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DESIGN OF A COMMUNICATION SCHEME IN A MODERN FACTORY IN ACCORDANCE WITH THE STANDARD OF INDUSTRY 4.0

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Abstract

This article first describes the current state of the problem in the area of communication in modern factories. Next in the article is given a summary of the requirements that must be implemented for the possibility of establishing a compatible and safe communication system. In the final part of the article is given a proposal of communication model suitable for the implementation.

Key words

Smart Factory, Industry 4.0, communication, system, protocol, standardization

INTRODUCTION

Recent developments in the area of communication in information technologies and process control are currently at an accelerated pace. The trend is the realization of large hybrid communication systems. Modern industries are undergoing a transformation in accordance with the standards of Industry 4.0. This is a modern standard used mainly in Germany and it is an approach to implementing new technology into production (15). In other countries, the process is known as Smart Factory (SF) (12). Individual enterprises in accordance with the standards of Industry 4.0 can be integrated into larger units, thus creating virtual enterprises known as Cyber Physical Systems (CPS) (14). Due to the complexity of such systems, it is clear that this part of production management needs the appropriate Enterprise Resource Planning system (ERP) associated with the appropriate Customer Relationship Management (CRM) system. In addition, it is necessary to create a direct connection with CRM systems on the side of suppliers and customers. The combination of these advanced software tools along with other production technologies together with BI and new methods of design and analysis is a really big challenge. The potential of such a solution is enormous but also presents a number of problems when applied in practice and in a dynamic environment of modern automated robotic manufacturing systems.

The general public is familiar with the term Internet of Things (IoT) (17), which represents the next generation of products and communication between them. The implementation of this technology in practice (IoT) is directly linked with the standard Industry 4.0. The existence of smart products (2) and communication between products is one of the main prerequisites for the realization of intelligent manufacturing. Due to the complexity of the whole process, it is necessary to include Customer Relationship Management (CRM) systems and supply systems into the communication process.

The implementation of new standards into the realization of manufacturing enterprises will place increased demand on industrial communication. Communication occurs at various stages of the production process. In CPS, this is with regards to communication between departments of production, on lower levels it is a communication between products and machines, machine and man, or alternatively between products (smart products). Communication paths represent the most vulnerable points especially in the use of wireless technology and connecting to a network.

PRESENT-DAY STATUS OF INDUSTRY 4.0 IMPLEMENTATION

Scientific and technical development can be divided into several revolutions. The first three were the result of the technical revolution and revolution in electronics and mechanics. The current stage of development of industry can be described as a revolution of informatics and communications. This results in a high degree of globalization and the creation of enterprises, whose existence is based on communication. Solutions realized in accordance with the standards of Industry 4.0, or Smart Factory, are slowly beginning to appear in all industry sectors. The overwhelming majority of solutions, however, exist only in the form of models or theories, exceptionally in test operation in specialized cases. According to the authors (18), the problem is caused by the lack of implementation of the following functions into production process:

- horizontal integration through value networks
- end-to-end digital integration of engineering across the entire value chain
- vertical integration and networked manufacturing systems.

Moreover, the authors in their work, set 8 different targets to be met in the future for the successful implementation of Smart Factory in practice. Similar conclusions are contained in the work of the author Defang Li (5). He clearly defines an estimated plan of implementation of necessary functions for specialized production. However, it is still in the stage of preconditions without any real deployment.

According to the authors of the source in reference (13), the particular focus is on the implementation of universal cells and their model production as a dynamic structure. The simulation and design of the flexible production line, in accordance with the Industry 4.0 standards, was developed further by authors in (29) and (11) that are also accompanied by diagrams and calculations with respect to quality optimization, resources availability and enterprise power consumption. The production unit real model is an outcome of the work presented by the collective of authors (19), and similar solutions are implemented in the aviation industry (25) and in the petrochemical industry (5). Similarly, the authors in (1) are carrying out a part of hybrid electric motor (hybrid electric drive) production. Reference (17) describes CPS (Cyber Physical Systems) representing the next stage of industry innovation. Implementation of virtual enterprises is described in other sources, too.

A very interesting approach to CPS production plant optimization, with respect to locating sources of raw materials and territorial conditions in the food industry, is outlined in (20).

In (16), the team deals with predictive maintenance and data management using Big Data and neural networks for corporate structure design (25). Authors of the article (26) and (7) define a framework for Industry 4.0, which complies with the requirements for the CPS implementation. They define a system of merging the real and virtual world by creating virtual objects within CPS. The processes in these objects are quite complicated and their solution requires use of the BMMN (22) MDCN (Multicriteria Decision Making) methods (21) or genetic algorithms (20).

