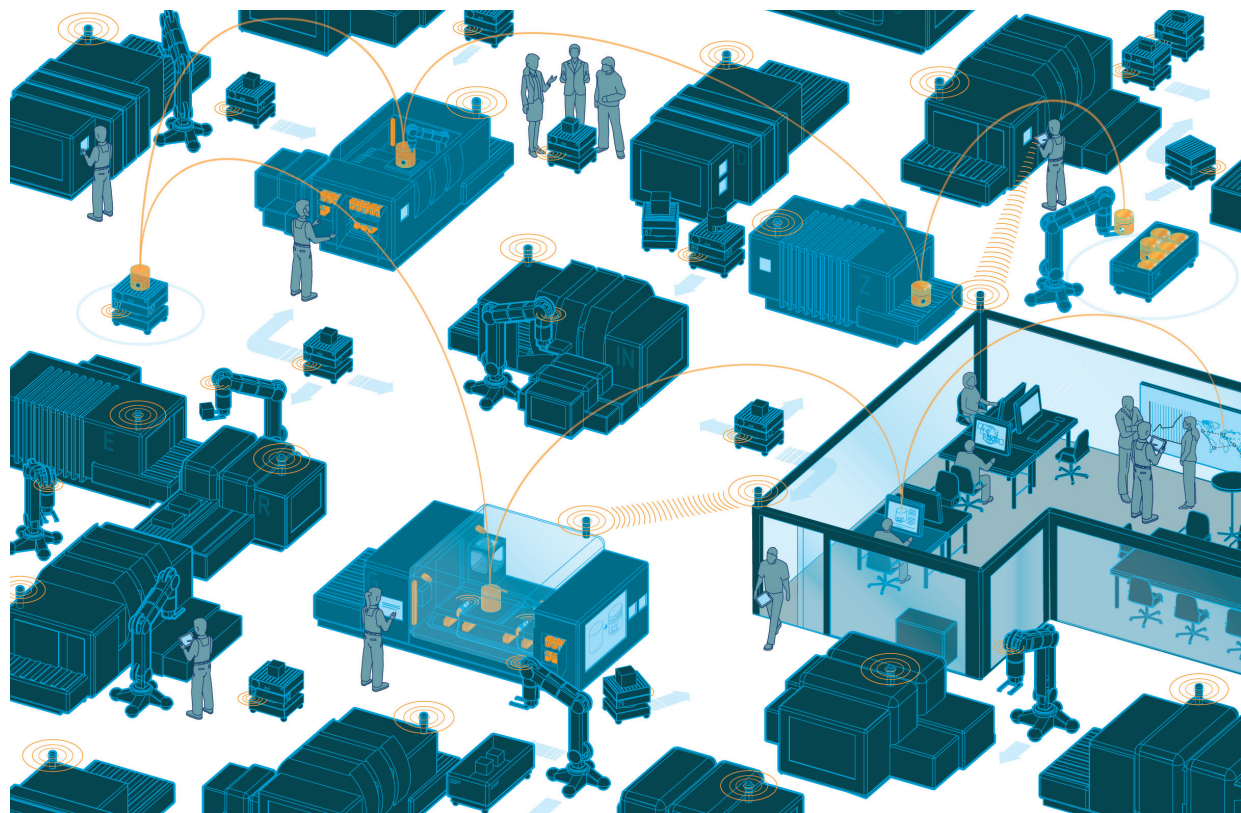


Industrial Software 4.0?

What challenges must industrial software development face as a result of emerging Industrie 4.0 concepts?



White Paper – Part 1



Die Elektroindustrie

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Industrial Software 4.0?

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This publication is part of a series of white papers:

Part 1 – Industrial Software 4.0?

Part 2 – Electrical Connectivity Industrie 4.0?

...other parts will follow.

A White Paper from the working group System Aspects in the Automation Division

The Automation Division works on topics and challenges within the German Electrical and Electronic Manufacturers Association (ZVEI) from the perspective of manufacturers and users of automation equipment. By far the most discussed topic in this context is Industrie 4.0 and the associated potential, architectures, standards and technologies.

