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Development and standardization of Cleats and Leads process

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ABSTRACT:
Cleats and Leads (C&L) team want to have a process standard instruction to use in every project. C&L team is one of the design teams in mechanical engineering subdepartment in Hitachi Energy Transformers Vaasa. At the same time, when creating the process instruction, the target is to find the biggest areas for development in the C&L process, which would need to be included in the process instruction. For the process instruction, the target was also to find a way to make a flowchart of the process according to global standards, from scientific sources. Also, the functionality of the process standard and C&L process developments needed to be tested.

The C&L team is responsible for C&L design. The C&L team designs the internal conductors of power transformers with their supporting components inside the main tank of the power transformer. C&L engineers create 3D models, drawings and Bill of materials (BOM) for C&L phase. The C&L engineers also make production instructions for each project. The conductors consist of, for example, copper cables and copper or aluminum busbars.

For the C&L process standard flowchart, the global standard symbols and three good process flowchart examples were found and used for reference. To find the most important development areas in C&L process, interviews were conducted with engineers in the mechanical department, mainly the C&L engineers. Based on the results of the interviews, the development projects that will be implemented in the thesis were selected.

Three development works were made based on research. First development was the creation of a C&L standard part library, which contains all reusable non-project specific components recorded and easily accessible for every project in C&L design. Second development was to create template folders for C&L projects, which will help with the C&L process efficiency. Third development was to develop a C&L 3D base model (Shrinkwrap), which allows for automatic geometry updates around C&L components, which significantly reduces quality issues. A plain C&L process standard instruction was created, which includes the development work made in the thesis. The functionality of the process standard and development works was tested in a pilot project, with positive results.

KEYWORDS: process, C&L, development, standard, instruction

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TIIVISTELMÄ:
Cleats and Leads (C&L) -tiimi haluaa prosessistandardiohjeistuksen käytettäväksi jokaisessa C&L projektissa. C&L-tiimi on yksi Hitachi Energy Transformers Vaasan mekaanisensuunnittelun alaosaston suunnittelutiimeistä. Samanaikaisesti prosessiohjetta luotaessa tavoitteena on löytää C&L-prosessin suurimmat kehityskohteet, mitkä tulisi sisällyttää prosessiohjeeseen. Prosessiohjeen osalta tavoitteena oli myös löytää tapa laatia prosessin vuokaavio globaalien standardien mukaisesti tieteellisistä lähteistä. Lisäksi prosessistandardin ja C&L-prosessin kehitysten toimivuus oli testattava.

C&L-tiimi vastaa C&L-suunnittelusta. C&L-tiimi suunnittelee tehomuuntajien sisäjohtimet tukikomponentteineen tehomuuntajan pääsäiliön sisällä. C&L-insinöörit luovat 3D-malleja, piirustuksia ja osaluetteloita (BOM) C&L-vaiheelle. C&L-insinöörit laativat myös tuotanto-ohjeet jokaiselle projektille. Sisäjohtimet koostuvat esimerkiksi kuparikaapeleista ja kupari- tai alumiinikiskoista.

C&L-prosessin standardivuokaaviota varten etsittiin globaalit standardisymbolit ja kolme hyvää prosessivuokaavioesimerkkiä, joita käytettiin verrokkina. C&L-prosessin tärkeimpien kehitysalueiden löytämiseksi haastateltiin mekaanisen osaston insinöörejä, pääasiassa C&L-insinöörejä. Haastattelujen tulosten perusteella valittiin opinnäytetyössä toteutettavat kehitystyöt.

Kolme kehitystyötä tehtiin tutkimukseen perustuen. Ensimmäinen kehitystyö oli C&L standardiosakirjaston luominen, joka sisältää kaikki uudelleenkäytettävät, ei-projektikohtaiset komponentit tallennettuina ja helposti saatavilla jokaista C&L-suunnitteluprojektia varten. Toinen kehitystyö oli luoda mallikansioita C&L-projekteille, mikä tehostaa C&L-prosessia. Kolmas kehitystyö oli kehittää C&L järjestelmän 3D-pohjamalli (Shrinkwrap), mikä mahdollistaa automaattiset geometrian päivitykset C&L-komponenttien ympärille, mikä vähentää merkittävästi laatuongelmia. C&L-prosessille luotiin selkeä standardiohje, joka sisältää opinnäytetyössä tehdyt kehitystyöt. Prosessistandardin ja kehitystyön toiminnallisuutta testattiin pilottiprojektissa positiivisin tuloksin.

AVAINSANAT: process, C&L, development, standard, instruction

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Akseli Myllymäki. Vaasa, 26. January 2026.

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Abbreviations

3D model	3-dimension model, created with modelling software products.
asm.	Assembly. Creo file format.
AutoCAD	Autodesk's software application.
BOM	Bill of materials.
C&L engineer	Cleats and leads team member.

C&L team	Cleats and leads team. Mechanical design subdepartment team.
C&L phase	Cleats and leads phase. Designing and its related production phase.
C&L process	Cleats and leads process. Different phases involved in the C&L design and production phase.
C&L project	Single cleats and leads project
CT	Current transformer.
DWG	Drawing. A file format.
MDS	Mechanical Design System. Hitachi Energy's PDM software product.
HR	Human resources. Hitachi Energy Transformers Vaasa department.
HV	High voltage.
LV	Low voltage.
OLTC	On-load tap changer.
PDF	Portable document format. A file format.
PDM	Product data management. software environment.
PLM	Product lifecycle management. software package.
PLM Windchill	PTC's PLM software product.
prt.	Part. Creo file format.
PTC	Parametric technology corporation. Software company.
R&D	Research and development. Hitachi Energy Transformers Vaasa department.
SCM	Supply chain management. Hitachi Energy Transformers Vaasa depdepartment.
TC	Tap changer.
xECM	Hitachi Energy Transformers Vaasa's internal database for instructions.

Greek symbols

Φ	Magnetic flux.

Other symbols

I	Electric current.
N	Number of revolutions.
P	Electrical power.
U	Voltage.

1 Introduction

Even if it is not noticed, in everyday work, in the work of every field, a person uses some kind of practical standard in the progress of their own work process. These practical standards will most likely differ in some way between different people, even if they work in the same team and even if the job description is the same. It would be beneficial for every organization's business process to be based on some kind of standard. Then, within the organization, it is possible to follow some kind of common thread among different employees. According to the British Standards Institution, (2025) there are five reasons to why standards matter to organizations, which are:

1. Standards boost your productivity
2. Standards support better outputs
3. Standards enable innovation
4. Standards facilitate global trade
5. Standards are tools for sustainability

Hitachi Energy Transformers Vaasa has an engineering department. The engineering department has a mechanical engineering subdepartment. The mechanical engineering subdepartment has a Cleats and Leads (C&L) team. Cleats in the thesis' context means some kind of support structure components for internal conductors, for example wooden or pressboard supports. Leads in the thesis' context means internal conductors, typically cables and busbars.

The C&L team consist of multiple engineers, where about half of are working in Vaasa and other half in Poland. However, every engineer in the C&L team are doing design projects for the Vaasa Transformers factory, which is located in Vaasa Finland. Engineers within the C&L team work on projects without a written process standard. C&L engineers still practically understand the C&L process flow and know in which order each phase of the process should be done. C&L engineers often differ in how and in what order they do their projects. In addition, the engineering methods can differ slightly or more from each other. This makes it difficult to keep track of where everyone's project is at within the team. A new employee for the C&L team needs the clearest possible instructions when starting their new job. Additionally, it is more challenging for other departments, subdepartments and engineering teams to collaborate with the C&L team because of the differences with engineering methods within the C&L team.

Continuous development of business and internal organizational practices is also key to ensuring that business is sustainable. Without discovering and implementing new development ideas, an organization is more likely to fall behind its competitors. The quality of processes affects output. Output affects customer satisfaction and the company's market value. According to the Harvard business school's research, written by Bussgang and Clemens, (2018) there are four different benefits listed for companies who continuously develop their organization, which are:

1. Faster time-to-market
2. Run more experiments
3. Fix errors faster
4. Maximize engineering productivity

Hitachi Energy Transformers Vaasa is implementing PLM Windchill in the future, which focuses on systematic and clear progress in every project's process. PLM Windchill is PTC's Product Lifecycle Management (PLM) software product. PLM means product lifecycle management. PLM Windchill enables information and modification sharing in real-time between organization's different functions, which will improve working efficiency (PTC, n.d. -b). PLM Windchill implementation requires many changes in working methods for every department inside the Vaasa Transformers unit.

The PLM Windchill implementation has already required a lot of changes to the C&L team's engineering methods, but it was known before the thesis that there were still some changes to be made before implementation. Other development areas were also known before the thesis' research was conducted, which are not necessarily related in any way to the Windchill implementation, but only to the design quality. Future implementation of Windchill, lack of a clear process standard and desire to improve design quality and efficiency are reasons why this thesis is made. This thesis is made for the mechanical engineering subdepartment, more specifically the C&L team. In ideal situation the thesis' research would find as many important development areas as possible, the most important of which will be implemented into practice and a new C&L process standard will be drawn up that is as functional, useful and above all as clear as possible, which all C&L team members would follow.

1.1 Main research questions

The thesis has four main research questions, which are the following:

1. What are the most essential development areas within the C&L process?
2. Which development areas will be implemented?
3. What are the different phases of the C&L process?
4. What kind of process flowchart is developed for the creation of a C&L process standard?

First, the most important development areas within the C&L process must be identified. The identified areas will then be implemented and included in the new standard process instruction.

Thesis will explore what the most important development areas are in the C&L process. Development ideas can relate to all kinds of things within the C&L process, such as 3D modelling, creating instructions, or even communication. The most important development areas will be identified by interviewing mechanical design engineers. The interviews target is to find out what each interviewee considers to be the most important development areas inside the C&L process. All C&L team members and some personnel from other mechanical design teams will be interviewed. The results of all interviews will be recorded and written down. After interviews the interview results will be compiled into single list.

The results of the interviews are used to identify the most common and critical areas for development. Once the most important development targets have been identified, it will be decided which development areas will be implemented in the C&L process. Choices are made based on what is seen as most important, i.e. what presents the most challenges and what are potentially the most important development areas for the Windchill implementation. The choices are also based on whether they are possible to implement and include in this thesis, given the time frame in which the thesis is being done. The answer to how development areas can be implemented will also be investigated.

The current C&L process needs to be examined at every stage of the process. First, what needs to happen before the C&L phase so that the C&L process can be done. What needs to be accomplished from the C&L process? Each step within the C&L process needs to be clarified. What happens during each step and in what order they should be. The process of the C&L design phase is already practically known before making the thesis, but it needs to be written down in the standard.

