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Enabling Digitalization with Plant Engineering Software COMOS

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This thesis seeks to discover the benefits of digitalization within the Finnish forest industry, and to represent tools for harnessing these benefits. The primary research question is how to obtain the advantages offered by digitalization as researched and predicted by the industrial community. Following this, interest is shown particularly to identifying the key-elements enabling this endeavor.

The Siemens' software selected for this case-study are briefly introduced and their roles explained. The most important of these tools is the plant and data management software COMOS. Concerning COMOS, the insertion of data, and the functionalities that allow for the most concise representation of an entire process are examined in detail. The emphasis is on representing the central role of COMOS within the conception of digital twins. The study is based on contemporary and qualitative research as well as hands-on-experience and instruction from professionals.

As a result, it is argued that the various engineering tools in use support the primary concepts of industrial digitalization and offer such advantages and opportunities to their users as foreseen by the advancements in digital transition.

Keywords	Digital Twin, Industry 4.0, COMOS

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Ammatillinen pääaine	Sähkövoimatekniikka
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Mitä hyötyä digitalisaatio voi tarjoa Suomalaiselle metsäteollisuudelle? Millä työkaluilla näiden etujen valjastaminen on mahdollista? Opinnäytetyön keskeisin tavoite on selvittää, kuinka saavuttaa sellaiset digitalisaation tuomat edut, kuin teollisessa yhteisössä on tutkittu ja spekuloitu.

Tätä tapaustutkimusta varten valitut Siemensin ohjelmistot esitellään ensin lyhyesti, ja niiden roolit jaotellaan. Tärkein näistä työkaluista on laitosdatan hallintaohjelmisto COMOS. Kokonaisen prosessin selkokielistä kuvaamista COMOS-ohjelmistolla tutkitaan tarkemmin. Painopiste on esitellä COMOS-ohjelmiston keskeinen rooli digitaalisten kaksosten synnyssä. Työ perustuu olemassaolevaan kirjalliseen ja kvalitatiiviseen tutkimukseen, tapaustutkimukseen, sekä käytännön kokemukseen ja ohjeistukseen prosessiteollisuuden ammattilaisilta.

Tuloksena esitetään perustelut, miksi valitut insinöörisovellukset tukevat teollisen digitalisaation keskeisimpiä konsepteja, ja tarjoavat käyttäjilleen sellaisia etuja kuin digitalisaation on arvioitu tuovan.

Avainsanat	Digitaalinen kaksonen, Industry 4.0, COMOS

Contents

List of Abbreviations

API	Application Programming Interface
COMOS	Component Object Server
CPS	Cyber Physical System
DCS	Distributed Control System
DFI	Digital Fiber Initiative
E&IC	Electrical Instrument & Control
FEED	Front-End Engineering Design
I/O	Input & Output
IOT	Internet of Things
MRO	Maintenance, Repair & Overhaul
MS	MindSphere
P&ID	Piping & Instrumentation Diagram
PFD	Process Flow Diagram
SCADA	Supervisory Control and Data Acquisition
SME	Small and Medium sized Enterprises
VTT	Valtion Teknillinen Tutkimuskeskus

1 Introduction

The Finnish forest industry requires a quickly scalable business-network to answer the demands of product innovation in the era of digitalization. The efficiency of both present and upcoming processes can further be increased with solutions enabled by digitalization. This thesis seeks to explore the benefits derived from industrial digitalization and represent tools used to realize these benefits.

The well-respected Finnish paper industry knowhow has demand around the world, and Finland has the possibility of being a leader in spreading new innovations and technologies globally. The key to the prospering of Finnish forest industry, and the growth of Finnish export is the value multiplication of native raw materials and the development of new products, both through recycled material and through various cellulose derivations. [1]

This demand is primarily answered in the digitalization of processes, and secondarily in the form of ecosystems functioning as business platforms for speeding up the market entry for new product and concept development.

1.1 Industrial Motives

In figure 1 there is depicted a projection of the export growth of the entire Finnish forest industry. It is estimated that the native growth will multiply to a value of 25 billion by the year 2050. This increase will likely consist of new products, for which new technology is required. It is imperative to note the proportionate shifts in the percentage of revenue resulting from traditional products and new innovations. Starting from virtually no market share around 2010’s, by year 2050 the projection displays that well over half the market value is held by non-traditional products. One of the reasons for such a change is the growing concern on climate-change, which pushes the replacement of fossil raw materials with bio-based materials to secure environmentally sustainable industrial development. [1]

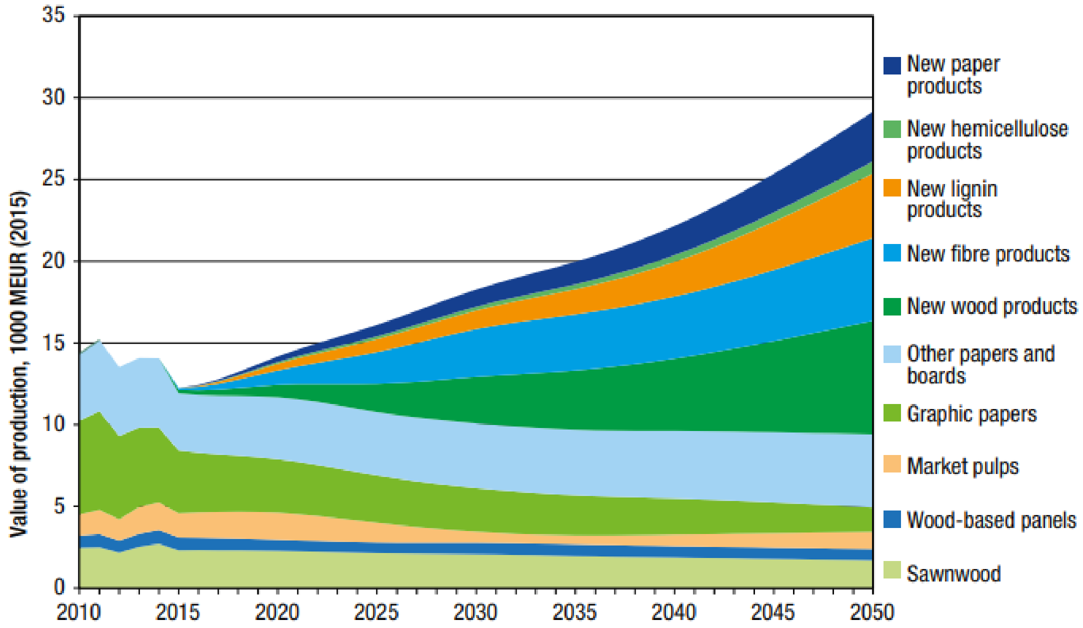

Figure 1 – Prediction of forest industry development in Finland [1]

This product development will partially be enabled by the digitalization of existing plants and the construction of new ones. Digitalized plants enable customers to collect process data at a detail and a rate never seen before, which brings new insights and possibilities for quality control and efficiency improvement, allowing for more complex processes to be conceived and operated with a high confidence. [17]

One of the chief elements in digitalization is the concept of a digital twin, which will be examined in greater detail in chapter 2. The ability of Siemens' plant engineering software COMOS to realize a digital twin will be examined in chapter 4&5.

Table 1 presents widely experienced challenges across traditional industries in developed countries, and suggested solutions offered by digitalization.

Table 1 – Challenges of manufacturing industries

Challenges:	*Possible answers by digitalization:*
High raw material costs with diminishing profit margins	Improved process efficiency and development of new products made possible by new technology
Skilled manpower shortage and loss of process knowledge, due to “silent knowledge” not being passed on	Cloud-based self-learning data-collection on plant operation to establish optimal process settings.
Lack of operational indicators and dashboards	Complete process data and analytics available in data cloud.

1.2 **Overview of the Research**

The research methods deployed for this study is the usage of existing material, qualitative document analysis and case study. Existing material refers to any published data, either printed or online. This includes anything between reviews of previous literature to analysis of existing available data.

The case study research method can be defined as an empirical inquiry that investigates a phenomenon within its real-life context. The requirements for case study can be listed as follows [11]:

-Empirical inquiry with evidence

-A phenomenon with real life context

-Relationship between these two

For the case study, a wet spinning process developed by Valtion Teknillinen Tutkimuskeskus (VTT) and operated by Infinited Fiber Combany (IFC) is examined.

The most relevant questions that this study poses are:

1. How can digitalization be deployed?
2. What benefits can be gained via digitalization?

For the scope of this study it is not intentional for the entire development to be finished, nor to account for every detail involved in creating a wholly realized digital twin of the asset. The approach is to examine global industrial trends, inspect the prerequisites of developing a digital twin, use the wet spinning process as a case-study, and extrapolate benefits based on available information. The study advances according to figure 2.

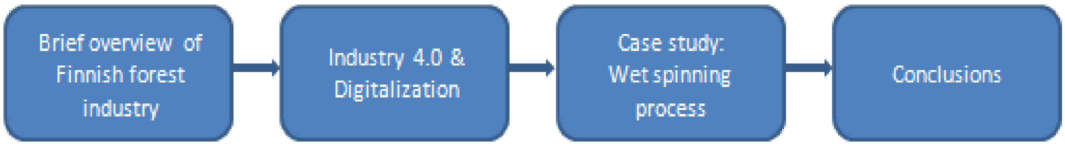

Figure 2 - Research process

2 Industry 4.0

The Industry 4.0 is a term coined by the German state in the early 2010's. The term denotes the upcoming or ongoing fourth industrial revolution globally acknowledged by all industries, containing such elements as digitalization, Internet of Things (IOT), digital twins and big data. [16]

Industrialization itself is classically divided into three (now four, which remains arguably ongoing) periods of revolutions. [18]

- The first period of industrialization consisted of mechanization of manufacturing equipment.
- The second period contained the electrification of said equipment, finally enabling mass-production for greatly reduced personnel costs.
- The third period, starting in the 1970's, is sometimes called the "Digital Revolution", when electronics and information technology first became available and convenient to be used.