The highest level of production virtualization is described in (14) and (15). They deal with the term Ubiquitous Manufacturing, which constitutes SF implementation of such a high degree that the product type, production technology and location are almost irrelevant. There are even functional models UM implemented in practice. For example Zhang et al. (21) established a real-time management system for a small flexible manufacturing system (FMS) by using smart objects such as RFIDs and auto IDs and Web services. The FMS was composed of three workstations, one trolley, and one shelf. RFID tags were used to identify operators, components, pallets, and locations on the shelf. RFID readers were integrated with a smart gateway and wrapped with Web services to be easily invoked. Thus, the material flows in the FMS could be automatically traced; the WIP level could be monitored and based on the monitoring results, proper shop floor control actions could be taken. Bose and Pal (30) installed auto-ID readers at point-of sale, storage, and receiving locations to automate data collection. During their investigation, several concerns were raised regarding whether an auto-ID application could be successful, including the acceptable initial investment, item-level or pallet- level tagging, data storage, analysis, privacy, big-band or phased adoption, and integration with existing management information systems (MISs). World leaders in automation have testing facilities, as well, where they test deployment and development of technologies for Industry 4.0 systems. The common element of all the work is only partial standards implementation, which is of course due to the lack of processes, devices and applications standardization. The team of authors in (15) identifies the causes in a large variety of materials, products and workflows. As a solution, they offer to create industrial clusters where businesses with similar orientation are grouped to the production units and they form together a Virtual Enterprise (VE). A similar approach, the authors (12, 3) presented. Means of communication and software interfaces need standardization (6), as well, and as the communication is often wireless, a consistent and reliable security system is also required. In such systems, a huge amount of data is to be processed and therefore, it needs to be evaluated with advanced processing methods such as big data (35).

PROBLEM IDENTIFICATION

The common element of all the work is the only partial implementation of standards, which is of course due to the lack of standardization of processes, devices and applications. The team of authors in (11) identify the causes of this condition. According to them, this is because of the great variety of materials, products and procedures. They offer solutions through the creation of industrial clusters, where are created groups of facilities with similar orientation to the production units and taken together form a Virtual Enterprise (VE). A similar approach asserts authors of the work (15, 20). Similarly, standardization is needed for communication tools and software interfaces. In addition, the communication is often wireless and it is also necessary to originate a unified encryption and security system.

Difficulties in implementing Industry 4.0 clearly arise due to the insufficient level of automation technology flexibility in general. Equipment at the lowest level is highly specialized for a particular function and maximum efficiency. Deployment results in poor variability and a low degree of compatibility.

