Development of an Automated Screwing Machine: Design, Production and Industrial Integration

TABOUBI Raja[1], Hajji Olfa [2] and Khalil Hamdi [1]

[1]Industrial computing and automation engineer, university teacher at ISET Béja, Tunisia National Higher School of Engineering of Tunis, Laboratory of Industrial Systems Engineering and Renewable Energy (LR16ES03, Tunisia

[2]University Teacher at Higher School of Engineering of Medjez-El Bab Route du Kef Km 5 University of Jendouba, TUNISIA- Environmental Hydraulics Laboratory, Tunisia

DOI: https://doi.org/10.51244/IJRSI.2025.120800258

Received: 14 Aug 2025; Accepted: 20 Aug 2025; Published: 04 October 2025

SUMMARY

The transition to automated production processes is a strategic requirement in modern industrial environments, particularly in the face of the intrinsic limitations of manual tasks in assembly lines.[1, 2]These limitations include high cycle time variability, significant ergonomic constraints for operators, and a lack of traceability and quality control over screwing operations.

In this context, this work is part of a technological innovation approach within the company Sagemcom Tunisia, by developing an automated screwing machine integrating the guiding principles of Industry 4.0[3, 4]. The project offers a complete solution for the automation of a screwing station, initially carried out manually, converting it into an intelligent, autonomous, traceable and secure system.

The designed machine is based on a robust and modular mechatronic architecture, integrating:

- Multi-axis electric axes controlled by FESTO servo drives for spatial movement of the screwdriving tool,
- A Siemens S7-1200 programmable controller providing control logic and sequential control of operations via structured programming in GRAFCET and Ladder,
- A touch-sensitive human-machine interface (HMI) for supervision, real-time control and technical alerts,
- A DEPRAG industrial screwdriver equipped with a torque controller to guarantee the quality and repeatability of tightening.

In compliance with the requirements of the 4.0 paradigm, the system offers integrated traceability of production parameters, securing of operations through redundant devices (light barriers, safety relays), as well as interoperability with industrial communication standards (PROFINET) [5].

The results obtained demonstrate a significant improvement in performance in terms of productivity, reliability and safety, while preparing the ground for future integration into connected, predictive and intelligent environments.

Keywords: Design, Production, Industrial Integration, Sagemcom Tunisia.

INTRODUCTION

The advent of Industry 4.0 represents a major shift in the industrial paradigm, combining digital intelligence, advanced automation and real-time equipment connectivity [6, 7 and 8]. This technological revolution requires

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IX September 2025

manufacturing companies to overhaul their processes, with the aim of optimizing productivity, ensuring fine-grained traceability of operations and reducing risks associated with human intervention.

In electronics assembly lines, screwdriving remains an essential task, but has historically been relegated to manual execution. Despite its apparent simplicity, this operation presents several challenges:

- Tightening torque accuracy, directly affecting the reliability of assemblies
- Cycle time variability, a source of inefficiency in production lines
- Lack of traceability, making quality auditing difficult
- Operator fatigue, linked to the repetitiveness and postural demands of the gesture

In order to overcome these limitations, the project proposed in this work aims to design and integrate an automated screwing cell in accordance with the principles of Industry 4.0.

This cell is based on a mechatronic architecture controlled by an industrial programmable logic controller (PLC), and includes:

- Multi-axis electric axes for three-dimensional tool positioning
- An intelligent torque controller guaranteeing the quality and conformity of screwing
- A human-machine interface (HMI) ensuring supervision and control of cycles
- A machine safety system with certified light barriers and relays

This project is part of an industrial retrofit approach, aiming to transform a manual workstation into a fully automated, traceable and interconnected workstation. It thus contributes to improving productivity, standardizing screwing operations, andto the integration of quality requirements into a proactive modernization approach.

Problem And Objectives Of The Project

Limits of manual screwing

Manual screwdriving, although still common in many industries, has several technical, ergonomic and organizational limitations [9, 10]. These constraints impact the quality of the final product, the performance of the production line and the safety of operators.

a. Torque variability

- The operator adjusts the tightening torque subjectively, often without measurement or digital verification.
- This variability compromises assembly reliability, particularly in electronic products where tightening must be controlled to the nearest newton meter to avoid breakage or loosening.