However, it is interesting to note that the speed of current breakthroughs defined in the fourth industrial revolution has no equal value in history. Compared to earlier revolutions, the ongoing fourth revolution one is evolving at an exponential rate opposed to linear. It is important to note that it is also disrupting virtually every industry across the globe, which heralds complete transformations of entire systems of production and management. [10]

The vision of Industry 4.0 consists of various key-transformations, the most noticeable of these being the global networks connecting industrial businesses and machinery; factories and other facilities as "cyber-physical systems" (CPS), which will connect with one another and control each other intelligently, thriving on data that triggers desired actions. The CPS elements will be mantled as "smart factories", "smart machines", "smart facilities" and "smart supply chains". The improvements brought by these in the industrial manufacturing processes will be tremendous in the area of engineering, material usage, supply chains and product lifecycle management (PLM). The vision of industry 4.0 is therefore concerned with a deep integration of each stage in a horizontal value chain to provide extensive improvements in the industrial process. [10]

2.1 On Digital Twins

In the highly competitive modern markets it is imperative to shorten the marketing time and to increase product development efficiency. The methods for realizing this manifest in the realm of digitalization, and chiefly in virtual models of products referred to as "Digital Twins". The combination of CPS' and the gathering and processing of cloud data enriches these digital models with previously unattainable production and operation data. This allows for the prediction of product and process development and operation and service decisions without a need for expensive and time-consuming physical mock-ups. Such realistic product models as Digital Twins allow uniquely early and efficient assessments of the consequences of design and various other decisions on the quality and functions of an asset. An illustrative list of properties defining the Digital Twin can be seen in figure 3. [5]

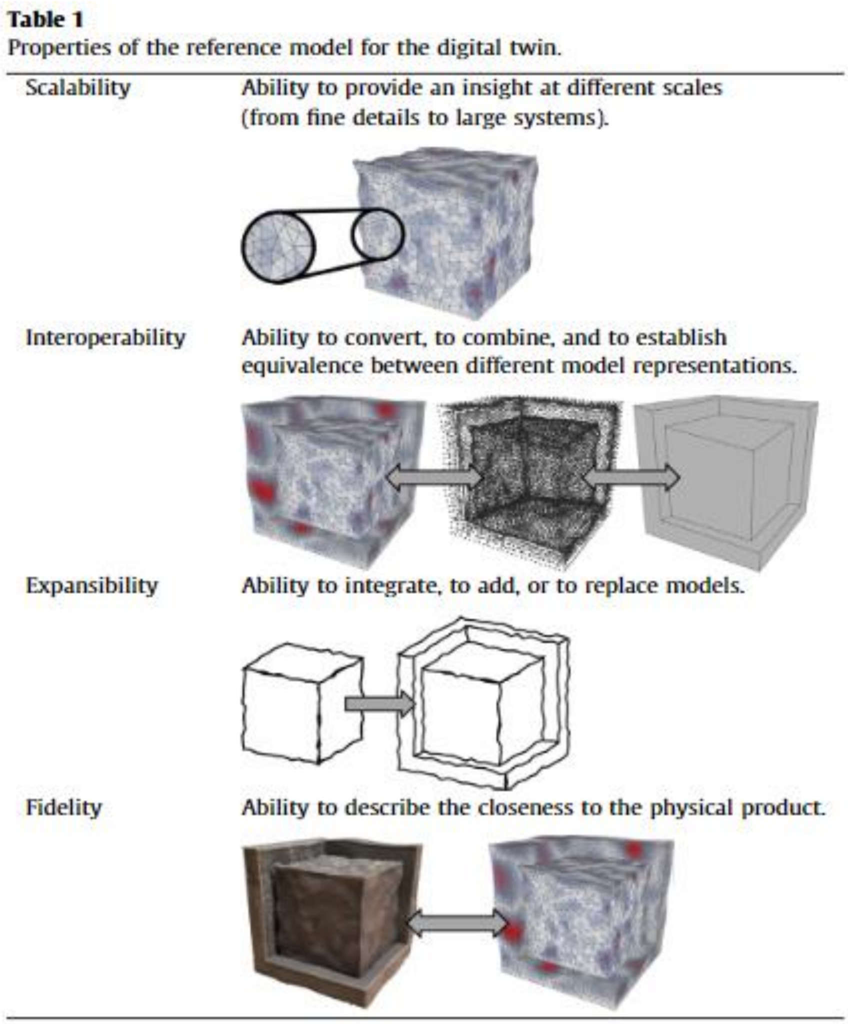

Table 1
Properties of the reference model for the digital twin.

Scalability	Ability to provide an insight at different scales (from fine details to large systems).
Interoperability	Ability to convert, to combine, and to establish equivalence between different model representations.
Expansibility	Ability to integrate, to add, or to replace models.
Fidelity	Ability to describe the closeness to the physical product.

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Figure 3 - Attributes of a Digital Twin [5]

It has been argued, that *"from a simulation point of view the digital twin approach is the next wave in modelling, simulation and optimization technology"* [5]

A concise description on the nature of a digital twin can be concluded as follows:

"However, the digital twin is not one *complete model of the physical product, but a* set *of linked operation data artefacts and simulation models, which are of suitable granularity for their intended purpose and evolve throughout the product life-cycle."* [21]

Therefore, the Digital Twin does not only serve as an accurate representation of any one asset but is highly applicable for conjuring derivations of asset behavior in the future. As a result, from the perspective of PLM, there is a consistent demand for integrating all available life-cycle data into a complete management system, which can be taken advantage of by different actors for various purposes, such as performance information and predictions of physical products from the digital twin for design optimization and process system improvement.

"The idea of building a twin *refers to producing a copy of a part or product and using it for reasoning about other instances of the same part or product – thus establishing a relation between multiple copies."* [21]

It is evident by multiple research that digital twins are a key-factor in maximizing the benefits brought by digitalization and the fourth industrial revolution. Another point of interest is that digital twins appear to be apt tools for deriving predictions of other instances of an asset, making it therefore ideal as a tool to estimate the challenges of up-scaling any asset into a greater value. However, the creation of digital twins is not a simple task and requires specific elements to enable its conception. A sufficient amount of data needs to be collected from the life cycle of an asset, or the asset must otherwise be extensively represented on a digital platform: the key-role in this endeavor is occupied by a suitable and complete data management system. Siemens offers an answer to this demand, which will be examined at greater detail in chapter 3 and 4.

It is important to not confuse Digital Twins with CPS itself. The following illustration (figure 4) describes the position of the Digital Twin between the realms of

Cyber Space and Physical Space. [16]

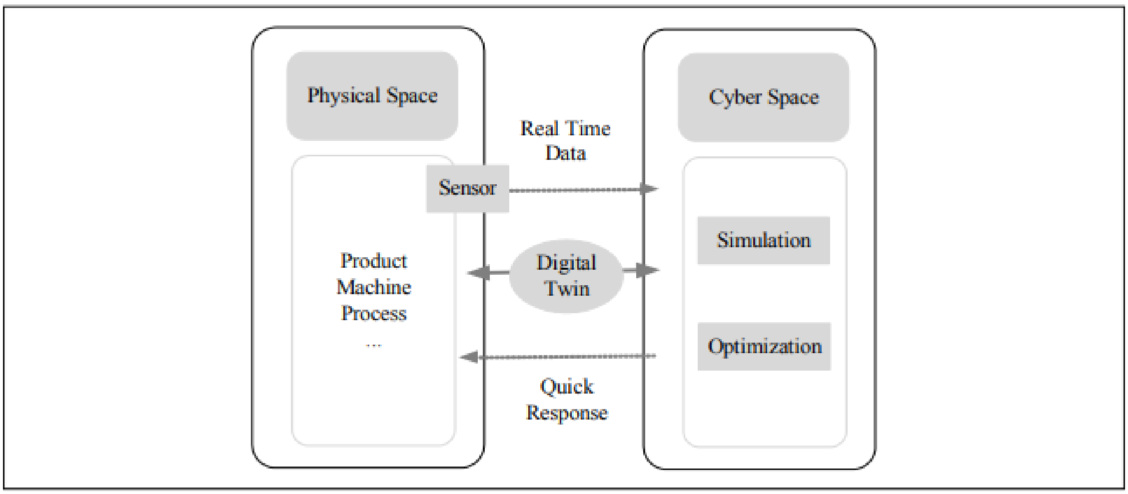

Figure 4 - The relation of digital twins to CPS [16]

3 A Solution for the Forest Industry

The primary testbed for meeting the requirements of the digitalizing forest industry, and to ensure that the native forest industry is able to retain and increase it's profitability, is The Digital Fiber Initiative (DFI)- ecosystem. In Digital Fiber the entire product cycle from the forest up to the manufactured product is going to be simulated, rendered and combined with cloud-services, all in a single data stream. Siemens IoT-platform Mindsphere is one of the central elements of the endeavor, and its development with various Small and Medium sized Enterprises (SME's) is a fundamental part of its concept. The endeavor also serves as a feed for the constantly developing processes of the forest industry.

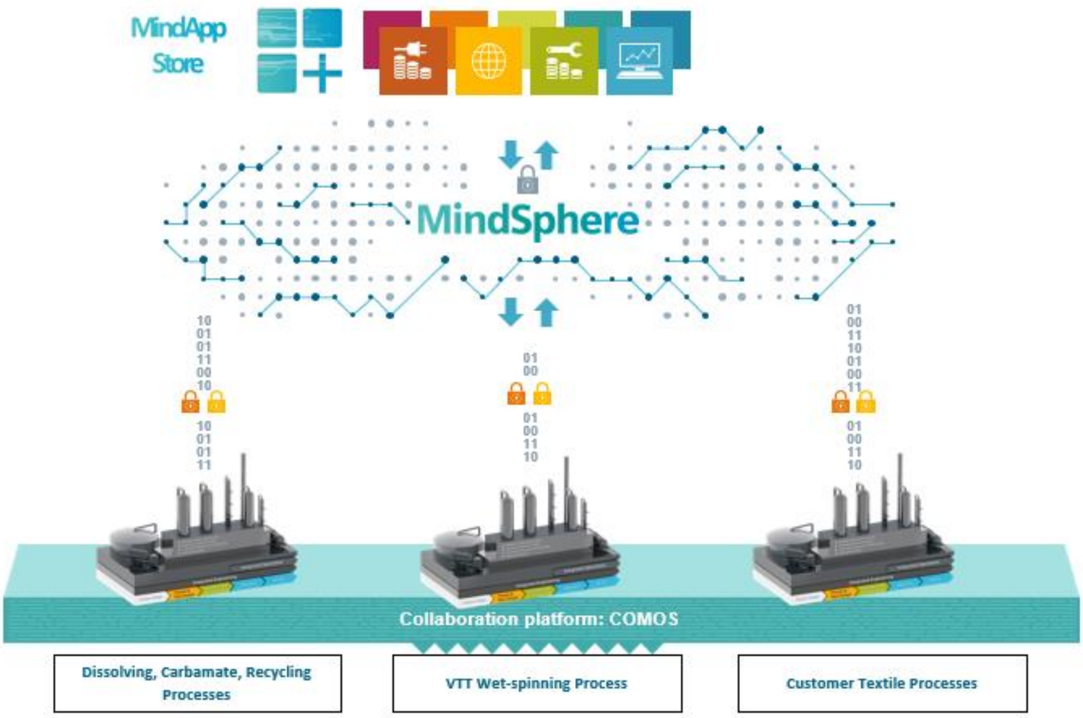

Figure 5 – Overview of the testbed [13]

To enable and to fuel the ecosystem and solution development, Siemens is providing its Digital Enterprise platform solutions, such as the MindSphere IoT platform and the COMOS engineering tools, and VTT opens parts of its Bio-ruukki Pilot Centre to be used as a testbed and platform for developing new digital innovations. The aim of DFI is therefore to achieve vastly increased levels of industrial efficiency by speeding up digital engineering processes of fiber production by creating standards and APIs for a continuous flow of digital information. This enables optimization of operations during life-cycle of manufacturing.

