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Configuration of SCADA System Graphical User Interface for Electrical Station

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***Abstract* - In order to efficiently and practically solve the problem of analyzing the performance of the SCADA (Supervisory Control and Data Acquisition) system of the power grid, this paper proposes to reconfigure the graphical user interface (GUI) in the substation, as well as to remap the signals according to the hardware structure used. After replacing the hardware solution with PLC and software for protocol conversion installed on the local HMI with a specialized remote terminal unit for data storage and protocol conversion in the substations, it is important to adapt the graphical user interface of the SCADA system according to the latest hardware configuration. This is necessary for the stability and reliability of the SCADA system. In the last part of the paper, the configuration of the graphical user interface of a SCADA system and the remapping of the signals in the specialized software in an electrical substation in Romania is presented and highlighted through screenshots.**

Cuvinte cheie: *SCADA, interfată utilizator, automat programabil, , stație electrică, flux de date*

Keywords: *SCADA, Graphical User Interface (GUI), Programmable Logic Controller (PLC), electrical substation, data flow.*

I. Introduction

The fundamental objective of most integrated monitoring and control systems for installations, networks, or power systems is to provide users with adequate information and facilities for monitoring and control. The aim is to enable the safe, secure, and economical operation of the specific power system. These systems are commonly known as Supervisory Control and Data Acquisition (SCADA) systems, as shown in Figure 1.

The most basic SCADA system is a two-tiered master-slave configuration. It involves a primary coordinating master computer with interfaces for user dialogue and data transmission, alongside a subordinate Remote Terminal Unit (RTU) process computer. The RTU is equipped with interfaces for both analogue and digital inputs and outputs, as well as a communications interface. These systems fall into the category of small-scale and are not frequently employed in the monitoring and control of power systems.

In [1], the authors present a brief overview of distribution system automation. Current implementation philosophies and current challenges in distribution system automation are discussed. In [2], a solution for the design of the GUI for a SCADA system on an industrial platform is proposed. The production and use of electricity from classical or renewable energy sources can no longer be conceived without the automation of the technological process.

Several projects of distribution and transmission stations that combine SCADA and Protection & Control (P&C) are reviewed in [3]. There are considerations on the analog input, digital status and control. Aspects of discrete and analog I/O operation within a substation for the SCADA system are also reviewed, considering the flexibility and maintenance benefits offered.

Owing to the intricate nature of processes in power engineering, it becomes imperative to employ multiple process computers distributed across various hierarchical levels. This results in the establishment of a hierarchical monitoring and control system, allowing for distributed control of the process in a hierarchical framework, as outlined in references [4], [5], [6].

II. Programmable Logic Controller

Programmable Logic Controllers (PLCs) are equipment designed for automatic monitoring and control of industrial processes. They are part of distributed monitoring and control systems and are real-time control systems.

PLCs perform two main tasks, concerning the monitoring and automation of a process, as illustrated in Fig. 2:

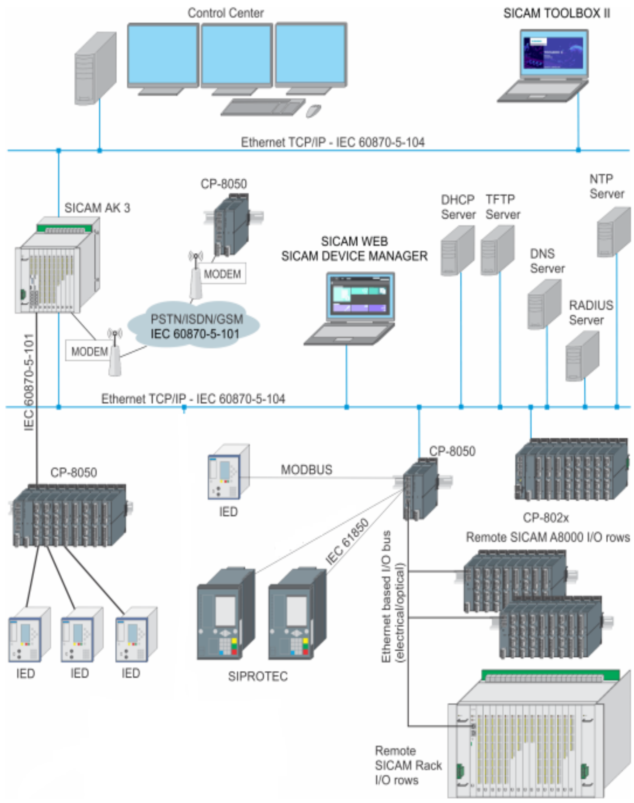

Fig. 1 A typical SCADA system architecture.

- acquisition, which involves monitoring the state of the process by acquiring via sensors, buttons, limit switches, the state variables in the process;
- control, which consists of processing the information received and generating the necessary commands to the execution elements of the automated process according to a specific software.

From a structural point of view, the following can be distinguished:

- PLCs with an open structure in the form of a printed circuit board without a housing - these are very cheap variants, but the number of inputs and outputs is limited and there is no possibility of adding extension modules;
- PLCs with a monobloc structure in a closed housing - these have all the components grouped together in a housing, the dimensions of which depend on the number of input and output terminals, and allow the connection of extension modules, which have a separate housing and are connected by means of connecting cables;
- PLCs with a modular structure with a large number of inputs and output, a multitude of control possibilities and consequently a large number of available extension models, presented in Fig 3.

The hardware of a PLC consists of a microprocessor (or microcontroller) based central processing unit (CPU), a memory, input modules (for signals coming from the transducers and the operator), output modules (through which commands are transmitted to the execution elements and signals to the operator) and serial/parallel interfaces for connecting the PLC with programming devices, PC computers or other PLCs [7], [8], [9], [10].

The operation of the programmable controller is based on the repeated execution of the program written in its memory.

Each program execution cycle consists of 3 steps:

- reading inputs;
- execution of the program instructions;
- updating outputs.

The duration of such a cycle depends both on the speed of the processor with which the PLC is equipped and on the length of the user's program.

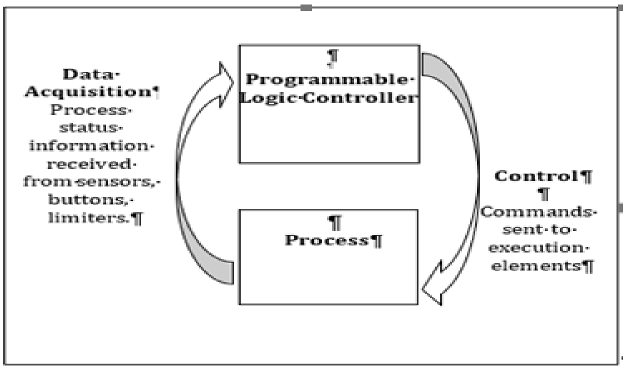

Fig. 2 Block diagram of a monitoring and automation system using a PLC.

Fig. 3. PLC in the SCADA panel.

The PLC executes the program from the first line to the last and then repeats this cycle which is carried out in 3 steps:

- Reading the inputs: the PLC scans each input in order to determine the ON or OFF status of the sensors or switches connected to the inputs, whether they are activated or not; the information collected during this step is stored in the memory to be used in the next step;
- Program execution: the PLC executes the program instructions sequentially (instruction by instruction), and, as a result, one or more outputs may be activated, or information may be stored in specific areas in memory, to be used in the next step;
- Update outputs: the PLC checks the states of the outputs and modifies them if necessary and the changes are based on the states of the inputs read during the first step and the results of the second step program execution.

After the execution of the third step, the programmable logic controller resumes the program cycle.

III. Remote Terminal Unit

In order to meet the performance requirements of the system user, the RTU equipment must fulfill several requirements.

A. *Remote Terminal Unit Equipment Design*

In the control center of each substation, the system contains at least one RTU, which "interrogates" all the terminals in the substation, acting as a data concentrator, a real-time data server, and a communication server to the higher hierarchy level providing the interface to a graphical console for the operator.

