

Commissioning and Start-up Process Improvement for DF-engines

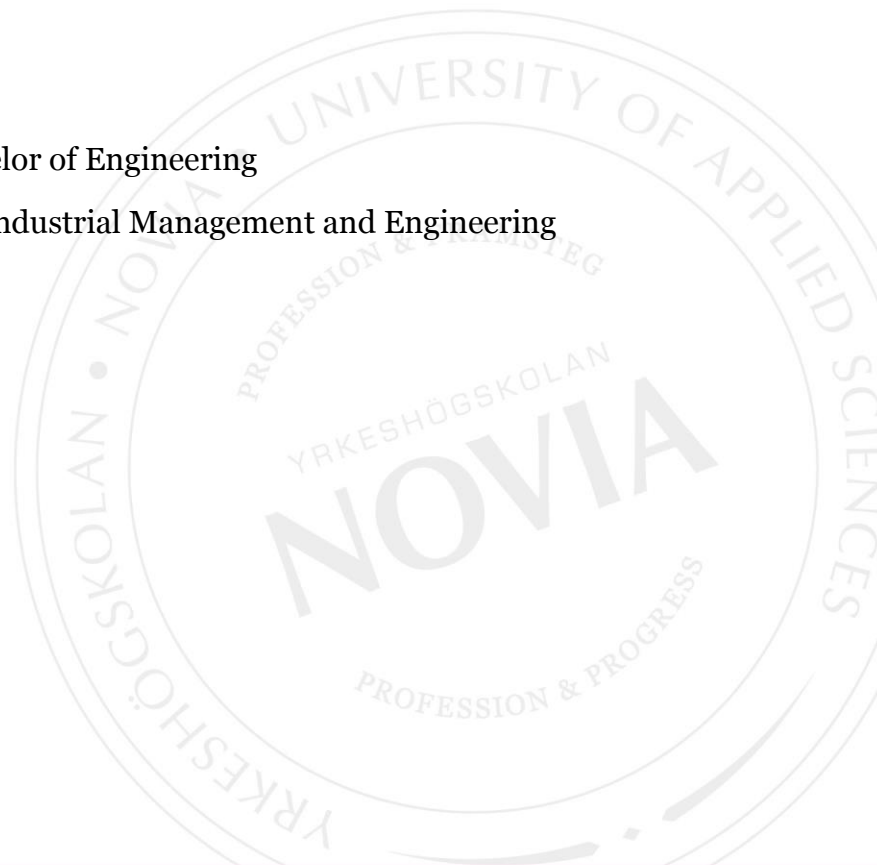
a commissioning manual upgrade

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BACHELOR'S THESIS

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Summary

This thesis is made on behalf of Wärtsilä Marine Solutions. The purpose with this thesis was to update the already existing Commissioning Manual. The Commissioning Manual contains information on how the commissioning and start-up process for Wärtsilä engines works.

Wärtsilä has limited control during pre – commissioning. During pre – commissioning the buyer's yard installs the delivered engines and external systems without the supervision of Wärtsilä, therefore it is important to have proper documentation on how to install the engines.

When pre – commissioning is finished Wärtsilä arrives to yard to conduct commissioning. Commissioning focuses on starting up the engines and making sure that they fulfill the contractual requirements. It seldom happens that pre – commissioning is sufficient when Wärtsilä arrives to buyer's yard to conduct commissioning, often Wärtsilä faces an unfinished installation and has to assist the yard with the pre – commissioning work in order to keep the schedule for handing over the vessel.

The previous Commissioning Manual left many unanswered questions for the reader. With this update, the Commissioning Manual is more informative and structured to follow the different phases of commissioning. Together with this update a new way of working during Pre – commissioning was introduced. The updates are described in the result chapter of this thesis.

Language: English

Key words: Commissioning, Project Documentation

EXAMENSARBETE

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Datum 23.3.2017

Sidor 28

Bilagor 0

Abstrakt

Detta examensarbete är gjort på uppdrag av Wärtsilä Marine Solutions. Syftet med detta examensarbete var att uppdatera den redan befintliga manualen för idrifttagning. Manualen för idrifttagning innehåller information gällande idrifttagningsprocessen för Wärtsilä motorer.

Wärtsilä har begränsad kontroll före idrifttagningen. Motorerna installeras av köparen utan uppsikt av Wärtsilä, därför är det viktigt att ha bra dokumenterad information över hur man installerar motorerna.

När motorerna har installerats av köparen reser Wärtsiläs personal till köparen för att påbörja idrifttagningen. Under idrifttagningen fokuserar man på att starta upp motorerna och se till att de uppfyller de kontraktuella kraven. Det händer sällan att motorerna har installerats enligt Wärtsiläs rekommendationer och Wärtsilä måste ofta assistera köparen med att installera motorerna för att kunna hålla tidsschemat med att ge över fartyget till köparen för kommersiellt bruk.

Den tidigare manualen för idrifttagning var svår att förstå för den som inte är insatt i ämnet. Med denna uppdatering är idrifttagningsmanualen mera informativ och uppställd enligt idrifttagningens olika faser. Med denna uppdatering kom också ett nytt sätt att arbeta före idrifttagningen när Wärtsilä har minst kontroll. Uppdateringarna är presenterade i resultatdelen i detta examensarbete.

Språk: Engelska

Nyckelord: Idrifttagning, Projekt Dokumentation

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1 INTRODUCTION

This thesis is made on behalf of Wärtsilä Marine solutions, which is part of the Wärtsilä Corporation. The task was to update the already existing commissioning manual for DF-engines that is followed during commissioning. The commissioning manual was originally made for conducting commissioning activities in a structured and well-documented way, in order to make commissioning run smoothly for both Wärtsilä and the buyer.

The commissioning manual is to be followed in every project. The purpose of the manual is to give the customer guidelines on how to install the delivered engines and external systems and further prepare for Wärtsilä commissioning engineers to arrive and actually starting up the engines.

The main focus when updating this manual is to review the material and make it more installation specific, make it more informative, and to make the customer more averted on what happens when Wärtsilä arrives to conduct commissioning.

