Industry 4.0 Concept: Background and Overview

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Abstract—Industry 4.0 is a strategic initiative recently introduced by the German government. The goal of the initiative is transformation of industrial manufacturing through digitalization and exploitation of potentials of new technologies. An Industry 4.0 production system is thus flexible and enables individualized and customized products. The aim of this paper is to present and facilitate an understanding of Industry 4.0 concepts, its drivers, enablers, goals and limitations. Building blocks are described and smart factory concept is presented. A Reference Architecture Model RAMI4.0 and role of standardization in future implementation of Industry 4.0 concept are addressed. The current status of Industry 4.0 readiness of the German companies is presented and commented. Finally it is discussed if Industry 4.0 is really a disruptive concept or simply a natural incremental development of industrial production systems.

Keywords:- Industry 4.0, Cyber-Physical Systems, Enterprise-Resource-Planning, Manufacturing Execution System.

1. Introduction

The transformative potential of technology in production systems is widely recognized, even while the precise configuration and extent of the possible transformation remain unknown. Trends towards higher levels of automation promise greater speed and precision of production as well as reduced exposure to dangerous tasks for employees. New production technologies could help overcome the stagnant productivity of recent decades and make way for more value-added activity.

2. Core idea of Industry 4.0

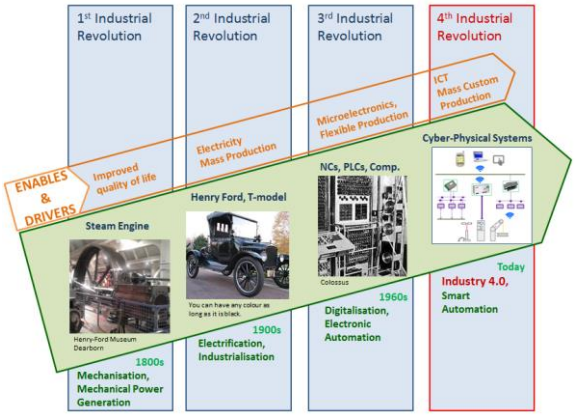
I. Through the industrial revolutions

Stages in the development of industrial manufacturing systems from manual work towards Industry 4.0 concept can be presented as a path through the four industrial revolutions. The development is depicted in Figure 1.

The first industrial revolution began with the mechanization and mechanical power generation in 1800s. It brought the transition from manual work to the first manufacturing processes; mostly in textile industry. An improved quality of life was a main driver of the change.

The second industrial revolution was triggered by electrification that enabled industrialization and mass production. Often mentioned in this context is a quote of Henry Ford, who said about the Ford T-Model car 'You can have any colour as long as it is black.. The quote captures well the introduction of mass production but without the possibility of products' customization.

The third industrial revolution is characterized by the digitalization with introduction of microelectronics and automation. In manufacturing this facilitates flexible production, where a variety of products is manufactured on flexible production lines with programmable machines. Such production systems however still do not have flexibility concerning production quantity.



II. Origin of Industry 4.0 concept

That the Industry 4.0 concept comes from Germany is not surprising, since Germany has one of the most competitive manufacturing industries in the world and is even a global leader in the sector of manufacturing equipment. Industry 4.0 is a strategic initiative of the German government that traditionally heavily supports development of the industrial sector. In this sense, Industry 4.0 can be seen also as an action towards sustaining Germany's position as one of the most influential countries in machinery and automotive manufacturing. The basic concept was first presented at the Hannover fair in the year 2011. Since its introduction, Industry 4.0 is in Germany a common discussion topic in research, academic and industry communities at many different occasions. The main idea is to exploit the potentials of new technologies and concepts such as:

- availability and use of the internet and IoT,
- integration of technical processes and business processes in the companies,
- digital mapping and virtualization of the real world,
- 'Smart' factory including 'smart' means of industrial production and 'smart' products.

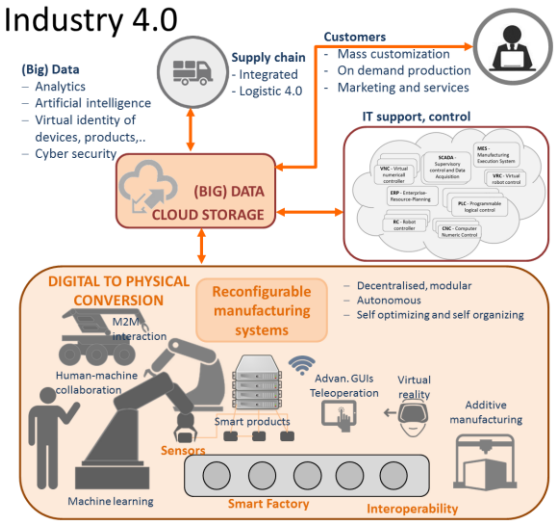
Besides being the natural consequence of digitalization and new technologies, the introduction of Industry 4.0 is also connected with the fact that many up to now exploited possibilities for increasing the profit in the industrial manufacturing are almost exhausted and new possibilities have to be found. Namely the production costs were lowered with introduction of just-in-time production, by adopting the concepts of lean production and especially by outsourcing production to countries with lower work costs. When it comes to the decreasing costs of industrial production, Industry 4.0 is a promising solution. According to some sources, Industry 4.0 factory could result in decrease of:

