HORIZONTAL AND VERTICAL INTEGRATION, AS A REQUIREMENT FOR CYBER-PHYSICAL SYSTEMS IN THE CONTEXT OF INDUSTRY 4.0

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Abstract: *The development in the information and communication technologies conditions the beginning of the fourth industrial revolution(FIR) The current report considers the peculiarities of the cyberphisical systems, as the basis of the fourth industrial revolution (Industry 4.0) and the need of their inner horizontal and vertical integration.*

.**Keywords**: INDUSTRY 4.0 , INFORMATION-TECHNICAL SYSTÉM, STRUCTURAL REORGANIZATION

1. Introduction

The key elements of the fourth industrial revolution are the cyberphisical systems (CPS), through which networks are created for the self-regulation of spatially distributed production resources. The introduction of the principals of this revolution in production requires the creation of conditions for its normal functionality. The vertical and horizontal cooperation between the machine and the internet, machine – person, and machine - machine along the value chain in real time, are the basis of the production cyber system and determines the actuality of the problem.

2. Theoretical foundations

The cyberphisical systems are „intelligent systems", which cover the hardware and software, as well as the effectively integrated physical components, , which interact closely with each other, so they can detect any change in the state of the real world, as defined by the "National institute of Standards and Technology" (NIST). In the world's scientific literature there is no "sharp" restriction on the notion of cyber-physical systems regarding the tendencies and ways in the development of complex informational – communication technical systems. Cyber-physical systems refer to physically mechanical complexes with IT systems, hardware and software digital components with mechanical or electronic components that can autonomously communicate with each other.

The creation of a cybernetic environment is imperative so it can provide:

- Functional compatibility: The capability of cyber-physical systems (for example – intelligent machines), people and "intelligent factories" (Smart Factory) so they can exchange information between "the internet of things" and "Internet services";
- Virtual compatibility: The creation of a virtual copy of a "Smart factory", which is created by connecting the data collected from physical sensors with virtual models of the production processes, specialized software and so on;
- Decentralized management: The ability of Cyber-physical systems, Separate components and so on, within the margins of one "smart factory" to make independent decisions;
- Data transfer in real time: The ability of gathering and analyzing data while making decision in real-time;
- Service orientation: Through the Internet of Services, people and "smart users" are provided with services;
- Modularity: Flexible adaptation of "Smart factories" to the changing requirements, either by replacing or expanding of individual or accession modules;
- Flexibility: Individualization of mass production, by using the principals of mass production by a customized system of planning.

3. Implementing of cyber-physical systems on the basis of horizontal and vertical integration

Interaction between implemented systems based on highly specialized software and specialized user interface, which are integrated in digital networks create an entire new world of the systems functionality for the horizontal and vertical integration.

Horizontal integration: Trough the integration of the Network IT technologies and manufacturing systems an exchange of data and information must be established between the firms and the geographically remote sites across the value chain. Therefore by "Horizontal integration" an integration of various information technology systems in the production and automated equipment for various stages of the production and planning process is understood.

Vertical integration: The "internet of things" and services grant immediate access to IT and production systems. Trough vertical integration of data and information directly from the workplace by controlling and operating on a production and corporate level, the data is processed and as a result, adequate information about the management is returned. Therefore "Vertical integration" can be understood as the integration of information technologies in IT systems in various hierarchy levels in production and automation equipment. (For example: sensors, level of management, level of production management). The vertical and horizontal Cooperation between machine and internet, machine and person and machine to machine on the chain of value, in real time, is the basis of the production cyber system.

In the transition to cyber-physical systems, implemented systems, production, logistic, engineering, coordination and management processes as well as internet services can be added, which with the help of sensors gather physical data and interact with physical processes with the help of digital networks, connected with each other. They can use current data and services, as well as multimodel interfaces person – machine.

On fig.1 the stages of development of the cyber-physical systems.It can be assumed that this concept will be transferred by a single factory to a whole network of sited with added value in the future, for the manufacturing of intelligent products or for the compensating of the production capacities, acc. to Scheer[1].

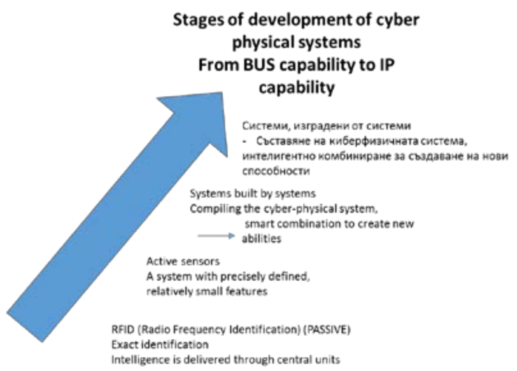


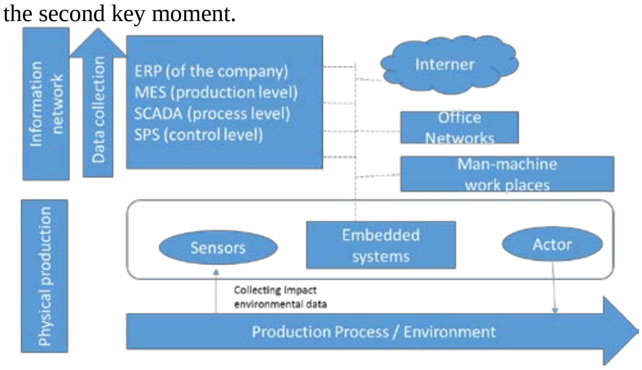
Fig.1. *Stages of development of the cyber-physical systems*

