Design and Development of Human Machine Interface (HMI) Simulation for Industrial Water Management System

P. Vijayalakshmi, T. Sivakumar, P. Venkateswari

Department of Electronics and Communication,

Rathinavel Subramaniam College (RVS), Sulur

Abstract

Industries are growing more complex and better equipped to handle multiple industrial processing and management operations in one place. In the absence of measures such as water, electricity, oxygen level, temperature etc. an industry will also be making losses. A certain level of measurement of different parameters in an industry will cause an increase in the profit gain and employment, and also minimize health risks. This water management system is more advantageous to business concerning the manufacture of vehicle, tire and chemical production. Presenting here is a creation of a simulation of Human Machine Interface (HMI) design for an industrial water management system with an ability to gauge and track the water level in each of the tanks (4000 litres/tank), regulate and oversee electronically-controlled motors physically embedded in all tanks (each tank contains 6 motors), to control the water outlet and measure its pressure using the Pressure Transmitter (PT) with the help of PLC. This particular simulation is developed in HMI to develop in the context of Industrial Internet of Things (IIoT). In future, the designs of graphics embedded HMI's are imported in a single window in desktop and also projected in mobile App using Vijeo Designer Air plus.

Keywords: PLC, Human Machine Interface (HMI), Industrial Internet of Things (IIoT)

1. Introduction

Automation in industrial practices enhances efficiency and competitiveness by combining machinery, software, and methods to produce better quality work faster and at a lower cost [1]. Ford automotive engineer in the 1940s developed automation using electromechanical devices, implementing simple motion playback through relays, timers, logic, and operator feedback [2]. Automation is a process that sets human decision-making mechanisms aside for logical programming commands and mechanized equipment, and intended to replace manual functions while allowing humans to accomplish physical needs [3]. To achieve this, automation offers more than does mechanization by reducing human sensory and mental requirements while maximising extremity [4]. Programmable logic controllers (PLCs), a large factor in the ability of companies to be extraordinarily efficient today, first came into use in the 1960s [5]. PLCs are commonly used for controlling machinery on factory assembly lines, amusement park rides and other control systems such as PLC is specialize in automation technology not only its versatile but reliable and it can have a high level of magnification [6]. A lot of ways have been devised to efficiently automate industrial processes with PLCs. In some work, RFID technology was implemented in signalling emergency-type detection using a ladder logic program designed for control of a PLC [7, 8]. Automation can also be achieved by getting support from an Android mobile application and the LabVIEW dashboard app [9]. This is illustrated in the case of a simulated prototype use for beverage sector bottle filling process based on SCADA (Supervisory Control and Data Acquisition) [10-13] and PLC (Programmable Logic Controller) [14, 15], that should do its job by filling bottles with few specified containers, by using various liquid formulations. The classical Distributed Control Systems (DCS) and programmable logic controllers (PLCs) are being used for cement manufacturing applications [16]. The state of the art in PLC/PAC and edge controllers employed in industrial automation is studied [17]. Some other platforms have emphasized non-continuous (on/off) control that is more typical in the industrial field [18]. To verify the performance of the controller, simulation studies are carried out in MATLAB/SIMULINK environment [19, 20]. The curves of the multi-crystalline PV panel type Kyocera KC200GT datasheet [19] will be compared with plotted I-V and P-V characteristic curves in Siemens Simatic WinCC flexible [21]. An entirely new type of PLC and SCADA for Smart Industrial Control Services (SICS) [22]. Industrial control applications and plant monitoring techniques are being covered in article [23]. The plant engineer knows how to pick an HMI [24] for a PLC-based automation system [25]. Human Machine Interface (HHI) is also used for teaching of industrial automation engineering [26]. Finally, the SCADA system (a mix of a Programmable Logical Controller PLC and the Human Machine Interface HMI) is utilized to copy and screen the gauging and pack stuffing process [27]. IoT, AI and human-machine interface and big data platform-cloud services through large language model: The intelligent factory (here also the machine becomes smart) achieves this by networking relevant components in terms of materials, energy flows to the cloud within sub-second capabilities [28]. The paper discusses the importance of decentralized production control in Industry 4.0, [29] emphasizing the need for high product customization while reducing reaction time for competitiveness and profit.

