VAASAN AMMATTIKORKEAKOULU
VASA YRKESHÖGSKOLA
UNIVERSITY OF APPLIED SCIENCES

Ville Tamssi

STANDARDIZATION OF THE SUPPORTING AND INSTALLATION OF GENERATOR CABLES

Tekniikka ja liikenne
2011

OPENING WORDS

This thesis was done in VAMK, University of Applied Sciences in the Degree Program in Electrical Engineering the Unit for Technology and Communication. The client of this work was Wärtsilä Finland Oy Power Plants engineering management office.

My thesis superior in Wärtsilä Finland Oy was Thomas Pellas, Engineering Manager, Electrical and my supervisor at VAMK, University of Applied Sciences was Vesa Verkkonen, Principle Lecturer. I want to thank everyone who has helped me with my thesis.

Vaasa 18.3.2011

Ville Tamssi

VAASAN AMMATTIKORKEAKOULU
Sähkötekniikan koulutusohjelma

TIIVISTELMÄ

Tekijä	Ville Tamssi
Opinnäytetyön nimi	Standardization of the Supporting and Installation of Generator Cables
Vuosi	2010
Kieli	englanti
Sivumäärä	38 + 2 liitettä
Ohjaaja	Vesa Verkkonen

Päättötyön aiheena oli tutkia generaattorikaapeloinnin asennusratkaisuja voimalaitoksissa. Kaapeloinnille ja tuennalle ei ole olemassa standardiratkaisua, vaan asennukset ovat toteutettu pääsääntöisesti urakoitsijan tai asennusvalvojan kykyjen ja kokemusten pohjalta. Asennusmateriaalit on hankittu yleensä paikallisesti tai pahimmassa tapauksessa lähetetty jälkikäteen Suomesta, mikä synnyttää turhia lisäkustannuksia projektille. Tästä syystä tarkoituksena on tuottaa standardiratkaisu, jota hyväksi käyttäen suunnittelijat ja urakoitsijat pystyvät toteuttamaan asennuksen luotettavasti ja kustannustehokkaasti.

Päättötyössä tutkittiin vuosien varrella syntyneitä ratkaisumalleja, saadaksemme selville onnistuneet ja epäonnistuneet ratkaisut. Työtä varten selvitettiin kaikki generaattorikaapelointiin vaadittavat tiedot ja käytännön ominaisuudet, joita käytettiin hyväksi standardiratkaisun suunnittelussa. Tiedot kerättiin Wärtsilän insinööreiltä ja asennusvalvojilta, jotka omaavat vahvan käytännön kokemuksen suunnittelusta ja kohteen asennustavoista.

Kerättyjen tietojen pohjalta toteutettiin generaattorin kaapeloinnille ja tuennalle standardiratkaisu, josta valmistettiin periaatepiirros. Piirustuksesta saadaan selville kaikki tarvittavat tiedot asennuksen suunnittelua sekä lopullista asennustyötä varten. Ratkaisu toteutettiin ensisijaisesti Wärtsilä 18V46- moottorille, jossa käytetään ABB:n valmistamaa AMG1600- generaattorimallia, mutta sitä tullaan myöhemmässä vaiheessa käyttämään kaikilla Wärtsilän käyttämillä generaattorimalleilla, kunhan varmistumme sen käytännön toimivuudesta. Standardiratkaisu vähentää suunnitteluun käytettävää aikaa, nopeuttaa asennustöitä ja ennen kaikkea se pienentää ylimääräisiä materiaali- ja kuljetuskustannuksia.

Avainsanat: generaattori, kustannustehokkuus, standardisointi Wärtsilä

VAASAN AMMATTIKORKEAKOULU
UNIVERSITY OF APPLIED SCIENCES
Sähkötekniikan koulutusohjelma

ABSTRACT

Author	Ville Tamssi
Title	Standardization of the Supporting and Installation of Generator Cables
Year	2010
Language	english
Pages	38 + 2 Appendices
Name of Supervisor	Vesa Verkkonen

The objective of this thesis was to research solutions for generator cable installation in the power plants from the view point of standardization. There is no standard solution available for cable installation and supporting to the generator, so the installations are usually made according to the contractor`s or the supervisor`s own experience. Installation materials are usually supplied locally or in the worst case, sent afterwards from Finland, which increase unnecessary additional costs for the project. For that reason the purpose was to produce a standard solution, utilizing which the designers and contractors are able to execute the installation reliably and cost effectively.

In this thesis the variation in cable installations of the generator was studied, which helped us to find out the successful and unsuccessful solutions. All needed information and practical aspects for the generator cabling were defined and used in the designing of the standard solution. Information was collected from the different project groups and specialists in Wärtsilä and from persons who have a strong practical experience in designing and experience in the installation methods of the subject.

From the collected information and details a standard solution was produced for the generator cables installation and supporting. Also a principle drawing of the solution was manufactured, in which all needed details can be found for helping design and the final installation work. The solution was produced primarily for the Wärtsilä 18V46 engine with the AMG1600 generator type produced by ABB, but after we can be sure of the practical functionality, it will be used for all generator models used in the power plant projects in Wärtsilä. The standard solution will decrease the time used in designing, make installation works faster and first of all, decrease the additional material- and transportation costs.

Keywords: generator, cost efficiency, standardization, Wärtsilä

USED TERMS AND ABBREVIATIONS

18V46	Wärtsilä 46-engine with 18 cylinders
EPC	Engineering, procurement and construction
EEQ	Engineered equipment delivery
EMO	Engineering management office
EG-set	Engine generator set
MV	Medium voltage
XLPE/PEX	Cross-linked Polyethylene

