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Title

Digital Factory – what is real about it?
Digitalizing plants – Integrated engineering from planning to operation

With an Editorial by Anton S. Huber, CEO Digital Factory Division, Siemens AG, for the complete edition of atp

Digital Factory – what is real about it?

This issue of atp edition focuses on the Digital Factory – referring to the industry of the future, including the discrete manufacturing and process industries. How will the Digital Factory influence companies' orientation? What does Digital Factory mean specifically, and how real is it already today?

According to certain prophecies all factory workflows will soon be also controlled via Big Data and the Cloud. Data at the start, data at the end– and in between a host of robots, machines and plants that are able to control themselves. Whether or not this is desirable, however, remains to be seen. But is this possible in principle? Siemens has been a pioneer in industrial automation for many years. The company's client base includes customers from discrete industries such as the automotive industry and also from process industries such as the chemical industry as one of its major business fields. Digitalization has played a key role in this development for many years, with the trend increasing. Siemens is well aware of all the challenges involved – last, but not least, from its many own manufacturing plants. Furthermore, Siemens knows exactly how much time and which investments are required in order to tackle these challenges.

Some years ago all the tools supporting the engineering of automation projects were combined into the TIA Portal which now provides a consistent user interface and enables parallel working with different software tools and even Drag&Drop across these tools. This required a consistent data model and thus the complete reprogramming of all the original tools. The implementation of the Digital Factory implies a similar technical challenge – with, of course, far greater dimensions in terms of its volume and impact. Computer assistance for individual work steps is not enough by far. What also matters is to overcome the many barriers between specialist departments, disciplines and technical areas. And if the Digital Factory does not include the suppliers, their expertise and globally distributed production, then essential elements are, in fact, missing.

Every company has its own prerequisites and targets and must therefore set up its own digital enterprise platform. This basically involves the implementation of a consistent data and information platform across all the different stages of the value creation chain. The powerful and future-proof systems required to achieve this are already available today.

Considering that a vast variety of technologies and products will also be used in future for the implementation of a digital company, existing and new standards are crucial in order to control the costs involved. It therefore goes without saying that the definition of these standards cannot be a mere ivory tower exercise, but must be based on results from daily practice.

The digitalization of the industry is a door opener for promising business opportunities. It will most certainly be tackled by German industry – as was the case with computerization in the 1970s and the Internet trade already established. There is no reason for pessimism nor for the hysterical atmosphere spread by certain associations.

The process industries will move towards digitalization their own way – and even must do so due to their particular characteristics. This issue of atp edition provides an overview of the differences and common ground.

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Digitalizing plants

Integrated engineering from planning to operation

Industrie 4.0 has raised the discussion about the digitalization of industry to a new level. Both product and Plant Lifecycle Management (PLM) are essential when the consistent digitalization of value creation becomes a prerequisite for further development. The authors of this article describe how the constraints governing the individual stages of planning and engineering must be overcome on the way there, as must the barriers still found between disciplines and the various specialist departments. Siemens faces a particular challenge as both a provider and a user of Industrie 4.0.

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The debate about the future-oriented Industrie 4.0 project as a core element of the German federal government's high tech strategy [1] has brought new impetus to the discussion about innovation in the field of plant engineering [2].

In the face of ever fiercer global competition, neither the plant owner nor the plant operator can afford to lose time tackling the digitalization of their value creation processes. For this reason we do not only have the Digital Factory of the manufacturing industry, but also the Digital Plant as the equivalent for the process industry. Both represent the vision for the industry of the future and both involve similar challenges.

The German designation Industrie 4.0 is based on the more general term the Internet of Things (IoT) [3]; the current fundamental changes will actually have a major impact on every industry. Thanks to the extremely small, inexpensive sensors, actuators and digital cameras available today, digitalization has now reached a level which allows communication between almost any object and people as well as with other objects via the Internet and other networks. This concerns almost everything and thus all areas of society – including automobiles, airline tickets and even cardiac pacemakers. The Internet of Things now enables us to grant many devices a high level of autonomy and even allow them to take discrete decisions as well as autonomous actions in certain situations.

This does not only apply to machines and plants, but also to the products manufactured by them. In fact, it is this part of the Internet of Things which is commonly referred to as Industrie 4.0 in Germany. It has become a synonym for the fourth industrial revolution which – after software-controlled automation in the 1960s – now enables the smooth interlinkage of software-controlled machines and products via the Internet and other networks. For the manufacturing industry Industrie 4.0 means that products are becoming more and more intelligent, thus enabling them to identify situations and develop appropriate actions.

Furthermore, machines and production facilities are provided with an intelligence that enables them to run more and more manufacturing and assembly steps fully automatically or even autonomously. The Digital Factory, as a complete digital image of the real factory, provides the basis for this.

For the process industries Industrie 4.0 involves plants being equipped with intelligence. In future an increasing number of steps, which used to be initiated manually in the past, can now run almost without human intervention over a plant's entire lifecycle from planning and commissioning through to operation and maintenance. At the core of this approach is a completely digital image of the real plant, i.e. the so called digital plant.

