AN INDUSTRIAL AUTOMATION ARCHITECTURE FOR A DEBURRING CELL WITH ROTARY INDEXING TABLE

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This paper presents the design and implementation of an industrial automated equipment used for deburring parts produced for the automotive industry. The system contains a rotary table with several machining stations in a PLC-controlled environment. The proposal consists of electrical design and the development of a logical control that coordinates the indexing, deburring, marking and verification operations. Process monitoring and traceability of parts are carried out with the help of sensors and code verification assisted by a code reader equipment. The proposed solution allows for space optimization, repeatability, accuracy and increased productivity through reduced cycle times.

Keywords: automation, deburring, indexing, control, verification, automotive

1. Introduction

The automotive industry is characterized by high production volumes and increasing requirements for quality, repeatability and traceability of processes. Thus, operations such as deburring of parts are important in ensuring dimensional conformity and overall product quality prior to assembly. The automation of these types of operations has become often adopted to simplify processes, limit dependency on the operator and improve consistency in series production environments [1], [2].

For the implementation of automated cells that integrate several processing and verification stations, an automation concept is needed, capable of coordinating mechanical movement, technological operations and decision-making logic. The Weiss rotary indexing table is used in automotive applications, as they allow the integration of sequential operations into compact and synchronized system arrangements [3].

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The development of such automated systems is based on the combined use of programmable control platforms and integrated engineering environments. PLC automation platforms enable the execution of sequential control logic, interlock conditions and operator interaction, while integrated automation portals for PLC and HMI software development [4] enable programming, configuration and commissioning of control systems. Dedicated electrical design environments [5] are used to develop detailed connection diagrams and technical documentation in accordance with international standards. Thus, the connection between the electrical architecture and the implemented control logic is ensured.

To ensure the traceability of components, automotive production systems are increasingly using automated identification and marking solutions, thus meeting the requirements of quality assurance and production control [6].

This paper presents the design and implementation of an industrial automation equipment used for an automotive deburring cell on a rotary indexing table (Fig. 1). The discussion is focused on electrical and control architecture by implementing PLC sequential logic and integrating operator interaction through an HMI interface. To highlight the process of automation and functional coordination of the system, the mechanical design aspects are not detailed.

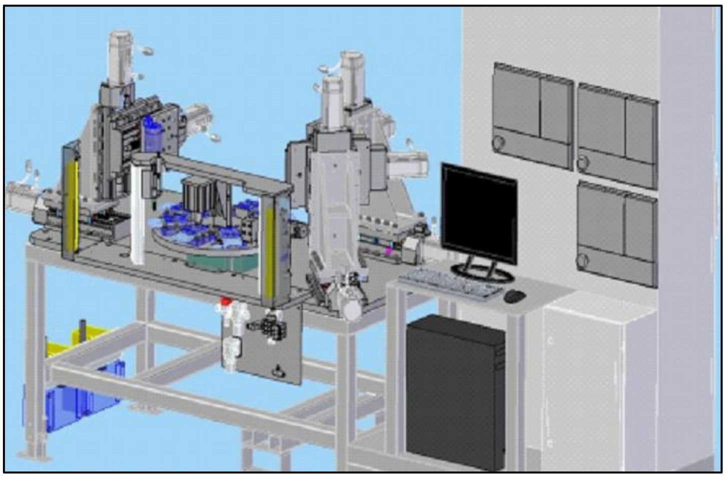

Fig. 1. Conceptual layout of the automated deburring cell

2. Overview of deburring cell

The automatic deburring cell is designed as a production system dedicated to the repetitive processing of automotive components in a controlled industrial environment. According to the classification criteria of industrial automation systems [7], this solution is identified as fixed or specific automation, characterized by a predefined process sequence, sequential transfer of parts and fixed roles for each station. The rotary indexing table is the central element of the cell and provides mechanical support for the positioning of parts and their controlled transfer between stations. This allows the integration of several processing and verification functions into a compact and synchronized system.

The deburring and verification process follows a logic whereby the rotational movement of the indexing table is conditioned by the completion of the actions at the station level and the imposed verification conditions. This establishes a controlled flow of parts within the cell, their correct positioning and the integration of decision points to distinguish OK from NOK components. The deburring and verification process aligns with the design principles of industrial automation systems, which prioritize functional separation and clear dependencies between processes [8].

At the system level, the cell represents an integrated assembly of mechanical units, electrical equipment, actuators, sensors and control elements. The operating diagram of this system is shown in Fig. 2.

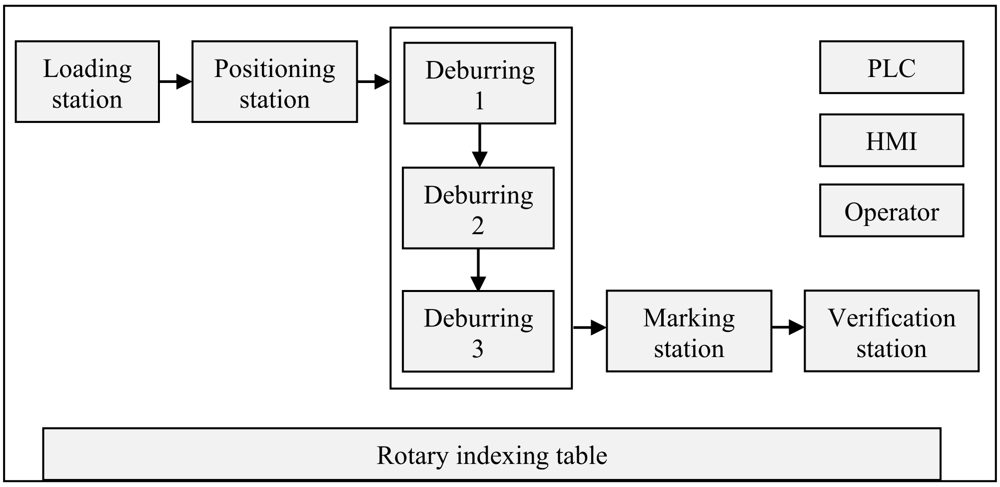

Fig. 2. Functional diagram of the automated deburring cell

As mentioned before, this paper does not cover aspects of the mechanical design and manufacture of components integrated into the deburring system. However, a 3D representation was created to provide an overview of the machine as well as the layout of the machining and parts testing stations (Fig. 3). Although the configuration identifies 7 processing and checking stations, position 4 was created to give more space to deburring stations 1 and 2, resulting in a total of 8 workstations. In this way, the rotary indexing movements are equal.

