



# **Design control and protection for medium voltage switchgear**

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Bachelor's thesis  
Electrical Power Engineering  
Vaasa 2012



## BACHELOR'S THESIS

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### Abstract

This thesis has been made for the Plant department at Wärtsilä in Vaskiluoto, Vaasa. Wärtsilä in Vaskiluoto is an engine laboratory. The engine laboratory tests different engines before they are put in the engine portfolio. There are several switchgears at the laboratory for load banks, generators and frequency converters. New switchgear will be installed for a new project. The old control panel for the switchgears will be updated with the new switchgear included. The infrastructure of the switchgear is also established.

The purpose of this thesis work has been to design a control panel for our switchgear, plan protection relays and plan the hardwire PLC system for a new switchgear. These drawings will be used when rebuilding the control panel and installing the new switchgear. The PLC drawings are for indicating alarms, breaker positions and earthing positions.

My work has resulted in several drawings for the switchgear and a new control panel for the laboratory switchgears. The drawings will be used only by Wärtsilä in Vaskiluoto.

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Language: English

Key words: engine laboratory, protection relay,  
switchgear.

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## EXAMENSARBETE

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Utbildningsprogram och ort: Elektroteknik  
Inriktningsalternativ/Fördjupning: Elkraft  
Handledare: Ronnie Sundsten

Titel: *Planera styrning och skydd för ett mellanspännings ställverk*

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### Abstrakt

Detta examensarbete är gjort för Plant avdelningen vid Wärtsilä i Vasklot. Wärtsilä har på Vasklot ett motorlaboratorium. Motorlaboratoriet testar olika motorer innan de blir sålda till konsumenterna. De har flera olika ställverk vid laboratoriet för testning av belastningar, generatorer och frekvensomvandlare. För ett nytt projekt behövdes ett nytt ställverk planerat och installerat. Vår styrpanel för ställverken kommer att bli uppdaterad med det nya ställverket. Infrastrukturen för ställverket skall också förverkligas.

Målet med detta examensarbete är att designa en styrpanel för våra ställverk, planera skyddsreläerna och planera kopplingarna för PLC. De ritningar som har blivit planerade kommer att användas när styrpanelen skall byggas om och ställverket skall installeras. PLC kommer att visa alarm, brytarens position och jordningens position.

Detta examensarbete avslutas med ritningar för ställverket och en ny styrpanel för laboratoriets ställverk. Ritningarna kommer endast att användas av Wärtsilä i Vasklot.

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Språk: Engelska    Nyckelord: motorlaboratorium, skyddsrelä, ställverk

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## OPINNÄYTETYÖ

Tekijä: Carl-Johan Nylund  
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Nimike: *Ohjauksen ja suojauksen suunnitteleminen keskijännitekojeistolle*

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### Tiivistelmä

Tämä insinöörityö on tehty Plant osastolle Wärtsilä Vaskiluodossa. Wärtsilä Vaskiluoto on moottorilaboratorio. Moottorilaboratoriossa kokeillaan erilaisia moottoreita, ennen kuin ne myydään kuluttajille. Laboratoriossa on useita eri kojeistoja kuormien, generaattorien ja taajuusmuuntajien testaamiseksi. Uuteen projektiin tarvitaan uusi kojeisto suunniteltuna ja asennettuna. Ohjauspaneelimme kojeisto päivitetään uudella kojeistolla. Myös infrastruktuuri pitää olla tehty.

Opinnäytetyön tarkoituksena on suunnitella ohjauspaneeli kojeistollemme, suunnitella suojareleet ja yhteydet PLC:lle. Piirustukset jotka on suunniteltu tässä opinnäytetyössä, käytetään kun ohjauspaneeli uudistetaan ja kojeisto asennetaan. PLC näyttää hälytyksen, kytkimen ja maadoituksen asennon.

Tämän opintönäytetyön tulos on sähköaseman piirustus ja uusi ohjauspaneeli laboratorion kojeistolle. Piirustuksia käytetään ainoastaan Wärtsilän Vaskiluodossa.

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Kieli: Englanti      Avainsanat: moottorilaboratorio, suojarele, kojeisto

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Vamp setup

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## **1 Introduction**

In autumn 2011 I started with my Bachelor's thesis work for Waskiluoto Validation Centre. The work consisted of designing control and protection for a MV-SWG. The infrastructures in engine test cells are critical for the engine testing. The control and monitoring of the infrastructure are vital parts of safely operating the engine. In order to test load steps and variable frequencies load banks are often used. Grid operation is available for the engine. My task was also to plan a "Mimic" where the switchgear will be controlled. This is a control panel where the breakers are controlled. My thesis includes planning and commissioning the control system and the protection relays of the MV-SWG.

### **1.1 Wärtsilä Finland Oy**

Wärtsilä is a Finnish corporation that produces combustion engines. These engines are made for making electrical energy or for marine purpose. Wärtsilä offers service for their products around the world. Wärtsilä has power plant engines that run on liquid fuel and gas. There are also dual fuel alternatives where you can use gas and different liquid fuels. Wärtsilä also offers engine solutions for marine use. These solutions can be for mega yachts, cruise ships and ferries. Wärtsilä supplies the merchant fleet with engine solutions for tankers, bulk carriers and container vessels. Wärtsilä has about 18.000 employees (2011). Wärtsilä is active in 170 locations in 70 countries. Wärtsilä has three sites in Vaasa. They are in Runsor, in Waskiluoto and in the centre of Vaasa. /17/

## 1.2 WVC

Waskiluoto Validation Centre is an engine laboratory for Wärtsilä Research & Development and Testing & Performance. Before the facility became WVC it was WPPP, Wasa Pilot Power Plant. The construction of WPPP began in 1997. WPPP was completed and started up in 1998. WPPP generated electricity and heat. Etelä-Pohjanmaan Voima Oy handled electricity sales and Vaasan Sähkö Oy was responsible for heat sales. WPPP became Waskiluoto Validation Centre in the year of 2005. When it became WVC it changed from a pilot power plant to a research facility. WVC is rebuilt for testing a new engine. WVC projects are exclusively for research and testing. The engines are not made for producing electricity to the grid. However, the option of grid operation is possible. The main goal is to test the engines, not produce electricity. The picture is taken from Wärtsilä website. /7/



*Picture 1, Wärtsilä Validation Centre (2001)*



## 2 Purpose and Objective

The purpose of this thesis has been to plan and commission necessary drawings for switchgear according to my commissioner's demands. The drawings were used for a project. The project is an engine that is not on the production line yet. The purpose is to test the engine before it will reach Wärtsila engine portfolio. It needed to be tested in different kinds of loads and frequencies. This was done with load banks. It is not possible to test the engine on grid operation with another frequency than (50 Hz). Operating the switchgear from the control room had to be realized. The positions in which the breakers are in the switchgear were to be visible on the indicators. The infrastructure needed to be established. The infrastructure means making SWG as safe as possible. This was realized with protection relays. Energy measurement was necessary, so that the efficiency would be visible.

### 2.1 Switchgear

The switchgear needs to be able to break and connect generators to load banks or to the grids. Open switchgears are big and they needed a lot of equipment. The switchgear is going to be a GIS (Gas Isolated Switchgear). This will be 10-15% smaller than an open switchgear. GIS are used where you cannot use an open switchgear, which may be because of the environment or because of the size of the switchgear. /6/

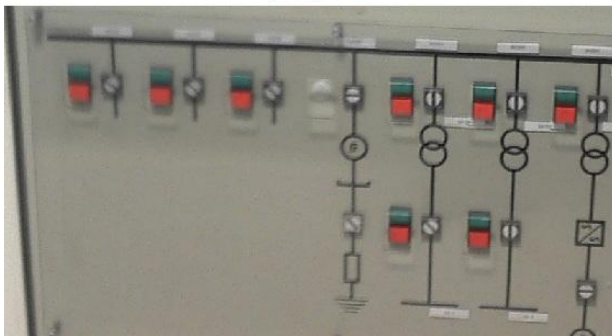
Switchgears are cabinets with breakers inside. With breakers in different positions the energy can be transported to load banks, transformers or to the grid. With the switchgear you can control high voltage transportation.



