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Cables Engineering Process and Interconnection Schedule Development

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Abstract

Staying competitive in the energy market requires constant development of products, services and business processes. Therefore, organizations must constantly find ways to improve the performance of the people, processes, productivity, quality and all other factors that add value.

Cables engineering in power plant projects is a complex and time-consuming process. Collaboration between stakeholders is required and information flow needs to be well managed. Proper engineering is essential for eliminating design mistakes and problems during installation.

The purpose of this thesis is to analyze and develop the cables engineering process for power plant projects. As well as to develop a new interconnection schedule template that can be used by all stakeholders in a project. Finally, the developed process and interconnection schedule needs to be seamlessly implemented without causing any problems to the project execution.

Current cables engineering process is analyzed and problems are identified. A developed process solution and a developed interconnection schedule to fulfil all needs during project execution is proposed. Implementation instructions are created for the developed process to achieve a successful change without causing any problems to project execution. Finally, as a result of this thesis, findings and proposed future developments are presented.

Language: English Key words: project management, process development, change management, engineering, documentation

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Abstrakt

Att behålla konkurrenskraften på energimarknaden kräver kontinuerlig utveckling av produkter, tjänster och affärsprocesser. Organisationer måste därför konstant hitta vägar att förbättra människornas prestationer, processer, produktivitet, kvalitet och andra faktorer som ger mervärde.

Kabelplaneringen i kraftverksprojekt är en komplex och tidskrävande process. Det krävs samarbete mellan intressenter och ett välfungerande informationsflöde. Ordentlig planering är väsentlig för att eliminera planeringsmisstag och problem som kan uppstå vid installationen.

Syftet med denna avhandling är att analysera och utveckla kabelplaneringsprocessen för kraftverksprojekt. Till uppgiften hör även utvecklingen av en ny mall för kabellista, som alla intressenter kan använda under ett projekt. Slutligen måste den utvecklade processen och kabellistan implementeras utan att orsaka problem vid projektutförande.

Den nuvarande kabelplaneringsprocessen analyseras och problem identifieras. En utvecklad processlösning och en utvecklad mall för kabellistan som uppfyller kraven för projektutförande föreslås. Instruktioner för implementering av den utvecklade processen utan att orsaka problem för utförande av projekt har skapats. Slutligen presenteras resultatet och förslag för framtida utveckling.

Språk: engelska Nyckelord: projekthantering, processutveckling, förändringshantering, planering, dokumentation

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Tiivistelmä

Kilpailukyvyn säilyttäminen energiamarkkinoilla edellyttää tuotteiden, palveluiden ja liiketoimintaprosessien jatkuvaa kehittämistä. Siksi organisaatioiden on jatkuvasti löydettävä keinoja parantaa ihmisten suorituskykyä, prosesseja, tuottavuutta, laatua ja kaikkia muita arvoa lisääviä tekijöitä.

Voimalaitosprojektien kaapelisuunnittelu on monimutkainen ja aikaa vievä prosessi. Sidosryhmien välistä yhteistyötä tarvitaan ja tietovirran on oltava hyvin hoidettu. Asianmukainen suunnittelu on välttämätöntä suunnitteluvirheiden ja ongelmien poistamiseksi asennuksen aikana.

Tämän opinnäytetyön tarkoituksena oli analysoida ja kehittää voimalaitosprojektien kaapelien suunnitteluprosessia. Lisäksi kehitettiin uusi kaapeliluettelomalli, jota kaikki hankkeen sidosryhmät voivat käyttää. Lopuksi kehitetty prosessi ja kaapeliluettelo on toteutettava saumattomasti ilman että se vaikuttaa hankkeiden toteuttamiseen.

Nykyinen kaapelien suunnitteluprosessi analysoitiin ja ongelmat tunnistettiin. Ehdotettiin kehitettyä prosessiratkaisua ja kehitettyä kaapeliluetteloa kaikkien tarpeiden täyttämiseksi projektin toteutuksen aikana. Kehitettyyn prosessiin on luotu toteutusohjeet, jotta pystytään saavuttamaan onnistunut muutos aiheuttamatta hankkeen toteuttamiseen liittyviä ongelmia. Tämän opinnäytetyön tuloksena esitellään työn tuloksia ja kehitysehdotuksia.

Kieli: englanti

Avainsanat: projektinhallinta, prosessien kehittäminen, muutoksenhallinta, suunnittelu, dokumentiointi

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Abbreviations

CHP	Combined Heat and Power
DC	Direct Current
FAT	Factory Acceptance Test
HV	High Voltage
LNG	Liquefied Natural Gas
LV	Low Voltage
MoPo	Monitoring Point
Mul	Multiple cable gland
MV	Medium Voltage
O&M	Operation & Maintenance
P2P	Point to Point
PO	Purchase Order
PV	Photovoltaics
RFQ	Request for Quotation
RFU	Request for Update
SLD	Single Line Diagram
VBA	Visual Basic for Applications

Preface

First of all, I would like to thank Thomas Pellas, Anders Paavola and Wärtsilä for the thesis work opportunity. Furthermore, I would like to thank all the people who have contributed to this research. I would also like to thank Stefan Emet at Novia for the support.

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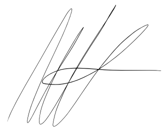

Mikael Huldin

1 Introduction

The global competition in the energy market is increasing constantly. Keeping competitiveness requires constant development of products, services and business processes to bring more value to customers and to strive for operational excellence. Operational excellence focuses on adding value and removing non-value adding activities for the benefit of all stakeholders.

The starting point of any development is analyzing and understanding the current process. Problems are identified and need to be minimized or eliminated, resulting in a more optimized process. Once the developed process is finalized, it needs to be tested and finally implemented. Implementing a change in an organization requires change management.

This thesis work has been done for the electrical engineering department at Wärtsilä Finland Oy, Energy Solutions. As the title states, this thesis is about cables engineering process and interconnection schedule development. A development of the interconnection schedule has been of interest in the engineering department for a long time. At the same time, the associated cables engineering process need to be analyzed and developed. Furthermore, there have been feedback on problems concerning the process that need to be tackled.

1.1 Employer

Wärtsilä is a global leader in the marine and energy markets, offering advanced technologies and complete lifecycle solutions. Their goal is to maximize the economic and environmental performances of the power plants and vessels of their customers. Wärtsilä also emphasizes sustainable innovation and total efficiency. In 2016, the company employed approximately 18,000 employees, operated in over 200 locations in 70 countries worldwide. [1].

Wärtsilä consist of three business units, Marine Solutions, Services and Energy Solutions. Marine Solutions provides ship machinery, maneuvering and propulsion solutions. Services provides customers support throughout the lifecycle of the installations, by providing service, maintenance and reconditioning solutions for both power plants and ship machinery. As a leading energy system integrator, Energy Solutions offers a wide variety of environmental friendly solutions. Energy Solutions offerings consist of flexible internal combustion engine-based power plants, utility-scale solar PV power plants, energy storage and integration solutions, also LNG terminals and distribution systems. Wärtsilä solutions are very flexible, which gives the customer great value and enables a transition to a more sustainable and modern energy system. Wärtsilä has a total power generating capacity of 63 GW, when calculating together all the power plants in 176 countries around the world. [1].

Wärtsilä has a good record of accomplishments in project management with thousands of executed projects in the last three decades. Project management consist of planning, leading, managing and executing projects for customers by doing cost estimations, scheduling and project planning. A project team, led by a project manager, executes the project. The project manager is responsible for the fulfilment of the contract requirements. [2].

1.2 Objectives and delimitations

The purpose of this thesis is to analyze the cables engineering process of power plant projects and the development of it. The purpose is also to develop a new interconnection schedule containing P2P information. Part of the interconnection schedule development, is also to analyze standard unit cables to find cables that are typically missing from the design, and list them for future reference.

Delimitation of the process development is set between Wärtsilä, control system supplier and the engineering company. Cables engineering between other suppliers is not part of this analyze because the control system supplier has the biggest amount of cables. The actual design of cables, sizes, types and routing, is not part of this thesis work.

1.3 Research questions

Currently there are no general guidelines for the cables engineering process during project execution. Project engineers have their own routines of doing things and it can differ from person to person. The engineering company has given feedback multiple times during a project about cables that need to be added. This is causing multiple loop through of the complex and time-consuming cables engineering process. Currently the result of the cables engineering process is a cable schedule with the basic information about cable routing. A desire for more information in the list exists, such as P2P information and cable gland size, to ensure smooth installation. In addition, the desire for a common interconnection list template that all suppliers can use in order to make the work of the engineering company easier. Furthermore, feedback that the same cables are always missing from the design and causing extra work during installations. Based on the discovered problems, the following research questions where developed:

- What problems is there with the current cables engineering process?
- How to reduce problems and optimize the cables engineering process?
- What information is relevant for an interconnection schedule?
- What cables are always missing from the design and how to reduce these?

Finally, the developed process needs to be implemented seamlessly, without causing problems to the project execution. Based on that, following research question was developed:

- How is the developed process implemented successfully and seamlessly without causing any problems to project execution?

2 Power plant projects

In this chapter, the theories behind power plant projects are described. First, combustion engine power plants are briefly explained and the different electrical systems a power plant is divided into, is also described. The functionality of the different electrical systems is explained as well as their main components. Furthermore, fundamentals in project management are explained, focusing on engineering and design. In addition, communications during a project and change management is described. Finally, documentation during project execution is described, as well as tools used and standards behind electro technical documentation.

2.1 Combustion engine power plants

The combustion engine power plants are based on one or multiple modular 4-19 MW, generating sets and are suitable for baseload, peaking power and CHP operations. A generating set consist of an internal combustion engine connected to a generator. Engines can be run on a wide selection of gas types, or in multi-fuel mode using both gaseous and liquid fuels. Due to the modular design, expanding the power plant is easy. Plant configuration is also simplified, and adding features is a matter of adding modules. [3].

Combustion engine power plants are divided into different electrical systems; control system, low voltage system, medium voltage system, high voltage system, auxiliary system and DC system as illustrated in Figure 1. Typical symbols used in the figure below, are described in Appendix 1.

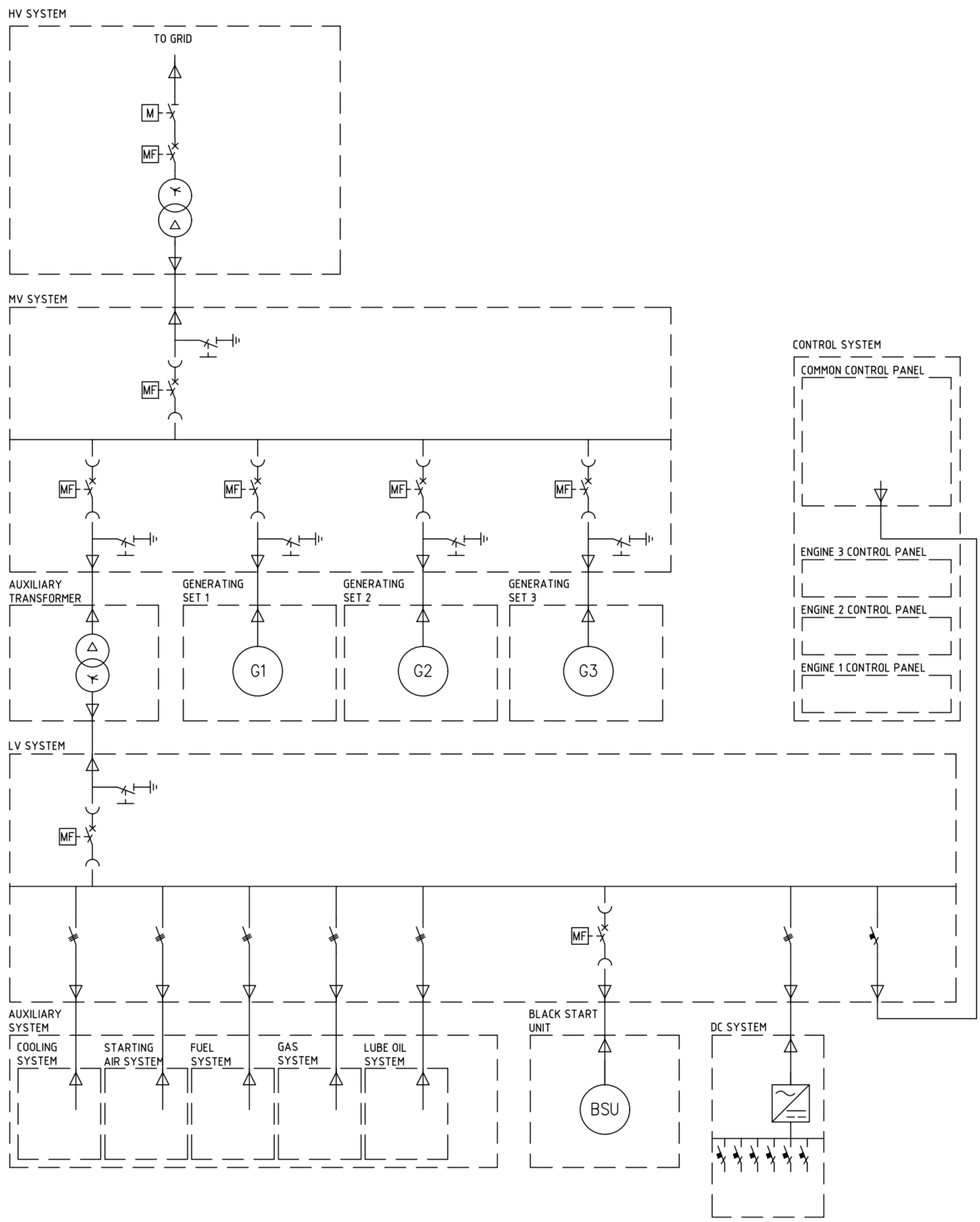

Figure 1: The electrical systems layout of combustion engine power plant.

