Factory acceptance test FAT and site acceptance test SAT work instructions for electrical and automation systems in a power plant

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BACHELOR'S THESIS

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Abstract

This Bachelor's thesis was commissioned by ABB Power Generation, located in Vaasa. The department designs and commissions automation and electrical systems for gas, diesel, nuclear and hydropower plants.

Currently there is a great variation in FAT and SAT work instructions depending on who performs these tests. My goal with this thesis work has been to get standard FAT and SAT templates and the company's goal is to get everyone to use the same templates.

The thesis consists of an investigation of what is to be tested with FAT and SAT, and also how to do the testing. The result of this investigation is a basic template of how these documents can be designed. The template applies mainly to system testing for hydro power plants, but can easily be modified for other plant types, since the system parts and functions designed by ABB do not differ that much between the plant types.

Language: English   Key words: FAT, SAT, work instructions

EXAMENSARBETE

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Titel: *Utveckling av fabriks godkännandeprov FAT- och godkännandeprov efter leverans SAT- arbetsinstruktioner för el- och automationssystem i ett kraftverk.*

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Abstrakt

Detta ingenjörsarbete beställdes av ABB Power Generation, som finns i Vasa. Avdelningen designar och tar i bruk automations- och elsystem för gas-, diesel-, kärn- och vattenkraftverk.

För tillfället finns det en stor variation mellan FAT- och SAT- arbetsinstruktioner, beroende på vem som genomför dessa tester. Mitt mål med ingenjörsarbetet har varit att få standardiserade FAT- och SAT- mallar. Företagets mål är att få dessa standarddokument och att få alla att börja använda samma mallar.

Avhandlingen består av en undersökning av vad som ska testas med FAT och SAT, och också hur testningen görs. Resultatet av undersökningen är en grundläggande mall av hur dessa dokument kan designas. Mallen gäller främst systemtest för vattenkraftverk, men kan lätt modifieras för andra anläggningstyper, eftersom systemens delar och funktioner som designats av ABB inte skiljer sig så mycket mellan olika anläggningstyper.

Språk: engelska Nyckelord: FAT, SAT, arbetsinstruktioner

TABLE OF CONTENTS

ABBREVIATIONS

Abbreviation	**Description**
ABB	Asea Brown Boveri
FAT	Factory Acceptance Test
SAT	Site Acceptance Test
EMC	Electromagnetic Compatibility
DIN	Deutsches Institut für Normung
AVR	Automatic Voltage Regulator
MTU	Module Termination Unit
HMI	Human Machine Interface
TWh	Terawatt hours
MVA	Mega volt ampere

1. Introduction

This Bachelor's thesis is about FAT and SAT work instructions and commissioning documents for the automation and the electrical systems in a power plant. Standard documents are needed for the business unit. Information about the main systems and components in a power plant and the electrification around it is also partly covered. More information about the background for this thesis is found in chapter 1.2. At a meeting held on 8 Feb 2013 it was decided that the thesis work will be restricted to hydro power plants.

1.1. The commissioner

ABB is a global leader in power and automation technologies with a turnover of about 40 billion USD in year 2011. ABB resulted from the merger of the Swedish corporation ASEA (Allmänna Svenska Aktiebolaget) and the Swiss company Brown Boveri & Cie (BBC) in 1988, but its history spans over 120 years.

ABB's success has been driven particularly by a strong focus on research and development. The ABB Group operates in approximately 100 countries around the world and employs about 145,000 people. ABB has offices in around 87 countries and their head office is located in Zürich, Switzerland. The firm's shares are traded in Zürich and the Stockholm Stock Exchange in Sweden since 1999, and the New York Stock Exchange in the United States since 2001.

The ABB Group consists of five main divisions:

- Power Products
- Power Systems
- Discrete Automation and Motion
- Low Voltage Products
- Process Automation

ABB’s slogan is “Power and productivity for a better world”. /1/

This thesis has been commissioned by ABB, Power Generation. The office is located in Strömberg Park in Vaasa and is part of the Power Systems division. The Power Generation department plans automation cabins for different power plants, e.g. diesel, gas, nuclear and hydro power plants.

1.2. Purpose

At the moment there are no standard FAT or SAT work instruction documents. Both testers and commissioners have variations of their testing/commissioning documents. The main goal of this thesis was to create standard testing documents, so that the business unit will get ABB standard FAT/SAT material and so that all testers/commissioners will use the same templates. Better quality can also be reached if everyone starts using identical templates.

Another possible goal of this thesis work is to create an Excel macro that produces these template documents according to which project properties you choose.

1.3. FAT (Factory Acceptance Test)

Factory Acceptance Tests are done at the factory to make sure that certain requirements are met, which results in high quality products. The tests are normally done with the customer, and also, in certain more demanding cases, with a third party inspection agency.

Although all cabins should be fault-free when they arrive from the subcontractors that assemble them, faults sometimes occur. Therefore these factory acceptance tests are needed.

At a FAT, installations are double checked so that they match the drawings for the specific project. Functions that should work when cabins are installed at site are also simulated to check the automation functionality. All possible faults, deviations and wishes are also noted.

1.4. SAT (Site Acceptance Test)

Site Acceptance Tests are done at the specific places where commissioning is done. These tests are also done to make sure that certain requirements and a high quality are met amongst ABB’s projects and to offer customers quality testing and documents. Normally the same test procedures as at FAT are followed, plus procedures that cannot be done at FAT. E.g. breaker control is excluded from FAT but done at SAT.

The results of the SAT are noted in the test protocols and then signed by both the customer and the commissioner.

2. Hydropower theory

Hydroelectric power generation involves storing a hydraulic fluid (normally water) and converting the energy of the fluid into mechanical energy in a turbine, and converting the mechanical energy into electrical energy in an electric generator.

This form of renewable energy production is the most widely used form of renewable energy, and accounts for 16% of the global electricity generation, which was 3427 TWh of the electricity production in 2010. It is expected to increase another 3,1% each year for the next 25 years. /12/

2.1. Hydropower introduction

Hydropower has been used since ancient times to operate various mechanical devices, such as watermills, sawmills, textile mills, lifts etc.

The first hydroelectric power plants came into use in the late 1800s. They provide significant flexibility in base load, peak and energy storage applications. The initial capital costs of hydropower plants are high, but thanks to low operating costs, simplicity, low operating and maintenance costs, high reliability and long service life, they make a very cost-effective option of generating electricity. /12/

Some valuable operating characteristics are their fast responses for starting, loading, unloading and following system load variations. Other advantages are their ability to start up without power from the power grid ("black start capability") and to transfer rapidly from generation mode to condenser mode, and the pumped storage application.

Capacities of hydroelectric power plant units can range from a few kilowatts to nearly 1 GW. Multi-unit plants can range up to around 20 GW. /11/

2.2. Plant overview

There are three main types of hydroelectric plant arrangements, classified according to the method of controlling the hydraulic flow:

1. Run-of-the-river plants, which have small amounts of hydraulic fuel storage and thus little control of the flow through the plant.
2. Storage plants, which have the ability of storing large amounts of hydraulic fuel and thus the ability to control flow through the plant on a daily or seasonal basis.
3. Pumped storage plants, in which the direction of rotation of the turbines is reversed during off-peak hours, pumping water from a lower reservoir to an upper reservoir, thus storing energy for production of electricity during peak hours. /11/

The storage plant type is the most common type of large hydroelectric power plant. Figure 4 below shows a model of this type of plant.

As it can be difficult to get a good understanding of how the different power plant parts interact for a person not familiar with hydroelectric power plants, a short introduction of how the different parts cooperate is presented below.

First there is a reservoir containing hydraulic fuel, which is connected to the penstock and control gate. The control gate controls the amount of water flowing into the penstock before reaching the turbine, which then starts rotating when water flows through it.

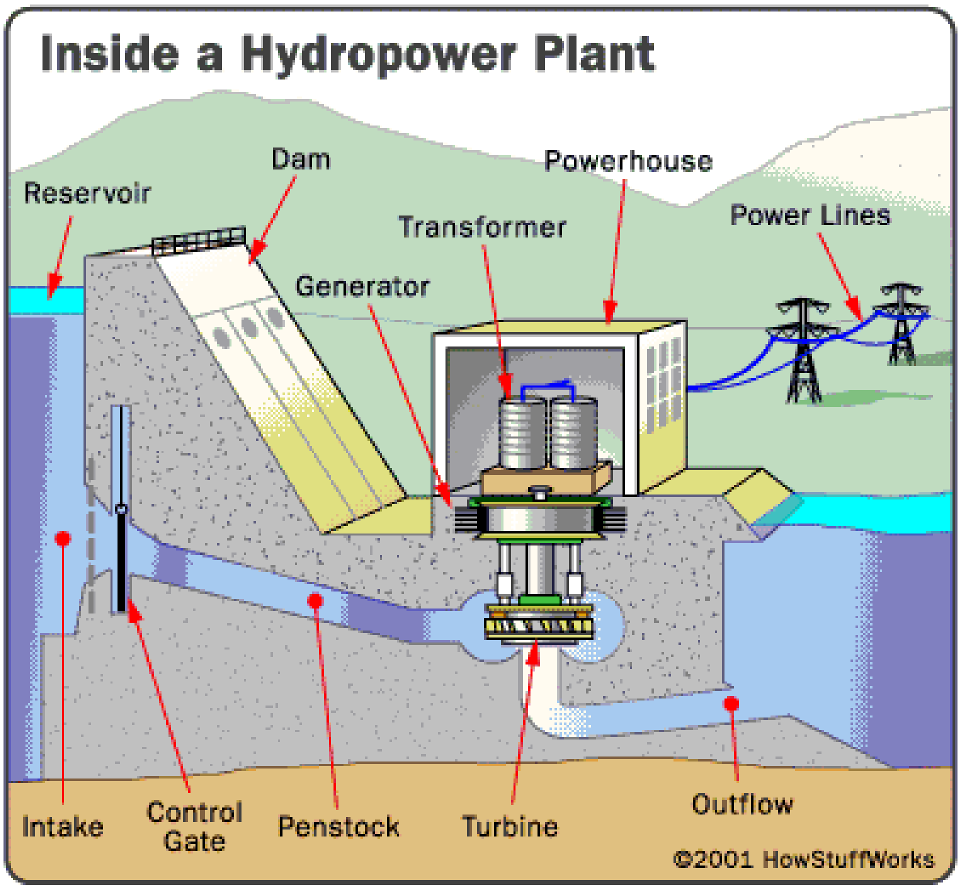

Figure 4. Inside a hydropower plant (http://static.ddmcdn.com/gif/hydropower-plant-parts.gif)

Powerhouse

Inside the powerhouse there is a series of different electrical components. The turbine is the first component after the penstock, and is connected mechanically to a generator, which produces electricity when the turbine rotates at a certain speed.

The generator is then connected to a transformer by a busbar, before transforming the produced electricity to the power grid.

Inside the powerhouse there is also a series of electrical cabins that control and protect the components mentioned above in the power plant network: automation, protection and excitation cabins. This thesis focuses on these cabins and the testing of them.

The systems and components inside the powerhouse are more thoroughly described in the following chapter.

2.3. Main systems and components

A power plant and its automation and electrical system are very complex, and thus only the main components will be covered in this thesis. The absolute must-have components to produce electricity from the power plant are the turbine and generator. A third vital set of components is the flow control equipment, which controls the fluid flow to the turbine, depending on the production need or the need to let through water. These components are explained more thoroughly in chapters 2.3.1 – 2.3.3.

Other than these vital components, we have a lot of automation and electrical equipment that is connected to the rest of our network of power plant equipment. They can be divided into three sets of component systems: automation, protection and excitation systems. These systems are described in chapters 2.3.4 – 2.3.6.

2.3.1. Flow control equipment

Flow control equipment is used to control fluid flow to the turbine. This can be done mechanically by wicket gates if reaction turbines are used or by needle nozzles if impulse turbines are used. This can be done by sending electrical signals to valves that either open or close depending on the flow that is needed.

2.3.2. Turbine

The turbine is the first main component in the electricity production part series of a hydroelectric power plant. It converts the water energy into mechanical energy.

There are two main types of hydraulic turbines: impulse and reaction. The type of turbine is chosen based on the head and the flow rate.

- Impulse turbine: this turbine is mostly used at high heads – approximately 300m or higher. High velocity jets of fluid or gas strike spoon shaped rotor blades and make the turbine rotor rotate.
- Reaction turbine: this turbine is used at low to average heads – from heads below approximately 45m up to approximately 300m or greater, depending on which type is used. There are two types of reaction turbines: propeller and Francis. The propeller type is mostly used for lower heads and the Francis type for higher heads. Fluid passes from a spiral casing through the stationary vanes, through the control gates and onto the runner blades at high pressure, making the turbine rotor rotate.