3.1 – Stages of development of the cyber-physical systems

The development of the cyber-physical systems can be characterized with three phases of implementation, namely:

- First Generation of CPS, which includes identification technologies, as RFID tags, which allow a unique identification.
- The storing and analyzing of information is a centralized service.
- The second generation of CPS is the equipped with sensors and executive mechanisms with a limited set of functions.
- The third generation can store, analyze data and is equipped with various sensors and executive mechanisms, all which are executed in compatible networks, acc. to Bauernhansl, Hompel, Vogel-Heuser [2].

This is a production revolution in terms of expense and saving time. The intelligent manufacturing brings with itself many advantages in comparison with the conventional manufacturing, or that is the intelligent production revolution. The cyber-physical systems require a network of informational technologic and production systems to be build, trough domains and hierarchy boundaries. The implementation of the cyber-physical systems in the production, for the establishment of an intelligent manufacturing is the second key moment.



***Fig,2** Implementing of the cyber-physical system in manufacturing.*

Because of that, interoperable communication interfaces and standard protocols are required. Furthermore, the products of manufacturing are intelligent, they carry information from their own manufacturing in machine-readable form (for example RFID chips), that way they can coordinate their own manufacturing actions. In order to meet the requirements for communication in real time, and also so that the cyber-physical systems meet the requirements for high availability and for a longer life cycle they must be built with standard IT elements. In that way, in order to establish a decentralized data collection , they must be continuously integrated into IT systems – best case scenario, included in Enterprise Resource Planning (ERP), manufacturing management (MES), systems for supervision (supervisory control and data acquisition, SCADA), programmable controllers (SPS) and integrated systems for vertical and horizontal integration. The structure of informational streams and networks is of most importance for the cyber-physical manufacturing as a whole. On pic.2 the transition from existing to cyber-physical systems is shown.

In this transition the cyber-physical systems usually include: Embedded systems, production, logistics, engineering, coordination and management processes, as well as internet services, whom with the help of sensors gather physical data and interact with physical processes with the help of digital networks connected with each other. They can use all current data and services, as well as multimodel interface person - machine. The production systems gradually evolve from planning systems (ERP, MRP, MRPII) and operational management of production (MES) to an integrated working platforms, which encompass business tools, supply and asset management, production schedules and solutions for an optimization of the production processes.

The cyber-physical systems are an openly social-technical systems and allow a number of new features, services and properties to be performed. Therefore one of the most important tasks in the field of design, development and management of cyber-physical systems is the question of co-operation between the cyber-physical system and the human factor. The questions which are with most importance in the context are the identification and modeling "awareness of the situation" the human experience with such kind of systems, the environment, as well as reflecting the changes.

4. *Methodology for the research of the factors for vertical and horizontal integration.*

In relations to the better structuring of the problem of accounting for the requirements of Industry 4.0. , the influencing factors can be grouped in the following directions:

- Factors influencing on the physical wear and tear, which leads to reducing their capacity capabilities. This group of factors are directly related with the requirements for Modularity (flexibility);
- Factors influencing on the innovation aging, which can be only partial, without having any affect on the on the productivity, or full innovation aging, which has a relative impact on productivity. This group of factors are directly related with the requirements from for operational compatibility;
- Factors influencing on the level of elements of the technical system, such as automation devices (Level / degree of automation), automated complexes (Level / degree of automation), self-regulating systems, technical compatibility (Level / degree of elements in the system), Base and bonding models. These factors are directly related with the requirements from Industry 4.0 for Decentralization;
- Factors influencing on the level of the technical system, related to modules, complexes and systems such as a Modular Network, complex network and a system network. This group of factors is directly related to the with the requirements from Industry 4.0 for information in real time, virtualization and orientation towards services;
- Factors related to the flexibility of the system (flexible adaptation towards the changing requirements: replacement, expansion and more.) All those factors are connected with the requirements from Industry 4.0 for modality (flexibility);
- Factors related to the automation of the elements and components of the system. (CAD/CAM/CAE, vertical and horizontal diversification and software). This group of factors is related with modality (flexibility), information in real time, virtualization and decentralization.
- Factors related to the operational and functional compatibility of the elements and components of the system, decentralization and usage of the information in real time;
- Factors related to the horizontal and vertical compatibility of the system (technological and business operations in a horizontal direction, technological and business operations in a vertical direction, targeted network models for compatibility and communication of the elements of the system in a horizontal or vertical way, self-regulating components of the technical and manufacturing systems;

This way and this grouping define the methodological basis of the approach of studying the possibilities for adapting the requirements of Industry 4.0 in machine building companies, see fig.3.

