Design and Implementation of a Real-Time Monitoring System for the Parameters of Electro-Electric Variables of the Electric Power Control and Backup Equipment of the ECU 911 Loja Integrated Security System

Cosme Xavier Gálvez Sánchez, Ángel José Ordóñez Mendieta

***Resumen*— La presente investigación tiene como finalidad el desarrollo de un sistema de monitoreo en tiempo real, que permite visualizar los parámetros electro-energéticos de la red eléctrica interna del edificio del Sistema Integrado de Seguridad ECU 911 Loja. El sistema eléctrico del SIS ECU 911 Loja, se encuentra actualmente integrado con equipos de control y respaldo de energía eléctrica, los cuales se encargan de la supervisión y control de dicho sistema. La propuesta de este artículo, dispone desarrollar un software que permita acceder a las variables electro-energéticas medidas por estos equipos, a través de una interfaz humano-máquina o HMI, por sus siglas en inglés Human Machine-Interface. Se inicia con un breve estudio de los sistemas de monitoreo y control utilizados en la industria, más conocidos como sistemas SCADA. Luego, se procede a la recopilación de información del campo de trabajo, así como de los que equipos que intervienen en él. Finalmente, haciendo uso de herramientas de software libre, que se detallan en la redacción, se diseña e implementa el sistema de monitoreo.**

***Index Terms*— Sistemas de Supervisión, Control y Adquisión de Datos (SCADA), Modbus RTU, Modbus TCP, Python, PostgreSQL, Pila ELK**

***Abstract*—The purpose of this research is to develop a real-time monitoring system that allows visualizing the electro-energetic parameters of the internal electrical network of the building of the Integrated Security System ECU 911 Loja. The electrical system of the SIS ECU 911 Loja, is currently integrated with electric power control and backup equipment, which is in charge of the supervision and control of said system. The proposal of this article, has to develop a software that allows to accede to the electro-energetic variables measured by these equipment, through a human-machine interface or HMI. It begins with a brief study of the monitoring and control systems used in the industry, better known as SCADA systems. Then, it proceeds to the collection of information from the work field, as well as the equipment that intervenes in it. Finally, using free software tools, which are detailed in the writing, the monitoring system is designed and implemented.**

Article history:
Received 16 July 2019
Accepted 03 September 2019

***Index Terms*— Supervision Systems, Control and Data Acquisition, SCADA, Modbus RTU, Modbus TCP, Python, PostgreSQL, ELK Stack**

I. Introduction

THE development of real-time monitoring system, oriented to the supervision of the electro-electric variables of the electric power control and backup equipment of the ECU 911 Loja Integrated Security System, was raised under the functional structure of the SCADA systems. From the investigation of the functional blocks that integrate the structure of these systems, it was possible to identify and integrate the equipment in a single monitoring system, under different buses and communication protocols, storing the information in a database and presenting the user the electro energy variables through an HMI and a web interface, which can be accessed from any place that has access to the internal network of SIS ECU 911 Loja.

The main objective of the SIS ECU 911 is to provide to the city with a technological tool that allows them to integrate all the resources devoted to public safety and the provision of services to the community. In this way, society is offered a simple and efficient method to channel their emergency situations. In this sense and with the premise of fulfilling this primary objective, it is of particular importance that the technology provided allows efficient processing of each and every one of the events involved in an emergency situation. For this reason, the energy control and backup systems of the entire technological infrastructure is a fundamental part in the provision and assurance of the aforementioned services. In order to achieve this, it is of fundamental importance that the power supply of the SIS ECU 911 is never interrupted under any circumstances and that it remains operational for as long as possible and in optimum conditions, so the electro-energy equipment responsible for supervising and controlling the Electrical supply

Cosme Xavier Gálvez Sánchez and Ángel José Ordóñez Mendieta belong to the Department of Electronics and Telecommunications Engineering of the National University of Loja, Loja, Ecuador (emails: cxgalvezs@unl.edu.ec; angel.j.ordonez.edu.ec).

must be monitored constantly and in real time to determine its status and correct operation.

