Journal of Electrical Engineering, Electronics, Control and Computer Science – JEEECCS, Volume 8, Issue 30, pages 33-38, 2022

Industry 5.0 vs. Industry 4.0 Reference Architectures, Challenges and Trends

Marius-Constantin Marica
University of Pitesti
maricamariusconstantin@yahoo.com

Nicu Bizon
University of Pitesti
nicubizon@yahoo.com

***Abstract* – Industry 5.0, like Industry 4.0, aims for success and efficiency, but to achieve these aspects will require large financial investments from factory owners, but also from companies that make equipment and devices for the industrial environment. This paper aims to make a brief presentation and comparison between the concept of Industry 5 and Industry 4.0. At the same time, the reference architectures, challenges and trends of the two concepts are presented. Finally, the differences between the two technologies are clarified.**

Keyword-Industry 4.0, Industry 5.0, challenges, trends, effiencency, sustainability, human factor;

I. INTRODUCTION

The integration at the level of the production flow of cybernetic systems, of the Internet of Things (IoT), of servers and of artificial intelligence, in factories and industrial processes is called Industry 4.0. Regarding the current industrial environment, the concept of Industry 4.0 implies a major transformation in the entire production chain. This involves in the first phase the use of the Internet and digital equipment in the current industry [1].

Industry 5.0 is a reaction to the concept of Industry 4.0 and has experienced rapid development, under the impetus given by the impact of the pandemic, the focus on issues such as sustainability and the need to place the human factor at the center of industrial processes and attention to social efforts.

This paper aims to make a brief presentation and comparison between the concept of Industry 4.0 and Industry 5.0, which are the reference architectures, challenges and trends between the two concepts, but also the advantages and disadvantages of these new technologies. In the following are presented some novelties and purposes brought by this paper:

- a simple comparison is made between the concept of Industry 5.0 and Industry 4.0.
- the reference architectures for two concepts are presented.
- the challenges and trends for two concepts are presented.
- are briefly presented some advantages and disadvantages of the two concepts.

II. INDUSTRY 4.0

The fourth industrial revolution involves the development of current technologies and the large-scale integration of new digital technologies (whether hardware or software), the large-scale acquisition of industrial process data and the equipment that controls it, and the optimization of production flow with in order to reduce pollution and increase production [2].

The concept promoted by the fourth industrial revolution, does not stop only at industrial processes in the factory, but is able to offer control of all processes in the factory through the Internet or through artificial intelligence systems, so as to optimize and maximize the integrity factory production flow.

A. Industry 4.0 – basic architecture

The Reference Architecture Model for Industry 4.0 is standardized under the RAMI 4.0 model. This model is a 3d coordinate system that essentially defines all the fundamental features of the Industry 4.0 concept. The purpose of this model is to simplify the complex relationships within the Industry 4.0 concept and to allow a quick analysis of the systems that fall into this concept.

The Reference Architecture Model for Industry 4.0 consists of the following three axes [3]:

- "**Hierarchical levels**" axis - is positioned on the right side of the RAMI4.0 model, being a horizontal axis containing the principles and regulations imposed by the IEC62264 standard for the industrial production process.
- "**Life Cycle Value Stream**" axis - is the left horizontal axis on which the life cycle of installations and products within Industry 4.0-based systems are indicated. This axis is based on the international standard IEC62890 which deals with the standardization of the way of managing the life cycle of systems and compacts in the industrial environment.
- "**Layers**" axis - is the vertical axis on which are indicated the six base layers used to create the virtual model of an equipment or industrial process. This is necessary to

simplify the way of solving equipment and process development problems and involves decomposing them into simple systems that allow a much easier analysis and understanding.

The main levels of the vertical axis are presented below:

- **Asset Layer** - represents the state that contains the physical resources of the process and industrial equipment, but it should be mentioned that the element is also a part of this layer. Transposition in the virtual environment of all the elements contained in this layer is done with the help of the integration layer.
- **Integration Layer** - deals with the provision of information about physical components or software in a form accessible to the virtual environment. At the same time, it deals with computerized process control, asset generation and contains components that are connected to the IT infrastructure (programmable logic controllers, graphical interfaces, input and output elements). It should be mentioned that the human factor is virtualized through its interactions with the equipment or process (through graphical interfaces, physical buttons).
- **Communication Layer** - standardize the way in which data is transmitted between the layers of the system or process, by providing the functions and methods for transmitting and interpreting this data.
- **Information Layer** - is the layer that handles the management of the data flow generated throughout the system and contains in the structure the rules according to which the information is managed and interpreted.
- **Functional Layer** - is the layer that deals with the management of the entire system and contains in its structure the basic rules, execution times for certain stages of the system and how the equipment or process must perform its activity.
- **Business Layer** - is the layer that deals with the management of system resources, otherwise the equipment or process to work in the optimal parameters of productivity and energy efficiency.

