

THE SCADA SYSTEM FOR THE CONTROL AND MONITORING OF A MICRO-HYDROPOWER PLANT

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ABSTRACT (TNR 10 pt Bold): Automation and monitoring play a crucial role in optimizing the performance of micro-hydropower plants. The primary goal of automating the plants is to enhance operational efficiency, ensure reliable energy production, and minimize human intervention. By automating processes such as turbine control, water flow regulation, and energy distribution, these plants can operate more consistently and efficiently, adapting to changing environmental conditions without manual oversight. Automation also helps in predictive maintenance by identifying potential issues before they escalate, thereby reducing downtime and extending the lifespan of the equipment. SCADA (Supervisory Control and Data Acquisition) systems are key in achieving these benefits, offering real-time monitoring and control of plant operations. SCADA provides operators with a comprehensive view of the plant's performance, including parameters like power generation, water levels, and turbine status. This data is crucial for optimizing plant operation, ensuring that energy production remains stable and efficient. Additionally, SCADA systems enable remote monitoring, allowing operators to intervene promptly in case of any anomalies. By integrating advanced data analytics, SCADA systems also facilitate performance optimization, energy forecasting, and troubleshooting. In the following we will show the use of SCADA in monitoring a micro-hydropower unit located in Romania.

KEY WORDS: SCADA, control, monitoring, automation, micro-hydropower.

1. INTRODUCTION

In Romania, micro-hydropower plants are an important part of the country's renewable energy landscape, contributing to sustainable power generation, especially in remote mountainous regions [3]. While many of these plants were initially built without advanced automation systems, there has been a gradual shift towards modernization in recent years. Some micro-hydropower plants have been successfully automated, with SCADA systems implemented for real-time monitoring and control of the plant's operations. These automated plants benefit from enhanced

operational efficiency, reduced human intervention, and improved maintenance practices.

However, a significant number of older micro-hydropower plants still operate without automation, relying on manual control and monitoring processes [4, 7]. These plants often face challenges such as less efficient performance, higher maintenance costs, and a greater risk of operational failures due to the lack of real-time data and remote monitoring capabilities [5, 6]. As the push for more sustainable and efficient energy sources grows, there is an increasing interest in upgrading these non-automated plants to incorporate

modern SCADA technologies, ensuring better performance, reliability, and long-term sustainability [11].

The current hydropower potential of Romania is estimated at around 32 MW, with approximately 6,000 MW being harnessed through existing hydropower plants, leaving significant untapped potential, particularly in small and micro-hydropower sectors [1, 2].

If Romania's non-automated hydropower plants were upgraded with automation and SCADA systems, their operational efficiency would significantly improve, leading to optimized energy production and reduced downtime [10]. This could unlock a higher percentage of the country's hydroelectric potential, allowing for more reliable and sustainable energy generation from both large and small-scale plants.

In the following we will present a SCADA system used for monitoring a micro-hydropower plant from Romania.

2. THE USE OF SCADA IN MICRO-HYDROPOWER PLANT

The SCADA system makes a significant contribution to the management of any type of equipment, but generally, it is used for automating complex industrial processes where manual control is not practical, distributed systems over large geographical areas with multiple parameters to monitor and adjust, or systems with high data processing speeds, where human control is difficult [8, 9]. SCADA (Supervisory Control and Data Acquisition) is an application model that collects data about a system in order to control that system. A SCADA system can be built using various types of technologies and protocols. A SCADA application targets two components [12, 13]:

- ✓ The process/system/equipment (such as a power plant, a water network, or a traffic management system) that is to be monitored and controlled.
- ✓ A network of intelligent devices that interface with the system through sensors and control mechanisms, enabling advanced monitoring and control of the considered system.

A SCADA system performs several key functions essential for efficient system management and control. These include real-time monitoring of processes and equipment, data acquisition from sensors and devices, and control of operations based on the collected data [14-16]. It also allows for remote access to system data, enabling operators to manage and intervene from distant locations. Additionally, SCADA systems support data analysis, providing insights into system performance, trends, and potential issues, while facilitating predictive maintenance and ensuring optimal performance. Alarms and notifications are also triggered by abnormal conditions, ensuring quick response to prevent failures.