II. ELECTRIC POWER CONTROL AND BACKUP EQUIPMENT OF THE SIS ECU 911 LOJA

The equipment that is responsible for the distribution, control and backup of the SIS ECU911 Loja electrical system are the following:

- Duca-LCD96 485-RELAY Network Analyzer.
- Module DSE7320
- Eaton 9390 UPS

The DUCA-LCD96 network analyzer is a measuring instrument for the main electrical quantities, in three-phase and single-phase networks, designed for local and remote monitoring and analysis of electrical parameters of the installation in low and medium voltage switchboards; and energy consumption of the installation. The model installed in the electrical system of the SIS ECU 911 Loja is the DUCA-LCD96 485-RELAY, which presents the Modbus RTU communication protocol.

A. DUCA-LCD96 585-RELAY

The DUCA-LCD96 network analyzer is a measuring instrument for the main electrical quantities, in three-phase and single-phase networks, designed for local and remote monitoring and analysis of electrical parameters of the installation in low and medium voltage switchboards; and energy consumption of the installation. The model installed in the electrical system of the SIS ECU 911 Loja is the DUCA-LCD96 485-RELAY, which presents the Modbus RTU communication protocol.

1) Technical Data

Next, the communication interface characteristics relevant to this work are indicated [1].

TABLE 1
RS485 COMMUNICATION INTERFACE, OF THE DUCA-LCD96 485-RELAY

Protocol	**Modbus RTU or ASCII Ducati**
Electrical Standard	RS485 with opto insulation
Baud Rate	4.8, 9.6, 19.2 kbps
Parity Number	Odd, Even, None
Stop bit	1, 2
Address	1-247 for Modbus RTU; 1-98 for ASCII Ducati
Connector	4-pole terminal (integrated 120 Ohm termination)

2) Electro-energy variables of the DUCA-LCD96 485-RELÉ network analyzer

The following are some of the electro-energy variables, with their respective Modbus addresses of the Duca-LCD96 485-RELE network analyzer [1], considered for real-time monitoring as required by SIS ECU911 Loja.

TABLE 2
ELECTRO-ENERGY VARIABLES OF THE DUCA-LCD96 485-RELÉ [1]

Address (Modbus register)	**Size (Byte)**	**Variable**	**Unit**	**Format (Long)**
0004	2	Three Phase Equivalent Voltage	Volts	no sign
0018	2	Three-phase equivalent current	Hundreds of Amperes	no sign
0034	2	Three-phase equivalent active power	Watts	no sign

B. Module DSE7320

The automatic boards developed for electric generators have the ability to automate the start-up of electric generators. The electric generator nowadays, is designed for the adaptation of said boards. The emergency electric generators have arrived to provide electric power whenever there is a fault in the network supply. There are equipment, capable of automating the work of the start-up of the electric generators before a failure in the supply, they are called automatic panels. These, start an electric generator, every time, for any reason, the electric power is cut off. Some of them require prior activation, and others do so automatically [2].

1) Models

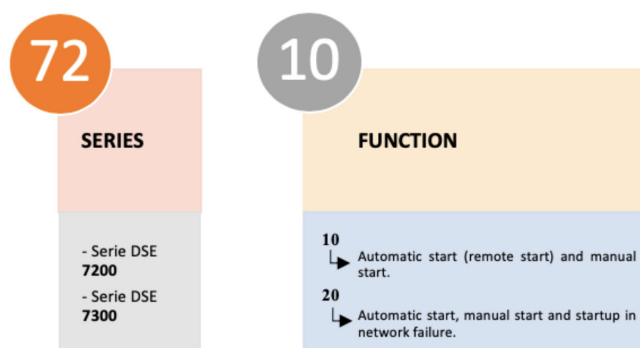


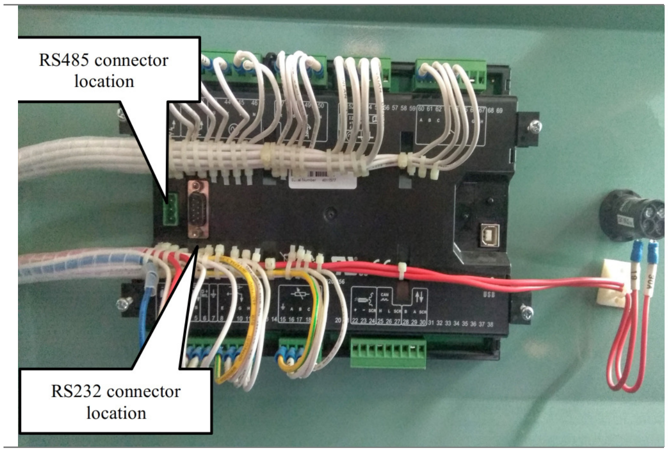
Fig. 1. Models of the DSE7000 series.

