[1.]Stanko P. STANKOV

AUTOMATION AND INDUSTRY 4.0

[1.]University of Niš, Faculty of Electronic Engineering, Niš, SERBIA

Abstract: For many years, Industry 4.0 has been a popular topic related to the application of digital technologies in various manufacturing processes. The basis of this concept is the acquisition and analysis of data from propulsion equipment, which enables the realization of faster, more flexible and more efficient production. The result is high quality products, cost reduction, increased production, changing labor profile, increasing the competitiveness of the country's economy. The fourth industrial revolution is characterized by smart factories and plants that are adaptable and efficiently integrate customers and business partners, with an emphasis on full automation. This is possible due to the increasing reduction of barriers between the elements of automation and communication and information technologies. Modern process automation means optimizing the quality of products, increasing safety at work, reducing unplanned downtime in production, efficient use of available resources, meeting strict environmental requirements. Improving technology consists of mass production, which saves energy, resources and labor. The following technical and technological elements essentially represent Industry 4.0: big data, autonomous robots, software for the development of simulation models, universal system integration, industrial internet, cyber security, cloud computing, additive production and augmented reality.
Keywords: process control, internet of things, cloud computing, additive technologies, digitization of processes

INTRODUCTION

Increasing production and reducing costs are the driving force in the development of industry and various technical - technological disciplines. Every revolutionary innovation in industry makes a great contribution to increasing the quality and production capacity of industrial enterprises on a global level. Nowadays, the global industry is in the process of intensive transition to *Industry 4.0*, a standard that implies a fully automated industry, in which the Internet of Things (*IoT*) platform enables more precise management of production and process activities, reduces production costs, minimizes errors and failures, thanks to systems for predictive maintenance, management and analysis.

Modern automation systems basically have a six-step model of industrial automation architecture, which is defined at Purdue University: level 5 - business system automation; level 4 - automation of production plant automation of production plant, enterprise resource planning (*ERP*) [1], production planning strategy (*MRP*) [2] and production process management (Manufacturing execution systems - *MES*); level 3 - automation of various branches of enterprises automation of various branches of the enterprisies; level 2 - automation of machines and technological processes automation of machines and technological processes; level 1 - supervisory control systems; level 0 - sensors and actuators. In the general case, the software is installed on PCs connected to levels 2, 3, 4 and 5. Levels 2, 3 and 4 usually have communication interfaces and databases in which data is buffered and information of individual levels and user interfaces is synchronized. This model of computer data processing is relatively complex, increases operating costs and complicates the administration process. This is also the reason for the tendencies that lead to the simplification of architecture.

The new controller models and devices in the field are in direct communication with all levels - from levels 0 and 1 to 4 and 5 levels, using appropriate communication protocols and especially WEB services based on Open Platform Communications Unified Architecture (*OPC UA*).

This tendency develops naturally and dynamically, since each new element of automation, as a rule, possesses a certain intelligence and richer functionality. This applies both to devices and equipment that are installed in the field - more intelligent sensors and controllers, and to equipment in operation - more powerful computer systems. The *Industry 4.0* initiative, *OPC UA* and the Industrial Internet of Things *(IIoT)* consortium also make a significant contribution to this direction of development [3]. The tight integration of field devices and corporate-level business systems is becoming increasingly important in increasing production efficiency - the next big step in the evolution of industrial automation.

Business production management systems such as those for enterprise resource planning - *ERP* or materials - *MRP* traditionally use a package architecture, which does not reflect the situation in real time [4]. This way naturally affects the quality of products, services and supply chains, and ultimately reduces the level of profit. Full automation of the company enables processing and monitoring of transactions in real time, which enables synchronized and timely operation. There are controllers that are in direct communication with the company's business systems using the *OLE* architecture - Object Linking and Embedding for Process Control. To achieve the set goals, we are also working on adapting existing industry standards such as *OPC*, *OPC UA*, *B2MML* (Business To Manufacturing Markup Language), *ERP* interfaces as well as those with *IT* (Information technology) databases.

