Digitization in Production: a Use Case on a Cloud-based Manufacturing Execution System

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ABSTRACT

All types of companies, including manufacturing companies, are facing a major shift due to the influence of digitization. To fulfill the requirements of digital production, the classic hierarchical architecture of the automation pyramid will change to decentralized distributed communication participants in the cloud. This will lead to a flattening of the pyramid towards service-oriented network architectures in the cloud. The paper focuses on the necessary theoretical aspects concerning dissolution of the automation pyramid in relation to Manufacturing Execution Systems and cloud computing. The second purpose of this paper is to show, how dissolution in an industrial environment can be realized by means of a use case. This demonstrates how manufacturing companies can participate in cloud solutions for Manufacturing Execution Systems.

CCS CONCEPTS

• **Information systems applications**; • **Enterprise information systems**; • **Manufacturing Execution Systems**;

KEYWORDS

Cloud Computing, Manufacturing Execution System, Enterprise Resource Planning, Automation Pyramid

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1 INTRODUCTION

Following the hype about digitization, the impression quickly appears that the industrial production of the future is taking on a science-fiction character. Within the smart factory of the future, Cyber-Physical Systems (CPS), Radio Frequency Identification (RFID), Embedded Systems (ES), sensors, actuators, mobile devices and production facilities are connected via the Internet of Things (IoT) and continuously exchange data inside and outside the factory. This networking enables independent logistic systems, cooperating robots and self-controlling manufacturing processes to work in unison with one another [1].

Production is currently facing a radical change. Autonomous objects (intelligent workpieces, storage and conveyor systems, robots, smart machines and equipment), mobile communication and cheap sensors are bringing changes in production planning and control. The ability to react fast and flexibly to customer requirements in a decentralized manner and to produce high diversity of variants with low batch sizes (ideally batch size 1) economically will increase and enhance competitiveness. New forms of customer integrated business processes will thus become possible [2].

Many industrial companies have already completed a good part of this "digital journey", often unconsciously, by using individual elements of Industry 4.0 concepts. Nevertheless, a substantial proportion of small and medium-sized (SME) manufacturing companies are not prepared for a digital transformation, either technologically or organizationally. This is illustrated by a study by Ernst & Young, in which 70 % of the Austrian SME mentioned, that they see digitization as an opportunity for the future, but 50 % of the company's digital technologies are not yet relevant [3]. In addition to the (sometimes lacking) awareness of management, the necessary strategic understanding of ICT (information and communication technology) is of significant importance in digitization projects. This is for example about the management of security aspects that must be considered in the merging of manufacturing and ICT industries, but also the sensitization of employees to the topic of digitization [2].

How can manufacturing companies achieve the decisive step from "merely" automated production to a smart factory, which means an intelligent, self-organized production? The following literature review describes the required aspects of digital production, such as dissolution of the classic automation pyramid, Manufacturing Execution Systems (MES) and cloud computing. This is followed by a description of a corresponding use case.

2 LITERATURE REVIEW

2.1 Dissolution of the automation pyramid

A crucial factor in the implementation of digitization in production companies is the possibility of efficient processing of production-relevant data and information. Today´s classic automation pyramid is based on the "CIM pyramid" that evolve in the 1970s and 1980s [4]. That means, production is still strongly characterized by the hierarchical system of the automation pyramid. The individual levels (see Figure1) are usually supported by different systems such as ERP (Enterprise Resource Planning), MES (Manufacturing Execution System), SCADA (Supervisory Control and Data Acquisition) and

