

COMPREHENSIVE AUTOMATION SYSTEM FOR LEVEL PROCESS OPTIMIZATION

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Abstract— In order to integrate Supervisory Control and Data Acquisition (SCADA), Human-Machine Interface (HMI), and Programmable Logic Controllers (PLC) without the use of physical sensors, this project entails creating a simulation model for level control using Siemens TIA Portal. The goal is to simulate the regulation and tracking of liquid levels in a tank, a procedure that is frequently employed in industrial settings like chemical production and water treatment. In this configuration, control logic and system behavior may be tested in a fully digital manner by simulating sensor feedback and actuator reactions in a virtual environment created using the TIA Portal. The PLC program is designed to regulate liquid levels by maintaining levels within specified limits based on simulated data. SCADA functionality provides centralized monitoring, data logging, and trend visualization, enabling real-time insights into level fluctuations and system performance. The HMI offers an intuitive interface for operators to monitor the process, adjust setpoints, and respond to alarms within the simulated environment. This simulation model demonstrates the integration and functionality of a PLC-SCADA-HMI system using TIA Portal, allowing for efficient testing, validation, and optimization of control logic without requiring physical sensors or hardware.

Keywords— PLC, SCADA, HMI, level control, Siemens TIA Portal, simulation, maintenance, centralized monitoring, regulation, data logging, visualization, system performance, optimization.

I. INTRODUCTION

One of the most important problems facing the world today is the management of water resources. In many areas, such as residential use, industry, and agriculture, water is essential. However, these sectors have seen significant waste due to the careless use of water. In order to reduce human mistake and guarantee constant tank liquid level monitoring, automation is essential. Automation systems successfully reduce water waste and scarcity issues by ensuring that the water level is maintained at a suitable level [1].

A computerized tool used to automate mechanical operations is called a Programmable Logic Controller (PLC). Its main purpose is to enable industrial automation by converting conventional techniques like "Relay Logic" or "Wired Logic" into a specific programming language called "Ladder Logic". PLCs, in contrast to traditional computers, are made especially to manage various input and output configurations, function in a wide range of temperatures, tolerate electrical noise, and survive shocks and vibrations.

In order to overcome these obstacles, this project uses Siemens TIA Portal to create a fully virtual simulation of a level control system, doing away with the requirement for

actual sensors and actuators. By simulating level feedback and actuator responses, the TIA Portal facilitates the development and testing of PLC, SCADA, and HMI integration in a digital setting. Without the need for real components, this technology offers a flexible and affordable way to experiment with different scenarios, validate control logic, and fine-tune system parameters [2].

By accepting simulated input values and modifying virtual valves to maintain desired levels within predetermined bounds, the PLC manages virtual level control through this simulation. While the HMI provides operators with an easy-to-use interface to assess system status, modify control setpoints, and react to simulated alarm circumstances, the SCADA system provides centralized monitoring, real-time data logging, and analytical capabilities. This project highlights the benefits of virtual testing in automation systems and provides a useful foundation for industrial-level control applications, showcasing the efficacy of a fully digital simulation in the TIA Portal.

II. LITERATURE SURVEY

In the realm of existing literature, various perspectives have been explored, providing a rich tapestry of insights into level controlling and visualizing. This literature survey navigates through these scholarly contributions, offering a comprehensive overview and critical analysis that forms the foundation for understanding the level controlling in a modern way.

Published in the International Journal of Advanced Research in Electrical, Electronic, Instrumentation, and Engineering (IJAREEIE) in 2017 by Prof. K. C. Mule. "Design and Implementation of Water Level Management Using PLC and SCADA Visualization. The researcher proposed to develop an experimental setup of PLC and SCADA based water level control. The system automatically controls water level with help of PLC. Three level sensors (float switches) are used to provide level data to the PLC. The PLC is connected to float switches which are placed in tank to generate control signals and turn ON and OFF the pump. Thus, the level in the tank is constantly monitored and brought to a constant level. The automation is further enhanced by constant monitoring using SCADA screen which is connected to the PLC. The proposed model can effectively supervise level control in multiple tanks. In this paper, the aim for automating the water level control process has been achieved successfully. No human supervision was necessary. The PLC S7-1200 also

offers many Input Output ports. Hence this single system can control many tanks making it efficient and cost effective [3].

