Remote Communication in the Substation's SCADA System

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Abstract **- The aim of this paper is the implementation and validation of a mobile phone remote connection to a Supervisory Control and Data Acquisition system (SCADA) of a railway traction substation. The implementation was done not only to optimize the time in which the user intervenes within the electrical substations, in case of a fault or other event, but mostly to be able to react in unforeseen situations where the person in charge is not and cannot quickly reach the electrical substation or even the remote desktop. For this, the operator can connect to the system using the mobile phone and the corresponding mobile phone software using an interface similar to the remote desktop. Therefore, the operator can hand the fault and make the required actions or improvements. The proposed system gives the ability to optimize the intervention costs considering the required trips to the electrical substation, and even more the trip to the SCADA remote desktop station. Therefore, a wireless remote connection method is approached via the mobile phone network to the SCADA system.**

Cuvinte cheie: *sistem de monitorizare, control și achiziții de date, telefon mobil, control wireless, control la distanță, sistem wireless, stație electrică, dispozitiv electronic inteligent.*

Keywords: *supervisory control and data acquisition, mobile phone, wireless control, remote control, wireless system, electrical substation, intelligent electronic device.*

I. INTRODUCTION

Primary and secondary devices are used to decrease the number of potential single points of failure. Components are deployed for collecting data from different constituents within a switchgear assembly. This configuration has a provision for managing older components where it uses a data concentrator that talks to other devices, for example, an intelligent electronic device (IED) [1], [2].

Four main functions of the distribution automation system are introduced in this paper: monitoring function, control function, protection function and management function. The distribution automation system is the inevitable result of the development of the distribution network and will become even more important in the future to provide users with high quality energy [3], [4].

Innovations in next-generation communication technologies play a vital role in optimizing the operation of energy distribution grids, facilitating the creation of smart grid systems [5], [6].

The Supervisory Control and Data Acquisition (SCADA) system includes all the equipment and technical systems necessary to measure the values of the parameters of interest in the electrical substation and to control the execution elements.

All this equipment is dimensioned appropriately according to the number of parameters monitored at each feeder, respectively, and to have the possibility of connection with the control elements at the higher hierarchical level in order to transmit data and receive control signals. The energy parameters to be measured and monitored shall refer to the measurement of the parameters and energy consumption at the input of the feeder IED and to the measurement of the consumption parameters on the utilization side on the electrical substation, and shall be as follows:

- Currents (actual value: I_R, I_S, I_T, I_N);
- Voltages (line voltage actual value: U_{RS}, U_{ST}, U_{TR}; phase voltage actual value: U_R, U_S, U_T; average/maximum value for phase and line voltages); - Frequency (actual value of frequency in the supervised network: F);
- Active, reactive and apparent power (current value for each phase: P1, P2, P3, Q1, Q2, Q3, S1, S2, S3; total current value on the three phases: Σ P, Σ Q, Σ S; average/maximum value: Σ P, Σ Q, Σ S);
- Harmonics (current total harmonic distortion: $THDI_R$, $THDI_S$, $THDI_T$, $THDI_N$; line voltage total harmonic distortions: $THDU_{RS}$, $THDU_{ST}$, $THDU_{TR}$; phase voltage total harmonic distortions: $THDU_R$, $THDU_S$, $THDU_T$.

  The SCADA system which was implemented in this paper had been applied to a railway electrical substation connected to the 110kV power grid. The catenary voltage for the Romanian railway system is 27.5 kV.

II. ARCHITECTURE OF WIRELESS MONITORING SYSTEM

The wireless monitoring system of the energy parameters for the electric substation is based on a SCADA architecture illustrated in Fig. 1, which assumes the existence of acquisition and control equipment at the local level for each consumer, one or more computers (servers) that centralize the monitored information and save it in a database and one or more computers on which a client application is running to present the monitored parameters.

The server applications acquire from the local acquisition and control equipment, in real time, the values of the monitored parameters of the electrical equipment, process them and then save them in a local or central database. The client application acquires information from the database and presents it to the user through a Graphical User Interface (GUI).

Tracking the energy behavior of the electrical substation is based on a process of acquiring and analyzing a large amount of remote data.

Remote monitoring and control of the electrical substation which is based on gathering information on the status of the electrical substation via appropriate acquisition interfaces, transferring the information to the central monitoring level, remote control and recording of significant changes of local consumers [7].

