Turkish Journal of Science & Technology
16(1), 179-185, 2021

Industrial Automation and Edge Computing: SCADA, PLC, PAC, IO-LINK

Fatih TOPALOĞLU[1*]
[1] Department of Computer Engineering, Faculty of Engineering and Natural Sciences, Malatya Turgut Özal University, Malatya, Turkey
[*1] fatih.topaloglu@ozal.edu.tr

(Geliş/Received: 21/01/2021; Kabul/Accepted: 01/02/2021)

Abstract: Increasing interest in Industry 4.0 applications has brought with it many new technologies and strategies for processing all kinds of production-related data, which are at the center of this trend. Although many of these technologies are not very new, they have not yet reached sufficient recognition in the industry. The term edge computing is among the concepts that need to be clarified in this context. Edge computing draws local intelligence and data processing capability to the parts of the communication network close to the end devices such as pumps, motors, sensors, relays that produce data, and performs the analysis of the data without the need to transfer it somewhere. However, this process also has difficulties. Edge computing architectures in industrial applications need to address bandwidth, management complexity, latency, and network security risks. With this study, four important architectural solutions that help to optimize resource usage on the edge computing platform for industrial applications are proposed and analyzed.

Key words: Edge computing, industrial automation, SCADA, PLC, PAC, IO-LINK.

Endüstriyel Otomasyon ve Uç Bilişim: SCADA, PLC, PAC, IO-LİNK

Öz: Endüstri 4.0 uygulamalarına artan ilgi, bu trendin merkezinde yer alan üretim ile ilgili her türlü veriyi işlemeye yönelik birçok yeni teknoloji ve stratejiyi de beraberinde getirmiştir. Bu teknolojilerin birçoğu pek yeni olmasa da, sektörde yeterli bilinirliğe henüz erişememiştir. Uç bilişim terimi de bu bağlamda netleştirilmesi gereken konseptler arasında yer alır. Uç bilişim, yerel zeka ve veri işleme kabiliyetini haberleşme ağının veri üreten pompa, motor, sensör, röle gibi uç cihazlara yakın kısımlarına çekerek verinin bir yere aktarılmasına gerek kalmadan analizini gerçekleştirir. Ancak bu sürecin de zorlukları bulunur. Endüstriyel uygulamalarda uç bilişim mimarilerin bant genişliği, yönetim karmaşası, gecikme süresi ve ağ güvenliği risklerine çözüm getirmesi gerekir. Yapılan çalışma ile endüstriyel uygulamalar için uç bilişim platformunda kaynak kullanımını optimize etmeye yardımcı olan dört önemli mimari çözüm için önerilmiş ve analiz edilmiştir.

Anahtar kelimeler: Uç bilişim, endüstriyel otomasyon, SCADA, PLC, PAC, IO-LINK.

1. Introduction

Edge computing technology offers important opportunities to system integrators and business owners to increase productivity in production in the age of Industry 4.0 or to ensure the most efficient use of data in industrial systems. With its computing ability in edge computing, it can perform near real-time insight and predictive analysis. While modern industry practices break down molds, they can also face many challenging and daunting demands. This is where the starting point for developing solutions for edge computing in industrial applications emerges.

While the previous studies covered the general features of edge computing for the sectors, the requirements of the industrial automation field in particular were taken as basis in the study. For this purpose, four important automation architectures, Supervisory Control and Data Acquisition (SCADA), Programmable Logic Controller (PLC), Programmable Automation Controller (PAC) and IO-LINK, have been proposed and analyzed.

Edge computing provides crucial transformations for industrial applications. Today, businesses are developing edge computing and cloud computing to store, analyze and process data faster for specific workloads such as latency-sensitive applications.In this study, an important set of criteria for edge informatics applications in industrial automation systems was defined by making a comprehensive literature review of online and printed copies of relevant journals and printed books.

For the purpose of the document, the remainder of the article continues as follows. The proposed architectures for the solution, considering the development of the industrial automation system, were firstly SCADA architecture, Secondly PLC architecture, Thirdly PAC architecture, fourthly data processing features of

* Corresponding author: fatih.topaloglu@ozal.edu.tr. ORCID Number of authors: [1] 0000-0002-2089-5214

IO-LINK architectures at the end, and finally, important requirements and solutions in the discussion and suggestions. recommendations have been put forward.