The working group System Aspects is aware of the significant importance of this topic area and has set itself the goal of examining and identifying the specific potential impact on basic technologies in our domains.

Frankfurt am Main, January 2015

Dr. Rolf Birkhofer
Convener of the working group System Aspects

This is being pursued as part of a small series of White Papers, and this document on the subject of software development is the first in this series. As the basic work on Industrie 4.0 topics is still in its early stages, the members of the working group do not see the White Paper as additional solution proposals, but rather as a (to some extent) critical examination of the anticipated implementation and application scenarios.

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1 Introduction

A buzzword is an expression that draws special attention from the person who reads or hears it. While this was previously reserved for the IT domain in particular (e.g. with terms such as Web 2.0 or the cloud), the term Industrie 4.0 has provided much food for thought since HANNOVER MESSE 2011 as the domain's own buzzword.

The industrial associations Bitkom, ZVEI and VDMA see significant potential in this topic and have created an infrastructure to support the implementation of the technology-driven ideas in products and systems under the umbrella term Industrie 4.0.

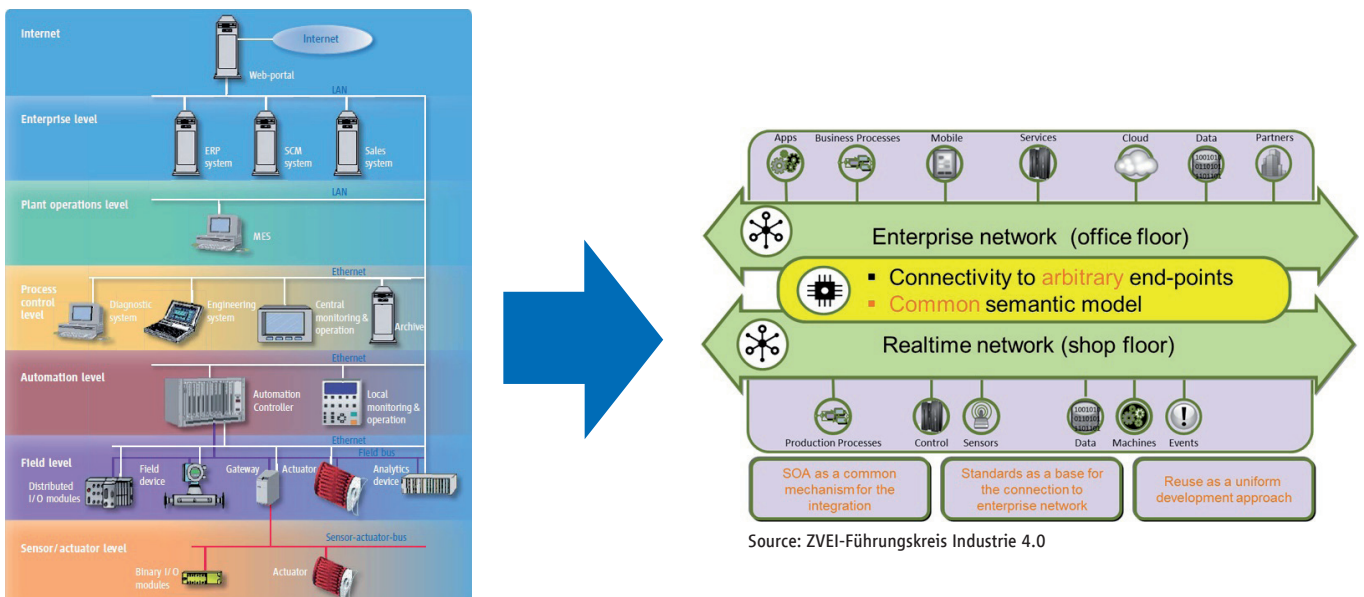
The ZVEI working group System Aspects has, in the past, looked at cross-cutting automation topics and published the results in a host of publications on topics, such as industrial Ethernet, web-based technologies and life-cycle management [4], [5], [8]. Their work currently focuses on selected topics relating to Industrie 4.0 with the aim of identifying the potential impact, and working out and describing opportunities. As always, careful analysis also includes identifying potential risks and proposals for avoiding them. The working

group System Aspects will publish its findings periodically in the form of White Papers; this document on the subject of industrial software is the first in the series.