The RTU has an open, distributed processing architecture with the following main features:

- low power consumption, able to work in a high voltage electrical installation, having a robust physical construction with immunity to the electrical noise;
- modular construction (Fig. 4 and Fig. 5); the failure of one module shall not affect the operation of the other modules, and the replacement of any module shall be carried out without disturbing the overall operation of the RTU equipment;
- be provided with serial ports for interfacing with electronic meters, digital relays, programmable logic controllers;
- communication with other SCADA-Master Stations using different communication protocols;
- microprocessor-based construction;
- after powering up the unit, it must be designed to operate without manual intervention; in addition, it must restart automatically and be able to communicate with the higher hierarchical level (Master Station) without affecting its operation, and the existence of appropriate indicators, such as LEDs, must provide staff with correct information to easily determine the status of the RTU;
- the Master Unit shall monitor the operation of the RTU with the possibility of diagnosing errors concerning overflow of memory capacity, local software operation, status of communication ports, status of input/output modules;
- to enable fault detection, there will be a separate list of events and each event will be identified with the ID number, event type, time of occurrence;

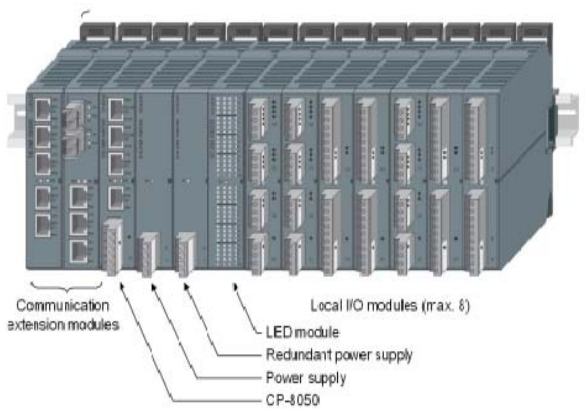

Fig. 4 Remote terminal unit.

Fig. 5 RTU in the SCADA panel.

- the RTU will allow storage of up to 2000 events;
- the RTU will be equipped with an internal real-time clock, with a resolution of one millisecond, synchronized via communication protocol by the master, for the list of events to be accompanied by the time stamp;
- the data associated with each event will be stored in the RTU for later transmission;
- within the RTU, events will be reported at certain time intervals with a time accuracy of +/- 1ms;
- input/output (I/O) modules;
- I/O modules will be intelligent modules containing microprocessors, and will be configured as slaves to the RTU mainframe module;
- inputs will be scanned at least every millisecond by the digital input module;
- there will be software filtering of parasitic pulses or some other method of reducing false alarms caused by devices that change state fairly quickly and for which it is not necessary to report this change of state every time;
- the RTU will be able to support point change detection of analogue and numerical magnitude highlights;
- the RTU shall not lose fast status changes, therefore status changes shall be determined by the RTU and stored until they can be transmitted to the next higher level (SCADA-Master Station).

Each RTU will have multiple communication ports (at least 8 communication ports. 7 ports will support communications with other equipment: electronic counters, microprocessor relays, sub-RTUs, and the 8th port will be a dedicated maintenance port: an RS-232 or RS-485 serial port that must provide connection to a local PC for diagnostics and configuration).

Each communication port will be selectable for operation in the (300...19,200) bps range.

RTU shall be able to communicate with another RTU at the same level or higher (SCADA-Master Station); each Master Station may use different communication protocols and transmission rates, which are in agreement with IEC 61850 and IEC 60870-104 standards [11], [12].

B. Internal Data Flow

The basis for remote terminal unit is a modular, open, and thus non-technology-dependent system architecture for processing, communication, and peripherals (single-processor system, firmware).

The adaptation to the specific needs of the application is accomplished by relying on an individual hardware configuration and by loading standard firmware and parameters. Within their defined limits, the parameters thereby not only influence the behavior of the firmware functions, but also that of the hardware functions. As a result, mechanical parameterizations such as the changing of jumpers or loads are no longer necessary on any of the module types. This permits not only online reconfiguration but also the gapless documentation of set parameters by the engineering system, as well as simplified inventory management.