3. System hardware design

The automated deburring cell is based on centralized control where a PLC coordinates the overall process flow, while secondary drive systems such as numerical controls equipment (CNC) manage the movements and processing functions at the station level. All of this follows the principles of PLC-based industrial automation [9], where a single control unit coordinates multiple subsystems to achieve predictable and repeated process executions [10], [11]. The PLC used, SIMATIC S7-1200, CPU model 1214C (6ES7214–1AG40–0XB0), executes the main logic of sequencing, interlocking and synchronization of the stations [12]. To support the required number of signals in the system, the integrated input and output resources of this CPU are expanded with three input and output modules (6ES7223–1BL32–0XB0). This creates a structure consisting of sensors, actuators and auxiliary control elements distributed throughout the system [13].

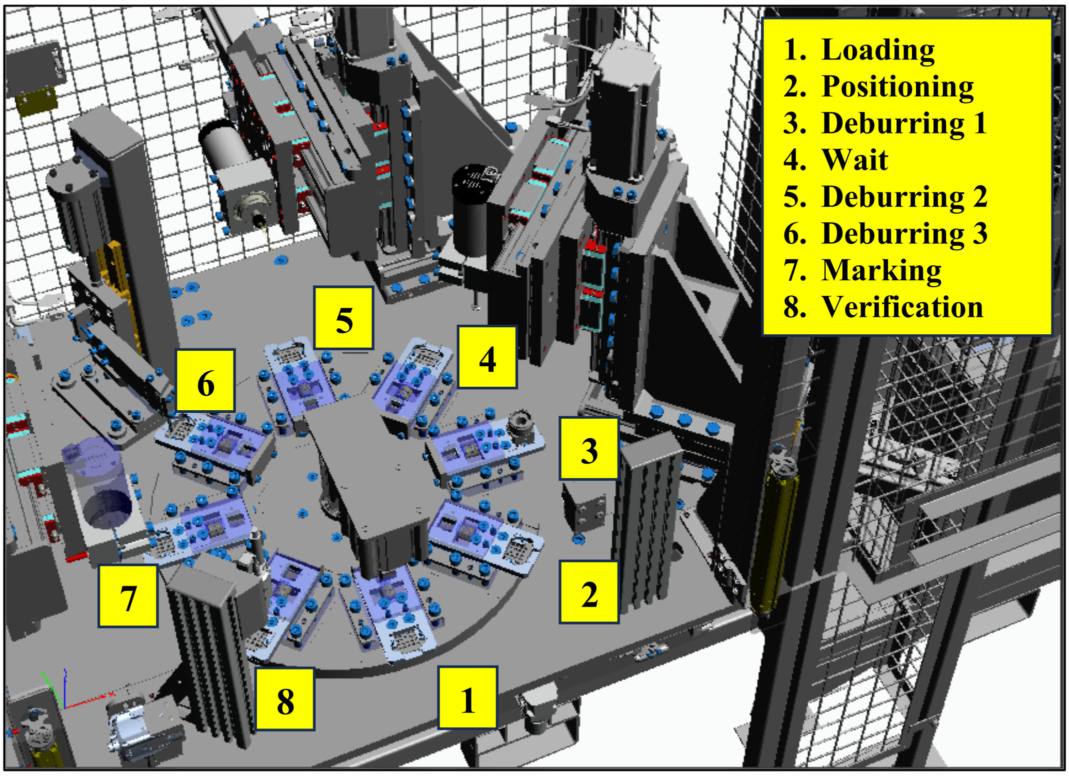

Fig. 3. 3D layout of the rotary indexing table and functional stations

The operator can monitor and interact with the system through a human-machine interface (HMI), model 6AV2124–1GC01–0AX0 [14]. This allows access to operating modes, cycle initiation and diagnostic information, while ensuring that all operator commands are processed by the PLC's control logic. The cyclic movements of the parts inside the deburring system are ensured by a rotary indexing mechanism driven by an electric motor controlled by a DELTA VFD037EL43A variable frequency drive (VFD). It controls the rotational speed and torque of the associated motor [15].

Deburring operations are performed at three dedicated workstations, each equipped with independent multi-axis positioning systems and machining axes. The positioning axes (X, Y and Z) of each deburring station are driven by ECMA–C20807RS servo motors [16]. The control of the main axes driving the deburring tools is provided by three OMRON KCC–REM–OMR–3G3MX2–AB007–E VFDs, ensuring stable operation of the main axis during material removal [17].

For the execution of machining and axis management programs, each deburring station is coordinated by a TM528A CNC controller. The only role of the PLC in this case is to decide when the parts are ready for machining.

Automation implements a sequence of dependent operations. Before the deburring steps are carried out, the correct positioning of the workpiece on the rotary table is checked. The deburring process continues with three consecutive deburring stages, treated as a single logical group. Only after the successful completion of all deburring steps can the system move on to marking operation (Fig. 2). The applied code is then verified using an image inspection system, implemented with a Keyence SR1000 reader. It confirms the accuracy and legibility of the marking without assessing the quality of the deburring process [18].

4. Electrical diagram

This section focuses on electrical architecture and wiring documentation. The wiring diagrams are created in an electrical engineering environment (Eplan Electric) and describe the organization of the control and power circuits, as well as the interfaces between PLCs, VFDs and peripheral devices. The diagrams presented form the basis for commissioning, troubleshooting and long-term maintenance of the deburring system.