The reason for this, in particular, is that software can be regarded as the key link between the components of the automation architecture, and its development or maintenance already makes up a large share of the total outlay.

The following topics will be examined in this White Paper: after a brief definition of the term industrial software, the Paper describes the anticipated user benefits of Industrie 4.0. The main part focuses on the technical challenges. Interoperability, data volumes and user centering are some of the terms that will be looked at more closely in this section. The Paper will then look at the commercial aspects, before finishing with an initial conclusion.

Figure 1: From the automation pyramid to Industrie 4.0



Source: ZVEI-Führungskreis Industrie 4.0

Source: Prof. Wollschlaeger, TU Dresden

Definition of industrial software

The term industrial software refers to software that is required in order to program¹, configure and operate an automation system. This currently includes:

- Software for embedded systems, often referred to as firmware
- Software drivers, which enable communication with embedded systems in a host application
- Host applications that use the software drivers (e.g. SCADA, DCS)
- Operations² software such as MES, plant asset management, maintenance management
- Engineering tools
- Apps for on-site operation and diagnosis

Underlying operating system software on which the above categories are used is excluded from the analysis.

Compared with software from the consumer sector, industrial software is usually issued in small quantities. The life cycle or usage period anticipated by customers is reciprocal to this.

Apart from a few exceptions, implementing a deterministic execution of programs up to within fractions of a second is also a key cri-

terion for industry-compatible software. It is generally designed for dedicated hardware and usually cannot be enhanced by the user (in terms of add-ons, plug-ins, etc.). Although technologies such as OPC and FDT/DTM provide clearly defined, open interfaces and break up this closed nature, a combination of software components from various manufacturers is not always possible without glitches.

For interaction between the entities shown in Figure 1 (right), industrial software will play a key role in the implementation of Industrie 4.0. The combination of intelligent software modules will be a means to bridge the semantic gap³ between the individual hardware components. It is also only possible to generate meaningful, useful information from the flood of individual data using suitable software (algorithms).

In summary, it can be concluded that the software already contributes significantly towards creating added value for manufacturers and users of automation technology. With Industrie 4.0, this contribution will (and must) continue to increase!

2 Anticipated user benefits relating to Industrie 4.0

Acceptance of Industrie 4.0 solutions depends to a large extent on how successful the manufacturers of smart products are in achieving real, tangible application benefits. This is anticipated due to more efficient production of goods by increasing the flexibility, adaptability, scalability and availability of production while reducing expenditure.

The standards set in the consumer sector, such as easy operation, app technology, and continuous mobile communications possibilities inspire these expectations. This can be illustrated using the example of predictive maintenance of production systems:

¹ In terms of "creating a project-specific application."

² Many companies make a distinction between enterprise, operational and control level. In this Paper, today's enterprise (ERP) systems are not taken into account, as they largely have higher-level tasks.

³ According to Wikipedia: "difference in meaning between two descriptions of an object."

In an Industrie 4.0 production network, the installed components ensure that the status data of all production means are constantly available, monitored and can be compared with online historical data. This means that maintenance tasks (servicing or an exchange) can be scheduled and performed at exactly the right time. In particular, the maintenance personnel have access to the right information when carrying out an exchange, including the right version and language, and additional information with appropriate granularity. The expert knowledge that will still be required is now available to a wider group of users and on a larger scale.

Self-description and self-configuration methods for Industrie 4.0 components promise a further reduction in engineering outlay across the system life cycle through simultaneous engineering methods currently used as standard for selection, planning, project design and set-up of production facilities and their

automation solutions. Some reasons for this are described in more detail in the “commercial aspects” section, in particular. The anticipated increase in the consistency and compatibility of an application’s development data across the entire engineering period also results in shorter set-up times and data of a higher quality.

New requirements for manufacturing companies, such as the wish to scale the output of a system, can be realized more easily in the Industrie 4.0. environment. This scenario, which is discussed under the title “Module-based production in process industry” [3] benefits above all from the open integration concepts and allows reduced capital commitment and the possibility to adapt to local markets, as well as a prompt reaction to fluctuating requirements. Open integration means making the characteristics of the individual components interrelated. Clearly specified semantics are a prerequisite for this.