*Picture 2, Switchgear cabinets*

## 2.2 Control panel (Mimic)

In order to control the switchgear you need a different panel. The switchgears are made so that you can disconnect breakers from the switchgear room, but you cannot connect them. To be able to control the different switchgear cabinets a control panel had to be designed. This panel needed to be simple to understand and have the different switches in the correct order so that there won't be any misunderstanding in which position any breaker is in. To see what positions breakers are in there are indicators that show if a breaker is connected, unconnected or outside the cabinet.



*Picture 3, Control for switchgear*

The Mimic consists of several indicators and switches where you can control the switchgear. The indicators will flip to another position depending on breaker position.

## 2.3 Switchgear protection

Switchgear protection has been around for as long as we have had switchgears. The idea of the protection is that when we have an overcurrent or overvoltage, a relay will notice it and react. The relay opens the breaker to avoid damage to the equipment. If the breaker is unable to break the circuit, then the feeders to that switchgear have to break the main breaker. That is how the infrastructure is established with switchgear protection. To get the relays to work properly different trip times for the relays were made. These have been calculated so that the correct relay trips at the right time. /5/



*Picture 4, Protection relays and switchgear*

The protection relays are mounted in the top compartment in the switchgear cabinet. Inside they are installed so they can disconnect the breaker, but never connect the breaker. Other modules that are installed in the top compartment are used for measuring the power going in and out of the switchgear cabinet.

## 2.4 PLC system

The PLC system contains several S800 series cards that have digital inputs. The Digital inputs are signals coming from the switchgear. These signals do not affect the switchgear, they only indicate to the HMI (Human Interface) what is going on. It is very common to have a different system giving the indications to the operator in a control room. The reason for not having the PLC system operating the breakers directly is that a PLC system is sensitive to changes. If a programmer changes the PLC system there is often something that results in a fault in the system. It would be harmful to have a system that starts flipping the breakers on and off like lamp switches when you have high voltage. To make it as safe as possible the protection for the switchgear is physically connected to the breakers, not through a PLC program.



*Picture 5, S800 series for switchgear.*

### 3 ZS1 Switchgear

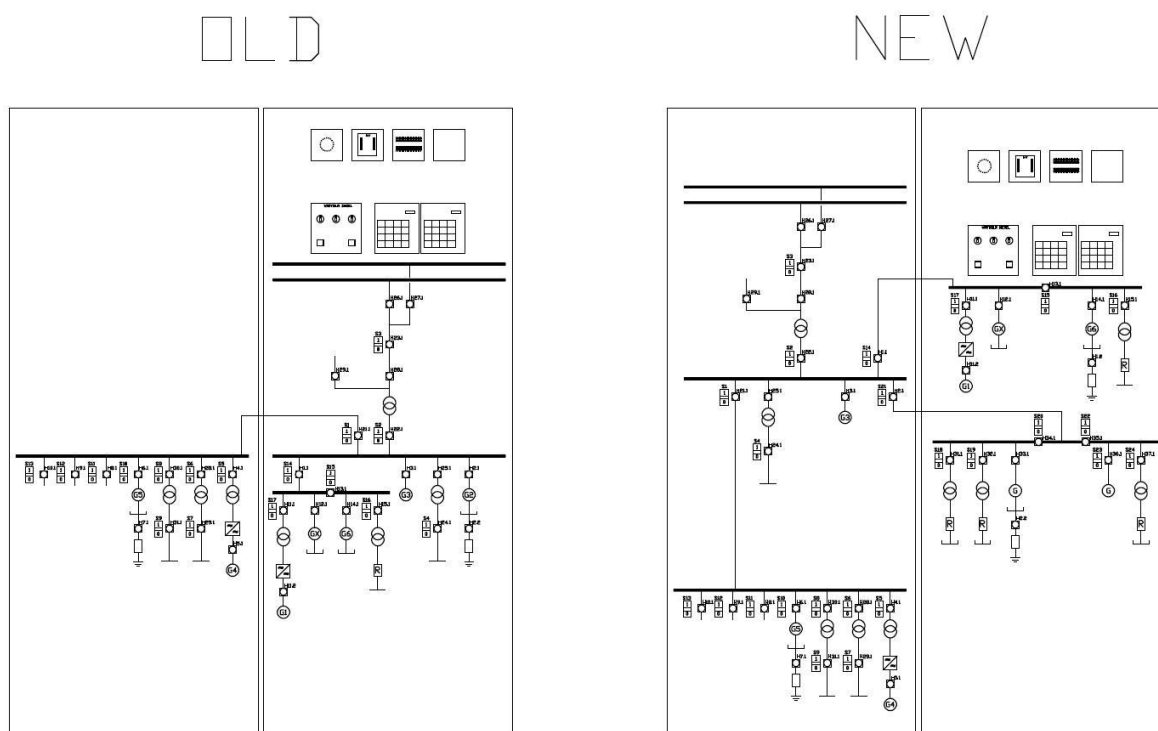
The switchgear is a ZS1 from ABB. This switchgear is a medium voltage switchgear for distribution. ZS1 has replaced 18 previous products. Because of a rich variety on the switchgear market, ABB introduced the ZS1 to meet the specifications of each country market. ZS1 was used because it is what you will find out on the market today. Ten cabinets were needed from the ZS1 series for the switchgear. It needed to be able to transfer the energy to the load banks or the grid. The switchgear controls three load banks and two generators. Two bus tie breakers and one incoming was needed. The switchgear is an 11kV switchgear. The bus bar can handle rated current up to 1250A. The switchgear can hold 4000A for 1s. The protection relays have to open the breaker faster than 1s in case of emergency. If an arc flash appears there is less time to get the breaker to open. Vamp protection relays will react after 7ms and the circuit breaker will open in 50ms. This will give a total of 57ms for the breaker to open in case of a dangerous arc flash. /4/ /6/



*Picture 6, Unigear ZS1 switchgear*

### 3.1 Mimic

Mimic is used for controlling the medium voltage system (MV). In this case this is on the doors in the control room. From the control room you can operate the whole bus-system in the building. The task with the mimic was to redesign it for a new test cell. In the beginning it was meant to fit in the new switchgear on the old mimic. After several versions of the design, it was clear that it would be better if it was designed from scratch. The mimic for the whole building was redesigned



*Picture 7, Old and new mimic*

From the picture above you can see some of the changes that have been done from the old to the new mimic. With the new drawing there will be room for 1 more switchgear.



### 3.2 PLC system

For the new SWG a hardware PLC system was needed. This system handles all the signals and control for our Medium voltage switchgear. These signals can be breaker positions, earth breaker positions and alarms. For the PLC system ABB products CI810B, DI810 and AI810 were used. The S800 series is a process I/O system that is used around the world. Different modules can be used to get digital or analog signals. /3/

The analog signals that were drawn for the PLC are going to take care of all the signals from the SWG. The PLC will then talk to WOIS (Wartsila Operator Interface System). At the WOIS we can see what happens with the SWG. Depending on what problem or situation the SWG is in, the PLC will then send a signal to the WOIS. WOIS is what Wärtsilä uses to connect a PC to various hardware in a power plant and to operate it and view operating parameters.



*Picture 8, ABB S800 series*

## 4 Protection relays

The protection relays protect the gear so that it is not exposed to damaging voltages from the grid or our own gear. The protection relays will react if we have harmful voltage in the system. It will open up breakers before any gear gets broken. The infrastructure has been improved with these relays. The pictures of Vamp modules are taken from Vamp website.