Process plants today are highly complex and have lifecycles of many years. For this reason it is even more important to replace cost-intensive physical tests and prototypes by simulation – from virtual commissioning, simulation parallel to operation, through to error identification and plant optimization. The repeated, and thus error-prone entry of data already captured in a different context, must be replaced by a consistent digital process chain. Documents no longer need to be available in printed form. Instead, updated plant descriptions and plant layouts should always be available online. The necessary storage and computing capacity is, in fact, available. Thanks to cutting edge software technologies plants in the process industries can become digital plants.

The benefit is clear: speedier and safer planning, parallel engineering, faster commissioning, safer operation and updated documentation. All the stakeholders involved benefit from this approach: the planners, the suppliers of field devices and instruments, the suppliers of plant units and, of course, the operators.

Siemens is active in many respects and has a clear attitude towards Industrie 4.0 [4]: In fact, various group companies are active themselves in discrete manufacturing areas and the process plant engineering business.

The Digital Plant therefore also challenges Siemens as a user. In addition Siemens has the software tools in its portfolio that are required to make the digital plant become reality. Siemens is both a user and a provider of digital plants. This holistic approach significantly influences the development of the tools which Siemens offers to its customers.

In spite of the unquestionable advantages of the digital plant, considerable effort, investment and time are required for its establishment. Digitalization cannot be procured like a new software tool, but must be implemented during operation and thus become effective step by step. The integration of all the existing documents of a plant which, for example, has already been in operation for 20 years into a new system is not practically feasible. In fact, all the relevant plant information – whether digital or in paper form – must be integrated, put in the right context and made available to all the project stakeholders involved.

To obtain a realistic assessment of the implementation options, subjecting the individual sections of a plant's lifecycle to close scrutiny is certainly worth the effort. What matters is to explore their current state and what they can look like when being integrated into a digital plant.

1. DIGITAL PLANNING MEANS PARALLELIZATION

Once laboratory research and recipe formulation have been completed, the planning design phase of a plant project starts with the concept design. A first concept of the process and the hardware is developed based on the customer's specific requirements and the laboratory results. From an economic point of view a plant's early planning phase is of prime importance. Up to 80 percent of a plant project's total cost is already defined upon the start of engineering, i.e. during the Front End Engineering and Design (FEED) phase. All the decisions made at this time will significantly influence subsequent planning steps as well as the safety, performance and cost efficiency of the overall plant. Any mistake occurring during this early phase and not eliminated effectively will impact all further planning. This can require complicated and cost-intensive corrections and might cause damage to property or even personal injury. The complexity of the subsequent engineering process requires precise planning, low risk potential and interconnected process sequences.

The subsequent basic and detailed engineering phases require the smooth cooperation of the many specialist departments involved so as to meet the extremely strict requirements for digitalization in this highly sensitive area. Data, devices and structures must be represented in a coherent, comprehensible and interlinked manner. The data volume to be managed increases as a consequence of the complexity of plants, and the risk of data loss at interfaces is therefore very high [5].

Commissioning, i.e. the transition from planning to plant operation, is playing a crucial role in this context.

The data model which, in many cases, has been created by several subcontractors during the preceding planning phase is handed over on the due commissioning date. All the data and documents from various sources must be available as soon as possible for maintenance work, plant walkthroughs and audits during operation. Since an industrial plant's operational phase can be up to ten times longer than its planning and construction phase, a sustainable multi-stage solution concept must be strategically planned.

The workflows which have been developed and proven their worth in the last 50 years are to a large extent sequentially organized. The results of a work step must be documented and released before the next step is initialized. Various disciplines are involved in this process – including process engineering, mechanics, electrics, hydraulics, safety and compliance, procurement as well as process control system automation. All of them are