Due to the different requirements in terms of functionality, also different data flow concepts are produced and can be illustrated by means of Fig. 6.

For telecontrol tasks and the distribution of user data in networked plants, the use of spontaneous transmission proves advantageous for optimizing the utilization in many cases limited communication bandwidth. This helps to avoid constant burdening of the data sinks with unnecessary data.

For the implementation of a freely definable open-/closed-loop control function, a deterministic guaranteed reaction time is needed. This is achieved by using the consistently periodic concept with regard to data acquisition, execution of functions, and data transfer, regardless of the number of changing signals [13].

IV. Graphical User Interface Configuration

The Zenon Energy Edition software platform is the foundation of the application used in the analysis of an electricity substation in Romania, providing facilities specifically designed to simplify the processes of (GUI) configuration and signal remapping. The objective of this platform is to efficiently configure and diagnose automation systems at the level of an electrical substation.

Figures 7, 8 and 9 show how to configure the signals in the RTU, remapping the signals in the GUI development application according to the list of signals implemented in the RTU. Fig. 10 shows a screenshot of the feeder during real-time tests.

The software platform has two ways of working:

- development - mode of work used when designing an application; the user has the possibility to create or modify files in the project, accessing available resources and configuring them through the specific properties of each type of object;
- runtime - mode used when running the program; the user has the possibility to view the data taken from the process and to enter the commands that were left available in the design phase [14].

The software works around a central core represented by the real-time database containing all the tags needed to run the program, a simple operating interface for the SCADA solution. The Communications Module is used to transfer information to and from the Real-Time Database from all devices connected to the network. To do this, the Communications Module uses a set of communication drivers that allow it to:

- connecting via network to a Client Server.
- connect to PLCs over Modbus;