The models of the DSE7000 series (Manton, 2009), are indicated in Figure 1. The model installed in the electrical system of the SIS ECU 911 Loja is the DSE7320 module.

2) Connection

The identification and correct connection of the communication interfaces is indicated in Table 3 [3].

TABLE 3
DESCRIPTION OF THE RS485 AND RS232 TERMINALS OF THE DSE7320



RS485 CONNECTOR	
No. of Pin	**Notes**
A (+)	Shielded twisted pair. 120Ω impedance suitable for RS485 use.
B (-)	
SCR (GND)	

RS232 CONNECTOR	
No. of Pin	**Notes**
1	Carrier detection (data transmission)
2	To receive
3	To transmit
4	Data terminal ready
5	Ground signal
6	Data adjustment ready
7	Request to transmit
8	Ready to send
9	Call indicator (modem only)

The information shown in Table 3, indicate the interfaces and communication protocols that these automatic control modules present, thanks to this, it was possible to identify which interfaces and protocols to use to establish communication with the monitoring software, together with the other equipment , in the same communication infrastructure [12].

3) Electro-energy variables of the DSE7320 module

Some of the electro-energetic variables of the DSE7320 automatic control module [3], considered for real-time monitoring as required by SIS ECU911 Loja are shown in Table 4.

TABLE 4
ELECTRO-ENERGY VARIABLES OF THE DSE7320 MODULE

Registry	Variable	Minimum Value	Maximum Value	Scale Factor	Unit	Bits/ Sign
1024	Oil pressure	0	10 000	1	KPa	16
1025	Coolant temperature	-50	150	1	DegC	16/S
1028	Load alternator voltage	0	40	0.1	V	16
1029	Battery voltage	0	40	0.1	V	16

C. EATON 9390 UPS

The Eaton 9390, is a system of uninterruptible power of double conversion. The system (UPS) solves all the power problems of the public network and supplies clean, continuous and uninterrupted power to the connected equipment. Currently, there are two models: the american and the european, the model installed in the electrical supply plant of the SIS ECU 911 Loja is the American.

1) Communication interface and protocols

Table 5 shows the main communication characteristics of the EATHON 9390 UPS [4].

TABLE 5
INTERFACE AND COMMUNICATION PROTOCOLS OF THE EATON 9390 UPS

Communication Cards	Two standard X-Slots. With the option Mini-CSB: up to 4 XSlots. The following connectivity card options can be installed at any time: ▪ ConnectUPS Web / SNMP / xHub card ▪ Modbus card ▪ Relay Interface Card (for AS400 's) ▪ Industrial Relay Card (5A @ 120V)

The EATON 9390 UPS, installed in the SIS ECU Loja, has the UPS Power Xpert® Gateway card (Figure 2) which allows you to connect the UPS directly to your Ethernet network and the Internet. With its embedded web server, the UPS Power Xpert Gateway card provides UPS information remotely, without additional software through the HTTPS and Modbus communication protocols over TCP/IP [11].

Fig. 1. Tarjeta de comunicación de UPS Power Xpert® Gateway.

2) Electro-energy variables of the EATON 9390 UPS

Some of the electro-energetic variables of the EATON 9390 UPS, considered for real-time monitoring as required by SIS ECU 911 Loja, are shown in Table 6.

TABLE 6
VARIABLES ELECTRO-ENERGÉTICAS DEL EATON 9390 UPS

Registro	Variable	Unidad	Tipo	Estados
1137	Check Battery	Alarma	Booleano	(0, 1)
1148	UPS On Battery	Alarma	Booleano	(0, 1)
2800	Battery Test in Progress	Test	Entero	(0, 1)
2801	Battery Test Result	Test	Entero	(0,1,2,3,4,5,6,7)
3000	System Status	Test	Entero	(0,1,2,3,4,5,6,7,8)

III. DESING

The process of design of the monitoring system was established once the electric power control and backup equipment of SIS ECU 911 was known and the electro-energetic variables to be monitored were identified, structured according to the block diagram shown in Figure 3.

