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Upgrade of a Water Level Control System Using SCADA

Project wokr

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Contents

List of Figures

1 introduction

1.1 Problem basis

Industrial processes have undergone remarkable development over the last decades. Technological progress has brought more complex and faster production procedures, which in turn require advanced solutions for their monitoring and control. Today, a high degree of automation is not only an advantage but a necessity, as it reduces the likelihood of errors, increases productivity, and ensures reliable and safe operation of equipment.

An important part of modern automation is the communication between humans and machines. In industrial environments, this communication is often achieved through graphical interfaces, which provide operators with an overview of the process and enable quick intervention in case of changes. SCADA systems (Supervisory Control and Data Acquisition) play a crucial role in this regard – they allow centralized monitoring, real-time data acquisition, and easy accessibility of information, all of which contribute to better decision-making, production optimization, and prevention of errors and system downtime.

In this project, an existing water level control system, which previously relied only on a local HMI interface, was upgraded with a computer-based SCADA interface. This approach enables improved process transparency, trend visualization, data archiving, and a more intuitive user experience. The purpose of the project was not only to present a concrete implementation, but also to provide an introduction to the fundamental principles of SCADA systems that are widely used in larger industrial environments with multiple production lines and more complex processes.

1.2 Task goals

The main goal of this work was to upgrade the existing water level control system by implementing the WinCC Runtime Advanced SCADA interface in the TIA Portal environment. Such an upgrade enables visualization of the process on a computer screen, real-time monitoring of parameter changes, data archiving, and the use of an alarm system.

The theoretical part of the thesis is focused on the basic concepts of automation, control systems, and SCADA technology, with an emphasis on their role in modern production environments. The practical part presents the integration of the SCADA interface into the existing system, the configuration of communication between the PLC and SCADA, and the design of the user interface.

The expected result is a system that provides better process transparency, easier parameter adjustment, and the possibility of expansion to more complex applications, similar to those known from industrial practice.

2 Theoretical basis of SCADA

2.1 SCADA Systems

SCADA (Supervisory Control and Data Acquisition) is a computer-based system for monitoring, collecting, and processing data in industrial automation. Its primary function is to provide remote insight and supervision of technical systems in production, energy, transport, or utility infrastructure. Through a graphical interface, it enables operators to observe the operation of a device or system, while also providing data storage, alarm handling, and reporting [1].

A SCADA system typically follows a hierarchical architecture, where individual components are divided according to their functional purpose [2]:

- **RTU (Remote Terminal Units):** devices that collect data from sensors and forward it to the supervisory system.
- **PLC (Programmable Logic Controllers):** used for local process control, often replacing RTUs due to their higher flexibility.
- **SCADA server (control center):** collects, processes, and archives data.
- **HMI (Human-Machine Interface):** provides the interaction point for operators to monitor processes, make decisions, and issue control commands.

A key feature of SCADA is the separation of monitoring and control. Decisions are typically not executed directly via the HMI but through programmed algorithms in PLCs. The SCADA system acts as a "supervisor," offering process transparency while forwarding commands to lower automation levels.

The main functions of SCADA include [1]:

- Real-time data acquisition and visualization (sensor values, flows, temperatures, pressures).
- Remote process control, such as switching valves or modifying process variables.
- Alarm management, notifying operators about limit violations or system faults.
- Data archiving and analysis, enabling trend visualization, reporting, and process optimization.
- Integration with higher-level IT systems, such as ERP or MES databases.

Modern SCADA solutions are designed with a focus on security, scalability, and integration with IoT devices. They provide access through web browsers, support for mobile devices, and cloud connectivity, making them a key component of smart factories within the framework of Industry 4.0 [3].