1.1 Background

Wärtsilä Marine Solutions sell the engines. Wärtsilä is in charge of delivering the engines and external systems, they are also required to make sure that the engines are installed according to Wärtsilä instructions and recommendations before the first start-up of the engines. But Wärtsilä does not participate in pre-commissioning, which means that the buyer installs the engine without the supervision of Wärtsilä. If pre-commissioning is done properly, the commissioning runs smoothly. That is why it is important to have proper instructions for the buyer on how to install the engine.

The buyer is responsible of contacting Wärtsilä when they have conducted pre-commissioning. This means that the shipyard work is ready, all equipment is in place, piping is ready and electrical and system control wiring is ready and done according to Wärtsilä instructions and recommendations. This is often not the case, the installation of the engines is seldom sufficient when Wärtsilä commissioning engineers arrive to the buyer's shipyard.

This means that Wärtsilä commissioning engineers travel to the buyer's shipyard to conduct commissioning, but instead they often face an unfinished installation that is no way near ready for commissioning. Commissioning engineers even have to assist

the yard with completing the installation, in order to keep the schedule for handing over the vessel, this costs money both for Wärtsilä and the buyer.

1.2 Purpose

The purpose with this thesis is to conduct interviews with responsible people in order to make an update on the existing commissioning manual.

The buyer often poorly executes pre-commissioning, and that does not enhance the commissioning process but makes it more difficult and time consuming. A good documentation on how to properly install the engines and on the whole commissioning process could prevent the poorly executed pre-commissioning.

The commissioning manual is done and sent by the responsible project engineer for each project. The purpose with this thesis is to review the content and make sure it is relevant and to create a more installation specific and informative commissioning manual. This will make the manual more relevant for the buyer and create a clearer picture of how commissioning is conducted.

1.3 Disposition

First chapter

Chapter 1 introduces the background and the purpose of this thesis.

Second chapter

Chapter 2 explains Wärtsilä in brief.

Third chapter

Chapter 3 explains the theory behind this thesis.

Fourth chapter

Chapter 4 explains the methods I have used to be able to make accomplish this update.

Fifth chapter

Chapter 5 includes the thesis result. Parts of the updated commissioning manual is introduced.

Sixth chapter

Chapter 6 contains a conclusion and some ideas for further development.

2 WÄRTSILÄ IN BRIEF

Wärtsilä was established in 1834 in Wärtsilä, Finland. Wärtsilä started as a milling company and have changed branch many times since the beginning. Today Wärtsilä is a global leader in providing complete lifecycle solutions for the marine and energy markets. Increasing environmental awareness and the energy markets changing needs are constantly shaping the product portfolio of Wärtsilä. Their main objective is to maximize the environmental and economic performance of the vessels and power plants of its customers.

Growth is achieved by having a high-end project management and their constantly developing engineering competences, supported by a superior global service network.

Net sales for 2016 was 4,801 million EUR., with approximately 18,000 employees. Wärtsilä operates in over 200 locations in more than 70 countries globally. Wärtsilä is listed on Nasdaq Helsinki. (Wärtsilä, Wärtsilä history, 2016)

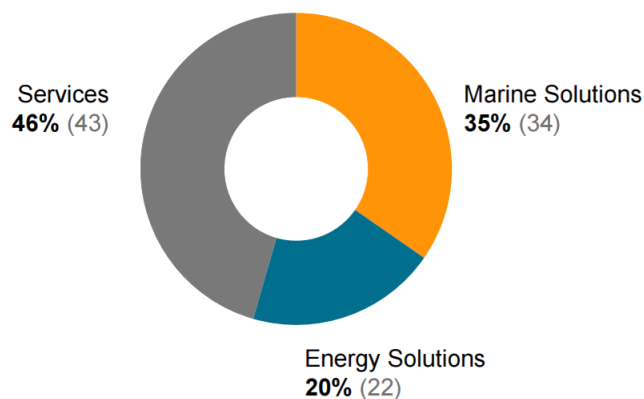


Figure 1. 2016 net sales by business area.

2.1 Wärtsilä Marine Solutions

Marine Solutions provides innovative products and integrated solutions that are safe, environmentally sustainable and efficient to their customers in the marine and oil & gas industry.

2.2 Wärtsilä Energy Solutions

Energy Solutions provides ultra-flexible power plants of up to 600 MW that can operate on different gaseous and liquid fuels. Their portfolio also includes utility-scale solar power plants, as well as LNG terminal and distribution systems.

2.3 Wärtsilä Services

Wärtsilä Services provides support for their customers throughout the whole lifecycle of their products by optimizing efficiency and performance. They provide a wide portfolio of services for both the energy and marine markets. (Wärtsilä, about Wärtsilä, 2016)

2.4 Project Management

This thesis was made for Marine Solutions and the Project Management department. Wärtsilä has over 30 years of experience from projects over 90 countries, that proves that their project management, engineering, procurement and commissioning services are of the highest quality. (Wärtsilä, Project Services, 2016)

3 THEORY

3.1 Organization improvement and development

The word improvement is often used within organizations. Sometimes an improvement is obvious and sometimes it is more difficult to identify if it is an improvement or just a change. (Sörqvist, 2004, p. 67)

The majority of organizations change because they are forced into it by the aggressiveness of their competitors in their specific market. The minority of organizations change because they have visionary leadership that is able to foresee a shifting market and position their organization ahead of their competitors.

To be able to be the minority of organizations who positions their organization ahead of the competitors, constant change is necessary. Reinventing, making minor changes constantly and problem solving are factors for success. When changes are introduced it may cause stress and anxiety for both the organization and the individual employees, but if reinventing and minor changes happens constantly and the concept of “what the change will accomplish” is clear, the organization will become more resilient to change and easier adapt the changes. (Beercroft, Duffy, & Moran, 2003, p. 4)

Before every problem can be solved, it first must be defined. There are several problem solving models used by different organizations. A general problem solving model consist of four basic steps:

1. Define the problem
2. Generate alternative solutions
3. Evaluate and select an alternative
4. Implement and follow-up the solution

An important aspect of this model is to consider multiple solutions before evaluating and selecting one solution, this can significantly improve the value of the final solution. A common mistake is to evaluate alternatives as soon as they are proposed, so the first acceptable solution is chosen, although that is not the optimal one. (Beercroft, Duffy, & Moran, 2003, pp. 18-19)

This thesis has followed a similar model, the problems with the commissioning manual were identified during my interviews with different commissioning experts at Wärtsilä. Alternative solutions were generated once the problems were defined, and together with the experts and my supervisor at Wärtsilä, alternatives were selected. The follow-up on the commissioning manual will continue after the update is launched in April this year.