Fig. 4 shows the main power supply and distribution scheme for the deburring cell. It is powered by a three-phase 400V/ 50Hz (*L1, L2, L3, N, PE*) power supply, routed through a three-phase + neutral 100A/ 500V distribution block, which provides distribution to the main power supply circuits. Upstream protection is done by means of a three-pole switch, followed by dedicated protection devices for the auxiliary branches. The diagram includes 230V AC auxiliary sockets, a 230V indicator light circuit, and dedicated power points for local subsystems, such as a cooling unit and connection cabinet interfaces.

Using the parameters showed in Fig. 5, the *11CV1* variable frequency drive of the indexing rotary table powers the *11M1 motor* (*AZKA 56L–T4 B14P78*). The control unit interface is connected to the PLC by activation and control signals, including *Q14.0* (COMANDA INAINTE/ STOP MOTOR MASA WEISS) and *Q14.1* (COMANDA INAPOI/ STOP MOTOR MASA WEISS).

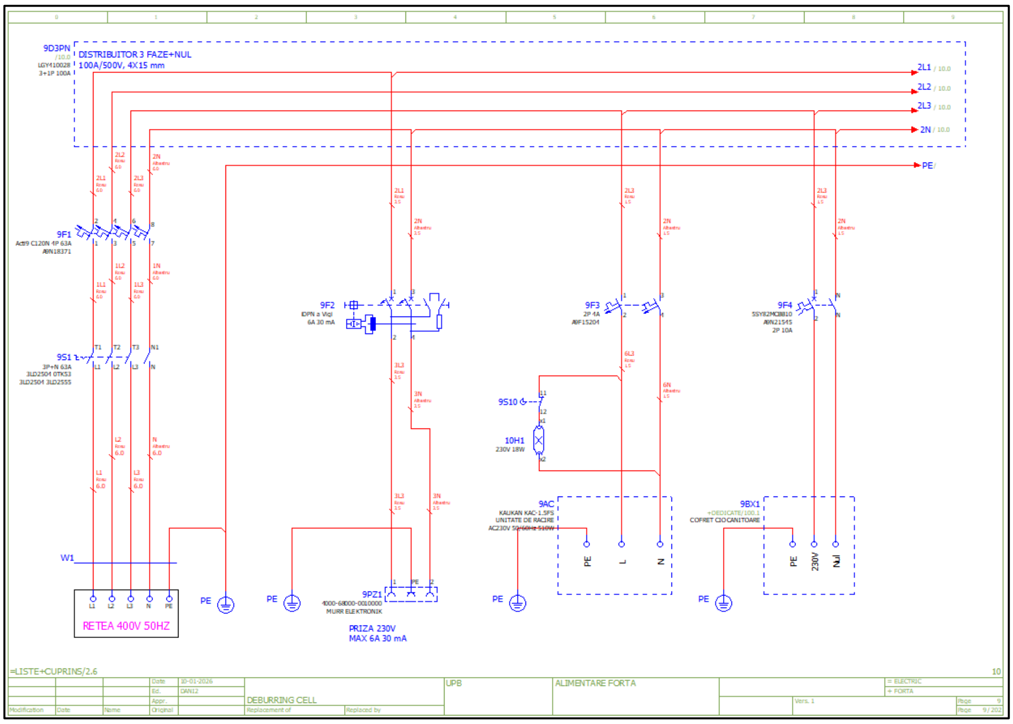

Fig. 4. Main AC power supply distribution and protection diagram

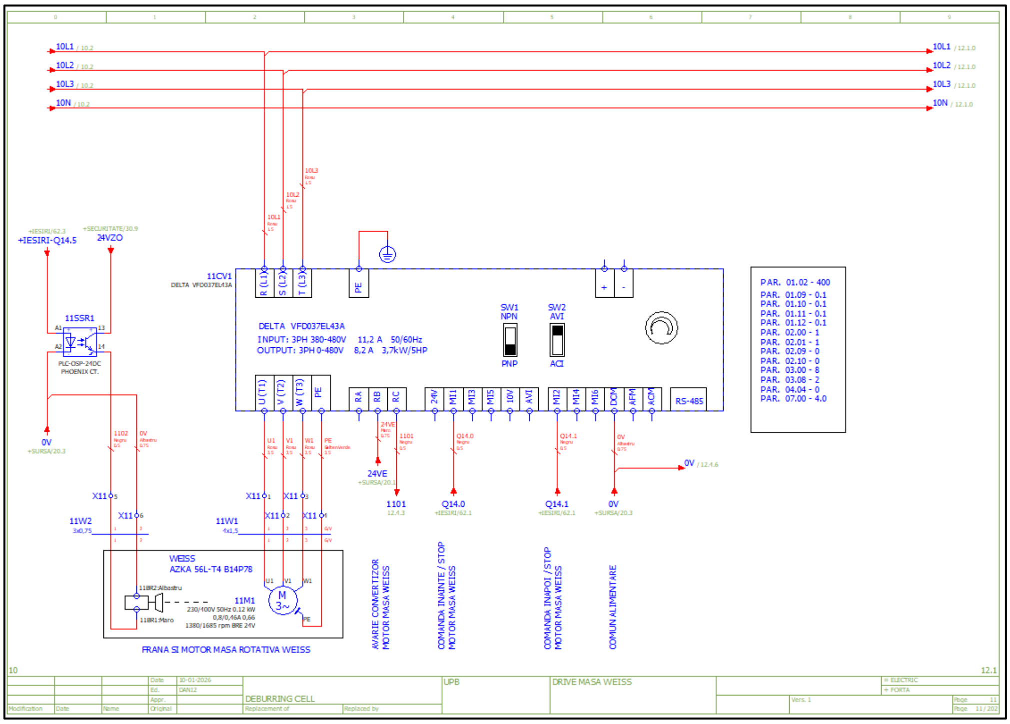

Fig. 5. Rotary indexing table drive and motor

Fig. 6 shows the 24V DC *20SG1* central power supply unit that generates the control voltage and distributes it via individually protected circuits. Protection of the DC power branches is provided by the *20F2, 20F3, 20F4* and *20F5* devices that allow selective isolation of loads. The diagram also includes the *20H1* voltage presence indicator for local confirmation of DC power supply availability. *X20.1... X20.21* output terminals provides power to control groups, including PLC and HMI.