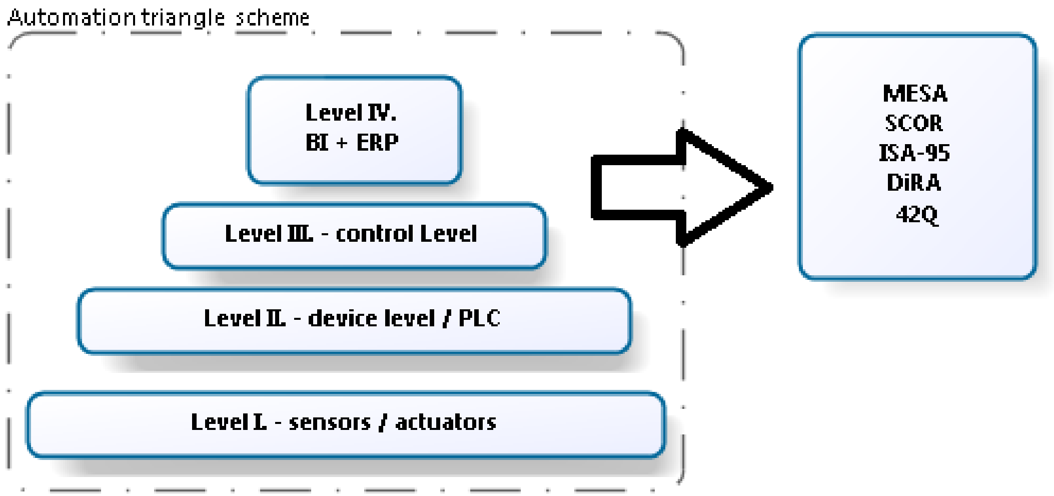

Fig. 1 *MES in automation*

For the realization of enterprises in accordance with the Industry 4.0 standard, it is necessary to solve the above conditions. This involves hardware and software interference with the essential elements of the current automation. It requires a comprehensive approach and solution from the highest level to the lowest level of the automation model. The current situation is opposite. For example, on the control level, to existing standards for MES systems (MESA, SCOR, ISA-95) has been added a new MES standard – DiRA. Behind the acronym is hiding the activity of companies Hewlett Packard and Microsoft (Reference Architecture Framework for Discrete Manufacturers) and according to source (32) it represents their "enterprise approach" to MES and "fits nicely within the Microsoft framework to help companies meet today's manufacturing challenges more effectively". The expansion of the family of MES systems however does not end. We have to add to them the latest MES system 42Q (33). As a consequence, standardization is strongly required for all processes and entities that occur throughout the enterprise model, implemented in accordance with the requirements of the Standard Industry 4.0. It means:

- standardization of communication protocols,
- standardization of connectors and physical interfaces,
- standardization of data exchange (standardization of applications),
- standardization of management (lack of a unified ERP or MES system).

The base element on which stands enterprises working under Industry 4.0 standards is communication between all parts and devices in the production process. These networks are generally separated from public networks and are using proprietary protocols (table 1.).

Table 1 Standardized protocols used in automation (34)

Name of protocol	*Standard IEC/PAS*
EPA	62409 Ed. 1.0
Ethercat	62407-2005
Powerlink EPL	62408-2005
Profinet IO	62411-2005
Ethernet/IP	62413-2005
MODBUS – RTPS wire protocol	62030-2004
P-NET on IP specification	62412-2005
VNET/ip	62405-2005
SERCOS III	62410-2005
Tcnet (Time-critical control network)	62406-2005
RAPIEnet	62573-2008

The difference from internet communication is the timing in automation networks. Timing is critical in automation and timing requirements must be satisfied (10). As a matter of course, it is impossible to neglect data and communications security (23, 28, 24), which requires the use of available technologies with a classic form or modern methods (31, 27).

DESIGN OF COMMUNICATION SCHEME

The communication model proposal in a CMS environment (Figure 4) presupposes the existence of a comprehensive communication system and solves logical problems of data transfer between single objects.