3.2 XML – programming

XML stands for Extensible Markup Language and is an essential technology for everyone working with data, whether it is publicly publicized on the web or privately within an organization. With XML you can design your own markup language which you can use to save and share data in a structured and well-documented way. It is important to understand that XML is not really a programming language, but rather a standard for creating your own programming language. (Hunter, et al., 2007, pp. 3-7)
(Loopia)

With XML you can define documents structure, meaning and visual appearances. Suppose you want to create a document where a certain type of text, say a headline, is bold, black, 20 point and arial font. And this type of headline appears many times in your document. Then you can set up a giant style sheet that acts as "mother" for all documents you want to create. (Microsoft, 2017)

Wärtsilä has a wide range of products with engines, propulsion and maneuvering systems for vessels and other offshore applications. Each product has different manuals for operation, maintenance etc. XML is used so every manual has the same visual appearance.

XML divides information into hierarchies. Items relate to each other in so-called parent and child relationships. This is visualized in figure 2, where the box numbered 1 is referred to as a parent, all boxes with number 2 and 3 is referred to as children. (Hunter, et al., 2007, p. 15)

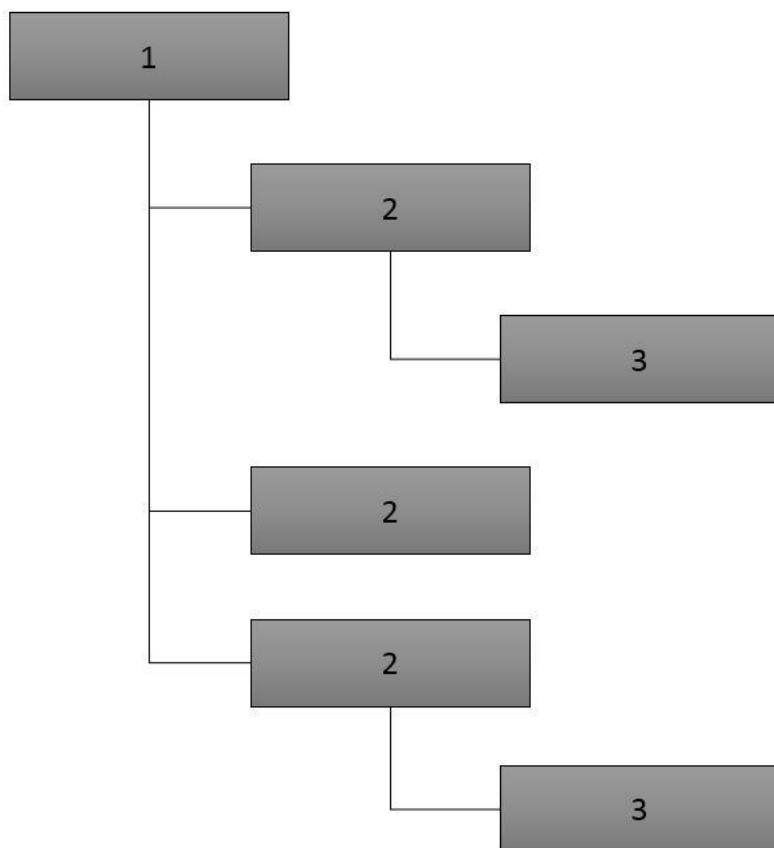


Figure 2. Hierarchy visualized

3.3 IPIX

IPIX stands for Information Publishing in XML, IPIX is a server and an XML-client. The XML-client is a tool for creating, editing and publishing documents such as manuals, product guides and document lists. The XML-client was developed by an external supplier, Excrosoft, and was adapted to suit Wärtsilä requirements and needs.

In IPIX you can easily locate, view and edit documents in various formats, regardless of where they are stored. (Excrosoft)

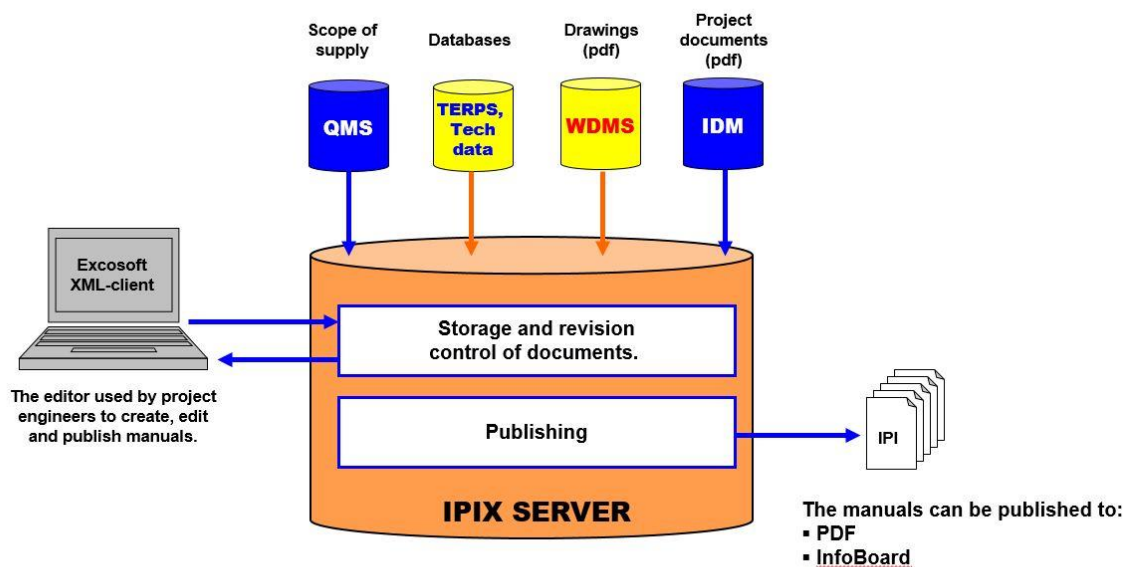


Figure 3. IPIX server workchart.

The templates for the manuals and product guides are stored in the IPIX server, as seen in figure 3. The IPIX server imports data from various sources within Wärtsilä.

