A CASE STUDY ON VIRTUAL COMMISSIONING OF COLLABORATIVE ROBOTS USING SCHNEIDER SOFTWARE PLATFORMS

Alexandru ANDREI [1*], Cristina PUPĂZA[2] Adrian-Florin NICOLESCU[3]

This research focuses on the development of a comprehensive Virtual Commissioning process for a collaborative robotic system. The environment utilizes collaborative robots from the Lexium series, a product of the Schneider Group. The study primarily examines the platforms provided by Schneider Electric for the integration and programming of Lexium collaborative robots. Specifically, the research describes the use of Schneider's proprietary development platforms, with a particular focus on EcoStructure Cobot Expert as offline programming environment for the collaborative robots under consideration, and EcoStructure Machine Expert as the environment for control and Virtual Commissioning. These platforms represent Schneider's solution for the integration of collaborative robots within their product range, designed to employ both software and hardware automation capabilities. The employed platforms also combine intuitive programming, safety, and seamless industrial integration. Although blockchains are not currently enabled, their openness to advanced connectivity and digital ecosystems suggests potential for future blockchain integration, for traceability, secure data exchange, and decentralized control in smart manufacturing environments.

Keywords: collaborative robots, Virtual Commissioning, automation, programming.

1. Introduction

Virtual Commissioning (VC) is transforming manufacturing by allowing the simulation and optimization of production systems before deployment. Over the last decade, learning factories have become crucial for testing new strategies, advancing technologies, and developing workforce skills [1]. The global rise in robotic automation has further driven to VC adoption, especially for faster robotic cell deployment and cost reduction [2]. A major challenge, such as the interoperability between heterogeneous software, has led to the development of integrated platforms that link tools from multiple vendors.

* Corresponding author

*[1] PhD Student, Faculty of Industrial Engineering and Robotics, National University of Science and Technology POLITEHNICA Bucharest, Romania, e-mail: aandrei2405@stud.fiir.upb.ro

[2] Prof., Faculty of Industrial Engineering and Robotics, National University of Science and Technology POLITEHNICA Bucharest, Romania

[3] Prof., Faculty of Industrial Engineering and Robotics, National University of Science and Technology POLITEHNICA Bucharest, Romania

This study evaluates the interoperability between Cobot Expert [3] and Machine Expert [4], focusing on their combined application for simulating, commissioning, and integrating collaborative robots. The work examines their offline programming capabilities and their potential for unified VC workflows. The analysis focuses on the configuration and parameterization of Digital Twins (DTs) in Machine Expert, reflecting real-world systems. The research highlights key functional limitations and missing features that can hinder VC adoption [5], emphasizing the need for ongoing platform development to ensure a smooth virtual-to-physical transition.

The paper is organized as follows: Chapter 1 summarizes VC concepts and their relevance to Schneider's programming platforms; Chapter 2 reviews recent progress in offline programming and integration tools, discusses Schneider cobot-specific hardware and blockchain-enabled programming approaches, highlighting current trends in secure data exchange, decentralized control, and the potential future integration in collaborative industrial environments, as well as the role of ROS 2 as an enabling middleware for advanced applications. Chapter 3 presents an original research on the integration of logic and cobot programming environments, as well as an evaluation of system constraints and benefits. Chapter 4 concludes with a synthesis of key observations, limitations, and advantages.

2. State of art

Recent developments in Virtual Commissioning (VC) have addressed several complex challenges, including the integration of high-fidelity Digital Twin models with parameter retention, efficient kinematic generation for solid and peripheral virtual components, and the creation of logical models for virtual devices [6]. Despite this progress, a significant unresolved issue remains: the lack of a standardized, vendor-agnostic interface. Current systems often require multiple programming environments tailored to specific robot manufacturers, increasing development time and complexity. A unified interface for parameterization, control, and configuration across diverse robot types can streamline VC processes and improve operational efficiency [7].