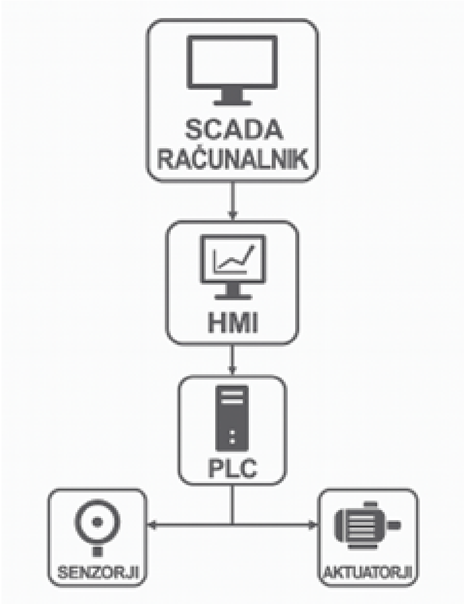

Figure 1: Hierarchical overview of a SCADA system in industry

2.2 Siemens SCADA Solutions

Siemens offers several SCADA platforms, developed within the TIA Portal environment, that differ according to application complexity:

- **WinCC Runtime Advanced** - Designed for single-user systems and local monitoring of smaller processes. It supports trend visualization, alarm handling, and data archiving, making it suitable for laboratory setups or single-line production systems.
- **WinCC Professional** - Intended for larger industrial systems with multiple production lines, several operators, and distributed access. It includes advanced functions such as centralized project management, multi-user environments, extended reporting, and integration with MES and ERP systems.
- **WinCC Unified** - The latest generation of SCADA/HMI solutions, developed for modern architectures with web-based interfaces. It enables access via standard browsers and mobile devices, supports scalable cloud integration, and provides high flexibility for Industry 4.0 applications.

All Siemens SCADA solutions are tightly integrated with the TIA Portal, ensuring seamless communication with PLCs, HMIs, and drives. They provide engineers with an efficient development environment for visualization, diagnostics, and process control [4].

3 Control System Setup

The project was carried out on a laboratory model of a water level control system, which served as the basis for implementing and testing the SCADA interface. The setup consists of the following main components:

- **Acrylic tank** – additionally equipped with a measuring scale, which allows monitoring of the water height.
- **Outlet at the bottom of the tank** – simulates a disturbance in the system (constant water outflow).
- **Water inlet** – depends on the valve setting, which is controlled by the output signal from the PLC based on the PID algorithm. The valve has a linear flow characteristic proportional to the actuator stroke, which enables effective control of the water supply into the system.
- **Level sensor (float)** – a mechanical float is connected through a lever system to a sensor that converts displacement into an electrical signal. The float characteristic as well as the calibration of the system were performed beforehand.
- **Recirculation system** – using a pump, the outflowing water from the collection tank, where water from the acrylic tank is discharged, is returned to the reservoir at the top of the frame.
- **PLC (Programmable Logic Controller)** – executes the basic control logic of the system and enables automatic water level regulation using the PID algorithm.
- **HMI (Human-Machine Interface)** – provides local supervision of the system operation and monitoring of basic process variables.

Figure 2: Control system

3.1 Control Logic

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The process is controlled by a PID regulator implemented in the PLC program. The sensor provides the measured water level, which is compared to a reference setpoint. The PID block calculates the control signal (LMN), which is then used to drive the control valve. This ensures that the actual water level follows the desired value with minimal steady-state error and stable dynamics.

3.2 System Operation

During operation, water flows into the tank, and the control valve regulates the outflow according to the controller output. If the water level rises above the setpoint, the valve opens further to reduce the level. Conversely, if the level drops below the setpoint, the valve closes to retain more water.

The HMI panel allows the operator to monitor the process locally and adjust basic parameters such as the setpoint value.

4 Project Work

The practical part of this project focused on upgrading the existing water level control system with a SCADA interface in the TIA Portal environment. The original control logic, based on a PID controller in the Siemens S7-1500 PLC, remained unchanged.

4.1 Adding the SCADA System to the Existing Project

The first step was to extend the existing project, which already contained the PLC (S7-1500 controller) and the HMI panel, with a new PC Station. Within this station, the module WinCC Runtime Advanced was inserted.

