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# TRENDS IN MANUFACTURING EXECUTION SYSTEMS

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## ABSTRACT

Today's manufacturing plants are equipped with heterogeneous software systems for different types of tasks, both manufacturing operations and factory planning. On the operating level software systems are neither yet integrated and thus support separate tasks such as production monitoring, sequence planning, work piece identification, maintenance order management, worker information and others. Nor are MES-systems parts of the integrated industrial engineering chain from mechanical engineering, electrical engineering, PLC-programming to operations. Today information technology becomes the main enabler for new processes and structures in manufacturing and logistics.

In this paper the author presents six relevant trends for MES-systems, derived from actual R&D-projects with industrial partners. The mentioned trends are illustrated by examples from projects.

## KEYWORDS

Manufacturing Execution Systems, Digital Manufacturing, Simulation, Engineering, Automation

## 1. INTRODUCTION

Manufacturing execution systems are evolving into factory information hubs. They support the MES tasks defined by the Association of German Engineers (VDI) in its VDI 5600 (VDI 2007) guideline and represent the interface between the manufacturing level and automation technology as well as between the enterprise management level and ERP systems. Any IT support required for a smooth production process is provided on the manufacturing control level using manufacturing execution systems (figure 1).

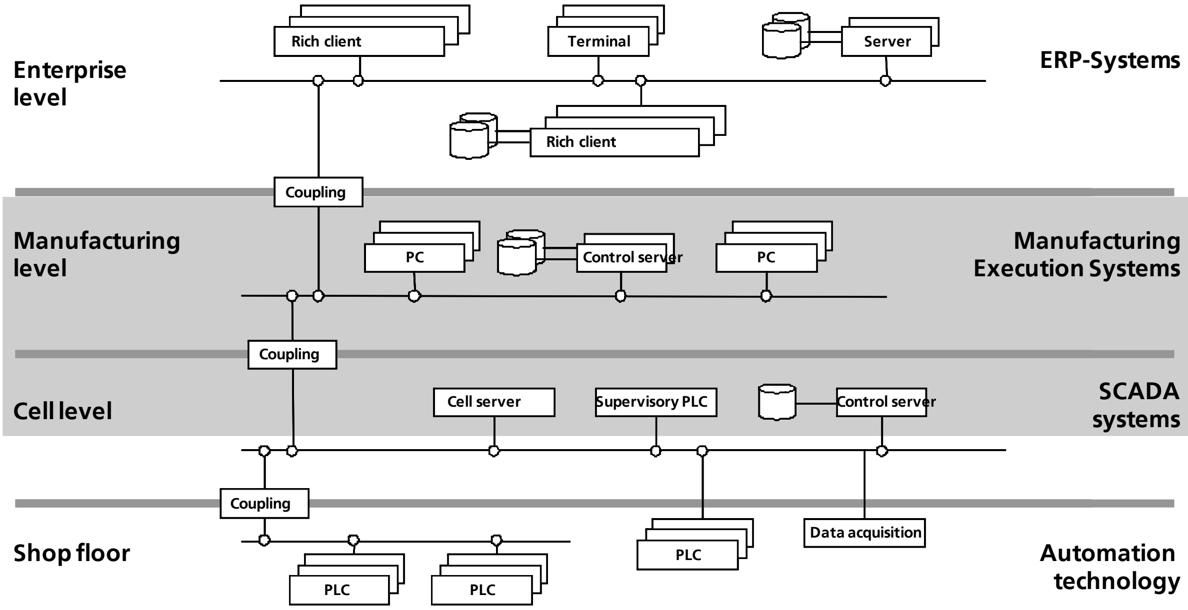


**Figure 1 – MES in the company's IT hierarchy (VDI 2007, Eversheim 1996)**

Owing to new demands in production, the developments on the MES market and current engineering efforts, six trends can be identified with relevance for tomorrow's MES systems. Users and suppliers of MES systems should be prepared for these trends even today.

(1) In the future, MES systems will be fully integrated within the digital factory. Among other things, this aims at permanent planning disposition, i.e. changes in production immediately result in the update of all systems involved.

(2) MES systems will, in the future, be supported by concurrent simulators. In this process, the simulator will act, as it were, as a front-end to the user in the sense of a real-time simulation, allowing users to respond to unforeseen events in production immediately and effectively.