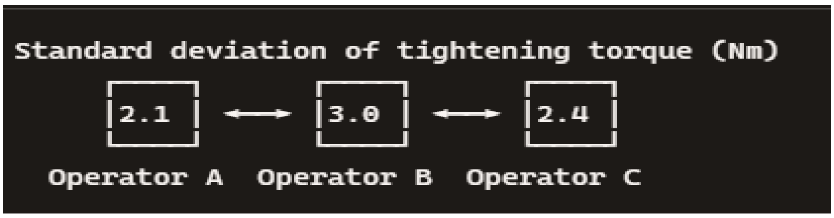

Figure 1: Indicators of variability in manual assembly tasks

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IX September 2025

b. Operator fatigue and ergonomic risks

- Repetitive movements, awkward posture and screwing efforts are sources of MSDs (musculoskeletal disorders).
- Ergonomic risk increases with work rate and exposure time, negatively impacting performance and quality.

c. Lack of traceability

- Unable to associate each screw with a dataset (applied torque, position, timestamp).
- In the event of a defect, quality monitoring is compromised, making retro-analysis difficult.

d. Low and uneven productivity

- Cycle time varies depending on operator, fatigue status, or experience.
- Lack of regularity slows down the flow and makes balancing positions impossible in an automated chain.

Project objectives

In a process of continuous improvement and integration with Industry 4.0 standards, this project aims to automate the screwing station in order to achieve the following objectives:

a. Fully automate the screwing process

- Eliminate human intervention by integrating a multi-axis Cartesian robot controlled by PLC.
- Allow constant cadence with high positioning accuracy.

b. Integrate digital torque control

- Use a Deprag controller capable of measuring, recording and adjusting the torque at each cycle.
- Ensure compliance with assembly standards and screwing repeatability.

```
[Electric Screwdriver] ⇄ [Digital Torque Controller] ⇄ [PLC Controller]
         ↑                          ↓
    Torque Sensor            Quality Data Logging
```

Figure 2: Functional architecture of screw control

c. Guarantee the traceability of operations

- Each operation is recorded: torque applied, cycle performed, result (OK/NOK), time stamp.
- The HMI allows access to history for quality audits and predictive maintenance.

d. Ensure operator safety

- Integration of safety light barriers (PILZ), certified relays, emergency stop, pressure switch.
- Automatic cycle blocking in the event of intrusion or failure of the safety chain.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IX September 2025

Table 1: Visual summary of issues and solutions

Manual Limits	**Automated Solutions**
Variable tightening torque	Digital control by Deprag
Fatigue and awkward postures	Removal of manual position
No traceability	Cycle history and recorded measurements
Non-uniform cycle	Constant cadence via PLC and multi-axis motors
Operator risk	Safety chain + automated emergency stop

DESIGN METHODOLOGY

The adopted design methodology is based on a comparative approach between the initial state of the manual station and the proposed automated solution. It relies on a functional analysis, a rigorous selection of components, and software integration compliant with Industry 4.0 standards.

Study of the existing situation

The current manual workstation relies on a portable screwdriver combined with a simple installation. This configuration has several major limitations [11, 12].On the one hand, the entire process is entirely operator-dependent, leading to variability in quality and production rates. On the other hand, the lack of software supervision prevents any traceability of operations, while quality control is non-existent: no sensor measures the tightening torque, and no data is archived. Finally, the ergonomic risks associated with repetitive movements and working posture are not negligible. These findings justify the transition to an automated solution that is more reliable, traceable, and secure.

Design of the automated solution

The proposed solution is based on a modular mechatronic architecture integrating proven industrial components.

a. Electric 4-axis Cartesian arm – Festo ELGC

The Festo ELGC Cartesian arm allows three-dimensional positioning of the screwdriver on the X, Y_1, Y_2 and Z axes. It is powered by EMMS-ST servomotors and controlled via CMMT-ST drives with PROFINET communication.

b. *Deprag screwdriver with torque controller*

The Deprag screwdriver incorporates a torque sensor for precise tightening control. It is capable of archiving screwing data (torque, duration, OK/NOK status) and communicates with the PLC to validate each cycle.

c. Siemens S7-1214C PLC

The Siemens S7-1214C PLC manages safety functions, time delays, and logic transitions. It is programmed in TIA Portal using Ladder, Grafcet, and function blocks, and communicates with other components via PROFINET.

d. KTP400 Operator Interface

The KTP400 operator panel allows monitoring of machine states, display of faults and manual control. It is configured under WinCC Basic for cycle and alarm logging.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IX September 2025

e. Safety light curtains – Pilz PSENopt II

Pilz PSENopt II light curtains protect the screwdriving area. Any intrusion interrupts the cycle via a safety relay, in accordance with EN ISO 13855 and EN ISO 61496.

f. Programming under TIA Portal & Festo Automation Suite

Programming is carried out using TIA Portal for the PLC and HMI, and using Festo Automation Suite for the axes. PROFINET telegrams are configured via GSDML, with initialization, production, and safety GRAFCETS.