2.1.1 Control system

The combustion engine power plants require a sophisticated control system to control the power plant operations. The automation system is designed for safe, reliable, efficient and easy operations of the generating sets, their associated auxiliaries and electrical systems. Like the generating sets, the control system has also a modular design, which provides flexibility for different sized installations. [4].

The control system consists of a common control panel and an engine control panel, for each engine. Both panels are located in the control room. The common control panel contains the operating switches, buttons and meters for manual synchronization, and the mimic for the plant MV system. It also contains the PLC system and the safety relays for plant emergency shutdown. The engine control panel contains buttons and switches for manual control of the engine, meters and generator protection relays. [4].

Depending on the size of the power plant, there can be additional control panels placed around the power plant area, to reduce cable lengths. [4]. A typical control system layout and its cables are illustrated in Figure 2.

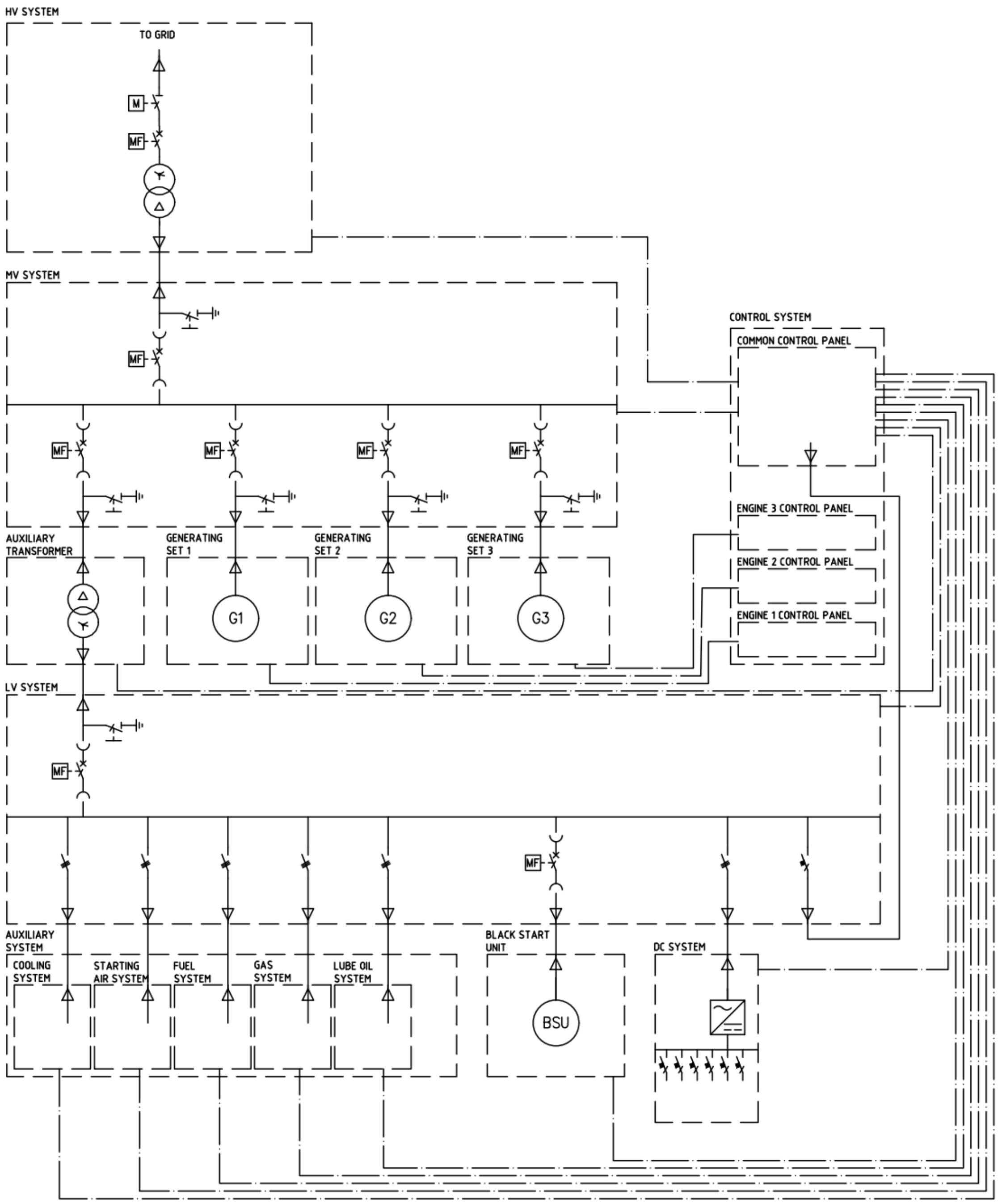

Figure 2: A typical control system layout and its cables.

2.1.2 Low voltage system

The low voltage system, or the LV system, consists of switchgears, auxiliary transformers and black start units. The LV switchgear distributes electricity to low voltage consumers. The auxiliary transformers supply the switchgears with electricity from the medium voltage side. A black start unit is for emergency situations, if the plant has been shut down and there is no connection to the grid. The main LV consumers are pumps, ventilation equipment, heating equipment, air compressors and lighting. Sizing of the switchgear and auxiliary transformers depends on the power consumption of the equipment connected. The purpose of the LV system is to provide auxiliary power to equipment inside the power plant area. [5].

2.1.3 Medium voltage system

Systems with rated voltage up to 36 kV are called medium voltage systems, or MV systems. The MV system consists of a switchgear, which distributes power from the generators to the HV system through a distribution transformer, and supplies power to the LV system through an auxiliary transformer. The MV switchgears consists of cubicles installed side by side and connected to a bus bar. Each incoming or outgoing feeder has a separate cubicle. Normally the main components of cubicles are circuit breakers, current and voltage transformers, earthing switches, cable terminals and secondary equipment for control and interlocking. [6].

2.1.4 High voltage system

Systems with higher rated voltage than MV systems and with a voltage up to 400 kV are called high voltage systems, or HV systems. These systems are primarily used for power transmission, but they can also be used for coupling and distribution of power supplies. In power plants, the HV system is used for interconnections with electrical grids, distributing the generated power. [7].

The interconnection to the electrical grid is normally achieved through an outdoor air insulated switchyard or a gas insulated switchyard. The main components of the switchyard are distribution transformer, circuit breakers, disconnectors, earthing switches, current transformers and voltage transformers. LV supply is needed for lighting, heaters inside equipment, transformer cooling fans and other possible loads. DC supply is also needed for control system, protection relaying, equipment motor operation mechanism and interlocking circuits. No matter what switchyard arrangements are used, interlocking is needed for the correct switching order. [6].

2.1.5 Auxiliary system

The auxiliary system consists of all process related units, which are controlled by the power plant automation system. The auxiliary system consists of starting air system, instrument air system, gas system, fuel system, exhaust gas system, cooling system, lube oil system and other systems, depending on the plant configuration. Some units are independently controlled, and others are controlled by the control system. All units have at least a common alarm signal, connected to the power plant control system. [4].

2.1.6 DC system

The purpose of the DC system is to supply the power plant with DC. Batteries are required to safeguard an uninterrupted supply, if the main supply is interrupted. The DC system supplies critical components in a power plant, such as control system units and protection systems in both LV and MV systems. Battery chargers supply the DC load while charging the batteries in parallel. [5]. The typical DC system layout and its cables are illustrated in Figure 3.

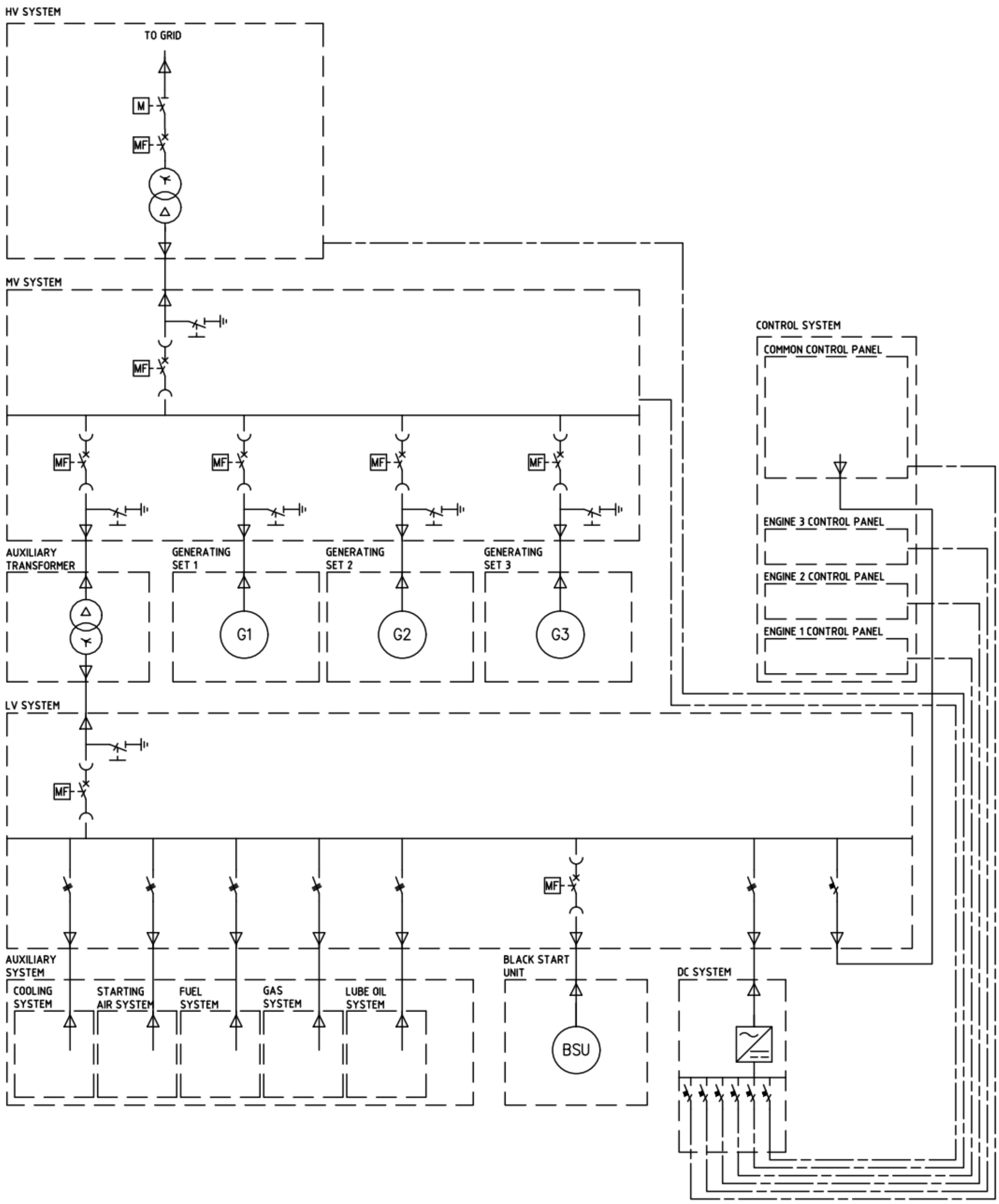

Figure 3: The typical DC system layout and its cables.

2.1.7 System interlocking

To ensure reliable and correct switching operations for circuit breakers and disconnector switches, interlocking is used. Interlocking also protects components and ensures human safety. Interlocking between circuit breakers and disconnectors is designed in such way that faulty operations are not possible in any circumstances. [8].

Every project is unique and have different configurations, and that is why every project needs to be carefully analyzed to know what interlocking is needed. The internal interlocking of the MV switchgear cubicle is mechanical and the interlocking between other cubicles or systems is achieved with electrical circuits. The typical interlocking between systems are as follows:

- MV switchgear outgoing cubicle earthing switch open signal to HV system circuit break closing circuit and also HV system circuit breaker open signal to MV switchgear outgoing cubicle earthing switch closing circuit.
- LV switchgear incoming cubicle circuit breaker open signal to MV switchgear auxiliary transformer cubicle circuit breaker closing circuit and MV switchgear auxiliary transformer cubicle circuit breaker closed signal to LV switchgear incoming cubicle circuit breaker closing circuit.
- LV switchgear incoming cubicle circuit breaker open signal to MV switchgear auxiliary transformer cubicle earthing switch close circuit. [8].

The typical interlocking layout is illustrated in Figure 4.