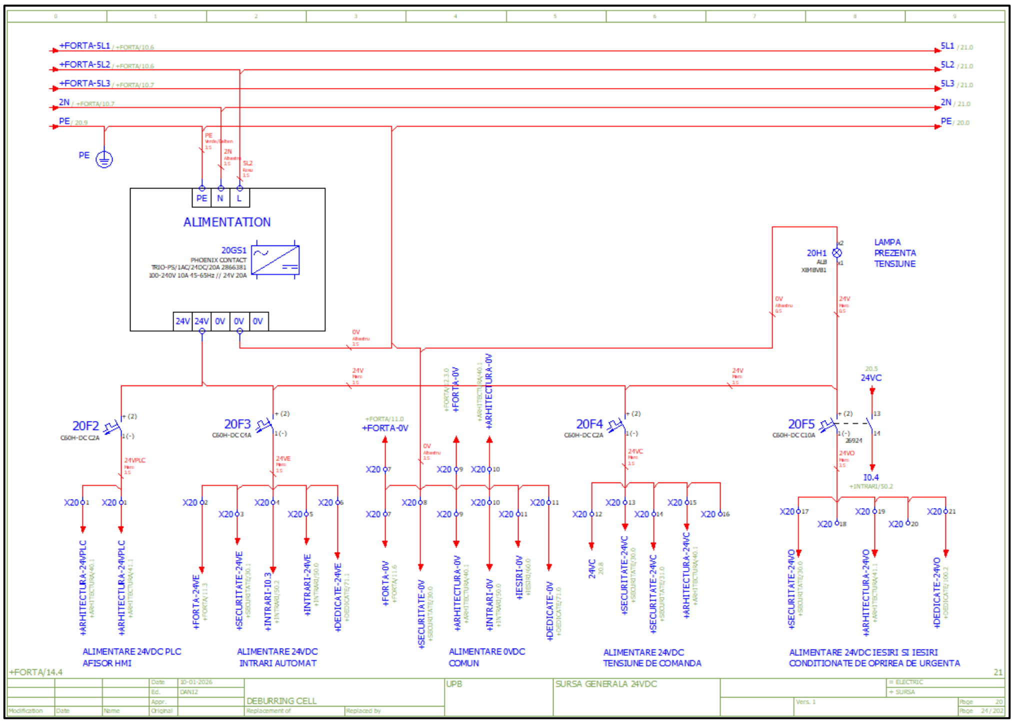

Fig. 6. 24V DC power supply with protected branch distribution

The emergency shutdown subsystem (Fig. 7) is based on the *30KAU* (*XPSAF5130P*) safety relay, which ensures the operation of the system only when the safety conditions are met. In the event of an emergency shutdown, the *30KAU* relay cuts off the power supply to the control circuits, putting the system in a safe state. The circuit also includes the auxiliary interface relays *30K1* and *30K2* which provide a doubling of the safety so that, if the contacts supplying the downstream loads with 24V DC will be locked in the CLOSED position, the circuit S31 – S39 of the *30KAU* relay will open causing its interruption action. At the same time, these two relays also interrupt the power supply to the *30EV1* general compressed air solenoid valve used by the cell.

The integration and wiring of the optical protection device (Fig. 8) is carried out using the *31KBO* safety unit (Keyence GL-T11R).