TABLE OF CONTENTS

OPENING WORDS ... 2

TIIVISTELMÄ ... 4

ABSTRACT ... 5

1 INTRODUCTION ... 8

1.1 Objective ... 9

1.2 Research Plan ... 9

2 INTRODUCTION OF THE COMPANY ... 10

2.1 Wärtsilä Oyj ... 10

2.2 Wärtsilä`s Values ... 11

2.3 Services ... 11

2.4 Ship Power ... 12

2.5 Power Plants ... 12

2.6 Engineering Management Office ... 12

3 STANDARDIZATION ... 13

4 GENERATOR ... 17

5 TECHNOLOGY RELATED TO THE GENERATOR SYSTEM ... 19

5.1 The Choosing of the Generator ... 19

5.2 Technical Details of the Medium Voltage Cables ... 19

6 RESEARCH WORK ... 22

6.1 Considerable Aspects ... 22

6.1.1 MV-Cables Supporting ... 23

6.1.2 Generator Cable Outlet ... 26

6.1.3 Cable Conduits ... 27

6.1.4 Control Cables ... 28

6.1.5 Other Generator Models ... 29

7 SOLUTIONS OF THE STANDARDIZATION ... 31

7.1 Layout of the Generator Cables Installation and Supporting ... 31

7.1.1 MV-Cables Supporting ... 32

7.1.2 Cable Conduits 33
7.1.3 Control Cables 34
7.1.4 Other Installation Details 35
8 SUMMARY AND CONCLUSIONS 36

REFERENCES

LIST OF APPENDICES

1 INTRODUCTION

During the last decades Wärtsilä has established its position in the power plant technology. Power plants with numerous out-puts are designed and produced by Wärtsilä. There are two main power plant project types, EPC (Engineering, procurement and construction) and EEQ (Engineered Equipment Delivery). Designing and diagram drawing are outsourced to Citec Oy and so Citec shares the responsibility of maintaining high quality designing in cooperation with Wärtsilä.

When designing a power plant, many aspects and matters must be taken into consideration and that is why designing is so time consuming. Designers can utilize methods used in the earlier projects because the principles are basically the same in every power plant project. Utilizing earlier projects in designing speeds up the process and leaves time for possible modifications. There are a few factors causing that some modifications to the designs are needed, the power output, fuel used and location of the power plant are three worth mentioning. The risk in utilizing designs from earlier projects is that some components from the earlier design that is not needed in the new design can be included in the design by mistake and can cause that the whole design needs to be redone from the beginning.

To avoid unnecessary designing work and develop designing of the power plant has Wärtsilä founded a work group that is in charge of designing. Engineering Management Office (EMO) is in control of designing, having its focus on how the installation of generator cables and supporting could be standardized. This thesis can prevent false designing and create useful standard drawings which designers, sales-and site personnel are able to utilize in the future.

1.1 Objective

The objective of this thesis is to make designing work clearer and to develop the quality by standardization. EMO work group had decided their next development target which relates to generator installations in power plant projects. There is no standard way of supporting and installing the cables to the generator. In the design, the supports are not always considered and the material for supports is usually not sent to the site so the installations are usually made according to the site electrician`s own experience out of left-over material from other disciplines.

The purpose of this thesis is to develop a standard solution for Wärtsilä 18V46 engine, installation and supporting of generator cables and to design and produce principle drawings of the solution that can be used in a pilot project. When ensured that the solution is working, the standard solution can be used with another generator models. The final standardization drawings are left out from the scope of the thesis.

There is a standard solution available for ABB`s W46 generators, but the model of the generator and the manufacturer are chosen depending on the type of the engine needed and the availability of the generator wanted. This is why the layout of the design and the style of installation vary according to each and every project.

1.2 Research Plan

The research begins by analyzing some previous projects and the variation in cable installations of the generator. Information was collected from the different project groups and specialists in Wärtsilä and from persons working in the project on site who are responsible for the practical execution of the project.

We studied solutions that are found technically and practically good. A few of the best solutions found are further developed and thereby the most reliable, safe and cost-efficient solution for the cable installations of the generator can be achieved.

2 INTRODUCTION OF THE COMPANY

2.1 Wärtsilä Oyj

Wärtsilä is one of the leading companies that supply complete lifecycle power solutions for the marine and energy markets. By being technologically innovative Wärtsilä is able to design, for example, power plants that are less harmful for the environment and economical for its customer. Wärtsilä’s strategic aim is to strengthen its leading position in its markets and to ensure continued growth by offering customers the best lifecycle efficiency and reliability available. This is made possible by an integrated equipment and service portfolio that matches customers’ needs worldwide. Wärtsilä's main business consists of three divisions, which are Service, Ship Power and Power Plants. (Figure 1) /6/

Wärtsilä has more than 17,500 employees its 160 locations in 70 countries and net sales totalled are EUR 4,6 billion (in 2010). Wärtsilä is listed on the NASDAQ OMX Helsinki, Finland. /8/

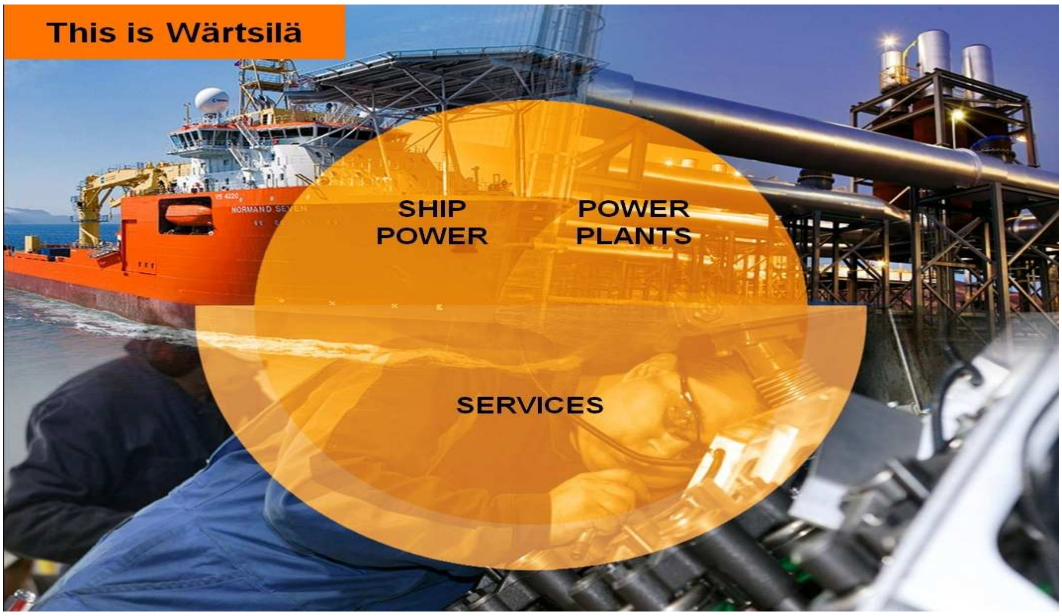

Figure 1. Main operations of Wärtsilä Corporation /6/

2.2 Wärtsilä`s Values

Wärtsilä`s values are the basis for how the staff should take a stand to do the job to reach the best results. Values (energy, excellence and excitement) have been described in the continuous circle. (Figure 2) /7/