### 4.1 Vamp 50 including arc function

The Vamp 50 protects the switchgear from overcurrents, earth faults and arc flashes. Arc flashes are one of the most dangerous faults for a human near the switchgear. The overcurrent is harmful for the switchgear as it can destroy it. Earth faults are also harmful for the switchgear and for other equipment in the laboratory. Earth faults may appear when a cable has a weak insulation, which will lead voltage and current to earth before reaching the load. Arc flashes appear when a breaker breaks voltage/current from a load. Every breaker makes an arc flash when it breaks voltage/current, the only difference is the size of the arc flash. With higher voltage/current the arc flash gets bigger and more dangerous. /9/



Picture 9, Vamp 50



## 4.2 PMU Vamp 260

Vamp 260 is a power monitoring unit. The vamp 260 is a multi function monitoring unit. It is based on the same hardware as protection relays but with extensive measuring possibilities. This is the module that is used for monitoring how much energy is put into an engine and how much energy is produced. This unit is needed to measure and calculate these values: /12/

- Active, reactive and apparent power
- Active and reactive energy
- Harmonics and THD of currents and voltages
- Programmable average value calculations
- For energy pulse outputs



Picture 10, Vamp 260

### 4.3 Vamp 55

Vamp 55 is a voltage and frequency protection relay. This protects the switchgear from overvoltage and frequencies that may be harmful for the gear. The protection of under voltage and underfrequencies will not be used. This is because the engines are connected to load banks where the frequencies are below nominal frequencies in certain tests. /10/

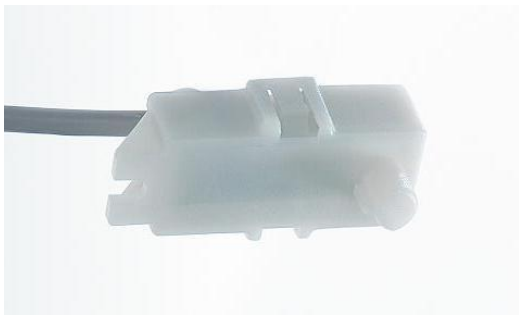


Picture 11, Vamp 55

#### 4.4 Arc sensor VA1DA-6

The arc sensors are placed in three places in one switchgear cabinet. They are optical sensors that activate when a flash occurs. The protection relay opens the breaker if one sensor sees a flash and the current transformer reaches high current. The advantages of using the VA1DA-6 are: /16/

- Easy installation and replacement
- Enables fault location indication
- Surface mounting
- Tube mounting
- Continuous self supervision



*Picture 12, VA1DA-X*

#### 4.5 Vamp 321 arc flash protection system

With the Vamp 321 the arc protection system can be built bigger and more extended. Vamp 321 includes overcurrent and arc supervision functions. The Vamp 321 can be built bigger with modules. Vamp 321 is used to build a significant arc protection system. /13/



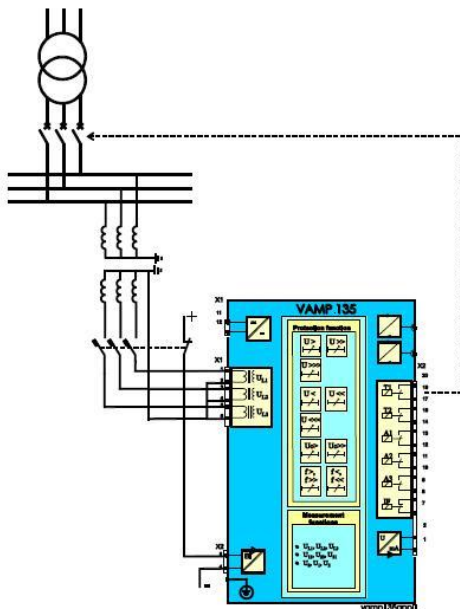
*Picture 13, VAMP321*

## 4.6 Vamp 135

Vamp 135 protect from overvoltage, undervoltage and residual voltage. It also protects from underfrequencies and overfrequencies. It is ideal for power plants.

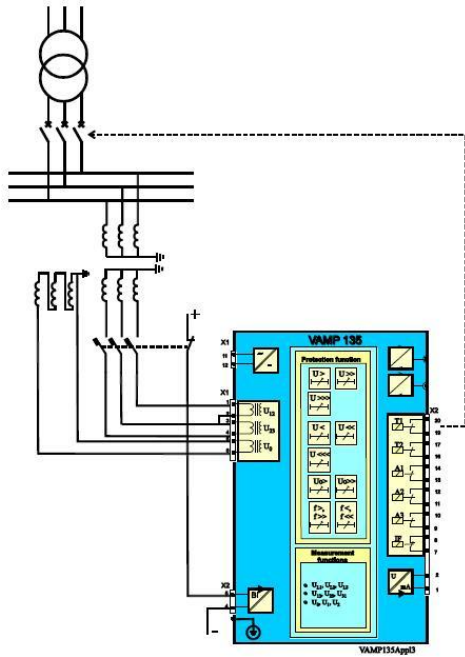
- Three overvoltage stages
- Three undervoltage stages
- Two residual overvoltage stages
- Two overfrequency stages
- Two underfrequency stages
- Circuit breaker failure protection

Three modes can be chosen for this relay, i.e. Line, Line+U<sub>0</sub> and Phase. Line mode will connect the relay to U<sub>12</sub>, U<sub>23</sub> and U<sub>31</sub>. Line+U<sub>0</sub> mode will connect the relay to U<sub>12</sub>, U<sub>23</sub> and U<sub>0</sub>. Phase mode will connect the relay to UL<sub>1</sub>, UL<sub>2</sub> and UL<sub>3</sub>. Based on the protection we need, we will choose the appropriate mode. /11/



Picture 14, 3 phase mode connection

This connection measures the phase voltages UL<sub>1</sub>, UL<sub>2</sub> and UL<sub>3</sub>. The residual voltage is calculated from the measured phase voltages. Here the relay is set to *3phase*. The picture is taken from Vamp website.



Picture 15, The 3 phase +U0 connection

Above you can see that we get the 3 phases and the residual measured. For measuring at this connection the mode to 2 line +U<sub>0</sub> is set.



Picture 16, Vamp 135

## 4.7 Fiber Sensor unit VAM3L

This unit is an I/O unit where the arc sensors are connected. This unit sends the signal to the Vamp 321, which makes the necessary action for the fault. The unit has three connections for arc sensors. It indicates which sensor channel is activated. VX-001 cable is between the Vamp 321 and the VAM3L. The VX-001 is for communicating between the modules. /14/



Picture 17, VAM3L

## 4.8 Current measurement unit VAM4C

The VAM4C unit can be used for 3-phase current measurement or 2-phase current measurement and one earth fault measurement. /15/



Picture 18, VAM4C

## 5 Calculations

For the switchgear it is necessary to calculate the different fault stages that are required for keeping the infrastructure. These calculations are needed to set up the protection relays correctly. They were calculated from a 10% fault and a worst case 250%. The protection relays were tested with the FREJA 306 relay testing system. A model of how the protection stages were calculated is shown in the next chapter.

### 5.1 Model for calculating protection relay

Here we have an undefined load that uses 1 400 kVA. It could be a transformer, a load bank or a generator.

S: 1 400 kVA

U: 11kV

Current transformer: 150/5 A

$$I = \frac{1\,400\text{ kVA}}{\sqrt{3} \times 11\text{ kV}} = 73.57\text{ A}$$

$$I >: 10\% \rightarrow 1,1 * 73.57\text{ A} = 80.93\text{ A}$$

$$I >= \frac{80.93\text{ A}}{150\text{ A}} = 0,54\text{ PU}$$

This calculation is for stage 1. The protection relay is set to 0.54 per unit on stage 1 for current fault. The stage 1 fault is when there is a 10% overcurrent.

K: 0, 1

$$I \gg: 250\% \rightarrow 2,5 * 73.57\text{ A} = 183.93\text{ A}$$

$$I \gg= \frac{183.93\text{ A}}{150\text{ A}} = 1.23\text{ PU}$$

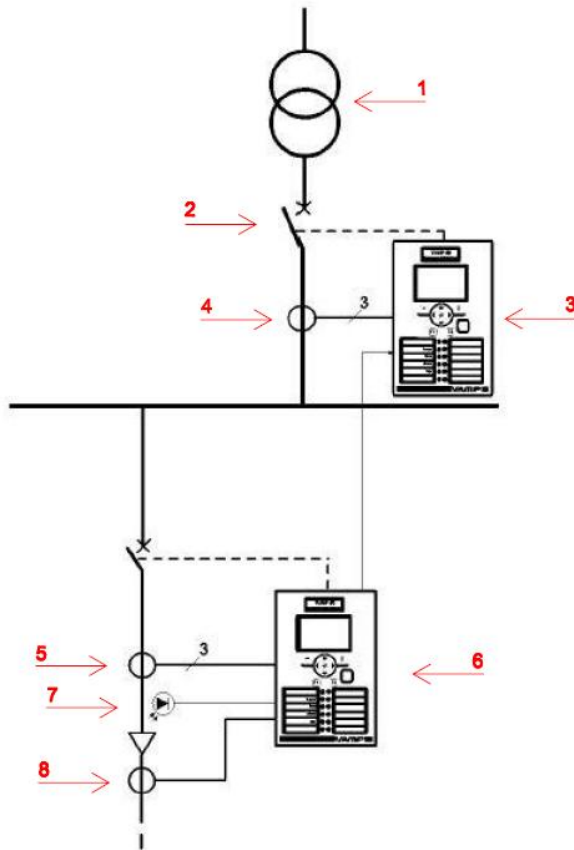
t= 0, 25 s

This calculation is for stage 2. The protection relay is set for 1.23 per unit for stage 2 fault. The stage 2 fault is when there is a 250% over current.