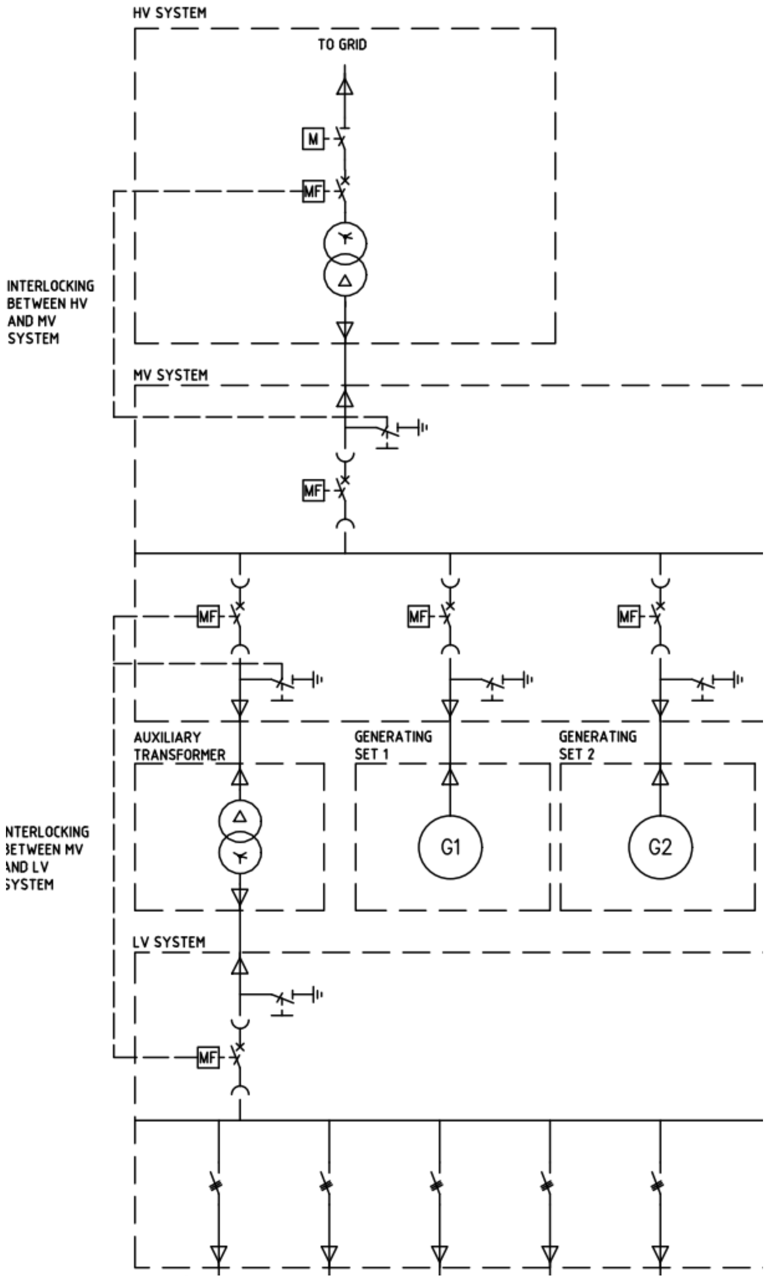

Figure 4: The typical interlocking layout.

2.2 Project management

Efficient and effective project management is critical in the fields of engineering and technology. All engineering and technology projects share common goals as of the following completion of projects on time, within budget and according to specifications. [9].

2.2.1 Engineering and design

Engineering process model varies for every organization, but they are all based on the same basic steps as illustrated in Figure 5. The process starts with identifying the needs and exploring suitable design concepts. When the needs are identified, a clear set of specifications needs to be determined. During the two first steps, the objective is to get a clear picture of the design problems. Based on the specifications a conceptual design is developed and reviewed based on costs and benefits. A design embodiment is the outcome of this, including key components, drawings and process plans. During the creation of the detailed design, it is turned into concrete plans, meeting the requirements and specifications. Building and testing is used to verify that the design satisfies the specifications and requirements. Finally, the customer accepts the product. [10].

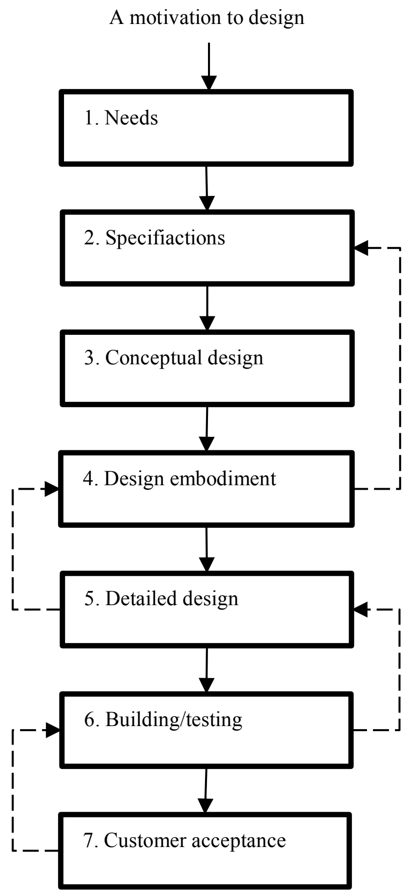

Figure 5: A seven-step model of project work [10].

According to this model, project work is divided into clean sequential steps. The progress through the project phases can clearly be measured. [10].

To achieve the target goals of a project, a planning process, as illustrated in Figure 6, is carried out on beforehand. It includes the starting and ending times of tasks so that the project team will carry out the right tasks at the right time. Multiple steps are included in the planning process, dividing the project into different tasks. [10].

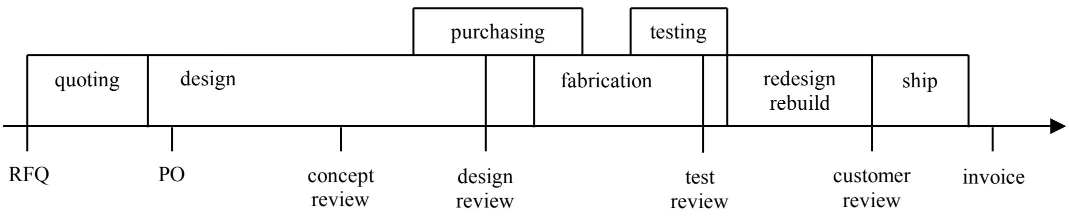

Figure 6: Project timeline planning [10].

Normally, a design project starts with a process of discovery. The process of discovery begins with defining the needs for the project, developing detailed specifications to guide the design and accepting the specifications. Identifying the needs initiates the design process. After the needs have been identified, the specifications need to be developed. Some of the needs will naturally become specifications and other needs can be harder to define as specifications. To be able to deliver as promised, the specifications needs to be precise. Detailed specifications may seem time-consuming to develop and it might also slow down the design process, but every detail that is left unexamined or is ignored will take 10 times longer to add during the detailed design phase, and 100 times longer to add during the build and test phase. An expectation of what the design should look like is formed by the needs and the specifications. [10].

When the specifications are determined, concepts are generated based on them. A combination of concepts will result in embodiments. The process of the conceptual design is handled differently for each company. Companies that have specialized departments, passes documents in between divisions and when a division has completed their tasks, they will send it to the next division. The traditional functional design is illustrated in Figure 7. In this structure, a sales engineering division handles customer interaction. They interact with the customer and develop needed specifications. These specifications are then passed on to the quotation department, which works out different design alternatives. A design alternative is selected that fits the customer´s business needs, and an offer is calculated based upon that. This structure allows more focus and efficiency on the design concept. The negative aspect is that this approach makes early decisions harder to change. [10].

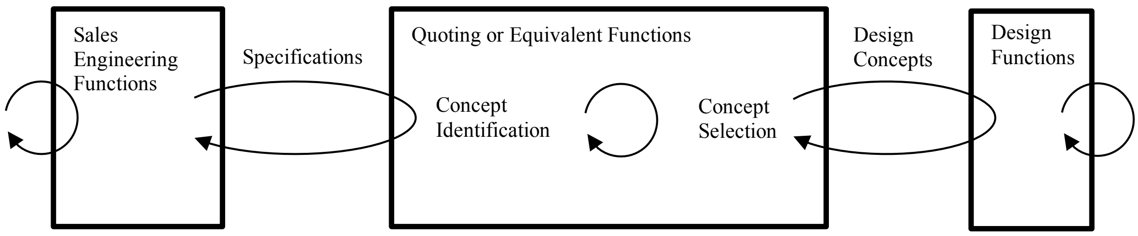

Figure 7: Traditional functional design [10].

Concept designs are suggestions on to how the design could be done. Embodiments are how the design will be done. Good embodiment designs include enough details, so that the development of parts and components can be done independently. Embodiment design usually consist of calculations supporting the design concept, electrical schematics and data sheets for major components, software, data flow and control system, flow charts, and bill of material for major or strategic parts. [10].

2.2.2 Communication

To ensure effective communication between all stakeholders during a project, a communication plan needs to be developed. Poor communications in a project will lead to problems. Different stakeholders need different input information, but all stakeholders need to be kept up-to-date. A good communication plan contains the following information:

- Each stakeholder's communication requirements.
- What information that needs to be communicated to each stakeholder, including how often, in what format and level of detail.
- The reason for providing information to each stakeholder.
- An individual responsible for providing the information.
- Flowcharts showing the information flow.
- Templates and guidelines.

By developing a communication plan, it can prevent unanticipated problems and answer possible questions about the communication during a project. [9].

2.2.3 Change management

All improvements require some kind of change. For the change to bring the desired result, it needs to be managed. People tend to get comfortable with how things are, resulting in a resistance to change. Sufficient leadership is needed to convince people to embrace a proposed change. [9].

In a competitive environment, technology and engineering companies must constantly find ways to improve the performance of the people, processes, productivity, quality, safety and all other factors that add value. Implementing change can be done by following the seven-step model illustrated in Figure 8. [9].

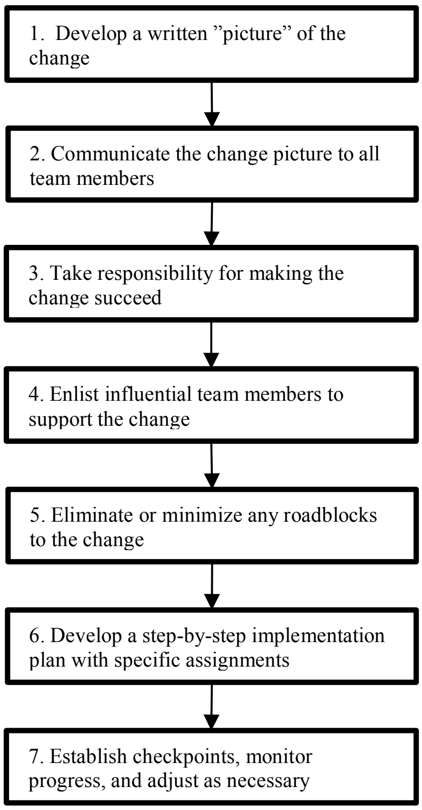

Figure 8: The seven-step change management model [9].

One of the main reasons people resist change, is the fear of the unknown. People know how things are right now, and even if they do not like the current situation, it brings a measure of comfort with the familiarity. What worries people is that they do not know how things will be after the proposed change. The first step in the change management model is eliminating the fear, by replacing the unknown with the known. This can be accomplished by developing a compelling and informative change picture, a brief written explanation of how things will be after the change. The key to make a compelling change picture, is to view the change from the affected peoples and team members' perspective. People take change personally, and the first thing they will want to know is how it will affect them. A change picture should answer all question that may appear among the affected people. A good change picture gives an explanation of what will change, when the change will occur, where the change will occur, who is affected by the change, the reason why the change is being made and finally how it will affect the team members.

Once a good change picture has been written, the second step is communicating it to all affected people. Communicating through face-to-face meetings is the preferred method. Unless people are situated in different locations, face-to-face meetings may not be possible and instead communications can be carried out electronically. The communication method does not matter, what matter is getting convenient feedback. Hence, affected people can ask questions, point out problems, express concerns or just discuss the proposed change. Another important part of communicating the change picture is analyzing roadblocks, by asking affected people to identify roadblocks that they think might be a problem during the implementation of the proposed change. [9].

A change in an organization does not just happen by itself, it requires a lot of work, commitment and persistence from all affected people. More than anything, it requires the affected people to take responsibility and do their part, for the change to succeed. The third step is to take responsibility for making the change. Some people will just openly resist the change, but many will opt to a more passive wait-and-see attitude. People with the wait-and-see attitude, will put no effort in making the change succeed, and they often switch between sides until they know whether the change will fail or succeed. Changes will only succeed if the affected people are willing to take responsibility and commit to doing what it takes to make the change succeed. [9].

Some team members are more influential than others are. This depends on their seniority, popularity, strength of personality, if other team members look to them for approval talent or a variety of other factors. These influential team members can play a huge role in the success or failure of a change. The fourth step is to enlist influential team members to support the change. It can be challenging enlisting influential team members, especially if they have the wait-and-see attitude or are against the change. It is important to have face-to-face, one-on-one conversations with the influential team members in order to determine, where the team member in question stands concerning the change. There are two options if influential team members are against the change, the first is to isolate them from the implementation process of the change, or secondly make them responsible for some aspects of the implementation process. Before making an influential team member responsible for any aspect regarding the implementation process, it is important to assure full cooperation from the person. [9].

Identifying obstacles or roadblocks was part of an earlier step in this model. The fifth step is to minimize or to eliminate these identified roadblocks. Minimizing or eliminating roadblocks can be done as soon as they are identified, this step can be executed in parallel with the already mentioned steps. [9].

When all roadblocks are minimized or removed, the sixth step is to develop a step-by-step implementation plan with specific assignments. Every action needed to be taken, is listed and assigned to a specific individual. It is important that assignments be to a specific individual, not to a team or a group. Though the implementation of the change often requires the effort of the entire team, the responsible individuals lead their teams to get their actions done. It is important to avoid confusion concerning assignments. Telling people that everyone is responsible for the change, is the same as saying no one is responsible. [9].

The final step is to establish checkpoints, monitor progress and make necessary adjustments. Ignoring the need to monitor the implementation process is one reason why changes fail. Even assigning tasks to specific people is no guarantee of success. That is why the implementation process needs to be monitored, and deadlines for completion of every task assigned to a specific person need to be set. Progress needs to be monitored and if problems occur, adjustments need to be made. Even the roadblock analysis may not anticipate all the problems, and it is common that unanticipated problems occur during implementation. These require immediate corrective actions to keep the implementation process on track. [9].

2.3 Documentation

Documentation is one of the most important parts of a project. It is equally important during all project phases; planning, design, manufacturing, installation, commissioning and operations. The main purpose of documentation is to provide information in the most appropriate form, but also prove that contractual requirements and specifications are met. [11].

