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INTERLOCKING AND DATA ACQUISITION IN A HIGH VOLTAGE SYSTEM

School of Technology
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FOREWORD

This thesis is made for Wärtsilä as a part of an Electrical Engineering studies at Vaasan ammattikorkeakoulu, - University of Applied Sciences. I would like to thank my thesis supervisors Nicklas Johansson and Juha Vertanen from Wärtsilä. Also, thanks to Mikko Ketonen, who at first gave me this opportunity to do this thesis and to Jari Koski who was my mentor during the thesis from VAMK.

Furthermore, I would like to thank everyone, who helped me during this thesis process.

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ABSTRACT

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The objective of this thesis was to find out on a general level if the ABBs new SSC600 Smart Substation Control and Protection relay is suitable for the Medium Voltage Switchgear to be used in Wärtsilä's new Smart Technology Hub, which is going to be built in Vaskiluoto, Vaasa. No decisions were made regarding protection devices for switchgear at this point of making thesis, so devices from other manufacturers were also considered as an option.

The research started by getting introduced to the SSC600, reading manuals and asking questions from the manufacturer if there are any constraints for the use of the device in new STH in the future. IEC 61850 standard set the frames for the thesis and the planned system and the Intelligent Electrical Devices should be interoperable with the standard.

In the making process of this thesis, the reliability and safety of the planned systems were the main thing. The grid in the new factory is going to be complex, many different protection functions are necessarily and interlockings need to be certain. Still the system needs to be editable for the possible extensions and changes. Based on the conclusions, the SSC600 is suitable for the use and together with the other IEDs, it is possible to build a functional system for a protection and control.

This thesis gives information and a good overall picture about the SSC600 to the company and it can be used, when decisions are made about the devices for the new STH.

Keywords SSC600, IEC 61850, grid, Smart Technology Hub

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Sähkötekniikka

TIIVISTELMÄ

Tekijä	Pertti Puurula
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Tässä opinnäytetyössä selvitettiin ABB:n älykkään sähköaseman ohjaus- ja suojauslaitteen soveltuvuutta tulevaan Wärtsilän tutkimus-, tuotekehitys- ja tuotantotehtaaseen, joka rakennetaan Vaskiluotoon, Vaasaan. Koska laitevalintoja ei ollut tässä vaiheessa vielä tehty keskijännitekojeistojen suojaukseen, myös muiden laitevalmistajien vaihtoehdot otettiin huomioon SSC600:n lisäksi.

Tutkimus alkoi perehtymisellä releen ominaisuuksiin ja käyttöohjeisiin sekä selvittämällä valmistajalta, onko laitteen mahdolliselle käytölle tulevaisuudessa esteitä. IEC 61850 standardi määritteli järjestelmän laitevalinnat ja kommunikoinnin tuli tapahtua noudattaen standardin protokollaa.

Suunnitellun järjestelmän luotettavuus ja turvallisuus olivat tärkeitä asioita. Verkko tulee olemaan monimutkainen uudessa tehtaassa ja se vaatii suojalaitteilta monia suojausfunktioita, sekä varmatoimisia lukituksia. Järjestelmän laajennettavuus ja muokattavuus tulisi olla myös mahdollista. Selvityksen mukaan SSC600:lla voidaan toteuttaa yhdessä muiden suojauslaitteiden kanssa toimiva ja IEC 61850 yhteensopiva järjestelmä keskijännitekojeistojen suojaukseen.

Tämä opinnäytetyö antaa yritykselle tietoa laitteesta ja sen ominaisuuksista, jota voidaan käyttää hyväksi, kun laitevalinnat uuteen tehtaaseen tulevat ajankohtaisiksi. Opinnäytetyö antaa hyvän yleiskuvauksen yritykselle SSC600:n ominaisuuksista.

Avainsanat SSC600, IEC61850, verkko, tehdas

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DEFINITIONS AND ABBREVIATIONS

ACSI Abstract Communication Service Interface

DAN Double Attached Node

GOOSE Generic Object-Oriented Substation Event, communication protocol for horizontal data transfer between IED devices defined in IEC 61850 standard

HMI Human-Machine Interface

IEC International Electrotechnical Commission

IED Intelligent Electronic Device

ISO International Standards Organization

LAN Local Area Network

MMS Manufacturing Message Specification

MS Millisecond

MU Merging Unit

NCC-GW Network Control Center- Gateway

OSI Open System Interconnection

PCM600 Protection and Control IED Manager

PRP Parallel Redundancy Protocol

SAN Single Attached Node

SAS Substation Automation Solution

SCL Substation Configuration description Language

SLD Single-Line Diagram

SV Sampled Values

STH Smart Technology Hub

TCP/IP Transmission Control Protocol / Internet Protocol

XML Extensible Markup Language

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APPENDIX 1. Technical data of SSC600

1 INTRODUCTION

1.1 Objective of Thesis

Wärtsilä is a company manufacturing reciprocating engines, amongst other things. This requires, from the testing and validation point of view, the possibility to test and develop engines in a real environment. From the production point of view the finished engines need to be tested in line with customer demands in so site-like condition as possible.

The planned High Voltage System for the new Smart Technology Hub in Vaskiluoto will be very flexible with many different loading possibilities depending on the engine set-up. There will be many different users operating the system simultaneously. This requires a highly dependent but still easily modified and transparent interlocking system. The Hub will consist of many innovative solutions related to Big Data, Digital Twin, for example. These data need to be collected also from the High Voltage System or at least be accessible.

This thesis is a research for ABB's SSC600 relay capability to protection and control on a substation level to the new STH. Other manufacturers' products are also considered as an option.

1.2 Wärtsilä Oyj

Wärtsilä Corporation is a globally leading supplier of Smart Technology and Global Solutions in the Marine and Energy Markets. The company was established in 1834. Wärtsilä's engine product family includes various diesel, oil, gas and multi-fuel engines, as well as various machinery and equipment such as propeller and transmission systems. Wärtsilä's business areas include Marine Business and Energy Business. Service Business has been incorporated into Marine and Energy Business since January 2019. Wärtsilä also offers solutions for all steps of exploration, production, transportation, storage and processing of oil and gas.

Wärtsilä in 2018:

- Net sales totaled EUR 5.2 billion
- Employees approximately 19,000
- Operations in over 200 locations in more than 80 countries in the world /12/

1.3 Wärtsilä Smart Technology Hub

Wärtsilä is building a new research center, STH, for product development and production, in Vaskiluoto, Vaasa. It is a remarkable step in Wärtsilä's vision of Smart Shipping and a Smart Energy Sector. The STH is going to be unique in its field, enabling efficient product development and testing for the maritime, oil and gas industries and New Energy Systems. /1/

2 BASICS ON THE STANDARDS

2.1 IEC 61850

2.1.1 Objective of the Standard

The international IEC 61850 standard sets frames for Substation Communications Networks and Systems. IEC 61850 consists of different parts ranging from the requirements on Substation Automation Systems to the details of a communication protocol.

The standard defines a wide set of protocol services for Substation Level Automation and an expandable object-oriented data model. It specifies how the functions expose their information to a Communication Network but not any protection or control functions. XML description language is also defined for Substation Automation System. /2/

The purpose of the standard is to provide interoperability between the IEDs from different suppliers and the functions to be performed by systems for power utility automation but residing in physical devices from different suppliers. /7/

Interoperability for devices from different suppliers must have the following aspects:

- The devices shall be connectable to a Common Bus with a Common Protocol
- The devices shall understand the information provided by other devices
- The devices shall together perform a common or joint function if applicable /8/

2.1.2 Structure of IEC 61850

The standard consists of 10 main parts which are listed below.