It is necessary to decide what kind of process flowchart would be used when creating a standard process. Research will be done to decide on a process flowchart and an attempt will be made to find global examples and standards that could potentially be used when creating a process standard. Based on the process model examples and the obtained subprocess steps, a standard process is formed that would follow global standard process guidelines, if possible.

1.2 Targets of the thesis

The first main target of the thesis is to clarify and implement the most important development areas within the C&L design process. The target should be achieved by finding out the answers to the 1st and 2nd main research questions of the thesis from the beginning of chapter 1.1. The target is achieved if the improvements made in the development work were successful and have been implemented. Also, a process chart about this thesis will be made, which will help to visualize the process.

The second main target is to make a standard instruction for the C&L process that all C&L team members will follow in C&L projects. The development areas will be included in the new C&L process standard instruction. The target can be achieved by finding out the answers to the 3rd and 4th main research questions of the thesis. The target has been achieved if the process instruction has been implemented and made sufficiently useful for C&L team.

The third main target is to test the functionality of the development implementations to the pilot project by doing it according to the new C&L process standard instructions. The 3rd main target is achieved if the project can be completed according to the new instructions, preferably without major challenges.

1.3 Structure of the thesis

The work in the thesis is a Research and development (R&D) project. In a R&D project, the target is to develop improved products and services. In this thesis, it means development work for the C&L design phase. The research phase in this thesis is the identification of development targets and process models. In this thesis, the development phase means implementation of the development areas, testing and verifying their functionality, and creating instructions on how to use them.

At the beginning of the thesis, in chapter 1 it was explained why the research is important and relevant, as well as for whom the thesis is being conducted and why. After this, chapter 2 talks about the company for which the thesis is being done. Chapter 3 talks about the product for which the thesis is being done. Chapter 4 examines what a process is and what its function is in this work. Chapter 5 delves into what R&D means and studies what an R&D project includes. Chapter 5 also studies what R&D project’s process structure is generally, according to globally available examples. Chapter 6 introduces the engineering process inside the Vaasa Transformers unit. Chapter 7 talks about the C&L phase, what kind of team the thesis is being done for, what is included in the C&L process before the thesis and what is the area of responsibility for the C&L team. Chapter 8 presents the tools used in the work.

Chapter 9 moves on to the practical side of the thesis, which first reports on how the interviews were conducted and their results, and presents the different process models that were found in the research work. Chapter 10 Presents the thesis' process chart, based on the research. Chapter 11 reports on the implementation of selected development work. Chapter 12 reports the making of the new C&L process standard instruction, what is the structure of the instruction and what is included in each chapter of the instruction. In chapter 13 a pilot project will be made according to the new C&L process standard instruction, to test the functionality of the process instruction. Chapter 13 also reviews the results of the thesis, compared with the targets of the thesis. Final chapters 14 and 15. Concludes and summarizes the thesis, as well as mentioning possible future development plans.

2 Hitachi Energy

Hitachi is a large Japanese technology company with many energy solutions and subsidiaries. Hitachi Energy is one of the subsidiaries of Hitachi. Hitachi Energy is a global modern technology company with sustainable and renewable energy products. Hitachi Energy provides solutions to accelerate the energy transition and strives to deliver customer success (Hitachi Energy Finland Ltd. 2025a). Hitachi Energy is a global leader in power technologies and energy systems. Hitachi Energy provides solutions across a range of industries, including power, transportation and IT, including data centers, industry and the Smart Life sector. Hitachi Energy operates in five global business units in 60 countries. Hitachi Energy's headquarter is located in Zurich, Switzerland. Hitachi Energy units are divided into five different categories, which are Grid automation, Grid integration, High voltage products, service and Transformers and Hitachi Energy has multiple units around the world, in every of those categories (Hitachi Energy Finland Ltd. 2025a).

In 2020, Hitachi acquired most of the Power Grids business, which was previously owned by ABB. The Power Grids business includes the Vaasa transformer factory. In 2022, Hitachi acquired the last shares in Power Grids from ABB, and the Vaasa transformer factory has been fully owned by Hitachi since then. The Vaasa Transformers unit has manufactured power transformers and reactors in Finland since 1914. The Vaasa Transformers unit has a total of approximately 350 employees (Hitachi Energy Finland Ltd. 2025b). The Vaasa Transformers unit manufactures power plant transformers, special power transformers and reactors. Special power transformers include furnace, rectifier, ship and offshore (oil and gas) transformers (Hitachi Energy Finland oy, 2025). The unit also manufactures transformers for frequency converters and railway electrification networks. The unit organization consists of several different departments, such as sales, engineering, project management, quality, supply chain management, research and development (R&D), human resources and finance (Hitachi Energy Finland Ltd. 2025b). The Vaasa Transformers unit is also responsible for the maintenance of transformers in Finland. There are three main subdepartments in the Engineering department in Vaasa

Transformers unit, which are electrical engineering, mechanical engineering and control engineering. There are also three production lines for different types of power transformers.

3 Power transformer

This chapter reviews the product on which the thesis is being conducted, which is a power transformer. Since the thesis involves developing the design process of a power transformer, as an R&D project it is important to understand the product's basics. These basics include the technical and structural aspects of the power transformer. It is important to know the basics of the product to understand the research and detailed developments in the thesis. In chapter 3.1, the thesis introduces power transformer technical specifications and chapter 3.2 the structure of the power transformer.

3.1 Power transformer technical specifications

A power transformer has a high voltage (HV) and low voltage (LV) side, also called the primary and secondary sides (Hitachi Energy Transformers, 2025). As the name suggests, the high voltage side has a higher voltage level than the low voltage side, while the low voltage side has a higher current level. Input power (P_1 or P_2) can be supplied to either the high voltage or low voltage side, which creates a magnetic flux (Φ) in the iron core. When the magnetic flux passes through the opposite winding of the input side, if the core is the same, a voltage U_2 is induced in the opposite winding. When electrical energy goes through the power transformer, the electrical energy is first converted to magnetic energy and then vice versa. The primary and secondary voltage levels (U_1 and U_2) are directly proportional to the number of turns of the windings (N_1 and N_2), while the primary and secondary currents (I_1 and I_2) are inversely proportional. This is called the ratio of a power transformer {$(U_1 / U_2) = (N_1 / N_2) = (I_2 / I_1)$}. The output power P_2 can be connected to the desired application with correctly radiated power and voltage levels. Figure 1 refers to this process.

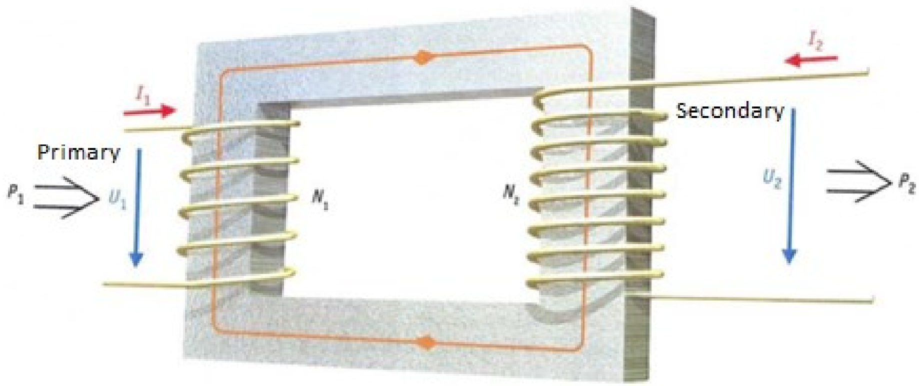


Figure 1. Operating principle of the power transformer (Adapted from Hitachi Energy Transformers, 2025).

Voltage levels are constantly changing in some applications, such as in the power grid, due to resistance and losses, which leads to voltage drop (Hitachi Energy Transformers, 2025). For this reason, it is necessary to be able to adjust the voltage to maintain the secondary voltage U_2. Adjustment is usually done by changing the number of turns on the high voltage side or the N_1 side of the power transformer due to the ratio $\{U_2 = (U_1 \cdot N_2) / N_1\}$. When using this formula, it can be concluded that as the number of turns on the high voltage side (N_1) increases, the voltage level on the low voltage side (U_2) decreases. If the number of turns on the high voltage side (N_1) decreases, the voltage level on the low voltage side (U_2) increases.

3.2 Structure of the power transformer

The structure of a power transformer can be divided into three areas, which are internal and external components and the control system. The internal components can be considered as the active area of the power transformer, because that is the area where the electric current is moving inside the power transformer. The internal parts consist of the iron core, windings, tap changer (TC), on-load tap changer (OLTC) and internal conductors. The internal components are located inside the power transformer's tank. The external components can be considered as the power transformer's body, which are placed around the internal components. The external components consist of the main tank, tank cover, expansion tank, bushings, cooling system, control cabinets, protection and monitoring devices, external conductors and other additional components. After the internal components are assembled inside the power transformer tank, the tank is filled with transformer oil. The type of oil is typically dielectric oil (Hitachi Energy Transformers, 2025), but synthetic ester fluids are also used. Figure 2 illustrates the basic structure of a power transformer.

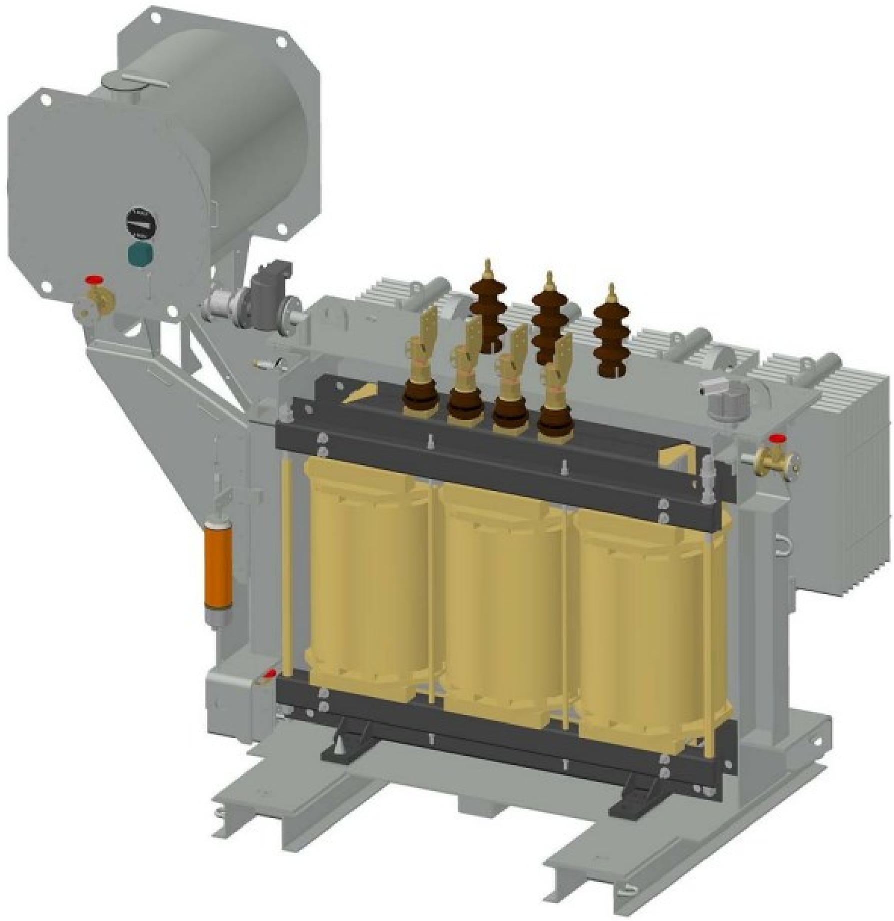


Figure 2. Power transformer (Adapted from Hitachi Energy Transformers, 2025).