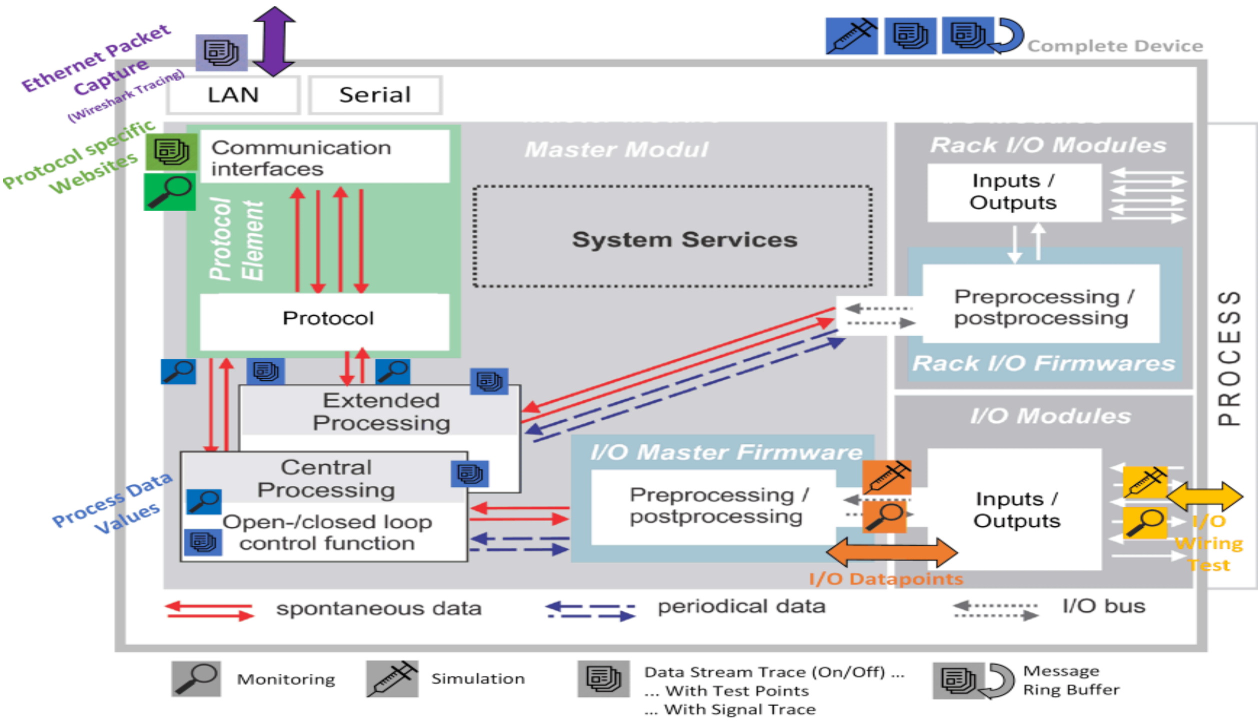

Fig. 6 RTU process diagram.

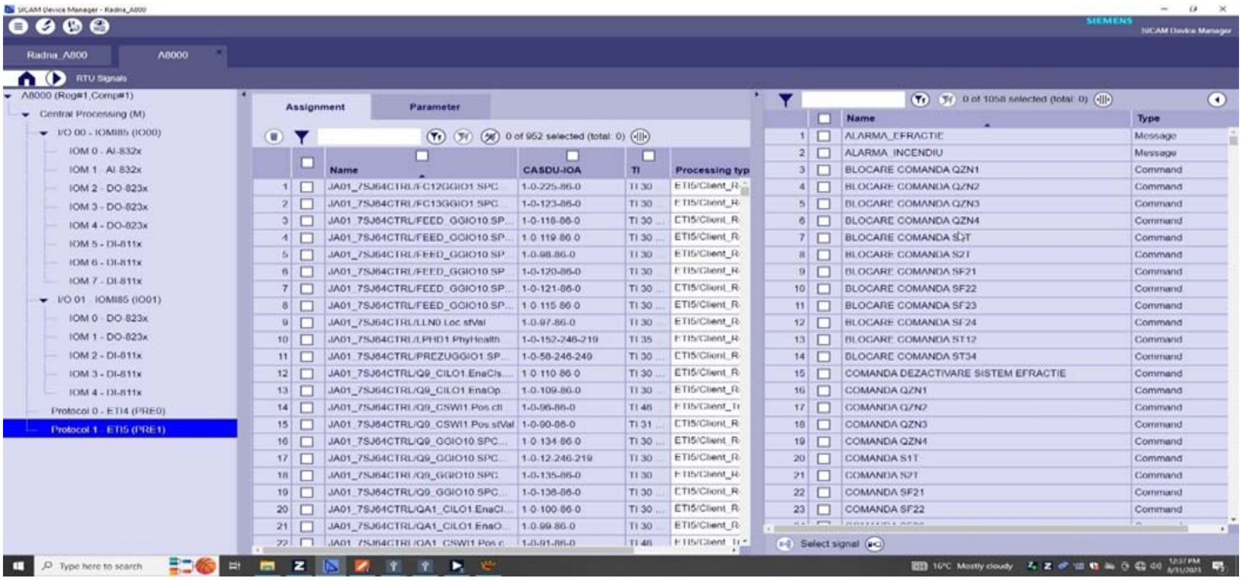

Fig. 7 List of signals implemented in RTU.