In journal of IOSR journal of Electrical and Electronic engineering (IOSR-EEE) Rishabh Das proposed a system called “Automation of Tank level using PLC and Establishment of HMI by SCADA”. In the proposed system an examination of the components and modeling needed to create an automated level control system using a programmable logic controller (PLC). The HMI was developed along with Supervisory Control and Data Acquisition (SCADA). The level control in several tanks can be efficiently supervised by the suggested model. The level data was supplied to the PLC by three level sensors. PLC turned a pump on and off by using this data to make the necessary judgments. Additionally, there was a manual switch to override the automated mechanism. The primary decision-making module was the SIMATIC S7-300 universal controller. The necessary Human Machine Interface (HMI) was created by implementing the system in SCADA. The float sensors model can be used to make changes. This project's goal of automating the level control procedure was easily accomplished. There was no need for human supervision. The system indicated the precise level without the usage of float sensors. As a result, the float sensors' drawbacks—unwanted vibrations and expensive cost—were readily resolved. Numerous input/output ports are also available on the Siemens SIMANTIC S7-300 PLC. As a result, this system is effective and economical because it can independently control up to 50 tanks [4].

The International Journal of Innovative Research in Science, Engineering, and Technology (An ISSN 2395-1052 Certified Journal) published a paper by Virendra Patel in November 2020. The paper contains project titled as “PLC Based Water Control System”, in this project Siemens plc is the water level control system that I have utilized. Since plc is a relatively basic programming language, a four-float switch sensor was employed in this project. An top tank and two float switch sensors are used. Bottom tank switch sensor is employed. This platform is where the need to reduce or monitor water waste. Water is a free gift from nature, but because humans need it free gift from nature, but because humans need it accessibility or adequacy [2].

Furthermore, to effectively address this issue of waste, a water level controller must be built. This will prevent needless water waste because it will ensure a reasonable amount of water that can be utilized at any time. Effort in this project has been developed to build a water controller that can of managing the operation of the electric water pumping motor in consider turning on or off at a specific water level in the reservoirs or storage tanks. Additionally, this project provides the clarity of the benefits of utilizing an automated technique for level of control over manual or human control methods.

Published in the journal of Pakistan Journal of Engineering Technology and Sciences (PJETS) in 2016 by Osama Mahafooz, “Project Review on Water level Sensing using PLC, he stated that any process or system that requires the measurement of a specific amount of water can use this prototype to transmit the precise amount of water that is desired. The autonomous procedure of our research is what makes it flexible in the industry. Our study is more likely to be accepted because it is very inexpensive and easy to use. Also, the paper discussed that in the modern world, industries

can only expand by pushing themselves to develop technologically and by modernizing their equipment and facilities. The author suggestion is to create an automated water level plant, which is now done manually in Pakistani industry [12].

III. PROPOSED SYSTEM

“In this project paper, we present a comprehensive automation system by integrating PLC, SCADA and HMI. The proposed system to control water level and being able to visualizing it in SCADA and HMI is an a one-stop modern solution to enhance the controlling of the water level, as it reduces the human effort, at a very negligible price using Siemens PLC Simulator. The comprehensive automation system for water level controlling helps to ~~reduce~~ the time and cost involved in the industry which comes along with the integration of plc, scada and hmi for process optimization thereby increasing the productivity and efficiency in controlling. Our innovative approach integrates PLC, SCADA and HMI technologies and strategic methods to provide a holistic solution for overcoming challenges in the industries where level controlling is the at most top priority which may cause a great loss for the industry if not taken care of it and may also cause loss of life's of the workers working in the industry. Join us as we delve into the details of our proposed system, showcasing its capacity to propel research, enhance efficiency, and contribute to the ongoing development of controlling the level [2,9].

The incorporation of set up not only ensures cost-effectiveness but also facilitates seamless interaction. The Block diagram of the proposed model is shown in Fig.1.

A. METHODOLOGY

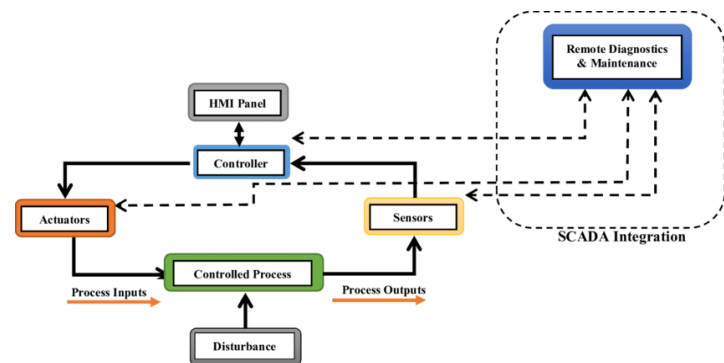


Fig .1. Block Diagram of Proposed Model.