2.1 EcoStruxure Cobot Expert

EcoStruxure Cobot Expert [8] is a Schneider Electric software tool designed for programming, simulating, and deploying collaborative robots (cobots) in industrial environments. As part of the broader EcoStruxure platform, it supports digital transformation through integrated automation, analytics, and software solutions. A core feature is the support for offline programming and simulation, allowing virtual development and testing of robot programs before physical deployment. This minimizes integration errors, reduces downtime, and ensures

system availability, which is crucial in uptime-sensitive operations. The intuitive, graphical interface with drag-and-drop functionality makes it accessible to users with limited coding skills. The platform also includes advanced kinematic path planning and optimization tools, improving efficiency and reducing mechanical wear [9]. However, it currently supports only Schneider's Lexium robot series, limiting interoperability with third-party robots. Despite this, Cobot Expert enables efficient Virtual Commissioning (VC) for streamlined setup and deployment. Cloud connectivity and real-time data integration allow for remote monitoring, predictive maintenance, and performance analytics [10]. Compliance with safety standards (ISO 10218, ISO/TS 15066) ensures safe human-robot collaboration. The software also shortens deployment cycles [11], reduces implementation errors [12], and extends the robot lifespan through optimized routines. Its flexibility supports future system modifications without major redesigns [13]. Cobot Expert is suitable for various industrial tasks, including assembly, packaging, inspection, and material handling, enhancing precision, reducing manual effort, and improving real-time quality control [14]. Simulation also strengthens safety measures for collaborative human-robot environments.

In summary, EcoStruxure Cobot Expert delivers a robust, integrated VC solution. With offline programming, Digital Twin capabilities, and seamless integration into the EcoStruxure ecosystem, it supports safe and efficient automation aligned with current industry demands.

2.2 EcoStruxure Machine Expert

EcoStruxure Machine Expert [15] is Schneider Electric's integrated software environment for programming and configuring machine-level automation systems. It unifies logic and motion control, HMI development, and fieldbus configuration within a single workspace. The platform targets Schneider's mid-range PLCs and motion controllers, including Modicon M241, M251, M262, and the PacDrive LMC series [16]. Built on the CODESYS framework, it supports multiple IEC 61131-3 programming languages and offers features like OPC DA/UA communication [17], SQL integration, Python scripting, and version control (e.g., SVN), supporting system integration and collaborative development. Its modular architecture allows for optional extensions, such as safety logic, motion configuration, and Machine Expert Twin, a tool for Virtual Commissioning and Digital Twin simulation [18], aligning with model-driven engineering practices.

Part of the broader EcoStruxure architecture, Machine Expert is designed for OEM machine-building, distinct from EcoStruxure Control Expert, which supports advanced PACs like Modicon M340/M580 [19]. Community feedback is mixed: users appreciate its integration flexibility but note a steep learning curve and usability challenges, particularly with device-specific setups and rebranding

transitions. Different releases target varying complexity levels: Machine Expert Basic serves entry-level controllers (e.g., Modicon M221), but lacks Structured Text (ST) support, while Machine Expert Motion caters to advanced robotics and servo control.

