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IOT Based Steam Control Valve Integration with SCADA System

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***Abstract*—The increasing demand for energy efficiency in industrial processes has driven the need for advanced automation systems that can optimize resources management. This paper explors the design and implementation of an IOT-integrated SCADA system for automated steam control valve management, with a focus on reducing steam loss in industrial application. Steam control in industries is critical for maintaining process efficiency, yet traditional systems often suffer from inefficiencies, such as overconsumption and mismanagement of steam flow. The proposed system utilized a programmable logic controller (PLC) to automate the control of steam valves, combined with an IOT-enabled SCADA framework to facilitate real time monitoring, data acquisition, and analysis. By leveraging IOT technology, the steam enables remote operation, instant fault detection, and enhanced decision making capabilities to minimize steam loss and energy waste. The integration of SCADA provides a comprehensive view of the entire steam system, enabling operators to track performance, optimize energy consumption, and implement predictive maintenance. This research demonstrate the feasibility and benefits of applying IOT and automation in industrial steam management, offering a sustainable solution to reduce costs and improve operational efficiency in industries that rely on steam for their process.**

***Keywords*—Programmable logic controller, Solenoid valve, Ladder logic, Supervisiory control and data acquition(SCADA)**

I. INTRODUCTION

A Steam supply company is typically a business that provide steam related services, including the production, distribution and management of steam for industrial, commercial or residential. These companies manage the infrastructure required to deliver the steam to client. which can involve extensive pipeline systems. The steam control system employs manual valve for regulating the flow of steam in the production process. However this manual valve approach is prone to human error and inefficient for real time control. The manual steam control valves are time consuming to operate and require constant monitoring, leading to potential delays, operational in-effeciences and inconsistent system performance. Replacing the manual steam control valve to solenoid valve is a common upgrade in systems where automation and remote control are needed. A solenoid valve can be operated electrically, which allows for more precise control, remote operation and integration into automated system. The "IOT based steam control valve system" based on programmable logic controller (PLC) technology. A PLC is mainly used in order to control the electromechanical valve process by using SCADA system.[1][7]

II. METHODOLOGY

A. System Analysis and Requirement specification

The first step in automating the steam supply system is conducting a detailed analysis of the existing steam supply infrastructure. This includes understanding the manual or semi automated processes, identifying ineffeciencies, and defining the functional and non-functional requirments of automation.

B. Hardware selection and integration

Based on steam requirement, suitable hardware componants are selected to facilitate automation. These include PLC, sensors,steam control valve (solenoid valve), SCADA system, communication protocols.

C. PLC programming and Logic development

The plc is programmed using ladder logic to control steam supply system efficiently. The control logic includes automatic start stop control , alarm and safety logic etc..

D. SCADA Devlopment

A SCADA system is designed to enable real time monitoring and control. The Scada performed Graphical used interface design , Data logging and Trend analysis, Alarm management system, Remote access capability.

E. System integration

After implementation, plc and scada a functionalities are verified. Ensuring seamless interaction between PLC, Sensor and SCADA. Simulating different operating scenario and fault conditions.

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III. PROBLEM STATMENT

In industries where steam generation and distribution are essential, controlling steam flow can be particularly challenging, as some companies require steam intermittently. The existing steam control system relies on manual steam control valves to regulate steam flow in the production process. However, this manual operation presents several challenges, including susceptibility to human error, lack of automation, and inefficiency in real-time control. In high-demand scenarios where rapid adjustments are crucial, the manual approach proves inadequate, as operators must physically adjust the valves, leading to delayed response times. Furthermore, continuous monitoring is required to maintain optimal steam flow, increasing labor demands and the risk of inconsistencies in system performance. These challenges result in operational inefficiencies, production delays, and potential fluctuations in process quality. Implementing an automated steam control system would enhance precision, responsiveness, and overall efficiency, ensuring a more reliable and consistent operation while effectively managing intermittent steam requirements.