Water discharged from the turbine is directed into a draft tube exiting to a tailrace channel, a reservoir or directly to the river. /11/

2.3.3. Generator

Two types of generators are used to convert the mechanical energy output of the turbine to electrical energy; synchronous generators or induction generators. Induction generators are used in small hydroelectric applications (usually if less than 5MVA), and synchronous generators are used in most hydroelectric installations. /11/

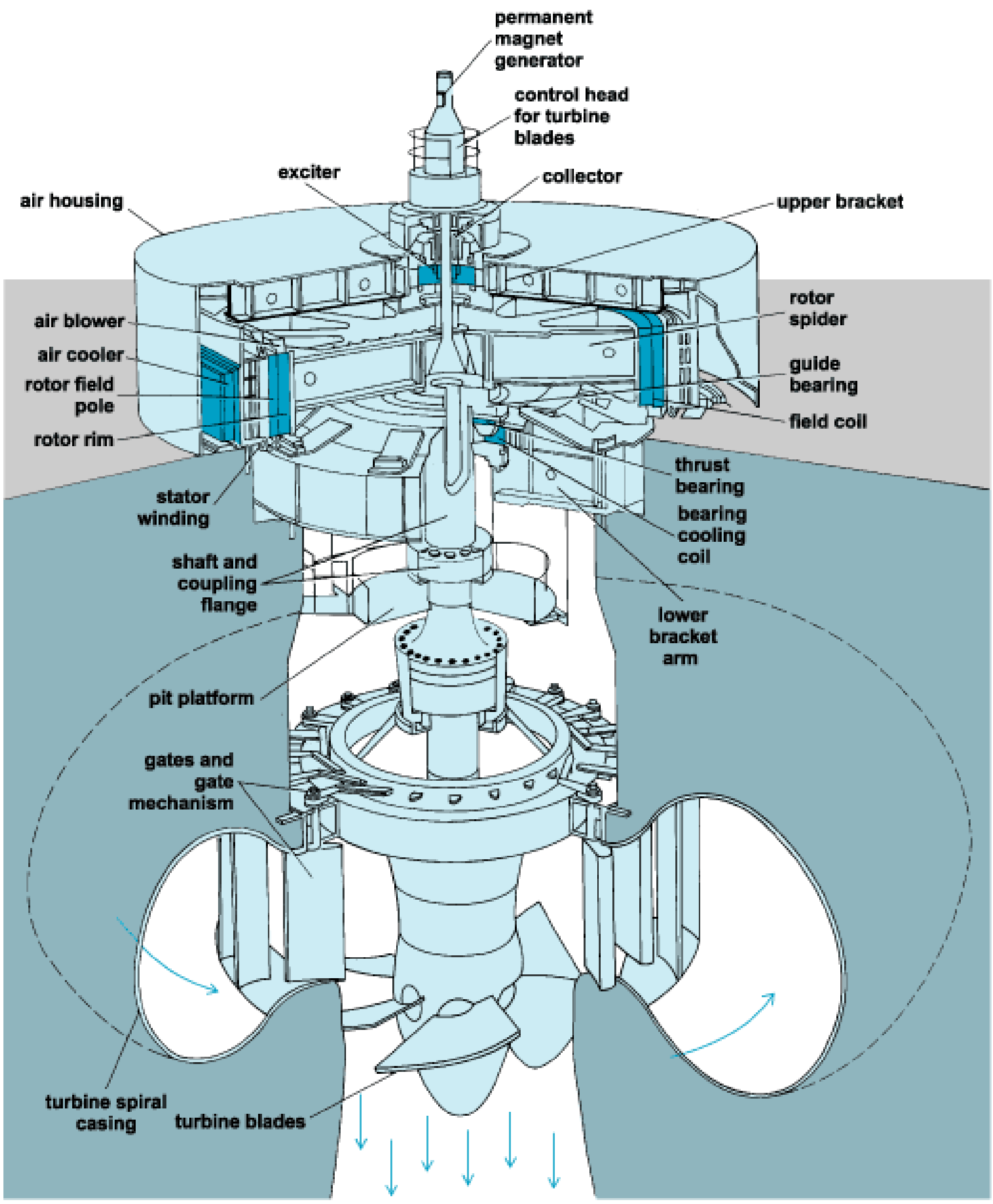

Figure 5. Large hydroelectric generator and turbine (http://www.answers.com/topic/hydroelectric-generator)

2.3.4. Low voltage systems

Low voltage equipment is equipment with a rated voltage between 50V and 1000V if alternating current (AC) is used, and between 70V and 1500V if direct current (DC) is used. These voltages are used by control and automation components inside the power plant.

2.3.5. High voltage & medium voltage systems

Since many people use the terms medium voltage and high voltage in the wrong way, it is worth mentioning what the voltage ranges are. Medium voltage ranges from 1000V AC (or 1500V DC) all the way up to 72,5kV.

Medium voltages are used between MV and HV substations, because it is not possible to transform low voltages to high voltages.

From 72,5kV and upwards, the voltage is called high voltage. High voltage is used for long distance electricity transmission.

2.3.6. Automation

Depending on the need, automation can be very complex or simple. If we just need the automation for small household applications, a few relays besides the main electrical equipment may be sufficient. However for modern industry and power generation automation, quite complex systems are often required. Automation usually consists of PLC(s), HMI systems, input and output modules, together with various sensors and protection equipment.

Functions that are very important and that should always work even if a fault occurs in the programming software or hardware are hardwired, which means that they are connected directly by a wire and not modified by computer or PLC software. Other functions that are not as important can be modified by microprocessors, PLCs or computer software.

Sensors

A sensor is a device that converts a physical unit into an electrical unit (usually). These devices are used in order to provide the PLC with a sense of what is actually happening within the system that one aims to control.

Sensors are divided into two main categories, discrete (digital, logic) and proportional (analog).

- Discrete: Discrete sensors produce a logical output (zero or one depending on if it is active or not). Worth noting is that these sensors cannot deliver any information about the current value of the parameter being sensed. They only provide information about the set point, if it is above or below the set point.
- Proportional: These sensors provide an analog output, e.g. voltage, current, resistance or a varying digital output. The output of these sensors can then be programmed in the PLC to display fluid levels, valve levels, fluid flow etc. /18/

Analog input/output modules

From the sensor an analog quantity, e.g. a voltage level, is transmitted to the analog input, which converts the voltage level into a digital value that can be stored and processed by a PLC or a computer.

Since one may want to send an analog unit instead of a digitally created unit, analog outputs may be needed. These modules are often used for controlling or monitoring e.g. valves or motors.

Digital input/output modules

Digital or discrete input/output modules are used to handle sensing or sending of digital signals. These signals consist of high or low signals which are set to a certain voltage or current level, e.g. 5V for a high signal, and 0V for a low signal.

Digital module application areas may be e.g. pulse detection with a high speed counter module capable of measuring a frequency of a frequency generating device, bit-processing the binary signals received or sent, or other pulse or frequency handling applications.

PLC

PLC means Programmable Logic Controller, which basically is a small computer. This device can be programmed to handle different operations, depending on what should be accomplished and what I/Os the system has. A PLC is constructed to suit industry needs, normally to detect actions from sensors or other devices, and to control devices. PLCs should also be able to handle some environmental strains. Although the PLC is often called “programmable controller” only, the abbreviation PC is not used since PC is usually used refering to a personal computer.

Brief history

Early machines were controlled mechanically by using cams, gears, levers or other basic mechanical devices. As the complexity grew, so did the need for a more advanced control system. This system was originally created by wired relay and switch control elements. These devices were then wired as required for the particular type of machine operation. This approach was acceptable for a machine that never needed to be changed or modified. However, as manufacturing techniques improved and changeover became more desirable and necessary, a more advanced means of controlling this equipment had to be developed. Hardwired logic was troublesome and time consuming to modify: a minor “bug” in the design could be a major problem to correct, due to a possible requirement of rewiring a large part of the system. A new means to modify circuitry was needed. The development for this means was the U.S. car industry, and the result was the programmable logic controller. The PLC provided an easy way to reprogram the wiring, rather than to rewire the system. /18/

Architecture

A PLC's architecture can be divided into three main parts, the central processing unit (CPU), the memory, and input/output interfaces. These three parts are connected by means of a bus. A bus is a group of wires over which digital information can be transferred. Normally there are three buses: the data bus, the address bus and the control bus.

CPU

The CPU is the PLC's control part. The CPU monitors the memory and the I/Os, and processes the data in accordance with the program. To initiate operations, clock cycles are used. The time it takes for the CPU to execute one clock cycle depends on the CPU speed, the complexity and the length of the program.

Memory

Memory in the system consists of two types of memory; ROM (read only memory) and RAM (random access memory). The ROM memory usually contains the program information that allows the CPU to act on the (often ladder) logic program stored in the RAM memory. The RAM memory is usually kept alive with a battery so that the logic program is not lost in case of a power failure or a temporary power disconnection. Newer PLC units are also available with EEPROM (Electrically Erasable Programmable Read Only Memory), which does not require a battery. /13/

Bus

A bus is a set of wires over which digital information can be transferred in parallel. In most systems there are three different buses:

1. Data bus
2. Address bus
3. Control bus

The data bus is a bidirectional bus over which data can flow between the microprocessor, memory and I/Os. The size of the bus varies depending on which microprocessor is used. E.g. if an 8-bit microprocessor is used, the data bus is 8 lines wide. If a 16-bit microprocessor is used, the bus will be 16 lines wide.

The address bus is a unidirectional set of wires over which binary number addresses are transferred. Addresses are generated by the CPU during the execution of a program to specify the source and destination points of the data items to be moved along the data bus. An address identifies a particular memory location or I/O point.

The control bus consists of a set of signals generated by the CPU to control the devices in the system. E.g. the read/write control line selects one of two operations, either a write operation where the CPU is outputting data on the data bus, or a read operation where the CPU is inputting data from the data bus. /13/

Input/output interface devices

Input and output devices from the machine or process to be controlled are connected to the PLC. A user enters a sequence of instructions (known as the program) into the program memory of the PLC. The controller then monitors the states of inputs and outputs according to the user’s defined program. Actions are then done automatically by the PLC which follows set instructions, depending on what should occur, e.g. a warning sensor reaches the set limit for the need to stop a motor from running. /18/

The PLCs and HMI systems of ABB are used to handle the automation needs of different projects.

ABB’s control system

ABB’s control system can roughly be divided into three main parts: the AC 800 processor, the 800xA HMI system and the S800 modular process I/O system. These parts build up the control system used in ABB’s own projects, unless the customer specifically demands another control system, such as e.g. Siemens S7.

800xA

ABB’s system 800xA is their latest product for their DCS users. The abbreviation “xA” means Extended Automation and utilizes the Industrial IT architecture built for integration in a fully redundant, reliable environment. System 800xA extends the reach of traditional automation systems to increase energy efficiency, asset utilization, energy savings and operator effectiveness. /3/

As can be seen from the figure below, it is easy to get a good system overview with the 800xA system. Other features that may be necessary to reach are also easily obtained from the same process image.

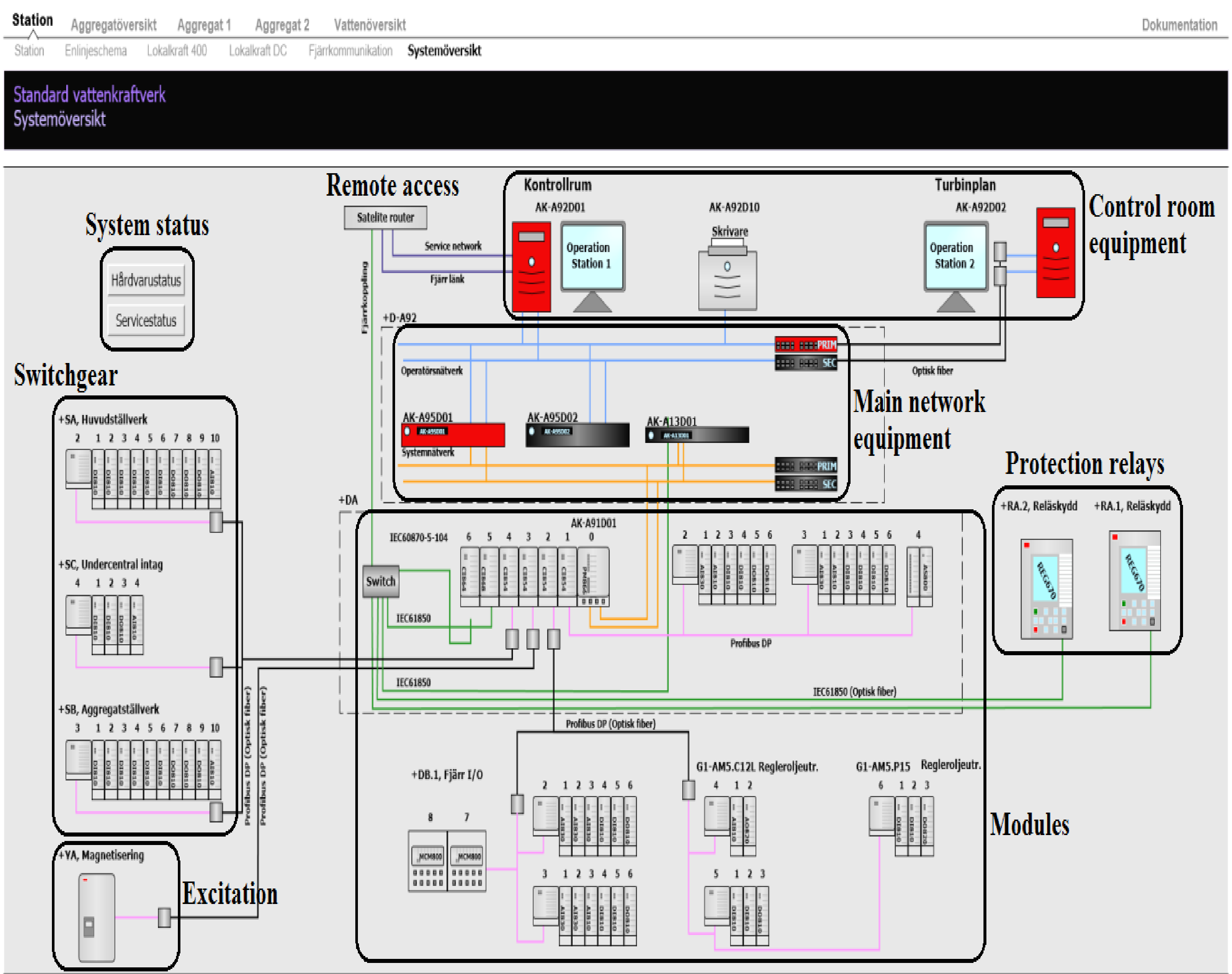

Figure 6. System overview 800xA /19/

AC 800

The processor unit AC 800 and its input and output modules are mounted on DIN-rails when installed.