In summary, EcoStruxure Machine Expert (Fig.1) provides a modular, standardized automation environment supporting virtualization and tight hardware-software integration, ideal for machine-centric applications within Schneider Electric's ecosystem.
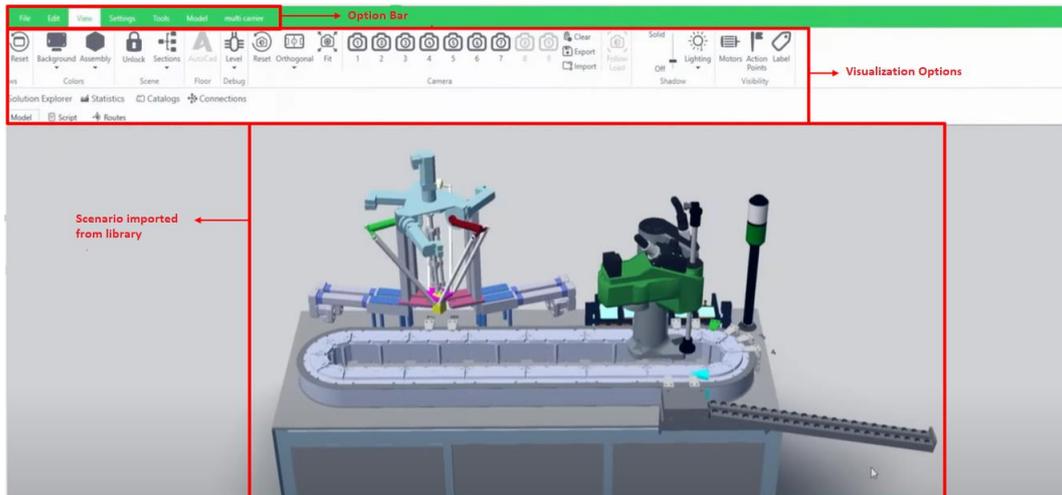

Fig. 1 Eco Structure Machine Expert Twin interface

Caiza and Sainz (2024) [20] experimentally validated an architecture integrating a Digital Twin with a Manufacturing Execution System (MES), demonstrating enhanced interoperability among heterogeneous control subsystems and improved process management. Their results highlight the Digital Twin's role in early detection and diagnosis of operational issues, leading to reduced downtime despite typical disturbances in industrial processes. Virtual Commissioning (VC) implementation [21] relies on simulating 3D machine and system components by integrating CAD data with automation parameters. This detailed parameterization facilitates complex system interactions, enabling in-the-loop simulations that simplify system expansion and testing.

2.3 Hardware features and limitations

From a hardware standpoint, Schneider Electric's collaborative robots differ notably from other leading manufacturers. Rather than employing dedicated cobot controllers, they utilize the standard controller common across Schneider's servo motor range (Fig. 2a). Additionally, a compact controller variant is available for

low-complexity applications with fewer signal requirements. Measuring approximately $300{\times}200{\times}50$ mm³, this represents one of the smallest cobot controllers on the market, offering advantages in space-constrained implementations (Fig. 2b).
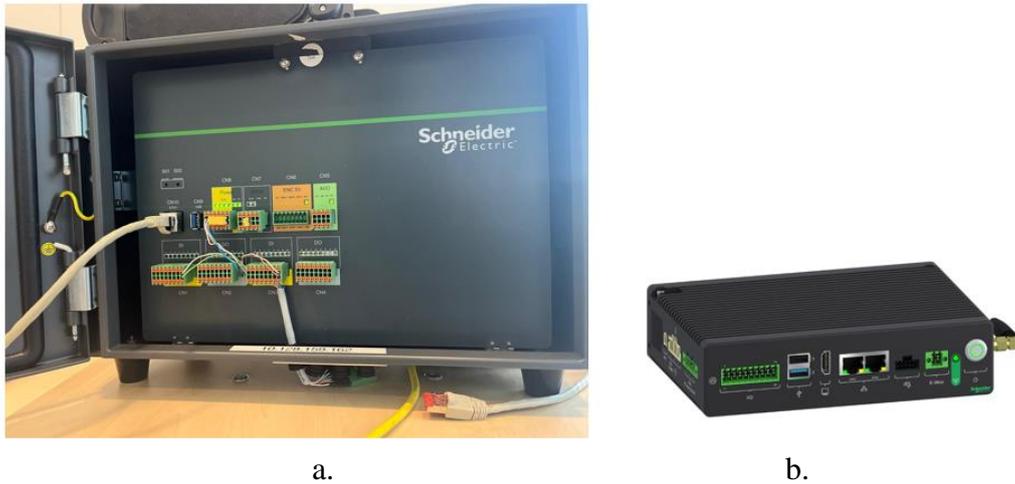

a.   b.
Fig. 2. Controller. a - adapted Lexium controller; b - compact controller

