

# Information Technology for the Factory of the Future – State of the Art and Need for Action

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## Abstract

Information and Communication Technology (ICT) is a key factor for the factory of the future – acting as an ‘enabling technology’, as it were. For production, ICT is a tool, not an end in itself. In the future, the shop floor will be increasingly supported by ICT components, which, in turn, will start to network themselves. In the following article, some of the areas of current activity and the effects of the increasing use of ICT will be described.

## Keywords:

Manufacturing Execution Systems; ICT for Manufacturing; Interoperability; Industrie 4.0

## 1 INTRODUCTION

ICT for the factory of the future has to support the well-known objectives [1] such as

- the quality required by the customer which also affects robust production processes
- speed and time with regard to innovations, lead times and start-up of production plants
- competitive production costs impacting investment in equipment and IT.

These objectives also have to be considered to be the limiting factors in the design of manufacturing IT architectures and systems. They also one of the reasons why a lot of modern technologies that conquered the market for consumer goods long ago are only gradually entering the manufacturing sector, such as the use of smart phones or three-dimensional visualization, for example.

In addition to the well-known triad of quality, time and costs, the following features will be decisive for the success of production in the future [2], including

- adaptivity to a wide variety of product variants, which also affects integration and interoperability in shopfloor-related IT,
- real-time compliance affecting the rapid availability of required information to authorized users
- network compliance and extended visibility into the entire compound of plants or organizations rather than just one location.

In addition, the IT support needs to span the entire life cycle of products and production, while the manufacturing IT needs to be integrated with the overall IT architecture of an organization.

## 2 ARCHITECTURAL MODEL OF ICT FOR MANUFACTURING

In the past, the architecture of information technology of manufacturing enterprises was reflected in various multi-tier models, the most famous of which is the Automation Pyramid (figure 1). Owing to the increasing IT support on all hierarchical

levels of the factory, a new trend is emerging today: an increase in information flows across all levels of the plant and thus the need for a new ‘reference model of industrial information architecture’ [3], which has to reflect the three dimensions of vertical and horizontal integration as well as integration spanning the life cycle of production equipment.

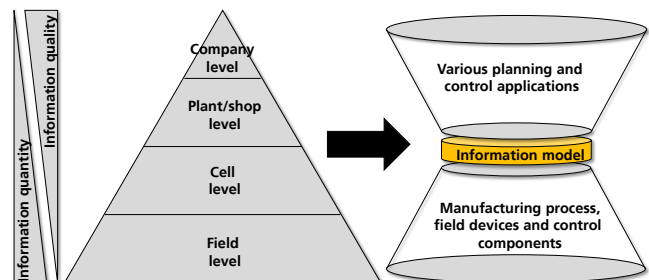


Figure 1: Changing Information Architecture in Manufacturing Enterprises (see [3]).

The compliance of shopfloor-related IT systems with consistent communication throughout the three aforementioned dimensions, for example, requires their systematic integration with Digital Factory systems (lifecycle dimension) and automation technology at the field level (vertical integration dimension). To this end, it is indispensable to use syntax and semantics that span all hierarchical levels. Other authors agree that there is this need for consistency, e.g. when it comes to the engineering of manufacturing execution systems [4].

## 3 EXAMPLES OF COMPONENTS FOR AN INFORMATION MODEL FOR THE FACTORY OF THE FUTURE

### 3.1 MES as Factory Information Hubs

In 2007, the Association of German Engineers (VDI) published Guideline 5600 on ‘Manufacturing Execution Systems’ [5], which will be abbreviated as MES hereinafter. The guideline does not contain a statement about the aforementioned necessary