Functional modeling

Functional modeling aims to decompose the automated system into elementary functions in order to clarify the interactions between the components and to guarantee the consistency of the screwdriving cycle.[13]It is based on a top-down approach, identifying the main functions such as presence detection, positioning, face, quality control and supervision. A simplified functional diagram allows this logic to be visualized (figure 3).

```
[Operator detection] → [System initialization]
        ↓                      ↓
[Workpiece loading] → [Arm positioning]
        ↓                      ↓
[Screwdriving cycle] → [Torque control] → [OK/NOK validation]
        ↓
[Data archiving] → [HMI display]
```

Figure 3: Simplified process flow of an automated assembly system

This model highlights the information flows between the sensors, the PLC, the screwdriver, and the operator interface. It facilitates the programming of GRAFCETS and the management of machine states.

Mechatronic flow diagrams

Mechatronic flow diagrams represent the exchanges of energy, information and material between the subsystems of the automated station. They are essential for validating the overall architecture and anticipating critical interactions [14, 15].

a. Energy view

The system relies on a centralized power supply that distributes energy to the Cartesian arm motors, the PLC, the screwdriver, and the safety sensors. Each subsystem consumes a specific amount of energy depending on its function.

b. Information flow

The sensor signals (presence, safety) are processed by the Siemens PLC, which controls the Cartesian arm and the screwdriver. The screwdriving data is then transmitted to the HMI for display and archiving.

```
[Presence sensor] → [S7-1214C PLC]
        ↓
[Festo arm command] → [Positioning]
        ↓
[Trigger Deprag screwdriver] → [Torque measurement]
        ↓
[PLC feedback] → [KTP400 HMI display]
```

Figure 4: Logic flow of the S7-1214C automated system

The design methodology presented allows for the transition from a manual workstation to a high-performance automated cell, compliant with the requirements of Industry 4.0. The analysis of the existing system highlighted the ergonomic, qualitative and safety limitations of the initial system. The proposed solution integrates robust industrial components, a coherent mechatronic architecture, and advanced software supervision.

Functional modeling and flow diagrams helped structure the interactions between subsystems, facilitating programming and validation. Performance analysis shows significant improvements in cycle time, traceability, and safety.

System Architecture

The architecture of the automated system is based on a coherent integration between the mechanical structure, the control components and the communication network [16, 17 and 18].. This configuration aims to guarantee the precision, flexibility and traceability of the industrial screwing process.

Mechanical structure

The mechanical structure constitutes the physical foundation of the system. It is designed to offer robustness, modularity and adaptability to different part formats.

- **Aluminum chassis**: The main frame is made of extruded aluminum profiles, ensuring sufficient rigidity while facilitating the assembly of components. This material is chosen for its lightness, its resistance to corrosion and its compatibility with industrial environments.
- **Adjustable multi-product installation**: The part holding device is designed to adapt to several product geometries. It integrates adjustable elements (slides, jacks, modular wedges) allowing rapid repositioning without specific tools, thus promoting production flexibility.
- **XYZ + rotation axis modules**: The Cartesian arm is equipped with translation modules on the X, Y and Z axes, as well as a rotation axis for tool orientation. These modules are motorized and controlled by digital drives, ensuring precise and repeatable positioning. The kinematics allows the entire screwing area to be covered with a tolerance of less than 0.1 mm.

Control Components

The system's intelligence is based on a distributed command chain, integrating interconnected industrial components (Table 2).

