IMPLEMENTATION OF IO-LINK TECHNOLOGY INTO THE HANDLING AND SORTING SUB-STATION OF THE FESTO FMS 500 AUTOMATED LINE

MAREK VAGAS[1], ROBERT RAKAY[1], JOZEF VARGA[2], JAROSLAV ROMANCIK[1], ONDREJ MAJERCAK[1]

[1]Technical University of Kosice, Faculty of Mechanical Engineering, Department of Mechatronics, Slovakia

[2]Technical University of Kosice, Faculty of Mechanical Engineering, Prototyping and Innovation Centre, Slovakia

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marek.vagas@tuke.sk

The article deals with implementing IO-LINK components in the sorting station of the FESTO FMS 500 automated line and their experimental verification based on the principles of IO-LINK technology. The implementation of such technology also includes the upgrade of the PLC control to PLC S7-1500 (SIEMENS), the addition of an IO-LINK device (BALLUFF BNI005H), and a signaling light device from the same company (SMARTLIGHT BNI007F), which ensures the indication of workplace state. Communication between the PLC device and the IO-LINK devices is carried out via the PROFINET communication network. Installing the signaling light device at the sorting station of the automated line provides light signaling messages for the operator (concerning the standard STN EN 61310-1). For example, the indication of the filling of the reserve warehouse using a light signaling message means the operator needs to empty the individual warehouses to repeat the sorting operation. In addition, part of the article is the implementation and evaluation of experimental measurements, the aim of which is to determine both the individual sorting times of various components, as well as determining their maximum number during the sorting process in connection with increasing the level of automation of the sorting station as such.

KEYWORDS

Automation Degree Increasing, PROFINET and IO-LINK Technology, Flexible Modular System

1 INTRODUCTION

The FESTO FMS 500 automated Line is naturally situated as a flexible modular system from FESTO Didactic and represents laboratory equipment intended for teaching mechatronics and automation. A significant advantage of such a line is its modular principle [Hajduk 2018]. The line is composed of four workstations, where each is composed of separate, fully functional sub-stations (1. Distribution and testing sub-station, 2. Handling and processing sub-station, 3. Assembly sub-station with the industrial robot, *4. Handling and sorting sub-station*, 5. Conveyor sub-station). Their positions are located around the belt conveyor. The conveyor creates a closed circuit and is the center of this automated line, and parts are transported between individual workstations using it.

However, the subject research is only one part, namely at the handling and sorting sub-station (Figure 1).

As is evident from the term (handling and sorting sub-station), its work activity is the realization of the sorting process of three different products: red, black, and silver (metal). These products are located directly on the part of this station in the appropriate storage capacities. The control was initially provided by two S7-300 PLCs (SIEMENS), whose performance based on the CPU was significantly lower than the current PLCs. Communication between the PLC, educational stations, and PCs was achieved via PROFIBUS communication [Vagas 2022].

The station itself consists of two parts: the handling and sorting parts. This handling and sorting sub-station are the last stop in the automated line. Both parts (handling and sorting) are dimensionally identical and built on the same principles. The individual sub-parts contain their source with DC-24V output voltage and PLC system. The sorting part of this sub-station is used to place products in three warehouses, according to the type and color. The handling part of the sub-station removes the product placed on the transport cart of the conveyor belt. After the product is grasped by the effector installed on the sliding crane by the PicAlfa module, it is transferred to the belt conveyor for sorting into the appropriate station place. It also includes a reserve warehouse, which will temporarily store products, regardless of the type or color, if the two primary warehouses in the sorting section are full [Kubr 2021].

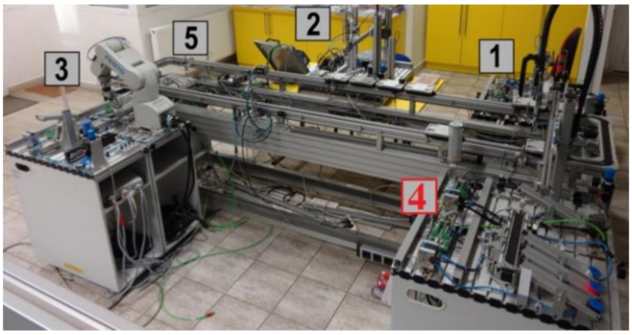

Figure 1. Location of the handling and sorting sub-station at FESTO FMS 500 automated line

If the reserve warehouse is full, the operation is terminated, and the storage process can only be started after the individual warehouses have been emptied. The station's handling and sorting parts differ by using a different layout of electronic and structural elements fixed on the assembly table since different operational tasks are performed on them. Combining both educational parts, we get a complete part of the line = handling and sorting sub-station FESTO FMS 500. The controlled products are the pneumatic pistons (Figure 2), assembled, checked, and stored on an automated line. These pistons have a triple design: black, red, and chrome (metal). All pistons have the same diameter, but their height is different. They comprise four parts: spring, piston, body, and piston cap. The process and individual steps of managing the handling and sorting sub-station start from the actual grasping of the material from the conveyor belt of the line through the recognition of the type of material to its classification in the corresponding warehouse [Juhas 2012].

