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VERIFICATION PROCESS AS A PART OF THE DEVELOPMENT PROJECT IN THE ABB DISTRIBUTION AUTOMATION

Technology and Communication
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FOREWORD

I would like to thank my supervisor Juha Ekholm for providing feedback and support for the documentation and the project manager Joni-Ville Aro for guiding assistance on faced problems. I would also like to thank all the design engineers who assisted me in the system building especially Tommy Byström and Joni Kentta.

I had previous experience of building testing systems in Product Verification Center, but this one was different because none of the products used in the project were familiar to whole Product Verification Center. The design of the new testing system was very interesting because of the freedom to use own methods. The documentation part was also interesting because it opened my own understanding of how the project proceeds.

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TIIVISTELMÄ

Tekijä	Perttu Eskelä
Opinnäytetyön nimi	Verification Process as a Part of the Development Project in Distribution Automation
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Ohjaaja	Jari Koski

Opinnäytetyön tarkoituksena oli dokumentoida ABB Oy Distribution Automationin tuotekehitysprojektien verifikaatioprosessi. Lisäksi tuli rakentaa testausjärjestelmä älykkään verkon tuotekehitysprojektille.

Verifikaatioprosessin hahmottaminen on hankalaa ja siihen kuluu paljon aikaa. Näin ollen dokumentaatiosta on hyötyä tulevaisuudessa, varsinkin uusille työntekijöille, mutta myös koko ABB Distribution Automation organisaatiolle. Materiaali opinnäytetyöhön kerättiin haastattelujen ja Online-koulutusten avulla sekä lukemalla ABB:n sisäistä tuotekehitysprojekteihin liittyvää dokumentaatiota.

Testausjärjestelmän rakentamiseen vaikutti asiakkaan- ja ABB:n tuotevaatimukset. Esimerkiksi asiakas halusi, että tuotteen kanssa pystyisi kommunikoimaan modeemi-yhteyden avulla. Nämä vaatimukset tuli sisällyttää testijärjestelmään siten, että ne pystyttiin testaamaan ja verifioimaan. Tiedon järjestelmän rakentamiseen sai suunnitteluinsinööreiltä, laitemanuaaleista sekä omasta työkokemuksesta ABB Product Verification Centerillä.

Testausjärjestelmä saatiin rakennettua ja otettua käyttöön. Testausjärjestelmä oli erittäin haastava, sillä vastaavanlaista järjestelmää ei ole aiemmin rakennettu kyseisille tuotteille. Järjestelmä suunniteltiin siten, että sillä voidaan toteuttaa kyseisten tuotteiden projekteja myös tulevaisuudessa.

Dokumentaatio avasi verifikaatioprosessin ja asiasta on nyt olemassa selkeä käsitys. Dokumentaation ohella sai havaita miten laajoja kaikki projektit luonteeltaan ovat. Esimerkiksi yhdessä tuoteprojektissa oli 70 uutta vaatimusta itse tuotteelle ja se lisäsi työmäärää kaikille ABB Distribution Automation organisaation eri funktioille.

Avainsanat verifikaatio, kehitysprojekti, testausjärjestelmä

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ABSTRACT

Author	Perttu Eskelä
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The purpose of this thesis was to document the verification process that is done to the product development projects by the Product Verification Center of ABB Distribution Automation. In addition, the system building for the smart grid products was included.

The background of this thesis was that there was no process documentation available about the verification process of the development project. The documentation of the verification process is useful for the new employees but also for the ABB Distribution Automation organization to understand how the product verification is done. The material for the thesis has been collected by interviewing, doing online trainings and reading ABB Oy, Distribution Automation internal documentation about the project management.

The system building was a challenge because the project schedule was delayed, there was no knowledge of how many products were to be distributed for testing and only some of the devices were familiar before for the Product Verification Center. The success was depending on collaboration with the project manager and cooperation partner. The goal was to build a testing system to test and verify smart grid relays together with fault indicators. This kind of testing system has not been built before for the smart grid products in the Product Verification Center. The substation switchgear was simulated by using the AC800M programmable logic controller. Information to build the testing system was obtained from design engineers, device manuals and working experience of previous projects.

The building of the testing system has been finished. The building phase consumed over 6 months because the system is built so that it can be used in the future projects. The documentation revealed the product verification process and there is now a clear vision how it proceeds. It was interesting to see how wide all of the product verification projects can be and how many organizational functions can be included.

Keywords Verification, development project, testing system

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LIST OF USED ABBREVIATIONS

ANSI	American National Standards Institute
CM	Configuration Management
DTS	Digitalo Testing System Solution
DUT	Device Under Test
GOOSE	Generic Object Orientated Substation Event
GPRS	General Packet Radio Service
I/O	Input and Output
IDR	Internal Defect Report
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
L2TP	Layer 2 tunneling protocol
LAN	Local Area Network
LED	Light-Emitting Diode
NTC	Negative Temperature Coefficient
PVC	Product Verification Center
R&D	Research and Development
RS-232	Recommended standard 232
RS-485	Recommended standard 485
SCADA	Supervisory Control And Data Acquisition
STWS	System Testing Web Server
TCP/IP	Transmission Control Protocol and Internet Protocol
VPN	Virtual private network
WAN	Wide Area Network

LIST OF APPENDICES

1 INTRODUCTION

The background for the thesis was that there was no existing documentation available concerning the verification process, and the upcoming product project was missing a special testing system. The nature of this thesis was a project.

The documentation is important for ABB Distribution Automation because it opens a clear vision of how the PVC verification is done in phases. This also helps every new employee to catch the idea of the product verification without wasting time on asking around and trying to figure it out by himself.

The testing system is important for Product Verification Center because this is the first testing system for testing smart grid products, and it was designed so that the upcoming tests in the future can also be executed. Every I/O channel of the products was simulated and the simulator application was built so that every function of the smart grid products can be tested and verified. The SCADA application was also built for every product to monitor what kind of data the product can transmit by using IEC 60870-5-104 or IEC 60870-5--101 communication protocols. This made possible to control disconnectors remotely over the GPRS or the phone line by using SCADA. Fault indicators measured voltages and currents from the DTS line and reported the values to the smart grid product by using the Modbus protocol. The smart grid product then transmits the data to the SCADA.

The timing of this thesis was good because the use-case project was just started when the thesis started. This way the use-case supported the documentation of the verification process.

2 ABB OY

This chapter relates to ABB group and the Distribution Automation Product Verification Center.

2.1 ABB Company

ABB is a leading global power and automation technology group that operates in around 100 countries and had employee for 147 700 in 2013. The revenue is almost 42 billion USD. ABB uses over 1.5 billion USD for R&D. /1/

ABB was established when engineering companies ASEA and Brown Boweri merged in 1988. After that ABB has bought many companies from different regions. /1/

2.2 ABB Distribution Automation Product Verification Center

ABB Distribution Automation has Product Verification Center for testing and verifying the medium voltage products and technologies e.g. protection relays that are developed by the R&D department. The purpose is to guarantee high product quality.

Product Verification Centers are located in Vaasa Finland, Bethlehem Pennsylvania United States, Xiamen China and Bangalore India /2/. Testing is split so that the China PVC is primarily responsible for testing products that are for China markets, Finland for the IEC market and US for the ANSI market. The testing laboratories are in tight collaboration within each other.

The focus of the PVC testing is in the system engineering, interoperability, functionality of the new product, system functions e.g. alarm and events, performance and capacity, stress test, long-term stability and security and usability. /3/

2.3 PVC Finland

PVC unit in Finland consists of seven design engineer and their supervisor. The laboratory is shown in figure 1. The control room is next to the products used in testing. It is better for a design engineer to apply tests and see the functioning of the product at the same time when sitting next to it. PVC Finland is the leading test center. /2/

Figure 1. PVC laboratory in Finland.

2.4 Products

ABB has a wide range of medium voltage products. Figures 2 and 3 represent the products of the Relion family that the ABB is selling. The number in the product name represents the series e.g. the REF615 IEC feeder protection relay is one of the 615 series relay. IEC in the name means that the product corresponds to the requirements of the International Electrotechnical Commission Standards Association. ANSI means that the product is manufactured to correspond the requirements of America National Standards Institute.

There is also logic in the name of the relays. For example, RE**F**615 means **f**eeder protection relay, RE**M**615 is a **m**otor protection relay and so on.

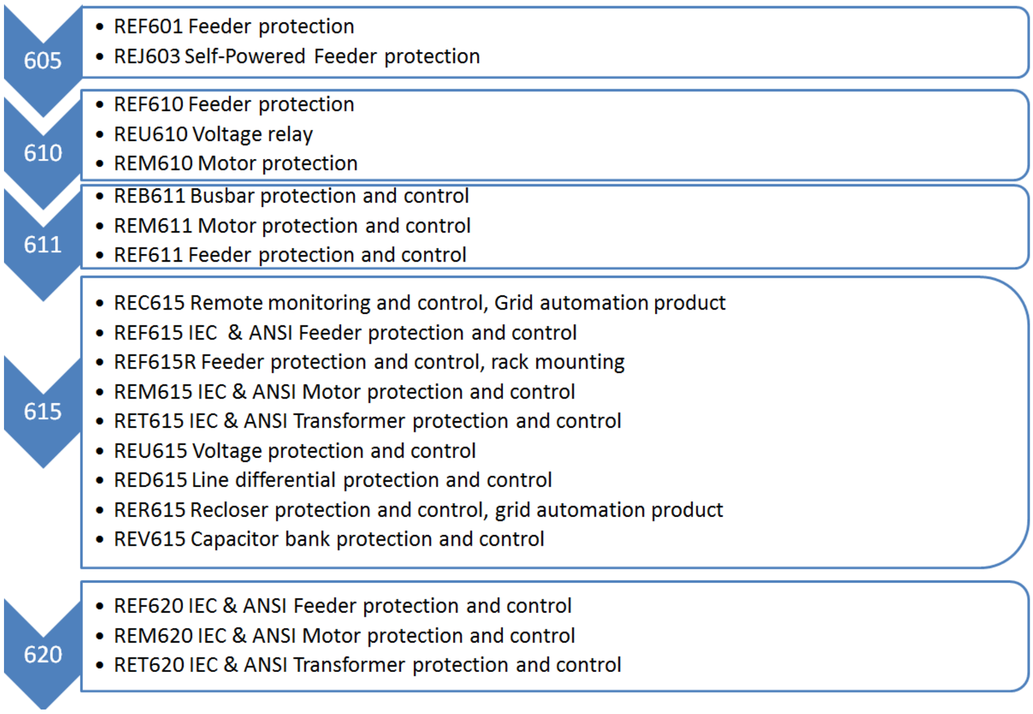


Figure 2. Products by 605 – 620 series.

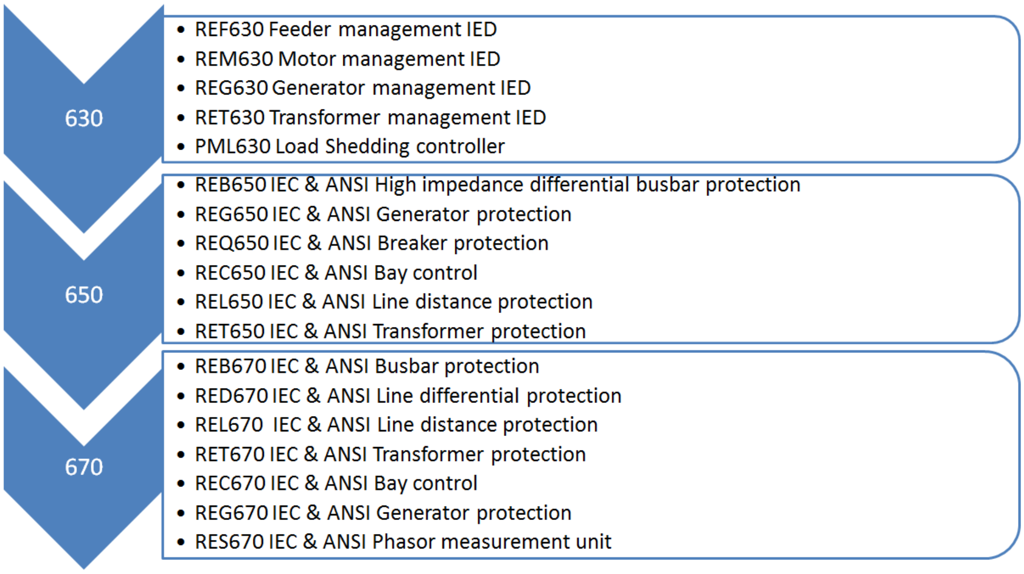


Figure 3. Products by 630 – 670 series.

2.5 Order Code of the Product

The order code determines what kind of features and hardware the product has once it is delivered. It is a code which e.g. 615 series consists of 18 characters and can include letters or numbers. The features are depending on the product. Figure 4 represents the order code for ordering REC615 with specific features.

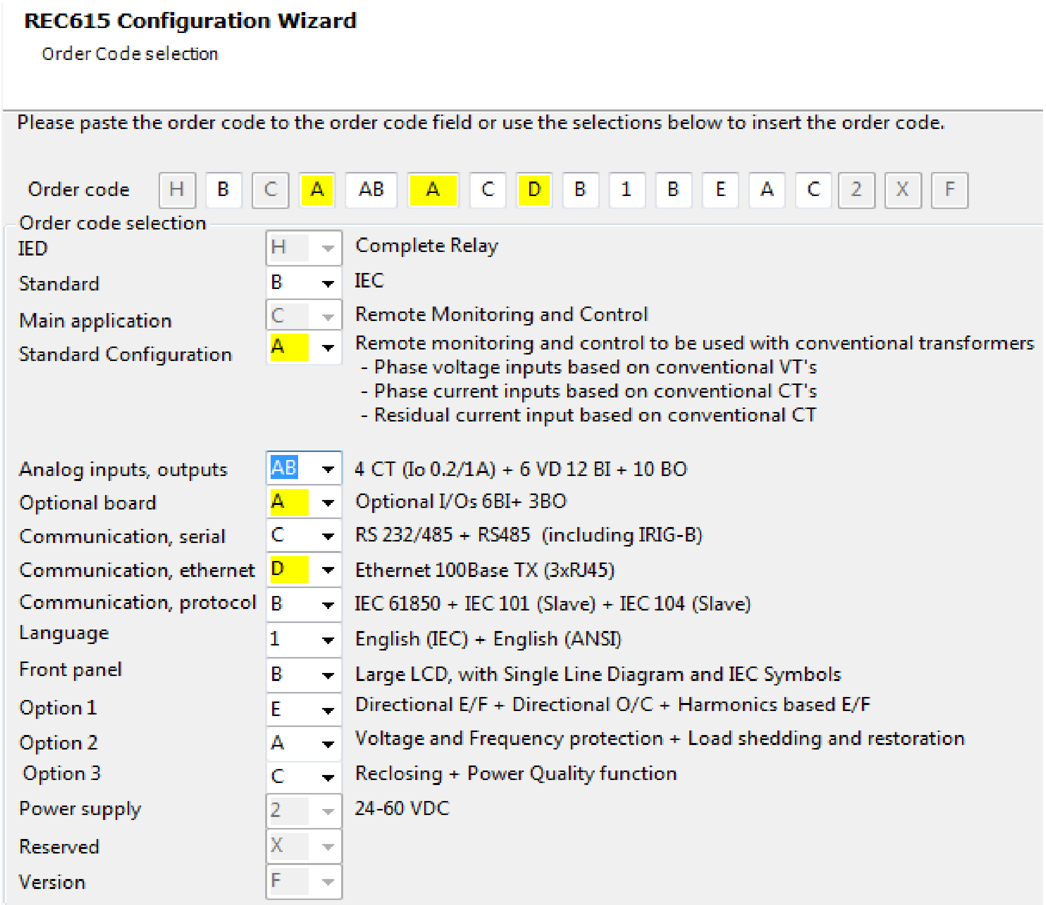


Figure 4. Order code for REC615.

3 DISTRIBUTION AUTOMATION

This chapter presents Distribution Automation.

3.1 Power Distribution

Almost every country has a large electrical network that has spread on very wide geographical areas. The network is split into transmission and distribution networks. High voltage of e.g. 110 – 400 kV is used for transmission. Medium voltage of e.g. 20 kV is used for distribution. Longer distances can be transmitted by using higher voltages. Figure 5 represents the electrical power distribution network model in Finland.