The reason for calculating in PU (Per Unit) is because the setting for protection relays in Vampset works with PU settings. With Vampset we set which measuring transformer is used. Based on the MT (Measuring Transformer) and the PU value, the protection relay will trip.

## 6 Vamp function description

To clarify the function of the protection relays, a description of how they are integrated in the switchgear system can be seen below:



*Picture 19, Vamp relay function*

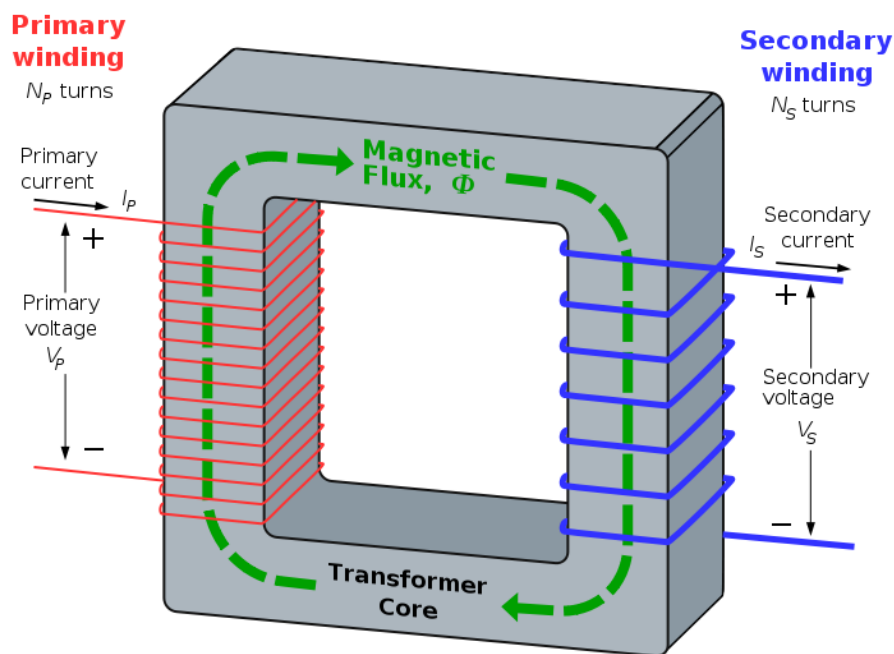
1. The transformer for the power from the grid, to the switchgear system.
2. MV breaker that can be opened from the protection relay.
3. Vamp relay. This can be a module that measures voltage, current or earth fault.
4. Measuring transformer. This is a 3 phase transformer that can scale down the current from 3000A to 5A (3000/5). A relay would never be able to handle currents of that size.
5. Here we have another measuring transformer, but we are now lower down in our infrastructure, so the measuring transformer here can be for example 300A to 5A (300/5). Notice that the transformers always go down to 5A. This is a standard for protection relays.



6. Vamp relay.
7. This is an arc flash detector. This small part will detect any arc light in our MV breaker. When the detector has noticed a flash and the measuring transformer gets a pike, the Vamp relay will open the breaker.
8. This measuring transformer is for detecting earth faults. It only measures if current goes to earth.

## 7 Measuring transformer

In the switchgear there are various measuring transformers. These are current and voltage transformers. ABB delivered the measuring transformers for the switchgear. To get a good measuring and safe protection gear, measuring transformers that have two coils on the secondary side were used. The first coil was used for measuring; this coil needs to be more accurate than the second coil. The second coil was used for protection. The coil needed to be durable and to be able to handle currents that are 10 times higher than nominal current. That is needed if a short circuit occurs in the switchgear. /2/



Picture 20, Transformer

The primary side of the measuring transformer was connected to the circuit. Because we have alternating current (AC) it produces a magnetic flux in the transformer core. This magnetic flux changes direction every time our primary side changes direction. This induced electricity to the secondary side. The secondary current/voltage is proportional to the winding difference between primary and secondary.

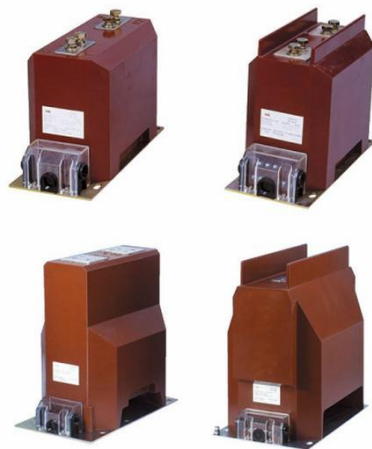
## 7.1 Current transformer

The current transformer is in the bottom compartment in a ZS1 cabinet and this is wired in series with the rail system. All three phases goes through the current transformers, so that the current and protection for the cabinet can be measured. The primary side of the current transformer can be between 300 and 600A. For the secondary side 5A was used. The secondary side will increase or decrease in ratio to the primary side.

Transformer formula:

$$\frac{U_1}{U_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

With this formula you can calculate how many windings a transformer has on the primary or secondary side. It is also used to calculate what voltage there is on the primary/secondary side. Notice that when you calculate the current, the I2 current is above the I1. A very common mistake is to write the formula incorrectly, and then calculate with errors. The transformer can handle voltages between 3,6 and 40,5kV. The primary side can handle 10 to 3 200A. The secondary side can handle 1 to 5A.



*Picture 21, Current measuring transformer*

## 7.2 Voltage Transformer

The voltage transformer measures the voltage on the primary side and secondary side. The primary side of the measuring transformer is 11kV. The measuring side has 50A. The voltage transformer also has a winding that will detect earth fault.



*Picture 22, Voltage measuring transformer*

## 8 HD4 breaker

For circuit breakers the HD4 was used. This breaker is filled with SF<sub>6</sub>. Sulphur hexafluoride (SF<sub>6</sub>) will prevent electric discharges. SF<sub>6</sub> is a dielectric gas. Dielectric gases are used as insulators in high voltage applications. SF<sub>6</sub> is the most popular insulating gas. It is popular because it has good cooling qualities and great arc quenching. SF<sub>6</sub> is a well known greenhouse gas. But through arcing or corona it can produce the highly toxic gas S<sub>2</sub>F<sub>10</sub> (disulfur decafluoride). The breaker is maintenance-free. The poles are sealed for life. /1/



*Picture 23, HD4 circuit breaker*

## 9 Installation of MV-SW

The switchgear was installed on a shelf in the test cell. This makes cable routes more difficult than if it was on ground level. The cables for the switchgear are not easy to bend or get through small spaces. ABB delivered the switchgear for the project. The job was to install it in the test cell and do the necessary wiring for the PLC system and controls.