(3) Future MES systems will be integrated vertically with the underlying shop floor level, ensuring that standard 'plug-and-work' mechanisms support this kind of integration.

(4) On the manufacturing level, individual MES components will be integrated horizontally even if they are provided by multiple manufacturers. This will be ensured by instruments such as ontologies, a service-oriented architecture and consistent data management.

(5) MES systems of the future will be scalable, including the support of decentral self-organizing production. Factory data acquisition will be replaced by automated capture using RFID systems, for instance.

(6) By providing users with information in a role and task-specific way – information needed to fulfill the users' exact task in the process– MES systems will be more human-oriented in the future than they are today.

## 2. EXAMPLES OF THE AFOREMENTIONED TRENDS

### 2.1 FULL INTEGRATION WITH THE DIGITAL FACTORY

Today, 'digital factory' tools are mainly used to plan production systems (Sauer 2004), whereas ongoing operation is supported by manufacturing execution systems. These two system worlds are still separated by nearly impenetrable walls today, i.e. data cannot be exchanged between them to the extent that would make sense in economic terms.

The projected integration of planning and operation calls for the standardization of the interfaces between the system worlds, for instance. Fraunhofer IITB with its 'Monitoring & Control Systems' business unit focuses on making digital factory data available to manufacturing execution systems. This implies, for instance, that data necessary to customize MES systems are collected from digital factory tools in a neutral exchange format such as XML and made available to MES engineering. The digital factory stores information on plant structure, plant parameters, manufacturing processes and the arrangement of equipment. MES engineering also requires information about the structure of production plants and their parameters, manufacturing processes as well as PLC programs and variables. In the future, information stored in 'digital factory' tools will be used to parameterize manufacturing plants and superordinated IT systems as well as to start and operate them virtually. This aims at having the relevant operational IT systems fully available when the modified or new production plants are taken into operation (see figure 2).

Thus, 'digital factory operations' will become a reality. It has been defined already, namely by a technical committee of the Association of German Engineers (VDI), which has just released the second part of the VDI 4499 guideline (VDI 2007b) on the digital factory. "*Digital factory operation refers to the use of methods, models and tools of the digital factory that are applied when taking into operation, starting up and executing real-world production processes. It is aimed at securing and accelerating the start-up as well as continually enhancing ongoing operation.*

*To this end, the structure as well as the sequential and dynamic behavior of individual production plants and complex production systems including the information and control technology are mapped close to reality. In this process, virtual and real-world components can be linked.*

*On the basis of consistent data management, digital factory operation uses the results of production planning in the digital factory and, in turn, provides data for the operational systems. If the concept is used in ongoing operation, the models are adapted to the real world.*"