The plant in discussion is a small scale hydropower unit in the Apuseni Mountains of Romania, a notable example of renewable energy production harnessing the power of water, which serves as an important part of Romania's renewable energy strategy.

The SCADA system of this micro-hydropower plant focus primarily on the most critical operational parameters: water flow, turbine performance, and electrical output.

2.1. The automation system of the micro-hydropower plant

The automation system controls the processes of starting, connecting to the grid, energy discharge into the 0.4kV network, automatic power factor compensation, and the normal or emergency shutdown of the micro-hydro units. The micro-hydro units deliver the produced energy at 0.4kV to the national energy system through a prefabricated transformer station, enclosed in a casing.

The proposed installation shown in figure 1 consists of:

- ✓ 2 generator power cabinets 0.4kV (G-1, G-2) which contain components for the protection and power supply of the generator, automatic power factor compensation, and measurement of electrical parameters. It is equipped with: a 0.4kV, 1600A three-pole automatic circuit breaker with overcurrent and overload protection, under voltage protection type Masterpact NT16, with Micrologic 6.0 P

protection, measurement, and control unit, current transformers, voltage monitoring relay, thermal-magnetic circuit breakers, capacitor banks, active power transducer, electronic power factor regulator, and contactors;

- ✓ 2 hydro unit control cabinets (DCA-1, DCA-2) which contain the equipment for the automation of the micro-hydro unit, AC power supply, 220V AC/24V DC rectifier, batteries, PLC, operator panel, and the electronic relay for speed measurement. The automation system ensures the starting, stopping, and monitoring of the hydro unit's operation, both through commands from the local plant dispatcher and remotely. It controls analog inputs (position of inlet valve, bypass and guide apparatus, cooling water flow for radial and axial bearings, speed, temperatures, downstream pressure, active power, GUP oil pressure) and binary inputs

(transformer circuit breaker, transformer protection relay, Watchdog relay, line isolator, oil level in the reservoir, motor thermal protection, voltage presence, generator couplings, M/O/A key position, unit start/stop) and initiates commands to the execution elements (open/close water valve, inlet valve, guide apparatus, brake solenoid valve, coupling/decoupling of circuit breakers, starting/stopping the electric pump, emergency shutdown).

- ✓ 1 general services cabinet DSG Contains bipolar and tripolar automatic circuit breakers, contactors, intermediate relays, signal interfaces, thermostat, heating resistor, lighting cabinet, outlets, clamps, and performs the AC and DC distribution for the internal services of the plant, as well as distributing the signals related to the common installations of the two control cabinets;