IV. BLOCK DIAGRAM AND COMPONANTS

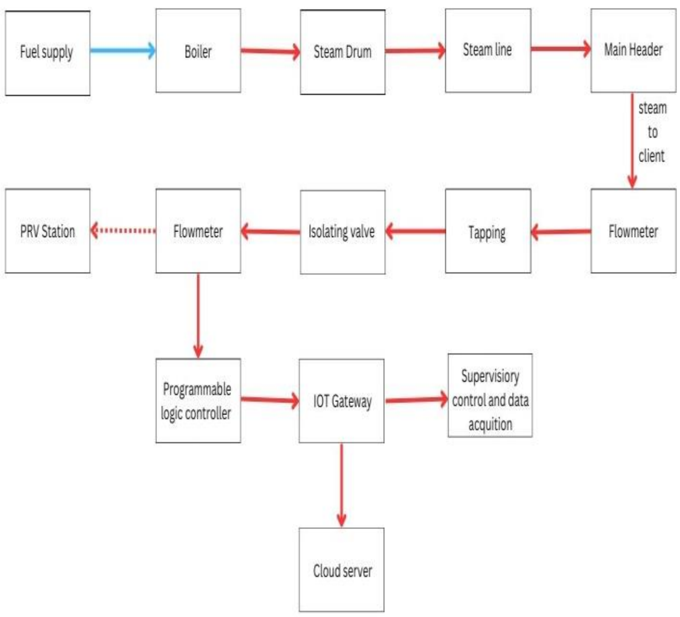

Fig-1: Steam flow monitoring and control system

The block diagram represents an automated steam control and monitoring system, integrating boiler operation, steam distribution, flow measurement, and digital control technologies such as PLC, SCADA, and IoT for real-time monitoring and optimization.

The process begins with a fuel supply system that feeds the boiler, where water is converted into steam. The generated steam is collected in a steam drum and transported through steam pipelines to the main distribution system. The steam line main header then distributes steam to different sections of the plant or external clients, while a flowmeter in the main line measures the total steam flow rate, ensuring accurate monitoring. Steam is tapped from the main line and regulated using an isolating valve, allowing selective steam distribution, and another flowmeter measures the steam flow after the isolating valve to ensure controlled and optimized distribution.

To enhance efficiency, a Programmable Logic Controller (PLC) processes flowmeter readings and controls steam flow accordingly. The PLC can adjust the pressure-reducing valve station to maintain optimal steam pressure based on system demand. Furthermore, real-time monitoring and data logging are enabled through an IoT gateway, which connects to a cloud server for analytics and predictive maintenance. The SCADA system provides a graphical user interface (GUI) for operators to monitor steam flow, pressure, and overall system performance while enabling remote control and historical data analysis.

This automated system ensures precise steam regulation, energy efficiency, and reduced manual intervention, leading to improved reliability and operational performance. The integration of IoT and SCADA allows for real-time visualization and remote accessibility, making steam control more intelligent and adaptive. Overall, this approach optimizes industrial steam distribution while ensuring sustainability and enhanced process control.

V. FLOWCHRT

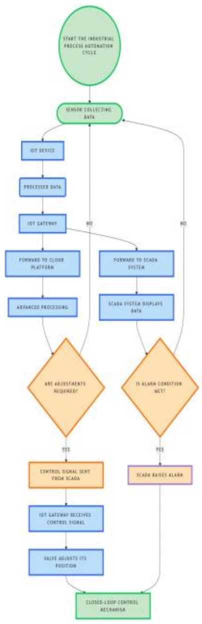

Chart-1: Flowchart

This diagram shows how data flows from a sensor, through IoT and SCADA systems, and leads to valve control and monitoring**.**

Sensor collect real time data from a physical systems. This raw data sent to the IOT device processing. The iot device process the sensor data. The processed data is then transmitted to an IoT gateway. The iot gateway acts a bridge between field devices and cloud/scada. It forwards to received data to both the cloud platform and scada system.