3.2.1 Internal components

The power transformer core is made of grain-oriented electrical steel with laminated sheets stacked on top of each other. The function of the core is to allow the magnetic flux to pass through the desired windings (Hitachi Energy Transformers, 2025). The core has vertically placed columns. A three-phase power transformer has three columns, while a single-phase transformer has two. The columns are connected to each other by a lower and upper yoke, which are also made of similarly oriented electrical steel sheets. The magnitude of the cross-sectional area of the iron core depends on the power rating of the power transformer.

The power transformer windings are placed around the core's columns. A power transformer always has high-voltage and low-voltage windings, but a special power transformer may have several low-voltage windings to adjust the voltage level on the high-voltage side. (Hitachi Energy Transformers, 2025). The high-voltage side may also have a regulating winding, which would be attached as an extension component around the high-voltage winding. The windings of power transformers are vertical, concentric cylinders. The windings are made of electrical copper or electrical aluminum. The conductors may be square bar wound into a spiral or radially rolled conductor sheets.

The on-load tap changer (OLTC) and the tap changer (TC) can be used to change the ratio of a power transformer. Typically, there is either an OLTC or a TC inside the power transformer, depending on the size of the power transformer and the magnitude of the technical values. OLTC is typically used when the power transformer has a regulation winding. The taps of the control winding are connected to the OLTC with a copper cable. TC's can be used in several cases.

The internal conductors of a power transformer are done by attaching the winding outputs to the bushings. The function of the internal conductor is to transfer the current through the bushing, winding, TC's and OLTC's (Hitachi Energy Transformers, 2025). The power transformer is separately connected with conductors on the low voltage and high voltage sides. The conductors can be either copper cables or busbars (usually made of copper or aluminum). When the current levels are too high for the resistance of the cable, which can happen especially on the low voltage side, busbars will be used instead of cables. However, cables are generally preferred over busbars, if possible.

3.2.2 External components

The power transformer tank functions as the power transformer body. The tank also operates as the oil tank and includes radiators. It must withstand environmental stress caused by alternating outside conditions (Hitachi Energy Transformers, 2025). The tank must also have the necessary cooling surface area or be equipped with an external cooling system. It must also be compact enough for the power transformer oil. The tank is filled with power transformer oil, once all the power transformer components are assembled.

The function of the expansion tank is to operate as an expansion space for the power transformer oil (Hitachi Energy Transformers, 2025). When the temperature of the power transformer oil changes, its volume changes more than the volume of the tank. Due to the change in volume, the height of the oil surface changes, which occurs inside the expansion tank. The expansion tank is located above the power transformer tank.

The function of bushing is to connect the power transformer to the desired applications. They also operate as an insulator for internal conductor connections from the windings, connecting cable and other cover parts that have zero electrical potential (Hitachi Energy Transformers, 2025). Bushings are typically installed on the cover of the power transformer, but they can also be located in the tank wall.

The power transformer can also have other additional components such as a cooling system and current transformers (CTs). The cooling system may consist of external radiators with natural oil, or air flow radiators with forced air flow. The cooling system may also consist of coolers with forced oil and forced cooling liquid. The cooling liquid is usually water. CTs can be used to modify and measure the alternative current that goes through the CT. CT is also a protection device.

The control system consists of protection and monitoring devices and external conductors. All these devices are protection and safety components. Protection and monitoring devices can be, for example, oil level sensors. External wiring is located outside the power transformer. External conductors connect the devices to the terminal boxes. The customer connects his external system to the terminal boxes.

4 Process

A process is an organized set of interrelated activities that together transform one or more inputs. A process transforms inputs into outputs. Output can be, for example, value to customers (Hessing, 2025), or value to internal processes within a company. In other words, a process is an activity or activities that have inputs and adds value and provides output to internal or external customers. The output of single process is often the input for another process. A process is a set of activities that interact with each other, activities that are related to a critical process should be documented and monitored. All actions taken on an individual, group or organizational level are always a certain kind of process. The bigger the process, or the larger the group involved, the more steps there are likely to be inside the process. For example, going to the store is a process and a customer project in a company is a process. Figure 3 Gives a simple example of a process' structure chart, which is adapted from Hessing's (2025) article.

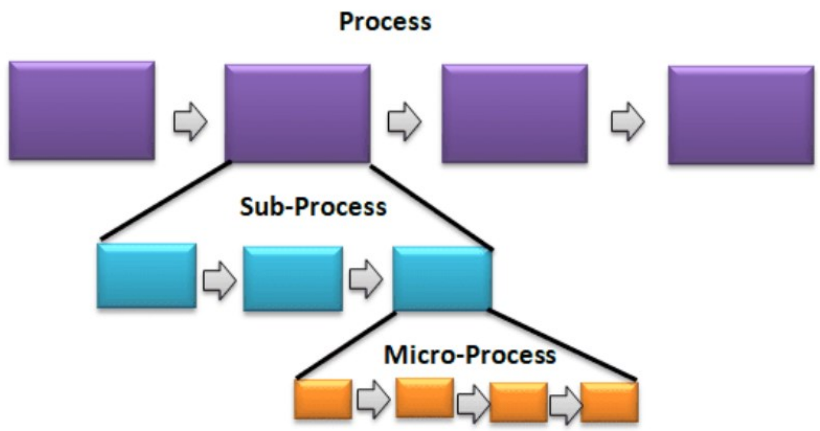


Figure 3. Simple process model (Adapted from Hessing, 2025).

Figure 3 shows how a process is divided into multiple processes, subprocesses and even micro-processes. All of these are different steps of the whole process. The term "process" is somewhat a problematic term to be used inside a process because it is easy to confuse what is meant by the entire process and the processes within the process when the same term is used in both. It is therefore important to clearly distinguish between processes and subprocesses so that it is as clear as possible to view the entire process.

5 Research and development

This chapter explains the type of this thesis, which is a Research and development (R&D) project. First, chapter 5.1 thesis explains what R&D means. Chapter 5.1 also studies what kind of R&D project is based on scientific sources and explains what type of R&D project this thesis is. It is important to understand how an R&D project is defined, in global sources, to know how a thesis is written and why its structure is how it is. In chapter 5.2 the thesis reviews one example of the R&D project's process, which is also compared to the thesis' process. Chapter 5.2 helps to understand the order in which the phases of the thesis are made and what everyone's role is in the thesis compared to the example.

5.1 Research and development project

R&D is a valuable tool for growing and developing companies, (Queensland government, 2025). R&D involves studying market and customer needs and developing new and better products and services to meet those needs. Companies that have an R&D strategy have a greater chance of success than those that do not. An R&D strategy can lead to innovation and productivity gains and can improve your company's competitive advantage. However, R&D projects are also made based on when problems are identified inside the company, for example in efficiency, tools or equipment functionality. R&D projects can therefore be external or internal. External R&D projects are typically customer projects and internal R&D projects are made to develop the internal process of the organization. This thesis is an internal R&D project for Hitachi Energy.

5.2 Research and development project's process

R&D projects can be done by smaller or larger groups of personnel, depending on the project. Bigger technology companies usually have a separate R&D department, whose focus is completely on the internal or external R&D projects within the company. R&D process usually consists of researchers, development workers, testers and even customers depending on whether the project is internal or external. Gleek's (2025) flowchart example in Figure 4 describes a R&D project's process.

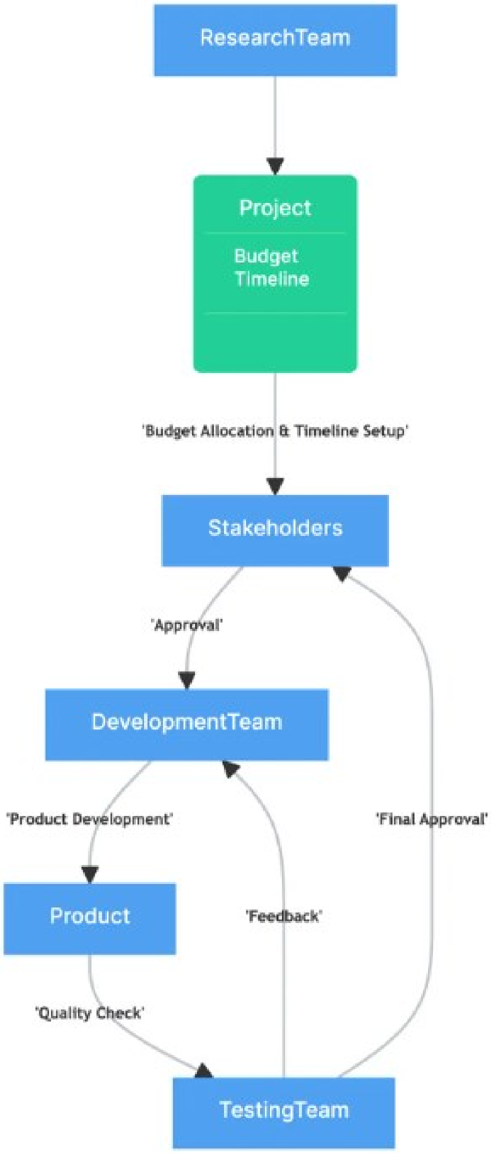


Figure 4. R&D project's process chart (Adapted from Gleek, 2025).