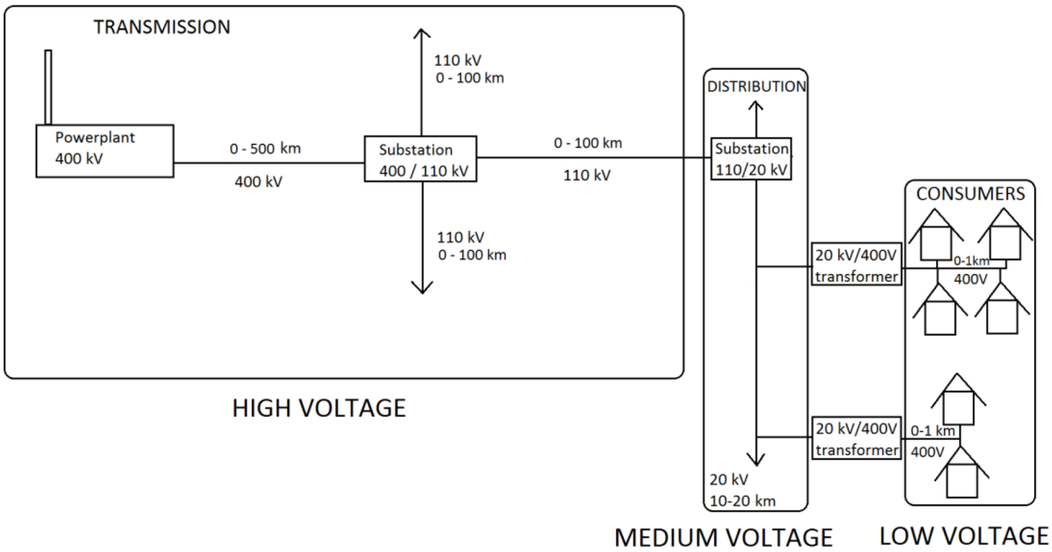


Figure 5. Electrical power distribution network model in Finland.

It is important to be able to manage the electrical network and shorten the delays of outages. The objective of electricity companies is to provide continuous electricity for customers with a good quality and the minimal number of outages. The standards define the quality of the electricity.

The outlet voltage in Finland is 230 V. So the quality means how many percent the voltage can be over and under of the 230 V. In addition, the quality means how many voltage spikes has occurred and what does the sine wave look like.

Electricity companies can charge for more of the distributed electricity if the quality is at a high level.

Distribution automation is developed to protect and manage the electrical network. It also collects valuable data, such as the number of outages and measurements the voltage, current, power etc. It collects how many times different switches has operated and informs when maintenance is needed.

3.2 Purpose of Protection

The purpose of the protection is to detect electrical faults and abnormal conditions. It is made to protect human beings and properties around the electrical network and that for the protection must be fast and sensitive. Operation must be selective to minimize power outages. Protection needs to be reliable and simple and must cover fully the protected network. /4/

3.3 Purpose of Controlling the Electrical Network

The purpose to control the electrical network is to be able to perform maintenance, tests, development, troubleshooting and to minimize power outages from the customers. The control of the electrical network is done by circuit breakers and disconnectors that can cut-off the power from the line. A breaker is used to cut-off high currents while a disconnector is used to make a clear separation between the disconnected points of the line to ensure safety. Breakers and disconnectors need a controlling unit, such as a protection relay that orders them to close or open. This controlling unit takes orders from e.g. the SCADA operator but can also operate by itself by means of protection.

3.4 Protection Relay

The protection relay is an intelligent device that protects and controls the electrical network. Companies sell these devices based on the number of protective functions the devices have. The protection relay can be parameterized and controlled from the control room or by a local human machine interface.

3.4.1 Types of Protection Relays

There are many types of protection relays. Relays have different functions and they are developed for different purposes. Usually protection relays measure network quantities and operates based on the measured values. It captures events and notifies from alarms.

Typical relay types are the following:

- Generator protection relay,
- Motor protection relay,
- Transformer protection relay,
- Voltage regulation relay,
- Overcurrent relay,
- Earth-fault relay,
- Distance relay,
- Line-differential relay and
- Control relay. /4/

Usually, only some of the functions are in use and others might not be needed. Many protection relays can share the most common protective functions e.g. many intelligent relays may have an over current protection, but are designed into different applications.

The ABB line differential relay has the following protection and supervision functions:

- Stabilized differential low stage,
- Instantaneous differential high stage,
- Over current stage for overload protection,
- Over current stage for backup protection,
- Directional and non-directional earth fault protection,
- Auto-reclosing,
- Current circuit supervision and

- Protection communication supervision. /4/

The transformer protection relay is shown in figure 6. Every relay belonging to the same series has the same look. The protection relays and other intelligent relays are also known as IEDs. The front of the IED has push buttons to control the IED locally.

Some of the IEDs are designed so that they can be pulled out from their casing easily. All hardware consists of circuit board modules that can be easily pulled out and changed. There are voltage, current, I/O, sensor and communication channels behind the IED depending on the standard configuration. The standard configuration determines what kind of circuit board modules are required to meet the requirements of the application the IED is designed for.

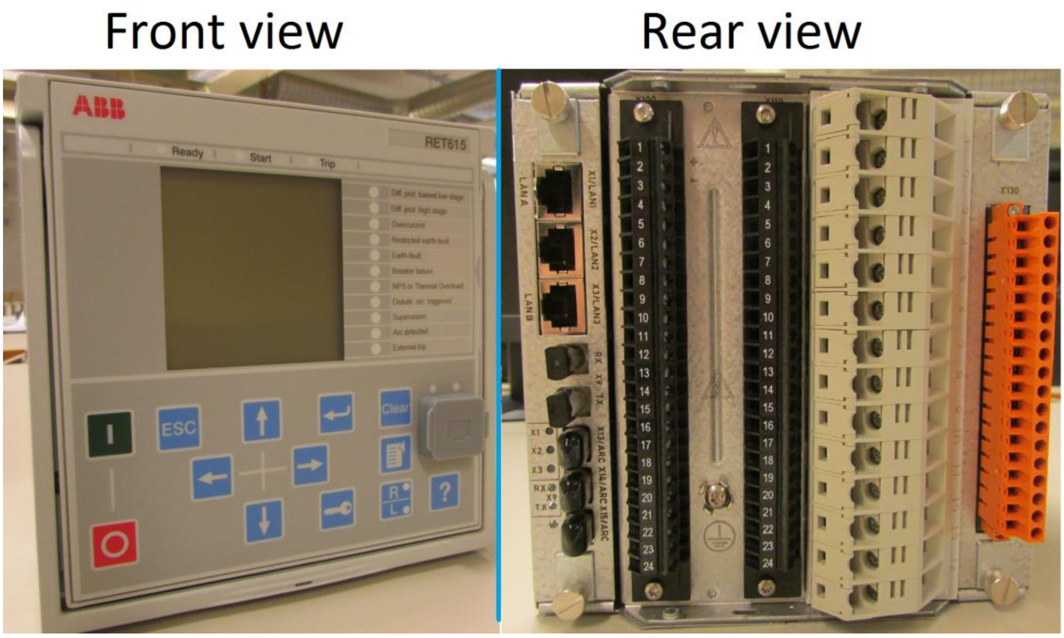


Figure 6. Transformer protection relay.

3.5 MicroSCADA

SCADA stands for "*Supervisory Control And Data Acquisition*". MicroSCADA is a computer software developed by ABB and it is used for the management of the electrical network. It collects data from the IEDs and other intelligent devices e.g.

to show in which state some circuit breaker is and which alarms are currently active. SCADA has several different communication protocols to communicate with the different devices on the electrical network.

3.5.1 MicroSCADA SYS600

SYS600 is used to control and monitor a substation. There are displays which show the single line diagram of the specific substation. The single line diagram includes the switchgear and most of the devices that are connected to the electrical network at the substation. It also shows the most important measurements of the substation. Usually these devices are disconnectors, circuit breakers, transformers, measuring units, fault indicators etc. Most important measurements are voltages, currents, powers and power factor from the primary and secondary side of the transformer.

It is a task of the system engineer to build the single line diagram and map all the process signals from the devices of the substation. The first task is to build the system configuration. The system configuration defines how the specific device communicates with SCADA.

The system engineer has to map all the process signals from the application to SCADA. With this knowledge SCADA understands e.g. that the circuit breaker can be opened and closed by using the specified protocol and command.

The creation of the process display can start once the signals are mapped. An example of process display is shown in figure 7. Once everything has been done the operator can use these displays to control one or many substation. Different voltage levels are shown in different colours.

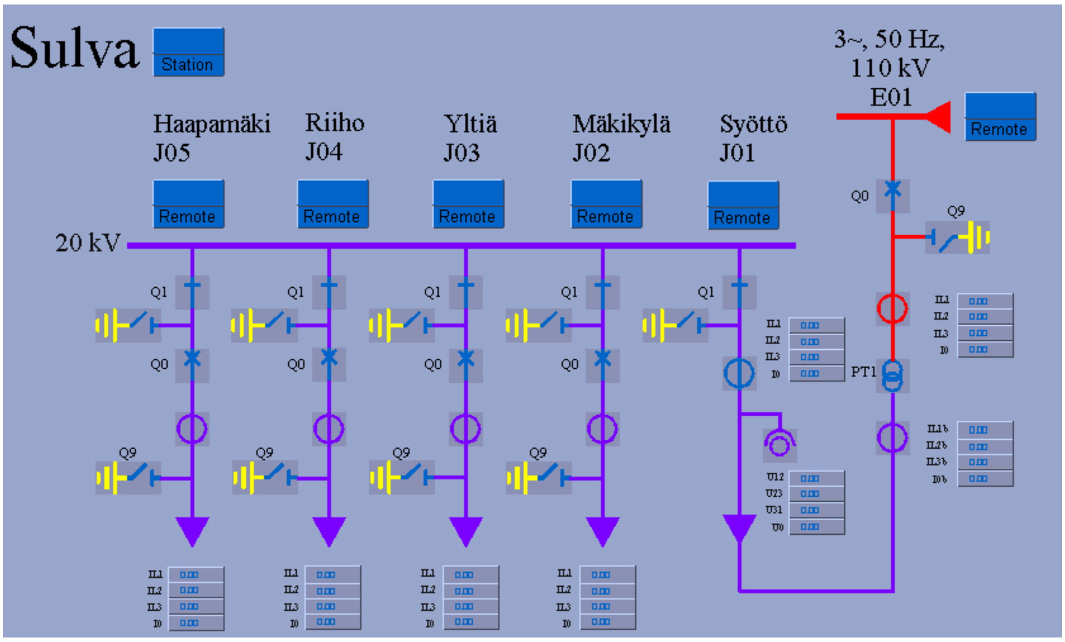


Figure 7. SYS600 process display.

3.5.2 MicroSCADA DMS600

DMS600 is a distribution management system that allows an operator to see all the electrical lines in the geographical view as shown in figure 8. SCADA operators have always both DMS600 and SYS600 window open on different screens. They can see from the geographical view which part of the network is functioning and which part of it is faulty. DMS600 calculates automatically the most probable location of the fault by using the available information of the network.

Operators can monitor the voltage drop across the network. There are different reporting tools that calculate different values of the network. The quality of the network can be analyzed by using these values.

Operators can easily send a maintenance team to fix a specific fault in the network with the help of the geographical view and the available information of the fault location. This view also helps to locate switches that must be opened before the maintenance can begin.

Figure 8. DMS600 distribution management system.

4 GATE MODEL

This chapter covers the idea of the gate model used in the development projects of the ABB Distribution Automation.

4.1 Principle of the Gate Model

The gate model is a business decision model and a road map for moving development projects from idea to launch. Good collaboration and communication with the customers is important because it creates ideas from the current needs and business requirements. ABB R&D of the Distribution Automation has history of using the gate model to guide project activities, however the gate model is not a project management model. /5/

The gate model consists of eight gates as seen in figure 9. A gate is a decision point where the results are evaluated from business and strategic point of views /5/. The Decision has four options which are:

- Go,
- Go with actions,
- Rework or
- Cancel the project. /5/

If the project passes the business and other requirements of the gate, then it will go forward. If it does not pass the requirements, the reasonability of the project must be evaluated by keeping markets in mind. This can lead to the cancellation of the project. Usually the rework applies and the project shall continue towards the same gate with a new schedule. /5/

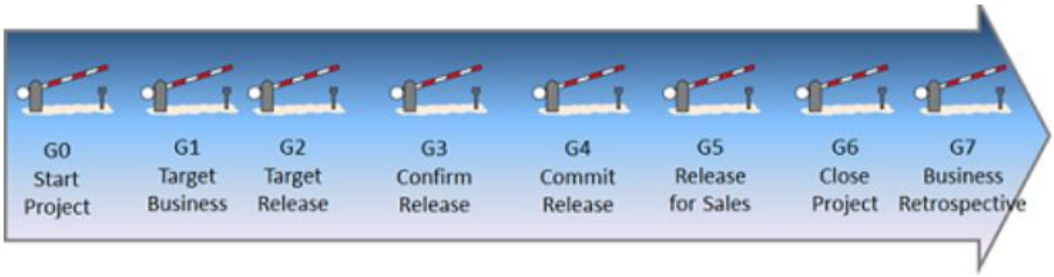


Figure 9. Business gate model. /5/

4.2 Gate Phases

4.2.1 Gate 0 – Start Project

Gate 0 is the formal start of the project that requires intentional business motivation /5/. The project starts when the product management has decided to meet the customer specification on some particular matter. For example, the customer may want to control some particular device remotely or the device must work under specific circumstances. The project can start as well from the internal needs to develop something new or by updating an old product to ensure a business place in the upcoming markets. Also a competitor can affect the launching of the project e.g. the competitor has new type of functionality or their product follows some particular standard. There can be many reasons to start a project.

4.2.2 Gate 1 – Target Business

Gate 1 requires an agreement on business motivation and intended offering. It also requires readiness from the organizational functions to start planning. /5/

4.2.3 Gate 2 – Target Release

Gate 2 requires an agreement on the targeted release in terms of scope, costs, time and priorities. All organizational functions must be ready to start the execution. /5/

4.2.4 Gate 3 – Confirm Release

Gate 3 represents the confirmation of the release. It requires confirmation of scope, cost, time, priorities and that the project is progressing according to the business needs. There must be a technical solution and enough resources to complete the project. /5/

4.2.5 Gate 4 – Commit Release

The business case and release are committed in Gate 4 and the organization is ready to start market introduction. /5/

4.2.6 Gate 5 – Release for Sales

Gate 5 represents that the organization is ready to release, manufacture and start sales. This means that the product has been validated and verified. /5/

4.2.7 Gate 6 – Close Project

Gate 6 represents the end of the project. It means that all project activities are completed or handed over to the organization. Lessons learned are to be captured and documented. /5/

4.2.8 Gate 7 – Business Retrospective

Gate 7 requires that the results of the project have been evaluated from the business perspective. /5/

4.3 Roles

4.3.1 Gate Owner

There are typically two gate owners for the whole project and the project gates are split for them. The gate owners decide what gates should be executed and will the gate assessor be needed for the project. Gates 1, 2 and 4 are mandatory and those should not be skipped. The gate owners decide whether to continue the project or not at the gate meetings with the support of the gate assessor and the project manager. The role of the Gate owner includes agreeing on the schedule with the gate assessor and the project manager. The gate owner evaluates gates by received recommendations from the Gate Assessor and by the self-assessment of the project manager. /5/

4.3.2 Gate assessor

The responsibility of the gate assessor is to assess the project with the project manager based on the available information. The gate assessor supports the gate owner in the decision making and presents assessment findings at the gate meetings. There can be more than one gate assessor in one project to take care of individual matters that may require expertise from the different fields. /5/

4.3.3 Project Manager

The project manager gathers the team for the project and leads them. The project manager starts the project based on the agreed schedule with the Gate owner. The project manager performs self-assessment during the project and involves the gate owner to resolve issues that have been found during the assessment. /5/

4.3.4 Functional Manager

The functional manager is a person who assigns a representative of an organizational function to collaborate within the project team. A function means for example marketing, support or R&D etc. /2/. Different functions are shown in figure 10.

Figure 10. Organizational functions. /6/

4.4 Gate Meeting

A gate meeting is a meeting where the current state of the project is evaluated. A gate meeting is held at every gate to make the decision what to do with the project.

5 TESTING DEFINITIONS

This chapter covers information about different types of tests, documents and tools.

5.1 Importance of Testing

Testing is important to ensure that the device is functioning correctly before it is manufactured and sold to the customers. This is also a quality question as it affects the imago of the products and the whole company. Incorrect functioning of the product can cost a lot to a customer e.g. it can cause a power outage or some fault to the electrical network. Exchanging a new product or updating old one typically requires expertise of an engineer and the process can be very time consuming. It is the most cost-effective to find the problems as early as possible. The project management takes all responsibility of the project and tests /2/.

5.2 Reporting Tools

5.2.1 Serena Configuration Management System

Serena CM is a Configuration Management tool that is used for reporting all the defects that has been found during the different tests and phases in the product development project. The software for the products used in the project also exist at the Serena CM. The container in the Serena CM is a database table for a project where all the reported defects have been linked. There are typically two different containers.