IEC 61850-1: Introduction and overview

IEC 61850-2: Glossary

IEC 61850-3: General requirements

IEC 61850-4: System and project management

IEC 61850-5: Communication requirements for functions and device models

IEC 61850-6: Configuration description language for communication in electrical substations related to IEDs

IEC 61850-7: Basic information and communication structure

- IEC 61850-7-1: Principles and models
- IEC 61850-7-2: Abstract Communication Service Interface (ACSI)
- IEC 61850-7-3: Common Data Classes
- IEC 61850-7-4: Compatible Logical Node Classes and Data Object Classes

IEC 61850-8: Specific communication mapping service mapping (SCSM)

- IEC 61850-8:1 Mappings to MMS (ISO/IEC9506-1 and ISO/IEC 9506-2)

IEC 61850-9: Specific Communication Mapping Service Mapping (SCSM)

- IEC 61850-9-1: Sampled Values over serial unidirectional multi-drop point to point link
- IEC 61850-9-2: Sampled Values over ISO/IEC 8802-3

IEC 61850-10: Conformance testing /7/

2.2 GOOSE

In IEC 61850, Generic Object Oriented Substation Event is the main way to specific communication services mapping. GOOSE is a method of exchanging messages between IEDs over a local Ethernet network and it is suitable for time-

critical applications such as protection functions in a substation. GOOSE connections replace transmission via contacts and binary inputs; for protection signals, transmission times under 10 ms are required and under 20 ms for switch positions and interlockings. Measured and metered values are transmitted in less than 100 ms. The GOOSE applications are generated in the system configurator for this purpose. This data is exchanged by the devices in a high-performance manner via GOOSE messages. GOOSE can carry both analog and binary values in their messages, although mainly GOOSE messages are carrying changes of state of substation parameters. Possible data functions are for example breaker tripping, status update, interlocking and event recording.

A message send by an IED can be received and used by several receivers. GOOSE is also supported between devices in different switchgears. The exchanged information is described in data terms via standard-confirming Substation Configuration description Language (SCL). The application layer in GOOSE is directly mapped to the data link layer, which means that the message is skipping intermediate layers including transport and network layers. That is why GOOSE message involves no IP address and can be transmitted only via a LAN. The LAN as a solution reduces total costs and time in engineering because hardwired connections are not needed to make. /10/

2.3 Communication Protocol

Ethernet and TCP/IP are used for the communication, which provides a broad range of features from mainstream communication. In IEC 61850 communication profiles can be divided into vertical and horizontal. The vertical profile uses MMS over TCP/IP and horizontal communication Layer 2 Ethernet multicast messages.

IEC 61850 defines SCL file types in the sequence of the engineering. In the engineering process for an IED three types of files are used:

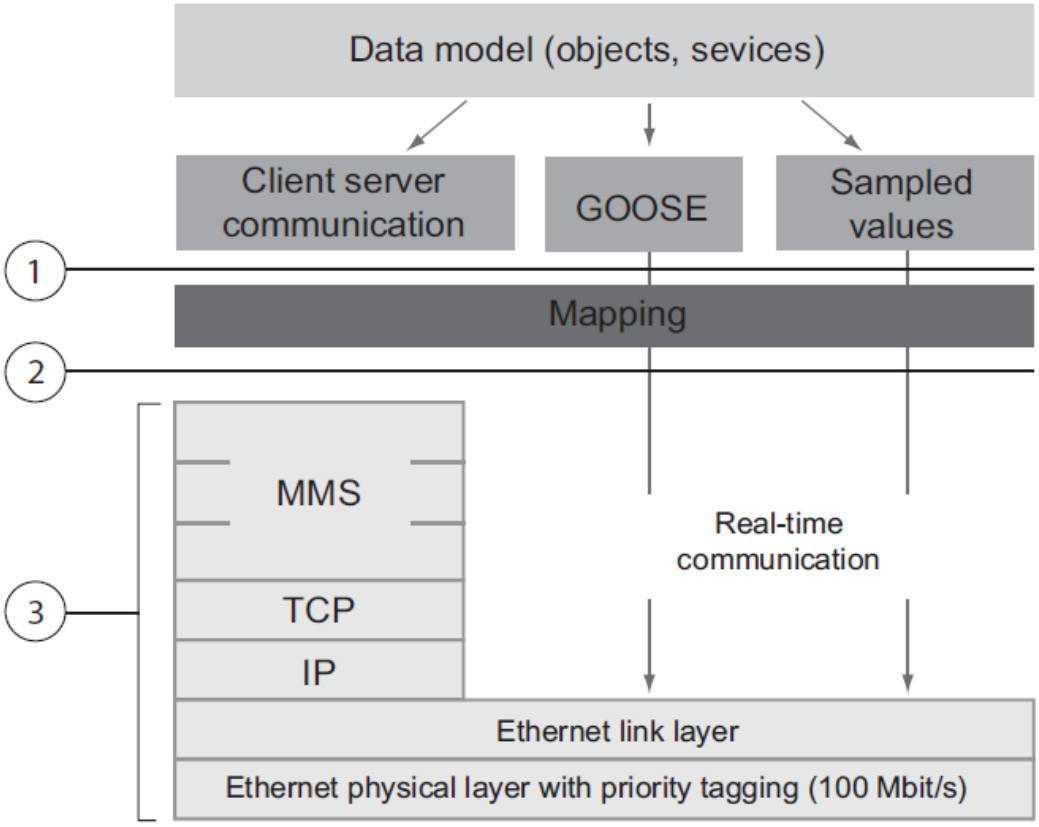

Figure 1. Communication stacks and mapping used in IEC 61850

As seen from Figure 1, Level 1 is Abstract Communication Services Interface (ACSI), which describes communications between a client and a remote server. It is for a fast and reliable system-wide event distribution between an application in one device and many remote applications in different devices and for transmission of Sampled Values. Sampled Values (SV) is a protocol for the acquisition of raw data, so it makes easier to transfer digitized samples of analog measurements. It is also time critical message.

Level 2 is a stack interface.

Level 3 is an ISO/OSI stack, which is a hierarchical set of rules how information is coded for transmission.

IEC 61850 provides a method for identifying all signals that belongs to a function. They are identified with the Logical Nodes representing the functions. All available signal information for commands is available in Logical Nodes. /2/