A digital transformation of business operations will be a key element in ensuring competitiveness in the globalizing world.

"*Digitalization promises lower costs, improved production quality, flexibility and efficiency, shorter response time to customer requests and market demands, and also opens up new and innovative business opportunities.*" [2]

Digitalization is the driving force behind changing business models and fundamentals of operation in every industry. With the help of IoT platforms companies can analyze data and derive previously unattainable information to help establish various business decisions. Digitalization is a key element in allowing any company, small or great, to remain competitive in the future. This is derived from increased process efficiency, shorter innovation cycles and faster development and production. The prerequisite is a seamless integration of data along the “value chain”, the idea of a product to the real-world asset and service. [2]

4 Siemens Industrial Software Solutions for Forest Industry

4.1 Plant Engineering Software COMOS

The Siemens’ answer to complete plant data management is COMOS. A life cycle engineering and plant asset management software that is developed to work in large infrastructures and to enable the planning and management of complex plant-systems and production processes.

At an elementary level, the entire data management platform is divided into four families: process, automation, operations and lifecycle, each of which are divided into more specified sections governed by licenses. Figure 6 represents the structure of COMOS, displaying the main components and their subsections.

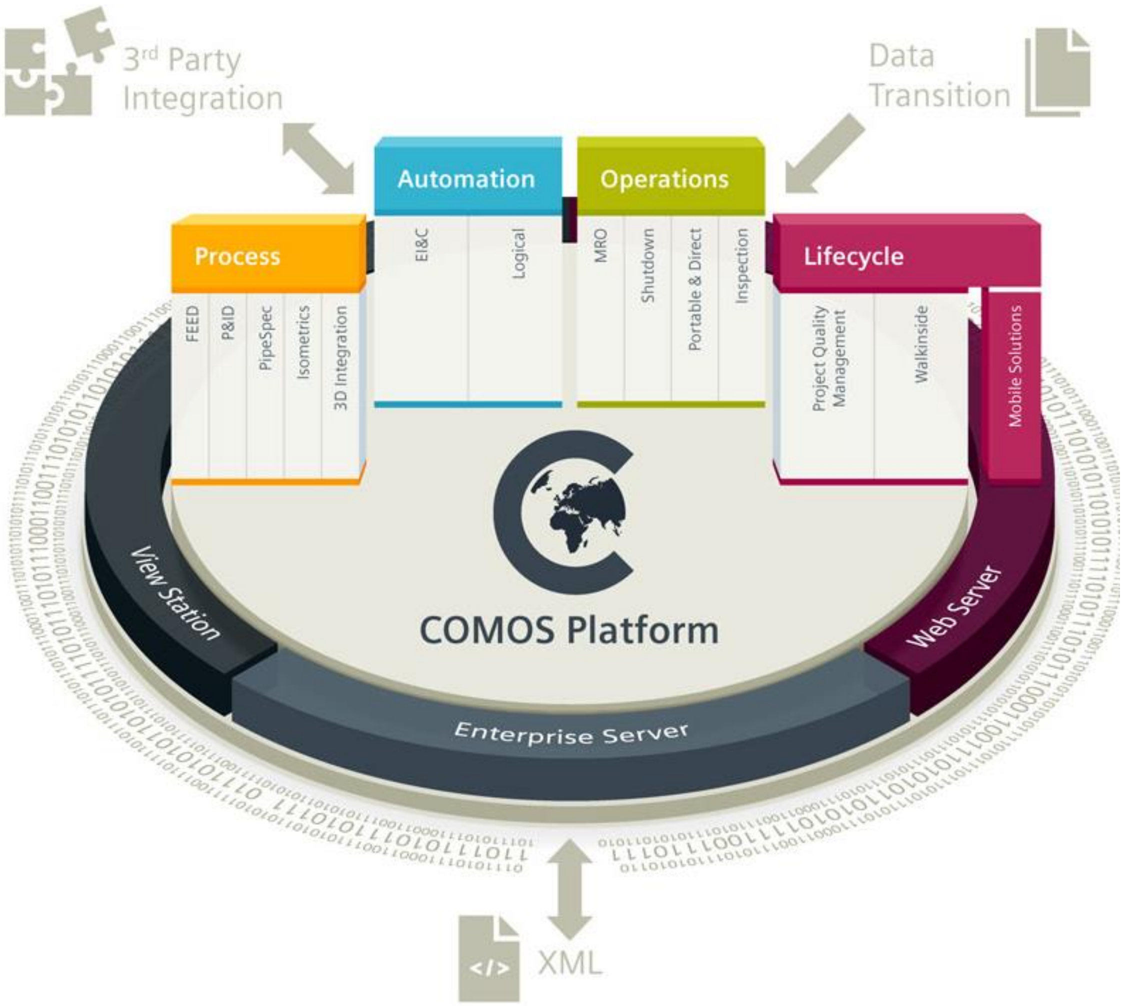

Figure 6 - Structure of COMOS [23]

The object-oriented philosophy behind COMOS renders every concept and abstraction into individual objects. Let us say, the abstract idea of ‘voltage’ is an object – without having a dependency to any other object or structure, other than the hardcoded system definitions containing such elements as unit-systems and certain broad categorizations - one of them being a group of elementary ideas called ‘object class’, under which, among else, the subset of attributes (like voltage) belongs. Figure 7 represents this is practical terms. Each of the listed properties belonging to the exemplary object in question are their own objects, which have similar capabilities of owning child-objects.

Figure 7 - Example object and what it may contain [13]

Therefore, the interface of COMOS is designed to allow free customizability and structure on presenting data. No object relation is hardcoded but is adjustable via definitions of each individual object. Ie. the interface is a set of independent atoms that can be combined, connected or interchanged with one another in an infinite amount of combinations.

COMOS uses this sophisticated approach of abstracting ideas from real world instances in its presentation of objects. Objects are divided into 'incorporeal' "base objects", and physical 'real-world' objects (or instances), called "engineering objects". One of the purposes for this Platonist approach is to permit the exchange or altering of ideas and concepts of objects at any stage in development. Engineering objects contain inheritance linkage to the concept they have been derived from. Any changes to the incorporeal notion of their definition, and the changes will apply to all instances. The idea behind a created instance may be exchanged to another, at any given time. Meaning that if, for example, the concept of “3-phase motor” is not suitable for a specific instance, it’s link can be changed, for example to “3-phase motor, modification X”. Everything in the instance-object will change according to the new master. This functionality extends engineering design flexibility to prevail even in environments where a system layout has already been set down.

Another distinctive feature of COMOS is the deployment of the concept of working layers. Any project or database may be divided into working layers that have a parallel or expanding structure, or a combination of these. The key advantage is the ability to divide any given work into separate fields that are unaffected by one another yet rely on an identical source. During the creation of a new layer, all data from the master layer will be inherited to that slave-layer. Parallel layer structure benefits from preventing data conflicts during the period of working. For example, there might be work packages that partially affect a common node of data. Later, each completed package may be released up from their respective branches to the release-area, and the administrator can view all conflicts and decide which ones to discard, and which overwrites to apply.

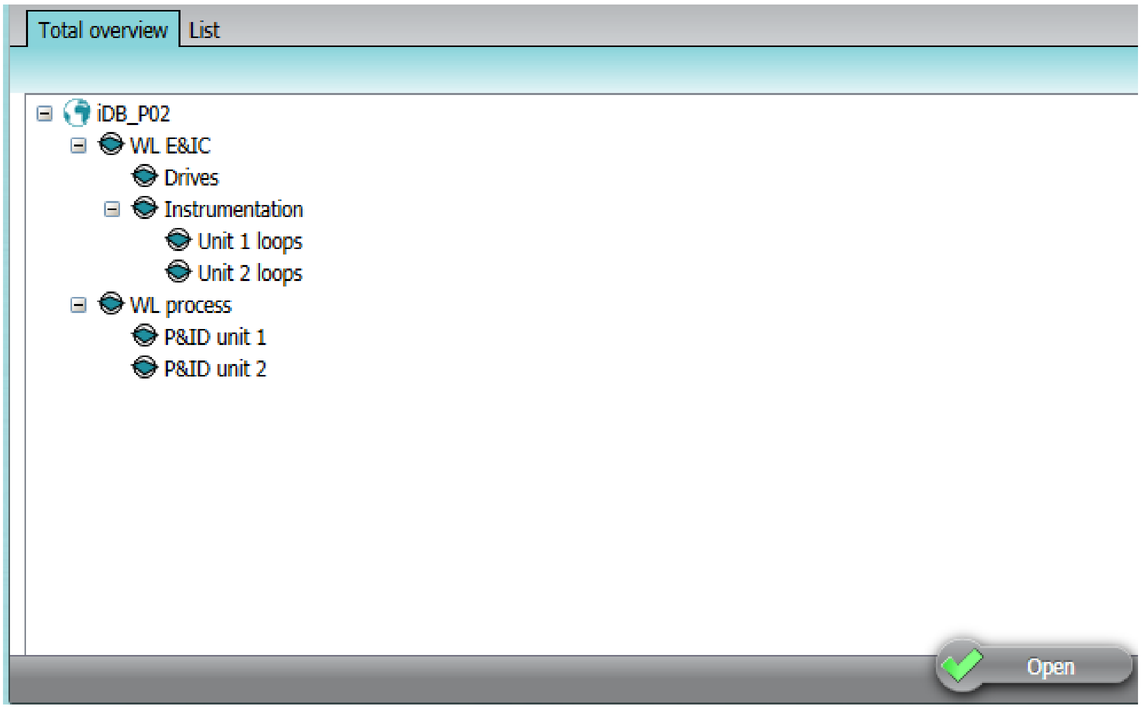

Figure 8 - Overview of working layers.