Digitization of products and services has a horizontal and vertical effect on the value chain, which means that the company must integrate processes and data flows from the procurement of raw materials and product development to technology, production and transport. In this process, it is necessary to network with suppliers, customers and other partners in a complex value chain. After the steam engine, conveyor belt, electronics and the Internet, there is now talk of 6 "Industry 4.0" - the fourth generation of industry characterized by the networking of smart digital devices. The characteristics of industrial revolutions are shown in Figure 1 [5. 6].

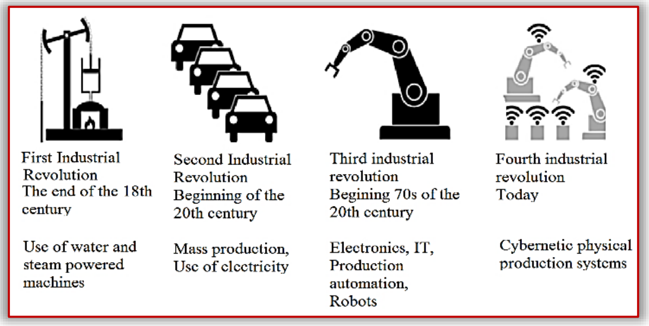

Figure 1. Basic characteristics of industrial revolutions

Condition maintenance (maintenance based on the forecast or predictive maintenance) is a way of anticipating possible problems in the plant and undertaking activities in order to neutralize those problems. Developed analysis systems can drastically improve the finding of solutions that will contribute to the precise conduct of the production process. Related to this are modern business models based on newly promoted services and new technologies. Countries differ in terms of digitalization goals, although companies around the world are largely in the vortex of *Industry 4.0*, with regionalization of their goals being observed: corporations in Japan and Germany use digitalization mainly to increase production efficiency and product quality.

In the USA, there is a trend of developing new business models with the maximum acceleration of digital offers and services. Enterprises in China place emphasis on strengthening their position in relation to international competitors through cost reduction. Some research predicts that most regions will be at almost the same level of digital integration within five years, and that some countries such as Japan, Germany and the United States will still be at the forefront [6, 7].

LARGE VOLUME OF DATAV EXCHANGE, ANALYSIS, OPTIMIZATION, CLOUD COMPUTING SERVICES

The development of automation is accompanied by a constant increase in the set of data used in the analysis and optimization of automated processes in order to increase productivity and production efficiency. The amount of information is constantly increasing due to the installed devices that generate real-time data. *The Cloud Computing* platform enables companies to access the *IT* infrastructure (servers, data storage equipment, etc.) and various fully developed software business applications via the Internet. An important feature of cloud architecture is flexibility in relation to users, which allows small and medium enterprises to keep pace with the constant change of technologies with their relatively limited *IT* resources [8].

OPC UA is the only open communication protocol so far, created on the basis of standards adopted in computer technology, which connect industrial software, controllers and sensors with corporate business systems, which enables increased productivity and creates conditions for the realization of a digital factory. *OPC UA* creates the possibility of efficient and reliable communication infrastructure - from sensors to corporate management system at all levels of production automation, *SCADA* system and process management. *PLC* (programmable logic controller) open *OPC UA* functional blocks are extensions of the IEC 61131-3 standard that traces the path to the IEC 61131-3 software model and the *UA* information model [9].

GSM devices are increasingly being used instead of remote monitoring systems. The implementation of techniques for connection to cellular networks, which are constantly being improved, and the sending of short texts (*SMS*) to controllers have been increased. The development of this area also includes technologies such as the Internet, cloud computing, software with various functions as well as *IP* (Internet Protocol) video and audio communications

APPLICATION OF COLABORATIVE ROBOTS

Robotics is the basis of the 4th industrial revolution. The question arises as to why these robots are different from those that have been used for ten years or more in various branches of industry (automotive industry, shipbuilding, military industry, pharmaceutical industry, etc.). The difference is that today robots and humans have become equal partners - robots now have a higher degree of artificial intelligence in a networked factory and can communicate with machines and workers via smart devices. Machines communicate with semi-finished products, and individual parts of machines with each other.