2. Literature survey

Aitor Ardanzaa's 2018 study reveals three use cases for 3D printer-specific HMI [30], HMI-based real-time motor control, and a digital twin of a robotic arm, analysing hardware usage under different task loads. S Fitriani's 2020 work aims to create an HMI simulator [31] using Visual Basic to model controlling processes in plants, converting analogue data into SCADA scale and displaying it. Dimitrios Mourtzis' 2023 concept of Humachine aims to define human-robot [32] capabilities and traits, fostering better human-machine interaction for a future that maximizes their respective abilities. Kartika 2022 research explores cellphones as a Human Machine Interface (HMI) [33] display in a conveyor control system with web server technology, a common feature in industrial systems. Shyr-Long Jeng 2021 demonstrated the SPA technique by transforming a traditional WINPC32 industrial controller [34] into a versatile Web-based HMI using GPX graphic user interface software. Shekhar Mehrotra's 2022 study offers ten recommendations for HMI design in driving automation systems [35], including auditory versus visual warnings, alert time, sensitivity, and position. Muhammad Saban's 2023 study presents a customized smart farming system using low-cost, low-power, and wide-range wireless sensor networks based on IoT [36], integrating LoRa connection with current Programmable Logic

Controllers via Simatic IOT2040. S Boobalan 2021 is a prototype designed to automate and control steam outflow from boiler units in power plants using a fuzzy logic-based PLC controller [37]. Adhy Kurnia Triatmaja 2024 highlights the significance of practical training in PLC education through a needs analysis, design, development, and testing of an IoT-based PLC Trainer [38]. Sarangapani 2020's control module detects faults, tolerates them, and switches components in sensitive areas. It can be combined with GSM for voice control and protective items [39]. Han-Chuan Hsieh's 2011 Internet of Things architecture integrates power line communication (PLC) and 3G networks [40] for scalability and practicality in supporting IoT applications, demonstrating their potential. Ti-An Chen 2022 developed a wireless Wi-Fi intelligent programmable IoT controller using the Theory of Constraints, capable of linking to and controlling PLCs [41]. Philipp Schmid plans to introduce a proof-of-work block chain in 2023 for PLC IoT ecosystem [42], enabling faster binary data transmission and logging, utilizing fewer resources.

3. Methodology

The research strategy involves designing, developing, and testing the HMI design in the PLC for the water management system through a series of methodological stages.

Human Machine Interaction (HMI) is a computer-assisted interface that integrates with an Industrial Control System (ICS) to provide information and controls for manufacturing processes. Its primary criteria are operation and resilience, with hardware designed for extreme weather conditions and software tested for crashes.

Existing HMI designer might uses one or two modes, manual or automated, depending on the operating conditions. In automated mode selection, the operator in-charge of the water management system is unable to adjust the process variable, because all are programmed and automated. The system will process it depending on the instructions that have previously been programmed into the system through the HMI [33] and PLC. However, in manual mode, the operator is allowed to adjust the process variable depending on present circumstances.

Based on the condition, the operator may be able to adjust the process variable depending on the operation in run-time, in this case, unable to change or modify the settings while they are set to automatic; however in this research it is capable of operating the HMI and PLC both automatically and manually. This is an additional feature in the suggested project design.

4. Block Diagram

Vijeo Designer was used to develop the simulation process that the operator uses for sending commands through the HMI, which is used to monitor and operate the whole industry. The driver receives the HMI signal once it has been configured with a PLC, which interprets the data and controls the motor and control valve to regulate the water flow.

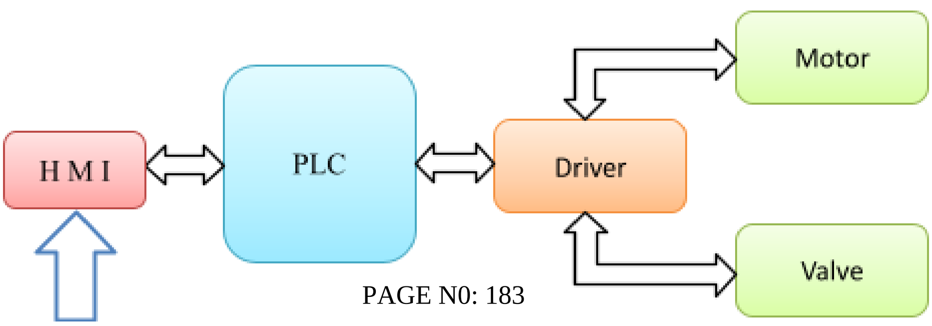

Fig. 1 Block diagram of the driver, PLC, HMI, and other control devices

Finally, the operator receives the processed data for monitoring and modifications. The automation of equipment and procedures is made possible by this integrated system, which improves reliability as well as productivity in an industry. Based on the application of an industry, the research work is focused on creating a Human Machine Interface (HMI) simulation technique for managing an industry through the use of a high quantity water management system, as shown in the Fig. 1 block diagram above.