The IoT gateway transmit data to the cloud for advanced data processing and analytics. Cloud computing services analyze and store data for future insights. This processed data can be used for predictive maintenance, historicsl analysis and long term monitoring.

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The IoT gateway also sends real-time data to the SCADA system. SCADA is responsible for monitoring and controlling industrial processes. The received data is stored in SCADA system for analysis and future refrences. The SCADA system visualizes data for operators in graphical dashboard, trends and reports.

The system checks whether any adjustment is needed based on predefined conditions.

- If NO, continuous monitoring continuous without any action.
- If YES, the SCADA system sends a control signal to make the necessary adjustment.

If an adjustment required, SCADA generates control signal and transmits it via the IoT gateway. The IoT gateway receives the SCADA control signal and forward it to the appropriate field device. The final control element responds to the control signal by adjusting its position to maintain system stability. The system continues monitoring and updating data for ongoing automation and optimization.

VI. WIRING DIAGRAM AND COMPONANTS

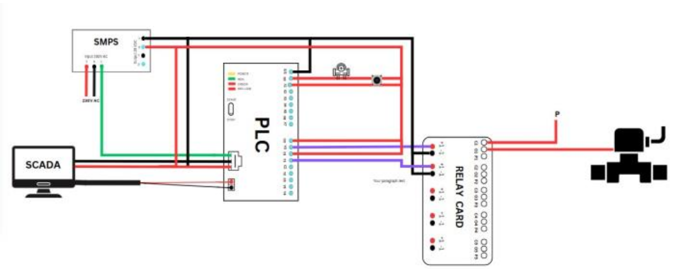

Fig-2: Wiring Diagram

The given wiring diagram illustrates an automated steam control system integrating a Programmable Logic Controller (PLC), Switch Mode Power Supply (SMPS), relay card, SCADA system, and an actuator-operated steam control valve. The system is designed to automate steam flow regulation and monitoring, reducing manual intervention and enhancing efficiency.

The SMPS converts 230V AC input into a 24V DC output, which powers the PLC and other low-voltage components. The PLC acts as the central control unit, receiving input signals from sensors and sending output signals to control devices. It is connected to the SCADA system, enabling real-time monitoring and visualization of process parameters. The relay card interfaces between the PLC and the actuator-driven steam control valve, allowing the PLC to operate high-power devices safely by using low-power control signals.

When the PLC processes input data, such as steam pressure or flow rate, it sends an appropriate output signal to the relay card, which then activates or deactivates the steam control valve. This ensures precise steam flow regulation based on real-time demand. The system may use MODBUS RTU/TCP for communication between PLC and SCADA, while discrete I/O connections control the relay card.

Additional components, such as pressure and temperature sensors, can be integrated to provide continuous feedback, improving system responsiveness. The system's automation minimizes human errors, optimizes energy usage, and ensures a stable steam supply, making it ideal for industrial applications requiring efficient steam distribution.

VII. COMPONANTS FOR SYSTEM ARCHITECTURE

For an IoT-based steam control valve system controlled by PLC and integrated with SCADA, the key components typically used in implementation.

A. Programmable Logic Controller

Fig-3: Programmable Logic Controller

In the IoT-based steam control valve system integrated with SCADA, the Programmable Logic Controller (PLC) serves as the core automation unit, ensuring precise regulation of steam flow based on real-time sensor data. The PLC continuously monitors inputs from temperature, pressure, and flow sensors, processes this data, and adjusts the motorized steam control valve accordingly to maintain optimal operating conditions. Using Modbus TCP/IP, OPC UA, or MQTT, the PLC communicates with the SCADA system for real-time monitoring, data logging, and remote control. Additionally, it implements safety interlocks and alarms to prevent hazardous conditions such as overpressure or temperature deviations. By integrating with IoT gateways, the PLC enables cloud-based monitoring, enhancing operational efficiency, predictive maintenance, and remote accessibility in industrial steam systems.[5][10]

