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Usability of ABB Devices Virtual Commissioning Concept

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This study was done for ABB Oy Digital Team that is located in Helsinki, Pitäjänmäki. ABB Oy is developing a program that can virtualize a frequency converter and as a result of that it is also developing a concept on virtual commissioning. Because of how new the concept and its crucial tools are, ABB needed an in-depth investigation on the usability of the concept in a real customer project.

ABB Oy has been developing the program for virtualizing frequency converters for a while now, but not until the tool has become more stable and versatile have they had the chance to start realizing the virtual commissioning concept. ABB Oy's customers have not had a virtualization model that could be used to simulate and test entire automation projects and also because how remarkable the benefits of virtual commissioning are, ABB has started developing their virtual commissioning concept.

This study included the creation of a virtualization model for a customer within boundaries set by ABB's virtual commissioning concept. This way the concepts usability, weaknesses and strengths were tested and evaluated in a real customer project. The study revolved mainly around one customer project, but mentions another project done for another customer. The study also included a customer survey and its answers were used to verify the results of the study.

As a result of the study, it could be noticed that ABB's virtualization concept is in too early development stage, so that it could be used in high capacity, but possible with unique projects. Due to the time when the study was conducted, several essential tools within the virtual commissioning concept did not possess the features required, in order to realize the fluent construction of virtualizing a whole project. This slowed the virtualization of the customer project.

At the end of the study the results and future proceedings were addressed. The study identified that the study was conducted in too early stage in the concepts life cycle in order to tend to the customer and its users in a sufficient way.

Keywords	Virtualization, commissioning, HIL, virtual commissioning, simulation and modeling

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Insinöörityö tehtiin ABB Oy Digital Team -yksikölle, joka sijaitsee Helsingin Pitäjänmäessä. ABB Oy kehittää sovellusta virtuaalisesta taajuusmuuttajasta, ja tämän tuloksena se luo uuden virtuaalisen käyttöönottokonseptin. Koska tuote ja konsepti ovat niin nuoria, ABB tarvitsi syventävän tutkimuksen konseptin käytettävyydestä asiakasprojektissa. Tällä tavoin nähtiin, mihin suuntaan tuotetta pitäisi kehittää ja mitkä ratkaisut ovat jo toimivia.

ABB Oy on jo pitkään kehittänyt virtuaalista sovellusta taajuusmuuntajasta, mutta virtualisointikonsepti on tullut kehitteille vasta sen rakentuessa vakaammaksi ja monipuolisemmaksi. ABB Oy:n asiakkailta on puuttunut ABB:n puolesta valmis virtualisointi-malli, jolla voisi simuloida ja testata kokonaista automaatioprojektia. Koska virtuaalisen käyttöönoton hyödyt ovat huomattavia, ABB on aloittanut virtualisointikonseptin rakentamisen.

Insinöörityössä luotiin asiakkaalle virtuaalinen malli asiakkaan projektista ABB Oy:n virtualisointikonseptin rajapinnoilta. Täten pystyttiin arvioimaan virtualisointikonseptin nykyinen käytettävyys, heikkoudet ja vahvuudet oikean asiakasprojektin tiimoilta. Työ keskittyi pääosin yhden asiakasprojektin ympärille, mutta työssä viitataan myös aikaisemmin tehtyyn projektiin eri asiakkaalle. Työ sisältää myös asiakaskyselyn, jonka tulokset vahvistavat työn tuloksia.

Insinöörityön tuloksena huomattiin virtualisointikonseptin olevan liian aikaisessa vaiheessa ison kapasiteetin käyttöön, mutta yksittäisillä projekteilla mahdollinen. Useat virtualisointikonseptille keskeiset työkalut eivät sisältäneet vielä nykyisellään kaikkia tarvittavia ominaisuuksia virtualisointikonseptin sujuvuuden varmistamiseksi ja hidastivat projektin etenemistä.

Työn lopussa käsiteltiin työn tulokset ja tulevat toimenpiteet. Insinöörityön tuloksena havaittiin työn olevan liian aikaisessa vaiheessa virtualisointikonseptin elinkaaressa palvellakseen asiakkaita ja sen käyttäjiä hyödyllisellä tavalla.

Avainsanat	Virtualisointi, käyttöönotto, HIL, virtuaalinen käyttöönotto, simulointi

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Appendix 1. Customer Survey

List of Abbreviations

PLC	Programmable logic
OS	Operating system
VC	Virtual commissioning
Soft-PLC	A virtually enabled PLC that can run on any PC hardware.
HMI	Human-machine interface
Drive	A common used word for a frequency converter in a technical environment.
OPC	Open Platform Communications, is a series of standards and specification for industrial telecommunication.
FAT	Factory Acceptance Test

1 Introduction

The study was made for ABB Oy, a pioneering technology leader, and more specifically ABB digital team which is located in Helsinki, Pitäjänmäki. The subject of this study is investigating the usability of ABB's virtual commissioning concept especially regarding one customer case. The virtualization concept is in development and is to be considered a concept that the ABB Virtual Drive has enabled. No other studies had been made of the virtualization concept rendering the importance of research on the subject valuable for both development and end-user purposes.

The written part of the project includes theory on the subject itself including general information on automation and virtual commissioning, a reason on why this investigation was commissioned and the goals on what should be achieved with the project. The thesis immersed in the meaning and usage of virtual commissioning related to manufacturing processes and different types of virtual commissioning models. The theory on virtual commissioning types revolves mostly around ABB's virtual commissioning concept but also introduces a tool made by Siemens and other manufacturers.

The main goal of the thesis was to investigate ABB's virtualization concept, find possible deficiencies, report them and make improvement suggestions on the findings. AP&T Groups press model case is referred to as the reference case of this thesis. The thesis will also include a written survey that AP&T will answer for the analysis and study of the thesis. The study will also include compact information on another virtual commissioning project with Veisto Oy.