The power supply for the AC 800 is usually from a switch-mode power converter, converting the supply voltage to a regulated 24VDC from either 115VAC or 230VAC. The three possible power units have rated outputs as follows:

- SD823 = 24VDC regulated at 10A
- SD822 = 24VDC regulated at 5A
- SD821 =24VDC regulated at 2,5A

If there is a need to power the controller with an external source, that is also possible. This source is common for many different types of plant equipment, resulting in long power cables. It is strongly recommended to use a DC/DC converter and an extra energy reservoir in case longer cables than 10m are used.

If there is a risk of the voltage dropping below 19,2V for more than 1ms, an energy reservoir must be used to power the units. /8/

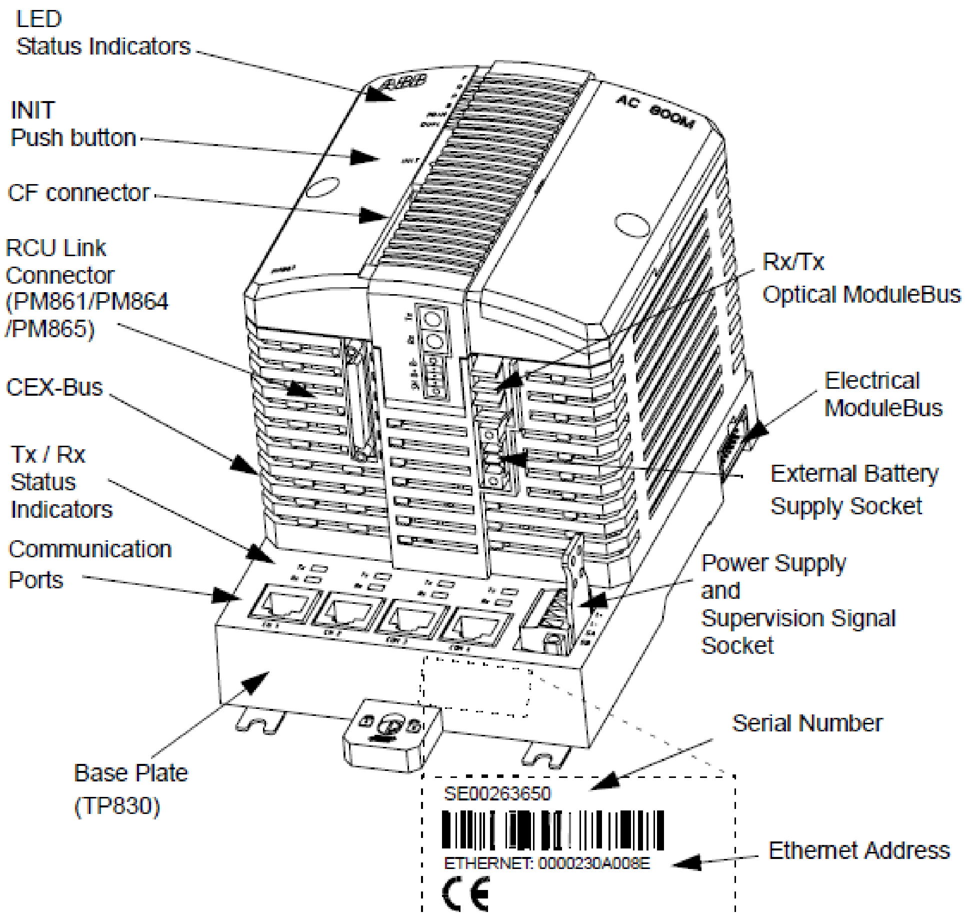

Figure 7. AC 800 processor unit – Overview /8/

S800

The S800 I/O is a distributed modular I/O for the 800xA system, which can communicate with numerous controllers over Advant Fieldbus 100 (AF100), Profibus-DP or directly. This modular I/O is used at ABB for various automation needs in projects. /7/

Figure 8. S800 I/O with fieldbus communication and digital I/O modules and analog input module mounted on DIN-rail /7/

2.3.7. Protection relays

Because of the risk of getting electrical faults, electrical protection relays have been invented. The main purpose of these relays is to detect electrical faults and prevent them from damaging other electrical components.

Other purposes that these relays serve are to prevent humans from being hurt and also to protect other properties around the power network.

A protection relay works by measuring electrical units (e.g. voltage, current, frequency or a circuit's impedance). If the measured electrical unit goes outside its allowed range continuously, the relay will send a signal to for instance a circuit breaker so that it will break the current. That operation is called "tripping". The time between the relay noticing the fault to the relay tripping is called operating time.

CE-marking

The relays need to fulfill given directives and bear the CE marking. By using extensive documentation the manufacturer must be able to prove that the product fulfills given requirements. This documentation needs to include both a "Declaration of Conformity" and a "Technical data", which among other things must include a test report for the product.

EMC-directive

The manufacturer is responsible for the apparatus to meet the protection requirements. It is adequately protected against both electromagnetic interference from other devices and from personal interference. The protection relays need to fulfill current EMC-requirements. All relay functions and indicators must be stabilized against over- and undertones. /2/

Earth-fault protection

Earth-fault protection relays work by measuring the currents in the live conductor and the neutral conductor. If the difference between these currents is bigger than a preset value ($I_{\Delta}n$), the protective circuit will dissolve and break the current. The relay must then be reset (usually manually) before the circuit begins to operate normally again.

Figure 9. Modern earth fault relay, ABB (http://www.relayspec.com/Company_listings/a/Abb/news/2012/05_15a/05_15a.jpg)

Generator protection

As a generator is a major component in a power system, it is quite necessary to take all preventive measures possible for the protection of the generator. /4/

Both fault conditions and operating condition faults may occur, and protection relays need to be able to protect the generator from both of these faults.

When connecting the generator to the step-up transformer an isolated phase bus is used. This separated phase greatly reduces the possibility of a phase-to-phase fault at the terminals of the generator. /4/

Possible fault conditions for generators are:

- Stator short circuits
- Stator/rotor interturn faults
- Stator earth faults
- Rotor earth faults
- External faults

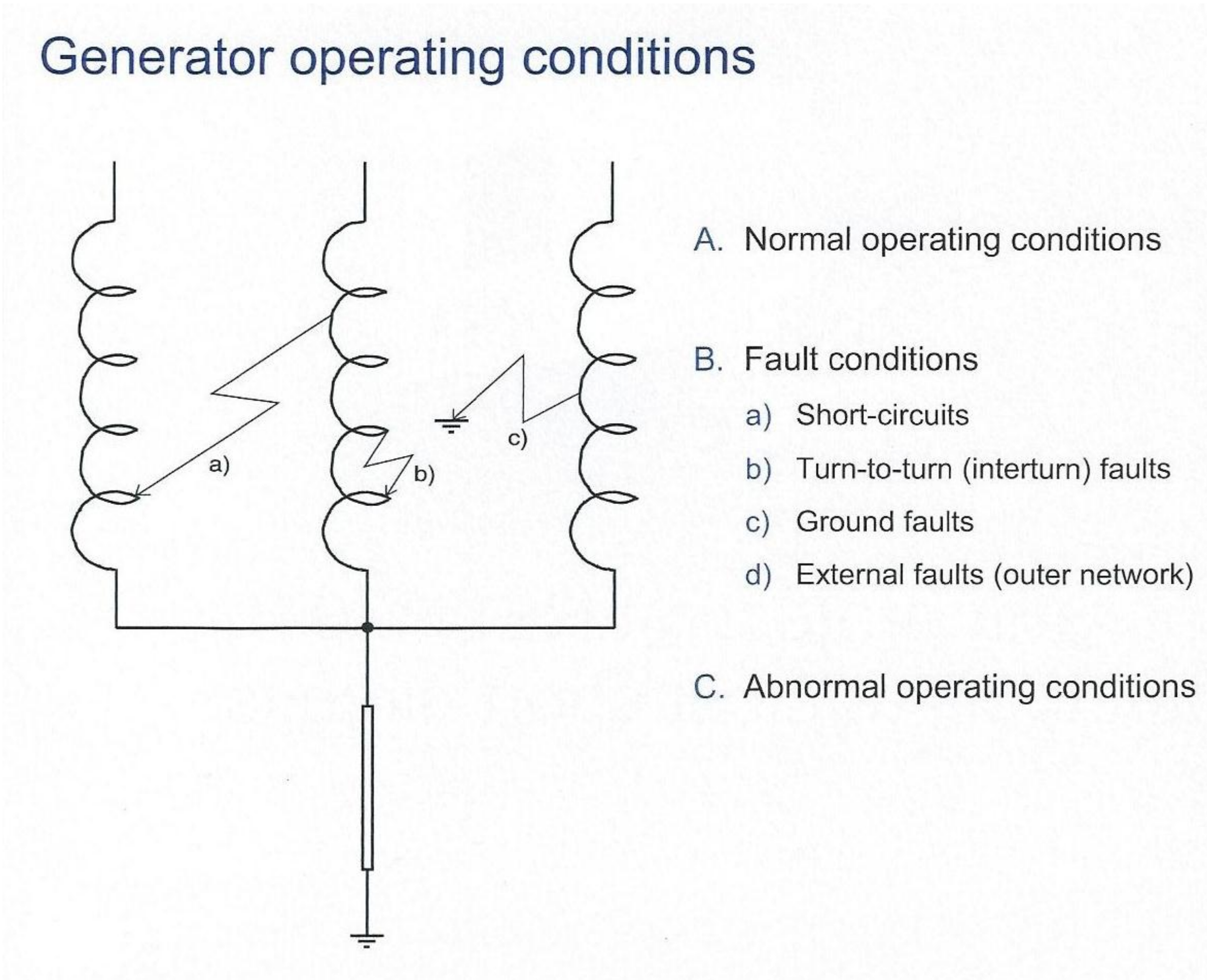

Figure 10. Possible faults in generator windings /4/

Stator short-circuits

Stator short-circuits are often caused by a deterioration of insulation, as deterioration occurs over time and usage.

The consequences of a stator short circuit can be:

- Insulation, windings and stator core can be damaged
- Large forces caused by large fault currents may damage other components in the plant
- Risk of explosion and fire
- Mechanical stress on generator and turbine shafts

Because the risk of getting large fault currents when short-circuits do occur, a fast operating (instantaneous) protection function is needed to prevent damages to the generator and other parts in the power network.

Fault current fed from the generator can trip the field breaker and interrupt the primary power to the turbine.

Turn-to-turn (interturn) faults

Generator differential protection will not detect these faults (even when 100% of the winding is short circuited!), which is why you may want turn-to-turn fault protection. However, this protection is often omitted because turn-to-turn faults are quite rare and they will sooner or later evolve into stator earth-fault. /4/

Stator earth faults

A stator core damage is dependent on the earth fault current, and to decrease the possible earth fault current (typically to less than 10A), different grounding methods are used, in order to:

- Reduce the iron core damage and mechanical stress
- Limit the transient voltages during the fault
- Provide a means to detect a ground fault

Causes for a stator ground fault can be:

- Transient overvoltage
  - Caused by e.g. lightning or switching overvoltages
- Temporary overvoltage
- Degraded insulation, caused by e.g.
  - High temperature
  - Aging
  - Vibration / mechanical impact

The consequences of a ground fault are:

- Damages to the stator iron
- Increased voltage on “healthy phases”

Rotor earth faults

The field circuit of the generator is normally isolated from earth. With a single fault in the rotor circuit it is possible to continue operation without any generator damages. However, if a second rotor ground fault occurs, there will be unbalanced currents in the rotor poles and risk of severe damages due to high vibrations. The requirement of fast fault clearance is moderate but has to be done. /4/

Possible operating condition faults are:

- Overcurrent/overload
- Unbalanced load/open phase
- Overtemperature
- Over- and undervoltage
- Over- and underexcitation
- Over- and underfrequency
- Over-fluxing (excessive V/Hz)
- Asynchronous running
- Out of step
- Generator motoring
- Failures in the machine control system (e.g. AVR or governor failure)
- Failures in the machine cooling system
- Failures in the primary equipment (e.g. CBF, breaker head flashover) /4/

Unbalanced load/open phase

If the generator load becomes unbalanced, negative phase sequence currents flow. This will cause a magnetic field rotation in direct opposite to the direction of the rotor field. The relative speed between the two is double the rotor speed. Double frequencies are induced in the rotor, which causes severe heating of the rotor and can damage it.

Unbalanced stator currents also cause severe vibrations and heating of the stator. Hence it is necessary to provide protection against unbalanced load condition.

Overtemperature

If the protection relay supports overtemperature protection, it can be configured to trip the generator offline when the generator's thermal limits are reached, or close an alarm contact to announce the operating personnel that actions need to be taken to prevent damage to the generator.

Over- and undervoltage

With faulty AVR, overvoltage can cause damage on the insulation system of stator windings and overexcitation of the generator transformer block. Measurement is done over all three voltages and by phase-to-phase or phase-to-neutral conductor with selectable x out of 3 logic for tripping. /4/

Undervoltage is not critical for the generator-transformer block itself, but critical for auxiliary services.

Over- and underexcitation

Overexcitation, also called overfluxing, can be caused by failure of the voltage feedback circuit to the AVR, which may ramp up the generator current in an attempt to achieve the desired voltage.

However, overexcitation can be used to protect the generator and the transformer magnetic core from overheating, especially during start-up and shut-down.

Underexcitation, also called loss of field protection, can like overexcitation be caused by faulty AVR operation or incorrect handling of the voltage regulator. This can also be caused by the generator running with too high a capacitive load.