B. Switched-Mode Power Supply(SMPS)

Fig-4: Switched mode power supply

A Switched-Mode Power Supply (SMPS) is a critical component in the IoT-based steam control valve system integrated with SCADA, providing stable and efficient power to the PLC, sensors, actuators, and communication devices. The SMPS converts AC mains power (230V AC) into regulated 24V DC, ensuring reliable operation of industrial automation components. In this system, the SMPS supplies power to temperature and pressure sensors, flow meters, solenoid valves, and motorized steam control valves, ensuring uninterrupted control and monitoring. Additionally, it protects sensitive electronics from voltage fluctuations, enhancing system stability and longevity. The use of an industrial-grade SMPS with overload and short-circuit protection ensures high efficiency, reduced heat dissipation, and improved reliability, making it an essential component in industrial PLC-SCADA-based steam control automation.

C. Flowmeter

Fig-5: Flowmeter

A Vortex Flowmeter is a crucial sensor in the IoT-based steam control valve system integrated with SCADA, providing accurate and reliable measurement of steam flow. It operates on the vortex shedding principle, where an obstruction (bluff body) in the steam pipeline creates vortices as steam flows past it. The frequency of these vortices is directly proportional to the flow rate, which is detected by a piezoelectric sensor and converted into an electrical signal.In this system, the vortex flowmeter continuously transmits real-time steam flow data to the PLC. The PLC processes this data and adjusts the steam control valve accordingly to regulate steam flow based on demand. The flowmeter is also integrated with SCADA, allowing operators to monitor steam consumption, detect anomalies, and optimize energy efficiency remotely. With its high accuracy, low maintenance, and wide temperature-pressure range compatibility, the vortex flowmeter ensures precise steam flow measurement, improving the overall efficiency and reliability of the industrial steam control process.

D. Solenoid valve

Fig-6: Solenoid Valve

A solenoid valve is a key actuator in the IoT-based steam control valve system integrated with SCADA, enabling precise and automated control of steam flow. It operates electromechanically, using an electric coil to generate a magnetic field that actuates the valve, allowing or restricting steam flow based on control signals from the Programmable Logic Controller (PLC).[4]
In this system, the PLC continuously monitors pressure, temperature, and flow sensors and sends digital output signals (24V DC or 230V AC) to the solenoid valve, opening or closing it as required. The solenoid valve plays a critical role in steam regulation, safety interlocks, and emergency shutdowns, ensuring controlled steam distribution in industrial processes. Integrated with SCADA, operators can remotely monitor and control valve status, receive alerts for malfunctions, and optimize system efficiency. With fast response time, reliability, and minimal maintenance, solenoid valves are essential components for safe and efficient steam automation in IoT-enabled industrial environments.

E. Communication protocol

In an IoT-based steam control valve system integrated with SCADA, communication protocols play a crucial role in ensuring seamless data exchange, real-time monitoring, and control across various components, including PLC, SCADA, IoT gateways, and field devices. These protocols enable efficient data transmission, remote accessibility, and enhanced automation, making the system more responsive and intelligent. Modbus (RTU/TCP**)** is widely used for communication between PLCs, sensors, and actuators, providing both serial (RS-485) and Ethernet-based connectivity. OPC UA (Open Platform Communications

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Unified Architecture) allows standardized and secure data exchange, ensuring interoperability between different automation devices and supporting both real-time and historical data analysis. MQTT (Message Queuing Telemetry Transport**)** serves as a lightweight, IoT-friendly protocol that enables efficient cloud-based monitoring and control, particularly beneficial for predictive maintenance and remote operations. Additionally, HTTP/REST API facilitates web-based access, enabling operators to visualize and manage steam flow through IoT dashboards and mobile applications. By integrating these advanced industrial and IoT communication protocols**,** the system ensures optimized steam flow control, remote supervision, and improved operational efficiency, making it a robust and scalable solution for modern industrial automation.