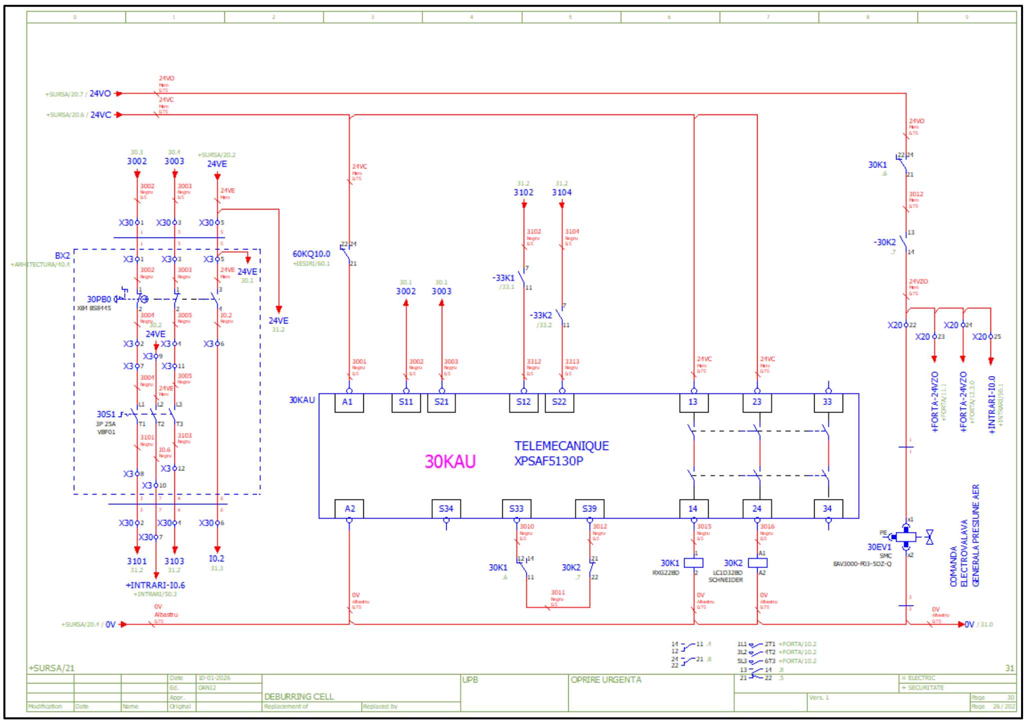

Fig. 7. Emergency stop safety relay circuit and safety controlled outputs

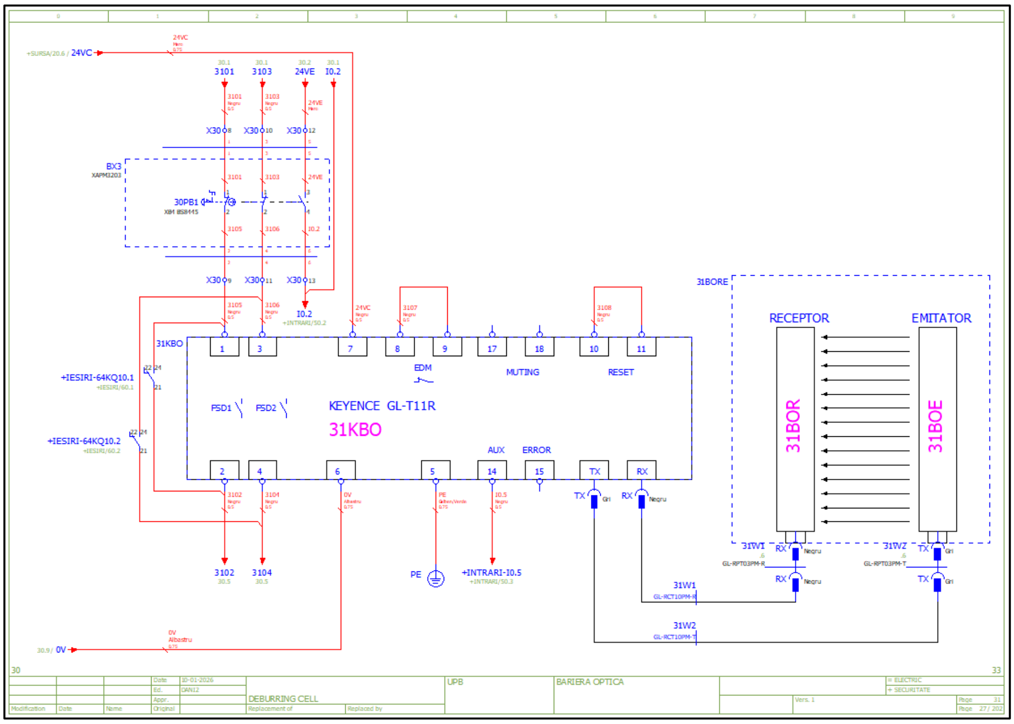

Fig. 8. Safety optic curtain integration

The protection field is generated by the transmitter/receiver pair *31BOE* and *31BOR,* connected by the interconnection wiring harnesses (*31W1/ 31W2*). The security outputs (*OSSD*) of the *31KBO* are routed to the security chain, while auxiliary functions such as *EDM* and *RESET* are unused. Configuration provides controlled access protection, allowing the machine to operate only when the status of the optical protection device is valid.

Fig. 9 illustrates the architecture of the control network that connects the *40CPU* PLC to the *40SM1*, *40SM2* and *40SM3* input and output modules, the *40HMI1* operator panel and the *40SR1000* code checker.

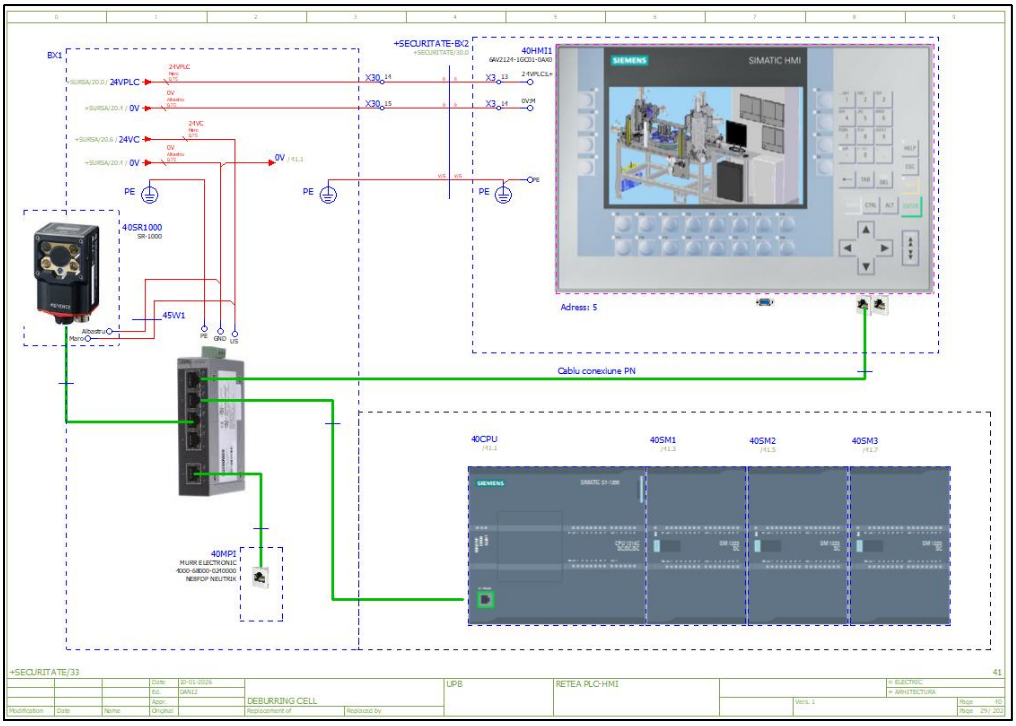

Fig. 9. PLC – HMI – SR1000 system diagram architecture

5. Software architecture and control strategy

This section introduces the software architecture and control of the automatic deburring cell. The program with which the PLC will run is implemented using the Tia Portal V15.1 platform [19]. The interface with the operator is provided by the KP700 Comfort HMI (Fig. 10). The program is structured in functional blocks dedicated to the coordination of subsystems and diagnostic services. This organization allows for a separation between sequential control and device interface, improves maintenance, and simplifies commissioning. Thus, the *OB1* (*Main*) block coordinates the cyclical evaluation of commands, feedback signals and interlock conditions, and the *FB12* block (*Gestiune Ciclu*) manages the logic transition between the phases of positioning, deburring, marking and verification of the written code.