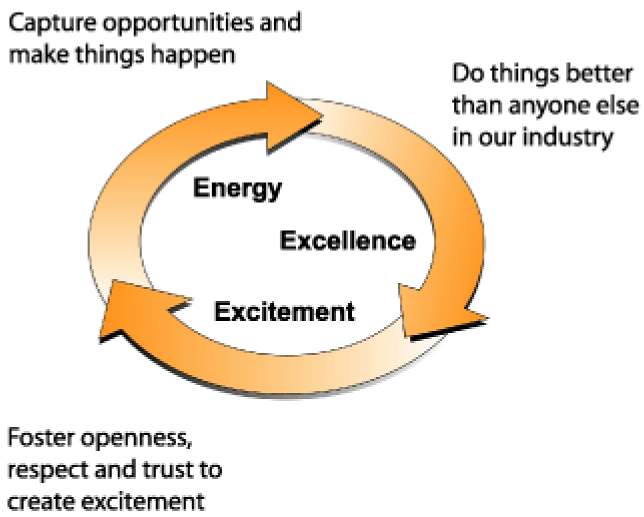

Figure 2. Wärtsilä`s values /6/

2.3 Services

Wärtsilä focuses on optimising the efficiency and performance of their installations throughout their life cycle. Wärtsilä provides the widest selection and best possible services for ship power and power plants. Customers can rely on competent and environmental friendly service that is available for all customers. /6/

2.4 Ship Power

Wärtsilä is a forthrunner in ship power solutions, such as ship design, engines, equipment, automation and power distribution systems. Besides providing ship power solutions, Wärtsilä also offers sealing solutions for the marine industry. The customers are leading companies within different segments, such as cruise and ferry. /6/

2.5 Power Plants

Wärtsilä is a leader on the centralised power generation market in supplying flexible power plants. Besides offering solutions for oil and gas industry, Wärtsilä focuses on power generation, industrial self-generation and grid stability and peaking. By providing distributed and environmentally friendly energy solutions Wärtsilä leads global transition to more sustainable usage of energy. There are two main power plant project types, EPC (Engineer, Procure and Construct) and EEQ (Engineered Equipment Delivery). /6/

2.6 Engineering Management Office

The objective of EMO is to lead and manage the customer solution engineering process including partnerships with engineering companies. The initial focus for EMO is to maintain, administrate and develop value added engineering activities and related information in order to reduce project engineering time while safeguarding quality. The vision is to release project engineering resources for product care activities, i.e. life cycle management, in order to improve re-use of pre-engineered and functionally optimized products. EMO will be the collaboration channel and introduce better practices that benefit both project management and full service engineering providers. /9/

3 STANDARDIZATION

Standardization is an activity that directs towards accomplishing standards. First actions are choosing the target, establishing a standard and ensuring the assent. After the first actions comes affirming the standard, promoting the introduction, following up of the standard and transmitting the received feedback to the product process.

The purpose of standardization is to reduce the irrelevant differences of the products considered both from the technical and mercantile viewpoint, find concept of definitions and ways of expression common to all and find appropriate procedures that meet up with all the requirements in different sectors. Standardization is not to limit possibilities, but to increase them. Standardization defines the terms of the adaptability of the different parts and parts adaptability to the whole complex. /4/

According to the SFS 3539 standard, ”The standard is universally available technical specification or other document, which is drawn up in cooperation with all parties involved in the general approval. The standard is based on the established science, technology and experience to help with the results advanced, and idea is to take the most advantage of society. Standard is adopted nationally, regionally or by internationally recognized organ.” /4/

The aim of the standardization is to reach goals by increasing safety, improving the economical aspects of the operation, facilitating the finding of a suitable solution and rationalizing the functioning.

Standards can be divided as follow:

- **Basic Standard**, which deals with such components as measurement units, concepts, symbols and signs
- **Method Standards**, which deals with measuring, testing and analysis, delivery terms and methods of work
- **Product Standards**, which deals, for example, with dimensioning of products, assortments such as quality, composition, structure and safety

Standardization benefits can be considered from many aspects, from international aspect, national aspect, industrial aspect, company and even consumer aspects. On company level standardization serves special needs of every company. Consumers are able to trust on the quality of the standardized products.

Standardization provides saving in costs, but causes costs in the preparation phase. On one hand, it is very difficult to predict the accurate sum that can be saved by standardization, because a standardized space cannot always be compared with the state it was before standardization. On the other hand, the benefits gained by basic standards (symbols, terms and definitions etc.) cannot be measured in monetary terms. Such significant benefits are interpersonal interaction, mutual understanding and saving time. /4/

Standardization and standards can be exploited as follows:

- To systematically develop the company`s operation and product
- To limit the range of component
- To improve customer service
- To receive marketing information
- To speed up the process of production
- To improve modification of product
- To improve the quality level
- To give the qualified specifications to acquisition
- To improve the profitability of a company
- To make the company well-known

The basic condition for a company to be able to operate is that it has a clear business idea and a growth strategy based on that. A clear business, to be working, idea needs an internal operation system that is based on standard. Business standards have an essential role when setting targets for control systems. Standards have to be easy to change flexibly and target-orientedly according to growth strategies. By using internal standards productivity and motivation of the workers can be significantly improved. Business standards have a fundamental task in function accomplishment of operation system. /4/

Productivity and motivation of the workers can be significantly improved by internal standards. Standardization of repeated operation absolves human resources out of routine tasks, leaving more time for designing and implementation of the unfinished works, which naturally increases the motivation of the workers.
Internal standards must not be too detailed, so that activities can be developed.
The number of standards cannot be an end in itself, more important is the quality and productivity. Internal standards can also reduce the number of misunderstandings, when everyone has the same written instructions.