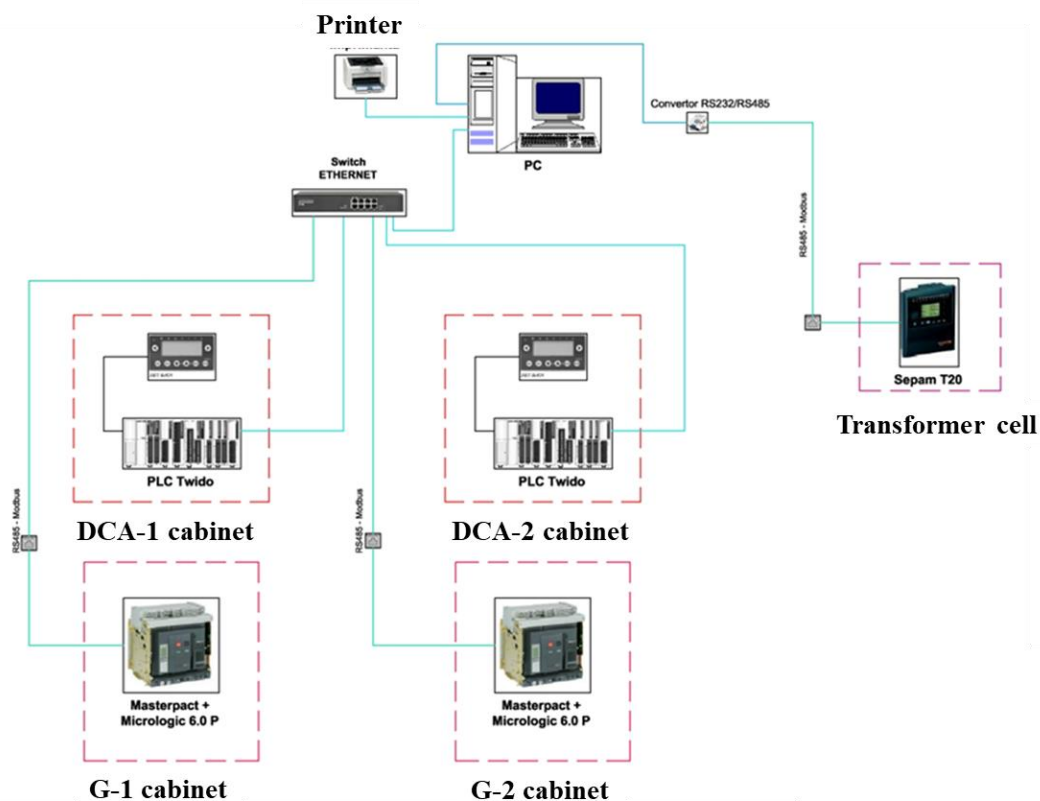


Figure 1. The automation system of the micro-hydropower plant

- ✓ 1 local plant dispatcher (control room) consists of a PC, UPS power supply, A4 laser printer, Ethernet switch, UTP cables, connectors and outlets, modem, application software;
- ✓ 1 energy evacuation station 20/0.4kV equipped with:
 - 20/0.4kV power transformer, 1600kVA, Dyn-5, fitted with a

combined relay with gas, pressure, and temperature protection type DGPT2

- Transformer cell equipped with a three-pole circuit breaker with motor drive, 24kV, 630A with SF6, bus bar separator, CLP, capacitive voltage presence indicators, 3 single-phase current reducers 50/5A, class 0.5S/5P20, transformer protection relay
- Measurement cell equipped with: 3 voltage transformers 20/ $\sqrt{3}$ /0.1/ $\sqrt{3}$ /0.1/3kV class 0.5/3P, with included HV fuses, 3 current reducers 50/5A, class 0.5s
- Line cell equipped with a load separator with CLP, 630A, 24kV, with motor drive, capacitive voltage presence indicators, zinc oxide surge arresters
- Electronic active and reactive energy meter

2.2. SCADA system designed for the micro-hydropower plant

The software for the SCADA system is Proficy Machine Edition 9.5. Through the SCADA system's GUI, we can monitor the key parameters of the process. Communication between the control room and the two generator units of the plant is done via two main channels:

- ✓ through the Ethernet port connected to a switch for TCP/IP communications
- ✓ through the serial port connected to an RS232/RS485 interface for Modbus/RTU communications.

The main screen of the SCADA application, as it can be noticed in figure 2, allows for an overview of the two generator units, displaying indicators for the positions of the inlet valves and bypass, as well as signals for the shutdown or operation of the hydro-generator units.