"ResearchTeam" in the Figure 4 are group of personnel or individuals, who are responsible for the research work and starting the R&D project (Gleek, 2025). They set a timeline budget and other critical initial information regarding the project. "Stakeholders" are involved in the "Budget allocation and timeline setup" step, where they approve the progress of the project. After the “Stakeholders” have approved the progress of the project the “Development team” can start to do the product development works to develop the actual “Product”, in a collaboration with the “ResearchTeam”. After the “Product” has been developed, the “TestingTeam” can start to do the Quality checking tests. “TestingTeam” feedback to the “DevelopmentTeam”. “DevelopmentTeam” will make corrections for the product according to the feedback if necessary. Finally, the “TestingTeam” seeks to get a final approval from the “Stakeholders” of the result. When comparing the Gleeks (2025) R&D process flowchart example in Figure 4 to the thesis’ process there are many similarities between. The differences are that the “ResearchTeam”, the “DevelopmentTeam” and the “TestingTeam” is the writer of the thesis. The “Stakeholders” are the supervisors of the thesis. Thesis does not include timelines or budgets but instead focuses on the actual content, the internal R&D work. The writer does research work, development work and the testing of the functionality. The supervisers approve every work phase of the thesis.

6 Engineering process in Hitachi Energy Transformers Vaasa

The engineering process inside the Transformers unit in Vaasa is divided into three main phases, which are electrical design, layout mechanical design and detailed mechanical design (Hitachi Energy Ltd. 2025b). Figure 5 describes the whole engineering process, which is made with Microsoft Visio.

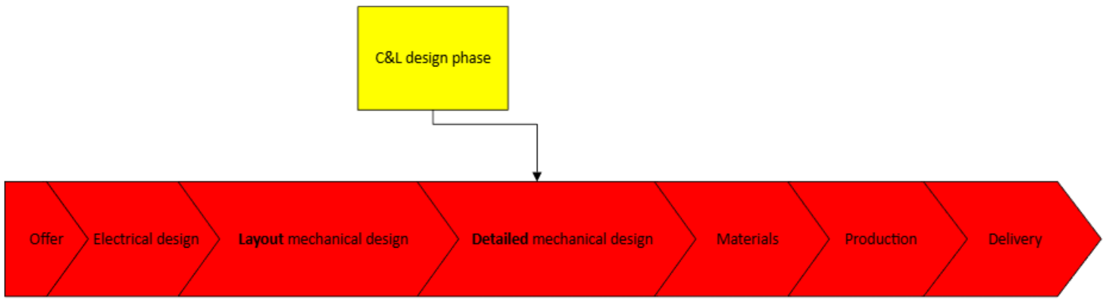


Figure 5. Engineering process' flowchart in Hitachi Energy Transformers Vaasa (Microsoft Visio).

In electrical design phase the engineers make power transformers' technical specifications, for customers to approve (Hitachi Energy Ltd. 2025b). Layout mechanical design is an engineering phase that focuses on a preliminary design, which means making outline drawing model's 3D model, drawing and Bills of materials (BOMs), where all the needed main components are listed which are customers' requirements. After customer has approved the needed information from the electrical and layout mechanical design, the detailed mechanical design phase can start. Detailed mechanical design is an engineering phase where engineers design detailed components (subassemblies) 3D models, drawings and BOMs for power transformer's main assembly, for example the core, windings, main tank, cover and expansion tank. C&L design phase is also one of the detailed mechanical design areas. In Figure 5 the C&L design phase's placement in the engineering process can be seen.

The Mechanical Engineering subdepartment uses PTC Creo as its primary design software for 3D modeling. The 3D models are used by mechanical engineers to create drawings and factory instructions for each project using PTC Creo and AutoCAD software, including DWG and PDF files. DWG from *Drawing*, is a file format that contains two- and three-dimensional vector graphics, (Adobe, 2025). For example, architects and engineers use DWG files to create design sketches, which are closely associated with CAD software. The 3D models, DWG and PDF files, and any other project-related files are stored in the company's internal database in different folders and drives. When the DWG and PDF files are created, they can be viewed using AutoCAD software and a browser that can be used by all functions in the Transformer unit's organization. The Mechanical Design System (MDS) is a component and material ordering and product data management (PDM) software developed and maintained within the Vaasa Transformers unit.

BOMs in MDS and 3D models in PTC Creo are created and maintained separately. BOMs are created by design engineers based on a 3D model that lists all components and materials needed for each project. Some components and materials are ordered separately from a subcontractor, and some are already available from the factory. The 3D model of the power transformer is divided into several 3D submodels with different drives and folders. In the future, the implementation of PLM Windchill means that it will replace MDS, as it is outdated software. There will be no use for MDS when BOMs are listed in PLM Windchill. PLM Windchill will also replace all drives and their folders inside the File explorer.

7 Cleats and Leads

Chapter 7.1 describes for which this project is made for, i.e. the Cleats and Leads (C&L) team of the mechanical design subdepartment of the Vaasa Transformers unit. Chapter 7.2 describes what is included in the Cleats and Leads process and what its structure is before the thesis. Chapter 7.3 presents the C&L 3D model, which makes it possible to visually see the C&L design team's area of responsibility and what components are included in the C&L 3D model. It is important to understand the target group and their practices for which the thesis is being written, so that it is easier to understand the benefits of the thesis.

7.1 Cleats and Leads team

The Cleats and Leads (C&L) team is responsible for designing 3D models of internal conductors. The meaning of C&L is described in the 2nd paragraph of chapter 1. Internal conductors are cables and/or busbars. A support structure is made for the conductors, along which the conductors are placed between the winding outputs and bushings. The C&L team is one of the teams in the Mechanical Engineering department. The C&L team uploads drawings, BOMs and production instructions for each project, which are created based on 3D models. The C&L team uses the technical information developed by the electrical design and layout mechanical design subdepartment prior to the detailed mechanical design phase to use the correct values for the components, distances and materials inside the power transformer in the 3D models, referring to the flowchart in Figure 5.

7.2 Cleats and Leads process

Cleats and Leads (C&L) process consists of multiple phases inside the process. C&L team needs plenty of information from the electrical engineering and mechanical engineering subdepartments, for example 3D base models, which are used as a reference in the C&L 3D model. C&L engineers have instructions and guidelines for the C&L design phase from different databases. C&L design requires use of different software and websites. C&L process has design reviews and product reviews. This process will be drawn as a separate instruction and flowchart, with new developments included, based on the thesis' R&D work.

7.3 3D model for Cleats and Leads

Figure 6 shows a Cleats and Leads (C&L) 3D model of the high voltage side of the main-stream power transformer.

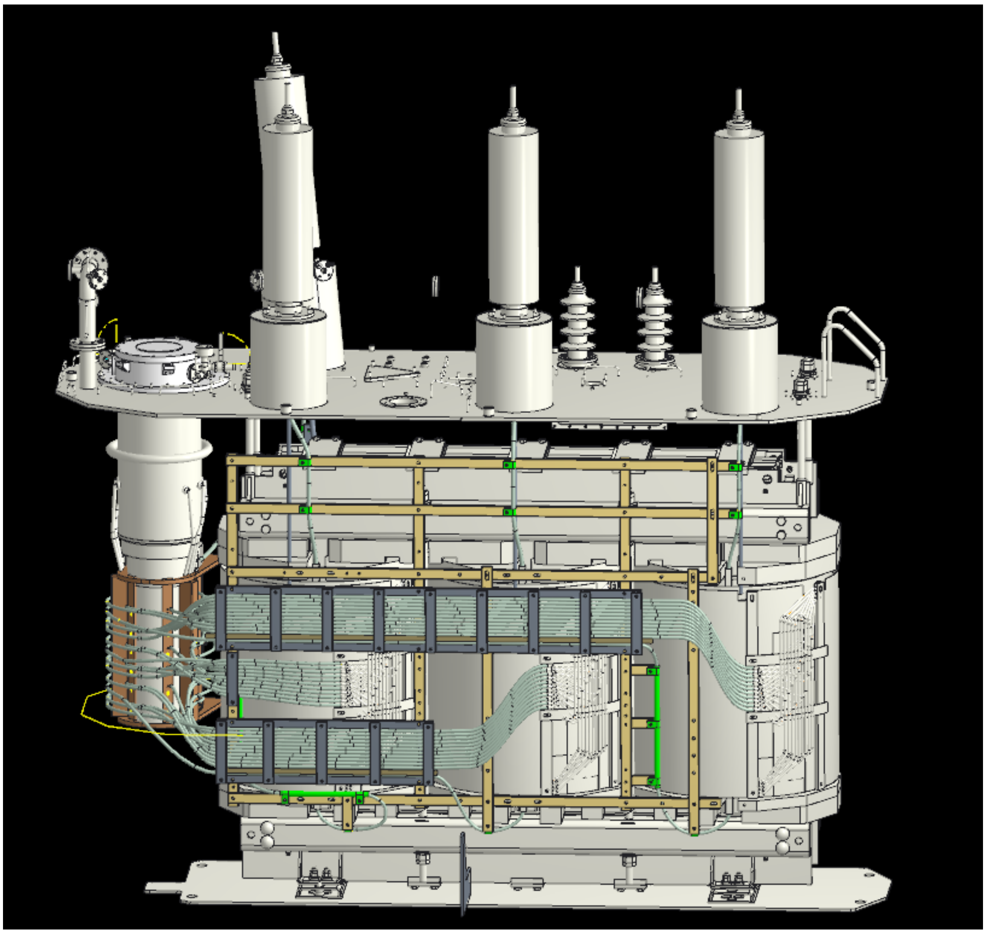


Figure 6. C&L 3D model (PTC Creo 8.0.10.0).

Mainstream 3D models are used in several projects with a typical power range of 25 MVA. In Figure 6, the different colors indicate the design area of the C&L 3D modeling, and the white area indicates other mechanical engineering 3D modeling areas. The white area is the base model of the C&L 3D model and is not included in the C&L BOM. The 3D base model for C&L 3D model is made by other mechanical engineering subdepartment's teams. The internal conductors are usually made of copper cables with paper insulation. The cross-sectional area depends on the current of the conductor. If the current in the winding outputs is high enough that there is no cable with a sufficient cross-sectional area, the cables can be replaced with copper or aluminum busbars with a cross-sectional area large enough for the high current level. The light turquoise components in Figure 6 indicate the cabling on the high voltage side of the power transformer, which has a lower current level and where there is a sufficient number of cables.

The support structure is usually made of wooden and pressboard supports, fastened with epoxy fiberglass composite bolts and nuts. Its function is to support and operate as a connection for the cables so that they can be fixed in the desired position with a sufficient distance from adjacent cables. The components in Figure 6 that are not white or light turquoise in color represent the components of the support structure on the high voltage side of the power transformer.

8 Software products used in the thesis

This chapter reviews all software products used in the thesis. Chapters 8.1 and 8.2 describe the mechanical engineering software products used in the detailed development of the thesis in chapter 10. Chapter 8.3 introduces the tool used to create all the flowcharts related to the thesis. Chapter 8.4 presents the tool that will be used in the research work in chapter 9.2. All these sections describe the purposes for which the products can be used in general and what they are used for in this thesis.