As can be seen, the three axes underlying RAMI 4.0, allow the analysis at a simplified level of all the characteristics of the systems and processes that base their operation on the concept of Industry 4.0., can thus be described and implemented using the RAMI 4.0 model.

B. Industry 4.0 – challenges

The concept of Industry 4.0 leads to the development of new equipment and technologies that due to the complexity require a lot of time to implement and involve collaboration between several branches of industry, very high research and implementation costs, aspects that are not easy to achieve. This paper presents the challenges in technology and science, such as the development of intelligent equipment, the construction of the network environment, the analysis and processing of big data and digital production.

Development of intelligent equipment

A factory that bases its operation on the technologies of the Industry 4.0 concept is much smarter than any factory built using the Industry 3.0 topology and will also require more intervention from artificial devices (such as robots), reducing the involvement of the human factor in the administration. its. However, factories developed around the concept of Industry 4.0 require in the basic structure smart equipment and devices that are currently difficult to achieve and require a lot of investment before they can be integrated into the production flow of a factory.

Network model construction

The network model in Industry 4.0 consists in the development of a platform of cyber production systems, but this is a very complicated process that is currently has a number of limitations, such as cooperation between different elements, resources and devices of the chain. of production.

Analysis and processing of large volumes of data

Industry 4.0, through its construction, involves the acquisition, analysis and processing in real time of a large volume of data. All the component elements (such as devices, machinery, products, services) of a system integrated in this concept must continue to generate data, which through their structure have a large volume and a high complex. Within Industry 4.0 systems, the efficient integration and real-time analysis of all data in the production flow within the industrial system must be ensured, so that the rapid and efficient optimization of all resources in the production flow can be achieved. It should be mentioned that due to the large volume of data and real-time acquisition, there are problems with IT security in Industry 4.0 systems and data confidentiality is endangered. At the moment, hardware-to-software systems for handling large volumes of data do not have an increased maturity and need further improvements, so that the data is securely protected against attackers.

Digitized production

The digitization of the production flow must be based on maximizing and using all the elements of digitization, but also of internet technologies, so that a hardware and software infrastructure can be obtained that is both reliable and robust. The development of technologies and standards will become a high difficulty as the process of implementing Industry 4.0 systems will increase, one of these difficulties being cyber security and espionage at the level of the chain and industrial factories.

C. Industry 4.0 – trends

The development of Industry 4.0 systems has gradually increased from existing industrial

technologies. International collaboration and a system-wide perspective are most desirable to address the challenges of Industry 4.0. Below are identified and presented some trends of the Industry 4.0 concept [4]:

- integration of cybernetic systems in the real word.
- checking and testing cyber systems in the real world.
- integration of Blockchain technology in the production flow.
- development and construction of intelligent equipment to facilitate the construction of factories.
- development and creation of autonomous factories that do not require the intervention of the human factor.
- mitigating the impact produced by Industry 4.0 in society.

III. INDUSTRY 5.0

Industry 5.0 is a reaction to the concept of Industry 4.0 and has experienced rapid development, under the impetus given by the impact of the pandemic, the emphasis on issues such as sustainability and the need to place the human factor at the center of industrial processes and attention to social efforts. The fourth industrial revolution involved the development of current technologies and the large-scale integration of new digital technologies (whether hardware or software), the large-scale acquisition of industrial process data and the equipment that controls it, and the optimization of production flow. in order to reduce pollution and increase production. The concept promoted by the fourth industrial revolution, does not stop only at industrial processes in the factory, but is able to offer control of all processes in the factory through the Internet or through artificial intelligence systems, so as to optimize and maximize the integrity factory production flow.

A. Industry 5.0 – basic architecture

Currently, for Industry 5.0 is not defined a reference architectural model as in the case of Industry 4.0 with the RAMI4.0 model, however, is defined the base of architectures that proposes the interconnection of three basic values, namely: focusing on the human factor, sustainability and resilience.