Other reasons for possible failures of excitation may be short circuit in the excitation circuit, or interruption in the excitation circuit. /4/, /6/

Transformer protection

Transformer theory

A transformer is an electrical device designed to transfer energy from one circuit to another by means of a magnetic field. There is no direct electrical wiring between the two circuits, transformation is done over the magnetic field.

When alternating current flows through a conductor, a magnetic field is generated around it. If a second conductor is placed in the field generated by the first conductor, voltage is also induced in the second conductor. The use of a magnetic field from one coil to induce voltage into a second is the basics of transformer theory and application. /11/

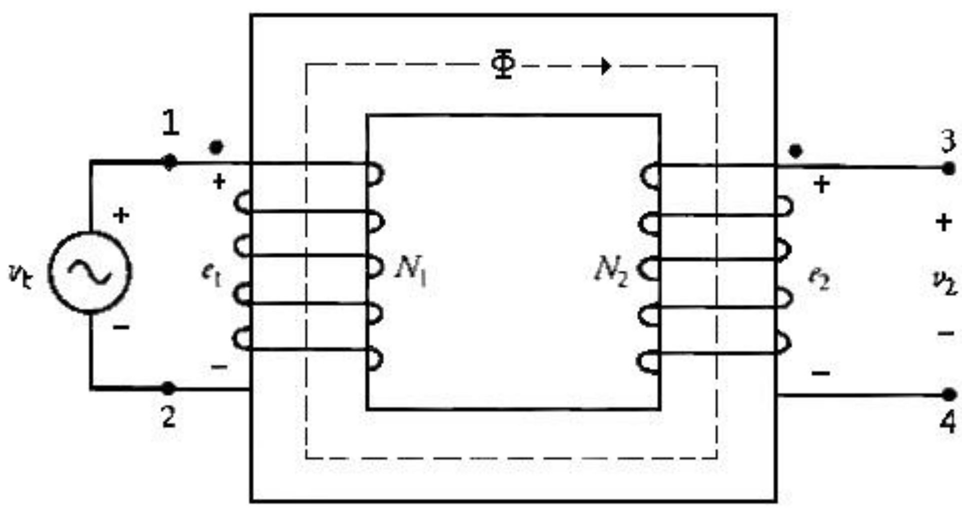

Figure 11. Transformer example (http://wiki.4hv.org/images/e/e0/Transformerex.jpg)

Air core transformer

Normally an iron or steel core is used between the two coils, but it is also possible to use air core transformers. However, such transformers are quite inefficient since the percentage of the flux from the first coil that links to the second coil is small. One way of improving the efficiency is to increase the number of turns in the coil, but this will increase the costs.

Iron or steel core transformer

The efficiency of these kinds of transformers is much greater than air core transformers. The ability to carry flux is called permeability, and modern electrical steels have the permeabilities of around 1500, compared to 1 for air. This means that a steel core is able to carry a magnetic flux 1500 times greater than an air core. /11/

Protection

Transformer failures need expensive and long time repairs. Because of this, good protection against possible faults is needed.

Although fuses can work in certain situations, it is not recommended that transformers larger than 10 MVA are protected with fuses. Larger transformers are to be protected with more sensitive devices, such as differential relays. /11/

Transformer faults can be caused by:

- Long time overheat caused by aging of the insulation
- Dirty or bad quality oil in transformer
- Overvoltages
- Overcurrents
- Short circuit forces at windings caused by external faults /16/

Motor protection

Induction AC motor

This motor, often called the squirrel cage motor is the most common type of large motors used in a thermal generating plant. These motors are very rugged and require very little maintenance. The induction AC motor consists of two main components: the *stator* and the *rotor*. As the name implies, the stator is stationary and does not move and the rotor is thus the rotating part of the motor.

The stator contains a pattern of coils arranged in windings. As alternating current is passed through the windings, a moving magnetic field is formed near the stator. A more thorough description of the induction phenomena can be found in chapter 2.3.8, excitation.

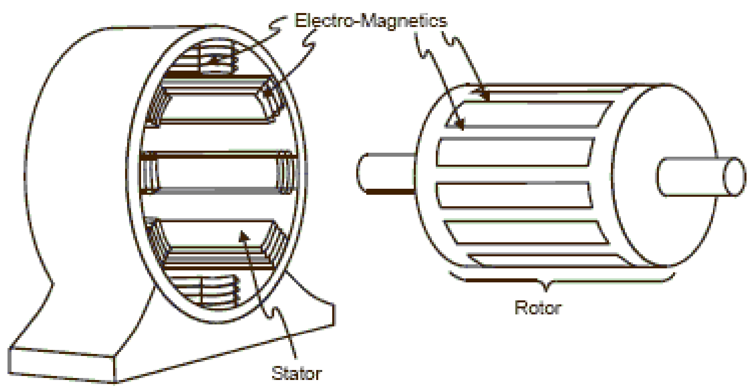

Figure 12. Rotor and stator /17/

Protection

Protection needs to be able to handle abnormal conditions. These faults can be internal or external.

- Internal: The cause of these faults may be insulation failure, bearing failure or under-excitation.
- External: The cause of these faults may be due to insufficient cooling, reverse starting, over- and undervoltage, vibration etc.

Testing

The protection relays are tested at FAT and SAT with Omicron CMC 356 plus "High precision relay test set and universal calibrator". Omicrons high accuracy and flexibility make it ideal for testing and measuring. /5/

With Omicron Control Center you can create automatically generated relay specific test reports. These automatically generated test reports are often too long to have people reading through them in detail, thus besides Omicron's automatically generated test reports, a checklist containing the most vital data is also brought to the FAT or SAT.

Omicron is connected to the protection relays, and a computer is then connected to the Omicron and tested with the omicron control center (OCC).

Figure 13. Omicron 356 Plus /5/

2.3.8. Excitation

The magnetic field may be produced either by **permanent magnets** or by **field coils**. If field coils are used, a current must flow in the coils to generate the field, otherwise no power is transferred to or from the rotor. The process of generating a magnetic field by means of an electric current is called **excitation**. /9/

Electromagnetic induction is the basis for all electric motors. When a conductor moves relative to a magnetic field, the two sides of the coil move in the opposite direction, and voltage is induced at each side. The value of the resulting voltage is equal to the minus of the rate of change in magnetic flux Φ times the number of turns in the coil: $\boldsymbol{V = -N * \Delta\Phi/\Delta t}$. This relationship has been found experimentally and is called **Faraday's law**. /9/

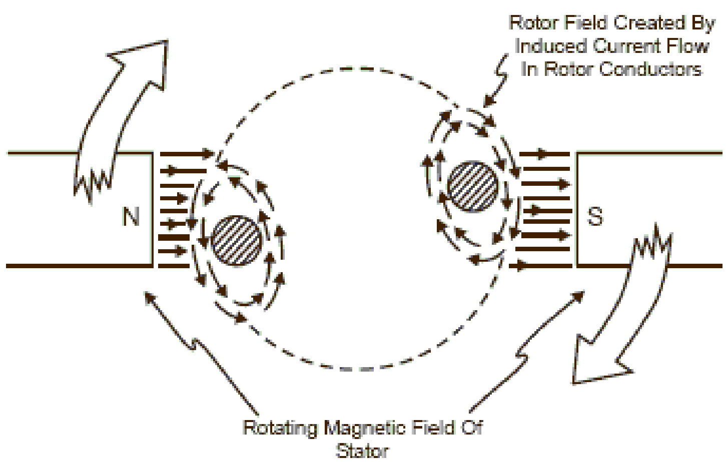

Figure 14. End view of two rotor segments (magnetic interaction with stator) /16/

Permanent magnet synchronous generators are usually used in ABB's excitation systems, since the planned power plants (usually bigger than 5MVA) are too big to use field coil generators in. In permanent magnet synchronous generators the magnetic field of the rotor is produced by permanent magnets. This excitation can be done either by having alternating north and south poles around the rotor diameter, or by having the same number of rotor poles as the stator poles. /15/, /11/

Synchronous generators require direct current field excitation to the rotor, provided by the excitation system. /11/

The main functions of excitation systems are to provide variable DC current with short time overload capability, to control the generator terminal voltage with suitable accuracy, to ensure stable operation with network and/or other machines, to contribute to the transient stability subsequent to a fault, and to communicate with the power plant control system. With these functions met the system will have a high reliability. /10/

3. The standard templates

The results of this thesis consist of an investigation of old FAT and SAT documents and an attempt to get good standardized documents for ABB's various automation and electrical system cabins.

The standardization is divided into several smaller areas around the main topic FAT/SAT:

- General
- 800xA + Panels
- AC800 + S800
- Turbine modules
- Protection relays
- Excitation

3.1. General

This part covers vital information that needs to be checked and/or filled in before starting any measurements of the actual FAT or SAT. In this part there are tables for filling in what is to be tested and when, the participants and the company they work for, the system structure and other necessary points of preparation. This part of the standard in found in appendix 1.

3.2. AC800 + S800

This part is the largest one, containing controller tests, IP address configurations, alarm configurations and signal test tables etc. After each successful test, the date and signature are noted in their respective fields.

3.3. 800xA and panel

The control panels and the 800xA system are tested according to this template. Since different systems contain differently programmed systems and panels, it is hard to create a standard template for this part. However, a basic template is found in the appendix 3.

3.4. Turbine modules

Normal turbine modules in hydroelectric power plant automation are the valve positioned module VP800, the frequency measurement module AS800 and the vibration measuring module MCM800. These are to be tested according to the test document template found in appendix 4. As these modules follow the same looking template, only one is attached in this thesis.

3.5. Excitation

The excitation part has not been dealt with at all in this thesis although this part also needs its own template. This is due to the fact that the standard documents are ready-made and finalized by ABB colleagues in Switzerland, and their standards have to be followed and used.

Consequently, when testing ABB’s excitation systems, the Swiss standard documents are used.

Besides these Swiss standard documents, there are boxes for filling in excitation tests in the same appendix as the protection relay appendix 5.

3.6. Protection relays

As mentioned earlier, protection relays are tested with Omicron CMC 356 Plus, which is connected to a computer with the Omicron Control Center (OCC). OCC can create automatically generated test documents, but these are often too long for anyone to read. Therefore a checklist of necessary information is good to bring to a FAT or SAT. This checklist has been created and can be found appendix 5.

4. Discussion

I got the assignment in the autumn of 2012 and had at that time only worked at the service department of Power Generation, where I handled after sales and warranties. Since I had not been involved in any projects at all other than looking at their list of apparatus to determine what spare parts to offer, there were quite many parts and functionalities I didn't know much or anything about.

When I started out with the thesis work I didn't really know where to start because it is such a wide area. Along with that I only had access to a handful of old test documents, and they differed quite much compared to one another. Consequently, the first thing I had to do was to make sure I would get access to the different network places where I could find the old documents. After getting access to the different network places where I could find the test documents I started digging through these places to get a good handful of them. While investigating the documents I then had gathered, a tip was given to sort the documents I had in different plant types and inside the plant types also in different systems. When this was done, a meeting was held and at that meeting decided that my work would be restricted to hydropower plants only.

With the restriction done I started reading about hydropower theory along with trying to figure out what to add in the standard test documents, by investigating old hydro FAT and SAT documents. From the old documents I chose the best summarized parts, with both instructions and ease of use in mind. These documents were then tidied up and translated into English.

While doing this work I have learned a lot about both how a hydropower plant works, functions of ABB's electrical and automation cabinets although I haven't actually been involved in any project or done any testing myself.

To succeed even better with the thesis work, better starting conditions would have been good. If I would have been able to participate in at a few FATs and SATs before I started, or while doing the work would have helped a lot. Furthermore, better planning from the start would have been good, since e.g. the hydropower restriction came quite late. However, the extra search and investigation of other power plant type tests is not wasted time.

Finally I want to thank my supervisors and all people that have helped me at ABB, and also my supervisor at Novia University of Applied Sciences.

5. List of references

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/2/ FK10-7-1S Reläskydd.pdf
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/3/ System 800xA introduction
http://www.abb.com
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/4/ SEP661 Generator protection REG670/650
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/5/ CMC 256 Plus
http://www.omicron.at/en/products/pro/secondary-testing-calibration/cmc-356/
(Read 30.01.2013)

/6/ Under Excitation Protection
http://www.scribd.com/doc/8690902/Under-Excitation-Protection
(Read 31.01.2013)

/7/ System 800xA – Modules and Termination Units
ABB internal document
(Read 04.02.2013)

/8/ AC 800M – Controller Hardware
ABB internal document
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/9/ How a Generator Works
http://www.generatorguide.net/howgeneratorworks.html
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/14/ How the PLC works?
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/17/ AC and DC Motors – AC Motors: AC Induction Motor
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/18/ Hackworth, J.R & Hackworth F.D (2004). *Programmable Logic Controllers: Programming Methods and Applications, chapter 2 and 8.* Pearson Education.

/19/ Standard processbilder Vattenkraftverk
ABB internal document
(Read 15.03.2013)

Appendices

Appendix 1 – General

Appendix 2 – AC800 + S800

Appendix 3 –800xA/Panel PP846

Appendix 4 – Turbine Modules

Appendix 5 – Protection relays & excitation

General

Scheme

Date	Time	Tests	Responsible

Place:

Participants

Name	Company	Title

Intention

The document describes the goal with FAT, what should be tested and approved after completion. This is done to get the delivery accepted by the customer and thereby minimize commissioning time at site.

Functions

- All functions meet given requirements and comply with given descriptions of the systems that are included. This applies to both standard features and specially developed ones.

- Functions cooperate globally as intended for the various systems that are interconnected.

Database content

- Input data is consistent with requirements according to scope of delivery. Includes all relevant types of data, images, I/O signals etc.

Performance and use of capacity

- Performance and capacity of individual systems and performance for functions meet given requirements for different operating conditions

Hardware included in the tests

- Verification that the hardware used in tests is the same as in final delivery

Conditions

Equipment at FAT should consist of the system that will be delivered as closely as possible.