Secondly, unlike most major manufacturers, Schneider Electric's collaborative robots omit a traditional teach pendant. Instead, they support any tablet running Machine Expert software, promoting compatibility with existing facility technologies and eliminating the need for specialized operator training. To ensure safety, Schneider offers a docking station for the tablet, equipped with an emergency stop button and integrated safety valves as part of the system's safety circuit. The cobot system also includes a compact "Mini-control interface" that provides fundamental operational controls for robot manipulation.

In conclusion, the state-of-the-art review highlights the integration of Schneider Electric's Lexium collaborative robots and emphasizes the role of Virtual Commissioning in enhancing deployment efficiency. The findings deepen the understanding of the capabilities and limitations of Schneider automation tools and provide recommendations for refining VC processes and improving the performance of robotic system in industrial settings.

Sections 2.1, 2.2, and 2.3 detail recent advances and existing constraints in Schneider's virtual integration technologies from both hardware and software perspectives. These insights form the foundation for the original research presented in Chapter 3 of this article.

2.4 Blockchain in robotics

Blockchain technology offers strong potential in industrial engineering by enhancing robot performance and reliability through secure, decentralized data logging and smart contracts. It enables traceability, autonomous coordination, and tamper-proof maintenance. Robots on blockchain networks can collaborate, validate component origins, meet compliance standards, and benefit from enhanced cybersecurity through verified identities and secure firmware updates. Although latency and integration remain challenges, studies using ROS 2 and Hyperledger Fabric demonstrate the viability of blockchain-robotics integration, supporting the shift toward autonomous and transparent manufacturing systems.

Although Lexium cobots do not natively support blockchain or similar IIoT technologies like OPC UA, several academic prototypes have explored:

• the integration of ROS 2 with Hyperledger Fabric smart contracts for robot control and secure data logging in industrial contexts, independent of commercial cobot platforms [22].

• the use of blockchain identities and smart contracts for multi-robot collaboration and warehouse inspection tasks in experimental setups, not involving actual Lexium units [23].

Among industrial robot manufacturers, ABB and Staubli are the closest to adopting blockchain technology. ABB has explored blockchain in energy trading, supply chain transparency, and smart contracts within the ABB Ability digital ecosystem [24], focusing on secure data exchange via standard IIoT gateways and protocols such as OPC UA and MQTT, approaching blockchain technology. Stäubli enhances AI-driven robotics, IIoT connectivity, and platforms like SCOPE for robot fleet monitoring and preventive maintenance [25].

In summary:

- Schneider Lexium cobots do not provide built-in blockchain programming capability.
- Academic projects show that blockchain robotics is possible, but it requires external frameworks and often relies on ROS 2 middleware, not proprietary robot APIs.
- While blockchain-enabled robotics is an active research domain, commercial cobots like Lexium currently rely on traditional PLC-based control and programming methods.

3. Proposed implementation

The main objective of the research (Fig. 3) is to test the platforms offered by Schneider supplier for a new integration of collaborative robots, determining the limits of these platforms for full integration of the Virtual Commissioning process.