B. SOFTWARE COMPONENTS

The project has been done as a digital project which includes simulation of logic-by-logic controller and testing it by virtual environment in TIA portal [13].

Siemens PLC (S7-1200):

Here's an overview of the S7-1200 PLC and its integration within TIA Portal. For small to medium-sized automation applications in sectors including manufacturing, process control, and infrastructure, Siemens' S7-1200 PLC is a strong, portable controller. Because of its modular design, users can readily add more I/O, communication, and specialist modules to the system for customized functionality. The S7-1200's built-in Ethernet connector allows it to easily connect to other devices and exchange data with SCADA and HMI systems. Because of its durability, versatility, and fast processing speed, this PLC is well-suited for real-time applications that demand dependable control [5,13].

When used in conjunction with Siemens' TIA Portal software, the S7-1200 provides a simplified, intuitive environment for testing, configuration, and programming. Different degrees of competence can use TIA Portal since it supports a variety of programming languages, such as Structured Text (ST), Function Block Diagram (FBD), and Ladder Diagram (LAD). Before deploying programs to the physical hardware, users can test and troubleshoot them using the software's integrated simulation and diagnostics capabilities, which reduces errors and downtime. The S7-1200 and TIA Portal work together to offer a scalable, effective automation solution that can be easily adjusted to meet changing project needs.



Fig. 2. Siemens S7-1200 PLC

Siemens PLC Simulator:

Without requiring actual hardware, users can test and debug PLC programs using the Siemens PLC Simulator, also known as S7-PLCSIM, a simulation tool available through the Siemens TIA Portal. Control logic can be developed, tested, and optimized in this virtual environment, which can assist minimize errors and guarantee a seamless deployment after the program is moved to the real PLC. TIA Portal's programming and configuration tools are frequently used in conjunction with S7-PLCSIM, which is compatible with Siemens S7-1200, S7-1500, and S7-300 PLCs [14,15].

Creating and simulating complicated control situations, real-time testing, and step-by-step debugging are some of the Siemens PLC Simulator's primary capabilities. In a secure, regulated setting, users may watch how their PLC programs react to simulated inputs, keep an eye on output signals, and modify code in response to performance. Because it enables users to find and fix problems early in the development process, this tool is useful for pre-deployment testing, training, and teaching. This reduces downtime and improves reliability in real-world systems.

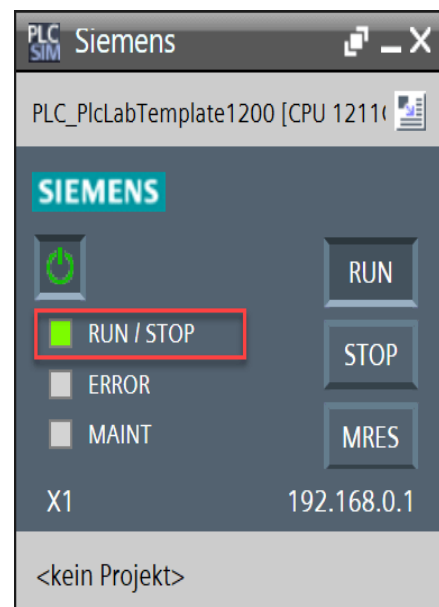


Fig. 3. Siemens PLC Simulator

Human Machine Interface (HMI):

Siemens PLCs such as the S7-1200 and S7-1500 may have their operator interfaces designed, configured, and monitored by users thanks to the smooth integration of Human-Machine Interface (HMI) technology in TIA Portal. By offering real-time data visualization, control options, and diagnostics to guarantee seamless operation and prompt resolution of any problems on the factory floor, HMI systems act as a link between the operator and the automated system. A variety of Siemens HMI devices, including Basic Panels, Comfort Panels, and Mobile Panels, are supported by TIA Portal, enabling developers to design customized user interfaces for particular application requirements [15].