2. Edge Computing Architectures in Industrial Automation

With the advancement of technology, the automation sector gains more value and tries to produce more innovations in order to keep up with technology. Industrial automation systems are also the basis of these production stages. Automation systems can also be referred to as a device or software set that allows the user to communicate with the machine and production facilities.

Edge computing brings significant advantages to industrial automation systems as it significantly optimizes resource usage. First of all, the processors used in the relevant devices provide more efficient hardware security with a relatively low power requirement. In this way, it quickly captures flow-related data in order to detect possible product defects.

2.1. SCADA

SCADA systems are used in critical infrastructure and industrial sectors [1]. SCADA system is a combination of data acquisition and telemetry (wireless data transfer). Their primary functions are data collection, data processing for use by the operator, and control of remote devices by the operator [2].

The data collected from the end devices actuators, drive motors, valves, lamps, speed measuring devices, proximity detectors, temperature, force and moment electronic sensors are converted to electrical signals and transferred to the SCADA system. The commands given from the SCADA system are converted to electrical signals in this layer, allowing the desired movements to occur in the real world.

In order for the SCADA system to undertake the monitoring and control functions, the input and output information of the process is defined in a database. When each information corresponding to the process variables in the database needs to be processed, the transaction blocks to be used are performed in the database definition phase. SCADA data to be processed in edge computing are quality data, production efficiency data, production cost data, maintenance data and statistical data.

SCADA systems have an alarm structure developed to continuously monitor process variables and warn the operator in case these variables reach undesired values. In addition, they report the production results made in different shifts in the factory, certain variables of the process, the results of the events on request or as events occur or periodically. Thus, production prescriptions are put into practice. Recipes can be associated with graphics, allowing the operator to easily access and modify recipes if necessary.

The SCADA system, the Remote Terminal Unit (RTU), which forms the data collection and control terminal units, the communication system that allows data or information to be sent mutually to another region in a region, the facilities spread over a wide geographic area are monitored and managed remotely with a computer-based structure. It consists of Master Terminal Unit (MTU) units. Efficient communication is required for efficient flow messages between MTU and PLCs / RTUs [3].

In a SCADA system, remote terminal units, main terminal units, communication networks, data collection units, sensors and sensors, software, central control room, control panels, scada system terminals, computer screens, printers, uninterruptible power supplies can be included. Figure 1. shows a typical SCADA system.

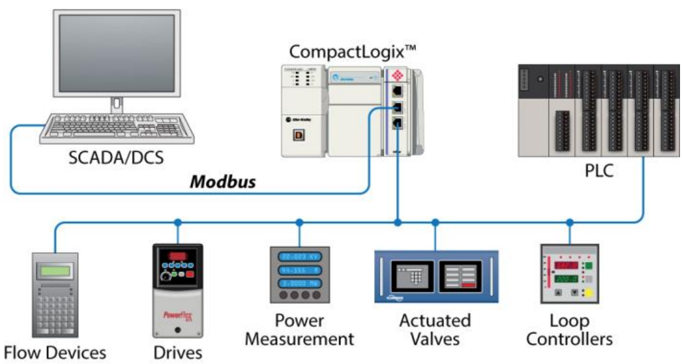

Figure 1. SCADA sytem

All kinds of information collected from control devices in the SCADA system are kept in a variable in the database called Tagname. This information should be processed and adapted to the needs and demands of the business. SCADA software helps employees to process and view data in the decision process.The software determines what to monitor, when to monitor, acceptable parameter ranges, response type, etc. determines [4].

2.2. PLC

PLCs are microprocessor-based devices used in the control of processes such as production departments in factories or control of machines. PLCs were first used by the automotive industry in the late 1960s [5–9]. This supervisory system scans the input information at speeds invisible to the naked eye, and works in a way to respond in close to real time with the corresponding exit information.

The most important feature of PLC is that the program commands are processed in real time, and it enables the realization of functions by sending it to the modules connected with the outside world such as input / output and communication in the shortest time possible. PLC can be more easily connected to sensors and actuators [10]. Thus, they can be used as a solution in industrial applications where timing is critical.

For this purpose, functions such as logic, sequencing, counting, data processing, comparison and arithmetic operations, PLC system, which evaluates inputs and assigns outputs with programming support, provides communication between processor - memory modules and power supply, and the brain of programmable controllers is the central processing unit, which is used to store the control program in the microcontroller. The memory unit consists of the input unit that enables it to be used by accepting the signal it receives from the controlled machines, the processor or an external switch or sensor, and the output unit where the controller provides output signals to control the process at the output. Figure 2. shows a typical PLC system.