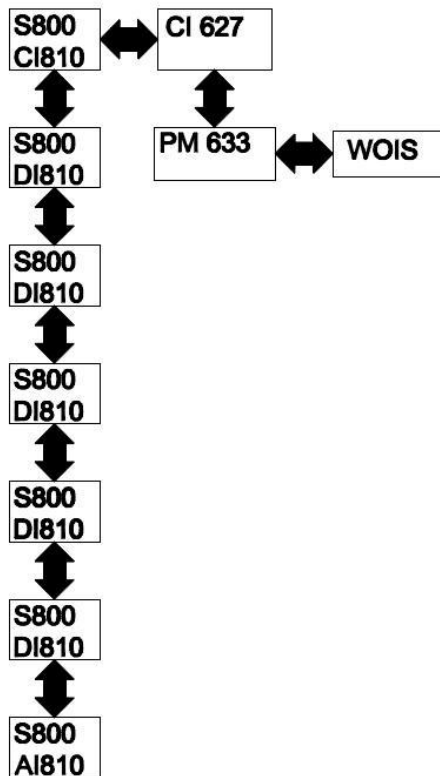


*Picture 24, The shelf for MV-SWG*

### 9.1 Wiring for PLC system

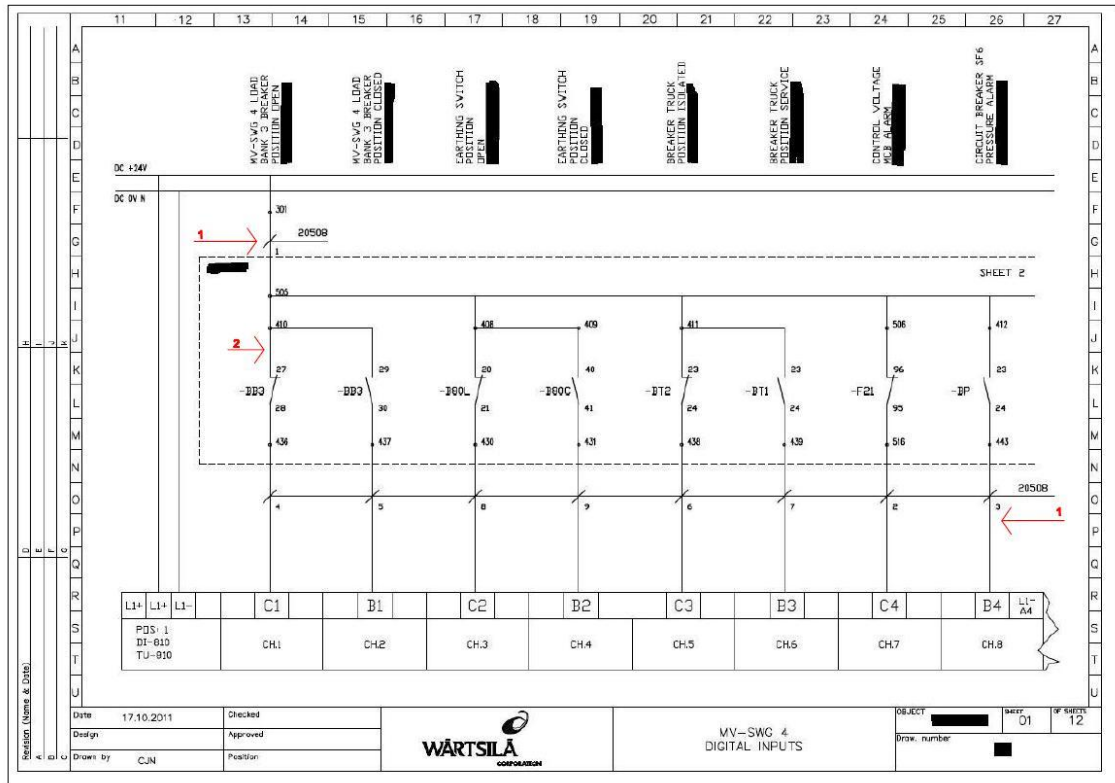
The wiring for the PLC system between the cabinets was drawn and done. There is one cabinet that has the whole S800 series inside. The other cabinets were connected to this cabinet with wires. The cable that was used was an MMO 12x1.5. This cable had enough wires inside it for handling the signals from each cabinet. The signals are the indications for the breaker positions, the earth positions and the truck positions. There are also several alarm indications that go to the PLC system. The signals then go to the HMI (Human Interface).

The S800 series was connected with each cabinet in the switchgear. From the S800 series the signals goes to another cabinet, where there is a CI 627 card communicating with a PM 633 card which sends the signals to the WOIS (Wärtsilä Operator Interface System).



*Picture 25, The communicating system*

For the PLC system new drawings were made which handles the signals. These drawings were made before the Switchgear arrived. During the planning process it was important to visualize how the wiring will be done in the switchgear. Old knowledge was used combined with the new demands during the planning process. The job for the PLC system was to make the drawings for every signal from the switchgear. The planning processes also included giving right tags for the signals from the switchgear and also plan the cable markings.

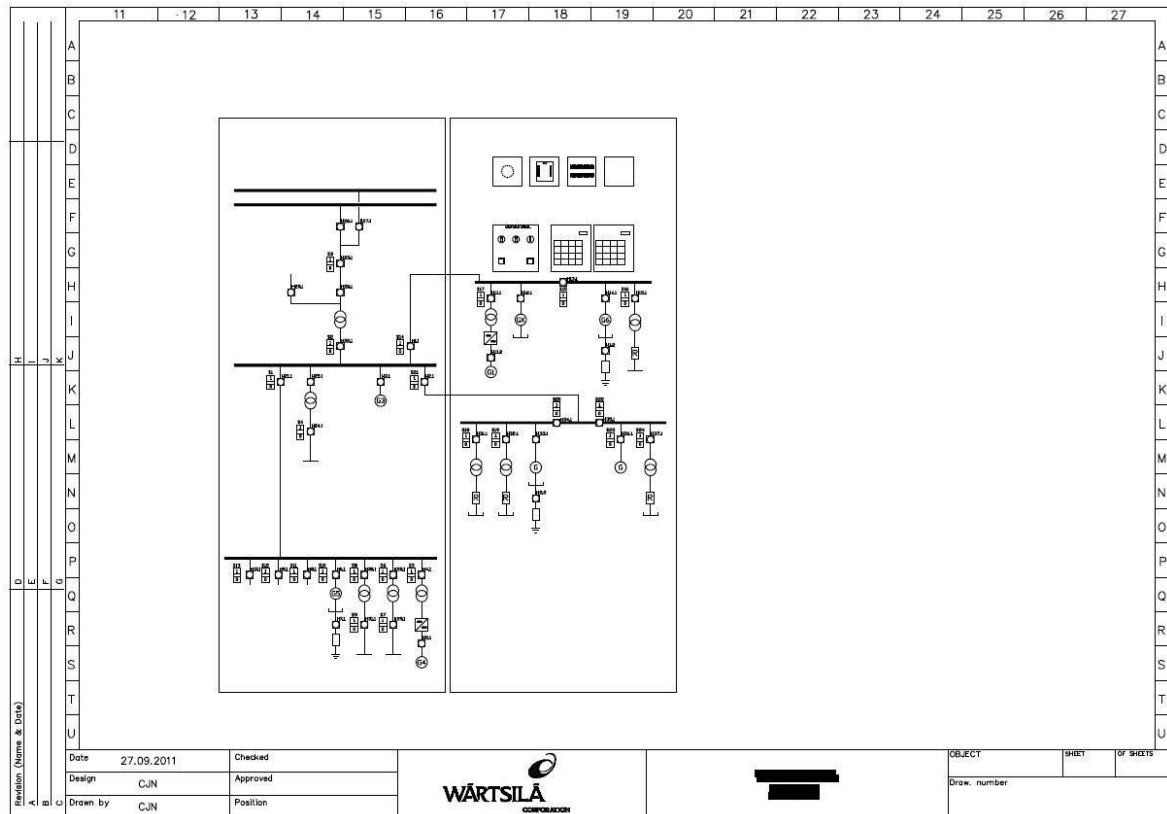


Picture 26, Drawing of PLC signals.

1. Here above we can see the MMO 12x1,5 cable with 12 wires that are connected in the cabinet and then they go to the PLC.
2. Here the different contacts are represented in the switchgear cabinet. Above the contacts there is a text explaining what the contacts represent. We also see which channel on the S800 series an indicator is connected to.

## 9.2 Mimic

The mimic is where all the switchgears in the WVC building can be controlled. There are also indicators showing what positions different breakers are in. New drawings for the mimic with the new switchgear included were needed.