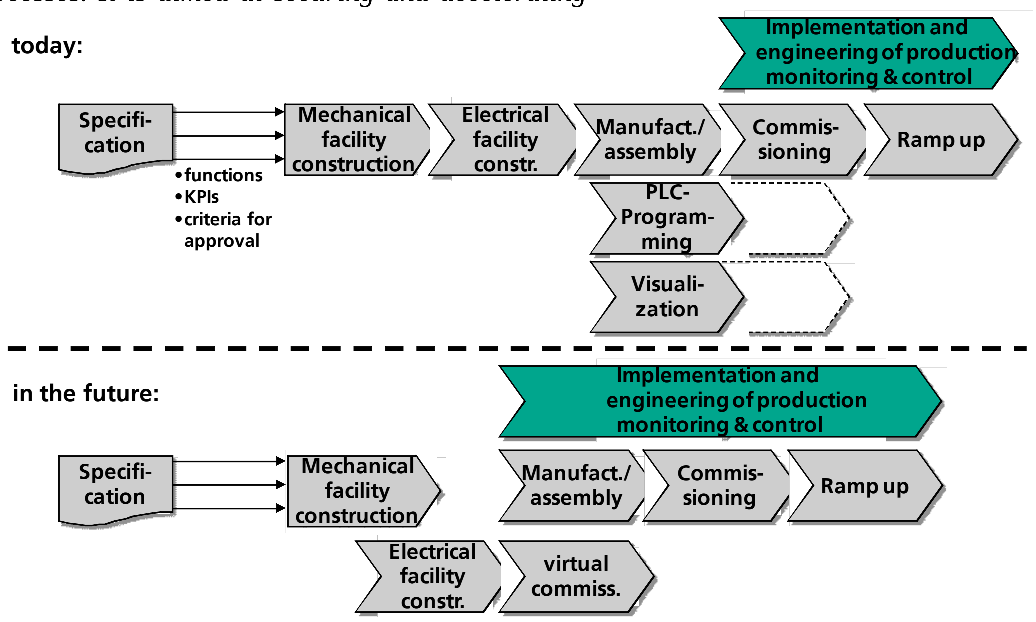


**Figure 2 – Benefits from early connection of planning and operation**

## 2.2 SIMULATION AS A FRONT-END IN THE SENSE OF CONCURRENT REAL-TIME SIMULATION

In the context of a project carried out in the automotive industry, a concurrent simulator for a production control system has been developed (Sutschet 2001). As soon as a fault occurs in a manufacturing equipment, the simulator predicts the output that is to be expected and the buffer statuses in the shifts to come. The immediate benefit for the user is that the effects of faults in complex production systems become transparent immediately. This allows for more room for maneuver for fault maintenance and to test the measures on the basis of the simulator. It uses the interface of the monitoring runtime system and is directly linked to the runtime system by means of software agents.

Furthermore simulation is used to test and verify complex production systems and its software by means of hardware- and software-in-the-loop. MES components can be tested already using virtual commissioning tools. The benefit for manufacturing equipment suppliers and operators is the early parameterization and test of equipment and MES in cooperation. Therefore the simulation of equipment is controlled by a PLC (hardware or software) to provide the MES with its signals and values. The MES can be connected to the PLC and the simulator via OPC or other automation standards (see figure 3).

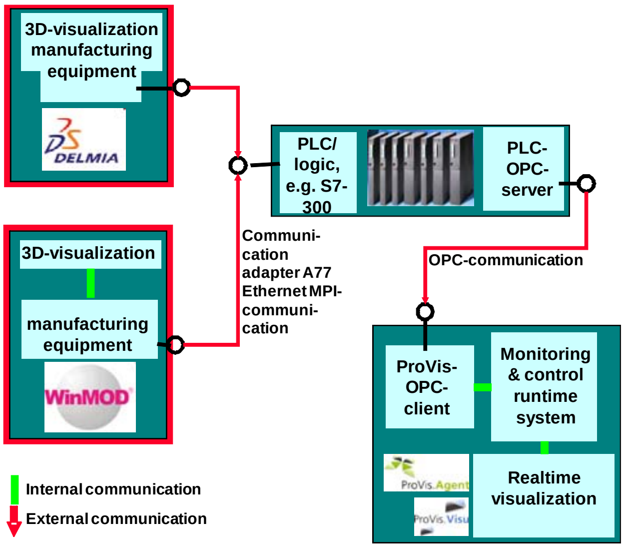


**Figure 3 – Connection of monitoring & control system to digital factory**

## 2.3 VERTICAL INTEGRATION WITH THE SHOP FLOOR LEVEL

Production systems are adapted continually as products change, capacities have to be re-adjusted owing to varying demands and more efficient manufacturing technologies are applied. In practice, modifications in production plants do not only result in equipment being shifted physically within a plant. Rather, they entail adjustments in the software controlling machinery and equipment, above all. This includes programmable logic controllers (PLCs) and the information technology superordinated to the immediate control of equipment. CIRP, the leading international organization of production engineers, considers the capability to undergo permanent change to be the strategic competitive advantage of factories and production systems in the future (Wiendahl 2007). In this article, "plug and work" refers to the automated recognition of equipment in the superordinated MES system. Fraunhofer IITB is specifically working on methods, software components and applications that can be standardized and that allow production equipment to be integrated into a production system simply, quickly and safely or modifications in equipment and its controls to be announced automatically to the MES (Sauer 2008).

To this end, existing standards are used, such as CAEX (Computer Aided Engineering Exchange) to describe the static features of production plants or OPC UA for dynamic components. CAEX is a process industry standard to describe the architecture and structure of process-engineered plants, whereas OPC UA is used for control-relevant variables the values of which change dynamically during production.