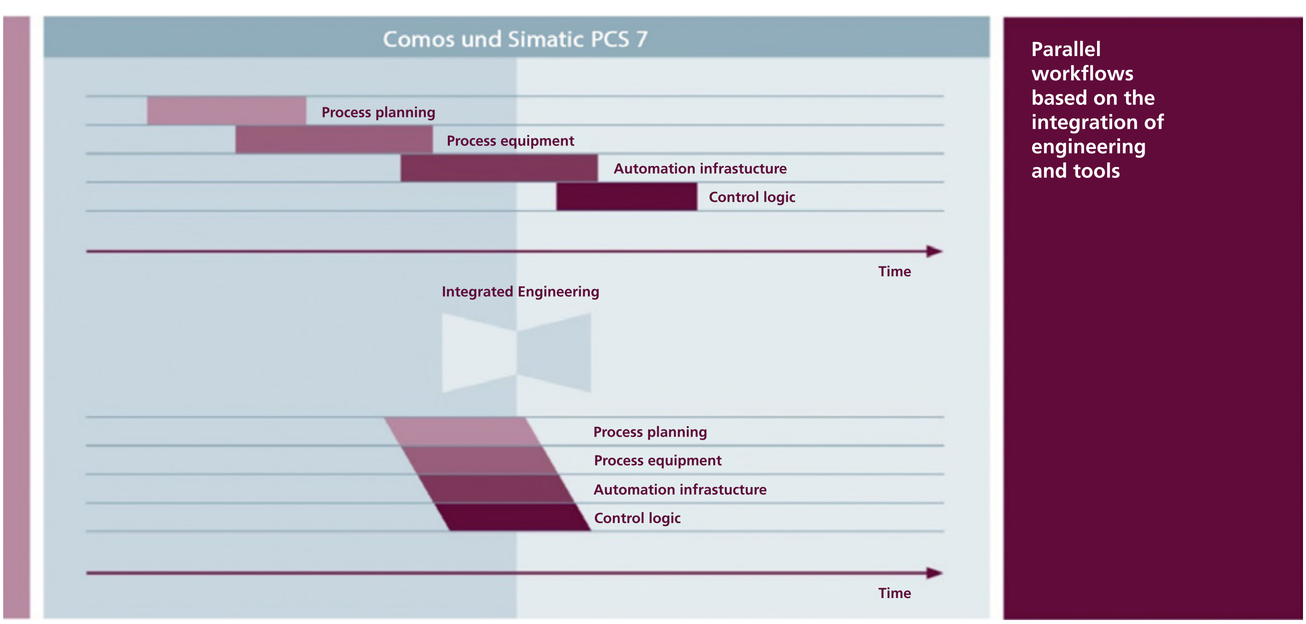

FIGURE 1: Integrated Engineering enables parallel workflows.

working with their special tools, most of which originate from different manufacturers and are based on special formats which complicate or even impede data exchange. Complex interfaces must be installed and updated with every new software version of a system involved. This problem is even aggravated by the fact that several other partners and suppliers are involved in addition to the EPC (Engineering, Procurement, Construction) company responsible for project management.

These additional stakeholders supply devices, instruments or package units for whose development and manufacture they have also used various tools.

The vision of the Digital Plant is based on a uniform data basis which includes all the plant elements in a digital form. The data of all the components and processes are related to each other. The pump recognizes its valves, pipes, connectors, electric circuit diagrams and the control technology. Every change to an existing component within the scope of engineering is recorded and documented in a single place. The corresponding data can either be generated with the same software or must be synchronized in the database.

Such consistent conditions positively influence the entire planning process:

- The engineering data of a specialist department can even be shared with engineers from other areas before being released. This common data basis allows parallel engineering and thus time savings, see Figure 1.
- Documented results are already available at the end of each planning phase, which significantly reduces the otherwise time-consuming documentation phase.
- Depending on the functionality of the software tools involved, the digital plant model enables various types of simulation and thus the testing of plant sections before the actual test run.
- Instruments and devices can be selected online and integrated into the planning process.

2. ON THE WAY TO VIRTUAL COMMISSIONING

Once testing and acceptance have been successfully completed, the plant is installed and commissioned at its owner/operator, including training by the EPC partner.

The operator's employees can be trained on a plant model – for example in 3D – well before the physical installation of the plant. A modern digital plant enables the virtual walkthrough and inspection of all components, see