5. Design and Implementation

The HMI should prioritize accessibility and simplicity for operators, using appropriate font styles, graphic colours, and design components. Effective data visualization, sensors, graphical representations, indicators, and real-time data can enhance comprehension and allow for future feature additions or modifications. Identify operator needs and processes for HMI monitoring to develop the control logic using programming languages to create a smooth interface between the HMI and PLC software. Examine PLC and HMI for reliability and ease of use to conduct user acceptability, integration, and unit testing which provides operator training and support materials.

Building a user-friendly interface can speed up the design process, but troubleshooting is necessary to ensure communication between PLC and HMI. Innovative approaches can adapt to changing requirements. Proper design and deployment can improve industrial process efficiency and safety by prioritizing user demands and adhering to systematic development procedures.

6. Human Machine Interface (HMI) Design

The Human Machine Interface, or HMI, is a technology that makes process operation and monitoring simpler. Here, the input and output variables are monitored by a tool called Vijeo Designer.

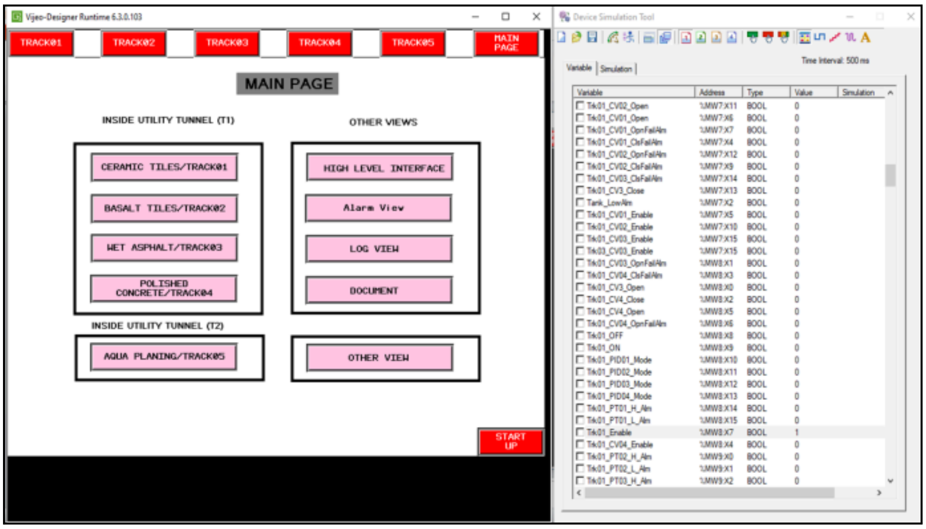

Fig. 2 The PLC is monitored and controlled via the main page of the Human Manual Interface (HMI) design in Vijeo Designer Runtime 6.3.0, developed by Schneider Electric Software.

The HMI system requires different software to operate and the variable can be monitored, such as the tank level, water temperature, valve position, and pressure transmitter sensor. The PLC Program, which is already coded in the PLC Controller, is to be mapped with the HMI design. Figure 2 represents the HMI's main page screen designed in Vijeo Designer 6.3.0 developed by Schneider Electric Software. Figure 2 represents two panels in a single page: the variable, address, type, and values are shown on the right panel, while the HMI simulation is shown on the left. With the help of this HMI design, each and every parameter that exists in the modules has a corresponding value that can be monitored and controlled. The purpose of this HMI design is to monitor and regulate industrial demands. If any changes happen in the devices which are connected with the PLC; then both the graphical and numerical representation of the changes will be provided in the single window. Although numerical representation is more significant for documentation purposes but, graphical representation is still preferable. To reduce the amount of effort required, this research project includes both graphical and numerical (variable) representations with accurate measurements.

As we previously stated, all automation processes are carried out both automatically and manually. Changes are represented in the HMI simulation image by a indicating in color in the panel image as well as the real-time alarms. A number of parameters are controlled and monitored by this automation, which includes the motor running status, motor trip status, motor pop-up window for manual or automatic operation, water tank high and low signal alarms signals and their corresponding pop-up window messages, pressure transmitter sensor valve control process, and acknowledgement panel. The following figure illustrates the automated mode of operation.