3 Technical challenges

In order to give life to the concepts for Industrie 4.0, all the components in the field need to be equipped even more consistently and extensively with computing capacity and communications connections. The requirement for data exchange to be continuously available and for decentralized data processing directly impacts the installed software through the following new or increased challenges:

- Increased interoperability between the communication participants
- Increase in the data volume
- New aspects of user centering
- (Data) security

3.1 Increased interoperability between the communication participants

In the course of Industrie 4.0, the communication structures between the components of automation will change fundamentally. This affects both the hardware modules and, above all, the software.

In contrast to today’s largely pre-defined, hierarchical communication routes, Industrie 4.0 brings with it active communication participants [6] that network independently and, in the process, can act as both data sources and data sinks, depending on the situation.

Furthermore, these communication relationships are highly dynamic and constantly adapt to the current situation, which will also have a significant impact on the engineering process. While, at present, all relationships between components need to be explicitly planned for during planning and commissioning, with Industrie 4.0, the steps that are currently performed during the offline planning process will be transferred to the live online process. In the future, more general provisions and framework conditions will be specified (for more information, see “Data managers” in [6]).

Example of temperature regulation:

- Today: "Get/use temperature value T1 from Sensor LT17!"
- In future: "Get/use temperature value (with meaningful quality and resolution) from plant area 4."

This is in the interest of the user benefit addressed in [1]. However, realizing such services and devices requires new cross-manufacturer international standards and their implementation.

This primarily involves the following:

- Open software interfaces without company-specific enhancements, such as OPC-UA, FDI and FDT
- Self-describing interfaces, including
 - The semantic description of their data
 - Standardized data formats
 - Definition of non-functional properties, e.g. quality of service, determinism, response time
 - Standardized, unique identification of objects and instances
- A defined change process for interfaces, which requires a corresponding life-cycle management – a negative example was the switch from .net 1.1 to .net 2.0. This is particularly significant against the background of the significantly longer useful life of automation technology in industry compared to commercial IT [8].

Moreover, software for Industrie 4.0 applications will also need to work on various platforms and runtime environments in the future. From today's point of view, this means that system platforms from the embedded area will need to be supported as well as Web environments, classic desktop operating systems and mobile devices (iOS, Android, etc.). No manufacturer of automation devices will be able to achieve this without great effort. In order to manage this with economically viable costs, development methods need to be found that will optimize or reduce the implementation and testing effort compared to that which is currently needed.

At the same time, it is important to ensure that multi-platform technologies are used as far as possible, for example HTML5 today.

Controller applications also need to be developed for various PLC systems. Here, a standard that goes far beyond a definition of basic language elements is absolutely essential – for example, it is necessary to ensure that a sufficient range of functions is available and that a clear exchange format is available for graphical languages as well. Although IEC 61131-3 is an implemented and proven standard, in practice it only partially fulfills these requirements.

Over the course of Industrie 4.0, more complex and larger networking structures will arise that will ultimately only perform the actual function together. The resulting requirement for interaction needs to be ensured in advance, for instance through offline engineering and simulation. This ultimately means that it will be increasingly necessary to deploy the future software in the phases before live plant operation as well. As well as the application cases that have already been mentioned – offline engineering and simulation – possibilities here are training, certification and acceptance scenarios.

However, a true advantage only arises if the data exchange between these phases is guaranteed in both directions (round trip engineering).

However, despite all interoperability, conflict nevertheless arises with regard to the planned Industrie 4.0 systems: the required dynamic interaction of the components including enhancement and exchange is diametrically opposed to the regulatory needs of classic industries. For example, in pharmaceutical plants (21CFR11), a dedicated risk analysis followed by certification must be performed following every change; this is also increasingly being demanded in the food sector as well as for cigarettes and beverages. A possible way out of this dilemma could be to implement restrictions for the regulated industries

with regard to the combination options, test scenarios and device selection. A prequalification of every component appears essential from today's viewpoint; however, this will not be sufficient.