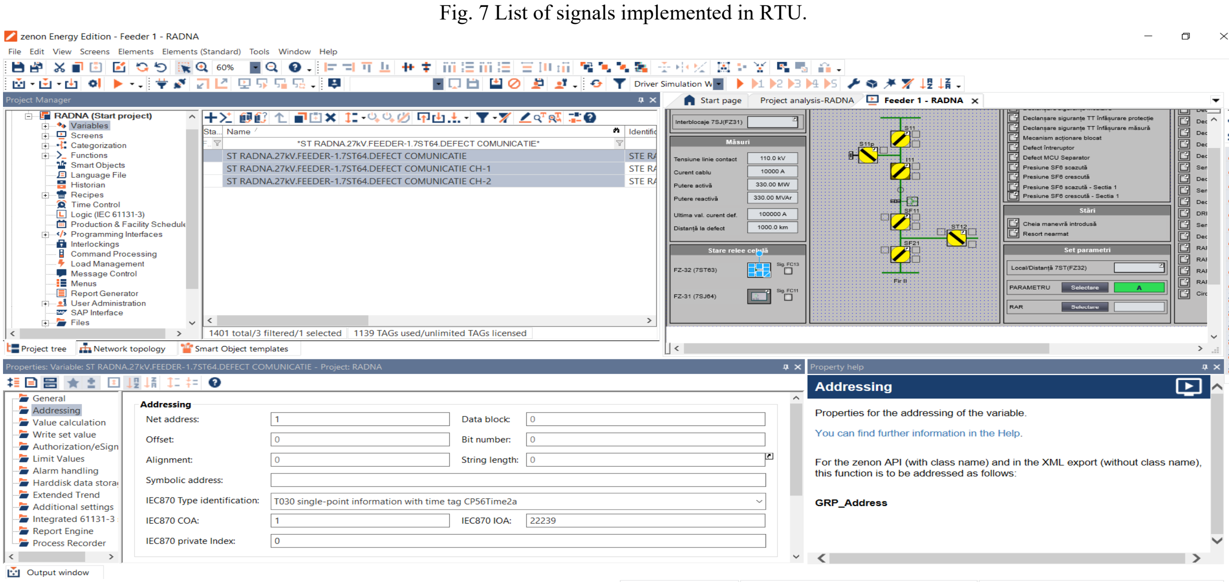

Fig. 8 Signal list configuration in the feeder of the electrical substation.