To develop standards on the company level is time-consuming, but when the persons involved in developing the standards complete their work, they are a good resource to improve the usage of standards in the company. /4/

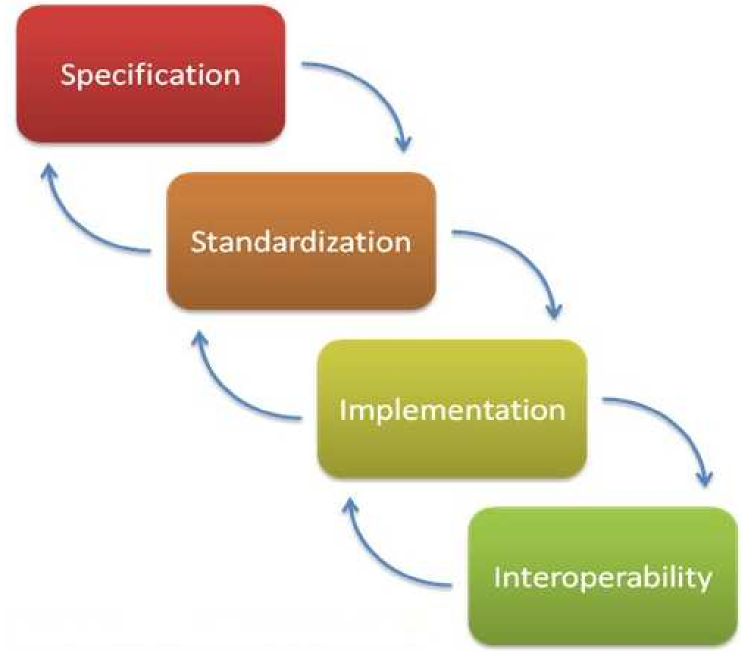

Figure 3. The Standardization Waterfall Model

4 GENERATOR

The purpose of the generator is to convert mechanical energy into electrical energy. Power plant generators that produce current to the national power-distribution network are alternators. An alternator is the most adjustable generator type at the moment. Power plant generators are usually synchronous generators because they can be made to produce exactly the desired frequency of the alternating current by adjusting the revolution of machine. That is because the whole national power-distribution network works everywhere with the same frequency and if a different frequency of current is supplied to the network, phase differences could cause short circuits and electrical equipment failure. That is the reason why all the power plant generators, which are planned to start-up or being stopped, are synchronized to operate exactly on the same phase and at the same frequency with the rest of the network, before the generators are connected to the national power-distribution network.

Figure 4.Wärtsilä generators are 3-phase synchronous machines.

The operation of a synchronous machine is based on the interaction of the two main windings:

- Stator winding
- Rotor (field) winding

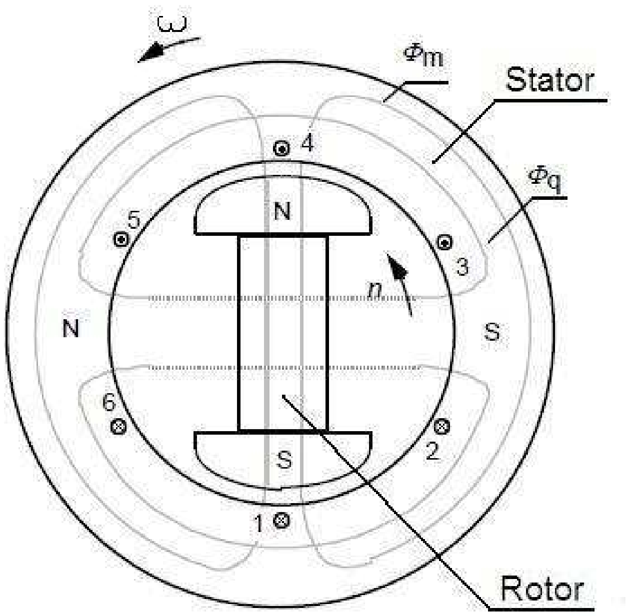

Figure 5. Generator windings

When the mechanical torque rotates the rotor anticlockwise, the directions of the current with resistive load are according the figure 5. /5/

Rotation is based on the pulling and pushing forces between the two magnetic fields – stator and rotor. The same poles (S-S) repel and different poles (N-S) attract each other, which enforce electrical torque.

The rotor (field) is rotating with the same speed as the stator field i.e in synchronism that is called synchronous machine.

5 TECHNOLOGY RELATED TO THE GENERATOR SYSTEM

5.1 The Choosing of the Generator

There are two types of 50 Hz generators available for Wärtsilä 18V46 engines, rated voltages are 11 kV and 15 kV. Generators for power plants are purchased from the supplier who is able to provide the best price and quality ratio and shortest time of delivery. Two generator suppliers worth mentioning are ABB and AVK.

Electro-technically speaking, 11 kV and 15 kV generators differ mainly with respect to short-circuit reactance, rated voltage and rated current section. When comparing electro technical features of generator model 11 kV to 15 kV we can find out that the chosen generator type has a significant impact on the sizing of cables and switchgear on phase currents and short circuit parts.

The price of 15 kV generator is approximately 10-15% higher than 11 kV and this is assumed to be the biggest reason why 11 kV generators are often used in the power plant projects. The choice of the generator affects also the voltage level of the customer`s distribution network, which will be attached to the power plant network system, or some other customer need. /1/

5.2 Technical Details of the Medium Voltage Cables

XLPE-insulated single conductor cables are the most commonly used medium-voltage cables at the power plants. In Finland XLPE-insulation is known as PEX-insulation which is the most popular insulation material in the medium- and high voltage networks, because of its features. XLPE-insulation has a low dielectric loss, it is mechanically durable and it has no actual melting point temperature. Therefore, XLPE-cables can be loaded with higher currents than the PVC-insulations.

Short-circuit- and overload endurances are also better on the XLPE-insulated objects. Conductor material is copper and the most commonly used cable cross-section areas are 185mm^2, 240 mm^2, 300 mm^2, 400 mm^2 and 500 mm^2. The rated voltages of cables are 12 kV and 20 kV. There are several cable suppliers and the cables are usually bought from the cheapest supplier available, closely considering also the time of delivery individually for each project. Cable prices are constantly changing according to the price changes of copper, so buyers need to be constantly alert and aware of the changes. On one hand, material costs for 12 kV rated voltage cables are lower than those of 20 kV, because its thinner insulate structure. On the other hand, by using a higher voltage level the number of cables per phase can be reduced or the cables cross-section area can be minimized. By increasing the voltage level and by so reducing the current inside the cables, significant cost savings can be achieved.

Necessary input data for sizing the generator cables are the short-circuit endurance of the medium voltage switchgear, generator rated voltage, generator output power and generator power factor. After the input data has been defined, the next phase is to choose the style of the cable installation. There are three different alternatives for its implementation, on ladder in free air, on ladder in trench or underground in conduit. In the case where power plant is designed on land, generator cables are always without exception installed underground in conduits. There are also a several considerable aspects which need to be taken into the consideration, such as other similar cables on the same route, distance between the conduits, the length of the cables, the temperature of the ground and the composition of the soil. /2/

Below is an example picture of the Cable Calculator software, with which all the medium voltage and the low voltage cables of the project are measured and designed by Citec Engineering Oy.

