INDUSTRY 4.0 IN BULGARIA – OVERVIEW, ANALYSIS, APPLICATION APPROACHES

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Abstract
An analytical overview of the features of „Industry 4.0" (theoretical and practical) and the possibilities for their application, some approaches for introducing the principles of the fourth industrial revolution in companies, as well as cyber-physical systems, information environment and security, the state of the industrial are presented companies in Bulgaria.
Keywords: *Cyber-Physical System, Industry 4.0, Smart Factory, Smart Economy.*

1. Introduction

The industry is currently operating in the face of increasing global competition, requiring reduced time and manufacturing costs. Increasing demand for individualized industrial products and services, coupled with the requirements for more efficient use of resources, flexibility and speed of production processes, significantly increase the complexity of modern production systems. In order to sustainably exist in this dynamic envi-ronment, businesses must not only increase their productivity and process flexibility, but also fundamentally change their technological development strategy [2,3].

„Industries 4.0" has become a top priority for many research centers, universities, and businesses over the past four years with numerous contributions from scientists and practitioners. The aim is to use the leading role of the industrial information technologies3, which are currently in a revolutionary phase (the fourth industrial revolution). Through interopera-bility and the use of smart factories (Smart Factory), it is possible to exchange real information to better meet customer requirements. This flexible development will lead to greater individualization in the provision and use of intelligent and tailored industrial products and services [1].

2. Exhibition

2.1. „Industry 4.0“ Overview

Industries 4.0‘s technological base is: cyber-physical systems, the „Internet of Things /Components/ CPS Subsystems“, the „Internet of Services“ and the „Intelligent Factory“[1,2].

The first industrial revolution was related to mechanization driven by water and steam. It was followed by a second industrial revolution of mass production through assembly lines and the use of electricity. The third revolution is the so-called the digital revolution, with the use of electronics and information technology to further automate production.

After the mechanization, electrification and computerization of the industry, the fourth industrial revolution began. This means the introduction of the Internet of Things (components of the cyber system) and services in factories and the increasing digitalization of production. In fact, this concept includes the so-called Internet of Things (components/subsystems/cyber systems), and data and services that can qualitatively change future manufacturing, logistics and work processes [2].

„Industries 4.0“ is also a change from „centralized“ to „decentralized“ production, and this is possible thanks to technological advances. Decentralized intelligence helps to create smart networks and independently manage the process, with the interaction of real and virtual worlds, a crucial new aspect of technological and manufacturing processes, whereby the product communicates with the machine to say exactly what to do.

Industry 4.0 is not only a technical challenge, a technological change that will have lasting organizational consequences and create opportunities for new production models and corporate concepts, but also a new concept for the network world. In an „intelligent world“, the Internet caters to all needs, leading to a shift in power consumption to smart grids (Smart Grids), sustainable mobile concepts (Smart Mobility, Smart Logistics), social care (Smart Health) and new technological solutions. In production, this leads to:

- increased intelligence of products and systems;
- their vertical network is connected to the Engineering, a
- horizontal integration through the product value chain.

The main element in the industrial revolution is cyber-physical systems (CPS), through which networks for the self-regulation of spatially distributed production resources are created. The cyber physical system includes:

- the physical mechanical complex with IT systems;
- hardware and software digital components with mechanical or electronic parts that autonomously communicate with each other.

An important element of Industry 4.0 is the Smart Factory. Smart Factory is complex, has less propensity for interference, and increases production efficiency. Smart Factory communicates people, machines, and resources independently on a social network. Smart Products have knowledge of their manufacturing processes and future applications. They actively support production processes („when will I be produced, what parameters must be produced, where should they be delivered").

Parts such as: Smart Mobility, Smart Logistics and Smart Grid form an intelligent factory, which is an important component of future smart infrastructures. Smart factories are a key feature of Industry 4.0. A „Smart Factory" is defined as a factory for which context-aware assists are people and machines in the performance of their tasks. These systems perform their tasks based on information received from the physical and virtual worlds. Information about the physical world is e.g. position or condition of the instrument, and information on the virtual world - electronic documents, drawings and simulation models.

In smart factories, production facilities, information systems and staff need to interact in real time. In smart factories, cyber-physical systems communicate through the Internet of Things and assist staff and machines in the accomplishment of their tasks.