- Production costs by 10-30%,
- Logistic costs by 10-30%,
- Quality management costs by 10-20%.

There are also a number of other advantages and reasons for the adoption of this concept including: (1) a shorter time-to-market for the new products, (2) an improved customer responsiveness, (3) enabling a custom mass production without significantly increasing overall production costs, (4) more flexible and friendlier working environment, and (5) more efficient use of natural resources and energy.

III. Industry 4.0 production system (Smart factory)

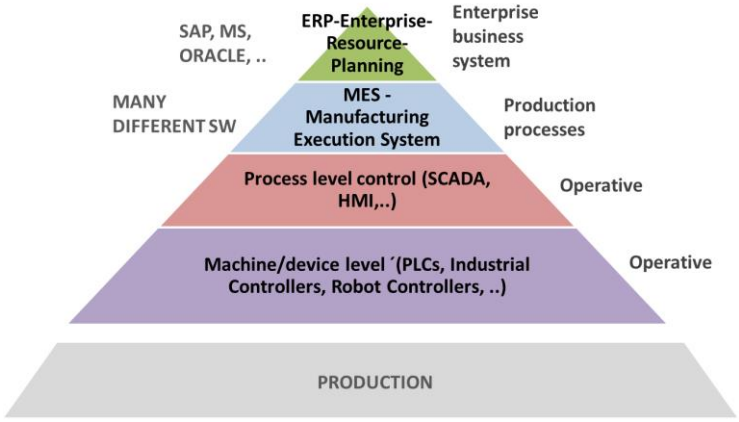
Figure 2 depicts the Industry 4.0 smart factory. The core process is digital to physical conversion in a reconfigurable manufacturing system. Reconfigurable manufacturing systems are the latest advance in the development of a manufacturing system. First step were fixed production lines with the machines dedicated to the performance of specific tasks so only one product could be produced. Next step were flexible production systems with programmable machines that allowed production of a variety of different products but offered no flexibility in the production capacity [5]. As the results of the latest development are reconfigurable manufacturing systems able to adapt their hardware and software components to follow ever-changing market requirements of type and quantity of the products. Machines in Industry 4.0 factory are Cyber-Physical Systems, physical systems integrated with ICT components. They are autonomous systems that can make their own decisions based on machine learning algorithms and real-time data capture, analytics results, and recorded successful past behaviours. Typically, programmable machines (CNC and NC) are used, with a large share of mobile agents and robots able of self-organization and self-optimization.



IV. IT support

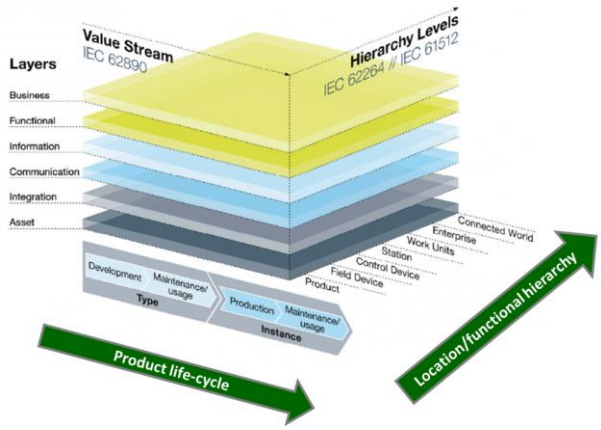
Software tools are crucial for operating of the Industry 4.0 smart factory. Figure 3 depicts the well known pyramid structure of support software of modern production systems.

On the business level, the Enterprise Resource Planning (ERP) tool is implemented. ERP supports enterprise-wide planning such as business planning, supply chain management, sales and distribution, accounting, human resource management and similar. Usually commercially available solutions are implemented. Currently the leading solution is SAP, by the German company SAP SE. In traditional ERP tools, the decision process is centralized on the highest level in the automation pyramid. Most of the available ERP solutions do not support fast adaptation in production planning due to the unplanned events.