2.3.1 Connection table

Tables, also known as lists, present information in columns and rows. Each row and column need to be clearly distinguishable from the other rows and columns, and the information presented in the columns need to be clearly indicated by using row or column headers. If the table consists of multiple pages, rows or column headers need to be on each page. Connection tables contain information about physical connections between internal components, units or physical connections between external units. A connection table is also known as terminal connection table, unit connection table, interconnection table and cable table. In a connection table, the connection points need to be identified by their reference and terminal designation. The connected cables and objects need to be identified with their reference designation. Depending on the cable type, core number or color identifies cable cores. Additional information that can be included in a connection table are:

- cable or conductor type information (for example, construction, size, number of conductors or other technical data)
- conductor or cable number
- reference of the connected components or units
- routing, termination or screening information
- cable length
- information about the signal
- special classifications or information.

Connection tables can be based on two kinds of sorting methods, terminal-oriented or connection-oriented. In terminal-oriented, the presented connections are sorted by the identification of the terminals. In connection-oriented, the presented connections are sorted by the identification of the cable or conductors. Example of a connection-oriented table is found in Table 1. [11].

Table 1: Example of a connection-oriented connection table [11].

Cable designation	Core designation	Terminal-A4-X1	Remote End-B4	Remarks
-W136	-GNYE	:PE	-X1:PE	
	-1	:11	-X1:33	
	-2	:17	-X1:34	
	-3	:18	-X1:35	
	-4	:19	-X1:36	
	-5	:20	-X1:37	Spare
-W137	-GNYE	:PE	-X2:PE	
	-1	:12	-X2:26	
	-2	:13	-X2:27	
	-3	:14	-X2:28	
	-4	:15	-X2:29	
	-5	:16		Spare
	-6			Not connected

2.3.2 Tools

Microsoft Excel is the most popular spreadsheet software and has been the standard for many years. Storing information in a structured list, also known as table, is a very common use of the spreadsheet. Excel can be customized and automated with macros. A macro is a sequence of instructions that executes different commands to improve efficiency and reduce errors. Macros can be recorded or coded in VBA editor. [12].

3 Analysis of current cables engineering process

In this chapter, current cables engineering process is analyzed. First, the tools the project engineers use during the design phase are explained. The purpose of the tools is to gather information and specifications about different systems and easily communicate it between stakeholders in a project. Furthermore, the process and the different phases are explained in more detail, as well as the current cable schedule. Throughout the project, project engineers work closely with suppliers and the engineering company, distributing input and reviewing designs. Finally, feedback regarding the cables engineering process is summarized. Problems are identified and enlightened.

3.1 Engineering tools

Project engineers work with different engineering tools or lists during the engineering process. These tools are used to gather information and specifications about different systems and they are used as communication input for suppliers. The purpose of these tools is to help project engineers to store information and to communicate the information to suppliers during the project execution. Monitoring point list is used for the power plant control system, a low voltage consumer list is used for low voltage switchgear and a DC consumer list is used for the DC system. These lists are generated according to the standard solution, depending on the engine type and the specifications. The lists are then edited to fulfil project requirements.

3.1.1 Monitoring point list

Monitoring point list, also called MoPo list, consists of all signals, inputs and outputs that are monitored or controlled by the power plant control system. These signals can be hardwired or by bus connected to the control panels. Based on what the sales department have offered the customer and what is in the scope of supply, a standard MoPo list is generated from a database of standard signals. Project engineers modify the list, according to the project specific details. The MoPo list is then used as a primary tool for delivering information about signals to the control system supplier and the engineering company.

3.1.2 Consumer lists

The LV consumer list consists of all power plant LV consumers. The list is used to list all low voltage consumers, fuse sizes, power consumption, voltages, phases and to calculate the entire consumption of the plant power. Depending on the size of the engine and the fuel type, a standard LV consumer template is used, and modified by the project engineers according to the project specific details. As for the MoPo list, the LV consumer list is used as a primary tool for delivering information to the LV system supplier and the engineering company. LV switchgear, station auxiliary transformers and cables sizes are designed according to the LV consumer list inputs.

The DC consumer list is used to list all DC consumers in the power plant. The list includes fuse sizes and consumptions during operations. Batteries and chargers are sized based on the consumption and number of fuses in the DC consumer list. Depending on the size of the engine and fuel type, a standard DC consumer list template is used, and modified by project engineers according to the project specific details. In addition, the DC consumer list is used as a primary tool to deliver information to the DC system supplier.

The engineering company uses consumer lists as input during the cables engineering process. Cable sizes are calculated based on fuse sizes and consumptions. Also, LV and DC cables are routed according to the lists.

3.2 Cables engineering process

Projects usually take a significant amount of time to execute. Project engineers are responsible for communications between the suppliers and the engineering company. The project engineers manage project related documents and are responsible of distributing documents to all stakeholders, suppliers, the engineering company and the customer. Project related documents are stored in a document management system called IDM. All project team members have access to IDM. Documents that are added to IDM gets a document number and are revision controlled. The cooperation between Wärtsilä and the engineering company is very close. The engineering company does a lot of design work for the projects, and therefore have access to project related documents in IDM.

Because there are no specific guidelines to the cables engineering process, project engineers have their own routines for the process. Therefore, the communication between suppliers and the engineering company is not always done correctly, and lack of information may occur.

The current cables engineering process can be divided into different phases; design, procurement, installation and documentation. Design and procurement parts are typically executed in parallel. This process may vary from person to person, but in general, it is executed as described in the following subchapters.

3.2.1 Design

The design process starts with an engineering kick-of meeting between Wärtsilä and the engineering company. During the meeting, details and specifications about the project is discussed. Depending on the scope of supply, project engineers start with the design, creates consumer lists, MoPo lists and MV-SLD. Some auxiliary units are also designed by project engineers, which are based on standard solutions. RFQ:s are sent out for each system. Consumer lists, MoPo list and MV-SLD are used as main input. Quotations are received and reviewed by the project engineers. When the supplier is chosen, a PO is released for each system. In addition, engineering input, drawings, process descriptions and other relevant information is delivered to suppliers. Suppliers starts designing, and the basic design is delivered within a few weeks. The control system supplier also delivers a preliminary cables list. The preliminary cables list usually includes around 70-80 % of the cables that are going to be used. The basic design is then delivered to the engineering company, who starts with the cable ladder and cable routing design. Cable sizes are calculated with a calculation software. Cable and cable ladder routing is done in a 3D design software. The output from the cable ladder and cable routing process is a cable schedule list, which is described in Chapter 3.3. The cable material and installation material lists are also generated during the cables engineering process.

The project engineers review the basic design. After the basic design, suppliers start working towards the detailed design. The detailed design is delivered and reviewed by project engineers. The control system supplier also delivers a detailed cables list, along with the detailed design. The detailed cables list is distributed to the engineering company along with the detailed design for cables engineering input. Right before manufacturing is ready, an invitation to FAT is sent out by the supplier. During FAT, manufactured units are tested, and drawings are crosschecked. If the manufactured units pass the testing and no additional changes need to be made, manufacturing is ready, and the units are ready for shipping. Final documentation is then made and delivered by the supplier. The control system supplier also delivers a final cables list, along with the final design. The final cables list is distributed to the engineering company along with the final design for cables engineering input. The engineering company executes the cables engineering process and updates the cable schedule and cable material lists.

3.2.2 Procurement

The engineering company creates cable material and cable installation material lists during the design. Material is bought according to the lists, from different suppliers. Cables are usually bought from a large cable supplier, and installation material is bought from an electrical material supplier. MV cables and bigger LV cables have longer delivery times and needs to be bought at an earlier stage. Smaller LV cables and control cables have shorter delivery time and can be bought at a later stage. The material lists are usually updated during the design, and material needs to be bought at different stages.

3.2.3 Installation

Once the design is done and units have been shipped to the project site, installation starts. The project engineers support the site engineers during the installation phase. The installation is usually done by sub-suppliers and supervised by site engineers. The installation is done according to the design, and during the installation, the supplied units are crosschecked against the design. Cables are installed according to cable schedule and terminations of cables are done according to panel drawings. If problems occur with the design, project engineers assist with solving these problems and takes care of ordering additional material. Changes to the design is documented on red-pen drawings and lists.

3.2.4 Documentation

The final, but equally important part in a project is the documentation. All changes, additions or design misses documented on red-pen drawings and lists, are delivered to the project engineers. The project engineers distribute the received red-pen documents to suppliers for update. The suppliers update the documents accordingly and return as-built documents. All as-built documents are gathered to an O&M manual, which will be delivered to the customer.

3.3 Cable schedule

Currently the engineering company creates a cable schedule. The cable schedule is a result of the cable ladder and the cable routing process. It consists of cable numbers, from-to information, description, cable type, cable construction, cable length, revision and routing information for all cables in the project. The cable schedule uses a connection-oriented sorting method and cable numbers from lowest to highest sorts cables. This schedule is used during the installation on site, to instruct sub-suppliers on what type of cable to use, how to route it and between which units it will be connected. An example of a cable schedule is illustrated in Appendix 1.

3.4 Process feedback

Feedback has been given about problems that have occurred during the project execution. From the site, there has been feedback about the same cables, which are always missing from the design, especially interlocking cables between switchgears. This has led to a lack of cable material and cable installation material. In addition, designed cables have been too big and do not fit the cable gland or terminals in the electrical panel. To solve these issues, cable material and cable installation material have been bought later on and airfreighted to the site. Often the price of the cable material and cable installation material is more expensive, due to smaller quantities and required faster delivery times. Also airfreighting cable material and cable installation material can be expensive. It takes more time to add a cable, during the installation than if it would be added during the design. These design mistakes need to be discovered and eliminated.

From suppliers there have been feedback, about having old revision drawings during FAT. Project engineers have done some last-minute updates and not distributed the latest revision documents to the supplier, and during FAT, the manufactured units are not matching the desired design. In addition, the engineering tools, MoPo and LV consumer lists, are only used during the RFQ phase and not updated afterwards. Instead, all updates and changes are communicated through emails or phone calls.

From the engineering company there has been feedback, about cables wanted to be added multiple times during a project and that input cables lists are in pdf-format. The cable ladder and cable routing process are complex and time-consuming. Adding one cable requires a loop of the whole process and takes approximately one week. The engineering company's cables engineering process is illustrated in Figure 9.

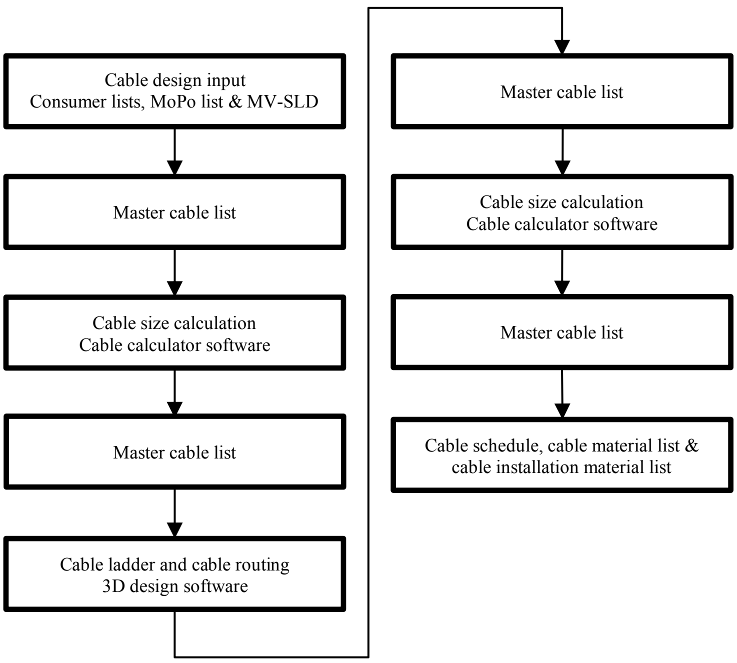

Figure 9: The engineering company's cables engineering process.

The process starts when inputs like consumer lists, MoPo lists and MV-SLD have been received. The information from the inputs are manually inserted to a master cables list. Cables sizes are then calculated in a calculation tool and updated on the master cables list. The information is imported for the design software, where cables and cable ladders are routed. Routing information is exported back to the master cables list. Cables sizes are calculated once again and updated on the master cables list. Cable schedule and material lists are exported from the master cables list. The lists are uploaded to IDM and project engineers are informed. Looping through this process for one additional cable is not worth it. It takes about the same time if there is one cable or one hundred cables to be added. Other common issues are that the cable input lists are delivered as pdf. This requires a lot of manual work, when adding cables to the master cable list.

4 Developed cables engineering process

This chapter consist of the methods used developing the cables engineering process and the interconnection schedule. First, the developed interconnection schedule and associated functions are explained. Standard unit cables and P2P information is listed for future reference. In addition, typical missing cables are investigated and a solution to reduce them during the design is developed. Furthermore, the developed cables engineering process and the communication plan for the developed interconnection list are explained. Finally, implementation instructions for the developed cables engineering process are set.

4.1 Interconnection schedule

The purpose of developing the interconnection schedule was to add P2P information and to have a common template that all stakeholders can use. P2P information means that you have, in addition to from-to information, strip and termination information for all cores in a cable. Other useful information, such as cable gland sizes on both ends, terminal size and cable category were also added. By having a standard template that all stakeholders use, the engineering company can easily extract information from it during the cables engineering process, which will reduce the manual work.

4.1.1 Cables P2P list template

The cables P2P list template is based on the existing cable schedule. In general, the layout is modified, and P2P data is added. Cables P2P list uses the same sorting method as the cable schedule, connection oriented. The template is made in an Excel spreadsheet, because it is very common to use, data can easily be imported, exported or manipulated with different macros.

The cables P2P list is divided into four parts; internal system, cable information, external system and cable routing. Example cables P2P list is illustrated in Appendix 3. The internal system part consists of information about from end and external system about to end. Both include columns for reference drawing number, unit identification, strip number, terminal number, terminal size and cable gland size, as illustrated in Figure 10.

