Solution for Power Quality and Energy Consumption Monitoring

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***Abstract*— Nowadays, power quality issues are more and more frequent due to disturbances such as harmonics, flicker, swells/sags, interruptions, unbalanced voltage, etc. This paper presents a solution developed by the authors for the monitoring of electrical energy consumption and power quality in one USV (University "Stefan cel Mare", Suceava) laboratory using two Janitza measurement devices (UMG507E and UMG96S). The UMG 507E device has the gateway integrated and can be used as a Modbus RTU master and UMG 96S is Modbus RTU (slave) in Modbus network. The data from both measuring devices is collected through Modbus master using ScadaBR software.**

***Keywords—SCADA systems, energy measurement, communication industry, power quality*.**

I. Introduction

This study aims to measure voltages, currents, and harmonics online to monitor energy consumption in USV buildings and identify buildings with disproportionately loaded phases. In addition to other parameters of the power supply network, we also want to measure the THD (Total Harmonic Distortion) parameter and identify any buildings that are outside the limits allowed by the legislation. Regarding the harmonics on the electrical supply network, the equipment used in this study can measure up to the 15th-order harmonic, which is satisfactory in order to be able to outline an overall view.

Power quality is a complex and typical issue in the power network that covers all aspects of a power system, from transmission and distribution level analyses to end-user problems [1].

To have higher power quality, ideally the most important disturbances have to be reduced or eliminated in concordance with standards (IEC 61000-4-30 plans on providing overall recommendations for monitoring all types of power quality phenomena, IEC 61000-4-7 deals with the requirements for monitoring and measuring harmonics, IEC 61000-4-15 describes the instrumentation and procedures for monitoring flicker, etc.). Knowledge of power quality indicators, the methods for determining them, and the limits allowed under the standards are essential to ensuring quality energy [2]. The researchers have been developing tools for accurate power quality monitoring, as well as devices to mitigate power quality imperfections [3].

The increased interest in power quality has become more important, especially in light of the European Community's electricity market regulations. Any comprehensive system of quality management needs to know the real level of power quality the supplier delivers.

Industry and commerce in the EU estimate that power quality problems cost about 10 billion per year, with less than 5% allocated to preventive measures. Ensuring good power quality requires good initial design, efficient correction equipment, cooperation with the supplier, frequent monitoring, and good maintenance.

SCADA is a system architecture comprising computers, networked data communications, and graphical user interfaces used for systems control and monitoring tags from processes [4-6]. Since the software for the implementation of SCADA applications is typically expensive, the authors propose a free, open-source SCADA solution in this paper. We have identified and studied various versions available in the market. The following list presents the applications that were considered more relevant, namely: ScadaBR [7], PRTG monitoring software [8], OpenSCADA [9], Argos-Scada [10], ProViewR [11], and Node-RED [12].

The paper's structure is as follows:

Section I presents a short introduction to power quality and energy consumption monitoring. Section II discusses the proposed solution's design and implementation. It explains how this solution is useful for monitoring power quality and energy consumption in one USV laboratory using two Janitza measurement devices (UMG507E and UMG96S) and ScadaBR software. Section III presents the experimental results. Section IV concludes the paper and recommends future actions for improving security for SCADA systems and achieving a cluster.

II. Proposed Solutions

A possible architecture for SCADA system, which can be implemented at the University Stefan cel Mare, Suceava, for electrical energy parameter monitoring, is illustrated in Fig. 1. In this case, we can use a measuring device with an integrated gateway (e.g., UMG 507E) for the main power supply of each university building [13].