8.1 PTC Creo 8.0.10.0

PTC Creo is a 3D CAD generative design modeling software that allows you to design a variety of products for manufacturing. You can create and edit 3D models and drawings for desired products and design projects from the design stage to the manufacturing stage (PTC, n.d. -a). PTC Creo allows 3D engineers to simulate and optimize the weight, performance, cost, and durability of products using a variety of materials and manufacturing processes. The C&L team uses PTC Creo to design 3D models, drawings, and production instructions for the C&L stage. PTC Creo 8.0.10.0 is used to create a 3D model for the thesis' pilot project.

8.2 Mechanical Design System

The Mechanical Design System (MDS) is a product data management (PDM) software that allows you to add BOMs for a project. Developed in-house at Vaasa Transformers unit, MDS is software that allows users to access a local database, standards, and materials. The mechanical design department uses MDS to create BOMs for each project. Users can also find all project drawings and production instructions in MDS, so that production can, for example, print these documents. MDS is used to create BOMs for the thesis' pilot project.

8.3 Microsoft Visio

Microsoft Visio is Microsoft's application product used as web version or application. Microsoft Visio helps to visualize parts or steps of manifolds (Microsoft, n.d. -b), for example organization or process. There are six different styles of charts and diagrams that can be done with Microsoft Visio, which are Flowcharts, mind maps, organization charts, network diagrams, floor plans and infographic timelines. Flowcharts and organizational charts are the most common styles used in companies, especially in technological companies, for example for processes and organization structures. Microsoft Visio is used in this thesis to make a flowchart for the process of the thesis and for the C&L process standard.

8.4 Microsoft Teams

Microsoft Teams is Microsoft's application product used as web version or application Microsoft Teams is used for communications in most modern companies and organizations. With Microsoft Teams users can have, for example, calendars, chats and channels (Microsoft, n.d. -a). Microsoft Teams is also connected to other Microsoft applications, for example Outlook, Word and Excel. Microsoft Teams is used in the research work in this thesis to interview the mechanical engineers about the C&L processes' development ideas.

9 Research

This chapter reports on the research done in the thesis. Chapter 9.1 presents examples of process flowcharts found from scientific sources and makes concluding decisions about which of them can be used as reference for the thesis flowcharts. Chapter 9.2 explains how the interviews were conducted and what results were obtained from them. Chapter 9.3 selects development works for the thesis based on the results of the interviews. The research work and its results can be used to carry out practical development work for the thesis.

9.1 Process flowchart examples

After the research there are three examples of flowcharts found from three different scientific sources. The flowchart examples in Figures 7 and 9 are the newer ones and the one in Figure 10 is from 2009. Figure 7, from (PresentationEze, 2025.) is an example of manufacturing process flowchart with a simple structure and progress flow that is easy to understand.

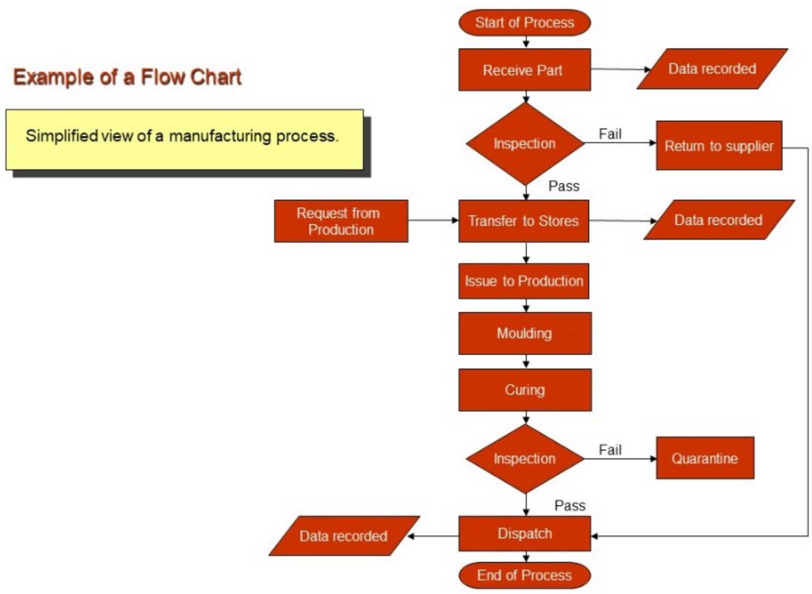


Figure 7. Manufacturing flowchart example (Adapted from PresentationEze, 2025.).

The flowchart example in Figure 7 (PresentationEze, 2025) is the one that is used the most in the thesis work. The structure is very easy to understand, and the flowchart is about manufacturing process, which is different from C&L process, but includes similar things like “Modeling” and “Inspections”. The symbols of each step are made according to International Standard ISO 5807 (2019). This Standard describes how every symbol represents different types of steps inside a process, for example see Figure 8.

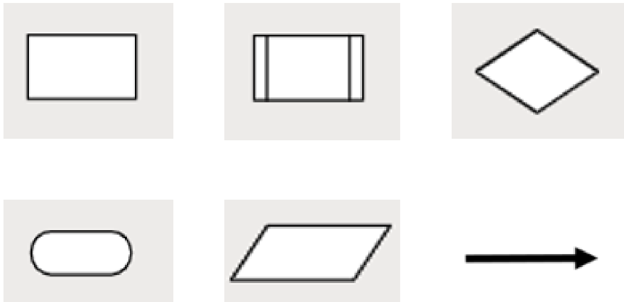


Figure 8. ISO 5807 standard symbols.

- Rectangle symbol: Represents process, see Figure 8.
- Rectangle symbol with side lines: Represents subprocess, Figure 8 Subprocess to process. Processes can also have lower subprocesses under subprocesses.
- Diamond symbol: Represents decision, Figure 8 For example, reviews or inspections.
- Oval symbol: Represents Start and end of a process, Figure 8.
- Parallelogram symbol: Represents data, or information, Figure 8.
- Arrow symbol: Represents flow between steps, Figure 8.

Next flowchart example is found from Hessing's (2025) customer project process chart example, see Figure 9.

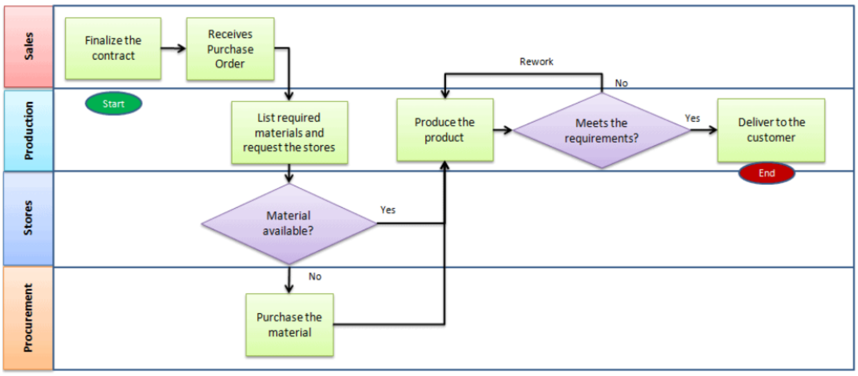


Figure 9. Simple customer project process chart (Adapted from Hessing, 2025).

Hessing's (2025) flowchart example has similarities to the PresentationEze's (2025) example in Figure 8. The symbol markings are the same, without data symbols. Hessing divides the process in the flowchart into four different areas of responsibility, which are four departments within the organization. Hessing's flowchart example is also customer project process flowchart example. The C&L process is an internal design process for the Vaasa Transformers unit and there is only one design team responsible for the C&L process, and not multiple different departments.

Ullman’s (2009) flowchart example in Figure 10, is older and way simplified than PresentationEze’s (2025) example in Figure 8 and Hessing’s (2025) example.

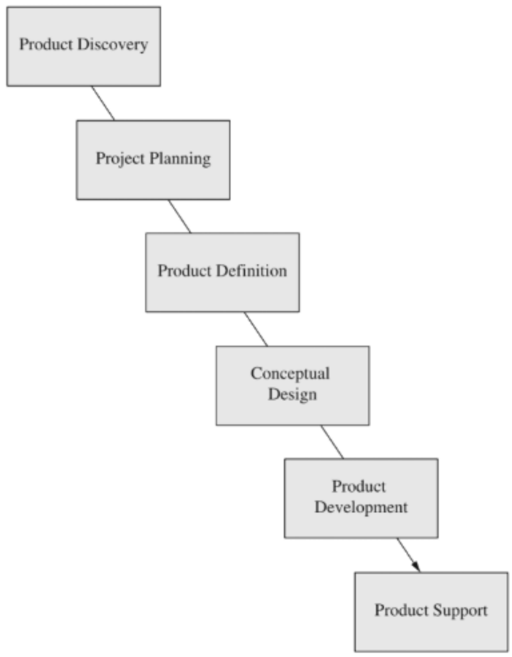


Figure 10. Mechanical design process chart (Adapted from Ullman, 2009).

This flowchart example is also chosen to be examined, because Ullman’s (2009) flow chart is mechanical design process chart example. Ullman’s Mechanical design process example’s theme is closely related to the C&L process, because C&L phase is one of the mechanical design phases in Vaasa Transformers unit. However, the example is a flowchart of an entire mechanical design process, not one of the steps inside the process, such as C&L. C&L design practically only begins at "Product Development" when describing the Vaasa Transformers unit’s mechanical engineering process. In the example, "Product Development" and "Product Support" are the only steps that describe the C&L process. Other steps are within the scope of responsibility of the entire mechanical design subdepartment. Ullman (2009) does also not use global standards in the example, which is why this example cannot be used as a template for a C&L process flowchart.

9.2 Interviews

Before starting to do the development work for C&L process it was necessary to do the research by interviewing mechanical engineers in Vaasa Transformers unit. Most of the interviews were done for C&L engineers and a couple of others with other mechanical engineers from other design teams and one electrical engineer. The target is to find out what the biggest development areas are in the current C&L process, before the development work of the thesis. The interviews were done via Microsoft Teams.

The interviews were conducted between March and April of 2025. The purpose of the interviews was to let the interviewees talk in their own words about what should be developed in the C&L process, without asking about a specific theme, such as 3D modeling or communication. The reason for this was that the interviewer would get honest and possibly surprising answers that were not previously known. No clarifying questions were asked, which would make the answer more likely to be predictable, and the interview would not produce good results. This way it was possible to find the answer to the 1^{st} main research question of the thesis, which can be found in chapter 1.1. The results of the interviews are separated, with the most important development areas from C&L engineers listed first and the results of all other interviews listed second. The development areas are listed with the most common/critical.