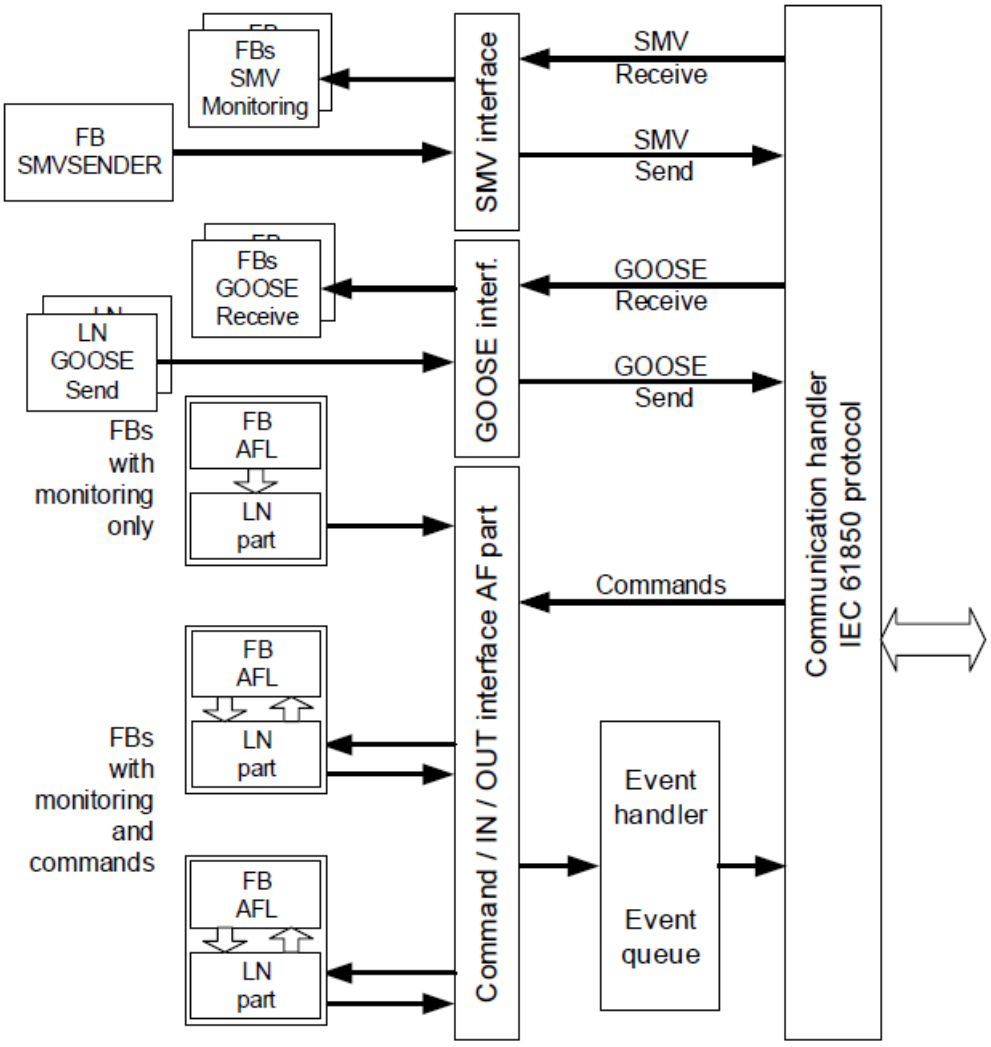

Figure 2. Principle interface for IEC61850 communication

2.3.1 Station Bus

The Station bus defines the communication between the Station level and the Bay level. In Substation automation, the station bus is used for event recording, reporting and interlocking. /2/

2.3.2 Process Bus

IEC 61850-9-2 defines the transmission of SV within the Substation Automation System. The process bus is used for distributing process data from the primary circuit to all process bus compatible IEDs in the local network in a real-time manner. Then the data can be processed by any IED to perform different automation, control and protection functions.

The signal transmission is automatically supervised so it also improves error detection in transmitting measurements. SSC600 supports the reception of sampled values of analog currents and voltages. This functionality gives the opportunity to replace galvanic interpanel wiring with Ethernet communication. The measured values need to be transferred as Sampled Values using the IEC 61850-9-2 LE protocol. /6/

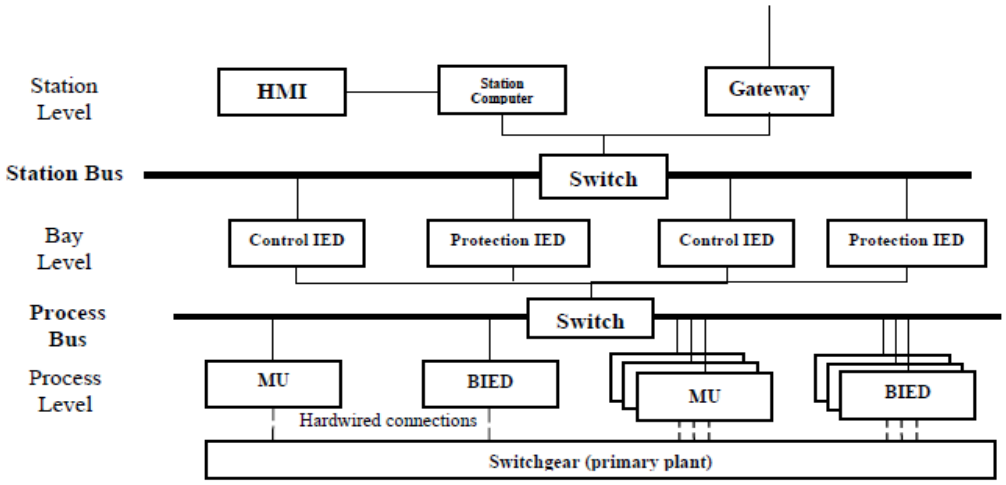

Figure 3. Principle structure of the devices

Shown in Figure 3, Process Level IEDs typically have remote process interfaces such as I/Os, intelligent sensors and actuators connected by a Process bus. All the Process Level devices should be connected to the Process bus using with a Local

Area Network (LAN), so hardwiring will not be needed. Bay level devices instead consist of control, protection and monitoring units per bay.

Station Level IEDs consist of the station computer with a database, Human Machine Interface (HMI) and gateways for connections to Network Control Center (NCC). /8/

3 ABB SSC600

3.1 Description

One possible protection relay for the new STH is ABB SSC600, which is a smart substation device for protection, control, measuring and supervision of utility substations and industrial switchgear and equipment. It has been designed in accordance with the IEC 61850 standard for communication and interoperability of substation automation devices.

Centralizing a wide range of protection and control functionality on a single device on a substation level is an evolutionary step. The modern software and ready-made application packages allow creating a unique solution that matches specific protection requirements. A single device on a substation level benefits station wide process visibility, which makes it easier to access valuable information and access lifecycle management is optimized for the entire digital substation.

Goose engineering is also reduced due to the logic being in SSC600. The device can add functionality and flexibility to an existing system where relays have the capability to send measurements according to IEC 61850 instantly upgrading the protection and increasing process visibility.

For new installations and for retrofitting substations SSC600 is equally suitable. Adding the device to an existing installation provides the entire substation with the latest technology within protection and control. Retrofitting the existing protection relays will serve as a backup protection after integrating SSC600. New installations will only need bay-level merging units in addition to SSC600. Centralized protection and control solution with full redundancy is created by adding another device to the system. /3, 4/

Figure 4. ABB SSC600

3.2 Protection and Control Functions

SSC600 comes with a variety of convenient, ready-made application packages from which to choose. They include various protection and control functions which can be flexibly combined to meet application-specific requirements. The application package concept is shown in Figure 5. The packages available support the following applications:

- Feeder protection
  - Line distance protection
  - Extensive earth-fault protection
  - Fault locator
- Interconnection protection
  - Protection of interconnection points of distributed generation units
- Power transformer protection
  - Two-winding differential protection
- Machine protection
  - Protection of asynchronous machines
- Arc protection option
  - Protection against arc flash
  - Light sensing in Merging Units
- Base protection functionality
  - Overcurrent
  - Earthfault

- Fault recorder
- Switchgear control
- Voltage
- Frequency

- Power quality measurements
  - Current and voltage distortions
  - Voltage variation
  - Voltage unbalance
- On-load tap changer control
  - Position indication
  - Voltage regulation
  - Line drop compensation