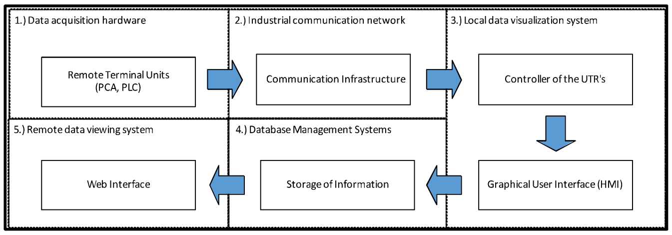


Fig. 3. Implementation of the real-time monitoring system of the electro-energy variables of the SIS ECU911 Loja

This block diagram shows the functional structure of a SCADA system, which was taken as reference for the development of this article based on the first stage (hardware acquisition data) to the last stage (system remote data display) [5].

A. Industrial Communication Network: Communication Infraestructure

The communication infrastructure refers to the interfaces and communication protocols shared by all the electric power control and backup equipment, which allows them to be integrated into a single monitoring system. As described above, the DUCA-LCD96 485-RELÉ network analyzers, the DSE7320 automatic modules and the Eaton 9320 UPSs present the Modbus protocol implemented in their system. The analyzers and automatic modules implement the Modbus RTU protocol (Master / Slave) through the serial interface RS485 and RS232, respectively. In contrast, the UPS implements the Modbus protocol over TCP / IP networks. For this reason, the developed program uses the Modbus RTU and Modbus TCP / IP protocol to integrate all these equipment into the same monitoring system at the logical level since the physical connection is made differently since as previously studied they use different technologies in Regarding access to the environment [6].

1) General scheme of physical connection of the monitoring system

The general scheme of physical connection of the monitoring system implemented in the SIS ECU 911 Loja is shown in figure 4. In this diagram, you can see two functional structures of a SCADA system; the first structure that corresponds to the data acquisition hardware, where the electric power control and backup equipment is located, such as the EATON 9390 UPS, the DSE7320 modules and the DUCA-LCD96 485 RELAY Boards. The second structure refers to the industrial communication network, here the Modbus RTU communication protocols (Master / Slave) were used to communicate with the modules and boards, through the RS485 fieldbus, in addition, the Modbus TCP protocol was implemented (Client / Server) to communicate with the UPS through the Ethernet network. All of them connected to the only existing master in the communication network, in this PC the master software of the Modbus network is executed, in which the other functional structures of a SCADA system are implemented.

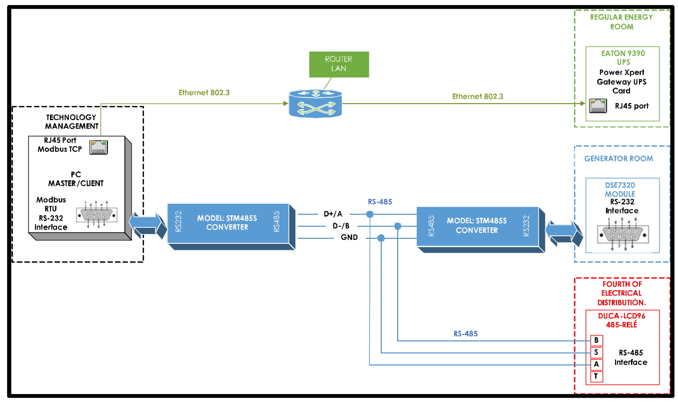


Fig. 2. General scheme of physical connection of the monitoring system.

B. Local Data Visualization System

In this section, it is indicated how the development of the monitoring software was carried out, with which, through the controllers of each electric power control and backup equipment, it allows to read the electro-energetic variables and show them to the end user. besides allowing to load the values of these variables in a database. The programming of the monitoring software was developed in the programming language Python 3 in its version 3.6.7 on the operating system Ubuntu bionic 18.04 LTS making use of IDE PyCharm Community 2018.3.2. The Python programming language was used because it is free, multiplatform, it has frameworks of great variety and usefulness, as well as a clear syntax, it also allows programming oriented objects [8], all these attributes contributed to the successful development of the research presented. The Ubuntu operating system where the present investigation was developed was a requirement given by the ECU 911 Loja, since the equipment given to operate the monitoring system works with this operating system.