Focusing on the human factor

Industry 4.0 diminished the role of the human factor in the production chain and led to job losses. To create jobs and reduce unemployment, the concept of Industry 5.0 wants the human factor to be at the center of the production flow. So, we can say that a close connection between the new equipment and man is necessary, but achieving this connection is a challenge if we want the production chain to be efficient, productive and qualitative [5].

Resilience

The principles that Industry 4.0 promotes have produced in the society the appearance of uncertainty and fear towards the role of industrial automation. Therefore, Industry 5.0 tries to balance the relationship between man and machine. The impact that the pandemic had on the industrial environment showed that the factories did not have a plan to take into account the temporary blockage of the supply and production flow. Industry 5.0 wants to solve this problem by defining clear measures that each factory and institution must comply with, so that production activity recovers quickly and continues in case of emergencies, and the impact on the economy and society to be as small as possible [5].

Sustainability

Both the sustainability and resilience of the production flow are addressed with great importance by the concept of Industry 5.0. The concept wants the production chain to be as standardized and regulated as possible, its center to be human and its efficiency to be maximum. At the same time, with increasing emphasis on regulations and investors on reducing carbon emissions and environmental impact, companies need to look at how the production chain works and determine where changes can be made to reduce pollution, environmental impact. and use technologies that have minimal energy consumption [5].

B. Industry 5.0 – challenges

The main problem of Industry 5.0 is to reduce the reluctance that the company has on industrial automation, and for this reason Industry 5.0 is based on the human factor. The concepts and development of Industry 4.0 have caused fear of job losses for the staff of Industry 4.0 factories, and Industry 5.0 is trying to eliminate this fear by collaborating between man and machine.

The Industry 5.0 revolution presents other unique challenges that have never been encountered in other industrial revolutions, such as:

- creating equipment that allows the realization of unique products on a large scale.
- increasing the efficiency of the production flow by integrating the human factor in the process.
- reducing the degree of pollution that factories have on nature.
- final customer integration in the production flow.
- reducing the construction costs of Industry 5.0 factories.

Industry 5.0, like Industry 4.0, aims for success and efficiency, but to achieve these aspects will require large financial investments from factory owners, but also from companies that make equipment and devices for the industrial environment.

C. Industry 5.0 – trends

Industry Integration 5.0 is still in its infancy and is viewed with limitations by governments and factories,

although it addresses from a clear perspective how sustainability, resilience and integration of the human factor into the core of the process. Below are identified and presented some trends of the Industry 5.0 concept [6]:

- the realization of systems and technologies that incorporate in their core the fusion between the human factor and the machine.
- check and test in the real world the systems in which man and machine are closely related.
- development of industrial equipment that allows the creation of unique products.
- diminishing the society's fear of industrial automation.
- integration of Blockchain technology in the production flow.
- developing efficient technologies that have the least possible impact on nature.
- reducing the costs of manufacturing factories and technologies used in Industry 5.0.
- reducing the construction costs of Industry 5.0 factories.

IV. DISCUSSION

Industry 5.0, like Industry 4.0, aims for success and efficiency, but to achieve these aspects will require large financial investments from factory owners, but also from companies that make equipment and devices for the industrial environment.

In the tables below, only some of the advantages and disadvantages of the Industry 4.0 and Industry 5.0 concepts have been presented. With the development of the two concepts, industry and society will know a series of new benefits and we hope that the confidence in industrial automation will be regained among the population. Although the concept of Industry 5.0 is similar to that of Industry 4.0, there are quite large differences between the two and each of them comes with their own problems and disadvantages.

Table 1 shows a brief comparison between the concept of Industry 4.0 and the concept of Industry 5.0.

TABLE I. INDUSTRY 4.0 VS 5.0

Criteria	***Industry 4.0***	***Industry 5.0***
Cost	Low	High
Sustainability	Low	High
Needed energy	Very high	Low
Productivity	Low	Very high
Resilience	Low	Very high
Smart manufacturing	High	Very high
Human-centric	Low	High
Optimization	High	Very high
Technology integration	High	Very High
CO_2 emissions	High	Low

Industry 4.0 hasn't yet reached its peak and its effect is only now beginning to be felt in the industrial environment. More and more factories and new equipment have the infrastructure developed around the principles and features of the Industry 4.0 concept.