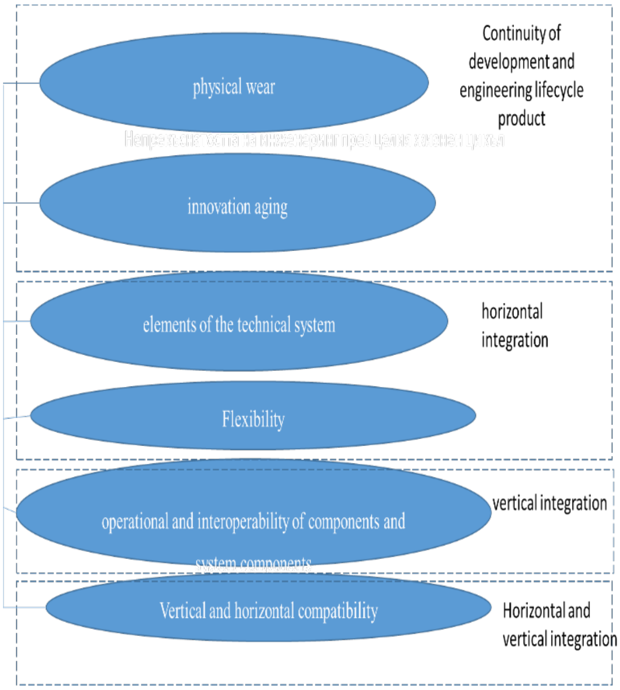


Fig.3 *Factors for the Horizontal and vertical integration*

The Innovative aging: is due to technology development and the speed of implementation of the innovations, physical wear is associated with machine parts without which the machine can not work.

Physical wear is a result of the constructive-technological and operational reasons. The development of new technologies is provoking innovation aging. A balance between the physical and innovational aging is necessary to be found.

Physical wear, can be considered in terms of changing the parameters of the equipment, without changing the productivity and with changing it (The change in physical condition of the details, machines, the quality, change in how it affects the environment, level of safety and so on.) or stopping work (cessation of operation).

The innovation aging is related with a delay due to technological reasons, for example: The appearance of a newer and more productive machine giving better quality of production.

The parameters and indicators that can characterize the conditions are:

Economically expressed in economic indicators: such as Operating costs, share of equipment per one unit of product, unit cost, depreciation costs.

Technical and technological parameters, expressed in technical parameters including operating life, reliability, efficiency, technological capabilities and more.

For the purpose of the study it is necessary to study the level of elements of the technical system in the enterprises: conventional type machines, machines with 2D control devices, machines with 3D control devices, automation devices (automation degree), automatic complexes (automation degree), self-regulating systems, technical compatibility (degree/level of elements in the system) and base and bonding models.

Degree of modularity through modular network, complex network and system network.

When creating a product, who is to be given to the costumer, there has to be a wide variety of options, as well as a big flexibility of the production capacities. The use if a “CPS” in the production process gives an opportunity for the firms to develop the different stages on a modular principal, as a result of that all the separate modules can be organized flexible and on their own. Thru a modular system, companies can make considerable savings in regards of the assembly and exploitation, but in the same time can offer optimal functionality when installing and maintaining the equipment. Often the importance of the full (or almost full) integration is underestimated and a decision is made for the purchase of software from different providers and also their assembly. This is when problems begin to show, the data exchange is not complete etc. Such an assembly of individual modules is only possible under certain conditions, such as unifies connection margins, implementation of certain geometric and constructive constrains, observance of certain conditions for a previously build system of block modules.

Regarding the flexibility of a system, it is represented by the degree of adaptation to different models, possibility of change regarding the needs of the costumer, system adequacy to the changing requirements (replacement, expansion and so on.)

Regarding the degree of automation of the elements and components of the system (CAD/CAM/CAE), vertical and horizontal diversification, software (models) etc.:

Regarding the operational and functional compatibility of the elements and components of the system as a decentralization and transfer of information in real time.

Regarding the horizontal and vertical compatibility of the system, as technological and business operations in a vertical state, network models targeted for compatibility and communications of the elements is the system in a horizontal and vertical state. Self-regulating components of the technical and manufacturing system.

The challenges of the cyber-physical systems include:

Reducing complexity in the development of the stabilizing architecture of management for the cyber-physical systems:

Distributed sensor networks;

Conclusion

• A systematization was made of the factors, regarding the horizontal and vertical integration.

• The functions if the cyber-physical systems was analyzed.real-time information, flexibility, interoperability, modularity, decentralization and virtualization.

References

As a result of the shown above, the following conclusions can be made:

• The key element of the fourth industrial revolution are the cyber-physical systems, through which networks are created for the self-regulation of allocated production recourses.

• Introducing the principals of “Industry4.0” in the manufacturing requires the creation of an environment for its normal functionality. This means that the horizontal and vertical co-operation between machine and internet, machine - person and machine – machine on the chain of value in real time. This is the basis of the cyber-physical production system.

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