The case study also identifies the implementation peculiarities and the necessary configurations. In this work, a pick and place virtual robotic cell was conceived consisting of a Lexium RL3 collaborative robot, a gripper type end- effector with electric drive and cobot support.
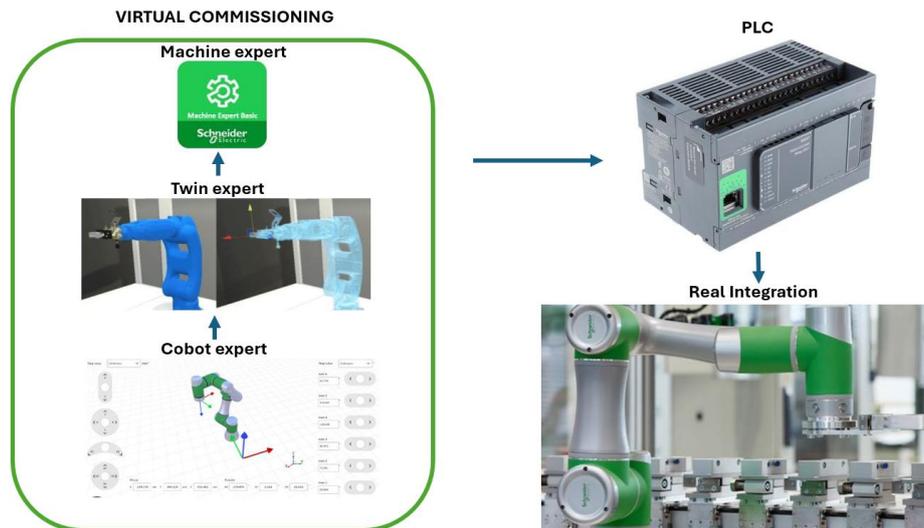

Fig. 3 Concept model of the methodology.

The applied research follows the subsequent steps:
➢ Selection of the experimental base, both hardware and software;
➢ Parameterization of the robot Digital Twin in Expert Twin;
➢ Writing the program and the trajectory of the cobot in the Cobot Expert interface;
➢ Integration of the PLC and Cobot in Machine Expert;
➢ Design of the PLC program to control the cobot;
➢ Convertion of the Function Block Diagram (FBD code) into Ladder;
➢ Hardware and software configuration of the PLC, Cobot and Gripper;
➢ Management and parameterization of the signals received in the PLC from the cobot and gripper;
➢ Assessment of the limits and advantages of the platforms.
The following hardware and software equipment were employed in this case study:
• Cobot Lexium RL3
• Controller Lexium LXMRL07C1000
• PLC Modicon M221- TM241CE24R (24 IO, relay, Ethernet)
• Cobot expert V 1.7.0.48
• Machine expert basic trial + Expert Twin module (integrated).

All the hardare and software components were selected since they were currently available for practical testing. To create the virtual environment, a TM241CE24R virtual processor was configured in Schneider Electric's Machine Expert platform, specifying the necessary input/output signals for the robotic application. The Expert Twin software was then launched, where the RL3 collaborative robot (3 kg payload) was selected from the library. A virtual mounting structure and an end-effector were added, with the Schmalz vacuum gripper chosen to match the "Click to Use" system configuration. A significant limitation was the restricted end effector library, which includes only two mechanical grippers and one vacuum gripper. Customizing or creating additional effectors requires advanced parameterization and programming skills, posing challenges for users seeking greater flexibility without extensive expertise.

The subsequent research phase utilized Cobot Expert to parameterize and program the robot, focusing on motion trajectory plan. Key parameters, including payload, speed, acceleration, mounting orientation, and center of gravity, were first defined. The core program governing the cobot's motion was then developed. Cobot Expert features a hybrid programming environment that integrates graphical tools with manual coding, enabling efficient creation and adjustment of robot behavior.