In order to enable communication, the module IE General was added as a network adapter. The IP address and subnet mask were configured to match the existing PROFINET network, ensuring that the SCADA station could exchange data with the PLC and HMI.

After configuration, the WinCC module was connected to the controller and HMI by creating a communication link in the Connections view. This link ensures that all variables defined in the PLC tag table are also available for visualization in SCADA.

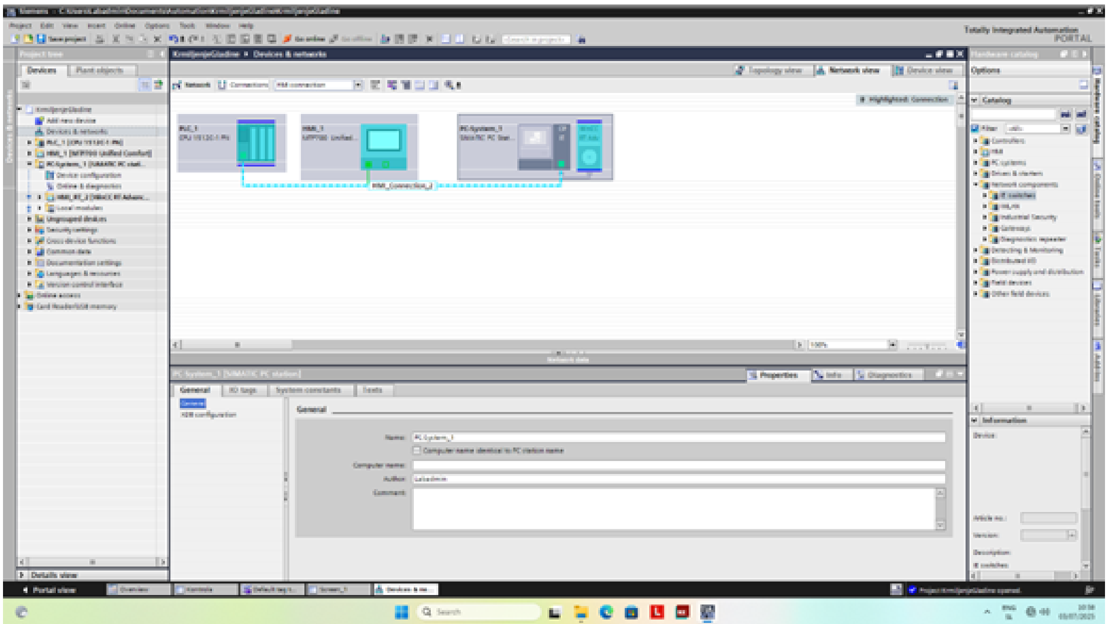

Figure 3: Connecting WinCC with PLC and HMI modules

4.2 Design of the SCADA Interface

Once the communication was configured, the design of the graphical interface could begin. A new screen was created in the Screens section of the WinCC module, serving as the main process overview.

- **Tank visualization:** A vertical bar element was used to represent the water level. Its fill value was dynamically linked to the sensor tag, allowing the level to rise or fall on the screen according to real-time measurements. The color of the bar was set to change when certain alarm thresholds were exceeded (e.g., red for overflow, yellow for low level).

- **Valve indicator and control:** An icon representing the outlet valve was inserted. The icon's state (open/closed) was directly linked to the controller output signal. In addition, animation was applied so that the symbol visually changes depending on the signal value.

- **Input/Output fields:** Numeric fields were added for the operator to view process values (e.g., measured level) and to enter parameters such as alarm thresholds. The fields were linked to PLC tags, with defined engineering units and formatting for clarity.
- **Alarm lights:** Small circular indicators were included to provide a quick overview of alarm conditions. These lights were color-coded and linked to Boolean alarm variables generated by the PLC program.
- **Navigation buttons:** Simple graphical buttons were placed at the bottom of the screen to allow switching between the main process screen and the secondary data screen.

