Implementation of a RFID Technology-Based Automatic Traceability System for Industry 4.0

Rafael G. Vastag, Milena M. de Campos and Cesar da Costa

***Abstract*—One of the main problems encountered in production processes is data acquisition on the factory floor. With the increase in production complexity, the amount of data to be collected increases. Currently, data are collected both manually and automatically. The manual collection involves documentation in a folder and storing in a separate room. However, there are other types of data that are automatically recorded into an information system. The data are registered and processed in different systems, which depend on the production stage in which the data are collected. The evolution of wireless technologies, such as wireless local area networks, sensor networks, and radiofrequency identification (RFID) systems, has favored the creation of mobile services related to the computing aspect. Therefore, this paper presents a model of the implementation of an electronic identification system based on RFID technology, for application in automatic traceability of products in a didactic manufacturing cell installed in the programmable logic controller (PLC) network laboratory of the São Paulo Institute, Brazil.**

***Index Terms*—RFID, Internet of Things, Wireless, Traceability.**

I. Introduction

The Internet of Things (IoT) and Industry 4.0 have eliminated the need of an operator to be physically present in the production process. With this, quality management is a major factor in the implementation of these new technologies [1], [2], [3]. Radiofrequency identification (RFID) sensors allow a link to be established between a product and a tag, using an individual code that is connected to a database. This code enables linking other information to the product, such as possible failures in its production, color, and size [4], [5]. The control, which is often performed manually by filling in a control sheet, has proved to be flawed and liable to inconsistencies, as it is performed by a human. Thus, quality management through automatic retrieval of the product's manufacturing history is needed; this can be realized by tag-recording of information such as location, product identification, and occurrences [4], [6].

. While many manufacturer's use some sort of system to catalog their products, RFID makes managing products more efficient [7]. There are numerous ways RFID continues to work in sync with manufacturers including producing customized products, making cataloging more effective, and producing better results [8]. All the information from the production floor is managed, and there are some plants that can run entirely on the machines. Humans can devote more time to making sure the plant is running as it should, and errors can become a thing of the past. RFID features benefiting application [6]:

- Unique serial number identification;
- Ability to store and modify data;
- Write speed;
- Fast scanning, up to 300 tags per second;
- No line-of-sight required;
- On chip security;
- Kill command for privacy protection;
- Easy integration into products.

According to Glover [6], "RFID adoption is slow and continuous, and probably all companies seeking improvements in their manufacturing chain will somehow apply this technology in an effort to lower costs, achieve quality, traceability, and efficiency in both the manufacturing and distribution of their products."

Cuihua et al [9] present an efficient approach to job shop scheduling actively by using RFID to collect real-time manufacturing data. Identified the workpiece by RFID which needs to be machined, it can "ask for" the resource actively for the following process. With these active asking for strategies, a double genetically encoded improved genetic algorithm is proposed for achieving active job shop scheduling solution during the actual manufacturing process. A case was used to evaluate its effectiveness.

Ying Li et al [10] develop an Internet of Things System for Library Materials Management using RFID and Android based UHF mobile reader as its entry to increase the efficiency of library materials management. The functions of the Internet of Things System for Library Materials Management include user identification, inventorying, adding, refreshing, searching, and self-help borrowing & returning library materials

Therefore, this research is relevant because it aims to automate a didactic manufacturing cell, to realize the traceability of process data via an RFID sensor, programmable logic controller (PLC) network, and supervisory system. The culled data will be transferred in real time to the cloud for storage, allowing access to this data through different intelligent Internet-connected devices, thus establishing the concept of a factory of the future. The proposed system will consist of RFID tags connected in an industrial network to a PLC. A microcomputer system using the Ethernet communication network (TCP/IP), which is based on the OPC communication protocol, will manage the

Published on August 15, 2019.

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acquisition of data from the factory floor and stores them in the cloud.

II. BACKGROUND

A. RFID Technology

Radiofrequency identification is a technology that uses radiofrequency to transmit data between a portable device and a computer and allows the use of a remote mechanism, such as a mobile device or a satellite to track the products [4]. The use of RFID has been growing rapidly in recent years, especially after the emergence of the IoT concept, and several studies are being conducted to improve this technology.