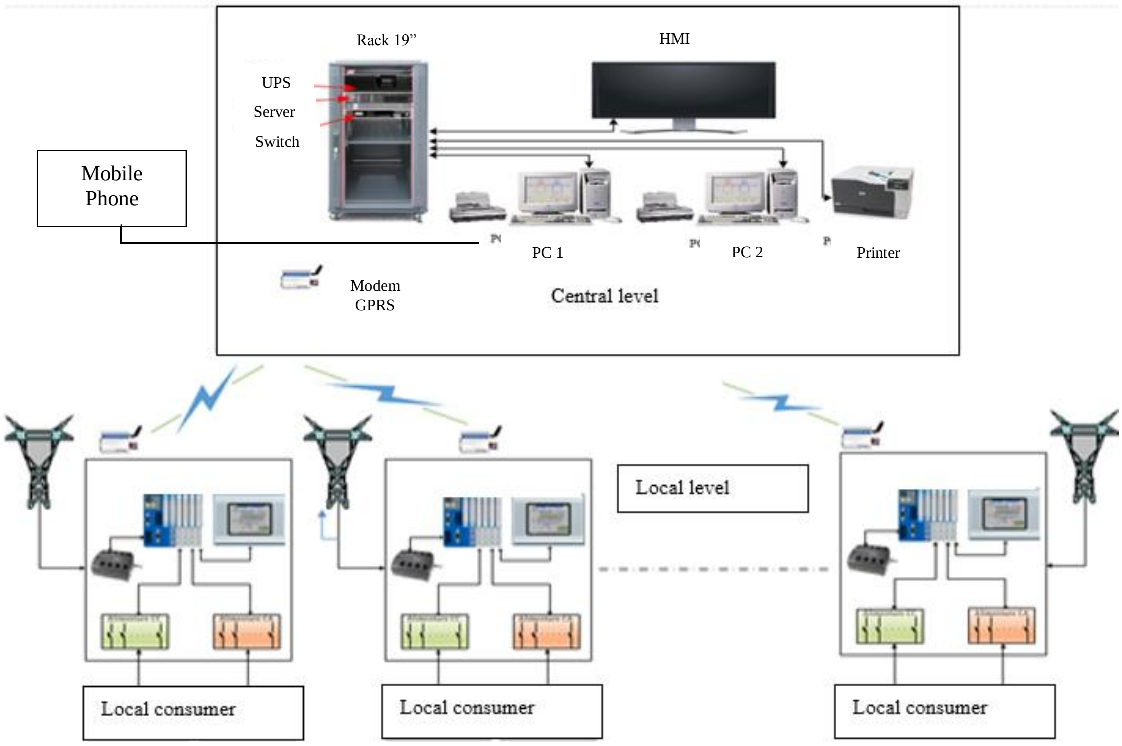

Fig. 1. Architecture of wireless monitoring system.

III. CENTRAL LEVEL

At the central monitoring level, a modular panel is placed inside, in which the computing and communication equipment necessary for the system operation is mounted.

SMART UPS type uninterruptible power supply ensures the operation of the SCADA equipment at the central level for a determined period of time in situations of accidental power supply voltage drops. It also provides protection for the equipment supplied by it in the event of variations in the supply voltage that may occur accidentally in the central supply network.

All the necessary hardware and software modules are installed in the Server computer for:

- data acquisition and processing from local consumers via the programmable logic controller (PLC) at the local level;
- real-time monitoring and storage of energy, configuration and status parameters for each local consumer
- ensuring quick and efficient access to stored information by authorized persons;
- real-time processing of commands to local PLCs;
- processing data from the system's non-volatile memory for displaying data on the Human machine interface (HMI) -Visualization Monitor;
- data processing for the preparation and printing of reports specific to system operation.

SWITCH equipment ensures the ETHERNET data communication between the system components: Server computer, GPRS (General Packet Radio Service) modem at the central level, workstation computers, HMI interface, and printer. Other computers with access rights in the SCADA network can also be coupled to the SCADA network at the request of the beneficiary.

4G Industrial Cellular 4G Router, with RS-232/485 port, with 10/100Mbps Ethernet ports and WiFi IEEE 802.11 provides GPRS communication with PLC equipment at local levels. The equipment also provides WiFi access to the SCADA system network for users with access rights.

In addition to the cabinet described above at the central level, other components of the SCADA system equipment are located.

HMI interface is represented by a 41" ultra HD display on which the information received from the local Programmable Logic Controllers, as well as the data processed by the central computer based on this information, are displayed. The display is coupled to the Server Computer as well as to the computing equipment connected to the internal SCADA network.