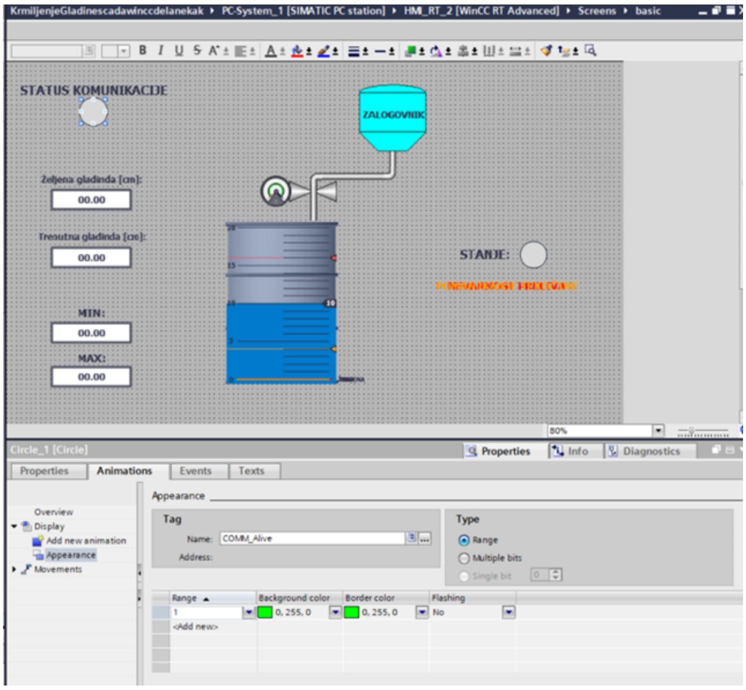

Figure 4: Main SCADA screen

4.3 Design of the Secondary Screen

In addition to the main overview, a secondary screen was created to provide advanced data monitoring and analysis. This screen is dedicated to historical process values and alarm management.

The main elements included:

- **Trend Control:** A chart element was inserted to visualize historical data of selected variables. In this project, the water level and valve actuation signal were chosen. The trend chart was configured with time-based axes, enabling the operator to review system behavior over both short and long periods. The scaling of the axes was adjusted to match the expected range of values.
- **Data Archiving:** To support the trend display, the SCADA system was configured to store selected process variables in the internal archive. This allows the operator to review past behavior even after the process has been running for a longer time.
- **Alarm table:** A table element was added to list active and historical alarms. Each alarm entry includes a timestamp, description, and state (active/acknowledged). This feature provides traceability and helps in diagnosing abnormal conditions.
- **Navigation buttons:** Similar to the main screen, buttons were included to return to the overview or switch to other process views.

This data screen complements the main screen by offering not just real-time visualization but also historical insight, which is crucial for process optimization and troubleshooting.