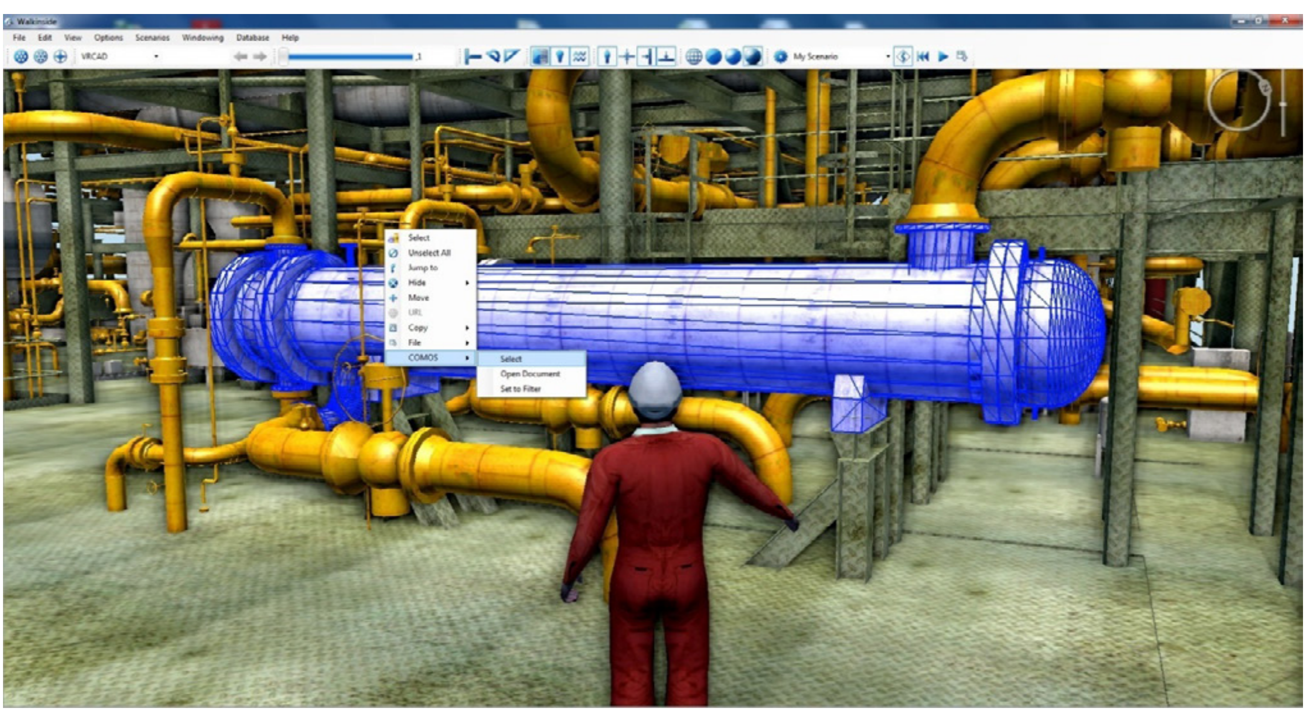

FIGURE 2: Virtual walk through a plant

Figure 2. In addition, service technicians can be instructed in maintenance interventions. Last, but not least, major commissioning tasks can be anticipated virtually using the control technology planned for the real plant.

Even though this is not the most important and longest project phase, the EPC company can score here by relying on digital planning. Representatives from industry already emphasize today that this approach has become a key competitive criterion.

3. MERGER OF THE DIGITAL AND REAL PLANTS

Once the plant is in operation, the goal is to keep it running for as many years as possible without the need for human intervention. Every change and every intervention can involve downtimes and temporary plant standstill. Avoiding any interruption of plant operation is the best way to prevent a measure having any negative effect detrimental to business success in addition to the desired positive effect.

This request is understandable, but is, of course, unrealistic. The plant process is not only extremely complex, but also highly dynamic. Even minor value discrepancies at individual measuring points can have an impact and even lead to a standstill of the entire plant– and this is especially so because malfunctions involve the risk of environmental damage and injury to persons.

For this reason the plant is permanently monitored. Innumerable measuring stations, sensors and cameras provide the control room personnel with valuable information on the functioning and states of all the plant sections. Based on this information the technicians in charge in the control room must then decide which action needs to be initiated.

The control room of a modern process plant (see Figure 3) often resembles the cockpit of an aircraft. Even though a large data volume is already available today, in an emergency technicians start searching paper documents with information on the potential causes of the incident, the components involved, spare parts suppliers and maintenance instructions.

This takes a great deal of time. Service work is often carried out too late and the weak points could have been detected and eliminated well before the process ultimately had to be stopped.

To avoid all this, the digital plant enables a paradigm change: Every item of information required is available in the same data basis and not just as hardcopy folders. Information is smoothly interlinked – the individual

FIGURE 3: View of a modern process control room

components being represented as digital objects – and refers to all the devices linked, see Figure 4. Thanks to 3D support the part causing the problem can even be detected and identified in plant sections difficult to access, see Figure 5. All the actions to be taken as well as any dismantling and assembly steps can even be mapped in virtual reality and used as maintenance instructions.

However, the digital plant not only helps to save time if a malfunction occurs during the operation of a real plant. Every action, every part replacement, every parameter change during operation must be documented. If no digital model is available, this information is still recorded in paper form today or in electronic storage which is, however, hardly ever linked to the planning data. The longer a plant is in operation, the greater are the discrepancies from its original planning data. When using a digital model with a consistent digital process chain to back up the real one, every activity is recorded in the right place in the same database in the planning data record. The planning data and the real plant thus form a unit. To optimize a plant, the plant owner usually only refurbishes individual plant sections. In this case, however, all the planning, test and release phases described above must basically be run through even if only on a small scale basis. Even without the use of a digital model a large amount of data has been recorded during the operation of the component concerned. However, all this data must be converted into requirements and integrated into the new specifications, and a large amount of planning data, in particular, must be re-entered for this purpose. In contrast to this the digital plant allows the operator to reuse the data of an existing component as a basis for modernization. Planners can re-access their planning data and reuse proven component parts which do not require change.

In the last few view years many process plant operators started to implement their modernization projects as pilot projects for the digital plant. The use of consistent software assistance and consistent data chains can be tried and tested in a well manageable framework. Many parts of a large plant, such as reactors or grinding and mixing plants, are of comparable complexity. However, they allow an immediate new-old comparison and thus support the operator in gaining experience with the new methods within a very short time.