The need to collect information in production environments has intensified the use of radiofrequency in production processes. According to Dobkin [4], systems that use RFID are among the main components in the context of the IoT and, as a result, this will provide greater scale and cost reduction. A complete RFID system is composed of tags, which are fixed on the product, an antenna that interrogates the tags through a radiofrequency link, and a controller (hardware/software) that interfaces with the computer and user [5]. An RFID system is illustrated in Fig. 1.

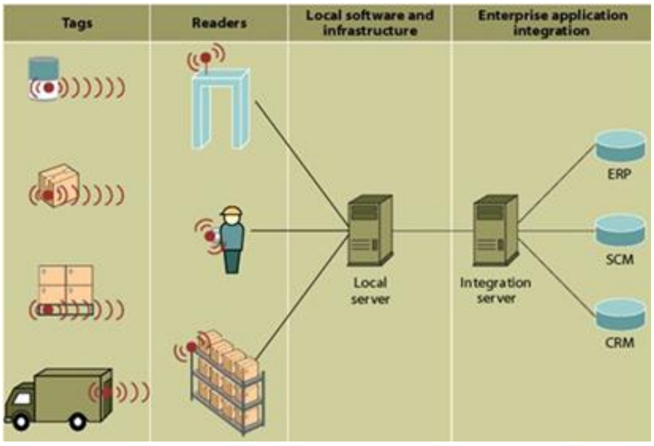

Fig. 1. RFID System.

The tags can be of different formats, sizes, and functionalities, depending on their applications. They are classified into two types: passive and active. The passive tags, which are the most used, differ from the active tags because the former does not need an energy source. Due to this feature, passive tags cost less than active tags. The tags can also be classified according to their forms of operation: reading and reading/writing [4], [5], [11]. When the tag passes through the coverage area of the antenna, the reader detects the magnetic field. The reader then decodes the data encoded in the tag, passing them to the human–machine interface (HMI) for processing. The frequency range (30 KHz to 500 KHz) operates for a short read distance, and the operating cost is low. Examples of an RFID tag and reader are presented in Figure 2.

Fig. 2. RFID Tag and Reader.

A common problem with RFID technology is readers collision and tags collision. Reader's collision occurs when the signals of two or more readers overlap. The tag is unable to simultaneously respond to two readers. The proposed system will be carefully and experimentally tuned to avoid this problem. Tags collision occurs when many tags are very close, but since the reading time is very small, routines will be implemented in the PLC software to ensure that the tags respond one at a time.

B. Traceability System

Traceability is defined as the ability to trace the production history of a product based on its serial number or batch number. Traceability allows one to establish a product history, and the complexity of the content of this history will depend on the goal to be achieved. With the attribution of the production data in the RFID sensor (tag), the product is made intelligent; it contains the pertinent information and can enable decision making according to the data recorded to its identification. Thus, the concept of Industry 4.0 (smart product), where the product itself contains the process data and occurrence history, is realized. According to Liu et al [12], information technology (PC) and process automation (PLC) are fundamental tools to ensure the reliability of traceability systems. A traceability system is illustrated in Fig. 3.

C. Internet of Things

The term IoT (Internet of Things) refers to physical and virtual objects connected to the Internet. It was developed at the Massachusetts Institute of Technology in 1999 by a group working in the area of identification by radio frequency. Since then, it has been improved by the emergence and widespread use of increasingly small and inexpensive sensors, as well as advancements in mobile devices, wireless communications, and cloud technologies. The IoT is also defined as the industrial internet, being a new technology in which global networks of machines and RFID sensors are capable of interacting with other networks [13, 14].