The project release container is used to collect every defect report that is made during the project. This allows the project management to easily check all the defects of the project. The number of unfixed defects can affect the decision making during the gates especially if there are critical defects. The project management can also assign capable persons to fix the defects.

The second type of container is a PVC container where all the defects found by PVC are collected. This allows PVC to monitor own defect reports. /2/

5.2.2 System Testing Web Server

The system testing web server is a user interface for project test cases and it is used for publishing the test specification document and test reports. The system testing web server is abbreviated as STWS. The project is built on the STWS by the PVC. The project includes all the test cases that are specified earlier by the project team. A typical test case is e.g. "Operation on normal situations (REF615) IEC-103". The test engineers who are participating in the project use the web server as a reporting tool.

The main things that are reported in a particular test case are:

- How the test has been performed?
- How the product was functioning?
- Created defect reports with the Serena ID.
- What is the product that the test was concerning?
- What is the version of the product and the testing tools?
- Which testing tools were used?

The status of the test case can be one of the following as shown in table 1.

Table 1. Different test statuses.

Test status	**Error handling**
untested	test case is not opened
ongoing	test case is currently ongoing
failed (low)	minor defect or an improvement proposal
failed (medium)	minor or major defects → test can usually continue
failed (critical)	Major defect or a show stopper → stops the test case or the whole testing process.

passed (remark)	improvement proposal e.g. usability issue
passed	test has been passed

5.3 Testing Done by Product Development

5.3.1 Software Module Testing

Software module testing is also known as unit or component testing. The purpose of software module testing is to ensure that a specific software module does not have unpredictable behaviour and it completes all the requirements. The software module is the smallest part of the whole software application that is to be tested. It is done to verify the functionality of the software modules based on the requirements. /8/

5.3.2 Hardware Module Testing

Hardware module testing is done to ensure that the hardware module meets requirements and is ready for integration tests. /8/

5.3.3 Integration Testing

The purpose of integration testing is to test the product against specification in the means of integration. It is important to test and verify that the hardware, software and the used tools are working together. The interfaces and interactions between integrated modules are verified. Also the communication of the product is tested that it can send and receive information by using a specific protocol determined in specification. The focus is to find early as many defects as possible before the product can be put to the further testing. /8/

5.3.4 Functional Testing

Functional testing is done to the product to ensure that the external and internal connections between the application and I/O are functioning as expected after the product has been built from the platform. The purpose is to detect defects in the standard configurations and product configuration tools. /8/

5.4 Product Testing

5.4.1 Type Testing

Type testing consists of testing the hardware of the product. The ISO standard defines how the device has to be tested. The device has to meet the specification that is defined at the manual of the product. For example, the REF615 nominal current in current input is 1 A but the thermal capability of the input shall withstand 20 A continuous current for one second /9/. ABB Distribution Automation has one type testing laboratory in Vaasa.

5.4.2 ATS Testing

ATS testing is testing the protection algorithms, logical operations, performance, accuracy and functional specification of the product. It is done after integration into the platform. The testing scope consists of the new and changed functions in the application function library and platform. /8/

5.4.3 System Testing

The purpose of the system testing is to verify the integration of the products in the system. Testing is done to ensure that product functionality works in a wide environment.

System testing is used for technology projects e.g. platform projects and IED development projects. The test scope is much wider than in the product verification. This means that many problems can be identified but the main focus is to repair the most critical ones /8/. The problems are usually related to the hardware or the software and it takes time to repair them depending on the type of the defect. Solving the problems requires effort from both R&D and the test and verification teams because the product must be retested after the repair has been applied.

5.4.4 Product Verification Phase

Product verification is used for the product projects and tool projects. The test scope is narrowed and the expectations are to identify none critical problem. Product verification test cases are usually based on the same test catalog with the system testing but it is actually only a small part of the whole testing scope. /8/

5.4.5 Regression Testing

Regression testing is retesting and validation of the product to ensure that the device is functioning in the same way as it functioned in the product verification phase. The expectation is to find none critical defect. Defects that are found in regression testing are either repaired immediately, in future or never depending on the criticality of the defect. /8/

5.5 System Verification

System verification is done by System Verification Center in Baden, Switzerland. The product is added to even a larger system than in the system testing so that the integrity can be properly verified. /8/

5.6 Interoperability Testing

Interoperability means that the product has to function together with another product from a different manufacturer or it can mean that a one small software application has to function on a larger software platform. Interoperability testing is done by both Product Verification Center and System Verification Center. /8/

5.7 Required Documents before the PVC Tests

5.7.1 Test Strategy

Test strategy is a document that is used as a common guideline for distribution automation. The purpose of the testing strategy is to support the test selection process to select the right testing phases for different projects. /8/

Well-proven test cases can be brought to a new project from the previous one as seen in figure 11. /2/

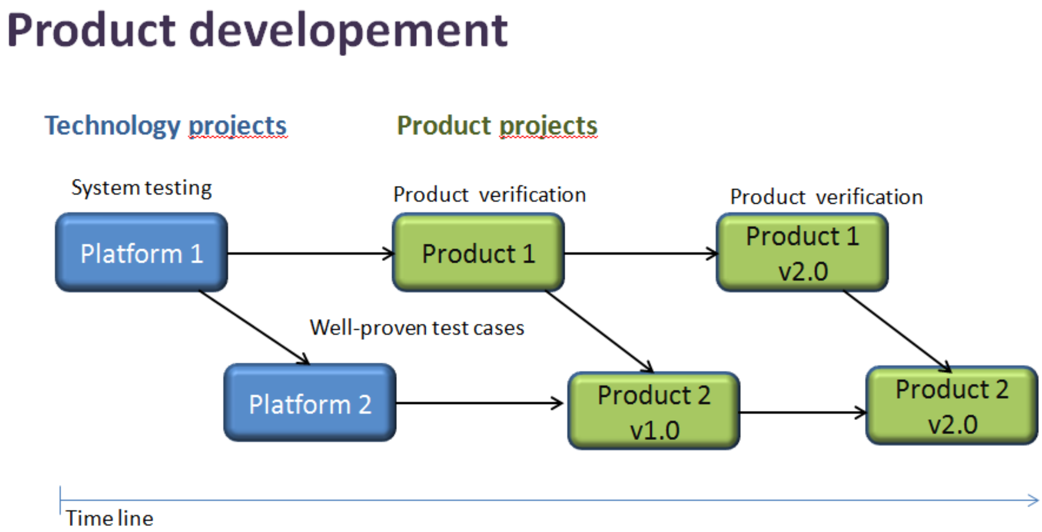


Figure 11. Well-proven test cases from the previous projects.

5.7.2 Test and Verification Specification

The test specification, also known as verification specification, is a list of test cases that has been selected for the product. It determines what products must be tested by using which protocol and priority. The project team usually chooses what tests must be applied for the product. Figure 12 represents what kind of information the test specification document includes. The information can vary. Test specification is property of product development. The test specification must be finished before gate 3. /2/

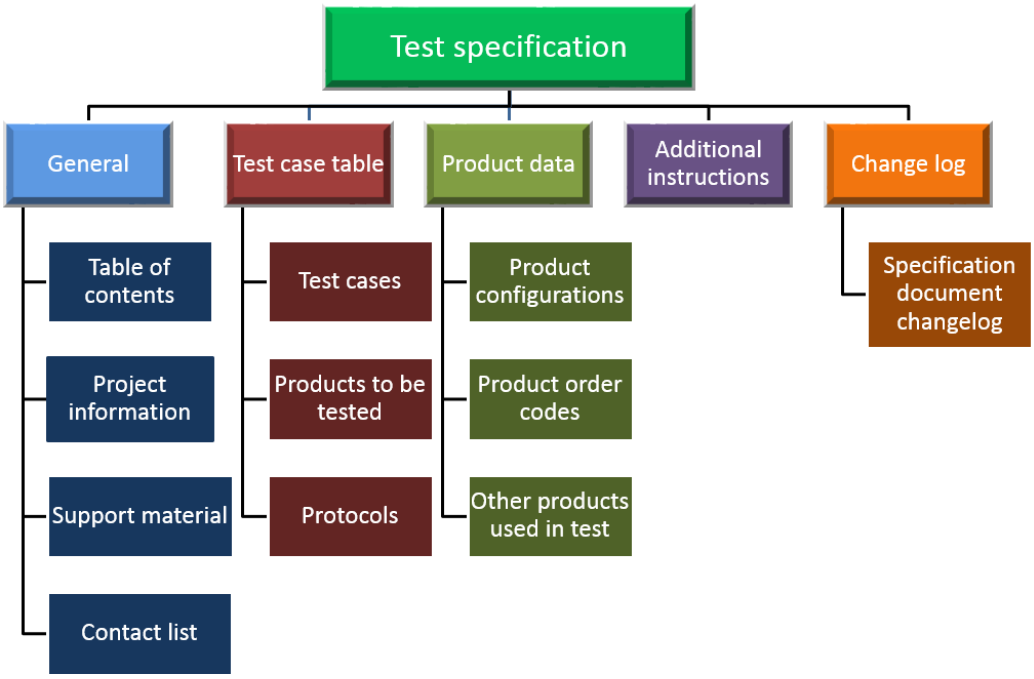


Figure 12. Test specification document.

5.7.3 Test Catalog

The test catalog is a list of test cases that the technology supports. It represents the purpose of a specific test and how the test should be executed. The test catalog can change during the tests. For example, the test engineer has to correct some steps of a test case or add new test cases into it. A snapshot of the document is taken for the project when the test reports are finished. The test catalog is made together with test specification and it must be ready before gate 3. The test engineer uses it as a guideline for testing. Figure 13 shows what kind of information the test catalog usually includes but it can vary. The test catalog is property of PVC. /2/

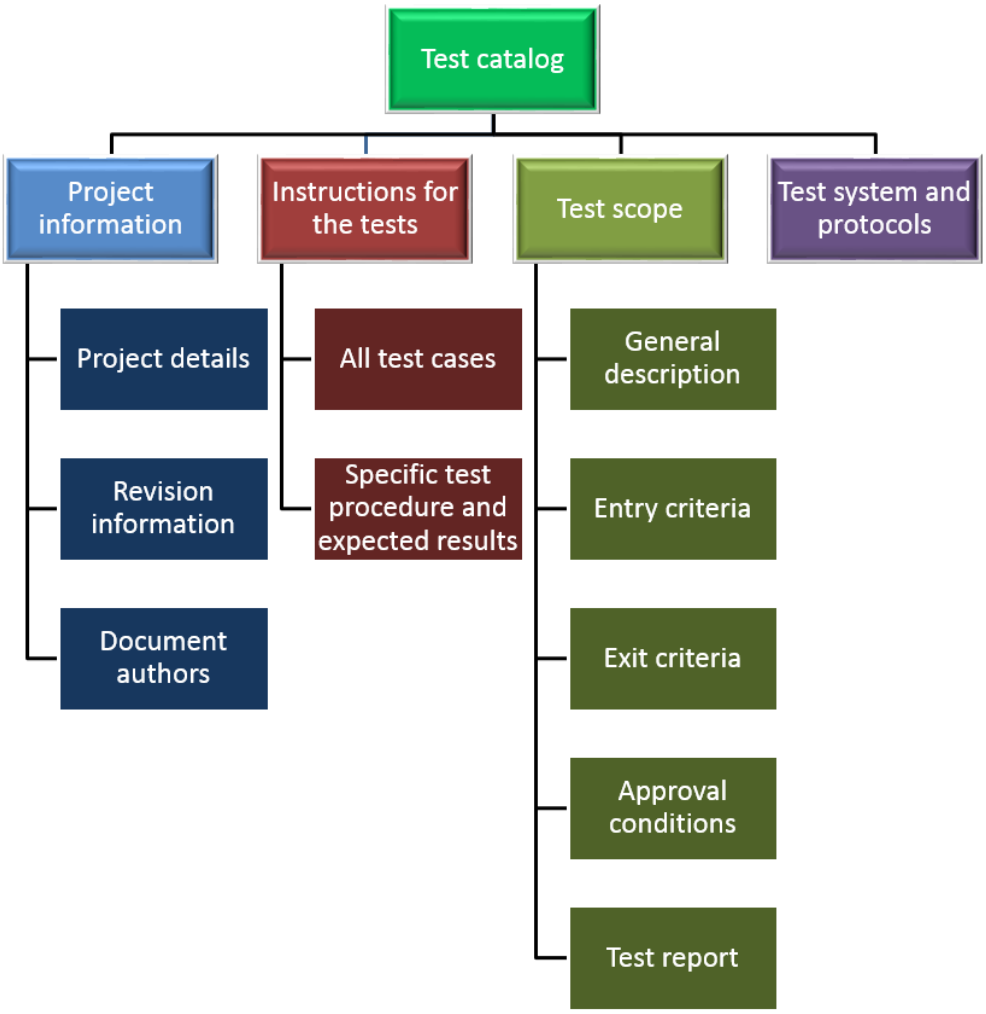


Figure 13. Test catalog.

6 PROJECTS

This chapter consists of project types used by ABB Distribution Automation and product creation process.

6.1 Technology Project

A technology project in ABB Distribution Automation is a project where a new platform is developed or the existing is modified for the new technology. Platform projects are not meant for sale, and can consist of new hardware, software, mechanics etc. /2/

6.2 Product Project

A product project is a project where a new product is developed but it is based on the existing platform. Product projects are meant for sale and do not include any new technology /2/. Product projects will affect all of the organizational functions so it is beneficial to inform the start of the project to every one of them. /5/

6.3 IED Development Project

An IED development project consists of technology and productization /8/. For example, the developed IED may include new technology which may require new hardware to support added functionality.

6.4 Project Management

There are a lot of things to manage during the product creation process. This includes project, business, requirement, configuration, resource, subcontractor and quality assurance management. Different tasks are given to different organizational functions to ease the management. Every function has its own check list so the project management can check the state of the given tasks. The project is separated to different phases during the gates as shown in figure 14**.** /10/

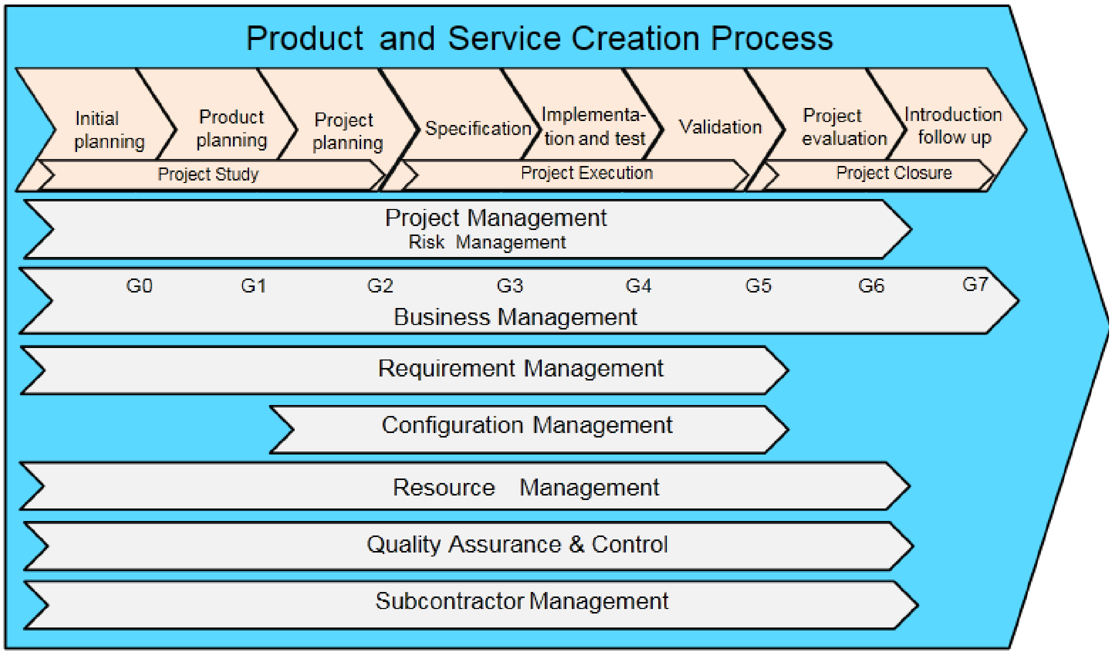


Figure 14. Project flow during gate model. /7/

- Gates 1 – 2 are used for planning the project. Organizational functions and the team members have to know what the project is and what their tasks in it are /10/. More time should be considered when planning the projects. Schedules will hold better if the project is planned with care and there are fewer chances that the project will be cancelled later /11/.
- Gate 3 – 5 are used for executing the project once plans are ready and confirmed. This includes the creation of specification and developing a prototype of the product. Tests can be applied once the prototype is ready with certain quality level /10/. Tests must be done properly and carefully to ensure high product quality. After testing the project can move to the gate 4. It does not always matter if the project gets delayed because the product life cycle is e.g. 14 years. /2/
- Gate 5 – 7 are used for ending the project. This includes manufacturing and publishing the product with its features. Also project evaluation applies and the project is reviewed to check if the goals were achieved in the point of business. /10/

6.5 Product Version Handling

If a new project has been created for the current product, the version increases. Usually the new product has a lot of new requirements or features that the market may require and those requirements grow all the time. So the new version of the product cannot include them all because it would require years of hard work and development to meet these requirements. Therefore, a typical product project usually focus only on some of these requirements so that the new version can be published and sold. /2/.