The printer is connected to the system via ETHERNET link and accessible to users with access rights coupled to the network, used to print specific operation reports (daily, weekly, monthly, etc.), malfunction reports and other reports according to user requests.

There are computers connected in network with the SCADA server and through which users with access rights realize:
- visualization of the status of the SCADA monitoring system component equipment;
- visualization of the electrical parameters received from each of the local equipment;
- remote control of the PLCs of each local consumer;
- visualization of the fault and alarm states of each local equipment;
- selection of the types of reports, of the visualization interval, to be printed for analysis and archiving;
- system configuration and maintenance.

The presented structure provides:
- CONTROL – the user can read and write/modify any parameter in the process (with password);
- VISUALIZATION - graphic screens, synoptic diagrams;
- ALARMS MANAGEMENT - they are cataloged by priority levels (can be acknowledged, deleted, archived, modified);
- DATABASE - high-performance database server, Microsoft SQL Server (allows multiple on-line access to the server database);
- RECIPES - allows the creation of upload to/from PLC of groups of point settings;
- REPORT MANAGER - allows the creation and generation of reports based on process measurements;
- GRAPHICS - facilities, based on ActiveX technology:
- multiple graphs in the same screen;
- unlimited number of lines in the same graph [8], [9].

IV. LOCAL LEVEL

At the local level of the monitoring system (illustrated in Fig. 2), the electrical substation has a workstation where the energy parameters can be monitored both from the single-wire scheme as well as the detail schemes of the feeder and auxiliary services in the substation. It must be mentioned that the diagram represents a single-phase system given the fact that the railway power system is single phase.

The substation includes the fixed installations for connection to the high-voltage power system and adaptation of the energy parameters (voltage, current, etc.) to the needs of the energy system:

- High Voltage Overhead Line (OHL) feeder (2-pole);
- High voltage power transformer feeder connected at the same phase-phase voltage;
- Single phase (1-phase) power transformer;
- Voltage Transformer for contact wire;
- Bus coupler bay;
- Feeder [10].