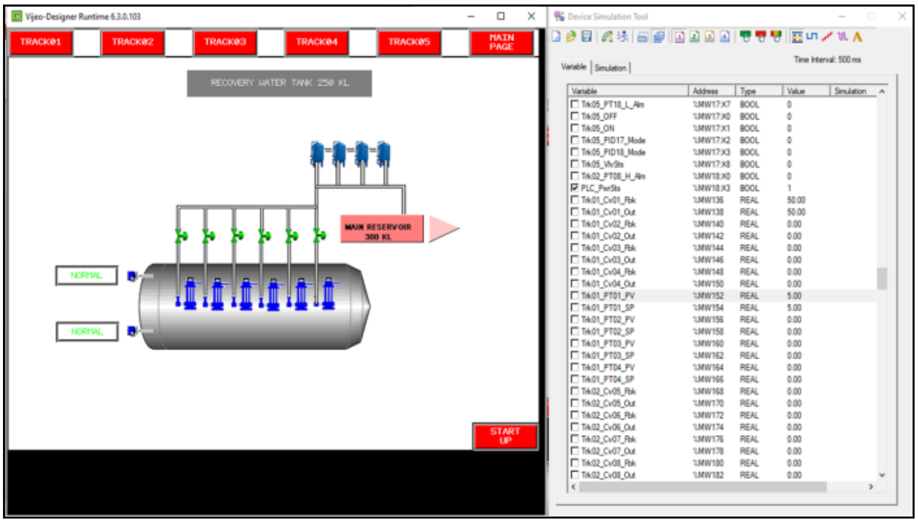

Fig. 3 Six motors in a single water tank, each of which has a pressure transmitter sensor to measure its control valve.

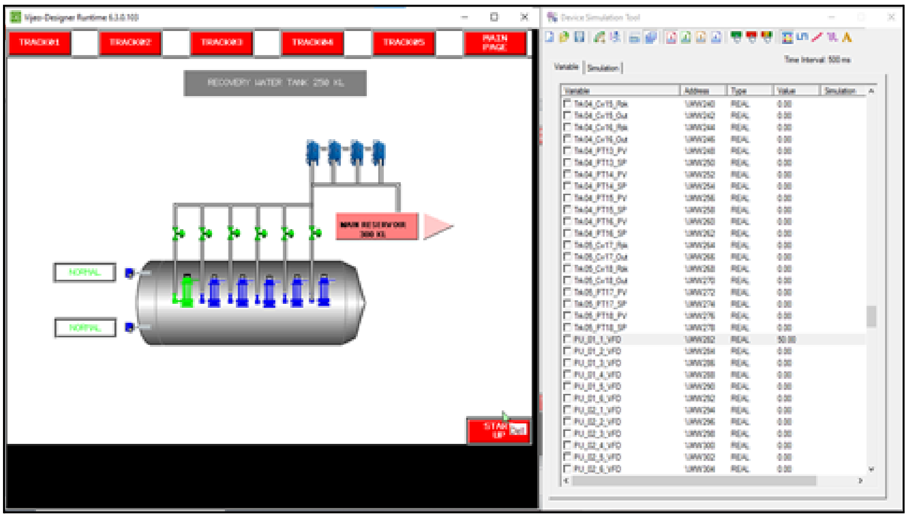

Fig. 4 Motor is in the operating stage, which is shown in GREEN, as well as the change in variables and their values for documentation purposes.

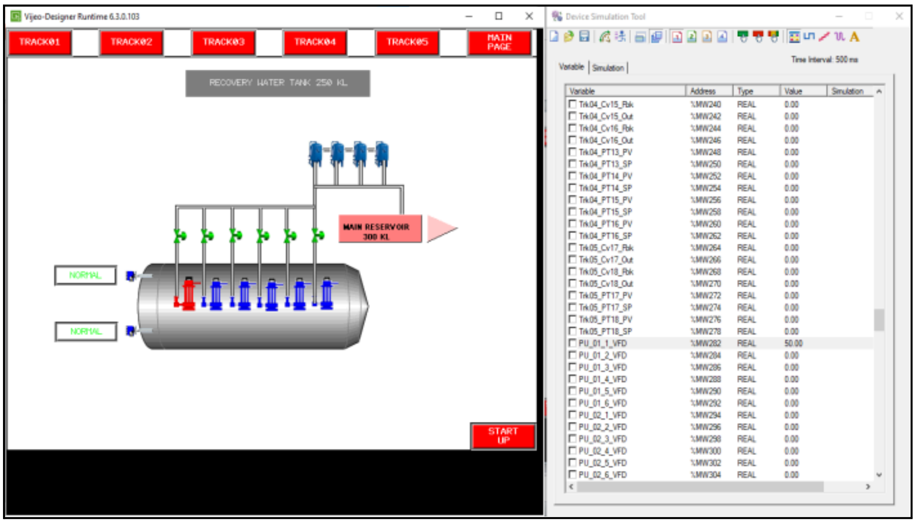

Fig. 5 Variable changes when the motor is in the trip state, which means it is not operating and is represented in RED.