This activity is ensured by a programmable logic controller (PLC S7-1500) based on the information obtained from the built-in sensors, which detect the required and specific quantities. A decision-making process occurs based on evaluating these measured values [Vagas 2013]. The topology of the communication network is set on the PROFINET bus, which connects devices and modules for process control and processes in general in general [Gulan 2017].

We use it for both parts of the sub-station to communicate information between PLC S7-1500 PC devices and IO-LINK devices.

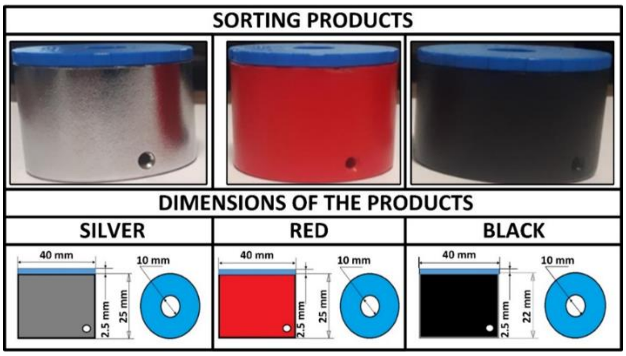

Figure 2. Sorting products and their dimensions

The PROFINET interface allows uploading a program created on a PC directly to the S7-1500 PLC device. In addition, it is mainly intended for the automation of discrete systems, is a replacement for the communication bus type PROFIBUS, and communicates in real-time [Modrak 2002, Kelemen 2021].

2 METHODOLOGY OF IO-LINK IMPLEMENTATION

The proposed approach for implementing the IO-LINK technology and installing all supported devices (SMART LIGHT, IO-LINK device, PLC S7-1500, etc.) presupposes initial recovery according to a predetermined procedure. It depends on the configuration settings of the individual devices, the software implementation (SIEMENS TIA PORTAL), and the process itself, which takes place in the mentioned place [Ostertag 2014]. In this case, we can say that implementing successive (consecutive) steps can achieve the desired idea of introducing IO-LINK technology. Therefore, we assume the following steps:

A. *Installation of the necessary devices into the handling and sorting sub-station*. This step requires the transfer of correct knowledge (both practical and theoretical) from the introduction of similar devices to existing (same-oriented) automated assembly.

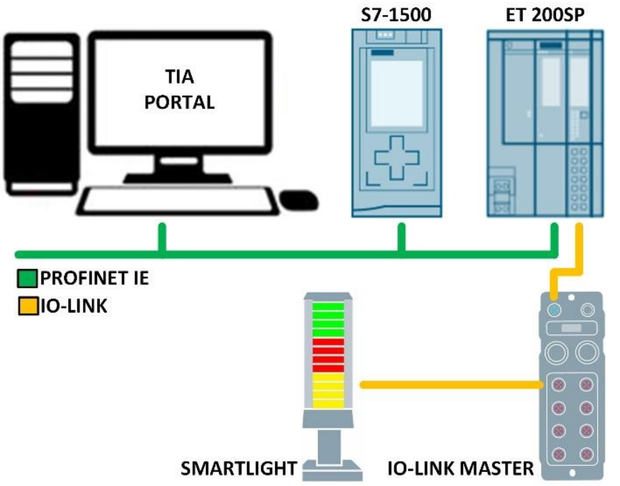

Figure 3. Communication topology based on the PROFINET and IO-LINK

In our case, the prerequisite for successfully implementing this step is to find a suitable layout space so that it does not interfere with the operator and, simultaneously, it is simple to implement the structure (supports, etc.). Part of this step is implementing the connection of these devices, not only physically (cable, power supply), but mainly software.

It means configuration, basic diagnostics, and testing these devices through the software TIA PORTAL, Figure 3.

B. Address the connected devices using the PROFINET approach. It includes setting their IP addresses to ensure network communication via the PROFINET communication protocol. The step is implemented - through the TIA PORTAL software. The address concerns the PLC device (SIEMENS S7-1500), the IO-LINK device (BALLUFF MASTER - BNI005H), the signaling device (SMARTLIGHT BNI007F, also from BALLUFF), and the expansion module (SIEMENS ET 200SP).