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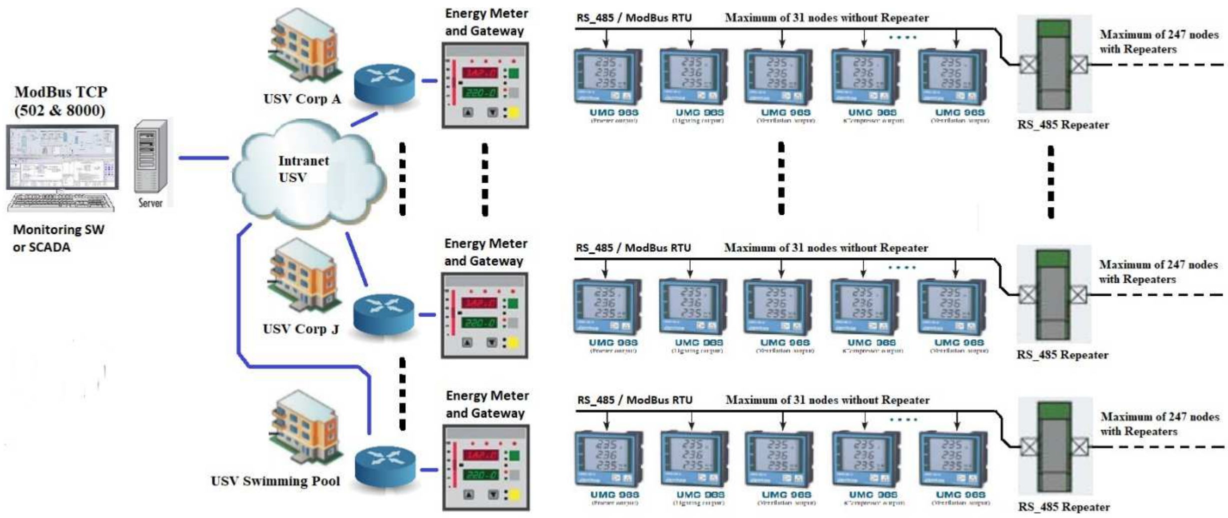


Fig. 1. General architecture system proposal for measurements using Janitza measurement devices.

a) b) c)

Fig. 2. The hardware testbench with measurement point in USV C001 laboratory electric distriburion board.

Each laboratory can also be monitored using a measurement device that can be Modbus RTU, connected to master and all data is collected through the Modbus master at SCADA server. The authors of this paper propose a simplified architecture with only one master (UMG 507E) and one slave (UMG96S) to test the possibility of acquiring different tags from master and slave devices in the SCADA database. The electrical panel of the C001 USV laboratory uses the UMG 507E device for monitoring electrical energy parameters. Additionally, we use an UMG 96S for testing Modbus RTU communication. The proposed architecture from Fig. 1 can theoretically monitor up to 61009 elements (247_with-IP x 247_on_RS-485 = 61009 elements).

The electrical panel of the C001 USV laboratory uses the UMG 507E device for monitoring electrical energy parameters. We use an additional UMG 96S to test the Modbus RTU communication via the RS485 interface [4]. The serial communication RS_485 is a robust electrical communication interface that can operate in heavy industrial environments up to 1200 m at a maximum speed of 100 Mbps. The Modbus protocol is prevalent in industrial environments because it is robust, easy to implement in a configuration with compatible devices, and is openly published. Regarding the tags used in this project, according to the documentation, the ModBus registers are obtained in float 4-byte big-endian format (ABCD).

Fig. 2 illustrates the hardware testbench of the proposed solution, while Fig. 3 displays the circuit diagram. The UMG-507E device is designed for measuring current using three current transformers (100 A/5 A).

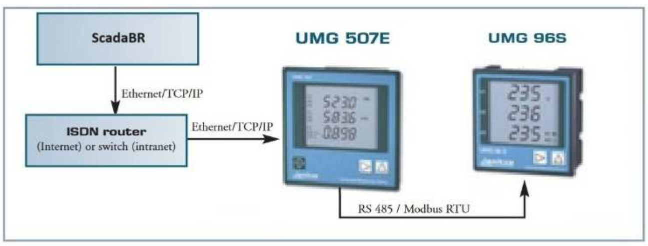


Fig. 3. The circuit diagram of proposed solution.

GridVis 7.4, as shown in Fig. 4, serves as the software for programming and configuring all Janitza measurement instruments. Janitza offers a free license for this software, that allows a maximum of five Janitza elements to be monitored [14].