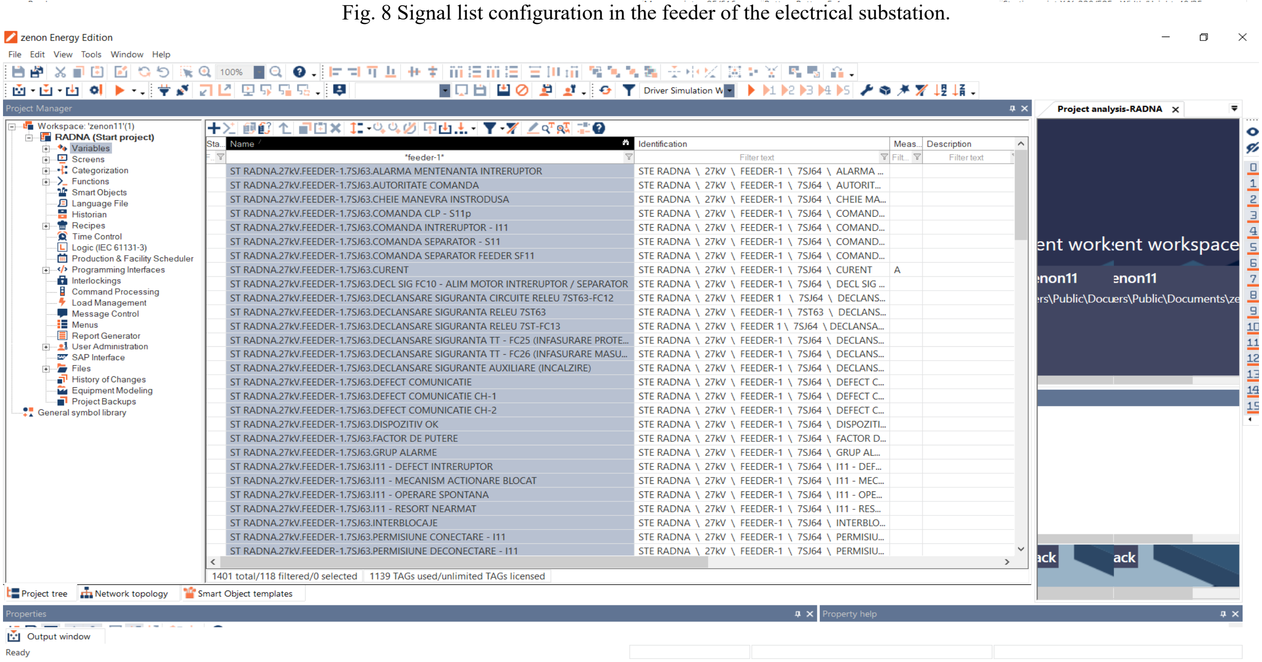

Fig. 9: Signal List of Feeder

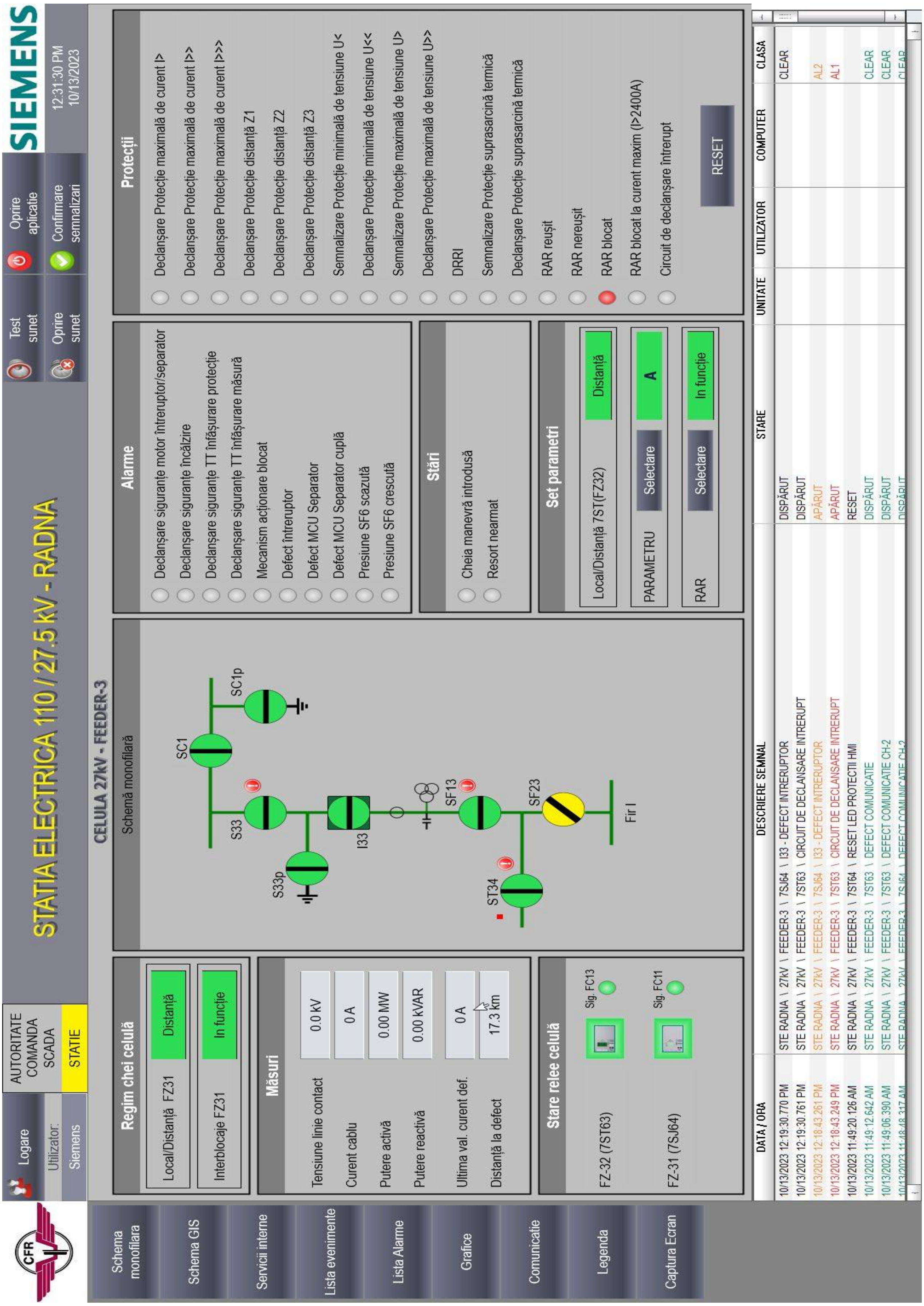

Fig. 10 Real-time test of feeder graphical user interface

The main feature of the program is to provide a number of powerful resources and tools (object libraries, symbol libraries, communication drivers, real-time databases, etc.) that make it easier to design and build an application [15].

The projects realized through the Zenon software platform are made up of a series of component groups (known as Project Resources) such as the Real-Time Data Base (DB Real Data Base), Data Records, Raptors, Alarms, etc. All these component groups are displayed in a tree-like structure in the main "Project Manager" window of the application.

V. CONCLUSIONS

This paper shows that by configuring the GUI and mapping the signals according to the hardware structure of the SCADA system, dedicated to these SCADA applications, there are many advantages.

By means of a case study in an electrical substation in Romania, the configuration of the GUI is illustrated, as well as the correct operation in real time.

The software application at the central monitoring level communicates wirelessly (GSM/GPRS) with the local acquisition and control system as well as with other monitoring systems.

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REFERENCES

[1] T. Frauenschlager and J. Mottok, "Security-Gateway for SCADA-Systems in Critical," *2022 International Conference on Applied Electronics (AE),* 19 October 2022.

[2] I. C. Hoarcă, N. Bizon, F. M. Enescu, "The design of the graphical interface for the SCADA system on an industrial platform*," 2020 12th International Conference on Electronics*, Computers and Artificial Intelligence (ECAI), 25-27 June 2020.