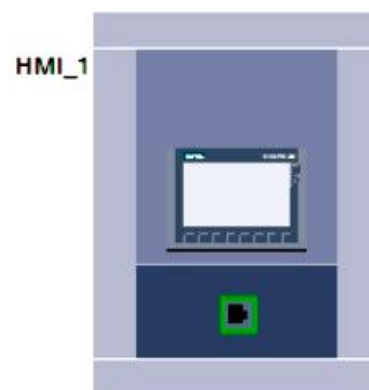


Fig. 4. Human Machine Interface (HMI)

Drag-and-drop graphical components including as buttons, sliders, gauges, and alarms are used for creating HMIs in TIA Portal in order to show data and make user interactions easier. Additionally, TIA Portal offers strong setup features including trends, recipes, and alarms. These make it simple to set up alarms, monitor historical data, and modify system settings. To guarantee that every user has access to the appropriate data and controls, HMI panels made in TIA Portal can be tailored for

multiple user levels (such as operator, technician, and supervisor) with varying permissions. The software is an effective and potent tool for managing industrial automation connections since it makes it simple for the HMI and PLC to exchange data, removing the need for complicated configuration and cutting down on setup time [8,11].

An HMI (Human-Machine Interface) is crucial to our level control project because it offers features like data logging, alarm management, and real-time monitoring. By displaying liquid levels via sensors, it enables operators to maintain levels within acceptable bounds and get early alerts for possible problems. Additionally, the HMI records data to monitor past patterns, aiding in maintenance and troubleshooting. If levels above predetermined thresholds, it can sound an alarm, allowing for prompt remedial measures to avoid shortages or overflows.

Secondary Data Acquisition System (SCADA):

Monitoring, data visualization, and alarm management are the main roles of SCADA in a level control project when there are no valves or actuators and the sensor serves as a start button. SCADA records the event when the sensor identifies a particular level and serves as a trigger (or "start button"), starting data collecting and display so that operators may monitor tank or vessel levels [10].

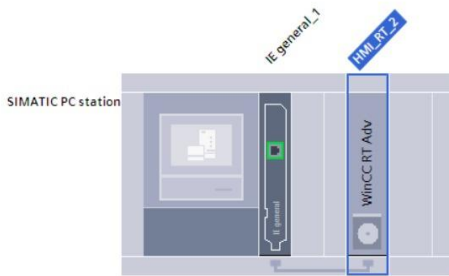


Fig. 5. SCADA System for our project

SCADA also offers **data logging** and **trend analysis** capabilities, recording every start event to provide insights into level patterns over time. This historical data aids in maintenance and planning, allowing operators to identify changes in level behavior. Additionally, SCADA can be set to trigger alarms when levels approach certain thresholds, ensuring that operators are promptly notified of any critical conditions. This setup helps maintain safety and provides useful insights for future adjustments or manual actions, even in a simple level control project.

Siemens Tia Portal V16:

An engineering software platform called Siemens TIA Portal (Totally Integrated Automation) V16 makes it easier to integrate and manage automation systems in a quick and effective way. With this edition, users can easily develop, run, and maintain their automation projects by combining many programming, configuration, and diagnostic tools into a single interface. With the help of the robust features in TIA Portal V16, engineers can easily and highly adaptably design sophisticated automation solutions. It is perfect for large-scale industrial applications where scalability and dependability are

crucial due to its support for a variety of PLCs (Programmable Logic Controllers), HMIs (Human-Machine Interfaces), and network setups [7].

The improved integration of sophisticated features for Industry 4.0 and IIoT (Industrial Internet of Things) applications is one of TIA Portal V16's most notable features. With the help of the platform, customers may more successfully apply edge computing, data logging, and real-time monitoring, all of which support predictive maintenance and increased operational effectiveness. Additionally, TIA Portal V16 facilitates easy communication with cloud-based systems, which can yield insightful information through data processing and analytics. Siemens has also concentrated on improving the user experience by introducing collaboration features and upgrading the UI, which allow teams to collaborate remotely on challenging tasks. TIA Portal V16 is a reliable option for contemporary automation requirements because of its capability and user-friendliness [10].

IV. RESULTS

In the envisioned setup depicted in Fig.6. The PLC, SCADA and HMI are integrated and the process for the integration is as follows:

There are numerous crucial phases involved in integrating PLC, SCADA, and HMI simulation in TIA Portal: Create a new project first, then add the required Siemens PLC and HMI devices to the project tree. Next, configure the hardware of the PLC and program the control logic using Structured Text, Function Block Diagram, or Ladder Logic. Then, for real-time monitoring and control, incorporate graphical components into the HMI panels that are connected to PLC tags. Next, define data points and communication protocols to enable the SCADA system to communicate with the PLC. Use the PLCSIM tool to verify the control logic and simulate PLC operation when the network configuration is finished, including IP address assignment. Make sure the HMI responds appropriately and shows accurate data.