*Picture 27, Mimic*

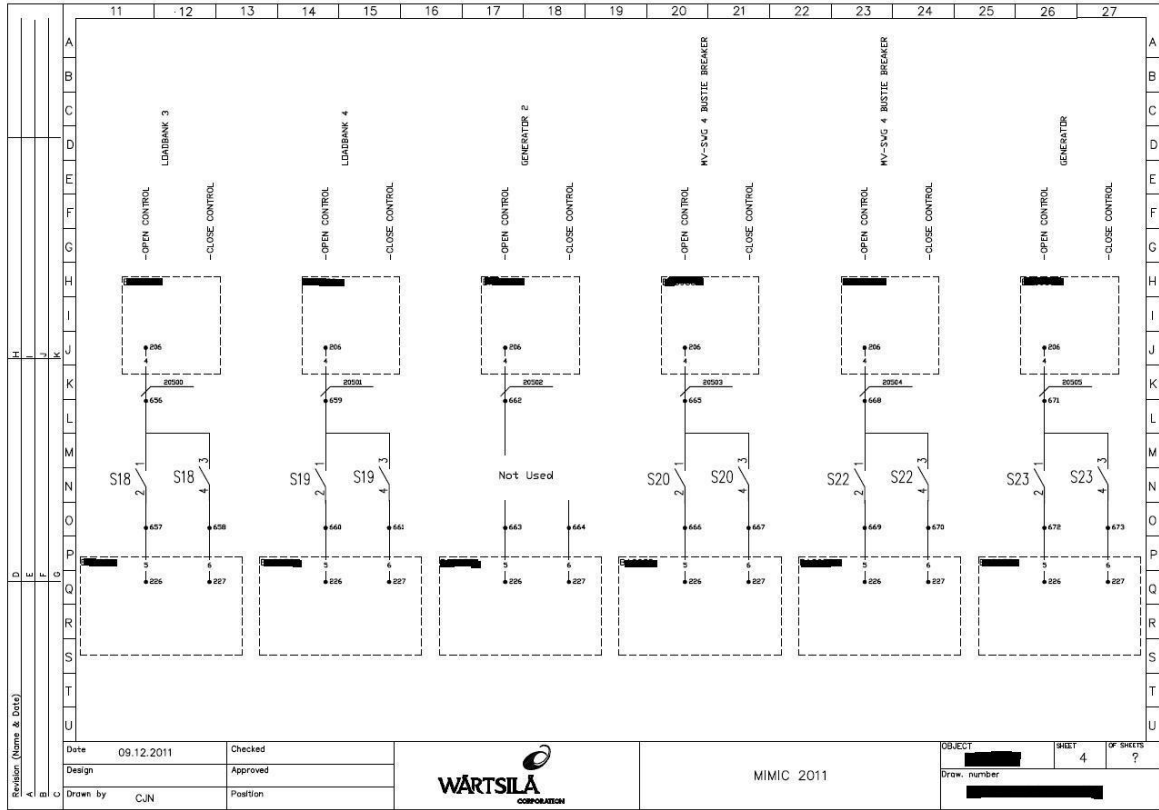
On the Mimic doors there are several indicators and switches for controlling the switchgears. The Mimic is where breakers are opened or closed. Depending on the tests needed breakers are open or closed so the engine generator starts feeding electricity to the load banks or to grid operation. In grid operation we feed electricity out to the grid in Vaasa.

New drawings have been made for the new switches and indications. The new drawings also make the mimic easier to use. This is because the switchgears are now in numerical order. The Mimic was functional before, but when the new switchgear was included we encountered problems such as “where will there be room for the new switchgear?”. The job was to re-draw the mimic and plan the new switchgear controls in it.



### 9.2.1 Controls for SWG

For the Mimic Controls and Indications were planned for the new SWG.



Picture 28, Switch control

This is an example of the controls. There are switches that are spring released and when you press down the switches, they send a signal to the cabinet that it shall close the HD4 breaker. When a breaker needs to be opened you press a button which will then send a signal to the breaker that it shall open. The task was to plan all the cables and switches for the new switchgear. These drawings will show how the switchgear breakers are connected to the Mimic, which is located in the operator room.

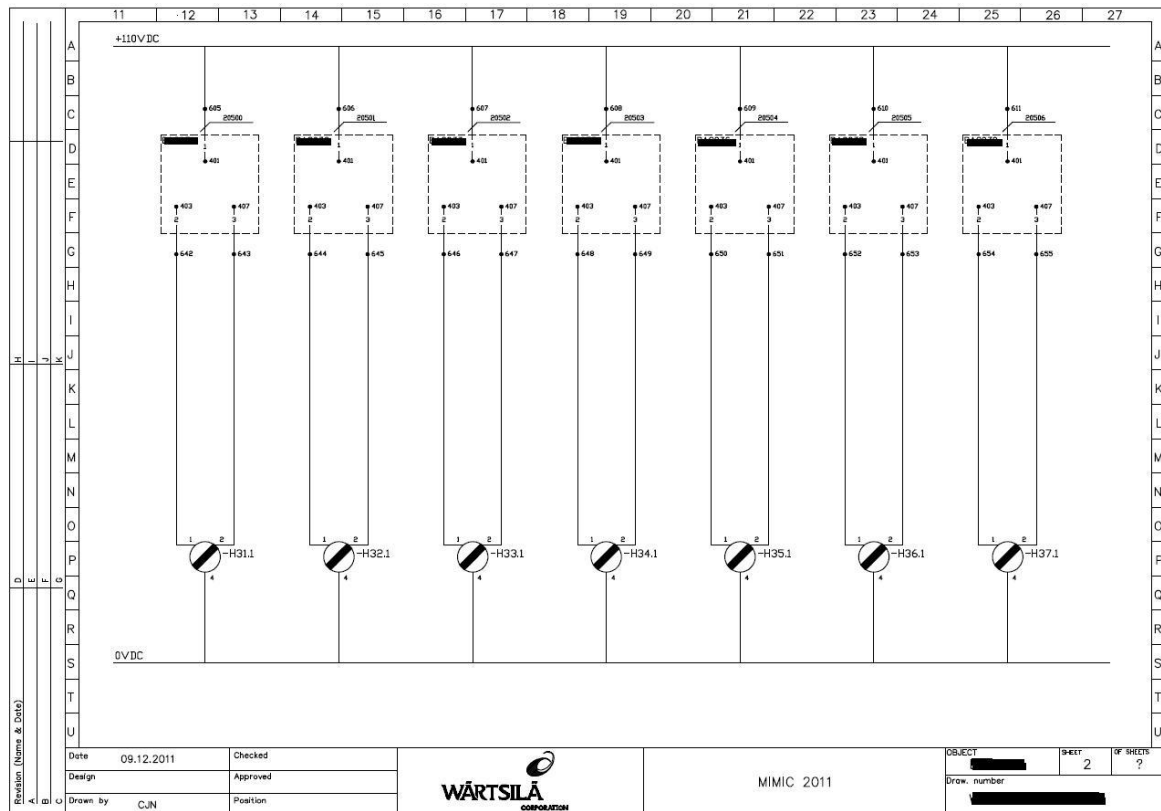


Picture 29, Switch

This is a picture of how the switch looks in real life (IRL). The Mimic switches are all the same model. They are all spring-released switches with one closing and one opening button.

### 9.2.2 Indications for SWG

Indications help us to see in which position the breaker is. These will tell us if the breaker is closed, open or if the breaker is taken out from the cabinet.



Picture 30, Indications

The indications will have one negative DC wire and two positive DC wires. The negative wire will always be connected. The two positive wires will give signals to the indicator so that it will change direction. The signals will only be pulse signals. The indicator stays in the position depending on which connector has got a pulse, nr 1 or nr 2. The indicators get their signals from the same cable where the SWG cabinet breaker is controlled. The cable MMO 7X1.5 is used for indicators. The task was to plan all the indicator signals from the SWG to the Mimic panel.