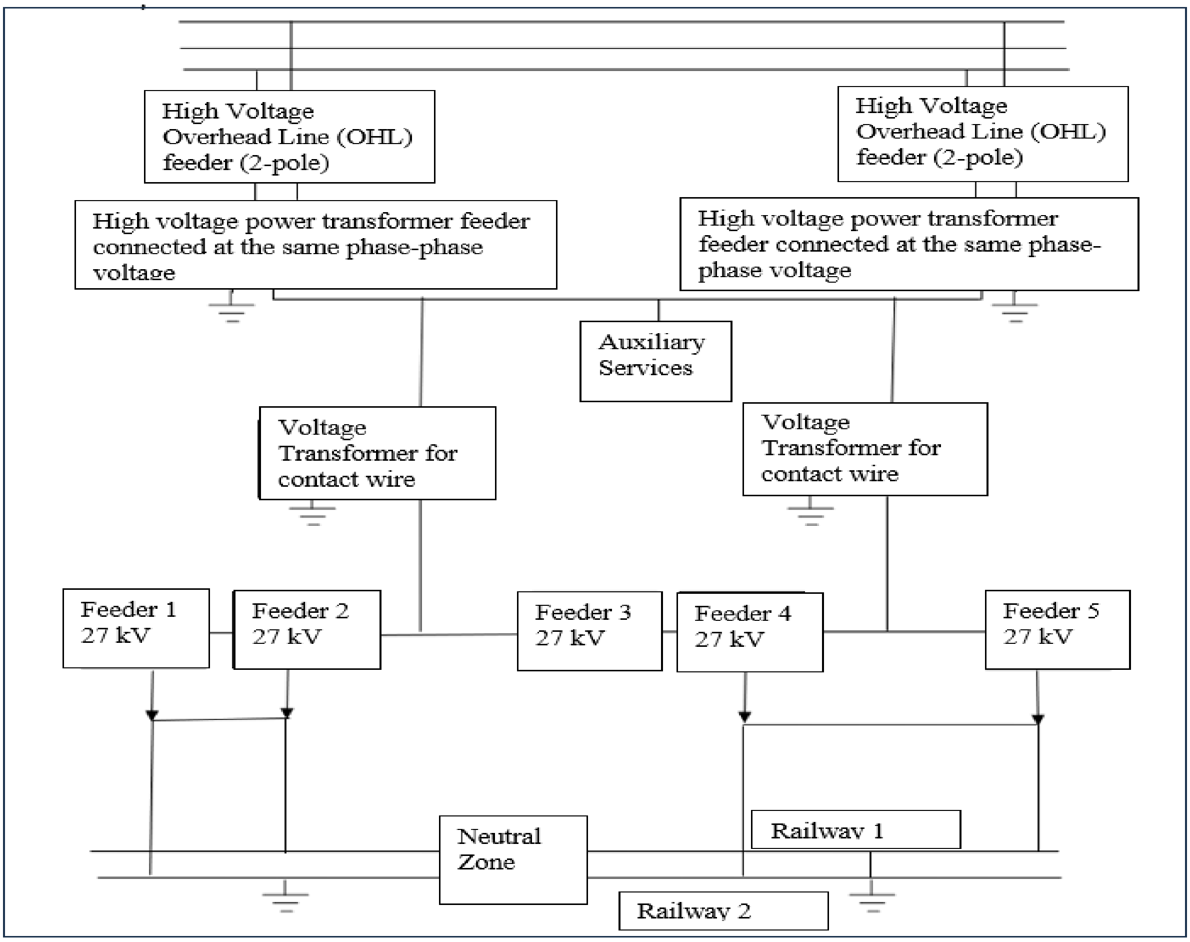

Fig. 2 Local level block diagram.

V. Communication in the Monitoring System

In the presented monitoring system, there are some specific data transmission situations.

The wireless communication is realized between the computer at the central level and a remote computer using dedicated software.

Communication at the central monitoring level, refers to:

- ETHERNET data communication between the system components at the central monitoring level and the need for a 4G industrial cellular router, with RS-232/485 RS-232/485 port, with 10/100Mbps Ethernet ports and WiFi IEEE 802.11 IEEE that provides GPRS communication with the PLC equipment at the local level.

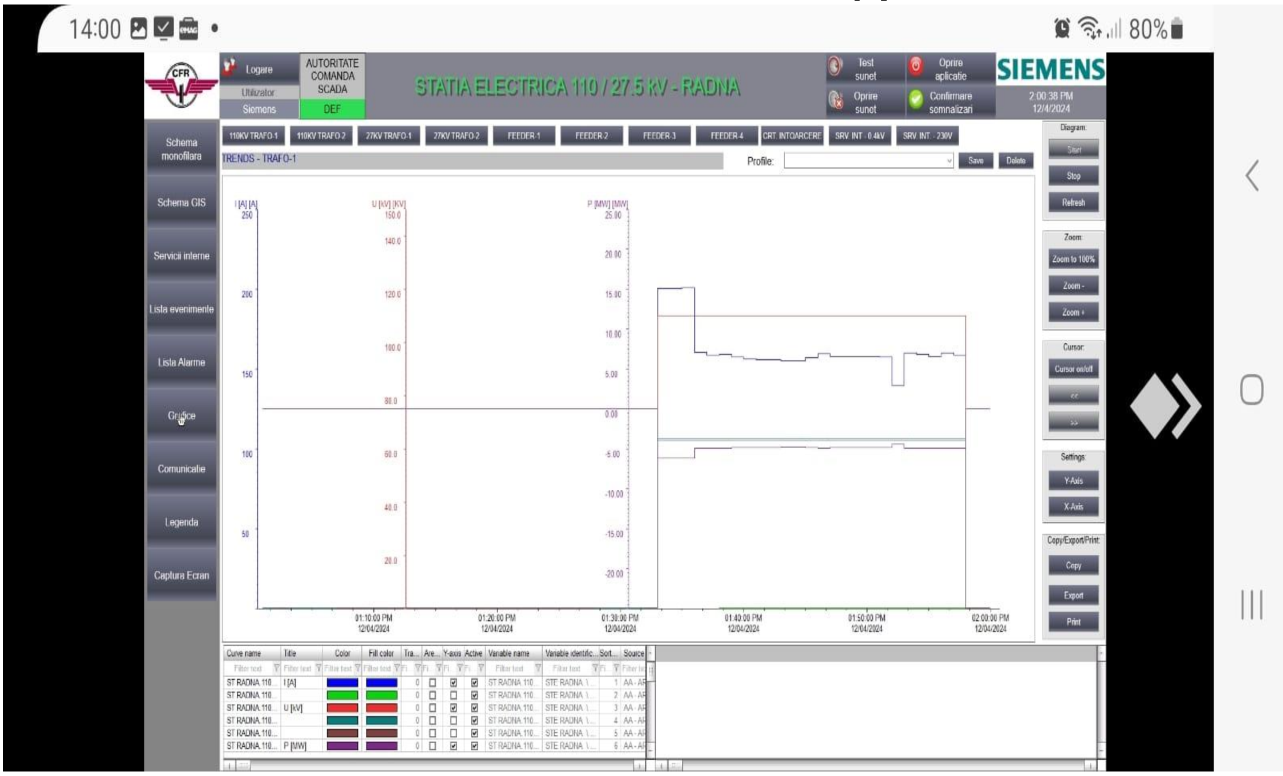

Fig. 3. Trafo 1 110kV trends.