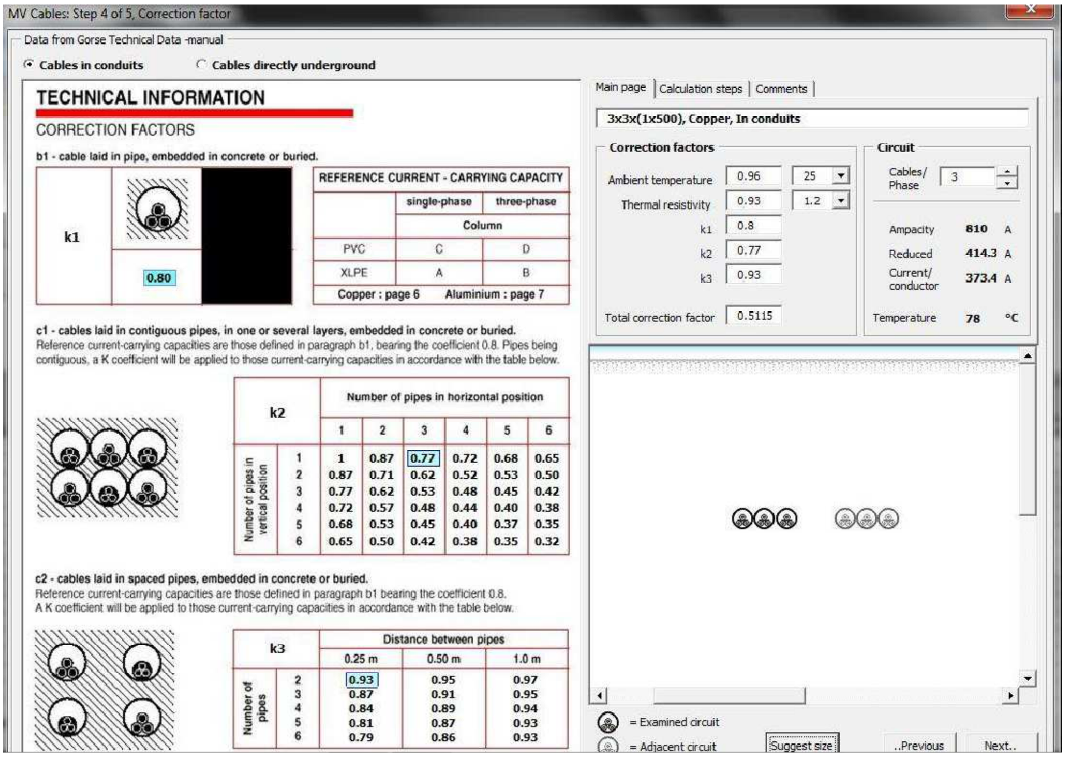

Figure 6. Cable Calculator software

6 RESEARCH WORK

The research work was started the collecting information from old projects, project groups and other engineers who have been involved in the construction of the power plants. Information was collected from those projects of which the development team had received the most positive feedback about the generator cable installations over the years. From the received information we chose a few solutions which we believe are the best and took them for further development.

6.1 Considerable Aspects

When planning alternative solutions we had to take into account that all the installation materials and equipment which we were going to use in our standard solution, needed to be already familiar to project/design teams and been used in the previous projects. This way it can be made sure that the right material is delivered on time.

The main facts of the installation to consider were cable conduits, MV-cables supporting and fastening, cable glands to the generator cable outlet and cable protection from external damages. Also, the most optimal route for control cables to the generator control box had to be determined.

In this case, because the standard solution was meant to be made compatible with all generator models Wärtsilä has been using in their projects, all the cabling support structures planned to be fastened to the original generator structure were left out off the design. Only an EG-set common frame can be used for fastening external supports. The fastening, of the external supports should be done by bolting and welding should be avoided. This is how potential electrical failure in the internal control system of the engine, caused by welding currents, can be avoided.

As mentioned earlier, the standard solution was designed primarily for ABB AMG 1600 generator model, but in designing we had to take into account also the other generator models and manufacturer`s suitability to the solution and cost-efficiency of the possible structural changes that needs to be made.

6.1.1 MV-Cables Supporting

The main thing is that upper part of the EG-set will undergo larger movements than parts on the floor level so it will be a very crucial issue where the cable connections are. During start / stop of the Wärtsilä 18V46 engine the measured side to side movement is +/- 6 cm at the top level of the generator. /3/

An important matter in cable supporting is how to execute the fastening of the cables on the ladder. This is to ensure that the cables remains on the ladder, for example, in a short-circuit situation. Because the longer the distances between the cable attachment points, the higher are the short circuit force impacts on the cables. (Figure 7)

Because the generator cables come up very close to the corridors where there will be traffic when the power plant is running or during maintenance, so we had to get the cabling also protected from all external damages. The protection cover of cabling is also a major fact of appearance.

Figure 7. ABB Standard cable support for W46

In some generator models, the phase cable comes out of the other side of the generator terminal than the neutral point cable. In these models neutral point cable is forced to be brought up from the other side of the floor than the phase cables.

Figure 8. Neutral point cable

6.1.2 Generator Cable Outlet

The penetrations are designed to seal the cable outlet and to function as a cable clamp. The penetrations must also be able to keep the cables in place during the possible short-circuit situation. The cables need to be brought vertically to the penetrations to minimize the stress directed towards the penetrations and the cable terminals when the engine is running.

Standard generators have an aluminium plate attached to the generator cable outlet. This cable outlet plate is used for installation of cable glands. Unless otherwise agreed the cable outlet is be provided with Roxtec type cable glands.