Table 2: Automated system configuration: references and functions

Component	**Reference**	**Role**
Automaton	Siemens S7-1214C DC/DC/DC	Global order
Variators	Festo CMMT-ST-C8-1C-MP-S0	Engine control
Engines	EMMS-ST-57-S-SE-G2	Axle drive
HMI	Siemens KTP400	Operator interface
Screwdriver	Deprag 330 OS BASIC	Torque-controlled screwing

Each component is selected based on compatibility, reliability, and CE compliance. The Siemens PLC ensures synchronization of actions, while Festo drives control the motors in a closed loop with feedback [18, 19].

Communication network

The system is based on an industrial communication architecture based on the PROFINET protocol, guaranteeing rapid, secure and deterministic exchanges between equipment.

- **Star topology**: The S7-1214C controller acts as the PROFINET master, while the drives, HMI, and screwdriver are configured as slaves. Each device has a fixed IP address and a GSDML file for integration into the TIA Portal project.
- **Real-time synchronization**: The PROFINET IRT (Isochronous Real Time) protocol enables movement synchronization with a latency of less than 1 ms, essential for controlled screwdriving applications.
- **Diagnosis and supervision**: PROFINET frames also carry diagnostic data, facilitating predictive maintenance and network anomaly detection.

This infrastructure ensures complete interoperability between components, system scalability and compliance with Industry 4.0 standards.

Machine Safety

Functional safety in automated systems is a major issue in industrial engineering. It aims to prevent risks associated with mechanical movements and motorized tools, in accordance with ISO 13849-1, IEC 62061 and ISO 12100 standards. In this screwdriving cell, the safety strategy is based on a redundant and reactive architecture (Table 3).

Table 3: Implemented security architecture

Component	**Reference**	**Main function**
Immaterial barriers	Light curtain type	Intrusion detection by interruption of optical beams
Safety relay	Pilz PNOZ s4	Interpreting signals and triggering emergency stops
Motor actuators	Festo CMMT-ST	Release of Cartesian axes in case of alert
Operator Interface (HMI)	Siemens KTP400	Manual reset after crash

Programming And Automation

The system is programmed using a modular logic architecture, compliant with the IEC 61131-3 standard, enabling efficient management of sequences, safety features and supervision. It is carried out using TIA Portal for the Siemens S7-1214C PLC and the KTP400 HMI, and using Festo Automation Suite for the Cartesian axes.

Automation

The control logic is structured around two main GRAFCETs, supplemented by custom functional blocks and safety logic diagrams [18, 20].

- **Initialization GRAFCET**This GRAFCET ensures the safe commissioning of the system. It includes sensor verification, axis zeroing, activation of light curtains, and waiting for operator validation. This sequence ensures that the system starts in a stable state and complies with safety conditions.
- **Production GRAFCET**This GRAFCET controls the automated screwdriving cycle. It combines the steps of loading the part, positioning the Cartesian arm, activating the Deprag screwdriver, torque

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IX September 2025

control, OK/NOK validation, and data archiving. It is optimized to reduce cycle time while ensuring screwdriving quality.

- **Custom Functions (FC/FB)** Each axis is controlled by function blocks (FB) or functions (FC) coded in Structured Text (ST) or Ladder Diagram (LD). These blocks encapsulate the position, velocity, acceleration, and sensor feedback parameters. For example:

FC_AxeX: management of horizontal movement.

FB_Screwing: torque control and screwing validation.

FB_Security: monitoring of barriers and PNOZ relays.

Safety flowcharts The logic diagrams define the emergency stop conditions and the system's reactions in the event of an intrusion or fault. They are integrated into the PLC logic and interact with the safety relays to cut power to the motors and disengage the axes. Any recovery requires a manual reset via the HMI.

Supervision

Supervision is provided by the Siemens KTP400 operator panel, configured under WinCC Basic, offering an intuitive and functional interface (figures 5, 6 and 7) [1, 8].

Home page with cycle visualization**:** The HMI displays in real time the system status, GRAFCET steps, performance indicators (cycle time, OK/NOK rate), and motion animations. This visualization facilitates process understanding and production monitoring.

Alarm management**:** Alarms are classified by criticality level (information, warning, critical). Each alarm is time-stamped, described, and requires operational validation.

Manual mode for maintenance: This mode allows the operator to individually control axes, test the screwdriver, and check sensors without running the full cycle. It is secured by access conditions and software limitations to prevent accidental activation.

History of screwing cycles and torques: Each cycle is recorded with the part ID, date, torque applied, tightening time, and final status (OK/NOK). This data is archived locally and exportable for quality audits, traceability, and statistical analysis.