3.2 Increase in the data volume

One of the key ideas behind Industrie 4.0 is that sensors can continuously communicate additional status and environmental data as well as the actual measurement data.

Example: There are already energy measurement devices in use that can supply more than 2,000 additional dynamic values in addition to currents and voltages. Theoretically, these values can be updated every second. With 4-byte float values, this means 8 Kbyte/sec or 28.8 Mbyte/h!

If you imagine such devices in a larger network, it becomes clear that huge data volumes need to be transported, distributed and processed. It is immediately apparent that such data volumes cannot be sensibly managed or evaluated with today's means. In particular in the area of embedded systems, performance aspects will gain even greater significance. This will have an impact on the pure processing power, for which greater potential is available in the areas of parallel computing and multi-core programming. In addition, progress still needs to be made when it comes to the flexible utilization of distributed resources (if a sensor fails, for example, an alternative option is sought).

When addressing the challenge of large data volumes, it can be assumed that

- Both decentral and central processing and storage will be used:
 - On the one hand, there will be data that needs to be processed immediately or is only relevant locally. In this case, decentral processing is required.
 - If, on the other hand, data is relevant system-wide, a data source (e.g. a sensor) makes it available in a cloud and can then be used and processed by any (authorized) participants.

- Today's components that are not based on Ethernet communication mechanisms will require an additional communication channel, preferably wireless. This will allow data streaming without impacting the real-time PV channel.
- There will be more analysis, preprocessing, compression and aggregation in the components; this means the software volume in the devices/components will rise, leading to increased complexity in the embedded area.
- New communication protocol services, such as publisher/subscriber models, will be used.
- Data mining methods will have to be used in order to recognize the relevant and coherent patterns from the huge data volume.
- Every generated date will have to be given a time stamp. There will be various classes of data that are subject to different levels of preciseness.

3.3 User centering

Today, most industry components have to be operated by specially trained personnel. This can often ultimately be attributed to the fact that usability aspects are not considered. This is already apparent during commissioning:

- No user management
- No self-learning functions
- Cryptic identifiers with restricted support
- Documentation too complex
- Important and unimportant things mixed

With the transfer of the system to the operators, the people who support the system are faced with major challenges. System operators⁴ are often already overloaded with messages from the field, be it warnings or alarms, meaning there is a risk of the key, higher-priority messages being lost in the flood. Conversely, therefore, the aim should be to place the focus back on the users of systems and components. Information needs to be intelligently filtered, compressed and prepared and presented in a role-specific manner. In the chemical industry, based on the analysis of various accidents, recommendations and guidelines were defined for this that are

⁴in the sense of "operator"

being incorporated into the operating interfaces of the automated devices and interfaces on a step-by-step basis under the term ASM [7] (especially in the petrochemical industry) and NE 107.

A first step has to be designing the user interfaces in a more intuitive, simple and standardized manner as well as adapting it to the operator. For this, the following technologies, among others, can be called upon in the software development area:

- Designing user interfaces (usability engineering)
- Role models
- Augmented reality
- Smartwear output devices (e.g. Google Glass)
- Output device-specific creation of graphical interfaces and information (responsive design)
- Gesture control
- Self-adapting graphical interfaces

The consumer goods industry has already set de-facto standards in the area of smartphones, which are also increasingly required or expected by the users of industrial components, such as multi-touch and gesture control or app technology. Due to the large number of components, the versions, the possible combinations and configuration options, it is easy to see that a more stringent consideration of user-friendliness is essential.

3.4 Security

Of course, open systems also offer an open flank for attackers and intruders. Malware programs already provide access to control systems in industrial environments [9]. In the world of Industrie 4.0, a significantly larger data volume will be generated with the corresponding need for communication; much of this data is classed as sensitive. Interception or even manipulation of this data can have serious consequences. Standardized security mechanisms like encryption, data signing and the authentication of components need to be analyzed and enhanced to guarantee secure

production in the future. Cyber security is a major topic, not only in industry but also in ordinary IT, and numerous activities are underway or currently being initiated.

For this reason, at this point we will not go into specifics, but refer you to relevant publications that are developed in ZVEI working groups among other things.

