AUTOMATION OF CONTROL AND PROTECTION SYSTEMS USING SCADA

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ABSTRACT: The Srisailam Hydropower Plant is one of the major hydroelectric stations in India, playing a key role in power generation and grid stability. To ensure safe, reliable, and efficient operation, SCADA (Supervisory Control and Data Acquisition) systems are used for automation of control and protection functions. SCADA enables real-time monitoring of vital parameters such as turbine speed, generator voltage, current, water level, gate position, temperature, and protection relays. It allows operators to control equipment remotely, detect faults quickly, and take im corrective actions. The protection system integrated with SCADA helps in preventing damage due to overload, short circuit, over-voltage, and mechanical failures. SCADA works by continuously collecting data from field devices installed in the power plant. Sensors measure important parameters and send signals to the PLC/RTU. The processes this data and sends it to the SCADA system through communication net works. Operators monitor all operations on the SCADA screen and can control equipment like turbines, generators, and circuit breakers remotely. If any abnormal condition occurs, the protection system automatically trips the equipment to prevent damage. SCADA is used to analyse the performance on the collected data. This data is compared with preset safe values to check whether the system is operating normally. If any value exceeds the limit, SCADA generates alarms and warnings and automatically trips the affected equipment to prevent damage. The system also stores historical data, which helps engineers analyse: Power generation efficiency, Fault occurrence, Equipment performance, Load variations. By using this analysis, operators can take timely decisions, reduce breakdowns, improve safety, and ensure continuous power generation Automation.

KEYWORDS: SCADA, PLC/RTU, FAULT, PROTECTION. OVER LOAD.

I.INTRODUCTION: Hydropower plants are essential for producing clean and renewable energy, and their efficient operation requires accurate control and strong protection mechanisms. To meet these requirements, modern hydropower plants widely use SCADA (Supervisory Control and Data Acquisition) systems for automation of both control and protection functions. SCADA provides centralized monitoring and control by collecting real-time data from field instruments such as sensors, transducers, and protection relays. Important parameters like water level, flow rate, turbine speed, generator voltage, current, frequency, temperature are continuously measured and transmitted to PLCs/RTUs. The SCADA interface presents this information in the form of graphical displays, trends, and alarms, enabling operators to easily monitor plant conditions and make quick decisions. Automation allows remote operation of gates, turbines, generators, transformers, and circuit breakers, ensuring smooth and coordinated functioning of all components.

In terms of protection, SCADA systems are integrated with advance protective relays that safeguard equipment from faults such as overloads, short circuits, over-voltage, under- frequency, and mechanical failures. When abnormal conditions are detected, the system immediately generates alerts and can automatically isolate or shut down the affected section to prevent damage and ensure personnel safety. Additionally, SCADA systems store large amounts of historical data, which is used for performance analysis, fault diagnosis, and maintenance planning. This supports predictive and preventive maintenance, reducing downtime and improving overall plant efficiency. By automating control and protection processes, SCADA significantly reduces human error, improves response time, increases reliability, and ensures continuous, safe, and efficient operation of hydropower plants.

II.LITARATURE SURVEY: Sajjad Ali et al. (2018) focused on predictive maintenance using SCADA data. Their research demonstrated that continuous data collected from sensors (such as vibration, temperature, and load) can be analyzed to predict equipment failures in advance. They used statistical and machine learning techniques to identify fault patterns in turbines and generators. This approach reduces unexpected breakdowns, lowers maintenance costs, and increases equipment lifespan, making hydropower plants more reliable and efficient.(1)

Md Rabiul Islam et al. (2020) studied the application of SCADA systems in renewable energy integration, including hydropower. Their work highlighted that SCADA enables real-time monitoring of generation units and helps in balancing power supply with grid demand. The study also emphasized remote operation and automatic control features, which are particularly useful for hydropower plants located in remote areas. SCADA improves load management, enhances grid stability, and ensures efficient utilization of available water resources.(2)

Zhang Yong et al. (2021) analyzed SCADA-based fault detection and protection systems. Their research showed that SCADA systems can continuously compare real time data with predefined safety limits. When abnormal conditions such as overload, over-voltage, under-frequency, or mechanical faults occur, the system generates alarms and automatically triggers protective actions like tripping circuit breakers. This minimizes equipment damage and ensures operator safety.(3)

Liu Wei et al. (2024) introduced smart SCADA systems integrated with data mining and analytics techniques. Their research demonstrated that large volumes of historical data stored in SCADA systems can be used to identify operational patterns and optimize plant performance.. The study also showed that intelligent SCADA systems can detect hidden faults and inefficiencies that are not visible through traditional monitoring methods.(4)

Chen Ming et al. (2025) discussed the digital transformation of hydropower plants using advanced SCADA systems integrated with IoT, Artificial Intelligence (AI), and cloud computing . They also emphasized the use of digital twins and smart sensors for continue condition monitoring. This leads to improved automation, enhanced protection systems, reduced downtime, and better overall plant performance.