QMS

From QMS the projects scope of supply is imported, i.e. what engines and external systems has been sold for a specific project.

Terps

Terps is a database, which holds the technical data of the scope of supply.

WDMS

WDMS is a database for drawings.

IDM

Wärtsilä Integrated Document Management system, from IDM all the project specific documents are imported. (Wärtsilä, IPIX training, 2009)

The responsible project engineer can do project specific changes before publishing the manuals, the manuals can be saved as PDF and be uploaded to Infoboard.

Infoboard is a portal where manuals for all projects are stored. The commissioning

manual is one of these manuals. Wärtsilä customers can be given access to Infoboard where their project specific manuals are stored. If there is new revisions made for certain manuals, the customers are notified by e-mail that there has been changes done to their manual. This way the customer always have access to the latest revision of their manuals. (Interview with projects and products information engineer, 2017)

3.4 Commissioning

The term commissioning is defined as a quality control process for achieving, validating and documenting that the installation of delivered engines and its systems are designed, installed, tested and capable of being operated and maintained to perform in conformity with the project's design and contractual requirements. The process extends through all phases of the project, from project offer preparation and design, through tests and inspections at equipment fabrication sites (Subcontractor's and Wartsila Factories) and continuing through erection and installation, up to performance testing, handing over process and commercial operation with evaluation checks at each stage to ensure validation of the performance. (Wärtsilä, Internal document, 2015)

3.4.1 Commissioning organization

The Wärtsilä Commissioning Organisation is decided based on the project needs. The commissioning activities are led by Commissioning Manager reporting to Site Manager and Project Manager. Needed resources are added on a timely basis to fulfil project requirements.

Wärtsilä roles and responsibilities:

- **Project Manager** is supporting the Site Manager with project specific information and required Commissioning Process documentation. He has also within Wärtsilä the overall responsibility for the project.

- **Site Manager** has the overall responsibility for the Commissioning Process activities commenced on Site.
- **Commissioning Manager** has the main responsibility for all Commissioning Process activities performed on Site.
- **Mechanical Commissioning Engineer** is responsible for the Mechanical scope of work.
- **Electrical Commissioning Engineer** is responsible for the work related to Electrical.
- **Automation Engineer is responsible** for automation system.
- Other engineers are used whenever needed and depending on scope of supply for project. (Wärtsilä, Commissioning Organization, 2015)

4 METHODS

In this section the methods for gathering information regarding commissioning and the practical work methods for updating the existing manual is presented.

4.1 Interviews

The main approach to gathering data for the manual update has been through several interviews with Wärtsilä employees who are, in different ways, working with commissioning. This way I have been able to identify the problems with the existing manual from different employee's point of view. Not every single conversation I have had regarding this project is included in this chapter, but the once that I feel has given the most input.

Before every interview a document was created with open questions that concerned the expert specific field of work. The questions were not too detailed, I rather have a more natural conversation where the experts could describe commissioning and the issues they have faced with the commissioning manual. Meetings with the experts included follow-up meetings and reviews.

4.1.1 Interview with Site manager

A site manager's task is to lead, manage and report status of Wärtsilä activities on yard. A site manager acts as project manager's deputy on yard, representing Wärtsilä in external meetings and signing documents with yard, owner and other parties as instructed and authorized by the project manager.

This Site Manager has for many years worked with commissioning; he is a E&A superintendent working for Wärtsilä North America at the New Orleans office. During the interview, he specified the problems with pre-commissioning, and pointed out that Wärtsilä needs to give more scheduled input to buyer when it comes to achieving mechanical completion, mechanical completion means that the shipyard work is ready and all equipment is in place.

On previous projects he participated in, they came up with a solution for pre-commissioning. When the buyer states that they have achieved mechanical completion, Wärtsilä sends one commissioning engineer, preferably from the nearest local office, to inspect the work. This is done to make sure that the installation is ready for commissioning, so when Wärtsilä arrives to buyers yard to conduct commissioning there is no waiting time for Wärtsiläs commissioning engineers, which saves money for both buyer and Wärtsilä. (Interview with Site Manager, 2016)

4.1.2 Interview with the Manager for marine commissioning & troubleshooting

This Manager has a lot of insight into commissioning. He has previously been working as a commissioning engineer for many years and he has been part of developing the previous commissioning manual.

He could identify the problems with the current commissioning manual. I had several meetings with him regarding the content of the manual, he requested some information to be added regarding the job safety analysis that is done when Wärtsilä commissioning engineers arrive to yard. He also pointed out that it is the commissioning engineers' responsibility to know how all the engines external systems works and to make sure that buyer have installed them correctly. (Interview with the Manager for marine commissioning & troubleshooting, 2016)

4.1.3 Interview with Technical Service

I interviewed two people from Technical Service, a senior technical superintendent and a product support engineer. They are both working with the documentation for the newly released Wärtsilä 31 engine.

They provided a commissioning and start-up checklist that is frequently used by Wärtsilä commissioning engineers in Norway, and suggested to contact commissioning engineers to get some input from the field on how commissioning is conducted.

I also got some insight on what is in progress for the new engine regarding documentation. (Interview with Technical Service, 2016)

4.1.4 Interview with commissioning engineers

I interviewed three commissioning engineers that work with commissioning regularly. Each of them has different tasks during commissioning, one handles the mechanical side, one completes the electrical and automation side and one handles the installation of Liquefied Natural Gas – package.

The interview with the commissioning engineers were mostly about the way of working during commissioning. They state that the time schedule often is too tight to be able to make a sufficient commissioning, this leads to incomplete documentation and might have a negative impact on the commissioning of the engines.

When I asked about trying to make a standardized way of conducting commissioning, they answered that it is difficult since every installation is different. In addition, every commissioning engineer has their own way of working that is passed on from older and more experienced colleagues. (Interview with Commissioning Engineers, 2016)

To get some guidelines on how to conduct commissioning, the commissioning and start-up checklist were added to the manual.

4.2 Data collection

While conducting the interviews, the essential documents and data needed for the update were collected. I have received a lot of data and during the interviews and there has been many different opinions on what content needs to be included in the commissioning manual, so the selection of valid data has been an important part of the update. The selection of data has been done in collaboration with my supervisor at Wärtsilä, Minna Jukola, and the Manager for marine commissioning & troubleshooting.