6.6 Baseline

The baseline is the version of the product during alpha, beta and release candidate phases. The baseline includes the software of the current version and a boot loader for the product. The baseline has an incrementing number.

7 PRODUCT VERIFICATION

This chapter covers the product verification process. The use-case project is also included.

7.1 Product Verification Process

Product verification is an important part of the project and it cannot be skipped. Product verification has several steps that apply within the project. It consists of kick-off meeting, specification, product verification, validation, reporting and closing of the project phases as shown in figure 15 /2/. The same figure can also be found in appendix 1 for a better visibility.

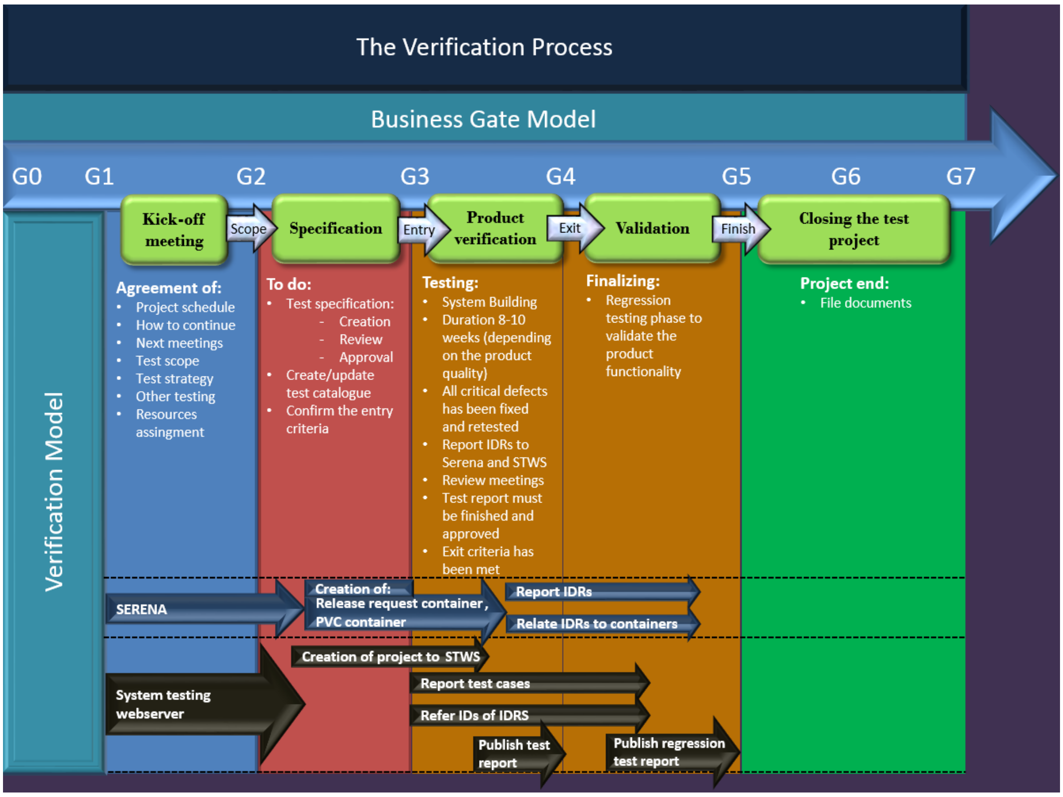


Figure 15. Product verification between the gates.

7.2 Kick-off Meeting

The product verification process starts with a kick-off meeting during gate 1 which is summoned by the project manager. The purpose is that the organizational functions and the project team members get familiar with the project. It also requires commitment from the participants to take care of the tasks planned for them /10/. Usually test engineers who will participate in the project are also summoned as they can affect the test scope and ensure that it will be good enough to be accepted by the PVC /2/. There are several things that must be agreed during the kick-off meeting and are shown in table 2.

Table 2. Agreements in kick-off meetings.

Agreement	**Explanation**
Project schedule	Preliminary target dates for the project gates. Also the schedule when testing takes place.
How to continue	Next steps to proceed with the project
Next meetings	Decision of cyclic meetings e.g. one meeting in every week.
Resources assignment	Give tasks for required organizational function and project team members
Test scope and strategy	Decision of which tests must be applied depending on if the project is technology or productization project
Other testing	Tests that are not part of product verification e.g. software module tests

Gate 2 meeting can be executed once the product and project plans are ready, the kick-off meeting has been held, the agreements are done and everyone knows how to proceed with the given tasks. /10/

The product verification of the use-case project started with the kick-off meeting. The project was introduced to the PVC and tasks were given to different persons as shown in table 3. The project schedule was presented e.g. when the next gate meetings are going to take place.

Table 3. Tasks given in the kick-off meeting during the use-case project

Task	**Responsible**
Input from the original developer was needed for verification specification.	Project manager
Product verification specification had to be ready for gate 3.	Project manager
RECs and RER relays had to be ordered to PVC.	Project manager
Validity of the test catalog had to be reviewed before gate 3.	Test engineer
Table of the test cases and protocols had to be finished.	Project manager
Test plan had to be ready for customer piloting	No responsibility for PVC
Test engineer 1 to participate in Grid automation configuration training.	Test engineer
System building	Test engineer

The project was special because it consisted of collaboration with the original developer of the product and a customer. The use-case project consisted of testing and verifying smart grid products REC601 and REC603 in different systems.

The product requirements for the use-case project came from the customer but also from the ABB Distribution Automation. There was a need to apply more features to the IED e.g. support for dial-up line and Kries IKI-50 fault indicator.

REC601/3 is a wireless control unit for distribution transformer and other closed cabinet applications. It includes e.g. the following features:

- Wireless control for three disconnector,
- GRPS and VPN support,
- Support for fault indicator Compass B,
- Can be supplied by 24 V battery,
- Temperature measurement and control of the cabinet heater,
- Supports IEC 60850-5-101 and 60850-5-104 communication protocols.

REC603 is shown in figure 16.

Figure 16. REC603 wireless control unit in action.

The testing scenarios were also presented and are shown in figure 17. The first situation was to verify that the SCADA could communicate with REC601/3 via the established GPRS link between REC601/3 and M2M. Viola M2M is an industrial router which has firewall, L2TP VPN and SSH VPN and many other functions. M2M also has Ethernet ports for LAN and WAN. LAN is used to communicate with the local devices and WAN is used to communicate through the Internet. M2M allows advanced network configuration. Fault indicators were connected to the REC601/3 by RS-485 cable by using the Modbus communication protocol. IEC 60870-5-104 Ethernet based communication protocol was used for communication between REC601/3 and SCADA. The purpose of the system was to verify that the SCADA could read measurements from the fault indicators Compass B and Kries IKI-50.

The second presented situation was to establish an IEC 60870-5-101 Slave Link over PSTN dial-up modem network. IEC 60870-5-101 is a serial communication protocol which uses RS-232 cables for moving information. SCADA was connected to the first dial-up modem via RS-232 and the REC601/3 was also connected to the second dial-up modem via RS-232. Both modems used separate phone numbers to communicate with each other.

The third presented situation was to verify that the SCADA could communicate with REC615 via a GRPS link between M2M and RER601/3. The RER601/3 is a router which has advanced network functionality. RIO600 is a device that consist of external I/O that can be used by IED.

The RER601/3 and RIO600 were connected to the REC615 via TCP/IP 61850-8-1 GOOSE horizontal communication protocol. GOOSE allows fast and reliable communication.

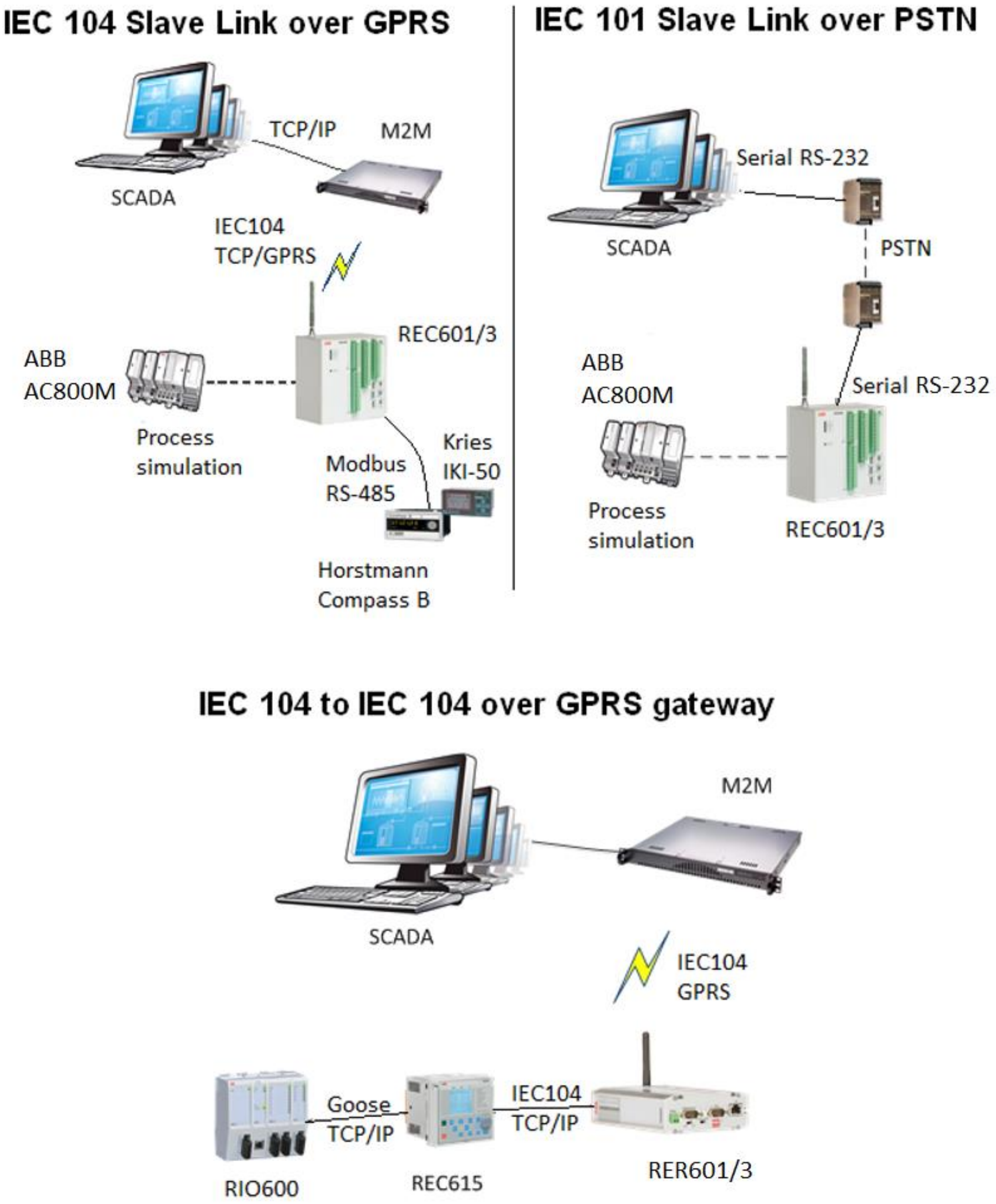


Figure 17. Test system scenarios in the use-case project. /13/

7.3 Specification

The second phase in the product verification is to create the test specification and test catalog documents. The test catalog is created and updated by the PVC during the creation of test specification. Test specification and catalog must be ready, reviewed and approved before gate 3 can be achieved. Test cases are also inputted to the STWS during the gate 2 and 3. /2/

The meeting was summoned in the use-case project by the project manager. The purpose of the meeting was to agree who writes the test specification for PVC. The decision after the meeting was that the project manager creates the test specification document while PVC builds the testing system. However, the original developer of the product should have been responsible for creating the test specification. The collaboration with the original developer was hard because they had other ongoing projects and it delayed the project schedule.

The product verification specification was reviewed. Necessary recommendations were applied and the product verification specification was approved. After that, the project was ready to face the gate 3.

7.3.1 Entry Criteria

The entry criteria consist of confirmation of the requirements that are needed to enter the testing phase. Table 4 includes all the entry requirements. There can be a few exceptions e.g. testing can be started by agreement between the project management and the PVC even if all of the entry criteria are not met /12/. The entry criteria can also change depending on the project /2/.

Table 4. Typical entry criteria in product verification.

Entry criteria	Requirement
Verification specification	written, reviewed and approved
Lower-level tests	module, integration, functional and system tests has to be passed and reports

	are reviewed and approved
Configuration tests	completed and reports are available
Documentation	preliminary user documentation for the product exists
Integration report	is available
Baselines	revised baseline is in use for building baselines
RELEASE request	has been created to the Serena CM
Project created to the system testing web server	project must be available
Baseline release note	sent to PVC representative
Resources	has been allocated for testing

As the use-case project was special the entry criteria were different.

7.4 Execution of the Product Verification Phase

The product verification step is between gate 3 and 4. Testing takes place during this phase /2/. It is expected that the product is of a proper quality and is ready for testing. For example, if the quality of the product is on too low a level, the testing resources are wasted because the product cannot be tested.

7.4.1 System Building

Product verification requires a built system where the product can be tested. The system building is the longest test case that requires a lot of designing. The test system is usually built on a 19” rack which is described in the following chapter. The purpose is to build a testing environment for the product where all tests can be performed according to the test specification and simulated in real environment. A typical testing system is shown in figure 18.

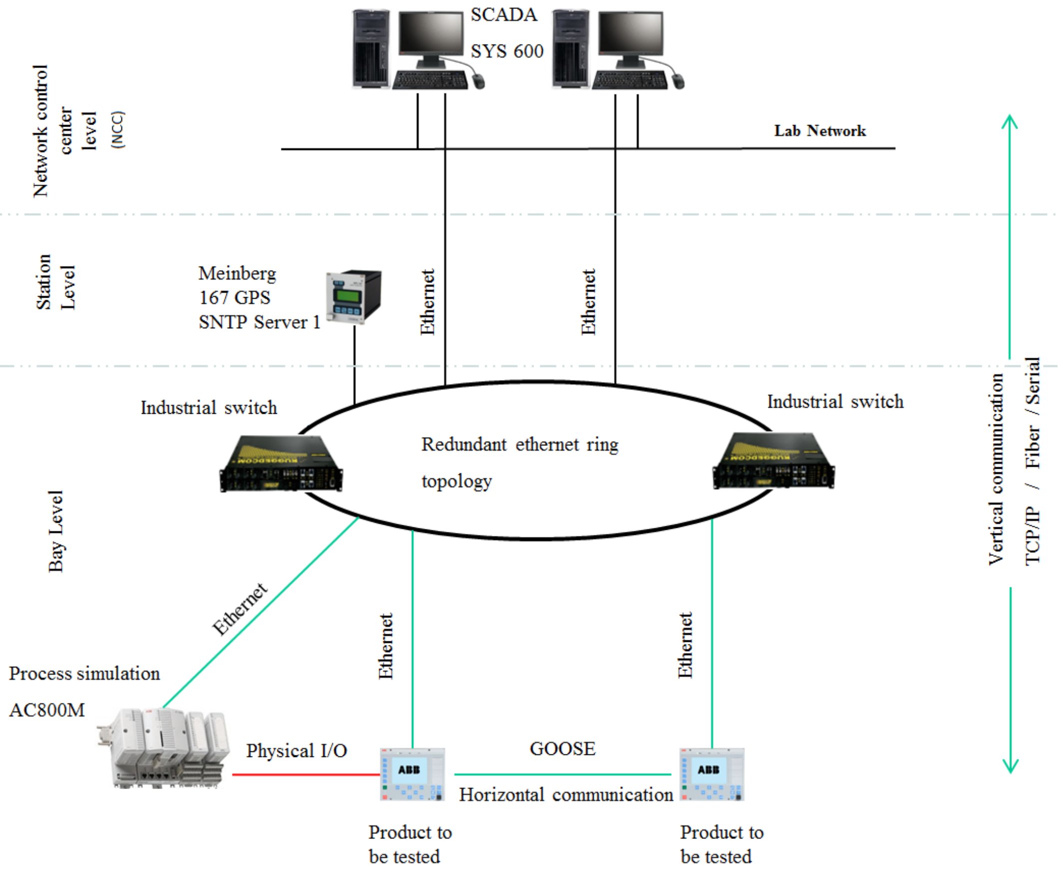


Figure 18. Typical testing environment.