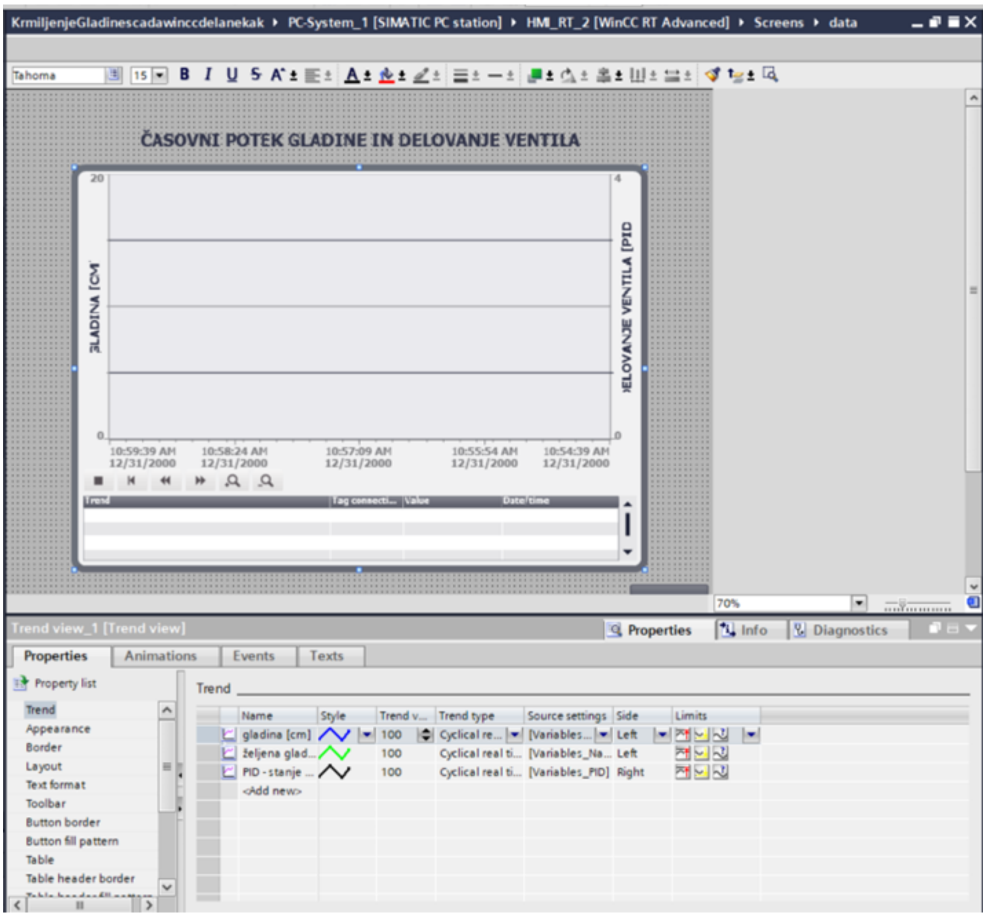

Figure 5: Creation of the trend chart

4.4 System Testing

After completing the design, the project was downloaded to the PLC, and the SCADA runtime was launched on the PC station. During testing, the following aspects were verified:

- **Communication:** The connection between the PLC, HMI, and SCADA was tested by observing whether real-time values from the PLC appeared correctly on the SCADA screens.
- **Main screen operation:** The tank level and valve indicators were checked against the actual process values. Alarms were triggered intentionally (by simulating low and high water levels) to confirm correct color changes and alarm notifications.
- **Data screen operation:** The trend chart was observed over time to ensure proper recording of archived values. Alarm events were logged in the alarm table, confirming that the system could store and recall historical data.
- **User interaction:** Input fields for setting alarm thresholds were tested to verify that operator adjustments were correctly transferred to the PLC program.

The tests confirmed that the SCADA system functioned as intended: it displayed real-time process data, triggered alarms at the right conditions, archived values for later analysis, and provided an intuitive interface for operators.

5 Results

The upgraded system with the integrated SCADA interface was successfully implemented and tested in the laboratory environment. The results confirm that the SCADA extension significantly improves process transparency and operator interaction compared to the original HMI-only configuration.

5.1 Main SCADA Screen

The main visualization screen provides a clear representation of the tank, the measured water level, and the valve status. Color-coded indicators show system states, while alarm signals notify the operator about critical conditions such as overflow or insufficient water.