The remote data transmission to the central monitoring level refers to the communication between the local level acquisition and control system with the next higher monitoring level, which is often quite far away; the most common and reliable solutions are GSM/GPRS communication networks, which implies the inclusion of a GSM/GPRS communication module at the local level.

Local communication refers to:

- the communication between the Programmable Logical Controller and the intelligent electronic device within the substation is an ETHERNET data communication;
- communication between intelligent electronic device and transducers which is realized by wire, in unified signal, usually (4...20) mA cc or (0...10) Vcc [11], [12], [13].

VI. Experimental Results

An efficient solution for monitoring the energy parameters needed for interpreting the post-default analysis in power substations is the connection to the SCADA system using a mobile phone. The required operating systems are Windows for the computer and Android for the mobile phone. The remote connection between the two devices is established using a remote-control application called AnyDesk. To secure the data, a username and password are set up on the computer and entered into the AnyDesk mobile app installed on the mobile phone used to access the SCADA system. Access to the monitoring system is only allowed to the authorized personnel, which is registered to the AnyDesDesk mobile app installed on the mobile phone used to access the SCADA system.

Access to the monitoring system is therefore allowed only to persons who know the login data. The computer to which the mobile phone is connected is located at the central level of the SCADA system. The information transmitted in real time to the mobile phone, which makes the visualization of energy parameters value more efficient, thus allowing a quick post-failure analysis. The evolution of the energy parameters is illustrated in Fig. 3. It can be seen that the current varies between 150 A and 200 A, and the voltage is constant at 110 V. The power varies between -5 MW and -3MW. Each energy parameter is graphically represented with a different color in order to be able to efficiently interpret the information by the station operator. The feeder where the values are recorded is shown in blue font on the top left and is labeled "TRAFO-1".

These values are recorded after simulating the energy parameters with an injection kit used to check the stability of the system. The injection kit is positioned in the clamps where the process signals arrive, thus simulating real situations. Along with the energy parameters, which are visualized on the phone, it is also possible to follow the list of events occurred in the electrical substation in chronological order, in order to understand the phenomena that occurred. This list gives necessary details about the name of the event, date and time, along with the place where the event had happened (illustrated in Fig. 4). A detail of the logged events is given in Fig 5.

An essential aspect in monitoring systems is the communication, which is represented on the graphical user interface with all its elements. This graphical user interface screen can be viewed on the phone, giving details of the communication status of each piece of equipment. Equipment marked with green color is in ok status and equipment marked with red color is affected by a communication problem.

Fig. 4. Event list.

TIMP APARITIE	DESCRIERE SEMNAL	
12/4/2024 1:31:16.160 PM	STE RADNA \ 110kV \ TRAFO-1 \ 7UT63 \ SEMNALIZARE NIVEL CURENT RETUR	DISPĂRUT
12/4/2024 1:31:14.960 PM	STE RADNA \ 110kV \ TRAFO-1 \ 7UT63 \ SEMNALIZARE NIVEL CURENT RETUR	APĂRUT
12/4/2024 1:31:06.607 PM	STE RADNA \ 110kV \ TRAFO-1 \ 6MD66 \ BLOCARE ANCLANSARE (F86)	DISPĂRUT
12/4/2024 1:31:06.442 PM	STE RADNA \ 110kV \ TRAFO-1 \ 6MD66 \ RESET LED PROTECTII HMI	RESET
12/4/2024 1:30:09.324 PM	STE RADNA \ 110kV \ TRAFO-1 \ 7UT63 \ DECLANSARE PROTECTIE CUVA I> (64-1)	DISPĂRUT
12/4/2024 1:30:09.324 PM	STE RADNA \ 110kV \ TRAFO-1 \ 7UT63 \ DEMARAJ PROTECTIE CUVA TRAFO	DISPĂRUT
12/4/2024 1:30:09.148 PM	STE RADNA \ 110kV \ TRAFO-1 \ 6MD66 \ BLOCARE ANCLANSARE (F86)	APĂRUT
12/4/2024 1:30:09.124 PM	STE RADNA \ 110kV \ TRAFO-1 \ 7UT63 \ DECLANSARE PROTECTIE CUVA I> (64-1)	APĂRUT

Fig. 5. Details of event list.