1) Development of the UTR's Controllers

Python presents some libraries that implement the industrial communications protocol ModBus, for this project the library "MinimalModbus" was used in its version 0.7 [9], for communication between the master and the slaves (boards and generators) of the Modbus RTU mode and the "pyModbusTCP" library in version 0.1.7 for communication with the UPS via the Modbus protocol over TCP / IP. For the connection to the database, the psycopg2 library was used in version 2.7.5 and for the graphical user interface (GUI) that presents the program, the PyQt5 library was used 5.11.2 [7].

The controllers of the electric power control and backup equipment are scripts developed in the Python language that allow reading or consulting the electro-energetic variables presented in Table 2, Table 4, Table 6:, because in these scripts they are stored the addresses of the Modbus registers, the variables and their respective units; as well as the sentinel, test and alarm values presented by these devices are stored as explained above. Next, the flow diagram of the controllers developed for these devices is detailed.

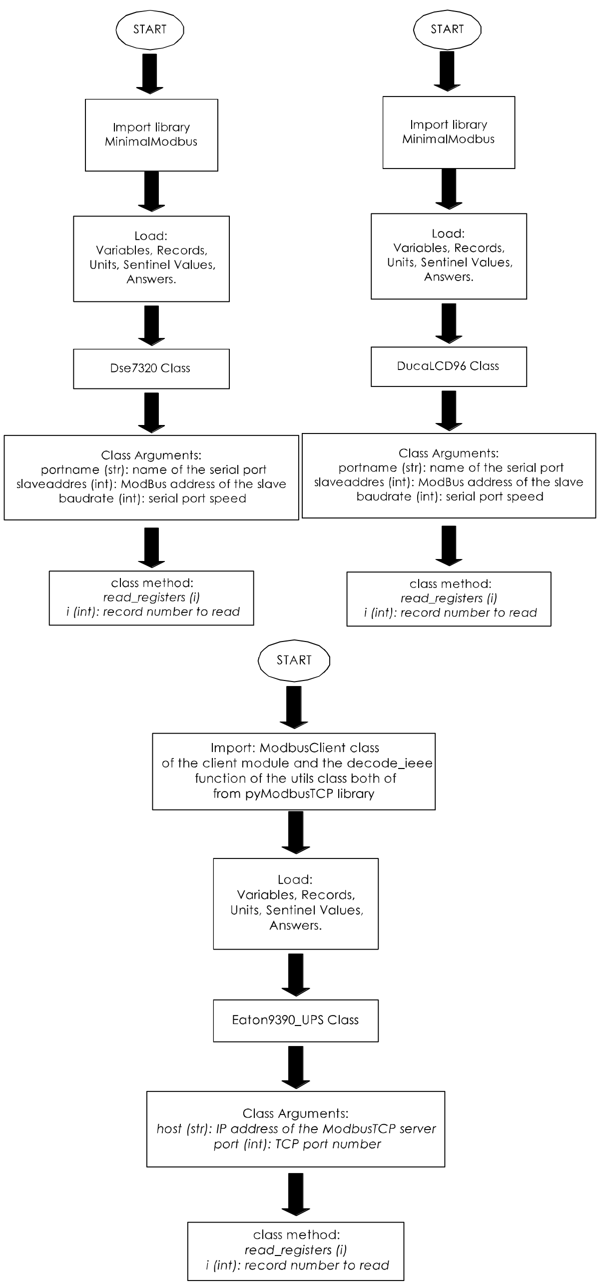


Fig. 3. Flow diagrams of the controller: **a)** DSE7320, **b)** DUCA-LCD96 485 RELÉ, **c)** EATON 9390

2) Design and Development of the Graphical User Interface of the Monitoring Software

The design of the Graphical User Interface (GUI) of the monitoring system was based on requirements requested by the ECU 911 for the configuration and visualization of the electro-energetic variables of the equipment that make up the power supply plant. The tool "main window" of the Qt Designer software was used to show the values of the electro-energetic variables of the equipment and is the main window of the monitoring software [8]. In addition, the "dialog boxes" of Qt Designer were used for the creation of the secondary windows where the configuration of the different parameters and functions presented by the program of which this article deals with is carried out.