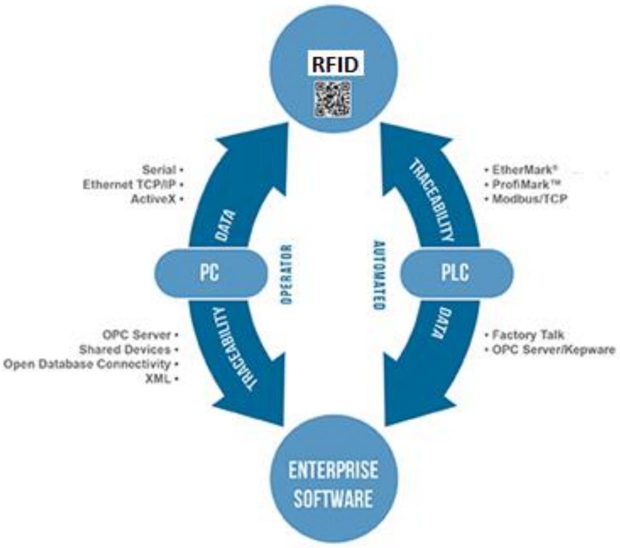

Fig. 3. Traceability Systems

The proposed system allows implementation of the data acquisition process of the RFID sensors via PLC and supervisory systems, storage of the obtained data in the cloud computing, and making them available to the related MES and ERP systems and various users via the Internet of Things (IoT). Figure 4 shows the proposed architecture.

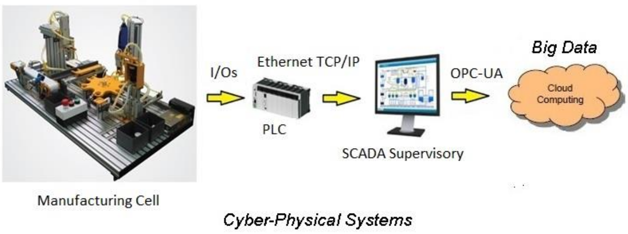

Fig. 4. Proposed Architecture

III. Experimental Procedure

The connectivity between shop floor automation devices (RFID) and management systems (IT level) is becoming an essential research and innovation concept, which is demonstrated in this work to make the Industry 4.0 paradigm an industrial reality. Figure 5 shows the manufacturing didactic mini cell used for experimentally testing the developed RFID system. The RFID system consists of (i) microcomputers, (ii) PLC, (iii) HMI, (iv) supervisory system, (v) RFID tags and readers, and (vi) switch/router.

Fig. 5. Manufactured didactic mini cell installed in the IFSP laboratory.

The proposed system was experimentally verified using a manufacturing didactic cell, model DLB CIM B, installed in block D of the PLC network laboratory of The Federal Institute of São Paulo (IFSP), Campus São Paulo, Brazil (Figure 5). A model of a traceability system was developed, which through RFID sensors, allowed creating a link between a product and a tag, through an individual code linked to a database. This code allowed the linking of other information of a product, such as possible faults in its production, color, and size. Relevant information such as product location, fault code, current stage of the production process, could be monitored and stored, allowing remote control over the process without the need for an operator to annotate such information. With the attribution of the production data in the product tag, the product is made intelligent; it contains the pertinent information and can enable decision making according to the data recorded to its identification. In the first phase of implementation, the production process was modeled and virtualized, considering, for future work, the application of artificial intelligence for automatic decision making.

IV. Methodology and Discussion

The main function of the implemented traceability system was to integrate computing (information technology), communication networks, PLC, RFID sensors, and physical processes, interacting and influencing each other. A HMI was developed, which enabled the connection between the RFID reader (responsible for reading and transmitting the tag value) and the supervisory system (a microcomputer). An algorithm was developed, which through the serial port (RS-232) of the HMI, linked the value read by the RFID sensor to a variable, which was incorporated into the supervisory system.

The SCADA supervisory system used in the traceability system allowed the information of the production process to be monitored and tracked. The OPC protocol was the industrial standard adopted for the interconnectivity of the manufacturing cell devices; this standard makes industrial applications that have different protocols exchange data, allowing their access by one or more computers that use a client/server architecture.

V. Conclusion

The automatic traceability system implemented in this work showed consistent results, through which it was possible to monitor by radiofrequency the location of a product in a manufacturing cell without human interference. In addition, the manufacturing cell trace data could be read, written, and stored in a database. A supervisory system was developed to monitor the manufacturing cell through the Elipse software (SCADA). The Ethernet TCP/IP industrial communication network was configured by connecting the PLC and RFID sensors to the system. The OPC protocol was used to acquire the system data (big data) and finally store them in the cloud, following the concepts of Industry 4.0.

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