Study methods used in this project include research analysis from other studies, a work project that is done with ABB's virtualization concept and analysis on how it performed within the project, and a written survey for analysis on how the end-user feels about the concept.

2 Background

2.1 Introduction of ABB Oy

ABB Oy is a pioneering electrical and automation- engineering company that works closely with various widely appreciated customers in roughly 100 countries. Its manufacturing facilities in Finland are mainly focused in Helsinki, Vaasa and Porvoo and ABB Oy employs around 136 000 people of which 5 200 are in Finland. [1]

ABB Oy (Asea Brown Boveri) was formed in 1988 with the merging of the Swedish Allmänna Svenska Elektriska Aktiebolaget (ASEA) and the Swiss Brown, Boveri & Cie (BBC). There are many major achievements ABB has since accomplished with the fusion; 1998 – ABB launches the FlexPicker, Delta which is designed exclusively for the needs of manufacturing automation and companies, 2004 – ABB launches the System 800xA – automation system that has since been installed in thousands of process automation manufacturing facilities, 2012 – ABB successfully designs and develops a hybrid DC breaker suitable for the creation of large inter-regional DC grids. This breakthrough solves a technical problem that has been unsolved for over a hundred years. [1]

The roots of ABB and particularly Pitäjänmäki, Helsinki come from the company Strömberg Oy which was a leading manufacturer in Finland of converters, motors, generators and different machines of its time. In 1987 Strömberg was sold to ASEA and has ever since been the headquarters of development and research in ABB regarding drives and motors. [1]

ABB Oy is mostly known for its digitally connected and enabled industrial equipment and systems with an installed base of more than 70 000 control systems connecting 70 million devices. [1]

2.2 Introduction of the Customer

AP&T (Automation presses tooling) is a Swedish company that develops production solutions that focus mainly on automotive, climate & energy and roof drainage industries. It was founded in 1964 and has since been a global producer of sustainable production

solutions. AP&T originally developed servo press models that were hydraulic and base on a single shaft but has since moved into developing more complex and sophisticated models. [2]

AP&T was interested in the virtual commissioning concept produced by ABB and wanted to simulate their production process. ABB's virtualization concept looked most suitable for the project and was the reason they wanted to work together with ABB. The press model system is also a very good option for ABB as it offers ABB evidence and results of the work because of how the press systems include many essential parts of simulation including power conversion optimization and the overall of the model resembling sequence programming.

3 Theory on the Background of the Project

3.1 Previous Investigations

Research on virtual commissioning has been ongoing since the early 2000s and knowledge of its pros and cons have changed over the years. Research and reviews are focused on one reference case or subject and an abstract research of virtual commissioning in full has not been conducted. The various researches can be used to acquire more than enough knowledge on the subject. Any research on particularly ABB's virtual commissioning concept has not yet been done.

3.2 Automation Technology

Automation technology has played its part in various industries ever since the industrial age. However, the word automation was first introduced in 1948 when an American Ford vehicle manufacturer Delmar S. Harder used it to describe a combination of a mechanically working machines with electronical control. The meaning of the word automation is rather self-explanatory, as it can be defined as a technology that is performed and produced or processed without the help of a human. Automation evolved in the 1960's when programmable controllers were included and has ever since been used in various industries around the world and has become a standard in the industry. Automation is divided

into several different groups with the means of the industry e.g. manufacturing, process, home and energy automation. [3]

3.2.1 Automation in Manufacturing

Highly automated manufacturing has been important for the industry to compete with low-cost countries due to the relative high salary costs in especially the US and Europe. Especially in the 20th century, manufacturing automation was developed to radically increase efficiency of product manufacturing processes and the sustainability of higher quality products. However, even in the 1980s there were attempts on making so called "lights-out factories" that were fully automated. These attempts are still being done and as an example Tesla Oy, a globally known manufacturer of electric cars, found themselves having a factory with a network of complex conveyor belts. According to Elon Musk, the founder of Tesla: "It was not working so we got rid of the whole thing." [4] Elon Musk also added: "To be precise, my mistake. Humans are underrated." [4] The majority of manufacturing processes are semi-automatic with them consisting a human-variable that does manual tasks because of different restrictions made by governments and standards. [3]

3.3 Virtualization

Virtualization can be referred to as creating a simulated version rather than the actual version of a subject. Virtualization was considered to start in the 1960s when computing power was not as significant as today and computer mainframes needed to divide its power into several applications. [5]

3.3.1 Virtualization Types

Hardware virtualization is a common name for hardware assisted virtualization and is thought to be misguiding as is. It is also a common name for two very similar technologies provided by Intel and AMD. Hardware assisted virtualization basically lets the user run multiple operating systems on the PC by sharing the existing hardware with the assistance of a hypervisor. A hypervisor is a program that helps the user run and manage

their virtual machines. Hypervisors also help interact with the multiple OS's ran by the host. [5]

As an opposite of hardware virtualization desktop virtualization uses an entirely different desktop computer or mobile phone to interact with the host, usually by the means of a network connection and a hypervisor. [5]

However, when talking about virtualization in this work it does not mean anything of the above but is a rather misguiding name set by the automation and technical industry.