[3] C. Wester, N. Engelman, T. Smith, K. Odetunde, B. Anderson, J. Reilly, "The role of the SCADA RTU in today's substation," *68th Annual Conference for Protective Relay Engineers,* March 30 2015-April 2, 2015.

[4] M. Moga, *Sisteme inteligente pentru conducerea reţelelor de distribuţie*, Editura AGIR, București 2000.

[5] M. Moga, *Introducere în sisteme informatice pentru electroenergetică*, Ed. Politehnica, Timișoara, 2008.

[6] T. S. Sidhu and Y. Yin, "IED modelling for IEC61850 based substation automation system performance simulation," *2006 IEEE Power Engineering Society General Meeting*, Montreal, QC, Canada, 2006, pp. 7.

[7] https://mctr.mec.upt.ro/wp-content/uploads/2017/12/Curs_AP_2017.pdf

[8] http://web.ulbsibiu.ro/laurean.bogdan/html/PLCprincipii.pdf

[9] http://electrical-engineering-portal.com/what-can-a-plc-do-why-do-we-use-them

[10] L. Fang, "Application of PLC technology in electrical engineering and automation," *Proceedings of the 2016 2nd International Conference on Materials Engineering and Information Technology Applications (MEITA 2016)*, February 2017.

[11] Remote Terminal Units (RTUs) for Substation and Distribution https://www.kalkitech.com/products/sync-2100/

[12] https://www.transport.nsw.gov.au/.../ep-11-03-00-02-sp.pdf

[13] Manual_A8000_CP-8031_CP-8050_ENG_DC8-026-2_18, https://support.industry.siemens.com/cs/document/109757272/sicam-a8000-series-manual-cp-8031-cp-8050-?dti=0&lc=en-RO

[14] A. Ramadhan, M. A. Murti and L. V. Yovita, "Implementation of networked control systems using programmable controller based Ethernet network," *2013 International Conference of Information and Communication Technology (ICoICT)*, Bandung, Indonesia, 2013, pp. 22-27.

[15] F. Fadhil, "Analysis and design of a modern SCADA system," *Thesis for: MasterAdvisor: Qutaiba Ali*, January 2019.