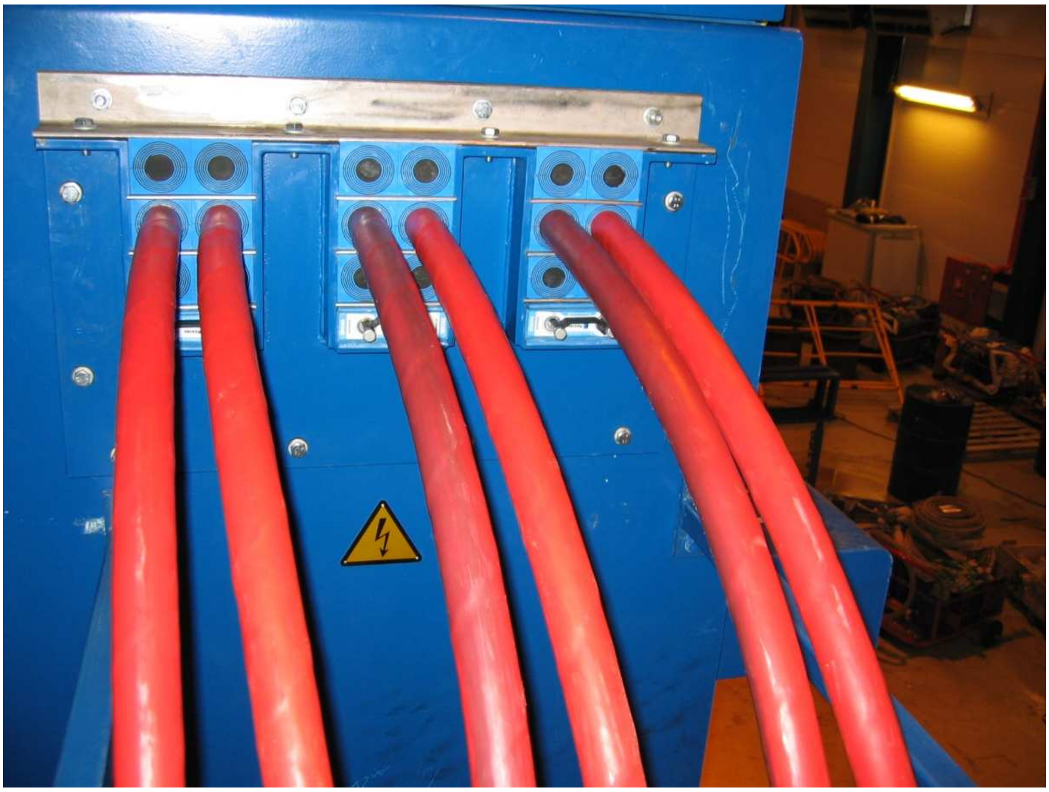

Figure 9. Roxtec type cable glands in ABB AMG1600 generator

6.1.3 Cable Conduits

The EG-set foundation is considerable heavily built, it needs much more wider concrete reinforcement and it goes much deeper than the rest of the floor area. At the moment, the conduits are brought up almost exclusively from inside the EG-set foundation and thus change the original structure of the foundation. Problems emerge when laying the engine foundation. Cable conduits should be lined up because the building workers do not use any tools to set up the conduits to the right position when making the foundation. It is very important to install the conduits into the designed place on the floor. (Figure 10)

One important aspect to consider is the impact of earthquakes on the floor structure. In earthquake areas cable conduits cannot under any circumstances be installed so that they pass through the joint between engine and floor foundation. The movements of the EG-set can be very remarkable during an earthquake (of course depending on the intensity of the earthquake). This can cause serious damages to the conduits and the cables inside them.

Figure 10. Cable conduits

6.1.4 Control Cables

The location of the generator control box varies depending on the model of the generator. The control box is either on the side or at the end of the generator. A crucial aspect to consider when planning the placing of the ladders was the vibration between the EG-set and the floor when the engine is running. Possible electromagnetic disturbances from the MV cables to the control cables needs to be considered, if they are installed too close to each other.

Figure 11. Generator control box in ABB AMG1600 generator

6.1.5 Other Generator Models

In the research work also comments on two other generator models were also included which are used in the power plant projects, one was manufactured by ABB and the other one by AVK. Some minor structural modifications to those previously mentioned generator need to be done in a later stage to make them more compatible with the standard solution. The implementation of these modifications is left out from the scope of this thesis, though researching the background information of the modifications were included in the thesis process. Below the problem spots in which modifications must be made are shown.

The problem in the ABB AMG1120 generator type is the MV-cable outlet and the way the cables come into the terminal. At the moment, cable penetrations are located on the side of the generator and the cables come there from below. (Figure 12)

Figure 12. Cable outlet in ABB AMG1120 generator

In the AVK DIG167 generator type the problem is the installation angle of the MV-cables to the generator outlet. Problems emerge because of too tight installation angle to the cable terminal, when using large diameter (500mm^2) MV-cables. For that reason, some modifications to the cable outlet are needed and extra special joint pieces to the cable terminals have to be added, which makes the cable lug junction to the terminal reliable and does not cause too much stress on them. (Figure 13)

Figure 13. AVK DIG 167 generator

7 SOLUTIONS OF THE STANDARDIZATION

7.1 Layout of the Generator Cables Installation and Supporting

Based on our research work, we created an example standard drawing of the generator cable installations (Figure 14). In this solution we aspire to take into consideration all the installation requirements showed above, as well protecting cables from external damages. In addition, we paid attention to the general appearance of the installation, because the generators are an important appearance factor in the power house. Below the most central details of the solution are shown.