1. C&L engineers, with eight interviewees in total

- **Shrinkwrap development**. 75% of interviewees found this critical.
- **Conductor tool development**. 50% of interviewees found this critical.
- **Filling the reusable components in library.** 75% of interviewees found this critical.
- **C&L template folders**. 50% of interviewees found this critical.
- **Standard instruction for bushings**. 25% of interviewees found this important.
- **Linkbox development.** 25% of interviewees found this important.
- **Communication improvements**. 100% of interviewees found this important.
- **More design and product reviews.** 75% of interviewees found this important.

2. Other engineers, with four interviewees in total
- **More design and product reviews.** 75% of interviewees found this important.
- **Communication improvements.** 100% of interviewees found this important.

The duration of the interviews was divided into 10–20-minute intervals, depending on the interviewee. The C&L engineers had a lot of technical development areas, some of which were known before the interviews. It was good that all designers recognized the problem without having to ask about it separately, which also makes it easier to understand what the most important development areas are in C&L process. Then, C&L engineers and other engineers mentioned the same development areas in the interviews, which were related to communication and design and production reviews.

9.3 Choosing the development works

Development works were chosen to be implemented based on what is the most critical need to improve the quality and efficiency inside the C&L process. Some of the development projects are also already being developed in C&L design, such as conductor tool development and Linkbox development. Standard instruction for bushings is such a broad topic that it may require a separate development project, or for example a thesis. There were different problems related to communication and reviews and people experience them differently. Some personnel feel they need more design reviews and some less. Some personnel have more communication development ideas and requirements than others. These problems need to be developed within the mechanical design subdepartment. For these reasons, it was easy to choose the development projects for this thesis.

First development work chosen to this thesis was to make a Standard part library. The reason for this development is that reusable, non-project-specific components are listed in different folders, and not in one place where it would be easy to find all the components. These non-project-specific components are called Standard Parts in the Vaasa

Transformers unit. In addition, the parts are randomly filled in the folders, making it difficult to know which parts are which.

Second development work chosen to this thesis is to make and implement template folders for C&L. The reason for this development is that C&L design gets its own template folder, which makes it easier and most importantly faster to start the process. In addition, when making this development, both sides of the internal conductors, the HV and LV side’s conductors, are included in the same 3D model. Previously, HV and LV side’s conductor 3D models were in separate 3D models, which caused that the quality of reviewing the model is not as good.

Third development work chosen to this thesis is to make and implement a new method on how to make Shrinkwraps for C&L projects. The term "Shrinkwrap" in C&L design refers to the feature that is used in Shrink parts in C&L 3D base model in PTC Creo. A base model is used to notice and understand differences between 3D model versions (IBM, 2023). The base model is the ancestor of the 3D model versions, which can be compared or merged. In C&L design the 3D base model, made by other mechanical engineering subdepartment’s teams, is merged with the C&L 3D model. The reason for this development is that the updating of the C&L 3D model geometry in the C&L 3D base model, for example tank, cover, core, windings etc. has been a challenge. 3D model versions may be old and components may be incorrect or modeled in the wrong places.
When 3D models, drawings, or BOMs are made incorrectly, the physical product will also be made incorrectly in the production. These problems caused quality issues in 3D modeling and production, which causes more time consuming in projects on reviews and corrections.

10 Process chart of the thesis

According to the research the process flowchart was able to be created. The symbol standards from International Standard ISO 5807 (2019) were used and Gleek's (2025) R&D process flowchart's principles were used as a reference. Figure 11 shows the flowchart made with Microsoft Visio application.

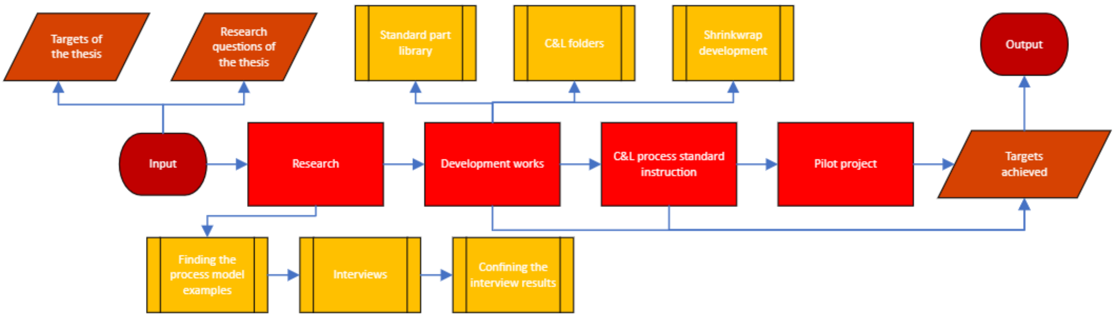


Figure 11. Flowchart of the thesis' process (Microsoft Visio).

In the flowchart in Figure 11 all the thesis' practical steps are listed in the order flow, from input to output. The flowchart was an opportunity to be formed into this chapter of the thesis, because the selected development works were only discovered after the research chapter (9. Research). The flowchart describes the R&D project, except for the part of the supervisors who collaborated with the author on a weekly basis, instead of certain stages. The so-called approval steps of the "Stakeholders" were not included in the process flowchart, like in the Gleek's (2025) R&D process flowchart.

In the flowchart of the thesis' process the "Input" start step includes data steps "Targets of the thesis" and "Research questions of the thesis". Based on the information in "Input" it was possible to do the "Research". "Research" is the first process step, with three subprocesses attached. Subprocesses of the "Research" are "Finding the process model examples", "Interviews" and "Confining the interview results". All the research work was done in chapter 9. Second process step is "Development works", with also three subprocesses. Subprocesses of the "Development works" are "Standard part library", "C&L

folders” and “Shrinkwrap development”. Development works will be done in chapter 11. Third process step is the “C&L process standard instruction”, which will be in the chapter 12. Fourth and final process step is the “Pilot project” where the functionality of the development works and C&L process standard instruction will be tested in chapter 13. Then there is “Targets achieved” data step after the “Pilot project”. When all the “Development works”, “C&L process standard instruction” and “Pilot project” were made, they are attached to the “Targets achieved”. After “Targets achieved” comes the “Output” of the thesis’ process, which is the final step of the process.

11 Development

This chapter reports on the implementation of the development work and the results obtained. The development work was selected based on the results of the interviews in chapter 9.3. In the first development work, chapter 11.1 developed the C&L standard part library. In chapter 11.2, new &L template folders are created. In chapter 11.3, development work related to C&L base models was made. All these developments will increase the efficiency and quality of the implementation of C&L projects. The development work will enable the implementation of a pilot project and the inclusion of them in the new C&L standard process.

11.1 C&L standard part library

C&L standard part library was done by first finding every folder made to collect all the reusable non-project-specific C&L parts. The parts were found from total of three different folders in three different locations in the Vaasa Transformers unit's local drives. C&L already had a Standard part library with few parts, but they were randomly listed in the folder, without any additional specifications that which part each one is, see Figure 12.

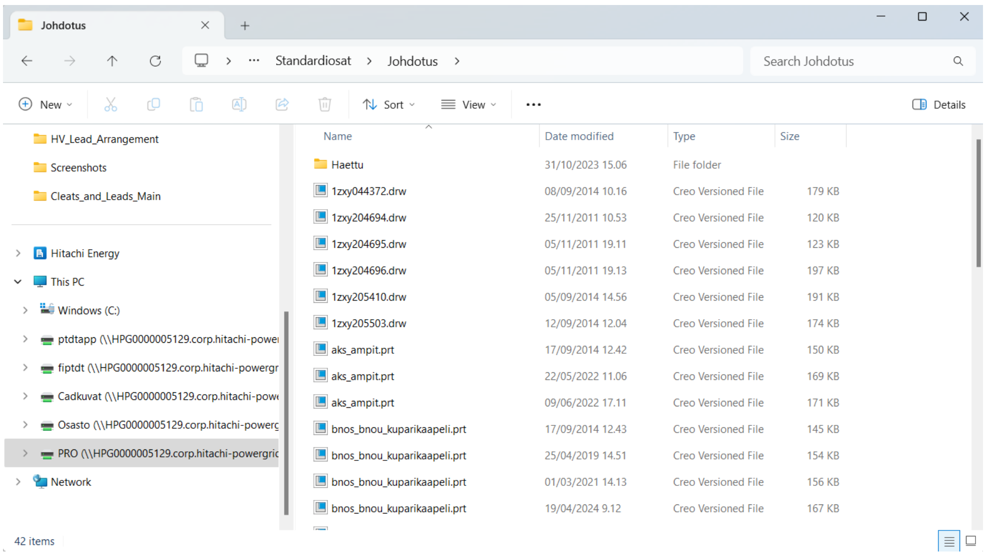


Figure 12. Old C&L standard part library.

When looking at the old C&L standard part library in Figure 12. It is very hard to know which the wanted part is. The library is also missing many important parts that are used in several C&L projects, which are in two other folders. In the new C&L standard part library there are now all the reusable non-project-specific C&L parts in single folder, collected from all three locations, see Figure 13.

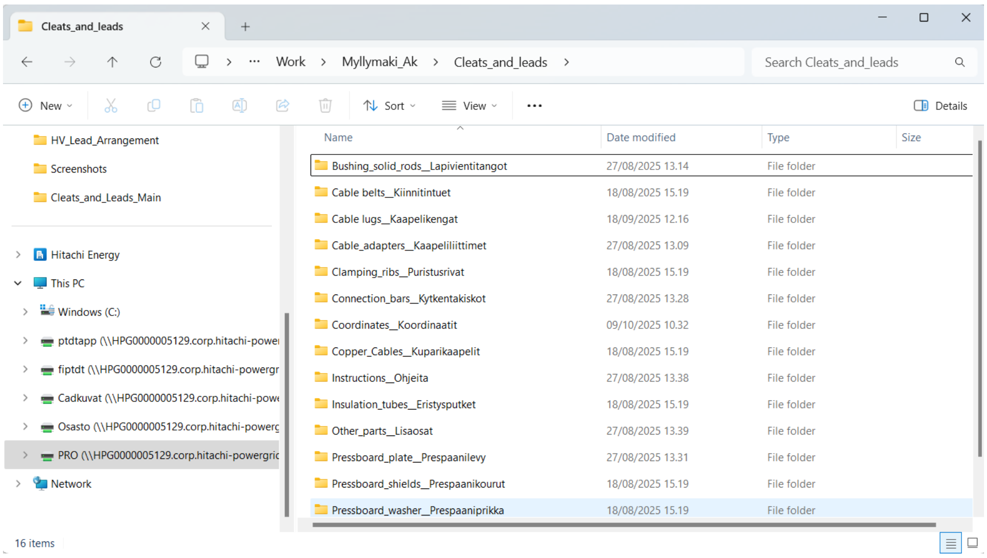


Figure 13. New C&L standard part library.