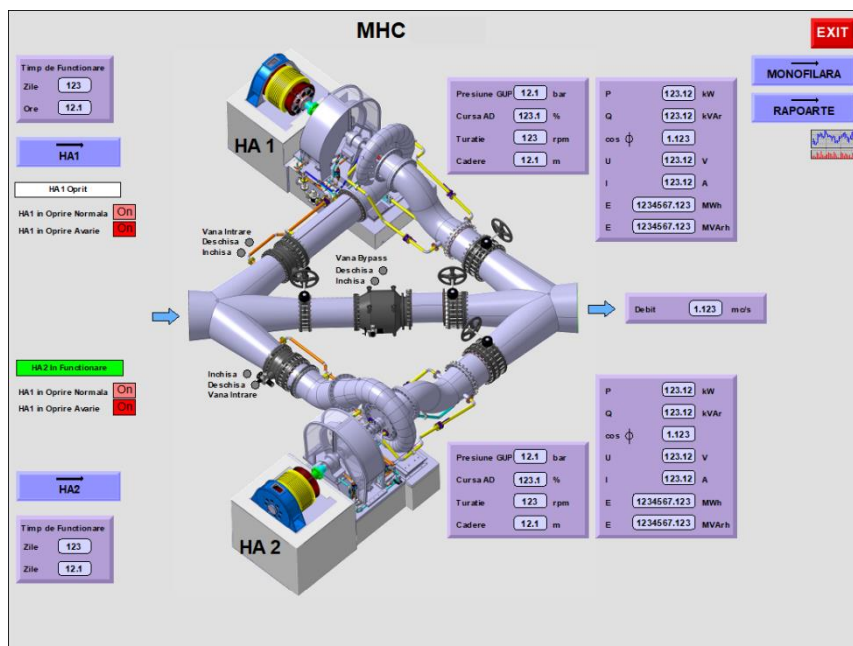


Figure 2. Main screen of the SCADA application

Here, it is possible to monitor the parameter values and the operating time for each hydro-generator individually. It can be observed from figure 2 that only HA2 is functioning, HA1 being stopped. One can also follow parametric values for GUP pressure (“presiune GUP”), rotational speed (“turație”), water fall

(“cădere”), as well as power, P, flow, Q, voltage, U, current, I, energy, E.

The main screen interface is provided with following buttons:

- button “MONOFILARA” which allows one to see a representation of the single-line diagram of the system;
- button “RAPOARTE” which allows one to see an *.xml file containing a table with all

chronological events registered for the hydro-power units functioning. All the events are saved in application database and can be printed or accessed remote;

- buttons “HA1” and “HA2” allow one to access and control each hydro-power unit;
- Figure 3 shows the single-line diagram of the system for the two hydro-power units HA1 and HA2. Form this screen one is able to monitor

electrical parameters, P, Q, U, I, E, active and reactive power. It also allows the command to increase/decrease the active power by closing/opening the control device, by means of UP/DOWN buttons from “P” option. In the right corner of the screen are available three buttons which allow access to the main screen, “MHC” and to the hydro-power units “HA1” and “HA2”.

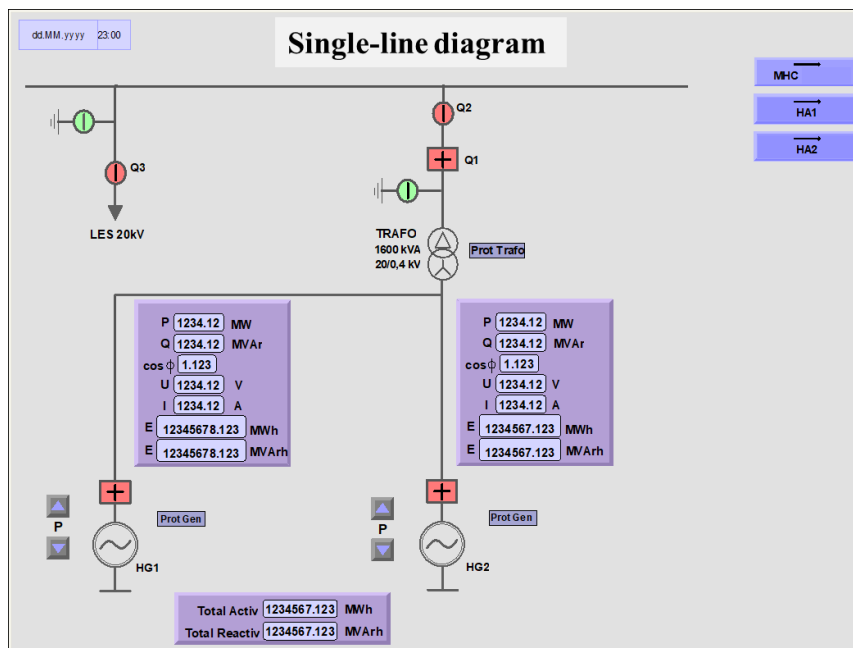


Figure 3. The single-line diagram of the system

The control of hydro-power units is made from the panel shown in figure 4. The screen from figure 4 corresponds to the control panel of

HA1 hydro-power unit. In similar manner is the screen for controlling hydro-power HA2.