Industry 5.0 wants to take the advanced technologies developed for Industry 4.0 and use them to create an environment where the human factor and industrial automation can easily work together [7].

The increasing involvement of governments in the industrial environment with the aim of increasing the quality of people's lives and managing the footprint that factories have on the environment, leads to a series of challenges and changes for the industry that are currently viewed with reluctance due to high costs of implementation [8].

Regarding to the Industry 5.0, more research needs to be done on the following topics:

- 5G technology in the production chain and in smart factories [8].
- predictive systems use to prevent production stoppages and to reduce maintenance time [8].
- analysis and processing of large volumes of data in Industry 5.0 [8].
- artificial intelligence and augmented reality in the production flow and in the equipment maintenance flow [9].
- algorithms for managing and optimization the production chain in a smart factory using artificial intelligence systems [9].
- Fuzzy systems for managing the production chain in an intelligent factory [9].
- analysis, development and implementation of the reference architectural model for Industry 5.0.
- analysis, development and integration of industrial equipment and systems with low energy consumption and high production.
- Safety systems with artificial intelligence for the protection of the human factor.
- algorithms for large-scale production of unique products.

CONCLUSION

The fourth industrial revolution involves the development of current technologies and the large-scale integration of new digital technologies (whether hardware or software), the large-scale acquisition of industrial process data and the equipment that controls it, and the optimization of production flow

with in order to reduce pollution and increase production.

Industry 5.0 is a reaction to the concept of Industry 4.0 and has experienced rapid development, under the impetus given by the impact of the pandemic, the emphasis on issues such as sustainability and the need to place the human factor at the center of industrial processes and attention to social efforts. The concept promoted by the fourth industrial revolution, does not stop only at industrial processes in the factory, but is able to offer control of all processes in the factory through the Internet or through artificial intelligence systems, so as to optimize and maximize the integrity factory production flow.

So, the main findings of this paper are:

- conceptual understanding of the two technologies of Industry 4.0 and Industry 5.0.
- clarifying the differences in architecture and implementation between the two technologies.
- clarifying the challenges and trends that the two concepts have to face during developments and implementations.

It should be mentioned that the concept of Industry 5.0 is still in its infancy and more regulations and research are needed to clearly establish the international standards by which this concept is guided.

REFERENCES

[1] https://en.wikipedia.org/wiki/Fourth_Industrial_Revolution (accessed June 2, 2022).

[2] https://www.techtarget.com/searcherp/definition/Industry-40; (accessed June 2, 2022).

[3] Brecher, C., Müller, A., Dassen, Y. et al. Automation technology as a key component of the Industry 4.0 production development path. Int J Adv Manuf Technol 117, 2287–2295 (2021). https://doi.org/10.1007/s00170-021-07246-5.

[4] Niharika Karnik, Urvi Bora, Karan Bhadri, Prasanna Kadambi, Pankaj Dhatrak, A comprehensive study on current and future trends towards the characteristics and enablers of industry 4.0, Journal of Industrial Information Integration,Volume 27, 2022, 100294, ISSN 2452-414X, https://doi.org/10.1016/j.jii.2021.100294.

[5] Xun Xu, Yuqian Lu, Birgit Vogel-Heuser, Lihui Wang,Industry 4.0 and Industry 5.0—Inception, conception and perception, Journal of Manufacturing Systems, Volume 61, 2021, Pages 530-535, ISSN 0278-6125, https://doi.org/10.1016/j.jmsy.2021.10.006.

[6] Akundi, Aditya & Euresti, Daniel & Luna, Sergio & Ankobiah, Wilma & Lopes, Amit & Edinbarough, Immanuel. (2022). State of Industry 5.0—Analysis and Identification of Current Research Trends. Applied System Innovation. 5. 27. https://www.doi.org/10.3390/asi5010027

[7] https://transmitter.ieee.org/how-industry-5-0-will-impact-work/ (accessed Juny 17, 2022).

[8] https://cmte.ieee.org/futuredirections/2021/11/03/2025-outlook-industry-4-0-digital-industry-society-5-0/ (accessed Juny 17, 2022).

[9] https://www.journals.elsevier.com/computers-and-electrical-engineering/call-for-papers/special-section-on-artificial-intelligence-ai-for-industry-5-0-vsi-aii5 (accessed Juny 17, 2022).