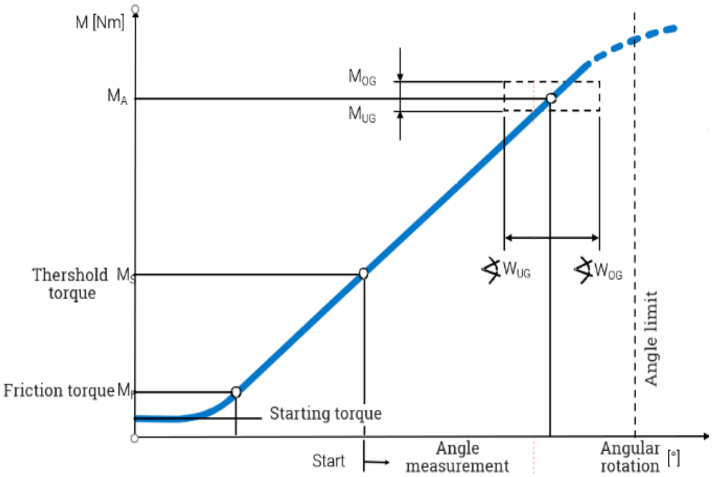

Figure 5: Screwing technology | WEBER Automatic Assemblies (www.weber-online.com)

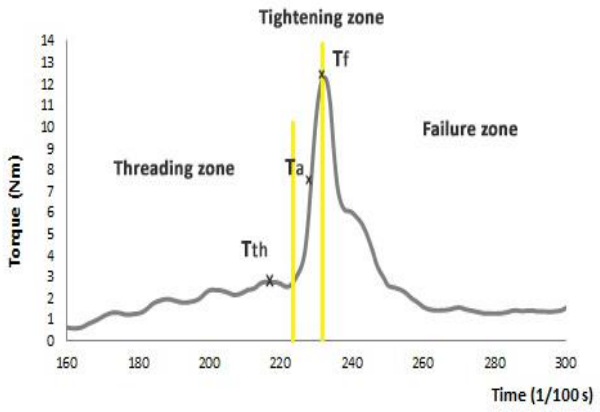

Figure 6: Analysis of the screwing curve (www.celofasteners.com)

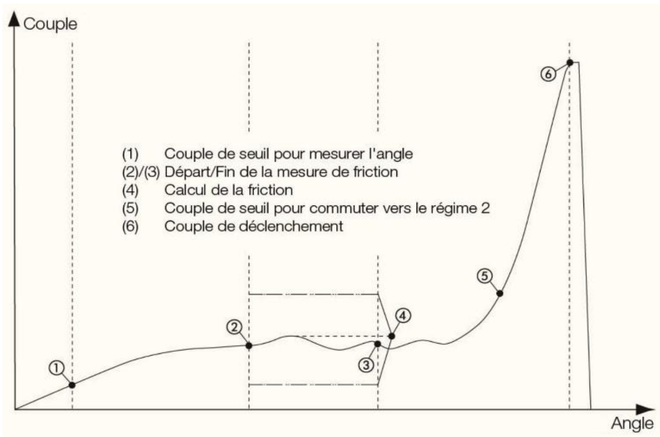

Figure 7: Tightening process in screwdriving technology: solutions & methods (www.deprag.com).

EXPERIMENTAL RESULTS

The comparative evaluation between the initial manual workstation and the automated solution was carried out using a series of tests under industrial conditions. These tests made it possible to analyze the performance of the automated system according to several key criteria: productivity, assembly quality, traceability and ergonomics [18].

The following data summarize the observed results:

Table 4: Evaluation criteria

Evaluation criteria	**Front (manual)**	**After (automated)**
Average time per part	14 s	6.5 s
Error rate	4%	< 0.5%
Tightening torque accuracy	Uncontrolled	±5% of nominal value
Traceability of operations	Absent	Total (cycle + torque)
Ergonomics for the operator	Weak	Excellent

These results demonstrate the effectiveness of the proposed solution, both in terms of throughput and quality.

Productivity

The average screwdriving time per part was reduced from 14 seconds to 6.5 seconds, a gain of more than 50%. This reduction is explained by the optimization of movements via Cartesian axes, cycle synchronization, and the integration of the Deprag torque controller.