In the implemented strategy, the sequence of the cycle depends exclusively on the verified conditions and not on time constraints. The positioning phase includes a confirmation stage that ensures the correct placement of the part before machining operations begin. Each deburring step is activated only after the previous one has been validated. The logic control maintains this dependency until all steps have been validated, thus preventing the premature start of the marking operation.

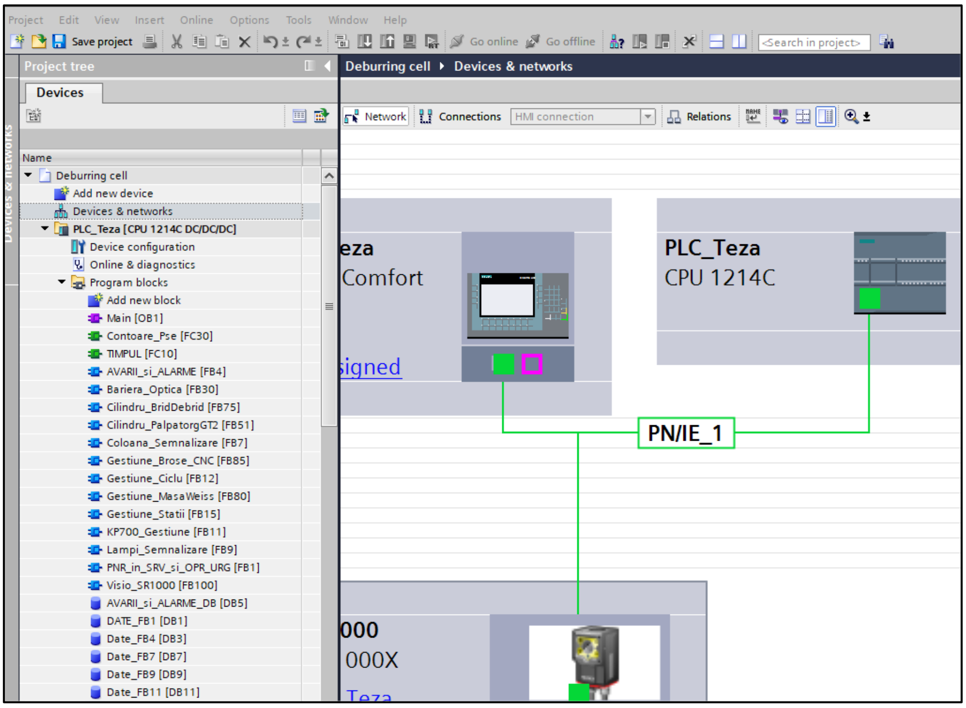

Fig. 10. PLC – HMI – SR1000 system software architecture

The rotary indexing table is managed by the *FB80* block (*Gestiune_MasaWeiss*) where the software executes the indexing command and monitors the corresponding feedback, confirming the positioning of the part. The *FB12* (*Gestiune_Ciclu*) block uses this information to synchronize table movements with workstation operations and verification. Errors related to the indexing execution, such as exceeding the set rotation time, are treated as monitored failures and recorded on the dedicated HMI page. This allows the cycle to be interrupted and resumed in a controlled manner.

After deburring, the part marking stage with the code DATA MATRIX begins. The process continues with the verification of the marking via the *FB100* block (*Visio_SR1000*). At this stage, the system issues a trigger command to the reader and evaluates the response received. The affirmative answer of reading the mark concludes the cycle of deburring, marking and checking the workpiece. Operator supervision is provided by the *FB11* block (*KP700_Gestiune*) which allows order management, operation mode and alarm visualization.

6. Human Machine Interface design

The HMI interface of the deburring cell is implemented with the same Tia Portal V15.1 platform [19] and allows the integration of pages for monitoring, counters, manual control, automated configuration verification and alarms.

The *HOME page* (Fig. 11) provides an overview of the deburring cell. Two main counters are displayed here: the total marked and scanned parts counter (conforming parts) and the total marked parts counter (non-conforming parts). At the same time, the buttons of the pages containing information and commands of the deburring cell are identified. The buttons from *F17* to *F24* are reserve.