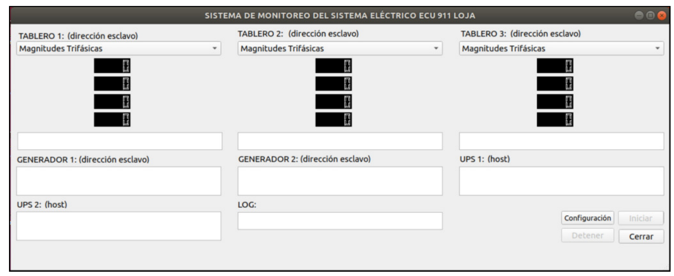


Fig. 4. Main window of the electro-energy system monitoring software of SIS ECU911 Loja

Figure 6 shows the main window of the monitoring software where you can see all the control and energy equipment that make up the SIS ECU911 Loja power supply plant, identified by board 1, board 2, board 3 to the network analyzers with their respective Modbus slave address, then generators 1 and 2 that refer to the automatic control modules that supervise and control the same generators; and finally UPS 1 and 2 with their respective IP address. The "Start", "Stop" and "Close" buttons allow you to start and stop communication with the slaves and close the program. The configuration button opens a secondary window where the general configuration of the program can be found, see Figure 7.

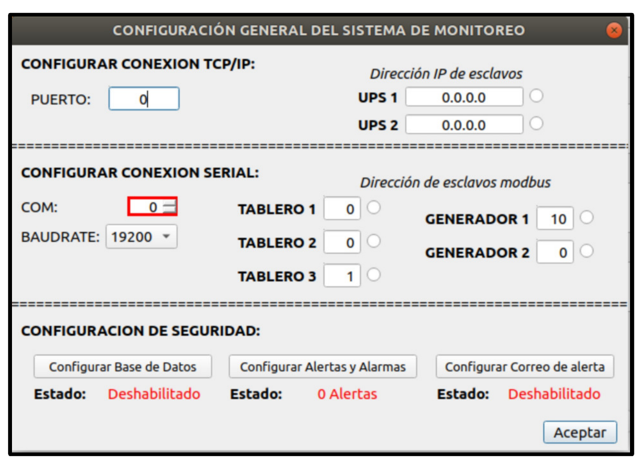


Fig. 5. Secondary window of general configuration of the monitoring software.

In the secondary window of the general configuration of the monitoring software, in the upper part, the configuration of the necessary parameters is made to establish the communication with the Modbus TCP server of the UPS. The section "CONFIGURE SERIAL CONNECTION" allows to establish the COM port through which it will connect to the Modbus

RTU network on the RS-485 fieldbus, the BAUDRATE option allows to configure the transmission speed of the data measured in baud; and finally in this section, is the configuration of the addresses of the slaves connected to the Modbus RTU network.

In the lower part of the window, the "SECURITY CONFIGURATION" section is indicated, where we find the configuration buttons to establish: the connection to the database, the configuration of alerts and alarms and the configuration of the alert mail ; each with a label that tells us the status of this configuration is to say if it is correctly configured and therefore enabled. By clicking on the "Configure Database" button, a secondary window is displayed, shown in Figure 8.

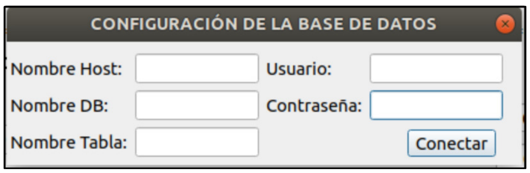


Fig. 8. Secondary window for configuring the connection to the database

In the secondary window, identified with the name of "DATABASE CONFIGURATION", the necessary options are presented to connect successfully to the database.

Fig. 6. Secondary configuration window for alerts

When clicking on the button "Configure Alerts and Alarms" we are shown a secondary window as indicated in Figure 9, where we can see the different options where we can choose the slave and their respective variables to establish them within normal operating ranges and in the case that a variable is outside this range, an alert mail is sent and, depending on the type of alert or alarm, the operation of the program is modified in some way. The option labeled with the word "TIME" allows us to modify the reading time that the program performs on the slaves, that is, it allows us to decide each time the queries of the electro-energetic variables of all the selected slaves are made. There is the possibility to choose between seconds, minutes and hours.