Trajectory programming is particularly intuitive and responsive (Fig. 4), making it one of the most user-friendly and time-efficient platforms available, especially for users with limited robotics programming experience. This phase highlighted the technical strengths and practical benefits of the platform, mainly reducing setup time and simplifying complex motion programming, thus supporting rapid prototyping and efficient implementation.
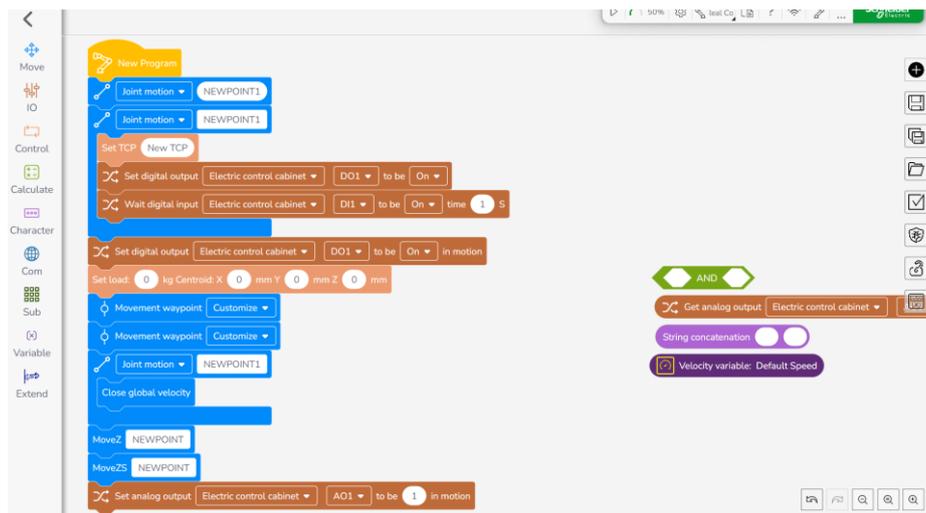

Fig. 4 Programming interface in Cobot Expert

The subsequent research phase focused on the development of the PLC program in Machine Expert, to control the robotic cell and to integrate it with the main production line. MODBUS communication was established to enable data exchange between PLC and cobot. This integration was enabled through the Expert Twin module (Fig. 5), which consolidates trajectory and logic data from Cobot Expert.
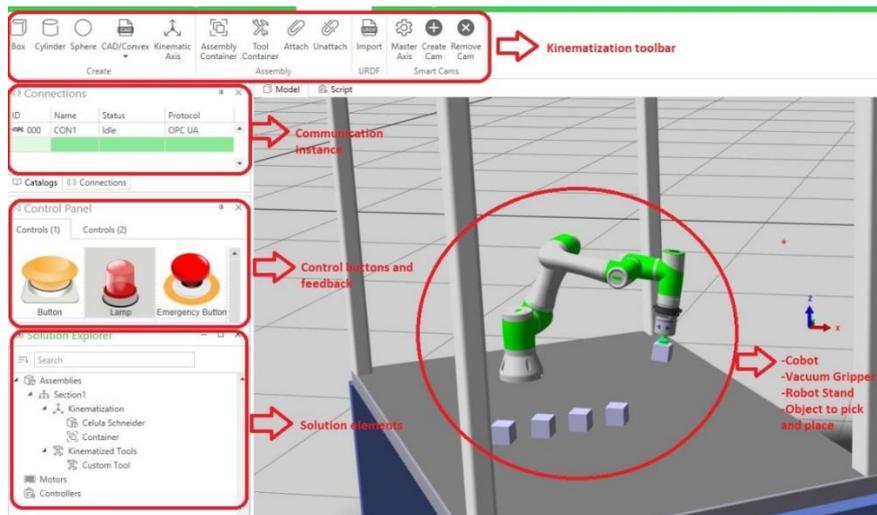

Fig. 5 Cobot RL3 implementation in Expert Twin

Key observations and limitations:

• Communication flow constraints: Although the physical robot can connect directly to Cobot Expert via "Click to Connect," and Cobot Expert interfaces with Expert Twin, a direct link between the cobot and Expert Twin is unsupported. Therefore, all configurations must pass through Cobot Expert, which adds complexity and reduces implementation efficiency.
• Model compatibility issues: Machine Expert allows the import of predefined twin models (cobot, gripper, conveyors) from its library, but custom Digital Twins created in Expert Twin cannot be directly imported. Full integration requires manual reconstruction in Machine Expert, limiting cross-platform flexibility and disrupting workflow continuity.
• Virtual PLC program performance: The PLC program developed in Machine Expert controls the virtual application with precision and stability in real time. The simulation runs error-free and is well-optimized, indicating the platform's suitability for designing and testing real-time control logic virtually before physical deployment.