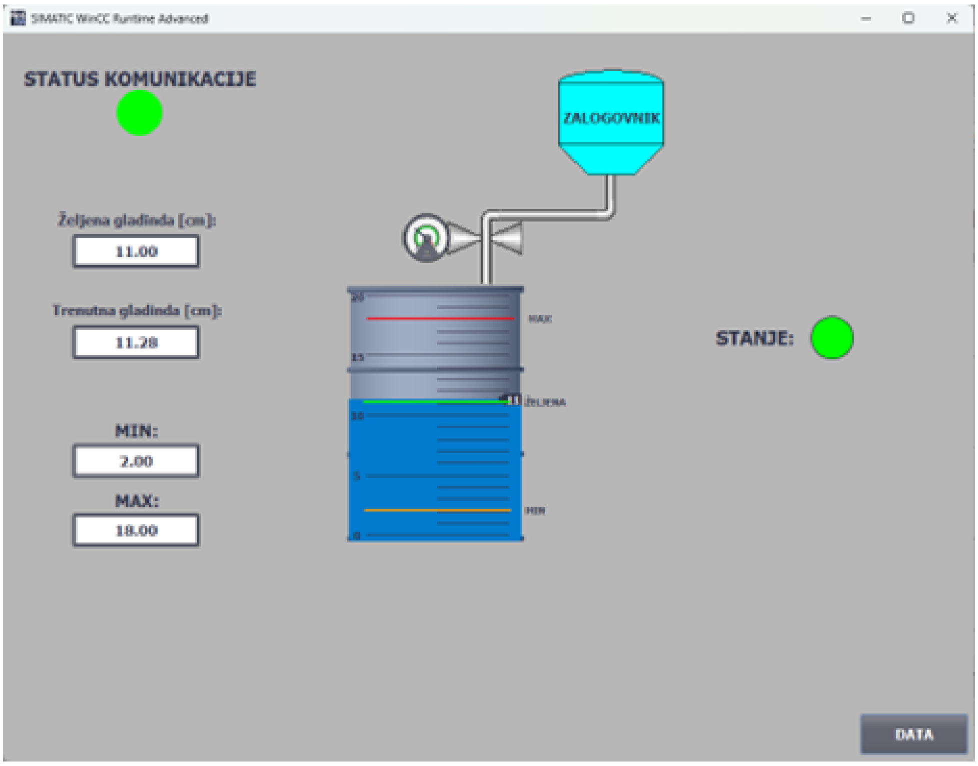

Figure 6: SCADA screen in normal operating conditions

The SCADA system successfully triggers alarms when process variables exceed predefined thresholds. The alarm messages are clearly visualized on the screen, making it easier for the operator to react in time and avoid critical system conditions.

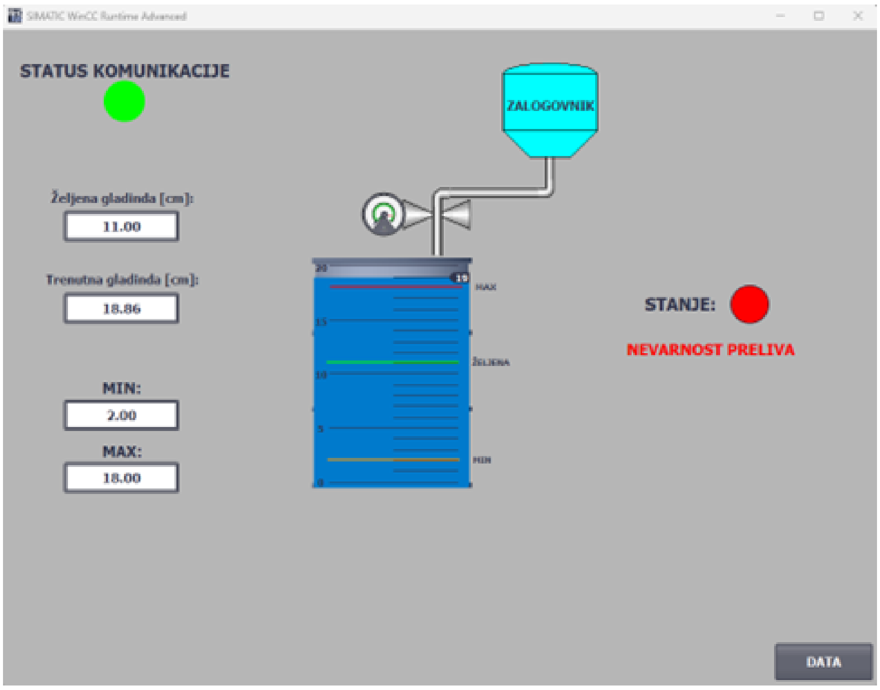

Figure 7: SCADA screen in abnormal conditions – Overflow

5.2 Trend View and Data Archiving

A dedicated trend view enables monitoring of historical data. The graph displays the time-dependent changes of water level and valve opening, allowing operators to analyze system dynamics and verify controller performance. Data archiving ensures that historical records can be used for further optimization or troubleshooting.