Both the Electrical Engineering and P&ID sections in figure 8 possess the exact same source material (derived from the project ‘release area’ “IDB_PO2”). Subsequent working layers beneath these sections will contain, respectively, what their upper level has changed or added in comparison to the release area. For example, on the release area a plant is defined, but not what is contained within. On the subsequent working layers the details of the plant may be further developed, and once a portion is ready for use elsewhere, or finalized, it may be released upwards to a common denominator from where it will descend again to the required sublayers.

In COMOS, a complete plant information is saved in a central database. Therefore, COMOS eliminates data discrepancies by letting the disciplines and engineering departments involved in design and operation to always access identical data for any given object. COMOS can process objects via data sheets as well as technical drawings, meaning that object or document changes are consistent and available to all users. [23]

The structuring of COMOS software allows for flexible customization based on the needs of the user. Since each section is governed by a license, any range of license combinations is possible.

The process section contains modules to allow complete Front End Engineering Design (FEED) and process design, including piping and 3d integration for 3d modeling. The automation section contains instrument control and logic and electrical drawings, as well as fluidics for designing pneumatic and hydraulic systems. The operations section contains modules to support various activities and events: maintenance, plant shutdown situations, data gathering from the plant, inspection and risk-analysis and documentation management. Lifecycle section is concerned with data presentation in various other interfaces such as documentation display on mobile solutions and handheld devices, as well as providing tools for interface creation towards any application.

It is evident that within the modules of COMOS a complete lifecycle can be constructed on a single platform.

4.1.1 Customer Benefit

The direct advantages of using COMOS can be speculated at length, but subjects of such scope and complexity as personnel time-investment or working efficiency throughout an entire lifecycle are difficult to examine and measure universally. However, the most fundamental advantage of COMOS is its role as a central data management platform, which allows differing engineering disciplines to come together (process planning, electrical planning, simulation etc.) by having them all work in the same virtual space, therefore being able to ensure every user operates on the same data, eliminating any possible discrepancies and inconsistencies.

Direct benefits may be speculated as follows: It is estimated that roughly 80% of plant capital costs are fixed in the early stages of a design. An optimized approach to FEED Engineering is a key element in reducing these costs, which provides significant business profit across the entire engineering lifecycle. [3]

Alike every member of the workforce, engineers aren't perfect in efficiency either. Approximately 13% of their working time is spent into searching data (who has access to the desired data, and is the found sample the latest version, and what are the previous sets of the same sample?) Roughly 30% of working time is spent into problem solving and analytical thinking, and towards this amount a role is played by the inadequacy of tools or their inaccessibility (tools are inadequate, or no standard set of tools has been defined, and access to these is insufficient.) Around 20% is undertaken by documentation, where one pain point is the lack of document standards (and therefore data consistency). Another rough 20% is demanded by consultation and support. [22]

The holistic approach of COMOS aids in relieving the efficiency challenges in all the aforementioned sectors. The amount of time spent on searching for valid data is drastically reduced in an environment where all plant data is hosted online in a central database accessible from everywhere. There is no need to question data consistency and required read or write access may be arranged through database administrators or any persons who hold administrative rights. Concerning problem solving and difficulties encountered in the usage of engineering tools or their lacking functionality; discussion, implementation, development and governance of used tools is easier to orchestrate in a common user environment as opposed to multiple differing software's.

Documentation management is more concise within the engineering environment itself. Standardization, document preparation and hierarchies, and criteria for detail can be managed far more efficiently within a single platform that is accessible even for users who may not be creating documents themselves.

Support and consulting requirements and need regarding the used engineering tools can be met and controlled far easier when user problems are delineated into a unified dimension. It is easier to support a user group and establish a support organization or persons around a common tool as opposed to requiring individualized specialists for an assortment of various engineering tools.

Another significant and continuous investment is maintenance, which can vastly be reduced by predictive operations. Predictive maintenance is a strategy that depends on monitoring the condition and performance of said equipment to preemptively determine necessary steps to correct the undesired trend. In practical terms this means that a continuous data collection is required from the devices. In this case, the data is provided by an IOT platform to the operator or any other personnel involved in the operation of the plant, which may be combined with the maintenance-data engineered in COMOS to gain higher efficiency in taking maintenance action.

The MRO functionalities of COMOS allow for unique maintenance plans for individual devices and specific errors or events. This typically includes pre-defined, preventive measures by scheduling certain maintenances to be taken at defined intervals. In addition, condition-based maintenance measures are also defined, ensuring that the most optimal maintenance plan is suggested or prompted by COMOS.

Predictive maintenance has numerous advantages over other commonly used strategies, because it reduces the chance of unexpected failures and increases the availability of said equipment, gaining a decrease to the overall cost of maintenance process. This results in direct economic advantage for the operator. Although the maintenance costs vary depending on industry, analytics have successfully concluded that the material cost savings range between percentages displayed in figure 9. The most obvious advantage is the possibility of carrying out repair functions just before a breakdown, helping avoid unplanned downtimes, which round up to a significant sum annually. In addition, necessary maintenance functions can be orchestrated to minimize the necessary system-wide downtimes. Predictive maintenance also further eases logistics by enabling the preemptive ordering of spare-parts. Inventory management and availability checks are a part of the tools offered by COMOS MRO. [8]

Figure 9 - Advantages of predictive maintenance [8]

4.2 PCS7

Simatic PCS 7 is a process control system from Siemens that is based on functionally compatible Siemens hardware and software components from the system spectrum of Totally Integrated Automation (TIA). Standard components include PC, controller, communication and distributed peripherals. It is used in all process industries such as chemical, pharmaceutical and food&beverage industries for the management of the main production process, but also for secondary processes such as wastewater treatment and energy distribution.

As a homogeneous and integrated overall system (Distributed Control System, DCS) with central engineering and a common database, Simatic PCS 7 enables the integrated automation of both production and process engineering processes and is used in the process, manufacturing and hybrid industries. Not only the documentation but also the quality assurance is intended for the whole system. In contrast, supervisory control and data acquisition (SCADA) solutions are based on combined individual components (some of them different manufacturers) and their functionalities are not coordinated with each other, resulting in more comprehensive data storage, more complicated functional additions, the use of individual programming tools and communication tools as well as the separate Quality assurance for each individual component. In the integrated DCS approach, all functions are contained in the functional and system-tested individual components with which an overall system can be built.

The Simatic PCS 7 process control system is operated by means of graphical user interfaces, e.g. with context-dependent, user-specific views. All measured values, messages and alarms that are to be available over a longer period are stored and managed in a central archive server.

Due to the modularity of hardware and software components, the process control system can be flexibly used in different plant sizes and adapted to changing requirements. This allows the expansion and expansion of facilities. The capacities range from a small single system (approx. 160 measuring points) to a multiuser system consisting of multiple operator stations and servers (client-server architecture) of a plant network (more than 100,000 measuring points).

In addition, the system can be combined with components from other manufacturers and integrated into existing infrastructures, as system architecture and communication are open. There are also programming and data exchange interfaces for user programs as well as for the import and export of data, texts and graphics. Process data is accessible on the basis of standardized interfaces and is available company-wide. The communication within the system takes place via the industrial standards Ethernet, PROFIBUS and PROFINET, partly at the field level but still via the automation station interface

4.3 SIMIT

SIMIT is a simulation platform software from Siemens that has native import support for both PCS7 and COMOS. It can be used for the following functions:

- Complete plant simulation of signals, devices and plant response
- Input and output simulator of test signals for an automation controller
- Testing and commissioning automation software

The role of SIMIT is to represent engineering data provided by either PCS7 or COMOS, or both in combination, in a simulation environment that mimics process equipment, instrument, actuators and behaviors, and stimulates both virtual and physical controllers to evaluate control configurations or even train operators. Data from either tool needs to be mapped to represent correct objects in SIMIT. Once SIMIT has all required data on equipment and devices belonging to a system and information on their programmed behavior, a live simulation can be launched. [15]

“The SIMIT virtual controllers can be regarded as a digital twin of a Siemens process automation configuration and can simulate the execution of control programs” [15]

4.4 MindSphere

MindSphere is a cloud-based open Internet of Things (IoT) operating system from Siemens. It is tailored to enable companies of any size from all industries to participate in the digital transformation of the world in partnership with Siemens. MindSphere hosts an array of Application Programming Interfaces (APIs) to assist users in producing applications that deliver digital services and data-analytics. The data from industrial processes may be selectively collected and stored in the MindSphere cloud by connecting the process control system in use via ethernet to the cloud. This obtained data may easily be visualized or processed through the API's offered my MindSphere. The position of MindSphere in connecting the process in this case-study into the data cloud is visible in figure 5.

5 Description of the Wet Spinning Process

The wet spinning process functioning as the case-study for this work is being piloted in Bioruukki, a testing facility owned by VTT. A new technology to recycle textiles is being deployed by Infinited Fiber Company to transform post-consumer textiles back into 'virgin' material. The core of the new fiber producing technology consists of three key processes

1. Fiber separation
2. Turning material into liquid
3. Turning liquid into fiber

The technology used in this wet spinning process has been developed by VTT. The produced fiber has a low environmental impact, with up to 20000 liters less water spent per kg than cotton. Compared to viscose, the wet spinning technology fares with 160000 ha less forest harvest required. The total cost in the textile industry supply-chain is therefore lowered. The textile produced has also higher color uptake, which results in a reduced need for bleaching chemicals and dyes and therefore also water. The new fiber material produced from recycled textiles has a broad range of applications such as clothes, home textiles, hygiene products and technical textiles. [19, 20]

The process efficiency and operation success may be bolstered by innovative engineering enabling the operators to access data which generates previously unattainable levels of understanding and insight into quality control and operation activities. The data management and engineering are implemented via COMOS, and the automation via PCS7.

5.1 A Brief Introduction to Industrial Process Control

As with other forms of industrial manufacturing, process plants underwent similar innovative reformations in the wake of industrial revolutions. Electronic and digital control systems have replaced the mechanical and pneumatic solutions used in the past. Actuators and various other process equipment are no longer controlled by hand but by programmable control systems. Distributed Control System (DCS) stands for a process control system that is made up from numerous components interconnected within a digital communication network. Such systems have Input and Output (I/O) signal computation in the form of multi-loop controlling microprocessors installed in control cabinets; which are designated racks hosting the computational hardware for signal processing and terminations for wiring the process equipment on the “field” (ie. part of or attached to the process). Figure 10 presents field devices connected to I/O controllers and their connection to the control room and other operation stations.