3. Reference architecture model RAMI4.0

It is clear that the Industry 4.0 concept will be in most companies realized by using already available equipment and technologies. Only when a new production system is planned, there is an opportunity to design the production system already from the beginning as Industry 4.0 system. Therefore one of the challenges is how already available standards will be integrated into the new concept. To address the standardization issue, a Reference Architecture Model for the Industry 4.0 (RAMI4.0), Figure 5, was developed in Germany.



4. Current state of Industry 4.0

When considering the current state of the Industry 4.0, it is important to understand the preconditions that have to be fulfilled so that a new concept can be introduced in industrial manufacturing system. At least the following has to be fulfilled:

- Stability of the production has to be guaranteed also during the transition phase.
- Stepwise investment should be possible as most of the industrial processes cannot bear big one-time investments.
- A good know-how protection is necessary. Closely connected is the cyber security issue.

Furthermore the industry concept is not limited just to the production system but it includes the complete value chain (from suppliers to the customers of one enterprise towards the 'Connected Word' of all enterprises) and all enterprise's functions and services. It is clear that it is not easy to fulfil these criteria, therefore only some 'islands' of the Industry 4.0 concept currently exist.

5. Conclusions and Discussion

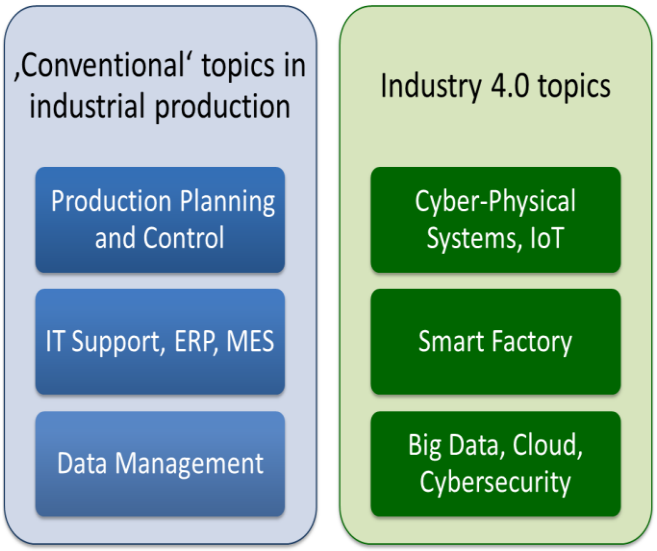
In this paper, the background and development of the Industry 4.0 concept are presented. Although the concept is very comprehensive and complex, three main points can be identified:

- The Industry 4.0 concept is not limited just to the direct manufacturing in the company but it includes also a complete value chain from providers to customers and all enterprise's business functions and services.
- The Industry 4.0 assumes broad support of an entire life cycle of systems, products and series, distributed both spatially and organizationally.

The smart products are not smart only during the manufacturing process but they continue to provide the data about their state also during their lifetime. These data can be used for preventive maintenance; it can provide the manufacturer useful information about lifetime and reliability of their products. The Industry 4.0 is a specialization of the Internet of Things applied to the manufacturing/ industrial environment. It assumes a real-time data collection leading to the issue of handling and analysing huge data and cyber security.

Finally, let us consider a generally accepted opinion about the role and future of the Industry 4.0 concept. Namely the Industry 4.0 is often considered as disruptive technology that will pave the way to a new generation of industrial manufacturing systems that will be completely different than the existing ones. Further, the Industry 4.0 is generally adopted as a concept of the fourth industrial revolution. This opinion does however require a closer look since the fourth industrial revolution is the first industrial revolution that was announced in advance and not when it was already fully developed.

On the other hand, Industry 4.0 can be also perceived as a natural transformation of the industrial production systems triggered by the digitalization trend. This hypothesis is supported by comparison of 'conventional' topics in industrial production systems and Industry 4.0 topics depicted in Figure 6. It is obvious that the main issues/topics did not really change, just the technology and approaches for tackling the connected issues are new.



Five years after the introduction in Germany, the Industry 4.0 concept is known worldwide and it has been also transferred from its original application field in industrial manufacturing to other engineering and non-engineering fields. The corresponding concepts such as Automotive 4.0, Logistic 4.0 and Education 4.0 have in common with original meaning of Industry 4.0 only extensive usage of ICT tools, connectivity and capture and analysis of real-time data. The way towards wider deployment of the Industry 4.0 production concept is still long. There are only very few Industry 4.0 enterprises, mostly new enterprises built to prove the concept. It can be expected that most of the enterprises will introduce the Industry 4.0 elements gradually and by building on already existing equipment and software solutions, thus not endangering the stability of their production.

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