F. Supervisiory control and data acquition

Fig-7: CITECT SCADA SOFTWARE

Citect SCADA is a powerful industrial automation software developed by Schneider Electric for real-time monitoring, control, and data acquisition in industrial processes. It provides a scalable and flexible platform for integrating IoT-enabled devices, PLCs, and field sensors, making it ideal for steam control valve automation. In an IoT-based SCADA system, Citect SCADA enables seamless data visualization, trend analysis, and remote operation, improving overall process efficiency. Through communication protocols such as Modbus, OPC, and Ethernet/IP, real-time temperature, pressure, and flow rate data from field sensors are transmitted to the SCADA interface, allowing operators to monitor and control the steam valve with precision. Additionally, alarm configurations and predictive analytics help detect anomalies, ensuring system reliability and safety. By integrating edge computing and cloud-based SCADA functionalities, operators can access process data remotely, facilitating proactive decision-making and energy optimization. This IoT-SCADA integration enhances automation, efficiency, and operational control in steam-based industrial systems.[11]

VIII. PLC LADDER LOGIC PROGRAMMING

Ecostruxure machine expert (formarly known as SoMachine)nis a comprehensive integrated development environment by schneider electric, designed for the programming, commissioning and maintenance of industrial automation system. It is primarily used for machine control applications, including PLCs, HMIs, motion control and safety solutions. In this application, we utilize EcoStruxure Machine Expert to program the PLC for precise control of the steam control valve, ensuring efficient and reliable operation.[6][10]

Fig-8: EcoStruxure Machine Expert

In this system the Ladder logic is designed to reulate the steam control valve based on process parameters such as temperature, pressure or flowrate. The PLC receives real-time sensor data via analog or digital inputs and processes it using Programmable logic to determine valve positioning. The ladder diagram typically includes start/stop conditions, Alarm activation conditions, Transient state , Fault handling mechanism. Timer and counters used to ensure smooth operation and rapid switching. The IoT module in the plc eneables remote monitoring by transmitting real time vzlve status and process parameters to the SCADA system over industrial communication protocols like Modubus, Ethernet/IP etc.. SCADA then visualizes this data,allowing operators to monitor and control the valve remotely. Alarms and trends are configured in SCADA system to enhance operational efficiency and safety.[5][10]

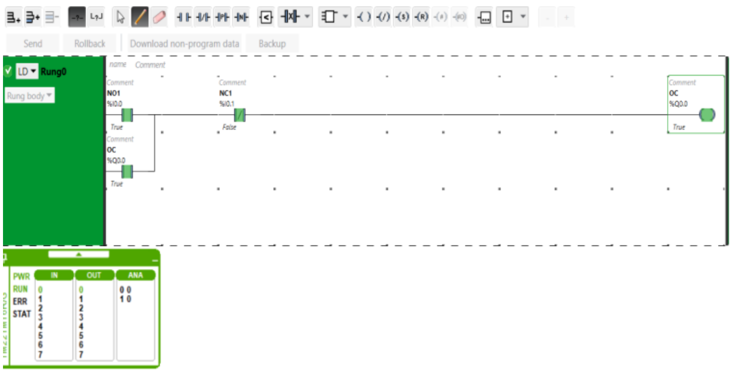

Fig-9: Valve open command

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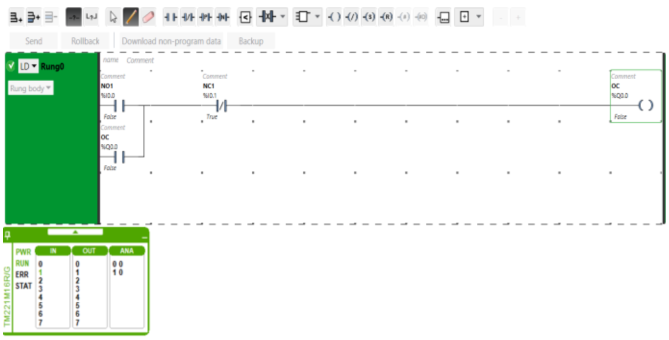