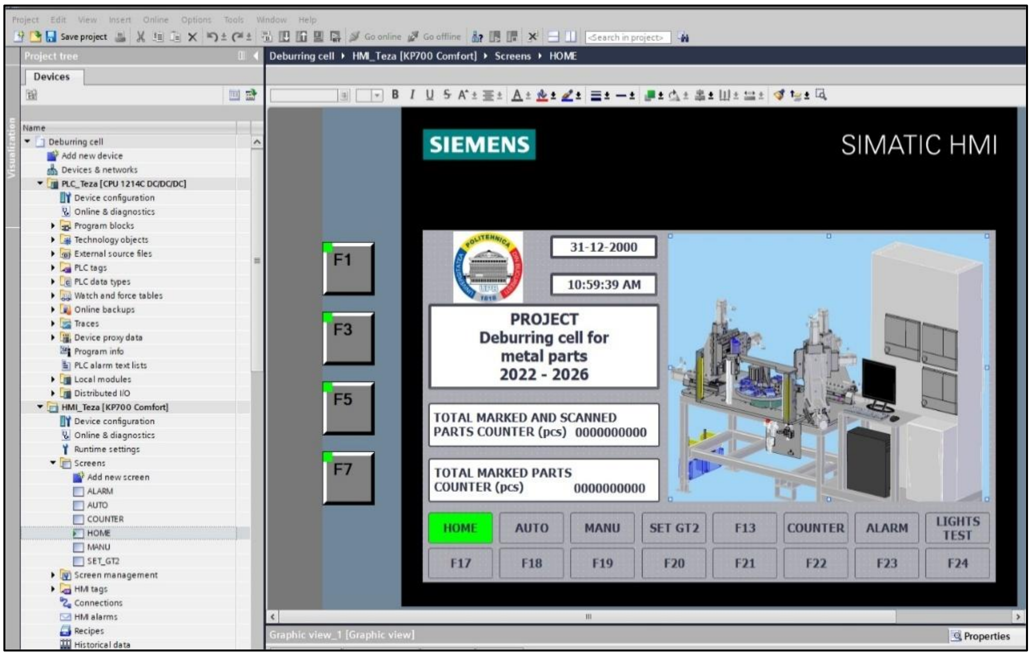

Fig. 11. Home screen – system overview of the main buttons and fields

The COUNTER page consolidates the quantitative production data required for traceability and reporting, separating the number of parts produced on the work shift from the total number of parts (Fig. 12). At the same time, data on the total number of completed cycles of the indexing table are provided.

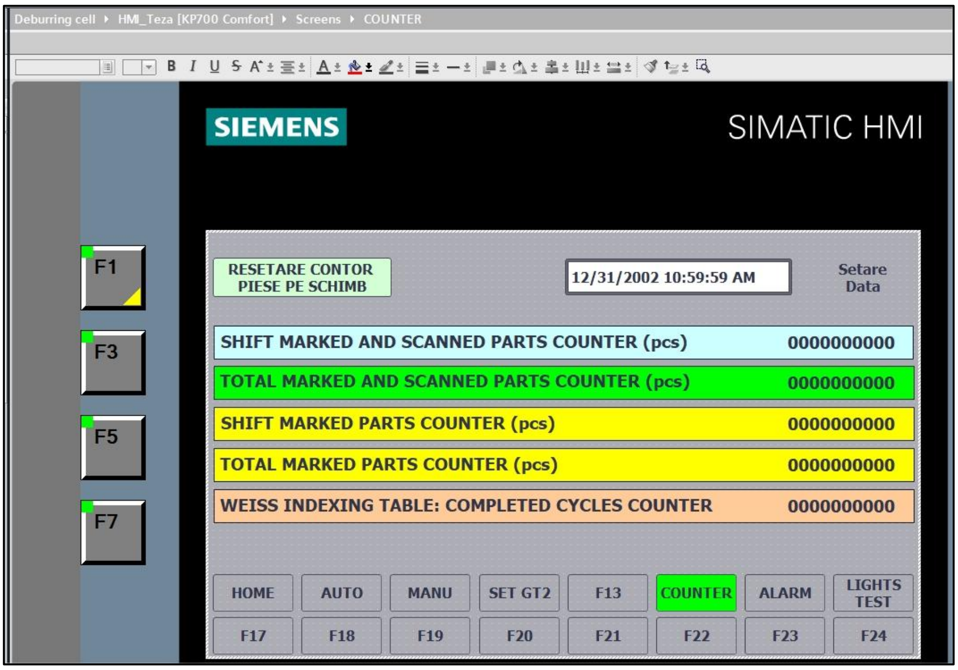

Fig. 12. COUNTER screen – part number counters

The MANU page (Fig. 13) helps to manually operate the deburring cell during setup and commissioning. The following are also allowed: clamping – unclamping of the workpiece, indexing the rotary table forward and backward, activating deburring in each of the three machining stations, checking the position of the workpiece.

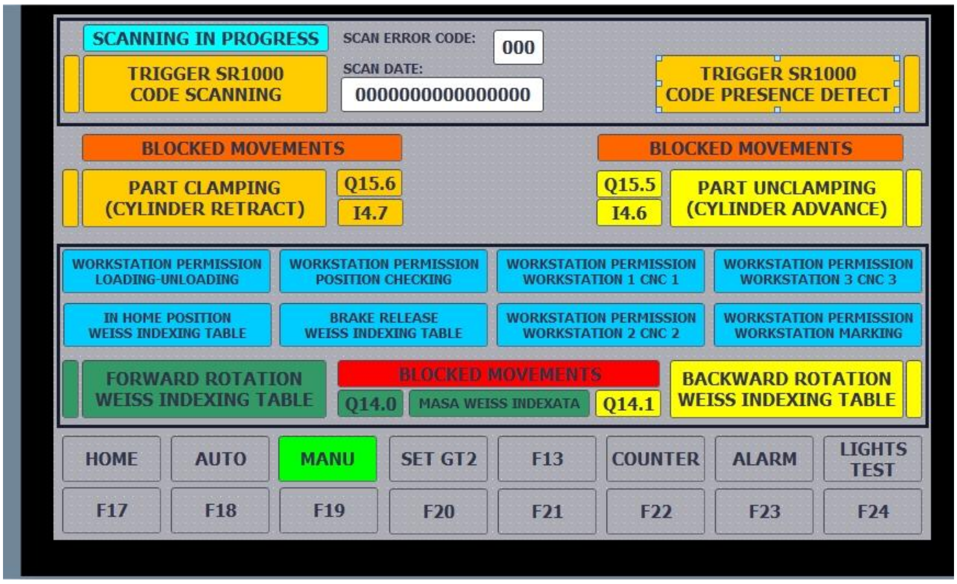

Fig. 13. MANUAL mode screen

7. Advantages of rotary indexing systems compared to conventional assembly lines

In conventional assembly line studies, such as the case study presented in [20], productivity improvement is achieved by redistributing tasks between workstations and reducing idle times caused by manual handling, part transfer and operator imbalance. The authors focus on minimizing waiting times between stations and reducing intermediate workpiece accumulation along the production flow. In comparison, the use of a rotary indexing table, as implemented in this present study, would allow an additional reduction of the total cycle time by eliminating several auxiliary operations specific to manual assembly lines. For example, the time associated with transferring parts between operators, repositioning components, or manually synchronizing consecutive workstations can be significantly reduced through automatic indexing system. Furthermore, the indexing table enables synchronization of all process stages through PLC control, reducing cycle time variations associated with human intervention and workstation imbalance.