In the new C&L standard part library on Figure 13 there are also subfolders made to categorize each part into the correct subfolder. Categorization makes it easy for the C&L engineer to find the desired part, while working on a C&L project. In summary the old library version in Figure 12 was replaced by the new improved library version in Figure 12.

11.2 C&L template folders

C&L template folders were created for every project's template structure, see Figure 14.

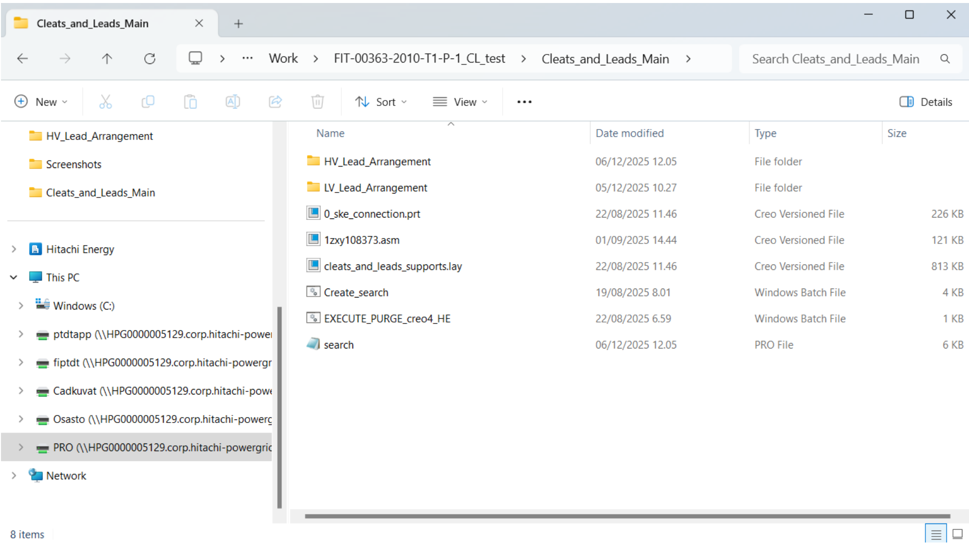


Figure 14. C&L template folder.

Inside the C&L template folder in Figure 14 there is a C&L main assembly "1zxy108373.asm", two subfolders and five other files. The C&L main assembly is a PTC Creo assembly, where the HV and LV conductor assemblies will be connected as subassemblies. Two subfolders are "HV_Lead_Arrangement" and "LV_Lead_Arrangement". Inside each subfolder are the HV lead arrangement and LV lead arrangement assembly, and template PTC Creo components. Five other files include initial information about project-specific data that C&L engineers need to manually add to the template when starting to work on every C&L project. PTC Creo files inside the C&L template folder do not initially have any geometry in the template, because they are done project-specifically when the C&L project is started, since all the projects differ from each other more or less.

11.3 Shrinkwrap development

Shrinkwrap development was done by making Shrink assembly (SHRINK.ASM) in PTC Creo, see Figure 15.

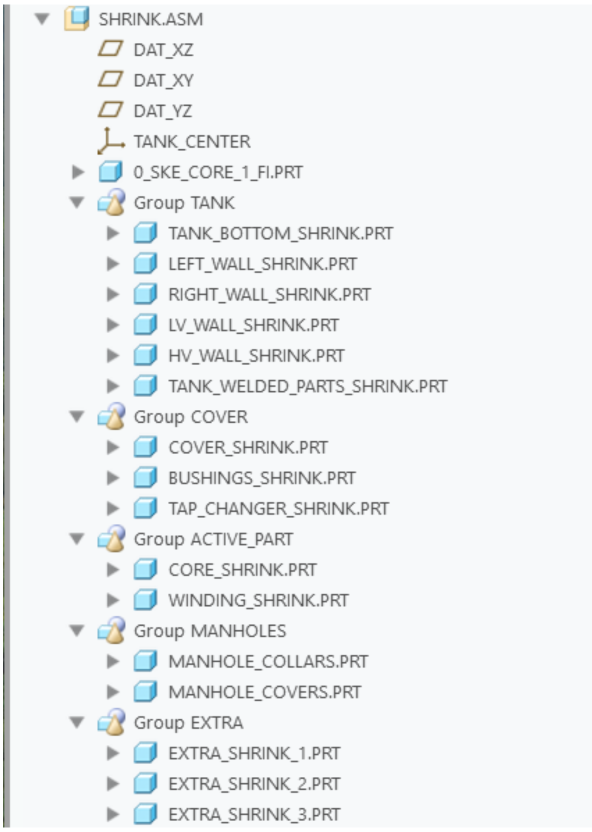


Figure 15. BOM of Shrink assembly (PTC Creo 8.0.10.0).

The meaning of Shrinkwraps and the difference between Shrinkwraps and Shrinks can be found from the 9.3 chapter’s last paragraph. When using Shrinkwrap feature in Shrink components the componets are in geometric external reference to other mechanical engineering subdepartment’s team’s 3D models, from which the C&L base model consists of. The difference between PTC Creo assembly (asm.) or part (prt.) is that part is a single component and assembly can include multiple parts or subassemblies.

Shrink components can also be found under the template folder structure of every project, like the C&L template folder. Shrink components are in PTC Creo like in the structure shown in Figure 15, where all the power transformer components needed in C&L 3D model are as Shrink parts inside the Shrink assembly (SHRINK.ASM) for which the C&L 3D base model consists of. The Shrink parts have been divided into groups inside the Shrink assembly to make it easier to distinguish between them. Inside every group there are one or more Shrink parts. New Shrink assembly also has an ability to automatically update the Shrink parts when the geometry of the 3D base model has been updated by another mechanical engineering subdepartment's design team, which means that the C&L 3D base model will automatically update to the newest version in C&L 3D model.

Instruction was also made on how to create Shrinkwraps for C&L projects. Figure 16. Shows the table of contents of the instruction.

Creating Shrinkwraps for Cleats and Leads projects

Contents

Figure 16. Contents of Shrinkwrap creation instruction.

The instruction's title is "Creating Shrinkwraps for Cleats and Leads projects", see Figure 17. The instruction was uploaded to Transformer unit's internal database, which is accessible to everyone inside the Vaasa Transformers unit. In the instruction there is a chapter for every Shrink part, on how to make the Shrinkwrap features for those, see Figure 16. Also, instruction guides the C&L engineer on what to do if some common issues might occur when making Shrinkwraps, see Figure 16. The instruction guides the C&L engineer to assemble the Shrink parts to the Shrink assembly correctly, see Figure 16. Instruction also has chapters where it mentions the updating of Shrink assembly, but there is a separate instruction made for that. In the later chapters of the instruction there is a chapter where there is a Shrink creation table, which summarizes the instruction for making Shrinkwraps for each Shrink part. This can be used, for example, by more experienced C&L engineers who do not need to go through every step of the instruction in detail.

Instruction was also made on how to update Shrinkwraps for C&L projects. Figure 17. Shows the table of contents of the instruction.

Updating Shrinkwraps for Cleats and Leads projects

Contents

Figure 17. Contents of Shrinkwrap updating instruction.

The instruction's title is "Updating Shrinkwraps for Cleats and Leads projects", see Figure 17. The Shrinkwrap updating instruction goes through the Shrinkwrap updating process in multiple chapters. The purpose is that every mechanical engineering subdepartment's engineer can update the Shrinkwraps for C&L engineers, although the responsibility on updating the Shrinkwraps is with the C&L engineer. This instruction was also included as an appendix to the Shrinkwrap creation instruction.

12 C&L process standard instruction

C&L process standard instruction is made by interacting with C&L engineers and listing all the process' phases to the standard, including the development works of the thesis in the process. A flowchart of the C&L process standard was made, see Figure 18.

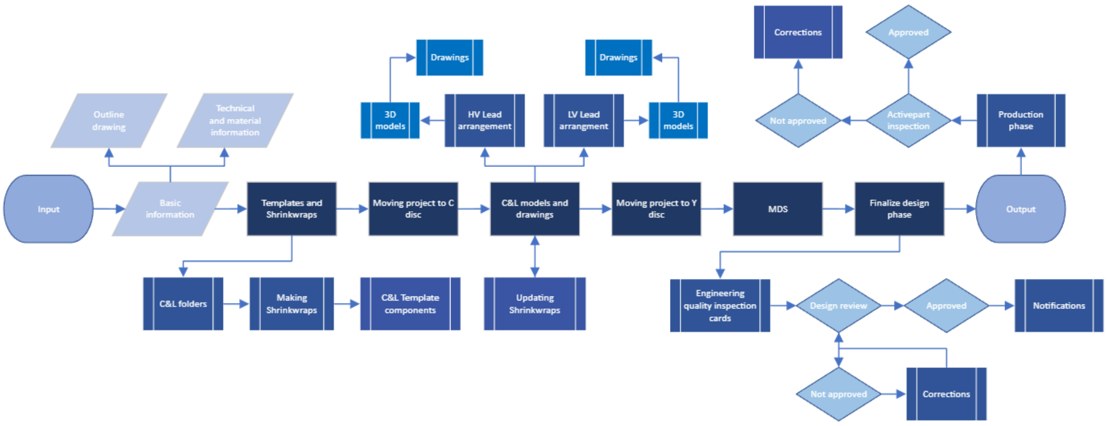


Figure 18. Flowchart of the C&L process standard (Microsoft Visio).

The Flowchart in Figure 18 is made using the symbol standards from International Standard ISO 5807 (2019). Also, the process examples obtained in the Research work in chapter 9.1 were also used to help to make the flowchart. In particular, the PresentationEze's process example in Figure 7 was used broadly as a reference, with subprocesses added. The C&L process standard is made for the individual C&L engineer working on a C&L project. However, there are steps in the process that also apply to others than the C&L engineer, such as "Design review" and "Activepart inspection", which involve reviewers, who approve or not approve the step. The flowchart shows each step in the C&L process in order.

"Input" start step is the first step in the C&L process. "Input" describes the situation before the C&L process in the process i.e. what needs to happen to begin the C&L process from other departments and teams. Data step "Basic information" in the process has "Outline drawing model" and "Technical and material information" data steps, which are basic information that C&L engineer needs to do the C&L project. “Templates and Shrinkwraps” is the first process step in the process with three subprocess steps, which are “C&L folders”, “Making Shrinkwraps” and “C&L Template components”. “Templates and Shrinkwraps” is so-called preliminary works in the process that C&L engineer needs to do before starting to work on C&L 3D models, drawings and BOM. “Templates and Shrinkwraps” includes C&L templates and the development works of the thesis.