The testing environment allows the test engineer to communicate with the devices by using SCADA or an Internet browser or some other specified method. SCADA has many protocols for communication but the browser only allows connecting to the WHMI of the device by using TCP/IP protocol. The system building also allows the integrity to be tested and verified.

The products in the system must be updated to the latest released software and hardware version available. The hardware configuration must be checked that it corresponds to the version required in the product version document of the project /2/.

The design of the test system starts by knowing which devices are to be tested and required in the testing system. Once the test catalog has been updated, it usually covers different system setups and test cases in which the DUT must function properly. DUT stands for device under test.

Typical things that the system designer must manage:

- Connect DUTs to the rack.
- Mount and connect external devices.
- Combine I/O of the product and the simulator AC800M.
- Build application to the simulator to control all of the I/O.
- Create system configuration and manage process signals in SYS600.
- Build application in SYS600 to control the device via protocols.
- Manage all cables and conductors and their connection.
- Design coupling channels and bus bars.
- Connect DTS voltages and currents to the measuring devices.

DTS is a process simulator for testing purposes that can supply the desired amount of current and voltage to the line with specified phase shift.

The system building for the use-case project started after the kick-off meeting because the products to be mounted on the rack were known. The system building for the use-case project was long lasting due to many encountered problem.

The following devices were specified by the project:

- REC603 wireless controller
- REC603 wireless controller
- REC601 wireless controller
- REC601 wireless controller
- REC615 control relay
- Compass B fault indicator
- Kries IKI-50 fault indicator
- 2 pieces Westermo modems for dial-up communication

- Viola Arctic M2M gateway
- PC
- MicroSCADA SYS600
- AC800M logic for simulation
- RER601/3

The decision was that all of the IEDs and AC800M would head the front side of the rack. Every other equipment were positioned at the back. The devices had to be constantly repositioned to create space for the remaining devices that were needed. Some of the devices arrived later e.g. Westermo modems. It took two months to get the most of devices mounted on the rack and another two to make all the couplings. It took also two months to create application in SYS600 and AC800M. Totally six months were spent on the system building. Figures 19 and 20 represent the built rack for the use-case project and show which devices are included.

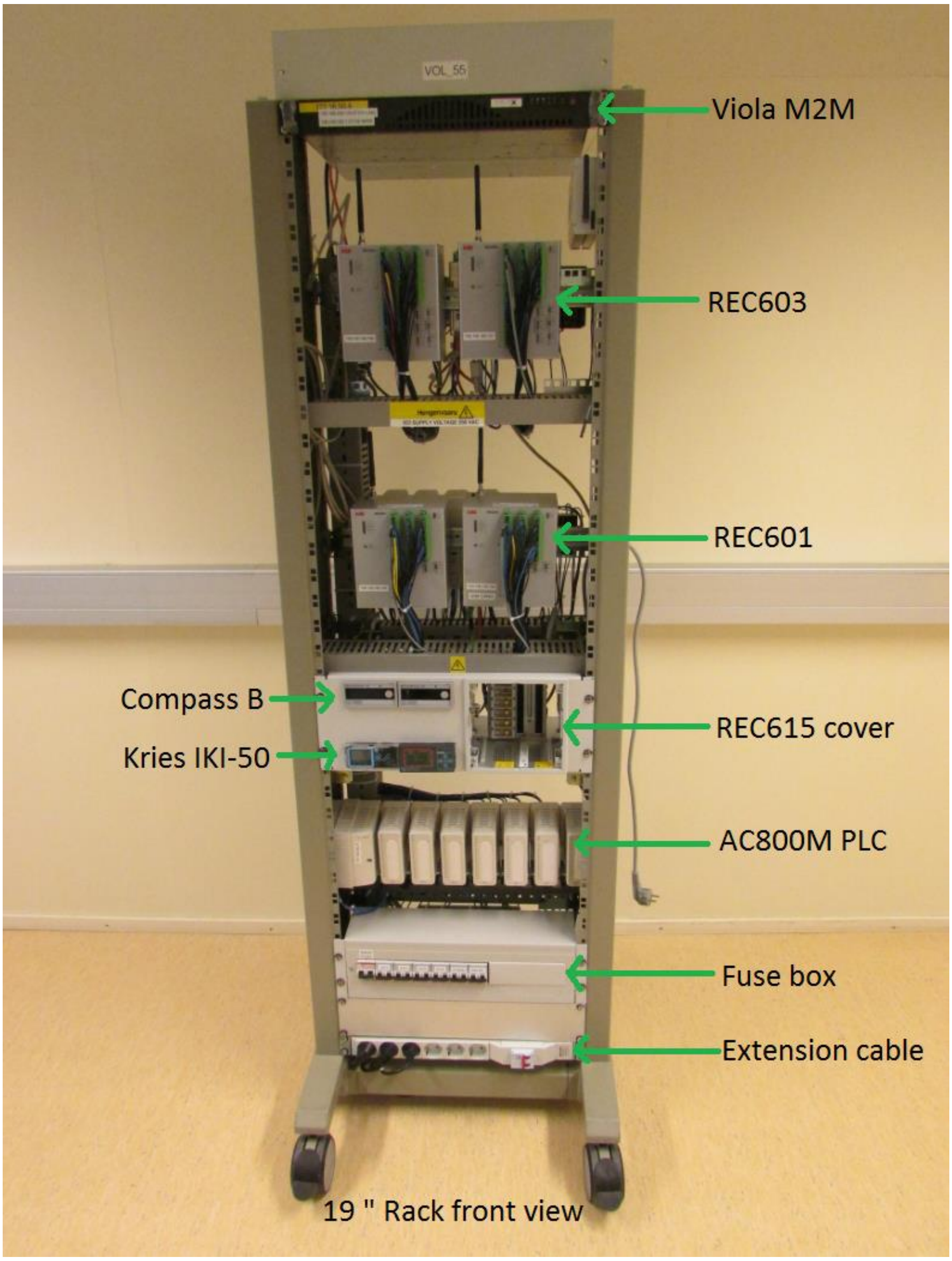


Figure 19. Front view of the use-case Rack.

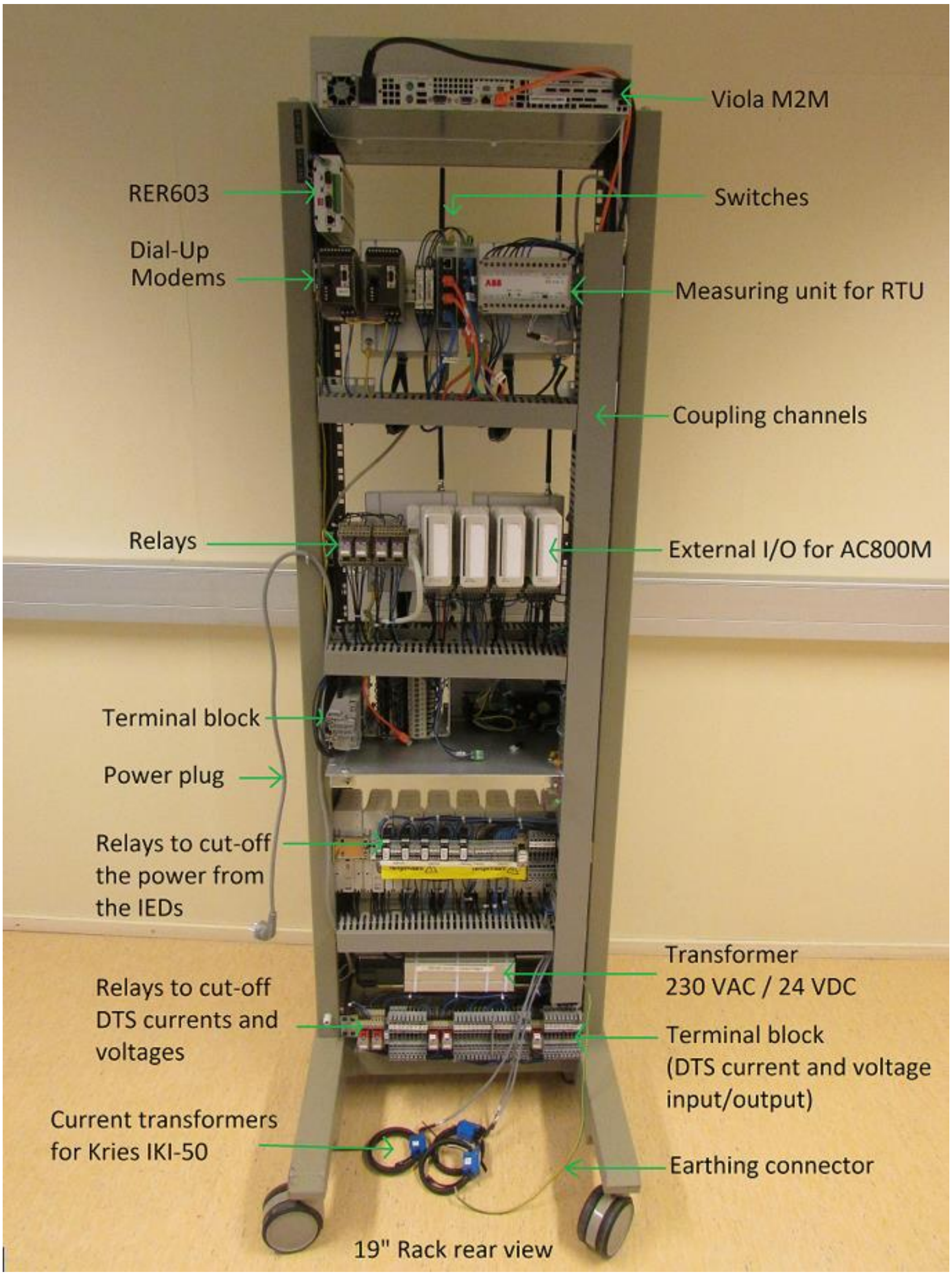


Figure 20. Rear view of the use-case Rack.

The Viola Arctic M2M gateway had to be replaced by another one which included Viola Patrol functionality. There were also problems in the couplings of the fault indicators. For example, it was not recommended to couple current channels of the DTS directly to the current inputs of the fault indicators. Fault indicators were designed to use a certain current sensor that was connected around the power cable. If the currents were connected directly, the voltage drop around the DTS loop was huge due to the high impedance of the inputs. The decision was to add external dummy relays to cut off the currents and voltages while the measurements were not needed.

The PVC laboratory did not have an ADSL-link installed so it had to be arranged from the other building by R&D. Viola M2M gateway required the ADSL for static public IP-address. The static public IP-address enabled a GPRS connection between M2M and REC601/3 without the need to change the configuration constantly because the IP-address could change otherwise.

The original developer of the product delivered the software update which consisted of the specified and required new functionality for the REC601/3. The software update was in two files. The first file updated the Linux operating system of the REC601/3 and the second updated the configuration file. The original developer also delivered installation instructions for the update.

A circuit board was built to be able to simulate the temperature of a closed cabinet. There was functionality in the REC601/3 to turn on a heater if the temperature of the cabined was too low. The temperature was normally measured by a small NTC resistor. When the temperature of the cabinet changes, the resistance of the NTC resistor changes.

The circuit board consisted of a push button controlled digital potentiometer microcontroller. One button increased and the other button decreased the resistance of the digital potentiometer. The push buttons were simulated by using optocouplers. The optocouplers were connected to the output of the AC800M. This allowed to increase and decrease the resistance of the potentiometer by using two output channels of the AC800M output module. The resistance channels of the digital potentiometer were connected into the NTC channels of REC601/3. The circuit board is shown in figure 21.

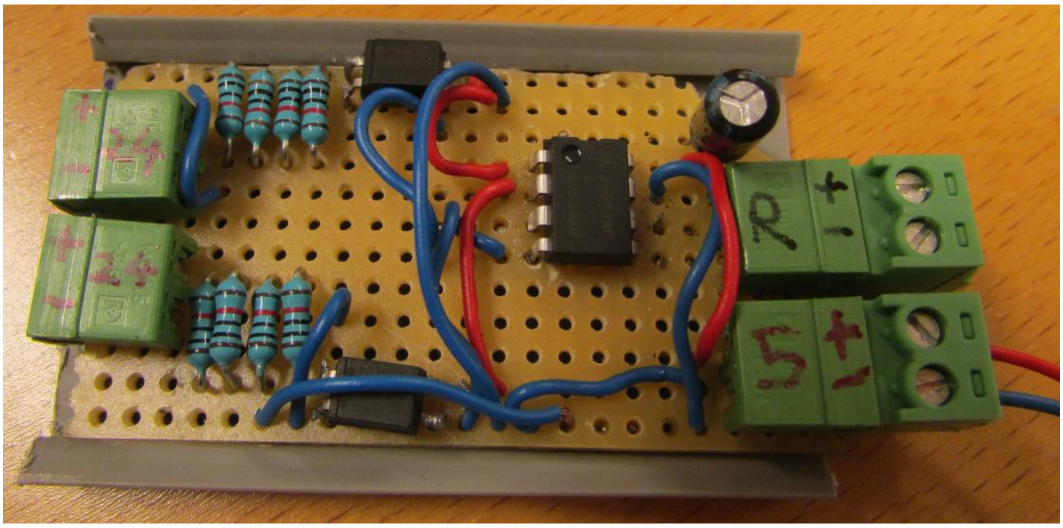


Figure 21. Circuit board for controlling NTC resistance.

Once the system was built and configured the creation of the application started. The first task was to create an application for AC800M to simulate the disconnectors of the REC601/3. The application is shown in figures 22 and 23. Q1, Q2 and Q3 stand for the disconnectors. Q9, Q11 and Q12 stand for the earth switches. AC800M made it possible to simulate all the switchgear and I/O.

The output module of the AC800M was connected to the input of the REC601/3 and the other way round. The particular input of REC601/3 was developed to indicate disconnector 1 open state when the positive edge of the input was reached. The input turned to positive when the input voltage was between 20 - 30 V. Every other inputs was connected and simulated by the same method.

AC800M application had the following functionality:

- Cut off DTS currents and voltages
- Connection of reference clock pulse
- Disconnect power from Ethernet switches 1 and 2
- Disconnect power from specific device
- Control of all the switchgear
- Execute interval close and opens of the switchgear to produce events
- Connect Battery voltage to the IED
- Simulation of load current controller
- Test I/O of fault indicators
- Control of NTC resistor resistance to change temperature

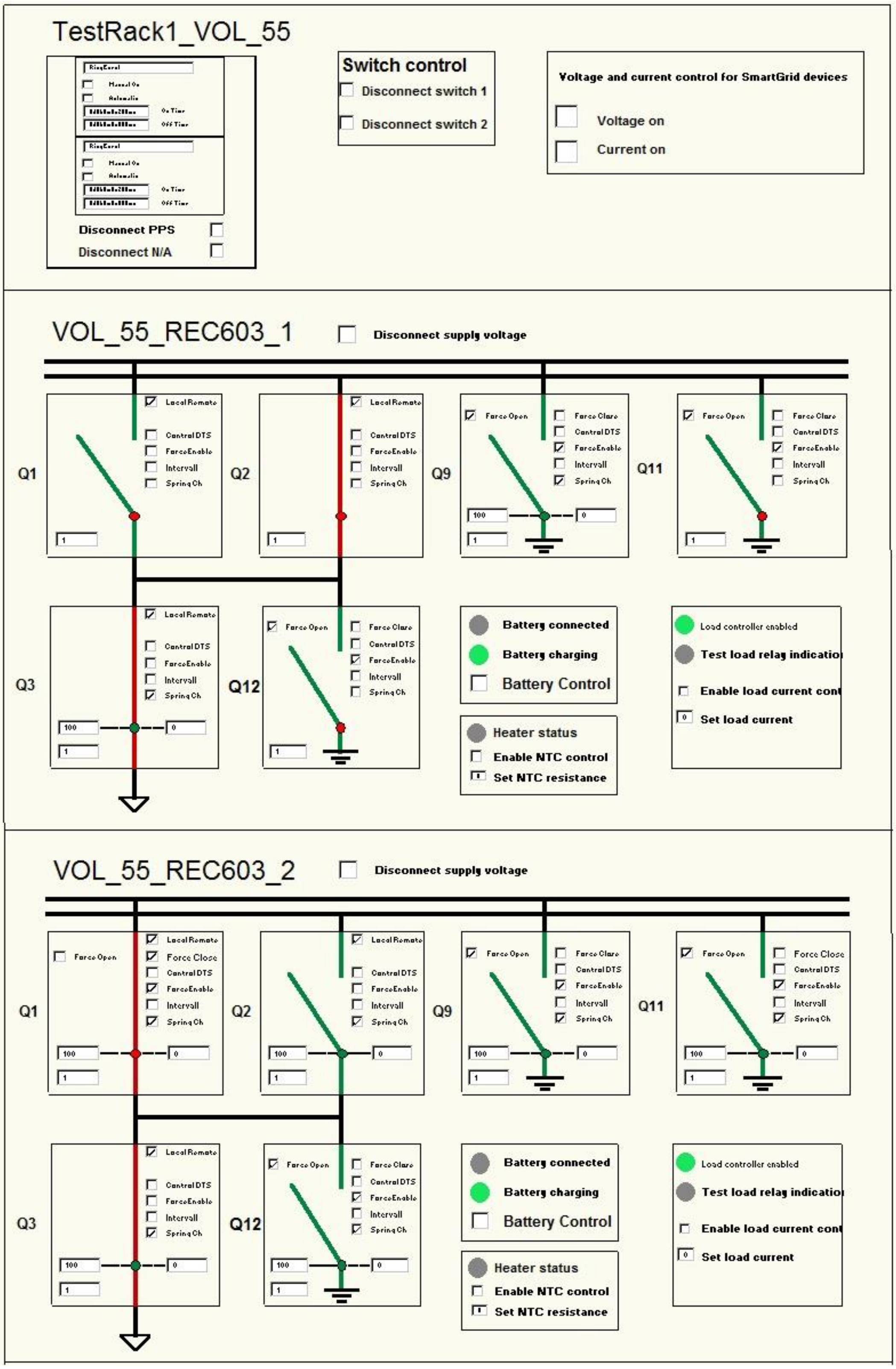


Figure 22. AC800 control modules 1 of 2.