Therefore, if the assembly architecture analysed in the [20] referenced study had an indexing rotary table, the optimization process would not have been limited only to task redistribution between operators but would also have included the direct reduction of nonproductive handling and transfer times, leading to a more stable and shorter production cycle.

8. Conclusion

This paper presents the design (electrical and software) of an automated equipment used in the automotive industry. The project aimed to eliminate residual time by identifying a modular architecture that allows quick access to components, software that can translate possible errors into diagnostic messages, as well as operational stability that guarantees parts quality, traceability and high production volume.

The implemented solution allows the simultaneous execution of several steps: positioning verification, three-step deburring, marking and verification of the code. Although the operations performed on the machined part seem simple, this machine contains many subassemblies necessary for the result to be safe, precise, fast and efficient. The Weiss indexing table used offers a higher productivity-to-space ratio than conventional production lines, transforming the voluminous production process into a compact work cell. By using the optical barrier and safety relays, the operator's exposure to accident risks is eliminated, transforming the working environment into a controlled and protected space. At the same time, easy access to troubleshooting was also pursued by introducing commands dedicated to manual movements used during maintenance.

R E F E R E N C E S

[1]. *A. Roșu,* PLC-based holonic manufacturing cell transport system, U.P.B. Sci. Bull., Series C, Vol. **73**, Iss. 2, pp. 117-126, 2011.
[2]. *C. Plăișanu, D. Clapa,* Developments in the holonic control of production flow, U.P.B. Sci. Bull., Series C, Vol. **73**, Iss. 2, pp. 127-142, 2011.
[3]. *J. Lee, B. Bagheri, H.-A. Kao*, A Cyber–Physical Systems architecture for Industry 4.0-based manufacturing systems, Manufacturing Letters, Vol. **3**, pp. 18-23, 2015.
[4].***https://cache.industry.siemens.com/dl/files/391/109987391/att_1345288/v3/109987391_AutomationFramework_Basic_DOC_V2_2_2_en.pdf, Accessed on 14.09.2025
[5]. ***https://www.eplan.com/us-en/products/eplan-electric-p8/ Accessed on 20.09.2025
[6]. ISO/IEC 16022:2006, Information technology – Automatic identification and data capture techniques – Data Matrix bar code symbology specification, Available: https://cdn.standards.iteh.ai/samples/44230/cbef655734684d6d9bd27d479f85895a/ISO-IEC-16022-2006.pdf
[7]. *V. G. Dogaru, F. D. Dogaru, V. Năvrăpescu, L. Constantinescu*, Analysis of different types of automation with emphasis on industrial applications, U.P.B. Sci. Bull., Series C, Vol. **86**, Iss. 2, pp. 341-354, 2024.
[8]. *M. Hermann, T. Pentek, B. Otto*, Design Principles for Industrie 4.0 Scenarios, 49th Hawaii International Conference on System Sciences, pp. 3928-3937, 2016.
[9]. *V. G. Dogaru*, *F. D. Dogaru*, *V. Năvrăpescu*, Stație de automatizare pentru aplicații didactice, APME – Actualităţi şi Perspective în Domeniul Maşinilor Electrice, Vol. **20**, Iss. 1, pp. 49-56, 2024.
[10]. *F. D. Dogaru, V. G. Dogaru, V. Năvrăpescu,* Design of a standard endurance testing equipment based on PLC control, U.P.B. Sci. Bull., Series C, Vol. **87**, Iss. 1, pp. 301-316, 2025.
[11]. *A. W. Colombo, S. Karnouskos, J. M. Mendes,* Industrial cyber-physical systems: A backbone of the Fourth Industrial Revolution, IEEE Industrial Electronics Magazine, Vol. **11**, Iss. 1, pp. 6-16, 2017.
[12].***https://cache.industry.siemens.com/dl/files/302/109977302/att_1307432/v1/s71200_system_manual_en-US.pdf Accessed on 05.10.2025
[13].***https://sieportal.siemens.com/en-ec/products-services/10594888?tree=CatalogTree Accessed on 05.10.2025
[14].***https://cache.industry.siemens.com/dl/files/233/49313233/att_904646/v1/HWComfortPanelsenUS_en-US.pdf. Accessed on 19.09.2025
[15].***https://deltaacdrives.com/Delta-VFD-EL-Series-Users-Manual.pdf. Accessed on 20.09.2025
[16].***https://www.vfd.com.ua/index.php?option=com_docman&task=doc_download&gid=103&Itemid= Accessed on 14.09.2025
[17].***https://files.omron.eu/downloads/latest/brochure/en/mx2_inverter_brochure_en.pdf?v=1 Accessed on 30.09.2025
[18].***https://f.nordiskemedier.dk/26jnrnluxx7bztea.pdf Accessed on 30.09.2025
[19].***https://support.industry.siemens.com/cs/document/109752224/delivery-release-tia-portal-v15?dti=0&lc=en-RO Accessed on 10.01.2026
[20]. *A. Saptari, J. X. Leau, N. A. Mohamad, E. Mohamad*, Regaining Productivity Through Line Balancing: A Case Study in an Electrical Manual Assembly Line, 24th Design Engineering Systems Division JSME Conference Japan Society of Mechanical Engineers, Iss. 14-27, 2014.