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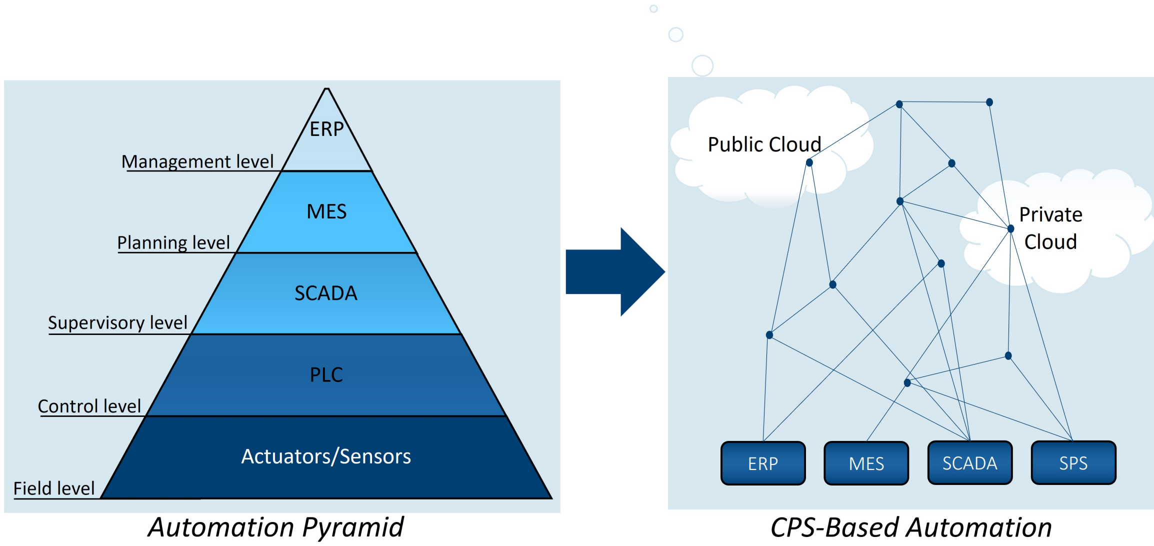

Figure 1: The dissolution of the automation pyramid [6–8]

PLC (Programmable Logic Controller) and extend to the input and output interfaces on the field level [4–6].

This approach has not led to consistent standardized vertical and horizontal integration. Due to a lack of standards, end-to-end networking in industrial manufacturing is currently only possible to a limited extent. This often results in data islands and inconsistent master and transaction data. Reliable order-, product-, material-, process- and quality data for production planning and control can only be collected with a high time and manual effort [5]. Industry 4.0 promises more flexibility and a higher degree of networking. Through Cyber-Physical Production Systems (CPPS) [14], services, data and functions are to be stored, provided and executed where they have the greatest benefit. Therefore, the classic automation pyramid will gradually dissolve. Networked, decentral organized or partially self-organized services (e.g. web services) are to be created for this purpose [6]. There are also communication participants outside the company boundaries who are connected via the Internet. Cloud services, as well as external services, can so be called upon demand.

The dissolution of the rigid structure of the automation pyramid does not mean, that the systems (e.g. ERP, MES) themselves will become obsolete. In this respect, Manufacturing Execution Systems will also in future fulfill their tasks for optimizing production in a smart factory [9].

2.2 Manufacturing Execution Systems – the hub of digital production

In the production environment, the striving for lean and transparent manufacturing is evident. For instance, production employees want to know, what is to be manufactured by whom, when and how. Production management, on the other hand, wants to be always informed about the progress of orders and the corresponding key figures (e.g. Overall Equipment Effectiveness - OEE) to have a "central data collection point" for controlling production. This is where Manufacturing Execution Systems (MES) [10–13] come in, whose main task is the detailed planning and control of production.

Practice shows that there is not always a clear conceptual meaning of the functions. Users often do not know which functions are covered by an MES and which tasks are taken over by the other IT systems. In short, an MES functions similarly to an ERP system, but with a much shorter time horizon and are based on real-time information. MES software solutions close the gap between machine plants, machine controls and sensor technology on the shop floor and the ERP systems on the top floor. To fulfill the requirements of digital production, the architecture of MES solutions will change from the classic, hierarchical automation pyramid to decentral distributed communication participants in the cloud (see Figure1). With this integration beyond company boundaries, dynamic adaptation of value creation processes - for example, integration of CPPS or cloud services - will become possible. The boundaries between ERP system, the MES, and the shop floor thus become more fluid [17]. However, a new generation of MES is needed to meet the future challenges of Industry 4.0 [14].

2.3 Digital Production needs Cloud Computing

The shift of information and communication technologies to the cloud is ongoing and does not even stop at ERP- or MES software. This means that cloud computing is an important pillar of Manufacturing Execution Systems of the future [15]. The flexible use of IT services is provided in real-time as a service via the Internet and billed according to use. Cloud computing thus enables users to shift from an investment to operating costs. Costs arise according to the "pay-per-use" principle exclusively for the actual use of the application [16, 17]. This involves the use of resources such as storage space, server performance, databases, software and network components, as well as updates and maintenance.