3.3.2 Hardware Abstraction Layer

Hardware abstraction layer (HAL) is used in programming worldwide. It is a layer implemented between the software and hardware that gives the program being developed direct access to hardware resources. The basic functionality of a HAL is to hide differences in hardware so that the software doesn't need to change to function. In a PC environment, a HAL can be considered as the driver for the motherboard so that higher level computing languages can access lower level components. [6]

3.4 Simulation and Modeling

The terms simulation and modeling go hand in hand, but don't mean the same thing. A model is a system of data, dimensions and postulates that is described as an entity. Then modeling is the process of arriving to at a set of data, dimensions and postulates. The models are set with mathematical and physical equations and logic rules to assume their behavior. In broader context simulating means assuming the appearance or attribute without thinking of the reality. In this projects context simulating means exercising the model to obtain results. The difference between simulation and modeling is thought to be that modeling is the development of the mathematical equations and logic rules and then again simulation is exercising the model, in order to get results. [7]

The lifespan of a simulation might exceed 10 years if a considerable amount of development and maintenance is done to the simulation. Usually constructing the model takes

the most time, but once done the need for maintenance is marginally lower than say the simulation. [7]

3.4.1 Hardware-in-the-Loop

Systems and machines are controlled by computers with intricate control systems and Hardware-in-the-Loop (HIL) is a solution to test and develop these control systems. The physical part of a system, e.g. plant or process, is connected to control system, but with HIL simulation the system is replace with a simulation of the system. Depending on the quality of the HIL-simulation, it should act as a real system would with the accuracy mandated by the said quality. The purposes of HIL simulators are to run test that result in saving time and money, increasing safety and enhancing quality of the actual process or plant. [8]

3.5 Commissioning

Commissioning is the part of any project that the producer would like to achieve as fast as possible as it is the part where the project is verified and is being put to use. This is reached only after having met the criteria of precommissioning. The criteria of precommissioning is that the process can handle real-world conditions and is certified. In addition to that, each industry has its own set of rules and standards on what the project should achieve before commissioning is started. Some projects undergo extensive precommissioning programs before putting into use because of the nature of the accidents that would occur if, something was to go wrong. As an example; the construction of a building can be mentioned. [9]

The process consists of planning, documenting, scheduling, training, adjusting, testing and verifying (Figure 1.) so that the subject in case, for example a product line of a factory, operates with the requirements set by the owner. The goal of commissioning is to enhance the quality of the subject delivered to the customer. Usually project owners try hire commissioning providers at the earliest state of the project process so that the commissioning provider can influence corrections without unnecessary loss. In the building industry LEED certification is the most widely used green building rating system in the world and in order to achieve LEED certification in any building manufacturing project,

the commissioning process is mandatory. As shown in figure 1, commissioning can also be done in a later state of a project or continuously. [10]

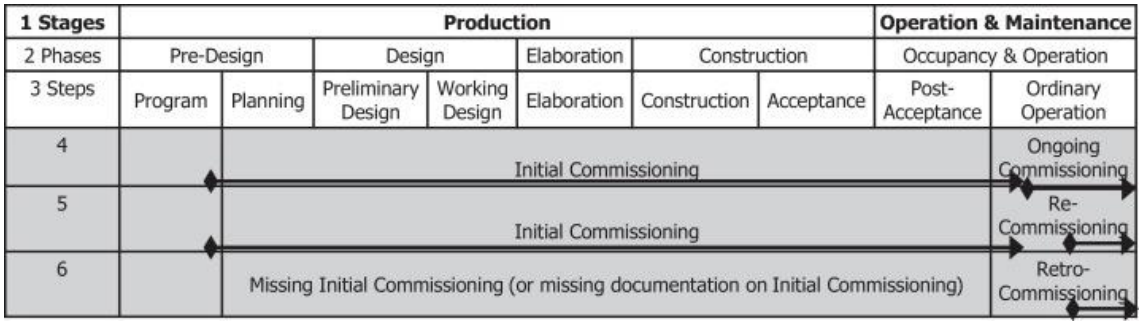

Figure 1. The Commissioning Process [11]

Retro-commissioning is a process for projects that have not been previously commissioned and for instance many buildings have been built without a commissioning process. This results in to having flaws in the construction or design that could further result in for example a poorly energy sufficient design or poor functionality of the building. [10]

Re-commissioning projects are projects that have already undergone the commissioning process, but due to, for example, the building process may have turned out flawed. [10]

Continuous commissioning is as the name would suggest, a continuously done commissioning process in order to perceive deviations from the requirements set by the owner. [10]

3.6 Virtual Commissioning

In its early ages virtual commissioning models were unattractive to users, especially small and medium-sized enterprises and developers, because using them required a large amount expertise and effort. In the present the use of virtual commissioning models has sky-rocketed as it has such a large impact in its environment and knowledge in it has obviously increased potentially. According the Zäh and Wünch 2005 [12], a study of VDW (German Association of machine tool builders), the commission time of a process takes up to 25% of the time available for plant engineering and construction, and up to

15% is used for correcting errors and bugs in the control software alone. This can be roughly calculated into 9-12.6% of the duration of the virtual commissioning process is used on correcting error and bugs. (Figure 2.) To tackle these highly negatively impacting percentages in commissioning virtual commissioning is proposed. [12]