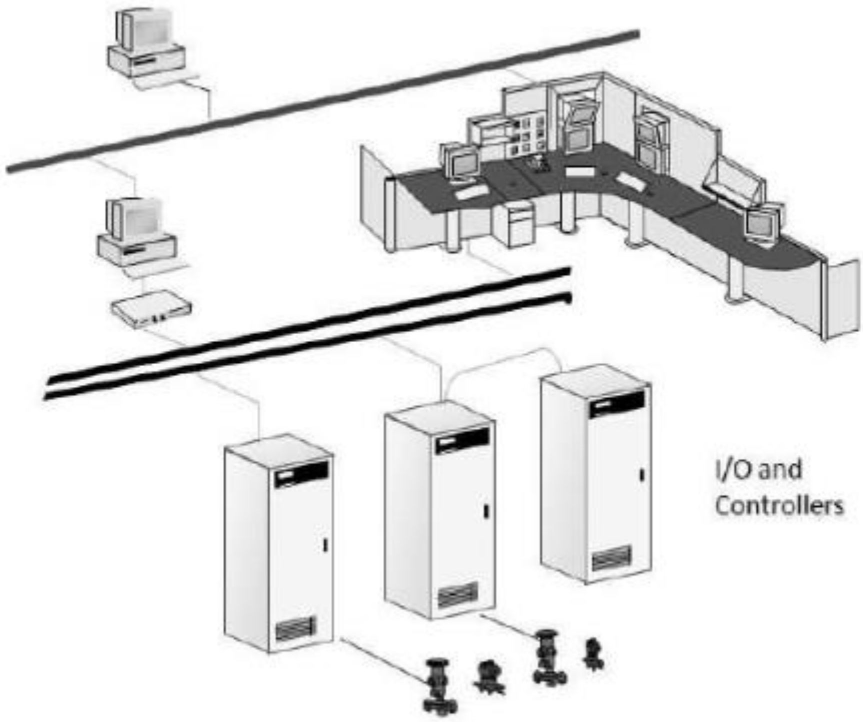

Figure 10 - Overview of Distributed Control System [7]

The devices referred to as “field devices” are used to provide the process control system with information about the process or to control elements that affect the process flow. These are, among else, various measurement devices with sensor units obtaining the readings (such as pressure, temperature or flow rate of liquids), and a transmitter unit handling the communication via 4-20mA signals to the control cabinet; and various types of valve actuators with positioners to adjust and control the process values compared to measured readings.

The personnel operating industrial processes are typically referred to as operators. Modern process control systems have graphical displays, often located in a designated control room. The displayed information is received from the control cabinets that transmit the field signals to the controller, where it is finally handled by a process control software such as PCS7.

Function blocks are logical processing units of software defined in the process control software, containing input and output parameters for various process equipment. A control module contains measurement, calculation and control implemented as function blocks. An equipment module contains control modules and function blocks. A process unit is a collection of associated equipment modules in which one or more of the processing activities can be conducted. [7]

5.2 Process & Automation

One goal of the work was to represent both the process and its automation within COMOS.

Each graphical symbol on the drawing corresponds to its engineering object (which defines the graphic of the symbol), and each engineering object contains all the relevant engineering data (specifications, dimensions, ordering data etc.) Each position is an “assembly object”, compressing each of its internal objects underneath a unified graphical symbol for positions. By double clicking the position-symbol, the loop diagram of that specific position will be displayed, where the field devices and the connections from the instruments to the cabinets are graphically described.

According to the layout in figure 10, the control cabinet will be linked to a profinet-bus system, connected to the process control system (PCS7). The junctions from the cabinet to field devices, and a complete set of according documents need to be prepared in COMOS.

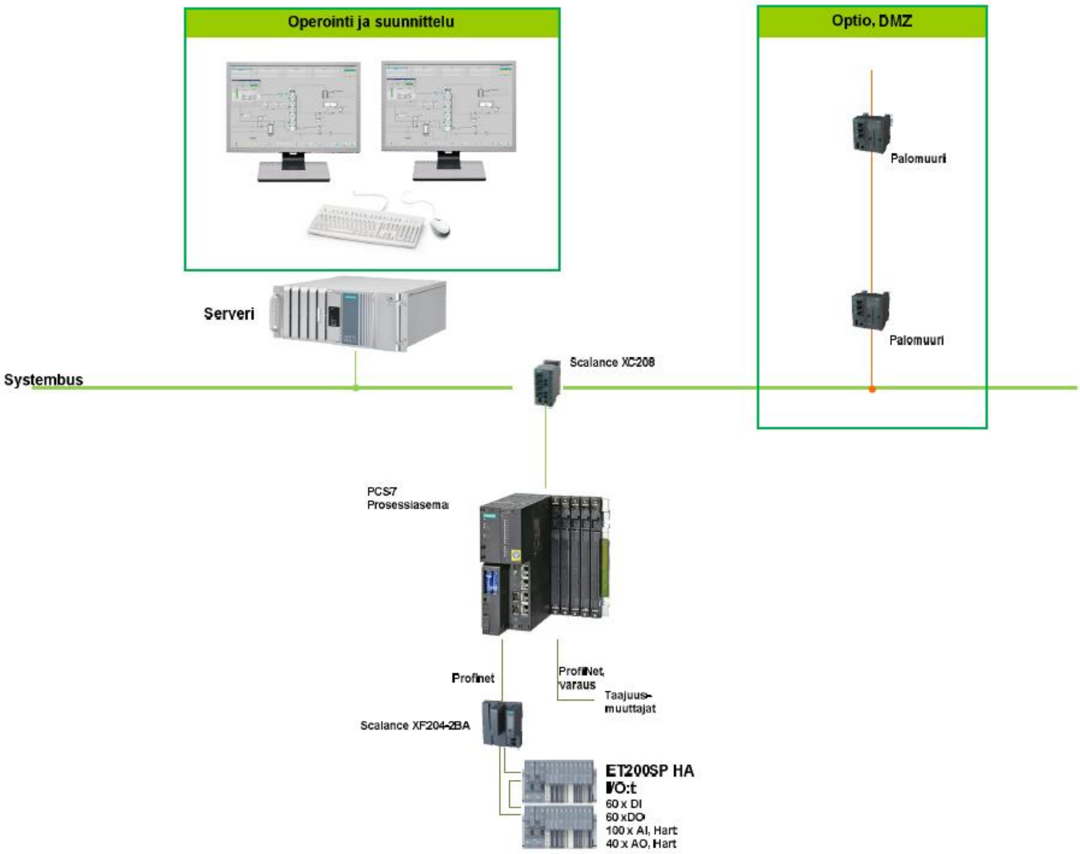

Figure 11 - Layout of an example automation solution [13]

The measurement loops are connected from the field devices to the input module cards residing within the cabinet, from where the data is provided further upwards to PCS7. By representing each field device (sensors, measurements, actuators etc.) and each component of the automation system in their true-to-life form and specification, and properly representing the model of the process and the locations and functions of each device, we can create an exact image of the asset in a virtual sphere. The Digital Twin will manifest itself in a loop of data exchange represented in figure 12.

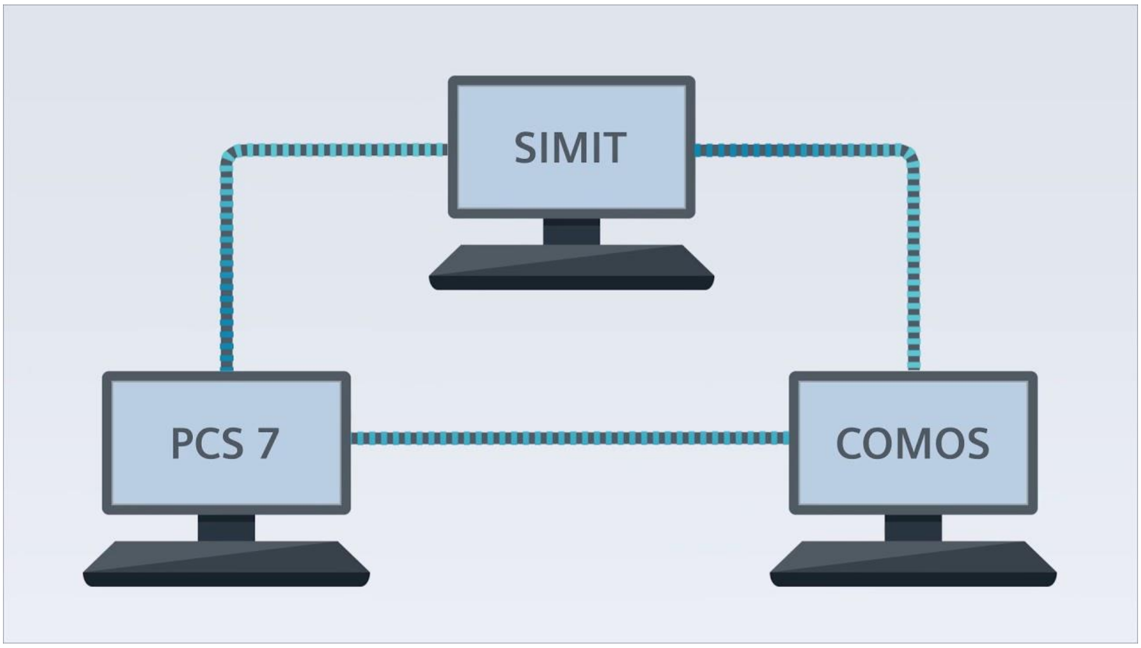

Figure 12 - Interconnectivity between COMOS, PCS7 and SIMIT [24]

A demonstration of the flow of data within COMOS is showcased stage by stage in an example setting (figures 13-18): from a block diagram into functional diagram and into P&ID, and finally into the electrical planning of an unspecified loop belonging to the example process unit.

In figure 13 there is displayed a block diagram from an example project in COMOS. The process unit labeled “Conditioning” is chosen, and the navigation options are visible in the context. ‘Object’ refers to the process unit “Conditioning” within the engineering project. ‘Base object’ refers to the definition of a process unit within the base objects. ‘Documents’ refer to any documents where information from this process unit is present. ‘Documents below’ lists only documents that directly belong to this process unit (such as the process flow diagram describing the unit itself). ‘Connections’ displays the sources this unit is connected to. Finally, ‘inheritance sources’ displays every source from which this particular process unit receives integral information (data that the process unit itself consists of.)