Smart factories are the future of industrial production. The merging of the virtual and physical worlds through cyber-physical systems leads to the merging of technological and business processes. They are leading the way to a new industrial era and best define the concept of Industry 4.0 for „smart factories". The deployment of cyber-physical systems in manufacturing gives birth to „smart factories". And intelligent factory products, resources and processes are realized through cyber-physical systems. On the other hand, receiving real-time data on quality, resources and costs provide significant advantages over conventional production systems. The smart factory must be built in accordance with sustainable and service-oriented technological and business practices. They are characterized by flexibility, adaptability and self-study, resilience to failure, and risk management. High levels of automation are becoming a mandatory standard in the „smart factory", which is possible thanks to the flexible network of cyber-physical-production-based systems that automatically monitor production processes. Flexible intelligent production systems and models that are able to respond in real time allow for in-house production processes to be radically optimized.

In intelligent industries, the ability to communicate and decentralize data processing, as well as self-optimization, is ensured through embedded systems equipped with special hardware and software. In this way, embedded systems, partly with wireless parts, are connected to the information systems of other systems (within the company or with external stakeholders such as customers or providers) in order to exchange data or access web-based services. Therefore, interoperable communication interfaces and standardized protocols are required. In addition, the production products are intelligent, since they carry information from their own production in machine-readable form (e.g. RFID chips) in order to coordinate their own production.

Therefore, information flows are crucial for cyber-physical production and security management.

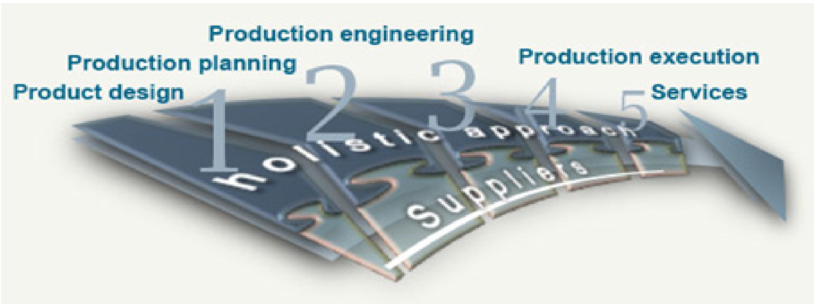

Figure 1. A holistic approach

This approach (on figure 1) starts with defining the product, exploring its maintenance and use in daily use until it goes out of use, with particular attention to integration and seamless technical connectivity and data exchange with the network. This means the intensity of the socio-technical interaction of all actors in production and resources. The focus is on a network of autonomous, situationally controlled, knowledge-based, sensor-based and spatially distributed production resources (machines, robots, transport and storage systems, control and planning systems).

Companies can use a new generation ERP system that is suitable for use in Industry 4.0. It is a smart ERP system using service-oriented architecture (SOA). Features and services of other software vendors may also be used through standardized interfaces. These ERP systems support the dynamic technological processes required for flexible manufacturing.

The Internet of Things allows direct communication of an ERP system with CPS (cyber physical systems) and intelligent production-level products. By using in-memory databases, large amounts of data can be used by

CPS sensors to process information in real time. Thus, with changes in production, simulation is performed using in-memory technology in real time. Production processes can be optimized. Direct is the access of production data to the ERP system, which ensures transparency of technological and business processes in individual orders. The ERP system utilizes the capabilities of Cloud Computing to access Internet Services (IOS). This section includes services and features that perform as web-based software components.

Information security risk management is an integral part of Industries 4.0 and involves defining precise context, analysis and continuous monitoring. The risk management strategy for information security is the decentralization of electronic information (modular approach), which guarantees the continuity of processes, while at the same time guarantees information security. Each stakeholder (operator, provider, customer) has access to limited information structured into modules. Cyber-physical systems have built-in user profiles that differentiate between different levels of access. The transfer of information in Intelligent Factories between cyber physical systems uses encrypted information that can only be processed by the particular cyber physical system, and beyond that it is incomprehensible.

This concept first minimizes the potential for information security hazards and secondly minimizes the damage in such a case because the information outside its environment will be encrypted, incomprehensible and incomplete.

Table 1. Security measures

TECHNICAL MEASURES	**Description**
Network security, Services and protocols	Segmentation of networks with different functionalities, determination of security levels and connection points, security of external interfaces, firewalls, intrusion detection and prevention systems (IDS / IPS), security protocols (e.g. SSH, HTTPS), encryption and cryptographic methods.
Security of implemented systems	Customizing settings (default) and user accounts (including Passwords), Disabling or removing unnecessary functionality.