Fig. 5 presents the proposed server hardware for the remote monitoring system. In order to virtualize monitoring systems and conduct various tests, we configured the following equipment in a 19-inch mobile rack: The configuration included 2x HP ProLiant DL360 G7 servers with 32GB RAM, 2x NAS HDD (Netgear NAS ReadyNas 3200), 1x Beckhoff server (model C5210-0010), a 24-port Cisco switch, and an HP ThinCentre mini-PC for querying and backup configurations.

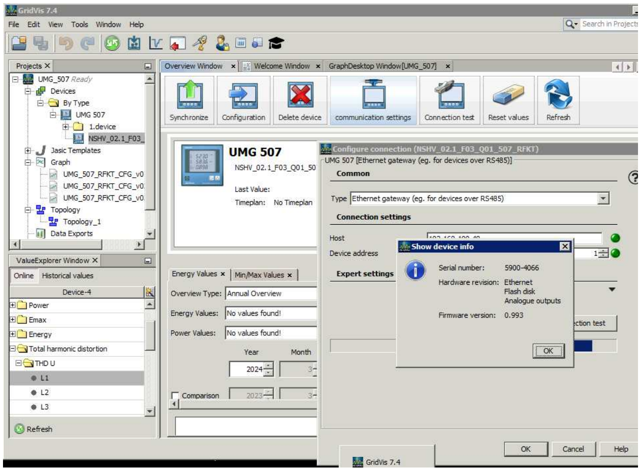


Fig. 4. GridVis 7.4 software for Janitza energy meter device.

VMWare [15] and ProxMox [16] were installed on both server systems and several operating systems were virtualized using Windows Server 2016 and Ubuntu Server 20-04 LTS.

Fig. 5. Server solution and virtual machines for Janitza devices monitoring.

It consists of the following element blocks: a server with data storage, routers, Janitza energy metre devices, ModBus-TCP network, ModBus RS_485 network, digital/analogue device for breakers monitoring, and the main power supply with battery backup. The presented workflow should be able to monitor all electrical connections in the USV building and laboratories.

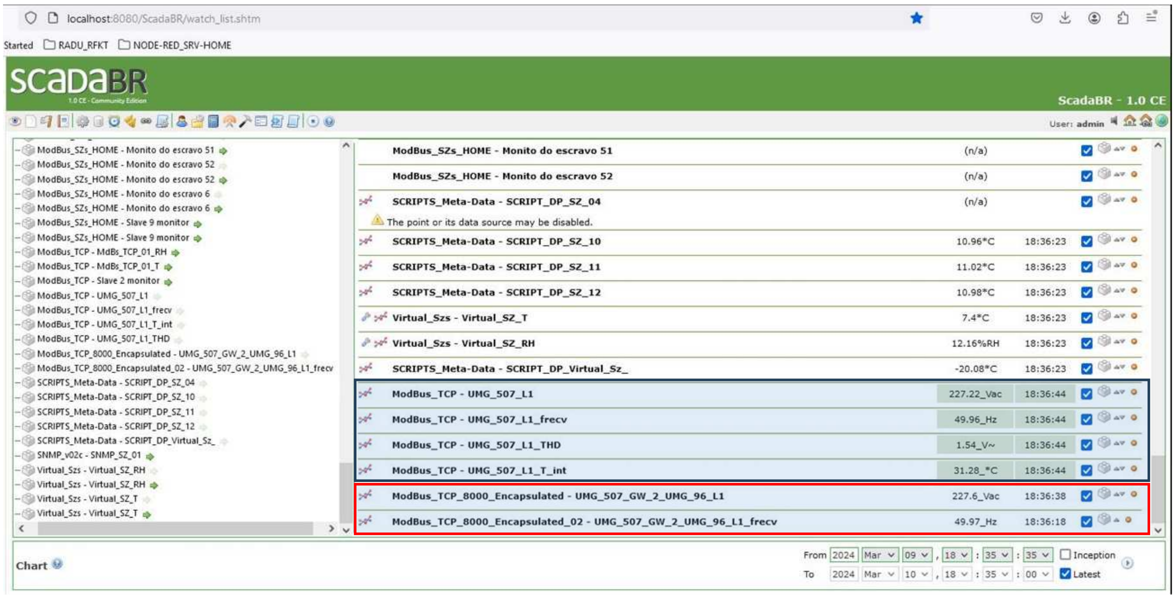


Fig. 6. List of signals acquired in ScadaBR.