requirements of vertical and horizontal integration and the integration spanning the entire lifecycle. In the meantime, VDI has published part 3 [6] of this guideline, which defines an interface between machinery and MES. Part 3 focuses on vertical integration of plant control and MES. „MES systems necessarily depend on the coupling with the machines and plants in production and assembly. Without this coupling, MES specific tasks cannot or can only inadequately be executed. Owing to the heterogeneity of the machinery used in the manufacturing industry, this coupling between machines and MES systems will differ in almost every application and therefore involves manual expenditure for configuration and integration on the part of the MES suppliers, system integrators and plant operators. In this regard, it is not sufficient to merely communicate data and to describe the communication channel. The motivation behind this part is to provide the user groups listed above with the possibility of standardizing the data contents that need to be exchanged between machinery and MES and thus to reduce the manual expenditure that defining the data to be exchanged involves.“ From the point of view of users, there is the following need for further action: MES suppliers ought to enhance their systems so as to account for neighboring IT systems such as Digital Factory or automation level tools to be ready for the factory of the future. MES play a far greater role than just providing features for manufacturing management. As factory information hubs, MES need to provide the following functions:

- online-linkage with the Digital Factory, data extraction and permanent synchronization with planning data to be able to respond to changing conditions in real time,
- online-linkage with the automation level in order to achieve consistent vertical integration; to this end, common plant models based on mechatronic libraries are required, for instance,
- consistent data exchange with other applications on the MES level, e.g. logistics applications, aiming at full horizontal integration,
- comprehensive evaluation of existing MES data volumes by means of data mining procedures to implement production according to the principles of a self-optimizing system [7, p. 65], e.g. by enabling the MES to identify connections between quality data and process parameters and to adjust the latter as necessary,
- identification of interrelated data in multiple, usually proprietary MES or factory data volumes so as to combine information to provide meaningful facts.

### 3.2 Basic Feature ‘Secure Plug-and-Work‘

The strategic ‘MANUFUTURE’ [8] research agenda promotes the vision of flexible, adaptive production. One issue addressed in this context is the automated recognition of changes in plants, their management and implementation. In order to achieve adaptive software in the factory of the future, however, more mechanisms are required to fully account for the following cases:

- The involved planning systems (mechanical and electronic and PLC programming) are modified, and the modifications have to be passed on to the field and MES levels in with the highest possible degree of automation and consistency.
- A new network-compliant field device, e.g. a drive unit with a new firmware version is added to the production system. The new device has to be connected to the network in an automated way and to be announced to all the subsystems involved. The participating systems have to be updated accordingly.

- An unconfigured field device is added to the production system, replacing, for example, a defective old device at short notice. In this case, the field device has to be individualized and parameterized on the basis of the information contained in the software component.
- A production line is upgraded or modified because a new product variant is to be manufactured. The modifications affecting the monitoring and control mechanism and the software need to be detected and to be announced to all the systems involved in an automated way.
- Following the alteration of a plant, it should be possible to shift protected software components for process control between decentralized controls in compliance with specific criteria such as output or availability.
- A (new) MES feature is added or modified, e.g. the visualization of a process that had not been required before. The visualization is to be generated automatically, including the automated retrieval of the required information from the field level.

The aforementioned issues result in the following need for action. On the one hand, there is a need for methods and tools that are based on existing standards as well as for approaches to information and software architectures that allow for consistent, reliable data processing in the case of modifications to one of the involved hierarchical levels. These approaches ensure that other parties involved in the factory, such as field devices, machinery and equipment or IT systems, are updated accordingly. The benefits include a more rapid start-up of machinery and equipment. Features are stored within the very components, ensuring that the required data is directly available to the control system by means of an interface at the time of physical integration. Component suppliers identify the information required for this purpose in advance so it is included in the components themselves. One appropriate and more and more common communication standard for manufacturers that fulfills these requirements is OPC UA. The use of the functional scope of OPC UA is scalable. It can be used both on small embedded devices with highly limited resources and in very powerful environments such as mainframes [9]. OPC UA is currently in the process of international standardization as IEC 62541.

In this process, the security mechanisms including authentication and authorization (rights management) have to be integrated in the architecture of CPS systems right from the start. The tools and development environments to generate objects compliant with AutomationML™ [10], for instance, are designed to ensure that sensitive data can be protected against spying and modification attacks at the earliest possible date. Standardized security mechanisms such as encrypting and signing data as well as authenticating data objects and control components are to be used to ensure that only authorized components can participate in the production system. Therefore, the aspired security for trustworthy plug-and-work mechanisms can only be achieved on the basis of protected and clearly identifiable components. The identification has to be carried out on both the hardware and the software levels including the associated control data.