Introduction of security systems	Dependable Systems, Security Hardware Modules (HSMs), Cross Platforms with Integrated Security Mechanisms, Unified Reference Architectures and Operating Platforms.
Authentication measures	Identity management (PIN, smart card, fingerprint), access rights and roles, password management.
Virus Security	Antivirus (including configuration and update) updates.
Ensuring mobile security	Restrictions on the use of removable media, Autorun and Boot functions.
Provision of data protection and monitoring	Backup strategies, and report on system status, (Logging, monitoring).
Physical security	Structurally secure systems and infrastructures for safety fences (e.g. for network industrial robots).
ORGANIZATIONAL MEASURES	**Description**
Organizational structure	Defining responsibilities and roles, integration in risk management
Documentation	Collecting, maintaining and archiving information of information and reliability (eg: threat analysis, network maps, IT systems reviews, applications and components, guides, audit reports)
Audit	Periodic IT security audit (e.g. entry tests, interviews), testing of components for operational safety.
Manage permissions	Allocation of access and access to rights, restrictions on access to necessary information, defining the processes for authorizing employees, and orders.

Security policy	legislation, development of safety strategies; events and guidelines for using personal devices (e.g. smartphones, laptops) on the corporate network, guidelines for using the Internet
Interviews with experts	Conclusion of confidentiality agreements with contractors (e.g. external service providers), knowledge of the safety of knowledge acquired, rules for liability for «errors and failures».
STAFF MEASURES	**Description**
Promoting safety awareness	Awareness of the aspect of information and operational safety, through inclusion, training or instruction at work, the publication of security policies.
Independent competence (empowerment)	Qualification and training programs for specialized training in information technology and operational safety.

In the context of Industry 4.0, the role of the human factor is considered in the light of the human-machine relationship and the following three scenarios are proposed [6]:

- *Automation Scenario*: Systems control people. Task monitoring and control is technology-driven. It prepares information and distributes it in real time. Employees are managed through cyber-physical systems (CPS) and perform executive tasks;
- *Hybrid Scenario*: Monitoring and control tasks are performed cooperatively and interactively through networked facilities and staff technologies. Requirements for employees are increasing since they need to be more flexible;
- *Specialization Scenario*: Businesses use cyber-physical systems to support the activity, with a dominant role for professionals.

The human factor plays a crucial role. New value chains and business technology models are creating new alliances and interconnections between businesses, and this has a huge impact on work organization. In addition, significant changes in the labor market are expected. Thanks to the rapidly evolving digital technologies in the industry and especially in the business services sectors, new forms of work organization and employment are constantly emerging and skills are being updated. All this leads to Industry 5.0 – which is the next stage in development.

2.3. State of the industrial companies in Bulgaria

After the changes in Bulgaria, which began in the late 1980s, three stages can be conditionally distinguished in the development of Bulgarian mechanical engineering.

- The first – from 1989 to 1999, the mechanical engineering companies were in a severe recession. Traditional markets have been eliminated, research institutes and development units have been eliminated, major staff cuts have been made. During this period unique equipment was sold at a price and opportunities for future development were reduced.
- In the second period, from 2000 to 2006, the sector was restructured. The companies refine the organization of management and production, improve the products, master new ones. The scope of activity of individual companies is changing, new industries are opened.
- The third stage begins with the accession of Bulgaria to the European Union in 2007. A distinctive feature of this stage is the change in the general conditions of operation of the companies – changes in the regulatory regime, increasing competition and market demands. Although the share of foreign investment in mechanical engineering is small compared to that of foreign investment in the country as a whole, they are in high-tech industries, mainly in the automotive industry, with a high rate of added value.

During the period 2009–2011, the sector slowed down as a result of the economic crisis. Damages to the activity and development of the companies in the sector are commensurate with those of the first years of transition. About 10%, incl. structure-determining companies (production of machinery) for individual subsectors ceased operations. After 2012, there is an increase in exports [4,5].

In terms of the level of technology, technology and production in general, industrial companies in our country can be grouped in the following directions:

- Conventional type of production and equipment with decentralized management;
- Automated production (CNC machines, automated technological and information systems, automatic complexes, CAD / CAM / CAE, etc.) with centralized control [6];

- Separate islands of automated technologies (with intelligence) and digitized communications and information flows with self-regulating components with centralized control.

According to a 2015 survey by the Bulgarian Chamber of Commerce and Industry (BCCI), about 500 companies expect to increase their export earnings, although they are squeezed by the volatility in the global environment. The survey was conducted among 734 companies. BCCI recalled that every second company had forecast growth in its exports in 2015, but only 37% actually achieved it. Those who operate on the local market are more pessimistic because they do not expect a shift in low domestic consumption. As many as 25% said they expect to keep their sales revenue at 2015 levels.