Cloud computing continues to gain importance in the Corona pandemic. Four out of five (82 %) German companies with 20 or more employees rely on cloud computing. 63 % rely on private cloud computing and about 48 % on public cloud computing. Companies see the greatest benefit in the digitalisation of processes such as the automation of workflows (80 %). 78 % see a major impact of cloud computing on better collaboration between business and IT departments and on building collaboration platforms with third parties (75 %). About half (48 %) of the companies see a benefit in the development of digital business models using cloud computing [18]. According to Statistic Austria, in the Austrian manufacturing sector (production of goods, energy supply and construction), cloud services are used in around 34,3 % of companies; Software as a Service (30 %), Infrastructure as a Service (23,4 %) and Platform as a Service (6,1 %) [19].

When it is about delivering information to the right destination at the right time cloud MES solutions in many cases have an advantage over on-premises MES solutions, which means software and hardware are in the company. Since on-premises solutions are usually applications that can only run on a specific operating system (usually MS Windows), they often have specific hardware requirements and are designed to run only on the local network of a production site. Such applications can often be used only with greater effort in distributed environments and on any end user's devices (terminal servers, virtualization, VPN, etc.). It is also more difficult to make them accessible to a wide range of users at any time without additional effort. Cloud MES solutions are per se designed for networked, distributed and heterogeneous environments. Special hardware and software are not required. The only requirement for use is an internet browser.

The target group for cloud software solutions are primarily small and medium-sized enterprises, as they have less IT expertise and fewer financial and personnel resources than large companies. Here, the respective software is operated directly by a SaaS provider (Software as a Service) and offered via the Internet. This provider takes care of installation, configuration, maintenance and updating. The company must pay only a monthly rent. In addition to provider dependency, unclear data protection regulations, data security, small internet bandwidth and the associated latency times concerns regarding the outsourced data are often cited as arguments against cloud solutions [16]. The General Data Protection Regulation (GDPR), which was adapted in May 2018, seems to exacerbate the uncertainty regarding the handling of personal data. According to a 2021 study conducted by KPGM in Germany, the following security concerns arise regarding public cloud computing: unauthorized access to sensitive company data (75 %), uncertainties regarding the legal situation (67 %), related regulatory provisions (60 %), concerns due to hardware vulnerabilities such as Spectre and Meltdown (60 %), loss of data (60 %) as well as lack of cost transparency (41 %) [18]. Therefore, the current number of cloud MES implementations in the production-related area that cover the full range of functions of an on-premises MES system is still low.

3 PRACTICAL USE CASE: THE EVOLUTION OF THE AUTOMATION PYRAMID

3.1 Initial Situation

The following describes an implemented use case in the Smart Production Lab to understand how a cloud-based MES works. The Smart Production Lab is one of Austria´s largest Industry 4.0 learning and research factories and is run by the Institute Industrial Management of the FH JOANNEUM University of Applied Sciences. The research activities include, among other things, the establishment of digital networking in the industrial environment, both vertically and horizontally. This data integration is realized in co-operation with industry and research partners and includes the implementation of all interfaces to demonstrate paperless digital production. From a vertical perspective, this means continuous bidirectional data integration from the shopfloor via the Manufacturing Execution System to the Enterprise Resource Planning level. The use case focuses on a cloud-based Manufacturing Execution System. It is an example of decentralized communication using cloud computing, beyond the classic automation pyramid.

3.2 Approach

In this chapter, the use of a cloud-based Manufacturing Execution System will be described. This use case is realized in the Smart Production Lab of FH JOANNEUM together with the industry partner and MES provider FACTORYMINER (see Figure2).

- For data acquisition on the shop floor, a laser cutter was retrofitted and equipped with a mechanical closing sensor. Through so-called retrofitting, old systems and machines can also be economically made ready for Industry 4.0. The closing sensor installed on the cover of the machine communicates with Internet of Things (IoT) components. The heart of the system is a microcomputer (Raspberry-Pi) that is sufficiently suitable for industrial purposes. It can withstand high temperature fluctuations and is flexible thanks to its Linux operating system and open-source tools. Raspberry-Pis have been tested many times in practice and they are inexpensive. This configured system and an industrial PC are available to the worker in a robust terminal. Here, order data is retrieved from the ERP system and operating data, such as output, scrap quantity or shift data, is recorded and stored in the cloud. In this context, the bidirectional transmission of real-time data means that data is transmitted within a defined time slot. Hardware and software are scalable according to requirements.
- The outsourcing of the IT infrastructure (data, storage capacity, computing power) to the MES provider is made possible via a server cluster where the contents are stored, processed, and continuously backed up. The failover cluster used is a network of at least two computers. If the active system fails, the passive backup system takes over the tasks without additional administrative effort.
- The XML-based SOAP protocol (Simple Object Access Protocol) is used for bidirectional communication with SAP S/4 HANA. The SOAP service does not use the standard SOAP, but a protocol adapted by SAP, which was designed for data exchange between heterogeneous systems [20]. This enables the transfer of production orders from the ERP system to the MES software, as well as the corresponding feedback (order confirmation) of the respective order status.
- Access to production data is possible at any time via desktop or mobile devices such as tablets, smartphones or laptops.