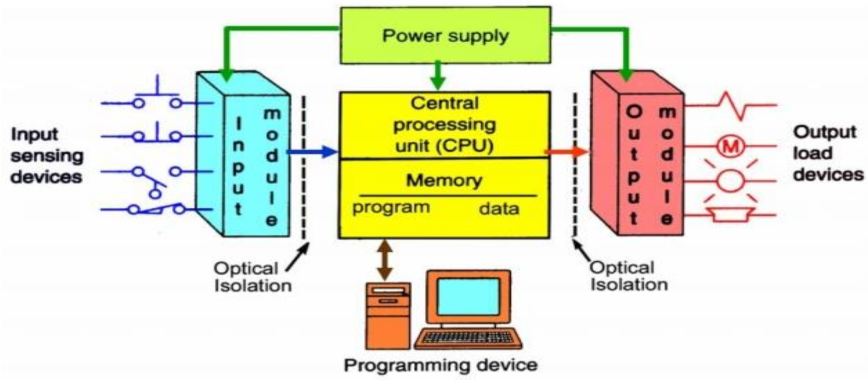

Figure 2. PLC system

Data management, including data collection, review and processing with PLC, has improved in recent years. PLCs can be used as data collectors about the process they control. This data is then compared with reference data in the controller's memory and transferred to another device for reporting.

The PLC system determines the physical events, changes and movements occurring in the field with various measuring devices and evaluates the received information according to the written user program. It also reflects the results resulting from logical operations to the field through the elements it commands.

Since PLCs replace relay-based logic circuits, a programming language consisting of open and closed key symbols called ladder logic is often used when programming PLCs. This programming language is designed to be programmed with schematic or ladder diagrams instead of common computer languages [6,11-14].

2.3. PAC

A typical control system has an interface created by signals from sensors or actuators. Since very extensive applications have been developed in modern industry, creating this interface is quite laborious and the controller requires many requirements. This is where the starting point for the development of PACs emerges.

Since PLCs and PC-based controllers are insufficient in modern industry applications where the features listed at the beginning are required; PACs have emerged as open, multi-functional and integrated control systems are needed. PACs expand the capabilities of PLCs, integrate with PC-based control devices and gather two separate branches together. Recent examples of the industrial use of the PAC framework are given in [15], where a coal preparation plant is automatically controlled using the PAC, and [16] where tide simulations are performed using the PAC framework.

PACs use modern data networks to interact with distributed I / O, drivers, other PAC devices, and corporate elements. They store data in a way superior to PLCs. PACs, which have a better computing power compared to PLCs, are also ahead with their control power. Combining all these features, PACs have revolutionized the field of automation. Figure 3. shows a typical PAC system.

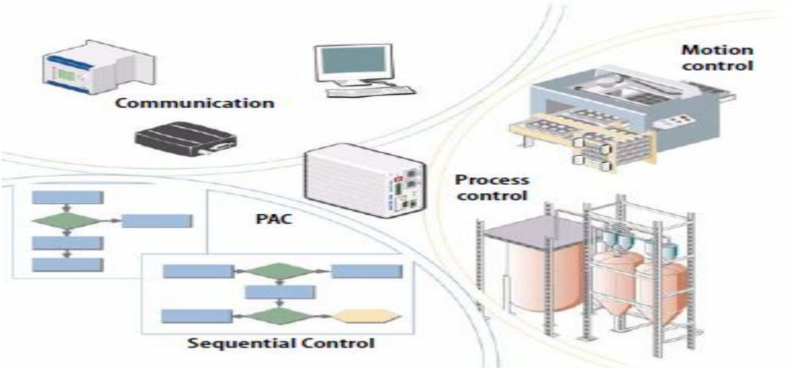

Figure 3. PAC system

In terms of edge information security, PACs use a single platform, it is a reliable platform because it is the Real Time Operating System (RTOS). Therefore, drives, motions, logic circuits and process control are carried out on a single platform. On the contrary, PAC has provided a better solution for this issue, since more than one platform is needed in PLCs. PACs have many functions in these modern industry applications, system studies, performance, status, etc. It monitors centrally, which results in an improved communication structure, machine performance and time savings.