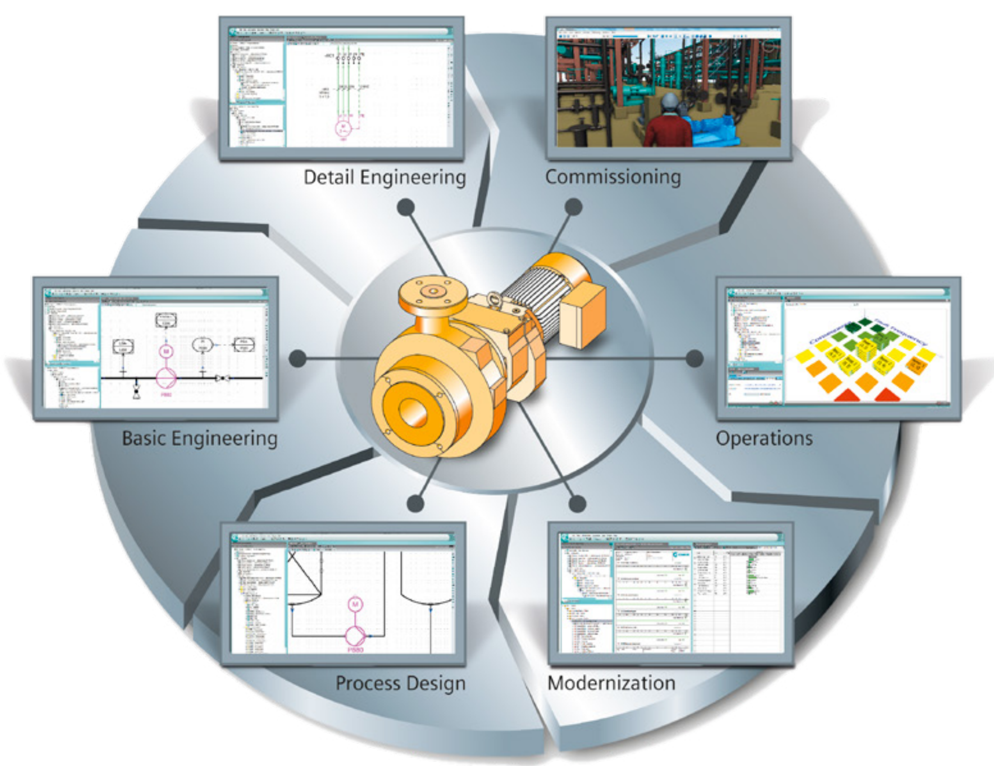

FIGURE 4: Object-oriented data management

To quote an example: Sanofi-Aventis was the first Siemens customer to implement an application for the integrated engineering of process control and technical functions for a 3000 liter batch tank for pharmaceutical production in Building H600 at the Frankfurt-Hoechst Industrial Park. Since this compact and straightforward plant includes many typical units and sequences, it was well suited for a Proof of Concept of integrated engineering.

While operations were continued in the real plant in Frankfurt, a team at Siemens in Karlsruhe worked on a shadow plant in order to further develop the functions required for the bidirectional transfer of engineering data between planning and process control engineering.

The digital plant provides major benefits during operation:

- Secure access to information on all the individual parts of a plant
- Reduced service times
- Avoidance or reduction of downtimes
- Complete and updated documentation
  Reuse of proven parts for modernization

4. PROCESS INDUSTRY AND DISCRETE MANUFACTURING: TWO MEANINGS OF PLM

PLM is a commonly used abbreviation in both the manufacturing industries and the process industries. In the discrete manufacturing industry it means Product Lifecycle Management, whereas in the process industry it means Plant Lifecycle Management.

In the manufacturing industry PLM stands for the aspiration to interlink all the data from the very first product idea to product development, production planning and manufacturing through to operation or the use of the product by the customer. Since the management of data over the entire product lifecyle in one single database provides many advantages for producers and also their manufacturers and partners, PLM is already a specific area or