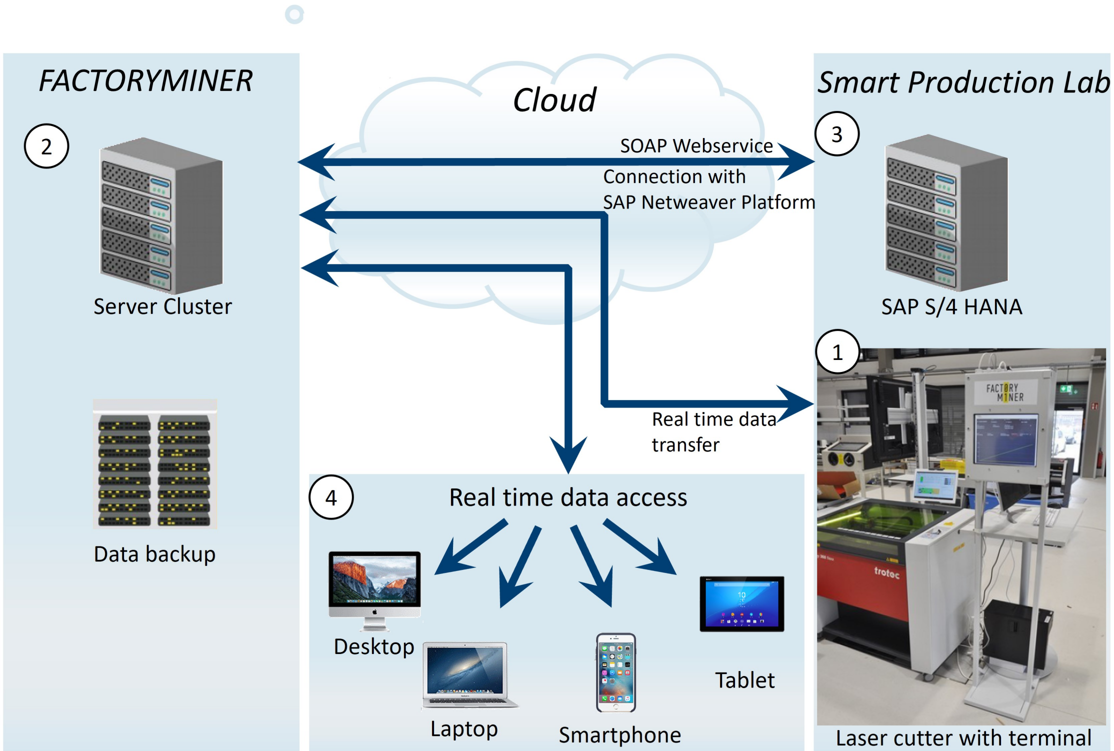

Figure 2: Cloud-based Manufacturing Execution System

Information on order progress, machine condition history, overall equipment effectiveness (OEE), quantity trends, etc. can be accessed regardless of location. Thus forms the fundamental basis for condition monitoring.

4 CONCLUSION

The realized use case in the Smart Production Lab shows that transparent production can be implemented quickly and without a high level of IT knowledge in a company. Both hardware and software are offered as a complete package by the software provider. In addition to the technical responsibility for customizing, data backup or maintenance, the MES provider also takes over the configuration of the dashboards. Digital retrofitting enables the modernisation of machines and plants and can save costs for new investments as well as extend the lifespan in an environmentally friendly way.

For this reason and due to the increasing digitalisation initiatives in the manufacturing sector, the architecture of MES systems is changing. Other reasons for the increase are the steadily falling costs for communication-capable sensors and the increasing networking via the Internet of Things. The advantages - such as low administration costs, high availability, higher scalability or worldwide access - are still countered by concerns about data security, excessive latency times and the limits of customizing.

The use of a cloud manufacturing execution system, as shown in the use case, enables access to current technologies and standards without having to worry about the implementation, maintenance and operation of an MES software. This benefits visitors to the Smart Production Lab as well as partners from industry and students.

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