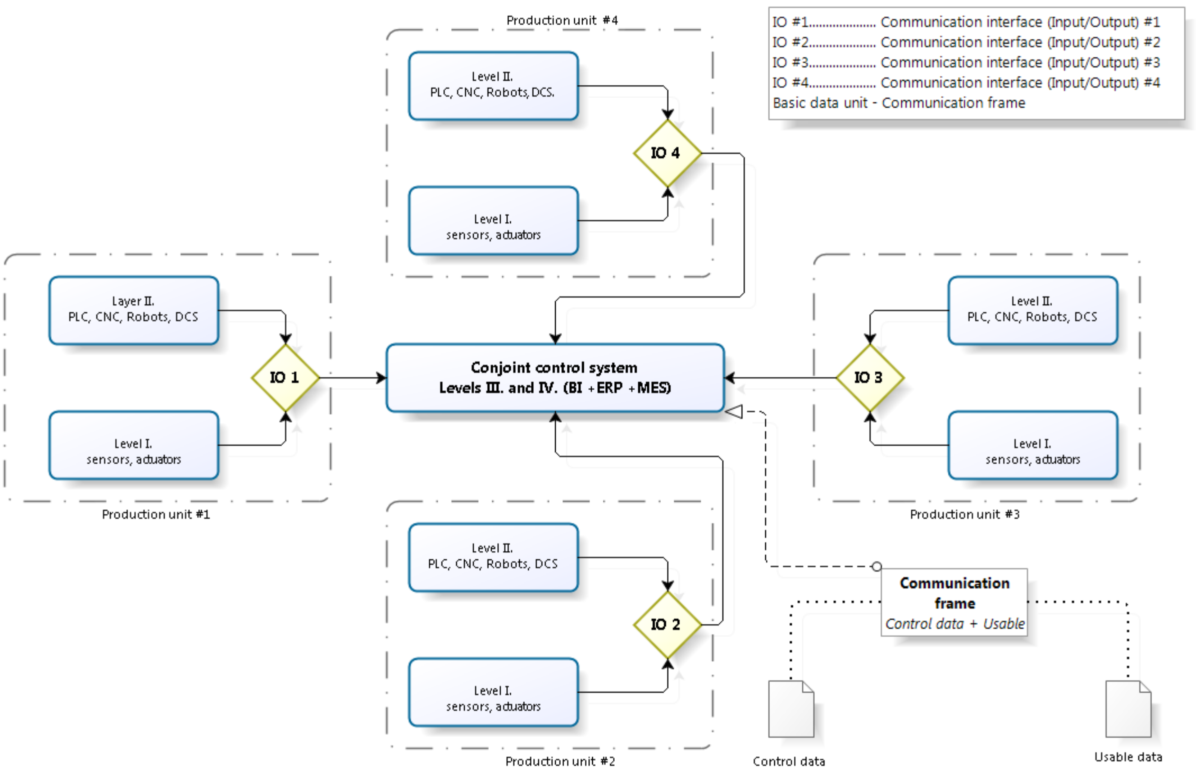

__Fig. 2__ Proposal of communication in a virtual enterprise

The advantage of this system is the possibility of implementing CPS together with devices that do not have the same basis. They do not even need to use a unified communication protocol and physical medium. The communication gates (I/O 1, 2,3,4.) are the system key elements. They provide data conversion. All communication in the CPS environment must only pass through IO gates. The I/O gate interface must be adapted to communicate in the given segment of industrial production.

In this model, communication is carried out so that objects in layers of Production units (PU #1,2,3,4) initiate data transfer through a communication gateway (I/O Gates #1,2,3,4). I/O Gates are pre-defined intelligent communication interfaces.

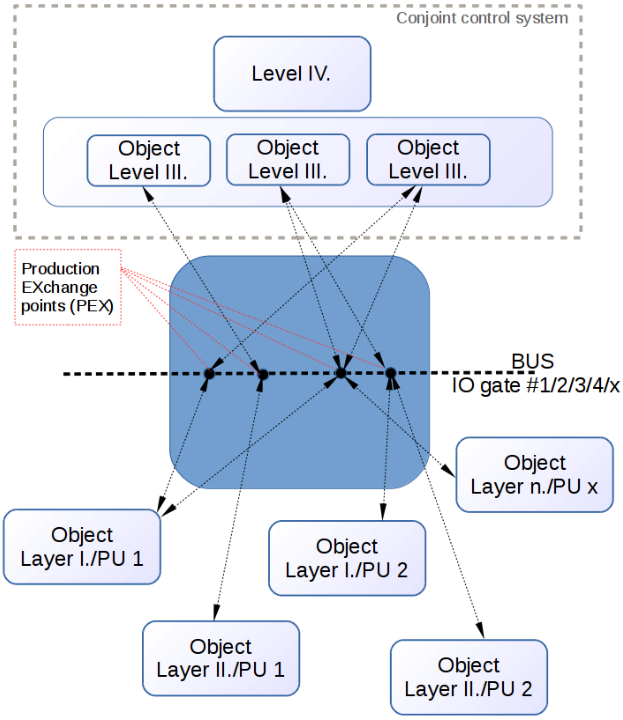

***Fig. 3** Communication of objects in IO gates*

In the presented model, data flows and interfaces are represented with the following objects:

- Production Unit #1,2,3,4 – in this model we assume four independent production units;
- Production Exchange Points (PEX) – are used to exchange and transform data between two objects;
- I/O # 1..4I. & II. – input/output gates with different communication interfaces, used to transform communications in the case of an incompatible device in the structure;
- Communication frame – data, consist of control data and useful data in the system;
- Production Units Levels - groups of the object on a given layer, which represent the level of individual elements in the production. They are corresponding to a classical model of the automation industry (Figure 3.).

Based on the control data from objects, Layer x/PU.x generates a request for an object belonging to another PU. However, that object is at the PEX point transformed into a format, which is able to communicate with a particular PU. Communication between two objects has to be done only through communication points (PEX) in a specified format. Communication can be secured by cryptography of a varying degree.

The I/O gates can be physically represented by one computer available from PU.x networks or it may be a set of cloud services in the Internet environment, which provides corresponding connectivity and defined transfer links.

CONCLUSION

The presented text makes it clear that the implementation of enterprises in accordance with Industry 4.0 standards in practice is a very complex process. The key to achieving a satisfactory state is mainly standardization. It means not only standardization of basic structural elements, but also standardization on higher levels, i.e. software, control systems and communication interfaces. The proposed communication model is usable as a universal scheme of communication in virtual enterprises.

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