/6/

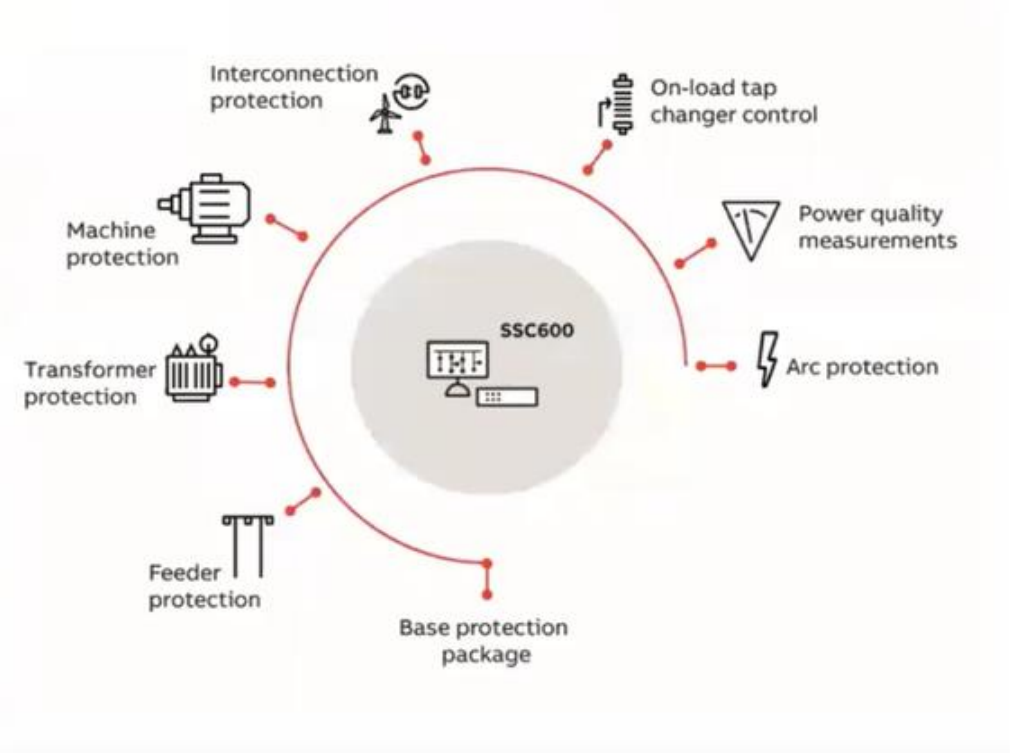

Figure 5. Application package concept

3.3 Communication

The IED supports the IEC 61850 standard and its specified GOOSE, MMS and SV communication profiles, so the control and the operational information goes through these protocols. The communication implementation of the IEC 61850 supports all monitoring and control functions. Parameter Settings, Disturbance Recordings and Fault Records can be accessed using the IEC 61850 protocol.

SSC600 can do horizontal communication which means that it can receive binary signals from other devices using the IEC 61850-8-1 GOOSE profile. Interlockings, inter-tripping signals, load shedding data and such are processed on a horizontal level. The horizontal level supports the highest performance class with a 3 ms total transmission time. The IED also supports the reception of Analog Values using the GOOSE messaging. Vertical communication means the capability of the relay to communicate with monitoring and control systems such as Protection and Control IED Manager (PCM600) or MicroSCADA. The device meets the GOOSE performance requirements for class P1, which is tripping application for distribution substations (10 ms) as IEC 61850 defines. /5/

3.4 Monitoring and Control System

ABBs PCM600 is a tool to make engineering process for SSC600. It is used for various tasks in the protection IED system:

- IED engineering management
  - Organizing the bay protection IEDs and Smart Substations IEDs in structure of the substation by defining voltage levels and bays below the substation.
  - Configuring protection and control functions and parameters and setting values.
  - Configuring connections between function block and physical hardware inputs and outputs.
- Communication management

- IEC 61850 Configuration tool or separate Integrated Engineering Tool (IET600).
- Configuring the GOOSE receiving data connections to the IED.

- Disturbance Record management
  - Generating overviews on the available Disturbance Recordings in all connected IEDs.
  - Manually reading the Disturbance Recording files from the IED.
  - Managing and creating Disturbance Recording files.
- Service management
  - Monitoring the selected signals of a IED for commissioning or service purposes. /2/

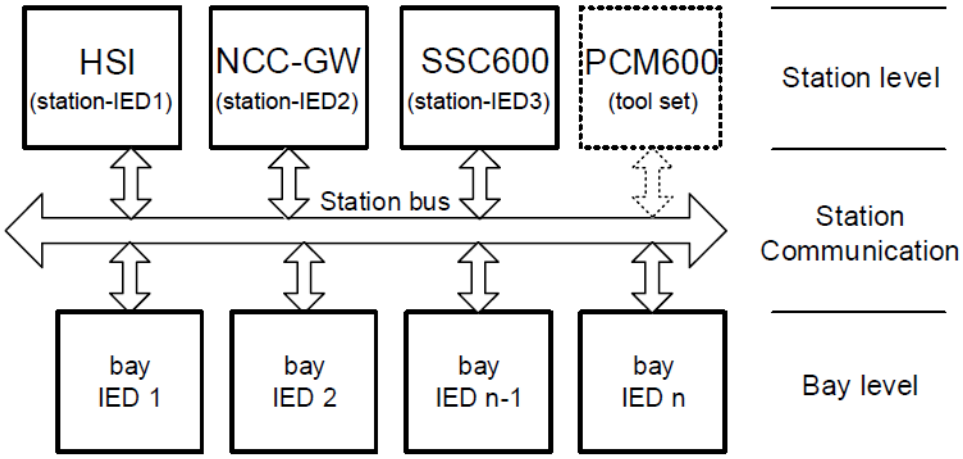

Figure 6. Structure of a monitoring and control system for a substation

As seen from Figure 6 monitoring and control system can be divided into three main parts.

- IEDs in a bay level
- Station communication
- IEDs in a station level

On a station level there is the Human System Interface (HSI), the same as Human Machine Interface (HMI) and Network Control Center- Gateway (NCC-GW).

ABBs device for NCC-GW and to the same system is COM600S which is described below. In addition, the SSC600 is on a station level.

Station communication means Ethernet layer communication. On bay level there are IEDs or Merging Units (MUs). These all three parts require specific engineering and configuration. SSC600 is normally inserted to the station level. For the PCM600 the maximum size of a project is 180 IEDs. /2/

3.5 Interlockings

The IEDs Logical Nodes are set with the Test mode, which is selected through one common parameter via the HMI path Tests/IED tests. The test mode can only be set locally through LHMI. The mode of all Logical Nodes under CTRL Logical Device is set with the Control mode, which is selected via the HMI or PCM600. Setting the Control mode locally on can be made only through LHMI. Test and Control mode descriptions are shown below in Tables 1 and 2. /2/

Table 1. Test mode

Test mode	Description	Protection BEH_BLK
Normal mode	Normal operation.	FALSE
IED blocked	Protection working as in "Normal mode" but ACT configuration can be used to block physical outputs to process. Control function commands blocked.	TRUE
IED test	Protection working as in "Normal mode" but protection functions are working in parallel with test parameters.	FALSE
IED test and blocked	Protection working as in "Normal mode" but protection functions are working in parallel with test parameters. ACT configuration can be used to block physical outputs to process. Control function commands blocked.	TRUE

Table 2. Control mode

Control mode	Description	Control BEH_BLK
On	Normal operation.	FALSE
Blocked	Control function commands are blocked.	TRUE
Off	Control functions disabled.	FALSE

According to IEC 61850, the physical outputs to the process should be blocked when the device is set to blocked or test Blocked mode. The usage depends on the actual configuration. In the protection blocking example, the main trip is blocked and in the control blocking example, the circuit breaker control is blocked. Both comply with IEC 61850. /2/

In the protection blocking example, shown in Figure 7, the physical outputs to the process can be blocked with IED blocked and IED test and Blocked modes. If the physical output needs to be blocked, the application configuration must block signals or function blocks that affect primary apparatuses. The blocking scheme needs to use BEH_BLK output of PROTECTION function block. /2/

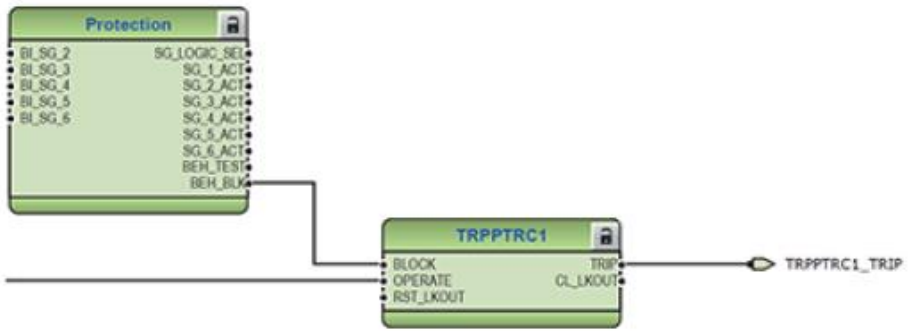

Figure 7. Master trip blocked

In the control blocking example, shown in Figure 8, the physical outputs to the process can be blocked with the blocked mode and the application configuration must block signals or function blocks that affect primary apparatuses. The blocking scheme needs to use BEH_BLK output of CONTROL function block. /2/