Error Reduction

The error rate has dropped from 4% to less than 0.5%, representing a significant reduction in facial defects. This improvement results from the automatic application of a controlled and reproducible torque, avoiding under-tightening or over-tightening.

Quality Control

The manual system did not allow any direct control of the tightening torque. In contrast, the automated screwdriver allows controlled tightening with a tolerance of ±5% around the nominal value. This precision guarantees that the assemblies comply with mechanical specifications.

Traceability and supervision

Automation introduces complete traceability. Each cycle is recorded, along with torque, duration, OK/NOK status, and product ID data. This information is accessible via the KTP400 HMI and archived locally. This facilitates quality audits, statistical analyses, and feedback in the event of non-conformity.

Ergonomic improvement

The automated machine eliminates the physical effort and repetitive movements associated with using a manual screwdriver. The operator is only required to intervene during the initial loading or maintenance phase. This reduction in ergonomic constraints helps improve working conditions and prevent musculoskeletal disorders.

Conclusion of the tests

These results convincingly demonstrate the added value of the automated solution. It enables a simultaneous improvement in throughput, quality, traceability, and operator comfort. This project thus represents a concrete step forward towards a connected and efficient industry, in line with the requirements of Industry 4.0.

DISCUSSION – INTEGRATION, DATA EXPLOITATION AND STANDARDIZATION PROSPECTS

The integration of the automated screwdriving machine is fully in line with an industrial digital transformation approach in line with the paradigms of Industry 4.0. This project goes beyond simple functional automation: it provides systemic optimization levers that affect production, quality, maintenance and information flow management.

Connectivity and Industry 4.0 approach

The automated cell is designed to be interoperable with existing digital infrastructures thanks to its PROFINET communication and integrated HMI. Components such as the Siemens S7-1214C PLC, the Deprag controller and Festo drives ensure distributed processing of technical data, facilitating their consolidation in local databases or in cloud environments.

This data, made available in real time, allows:

- Production monitoring: continuous control of the number of parts produced, cycle status and performance indicators (cycle time, OK/NOK rate).

- Online quality control: systematic measurement and recording of the screwing torque, associated with each product ID.
- Digital traceability: complete history of events and structured archiving, facilitating quality audits and traceability of defects.

Predictive maintenance and reliability

Continuous recording of operating states and warning signals (faults, interruptions, sensor anomalies) opens the way to predictive maintenance. By integrating trend analysis algorithms on critical parameters (screwing torque, power consumption, error frequency), it becomes possible to anticipate failures before they impact production.

Festo mechatronic axes, thanks to their integrated status feedback, can measure motor forces, actual positions, and load cycles. This data can be used to establish aging curves, calculate the MTBF (Mean Time Between Failures) and plan preventive interventions.

Prospects for industrial standardization

Beyond its immediate use, this project constitutes a reproducible technological building block. Its modular design and comprehensive documentation (electrical diagrams, PLC programs, GRAFCETs, HMI interfaces) facilitate duplication on other similar screwdriving or assembly stations.

This standardization could extend to:

- With several production lines within the same site,
- At multi-reference screwing stations (various products),
- To other assembly operations such as clipping or functional testing,
- And even the establishment of collaborative cells with operators.

Reusing functional blocks (FC/FB), safety routines and user interfaces would reduce development costs and accelerate commissioning time.

The machine developed is not a simple technical response to a specific problem, but a prototype of intelligent integration, capitalizable in a logic of industrial scalability. Its capacity to generate, exploit and structure data makes it compatible with scalable, demanding production environments oriented towards sustainable performance.