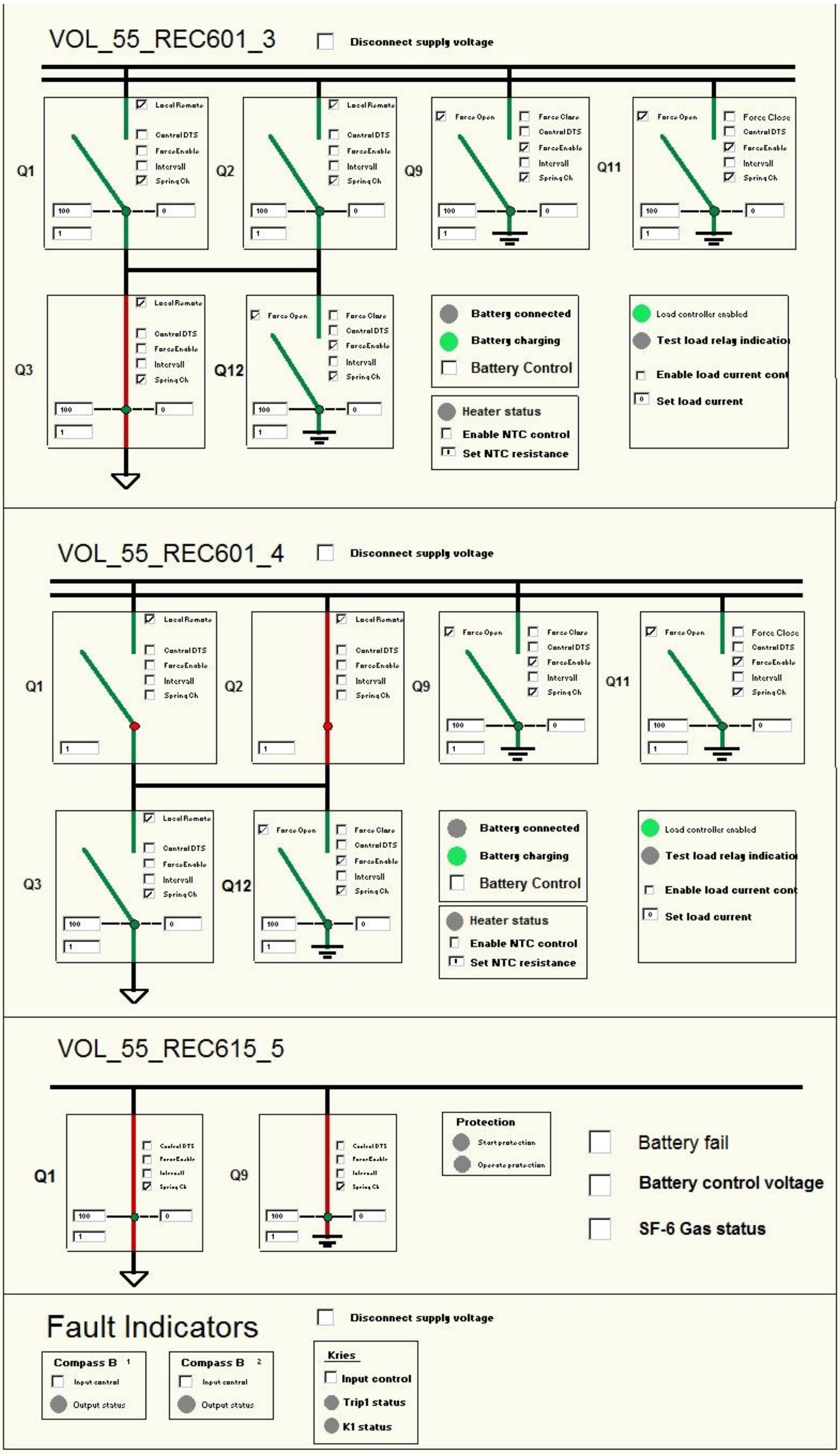


Figure 23. AC800 control modules 2 of 2.

The next application that had to be built was created in SYS600. The first thing that had to be created was the system configuration. The IEC 60870-5-104 line had to be created first as shown in figure 24. The line had to have the IP-address of the PC and the line had to be taken into use.

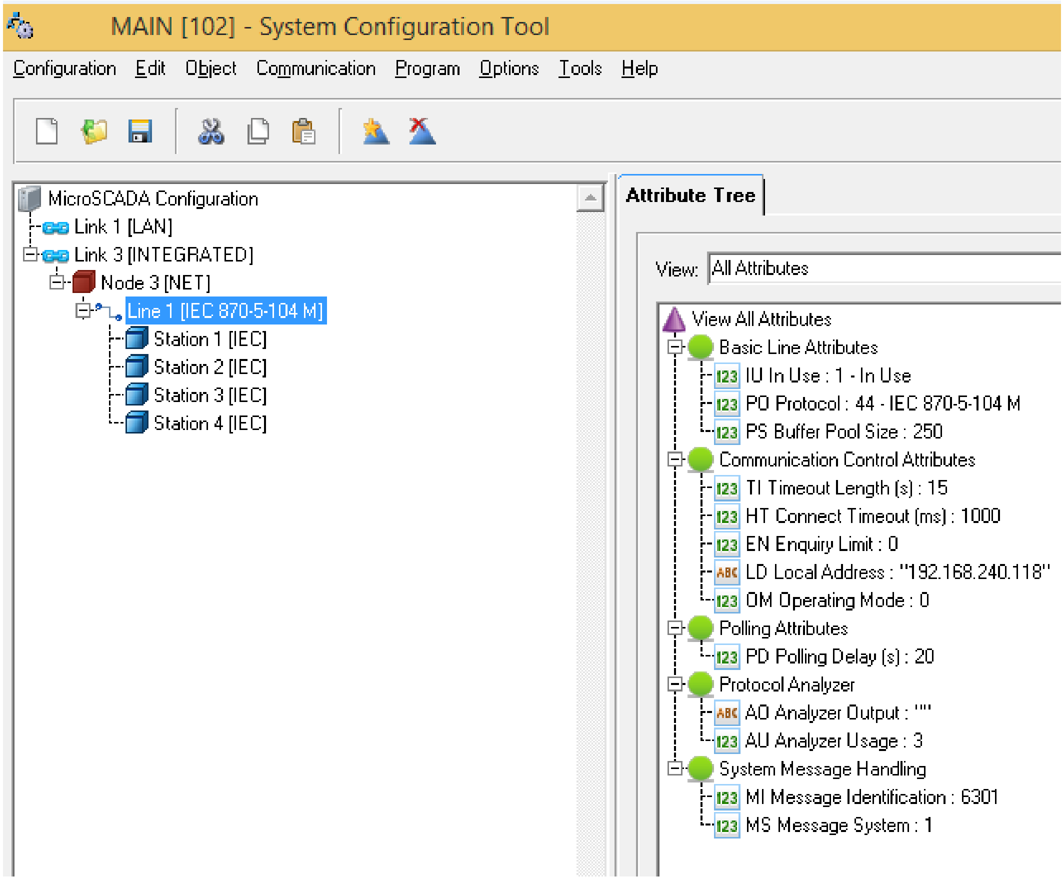


Figure 24. Created line for IEC-104 protocol.

Then four stations were created under the IEC 60870-5-104 line 1. Every station corresponded to a particular REC601/3 IED. The station had to have the IP-address of the corresponding IED, as shown in figure 25.

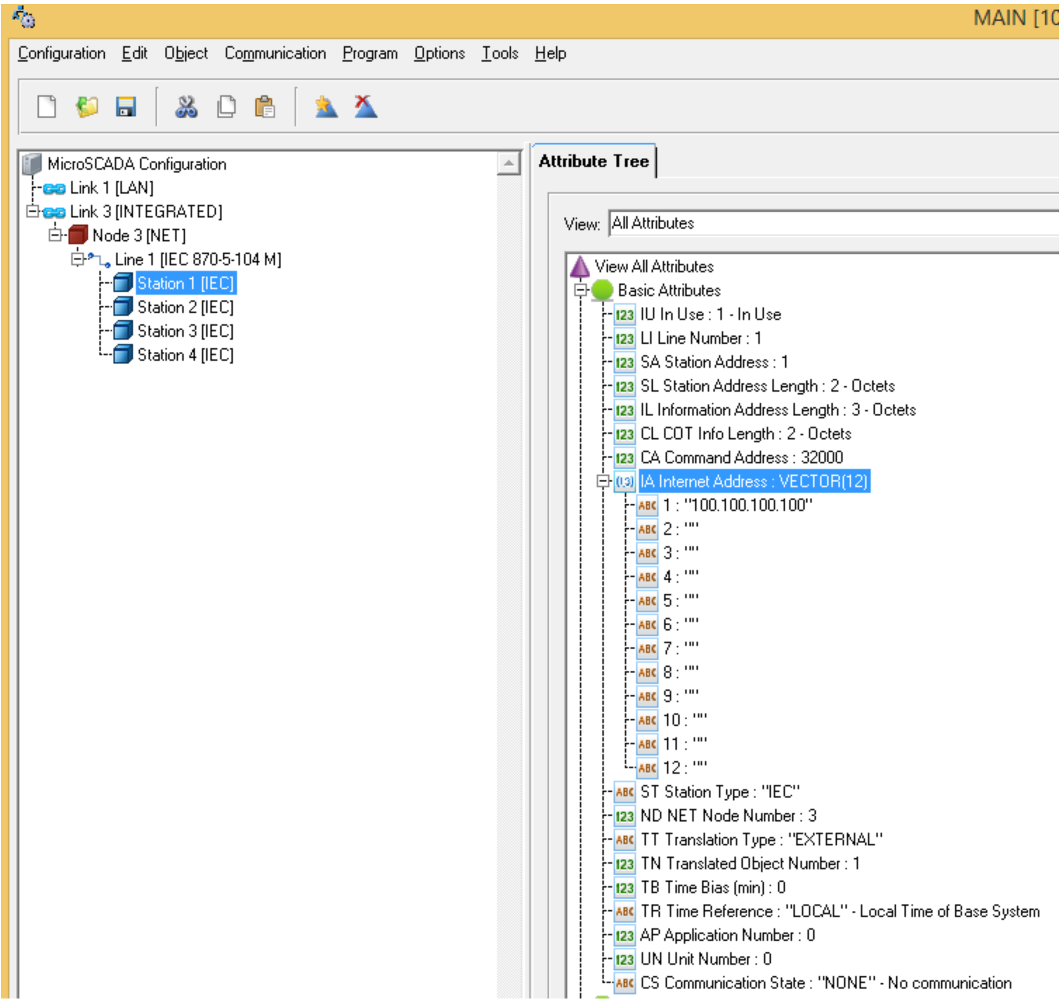
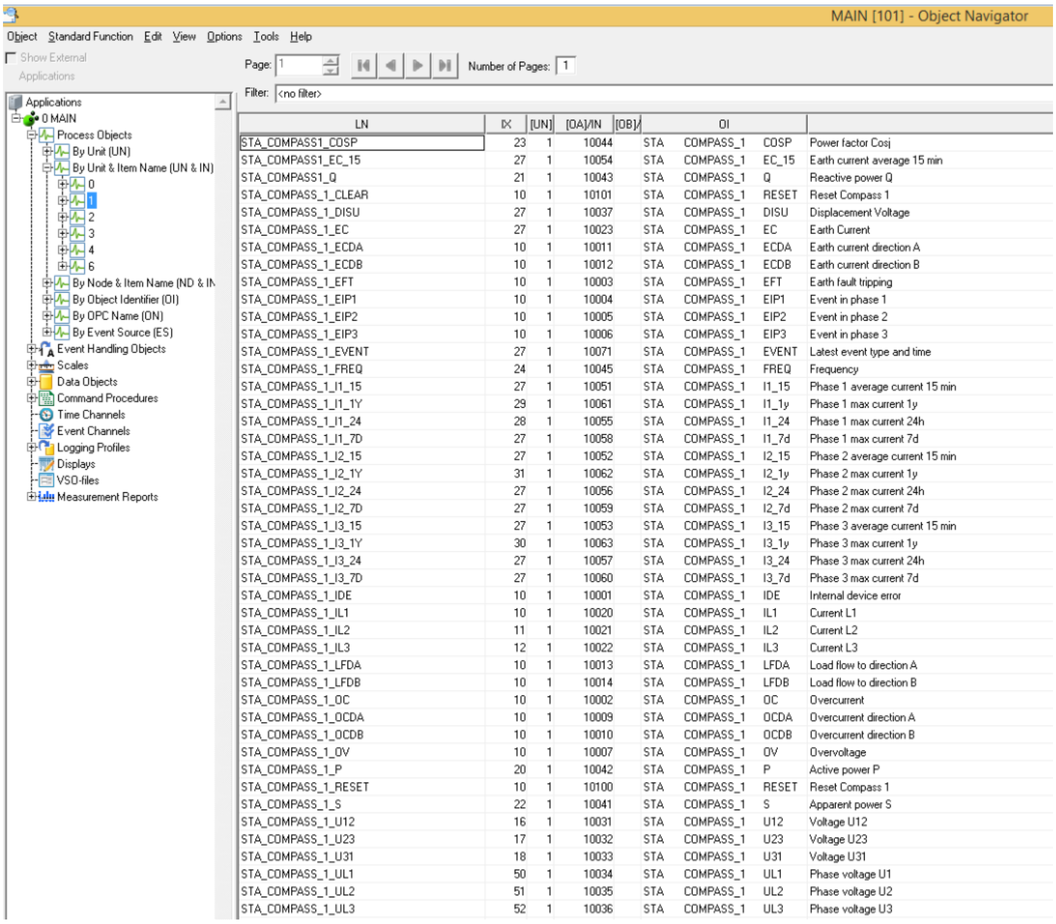


Figure 25. Created station on the IEC 60870-5-104 line.

Process signals had to be done after the system configuration was ready. The process signals of one station are shown in figures 26 and 27. Station 1 consisted of REC603 relay and Compass B fault indicator. Compass B was connected to REC603 via RS-485 Modbus protocol. However, REC603 was also connected to SCADA via Ethernet based IEC 60870-5-104 protocol. This way the REC603 passed data from the fault indicator to SCADA. All the process points were mapped for four REC601/3 and for three fault indicators.