System documentation is available in either electronic and or paper form.

At FAT, all errors, deviations and eventual wishes is to be noted down. When the decided measure is taken, it is controlled and the form is signed again.

Signed FAT-description by purchaser and supplier is the record of an executed FAT.

System configuration

FAT connection

At FAT configurations will be made as closely as possible according to delivery system with correct IP addresses.

System structure – *Project*

Preparations

Make sure, that:

- Hardware is delivered
- Hardware is correctly installed
- Test equipment and tools are available
- Necessary documentation is available

FAT-layout

Items:

1. Control that all test equipment is present, correctly installed and that FAT can be performed safely.
2. Control the system's general layout.
3. Control hardware grounding.
4. Control voltage feeds and their connections.
5. Control bus interface.

Expected results:

1. All equipment that will be tested is delivered and installed correctly.
2. The system layout is in accordance with latest, approved documents. FAT area must be clean and cabinets must be placed clearly.
3. Cabinets that will be tested are connected to earth.
4. Voltage feeds are connected to switching device in accordance to drawings.
5. Bus connection should if possible, be connected to the corresponding hardware according to final form.

Documentation

Ensure that the following documents are available:

1. FAT document
2. Drawings and layout
3. I/O-lists
4. Application program (Control builder)
5. Progress reports
6. Manuals

Expected results:

Documentation is available in either paper- or electronic form.

Test equipment and tools

Items:

Control that the following equipment is available:

1. Programming tools
2. Multimeter
3. Synchronization simulator
4. I/O-test simulator

Expected results:

- Test equipment and tools are available.

AC800 controller test

Configuration of AC800 controller

IP addresses for the system is as follows:

(Note: this is just an example of a configuration)

Description	IP address	Node no.	IP address configurated	Controller commissioned
AC800 Unit G1 (PM861) Primary	172.16.80.10	10		
AC800 Unit G1 (PM861) Secondary	172.17.80.10	10		
AC800 Unit G2 (PM861) Primary	172.16.80.20	20		
AC800 Unit G2 (PM861) Secondary	172.17.80.20	20		
AC800 Station computer (PM851) Primary	172.16.80.40	40		
AC800 Station computer (PM851) Secondary	172.16.80.40	40		
Excitation processor module G1	172.16.80.11	11		
Excitation process panel PP836 G1	172.16.80.12	12		
Excitation communication interface G1	172.16.80.13	13		
Vibration monitoring MCM G1	172.16.80.17	17		
Vibration monitoring MCM G2	172.16.80.18	18		

Excitation processor module G2	172.16.80.21	21		
Excitation process panel PP836 G2	172.16.80.22	22		
Excitation communication interface G2	172.16.80.23	23		
PCU400 (Ethernet kort 1)	172.16.80.5	5		
PCU400 (Ethernet kort 2)				
Station computer AK-A95D01 (800xA) (Ethernet card 1) primary control network	172.16.80.2	2		
(Ethernet card 2) secondary control network	172.17.80.2	2		
(Ethernet card 3) primary server network	172.16.4.2	2		
(Ethernet card 4) secondary server network	172.17.4.2	2		
(Ethernet card 5) RAP network	Dynamic IP			
(Ethernet card 6) IEC61850 network	172.16.20.2			
Station computer AK-A92D01 (PGIM) (Ethernet card 1) primary server network	172.16.4.3	3		
(Ethernet card 2) secondary server network	172.17.4.3	3		
(Ethernet card 3) primary server network	Dynamic IP			
(Ethernet card 4) spare network	Dynamic IP			
(Ethernet card 5) spare network	Dynamic IP			

(Ethernet card 6) spare network	Dynamic IP			
(PP846 process panel unit G1)	(172.16.4.45)	(15)		
Printer	172.16.4.16	16		

Unit G1 protection relay sub 1	172.16.20.191	191		
Unit G1 protection relay sub 2	172.16.20.192	192		
Unit G2 protection relay sub 1	172.16.20.193	193		
Unit G2 protection relay sub 2	172.16.20.194	194		
Line L115 protection relay	172.16.20.195	195		
Line L116 protection relay	172.16.20.196	196		
50A rail NUS protection	172.16.20.197	197		
Synchrotact synchronization	172.16.20.200	200		
Synchrotact powering	172.16.20.201	201		

Switch EDS-408 control network	172.16.80.200	200		
Switch EDS-405 excitation G1	172.16.80.201	201		
Switch EDS-405 excitation G2	172.16.80.202	202		
Switch EDS-308	N/A			
Switch EDS-308	N/A			
Switch EDS-316	N/A			
Switch RuggendCom RS900 Unit G1	N/A			
Switch RuggendCom RS900 Unit G2	N/A			
Switch 1 RuggendCom RS900 (Fortum Dist.)	N/A			
Switch 2 RuggendCom RS900 (Fortum Dist.)	N/A			

Description	Date	Sign
G1 & Station, system monitoring list completed for all components regarding HMI system. (Service tags noted, MAC addresses noted).		
The system is connected according to system layout, layout is controlled. Cable markings for all communication units that are connected are also controlled.		
All MAC addresses for switches noted down (following page).		

(NOTE: IP gateway address is set to 172.16.80.255, this is necessary to get communication to the switch online after a power failure. In case the IP gateway is set to 172.16.80.0, the operator control station won't get contact after a power failure).

Screenshots of MAC addresses for switches:

Switch EDS-408 Station

Model : EDS-408A-MM-ST	IP : 192.168.127.253	MAC Address : 00-90-E8-30-ED-51
Name : Managed Redundant Switch 06987	Serial No : 06987	Firmware Version : V2.7
Location : Switch Location		

Port Events

Port	Link
1	Off
2	Off
3	Off
4	Off
5	Off
6	Ignore
7	Off
8	Ignore

Switch EDS-405 Unit G1

Model : EDS-405A-MM-ST	IP : 172.16.80.201	MAC Address : 00-90-E8-2A-6F-DB
Name : Grada Magnetisering G1	Serial No : 05748	Firmware Version : V2.7
Location : YA11		

Switch EDS-405 Unit G2

Model : EDS-405A-MM-ST	IP : 172.16.80.202	MAC Address : 00-90-E8-2A-6F-C8
Name : Grada Magnetisering G2	Serial No : 05729	Firmware Version : V2.7
Location : YA21		

Switch RuggendCom RS900 Unit G1

-N/A-

Switch RuggendCom RS900 Unit G2

-N/A-

Switch 1 RuggendCom RS900 (Fortum Dist.)

-N/A-

Switch 2 RuggendCom RS900 (Fortum Dist.)

-N/A-

Switch EDS-405

-N/A-

Switch EDS-308

-N/A-

Switch EDS-308

-N/A-

Switch EDS-316

-N/A-

Controller load and capacity

Processor load (”Cyclic load” and ”Total System Load”) is controlled for all controllers in the system. Processor load is controlled by the programming tool (Control Builder) set to on-line mode by choosing ”System Diagnostics” for all controllers. The observed results are inserted in the table below:

<table>
<tr><th>Data</th><th colspan="2">N10 FAT</th><th colspan="2">N10 SAT</th><th colspan="2">N40 FAT</th><th colspan="2">N40 SAT</th></tr>
<tr><th></th><th>IO</th><th>Appl</th><th>IO</th><th>Appl</th><th>IO</th><th>Appl</th><th>IO</th><th>Appl</th></tr>
<tr><td>Exectime act</td><td>13</td><td>31</td><td>16</td><td>35</td><td>14</td><td>31</td><td>16</td><td>73</td></tr>
<tr><td>Exectime max</td><td>14</td><td>32</td><td>16</td><td>36</td><td>14</td><td>32</td><td>17</td><td>76</td></tr>
<tr><td>Intervaltime req</td><td>130</td><td>260</td><td>130</td><td>260</td><td>50</td><td>250</td><td>130</td><td>260</td></tr>
<tr><td>Intervaltime max</td><td>370</td><td>468</td><td>447</td><td>671</td><td>467</td><td>619</td><td>431</td><td>591</td></tr>
<tr><td>Modulebus scan</td><td colspan="2">100ms</td><td colspan="2">100ms</td><td colspan="2">100ms</td><td colspan="2">100ms</td></tr>
<tr><td>Cyclic load</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="2">%</td></tr>
<tr><td>Total system load</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="2">%</td></tr>
<tr><td>Used memory</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="2">%</td><td colspan="2">%</td></tr>
<tr><td>Max used memory</td><td colspan="2">17%</td><td colspan="2">17%</td><td colspan="2">66%</td><td colspan="2">65%</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Max used memory at stop</td><td colspan="2">17%</td><td colspan="2">17%</td><td colspan="2">66%</td><td colspan="2">65%</td></tr>
<tr><td>Warmstart stop time</td><td colspan="2">ms</td><td colspan="2">ms</td><td colspan="2">ms</td><td colspan="2">ms</td></tr>
</table>

FAT: __.__.____ / ____________________ (Completed with all I/Os connected)

Sitetest __.__.____ / ____________________ (Completed with all I/Os connected)

Control that expected load is lower than recommended load / total load (max 70%).

Data	N10 FAT	N10 SAT	N40 FAT	N40 SAT
Max allowed cyclic load = 70%				
Max allowed total system load = 70%				

AC800 power supply monitoring

Monitoring of ”power supply” to controller and remote I/O modules.

Tests are done at both FAT and SAT.

No.	Description	Node	FAT	SAT	Sign
1	Disconnect 24V power supply A F1 (from DC distribution panel) for controller. Alarm to alarm list and remote.	10			
2	Disconnect 24V power supply B F2 (from DC distribution panel) for controller. Alarm to alarm list and remote.	10			
3	Disconnect power supply for both F1 and F2 (from DC distribution panel). So that controller becomes powerless. STALL alarm is activated immediately and alarm is generated at station computer.	10			
4	Disconnect 24V power supply A F1 for remote I/O panel (Panel MP1-G1), alarm to alarm list and remote.	10			

5	Disconnect 24V power supply B F2 for remote I/O panel (Panel MP1-G1), alarm to alarm list and remote.	10			
6	Disconnect 24V power supply A and B for I/O cabinet (Panel MP1-G1), this gives DI/DO alarm after 2min and STALL alarm after 10s	10			
7	Disconnect 24V power supply A F1 (from DC distribution panel) for controller. Alarm to alarm list and remote.	40			
8	Disconnect 24V power supply B F2 (from DC distribution panel) for controller. Alarm to alarm list and remote.	40			
9	Disconnect power supply for both F1 and F2 (from DC distribution panel). So that controller becomes powerless. STALL alarm is activated immediately and alarm is generated at unit 1 & 2.	40			
10	Disconnect 24V power supply A F1 for remote I/O panel (Panel LU1), alarm to alarm list and remote.	40			
11	Disconnect 24V power supply B F2 for remote I/O panel (Panel LU1), alarm to alarm list and remote.	40			
12	Disconnect 24V power supply A and B for I/O cabin (Panel LU1), This gives DI/DO alarm after 2min and STALL alarm after 10s	40			

All controllers have their own DO which is normally high. This shows that the controllers have normal status (no critical fault).

At critical fault this DO goes down and activates DI in another controller (alarm from the other controller) and STALL alarm to protection relay sub 1 & sub 2.

				Date	Sign
N10	DO124.15	=G1-A91.A01.XH11	UNIT G1 STALL (OFFLOAD STOP) Alarm from own controller and offload stop to protection relay sub 1 & 2		
N10	DO124.16	=G1-A91.A01.XH12	UNIT G1 STALL (SNABBSTOPP) Alarm from station computer and fast stop from protection relay 1 & 2		
N40	DI125.15	=AK-A91.A10.XG01	UNIT G1 STALL STATION COMPUTER		
N10	DO124.14	=G1-A91.A01.XH10	UNIT G1 STALL STATION COMPUTER		
N40	DO129.5	=AK-A91.A01.YH01	STATION COMPUTER STALL TO G1		
N10	DI103.4	=AK-A91.A01.XG01	STATION COMPUTER STALL ALARM TO G1		

Monitoring test of AC800 STALL

Tests are done at both FAT and SAT.

No.	Description	AllUnitStatus	
1	Take out an S800 I/O card (DI/DO/AI) After 2min STALL alarm occurs		All nodes
2	Take out an S800 I/O kort (DI/DO/AI) Put it back within a minute, only gives alarm, no STALL alarm.		All nodes
3	Disconnect fiber/profibus between controller and CI801. Put it back within 1min. Only gives alarm (in case no STALL alarm is on remote I/O. Critical fault (STALL) if controller doesn't manage to update within 2min.		All nodes
4	Disconnect AO card from runner control, gives STALL alarm instantly and station computer assumes combining.		All nodes

	Description	Date	Sign
5	Test that alarm is generated at communication fault against controller. Disconnect both Ethernet cables to unit G1 controller. Activate an alarm in controller for G1. Reconnect both Ethernet cables and verify that alarm is generated in correct time. (Note. alarm to panel846 will not be generated (no event conf). But alarm to 800xA and remote will be generated).		
7	Test that alarm is generated at communication fault against controller. Disconnect both Ethernet cables to station controller. Activate an alarm in controller for station. Reconnect Ethernet cables and verify that alarm is generated in correct time. (Note. alarm to panel846 will not be generated (no event conf). But alarm to 800xA and remote will be generated).		

Tests are done for the following controllers:

Node	Description	FAT Date	SAT Date	Sign
N10	Unit G1 controller			
N40	Station controller			

Test of communication monitoring

Nr	Description	Date	Sign
1	Separate scheme available for communication (system layout). Mark controlled communication units with green, also control that cable numbers are available on all communication cables.		
2	Disconnect ethernet cable to excitation for unit G1, control that alarm is generated and that start conditions are no longer fulfilled.		
3	Disconnect ethernet cable to PCU400, control that alarm is generated and remote access is connected automatically and alarm is sent through reserve alarm sender.		
4.	Disconnect communication cable to operating center, control that alarm is generated and remote access is connected automatically and alarm is sent through reserve alarm sender.		