To exemplify this scenario, we have interrupted the communication of the time server (NTP) - in the corresponding screen it can be visualized the time server (NTP) marked with red color having a communication problem (illustrated in Fig. 6).

VII. Conclusions

This paper shows a case study corresponding to a traction substation in Romania, for which the maintenance and monitoring time of the substation can be optimized by establishing mobile phone connectivity in the SCADA system.

In a substation, time is essential, so the SCADA system is completed with a mobile phone connection method, which gives a major advantage to the SCADA system. With this method of control, the system availability is higher, as well as the operator response time and the basic function of the SCADA system which is to remotely guarantee the control the electrical devices and networks, and to ensure their maintenance and reliability, is, therefore, realized.

The security of the system is a sensitive point, but adopting a user and password security solution can provide the necessary stability to the SCADA system.

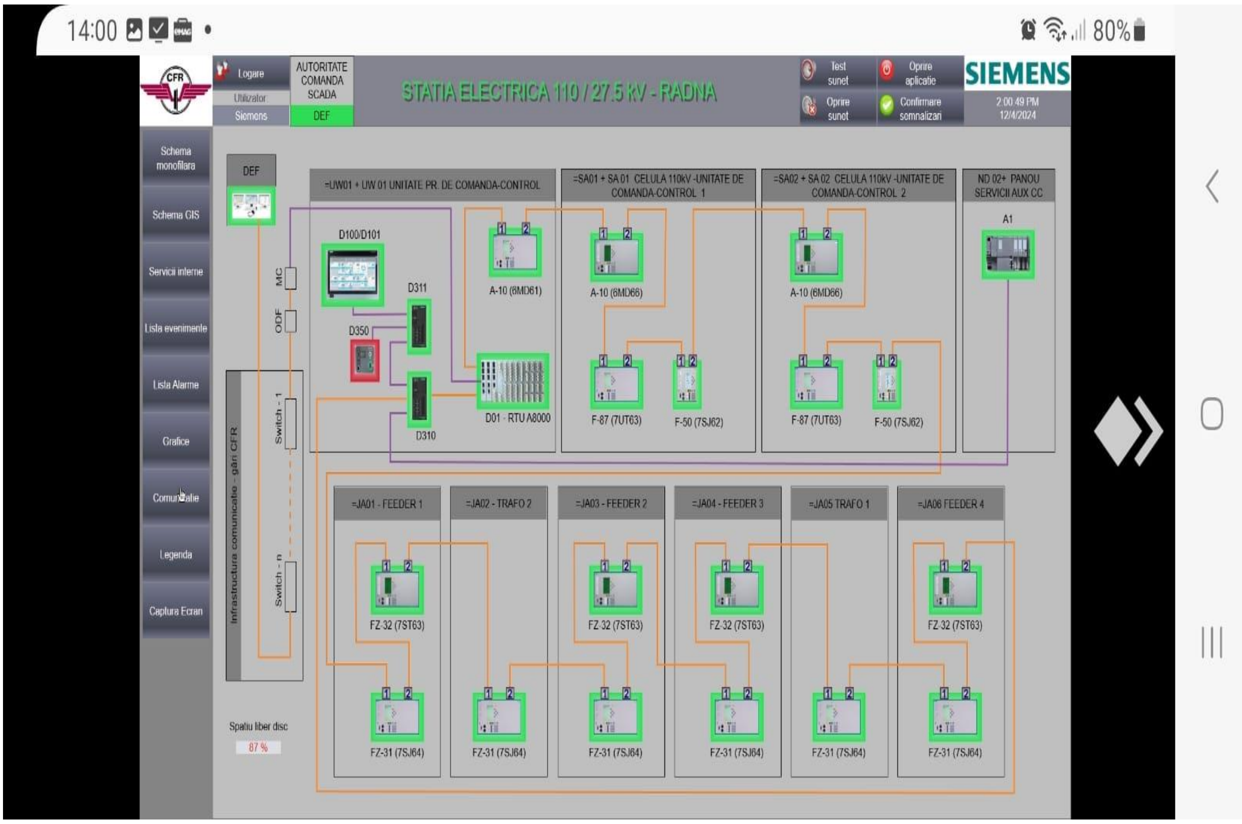

Fig. 6. Communication Screen.

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