Internal system						
Ref.	**From**		**Strip**	**Term.**	**Size**	**Gland**
CBG034718 01 A1(	CFC011		A2	2	SC	Mul
CBG034718 01 A1(	CFC011		A1	P1	RJ45	Mul
CBG034718 01 A1(	CFE011		X1	2T1		Mul
CBG034718 01 A1(	CFE011		X1	4T2		Mul
CBG034718 01 A1(	CFE011		X1	6T3		Mul
CBG034718 01 A1(	CFE011		PE	PE		Mul
CBG034718 01 A1(	CFA901		X103	25+	2,5/1,5	Mul
CBG034718 01 A1(	CFA901		X103	25	2,5/1,5	Mul

Figure 10: Cables P2P list internal system information.

The reference columns contain drawing document number. From column contains panel or unit code, according to predefined number structure. Strip column contains the strip number, for example A2, X1 or X103. Terminal number column contains terminal number, for example 2, P1, 4T2, PE or 25+. Size column contains the size or type of the terminal, for example SC, RJ45 or 2,5/1,5 mm2. Gland column contains information of the cable gland used, for example Mul or M32. External system consists of the same columns as internal system, but in the opposite order.

Cable information part consist of information about cables and cable cores. There are columns for cable number, cable category, cable type, cable construction, cable length, cable diameter, cable core number and function or signal, as illustrated in Figure 11.

Cable							
Number	Cat.	Type	Cons.	Length	Dia.	Core	Function / Signal
11116	FO	50/125 SC/SC	50/125 SC/S	55,6		1	Fibre optic
11121	ETH	CAT5e/FTP	CAT5e/FTP	26,2	5,1	1	Ethernet
11201	CC	1kV 2XY	4x2,5 rm	9,9	12	1	Phase 1
11201	CC	1kV 2XY	4x2,5 rm	9,9	12	2	Phase 2
11201	CC	1kV 2XY	4x2,5 rm	9,9	12	3	Phase 3
11201	CC	1kV 2XY	4x2,5 rm	9,9	12	4	PE
51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	1a	Common +
51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	1b	Filter ready

Figure 11: Cables P2P list cable information.

Cable number column consists of the cable number and cables are numbered according to predefined numbering structure. Category column consist of the cable category, which are described in Chapter 4.1.3. Type column consist of the cable type, cables types are defined according to project specifications. Construction column consists of the cable construction, for example, 4x2,5 rm, 4x2x0,5 or CAT5e/FTP. Length column consists of the length of the cable in meters. Diameter column consist of the diameter of the cable in millimeters. Core column consists of the cable core number, for example 1, 2, 3, 1a or 1b. Function or signal column consists of a short description of the cores signal or function.

Finally, there is revision, revision note and cable routing information columns, as illustrated in Figure 12.

Rev.	Revision note	Routing information						
-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-25/01
-		CL337-01/01	CL302-06/01	CL347-01/01	CL348-01/01	CL302-01/01	CL302-02/01	CL302-03/01
-		CL305-04/01	CL305-03/01					
-		CL305-04/01	CL305-03/01					
-		CL305-04/01	CL305-03/01					
-		CL305-04/01	CL305-03/01					
-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01
-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01

Figure 12: Cables P2P list revision, revision note and cable routing information.

Revision column consist of the revision letter, for example -, a, b or c. Revision note column consist of notes for the revision change. Finally, routing information columns consists of information about how the cables are routed.

4.1.2 Functions

A power plant has a large number of cables and many of them have multiple cores, every core has its own row, resulting in a cables P2P list with a huge number of rows. In addition, a lot of information is stored in this list, but not all information is relevant all the time. Filter functions are needed to easily find information in the list. By implementing macro buttons in the list, it is possible to show different views depending on what is desired. For example, during cable routing, the termination information is not relevant and can be hidden. During termination, again, cable routing information is not relevant and can be hidden. In addition, the lists need to be easy to use, due to many different users. It will be used by project engineers, the control systems supplier, the engineering company and site engineers. That is why the main objective when creating the list has been to keep it simple, containing no unnecessary nor complicated functions.

Functional description for macro buttons are as following. Default view of the cables P2P list shows all information and a visible macro button named “Create list” as illustrated in Appendix 3. By pressing the “Create list” button, all rows with the same cable number are grouped together and all rows except for the first row is hidden. Cable routing columns are hidden, filter function is applied, printing area is set according to last used row and column, button description changes to “Revert to original” and macro buttons “Cable routing list”, “Show cores” and “Clear filters” become visible. This is the cable list view and it is illustrated in Appendix 4.

By pressing “Show cores” button, all hidden grouped rows or cable cores will be shown, and button description changes to “Hide cores”. This is the cables P2P list view and it is illustrated in Appendix 5. By pressing it again, it will hide cores and return to earlier view.

By pressing “Cable routing list” button, reference, terminal, strip and size columns will be hidden, and routing information columns will be unhidden. Button description changes to “Cables P2P list”. This is the cable routing view and it is illustrated in Appendix 6. By pressing it again, it will return to earlier view.

By pressing “Clear filters”, all current filters will be cleared, and filtered rows will be shown. Lastly, by pressing “Revert to original” it will revert to default view and show all columns and rows.

4.1.3 Cable list categories

As described in Chapter 2.1, combustion engine power plants have several systems with different voltage levels. Depending on the voltage level or signal type, a specific type of cable may be required. To easily separate the difference between voltage levels and signals types, the cables are divided into different categories. The category explains what type of signal and what type of cable is used. Categories have been set according to Table 2.

Table 2: Cable list categories.

Category	Description
PMV	MV Power cable
PLV	LV Power cable
PDC	DC Power cable
CD	Control cable, digital signals
CA	Control cable, analog signals
CC	Control cable, high current signals
FO	Fibre optic cable
ETH	Ethernet cable
BUS	Other bus cables
PF	Prefabricated cable, supplied with unit

4.2 Standard unit cables

The units used are mostly standardized, but they can vary depending on the engine type or specifications, and also depending on the supplier. First, what units are standard and typically used, must be identified. This is accomplished by checking with people responsible for each system. Standard units that have an electrical panel or require cables to be installed at site are listed. For each unit, electrical drawings are analyzed and crosschecked with the database of standard MoPo list signals. Cables that are required for these units are listed on a cables P2P list template, including information on panel code, strip and terminal numbers, terminal size, cable gland size and function or signal description. By listing these standard unit cables, the engineering company can use this information during the cables engineering process, which will reduce manual work. In addition, by listing standard cables for each unit and using this information during cables engineering, cables are less likely to be missing from the design.

4.3 Typical missing cables

According to the feedback in Chapter 3.4, site engineer's state that usually the same cables are missing from the design. To reduce design mistakes and expensive airfreights of cables during installation, these missing cables needed to be identified. Identification is done by choosing a few projects with well-documented red-pen drawings from site. The final design is compared against red-pen drawings. Cables that are not included in the design and added at site are documented.

All analyzed project has one missing cable in common, interlocking cable between MV auxiliary transformer cubicle circuit breaker and LV incoming cubicle circuit breaker. The main reason why this cable is missing from the design is that it is not indicated in MV or LV system design drawings. In addition, some other cables are noted missing but are not the same for all projects.

There are guidelines stated for interlocking design, as explained in Chapter 2.1.7, and an interlocking template to be used during project execution. However, the interlocking template is rarely used during the design. The interlocking template should therefore be used in every executed project. Once the interlocking design is finalized for the power plant, the document should be distributed to affected system suppliers; HV, MV and LV system suppliers, so that the cables needed are included in the design.

Other missing cables are caused by design mistakes and are difficult to list when they are not the same for every project. The standard unit cables list in previous chapter will at least eliminate missing cables from standard units. Project specific units needs to be checked case specific and carefully, to include all necessary cables in the design.

4.4 Cables engineering process

The aim when developing the cables engineering process is to limit the engineering company loop through of the complex and time-consuming cables engineering process. In addition, reducing design mistakes and improve the quality of the design. The engineering tools, consumer lists and MoPo list, are used as primary tools for communication between stakeholders. The result from the consumer lists and MoPo list is the cables P2P list. The engineering tools needs to be used throughout the entire process, which means all changes during the design needs to be communicated with the engineering tools. Furthermore, the process needs to be developed around the cables P2P list.

The process guidelines focus on MV, LV, DC and control systems because almost all cables are connected to them. Auxiliary system units are mostly standardized, and their cables have already been listed as explained in Chapter 4.2. The developed cables engineering process flowchart is illustrated in Figure 13.

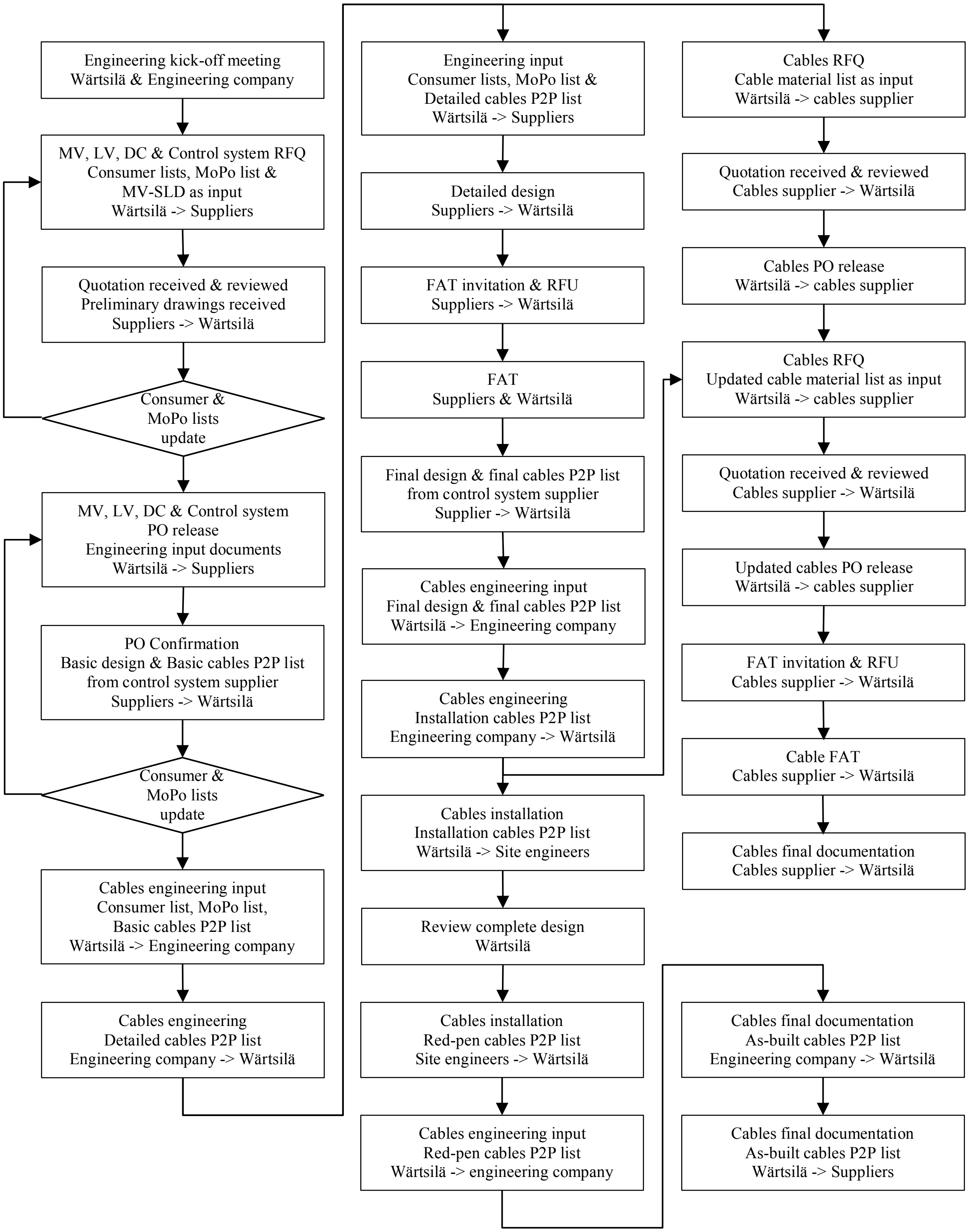

Figure 13: Cables engineering process flowchart.

The process starts, as before, with a kick-off meeting between Wärtsilä and the engineering company. During this meeting, project specifications are discussed. Depending on the scope of supply, project engineers starts with the design, creating consumer lists, MoPo list and

MV-SLD. Some auxiliary units are also designed by project engineers, which are based on standard solutions. RFQ:s are sent out for each system, consumer lists, MoPo list and MV-SLD are used as main input. Quotations are received with preliminary drawings and reviewed by project engineers. During this phase, if MoPo or consumer lists have been updated, an updated quotation needs to be requested from the suppliers. Looping through this step until the specifications are thoroughly developed. When the specifications are set, and a supplier is chosen, PO is released for each system. Engineering input, drawings, process descriptions and other relevant information is delivered to suppliers.

The suppliers confirm the PO, and the basic design is delivered by the suppliers. The control system supplier also delivers a basic cables P2P list. The basic cables P2P list contains the following information:

- Cable numbering, construction and function.
- From-to information.

The control system supplier is responsible for the internal system part of the cables P2P list, and unknown fields are left empty at this stage.

Project engineers forward the basic cables P2P list along with basic engineering input, drawings, process descriptions and other relevant information, to the engineering company. The engineering company starts with the cables engineering, by editing the received basic cables P2P list and adding MV, LV, DC and other cables. The result is a detailed cables P2P list, containing the following information:

- Verified basic information.
- Cable categories, types and diameters.
- Cable lengths and routing information.
- Cable glands size.

Revision changes are marked with bold text, but only the cells that have changed are marked. This makes it easier to identify changes that need some kind of action. For example, if a cable size is updated to a bigger one, it needs to be verified if terminals and cable glands fit.