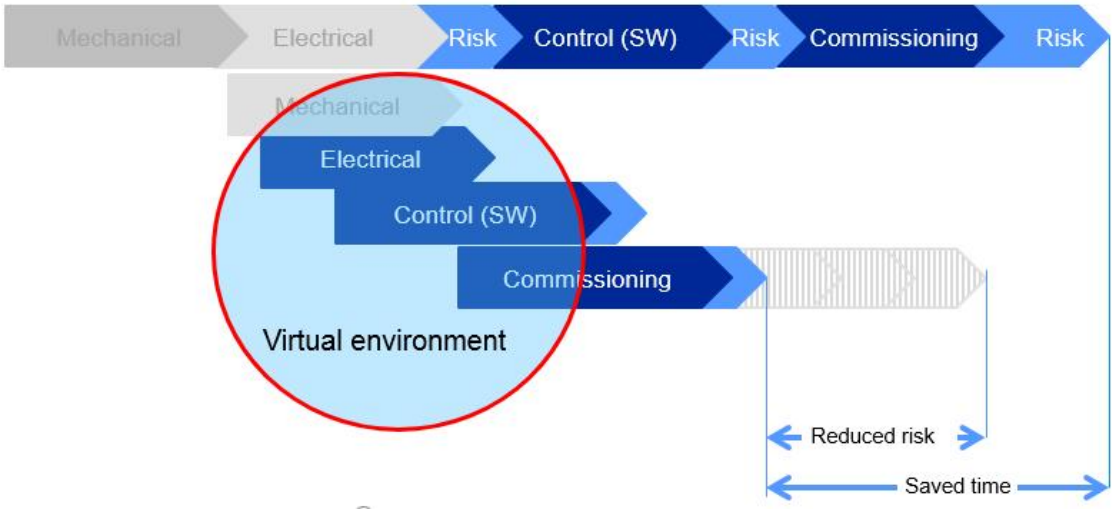

Figure 2. The Benefits of Virtual Commissioning

Virtual commissioning means exactly what the word would suggest; “Virtual” meaning simulated and “commissioning” meaning designing, installing, testing, operating and maintaining. When combined as “virtual commissioning” it means using simulation technology, in order to test various changes and variations on the subject before the real system is made and that way avoiding the risk of downtime and revenue loss. [12]

Investigating the feasibility and usability of virtual commissioning has been a major objective in research of the topic. With the usage of geometry, kinematics and mechanical design, realizing a 3D simulation of the subject specified is sufficient. virtual commissioning can be used to detect mechanical and geometrical planning errors. To simulate the process, the specification of a control program is needed at the I/O level and that way virtual commissioning can run the 3D simulations specified by the project. With a model as this, virtual commissioning can detect errors in the specified control program by monitoring the 3D simulation reflecting any unwanted behavior. [12]

3.7 Virtual Commissioning vs. Traditional Commissioning

Virtual commissioning is a way of realizing commissioning. Figure 3 helps understanding the differences of virtual commissioning against other more traditional commissioning methods.

1. Traditional commissioning with a real control system and hardware.

2. Hardware-In-the-Loop (HIL) commissioning, virtual commissioning. The control system is real but the hardware is virtual

3. Reality-In-the-Loop (RIL) commissioning. The hardware is real and the control system is virtual.

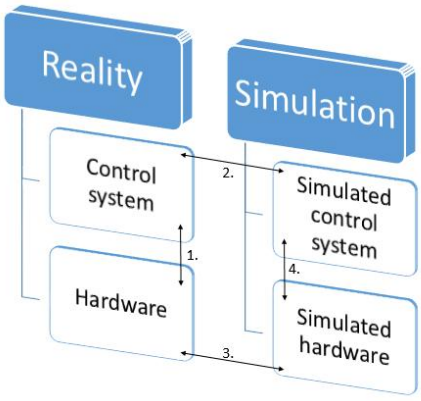

Figure 3. Ways of Commissioning

4. Software-In-the-Loop (SIL) commissioning. Both the control system and hardware is virtual.

A fact that should be noticed is that in the In-Loop principle RIL commissioning can be thought of as Hardware-In-the-Loop commissioning because the simulated control system is in interaction with the real hardware. [13]

In relation to system technical applications the commissioning process can be explained as the following. As an example the commissioning steps of realizing a power plants control system (step name is in brackets).

- Verifying of requirements and standards (System Requirements)

- Realizing of the control and model (High-Level Design)

- The creation of the simulated control and its testing (Detailed Design)

- The testing of the simulated control against the real plant. RIL commissioning * (Detailed Design)

- The release of a prototype (Implementation)

- Testing the prototype against a simulated plant. Virtual commissioning (Unit / Device Testing and Subsystem & Verification)

- Creation of the power plant (Implementation)

- Testing of a real control system against the real plant. Commissioning (Subsystem & Verification)

- Realizing the prototype as a real commissioned control system

* = system technically close to impossible

The benefits of virtual commissioning in such systems is the possibility of verifying and developing the control system when the commissioning process is still in the designing phase. In many cases and especially the designing phase, the developed control system cannot be tested against real hardware rendering the creation of the virtual model the only option. [13]

3.8 Current State of Virtual Commissioning

As virtual commissioning is being thought of as a necessity in the current world of production. A fair share of different virtual commissioning types are available on the market and with no doubt double that being developed. The most known virtual commissioning solutions are Tecnomatix® from Siemens PLM and the one developed by ABB.

3.8.1 Virtual Commissioning Tools and Concepts

During the last 10 to 20 years many packages that can be used in the implementation of a virtual commissioning project have been developed and are available in the current

market. WINMOD is a software that utilizes Macro file concept and can be linked to the control software and hardware in the same way as a user would a real system. It can be used to observe I/O signals in a close way. INVISION is a simulation system that can be used to plan and visualize product operations in real-time. It can be coupled with WINMOD for real-time HIL-simulation. Delmia, developed by Dessia Systemes allows the virtual realizing of PLC control systems for production lines, machines and cells. It uses OPC communication for the linking of real control systems with its simulated resources. [14]

Finally, Tecnomatix is introduced to work similar to Delmia as it uses real PLC programs with real hardware through OPC. Tecnomatix is a portfolio of multiple different Siemens products that each play a part in product engineering, manufacturing engineering and production. The programs used are: Part Planning and Validation, Assembly Planning and Validation, Robotics and Automation Planning, Plant Design and Optimization, Quality Management, Production Management and Manufacturing Process Management. [15]

These programs help create and simulate endless types and variations of the customers' needs. However, these processes can't be linked with actual devices and processes making them simulation only.

3.8.2 ABB's Virtual Commissioning

The virtual commissioning solution developed by ABB is used for the products released by ABB, alongside the compatible program platforms designed, in order to ease the user into the virtual commissioning environment with the use of already known programs. Nevertheless, the concept can also be used in 3rd party systems. As it uses several programs, they can be interlinked, resulting in a full monitoring, configuring, programming and simulating platform. (Figure 3.) The virtualization of ABB drives offers the possibility of monitoring and debugging a real time drive within the 3D-simulation and all its signals like it was a normal drive in a normal system. The concept consists of six steps; Mechanical design, modelling, electrification, automatization, on-site commissioning and training.