5	Disconnect profibus to VP800, control that control signal becomes 0V (In case turbine regulator tries to control the throttle control error occurs after 10s and mechanical stop is enforced. (Alarm is generated immediately for the communication fault). Start disable is activated.		
6.	Disconnect profibus to AS800 (frequency measurement), control that turbine regulator transitions to RPM regulation. (Alarm is generated immediately for communication fault).		
7	Disconnect profibus to MCM800. Alarm is generated immediately for communication fault, (Start conditions still ok!)		
8	Disconnect profibus to remote I/O (+DA11), Start conditions not fulfilled and alarm is generated for communication fault, in case STALL DO is on remote I/O the unit trips STALL. A-Alarm is generated.		
9	Disconnect one profibus fiber to remote I/O (MP1-G1), alarm is generated but communication is still OK! (Both ways tested).		

10	Disconnect the second fiber to remote I/O (MP1-G1), start conditions not fulfilled and alarm is generated for communication fault, in case no STALL DO is on remote I/O everything works normally, after 2min STALL alarm will be generated. A-Alarm is generated.		
14	Disconnect one profibus to remote I/O (+DA1), alarm is generated for communication fault, STALL alarm is generated to unit computers. A-Alarm to alarm list and remote.		
15	Disconnect one profibus fiber to remote I/O (LU1), alarm is generated but communication is still OK! (both ways tested)		
16	Disconnect the other fiber to remote I/O (LU1), alarm is generated for communication fault. A-Alarm is generated.		

Test of communication monitoring RNRP

(primary/secondary ethernet communication)

Nr	Description	AllUnitStatus	
1	Disconnect primary ethernet cable from AC800M controller for unit G1, control system alarm list (network connection lost). Alarm should trip as D-Alarm to remote! Communication is still operational.		
2	Disconnect secondary ethernet cable from AC800M controller for unit G1, control system alarm list (network connection lost). Alarm should trip as D-Alarm to remote! Communication is still operational.		
3	Disconnect primary and secondary ethernet cables from AC800M controller for unit G1, control system alarm list (communication error). Alarm should be generated as A-Alarm to remote!		
7	Disconnect primary Ethernet cable from AC800M controller for station computer, control system alarm list (network connection lost). Alarm should trip as D-Alarm to remote! Communication is still operational.		

8	Disconnect secondary ethernet cable from AC800M controller for station computer, Control system alarm list (network connection lost). Alarm should be generated as D-Alarm to remote! Communication is still operational.		
9	Disconnect primary and secondary Ethernet cables from AC800M controller for station computer, control system alarm list (communication error). Alarm should be generated as A-Alarm to remote!		
10	Disconnect primary control network cable from AK-A95D01 (800xA workplace) control system alarm list (network connection lost). Alarm should be generated as D-Alarm to remote! Communication is still operational.		
11	Disconnect secondary control network cable from AK-A95D01 (800xA workplace) control system alarm list (network connection lost) Alarm should be generated as D-Alarm to remote! Communication is still operational.		
12	Disconnect primary & secondary control network cables from AK-A95D01 (800xA workplace) Control system alarm list (network connection lost) Port fault in switch generates D-Alarm.		

13	Disconnect primary server network cable from AK-A95D01 (800xA workplace) Control system alarm list (network connection lost) Alarm should be generated as D-Alarm to remote! Communication is still operational.		
14	Disconnect secondary server network cable from AK-A95D01 (800xA workplace) control system alarm list (network connection lost). Alarm should be generated as D-Alarm to remote! Communication is still operational.		
15	Disconnect primary & secondary server network cables from AK-A95D01 (800xA workplace) Control system alarm list (network connection lost). Alarm should be generated as A-Alarm to remote!		
16	Disconnect primary server network cable from AK-A95D02 (PGIM workplace) Control system alarm list (network connection lost). Alarm should be generated as D-Alarm to remote! Communication is still operational.		
17	Disconnect secondary server network cable from AK-A95D02 (PGIM workplace) control system alarm list (network connection lost). Alarm should trip as D-Alarm to remote! Communication is still operational.		

18	Disconnect primary & secondary server network cables from AK-A95D02 (PGIM workplace) Control system alarm list (network connection lost). Alarm should trip as A-Alarm to remote!		
19	Disconnect primary control network cable from PCU400 control system alarm list (network connection lost). Alarm should trip as D-Alarm to remote! Communication is still operational.		
20	Disconnect secondary control network cable from PCU400 control system alarm list (network connection lost). Alarm should trip as D-Alarm to remote! Communication is still operational.		
21	Disconnect primary & secondary server network cables from PCU400 (PGIM workplace) control system alarm list (network connection lost). Alarm should trip as A-Alarm to remote!		

Communication

Test of fiber/copper ring station communication: Test is done at FAT.

In case 2 switches are connected as a ring-connection.

Testing will confirm that communication still works if failure in the ring occurs, and that alarm is generated from every Ethernet switch in case a port is not connected.

Continued communication at fiber failure is controlled from OPC server in 800xA workplace and that screenshots have delivered values.

1	Ring configuration between RuggedCom for unit is tested. In case the ring is broken, alarm is generated to unit computer 1 & 2.		
2	Control that communication works after power failure, is tested for:		
	Switch RuggedCom RS900 (IEC61850 G1)		
	Switch RuggedCom RS900 (IEC61850 G2)		
	Switch 1 RuggedCom RS900 (Fortum Distribution)		
	Switch 2 RuggedCom RS900 (Fortum Distribution)		
	Switch primary Control Network, EDS-408 (+DA1)		
	Switch primary Control Network, EDS-405 (Excitation G1)		
	Switch secondary Control Network, EDS-316		
	Switch primary server/client network, EDS-308		
	Switch secondary server/client network, EDS-308		

3	Control that alarm occurs when an Ethernet cable is disconnected from the switch, is tested for:		
	Switch RuggedCom RS900 (IEC61850 G1)		
	Switch RuggedCom RS900 (IEC61850 G2)		
	Switch 1 RuggedCom RS900 (Fortum Distribution)		
	Switch 2 RuggedCom RS900 (Fortum Distribution)		
	Switch primary control network, EDS-408 (+DA1)		
	Switch primary controlNetwork, EDS-405 (Excitation G1)		
	Switch secondary control network, EDS-316		
	Switch primary server/client network, EDS-308		
	Switch secondary server/client network, EDS-308		

Test of communication between AC800 controllers

The testing should verify that controllers can communicate with each other and that communication stop generates alarm to alarm list. Communication alarm occurs after controller has not been updated within 30s.

No.	Description	Date	sign
1	Disconnect Ethernet cables to unit computer G1. Observe alarm from station computer.		
2	Disconnect Ethernet cables to station computer. Observe alarm from unit computer G1.		

STALL Alarm and OSP configuration

Stall alarm gives start blockage.

OSP (output set as predetermined) configuration, stall alarm signals are configurated to give low signal instantly at communication fault, other DO maintain their actual value. OSP value is to maintain actual value, except for STALL alarm, switch on brakes and hatch closing/opening where OSP value should become a low signal.

No.	Description	Date	sign
	Control and mark controlled logic schemes with green for G1 STALL (mechanical and electrical stop)		
	Disconnect fiber during operation to G1 remote I/O cabinet, control DO status that these don't change status at communication fault. In case communication is gone more than 2min, STALL alarm will occur. Note. Interlocks of pumps are hardwired.		
	Disconnect profibus to G1 remote I/O which contains a STALL output. Output signal will immediately go low (doesn't wait 2min)		
	At unit G1 stall alarm brakes won't activate! OSP value = 0.		
	Disconnect profibus for station remote I/O, outputs maintain actual value.		
	OSP configuration for open/close hatch 2 OSP value = 0, input goes low at communication fault to remote I/O.		
	OSP configuration for open/close hatch 4 OSP value = 0, input goes low at communication fault to remote I/O.		

Signaltest

Test of signals to alarm/event list for PP846, 800xA and remote control.

DI signals are activated from process where it is possible or from simulated I/O card (FAT, at SAT all signals are controlled according to circuit diagram). Calculated signals are controlled from process and PLC-program.

No.	Description	Date	sign
	DI signals unit G1		
	Calculated signals unit G1		
	PT100 signals unit G1		
	AI signals unit G1		
	DO signals unit G1		
	AO signals unit G1		
	DI signals station computer		
	Calculated signals station computer		
	PT100 signals station computer		
	AI signals station computer		
	DO signals station computer		
	AO signals station computer		
	Remote control (PCU400)		

See green marked I/O lists for documentation.

No.	Description	Date	sign
	Visual check I/O list to hardware configuration in controller unit G1		
	Unit G1, control mA measurements with account for correct scaling hardware configuration. Jämför mot panelinstrument.		
	Unit G1, visual check of signal list for calculated analogue signals to PLC program. Control that all are printed in program.		
	Visual check I/O list to hardware configuration in station computer.		
	Station computer, control mA measurements with account for correct scaling in hardware configuration. Compare to panel instrument.		
	Station computer, visual check of signal list for calculated analogue signals to PLC program. Control that all are printed in program.		

Function test sequences G1

Sequences

Whole sequence FAT simulation. Activate simulation mode for all objects that will be run from sequence. For turbine regulator a separate simulator is built.

No.	Description	Unit 1	sign
	Start to idle running without voltage		
	Start to idle running with voltage		
	Start to operation synchronization G1-S		
	Start from idle running without voltate to idle running with voltage		
	Start from idle running without voltage to operation		
	Start from idle running with voltage to operation		
	From operation; Disconnection to idle running with voltage		
	From operation; Disconnection to idle running without voltage		
	From operation; to quick stop		
	From operation; to mechanical stop		
	From operation; to normal stop		

	Verify the following function: In case T1-50-S breaker opens when unit is in operation, sequence will go to idle running with voltage, turbine regulator goes to idle mode. Operator now has 2 possibilities, synchronize T1-50-S or open G1-S and then switch T1-50-S breaker and afterwards pressing start operation.		
	Verify the following function: Unit is idle running with voltage, operator switches field breaker off, excitation is de-excited and field breaker is turned off.		
	Verify the following function: Unit is operational, operator tries to switch off field breaker, this is not possible because G1-S blocks off switching of field breaker.		
	Verify the following function: At synchronization of G1-S operator switches off G1-S (cancel synchronization). Sequence is cancelled and jumps to idle running with voltage. It is now possible to give a new start sequence.		

Sequence interrupts

Simulation of faults that interrupts the sequence.

No.	Description	Unit 1	sign
1	**Long start time – step 1,2,3, and 4** Start time set to 10s/step. Press start, sequence starts. Sequence step is blocked and after 10s stop sequence is activated. Alarm for actual step is generated with the message ”STOP”		
2	**Long excitation time – step 5 and 6** Set step time to 10s/step and block that field breaker goes to/excitation starts. After 10s stop sequence is activated. Alarm for actual step is generated with the message ”STOP”		
3	**Long synchronization time – step 7 and commanded phasing of G1-S** Step time is changed to 10s/step. After 10s sequence is cancelled and unit indicates idle running with voltage. Press G1-S phasing and change max synchronization time in faceplate to 10s. Control that cancel phasing occurs after 10s.		
4	**Long mechanical stop time – stop step 1** Change step time so that mechanical stop won’t occur, stop sequence goes on to step 2. Control that alarm is generated (long stop time step 1).		

5	**Long disconnection time – G1-S** Block output for G1-S switching off. At long step time STALL alarm will activate and switch off breaker through SUB2. Control that alarm is generated (long stop time step 2).		
6	**Long disconnection time/de-excitation time – G1-FB** Block output for G1-FB switch off. At long step time STALL alarm will be activated and disconnect breaker through SUB2. Control that alarm is generated (long stop time step 3/4).		
7	**Long closing time – D/S-valve** Block output for D/S valve. At long step time intake hatch will close. (sequence will not continue before D/S-valve is in stop mode or throttle closed)		
8	**Long stop time – step 9** In case any object is in manual mode these will not be stopped from stop sequence. After step time has expired, sequence jumps to next step and unit doesn’t go to start blockage. (Unit is still start ready).		

Stop/Electrical stop/Mechanical stop Unit G1

Test of function

Nr	Description	Unit 1	sign
1	Control that all stops generate stops, control against logic schemes.		
2	Control that all quick stops generate quick stops, control against logic schemes.		
3	Control that all mechanical stops generate mechanical stops, control against logic schemes.		

Control of blocking interlocks

Test of function from logic schemes.

No.	Description	Date	sign
1	Control all logic schemes to real process. Interlocks stops pumps according to logic scheme. G1 Control.		
2	Control all logic schemes to real process. Interlocks breaker according to logic scheme. G1 Control.		
3	Go through all start blockings for unit G1.		
7	Control all logic schemes to real process. Interlocks stop pumps as they should. Station control.		
8	Control all logic schemes to real process. Interlocks stop breakers according to logic scheme. Station control.		

Test of panel 800xA/PP846 process pictures

Panel for station, unit 1 and unit 2

No.	Description	Unit G1	Unit G2	Station
	Panel pictures controlled. Breaker positions and measurements done.			
	Commands and setpoints tested (see controller part).			
	Alarm/event list controlled to I/O list.			

Panel pictures for station, unit G1 and unit G2

Process panel is backup control for 800xA system, from which one can see the objects that are criteria to be able to start unit. It is possible to see start criteria/start blockings, alarm and event list. It is not possible to control from this (breaker control is in adjacent panel, start/stop of unit is also in adjacent panels). There are setpoints that can be changed from process panel.