The detailed cables P2P list is delivered to the project engineers and forwarded to the control system supplier. The control system supplier can easily filter the list, to see if the changes that affects them. The engineering company also delivers material lists, along with the detailed cables P2P list. The RFQ for cable material and cable installation material is sent out to suppliers. Quotations are received and reviewed by the project engineers. A supplier is chosen, and the PO is released.

The suppliers deliver a detailed design, which is reviewed by the project engineers. Right before the manufacturing is completed, a FAT invitation is sent from the control system supplier, along with a request for an update. A lot can change between the detailed design and the FAT. A RFU is to align the design and the lists between the control system supplier and Wärtsilä, to ensure that both have the latest drawings during the FAT. During the FAT, the manufactured units are tested, and drawings are checked. The final documentation is made on the manufactured units, and suppliers deliver them. The control system supplier also delivers a final cables P2P list, containing the following information:

- Verified detailed information.
- Strip and terminal numbering.
- Reference numbers.

The final cables P2P list is forwarded along with detailed engineering input, to the engineering company. The engineering company does the final loop through of the cables engineering process, resulting in an installation cables P2P list and updated cable material lists. The installation cables P2P list and updated material lists are delivered to the project engineers.

The project engineers ask for RFQ for additional cables, based on the updated cable material lists from the cables supplier. The quotation is received and reviewed, and the PO is updated according to it. Once the manufacturing of the cables is almost finished, a FAT invitation and a RFU is sent out from the cables supplier. A RFU is to align documents between Wärtsilä and the cables supplier. Cables FAT is performed, and final documentation is created and delivered to Wärtsilä and O&M manuals.

The project engineers review the complete design. This is to find design mistakes before the installation starts, when there is still time to fix mistakes. For example, if cable glands are too small to fit the cable, correct size of glands can be arranged for, before the problem arises during installation.

The installation cables P2P list is distributed to the site for installation. The site engineers use the list for cable routing and termination. Changes to the design is marked on a red-pen cables P2P list. When installation is finished, the red-pen cables P2P is returned to the project engineers. The project engineers distribute the list to the engineering company, who updates the installation cables P2P list, according to the red-pen markings and an as-built cables P2P list is created. The as-built cables P2P list is delivered to the projects engineers and to O&M manuals. The list is also distributed to the control system supplier for input.

4.5 Communication and approval flow

Because one list is used throughout the entire project, it needs to be communicated between stakeholders in the right way. In addition, revision management needs to be done correctly to enable to track changes. Therefore, a communication plan for the cables P2P list is developed to ensure effective communications and elimination of problems. Applying the communication theories in Chapter 2.2.2, a communication plan is developed and illustrated in Figure 14.

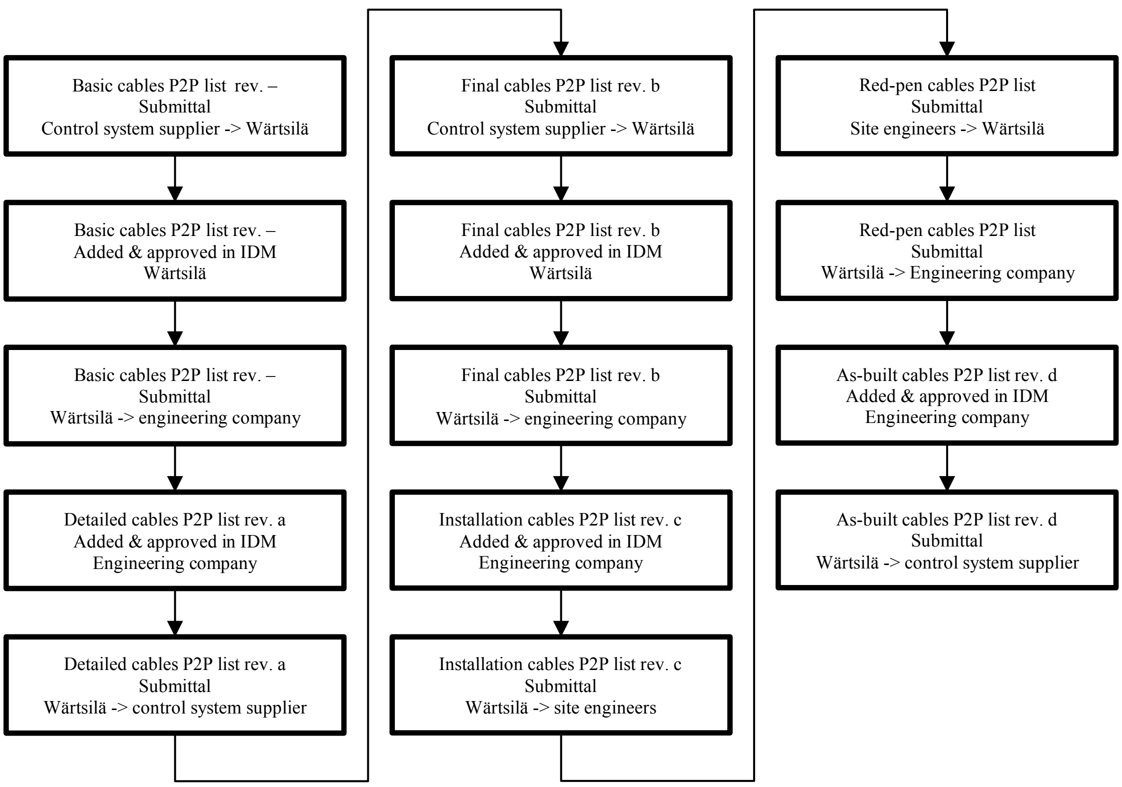

Figure 14: Cables P2P list communication and approval flowchart.

The control system supplier creates the basic cables P2P list, revision -, on the cables P2P list template. The list is delivered with the basic design documents to the project engineers. The project engineers add the list to IDM and approves the first revision. The list is distributed along with other engineering inputs to the engineering company.

The engineering company exports information from the list to their design software and begins the cables engineering. The cables engineering result is then imported back to the cables P2P list. Changes to the list are marked with a new revision letter and the changed cell with bold text. The engineering company adds the detailed cables P2P list to IDM as a new revision, revision a, and approves it. The project engineers are informed about the new revision and forwards it to the control system supplier.

The control system supplier is only interested in the cables that affect their system. By using the filter functionality, the control system supplier can easily filter out cables that affect them and check for changes. When manufacturing and FAT have been completed, changes are listed on the final cables P2P list. The list is delivered with the final design to the project engineers. The project engineers add the list to IDM as a new revision, revision b, and approve it. The project engineers distribute the final cables P2P list with the final design documents to the engineering company.

The engineering company exports the information from the list to their design software. Cables engineering is executed, and information is imported back to the cables P2P list. Changes are marked with a new revision letter, and the changed cell is marked with bold text. The engineering company adds the installation cables P2P list to IDM as a new revision, revision c, and approves it. The project engineers are informed about the new revision.

The installation cables P2P list is distributed to the site, with other installation documents. The site engineers use the list during installation and mark changes with red-pen markings. When the installation is finished, site engineers deliver the red-pen cables P2P list to the project engineers. The project engineers forward it to the engineering company, who updates the list according to red-pen markings. The engineering company adds the as-built cables P2P list to IDM as a new revision, revision d, and approves it. The engineering company informs the project engineers of the new revision and sends it to O&M documentation, who makes the O&M manual. The project engineers forward the as-built cables P2P list to control system supplier as feedback for the design.

4.6 Implementation

There is no point in developing a process unless it will be used. A development needs to be implemented, to be successful. Implementation of a change to an engineering team needs to be done correctly. People may resist change and needs to be convinced that change brings improvements. In this process there is also external stakeholders that needs to be taken into consideration, such as suppliers and the engineering company. By following the change management model in Chapter 2.2.3, case specific implementation instructions are set.

The first step when implementing a change is informing all effected people about the change. This is accomplished with a so-called change picture, a brief written explanation of how things will be after the change. Already before the process is finished and ready to be implemented, affected stakeholders need to be informed about what is under the development. At the same time opinions and concerns of the affected stakeholders are noted. Once the development of the cables P2P list and its associated process is finished, a change picture can be developed. The following change picture is created for the developed cables engineering process:

- Developed cables P2P list template will replace cable schedule as a master cable list. It will contain P2P data as well as cable routing information.

- Communication process between suppliers and the engineering company is developed around the cables P2P list and consist of two loops between the control system supplier and the engineering company.

- Project engineers distributes the list between the control system supplier and the engineering company.

- The engineering company is the master user of the cables P2P list, i.e. the only one allowed to make changes in it.

- Control system supplier creates the basic cables P2P list on the cables P2P list template. The control system supplier is responsible for cables regarding the control system.

- The engineering company adds all other cables to the list, calculates cable sizes and does the cable routing.

- The benefit with the cables P2P list is that project engineers can use the list as a tool to get a clear overview of the cables. Also, to be able to identify design mistakes before installation starts. Finally, installation and termination can be done entirely by using the list.

Once the process is finalized and the change picture is created, it can be communicated to all affected people. In this case, both internal people, project engineers and external people, suppliers and the engineering company are affected by the change. Communication to project engineers should be done face-to-face, preferably one-on-one meetings. Communications to suppliers and the engineering company should be carried out by face-to-face meetings with responsible persons. During the meetings, the change picture is presented, also the new cables P2P template and the developed process is briefly walked through.

When the change has been communicated to all affected people, the next step is to get affected people to take responsibility for the change. Project engineers, engineering company and control system supplier need to take responsibility for their part of the process. The project engineers need to be familiar with the way of working and how communication between stakeholders is done. The engineering company needs to be able to use the new template. The control system supplier need to make sure that based on the input from the consumer lists, MoPo list and other documents, they are able to create the first cables P2P list.

Once all stakeholders have taken responsibility for their part of the process, influential team members need to be enlisted to support the change. An influential team member is someone who is more experienced, someone who people look up to and ask for advice from, and most importantly someone who is supporting the change in the first place.

Roadblocks will certainly arise during the implementation. Once they are identified, they should immediately be minimized or eliminated. To identify all problems and roadblocks, a test run of an already executed project should be done. In this manner, problems that have not been thought of in the development process, might appear and can be eliminated.

Once all identified roadblocks are minimized or eliminated and a successful test run has been completed, a step-by-step implementation plan can be set. The following implementation plan is created for the current implementation:

- Presentation of the developed cables engineering process and announcing it will be affective for all new projects.
- Distribution of instructions, standard unit cables lists and templates to all stakeholders.
- Inform engineering company and control system supplier to start using the process and the cables P2P list for all new projects.

The final step is to monitor the implementation process, by establishing checkpoints. In this way, the progress can easily be monitored. If problems occur, adjustments need to be made and require immediate action to keep the implementation process on track. The following checkpoints are created for this implementation plan:

- First cables P2P list created by control system supplier and distributed to the engineering company.
- The engineering company has added cables and the cables P2P list is distributed to control system supplier.
- Control system supplier has made final updates to the cables P2P list and it is distributed back to the engineering company.
- The engineering company has made final updates to the cables P2P list and it is distributed to site for installation.
- Red-pen cables P2P list is returned from site and distributed to the engineering company.
- The engineering company has made as-built cables P2P list and the list is distributed to control system supplier and O&M manuals, project is executed.

Once all checkpoints have been accomplished and no further problems have occurred, the change has been successfully implemented.

5 Conclusion and summary

This chapter summarizes this thesis work. First, the meeting of the objectives and the answering of the research questions are evaluated. How the objectives are met and how the research questions have been answered is reviewed. Furthermore, findings and future developments ideas are proposed. Finally, the thesis is summarized, and benefits are highlighted.

5.1 Meeting objectives

The purpose of this thesis was to analyze the cables engineering process and the development of it. In addition, the purpose was the development of a new interconnection schedule containing P2P information. Part of the interconnection schedule development was to list standard unit cables for future reference and identifying typical missing cables from the design.

Based on the objectives, following research question were developed:

- What problems is there with the current cables engineering process?
- How to reduce problems and optimize the cables engineering process?
- What information is relevant for an interconnection schedule?
- What cables are always missing from the design and how to reduce these?
- How is the developed process implemented successfully and seamlessly without causing any problems to project execution?

The thesis work can be considered successful, because all research questions have been answered. The current cables engineering process was analyzed, and a developed process was proposed. A developed interconnection list was proposed containing useful information, during both the design and the installation phase in project execution. The typical missing cables were identified and a solution on how to reduce them is proposed. Finally, implementation instructions are developed for a seamless implementation of the development.

The current cables engineering process was analyzed and described. Similarities between the analyzed process and the seven-step model described in Chapter 2.2.1 are noted.

Therefore, the current process was a good starting point for the developed process. The developed process is a more optimized process with clear guidelines and a communication plan for the cables P2P list to ensure a correct information flow. The benefit with the developed process is that the project engineers have clear guidelines on how things should be done during project execution. Hence, problems with different drawings during FAT are eliminated. In addition, by adding a step in the process for review of the complete design, design problems can be identified before installation starts.

The interconnection list is developed based on the needs during project execution, but also taking into consideration the theories behind the connection lists. The developed interconnection list contains all the information needed for both design and installation. The benefits with the developed interconnection list is that all installations, cables routing and cable termination, can be done entirely by using the list. In addition, the list is a useful tool for the project engineers, who can get a clear overview of the cables and be able to identify problems already during the design phase. Hence, problems that are discovered during the design phase can be fixed before installation starts, which will save time and money compared to if it would be discovered at the site during installation.

Part of the interconnection schedule development was to list standard unit cables. By listing the standard unit cables on the developed cables P2P list template, engineering company can use the list as reference during the design, which will reduce manual work.