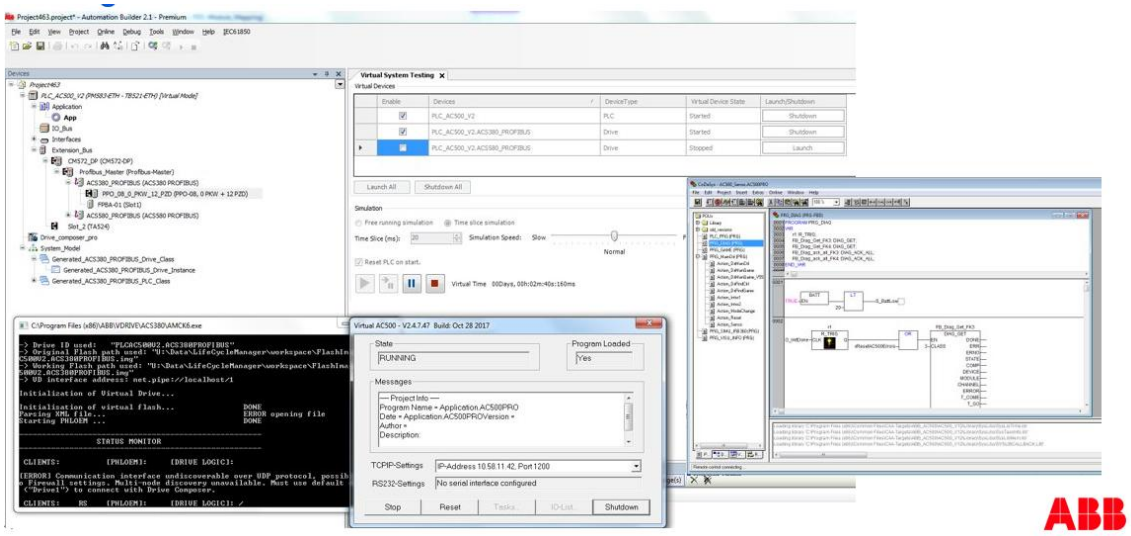

Figure 3. Interlinking of ABB Programs

Mechanical design in this instance meaning importing mechanics into the Robotstudio environment with the building of a 3D model. This allows modelling of the design and the modelling of the machine's behavior. Robotstudio can be used with SimuLink to simulate complex physical behaviors. Electrification meaning analyzing and selecting the compatible components required by the virtual commissioning from the large repertoire of components that ABB has to offer, and which are implemented in all of the said program platforms. The automatization of ABB's virtual commissioning concept includes programming, configurating and testing (FAT) of the projects in work. This is done with Automation Builder, as it is a tool that can do all the above. In the case of virtual commissioning, on-site commissioning means the installation of said virtual commissioning onto the customers' desktop with its tools and control programs. Finally, the concept includes training for the customer on use of the said project. This step usually means training the customer on how to use the tools provided by ABB and how to use them together. (Figure 3.)

In summary the virtual commissioning concept can be divided into three different use cases which increase in difficulty of use, but provide a more in depth solution to the customer;

The first use case encases the use of ABB's virtual drive in parameter configuring of the drives for parameter backup or restore solutions. This case uses only two tools which are Drive Composer pro and the ABB virtual drive. As a virtual commissioning solution

this use case handles only the commissioning of the drive. The benefit of virtual commissioning in this way leaves the customer more time for other tasks as parametrization and commissioning of a drive can take up to two hours.

As a second use case of the solution ABB proposes to add the control system commissioning along with the parametrization of the drive. This adds one tool into the equation: Automation Builder. This program handles the IEC programming and control system modelling. Automation Builder has the option of using a soft-PLC as opposed to a real PLC and fieldbus simulation between the PLC and virtual drive can be used for virtual commissioning purposes. This use case reduces the time spent on the testing and debugging of the IEC-program and control system marginally. This eliminates the biggest deficiency in traditional commissioning as referred to in Chapter 3.3.

The third use case introduces system modelling and 3D-simulation with the tool RobotStudio. RobotStudio can be traditionally used to model systems and create 3D-simulations, but it can also be linked to Automation Builder or the Virtual Drive providing the possibility of virtual commissioning. It can be used to test the system and its geometrical and kinematical models resulting in the testing and designing being done before hand.

3.8.3 ABB Virtual Drive

In short, the ABB virtual drive (VD) is a program that simulates a normal drive on a desktop and is in a major role in the virtual commissioning concept. It has all the possibilities of a real drive from I/O configurations and parameter list selection to built-in IEC programming capabilities. The virtual drive is based on the ACS880 model developed by ABB and all of its different types. It runs similar firmware that is used in real drives and because a PC doesn't have the hardware required for a drive it is simulated with HAL.

As the ACS880 drive is based on maximizing modularity for the most efficiency, the virtual drive behaves in a similar way. Each drive module type can be simulated with all of the accessories available for that specific drive. This reduces the load that the virtual drive generates on the computer it is running on and helps the user with the selection of the drive module and accessories.

4 Reference Cases

4.1 AP&T's Press System as a Reference Case

The current state of the customer's press system manufacturing model cannot implement ABB drives into the current virtual commissioning solution they are using. Using ABBs virtual commissioning solution would allow the simulation to be more precise and increase the quality of the simulation.

AP&T is interested in three main aspects of benefits that ABB's virtual commissioning concept has an effect on; dimensioning, program testing and training. Because the press system can consist of up to 23 motors and multiple drives the electrical bill alone is of significant importance in the design of the press systems.