C. Creation of the control program. Among the programming languages that TIA PORTAL offers us, the programming environment in the LAD language was used, in which the control program was created. We realize the logic of the program via the programming block "MAIN" by the function block, which was developed through the function "ADD NEW BLOCK".
Part of this step is the solution and design of the sorting sub-station's initial (initialization) state. It is necessary to ensure all actuators are in their initial positions without active errors [Tlach 2017, Kelemenova 2020]. After this condition is met, the program checks the filling of the reserve warehouse of parts so that, in the event of its filling, the entire process at the sorting station stops. Further activity is subject to manual intervention by the operator so that the warehouses are emptied.

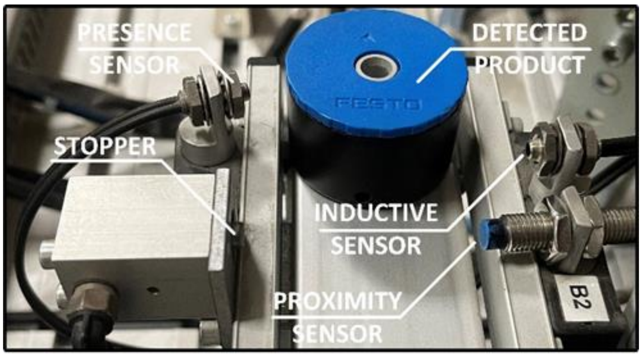

Figure 4. Layout of the sensors at the handling and sorting sub-station

A part of the control program handles the sorting status of the products that arrive on the transport carts. We use an optical and inductive sensor directly from the conveyor belt (at the handling and sorting sub-station) to distinguish between red, black, and silver (metal) parts [Oravcova 2013]. The optical sensor detects the red and silver parts. The inductive sensor detects the silver part, Figure 4.

3 EXPERIMENTAL VERIFICATION AND TESTING OF THE PROPOSED APPROACH

The emphasis on testing and overall verification of the abovementioned approach is based on using innovative IO-LINK devices, high-performance PLC, and communication-based on PROFINET. Individual devices enable self-diagnosis and self-reconfiguration during the running process at the sorting sub-station [Sobaszek 2018]. This results in ease of Installation, predictive maintenance, and, thus, more efficient operation of the entire FESTO FMS 500 automated system [Dado 2016]. The course of verification and testing was divided into the following four stages:

A. Stage. Testing the functionality of the IO-LINK device (BALLUFF - SMARTLIGHT) for individual states at the sorting sub-station, Figure 5. Based on the running process of the automated line, individual states were selected (1. filled main warehouse, 2.

filled reserve warehouse, 3. standard operation - sorting operation, 4. idle state - operator intervention required). We can monitor the resulting states by configuring individual segments of the IO-LINK device via output addresses ("WATCH" table). The SMARTLIGHT output address starts from address Q82.0, representing the first bit of the SMARTLIGHT LED [Sincak 2021]. Individual address bits have a defined LED color at the output in the sequential order of GRB (GREEN, RED, BLUE) and flashing. The color designation is G - green, R - red, B - blue, and BL - flashing.

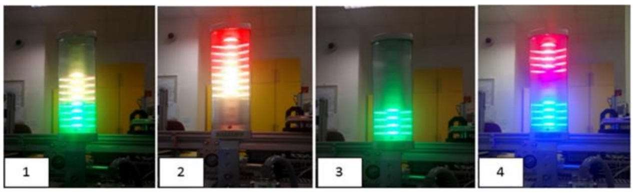

Figure 5. IO-LINK device functionality testing

In the first case (state 1), the main warehouse is full of products. We provide the information with the output address QW82 = 45.057. In practice, this means that the third segment of the IO-LINK device is constantly lit in green, and at the same time, the second segment flashes a yellow warning light. The device tries to alert the surroundings (operators) that the automated operation will soon be stopped [Galajdova 2021].

The case, or state 2, occurs if intervention in the running process does not happen or he will be late. In this case, the reserve warehouse will also start to be filled with products, which is ensured by the output address QW82 = 14848. The visual state is that the second segment starts flashing orange light, and the first segment is permanently lit in red. In such a case, manual operator intervention will soon be required. In the third case, we tested the standard operation at the sorting sub-station, visualized by a permanent green light and setting the output address QW82 = 1. In the last case, we simulate a fault at the output address QW82 = 524 and visually warn of the fault condition. The process stops and waits for an external intervention (the third segment flashes blue, and the first segment lights up permanently in red warning color).

B. Stage. We are measuring the time to fill the reserve warehouse with products. The measurement methodology was based on the sorting of components in random order. These products come from a transport cart, so the time to fill the warehouse may vary. The measurement was performed 20 times with a classic stopwatch, starting after filling the primary storage and stopping after filling the reserve storage. It documents the obtained results in graphic form, Figure 6. The average time is 29.1 s.