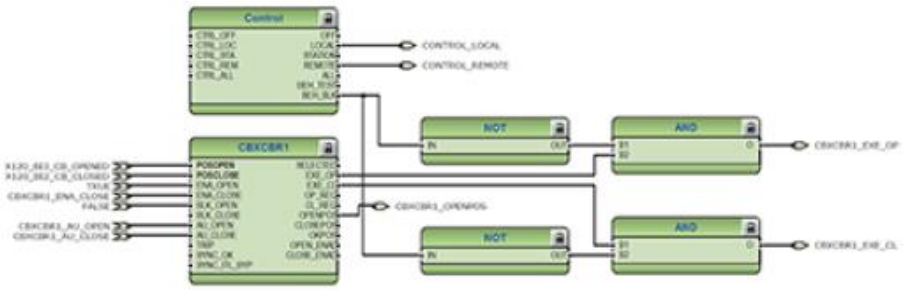

Figure 8. Control function trip blocked

The opening and closing operations are available via communication, binary inputs or WHMI commands. As a prerequisite for control commands, there are enabling and blocking functionalities for both opening and closing commands. If the control command is executed against the blocking or if the enabling of the corresponding is not valid, Circuit Breaker control, Disconnector control and Earthing Switch control generates a message.

3.6 Limits from the Device

The IED supports five simultaneous clients for IEC 61850 MMS reporting. ABB has tested SSC600 for that number of clients because in most of the cases that will be enough for many different systems. Simultaneous clients mean operation and management systems. The device can communicate to five separate clients to receive events, read or write data. It supports receiving sampled analogue measurements according to IEC 61850-9-2LE from up to 20 Merging Units or other IEDs. Therefore, the IED can protect effectively 20 different objects.

SSC600 includes control functions for 40 circuit breakers and 60 switches but it cannot have different measurements for each of them. If there is a need for more objects, it is possible to stack SSC600 devices on top of each other. For example, by stacking 5 IEDs protection for 100 different objects can be obtained. Because the all I/O comes as GOOSE messages to SSC600, the number of the supported I/O is a relative concept. The IED can receive 400 binary GOOSE signals and 200 Double Point type Status Data. In addition, SSC600 can receive analog data with GOOSE.

Two physical binary inputs and outputs are needed on the bay level MU or in the IED (not in SSC600) for each controllable primary device taken into use. An external input or output module can be integrated to the IED, if the number of available binary inputs or outputs is not enough. The disturbance recorder in SSC600 provides up to 160 analog channels and 512 binary channels. Analog channels can be set to record the waveform, or the trend of currents and voltages measured. Meanwhile, binary signals can be set to start a recording either on the rising or on the falling edge of the binary signal or on both.

4 OTHER MANUFACTURERS' OPTIONS

The devices from the other manufacturers for centralized protection are also part of this thesis and based on the questions to different manufacturers' they do not have an exactly similar device like the SSC600. Siemens offers a device for a small centralized protection to substations.

4.1 Siemens SIPROTEC 5

From the SIPROTEC family of devices the model 7UT87 could be in use in a small substation. 7UT87 is a transformer differential protection relay and it is to be used where numerous measuring points (up to nine 3-phase current measuring points) are required. The relay contains many other protection and monitoring functions and the additional protection functions can also be used as backup protection for subsequent protected objects, such as cables or lines. The modular structure of the relay, flexibility and the high performance DIGSI 5 engineering tool offers a future-oriented system solution with high investment security and low operating costs. Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR) is possible to build with this device. It also complies with the IEC 61850 standard.

Figure 9. SIPROTEC 7UT87

As in SSC600, 7UT87 is planned to communicate with MUs and Siemens has MU model 6MU85 for data digitalization in a process bus. With 7UT87 it is possible to build a system for 9 units, so it is less than with SSC600. Inputs and outputs have two predefined standard variants with 20 current transformers, 4 voltage transformers, maximum of 27 binary inputs and 38 binary outputs. /13/

5 CONNECTION TO THE SYSTEM

SSC600 and all the other ABBs relays and Merging Units are always engineered with the PCM600 software so defining the behaviour of the devices needs to be made with PCM600. After the system is engineered, PCM600 is not needed necessarily and all the other operational activities can be done with some other control system. The requirement is that the system and the all devices must have IEC 61850 support. In case some other control centre protocol is needed, an external gateway for protocol conversion can be used.

5.1 COM600S

In ABBs substation solutions, COM600S is an important device because it is deployed together with Protection and Control Relays, Remote Terminal Units (RTUs), meters and Programmable Logic Controllers. Third party protection relays can be enabled so the devices do not need to be ABBs own products. This unit is performing the combined role of a HMI, a Communication Gateway and an automation controller. COM600S manages real-time and historical data of the substation.

Figure 10. ABB COM600S

The device is best suited to small- and medium-scale Substation Automation Solutions, normally 20 to 60 feeders slip between multiple medium voltage switchgear panels, in an existing or new utility or industrial primary or secondary substations. All controls come from the WebHMI through this COM600S device. /11/

5.2 SMU615

ABBs Substation Merging Unit (SMU615) is a dedicated device with a standard digital interface, making it possible to connect ABB sensors and conventional instrument transformer to an IEC 61850-9-2 LE based process bus for extended interoperability of substation automation devices.

SMU615 provides a physical interface between the primary equipment in the switchgear and the protective devices in power system. SMU615 measures the current and voltage signals from the instrument transformers, merges and sends them to the protective devices, in this case of the SSC600, in a standard based digital output format. Traditional protection relays are not necessarily needed when SMUs are in use in the system with SSC600.

SMU615 fully supports:

- Fast GOOSE messaging
- IEEE 1588 for high-accuracy time synchronization
- Sending of Sampled Measured Values over redundant Ethernet communication and sensors – all of which support the increasing digitalization of substations.

The device also supports Current and Voltage Transformers and modern sensors. It is a device for all the measurements and I/O data transmission per one bay which makes configuration and installations work to the minimum. /13/

Figure 11. SMU615

5.3 PCM600

ABBs Protection and Control IED Manager (PCM600) provides functionalities for planning, engineering, commissioning, operation and disturbance handling and functional analysis in the whole substation on all voltage levels. It interacts with IEDs over the fast and reliable TCP/IP via corporate LAN or WAN, or alternatively directly through the communication port at the front of the IED. PCM600 complies with the IEC 61850 standard, which simplifies the IED engineering and enables information exchange with other IEC 61850 compliant tools. The user interface in PCM600 is divided into different windows as seen from Figure 12 below. /15/

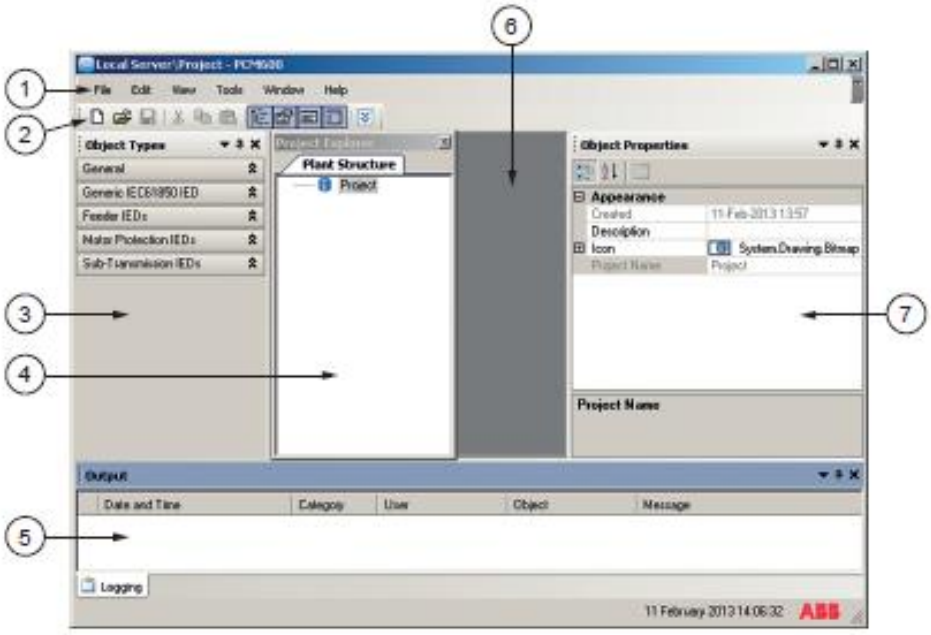

Figure 1: PCM600 interface

1 Menu bar
2 Toolbar
3 Object Types window
4 Project Explorer window
5 Output window
6 Tool window
7 Object Properties window

Figure 12. PCM600 interface

The Object Types window shows all the available objects for the selected IED. All objects must be imported from the connectivity package to PCM600 by using Upload Manager.