After an in-depth study, the option called ScadaBR was chosen because it offers a web interface for configuration, supports user definition with different creation and viewing rights, and supports many industrial protocols, including Modbus RTU (Ethernet encapsulated), necessary for communication with UMG96S through UMG507E gateway. For various tests or simulations, virtual sensors can have incremental/decremental, random, or Brownian values. ScadaBR can integrate a communication server, a real-time database server, an HMI server, and a historical data server. There are other uses for the ScadaBR platform. In [17], medical facilities can use ScadaBR in conjunction with IoT systems to monitor air quality, and in [18], [19], houses and small industries can use it for energy monitoring. Other implementations target hydraulic systems [20], and in [21], it is used for smart Grid (SG) monitoring.

The ScadaBR application was designed to be installed on a PC (OS Windows or Linux), there are two versions (v1.0

and v1.2), and requires a specific version of Java to run. Configuring the "Apache Tomcat" server and sensors requires study, and where documentation is lacking, the application's well-supported forum should be investigated [9].

For the ScadaBR implementation, the following strengths can be emphasized:

- native Modbus-TCP encapsulated library for fetching data from the RS_485 network through the Modbus gateway;
- virtual sensors with different behaviour for simulations;
- scaling the received values and history;
- individual slave sensor randomizes data generator;
- can be extended to 247 Modbus nodes if needed (Modbus address number 0 is reserved for broadcast);
- maps can be created for better visibility;
- different Dew Point formulas for each sensor implemented (2 formulas in the current case);
- alarms declaration for errors or other criteria.

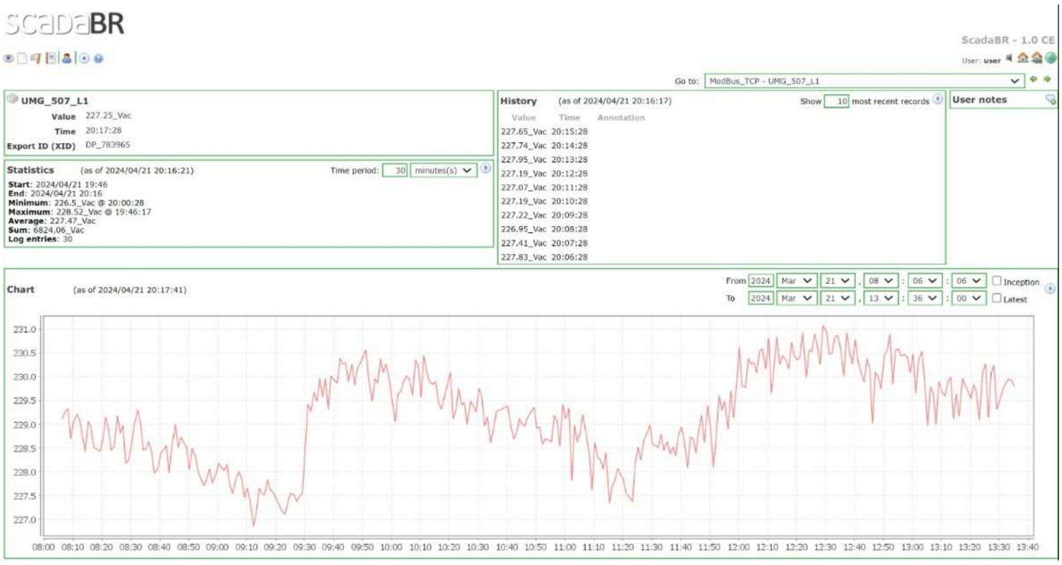
ScadaBR has the following weaknesses:

- it works only on x86 architecture (no arm solution);
- server uptime is missing in the application;
- a history of more than one year will slow the server.