### 3.3 Visualization of Production and Business Processes

Basically, visualization refers to nothing else than the user interface of an IT application, say a manufacturing control system, a monitoring and control system for the operation of production equipment or a PLM system for the management of product and planning data. This means that, up until now, individual IT systems have been supporting individual steps of an enterprise process. Today and in the future, however, IT systems need to map and

support entire business processes, which implies that the corresponding visualizations also need to reflect more than just individual details of business processes [1, p. 145f]. Let us take a project carried out in a press shop of a car manufacturer [11] for example. In that plant, various IT applications were consolidated in one user interfaces, allowing users to view the factory at one sight and to understand how their activities will affect the production process. The latest requests from industry confirm that it is necessary to overcome stand-alone systems and to consolidate complex information in real-time and present it transparently. These requirements result in the following need for action. To provide a general view of the complex, interrelated processes on the shop floor, there is a need for new, intuitive ways of human-machine interaction. To replace conventional input devices such as mouse and keyboard, new input technologies such as touch screens [12] or gesture recognition [13] have to be enhanced so they are industry-ready for the factory of the future. So far, the integration of multiple IT systems with the objective of a unified user interface has been a manual engineering service. Open interfaces, data exchange formats and enhanced mechanisms of semantic interoperability are required to reduce manual work while extending the use of control rooms across operations.

To avoid that every user is overloaded by all the information of the individual systems, the information has to be shared in a role-based, distributed way. This means that all the users will receive just the specific information they need to complete their tasks. We think that there is also a need for every specialist unit to be able to generate their specific views in line with the role they have been assigned. However, it should be possible to visualize and modify these views in line with those of other specialist units. [14].

#### 4 IMPACT OF INCREASING IT SUPPORT ON PRODUCTION EQUIPMENT

The German mechanical and plant engineering industry is successfully equipping manufacturing plants and factories around the world. For decades now, "Made in Germany" has been synonymous with the high quality of German engineering skills. It is true, however, that manufacturers of machinery and equipment and their engineers are facing increasing international competition, which results in the well-known pressure with regard to costs and/or price, time and quality.

Providing highly productive, reliable machinery and equipment capable of producing high-quality products on a global scale will not suffice to ensure the business success of the mechanical and plant engineering sector in the future. Rather, customers tend to purchase benefits, which, in an extreme case, might just be the product manufactured by the machinery and equipment. As a consequence, complimentary services relating to the machine itself are gaining increasing attention. According to a survey performed by ifo institute [15] on behalf of the European Commission, these additional services boost the global competitiveness of Germany's mechanical and plant engineering sector as they add value and thus create jobs for highly skilled staff. In addition, services relating to machinery allow for new business models which are less susceptible to variations in sales and investment cycles.

The aforementioned information and communication technologies (ICT) are the key to these kinds of new, product-related services. They increasingly penetrate the traditional mechanical and plant engineering sector and open up potentials for innovative services. Many suppliers of machinery and equipment, however, are not systematically prepared for the new ICT-based services yet. A survey by Fraunhofer IAO [16] has shown that merely 25% of mechanical engineering enterprises have an explicit strategy

regarding the Internet-based services they want to establish and enhance. Just 20% of these enterprises have an appropriate business model in place. Consequently, there is still need for action, particularly because software will evolve into a full-fledged part of the product portfolio in the future, including the associated challenges ranging from a professional software engineering process, quality assurance for software, models for software maintenance and professional services to the adaptation of a sales organization capable of selling ICT products and their benefits.

#### 5 CONCLUSION

Unlike many other industries, comprehensive and consistent digitalization is still at an early stage in manufacturing. In the future, factories will fully rely on realtime-compliant software that can be interlinked spontaneously [17]. This will have major consequences for the structure of added value in the mechanical and plant engineering sector. All efforts have to be aimed at maintaining and strengthening production and value creation in Germany. Germany needs a strong industrial basis for future economic turbulences.

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