparing for the project.

Project Engineer Interview

I interviewed a project engineer about the target, problems, and solutions of pre site work, after site work. The interview had 3 main questions:

- What important jobs and targets are there is this phase of the project
- What are the most typical mistakes and problems in this phase of the project
- How could these be prevented

The following topics were discussed.

Pre-site

- Sales support -> Helping with technical aspect.
- Initial mapping of the project, kick off with different departments and subcontractors.
- Site audit -> important input to project engineering.
- The purchase phase is done early enough to ensure that material is available on time. Items must be followed also to ensure that the material is available on time.
- Monitoring of goods and subcontractors to ensure that everything stays on schedule.
- Layout of the engine rooms is a problem when designing especially the external cabling but also with engine cabling. This is why thorough site audit is important for the success of the project.
- There can be challenges in accessing planning resources. Being early on topic and communicating helps here too.
- Big differences between classifications agencies and even internally which pose challenges to classification. Communication here helps also much.

After-site

- Communicating with customer with technical topics until handing over
- Can be much to do in punch list after handing over has been done that causes costs.