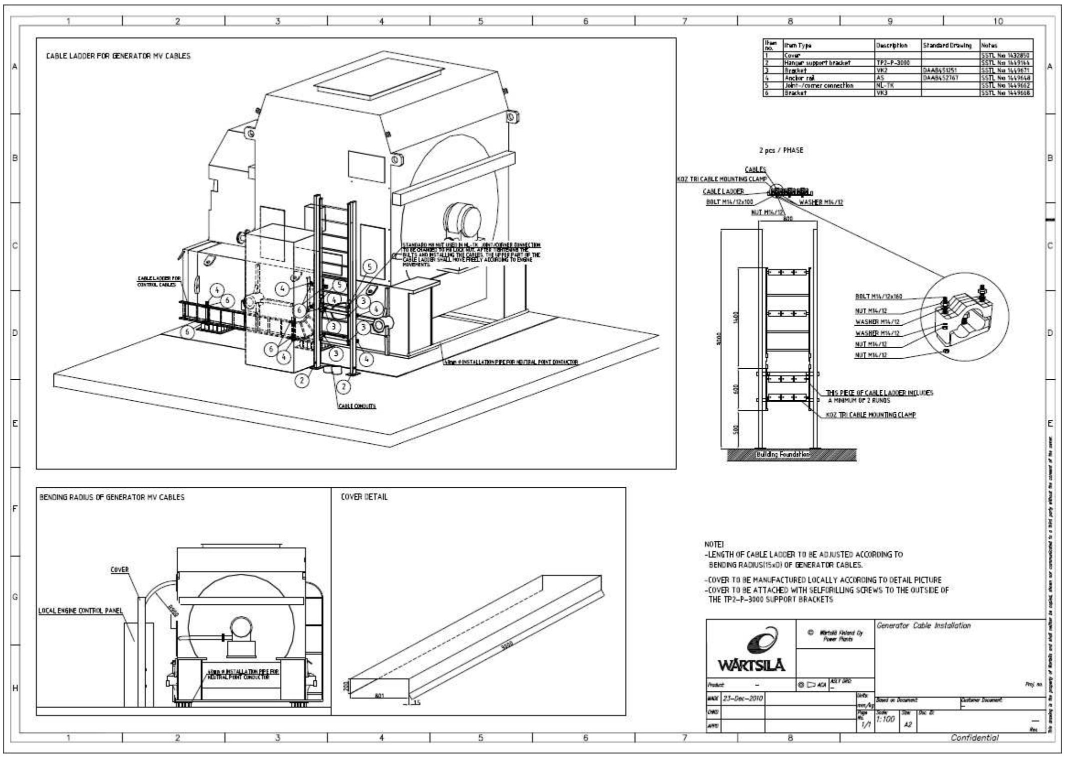

Figure 14. Design drawing of the generator cable installations

7.1.1 MV-Cables Supporting

One of the most important details in the solution was the MV-cable supporting, which is intended to prevent the stress to cable attachments and penetrations because of the generator movements. In this solution, the MV-cable support structure is composed of two different parts. The lower part is fixed to the floor supports and its purpose is to support the cables after they come up from conduit. After the fixed ladder part is placed hinged movable part, which is intended to move freely according to engine side to side movements in the start/stop situation, see also a note in appendix 1. To fasten the cables on the ladder we are using KOZ-cable mounting clamps, specially designed for fastening the cables. They will give strong and reliable enough fastening. For choosing the right clamp type previously designed specific drawing of the mounting clamps is used (Appendix 2). As selection criteria in the drawing cable diameter and the number of cables per phase are used. In the drawing the required maximum distances in between the clamps rows are shown, to get enough reliable installation. (Figure 15)

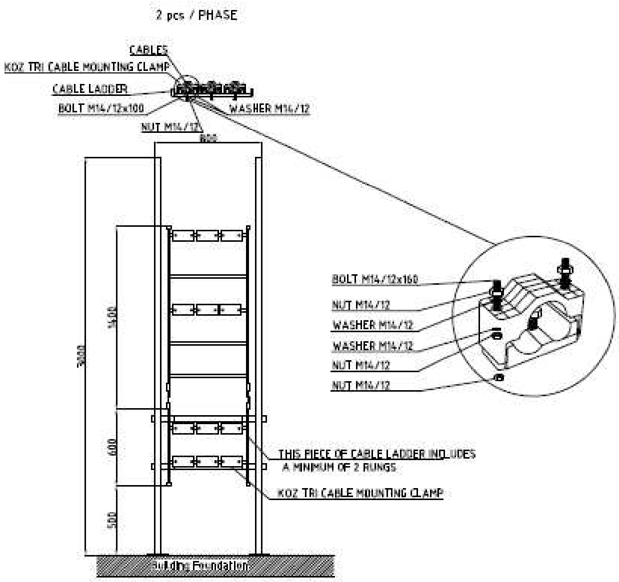

Figure 15. MV-Cables supporting

7.1.2 Cable Conduits

Cable conduits were moved outside engine foundation because it is easier to install conduits while casting the floor. The idea is first to cast the engine foundations and then to bring the conduits next to the side of the foundation. Then the conduits are fastened to their right position with u-shaped bands, which are easy to anchor to the side of the foundation. After this we are able to cast the rest of the floor area between the engine foundations and because of the anchoring conduits maintain their places. (Figure 16)

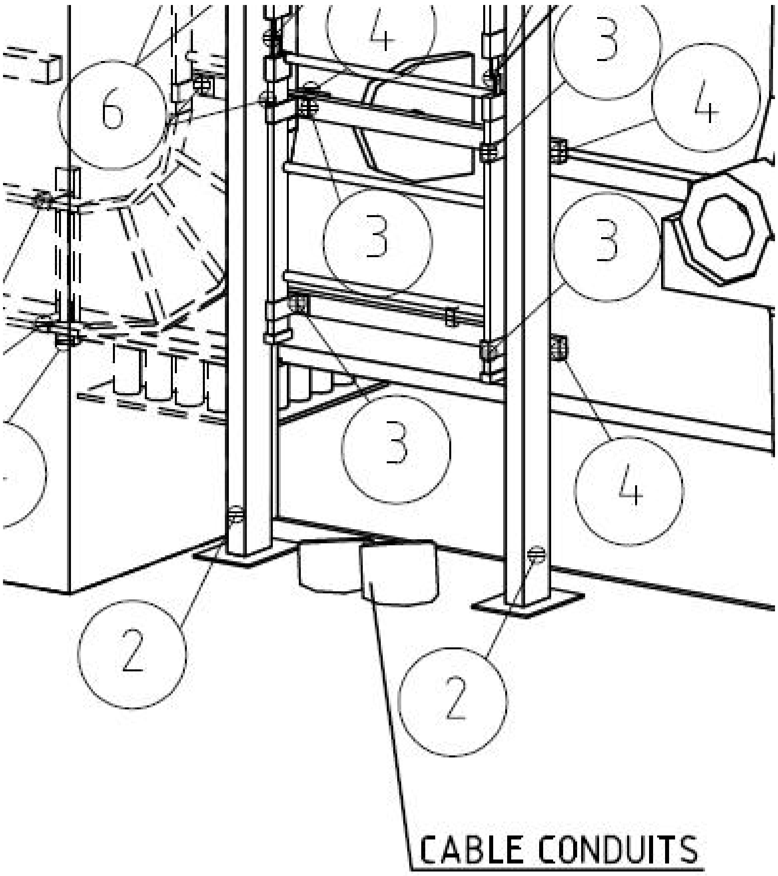

Figure 16. Cable conduits location on the floor

7.1.3 Control Cables

A cable ladder is installed for the control cables, which moves on the bottom level of the EG-set common frame and is brought up under the control box. This solution saves space around the generator and it can be well protected from external damages. The control cables can be installed far enough from the high current level phase cables whose electromagnetic fields can cause failure commands in the engine control system. This kind of cable route can be also used in the generator model where the control box is located at the end of the generator head, because it is easy to continue the ladder even to the other side of the generator. Commonly the control cables are brought up from the conduit as well as MV-cables, so now when the ladder is installed as near the floor as possible, the cables have to handle the smallest stress possible caused by EG-set movements. The ladder fastening to the EG-set common frame is made by bolting. (Figure 17)