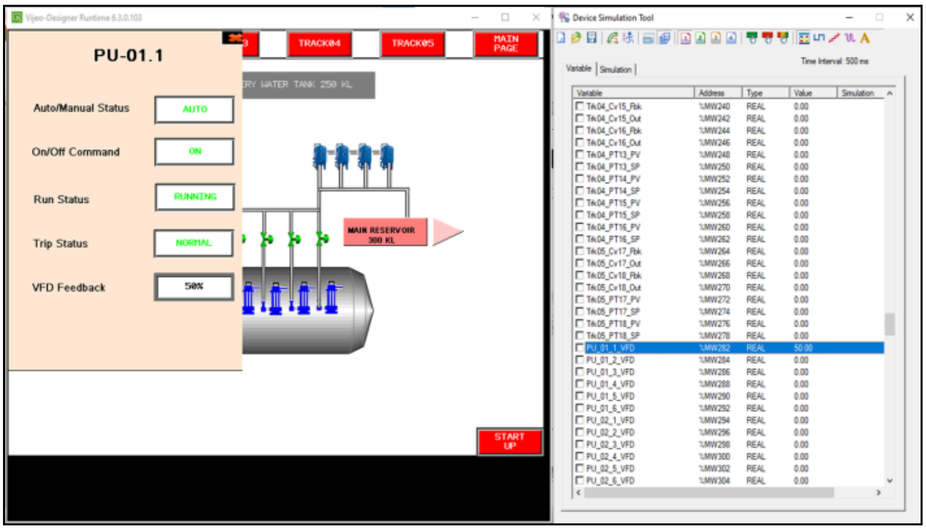

Fig. 6 The graphical panel displays a pop-up window displaying the motor status (trip or running).

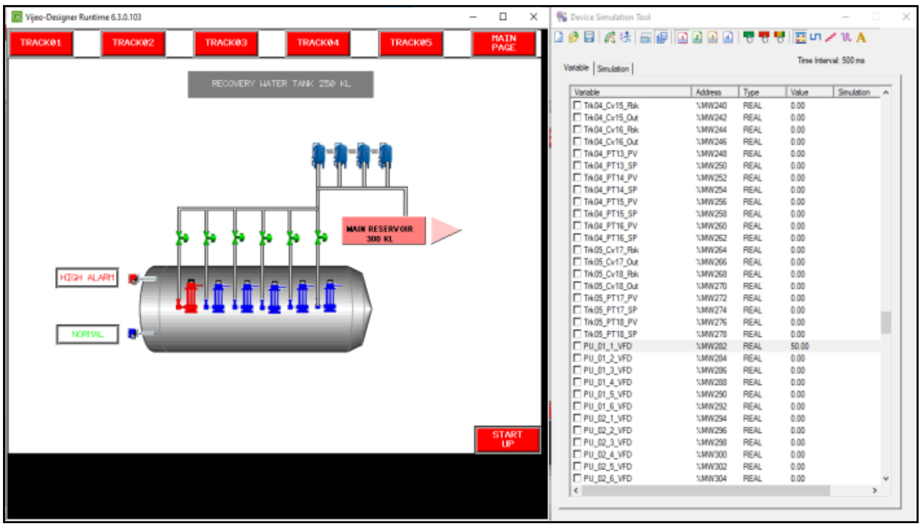

Fig. 7 High alerts when water reached the top of the tank level, it stops the incoming of water and creates the alarm for in-charge.