4.1.1 Overview of the Project

The to-be virtualized project is a system press model that is currently using ABB's drives and Beckhoff PLC's. For now, the press model has one main axes and two secondary axis which all work in coordinated motion in order to control the press. AP&T has set a specific set of requirements for the project regarding the 3D-simulation done with Robotstudio.

The press model is set to have one to three pumps per axis which are all controlled by the ABB drives and ultimately, they are controlled by the control system which is for now a Beckhoff PLC. The control system side of the project should be converted from a Beckhoff PLC into an ABB PLC with Codesys 3 support. ABB's new AC500 PMXXXX PLC series that is to be released this year was chosen for the conversion of the control system.

This instance of the press model has one main axes and two tertiary axes that are used for the actual pressing and vertical motion of the press. Each axis is controlled hydraulically with a certain number of pumps which are then controlled by a motor connected to an ABB drive and from there the Drives are connected via Fieldbus to a controlling

Beckhoff PLC and motion system. The main axis is a simulated axis of which the two-secondary axis get the speed or position reference from. (Figure 4.)

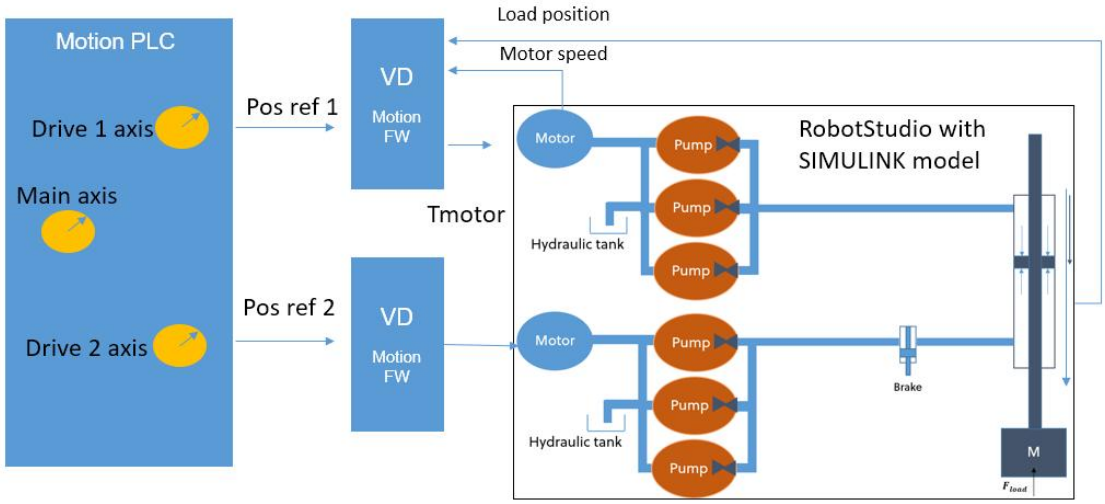

Figure 1. Overview of the Press Model

In order for the virtual commissioning not to be set to a specific project the requirements of the virtual commissioning solution would be extended e.g. the number of pumps and the physical modelling of the press, and these would be interchangeable in virtual commissioning system. This will allow the customer to use the virtual commissioning model in other press projects and eliminate the need of future virtual commissioning.

4.1.2 Tools Used in the Project

The virtual commissioning concept introduced by ABB revolves mainly around three programs, but many more are needed in order to perfect the commissioning process. The main programs used are the virtual drive, Automation Builder and RobotStudio with the configuration tools being Drive Composer pro and SimuLink.

ABB Automation Builder is an IEC-application development platform that covers the engineering of ABB PLCs, control panels, drives, robots, etc. It can be configured with system modelling for the configuration of virtual drives in a project and used to run soft-PLCs. Other similar tools include Siemens Tia Portal and Beckhoff TwinCAT. [16]

Drive Composer Pro is a start-up and maintenance tools for use with ABB's drives. It can be used to configure parameters and monitor performance. It includes the option to create parameter lists for the ease of configuring and commissioning. [17]

RobotStudio is a PC-based platform for simulation training, programming and optimization which can be linked with automation builder to a virtual drive or directly to the virtual drive. It is mostly known with the use in configuring ABBs mechanical robot hands. [18]

4.1.3 Work Progression

The project started with setting the requirements for the virtual commissioning implementation into the customers' press model system. The project moved onto following the basic guidelines of any project. The development part of the work was divided into three separate groups; simulation and modeling, IEC-programming and connecting the separate tools to realize the virtualization concept.

A part of the work progression included the building of a 3D-simulation in Robotstudio (Figure 5) with correct physical and kinematical calculations and formulas. The calculations are implemented into the simulation in RobotStudio via SimuLink. The formulas included basic pump related calculations and equations that were confirmed to be accurate by the customer. (Equations 1-5)

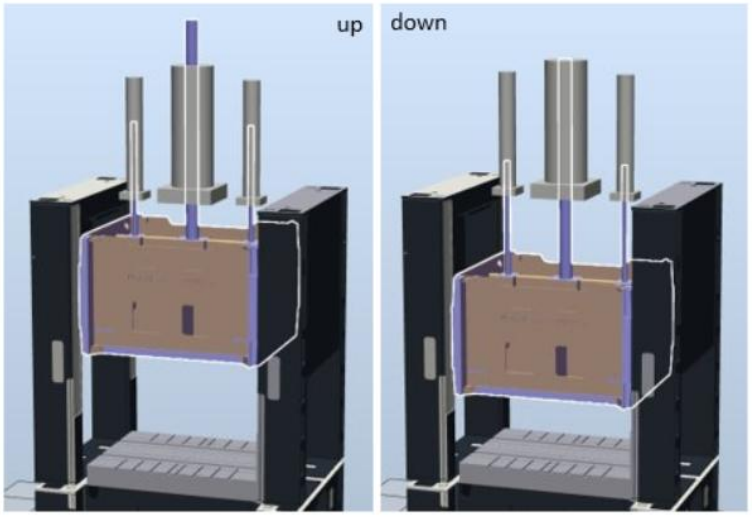

Figure 5. A 3D-model of the Press System

$$Flow\ q_v = \frac{V_g * n * n_v}{1000} \quad (1)$$

$$Torque\ T = \frac{V_g * \Delta p}{20 * \pi * n_{mh}} \quad (2)$$

$$Power\ P = \frac{2\pi * T * n}{60000} = \frac{q_v * \Delta p}{600 * n_t} \quad (3)$$