4.3 Template creation

The manual template is created in IPIX. I started from the existing commissioning manual template and, based on the interviews and the documents I have gathered, updated it accordingly.

I have worked with IPIX previously as a trainee within Wärtsilä, so I was familiar with the software before this project. However, this time my task was to change the template that is the foundation of the commissioning manual. From the template, the responsible project engineer makes small project specific adjustments before it is sent to the buyer.

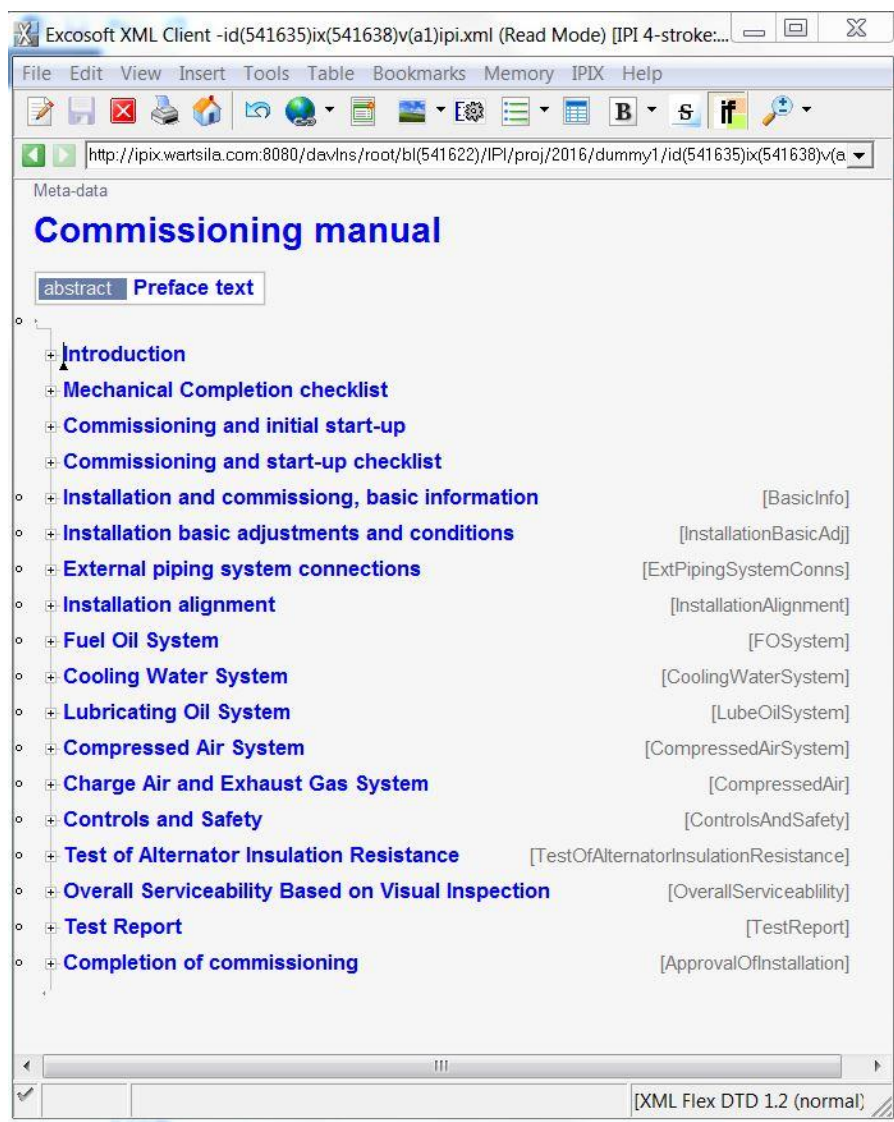


Figure 4. Capture of IPIX - Layout.

Figure 4. is a screen shot of the XML – client with the commissioning manual template opened. This is where the commissioning manual is created. In figure 4. All headlines of the manual is shown, it starts with the Introduction and ends with Completion of commissioning. These are parents in the hierarchy. The headline “Commissioning and start-up checklist” has been added and some of the headlines has been renamed.