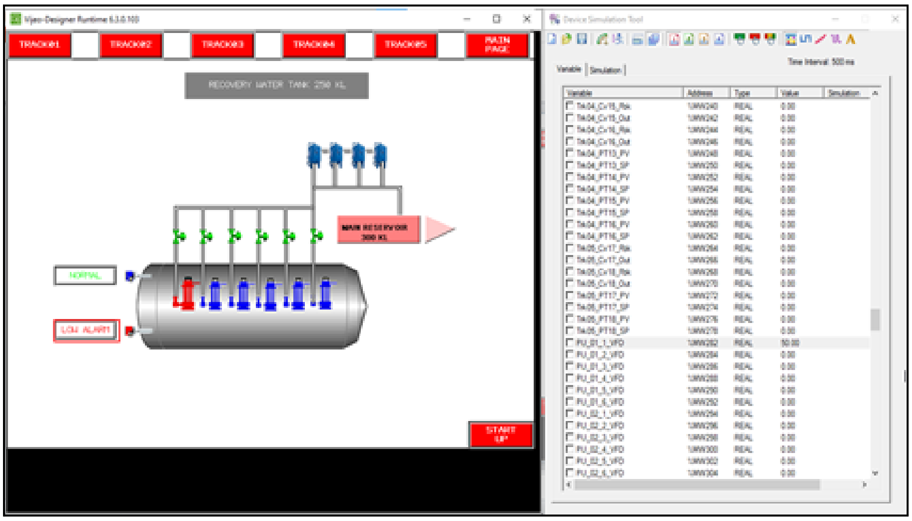

Fig. 8 Low alarm signal when water reached the bottom of the tank, which starts the incoming of water and creates the alert for in-charge.

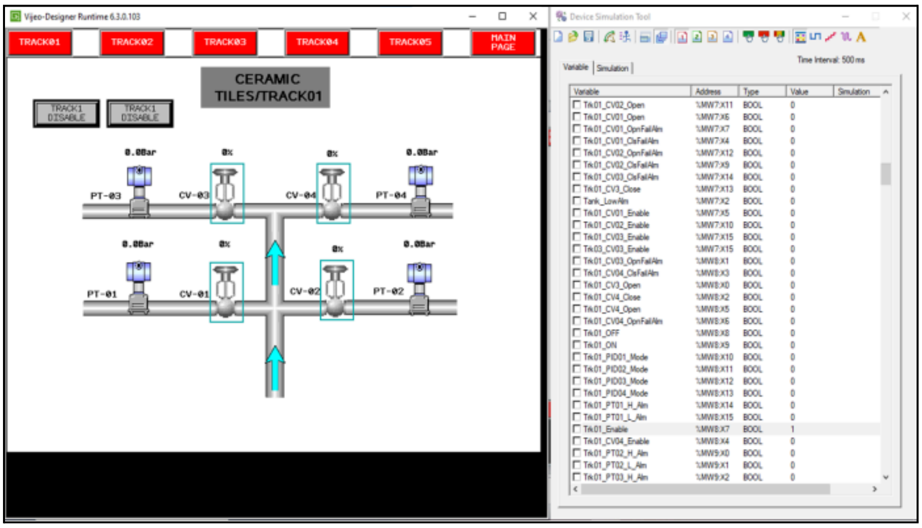

Fig. 9 In the valve control simulation process, all control valves are coupled with pressure transmitter sensors to gather data from the valve to the PLC to regulate the value pressure.

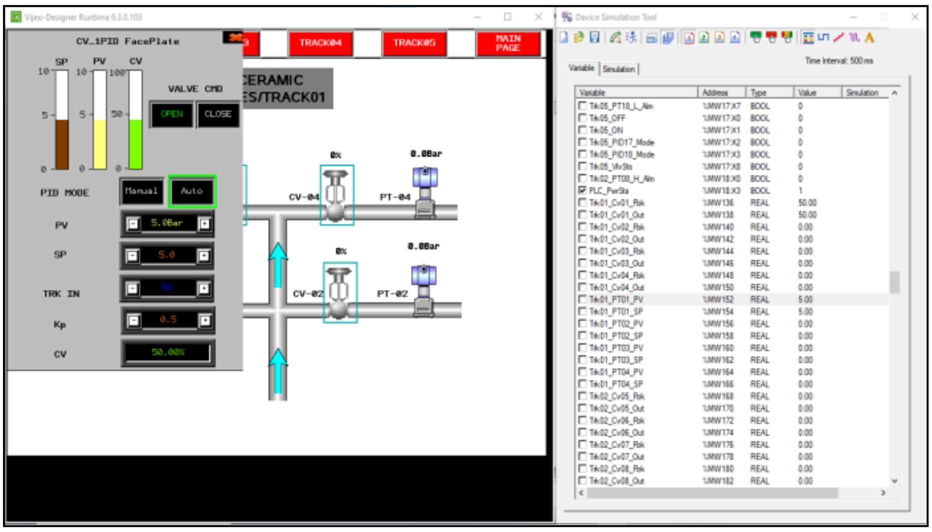

Fig. 10 The pop-up window displays the reading of the pressure transmitter sensor value, either automatically or manually.