The robots have built-in sensors - each individual joint of the robot has a sensor and responds to the slightest touch. If a glass of water is suddenly placed in front of the robot's hand, it will slowly slow down its movement so that not a drop is spilled. With that collision hazard recognition, human-robot collaboration is now possible. Until now, people and robots in the halls have always been separated by fences. Modern robots now work closely with humans. The development of robots goes in the same direction as with PCs - the goal is to produce at the lowest possible cost during operation, with at the same time greater power and functionality, which makes robots suitable for performing a number of tasks in the industry.

Colaborative robots safely and efficiently assist workers in the production process, with no need for experts to program, install and maintain them. Installing and configuring these robots is intuitive and does not require much time. Robots can be switched off during idling while waiting for processing materials, which can save up to 15% of the energy now consumed in the production process. In addition, their price is several tens of thousands of euros, and the efficiency and time of exploitation enable a quick return on investment. These robots provide optimal speed, high precision and safety at work. Nowadays, new generations of robots are appearing on the market, which are more compact and work in a working environment with workers. Their prices are significantly lower compared to the prices of conventional industrial robots and are very interesting for relatively small production plants [10, 11].

INTEGRATED DESIGN

Recently, the design of various products, machines and production processes has been intensively and dynamically developed. At the same time, we are working on the development of efficient management systems. A key component of this concept is simulation software, which is becoming increasingly accessible and easy to use. The goal is to create software that will enable the design of products, production processes and automation platforms, with the idea of enabling the verification of these projects through simulation before physical realization. The simulation enables the cooperation of designers of production processes and automation, which contributes to the relatively easy adoption of new technologies, while improving product quality, increasing the level of production and ultimately the profit of the plant.

Control and supervisory systems can be developed in the direction of software and system-oriented architectures, which are based on devices for analysis, modeling, design and evaluation of human-machine interaction, including methods that enable modeling of human behavior, real and virtual environments for simulations, complex methodologies design, task assignment, etc. Advances in modern human-machine systems in process automation include intelligent *HMI* (Human-Machine Interfaces) devices for operator navigation, automatic generation of machine control programs, various trends and graphics, as well as training programs based on ready-made functional modules and blocks. The global transformation of industrial automation is in full swing. An increasing number of connected devices, unlimited Internet access, permanently growing *IT* infrastructure are prerequisites for the development of new business potentials [12, 13, 14].

ADDITIVE TECHNOLOGIES AND 3D PRINTING

Advances in the field of additive methods have enabled the development of *3D* printing - modern technology in the production of three-dimensional objects. *3D* printers are widely used to make prototypes and even regular products, which allows production at far less cost compared to conventional technologies. Another advantage of additive technologies is reflected in the fact that a single machine can produce a large number of different products, which is practically impossible with traditional production lines. At the same time, *3D* printing enables the creation of very complex shapes and structures that would not be profitable in classic production. This is likely to lead to radical changes in the way a wide range of industrial products are designed, developed and manufactured.

The technique of *3D* printing has found application in the military industry. The US military printed a spare part for the *F-16*, and the British for the *Tornado* [15].

The principle of operation of *3D* printers is similar to the operation of ordinary printers - printing takes place in a plane, except that not one layer is printed but the appropriate number of layers to get the third dimension. Graphic *3D* software packages are used to design the element to be created as the final product. The printer driver converts this model into layers. A simple presentation does not reflect all the complexity of this procedure. One of the first materials used for these purposes (along with liquid photopolymers that harden) is ceramics. Various powders are used as raw material *for 3D* processes. Since materials have different properties, certain technologies cannot be used for certain types of materials. It should be expected that with the further advancement of *3D* technology and printers, as well as the materials used in the production of samples, there will be improvements and even greater efficiency and applicability of this technology [16].