LN	IX	[UN]	[OA]/IN	[OB]/	OI			
STA_COMPASS1_COSP	23	1	10044		STA	COMPASS_1	COSP	Power factor Cosj
STA_COMPASS1_EC_15	27	1	10054		STA	COMPASS_1	EC_15	Earth current average 15 min
STA_COMPASS1_Q	21	1	10043		STA	COMPASS_1	Q	Reactive power Q
STA_COMPASS_1_CLEAR	10	1	10101		STA	COMPASS_1	RESET	Reset Compass 1
STA_COMPASS_1_DISU	27	1	10037		STA	COMPASS_1	DISU	Displacement Voltage
STA_COMPASS_1_EC	27	1	10023		STA	COMPASS_1	EC	Earth Current
STA_COMPASS_1_ECDA	10	1	10011		STA	COMPASS_1	ECDA	Earth current direction A
STA_COMPASS_1_ECDB	10	1	10012		STA	COMPASS_1	ECDB	Earth current direction B
STA_COMPASS_1_EFT	10	1	10003		STA	COMPASS_1	EFT	Earth fault tripping
STA_COMPASS_1_EIP1	10	1	10004		STA	COMPASS_1	EIP1	Event in phase 1
STA_COMPASS_1_EIP2	10	1	10005		STA	COMPASS_1	EIP2	Event in phase 2
STA_COMPASS_1_EIP3	10	1	10006		STA	COMPASS_1	EIP3	Event in phase 3
STA_COMPASS_1_EVENT	27	1	10071		STA	COMPASS_1	EVENT	Latest event type and time
STA_COMPASS_1_FREQ	24	1	10045		STA	COMPASS_1	FREQ	Frequency
STA_COMPASS_1_I1_15	27	1	10051		STA	COMPASS_1	I1_15	Phase 1 average current 15 min
STA_COMPASS_1_I1_1Y	29	1	10061		STA	COMPASS_1	I1_1y	Phase 1 max current 1y
STA_COMPASS_1_I1_24	28	1	10055		STA	COMPASS_1	I1_24	Phase 1 max current 24h
STA_COMPASS_1_I1_7D	27	1	10058		STA	COMPASS_1	I1_7d	Phase 1 max current 7d
STA_COMPASS_1_I2_15	27	1	10052		STA	COMPASS_1	I2_15	Phase 2 average current 15 min
STA_COMPASS_1_I2_1Y	31	1	10062		STA	COMPASS_1	I2_1y	Phase 2 max current 1y
STA_COMPASS_1_I2_24	27	1	10056		STA	COMPASS_1	I2_24	Phase 2 max current 24h
STA_COMPASS_1_I2_7D	27	1	10059		STA	COMPASS_1	I2_7d	Phase 2 max current 7d
STA_COMPASS_1_I3_15	27	1	10053		STA	COMPASS_1	I3_15	Phase 3 average current 15 min
STA_COMPASS_1_I3_1Y	30	1	10063		STA	COMPASS_1	I3_1y	Phase 3 max current 1y
STA_COMPASS_1_I3_24	27	1	10057		STA	COMPASS_1	I3_24	Phase 3 max current 24h
STA_COMPASS_1_I3_7D	27	1	10060		STA	COMPASS_1	I3_7d	Phase 3 max current 7d
STA_COMPASS_1_IDE	10	1	10001		STA	COMPASS_1	IDE	Internal device error
STA_COMPASS_1_IL1	10	1	10020		STA	COMPASS_1	IL1	Current L1
STA_COMPASS_1_IL2	11	1	10021		STA	COMPASS_1	IL2	Current L2
STA_COMPASS_1_IL3	12	1	10022		STA	COMPASS_1	IL3	Current L3
STA_COMPASS_1_LFDA	10	1	10013		STA	COMPASS_1	LFDA	Load flow to direction A
STA_COMPASS_1_LFDB	10	1	10014		STA	COMPASS_1	LFDB	Load flow to direction B
STA_COMPASS_1_OC	10	1	10002		STA	COMPASS_1	OC	Overcurrent
STA_COMPASS_1_OCDA	10	1	10009		STA	COMPASS_1	OCDA	Overcurrent direction A
STA_COMPASS_1_OCDB	10	1	10010		STA	COMPASS_1	OCDB	Overcurrent direction B
STA_COMPASS_1_OV	10	1	10007		STA	COMPASS_1	OV	Overvoltage
STA_COMPASS_1_P	20	1	10042		STA	COMPASS_1	P	Active power P
STA_COMPASS_1_RESET	10	1	10100		STA	COMPASS_1	RESET	Reset Compass 1
STA_COMPASS_1_S	22	1	10041		STA	COMPASS_1	S	Apparent power S
STA_COMPASS_1_U12	16	1	10031		STA	COMPASS_1	U12	Voltage U12
STA_COMPASS_1_U23	17	1	10032		STA	COMPASS_1	U23	Voltage U23
STA_COMPASS_1_U31	18	1	10033		STA	COMPASS_1	U31	Voltage U31
STA_COMPASS_1_UL1	50	1	10034		STA	COMPASS_1	UL1	Phase voltage U1
STA_COMPASS_1_UL2	51	1	10035		STA	COMPASS_1	UL2	Phase voltage U2
STA_COMPASS_1_UL3	52	1	10036		STA	COMPASS_1	UL3	Phase voltage U3

Figure 26. Process signals of the first station 1 of 2.

STA_COMPASS_1_UV	10	1	10008	STA	COMPASS_1	UV	Undervoltage
STA_REC603_1_AEI	27	1	602	STA	REC603_1	AEI	Analog extra input
STA_REC603_1_BATON	10	1	717	STA	REC603_1	BATON	Battery connected
STA_REC603_1_BCC	27	1	444	STA	REC603_1	BCC	Battery charge current
STA_REC603_1_BCV	27	1	443	STA	REC603_1	BCV	Battery charge voltage
STA_REC603_1_BL	10	1	441	STA	REC603_1	BL	Battery low
STA_REC603_1_BP	10	1	442	STA	REC603_1	BP	Battery protect
STA_REC603_1_BRS	10	1	440	STA	REC603_1	BRS	Battery relay status
STA_REC603_1_BTC	27	1	446	STA	REC603_1	BTC	Battery test charge
STA_REC603_1_BTCO	10	1	540	STA	REC603_1	BTCO	Battery test control
STA_REC603_1_BTS	10	1	445	STA	REC603_1	BTS	Testing
STA_REC603_1_CRS	10	1	420	STA	REC603_1	CRS	Charger relay status
STA_REC603_1_D1LR	10	1	101	STA	REC603_1	D1LR	Local remote switch for disconnector 1
STA_REC603_1_D1TCH	27	1	106	STA	REC603_1	D1TCH	Disconnector travel charge 1
STA_REC603_1_D1TCU	27	1	105	STA	REC603_1	D1TCU	Disconnector travel current 1
STA_REC603_1_D1TT	27	1	103	STA	REC603_1	D1TT	Disconnector travel time 1
STA_REC603_1_D1TV	27	1	104	STA	REC603_1	D1TV	Disconnector travel volt
STA_REC603_1_D2LR	10	1	201	STA	REC603_1	D2LR	Local remote switch for disconnector 2
STA_REC603_1_D2TCH	27	1	206	STA	REC603_1	D2TCH	Disconnector travel charge 2
STA_REC603_1_D2TCU	27	1	205	STA	REC603_1	D2TCU	Disconnector travel current 2
STA_REC603_1_D2TT	27	1	203	STA	REC603_1	D2TT	Disconnector travel time 2
STA_REC603_1_D2TV	27	1	204	STA	REC603_1	D2TV	Disconnector travel volt 2
STA_REC603_1_D3LR	10	1	301	STA	REC603_1	D3LR	Local remote switch for disconnector 3
STA_REC603_1_D3TCH	27	1	306	STA	REC603_1	D3TCH	Disconnector travel charge 3
STA_REC603_1_D3TCU	27	1	305	STA	REC603_1	D3TCU	Disconnector travel current 3
STA_REC603_1_D3TT	27	1	303	STA	REC603_1	D3TT	Disconnector travel time 3
STA_REC603_1_D3TV	27	1	304	STA	REC603_1	D3TV	Disconnector travel volt 3
STA_REC603_1_ES1	10	1	102	STA	REC603_1	ES1	Earth sw. position indication 1
STA_REC603_1_ES2	10	1	202	STA	REC603_1	ES2	Earth sw. position indication 2
STA_REC603_1_ES3	10	1	302	STA	REC603_1	ES3	Earth sw. position indication 3
STA_REC603_1_HRS	10	1	430	STA	REC603_1	HRS	Heater relay status
STA_REC603_1_LCM	27	1	601	STA	REC603_1	LCM	Load current measurement
STA_REC603_1_LI_OUT	10	1	0	STA	REC603_1	LI	Line indicator
STA_REC603_1_LLC	27	1	482	STA	REC603_1	LLC	Load limiter charge
STA_REC603_1_LLCO	10	1	580	STA	REC603_1	LLCO	Load limiter control
STA_REC603_1_LLR	10	1	481	STA	REC603_1	LLR	Load limiter reason
STA_REC603_1_LLS	10	1	480	STA	REC603_1	LLS	Load limiter status
STA_REC603_1_LLT	27	1	483	STA	REC603_1	LLT	Load limiter time
STA_REC603_1_MRS	10	1	410	STA	REC603_1	MRS	Modem Relay Status
STA_REC603_1_PPS	10	1	716	STA	REC603_1	PPS	Second pulse
STA_REC603_1_PSS	10	1	400	STA	REC603_1	PSS	Power supply status
STA_REC603_1_Q1	10	1	100	STA	REC603_1	Q1	Disconn. position indication 1
STA_REC603_1_Q1	13	1	150	STA	REC603_1	Q1	Disconn. command 2
STA_REC603_1_Q2	10	1	200	STA	REC603_1	Q2	Disconn. position indication 2
STA_REC603_1_Q2	13	1	250	STA	REC603_1	Q2	Disconn. command 3
STA_REC603_1_Q3	10	1	300	STA	REC603_1	Q3	Disconn. position indication 3
STA_REC603_1_Q3	13	1	350	STA	REC603_1	Q3	Disconn. command
STA_REC603_1_TEMP	26	1	462	STA	REC603_1	TEMP	Temperature
STA_REC603_1_TH	10	1	461	STA	REC603_1	TH	Temperature high
STA_REC603_1_TL	10	1	460	STA	REC603_1	TL	Temperature low

In use | 2 - Automatic | Analog Input [IEC/Analog Input]

Figure 27. Process signals of the first station 2of 2.

Once all of the process signals were mapped it was time to create the displays by using display builder in SYS600. Figure 28 represents the created display for single IED. The display shows every status that has been brought via IEC 60870-5-104 or IEC 60870-5-101 from REC603. Also the statuses of the switchgear are shown. The control of the switchgear was possible from the display. The switchgear shows the same position that was determined in the AC800M application.

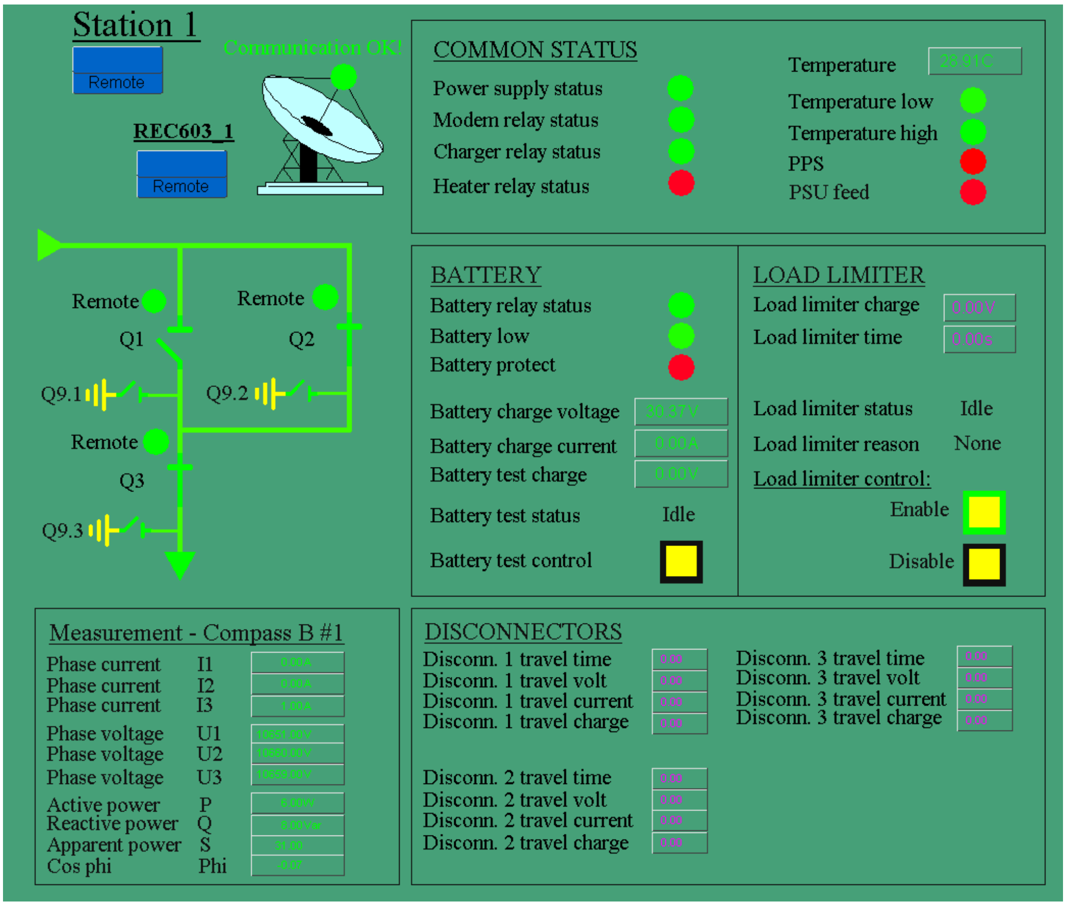


Figure 28. REC603 relay display.

The display for the fault indicator is shown in figure 29. The measurement and I/O status are shown. The fault indicator also had some simple protection functions to indicate alarms.

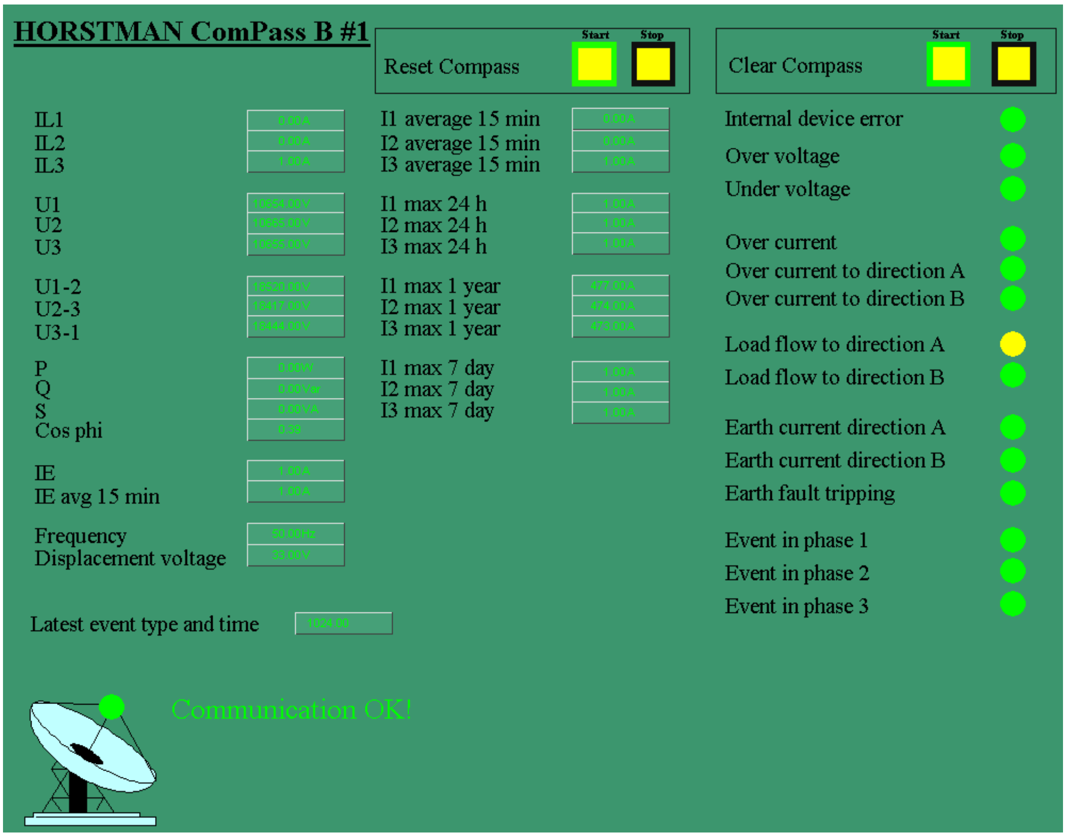


Figure 29. Display of fault indicator.

This was the formal end of the system building process for the use-case project. Everything was set so that the testing could begin.

7.4.2 Rack 19”

The rack is a standardized mounting frame for different devices. The rack mounting supports e.g. industrial switches, smart relays and other devices. Different sized devices can be mounted with a proper mounting plate. The rack creates an elegant and clear view of the devices that the system includes. The rack has wheels so it is easily movable.

PVC Finland has created definitions how the rack is supposed to be built for testing. Figure 30 represents the building definition. All of the DUTs are at the top and feeding electrical connections and process simulation are at the bottom. DUTs are marked as IEDs. There are terminal blocks behind the rack that are mounted on the bus bar. There are also all coupling channels for the devices.