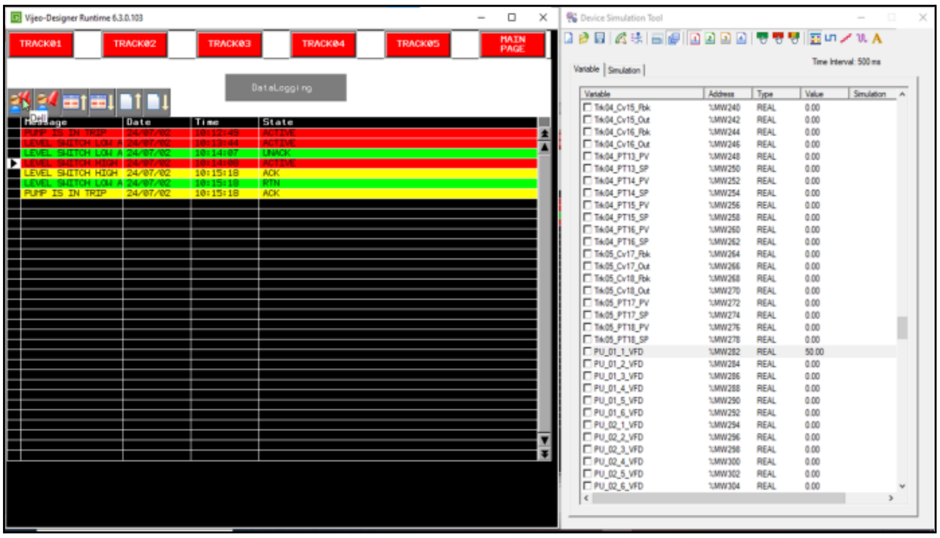

Fig. 11 The recognize panel for modifications occurred and was acknowledged by the individual in person.

Depending on this suggested study, a human-machine interface (HMI) simulator was created using Schneider Electric Software, Vijeo Designer 6.3.0, and a Graphical Interface with PLC controller-based programming capabilities. The measurements are revealed using a number of equipment, including running status, trip status, high alarm, low alarm, motor ON, and OFF, and valve status. Every measurement also has a status method that produces alarm to person in charge of the next procedure. The following procedures are taken during the simulation of the Human Machine Interface (HMI) by employing PLC controller. The desired functionality of a HMI with PLC contains the following limitations.

- Monitoring, tracking and displaying the processed data in real-time
- The role of observation, which enables by modifying the process's operating parameters directly from the HMI
- Alarms maintenance is to identify the errors or improper conduct in the production process.
- Manage the procedure to maintain certain variables inside safety bounds
- Monitor and analyse previous activity while offering options to access and obtain the most recent manufacturing process data and information.
- Graphical and Numerical data storages for documentation's purposes.

7. Result and Discussion

The whole industrial control and monitoring unit is shown in a single window in the Fig. 12. On the bottom left side of Fig.12 have two distinct 4000-liter water tanks, each with six motors. Each motor is coupled to a Pressure Transmitter (PT) sensor as shown in the Fig. 13, which regulates the valve that is connected to the user. Depending on how it is used, the user can access it manually or automatically at that time. The next two small tanks each with three motors, are used for emergency preparedness, on the right is utilized for the aqua plant's drinking process. This data is used to support the research project's implementation of the HMI design of simulation work, which is beneficial for large-scale companies. The process is also managed and observed online.