The step after “Templates and Shrinkwraps” in the C&L process is “Moving project to C disc” process step, where the C&L engineer copies the project to own C disc. Then C&L engineer starts to work on with C&L 3D models, drawings and BOM in its own C disc in the process step “C&L models and drawings” in the process. “C&L models and drawings” process step has two subprocess steps, which are “HV Lead arrangement” and “LV Lead arrangement”, which is because both are done as separate works, 3D models, drawings and BOMs. After the 3D models, drawings and BOMs are ready, the project needs to be published to local server, which is the process step “Moving project to Y disc” in the process. Once the project has been transferred to the server, the 3D models from both sides (HV Lead arrangement and LV Lead arrangement) are combined into a single 3D model (C&L main assembly). Next process step in the process is “MDS” where the C&L engineer needs to make a C&L BOM to the MDS (Mechanical Design System), which is the BOM data software used in C&L projects.

Final step in the C&L process’ design phase is the “Finalize design phase”. In “Finalize design phase” there are three subprocess and three decision steps, which are “Engineering quality inspection cards” “Design review”, “Approved”, “Not approved”, “Corrections” and “Notifications”. The purpose of process step “Finalize design phase” is to finalize the C&L design phase with design reviews, where necessary corrections are made to the project, inspection cards are filled out, and the completion of the C&L project is notified to the necessary databases and personnel, for example team leader. “Output” end step in the process means the end of C&L design phase. The “Output” has however two subprocess and three decision steps, which are “Production phase”, “Activepart inspection”

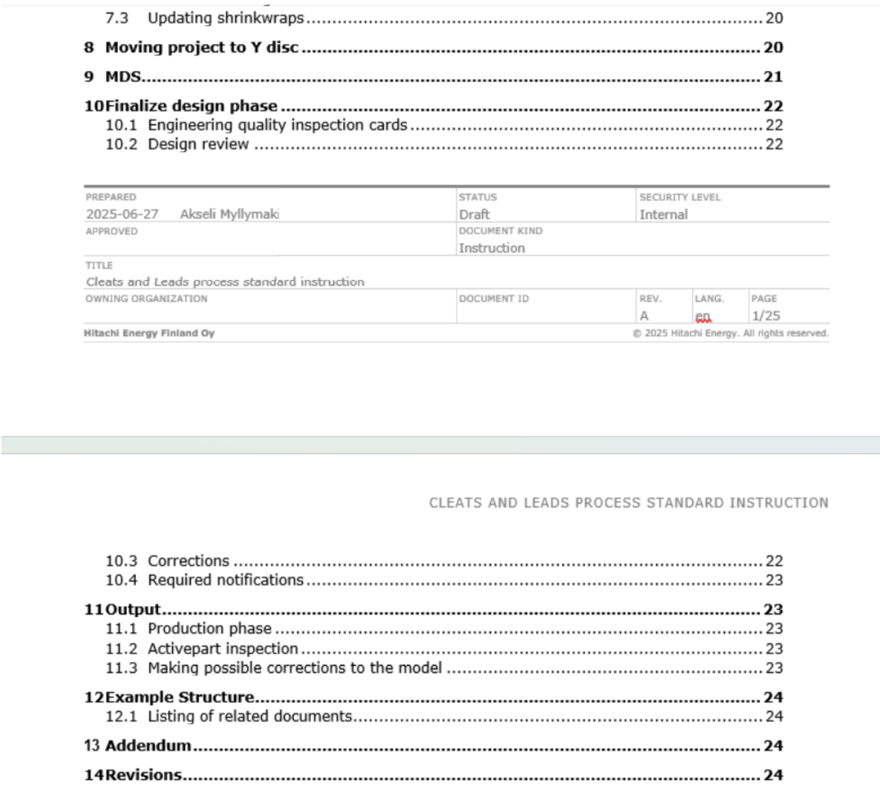
“Approved”, “Not approved” and “Corrections”. There are still steps in the “Output” because, even though the C&L design process ends, supporting production for the designed project is the responsibility of the C&L engineer. If, based on the production review, corrections need to be made to the C&L 3D model, drawings, or BOM, the responsibility lies with the C&L engineer who designed the project.

Separate instruction is also made for the new C&L process standard. Figures 19 and 20 shows the table of contents of the instruction.

Cleats and Leads process standard instruction

Contents

Figure 19. Contents of C&L process standard instruction 1.



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CLEATS AND LEADS PROCESS STANDARD INSTRUCTION

Figure 20. Contents of C&L process standard instruction 2.

The instruction’s title is “Cleats and Leads process standard instruction”, see Figure 19. The C&L process standard instruction goes through each step of the C&L process, in the same order as in the C&L process flowchart, in Figure 18. The C&L process flowchart is also included in the instruction as a separate figure, look at Figure 19 “2. C&L process chart”. Many additional technical instructions related to C&L design are also listed as a separate appendix to the C&L process standard instruction. The instructions made in the thesis, which were "Creating Shrinkwraps for Cleats and Leads projects" and "Updating Shrinkwraps for Cleats and Leads projects" can also be found as a separate appendix in the C&L process standard instruction

13 Pilot project and results of the thesis

This chapter presents the results of the pilot project and the thesis. Chapter 13.1 reports on how the pilot project was completed and whether the development works done in the thesis worked properly in the project. Chapter 13.2 reviews all the results obtained in the thesis, comparing them with the targets of the thesis.

13.1 Pilot project

Development work and the new C&L process standard instruction functionality were tested in a pilot project. The pilot project was able to start once the development work and C&L process standard instruction were implemented and ready for testing. The pilot project was a C&L customer project, which focused on new engineering methods, based on the development work, in the C&L process. Every new engineering method worked correctly in the pilot project and the project was completed according to the C&L process standard instruction.

13.2 Results of the thesis

The first main target of the thesis was to clarify and implement the most important development areas within the C&L design process. The development areas that were important in the C&L process were identified through interviews. The results of the interviews and their analysis helped to choose which developments were wanted to be implemented in this thesis. Every development work, which was C&L standard part library, C&L template folders creation and implementation and Shrinkwrap development, were successfully made, which means that the 1st target of the thesis were achieved.

The second main target of the thesis was to make a standard instruction for the C&L process that all C&L team members will follow in C&L projects. First, each step in the C&L process was recorded. The process was described in a flowchart with all steps. The developments made in the thesis were included as a separate step in the new C&L

process standard. The instruction was completed with positive results, which means that the 2nd target of the thesis was achieved.

The third main target was to test the functionality of the development implementations to the pilot project. The pilot project was carried out after the development works and C&L process standard instruction had been implemented and ready to be tested. Functionality of the development work and new C&L process standard instruction was able to be tested. The results of the test were positive when every new engineering method worked correctly. Also, the project was done correctly according to the instruction. The results mean that the 3rd target of the thesis was achieved.

As an addition, all three instructions made in this thesis, which were "Creating Shrinkwraps for Cleats and Leads projects", "Updating Shrinkwraps for Cleats and Leads projects" and "Cleats and Leads process standard instruction" were uploaded to the internal xECM database of the Vaasa transformers unit, see Figure 21.

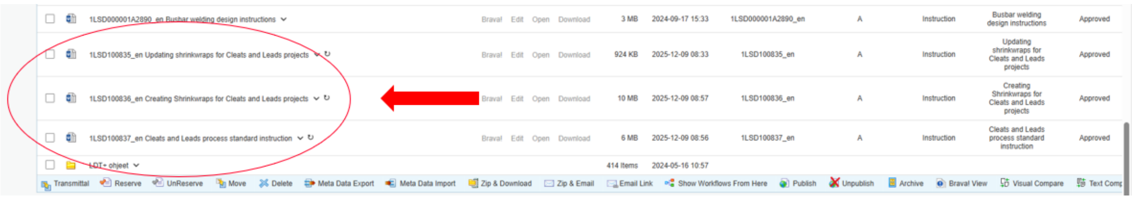

Figure 21. New instructions in xECM (Hitachi Energy’s local database).

14 Conclusions

C&L standard part library benefits are that all reusable, non-project-specific components are stored in a quickly accessible location, and it is almost impossible for components to be lost, when all of those are stored in single location. The improved version of C&L standard part library helps the C&L engineer to find the right components faster, which increases efficiency. C&L temp folder development improves the efficiency in C&L projects and design review quality, when there is the C&L 3D model in single assembly. Shrinkwrap development reduces quality issues in 3D modeling in C&L design, when the C&L 3D base model (geometry around the C&L 3D model) updates automatically. When quality issues are lower in 3D model it also improves the physical product's quality, since they are made based on the 3D model and its drawings.

C&L process standard instruction facilitates work, both within the C&L team and in other teams in the mechanical design subdepartment, because it is easier for everyone to stay up to date on what phase of the process a C&L engineer is in their project. The standard instruction also helps new C&L team members in their new job role when a process standard has been written. The standard instruction also facilitates in finding the additional technical instructions related to C&L design, when those are listed in the standard instruction. The standard instruction also makes it easy to implement new C&L engineering methods, by modifying the standard instruction if the process needs to be modified.

In chapter 9.2 it was determined that Standard instruction for bushings is one development area which requires a separate thesis work. This is one R&D work that, based on the interviews, was an important development area for C&L design. The topic should be made into a separate user instruction in the same way as the three that were made in this thesis. The instruction should be attached as an appendix to the C&L process standard instruction and referenced to the correct chapter.

Like mentioned in chapter 1. Vaasa transformers unit will implement the PLM Windchill application, which will, replace MDS and otherwise change quite a lot of C&L engineering methods. C&L process standard instruction needs to be updated to work with PLM Windchill. There will be changes in the process, because of the PLM Windchill implementation, but with the improvements made in this thesis, the implementation process is easier for C&L design. Having a clear process standard, which is the requirement of PLM Windchill and the way in which Shrinkwraps are made after the improvement in the thesis, helps a lot with the PLM Windchill implementation for C&L design.

15 Summary

At the beginning of the thesis, it was stated why the thesis work is current and important for the target group for which the thesis was done. Several methods and practices are used in the C&L design of a power transformer, which is why it is necessary to prepare and implement a C&L process standard instruction. C&L design quality also wanted to be improved by making development works to the C&L design process. With the research work of the thesis, it was possible to choose the C&L process standard's structure, and the development works for the thesis. The development work and C&L process standard instruction improved the quality and efficiency of the C&L design phase. A pilot project was a good way to test the functionality of the changes made and analyze the results. The pilot project verified the functionality of the standard instructions and development work of the thesis. Improvements affect the whole C&L process, from the beginning of the design phase to the production phase. With the thesis it is possible to make future developments for the implementation of PLM Windchill.

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