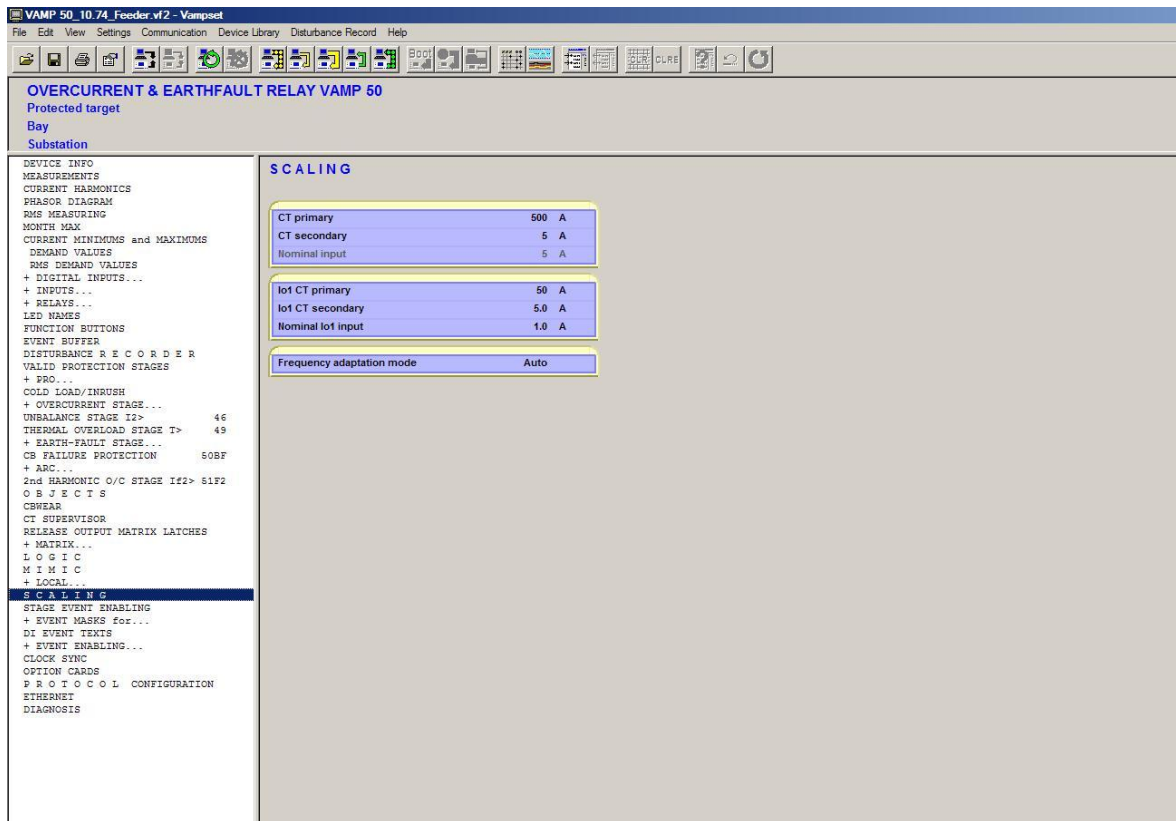
*Picture 31, Indicator*

This is a picture of a real indicator on the Mimic. This indicator shows that the breaker is closed.

### 9.3 Vamp setup for SWG

To explain where different vamp modules are located in the SWG, there are drawings in AutoCAD of where they will be installed in the SWG (see enclosure 1).

The Vamp modules had to be configured so that they protect the SWG and equipment connected to the SWG. Vampset was used to configure the Vamp modules.



Picture 32, Vampset

In this picture we can see what the Vampset program looks like. In this example we see that we are in the Scaling menu. In this menu we choose which measuring transformer we will have in the SWG. The example above is for the vamp 50, which measures current. Then the values for the primary side current and the secondary side current are inserted.

In Vampset the calculations for the individual vamp modules come to use. There the PU units for stages 1 and 2 are set. These stages are important when the protection relay shall trip.

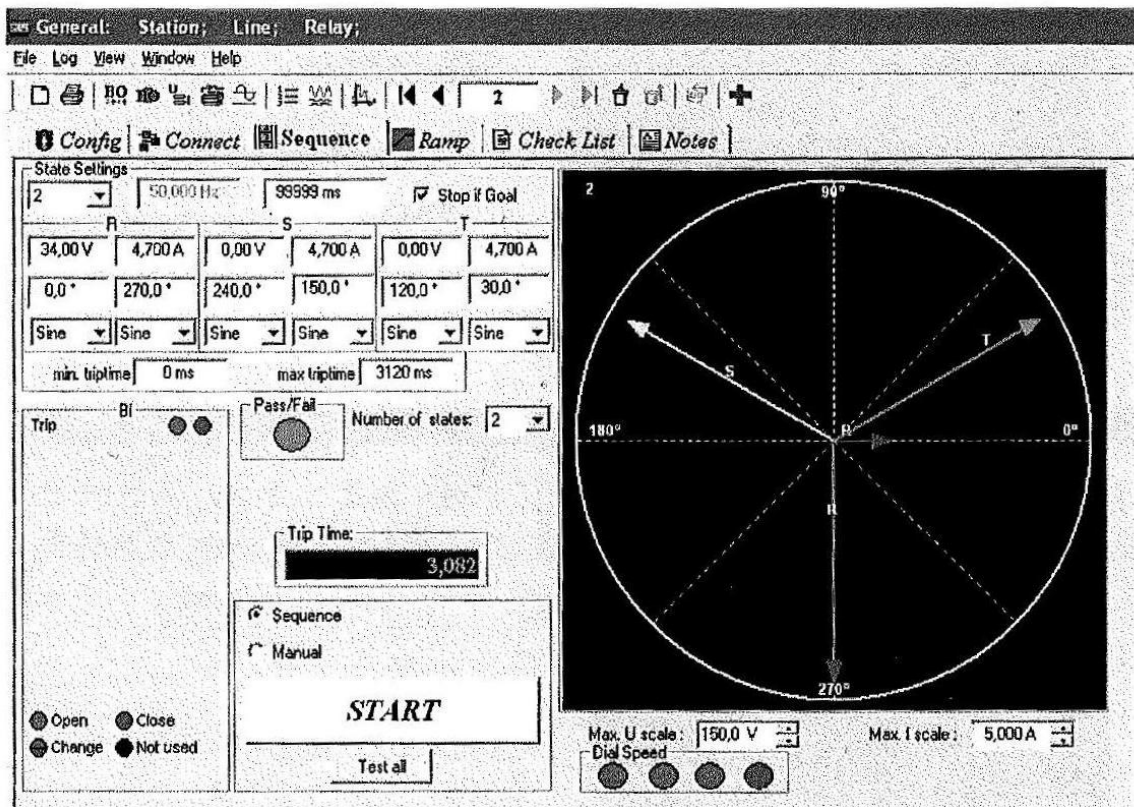
## 10 Testing protection relays

The Vamp modules must be tested before their functionality can be relied on. To test the relays FREJA 306 Relay testing system was used. This is expensive equipment for testing protection relays. With this equipment it is tested that the calculated trip stages were working in reality. There you get useful information about whether the calculations were correct and functional. The FREJA system simulates overcurrent, overvoltage and fault frequencies. Before the protection relays are reliable they all needed to be tested. I had the responsibility for testing all protection relays, making a test report and installing the relays into the SWG.

				Used	Estimated	Actual
	A	PU		Current	time	time
K	0,05					
I>	252	4,2	0,84	4,7	3,108	3,082
I>>	571	9,5	1,9	9,7	0,15	0,151
Io>	2	0,2	0,04	0,21	0,8	0,794