The Project Explorer window is used to navigate to the used IEDs within a project. With the Project Explorer, a plant structure with a substation, voltage levels, bays and IEDs can be created. All the configuration work, such as communication configuration, can be done with via this structure by using the Configuration Wizard.

The parameter setting, which is shown in Figure 13, in PCM600 is possible in offline (stored in the tool) and online (stored in both the tool and the IED). The parameters can be read from the IED to PCM600 or written from PCM600 to the IED while the IED is in service. Parameters can be exported and imported for test sets in the Comma-Separated Values (CSV) format (for example Omicron Test Universe). /15/

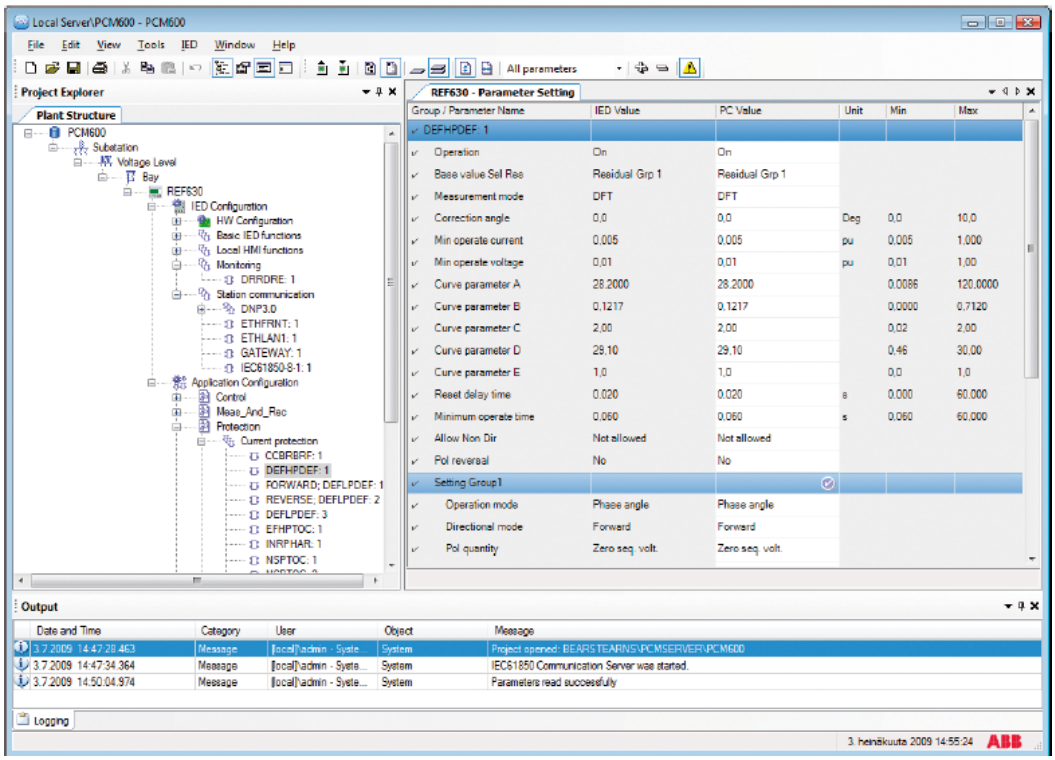

Figure 13. Parameter setting view

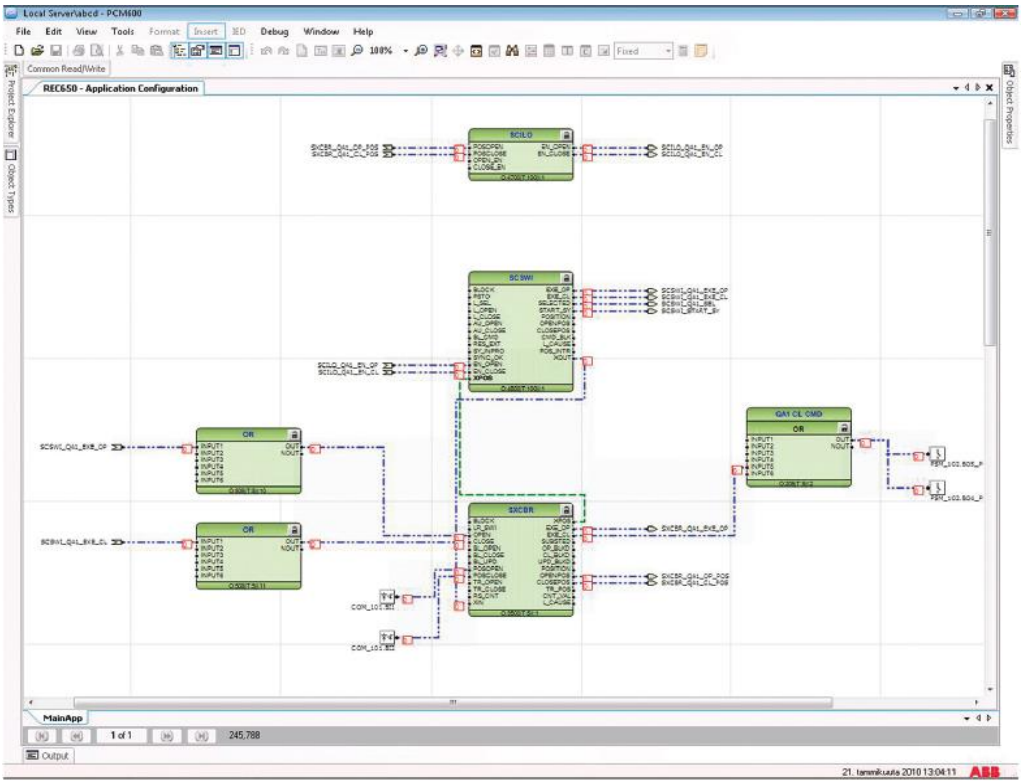

Figure 14. Application configuration, Online monitoring

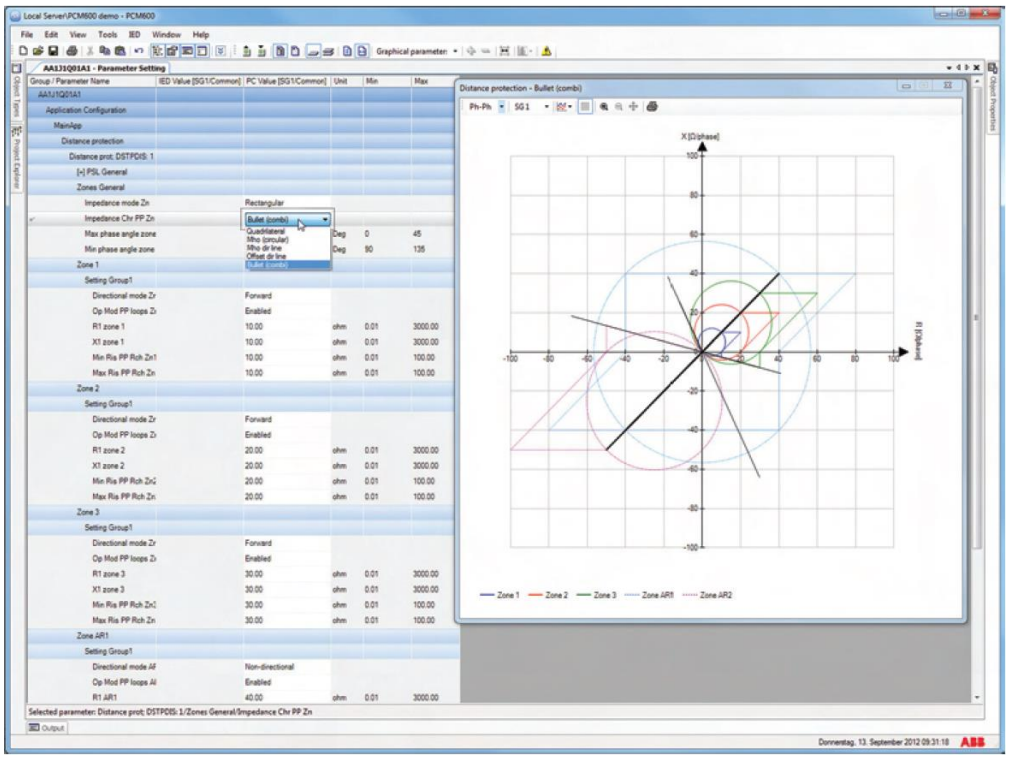

Figure 15. Distance protection function

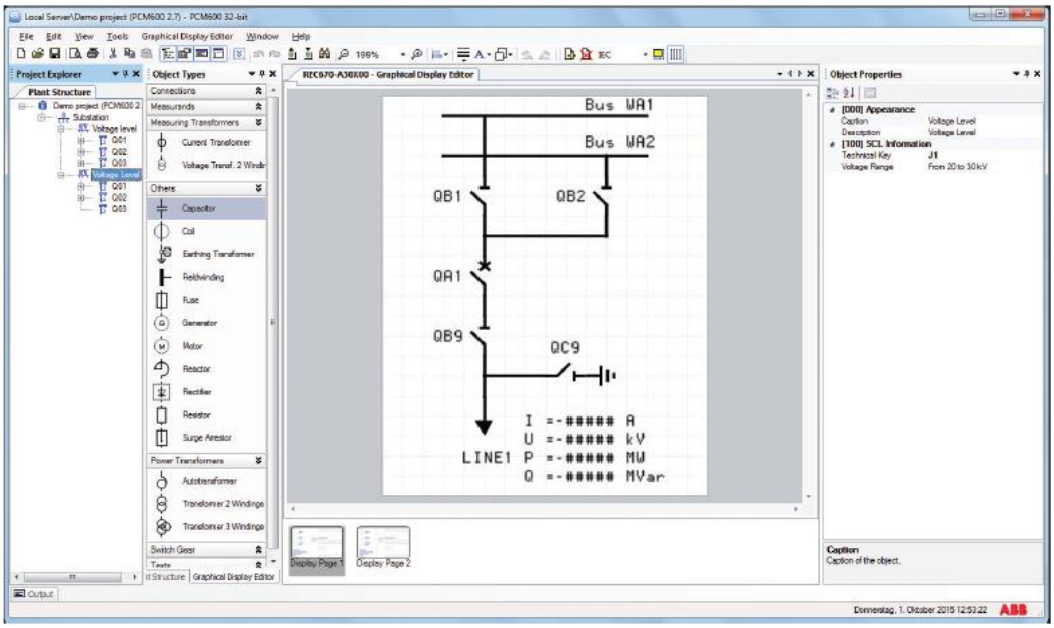

Figure 16. Graphical display editor

5.4 WOIS

The Wärtsilä Operator's Interface System provides a user interface for the PLC system. It is the main HMI point for the most Power Plant applications. WOIS consists of PC running HMI software which is connected to the various hardware in a system to operate and view operating parameters. WOIS is InTouch based operating system.

SSC600 supports a Single-Line Diagram for a substation up to 20 bays. SLD, control functions, measurements, events and alarm can be read explicit from different tabs in SSC600s WebHMI interface. Controls can be made also through the SSC600 own local port when controls go in accordance with IEC 61850 protocol.

5.5 LVRT

A Low Voltage Ride- Through means the ability of a generating unit to stay connected to the grid during a voltage dip caused by short-circuits, result of grid faults such as lightning strikes or when large loads are connected to the grid.

6 REDUNDANCY

Redundancy in an electric field means systems reliability for example by duplicating critical components or functions in a system. It is a backup safe to improve system performance.

6.1 Ethernet Redundancy