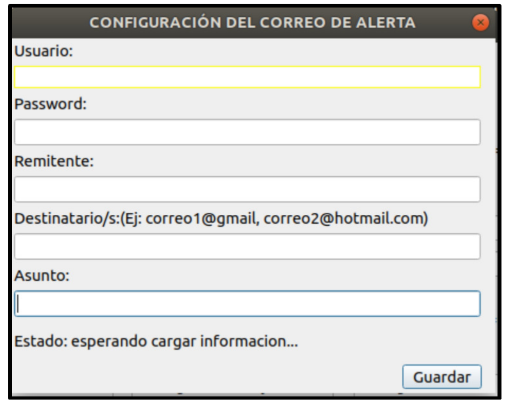


Fig. 7. Secondary window for alert mail configuration

Finally, the last secondary window is shown in Figure 10 that is presented when selecting the option "Configure Alert Mail", here the User option is shown where the sender's mail is written and its respective provider's password of the electronic mail (Gmail, Outlook, etc.) to allow to send the mail of alert, soon the mail of the recipient or recipients with its respective subject in case it requires it. The content of the message is the team that presented an average out of range of one or some of the electro-energetic variables at the moment that was raised, indicating the variable, the value, the unit and the date.

3) Storage of Information

The connection to the database in the SGDB PostgreSQL version 10.0 was made with the help of the psycopg2 library. The database called "scadaecu" is located on a local server ("localhost") within the SIS ECU 911 Loja network. The creation of the database in PostgreSQL, was carried out with the following instructions in SQL language: a) a table with the name "slaves" is created, where a primary key is used to identify each field of the table with the name "Id"; b) the following columns are declared as: "slave", "variable", "value", "unit", "date", in each of them the necessary information is stored to identify each slave that integrates the monitoring system.

4) Remote Data Visualization System: Web Interface

The set of computer tools of the ELK stack, allow to work with the data stored in the database created with PostgreSQL in different [10]. First, Logstash is required to request information from the database and transform it for analysis. From the information compiled by Logstash, Elasticsearch allows to establish conditions of search and analysis to finally present it in the third stage that is Kibana. This tool allows you to create a dashboard that shows the information in an organized and understandable way for the user.

- Configuration of the Elasticsearch Tool

Elasticsearch is configured so that an index scheme is established, this is called mapping, and it refers to establishing in Elasticsearch the type of attributes that are given to the logs that contain the information. The data entered from the sensor table into Elasticsearch are indexed as logs (line of words) in .json format, which contains the fields and values of the original data, which allows them to be stored and retrieved (when a query is needed). The basic scheme of the index consists mainly of: the name of the index, type, id (provided by Elasticsearch) and version. If this type of configuration is not carried out, Elasticsearch adds by default a generic format for indexing the data, which does not satisfy the query requirements of this system.

- Configuration of the Kibana Tool

Kibana allows defining the presentation structure of the monitoring system information in graphic form, where the most suitable type of metric is selected to represent the data. The Kibana dashboard allows to select the type of data visualization, in this case the "Goal" environment was used. After selecting the appropriate dashboard, you configure the levels of the metrics that are used for visual monitoring. The style parameters are set for the data obtained in this case from the variable of "Three Phases Equivalent Voltage" for each one of the boards. This procedure is carried out for each of the power supply and backup control equipment from which the data of the electro-energetic variables are obtained. In Figure 11, the detail of the configuration is verified.

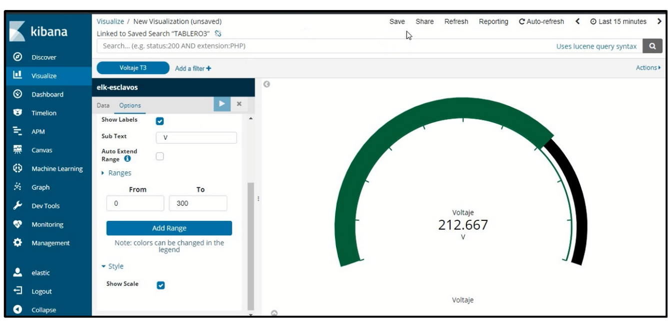


Fig. 11. Configuration of the Goal for the presentation of the data through Kibana.

IV. Implementation of the Monitoring System

In this section, the total implementation of the electrical system monitoring system of the ECU 911 Loja is indicated, from the physical connection of the electric power control and backup equipment, to the configuration of all the windows of the monitoring program, the storage of the electro-energetic variables in the database and their visualization in the web interface.