III.PROPOSED SYSTEM: Circuit breakers, isolators, transformer tap changers, and generator excitation systems can be operated remotely. This reduces the need for manual intervention and improves response times during emergencies. Remote control of equipment in a SCADA (Supervisory Control and Data Acquisition) system refers to the ability to operate and manage field devices such as circuit breakers, transformers, motors, valves, and pumps from a centralized control room without physical presence at the site. In this process, the operator sends control commands through the Human Machine Interface (HMI), which are transmitted via communication networks like fiber optics, radio, or the internet to Remote Terminal Units (RTUs) or Programmable Logic Controllers (PLCs) installed at the field location. These devices execute the commands by actuating the connected equipment and then send feedback signals to the control center to confirm the operation status. Remote control in SCADA enhances operational efficiency, improves safety by reducing human intervention in hazardous areas, and enables quick response during faults or abnormal conditions. However, its effectiveness depends on reliable communication systems and proper cyber security measures.

A Remote Terminal Unit (RTU) is an electronic device used in SCADA systems to monitor and control field equipment. It acts as a bridge between the central SCADA system and field devices such as sensors, motors, and valves. The RTU collects realtime data like temperature, pressure, and flow from the field devices and sends it to the control center. It also receives control commands from the SCADA system and executes them by operating the connected devices. Thus, the RTU plays a key role in ensuring smooth communication and control in industrial automation systems.

Fig 1 SCADA RTU Control Panel (Electrical Control Cabinet)

The figure shows a SCADA RTU control panel, also known as an electrical control cabinet, which is used in industrial automation systems for monitoring and controlling field devices. It contains components such as RTU/PLC modules, relays, wiring, and communication units arranged inside a protective enclosure. This panel acts as an interface between the SCADA system and field equipment like sensors, motors, and valves, enabling real-time data collection and control operations. It ensures safe, reliable, and efficient functioning of the overall system.

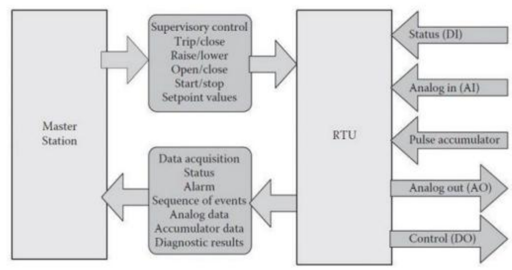

Fig 2 SCADA Communication and Data Acquisition Flow Between Master Station and RTU

The Master Station acts as the central monitoring and control unit. It sends supervisory commands such as trip/close, open/close, start/stop, raise/lower operations, and setpoint values to the RTU. These commands are used to control field equipment like circuit breakers, valves, and motors. The control actions flow from the Master Station to the RTU, which then executes them at the field level. The RTU (Remote Terminal Unit) serves as an interface between the control center and field devices. It receives control commands from the Master Station and converts them into appropriate signals for field equipment. At the same time, it collects data from various sensors and devices installed in the system. On the input side of the RTU, different types of signals are received. These include Digital Inputs (DI) representing equipment status (ON/OFF), Analog Inputs (AI) representing continuous values such as voltage, current, temperature, and pressure, and Pulse Accumulator inputs used for counting operations like energy consumption. On the output side, the RTU sends Digital Outputs (DO) for switching operations and Analog Outputs (AO) for controlling variable parameters.

SCADA/DCS Systems: Central platforms for processing, visualizing, and controlling based on the processed data.

Energy Management Software: For optimization and predictive analytics. Enables automatic control of turbines, gates, and generators. Supports fault detection and protection by interpreting abnormal conditions. Facilitates energy optimization by analyzing operational efficiency. Provides historical trends for maintenance planning and performance improvement.

Fig 3 Unit Wise Load And Frequency Monitoring In SCADA

The image shows a SCADA (Supervisory Control and Data Acquisition) system screen used in a power plant to monitor and control multiple generating units. It displays unit-wise generator parameters, which help operators track performance and maintain system stability in real time. Each row represents a generating unit (UNIT-1 to UNIT-7), and key parameters are shown such as frequency (Hz), power set (MW), actual load (MW), and governor valve position (GV %). The frequencies are close to 50 Hz, indicating stable operation, while the power set and actual load values show how much power is scheduled versus actually being generated. At the bottom, the screen shows overall station data like bus frequency, total station load (722.86 MW), average load per unit, and number of units in operation (7 units). This helps operators understand the total output of the plant and balance power demand.