*Table 33, Vamp module test*

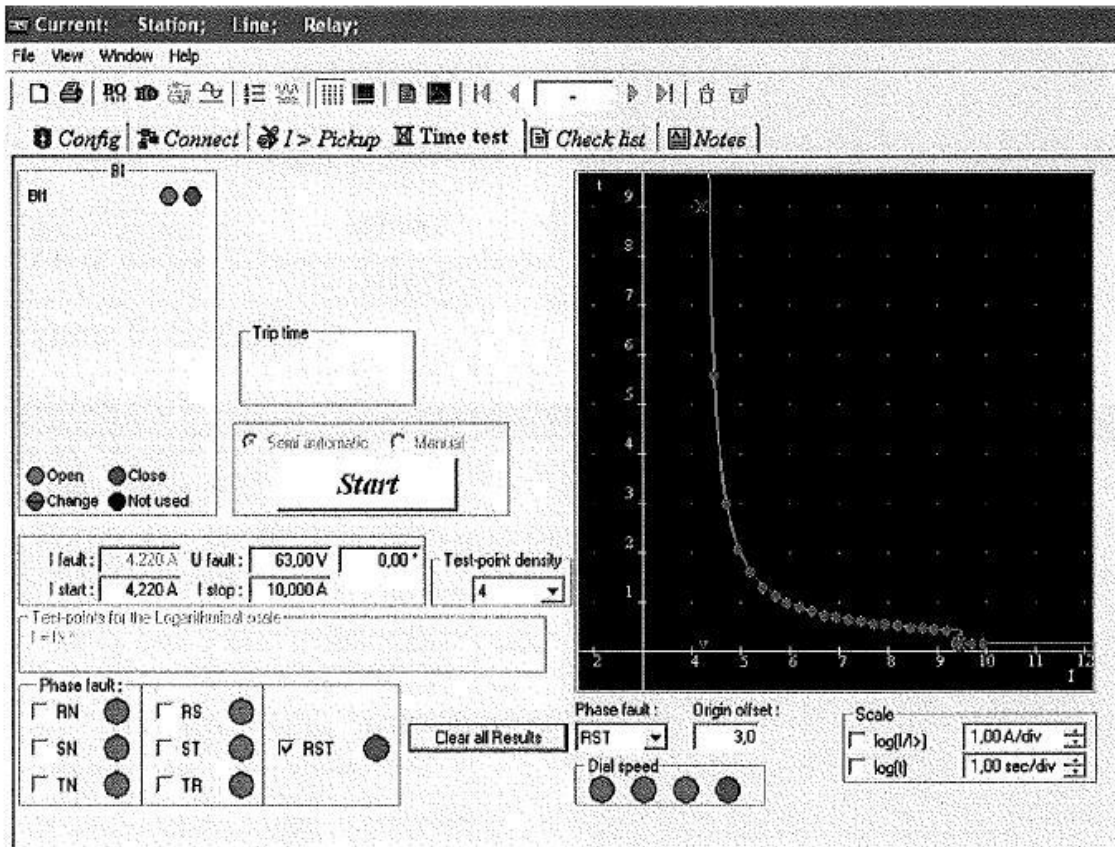
When the module was tested we see how long it takes for the protection relay to trip with the calculated currents. Here we can see that the calculations were close to reality. This gives us the information that the protection relay has been configured correctly.



Picture 34, FREJA testing system

Here above we can see the user interface for FREJA 306 Relay Testing System. The different values from our PU calculations were set here. We were informed if the phase angles were remain through different fault stages.





Picture 35, Inverse curve in FREJA

In FREJA it is also needed to test the different Vamp modules with an inverse curve. The inverse curve gives information if the protection relay reacts at different overcurrents. In the picture we see that the inverse line represents how high the current is. The circles inform when the relay trips. The relay needs to trip fast at high currents, and slower at lower currents. In the picture we can see that the relay responds very well and is functional.

The task was to determine that the Protection relays are functional and safe. Every protection relay was tested with FREJA followed up with a test report.

## **11 Results**

My work was to draw and design a hardware PLC system that will handle all signals and controls for a Medium Voltage Switchgear (MV-SWG). These drawings have been done and are ready to be used in the project.

The next step in my work was to design the wiring for the “Mimic”. I have designed the “Mimic” and made necessary drawings for it. These drawings will be used in the project.

The last task for this thesis work was to calculate the settings for the protection relays. This has been done and approved by my client. The protection relays are tested with the FREJA testing system and Vampset built in simulator.



## 12 Conclusion and discussion

The bachelor thesis work has been very educating for me. I have improved my skills in designing electrical drawings. I have made all the drawings and plans that Wärtsilä has demanded of me. This project has been very educational and I have got more experience of working as an engineer.

My work with this project is not done yet. I will also be part of the team that will construct the Switchgear.

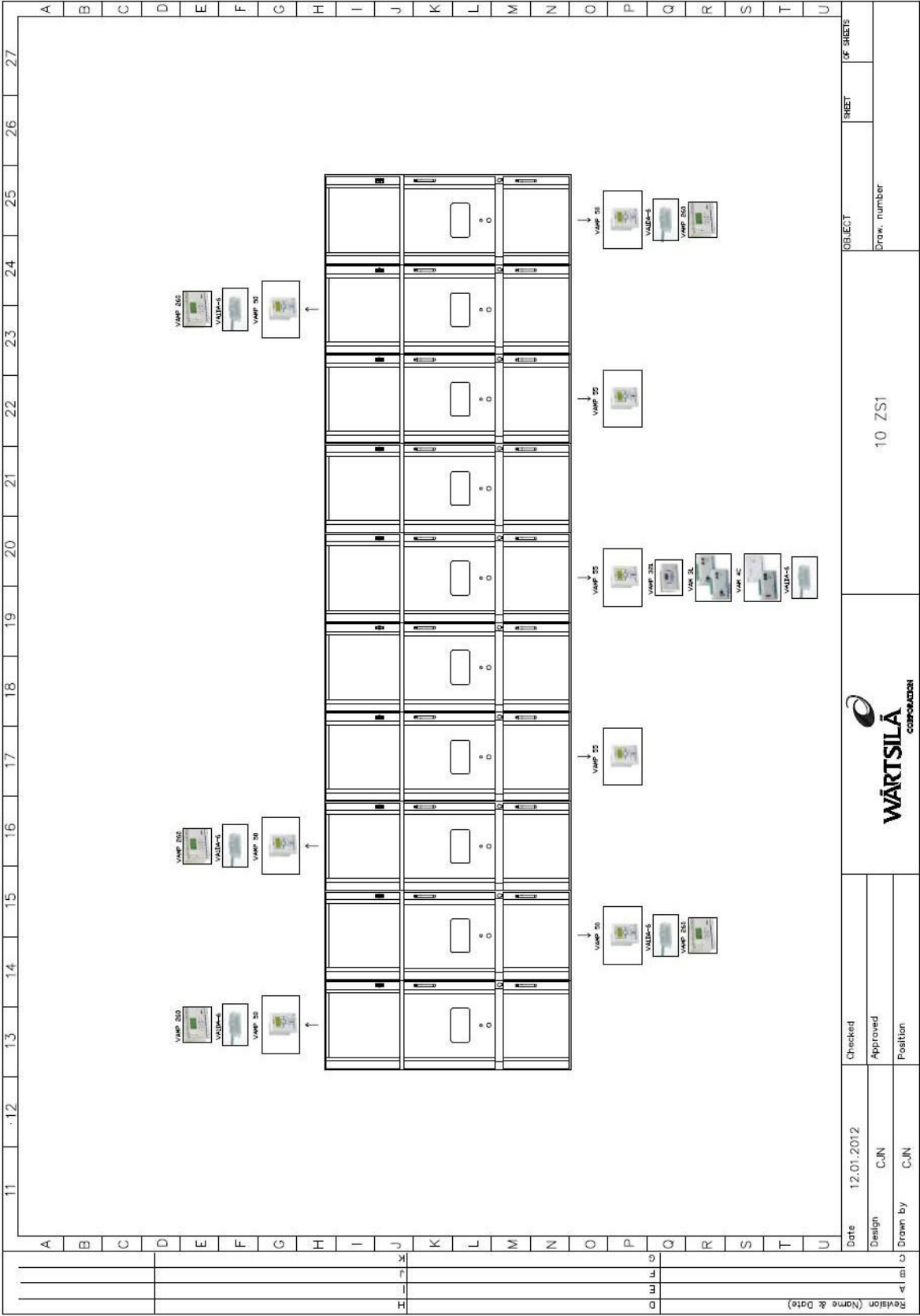
I will have the responsibility for configuring all the protection relays for this project. This will be important for the infrastructure and safety of this project.

In the future an option would be to use a display that is programmable for the control of switchgears. It will be easy to update and get an easy overview of the switchgears. This system should also have an emergency supply power, so it can be used even if the power is out.

The main goals of this thesis have been accomplished. Wärtsilä has got the necessary drawings and designs that they required from me. It will be interesting to continue my work at Wärtsilä and take part in future projects.

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10 ZS1

SUBJECT  
Draw number

SHEET  
OF SHEETS

Date	12.01.2012	Checked
Design	C.JUN	Approved
Drawn by	C.JUN	Position

Revision (Name & Date)

D	
F	
G	
H	