After the precise parameterization of all the components of the robotic cell, robot, conveyor, robot effector, and after the creation of level 1 local logic for each of these components, the level 2 control logic was created, which includes the priority cases in the control of the component elements of the robotized cell. The level 2 operating logic (Fig. 6) was designed in the form of a logic diagram, and transposed into ladder code for PLC according to the following mathematical methodology.
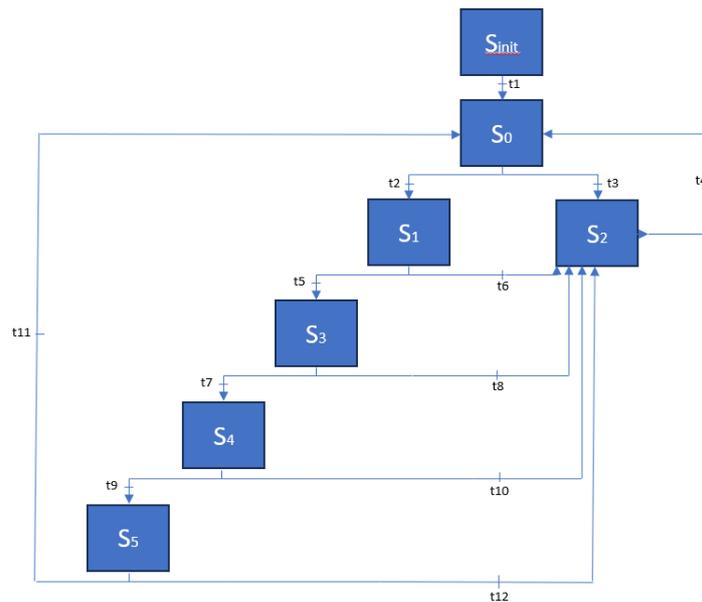

Fig 6. Level 2 control logic

s_{init} represents the initial state of the system and has the access formula:

$$\sum s_{init} = \overline{S0} + \overline{S1} + \overline{S2} + \overline{S3} + \overline{S4} + \overline{S5} \tag{1}$$

Where $\overline{S0}$; $\overline{S1}$; $\overline{S2}$; $\overline{S3}$; $\overline{S4}$ and $\overline{S5}$ are all the states of the logic control system. For the ladder conversion $\overline{s}$ represents the close contact, and $\overline{s0}$ the open contact. The initial state is accessed when the PLC starts the first time, and requires that the system is not blocked in any of the states.

$$s_0 = s_{init}t_1 + s_2t_4 + s_5t_{11} + s_0\overline{s_1s_2} \tag{2}$$

Where s_0 is the state in which all the equipment state is checked as well as the conveyor, and the state of the effector. s_1 is the state that commands the Home movement cycle, s_2 is the state that triggered the stop cycle, t_1 means the "Transition

1", which represents the "play button", t_4 is a 300 ms timer, t_{11} is the transition triggered by the conveyor presence sensor. S_5 is the sequence of pallet palletization and t_{11} is the signal transition for end_cicle_ok.

$$s_1 = s_0 t_2 + s_1 \overline{s_2 s_3} \tag{3}$$

Where t_2 is the local variable that confirms if all the elements of the system are ready, S_3 is the pick up sequence control.

$$s_2 = s_0 t_3 + s_1 t_6 + s_3 t_8 + s_4 t_{10} + s_5 t_{12} + s_2 \overline{s_0} \tag{4}$$

Where t_3 is the local variable for not ok equipment, t_6 is the local variable for effector not ready, t_8 is the ocal variable for pick up not ok, S_4 is the sequence for pick up pallet cycle, t_{10} is the local variable for pick up sensor presence not ok, S_5 is the sequence for drop and place up and t_{12} is the local variable for place up not ok.