INTERNET OF THING (IoT) PLATFORM IN INDUSTRIAL AUTOMATION

The integration of IoT functionality in industrial automation has significantly reduced operating costs, contributed to the optimization of production process time, energy and resource use. In this context, the *Internet of Thing* is a set of physical objects or devices that connect to the Internet using embedded technologies and have the ability to observe, measure and interact with other things around them.

The realization of an intelligent production infrastructure, based on the IoT platform, provides owners and managers of industrial plants with information related to production and business at any time and at any point. Data on the operation and functionality of equipment are the starting point in optimizing productivity, developing process control, increasing energy efficiency, safety at work, reliability and flexibility of industrial production.

The *IoT* platform basically has sensors and devices with a relatively low price and low energy consumption, which contributes to a significant reduction in costs in modern industrial production. This technology enables direct communication between sensors, devices and infrastructure in the plant, which provides servers, operators and management with the necessary information about the operation and efficiency of the system [17, 18].

Cloud platforms, intelligent buildings, the current development of automation in construction and industry, the possibility of acquisition, processing and storage of extremely large amounts of data (big data) and other technological innovations in this area have accelerated the development of the concept of industrial Internet elements - *IIoT*.

NEW STRATEGIES AND TECHNOLOGIES

According to *Berg Insight*, the number of automation systems is constantly increasing globally. At the same time, the number of interconnected devices and the amount of collected data to be processed is increasing. This results in the need for new, more powerful management systems to fully exploit the potential of the data collected. About ten years ago, there was a significant difference in the price of technical means (especially controllers and accompanying equipment) of various manufacturers.

Recently, there are differences in the price of processors, memory, *embedded* software, communication components, etc. they become minor. Conventional processes and technologies, which have had a satisfactory performance in the industry for a relatively long period of time, are already becoming inefficient. The transition to *Industry 4.0* requires new strategies and technologies, which will reduce the time and effort to perform industrial operations. Renowned experts believe that in addition to technological innovations, work will have to be done on improving the system for data acquisition, processing and analysis, and that the problems related to that will be solved in the *IoT* environment.

The growing role of automation in the realization of industrial production and the "transfer" of increasing human rights and tasks to automated equipment and robotic systems represents a huge potential for more precise control and increased production efficiency. For the application of *IoT* in industrial automation, a new generation of controllers and sensors has been developed, with advanced capabilities and increased intelligence, which enables more precise management and efficient operation with a minimum of downtime. The main challenge of today's development of process automation is the design of complex and global decentralized systems. This requires new methods and techniques of modeling, improving the design and functionality of control - monitoring systems, the ability to manage complex networks with a large number of interconnected control systems and the coordination of many autonomous network elements.

DEVELOPMENT OF COMUNICATION TECHNOLOGIES AND PROTOCOLS

The evolution of communication technologies has a decisive role in the transformation of the structure of industrial automation systems. Until recently, plant automation was based on the concept of Computer Integrated Manufacturing (*CIM*). In such a hierarchical structure, certain devices are designed for specific tasks and use specific network connections.

With the development of technology in this area, devices are becoming multifunctional, the intelligence of devices and equipment is increasing, and there is a need for modular devices. For example sensors, which are traditionally used to measure certain process variables, are increasingly being integral parts of monitoring and predictive maintenance systems in modern process automation. It is noticed that the traditional hierarchical concept of process management is becoming insufficiently functional, and its place is taken by decentralized distributed architecture.

Industry 4.0 integrates modern information technologies with conventional physical production and processes, enabling the development of new markets and business models. *Industry 4.0* is thus oriented towards integration and the provision of services that the individual customer is willing to pay for [19]. *Industry 4.0* is projected to transform the industrial workforce by 2025. According to research in ermany, the introduction of digital industrial technologies will create more jobs than jobs that will cease to be needed, with new jobs requiring significantly different workers. Detailed modeling predicts an increase of about 350 000 jobs in Germany by 2025.