On the right side, there are control indicators like raise/lower commands and trigger status, which are used to adjust generator output. Overall, this SCADA display is essential for real-time monitoring, control, and efficient operation of a power plant system.

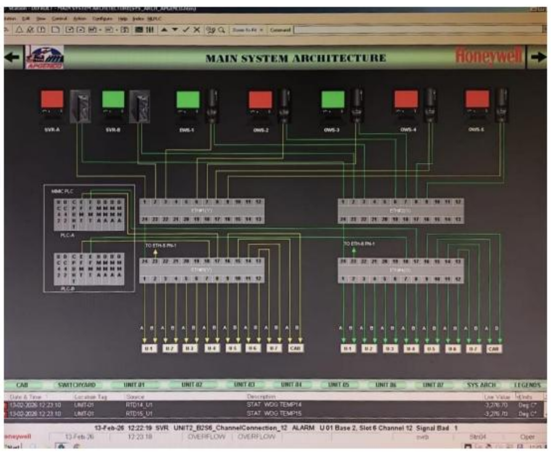

Fig 4 HMI Display of SCADA System Architecture and Connectivity

This image represents how different computers, servers, and controllers are connected in an industrial environment, such as a power plant. At the top, multiple systems like servers (SVR-A, SVR-B), engineering workstations (EWS), and operator workstations (OWS) are displayed, which are used for monitoring, controlling, and managing the entire process. In the middle section, the diagram highlights the Ethernet network switches (ETH) that act as communication links between all devices. These switches ensure reliable data transfer between the servers and field equipment. The connections shown (green and yellow lines) indicate redundant communication paths, which improve system reliability and prevent failures in case one path is lost. At the bottom, the architecture connects to PLCs (Programmable Logic Controllers) labeled PLC-A and PLC-B, along with multiple units (U-1 to U-7 and CAB). These PLCs collect real-time data from sensors (like temperature readings shown below) and send it to the SCADA system. Overall, the diagram explains how data flows from field devices to control rooms, enabling operators to monitor conditions, detect faults, and control industrial processes efficiently.

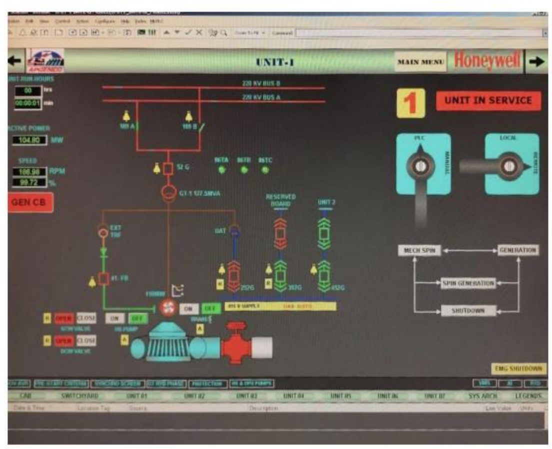

Fig 5 Single Line Diagram of Generator Unit

These values help operators monitor the generator's performance in real time. Status indicators (green/red lights and symbols) show whether components like breakers, relays, and transformers are active or inactive. The center diagram illustrates the generator (GT-1 rated ~127.5 MVA) connected to auxiliary systems like UAT (Unit Auxiliary Transformer) and external transformers. It also shows switching devices, protection relays (like 86T), and supply lines (415V), giving a simplified electrical layout of the plant. On the right side, there is a control logic section with modes such as PLC/manual and local/remote operation, along with process stages like mechanical spin, generation, spin generation, and shutdown. This helps operators control and transition the unit safely between different operating states, including emergency shutdown if required.

Fig 6 SCADA Display of HAS Oil Pumps and Bearing System

The image shows a labeled "UNIT-2 HS & OPU Pumps," indicating it monitors and controls pump operations in a plant. The screen displays tanks (sumps), pipelines, and pumps (P1 and P2), along with real-time numerical values such as temperature and pressure. On the left and right sides, there are sump tanks connected through pipelines, with flow controlled by pumps. Status indicators (green lights) show that various conditions like pump trips, supply failures, and low pressure levels are currently normal or inactive. This suggests the system is running smoothly without alarms at that moment. In the center, a "Thrust Bearing Sump" is displayed, which is important for lubrication and cooling of rotating equipment. The values shown indicate monitoring of fluid levels or temperature inside the sump to ensure safe operation of machinery. A popup window titled "UNIT-02 RTD (Trend No: 9)" shows multiple RTD (Resistance Temperature Detector) readings. These sensors measure temperatures at different points such as windings, pads, and bearings. The green-highlighted values indicate acceptable temperature ranges, helping operators quickly identify any abnormal conditions. At the bottom, there is an alarm/event log that records system messages, timestamps, and signal issues. This helps operators track faults and maintain the system efficiently.