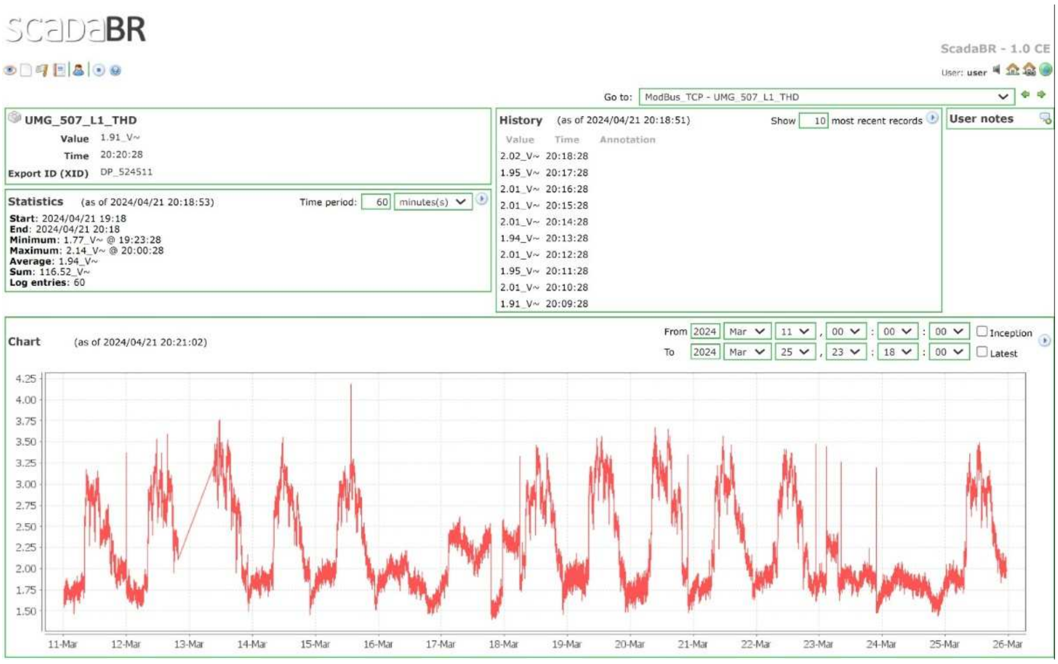
In addition to various industrial libraries, ScadaBR's greatest advantage is that it offers a configuration Web page and allows for the declaration of users with individual configuration and viewing rights (e.g., http://IP_Server_ScadaBR:8080/ScadaBR/login.htm). The port address can be changed from the server configuration.

III. Experimental Results

In order to test the proposed solution, several electrical parameters were acquired from both UMG507 (VL1,) and UMG96. and recorded with the ScadaBR application in Database. ScadaBR allows you to visualize data (variables or "tags") in real time.



a)



b)

Fig. 7. V_{L1} and THD_U_{L1} tags of UMG507E acquired with ScadaBR.