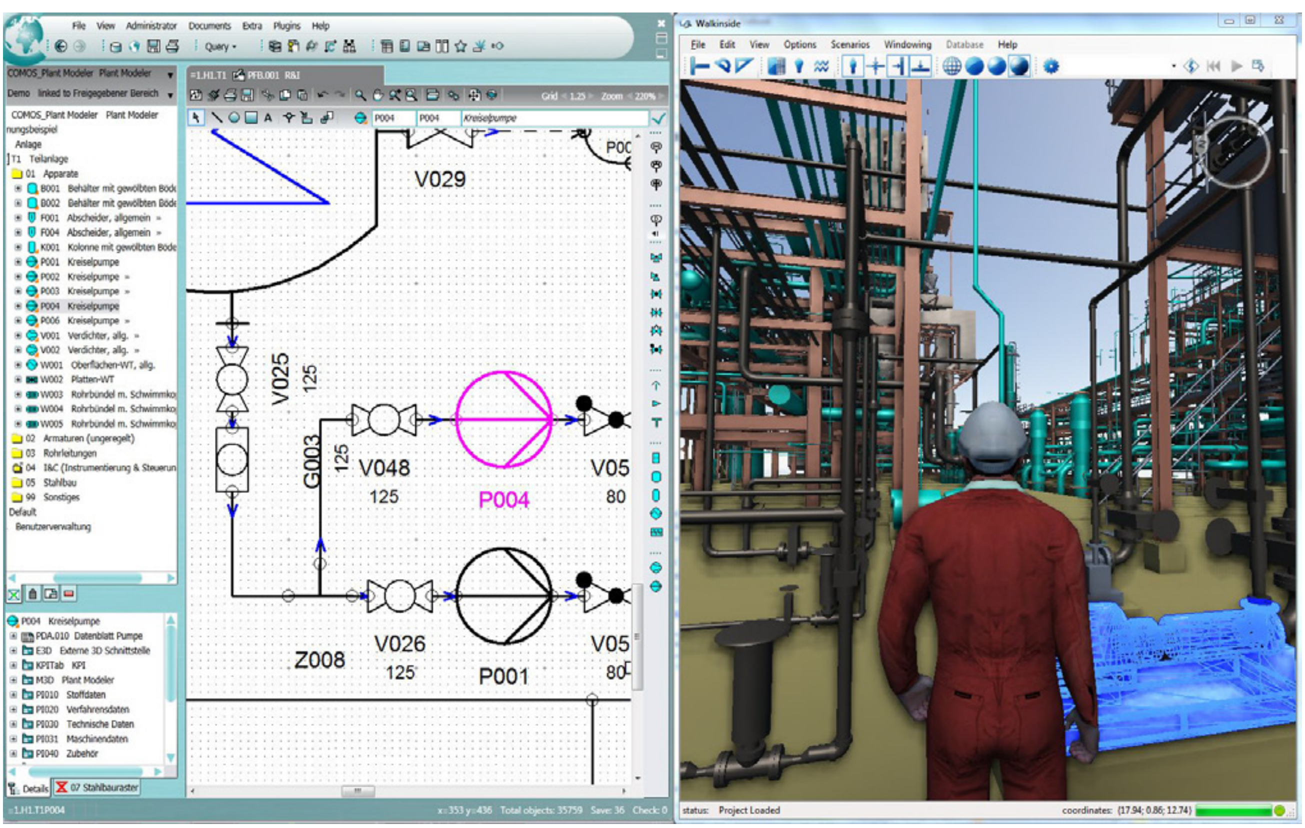

FIGURE 5: The virtual plant helps to quickly identify problems

responsibility in many companies today. The complete digitalization of a product must be reflected in a consistent data chain which, in turn, is an image of the actual value added chain.

In the process industries PLM stands for a globally integrateable and comprehensive software solution concept which enables the consistent flow of project-relevant data across all corporate levels and project phases. This comprehensive data consistency is a key prerequisite for cost effectiveness and efficiency. In fact, rationalization effects are basically the result of the smooth, IT-based flow of information over a plant's entire lifecyle, extensive data standardization and comprehensive automatic sequences.

If these two approaches are implemented (see Figure 6), the plant planning engineer can already use the device manufacturer's data in a digital format that can be simulated for planning purposes. In turn, the results from plant testing and operation can include valuable data for the device to be supplied which, for example, the device manufacturer can directly use for modernization purposes.

For the entire industry PLM represents the challenge to benefit from digitalization in order to establish a virtual value creation chain each step of which can be simulated, calculated and tested virtually – i.e. cost-efficiently and within considerably less time than if physically performed – and, last but not least, documented accordingly. This is the key prerequisite for process and manufacturing results being sufficiently intelligent in order to meet the requirements for the vision of Industrie 4.0. Without this complete digitalization there will neither be an economically successful product memory nor any advanced autonomization of individual value creation steps.

5. SIEMENS AND THE DIGITAL ENTERPRISE PLATFORM

In theory it can be quite easily and quickly described what the digital plant will look like and what its benefits will be. In practice, however, the industry is facing a dilemma.

The high costs involved in advanced digitalization, the considerable amount of time and money to be invested in employee training – all this expenditure does not pay off as quickly as decision makers would wish. The change must rather be based on progressive evolution. Modernization should start with small pilot projects and be implemented step by step in reasonable doses which can be coped with during plant operation. In view of the far-reaching dimensions a radical change to new methods would not be the right approach. A great deal of preliminary work is required.