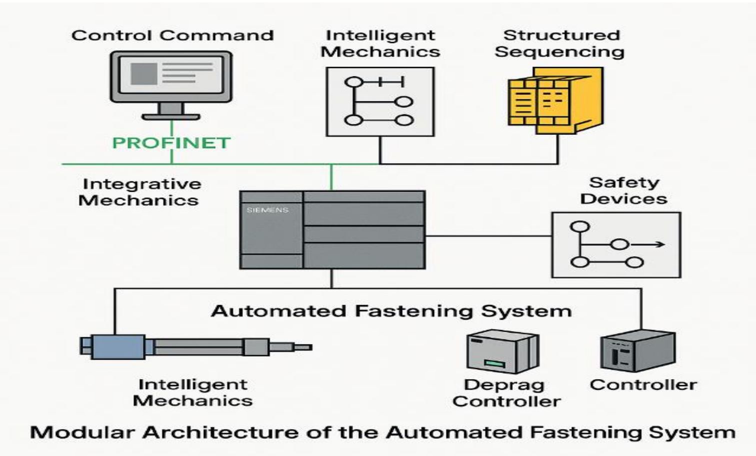

Figure 8: Modular architecture of the automated fastening system

GENERAL CONCLUSION – MECHATRONIC CONTRIBUTIONS, INDUSTRIAL PERFORMANCE AND EVOLUTIVE MODULARITY

The project presented illustrates a major step forward in the digital transformation of manual workstations in industrial environments. By replacing a critical manual screwdriving process with an automated cell, the implemented system now ensures operational robustness, functional precision, and enhanced traceability, meeting the sector's quality and productivity requirements.

The success of this transformation is based on a coherent integration of three fundamental disciplines:

- Control via the Siemens S7-1214C PLC, allowing fine cycle management and real-time monitoring.
- Intelligent mechanics, represented by Festo electromechanical axes and the Deprag controller, ensuring precision, repeatability and adaptability to different configurations.
- The structured scheduling logic, embodied by GRAFCETs, guarantees the clarity and reliability of operating sequences.

This unified mechatronic architecture, interconnected by the PROFINET bus, promotes smooth data flow and efficient synchronization of actions, while pThe system allows complete supervision of key variables:

- Screwing torque: guarantees consistent assembly quality.
- Angular position: essential for reproducibility and compliance with mechanical tolerances.
- Product identification: facilitating traceability and structured archiving.

The integration of safety devices, inspired by Pilz recommendations (2024), ensures compliance with current standards (ISO 13849, IEC 62061), while protecting operators and equipment.

One of the essential added values of the project lies in the flexibility of the architecture, which allows:

- Adaptation to multiple product ranges, thanks to intelligent parameterization of sequences.
- Rapid modification in the event of changes to the specifications, without major overhaul of software or hardware infrastructures.
- A reassignment of the position to other assembly lines, retaining the functional blocks and safety routines.

This degree of modularity and reusability positions the cell as an internal technological standard, capable of being deployed on several stations and lines, with substantial gains in engineering time and deployment reliability.

The project thus goes beyond a simple one-off need. It constitutes a technological building block that can be capitalized on in a global industrial transformation process:

- Promoting the scalability of automation solutions.
- Enabling seamless integration with MES, ERP systems and cloud platforms.
- Providing a reproducible example in the context of inter-line standardization, with a reinforced return on investment.

REFERENCES

1 Siemens. (2024). TIA Portal Documentation. Siemens AG.
2 Festo. (2024). Festo Automation Suite Guide. Festo GmbH & Co. KG.
3 Deprag Schulz GmbH. (2023). Industrial screwdriving systems.
4 Pils. (2024). Safety Light Curtains and Relay PNOZ s4 Manual. Pilz GmbH
5 Autodesk. (2023). AutoCAD Electrical – Electrical Design Solutions.
6 IEC. (2018). IEC 61131-3: Programmable Controllers – Programming Languages.
7 ISO. (2021). ISO 13849-1: Safety of Machinery – Safety-related Parts of Control Systems.
8 Siemens. (2023). SIMATIC HMI Panels Technical Specifications.
9 Festo. (2023). Electromechanical Axes ELGC Product Data Sheet.
10 Siemens. (2024). S7-1200 PLC Data Manual.
11 Pils. (2023). PNOZ s4 Safety Relay Datasheet.
12 RS PRO. (2023). Industrial electrical components – online catalogue.
13 Keyence. (2023). Industrial Safety Light Curtain System Overview.
14 Deprag. (2024). MINIMAT EC-Servo Screwdriver System.
15 SICK. (2023). Industrial inductive and optical sensors – GTE6 series.
16 TDK-Lambda. (2024). Industrial DIN Rail Power Supplies – DRB Series.
17 MEAN WELL. (2023). 48V Power Supply – TDR and NDR Series.
18 Khalil, H. (2025). Internship report – Sagemcom Tunisia. Higher Institute of Technological Studies of Béja.
19 ISA. (2010). ISA-88: Batch Control Standard. International Society of Automation.
20 IEC. (2019). IEC 60848: Graphical symbols for Sequential Function Charts (GRAFCET).