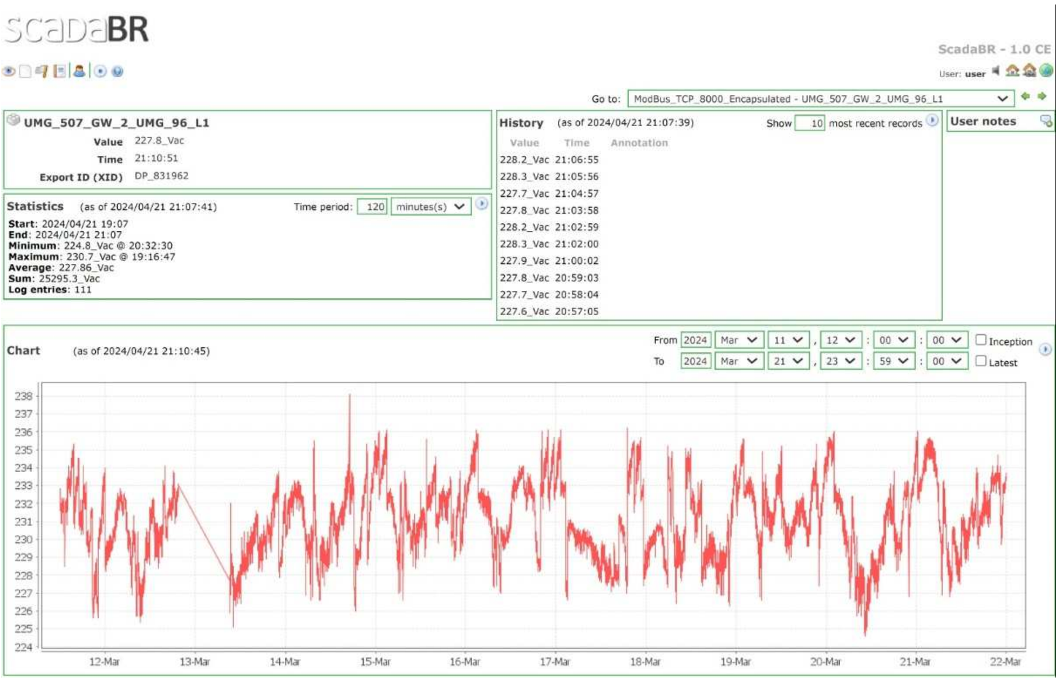


Fig. 8. V_{L1} tag of UMG96S acquired using ScadaBR.

The same acquisition rate (1 scan/min) for all tags in ScadaBR is set. The Database is created with values recorded in the time interval March 1, 2024 - March 31, 2024. Fig. 7.a shows the RMS of V_{L1} recorded in the ScadaBR, where the variation of the value over a measurement interval of 23 minutes is illustrated. In this interval, the application identifies the minimum value of the tag (226,5 Vac at 20:00:28), the maximum value of the tag (228,52 Vac at 19:46:17), and calculates the average value of the tag (227,47 Vac).

The monitoring of points within the system during these 30 minutes can be done by creating a graphical view of points using drag-and-drop functionality to position graphical representations of points. Fig.7.b illustrates the graphical view for THD_U_{L1} tags of UMG507E acquired over the measurement period between March 11, 2024 and March 25, 2024. The maximum values of THD_U_{L1} = 3.1 Vac, representing 0,93% (much below the maximum allowed value).

Fig. 8 depicts the V_{L1} tag of UMG96S, which was acquired through UMG507E (master) with ScadaBR.

The laboratory experienced a power outage around March 13th, causing even the Janitza measuring devices to lose power. So, in both the graphic views illustrated in Fig. 7.b and Fig. 8, we have no data acquired in the database during that time.

IV. Conclusions

SCADA systems are widely used in industrial applications. But SCADA Software usually has high prices. The authors of this paper introduce the ScadaBR software, a cost-free solution suitable for small SCADA applications. The ScadaBR collects various tags from two Janitza universal measuring devices (UMG507E and UMG96S). These devices are used for the measurement of electrical variables such as voltage, current, power, etc. in the electric panel of the C001 laboratory of Stefan cel Mare University of Suceava.

Using ScadaBR software offers the great advantage of being a well-supported free SCADA software, which includes the ModBus encapsulated library (port 8000). This library enables the querying of RS_485 nodes through the Modbus TCP gateway. The software supports map creation and can record data in a MySQL database for one year. Recording data for more than one year is possible but will slow the server.

A future goal is to improve security [22]. This can be done by encrypting data on the communication channels and using a better data transfer protocol.

As previously presented, we need additional studies to determine which of the proposed versions can meet the requirements for long-term use in the software monitoring part. For Node-RED, a ModBus-TCP encapsulated library is needed to query Janitza RS_485 nodes using the ModBus-TCP gateway. Another very promising open-source software that could integrate such monitoring is Zabbix (version 7). It runs only under Linux distributions and has the great advantage of running on Raspberry Pi4-type boards. The ModBus-TCP data can be fetched by using external scripts. As a future study, it is proposed to create a cluster with RPi4 boards (rack 19 inch, 3U, maximum 16 boards) by using the Kubernetes clustering application, which will facilitate increasing the processing power of a Zabbiz server. Cloud monitoring can also be considered a good solution at a low price.

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