$V_g = Displacement\ per\ revolution\ in\ cm$^3

$\Delta p = Differential\ pressure\ in\ bar$

$n = Speed\ in\ rpm$

$n_t = total\ efficiency$

$$n_{mh} = Mechanical - hydraulic\ efficiency \quad (4)$$

$n_v = volumetric\ efficiency$

$$n_t = n_{mh} * n_v \quad (5)$$

It was decided among the team, as mentioned earlier, to convert the PLC into an ABB PLC and this turned out to be challenging, as the new ABB PLC series PMXXXX that are Codesys 3 compatible are still in development and had unfinished features. One missing feature included the usability of ABB soft-PLCs in Automation Builder, as it is still in development. This feature was added into a newer version of Automation Builder and set back the timetable of the project.

A big part of the project was the re-programming of the control system from the Codesys 3 utilizing Beckhoff environment into the ABB environment, as the motion library made by Beckhoff was different to the counterpart from ABB. Both the libraries were made with OpenPLC motion control standards and because the Codesys 3 implementation to ABB PLCs was made to such a new product, the motion libraries made by ABB had rather pendent documentation. This resulted into studying the motion library, in order to create

a program that was among the requirements set by the customer and a prominent setback in the timetable of the project. After consulting the customer requirements were reduced to create a working virtual commissioning tool for the customer as a first step in the process. One of these reductions included the simplifying of the control program to include only the essential components.

The control program utilizes a motion control library developed by ABB and has the earlier mentioned three axis that work as mentioned. The main axis being a continuous rotator that gives position or speed reference to the secondary axis with the help of the load position feedback signal from the press model and a set speed gave by the controller. (Figure 4.) The control program is connected to Robotstudio with the help of a component added into Robotstudio called a SmartComponent. The SmartComponent is an additional component for RobotStudio that enables the connection from RobotStudio to either the virtual drive or PLC. This component, at its current state, is to be configured for every project separately.

The project was put on hold as the latest Automation Builder version does not have the features needed in this project and a full virtual commissioning solution was not yet provided to AP&T by ABB. The project will resume as soon as a work around has been figured or the development of the tools used have proceeded to a degree where the features exist.

4.2 Veisto

ABB was a part of a virtual commissioning project with Veisto Oy throughout the year 2017 and had calculated to be able to save up to 25% of costs. According to Jarkko Lalu, Desing Manager, ABB Drives: “ABB’s virtual commissioning can provide benefits at every stage of the automation lifecycle. Integrators can test design concepts, save engineering and commissioning time and de-risk projects, whereas machine operators can improve training and test configuration changes offline.” [17] The calculations also estimate that with the use of the solution on a €600,000 project it could save up to €120,00, including a 20% cut in engineering time, a 25% cut in capital outlay, and 50% cuts in training and quality costs. According to ABB the investment to virtual design techniques and tools easily pay back.

The customer project for Veisto Oy was to implement the virtual commissioning tools and concept into Veisto Oy's sawing line model that Veisto had developed. This project did not include any surveys, but only comments from the customer as feedback for ABB. Veisto Oy provided ABB with a ready 3D-model that was then converted into a simulation. The project included the implementation of the system control and HMI that interacted with the simulation and was meant for training and presentational usage.

The Vice President of Veisto Oy, Tuomas Halttunen, gave the following comment: "It's very beneficial to use ABB's virtual commissioning software, for example, in training of machine users". [18] Tuomas Halttunen also added that after the usage of the virtual machine they are more confident in taking a real production line into use.

5 Customer Survey

This study includes a customer survey in addition to the study. The survey was carried on as a written survey delivered to the customer via email. This form of collection of study was chosen because of the record ability of the survey method itself and as the written survey had freely answerable questions it would include profound answers related to the thesis and the reference case.

Written surveys allow the respondent the greatest latitude in pace and sequence of response and imminent responses from the customer could leave essential information unanswered. There are also minimal interviewer and respondent measurement errors due to the absence of direct contact. [19]

The survey was directed to only one customer, AP&T, rendering the considering of the sample size to none and enabling the possibility of making unique questions directed straight to the answerer. This makes the survey have no statistical power, but due to the stage of development the answer wanted need more specific answers.

The survey includes a "willingness to cooperate form" in order to quote and analyse the survey in this study and the survey was done during the spring of 2018.

6 Conclusions and Summary

The purpose of this study was to find the strengths, weaknesses and improvement points of the virtual commissioning concept introduced by ABB. Because the virtual commissioning solution is still in development this study is of certain importance to ABB as they can review the virtual commissioning concept more thoroughly and adjust development according to the findings. As studies on the concept have not been done before, we can only rely on facts on other project studies and discoveries made by the customer reference cases in Chapter 4. Statistics, except the customer survey, cannot be reflected from this study as two customers is not enough to build statistic data.

As the tools used in ABB's virtual commissioning concept are still in development the users' expertise and skills in the development of the project is a factor that may falsify the results of the study. Also, the fact that the projects done for Veisto and AP&T were made by ABB and this study is conducted on an ABB product may render the point of view of this study non-objective to a certain degree.