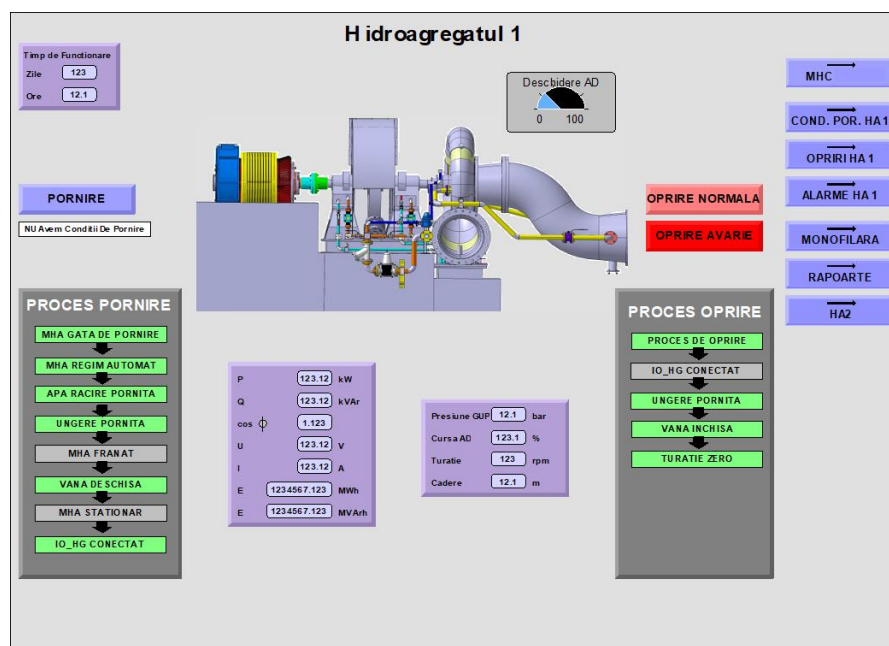


Figure 4. The control panel for HA1

Here, the starting and stopping sequences of the hydro-generator can be visualized. Each stage of the sequence is marked by a color change from gray to green. The generator will start only after the start conditions are met, with all signal boxes turning green and the operation mode set to “AUTOMAT”. The stopping process is handled unilaterally, with the difference between normal and emergency shutdown being the phase of active power discharge by the governor control system during a normal shutdown, before disconnecting the main circuit breaker of the hydro-generator.

Only after all the start conditions are met can the automatic startup process of the generator

be initiated by pressing the “PORNIRE” button. As it can be noticed in figure 4, at that moment not all starting conditions were met for HA1.

In terms of monitoring, at this panel are signaled the coupling of the hydro-generator circuit breaker to the 0.4/20 kV transformer, the state of the control device (closed or blocked).

To facilitate the operator's intervention in the event of a failure, the SCADA application provides the “OPRIRE HA1” panel, which can be seen in figure 5. Here, the conditions that lead to a normal stop command or an emergency stop command are detailed.