Namely, the increased use of robotics and information technologies will reduce the number of jobs by about 610.000 in assembly and production, which will be compensated by the creation of about 960.000 new jobs, especially in the *IT* sector and data science. For this country, Fig. 2 illustrates the gross revenues of certain industries for 2013 and forecasts for 2025 [20].

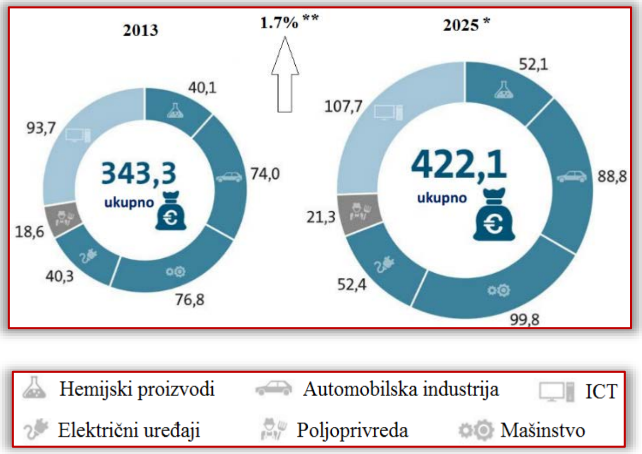

Figure 2. Gross revenues (in billions of €) in individual sectors in Germany

DATA TRANSFER

The increasing speed of data exchange has imposed the need for mass use of Ethernet technologies in industrial networks. This also applies to wireless architectures that are increasingly present in the process industry. They can integrate remote, geographically remote measuring elements and devices in the field, have flexibility, are easy to install and operate, enable visualization, remote configuration, diagnostics and control. Another leading trend, in terms of communication in process automation, is the integration of interfaces that support the transfer and exchange of various types of device data - data from process measurements, control signals, various diagnostic data, monitoring data, hierarchical information and more. In order to respond to the needs and challenges of the modern process industry, it is necessary to implement horizontal and vertical integration of information and communication technologies as well as automation systems in the entire structure of the industrial enterprise. This can be achieved by efficiently integrating various processes into a single platform and connecting all individual subsystems.

CONTROL WITH THE USE OF PREDICTIVE MODELS

Model predictive control - *MPC* is already a standard solution in process control in the industry. There are mainly two models of predictive control - linear and nonlinear. The main advantage of this control method is the possibility of regulating multivariable systems, which have numerous limitations of input and output values. Solutions in the field of process control and automation of fourth generation *MPC* technologies are available on the market, which enable parallel optimization of a number of levels, priority realization of control tasks, improvement of product quality and efficient use of resources. There are also various advanced identification devices based on error and fault prediction methods. This concept is used in various fields including the chemical industry, food, oil and gas processing plants, the pharmaceutical industry, the rubber industry and a number of other sectors.

The development of optimal control of nonlinear systems, estimation of status and parameters, as well as stability analysis and synthesis of nonlinear systems are also part of the field of predictive control. Modern solutions of predictive control systems enable decentralized control and horizontal integration of global nonlinear processes that can be connected by a network, as well as the application of hybrid discrete - continuous control systems.

In process automation the application of artificial intelligence is increasing, especially in the field of product quality control, where slight improvements in process management can lead to significant advantages over the competition. The most important thing of technologies based on artificial intelligence in the industry is real-time process control and resource planning and management where their further development and mass application is yet to come. Monitoring of the production process, the possibility of forecasting failures, unplanned downtimes and accidents, are key elements for increasing efficiency. The basic task of the management system is to enable product quality, safety and security of people and equipment. The consequences of unplanned and unwanted events due to various causes lead to a drastic increase in costs, to the interruption of the production process in a certain period with significant negative effects on the reliability and economy of the company, as well as on its image. The more complex the control process, the more complex the monitoring and diagnostics that will prevent the occurrence of failures and breakdowns. In modern process automation, based on knowledge of the nature of the controlled process, there are two methods: one is based on previous process modeling, which includes various quantitative and qualitative simulation methods and predictive calculation of values of certain variables of systems over time; the second method is based on the experience and historical data of the managed process with the application of quantitative, qualitative and statistical methods. The development of automation and information technologies in the process industry and the increase of its complexity and intelligence have resulted in the generation of a huge amount of data and the need for their processing and analysis. At the same time, the need for the number of executors engaged in management processes has decreased. Today, operators are faced with very responsible tasks in terms of taking action in certain critical or crisis situations, when it is necessary affect quickly and energetically.