Fig-10: Valve Close command

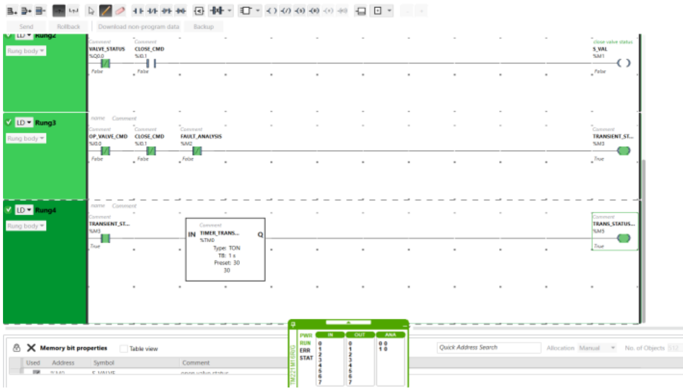

Fig-10: Transient valve status

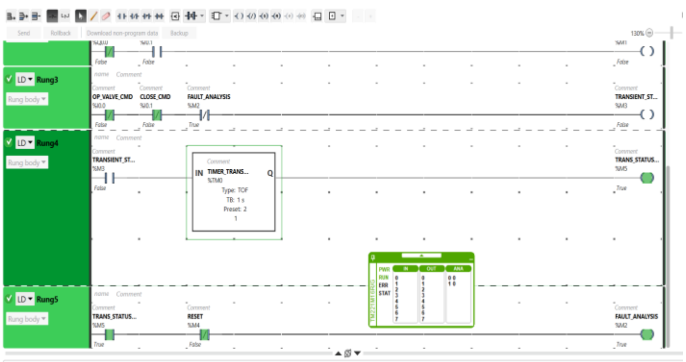

Fig-11: Reset Transient valve

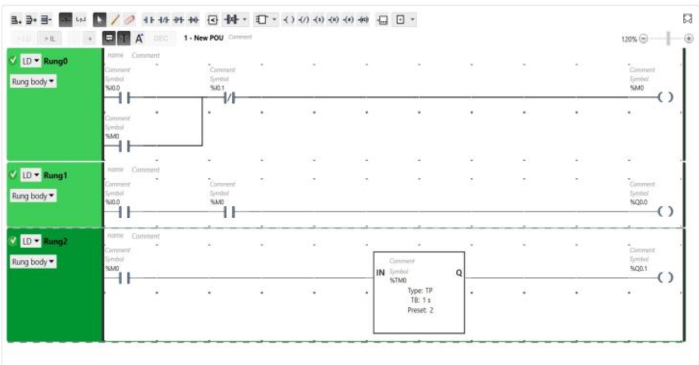

Fig-12: Valve open alarm (Analysis)