To be able to work out a solution for the typical missing cables from the design, a couple of executed projects were analyzed. By crosschecking designs with as-built drawings, design mistakes were noted. All analyzed projects had something in common, the interlocking cable between MV and LV systems. The proposed solution was to use the interlocking template for all projects. The combination of the standard unit cables reference list and the interlocking template should reduce the missing cables from the design.

Implementing a development in an organization requires change management. Implementation instructions for a seamless implementation were developed, based on the seven-step change management model described in Chapter 2.2.3.

5.2 Findings and proposed developments

During the process of analyzing standard unit electrical panels and cabling, a couple of things came to my mind. First, carrying out a standardization of terminal numbering in auxiliary systems electrical panels, i.e. having predefined terminals for internal cables, feeder cables and external cables. Most of the units require an electrical feeder and digital signals to the control system. These cables could have predefined terminal numbers in all auxiliary system panels. Currently panels designed by Wärtsilä have incoming feeder connected to strip X1 or straight to main breaker. All other cables are connected to strip X2. The following is a proposed solution for predefined strip and terminal numbers:

- Incoming feeder cables to use strip X1.
- Unit cables, internal cables, to use strip X2-X9.
- Emergency stop cables to use strip X10. For example, plant emergency shutdown to use terminals 1 and 2, local emergency shutdown to use terminals 3 and 4.
- External digital, potential free, signals to use strip X11. For example, common input to use terminal 1 and common alarm to use terminal 2.
- External analog signals to use strip X12.

Furthermore, this standardization could be suitable for both Wärtsilä designed panels, as well as units designed by suppliers.

During some interesting discussions about future developments of the electrical engineering process, I found that the cables engineering process could be developed even further. Now the cables P2P list is created quite early in a project, and, in the developed process, communicated two rounds between control system supplier and the engineering company. The list is not necessary this early in a project, only material lists are needed for purchasing purposes. The first communication round could be removed, due to the fact that standard cables are already known in the beginning of the project, based on what units are in the scope of supply. Therefore, the first cables list could be generated from the same database as the standard signals in MoPo list is generated from. This database is undergoing an update right now and this cable data could be added to it in the future.

The engineering company could also create the first basic cables P2P list including all cables. The engineering company would need to know the units included in the scope, and by using the unit standard cables P2P lists described in Chapter 4.2, standard cables can be listed for the project. In addition, if the engineering company creates the first list, cable sizes are calculated and correct from the beginning. The basic cables P2P list would include:

- From-to information.
- Cable number, category, type, construction, diameter, and function.

This list would be distributed to the control system supplier, before the detailed design phase, for verification. Once the FAT is completed and the final design is delivered, a detailed cables P2P list would be delivered alongside, by the control system supplier. The detailed cables P2P list would include:

- Verified basic information.
- Strip and terminal numbering.
- Terminal and gland sizes.

The list would be distributed to the engineering company, who would finalize the cables engineering. Resulting in a final cables P2P list including:

- Verified detailed information.
- References
- Cable lengths and routing data.

The process would continue, as the developed cables engineering process in Chapter 4.4. This process would only include one communication loop between the engineering company, Wärtsilä and the control system supplier.

5.3 Summary

To summarize, the results of this thesis work can be considered successful. The objectives were met, and research questions answered. Developed cables engineering process was proposed, including a developed interconnection list. Standard unit cables were listed for future reference. In addition, a solution for the typically missing cables was proposed. Finally, implementation instructions were set for seamless implementation of the developments.

The benefits with the developed process and interconnection list are first of all, that there are guidelines for how the cables engineering process is executed and how communication of cables engineering input between stakeholders should be carried out. Also, the developed process eliminates the problem with old revision drawings during FAT. Furthermore, the cables P2P list works as a tool for the project engineers, to get a clear overview of all cables and now they are able to identify design mistakes before the installation phase. Finally, the standard unit cables list reference will reduce manual work for the engineering company, and the combination with using the interlocking template for all projects, will reduce the risk of missing cables in the design.

The developed process is how things need to be done right now, to enable the use of the cables P2P list. The proposed future developments are the next step in the development of the cables engineering process, and the direction where things need to be heading to achieve operational excellence.

Due to the fact that a project takes a long time to execute, there was not enough time to do actual testing for a project. The control system supplier also needed to create some tools to be able to use the cables P2P list template and therefore no testing on an already executed project was possible to carry out during the time schedule. It will be interesting to see how the developed process will work during actual project execution. It remains to be seen if problems will arise that have not been taken into consideration during the development or if it will work smoothly. But, the most interesting part will be to see how the project engineers respond to the change, and if they see the benefits of it.

The electrical engineering process is quite complex in power plant projects. The process gets even more complicated when there are many different suppliers and engineering company, who all have to work in synchronization to achieve the desired result. There have been many variables to take into consideration and that is why the development of this process has been challenging. All in all, I am proud of my achievement, the result is satisfying, and the research has led to findings that enables a further development of the engineering process.

6 Bibliography

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Typical symbols used — Appendix 1

DC CABLE

CONTROL CABLE

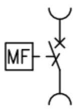
INTERLOCKING CABLE

CABLE

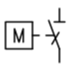

SYSTEM BOX


CABLE END

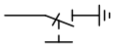
CIRCUIT BREAKER



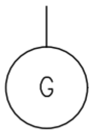
WITHDRAWABLE CIRCUIT BREAKER



MOTOR OPERATED DISCONNECTOR


MANUAL EARTHING KNIFE


TRANSFORMER



GENERATOR


AC/DC CONVERTER


MCB (MINIATURE CIRCUIT BREAKER)


MCCB (MOULDED CASE CIRCUIT BREAKER)

WÄRTSILÄ

- General
Energy Solutions

Doc. Classification: Internal

Title:	Cable schedule example	**DocID:** **Revision:**	DBAE795709 -
Author:	Mikael Huldin	**Sheets:**	1
Approved by:	Mikael Huldin / 25-Feb-2018	**Status:**	Approved
Project:	IN031 W-P EL&AUTOMATI		
Description:			
Type:	List		

CC=Cable conduit
CL=Cable ladder

Cable Number	From	To	Description	Cable Type	Conductors	Cable length	Revision	Routing Information						
11116	CFC011	BJA011	Fibre optic	50/125 SC/SC	50/125 SC/SC	55,6	-	CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-25/01
11121	CFC011	BLP011	Ethernet	CAT5e/FTP	CAT5e/FTP	26,2	-	CL337-01/01	CL302-06/01	CL347-01/01	CL348-01/01	CL302-01/01	CL302-02/01	CL302-03/01
11201	CFE011	BAG011	Feeder	1kV 2XY	4x2,5 rm	9,9	-	CL305-04/01	CL305-03/01					
51201	CFA901	BJE901	Digital input	75V 2XPiMF(St)Y	4x2x0.5	98,7	-	CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01
52303	CFA902	BJL901	Analog input	75V 2XPiMF(St)Y	12x2x0,5	21	-	CL403-05/01	CL403-06/01	CL331-01/01				
62008	BFA902	BJL901	Feeder	1kV 2XCY	3x2,5+2,5 rm	20,8	-	CL217-01/01	CL217-02/01	CL331-01/01				
71002	BEY901	CFC011	DC feeder	1kV 2XY	3G6 rm	23,8	-	CL302-05/01	CL302-04/01	CL347-01/01	CL302-06/01	CL337-01/01		
89016	BLN907	BLN910	Fire system cable	Fire line 750	2x1,5		-							
91001	BAG011	BAE011	MV cable	17,5 kV 2XSY	1x300 m/v	40,8	-	CL101-01/01	CC102-01/01	CC102-02/01				

WÄRTSILÄ

- General

Energy Solutions

Doc. Classification: Internal

Title:	Example Cables P2P list	**DocID:**	DBAE795708
		Revision:	-
Author:	Mikael Huldin / 25-Feb-2018	**Sheets:**	2
Approved by:	Mikael Huldin / 25-Feb-2018	**Status:**	Approved
Project:	IN031 W-P EL&AUTOMATI		
Description:			
Type:	List		

Create list

Internal system							Cable								External system								Routing information						
Ref.	From		Strip	Term.	Size	Gland	Number	Cat.	Type	Cons.	Length	Dia.	Core	Function / Signal	Gland	Size	Term.	Strip	To	Ref.	Rev.	Revision note							
CBG034715 01 A1(	CFC011		A2	2	SC	Mul	11116	FO	50/125 SC/SC	50/125 SC/S(	55,6		1	Fibre optic	Mul	SC	P5	A1	BJA011	CBG034715 01 A1(	-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-25/01
CBG034715 01 A1(	CFC011		A1	P1	RJ45	Mul	11121	ETH	CAT5e/FTP	CAT5e/FTP	26,2	5,1	1	Ethernet	Mul	RJ45	RJ45	RJ45	BLP011	TAD+RPT1/1	-		CL337-01/01	CL302-06/01	CL347-01/01	CL346-01/01	CL302-01/01	CL302-02/01	CL302-03/01
CBG034715 01 A1(	CFE011		X1	2T1		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	1	Phase 1	3,5-16,5mm		c	S1	BAG011	3AFP9073434/B	-		CL305-04/01	CL305-03/01					
CBG034715 01 A1(	CFE011		X1	4T2		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	2	Phase 2	3,5-16,5mm		b	S1	BAG011	3AFP9073434/B	-		CL305-04/01	CL305-03/01					
CBG034715 01 A1(	CFE011		X1	6T3		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	3	Phase 3	3,5-16,5mm		a	S1	BAG011	3AFP9073434/B	-		CL305-04/01	CL305-03/01					
CBG034715 01 A1(	CFE011		PE	PE		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	4	PE			PE	PE	BAG011	3AFP9073434/B	-		CL305-04/01	CL305-03/01					
CBG034715 01 A1(	CFA901		X103	25+	2,5/1,5	Mul	51201	CD	75V 2XPIMF(St)Y	4x2x0.5	95,7	10,6	1a	Common +	M25	2,5mm	1	X3	BJE901	10735-5210D0M0-(	-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01
CBG034715 01 A1(	CFA901		X103	25	2,5/1,5	Mul	51201	CD	75V 2XPIMF(St)Y	4x2x0.5	95,7	10,6	1b	Filter ready	M25	2,5mm	2	X3	BJE901	10735-5210D0M0-(	-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01
CBG034715 01 A1(	CFA901		X103	26	2,5/1,5	Mul	51201	CD	75V 2XPIMF(St)Y	4x2x0.5	95,7	10,6	2a	Cleaning active	M25	2,5mm	4	X3	BJE901	10735-5210D0M0-(	-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01
CBG034715 01 A1(	CFA901		X103	27	2,5/1,5	Mul	51201	CD	75V 2XPIMF(St)Y	4x2x0.5	95,7	10,6	2b	STU service	M25	2,5mm	6	X3	BJE901	10735-5210D0M0-(	-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01
CBG034715 01 A1(	CFA901		X103	28	2,5/1,5	Mul	51201	CD	75V 2XPIMF(St)Y	4x2x0.5	95,7	10,6	3a	Common alarm	M25	2,5mm	9	X3	BJE901	10735-5210D0M0-(	-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01
CBG034715 01 A1(	CFA901		PE	PE	2,5/1,5	Mul	51201	CD	75V 2XPIMF(St)Y	4x2x0.5	95,7	10,6	S	PE	M25	2,5mm	PE	PE	BJE901	10735-5210D0M0-(	-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01
CBG034715 01 A1(	CFA902		X104	21	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	1a	Pressure transmitter befor	M25	2,5mm	62	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X104	22	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	1b	Pressure transmitter befor	M25	2,5mm	63	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	1s	Screen	M25	2,5mm	TE	TE	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X104	25	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	2a	Pressure transmitter befor	M25	2,5mm	64	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X104	26	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	2b	Pressure transmitter befor	M25	2,5mm	65	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	2s	Screen	M25	2,5mm	TE	TE	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X103	14	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	3a	HFO temperature after HF	M25	2,5mm	66	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X103	16	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	3b	HFO temperature after HF	M25	2,5mm	67	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	3s	Screen	M25	2,5mm	TE	TE	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X103	13	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	4a	HFO temperature after HF	M25	2,5mm	68	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	4s	Screen	M25	2,5mm	TE	TE	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X104	29	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	5a	Pressure transmitter befor	M25	2,5mm	69	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X104	30	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	5b	Pressure transmitter befor	M25	2,5mm	70	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	5s	Screen	M25	2,5mm	TE	TE	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X104	33	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	6a	Pressure transmitter befor	M25	2,5mm	71	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X104	34	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	6b	Pressure transmitter befor	M25	2,5mm	72	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	6s	Screen	M25	2,5mm	TE	TE	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X103	22	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	7a	HFO temperature after HF	M25	2,5mm	73	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X103	24	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	7b	HFO temperature after HF	M25	2,5mm	74	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	7s	Screen	M25	2,5mm	TE	TE	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		X103	21	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	8a	HFO temperature after HF	M25	2,5mm	75	X2	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	8s	Screen	M25	2,5mm	TE	TE	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
CBG034715 01 A1(	CFA902		PE	PE	2,5/1,5	Mul	52303	CA	75V 2XPIMF(St)Y	12x2x0,5	21	20,5	S	PE	M25	2,5mm	PE	PE	BJL901	DBAE241067/a	-		CL403-05/01	CL403-06/01	CL331-01/01				
525535-2-111	BFA902	0103	F06	L1	1-6mm	Mul	62005	PLV	1kV 2XCY	3x2,5+2,5 rm	20,5	14	1	Phase 1	M25	6mm2	1	X1	BJL901	DBAE241067/a	-		CL217-01/01	CL217-02/01	CL331-01/01				
525535-2-111	BFA902	0103	F06	L2	1-6mm	Mul	62005	PLV	1kV 2XCY	3x2,5+2,5 rm	20,5	14	2	Phase 2	M25	6mm2	2	X1	BJL901	DBAE241067/a	-		CL217-01/01	CL217-02/01	CL331-01/01				
525535-2-111	BFA902	0103	F06	L3	1-6mm	Mul	62005	PLV	1kV 2XCY	3x2,5+2,5 rm	20,5	14	3	Phase 3	M25	6mm2	3	X1	BJL901	DBAE241067/a	-		CL217-01/01	CL217-02/01	CL331-01/01				
525535-2-111	BFA902	0103	PE	PE	1-6mm	Mul	62005	PLV	1kV 2XCY	3x2,5+2,5 rm	20,5	14	4	PE	M25	6mm2	PE	PE	BJL901	DBAE241067/a	-		CL217-01/01	CL217-02/01	CL331-01/01				
DOC069931 A.00/A	BEY901		F2.2	+	35mm	Mul	71002	PDC	1kV 2XY	3G6 rm	23,5	14	1	24V DC supply +	Mul		1	X9	CFC011	CBG034715 01 A1(	-		CL302-05/01	CL302-04/01	CL347-01/01	CL302-06/01	CL337-01/01		
DOC069931 A.00/A	BEY901		F2.2	-	35mm	Mul	71002	PDC	1kV 2XY	3G6 rm	23,5	14	2	24V DC supply -	Mul		2	X9	CFC011	CBG034715 01 A1(	-		CL302-05/01	CL302-04/01	CL347-01/01	CL302-06/01	CL337-01/01		
DOC069931 A.00/A	BEY901		PE	PE	35mm	Mul	71002	PDC	1kV 2XY	3G6 rm	23,5	14	3	PE	Mul		PE	PE	CFC011	CBG034715 01 A1(	-		CL302-05/01	CL302-04/01	CL347-01/01	CL302-06/01	CL337-01/01		
3AFP9073434/B	BAG011		B1	W1	M12	24-54n	91001	PMV	17,5 kV 2XSY	1x300 m/v	40,5	46,5	1	Phase 1_1		M12			BAE011	5736335-172/C	-		CL101-01/01	CC102-01/01	CC102-02/01				