System availability for substation communication is specified in the IEC 61850 network redundancy scheme. It is based on parallel redundancy protocol PRP-1 defined in IEC 62439-3:2012 standard. The idea of the protocol is a duplication to transmit information via two Ethernet ports for one network connection. PRP defines that each device is connected in a parallel to two local area networks. Depending on the product variant SSC600 offers either two optical or two galvanic Ethernet network interfaces. IED has dedicated Ethernet interfaces for local WHMI and engineering. /3, 5/

6.2 Parallel Redundancy Protocol

Each PRP node, called a doubly attached node with PRP (DAN), is attached to two independent LANs operated in parallel. These parallel networks in PRP are called LAN A and LAN B. To ensure failure independence the networks are completely separated, and they can have different topologies. The networks are providing zero-time recovery and continuous checking of redundancy, so communication failures can be avoided. Non-PRP nodes which are called single attached notes (SANs), are either attached to one network only (where communication is happening only with DANs and SANs attached to the same network) or through a redundancy box, which is a device that behaves like a DAN. /5/

Ethernet-based communication can be implemented by connecting systems via the RJ-45 connector (100Base-TX) or the fiber optic LC connector (1000Base-SX), depending on the product variant. /3/

6.3 Centralized Protection and Control with a Redundant SSC600

One solution is to build a system, as seen in Figure 17, with Merging Units utilized in every bay /feeder and redundancy with regards to:

- SSC600 units (with or without LHMI) with hot standby in protection and control
- IEC 61850 PRP based communication in process and station bus
- Time synchronization is implemented with
    - IEEE1588v2 GPS master, where MU as backup time master and secondary GPS master is also possible
- Preferred new installation use case, where the requirement is a redundant centralized functionality
- A single IEC 61850 network for Process and Station bus
- System visualization via SSC600 with WebHMI
- Substation gateway is doubled up as HMI
- Substation HMI is doubled up as gateway for local and remote control /3/