$$s_3 = s_1 t_5 + s_3 \overline{s_4} + s_3 \overline{s_2} \tag{5}$$

Where t_5 is the local variable for effector ready.

$$s_4 = s_3 t_7 + s_4 \overline{s_5} \overline{s_2} \tag{6}$$

Where t_7 is the local variable for pick up ok.

$$s_5 = s_4 t_9 + s_5 \overline{s_0} \overline{s_2} \tag{7}$$

Where t_9 is the local variable for pick up sensor ok.

The reason for using this conversion approach is that the functional logic is easier to conceptualize in the form of a SFC, but the Ladder Diagram remains the most widely used [26] and the appropriate language for the maintenance departments in industrial environments. Therefore, the control logic was initially structured using SFC for clarity and logical sequencing, and then converted into LD to ensure compatibility with industry-standard PLC platforms and ease of use for on-site technicians.

4. Conclusion

The study presents a Virtual Commissioning environment developed with Schneider Electric industrial software tools, including Machine Expert and Cobot Expert. It identifies key limitations and gaps in Virtual Commissioning for cobots, mainly the lack of effective control solutions for collaborative robots within Schneider's automation ecosystem.

Key observations:

- The approach combines graphical and code-based programming, facilitating efficient robot behavior development, even for users with limited coding experience.
- The original procedure simplifies trajectory and motion programming via drag-and-drop and visual path setup, enabling faster and more accurate motion planning.
- Virtual Commissioning for cobots requires separate environments (Expert Twin and Machine Expert SoMachine) for modeling and implementation, which disrupts workflow continuity and may reduce deployment efficiency.
- It supports both digital and physical commissioning through hardware-software integration, ensuring realistic testing and validation of robotic operations.
- Users benefit is mostly within Schneider's ecosystem. External use adds complexity.

Main limitations:

- Built-in library is limited (e.g., only two grippers and one vacuum effector), constraining the adaptability for complex tasks.
- The environment has low flexibility for supporting different or custom robotic components, restricting the system customization for specialized applications.
- Real robots cannot connect directly to Expert Twin. Communication must be routed through Cobot Expert, adding complexity.
- Digital Twins fully created in Expert Twin cannot be imported into Machine Expert, requiring manual rebuilding, which increases the configuration time and the risk of errors.
- Custom component configuration demands advanced programming skills and detailed parameters.
- Optimal performance is confined to Schneider Electric's environment.
- Poor compatibility with third-party or open-source systems.
- Integration with external platforms can be challenging or may require custom interfaces. For example, when integrating Kuka.Sim with TIA Portal.
- Limited variety of complex automation parts in the default library, constraining advanced system design.
- Technical expertise is essential when components are missing from the library.

Advantages:

- Easy integration with Schneider tools like Machine Expert, Modicon PLCs, and Expert Twin enables unified control.

- Predefined robot models (e.g., RL3) and end-effectors speed up prototyping, accelerating design-to-deployment cycles.
- Built-in simulation allows the preview and validation of the real-time cobot action.
- The system supports IEC 61131-3 programming languages (ST, FBD, LD), ensuring the standardization.
- Enables virtual testing of control logic, reducing real-world errors, and minimizing real-world implementation risks.
- Streamlines deployment by integrating hardware layout and software logic for efficient commissioning.

This research presents an original Virtual Commissioning process for Schneider Electric's Lexium collaborative robots using Cobot Expert and Machine Expert. The platforms allow intuitive programming, offline simulation, and both digital and physical commissioning. Some limitations remained, such as: the need to use separate environments and the restricted component libraries. The tools provide predefined robot models, real-time simulation functionality, and easy integration within Schneider's ecosystem, supporting faster prototyping and reliable testing. The study highlights the main advantages and drawbacks of Schneider's solutions, offering recommendations for future improvements.

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