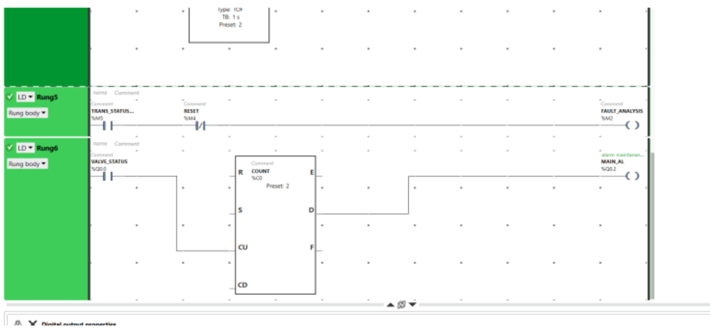

Fig-13: Count the valve operations

IX. INTERFACING OF PLC WITH SCADA

To successfully interface a Schneider PLC with a SCADA system, a structured approach must be followed must be followed. First, gather the necessary hardware, including the Schneider PLC, SCADA system, appropriate communication protocol and a reliable power supply. Additionally, ensure the required software is available , such as Ecostruxure Machine Expert for PLC programming, SCADA software like Citect, wonderware, Ignition, and Modbus TCP/RTU drives for communication. Next configure the PLC by establishing communication through Ethernet or serial connection, IP address, Modbus protocols. After programming the PLC, download and test is functionality. The SCADA system must be configured by adding the appropriate communication drive (Modbus/Rtu), defining PLC tags mapped to Modbus registers, and verifying real time data exchange. Once communication is established, tge SCADA interface is developed by designing screens with buttons, indicators, and trends while configuring alarms and valve stop start buttons. Finally, the system is tested runtime mode to sure seamless data exchange between the PLC and SCADA.[10][11]

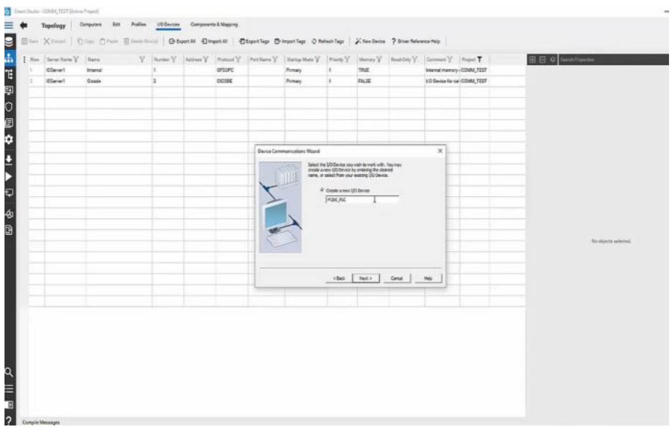

Fig-14: SCADA I/O device creation

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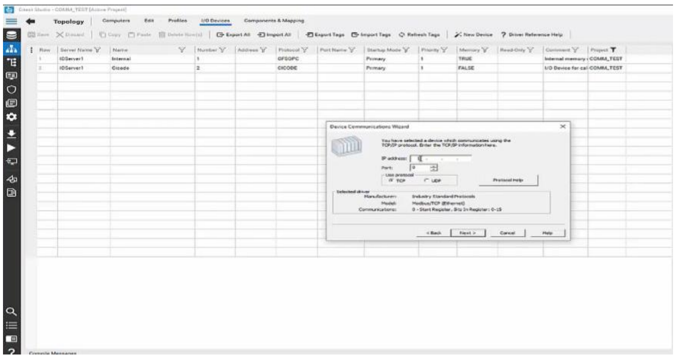

Fig-15: SCADA I/O device configuration

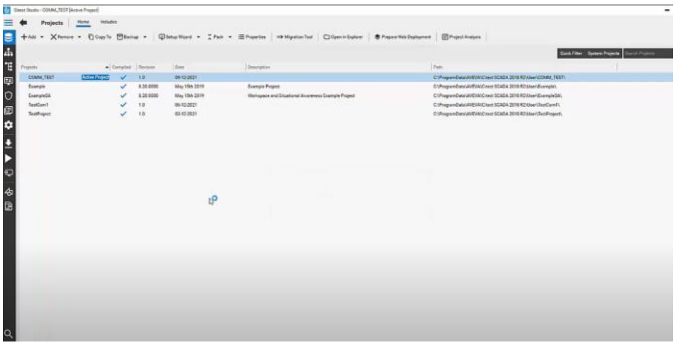

Fig-16: Citect scada project workspace

X. CONCLUSION

The integration of Internet of Things (IoT) technology with solenoid valves, controlled via Programmable Logic Controller (PLC), provides rebust and efficient solution for automated industrial processes. By incorperating IoT with PLCs, the system enable remote controlling, precise control, real time data analysis, resulting in improved operational efficiency and predictive maintenance.

Evaluate and enhance steam management system with IoT solutions amd overcome losses, optimizing steam control valve design through SCADA system is essential for modern industrial applications.

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