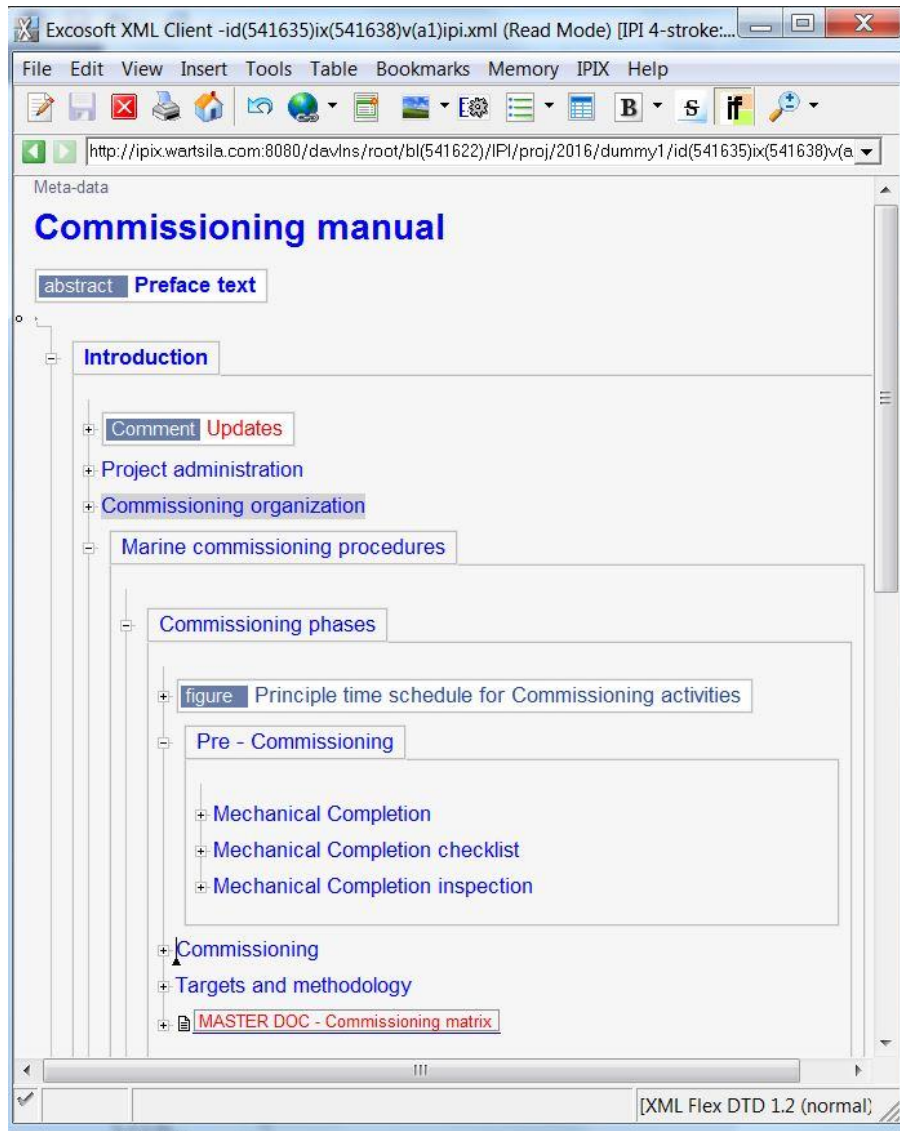


Figure 5. Capture of IPIX - Layout.

In figure 5. The parent “Introduction” has been opened. When opened, all subtitles are shown. This is how the manual is going to be structured when published, with “Introduction” as headline, “Project administration” and “Marine commissioning procedures” as subtitles and “Commissioning phases” as sub subtitle and so on. Figure 6. Shows the Introduction section when published.

1. Introduction

1.1 Project administration

Wärtsilä internal order number: SP/02070
 Wärtsilä project name: dummy1
 Wärtsilä project organisation:

Commissioning manager: to be added by PE
 Project manager: to be added by PE
 Project engineer: Jacob Åbonde
 Tel: to be added by PE
 Mobile: to be added by PE
 Fax: to be added by PE
 E-mail: to be added by PE

Site manager: to be added by PE
 Contact person (control system): to be added by PE

1.2 Marine commissioning procedures

1.2.1 Commissioning phases

Pre-commissioning Commissioning

Fig 1-1 Principle time schedule for Commissioning activities

dummy1 - a1 (working) - 20 February 2017

Figure 6. Capture of published manual.

4.4 Review of the updated manual

When the renewed version of the commissioning manual was finished, it was introduced for the same people as I had previously interviewed. It was also introduced to people who had shown interest in being part of the update in any way. Among those were Project Managers and people from testing and validation team who will have the technical ownership of the manual when published. The manual was also introduced during the Project Management's monthly meeting in March.

Based on the reviews some minor changes were additionally made before the new template was launched.

5 RESULT

In this section, the essential parts of the update are presented. There has been many minor updates in the content of the commissioning manual that will not be covered in this section.

The commissioning manual is updated according to my own investigations and observations, data collection and creation, and comments from the people responsible for commissioning and the manual.

5.1 Table of contents

As seen in figure 7, the commissioning manual did not have any real structure before; the content consisted of an introduction where all information regarding commissioning were included.

Besides the introduction chapter there is no more explanation of activities. The rest of the content is different checklists used by both Wärtsilä and the buyer.

Table of contents

1. Introduction	1-1
1.1 Project administration	1-1
1.2 Marine commissioning procedures	1-1
1.2.1 Targets and methodology	1-1
1.2.1.1 Commissioning responsibility matrix	1-2
1.2.2 Mechanical Completion	1-3
1.2.3 Procedure for pre-commissioning at yard	1-4
1.2.4 Commissioning and installation approval	1-4
1.2.5 Implementation of this plan	1-5
1.3 Health, Safety and Environment	1-5
2. External system checklist, Mechanical completion / pre-commissioning	2-1

Figure 7. Previous table of contents.

In figure 8, the content after the update is shown. The content is now structured to follow the different phases of commissioning. In chapter 1 the whole commissioning process is explained, followed by chapter 2 which includes information about pre – commissioning. In chapter 3 and 4 there is information regarding commissioning and actually starting up the engines.

Table of contents

1. Introduction	1-1
1.1 Project administration	1-1
1.2 Marine commissioning procedures	1-1
1.2.1 Commissioning phases	1-1
1.2.1.1 Pre - Commissioning	1-2
1.2.1.2 Commissioning	1-2
1.2.1.3 Targets and methodology	1-2
1.2.1.4 Commissioning responsibility matrix	1-3
2. Mechanical Completion checklist	2-1
2.1 Pre-commissioning at yard	2-3
3. Commissioning and initial start-up	3-1
3.1 Load test and installation approval	3-1
3.2 Implementation of this plan	3-1
3.3 Health, Safety and Environment	3-2
4. Commissioning and start-up checklist	4-1

Figure 8. Renewed table of contents.

5.2 Commissioning phases

The previous commissioning manual looked at commissioning from a testing point of view. The total installation period for a Marine installation could be divided into five phases:

- Installation checks and tests
- Pre – commissioning tests
- Load tests
- Commissioning
- Sea trial

1.2 Marine commissioning procedures

1.2.1 Targets and methodology

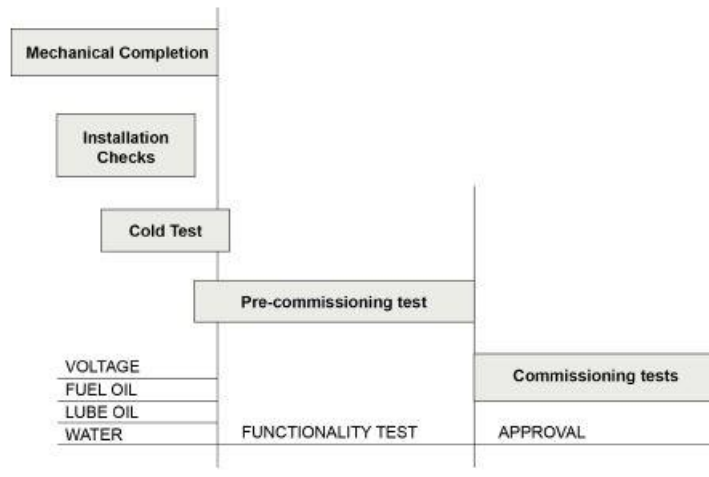


Fig 1.2.1.1 Principle time schedule for testing and checks

Figure 9. Previous time schedule for commissioning.