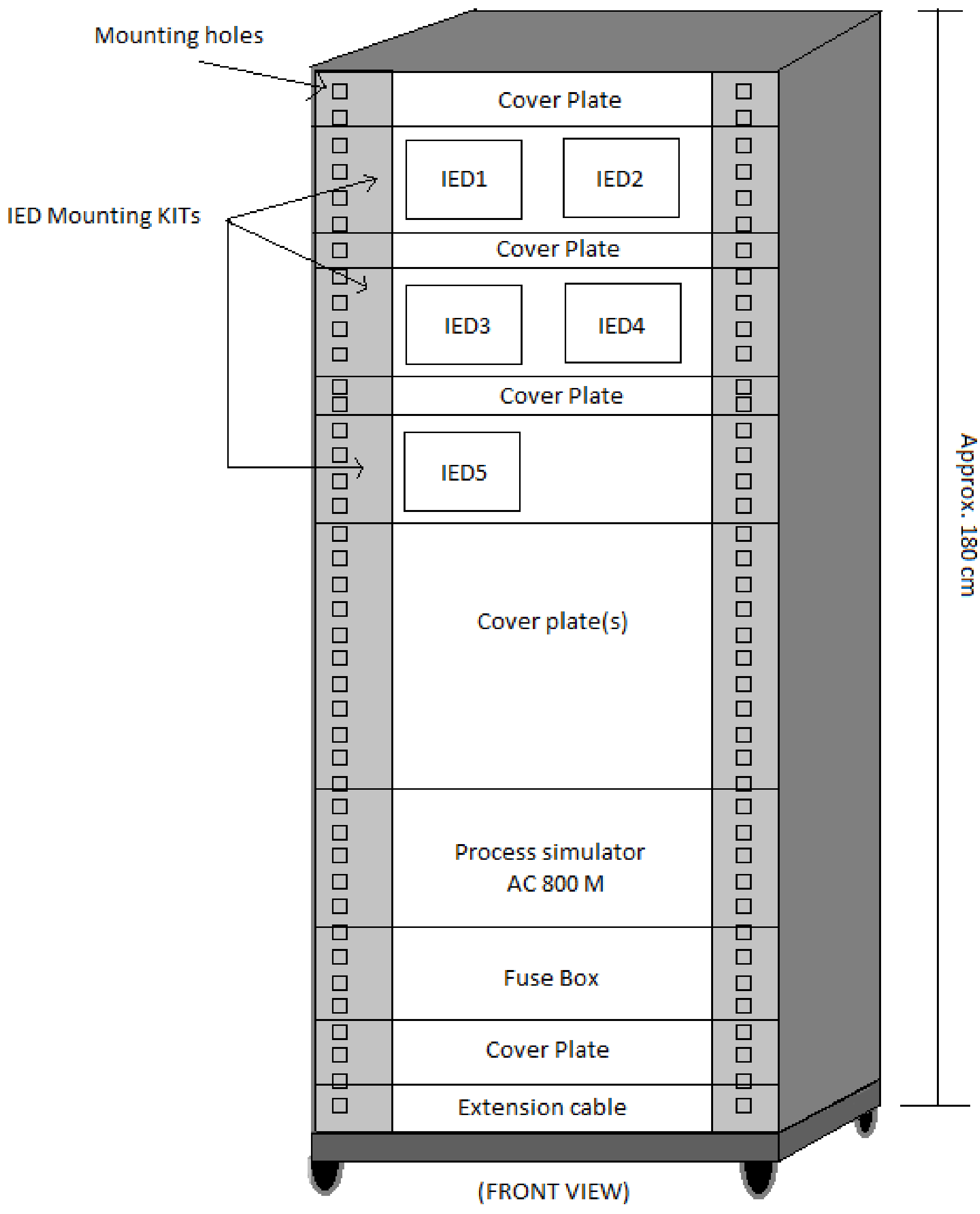


Figure 30. Rack 19”.

7.4.3 Testing

Testing can start after the system building has been completed, the project has passed gate 3, the project exists in the STWS and the containers have been created to the Serena CM. The duration of the testing usually takes 8 to 10 weeks depending on the product quality. Some of the low severity defects can be deferred for future release by the Configuration Control Board. The members of the Configuration Control Board are determined in the Quality Assurance Plan. /2/

Once the testing of the use-case project started, it was noticed that there was some problems on the product which delayed the testing. A meeting was summoned and it was decided to continue the project even some test cases would fail. This was the last step that was done for the project during this thesis.

7.4.4 Execution of a Test Case

The execution of a test case goes as shown in figure 31. At first the test engineer opens a test case and the status of the test case changes to the ongoing state. The test engineer performs the test case and reports it to the STWS.

If the test case fails, the test engineer creates an IDR to the Serena CM database. IDR stands for internal defect report. At the same time the test engineer changes the state of the test case to be failed. The IDR is then related to the PVC and project release request containers in Serena CM. The ID of an IDR is linked back to the STWS test case documentation so that the particular IDR can easily be found from the Serena while reading the test report. /2/

The open IDR is pending the project manager who receives an email notification message from it. Once read, the project manager delegates the IDR to someone who can analyze and fix the defect.

The analyzer applies a possible fix for the defect and then the IDR is pending for the test engineer to be retested. Usually the fix comes within the next software update package that includes other fixes as well. If the retest fails, it is pending the analyzer to apply a better fix. Retesting is also documented into the corresponding test case in the STWS.

Once the test case has been passed, then it is completed. The test engineer then changes the state of the test case in the STWS to be passed. If the test case fails, the test engineer changes the status to the failed state.

The test engineer can also put the state to "passed with remarks". It means that there is something notable on the test case. This is usually categorized as an improvement proposal.

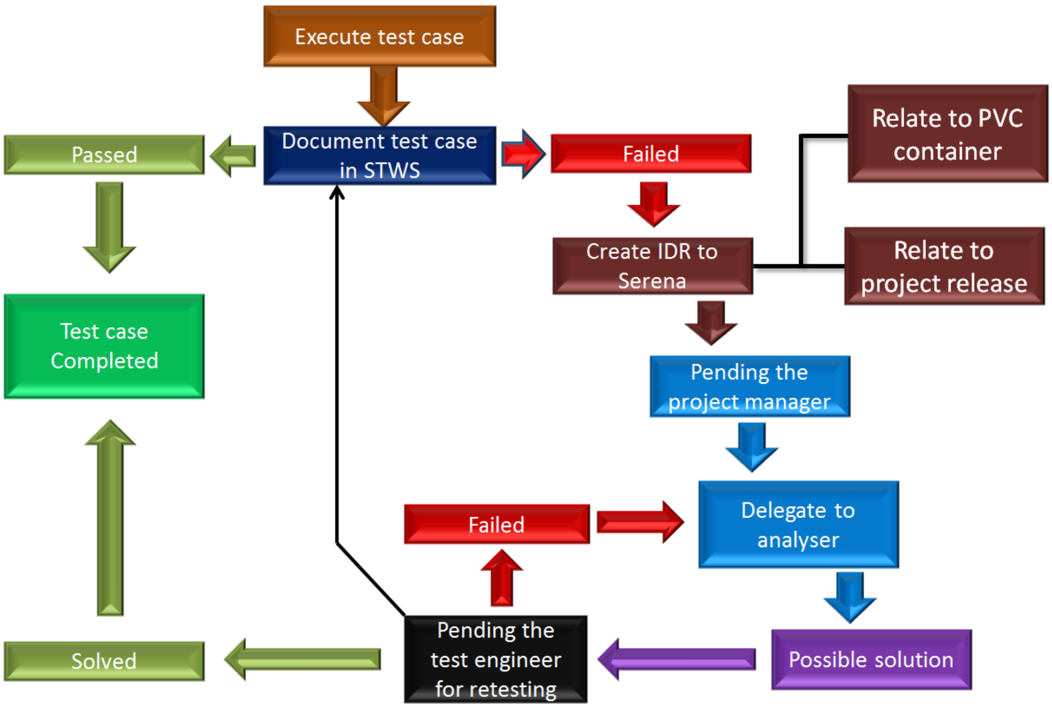


Figure 31. Execution of a test case.

7.4.5 Review Meetings

The purpose of the product verification review meetings is to check the current state of the verification process and come up with a solution what to do with the remaining IDRs. The number of defects is weighed and none critical defect must exist to proceed with the project. /2/

7.4.6 Test Report

Once the project management has come to the point where the remaining IDRs can be skipped or deferred to the future improvement, the test engineer can print out the test report by using a tool in the STWS. The test report is then to be reviewed and approved before the gate 4 meeting. The test report is filed as a part of the project documentation. /2/

7.4.7 Exit Criteria

The exit criteria consist of requirements that must be fulfilled before the project can pass the gate 4. The exit criteria is shown in table 5. /2/

Table 5. Exit criteria requirements

Requirement	**Explanation**
All test cases are run	None test case are open
Tests are passed or moved to future improvement	Decision what to do with the remaining IDRs has been made
No critical defect reports are open	Critical defects has been handled
Test report has been written, reviewed and approved	End point of product verification
All IDRs has been analyzed and action plan has been made	None open IDR exist

7.5 Validation

The validation phase consists of regression testing of the product to ensure that the product is properly tested in the product verification phase.

This is done between gate 4 and gate 5 after the product verification test cases are done. The test cases for the regression testing are selected from the product verification specification document. The regression testing scope is only a small part of the testing scope that is used for product verification. /2/

7.6 Closing the Project

Once every document has been analyzed, reviewed, approved and gate 5 meeting has been held and the gate have been passed the verification process has ended. Filing the documents is the last remaining thing to be carried out. The project files are filed and the project is saved in the STWS and all the IDRs are saved in the STWS.

8 CONCLUSIONS

The nature of this thesis was a project and it was very wide. Many problems were faced during the system building. The test verification specification document was delayed because the original developer of the product did not provide their specification. The original developer was also delayed in developing the software for the product used in the use-case. In addition, there was a problem in the connection of the fault indicator which caused the communication ports between REC603 and Kries IKI-50 to burn. This happened due to bad manual of the fault indicator. Kries IKI-50 had to be replaced. All in all, the delay of the project was about four months. The schedule of the thesis could not be met because of the appearing problems. The delay of the thesis was a month.

The thesis started in October 2013 and lasted till the end of May 2014 so the thesis included a lot of work. In my opinion the documentation of the verification process succeeded well and the testing system is ready and flexible for the use-case project as well as for future testing. Everything can be simulated that the PVC testing may require.

The specific documentation of the system building will be created and delivered to the PVC after this thesis due to limited time. This thesis has taught me very much and it has been interesting from the start. Good collaboration with design engineers and the project management was required to succeed. Despite the problems I am very happy with the results. This documentation will help new employees to get familiar with the product verification process.

I developed the old application of AC800M to fit the purposes of the use-case project by creating new control modules and function block diagrams for disconnectors and earth switches. The SYS600 application was created from the scratch and required hard signal mapping. I also created a tutorial for PVC during this thesis of how to establish communications between MicroSCADA and the REC601/3. The tutorial also included a simple AC800M simulation of a circuit breaker and how it can be controlled by using MicroSCADA.

REFERENCES

/1/ Description of ABB. Internal ABB website. Accessed: 16.5.2014.

/2/ Ekholm, Juha. Interview 15.4.2014 and 28.4.2014.

/3/ PVC Presentation. Internal ABB website. Accessed: 28.4.2014.

/4/ P202 Relay Applications. Internal training material. Accessed: 7.5.2014.

/5/ ABB Gate Model. Internal Online training. Accessed: 24.4.2014.

/6/ Functions. ABB Inside website. Accessed: 19.4.2014.

/7/ Product and Service creation process. Internal presentation. Accessed: 2.5.2014.

/8/ DA Strategy. Internal presentation. Accessed: 21.4.2014.

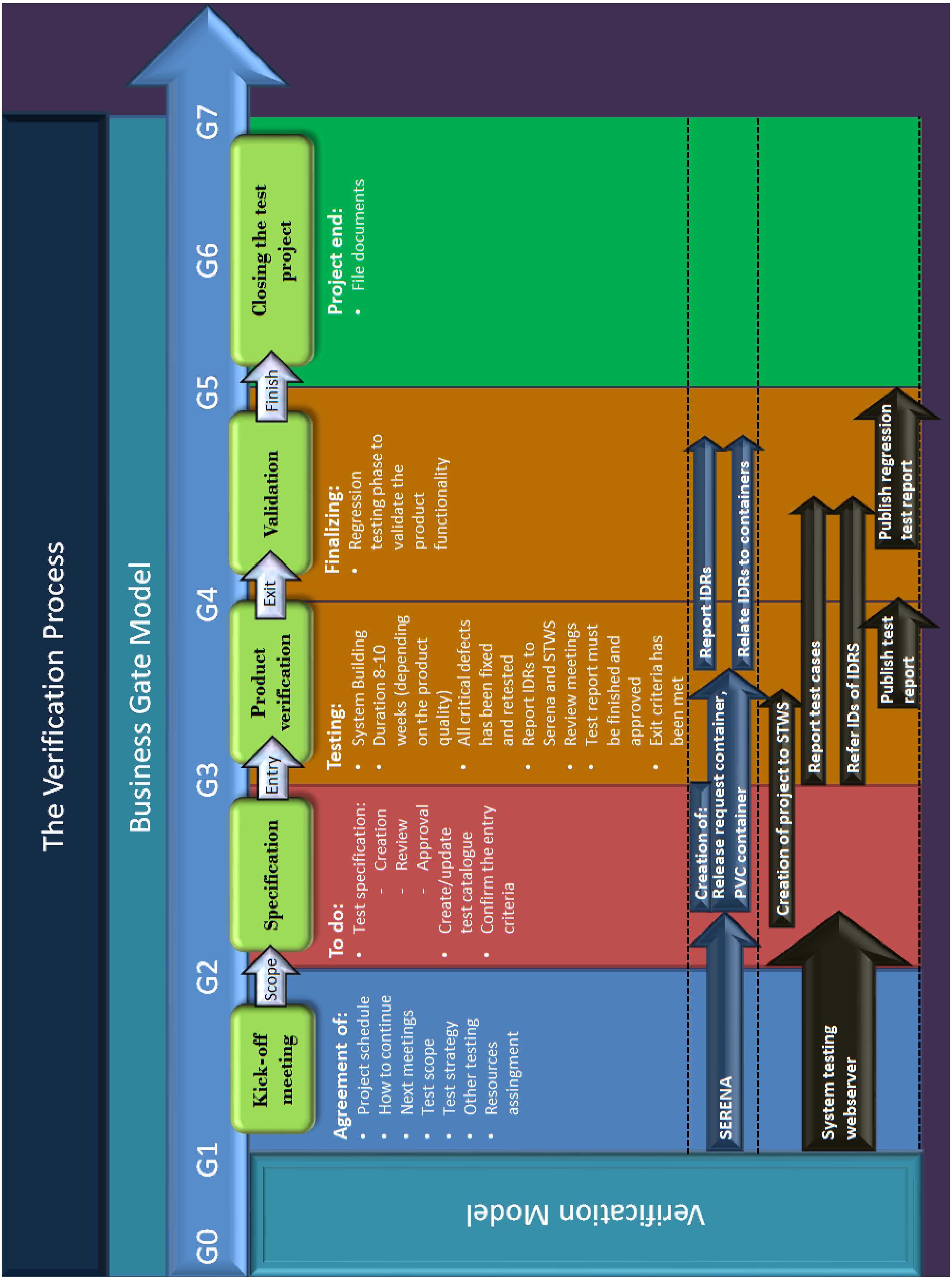
/9/ REx615 Technical Manual. Accessed: 21.3.2014. http://www05.abb.com/global/scot/scot229.nsf/veritydisplay/914248a57c92fc10c1257c6a0048fb6f/$file/RE_615_tech_756887_ENk.pdf

/10/ Product and service creation process. Internal website. Accessed: 5.5.2014.

/11/ Kiikkala, Marko. Interview 16.4.2014.

/12/ REx IEC 5.0 project documentation. Internal material. Accessed: 8.5.2014.

/13/ REC 601/3 project documentation. Internal material. Accessed: 9.5.2014.



The Verification Process
Business Gate Model
G0
G1
G2
G3
G4
G5
G6
G7
Kick-off meeting
Scope
Specification
Entry
Product verification
Exit
Validation
Finish
Closing the test project
Agreement of:
• Project schedule
• How to continue
• Next meetings
• Test scope
• Test strategy
• Other testing
• Resources assingment
To do:
• Test specification:
- Creation
- Review
- Approval
• Create/update test catalogue
• Confirm the entry criteria
Testing:
• System Building
• Duration 8-10 weeks (depending on the product quality)
• All critical defects has been fixed and retested
• Report IDRs to Serena and STWS
• Review meetings
• Test report must be finished and approved
• Exit criteria has been met
Finalizing:
• Regression testing phase to validate the product functionality
Project end:
• File documents
SERENA
Creation of: Release request container, PVC container
Report IDRs
Relate IDRs to containers
System testing webserver
Creation of project to STWS
Report test cases
Refer IDs of IDRS
Publish test report
Publish regression test report
Verification Model