4 Commercial aspects

Based on today's state of the technology, it is already possible to assemble products from various manufacturers into an automation system using standards such as Profibus, Modbus, CAN, EDDL, FDT, OPC, etc. However, the effort required until the required data is exchanged within the system is considerable and generally involves significant testing effort. However, the responsibility for the correct functioning is always clear: it lies explicitly with the person who acts as the application designer, as this person also has to procure the correct version of the individual modules/drivers/firmware. This role can be performed by the end user personally, a manufacturer as the main automation vendor or a dedicated system integrator.

Due to the components' self-configuration ability and the option of connecting each individual component to the cloud/the Internet, project planning costs will be significantly reduced in the scope of Industrie 4.0. For example, it is conceivable that a drive will independently ensure that the latest drivers and modules are loaded on the control system. It is even possible that application designers will be supported with application examples and more.

To allow these convenient functions, manufacturers will be required to make significant investments in such products, also viewed over the entire life cycle.

In addition, with regard to

- Seamless interaction with other components
 - Automatic identification in the cloud so that the correct software modules for the phase of the life cycle can be provided
 - Documentation and maintenance of the drivers, modules, etc.
 - Logging of downloads, updates and upgrades for reasons of comprehensibility
- part of the responsibility is also transferred to the individual manufacturers supplying the goods.

As part of the responsibility, the following questions arise that need to be unambiguously clarified:

- Who is responsible if a function in the network does not work correctly?
- Who is liable for the costs?
- What is to be done if an incorrect driver or version is loaded?
- What is a manufacturer's responsibility for a system network if he withdraws a component?

Only detailed standardization can contribute to designing this topic in a manageable way.

In the scope of Industrie 4.0, further commercial challenges will arise. In the same way as the consumer world of smartphone apps, the management of software licenses will become extremely important. It can be assumed that the number of licenses will also increase substantially in industrial systems. New business models for licensing (e.g. renting, leasing, pay-per-use) and license management will arise, not least to ensure return on investment. One possibility could be special Internet portals as we already know them from Microsoft, Apple, Google and others. A possible success criterion in the industrial environment may be that such a portal is manufacturer-independent. It is also possible that the providers of such portals will take on a certification role so that only adequately assessed components, drivers, modules and programs come into circulation. Such certification must also include signing of the artefacts, for example to prove the integrity of the software. In order to fulfill the increased requirements on the software and validation process, it is important to ensure that a certain probability of faults cannot be exceeded, for example by developing in accordance with functional safety aspects (see IEC61508, for example). Today, only a few software engineers have the required qualifications and experience for this; however, in the future they will play a much greater role.

New models for service provision could also be used in the (automation) cloud – for example energy management or the energy optimization of field components could be tendered virtually and performed by specialist companies.

Among others, applications cases are described in [2], for example data replication. A wide range of scenarios can also be imagined when it comes to asset management – specialists for pumps, heat exchangers, turbines and other aggregates could provide data access services via the cloud. The low sales costs compared with today – thanks to the portals – will allow small, specialized companies in particular to reach the market with good solutions.

In order to set up such interactions between software components, contracts will need to be concluded in the sense of service level agreements⁵. Here, it is also necessary to regulate how the topic of data protection will be addressed.

Conclusion

“In the future, 50 percent of development teams in industrial companies will be made up of software engineers,” Joe Kaeser, CEO of Siemens, stated at the ZVEI annual members’ meeting in 2014. The discussion of technical and commercial aspects in this White Paper underlines this statement. It becomes clearly evident that software will be a central architecture component of the information world specified in Industrie 4.0 and the development of this will therefore take on immense significance.

In particular the high demands for interoperability will require consistent standardization of interfaces. When it comes to this critical success factor, it will be important to define standards as quickly as possible and make them usable in order to make rapid implementation possible for the industrial companies. Only then will the users benefit from the advantages.

This will make it clear that the term Industrie 4.0, which was initially labeled a buzzword, will have great potential for new and changed business models and also provide great potential for productivity improvements. However one looks at it, industrial companies will be obliged to deal with the topic in general and, specifically, with modern software development.

⁵SLA is machine-readable additional information that describes the agreed services.

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