In this process, equipment and its controls provide files describing their features in CAEX, according to IEC-PAS-62424 (Drath 2004). By way of transformation, the files are classified into information relevant for system engineering and for visualization. This is used either to generate process control images or transmitted to a database, on the basis of which I/O and plant system engineering are generated for the process map of the runtime system (Sutschet 2006).

## 2.4 HORIZONTAL INTEGRATION BY MEANS OF A SERVICE-ORIENTED STRUCTURE AND CONSISTENT DATA MANAGEMENT

Owing to the organization and characteristics of multi-variant mass production, which is based on the division of labor, there are stand-alone IT systems for various MES tasks in the automobile industry, for example. In most cases, these systems do not exchange data nor are they linked with other MES components today. Automobile manufacturers are currently making efforts to interlink the stand-alone systems in the years to come to open up synergy potentials (figure 4). This will allow decisions taken on the shop floor to be supported transparently and consistently. For instance, the effects of a fault of machinery or equipment on just-in sequence component parts can be illustrated.

The main driving force behind new, integrated software solutions is the increasing number of new vehicle models and shorter development, start-up and life cycles. IT systems usually have longer life cycles than products, which is why they have to become more flexible.

However, genuine integration of existing systems is hardly feasible with the software technologies currently in use. Today, integration is usually based on large data bases requiring a common data model. This makes it impossible to integrate those applications, in particular, that require real-time data processing due to poor performance. Approaches to integration based on a common data model and a database are not flexible enough to allow for modifications or upgrades. As soon as a new application is to be integrated, the solution using a common data model comes up against limiting factors. On the other hand, it is not conceivable that there will be a single supplier or system house in the near future capable of providing all MES components of a vehicle plant in an integrated way. For this reason, other technological solutions have to be found to integrate the MES components so as to allow for consistent data processing.

In the future, software systems need to provide mechanisms that possess knowledge about the contents to be communicated on a semantic level. In ProVis.Agent, IITB's agent-based monitoring & control system, the structure of the information to be transmitted is stored in an ontology. In addition, the ontology contains a semantic interpretation of the syntactic definitions. As a consequence, the meaning of the communication contents has been defined unambiguously for any two software systems communicating on the basis of the same ontology. This concept enables the integration with system from other suppliers on the MES level.

Fraunhofer IITB's current efforts focus on enabling production control systems and sequence planning systems to be integrated, which is based on the specific example of an automobile plant.

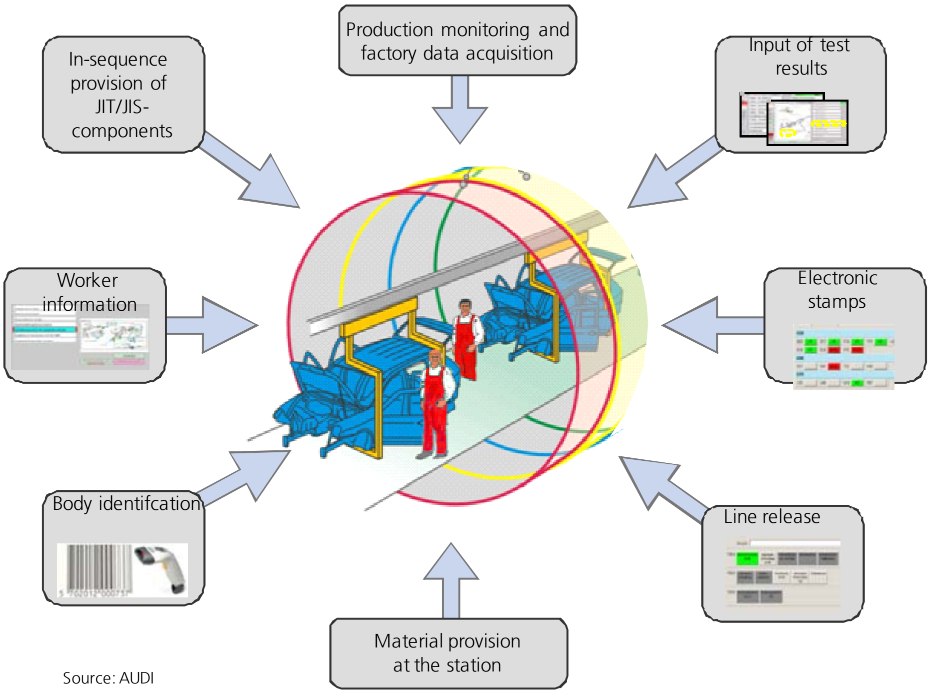


**Figure 4 – Links between those production related applications, which data is required at a certain work station in the line (Fiebig 2006)**