The study method being producing a virtual commissioning environment for AP&T and producing a written survey resulted that the study could not completely investigate ABBs virtual commissioning concepts development as the preference case was delayed. This forces the analysis of the study to concentrate on earlier completed virtual commissioning solutions provided to customers and emphasizing feedback from e.g. the project done for Veisto Oy. The written survey that was performed can be used as general feedback from AP&T and their relations to virtual commissioning solutions but cannot be reflected straight to ABB's virtual commissioning concept, as they only have general knowledge on the subject acquired from demo presentations performed.

The customer survey conducted (Appendix 1) indicates that the customer has not yet used the commissioning product and does not have any experience with the usage in order to criticize or give feedback on it. It also reflects the customers need for an educational tool that has minimal costs compared to running the press system that consumes large amounts of electricity. In addition to that the survey indicates that AP&T are willing to dimension their press systems in simulation and use the simulation to demo their systems to end customers.

6.1 Conclusions

A subject that cannot be overlooked is the usage of products that are in development. This meaning that they do not have fully functioning features as they are not yet finished products. Several parts of the virtual commissioning process required the usage of these products as mentioned in chapter 4.3 Work progression, resulting in downtime in the development of the project. This factor would have been eliminated with the usage of released products. However, some of the functionalities needed in the process were not included in the older products. As an example, the need of the development version of Automation Builder with Codesys 3 support and specifically the soft-PLC that was not yet released.

When implementing a new system or tool into a successful organization appropriate personnel must train themselves and acquire enough knowledge of the tool in order to train new users into the system. The training of the tool to customers, from ABBs perspective, was lacking in the preference case as it was not yet completed and delivered to AP&T. In the completed solution provided to Veisto Oy the customer was trained in a manner that they could present the solution in technical event in Germany. This reflects only a partial amount of training that a complete virtual commissioning solution providing would require.

The tools apparent with ABB's virtual commissioning concept had insufficient documentation making the usage of the tools difficult. This would reflect to new users of the concept, at its current state, and making the usage of the tools difficult. The answer to insufficient documentation will be resolved once the tools are officially released and the documentation will be apparent.

A general issue that the study was influenced by was the dependency of other factors e.g. tool development teams, AP&T in the progression of the project. This resulted in many setbacks in the timetable of the project and this study. Because of a project of this size any attempts to make a more successful study, except making a study on the matter later on in the development of the virtual commissioning concept, could not have been done.

The research conducted by Zäh and Wünch in 2005 [11] indicated that the time spent on program fixes and debugging would calculate to 9-12.6% downtime in a traditional commissioning project. And the calculation regarding the virtual commissioning implementation for Veisto indicated a rough 20% saving in overall costs. Because, commissioning time spent can be compared to downtime of the project and the overall losses, the calculations give the study analysis a direction but cannot be directly related to the strengths of ABBs virtual commissioning concept.

A customer survey was done to get feedback from the customer (Appendix 1) and the answers indicate two main subjects. The first one includes the fact the customer has no experience in using the virtual commissioning tools which reflects the lack of training which also reflects from the project not being completed. As pointed out in Chapter 3.8 that ABB's virtual commissioning concept provides training to the end user this factor only stands out in this project and will not have any value in projects done in the future. The second factor is that AP&T will use the ready virtual commissioning project for training and demonstrating their press systems to their end customers. This will eliminate unnecessary costs in electricity and construction.

6.2 Summary

The subject of the thesis was to study the usability of ABB's virtual commissioning concept especially around the reference case done for AP&T. The main goals of the study were to find the weaknesses and strengths of the subject and report them to ABB. The reference case, which was of great importance in the findings of this thesis, was not completed, rendering the findings incomplete in the scope of the whole project. ABB's concept is to the findings of this study the only virtual commissioning solution that can include the virtualization and simulation of a drive, a 3D-model and a control system. That indicates that the possibilities of the solution in market are tremendous, but only if the fundamentals of why virtual commissioning is "required" in today's market are followed. The study also indicates that virtual commissioning has a positive effect on cost savings compared to traditional commissioning but is still in a development stage. The strengths of ABB's virtual commissioning concept include its versatility and comprehensiveness due to the amount of tools and their connectivity to each other and the possibility to include every part of process into account. The weaknesses of the concept are

also relatable to the tools, only in its current state of development, as they are still unfinished and require more amount of work to operate and learn then necessary. Also the fact that the tools are still in development made it impossible, for now, to complete the virtualization of AP&T's press system while fulfilling their requirements.

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ABB Oy Kasperi Karjalainen 25.4.2018

AP&T – Customer Survey

My name is Kasperi Karjalainen and I am making a thesis, for my bachelor's degree, studying the usability of the virtual commissioning concept developed by ABB. I would like to use this case as a reference case for my investigation of the thesis so that I would have actual feedback from a customer to support and add findings on the subject. This case would also be used to explain the work progression that comes into virtual commissioning.
Please answer freely to the questions asked.

1. What kind of pros / cons do you see in the virtual commissioning concept from ABB?
   I see only pros in the long term.

2. Would you consider this purely PC-based simulation beneficial? What do you see as potential problems?
   Yes,
   It must handle motion functions as well, How to solve position feedback?

3. Is the concept and the usage of its tools easily understandable?
   No idea, have not used it by myself, only as demo

4. What improvements would you like to see in the environment and its tools?
   No idea yet.

5. How do you think the virtual commissioning tools provided by ABB would affect your manufacturing and planning processes?
   Yes, as education and we will get the opportunity to run our machine on "desktop"

6. In which field would you find the environment most valuable and most useful in?

   Automation and testing / Operative training / Physical dimensioning
   Why?

   All, If we could simulate a complete hydraulic press that give us the opportunity to check the dimension of complete power train before selling it to our customer. It also give us the opportunity to show a full press simulation for our end customer.

6. What simulation environment and concept are you currently using?
   none

7. How do you feel using Automation builder & RobotStudio compared to the other simulation / IEC-programming platforms you have used?
   No idea