Overall, the screen provides a real-time overview of pump performance, safety conditions, and equipment health in an industrial setup.

Fig 7 SCADA Based Real-Time Monitoring of Generator Parameters For Multiple Units

At the bottom, there are status indicators and alarms showing system conditions like supply failures, disturbances, and faults. Green indicators represent normal conditions, while red signals warnings or failures. Overall, this interface helps operators safely control and monitor power generation systems in real time.

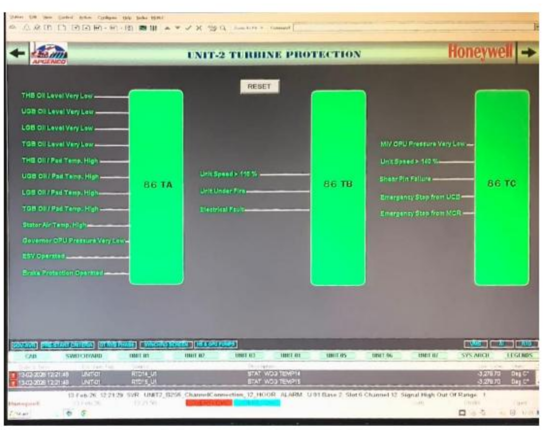

Fig 8 Turbine Trip and Protection Monitoring(SCADA)

It belongs to Unit-2 Turbine Protection, where different safety conditions of a turbine are continuously monitored to prevent damage or failure. The screen is divided into three main protection categories labeled 86 TA, 86 TB, and 86 TC. These are protection relays or trip signals. Each section lists different fault conditions. For example, 86 TA includes issues like low oil levels, high oil/pad temperature, stator air temperature, and brake protection. If any of these conditions become critical, the system can automatically trip the turbine to avoid damage. The 86 TB section focuses on operational faults such as turbine over speed (above 110%), fire detection, and electrical faults. Meanwhile, 86 TC includes more critical emergency conditions like very low pressure, extreme over speed (above 140%), shear pin failure, and emergency stops from control systems. All the green indicators suggest that the system is currently in a normal or safe condition, with no active trips. The “RESET” button at the top is used to clear faults once issues are resolved. Overall, this screen helps operators quickly identify problems and ensure safe turbine operation.

IV.CONCLUSION: Automation of control and protection of power systems using SCADA in a hydropower plant significantly enhances the efficiency, reliability, and safety of operations. By enabling real-time monitoring and automatic control of critical parameters such as water flow, turbine speed, and generator output, SCADA ensures optimal power generation and system stability. It also provides rapid fault detection and immediate protective actions, minimizing equipment damage and reducing downtime. The integration of automated control and protection reduces human intervention, improves accuracy, and supports better decision-making. Overall, SCADA-based automation is an essential advancement in modern hydropower plants, contributing to reliable power supply and sustainable energy management.

REFERENCES: P. Kumar and A. Singh, “SCADA-based automation and monitoring of hydropower plants,” IEEE Access, vol. 8, pp. 189765–189774, 2020. [1]

S. Das and R. Patel, “Real-time control and protection of hydroelectric power plants using SCADA systems,” IEEE Transactions on Industry Applications, vol. 57, no. 4, pp. 3456–3464, July–Aug. 2021. [2]

M. Ali, K. Rahman, and T. Ahmed, “Fault detection and protection in hydro power plants using SCADA,” in Proc. IEEE Int. Conf. on Power and Energy Systems, 2021, pp. 1–6. [3]

N. Gupta and V. Sharma, “Automation of hydroelectric stations using SCADA and IoT technologies,” in Proc. IEEE Int. Conf. on Smart Energy Systems, 2022, pp. 120–125. [4]

R. Verma and S. Kulkarni, “SCADA-based monitoring and control for small hydropower plants,” IEEE Transactions on Sustainable Energy, vol. 13, no. 2, pp. 987–995, Apr. 2022. [5]

A. Mishra and P. Tiwari, “Advanced protection schemes for hydroelectric power plants using SCADA,” IEEE Trans. on Power Delivery, vol. 38, no. 3, pp. 1678–1686, June 2023. [6]

K. Reddy and B. Rao, “Digital automation and SCADA integration in modern hydropower plants,” in Proc. IEEE PES General Meeting, 2024, pp. 1–5. [7]