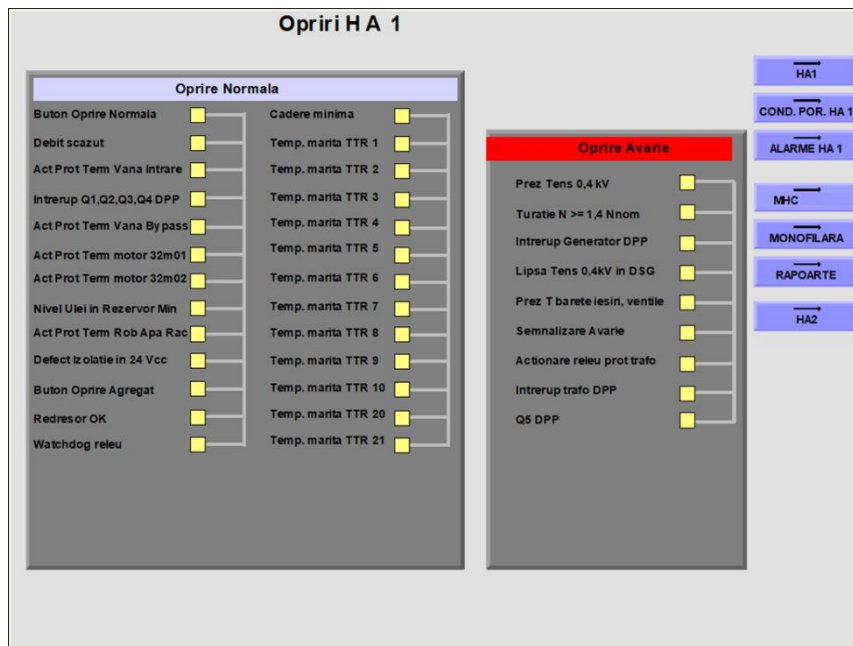


Figure 5. The STOP control panel for HA1

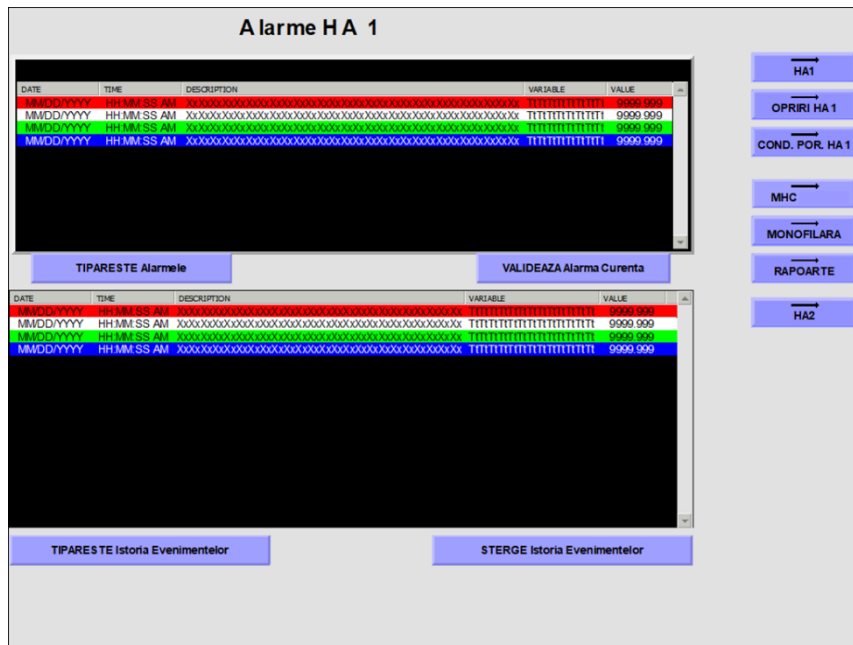


Figure 6. The ALARM panel for HA1

When a normal stop or emergency stop condition occurs, the corresponding event box turns red, and the line leading to the associated stop box is also highlighted. After any fault is triggered that results in a specific type of generator shutdown, the fault table can be accessed by pressing the “ALARME” button on the hydro-generator screen.

Figure 6 presents the alarm panel for hydro-power unit HA1. The panel contains two ActiveX controls that display, specific to each generator, the alarm table stored in the SCADA application's database. The control at the top of the panel shows the current alarms, which can be printed and validated, and are removed from the list once the fault signal disappears. Depending on the nature of the alarm, intervention can be done online by adjusting the parameter values, or onsite in the operation of the hydro-generator. The alarms displayed in the control at the bottom of the panel are from the database, stored on the hard disk in files with the *.alm extension.

3. CONCLUSION

The implementation and utilization of SCADA systems in the monitoring and control of micro-hydropower plants play a crucial role in enhancing operational efficiency, safety, and energy production management.

SCADA systems provide real-time data collection, enabling operators to monitor various parameters, such as turbine performance, water flow, and energy output, while ensuring immediate responses to faults or operational issues. This capability significantly reduces human intervention, minimizes downtime, and optimizes energy distribution, making it essential for improving the overall effectiveness of hydropower plants. Furthermore, SCADA systems offer advanced control over power factor correction, load balancing, and remote operations, which are vital for maintaining the reliability and stability of the energy grid. The integration of such systems in micro-hydropower plants not only improves energy efficiency but also contributes to more sustainable practices in the renewable energy sector.

SCADA system implemented for the micro-hydro-power plant in discussion have proven to be a highly advantageous solution for the management and automation of hydropower facility, enhancing its productivity and long-term sustainability.

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