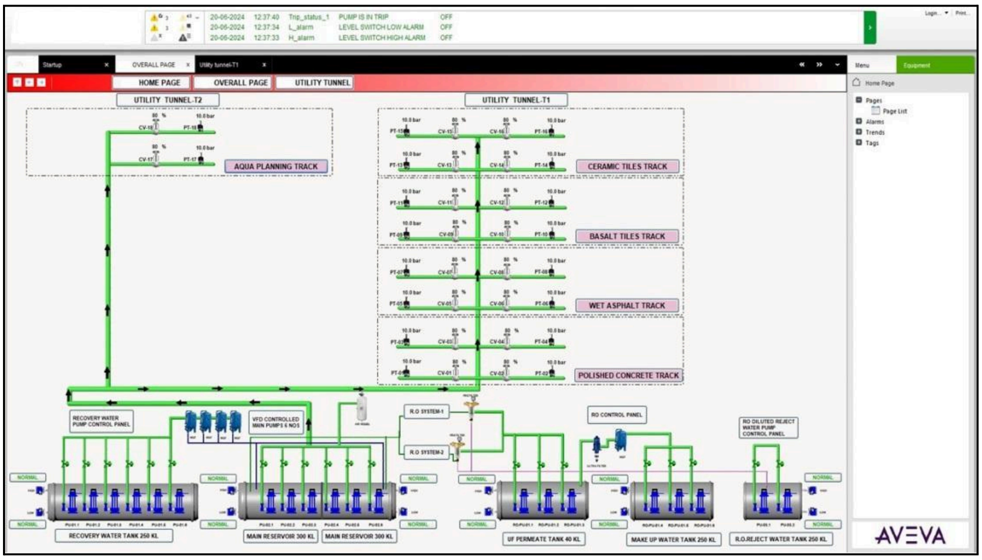

Fig. 12 The Aveva Screenshot picture for HMI controlling system has been converted into a mobile application for internet use using the Vijeo Designer mobile app.

According to this survey, all HMI designs are configured with PLCs via network connections. Figures 3 to 11 depict the individual performance of the HMI design, which works to sustain the entire industry. Each device simulated here has been tested with a PLC and is ready for use in industries such as vehicle manufacture, tire manufacturing, food processing, and chemical processing industries. Furthermore, the results provide the best performance in both the simulation and remote processes. PLC is a sophisticated controller for industrial automation; however, this automation now encompasses simpler processes such as controlling the above HMI design from a mobile device via IoT.

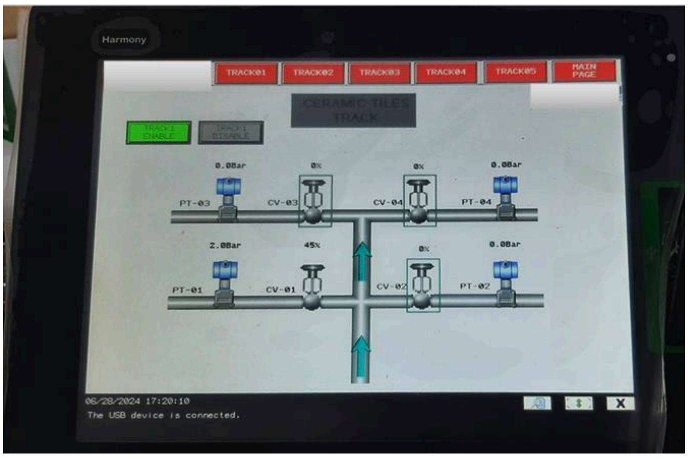

Fig. 13 HMI display design for the pressure transmitter (PT) control section.

The industrial monitoring station is depicted in Fig. 13 via the HMI. The Pressure Transmitter (PT) sensor (a part of HMI design) and its control valve are shown. Here, we keep on monitoring the pressure readings, high and low limit status, motor status, and valve status remotely.

8. Conclusion

The HMI simulation design for a water management system is an important tool for maximizing water resources, increasing operational efficiency, and promoting user engagement. The HMI helps operators and stakeholders make better decisions by providing intuitive interfaces, real-time monitoring, and data visualization.

Simple navigation and interaction are provided by user-friendly designs, guaranteeing that operators can quickly get crucial information. Proactive management and timely resolution of any issues are made possible by continuous monitoring of water levels, quality, and usage trends. Regular task automation and anomaly detection help to reduce downtime, streamline processes, and protect resources. The HMI's analytical tools can identify patterns and trends, which helps with resource allocation and strategic planning. Transparent data sharing fosters cooperation and confidence between service providers, regulators, and members of the community.

Overall, the implementation of an HMI simulation design not only enhances the operational effectiveness of water management systems but also contributes to sustainable water resource management, benefiting both current and future generations.

The performance of the creation of HMI instruction equipment as a monitor and input components such as buttons and sliders, as well as the HMI as a display and output components like as indicator lights, text data, and graphics, were all tested and found to be completely accurate. According to industry specialists, the design, technical aspects, and usability factors were all scored very well, placing the industrial aspect in the extremely practicable category.

9. Future work

Future developments might focus on integrating advanced technologies like IoT for even greater capabilities. The advent of the HMI is closely related to the Internet of Things (IoT). Considering the volume of data generated by IoT devices, the methods for accessing and visualizing this data are changing.

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