For these reasons, they need processed and easily accessible relevant data. Therefore, the basic tendency in process control is the integrated connection of management, knowledge and information. This development is based on in-depth research into the interrelationships that exist between humans and machines in the production process, covering all possible technical and social aspects of that communication, as well as all activities in which people control or supervise machines, equipment or complete technological processes.

DIGITAZION OF PRODUCT AND SERVICE PORTFOLIOS

Industry 4.0 goes far beyond process digitization. This revolution is leading to a greater degree of digitization of product and service portfolios. The perfect mechanical properties of one product are no longer enough to compete on the world market. The advantage is on the side of digitized products with built-in sensors, software, the ability to generate data and network. Digital products are phenomena that can be found in all branches of industry. For example in the automotive industry, instead of classic braking systems, *ABS* (Anti-lock braking system) devices with implemented modern control systems are installed. It is an electro-hydraulic system that prevents the wheels from locking when braking, which usually happens when braking very hard or when driving on slippery sur the risk of blocking the wheels. In production and engineering, the use and connection of appropriate sensors enables optimal maintenance of machines and provides efficient operational control. It is understandable that the percentage of digital products is the highest in the information and communication technology sector. In the manufacturing industry, the degree of digitization is currently between 22 % and 27 %. The general tendency of all sectors is an intensive increase in the level of digital products and services in the coming years. At the core of *Industry 4.0* is the complete digitization of processes, products and services and integration into digital ecosystems with value chain partners.

CONCLUSIONS

The perspective of automation is considered with special reference to *Industry 4.0*. Various corporations around the world are projected to invest more than $ 1000 billion a year by 2022 in the conquest of *Industry 4.0*, which will lead to a significant reduction in costs, increased efficiency and profits, and it is predicted that the investment will pay off in two years, with the need for *IT* experts to increase permanently. In the countries of the developed world, it is estimated that one third of their companies have a high level of digitalization, and it is expected that this percentage will reach the value of 75 % in the next five years. Worldwide, large companies are investing 5 % of their digital sales revenue annually, or approximately $ 907 billion, which will be further invested in digital technologies such as sensors and various devices, and in the development of software and applications such as production management systems. It is believed that in the next five years, data analysis will have a major impact on decision-making processes. *Industry 4.0* is based on the smart factory model that integrates the knowledge and skills of participants at all levels (scientific corps, managers, engineers, workers). The basic features of a smart smart enterprise are: smart personalized product, unified role of manufacturers and service providers (offer of extended products - integration of products and services), high level of cooperation at the level of business system and environment. The essence of the vision of *Industry 4.0* and *IoT* is a versatile connection of people, products, machines and equipment in the production plant in order to realize new products and services.

Products, transport system and devices will be able to "negotiates" within the virtual market regarding the most efficient steps that would allow maximum efficiency of the production process. This would provide a connection between the virtual world and the physical objects of the real system. In the last 15 years, progress has been evident in the development of additive technologies (*3D printing*), which has significantly increased the potential for design, development, production and distribution of certain products. This progress is e.g. in the automotive industry opened the door to innovative technical solutions that have contributed to cleaner, easier and safer production, shorter delivery times and reduced costs. It is a question of the near future when *3D printing* will begin to be used not only for prototyping but also for innovative elements in mass serial production.

Note:

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