PACs have a much more advanced role thanks to their ability to monitor remotely, data collection, data processing, and organize simple interfaces with Human Machine Interface (HMI) using their large network capacity, memory and processing power. For example, a typical PAC has three basic networks (Ethernet, TCP / IP and web services such as http or SNMP), expandable flash memory, and multitasking functionality.

Among the basic features of PAC components that will provide data processing at the edge, having a more open architecture, better and easier communication and control capabilities, multi-language support, multitasking applications, modular design, more analog I / O (Input / Output) options, Integration with many databases such as SQL and easy programming with USB port.

2.4. IO- LINK

IO-Link ensures the availability of the data requested by the industry operating with the internet in the Industry 4.0 process. All information about this sector is based on the internet. Usually these sources of information are sensors. Thanks to IO-Link, sensors will be solved in transactions such as passage information and status tracking. In the industry sector where the internet is important, standards and continuity are important. IO-Link steps in on this issue and tries to strengthen the communication of sensors that will ensure this continuity.

IO-Link; It is a point-to-point distributed serial communication protocol that is used to communicate with sensors and actuators, and has been found in search of an easier and global solution. The IO-Link technology, developed to communicate with the lowest level of controller automation, has an efficient point-to-point link. It is only designed for the further development of the connection technology between sensors and actuators. Performance characteristics for wireless sensor / actuator communication systems are typically defined by sequential response times of 10 ms or less, and up to 100 sensors and actuators in a production cell spanning several meters [17-19].

The IO-Link Wireless system can be classified as narrowband communication systems [19,20]. Transmits between IO-Link and devices at a speed of 230 kBaud in 400 micro seconds. Large data packages can also be selected if desired. Processed data, manufacturer ID data, system parameters and configuration data, control data can be sent via IO-Link if required. With complex sensors, data can be transmitted in real time. Thus, a very effective and economical automation solution is provided and the cabling process becomes much simpler. Figure 4. shows a typical IO-Link system.

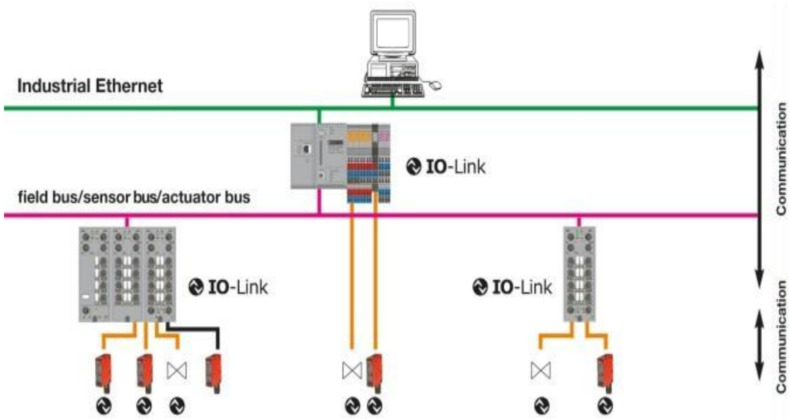

Figure 4. IO Link system

One of the strong advantages of IO-Link is data availability with far-reaching implications. Access and management of sensor data keeps system components running smoothly, streamlines device replacement and optimizes machine maintenance; thus, costs are reduced and the risk of downtime is reduced.

In edge computing applications, in addition to the remote adjustment of IO-Link's sensors, the data storage feature provides automatic reloading of data when changing the device. Users can transfer the existing sensor parameter values to the changed sensor in order to make the device change quickly.

3. Discussion and Suggestions

It is necessary to transfer data to the management in the field by exchanging data with SCADA Application Enterprise Resource Planning (ERP) software and reflecting the writings made by the management to the field. This can be achieved if the databases to be used with the programs are standard and accessible such as SQL or MySQL.

To develop application software using SCADA systems, communication protocols must be defined and the database structure must be defined. Communication protocols provide communication between units that need to communicate with each other in order for SCADA to be the information backbone of the enterprise.

In order for the SCADA system to undertake the monitoring and control functions, the input and output information of the process is defined in a database. Each information corresponding to the process variables in the database is defined as a label, gate or point. The alarms related to the levels where these process variables should be found and the transaction blocks to be used when these variables need to be processed are performed in the database definition phase.

In whatever form, a SCADA software must support the PLC system in order to be applied to the system. If an automation system is to be newly installed and the SCADA system is included in the planning, the selection of SCADA software is easier. However, if SCADA will be installed on an existing automation system, it should be examined whether it supports these PLCs while selecting the driver software of the installed PLC devices.