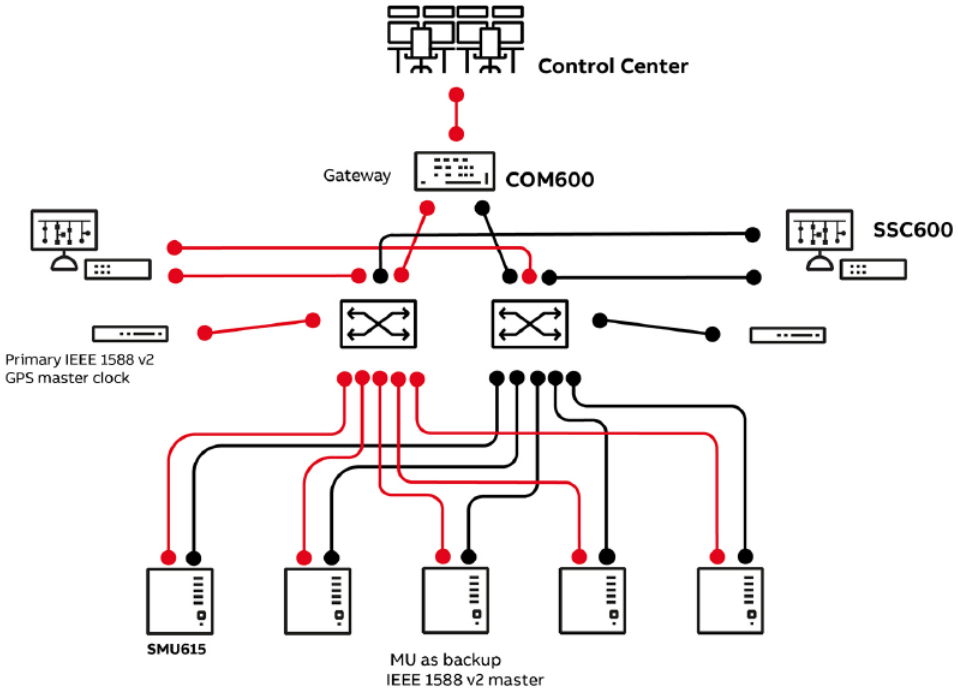

Figure 17. Example of the PRP solution

With SSC600 it is also possible to build partly redundant protection for the system if that would be needed. It means that for example one bay can be duplicated if that is considered critical for the system. The redundant solution makes also the updating of the device easier and possible even when the system is running. However, the same configuration needs to be in use with both devices when redundant solutions are used.

7 EXISTING SYSTEM

The Wärtsilä's diesel motors test run laboratory in the Vaasa factory houses medium voltage switchgear which is used in this thesis as an example to describe what kind of system is now in use and furthermore what kind of changes there could be when using SCC600 in the new STH in Vaskiluoto. There are three cells for driving and testing engines in the test run, so it is possible to do for example Factory Acceptance Tests to the three different engines simultaneously.

Vaasan Sähköverkko Oy supplies the electricity to the factory area. There are links from switchgears 2A and 2B to the grid if there is need to produce power to that way. On the side of Vaasan Sähköverkko 110 kV is stepped down to 21 kV with two 31.5 MVA transformers. The Medium Voltage Switchgear on the second floor in the diesel motors test building is made as a double busbar system and it consists of eight cubicles. The nominal current of the circuit breakers is 1250 or 800 A and that of the disconnector 630 A. Behind the second cubicle there are two transformers which are step down the voltage level from 21 kV to 400 V and that 400 V is used for building electrification.

For the protection in cubicles VAMP 57 relays are used, which are a multipurpose feeder and motor protection relays. Overcurrent, overload and earth-fault and motor protection is made with this relay. The relay includes also the IEC61850 protocol. Arc protection is added afterwards to the protection system. Interlockings to the system are made with hardwired connections to a separate cabinet where all the relays are located. Troubleshooting is challenging and if the modifications are required or needed, it takes a lot of effort with this solution.

8 CONCLUSIONS

The main goal of this thesis was to find out if SSC600 relay is suitable for the new STH and what benefits it could bring to the system. At this moment, during this thesis process, there were planned Single Line Diagram was designed on which I have based my conclusions.

Based on my knowledge and the information what I have obtained from the manufacturer so far, SSC600 could be in use in the new STH. However, during the examining of the device some challenges emerged. The IEC 61850 standard sets the frames for the whole system and all devices which are installed to the new system should be compatible with IEC 61850. This is if full interoperability to the system is wanted with efficiency and reliability. There can be devices which are not IEC 61850 compatible, but devices then need to be installed with a gateway device. For example, normal binary I/O data can be changed to GOOSE with a gateway device. ABB offers other devices for the system and with they it is easy to build an IEC 61850 compatible solution. Using the third party, other manufacturers' devices is possible according to SSC600, but it would make device engineering and fitting to the system harder.

The SSC600s protection functions seems to be comprehensive for the new factory, where the requirements are going to be strict. The relay has the base protection functions for overcurrent, earth-fault, voltage, frequency and switchgear control. Feeder protection and power quality measurements are included. There are also interconnection, power transformer and machine protections in the relay, so it could cover the protection for the ready system. Arc protection is one of features of the relay, so that is how switchgears safety and costly equipment damages and long outtakes can be avoided. At this point SSC600 does not have all the generator protection functions but it may come in the future, when software updates are made to the IED. From the ABBs devices REG615, generator and interconnection protection relay, could be used for generator protection. REG615 can work as a backup protection for SSC600 and the interlockings can be done centralized with

REG615. The device is also IEC 61850 compatible, so it can also communicate with SSC600.

GOOSE messaging in use makes installations simpler and much more cost efficient because the hardwired connections are not needed. The Ethernet Layer can replace the copper wire cables. Horizontal communication makes fast communication between devices possible, which is important, when there are time critical functions and high reliability is demanded. The capacity of the IED to data transfer seems to be enough for the planned switchgear, where is most likely going to be seven cells for engine testing and running.

Different monitoring systems can be adapted to SSC600, so Wärtsilä's own WOIS system could come also in use. The Single Line Diagram is up to 20 bays, so the capacity is enough and there is going to be then space for extension if needed. Adding another SSC600 to the system is also an option for expanding the size.

Building a highly interoperability system with the ABBs devices seems to be the most sensible solution but also the price is most likely going to be high.

The benefits what SSC600 brings are:

- Allows for complex protection and operation of applications for simpler implementation.
- All protections are in the same place.
- Easily accessible with the network, easy to update.
- Allows easy adding of new application protections later. New features of the future can be updated later.
- Faster deployment time, easier to build internal logic, interlockings, arc protection, all in one place.
- In case of a problem: faster clearing, fewer wiring and fewer damaged devices.
- Disturbance Recorder

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APPENDIX 1

Technical Data of SSC600

Dimensions

Dimension	Value
Width	440 mm / 17.3”
Height	88 mm / 3.4”
Depth	220 mm / 8.6”
Weight	6.0 kg
Mounting	2U Rack mount (19”), fits into standard 19” rack

Power supply

Description	High Voltage variant	Low Voltage variant
Nominal auxiliary voltage U_n	100...240 VAC 50 and 60Hz 100...240 VDC	36...72 VDC
Maximum interruption time in the auxiliary DC voltage without resetting the device	50 ms at U_n	
Auxiliary voltage variation	85...110% of U_n (85...264VAC) 80...117% of U_n (80...280 VDC)	
Start-up threshold		
Power consumption	35 W (Typical)	35 W (Typical)
Ripple in the DC auxiliary voltage	Max 10% of the DC value (at frequency of 100 Hz)	
Fuse type		

Data communication interfaces

All physical ports dedicated for station bus communication can be opened and closed in device configuration. Local port is used for engineering and it can be used only for point-to-point configuration access with PCM600 or WHMI. Local port should not be connected
to any Ethernet network.

Physical ports on devices communication cards

Port ID	Type	Default state	Description
LAN1	RJ-45	Enabled	Local port
LAN2	RJ-45	Disabled	Remote port (for engineering)
LAN3	RJ-45 or fiber optic	Disabled	Process bus A
LAN4	RJ-45 or fiber optic	Disabled	Process bus B
LAN5	RJ-45	Enabled	Rear port
LAN6	RJ-45	Disabled	not in use
LAN7	RJ-45	Disabled	Service port
LAN8	RJ-45	Disabled	not in use

IEC 61850 protocol and LAN1 and LAN5 ports are by default activated as those are used for engineering of the protection device.

Fibre optic communication link

Connector	Fiber type	Wave length	Typical max. length	Permitted path attenuation [120]
SFP	MM 62.5/125 or 50/125 µm glass fiber core	850 nm	550m	<9,5 dB

Fiber optic communication in SSC600 is implemented with SFP connectors. Type of SFP connectors are freely choosable and should be selected based on the application needs.

Enclosure class

Description	Value
Enclosure	IP 30

Environmental conditions

Description	Value
Operating temperature range	-20...+55°C (continuous)
Short-time service temperature range	-25...+70°C (<16h)[121]
Relative humidity	<95%, non-condensing

Description	Value
Atmospheric pressure	
Altitude	
Transport and storage temperature range	-30...+85°C