Uncertainty about energy and raw material prices and expectations of increased regulatory and tax burdens are the main reasons for skeptical expectations.

Only 23% say they plan to invest in new facilities in 2016, and 27% plan to invest in new products and innovations. The emphasis in the investments of the companies is placed on the development of human potential. About 25% of them plan to hire new staff, while the share for 2015 was about 30%. At the same time, the lack of qualified staff is one of the major obstacles to business growth for about two-thirds of all companies surveyed. The most serious is the shortage of close specialists and executive staff.

More than half of respondents do not want to take out loans in 2016. Interest in using EU funds is constant. One of the reasons for the reluctance of companies to implement europrojects is the lack of resources for advance financing, doubts about the objectivity of project evaluation and the difficult procedures.

The industrial companies in our country participate in the European projects of the Horizon 2020 program, which is essentially an initiative of Industry 4.0.

In 2015, a survey was conducted of 235 companies in the German Chamber of Commerce, which for five years intend to invest 3.3% of their annual turnover in Industry 4.0 technical solutions. This represents 50% of the investment for new facilities or EUR 40 billion. The trend is continuing and there is a lot of investment in this sector. Now the picture is much better and there are many Class A investors in Bulgaria. Industries 4.0 is not only a technological project, but a concrete attempt to increase the competitiveness of the manufacturing sector in the future, which was done by Bulgarian entrepreneurs.

3. Conclusion

Based on the analytical study of the approaches and methods for applying the principles of Industry 4.0, the following conclusions can be drawn:

- The term „Industries 4.0“ was first introduced in Germany in 2012 to promote the computerization of the industry and is the basis for the construction of the so-called „Smart Factory“.
- “Industry 4.0” is becoming a top priority for many research centers, universities, and businesses.
- The technical characteristics of the “Industry 4.0” philosophy can be seen as inherent in the fourth industrial revolution.
- The basis of “Industries 4.0” is Cyber Physical Systems (CPS), which include physical mechanical complexes with IT systems, hardware and software digital components with mechanical or electronic parts, and which communicate autonomously with one another. In this regard, cyber physical systems are „intelligent systems that encompass hardware and software, as well as effectively integrated physical components that interact closely to reflect change in the real world.
- An important requirement of “Industry 4.0” is the so-called horizontal and vertical integration. Vertical integration means the integration of information technology into IT systems at different hierarchical levels in manufacturing and automation (e.g. actor and sensor level, control level Horizontal integration refers to the integration of different information and technological systems in the production and automated environment at different stages and the production process. The vertical and horizontal cooperation between machine and internet machine man and machine and real-time forms the basis of the production cyber-physical system.
- The development of cyber physical systems is characterized by three phases of implementation and application. The first generation of cyber-physical systems includes identification technologies, such as RFID tags, that allow unique identification. Storage and analysis should be provided as a centralized service. The second generation of cyber-physical systems are equipped with sensors and actuators with a limited range of functions. The third generation can store and analyze data for multiple sensors and actuators, and are implemented in compatible networks.
- The basis for the development of CPS is the three generations of intelligent systems. The first generation of intelligent systems of the most advanced in automation, control and regulation of technology. The second generation of intelligent systems with greatly expanded machine learning features. The third generation is characterized by perception, thought, and actions that bring human fulfillment closer.

- The introduction of Industries 4.0 requires the creation of conditions for interoperability, virtualization, decentralization, real-time information, service orientation and modularity.
- New generation ERP systems are suitable for use in Industries 4.0. It is a smart ERP system using service-oriented architecture (SOA), with service oriented architecture (SOA). The Internet of Things allows direct communication of the ERP system with cyber physical systems and smart products at the production level.
- Information security risk management is an integral part of Industries 4.0, which involves defining accurate context, analysis and continuous monitoring. The risk management strategy for information security is the decentralization of electronic information (modular approach), which guarantees the continuity of processes and, at the same time, information security.
- The role of the human factor in Industries 4.0 is considered in light of the human-machine relationship, and three options are offered: an automation scenario, a hybrid scenario, and a specialization scenario.
- In terms of the level of technology, technology and production in general, industrial companies in our country can be grouped in the following areas: Conventional type of production and equipment, with decentralized management, Automated production (CNC machines, automated technological and information systems, automatic complexes, CAD/CAM/CAE, etc.) with centralized control; Separate islands of automated technology (with intelligence) and digitized communications and information flows with self-regulating components with centralized control.
- The industrial companies in our country participate in the European projects.

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