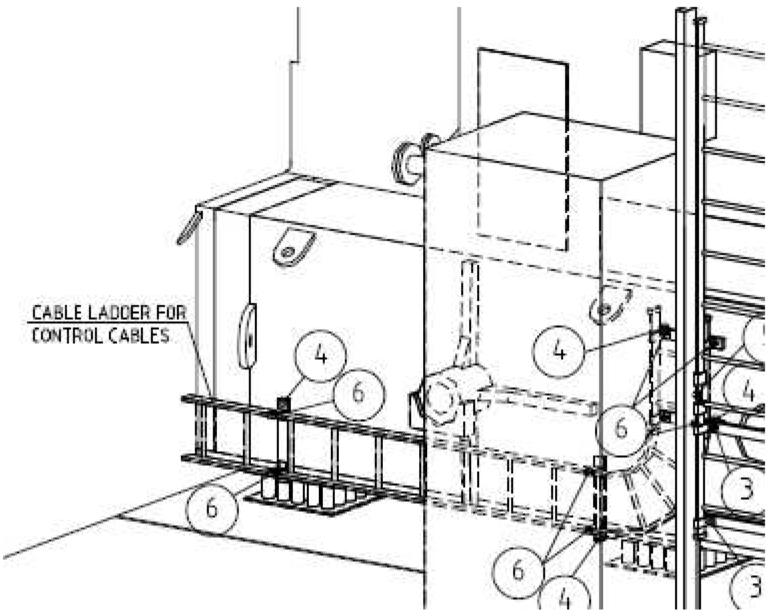

Figure 17. Cable ladder for control cables

7.1.4 Other Installation Details

In the drawing the specific details of the dimensioning the MV-cables to the generator terminal are also mentioned. The bending radius of the cables is calculated according to the used cable diameter, which in this case is 900 mm, for 500 mm^2 cable (Figure 18). It is very important to get the right dimension for the cables, because it has a major effect on the structural permanence in the future, see also a note in appendix 1.

Because the MV cables need to be protected, we designed a special cover, which will protect the whole cabling support structure. The cover structural dimensions are showed in appendix 1.

In the drawing it is also shown, how the neutral point cable installations should be done.

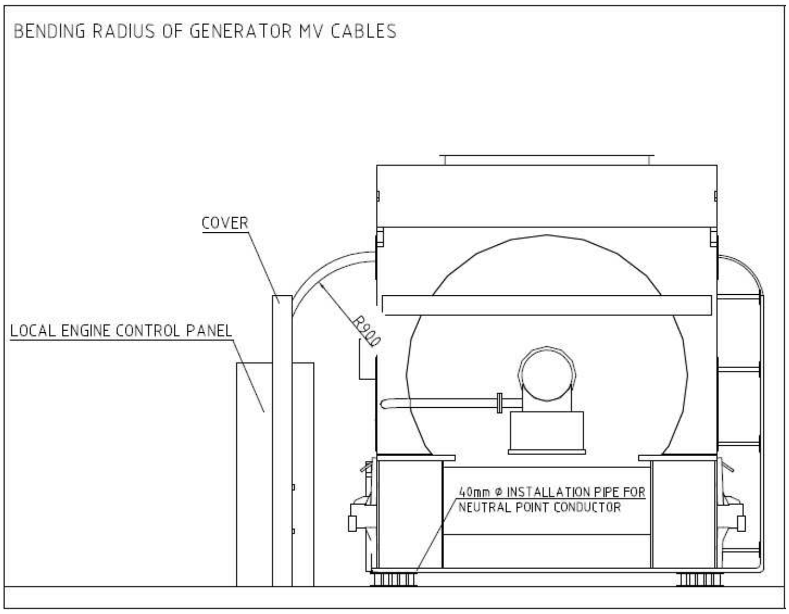

Figure 18. Bending radius of the generator MV-cables

8 SUMMARY AND CONCLUSIONS

The subject of the thesis was standardization of the supporting and installation of generator cable in the power plants. I have worked in Wärtsilä power plants as an electrical supervisor and my work experience was for great help in study of the this thesis. The topic in this thesis was previously familiar to me from the projects I have participated in, so I already had a vision of the implementation of the solution. The purpose of the thesis was to produce principle drawings of the standardization. The final modifications and standardized drawing will be created at a later stage, after we have made sure the functionality of the solution by making the first pilot project.

The thesis was started by collecting information of those generator cabling and supporting installations of which EMO had received the best feedback over the years. Based on the feedback and on our own experience we produced a solution, which helps in making the cable installations and supporting more reliable and cost-effective.

The thesis process was challenging and interesting. I had an opportunity to become familiar with different areas of engineering in Wärtsilä. I was able to get a lot of experience from the field of standardization. From my own point of view the thesis was successful and the employer is also very satisfied to obtained outcome of the thesis.

REFERENCES

/1/ ABB Wärtsilä Standards (Standard generators) [Referred 7.1.2011] Available in www-format: http://www02.abb.com/global/fiabb/fiabb250.nsf!OpenDatabase&db=/global/gad/gad02143.nsf&v=1466&e=us&c=F52734DA3FB2CBC0C1256D900038EE43

/2/ Nygård, Rickard, Chief Design Engineer 28.12.2010. Citec Engineering Oy Ab, Vaasa, Interview.

/3/ Rintamäki, Tommi, General Manager, Structural Dynamics 6.10.2010. Wärtsilä Oyj, Vaasa, Interview.

/4/ SFS käsikirja 1. Standardisointi, tarkoitus ja hyödyntäminen. Suomen standardoimisliitto SFS r.y. [Referred 2.1.2011]

/5/ Tahtikoneet, Vesa Verkkonen. [Referred 18.3.2011]

/6/ Wärtsilä 2010a. Annual report 2009. [Referred 3.1.2011] Available in www-format: http://www.annualreport2009.wartsila.com/Default.aspx

/7/ Wärtsilä 2010b. Presentation of the Wärtsilä. [Referred 4.1.2011] Available in www-format: http://compass.wartsila.com/Our_Wartsila/Values/Pages/Default.aspx

/8/ Wärtsilä 2010c. Presentation of the Wärtsilä. [Referred 4.1.2011] Available in www-format: http://compass.wartsila.com/Our_Wartsila/Pages/Default.aspx

/9/ Wärtsilä 2010d. News release in Wärtsilä Compass internal information channel. [Referred 5.1.2011] Available in www-format: http://compass.wartsila.com/localsites/finland/English/Uutiset_ja_tapahtumat/Appointments_and_New_faces/Pages/powernimitys.aspx

LIST OF APPENDICES

Appendix 1. Design drawing of the generator cable installations

Appendix 2. Specification for cable mounting clamps