As a prerequisite for consistent digitalization industry must develop a common basis for its tools and methods. This could mean that many of the existing data and process models must be replaced. However, the necessary

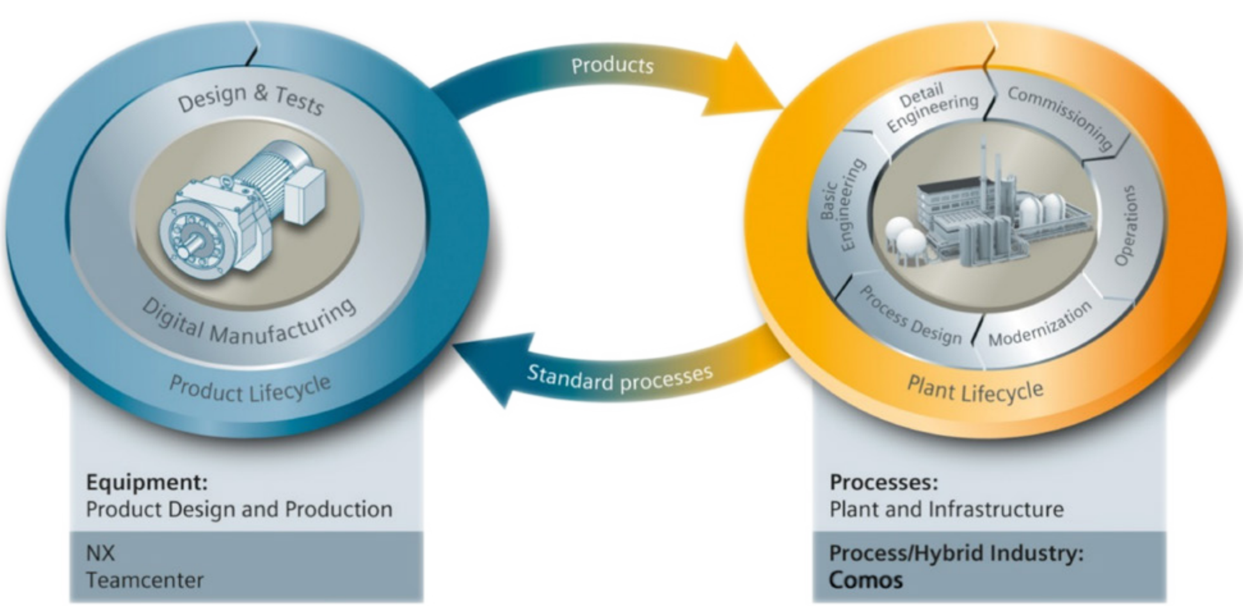

FIGURE 6: Plant Lifecycle Management and Product Lifecycle Management seamlessly interact with each other.

level of consistency cannot be achieved without a common data basis. What is required is a platform that synchronizes all the software tools used in all the involved areas and units of the globally extended enterprise. Since no individual system is currently able to cover all the tasks and requirements – and presumably will not be in future either –, corporate-wide or even cross-corporate platforms must be capable of integrating data originating from the most versatile systems. These platforms must be open and non-proprietary. This requires the use of standards, some of which are already available today and some of which should be adopted by industry within the shortest possible time.

In December 2013 the DKE (German Commission for Electrical, Electronic & Information Technologies) / VDE (German Association for Electrical, Electronic and Information Technologies) already published the German Standardization Roadmap Industrie 4.0 [5] which describes all the topic areas concerned in full detail and provides concrete recommendations for the standardization of Industrie 4.0.

To achieve this, the special needs and requirements of the process and manufacturing industries must be taken fully into consideration. For this reason Siemens has structured its industry business into the Process Industries and Drive Division on the one side, and the Digital Factory on the other.

Driven by both the requirements of its own plants and the requirements of its customers from the discrete manufacturing and process industries, these two Siemens Divisions have set up a comprehensive industry software pool which basically focuses on COMOS and the Siemens PLM software.

The integration of COMOS and the decentralized SIMATIC PCS 7 process control system has enabled Siemens to bridge the gap between engineering and automation and thus also between the engineering and the operational phases. This integration provides the basis for holistic engineering across all the planning phases of an industrial plant with a reduced number of interfaces. The entire plant structure can be generated from the engineering data available in the control system at the push of a button, which simplifies automation engineering and significantly reduces the time required.

The SIMATIC PCS 7 also transfers changes to automation components during operation – for example the replacement