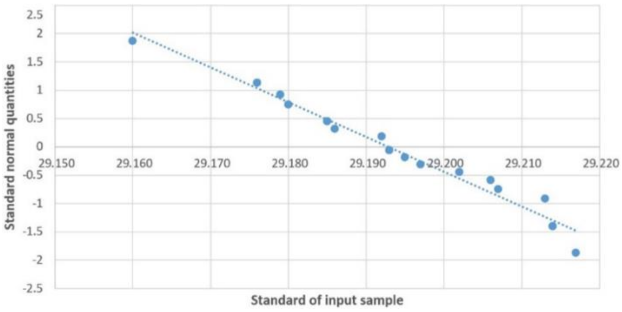

Figure 6. Measuring the time of filling the reserve warehouse with products

The measurement was evaluated by statistical analysis (normality testing). We used a graphical normality test, the quantile-quantile plot (Q-Q plot), to verify normality [Kascak 2022]. If the obtained data is from a normal distribution, the points lie on a straight line, which is approximately fulfilled in our case.

C. Stage. We measure the sorting time of ten randomly consecutive parts. This measurement aimed to determine the average time for sorting the specified number of products into the warehouse part of the sorting sub-station, Figure 7.

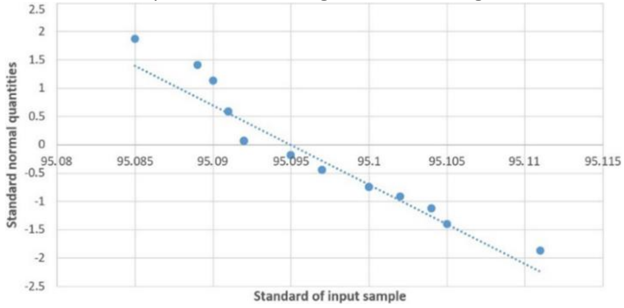

Figure 7. Measuring the sorting time of ten randomly consecutive products

We realized the measurement 20 times with a classic stopwatch, starting after the part was grabbed by the manipulator and stopping after the warehouse was filled with the last (tenth) product. We document the obtained results in graphic form. From the following, it can be deduced that the measured values of the sorting time of ten consecutive random components differ slightly during repeated measurements. We can more accurately determine the average classification of ten parts into their assigned warehouses in an average time (95 s).

D. Stage. We measured the sorting time of the black, red, and silver products. We wanted to determine the average time to sort the red, black, and silver products into the respective warehouses by measuring. The measurement began with the manipulator grasping the product to interrupt the optical sensor by the product located on the sorting sub-station.

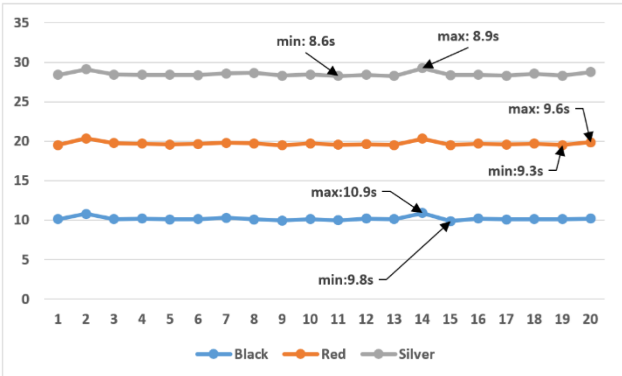

Figure 8. Measuring the sorting time of the black, red, and silver products

The individual components were measured 20 times in a row, after which we found the average times sorting the red, black, and silver components into their warehouses from the subtracted measured values, Figure 8.

4 CONCLUSIONS

By implementing IO-LINK devices, we wanted to verify and innovate the existing process of sorting products at the handling and sorting sub-station at the FESTO FMS 500 automated line. Through measurements and experiments, we state that the workplace gained additional possibilities for monitoring and managing the running process thanks to the addition of newer devices (IO-LINK, PLC S7-1500, and others). On the one hand, workplace status signalling was added, but in the end, we got a few free I/O ports. With their help, we can expand the existing workplace, e.g., a special reserve warehouse, as currently there are four warehouses of the same (capacity) size available at the handling and sorting sub-station (two of them serve as a reserve). In this way, we can expand the storage capacity of products. In addition, adding IO-LINK devices (sensors) gives us a more advanced (qualitatively deeper) status check at the handling and sorting sub-station and the entire automated line. We have achieved informative sorting times for individual parts through the measurements, which can be further processed concerning running processes and their synchronization.

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CONTACTS:

Marek Vagas, Assoc. Prof. Ing. PhD.
Technical University of Kosice
Faculty of Mechanical Engineering
Department of Industrial Automation and Mechatronics
Park Komenskeho 8, 042 01 Kosice, Slovak Republic
marek.vagas@tuke.sk