Generally, SCADA systems are selected in accordance with the operating system platform used in the information processing and automation systems of the enterprises. In addition to Microsoft's operating systems as a stable and common operating system, some businesses may prefer open source (Linux) operating systems in terms of cost. SCADA systems running on almost zero-cost Linux are also available for such open source platforms. However, this requires PLC driver software.

Data acquisition and control speed of communication channels significantly affects the SCADA system. Consequently, the user interface and application software in the control center are also affected. The application of the SCADA System with the highest level of success depends on the communication system.

The most important part of the SCADA system that affects the speed performance is the communication network. All operations involving data transfer and updating between units that are connected to each other at various automation levels of the controlled systems are carried out over communication networks. Therefore, communication is of great importance in SCADA applications.

Digital controllers with relay and hardware program work in real time. In other words, the change in the input information is immediately reflected on the output. This is called parallel signal processing. Memory programmed command orders in PLC are evaluated depending on time. In other words, a change in input is not reflected on the output immediately. This form of signal processing is called serial signal processing, and this is a disadvantage for the PLC.

Control devices are the input, output, communication module etc. of many modules. It is formed by combining. Of course, in such a modular system, there is a complete harmony between all modules when the device is enlarged.

These modules, which were initially independent from each other, are interconnected with a "BUS" system. The CPU creates a closed unit over this "BUS" system and organizes the transport of all data and orders. There are also compact devices created for minor control problems (eg LOGO). These are generally in a closed unit with a fixed number of inputs and outputs. These are generally in a closed unit with a fixed number of inputs and outputs.

In the PLC, the information from the field is the transformation of the actions that occur in the environment into electrical signals.This information can be analog or digital. If the incoming information is analog, query can be made for a certain range of the incoming value, if it is digital, it can be queried according to the presence or absence of the signal. These sensing events are carried out with entry cards, and intervention events with exit cards.

The system to be controlled by PLC may vary in size. Only one machine can be controlled or a complete control of a factory can be performed. The only difference is the capacity of the controller used.

As the systems used develop, PACs also develop in terms of their expandable structures. This expansion is provided by the PLC-type suspension module or by networkable devices such as distributed I / O blocks.

The modularity inherent in PAC in data processing at the edge also offers the possibility of distributing intelligence into a system using network communication or removable memory cards. This is possible because the development environment of the PAC uses logic I / O maps to separate hardware details from the program. Therefore, program modifications are not required for adding, removing, modifying or replacing a device connected to the PAC.

The flexible and modular designs of the PACs enable the creation of independent automation cells that can be added to larger networks for edge computing. This offers infinite modular design capability and increased flexibility and scalability while simplifying maintenance and reducing downtime.

The use of portable storage devices increases the availability of PACs compared to PLC and PC-based controllers in remote control applications where network access is not possible. For example, large data sets can be maintained with local SQL databases on flash cards so that they can be disassembled and replaced at regular intervals.

In edge computing, IO-Link can be integrated into all standard open communication systems and automation systems and can be operated comfortably from the control. It is advantageous to use IO-Link technology for sensors with simple structures such as scanners, reflective sensors or fiber optics.

Even a sensor that does not know the IO-Link language can be connected to the IO module. However, the difficult part is that it needs to use an extra interface. With its developed versions, it has provided an external data management feature and thus has given itself another momentum. With its data management feature, the possibility of changing the sensor is provided without the need to make parameter settings again.

When processing data at the edge, IO-Link allows users to view errors and the status of the device. Thus, users can see the sensor's performance as well as its performance and evaluate the machine's efficiency.

Safety is very important for edge computing devices used in industrial automation applications. Security solutions in electronic markets today are very expensive. However, low-cost solutions are essential for these systems to become widespread across all industrial applications [21].

4. Conclusion

Edge computing is a type of edge computing method used extensively in smart application applications. Depending on the type of industrial applications, data takes place in the edge information system as time sensitive. At this point, SCADA, PLC, PAC, and IO Link architectures are important issues in the industrial automation industry, and the future of the industry lies in the hands of these technologies. With this study, the architectures proposed for edge information applications in industrial automation systems are analyzed and solutions are offered for the determined requirements.