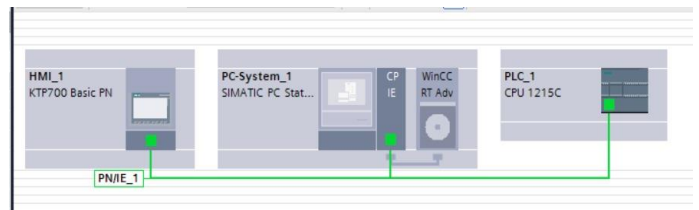


Fig. 6. Integration of PLC, SCADA and HMI for our project

The integration of PLC, SCADA, and HMI enables efficient monitoring and management of liquid levels in tanks or vessels in a level control project created in TIA Portal without actuators or valves. The PLC can track liquid levels in real time since it is configured to receive data from level sensors, which are the main input source. Operators may easily access current levels, historical trends, and warning notifications by visualizing this data on user-friendly panels via the HMI. The control logic is made simpler by the lack of actuators or valves, concentrating only on monitoring and alerting, which aids in maintaining safe operating limits and offers information for preventive actions.

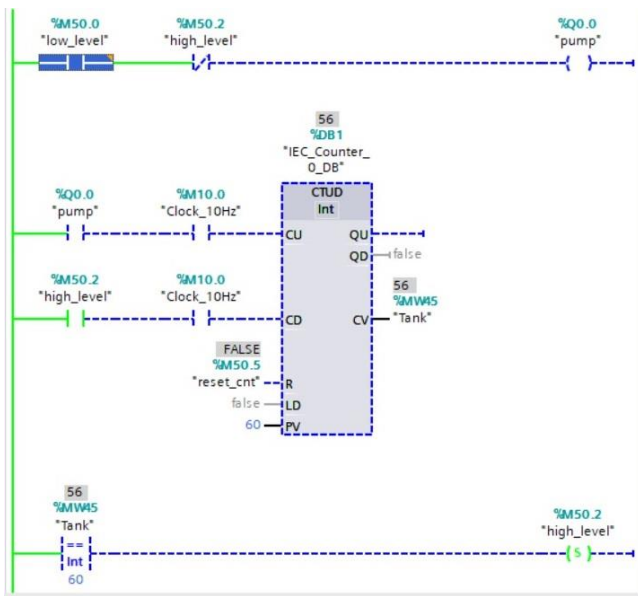


Fig. 7. Ladder Diagram of the System

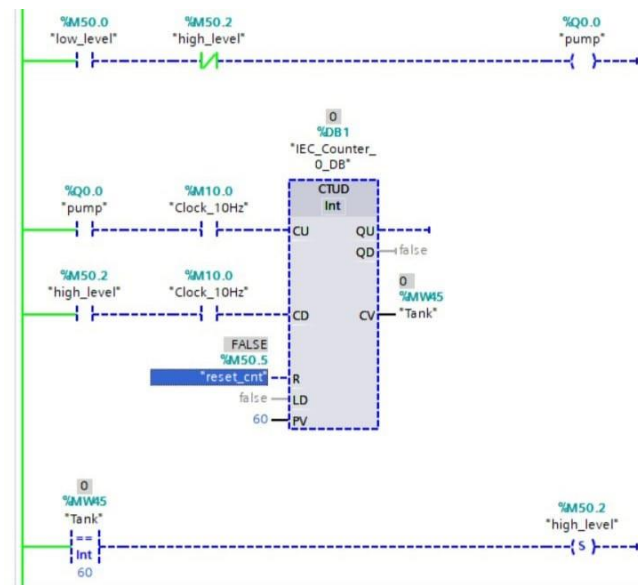


Fig. 8. Ladder Output of the System

By combining data from the PLC and providing thorough supervision of the level control procedure, the SCADA system is essential to expanding the project's potential. The SCADA system's ability to continually log historical data facilitates trend analysis, which helps operators make well-informed decisions regarding system performance and maintenance. Alarms are set up to notify staff members when liquid levels go close to important thresholds, guaranteeing prompt action to avert possible problems. Even in a more straightforward configuration without active control components, the combination of PLC, SCADA, and HMI produces a strong monitoring solution that improves safety, operational effectiveness, and data-driven decision-making.