The principle time schedule did not quite correspond to how commissioning is conducted today. These tests were briefly explained in the commissioning manual, but it left many unanswered questions for the reader.

Since one of the goals with the update was to make the commissioning manual easier to understand for the reader, a renewed principle time schedule was created (figure 10.). This time schedule is no longer looking at commissioning from a testing point of view. Instead the focus is put on the different phases of commissioning, from that the engines are delivered to buyer to the completion of commissioning.

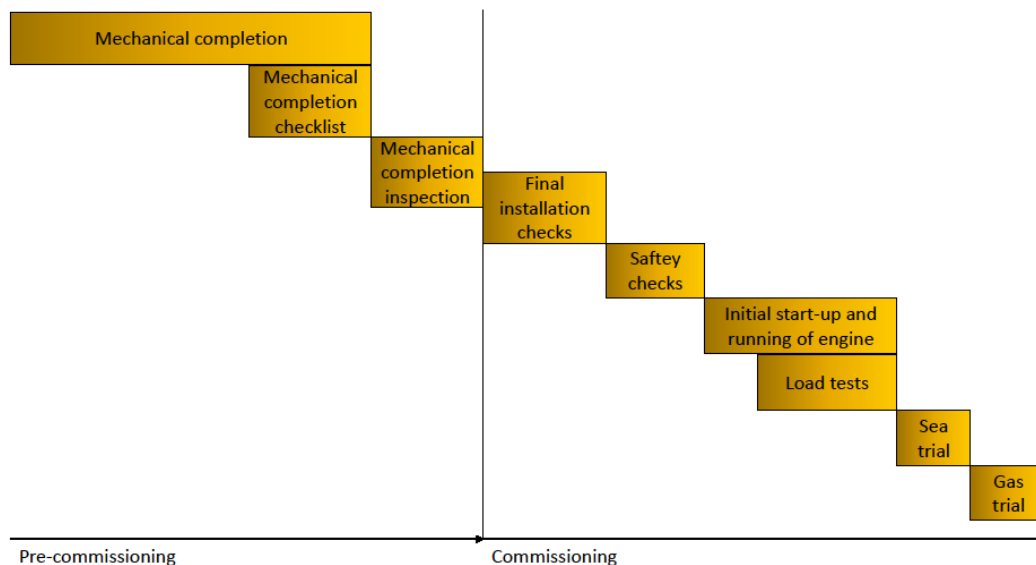


Figure 10. Renewed principle time schedule for commissioning.

The different phases are described below. The explanation of the different phases are also included in the updated commissioning manual.

Commissioning is now divided into four main phases:

- Pre – commissioning
- Commissioning
- Sea trial
- Gas trial

5.2.3 Pre – commissioning

Pre – commissioning is conducted by the buyer, without the supervision of Wärtsilä.

Pre – commissioning has three steps:

Mechanical completion

The installation is considered mechanically completed when the shipyard construction is ready, all the equipment are in place, the piping is ready, the electrical and control system wiring has been done in accordance with Wärtsilä recommendations. At this time the Mechanical completion checklist will be issued per system.

Mechanical completion checklist

Filled in by buyer and forwarded to responsible Project Manager, together with pictures of the engines showing that the mechanical completion is sufficient. When received, the Mechanical completion inspection will be ordered.

Mechanical completion inspection

Wärtsilä arrives to yard to ensure that the mechanical completion is sufficient. If the mechanical completion is not done according to Wärtsilä recommendations, a punch list will be created. The punch list has estimated completion dates depending on how extensive the corrections are to be made.

5.2.4 Commissioning

When commissioning commences, Wärtsilä is involved. Wärtsilä either conduct or supervises tasks during commissioning. Commissioning can be divided into three steps:

Final installation inspection

The first phase of commissioning, Wärtsilä arrives to yard to conduct commissioning. Open tasks are checked from the punch list created during Mechanical completion inspection. Overall, the engines are made ready for initial start-up.

Safety checks

All engines are safety checked before first start. This is to ensure that all shutdown functions are working properly.

Initial start-up and running of engine

In the initial start-up, the engines runs for 5 minutes and are then stopped. At this point the bearing temperatures are checked. When bearing run is completed the load tests will take place, the engine is then operated on different loads depending on class requirements.

5.2.5 Sea trial

Wärtsilä commissioning engineers that participated in commissioning is also part of sea trial, they will provide technical assistance if necessary. Engines are operated in diesel mode and adjustments are made for continued operation.

5.2.6 Gas trial

Wärtsilä commissioning engineers that participated in commissioning is also part of gas trial, they will provide technical assistance if necessary. Engines are operated in gas mode and adjustments are made for continued operation.

5.3 Mechanical completion checklist

Before the update referred to as “external system check list”, which was easy to confuse with the external system check sheets filled in by Wärtsilä commissioning engineers. Hence the name has been changed to “Mechanical completion checklist”. Together with the checklist, a request has been added in the commissioning manual for the buyer to send pictures of the engines, showing a successful mechanical completion.

5.4 Way of working

The biggest change with this update is the way pre – commissioning is executed. Earlier when the buyer stated that Mechanical completion was achieved, Wärtsilä sent their commissioning engineers to buyers’ yard and was often faced by a insufficient Mechanical completion.

With this update, the Mechanical completion inspection were introduced. This means when the buyer states that they have achieved Mechanical completion, a Wärtsilä employee, preferably from the nearest local office, will travel to yard to inspect the installation. Pictures will be taken of the installation and sent to the responsible Project Manager. If the installation is not completely done according to Wärtsilä instructions and recommendations, a punch list is created here the items to be corrected are explained. When the open tasks on the punch list has been corrected, the buyer can again contact Wärtsilä for commissioning commencement.

5.5 Commissioning responsibility matrix

The commissioning responsibility matrix is well known to the Wärtsilä network, even for those who might not be working with commissioning. The matrix shows who has the responsibility during the different phases of commissioning. Below is the commissioning responsibility matrix for pre – commissioning.