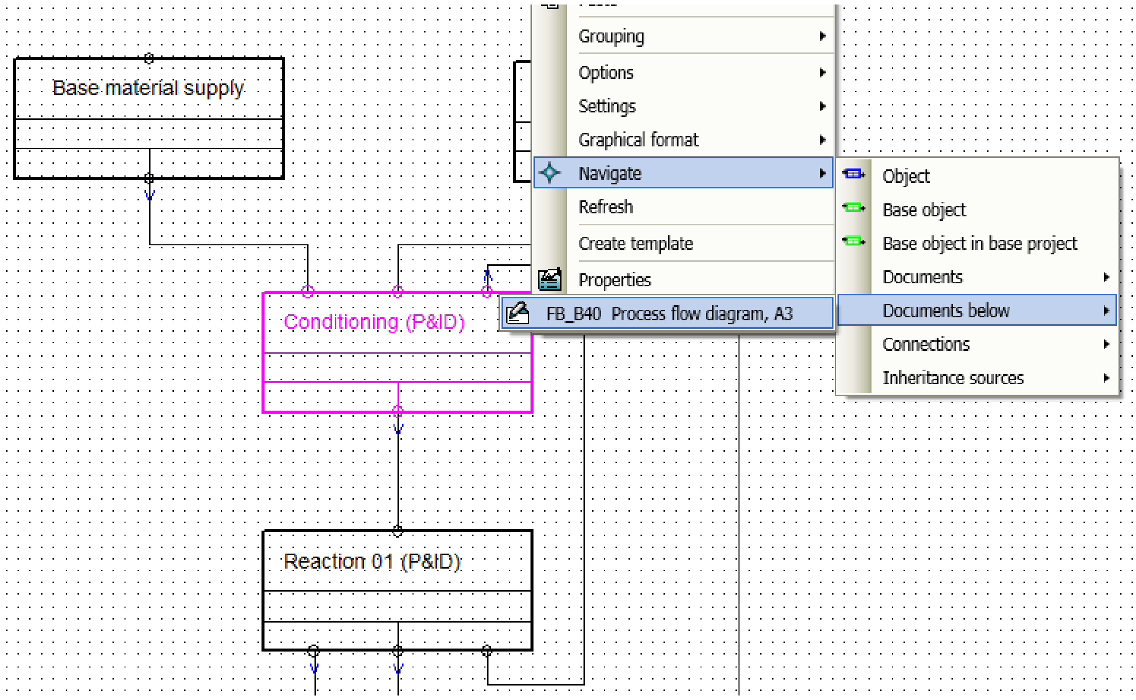

Figure 13 - Block Diagram, navigation into selected process unit

From the ‘Documents below’ option, the user selects “Process flow diagram, A3”. Below in figure 14 the conents of the flow diagram are represented.

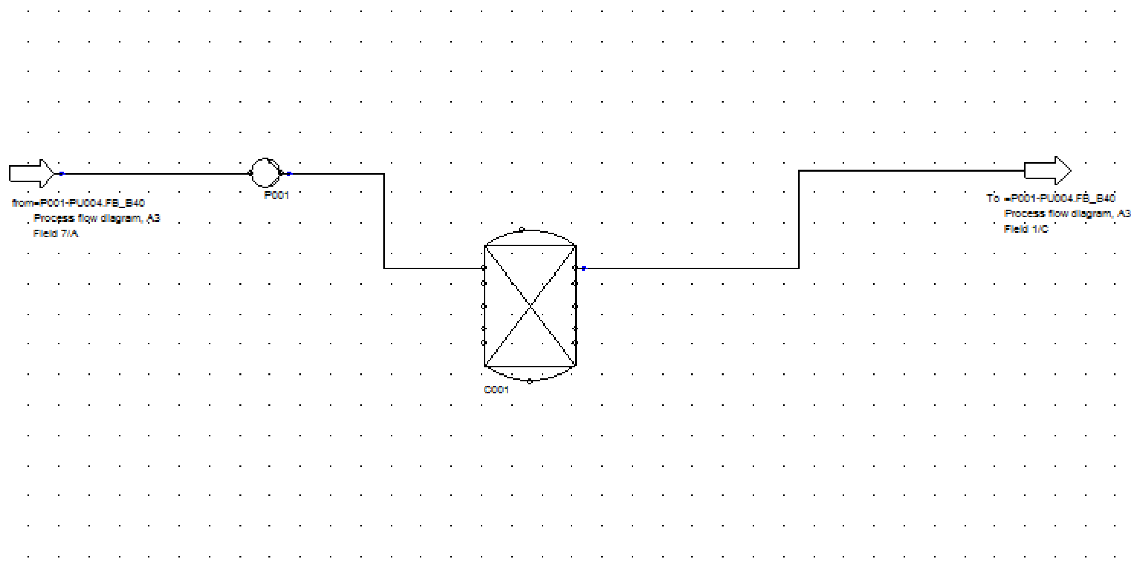

Figure 14 - Functional diagram of “Conditioning”-unit

The vessel in the flow diagram is selected, and a P&ID can be automatically generated for this particular device based on available templates.

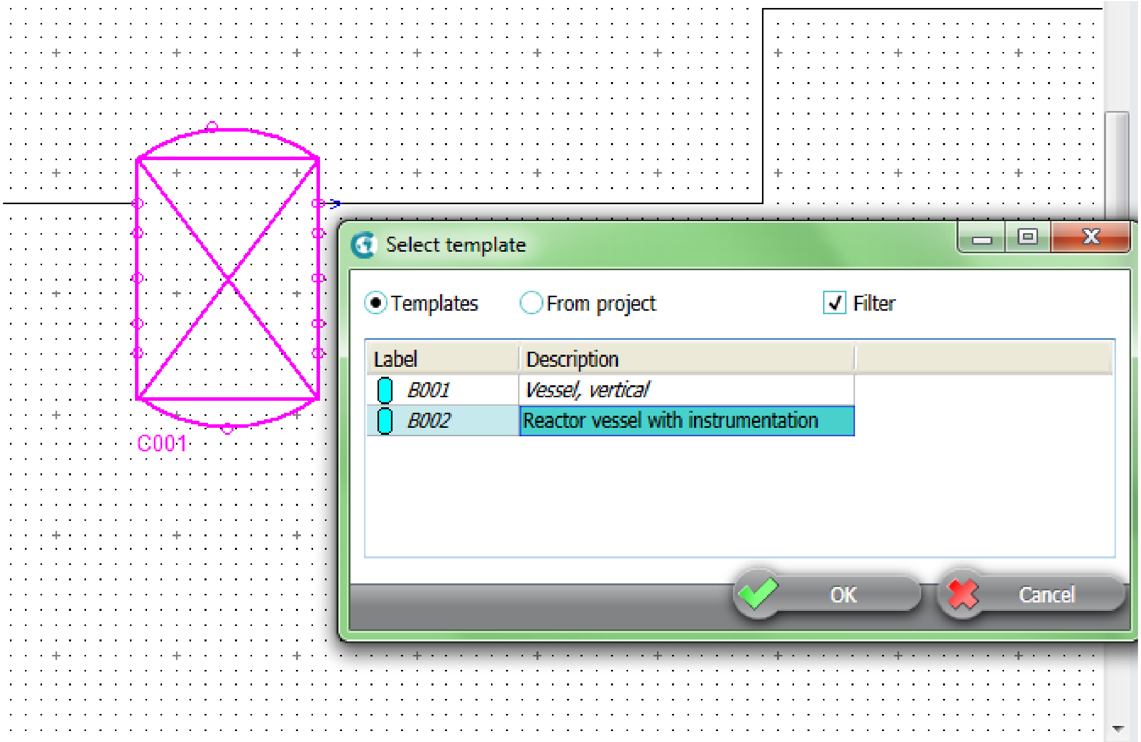

Figure 15 - Selecting appropriate P&ID to be generated

The P&ID will be created in it's own sublocation beneath the process unit. Later this template can be moved via drag&drop to other P&ID's where whole parts of the process will be depicted.

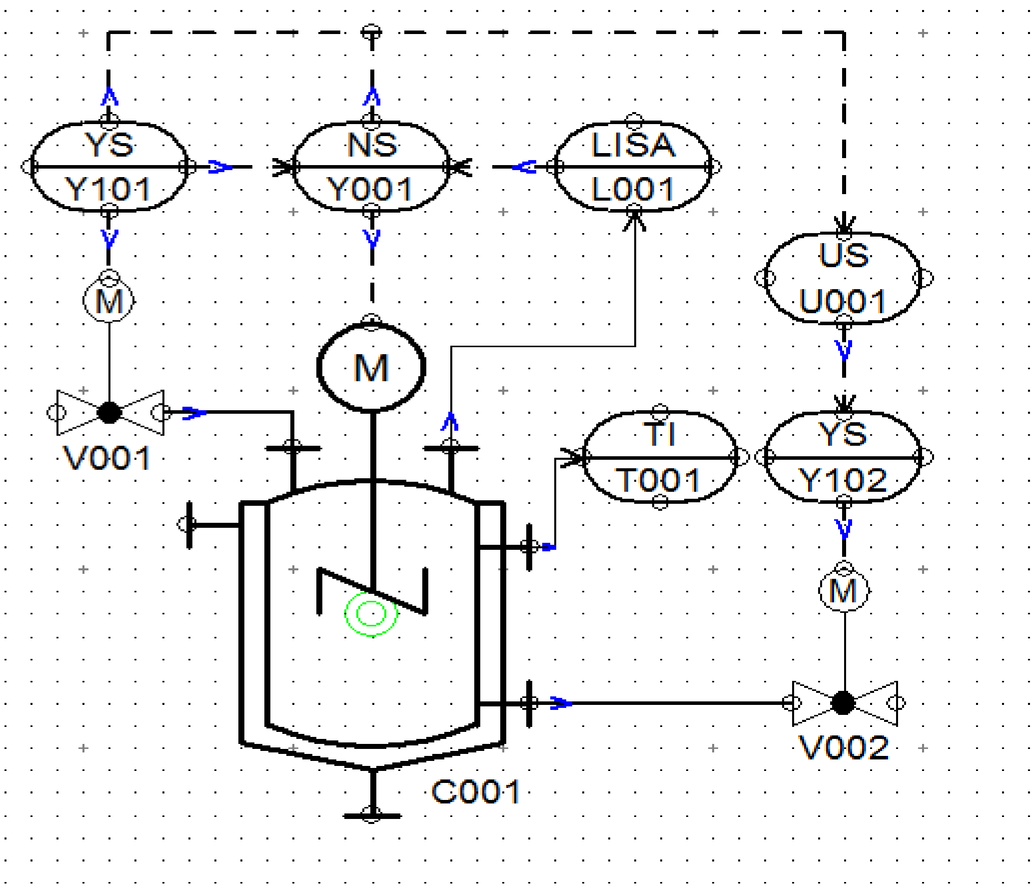

Figure 16 - The created P&ID for the vessel

Such instrumentation loops as shown in figure 16 (such as temperature indication “TI” T001) often contain measurement devices and various other equipment that will be connected to a control cabinet. Starting from an input-output module that processes the data signals exchanged between the automation system and the field devices and therefore also controls the field devices, a simple loop connection is illustrated. In figure 17 a failsafe digital input module is displayed. Upmost is shown the 24v power distribution arriving from another cabinet. Following these connections, it is possible to navigate “backwards” in diagrams to the source. Channels 1 and 13 (address I0.0 and I1.4 respectively) are junctioned with a field device.