With the models suggested in the article, you can manage workloads across all devices in industrial applications, regardless of number and cloud, deploy applications reliably and seamlessly in all edge locations, maintain openness and flexibility to adapt to evolving needs, and operate more securely and with confidence It will help to perform such operations.

Edge computing architectures proposed and analyzed for industrial applications will increase functionality in businesses by processing large amounts of data and reveal the potentials of this data, while also offering new business opportunities. This will produce faster, more reliable and more consistent results for operators and customers. In the process of Industry 4.0, the analytical features of these architectures will greatly strengthen innovation.

References

[1] Stouffer K, Falco J, Scarfone K. Guide to Industrial Control Systems (ICS) Security, National Institute of Standards and Technology, Gaithersburg, MD, USA: NIST Pubs, 2011.
[2] Gaushell DJ, Darlington HT. Supervisory Control and Data Acquisition. Proc. IEEE, 1987; 75(12): 1645–1658.
[3] Oliveira RM, Facina MSP, Ribeiro MV, Vieira AB. Performance Evaluation of In-home Broadband PLC Systems Using a Cooperative MAC Protocol. Computer Networks 2016; 95: 62–76.
[4] Li H. Wide Area Voltage Monitoring and Optimization. Ph. D, dissertation, Dept. Elec. Eng., Washington State University, Pullman, USA: Pubs, 2013.
[5] Bartelt TLM. Industrial Electronics: Devices, Systems and Applications. Albany, New York, USA: Delmar Publishers, 1997.
[6] Herman SL, Sparkman BL. Electricity and Controls for HVAC/R. 6th ed. Clifton Park, New York, USA: Delmar Cengage Learning, 2010.
[7] Kilian CT. Modern Control Technology: Components and Systems. 2nd ed. Novato, CA : Delmar Thomson Learning, 2000.
[8] Parr EA. 16-Programmable Controllers. In: Laughton MA, Warne DJ, editors. Electrical Engineer's Reference Book. 16td ed. Nestfield, London, UK: Newnes, 2003.
[9] Edan Y, Pliskin N. Transfer of software engineering tools from information systems to production systems. Comput Ind Eng 2001; 39(1–2): 19–34.
[10] Kiran AR, Sundeep BV, Vardhan CS and Mathews N. The principle of programmable logic controller and its role in automation Int. J. Eng. trends Technol. 2013; 4(3): 500–502.
[11] Rehg JA, Sartori GJ. Programmable Logic Controllers. 2nd ed. Saaddle River, New Jersey, USA: Pearson, 2009.
[12] Petruzella FD. Programmable Logic Controller. 4th ed. New York, USA: Mc Graw-Hill, 2011.
[13] Michel G. Programmable logic controllers-Architecture and applications.1st ed. New Jersey, USA: Wiley, 1990.
[14] Rullán A. Programmable logic controllers versus personal computers for process control. Comput Ind Eng 1997; 33(1–2): 421–4.
[15] Zhang L. Applications of PAC in control system at Xeiqiao new coal prepartaion plant. Coal Preperation Technology 2013; 3: 80-81.
[16] Zhang XD. Tide Simulation System Based on PAC. Modern Electronic Technique 2008; 21(11): 113-116.
[17] Koerber HJ, Wattar H, Scholl G. Modular Wireless RealTime Sensor/Actuator Network for Factory Automation Applications, IEEE Transactions on Industrial Informatics 2007; 3: 111–119.
[18] Frotzscher A, Wetzker U, Bauer M, Rentschler M, Beyer M, Elspass S, Klessig H. Requirements and current solutions of wireless communication in industrial automation, in: 2014 IEEE International Conference on Communications Workshops (ICC), June 2014; Sydney, Australian: pp. 67–72.
[19] Krush D, Cammin C, Heynicke R, Scholl G. Standardisierung eines schnellen drahtlosen Sensor/Aktor-Netzwerkes fuer die Fertigungsautomatisierung, Technisches Messen 2016; 83 (4), 201–207.
[20] Heynicke R, Krush D, Scholl G, Kaercher B, Ritter J, Gaggero P, Rentschler M. IO-Link Wireless Enhanced Sensors and Actuators for Industry 4.0 Networks, in: Proceedings – AMA Conferences 2017 with SENSOR and IRS2; June 2017; Wunstorf, Germany: AMA Service GmbH, pp. 134–138.
[21] Al - Saffar H, Erçelebi E. Development of smart security system for remote control using small computer. Turkish Journal of Science & Technology 2017; 12(2): 107-112.