Doc. Classification: Internal

WÄRTSILÄ

- General
Energy Solutions

Title:	Example Cables P2P list	**DocID:**	DBAE795708
		Revision:	-
Author:	Mikael Huldin / 25-Feb-2018	**Sheets:**	2
Approved by:	Mikael Huldin / 25-Feb-2018	**Status:**	Approved
Project:	IN031 W-P EL&AUTOMATI		
Description:			
Type:	List		

Revert to original | Cables routing list | Show cores | Clear Filters

Internal system							Cable									External system						Rev.	Revision note
Ref.	From		Strip	Term.	Size	Gland	Number	Cat.	Type	Cons.	Length	Dia.	Core	Function / Signal	Gland	Size	Term.	Strip	To		Ref.		
CBG034718 01 A1(	CFC011		A2	2	SC	Mul	11116	FO	50/125 SC/SC	50/125 SC/S(	55,6		1	Fibre optic	Mul	SC	P8	A1	BJA011		CBG034718 01 A1(	-	
CBG034718 01 A1(	CFC011		A1	P1	RJ45	Mul	11121	ETH	CAT5e/FTP	CAT5e/FTP	26,2	5,1	1	Ethernet	Mul	RJ45	RJ45	RJ45	BLP011		TAD+RPT1/1	-	
CBG034718 01 A1(	CFE011		X1	2T1		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	1	Phase 1	3,5-16,5mm		c	S1	BAG011		3AFP9073434/B	-	
CBG034718 01 A1(	CFA901		X103	25+	2,5/1,5	Mul	51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	1a	Common +	M25	2,5mm	1	X3	BJE901		10738-8210D0M0-(	-	
CBG034718 01 A1(	CFA902		X104	21	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	1a	Pressure transmitter befo	M25	2,5mm	62	X2	BJL901		DBAE241067/a	-	
528535-2-111	BFA902	0103	F06	L1	1-6mm	Mul	62008	PLV	1kV 2XCY	3x2,5+2,5 rm	20,8	14	1	Phase 1	M25	6mm2	1	X1	BJL901		DBAE241067/a	-	
DOC069931 A.00/A	BEY901		F2.2	+	35mm2	Mul	71002	PDC	1kV 2XY	3G6 rm	23,8	14	1	24V DC supply +	Mul		1	X9	CFC011		CBG034718 01 A1(	-	
3AFP9073434/B	BAG011		B1	W1	M12	24-54n	91001	PMV	17,5 kV 2XSY	1x300 m/v	40,8	46,5	1	Phase 1_1		M12			BAE011		8736338-172/C	-	

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- General

Energy Solutions

Doc. Classification:	Internal
Title:	Example Cables P2P list
DocID:	DBAE795708
Revision:	-
Author:	Mikael Huldin / 25-Feb-2018
Sheets:	2
Approved by:	Mikael Huldin / 25-Feb-2018
Status:	Approved
Project:	IN031 W-P EL&AUTOMATI
Description:	
Type:	List

Revert to original | Cables routing list | Hide cores | Clear Filters

Internal system							Cable														External system		
Ref.	From		Strip	Term.	Size	Gland	Number	Cat.	Type	Cons.	Length	Dia.	Core	Function / Signal	Gland	Size	Term.	Strip	To		Ref.	Rev.	Revision note
CBG034718 01 A1	CFC011		A2	2	SC	Mul	11116	FO	50/125 SC/SC	50/125 SC/S	55,6		1	Fibre optic	Mul	SC	P8	A1	BJA011		CBG034718 01 A1	-	
CBG034718 01 A1	CFC011		A1	P1	RJ45	Mul	11121	ETH	CAT5e/FTP	CAT5e/FTP	26,2	5,1	1	Ethernet	Mul	RJ45	RJ45	RJ45	BLP011		TAD+RPT1/1	-	
CBG034718 01 A1	CFE011		X1	2T1		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	1	Phase 1	3,5-16,5mm		c	S1	BAG011		3AFP9073434/B	-	
CBG034718 01 A1	CFE011		X1	4T2		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	2	Phase 2	3,5-16,5mm		b	S1	BAG011		3AFP9073434/B	-	
CBG034718 01 A1	CFE011		X1	6T3		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	3	Phase 3	3,5-16,5mm		a	S1	BAG011		3AFP9073434/B	-	
CBG034718 01 A1	CFE011		PE	PE		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	4	PE			PE	PE	BAG011		3AFP9073434/B	-	
CBG034718 01 A1	CFA901		X103	25+	2,5/1,5	Mul	51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	1a	Common +	M25	2,5mm	1	X3	BJE901		10738-8210D0M0-	-	
CBG034718 01 A1	CFA901		X103	25	2,5/1,5	Mul	51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	1b	Filter ready	M25	2,5mm	2	X3	BJE901		10738-8210D0M0-	-	
CBG034718 01 A1	CFA901		X103	26	2,5/1,5	Mul	51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	2a	Cleaning active	M25	2,5mm	4	X3	BJE901		10738-8210D0M0-	-	
CBG034718 01 A1	CFA901		X103	27	2,5/1,5	Mul	51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	2b	STU service	M25	2,5mm	6	X3	BJE901		10738-8210D0M0-	-	
CBG034718 01 A1	CFA901		X103	28	2,5/1,5	Mul	51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	3a	Common alarm	M25	2,5mm	9	X3	BJE901		10738-8210D0M0-	-	
CBG034718 01 A1	CFA901		PE	PE	2,5/1,5	Mul	51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	S	PE	M25	2,5mm	PE	PE	BJE901		10738-8210D0M0-	-	
CBG034718 01 A1	CFA902		X104	21	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	1a	Pressure transmitter befo	M25	2,5mm	62	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X104	22	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	1b	Pressure transmitter befo	M25	2,5mm	63	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	1s	Screen	M25	2,5mm	TE	TE	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X104	25	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	2a	Pressure transmitter befo	M25	2,5mm	64	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X104	26	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	2b	Pressure transmitter befo	M25	2,5mm	65	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	2s	Screen	M25	2,5mm	TE	TE	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X103	14	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	3a	HFO temperature after HI	M25	2,5mm	66	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X103	16	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	3b	HFO temperature after HI	M25	2,5mm	67	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	3s	Screen	M25	2,5mm	TE	TE	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X103	13	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	4a	HFO temperature after HI	M25	2,5mm	68	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	4s	Screen	M25	2,5mm	TE	TE	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X104	29	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	5a	Pressure transmitter befo	M25	2,5mm	69	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X104	30	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	5b	Pressure transmitter befo	M25	2,5mm	70	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	5s	Screen	M25	2,5mm	TE	TE	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X104	33	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	6a	Pressure transmitter befo	M25	2,5mm	71	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X104	34	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	6b	Pressure transmitter befo	M25	2,5mm	72	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	6s	Screen	M25	2,5mm	TE	TE	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X103	22	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	7a	HFO temperature after HI	M25	2,5mm	73	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X103	24	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	7b	HFO temperature after HI	M25	2,5mm	74	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	7s	Screen	M25	2,5mm	TE	TE	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		X103	21	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	8a	HFO temperature after HI	M25	2,5mm	75	X2	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		TE	TE	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	8s	Screen	M25	2,5mm	TE	TE	BJL901		DBAE241067/a	-	
CBG034718 01 A1	CFA902		PE	PE	2,5/1,5	Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	S	PE	M25	2,5mm	PE	PE	BJL901		DBAE241067/a	-	
528535-2-111	BFA902	0103	F06	L1	1-6mm	Mul	62008	PLV	1kV 2XCY	3x2,5+2,5 rm	20,8	14	1	Phase 1	M25	6mm2	1	X1	BJL901		DBAE241067/a	-	
528535-2-111	BFA902	0103	F06	L2	1-6mm	Mul	62008	PLV	1kV 2XCY	3x2,5+2,5 rm	20,8	14	2	Phase 2	M25	6mm2	2	X1	BJL901		DBAE241067/a	-	
528535-2-111	BFA902	0103	F06	L3	1-6mm	Mul	62008	PLV	1kV 2XCY	3x2,5+2,5 rm	20,8	14	3	Phase 3	M25	6mm2	3	X1	BJL901		DBAE241067/a	-	
528535-2-111	BFA902	0103	PE	PE	1-6mm	Mul	62008	PLV	1kV 2XCY	3x2,5+2,5 rm	20,8	14	4	PE	M25	6mm2	PE	PE	BJL901		DBAE241067/a	-	
DOC069931 A.00/	BEY901		F2.2	+	35mm	Mul	71002	PDC	1kV 2XY	3G6 rm	23,8	14	1	24V DC supply +	Mul		1	X9	CFC011		CBG034718 01 A1	-	
DOC069931 A.00/	BEY901		F2.2	-	35mm	Mul	71002	PDC	1kV 2XY	3G6 rm	23,8	14	2	24V DC supply -	Mul		2	X9	CFC011		CBG034718 01 A1	-	
DOC069931 A.00/	BEY901		PE	PE	35mm	Mul	71002	PDC	1kV 2XY	3G6 rm	23,8	14	3	PE	Mul		PE	PE	CFC011		CBG034718 01 A1	-	
3AFP9073434/B	BAG011		B1	W1	M12	24-54n	91001	PMV	17,5 kV 2XSY	1x300 m/v	40,8	46,5	1	Phase 1_1		M12			BAE011		8736338-172/C	-	

Cables P2P list with cables routing list view

Appendix 6

WÄRTSILÄ

- General

Energy Solutions

Doc. Classification: **Internal**

Title:	Example Cables P2P list	**DocID:**	DBAE795708
		Revision:	-
Author:	Mikael Huldin / 25-Feb-2018	**Sheets:**	2
Approved by:	Mikael Huldin / 25-Feb-2018	**Status:**	Approved
Project:	IN031 W-P EL&AUTOMATI		
Description:			
Type:	List		

Revert to original

Cables P2P list

Clear Filters

Internal system			Cable							External system			Rev.	Revision note	Routing information						
From		Gland	Number	Cat.	Type	Cons.	Length	Dia.	Function / Signal	Gland	To										
CFC011		Mul	11116	FO	50/125 SC/SC	50/125 SC/S	55,6		Fibre optic	Mul	BJA011		-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-25/01
CFC011		Mul	11121	ETH	CAT5e/FTP	CAT5e/FTP	26,2	5,1	Ethernet	Mul	BLP011		-		CL337-01/01	CL302-06/01	CL347-01/01	CL348-01/01	CL302-01/01	CL302-02/01	CL302-03/01
CFE011		Mul	11201	CC	1kV 2XY	4x2,5 rm	9,9	12	Phase 1	3,5-16	BAG011		-		CL305-04/01	CL305-03/01					
CFA901		Mul	51201	CD	75V 2XPiMF(St)Y	4x2x0.5	98,7	10,6	Common +	M25	BJE901		-		CL402-01/01	CL402-02/01	CL402-03/01	CL402-04/01	CL402-05/01	CL402-06/01	CL301-23/01
CFA902		Mul	52303	CA	75V 2XPiMF(St)Y	12x2x0,5	21	20,5	Pressure transmitter befo	M25	BJL901		-		CL403-05/01	CL403-06/01	CL331-01/01				
BFA902	0103	Mul	62008	PLV	1kV 2XCY	3x2,5+2,5 rm	20,8	14	Phase 1	M25	BJL901		-		CL217-01/01	CL217-02/01	CL331-01/01				
BEY901		Mul	71002	PDC	1kV 2XY	3G6 rm	23,8	14	24V DC supply +	Mul	CFC011		-		CL302-05/01	CL302-04/01	CL347-01/01	CL302-06/01	CL337-01/01		
BAG011		24-54r	91001	PMV	17,5 kV 2XSY	1x300 m/v	40,8	46,5	Phase 1_1		BAE011		-		CL101-01/01	CC102-01/01	CC102-02/01				