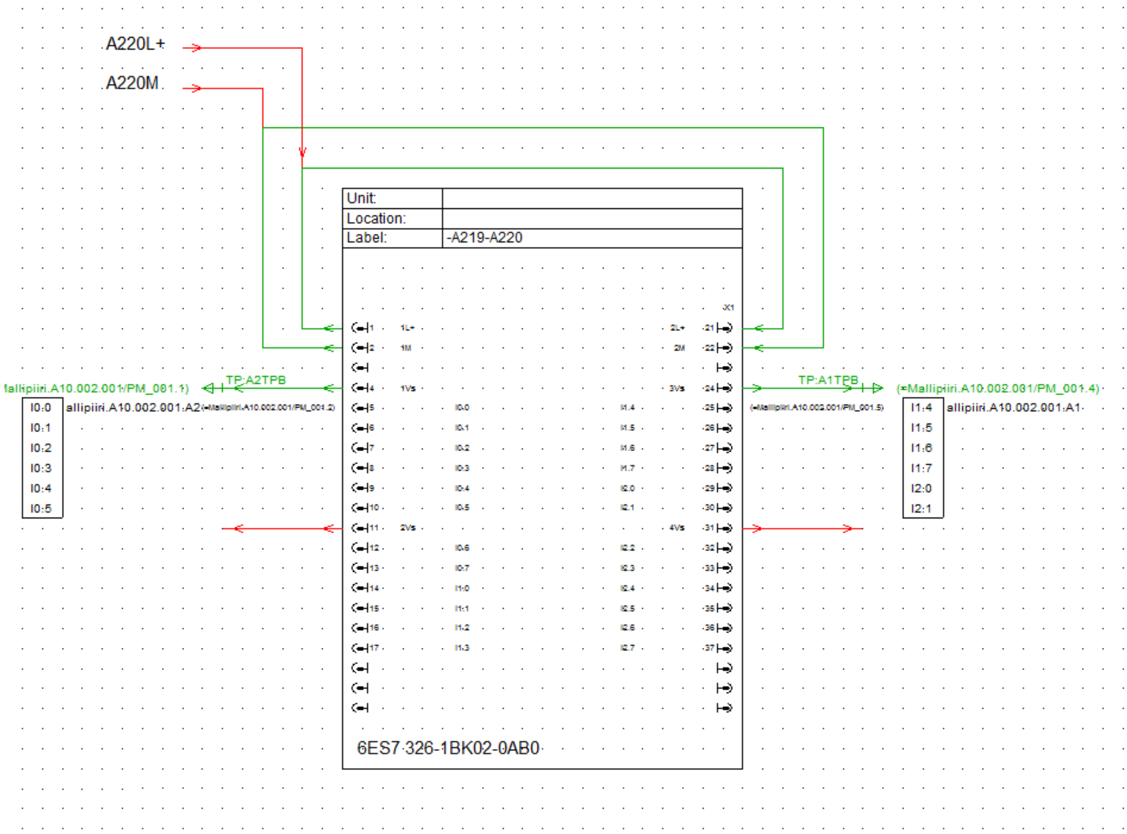

Figure 17 - Failsafe digital input module junctioned with various loops

Figure 18 presents a field device implementation from channels 1 and 13 of the digital input module shown in figure 17. Channel and terminal implementation may be bulk processed through queries, and from these I/O and channel lists may be derived. The terminal markers on diagrams as well as the I/O modules and all other equipment exist in the project in their respective real-life locations, which allows the user to trace from objects to their related objects in an identical manner as showcased earlier. This means that from figure 18 we can, for example, through some clicks navigate from a selected terminal into the cabinet where the specific terminal resides and view it's physical placement on the layout diagram. This greatly helps maintenance or installation personnel in tracking down specific details or components in the system since the data can be accessed also via handheld devices.

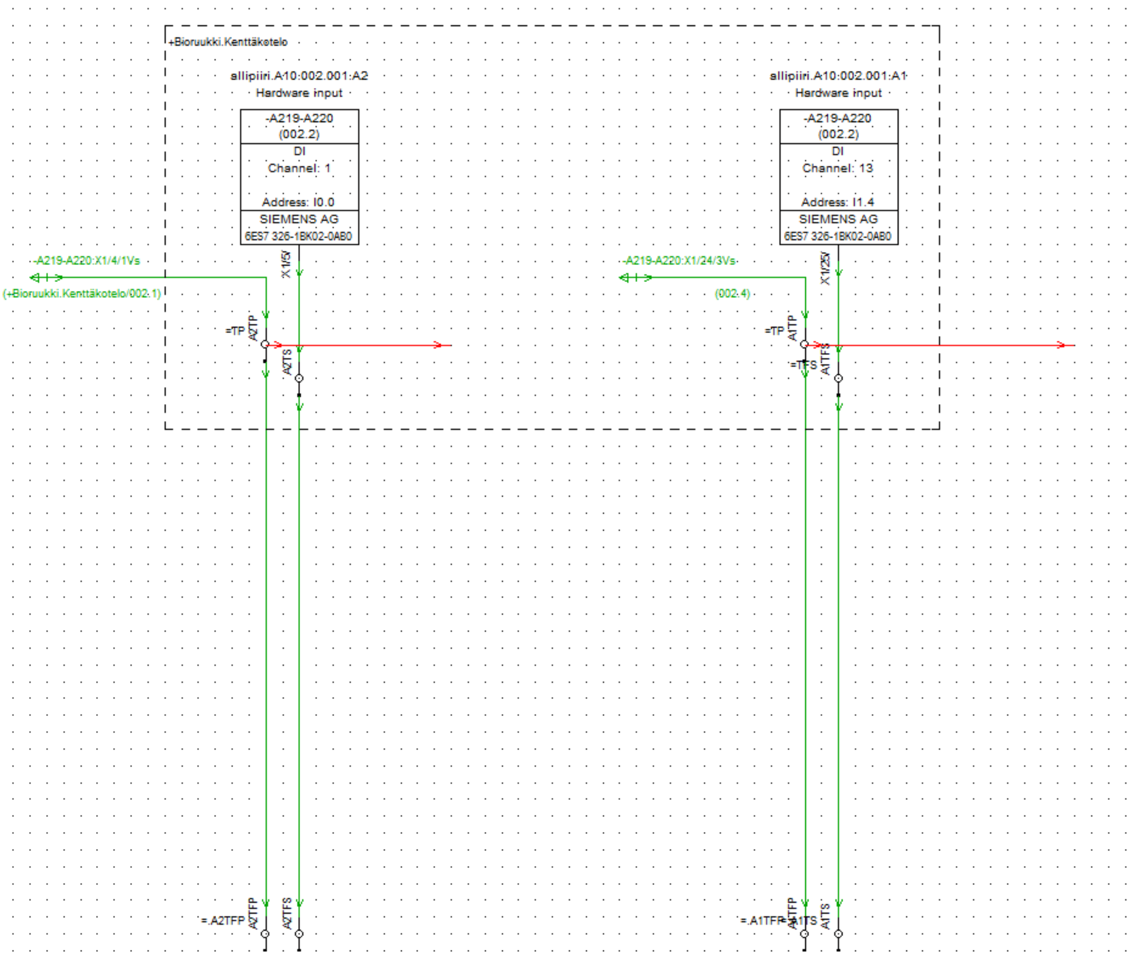

Figure 18 - Example of failsafe implementation of 2 channels for a single loop

The function blocks for loops can be engineered either in COMOS or in PCS 7, and both results may be imported between one another through a designated PCS7 import/export interface in COMOS.

In terms of an optimized approach to FEED, the above functionalities display a working solution for increasing the speed of engineering cumulatively over time. When processes are depicted as block diagrams and divided into process units, each functioning as their own object with graphical properties and relevant documentation, the design-cycle can be accelerated by taking advantage of templates: each standard solution need only be created once. With a developed database the specifying of the initial process units is fast and effortless. Functional diagrams consist of equipment modules (such as the vessel depicted previously) for which standard solution P&ID's can be stored and immediately implemented from memory. This allows engineers to quickly set down an accurate overall presentation of a plant, leaving more time for tailoring individualized solutions where required.

5.3 SIMIT interface

The interface between COMOS and Simit is a standard tool offered by COMOS.

To import engineering data from COMOS to Simit the user must build a mapping table between COMOS and SIMIT objects, so that the export file from over COMOS including FEED and E&IC engineering can instruct which objects SIMIT will choose to represent each symbol. The export file will contain symbol positions, which means that a correct mapping results in a complete transformation the COMOS diagrams into SIMIT diagrams without additional work required in between.

The SIMIT-import interface of COMOS requires SIMIT library components to be loaded from archive or file. Desired objects from this component list will be further selected and brought to the “Component mapping” tab (displayed in figure 19). The “COMOS source object” view lists user-selected COMOS objects chosen from any location in either an engineering project or a base project. The mapping happens via simple drag&drop connection between two appropriate components in COMOS and SIMIT. Each completed mapping-link will display additional modifiable data below in the “Detail mapping” view. Extra modifications can be completed here concerning such elements as naming and object-connections.