No.	Process picture:	Symbols	Signals	Date	sign
	Main (object switch)				
	Electrical line diagram				
	Unit G1, Start/Stop				

	Unit G1, Start blockings				
	Unit G1, Start conditions page 1				
	Unit G1, Start conditions page 2				
	Unit G1, Turbine_SP				
	Unitt G1, Voltageregulator_SP				
	Unitt G1, Temperature/Vibration				
	Unit G2, Start/Stop				
	Unit G2, Start blockings				
	Unit G2, Start conditions page 1				
	Unit G2, Start conditions page 2				
	Unit G2, Turbine_SP				
	Unit G2, Voltagereg_SP				
	Unit G2, Temperature/Vibration				

800xA process pictures for station, Unit 1 and Unit 2

Following pictures defined and controlled, control all links by clicking diagnostics for every process picture, no conflicts may occur. Max time for picture change until all objects are loaded is 3s (for analogue signals and 1s for digital signals)

No.	Process picture:	Diagnostics	Timing (subscription)	Errors & Warnings	Date	sign
	Stationssida contains information about object switch and production. In case PCU400 is used for remote control there is a link to remote control PCU400 at the right side of process picture. Links to various plant parts is also at start page.					
	Aggregatöversikt contains information about all units operation status, MW, RPM, ongoing start/stop, start ready etc.					
	Aggregat shows submenu for chosen unit.					
	Station shows submenu for station.					
	Vattenöversikt contains station control, unit flow, wicket flows and water levels.					
	Dokumentation contains links to documentation folders.					

800xA process pictures for station

No.	Process picture	Diagnostics	Timing (subscription)	Errors & Warnings	Date	sign
	Station contains station overview, flows, power, MWh, object switch.					
	Enlinjeschema contains information about switchgear: breaker, disconnector and measurement values.					
	Lokalkraft 400V contains information about local power, switching automation and backup power.					
	Lokalkraft DC contains information about distribution, battery voltage, rectifiers and inverters.					
	Ventilation contains information about ventilation, fire dampers etc.					
	Systemöversikt contains overview over control system like status for PC/Server and PLC system.					

800xA process pictures, unit G1

No.	Process picture:	Diagnostics	Timing (subscription)	Errors & Warnings	Date	sign
	Aggregat contains information about unit status, MW, RPM, ongoing start/stop, start ready etc.					
	Generator contains information about generator, excitation and auxiliary equipment like brakes and lubrication oil pumps.					
	Turbin contains oil system regulation, turbine signals and auxiliary equipment for turbine control.					
	Start/stoppsekvens contains sequence for stop and start. And also trend for start-up containing throttle setpoint/actual value runner position and effect.					
	Startfrigivning contains all of the starting approvals.					
	Startblockering contains all of the start blockings.					

	Kylvatten contains coolant water system and drainage system.					
	Temperatur contains all temperatures for actual unit and all stations temperatures.					
	Drifttider contains operating times for actual units’ objects and all station objects.					

800xA process pictures, unit G2

No.	Process picture:	Diagnostics	Timing (subscription)	Errors & Warnings	Date	sign
	Aggregat contains information about unit status, MW, RPM, ongoing start/stop, start ready etc.					
	Generator contains information about generator, excitation and auxiliary equipment like brakes and lubrication oil pumps.					
	Turbin contains oil system regulation, turbine signals and auxiliary equipment for turbine control.					
	Start/stoppsekvens contains sequence for stop and start. And also trend for start-up containing throttle setpoint/actual value runner position and effect.					
	Startfrigivning contains all of the starting approvals.					
	Startblockering contains all of the start blockings.					

	Kylvatten contains coolant water system and drainage system.					
	Temperatur contains all temperatures for actual unit and all stations temperatures.					
	Drifttider contains operating times for actual units' objects and all station objects.					

800xA screenshots of process pictures

No.	Description	Unit G1	Unit G2	Station
1	800xA, take a screenshot of every process picture, and copy these into an excel document.			
2	800xA, take a screenshot of every process picture, and copy these into an excel document.			

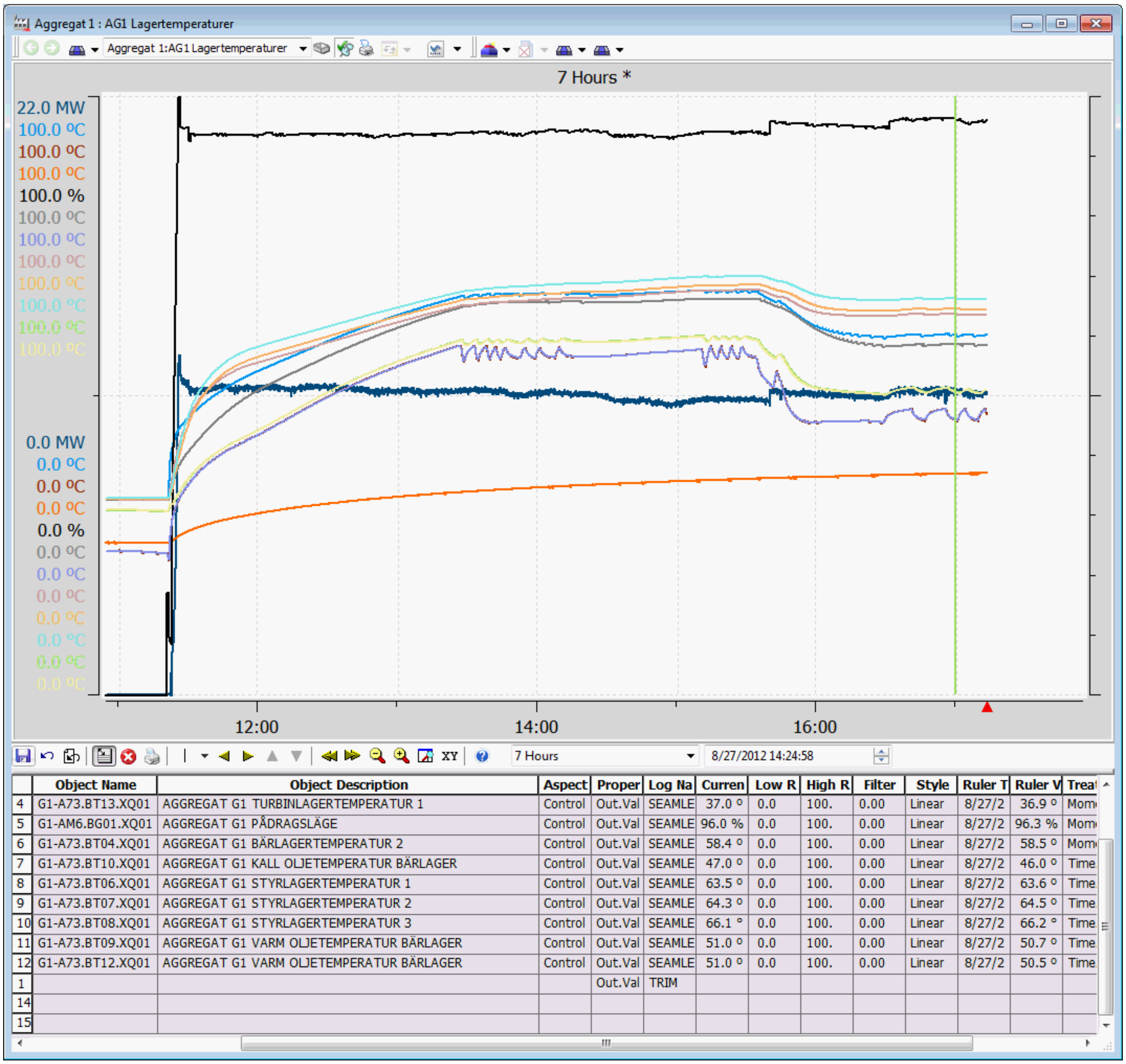
Temperature monitoring Test Report

STATION : Project Name
Functunal Structure : =Gx-A73
EQUIPMENT : 800xA Trends

Idle Mode, bearing temperatures:

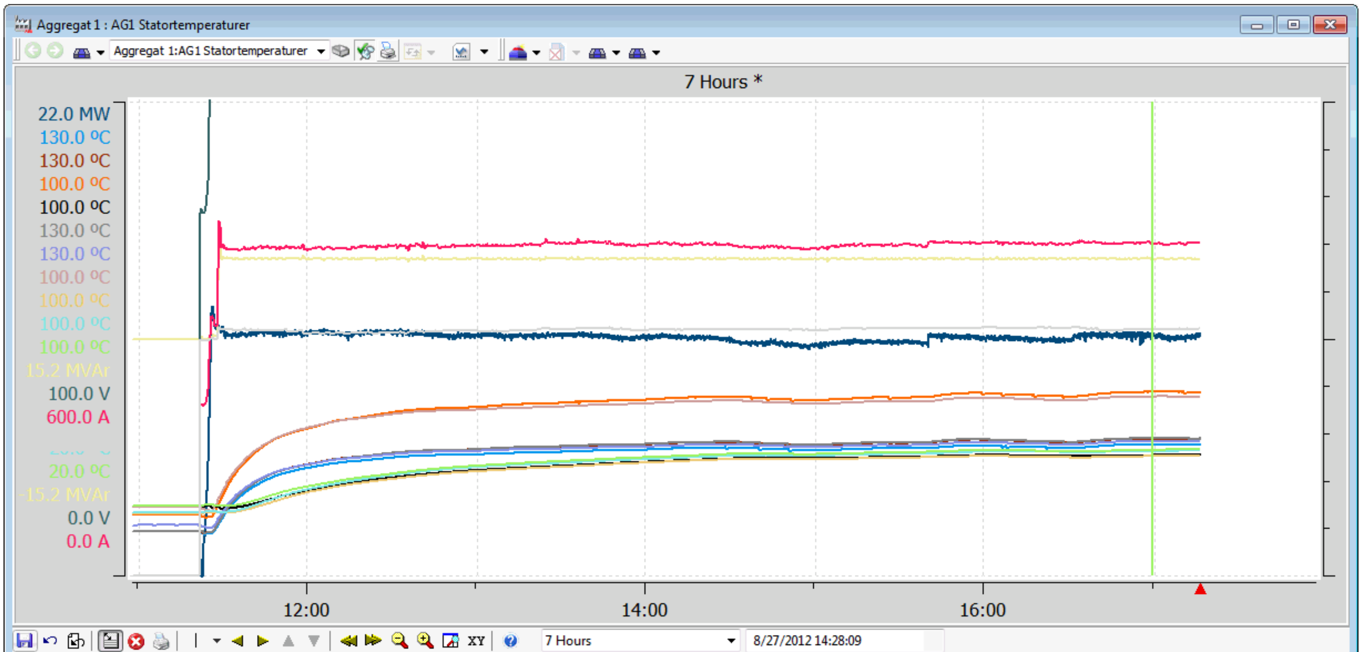
N/A

Full load, bearing temperatures:



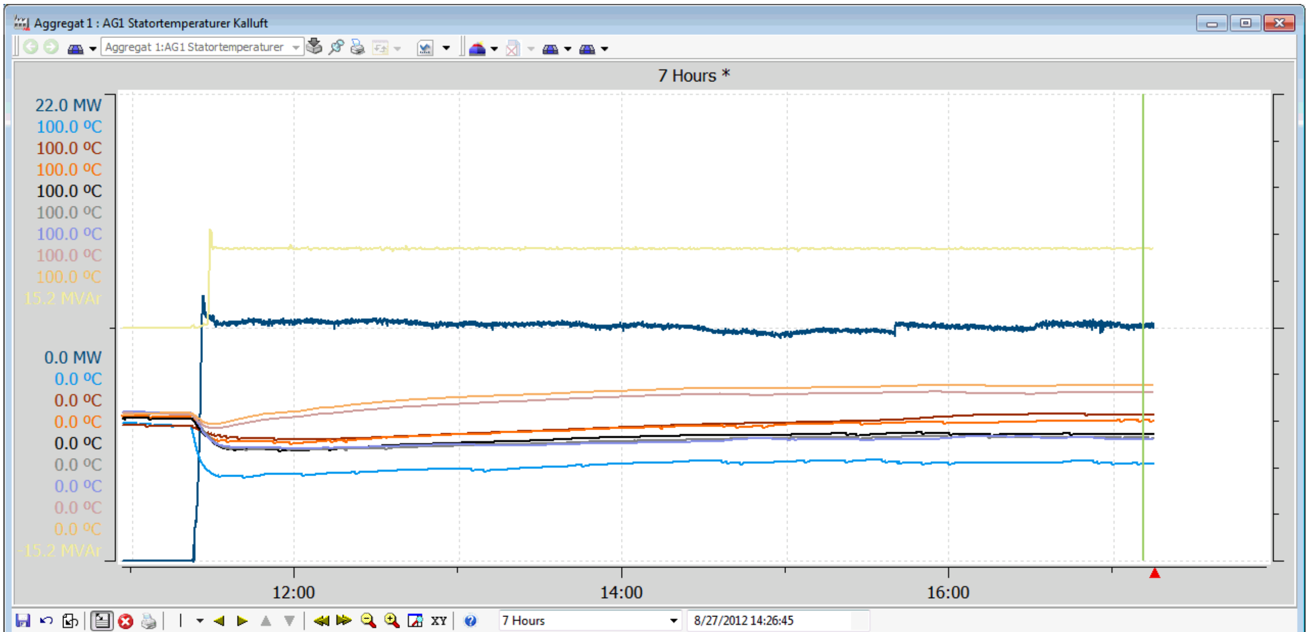
	Object Name	Object Description	Aspect	Proper	Log Na	Curren	Low R	High R	Filter	Style	Ruler T	Ruler V	Treat
4	G1-A73.BT13.XQ01	AGGREGAT G1 TURBINLAGERTEMPERATUR 1	Control	Out.Val	SEAMLE	37.0 º	0.0	100.	0.00	Linear	8/27/2	36.9 º	Mom
5	G1-AM6.BG01.XQ01	AGGREGAT G1 PÅDRAGSLÄGE	Control	Out.Val	SEAMLE	96.0 %	0.0	100.	0.00	Linear	8/27/2	96.3 %	Mom
6	G1-A73.BT04.XQ01	AGGREGAT G1 BÄRLAGERTEMPERATUR 2	Control	Out.Val	SEAMLE	58.4 º	0.0	100.	0.00	Linear	8/27/2	58.5 º	Mom
7	G1-A73.BT10.XQ01	AGGREGAT G1 KALL OLJETEMPERATUR BÄRLAGER	Control	Out.Val	SEAMLE	47.0 º	0.0	100.	0.00	Linear	8/27/2	46.0 º	Time
8	G1-A73.BT06.XQ01	AGGREGAT G1 STYRLAGERTEMPERATUR 1	Control	Out.Val	SEAMLE	63.5 º	0.0	100.	0.00	Linear	8/27/2	63.6 º	Time
9	G1-A73.BT07.XQ01	AGGREGAT G1 STYRLAGERTEMPERATUR 2	Control	Out.Val	SEAMLE	64.3 º	0.0	100.	0.00	Linear	8/27/2	64.5 º	Time
10	G1-A73.BT08.XQ01	AGGREGAT G1 STYRLAGERTEMPERATUR 3	Control	Out.Val	SEAMLE	66.1 º	0.0	100.	0.00	Linear	8/27/2	66.2 º	Time
11	G1-A73.BT09.XQ01	AGGREGAT G1 VARM OLJETEMPERATUR BÄRLAGER	Control	Out.Val	SEAMLE	51.0 º	0.0	100.	0.00	Linear	8/27/2	50.7 º	Time
12	G1-A73.BT12.XQ01	AGGREGAT G1 VARM OLJETEMPERATUR BÄRLAGER	Control	Out.Val	SEAMLE	51.0 º	0.0	100.	0.00	Linear	8/27/2	50.5 º	Time
1				Out.Val	TRIM								
14													
15													