Act. Nr.	Main activities related to Wärtsilä scope of supply	Execution by	Guidance provider	Witnessed by Wärtsilä
A. Pre-Commissioning				
A.1	Installation of the engine	Buyer	IPI	No
A.2	Installation of external pipe systems	Buyer	IPI	No
A.3	Installation of flexible pipe connections and supports	Buyer	IPI	No
A.5	Installation of auxiliaries delivered by Wärtsilä	Buyer	IPI	No
A.6	Installation of electrical grounding between engines and hull	Buyer	Buyer	No
A.7	Installation of external cabling to engine & auxiliaries	Buyer	IPI	No
A.8	Installation of interface cabling between Wärtsilä supplied equipment	Buyer	IPI	No
A.9	Alternator megger test	Buyer	Buyer	No
A.10	Cleaning, flushing, testing and inspection of fuel oil pipe systems, including expansion and day tanks	Buyer	IPI	No
A.11	Cleaning, flushing, testing and inspection of lube oil pipe systems, including sump tank	Buyer	IPI	No
A.12	Cleaning, testing and inspection of compressed air system	Buyer	IPI	No
A.13	Cleaning, testing and inspection of cooling water system	Buyer	IPI	No
A.14	Cleaning, testing and inspection of fuel gas system	Buyer	IPI	No
A.15	Cleaning, and inspection of combustion air and exhaust gas system	Buyer	IPI	No
A.16	External cable loop checks (ref. A7 and A 8)	Buyer	Buyer	No
A.17	Power supplies available (ref. A7 and A 8)	Buyer	Buyer	No
A.18	Mechanical completion checklist to be sent to Wärtsilä <i>(To be sent to Commissioning coordinator and MS PM before Wärtsilä can order Mechanical Completion inspection)</i>	Buyer	Buyer	

Figure 11. Commissioning responsibility matrix.

The matrix shows activities to be performed and who has the responsibility to execute these. It also shows where guidance for the different activities can be found, guidance is mostly found in the projects IPI(Installation Planning Instruction) provided by Wärtsilä. If it is required for the activities to be supervised by Wärtsilä, it is stated in the “witnessed by Wärtsilä” column.

Since the Commissioning responsibility matrix is an essential part of the commissioning manual, only a few minor changes has been done. Some activities related to Wärtsilä scope of supply has been added. Earlier it was also required to sign each step in another column, that column has been removed and the signing is no longer required.

5.6 Commissioning and start-up checklist for Dual fuel-engines

The previous commissioning manual did not contain any vital information for Wärtsilä commissioning engineers. The way commissioning is conducted differ from project to project, mostly depending on the commissioning engineers and their different way of working. Therefore, I wanted to include a standardized way of conducting commissioning.

I got in contact with a Site Manager working for Wärtsilä Norway. He has created commissioning and start-up checklists for DF-engines, which their commissioning engineers have enjoyed using. The start-up procedures are similar for all Dual fuel-engines so a universal checklist for all Dual fuel-engines were made. The checklist describes more in detail each work step for the commissioning engineers, from the point they arrive to buyer's yard to completed commissioning.

11	Air pipe and valves checked for correct size, connections and pressurised.		
12	Lub.oil pipe and valves checked for correct size, connections.		
13	Fuel oil pipe and valves checked for correct size, connections.		
14	Lub.oil pipes flushed.		
15	Fuel oil pipes flushed.		
16	Cooling water pipes flushed.		
17	Start air pipes blown / flushed.		
18	Check of crank shaft alignment cold. Send in for approval		
19	Check of alignment flexible couplings cold. Send in for approval		
20	Electrical grounding checked between engineblock and hull.		
21	Check of electrical system before powering up, according to check list.		
22	Power supply voltage checked.		
23	Check and load in correct / latest software.		
24	Check external control signals according to electrical drawings.		
25	Check all signals to IAS, PMS and Control systems.		
26	Check and tuning of waste gate and by pass valves, if installed.		
27	Rotation direction of el- motors checked.		
28	Check for leaks when running pumps.		
29	Power up and adjust the electrical cooling water pre-heater (60-80°C).		
30	Fuel oil system adjusted acc to instruction, document No. 4V17L0280.		
31	Adjust lub.oil pressure on pre-lub oil pump to correct value.		
32	Adjust lub.oil pressure on st.by lub.oil pump to correct value.		
33	Ensure that lubricating oil flows freely to all required spots.		
34	Free movement of Linkage for fuel rack and governor		
35	Activate stop solenoid, with governor power shaft at maximum and stop lever in operating position and check all HP fuel pump racks move to zero at once.		
36	Check for oil level on all connected equipments to engine, e.g. Alternator, gear, etc. and auxiliary's pumps are running if applicable.		

Figure 12. Capture of Commissioning and start-up checklist.

6 CONCLUSION

6.1 Summary

The goal with this thesis was to make the commissioning manual more project specific and informative for the customer, the customer needs to be more averted of what happens when Wärtsilä commissioning engineers arrive to buyers yard.

It has been difficult to come up with a solution for making the manual more project specific. That would require additional work for the Project Engineer that is responsible for sending the manual to the buyer. For now the commissioning manual is universal to the point that if the project only have delivered diesel engines, the parts regarding dual fuel-engines are automatically left out. This means that there is no additional work for the Project Engineer, they just create the manual, add contact information to the project administration page and send it to customer.

When it comes to making the commissioning manual more informative, I would say I succeeded well. With the revised principle time schedule for commissioning with the corresponding explanations of each commissioning phase, it is now easier to understand and follow the whole commissioning process.

The poorly executed pre – commissioning is a major issue that is hard to control for Wärtsilä, hopefully the Mechanical completion inspection will reduce the amount of work that commissioning engineers face when they arrive to conduct commissioning.

6.2 Further development

I received many request and ideas on what needs improvement regarding commissioning during this project. One request was regarding the reporting of the commissioning work, commissioning engineers should be able to report, in a fast and easy way, the progress they have made during commissioning on a daily basis. This way it would be easier for the commissioning management to follow the work at yard.

6.3 Comments

With this thesis, I have gained a lot of insight into commissioning. It has been challenging considering my very limited experience with commissioning work. There is still a lot of improvements that can be made when it comes to documentation of commissioning, and to be able to develop the complete commissioning process further I think experience in commissioning work at yard is necessary.

However, I have gained a lot of new experiences and I have had the opportunity to meet a lot of people which I know will enhance my further career at Wärtsilä.

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