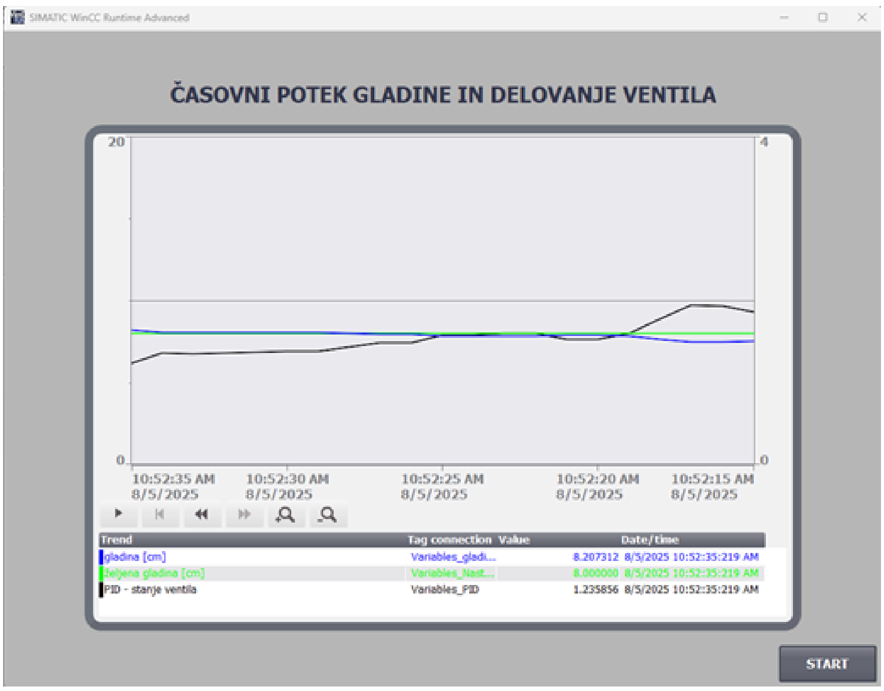

Figure 8: Trend chart showing the water level and valve actuation

6 Conclusion

The main objective of this project was to upgrade the existing water level control system by integrating a SCADA interface (WinCC Runtime Advanced) into the TIA Portal environment. The original PLC control program with a PID regulator remained unchanged, while the SCADA layer added significant value to the system.

The results demonstrated that SCADA integration provides:

- **Improved process transparency:** Operators can observe the entire system on a computer screen rather than relying solely on the local HMI panel.
- **Real-time monitoring and alarms:** Ensuring timely operator response to critical situations such as overflow or insufficient water level.
- **Data archiving and trend visualization:** Enabling analysis of system behavior and offering a basis for further optimization.
- **Enhanced user experience:** With a clearer and more intuitive interface.

Despite these advantages, the chosen solution (WinCC Runtime Advanced) is primarily suitable for single-line systems with local access. For larger industrial applications involving multiple production lines, distributed users, or remote access, WinCC Professional or the WinCC Unified platform would be a more appropriate choice.

In conclusion, the SCADA upgrade successfully achieved its objectives. It improved system supervision without altering the underlying control logic and demonstrated the practical benefits of SCADA technology in laboratory conditions. Furthermore, the project provides a foundation for future expansions into more complex industrial environments and illustrates the importance of SCADA solutions within modern Industry 4.0 concepts.

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