Full load, temperature stator windings/core:



	Visible	Status	Trace C	Object	Object Name	Object Description	Aspect	Proper	Log Na	Curren	Low R	High R	Filter	Style	Ruler T	Ruler V
1	☑				G1-AG1.U03.XQ01	G1-P AKTIV EFFEKT	Control	Out.Val	SEAMLE	11.2 M	0.0	22.0	0.00	Linear	8/27/2	11.2 M
2	☑				G1-A73.BT101.XQ0	AGGREGAT G1 STATORTEMPERATUR L1	Control	Out.Val	SEAMLE	50.3 º	20.0	130.	0.00	Linear	8/27/2	50.4 º
3	☑				G1-A73.BT105.XQ0	AGGREGAT G1 STATORTEMPERATUR L2	Control	Out.Val	SEAMLE	51.7 º	20.0	130.	0.00	Linear	8/27/2	51.8 º
4	☑				G1-A73.BT109.XQ0	AGGREGAT G1 STATORTEMPERATUR L3	Control	Out.Val	SEAMLE	51.0 º	20.0	100.	0.00	Linear	8/27/2	51.0 º
5	☑				G1-A73.BT201.XQ0	AGGREGAT G1 STATORKÄRNA 1CVB01 TEMPERATUR	Control	Out.Val	SEAMLE	40.4 º	20.0	100.	0.00	Linear	8/27/2	40.3 º
6	☑				G1-A73.BT104.XQ0	AGGREGAT G1 STATORTEMPERATUR L1	Control	Out.Val	SEAMLE	51.8 º	20.0	130.	0.00	Linear	8/27/2	51.9 º
7	☑				G1-A73.BT107.XQ0	AGGREGAT G1 STATORTEMPERATUR L2	Control	Out.Val	SEAMLE	51.1 º	20.0	130.	0.00	Linear	8/27/2	51.2 º
8	☑				G1-A73.BT111.XQ0	AGGREGAT G1 STATORTEMPERATUR L3	Control	Out.Val	SEAMLE	50.2 º	20.0	100.	0.00	Linear	8/27/2	50.2 º
9	☑				G1-A73.BT202.XQ0	AGGREGAT G1 STATORKÄRNA 1CVB01 TEMPERATUR	Control	Out.Val	SEAMLE	40.2 º	20.0	100.	0.00	Linear	8/27/2	40.2 º
10	☑				G1-A73.BT204.XQ0	AGGREGAT G1 STATORKÄRNA 1CVB02 TEMPERATUR	Control	Out.Val	SEAMLE	41.1 º	20.0	100.	0.00	Linear	8/27/2	41.0 º
11	☑				G1-A73.BT205.XQ0	AGGREGAT G1 STATORKÄRNA 1CVB02 TEMPERATUR	Control	Out.Val	SEAMLE	41.3 º	20.0	100.	0.00	Linear	8/27/2	41.2 º
12	☑				G1-AG1.U03.XQ02	G1-Q REAKTIV EFFEKT	Control	Out.Val	SEAMLE	5.1 MV	-15.	15.2	0.00	Linear	8/27/2	5.1 MV
13	☑				G1-AG6.A01.XQ06	AGGREGAT G1 FÄLTSPÄNNING	Control	Out.Val	SEAMLE	156.8	0.0	100.	0.00	Linear	8/27/2	157.0
14	☑				G1-AG6.A01.XQ07	AGGREGAT G1 FÄLTSTRÖM	Control	Out.Val	SEAMLE	420.1	0.0	600.	0.00	Linear	8/27/2	419.9
15	☑				G1-AG1.U03.XQ04	G1-U SPÄNNING	Control	Out.Val	SEAMLE	10.9 k	0.0	21.0	0.00	Linear	8/27/2	10.9 k

Full load, temperature stator air:



	Object	Object Name	Object Description	Aspect	Proper	Log Na	Curren	Low R	High R	Filter	Style	Ruler T	Ruler V	Treatm	Mean	Min Val	Max Va
1		G1-AG1.U03.XQ01	G1-P AKTIV EFFEKT	Control	Out.Val	SEAMLE	11.2 M	0.0	22.0	0.00	Linear	8/27/2	11.0 M	Momen	10.4 M	-0.0 M	12.5 M
2		G1-A73.BT301.XQ0	AGGREGAT G1 GENERATOR KALL LUFT 1CVB01 TEMPERATUR	Control	Out.Val	SEAMLE	20.8 º	0.0	100.	0.00	Linear	8/27/2	20.9 º	Momen	21.0 º	18.0 º	29.6 º
3		G1-A73.BT302.XQ0	AGGREGAT G1 GENERATOR KALL LUFT 1CVB01 TEMPERATUR	Control	Out.Val	SEAMLE	31.4 º	0.0	100.	0.00	Linear	8/27/2	31.4 º	Momen	28.9 º	26.0 º	31.5 º
4		G1-A73.BT303.XQ0	AGGREGAT G1 GENERATOR KALL LUFT 1CVB01 TEMPERATUR	Control	Out.Val	SEAMLE	30.0 º	0.0	100.	0.00	Linear	8/27/2	30.1 º	Momen	28.4 º	25.2 º	31.2 º
5		G1-A73.BT304.XQ0	AGGREGAT G1 GENERATOR KALL LUFT 1CVB02 TEMPERATUR	Control	Out.Val	SEAMLE	27.2 º	0.0	100.	0.00	Linear	8/27/2	27.2 º	Momen	26.5 º	23.6 º	30.5 º
6		G1-A73.BT305.XQ0	AGGREGAT G1 GENERATOR KALL LUFT 1CVB02 TEMPERATUR	Control	Out.Val	SEAMLE	26.3 º	0.0	100.	0.00	Linear	8/27/2	26.4 º	Momen	26.0 º	23.8 º	31.7 º
7		G1-A73.BT306.XQ0	AGGREGAT G1 GENERATOR KALL LUFT 1CVB02 TEMPERATUR	Control	Out.Val	SEAMLE	26.0 º	0.0	100.	0.00	Linear	8/27/2	26.1 º	TimeAv	25.9 º	24.0 º	31.9 º
8		G1-A73.BT401.XQ0	AGGREGAT G1 GENERATOR VARM LUFT 1CVB01 TEMPERATUR	Control	Out.Val	SEAMLE	36.1 º	0.0	100.	0.00	Linear	8/27/2	36.1 º	TimeAv	34.2 º	28.4 º	36.3 º
9		G1-A73.BT402.XQ0	AGGREGAT G1 GENERATOR VARM LUFT 1CVB02 TEMPERATUR	Control	Out.Val	SEAMLE	37.7 º	0.0	100.	0.00	Linear	8/27/2	37.7 º	TimeAv	35.4 º	29.2 º	37.7 º
10																	
11																	
12		G1-AG1.U03.XQ02	G1-Q REAKTIV EFFEKT	Control	Out.Val	SEAMLE	5.1 MV	-15.	15.2	0.00	Linear	8/27/2	5.1 MV	TimeAv	4.7 MV	-0.1 M	6.4 MV
13		G1-AG6.A01.XQ06	AGGREGAT G1 FÄLTSPÄNNING	Control	Out.Val	SEAMLE	156.9			0.00	Linear			TimeAv	143.9	0.0 V	158.7
14		G1-AG6.A01.XQ07	AGGREGAT G1 FÄLTSTRÖM	Control	Out.Val	SEAMLE	420.9			0.00	Linear			TimeAv	388.3	0.0 A	449.8
1		G1-AG1.U03.XQ04	G1-U SPÄNNING	Control	Out.Val	SEAMLE	10.9 k			0.00	Linear			TimeAv	10.2 k	0.0 kV	11.0 k

REMARKS:

Inspected by :______________________________________Date :____________________

Approved by :______________________________________Date :____________________

Signature of the Engineer or Client

ABB	CUSTOMER NAME PROJECT NAME			ABB OY PSP/BGEE	
Tester: Name	Date: 9.4.2013	Department Dep. Name	Project No:	Page Number: 1/3	Attachment: -

Owner of the facility:	Owner name
Facility:	Facility name
Hardware:	Generator G1 protection and excitation
	Main transformer protection

1. TESTING EQUIPMENT

1.1. Test apparatus Omicron CMC356	serial number	FC065K
	calibrated	
1.2. Multimeter FLUKE 87V	serial number	18320296
	calibrated	

2. GENERATOR PROTECTION

	OK	Deficiencies
2.1. Generator protection relay F11, REM545-BG226-AAAA		
- Differential protection		
- Overcurrent protection 2 steps		
- Overload protection		
- Unbalance protection 2 steps		
- Over frequency protection 2 steps		
- Under frequency protection 2 steps		
- Relay inputs		
- HMI-measurements		
- Alarm indications		
- Tripping		
- Alarms to the program control system		
2.2. Generator protection F31, REM545-BG222-AAAA		
- Under-impedance 2 steps		
- Under excitation 1 step		
- Reverse power 2 steps		
- Overcurrent protection 1 step		
- Unbalance protection 1 step		
- Overcurrent protection 2 steps		
- Undervoltage protection 1 step		
- Over frequency protection 1 step		
- Under frequency protection 1 step		
- Stator earth-fault protection 1 porras		
- Rotor earth-fault protection 2 steps		
- Relay inputs		
- HMI-measurements		
- Alarm indications		
- Tripping		
- Alarms to the program control system		
2.3. Excitation transformer protection relay F12, REJ523-B414-BAA		
- Overcurrent protection		
2.4. Shaft power protection K51, RARIC		
- Shaft current protection		

ABB	CUSTOMER NAME PROJECT NAME	ABB OY PSP/BGEE

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Facility:	Facility name
Hardware:	Generator G1 protection and excitation
	Main transformer protection

Item	OK	Deficiencies
3. MAIN TRANSFORMER PROTECTION 16S711-03		
3.1. Main transformer protection relay RET541-AM231-AAAA		
- Differential current protection		
- Overcurrent protection 3 steps		
- 110kV side, earth protection 2 steps		
- Relay inputs		
- HMI-measurements		
- Alarm indications		
- Tripping		
- Alarms to the program		
3.2. Main transformer protection relay REF541-AM231-AAAA		
- Overcurrent protection 3 steps (undirected)		
- Overcurrent protection 2 steps (directed)		
- 6kV side, earth protection 2 steps		
- Relay inputs		
- HMI-measurements		
- Alarm indications		
- Tripping		
- Alarms to the program		
4. GENERATOR EXCITATION 16T405-01/02/03/04		
4.1. Excitation channel 1		
- Manual controller step response		
- Voltage controller step response		
- Voltage regulator step response online		
- Limiters (V/Hz, If, Is, PQ)		
- Change of control mode A->M->A		
4.2. Excitation channel 2		
- Manual controller step responce		
- Voltage controller step response		
- Voltage regulator step response online		
- Limiters (V/Hz, If, Is, PQ)		
- Change of control mode A->M->A		
4.3. Excitation channels 1 - 2		
- Channel change at idle		
- Channel change online		
4.4. Excitation control		
- Running/off automatically/locally		
- Set-point up/down automatically/locally		
- Synchronization and circuit-breaker status		
- Trip from protection relay		

ABB	CUSTOMER NAME PROJECT NAME				ABB OY PSP/BGEE
Tester: Name	Date: 9.4.2013	Department Dep. Name	Project No: 0	Page Number: 3/3	Attachment: -

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Facility:	Facility name
Hardware:	Generator G1 protection and excitation
	Main transformer protection

5. REMARKS

	Corrected	Date
5.1.	☐	
5.2.	☐	
5.3.	☐	
5.4.	☐	
5.5.	☐	