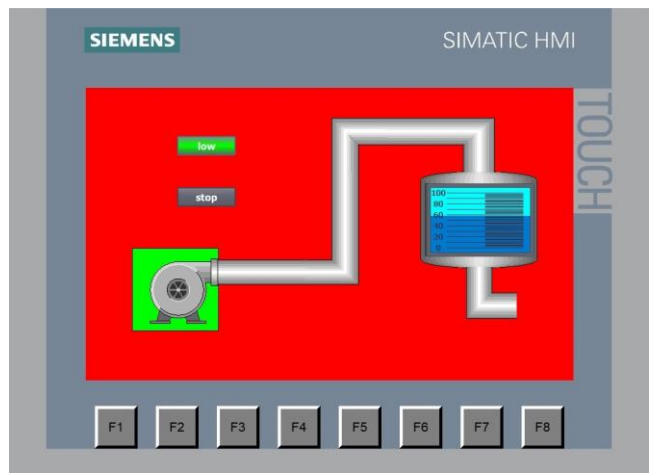


Fig. 9. Output in HMI screen in Animated form

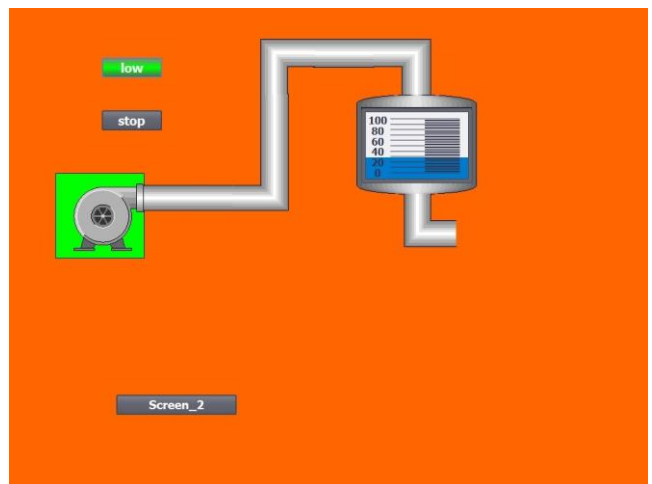


Fig. 10. Water level being controlled and that is shown in SCADA screen

V. FUTURE WORK

Adding more complex simulation scenarios could be a major improvement for future work on a level control simulation project in TIA Portal that combines PLC, SCADA, and HMI without actuators or valves. The project could offer operators a thorough training environment by extending the simulation capabilities to incorporate different disturbances and failure types. To assess the system's reaction, this would entail modeling situations like sensor failures, abrupt changes in liquid input or output levels, and alarm conditions. In addition to increasing operator readiness, this testing would improve the control logic and alarm management techniques, guaranteeing that the system is resilient in a variety of scenarios.

Future research can also concentrate on incorporating dashboards and data visualization tools into the SCADA system to offer more in-depth understanding of the simulation outcomes. Key performance indicators (KPIs) pertaining to level control efficiency, predictive analytics for maintenance, and sophisticated graphical depictions of data trends could all fall under this category. By enabling operators to identify problems or recommend improvements based on their experiences during simulations, user feedback methods could also help with ongoing improvement inside the HMI. In general, the goal of these upcoming improvements is to develop a more engaging and instructive simulation environment that will promote proactive monitoring.

CONCLUSION

Tosumup,thelevelcontrolsimulationprojectcreatedin TIA Portal shows a reliable method for keeping an eye on and controlling liquid levels in a controlled setting. It integrates PLC, SCADA, and HMI without the need for actuators or valves. The system efficiently gives operators vital information about the operational state by utilizing real-time data from level sensors. This allows operators to make well-informed decisions and react quickly to any alerts or notifications. The project demonstrates how well sophisticated software tools can be used to create an intuitive user interface that makes it simple for operators to see data patterns and keep operating conditions safe.

Additionally, this simulation project provides a useful foundation for upcoming improvements, opening the door for more complex user interactions and analysis. Exciting prospects for ongoing enhancement of system performance and operator training are presented by the possibility of integrating sophisticated simulation scenarios, predictive maintenance analytics, and interactive dashboards. All things considered, the level control project's successful integration of PLC, SCADA, and HMI not only demonstrates the possibilities of automation technology today, but it also lays the groundwork for future advancements that could further improve operational efficiency and dependability in industrial processes.

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