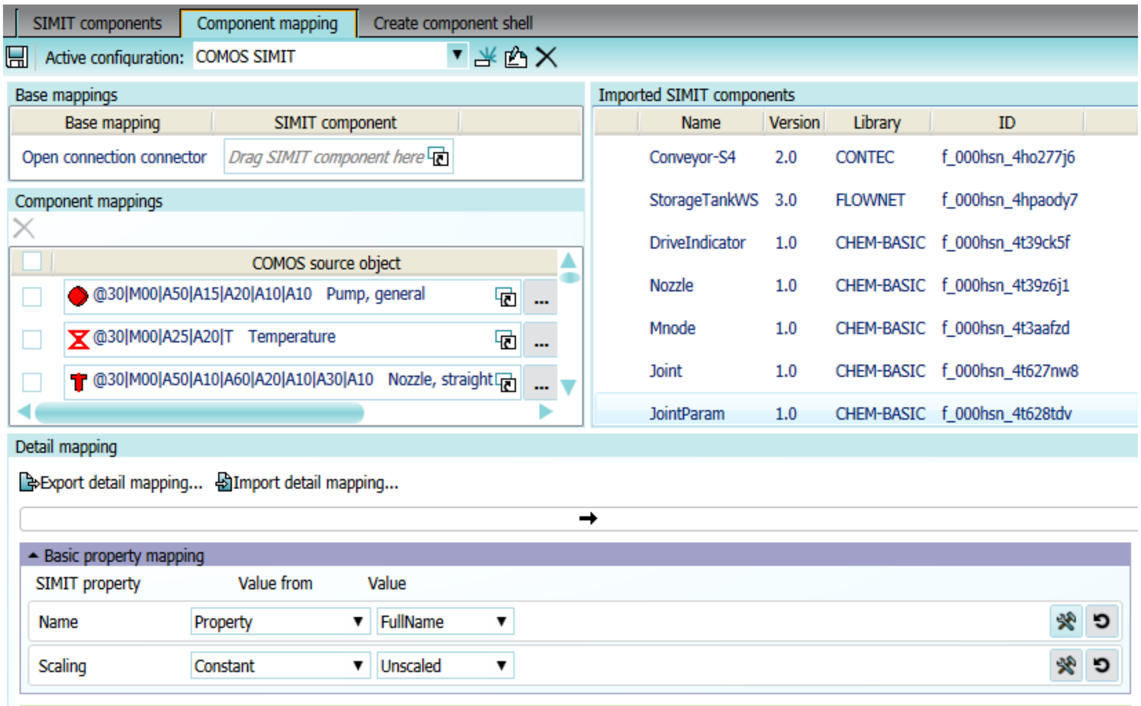

Figure 19 - COMOS mapping interface for SIMIT objects.

Figure 20 displays the result of a properly assigned object mapping.

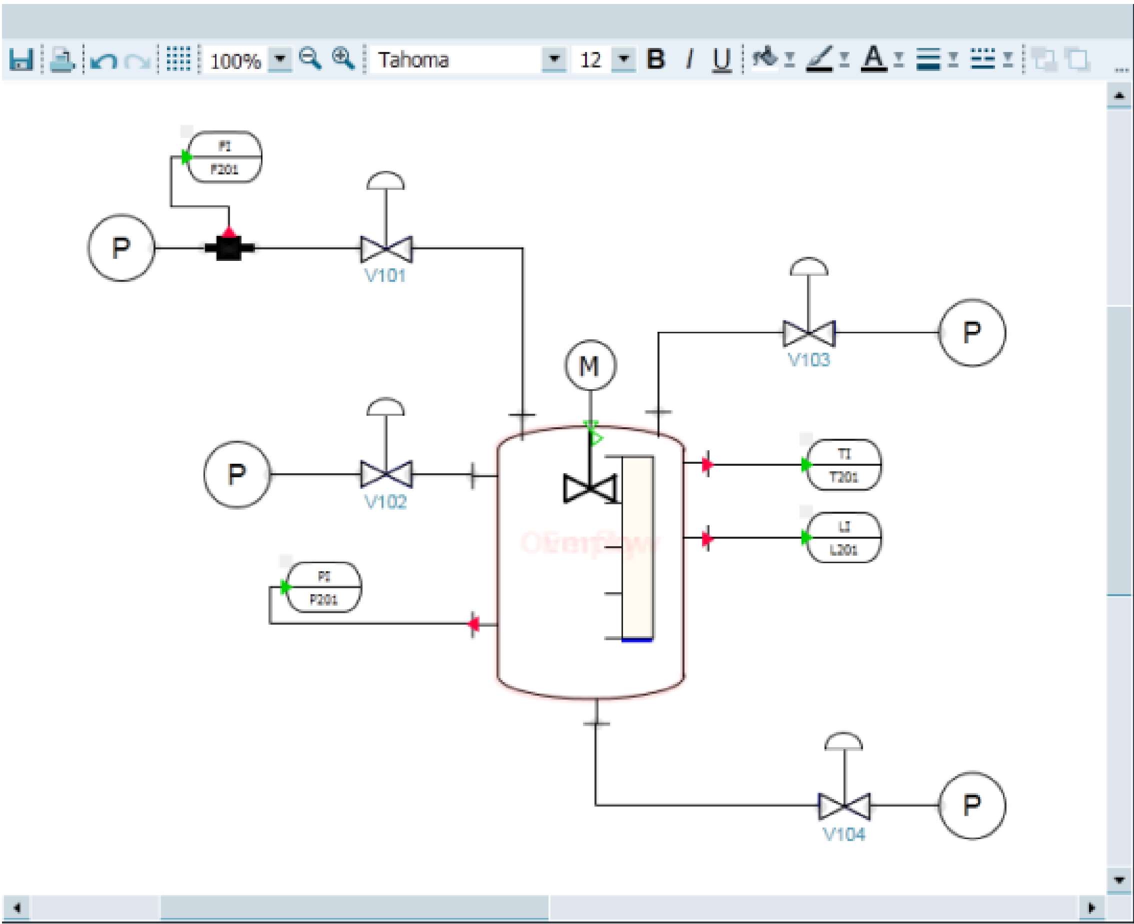

Figure 20 - Imported asset in SIMIT simulation platform after successful mapping. [14]

6 Results

The prerequisite for maintainable digital twins is to gather all process data. The availability of information and the proper tools to use and change the digital twin is a cornerstone for digitalization. At design stages the challenge lies often in information management:

- Lack of data quality and consistency
- Engineers spend over 20% of their time in searching for data and accessing or processing it
- A significant portion of engineering and production costs are defined in the design stages

COMOS offers a complete data platform that supports integrated engineering across the entire lifecycle of a plant. This means the data is consistent and of high quality, and tightens the collaboration of differing engineering disciplines, aiding in cross-disciplinary communication and accessibility.

This supports directly the principles of lean in engineering. By reducing the number of interfaces between software’s and solutions that each host a part of the data, and representing the whole within a singular database eliminates several problems and reduces the amount of required expertise and know-how to ensure successful operations. Data discrepancy will be effectively removed by concentrating all related data in a singular database that remains in an ‘online’ state, meaning that no user can have a different view of its contents at any one time.

The complete plant data representation and its integration to SIMIT lay the functional basis for a digital twin. The programmed process behavior and live data will be retrieved from PCS7 in order to actualize an operational twin. Finally, the insights provided from analyzing and processing real process data in MindSphere create a fully digitalized development environment where testing, design and training work can be undertaken without the need to resort to expensive operations performed on the actual process machinery.

“The Finnish forest industry is leading the way for a new bioeconomy by developing customer-oriented product, service and technology innovations. The future of Finland’s forest sector is being built with new approaches using state-of-the-art technologies, interdisciplinary solutions and products that diversify conventional forest industries.” [17]

The transitions in plant development and process operations and various other sectors that are brought by using digital solutions therefore support also the vision of the Finnish Forest Industries Federation on the development of the native forest economy.

7 Targets for further development

The primary target of instantiating the entire asset and establishing its connection to a data-cloud, is to benefit from the various use-cases enabled uniquely by cloud-computing and data-analytics. For a full spectrum of data relevant for the process be made available, every field device and pipe, drive and motor, vessel and tank must necessarily be implemented, rendered, and connected. It is imperative to have the data available on every input, manual cock and valve, sensor values and speed values. Once the cloud receives a sufficient richness of data, self-learning and in-depth analysis become possible.

The targets for usage of this data include various innovations on product quality control, such as a preventive analysis for rope-cutting, and a self-learning cloud-mechanism to pattern out the optimal setup for operating the plant.

Rope cutting is a frequently occurring problem across all fiber processes. Once the chemicals coagulate into filament strands and are supplied from within the vessels to the motor axis' pulling them into a stretched rope (which ends up in a cutting machine, and finally to the wire to undergo the finalization of the fiber), there is often a cut on the stretched rope, causing a halt in the latter part of the process. The cuts occur due to the filament being relatively fragile, and the strain on the motor axis changing due to several reasons. Torque trends are one type of data that can be used analyze the cause of a cut (increased torque, in practical terms, means the filament is not evenly supplied, or is getting stuck in the structure of one motor axis, causing abnormal stretching for the latter part). Another way to analyze the root causes is to control the fiber quality at the end of the process, combined with the readings on sensor values from the dissolving section, and find correlation between chemical values, measured final product quality, and the occurrence of rope cuts.

A suggested method of surveying product quality would be instantiated in a self-learning process on complete process data uploaded into the cloud. A perceived way of doing so would be collecting full operational data from every plant operator, and with enough build-up, comparing these data sets to determine whose manner of driving the machine yields best results in terms of product quality, then use that assortment of process variables to establish the defining settings for operating the process. A desired goal would be to let the cloud control the process on its own based on the reference gained from each control value and their respective impact on the product quality.

8 Conclusion

By examining the global trends of industrial transformations, the need for new business-models and operation-concepts can easily be perceived. The digitalization of forest industry will arrive at the nick of time to solve persistent and growing concerns. The chief challenge is to increase the profit margin at a time when raw-materials are becoming increasingly expensive. This aim is reached by vastly improved process efficiency enabled by the IOT platform and digital twins.

Scalability, operation, problem-encounters and situations can be evaluated in a virtual domain with the help of the digital twin, which dramatically reduces poorly asserted investments, as potential pain-points and faults may be discovered before the physical conception of the asset, or without needing to resort to testing operations leading to process down-time.

The wet spinning process supplied by VTT operated as a preliminary test-tool for these instruments, and already at the early implementation stage it is made evident that the tools offered by Siemens and the concept of the ecosystem are able to tackle issues faced within the particular process and forest industry as a whole, and in a way that simultaneously supports the predicted leverage of digitalized solutions over traditional know-how and experience.

The unique ability of COMOS as a planning and management software enables the virtual creation of a complex process down to its every minutiae detail which is a necessity to the forming of a simulation and the creation of a digital twin. The digital solutions offered by Siemens successfully answer the rising demands of the forest industry and the demands of Industry 4.0 in a way that backs up research on the new requirements of digitalized industries.

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