## 2.5 SCALABILITY RANGING TO DECENTRALLY SELF-ORGANIZING PRODUCTION

For quite some time now, production has been faced with increasing challenges, resulting from smaller lot sizes, shorter delivery times and a wider range of variants, while the requirements with respect to deadlines, low set-up costs and minimum stocks remain unchanged. In a highly inconstant production environment, there is no point in drawing up an exact plan because even the near future of the shop floor is unpredictable. For this reason, a decentral control solution seems ideal (Kresken 2006). It allows users to respond immediately to unforeseeable events such as failures or urgent orders. This is supported by distributed approaches using purely local coordination forms. In this process, decisions are no longer taken by a central entity and imposed on orders and resources. Rather, work pieces, machines and material flow systems act as agents that are free to take decisions, allowing them to pursue their own objectives, which results in self-organizing production (figure 5). Unpredictable events such as failures are integrated almost smoothly into the autonomous decision-making process of orders and resources.

## 2.6 TASK AND ROLE-SPECIFIC PROVISION OF USERS WITH INFORMATION

MES systems of the future will provide staff members that have different roles and interest with information that meets their specific demands and takes account of their role and authorization in a context-sensitive way. This can be done centrally in a control room (figure 6) for different roles and tasks or decentrally using mobile end devices. Smart players in factories with decentralized intelligence assist staff and teams in solving complex tasks such as start-up or fault management. Using mobile end devices such as cellular phones or PDAs, shop-floor staff, managing clerks or foremen automatically get connected to the equipment while they are on the shop floor. Information on the operating condition or the order currently processed are presented to them in an adequate way.

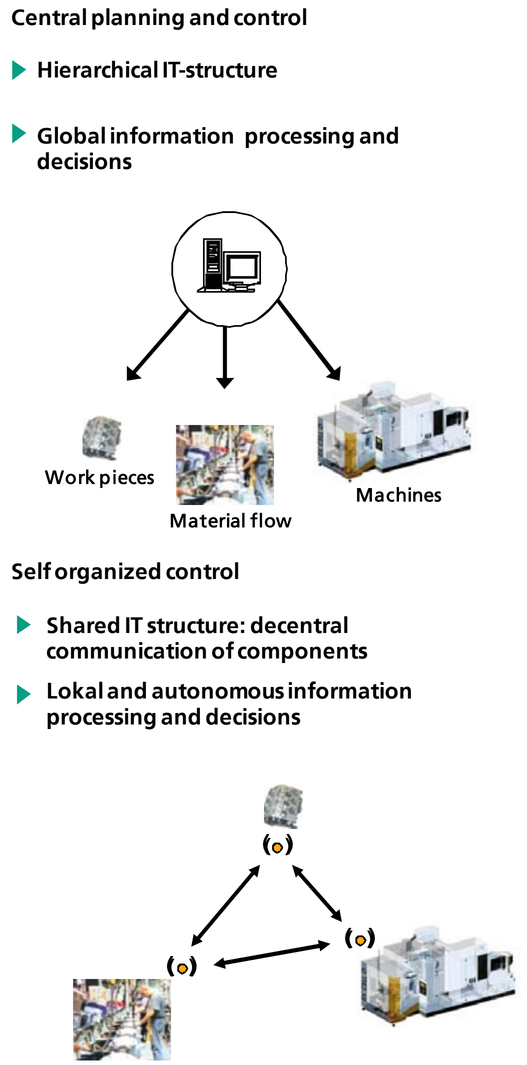


**Figure 5 – Principle of self-organizing production**

**Figure 6 – Control room in a press shop – the entire factory on a glance (source: Jungmann Systemtechnik/Daimler)**

## 3. CONCLUSIONS

The aforementioned examples illustrate that manufacturing execution systems will be indispensable in the factory of the future. Rather, information technology will be a catalyst of new processes and structures in production and logistics. One prerequisite for the trends is the interoperability of systems and more, a semantic understanding of the systems information. This will be a demand for further research in the years to come.

There will be an urgent need for specialists and academic courses which will teach both production and automation technology as well as information technology.

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