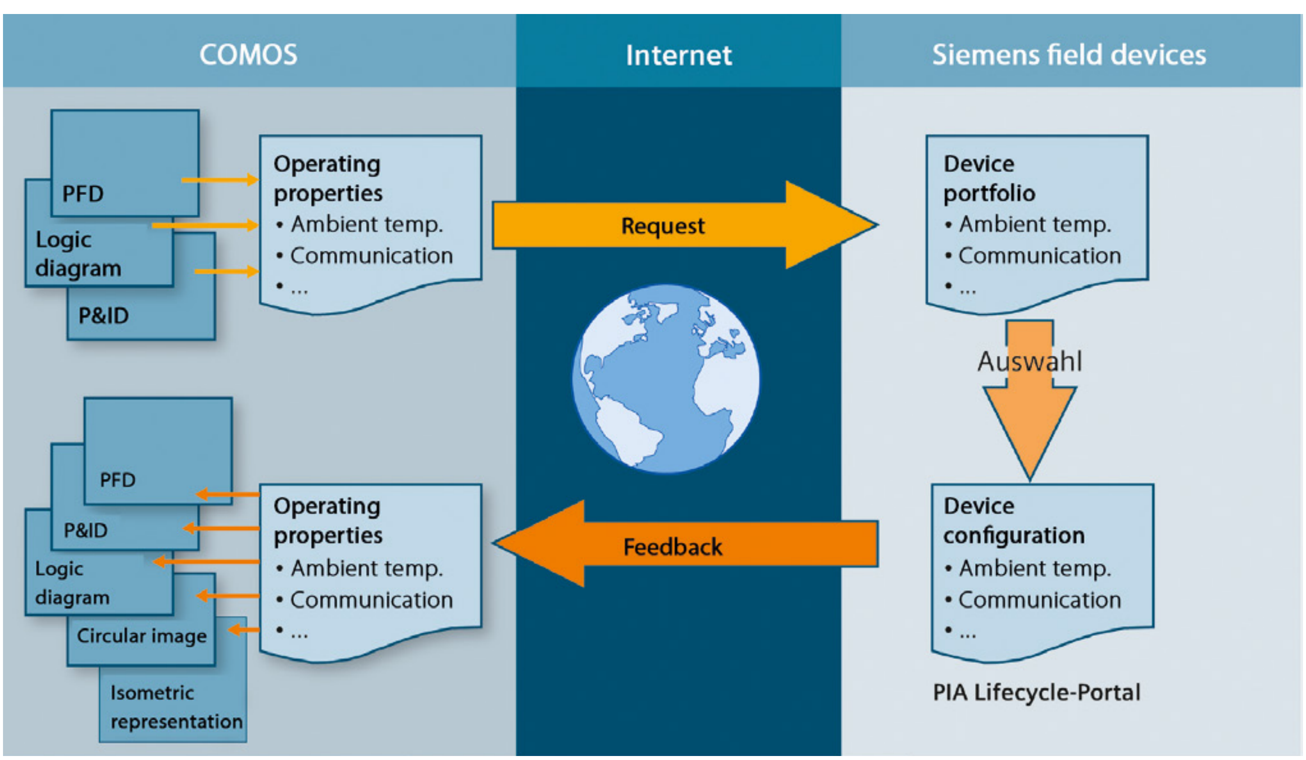

FIGURE 7: Bidirectional data exchange between engineering and field devices

of field devices – back into COMOS. The engineering data basis is thus updated immediately, including the plant's entire documentation. In addition, the PIA Lifecycle Portal provides online access to devices and instruments and automatically generates suggestions from the COMOS planning data, see Figure 7.

SIMIT is a valuable tool for testing and virtual commissioning.

Furthermore, COMOS Walkinside provides a 3D Virtual Reality Viewer which enables the reuse of the 3D data generated during the engineering phases during all plant lifecycle phases – including operation, maintenance planning, simulation and workforce training. Plant operators and engineers can thus rely on a realistic representation of complex plant models that simulate the impression of being physically present on site. Typical applications include project progress controls, problem solution sessions, immersive off-site training, the provision of spatial context for engineering and maintenance tasks as well as decision making support for emergency cases.

Every single step on the way to integrated engineering provides major benefits:

Provided that all the relevant tests have been successfully passed, models of individual instruments or devices can be used any number of times and for many different plants.

A device does not need to be redesigned from scratch in order to implement minor changes if minimal changes to an existing digital model also fit the purpose. The results of a digital plant layout plan can already be used for virtual walkthroughs, e.g. for training purposes, before actually bridging the gap to the process control technology. Consistent digitalization is performed in individual steps and phases which, of course, all serve a strategic goal and must be interlinked with each other. However, each individual step already has a great effect.

With its focus on the discrete manufacturing industries the Siemens PLM software supports the management of the Digital Factory across the entire product and production lifecycle. With its focus on the process industries the Siemens COMOS and SIMATIC PCS 7 solutions enable the integrated engineering of plants.

SUMMARY

Industrie 4.0, a future-oriented project launched by the German federal government, is on everybody's lips today.

Amongst entrepreneurs it created awareness for the potential effects of the Internet of Things on a major industrial nation such as Germany where both the manufacturing industry and the process industry play a key role for the country's economy. Both industries are facing the challenge to make a big leap forward towards digitalization. In addition to real engineering and operation, companies in both industries must set up a parallel digital world which includes all the individual phases of a product's and plant's lifecycle– from the very first idea through to final discontinuation/shutdown.

To achieve this, providers must close ranks with their customers in order to establish digital enterprise platforms together which are open for the many tools used by industry and able to integrate their data. Siemens is acting on both sides: as a provider and also as a user. Due to this double role we, at Siemens, have a holistic view that drives us in our development towards the industry of the future and also provides the necessary basis.

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