Fig. 12. Connection of the DSE7320 modules of generator 1 and 2.

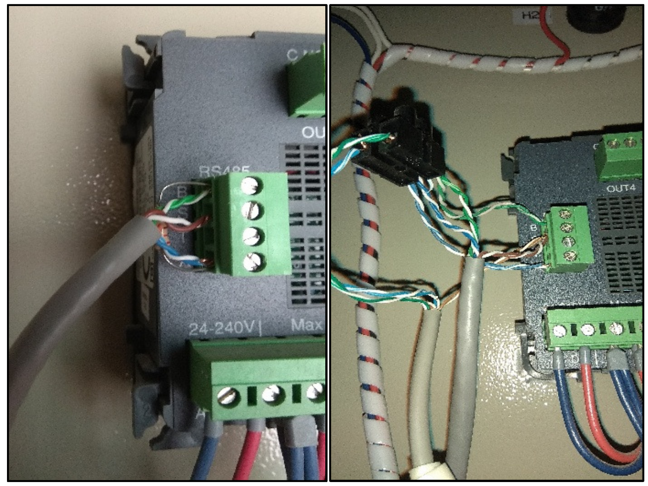


Fig. 13. Connection of DUCA-LCD96 485-RELAY measuring boards.

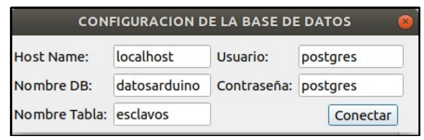


Fig. 14. Successful connection settings to the database.

Fig. 15. Successful configuration of alerts.

Fig. 16. Successful configuration of the alert mail.

Fig. 17. Successful configuration of the power control and backup equipment of the ECU 911 Loja.

V. Integral Operation of the Monitoring System

The complete functioning of the real-time monitoring system of the electro-energetic variables is described in the diagram shown in Figure 18. This system consists of three main stages, which describe in a general way the whole process that the system monitoring carried out for: reading, processing, storage and presentation of information. These stages are:

1. Acquisition of the data
2. Data processing
3. Storage and presentation of data

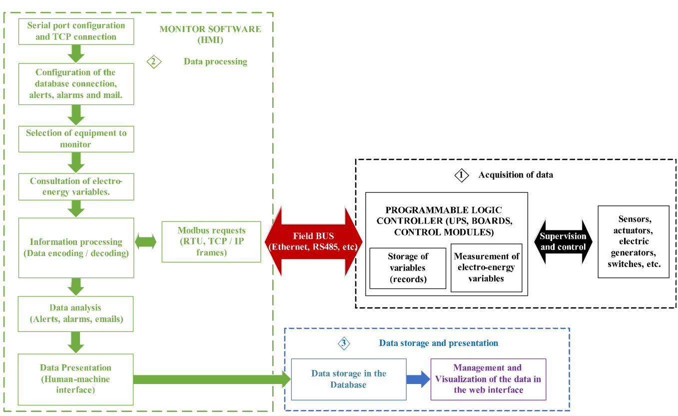


Fig. 18. General outline of the operation of the monitoring system of the electric power control and backup equipment of the ECU 911 Loja.

In the following figures, the results obtained are shown based on the operation of the real-time monitoring software of the electro-energetic variables of the electric power control and backup equipment of the ECU 911 Loja.

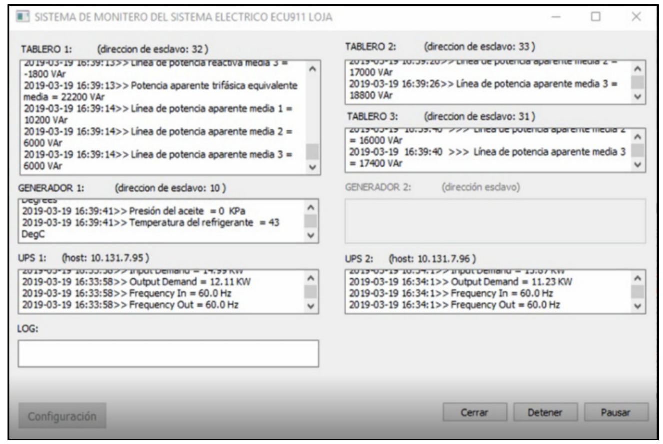


Fig. 19. Reading of electro-energetic variables obtained with the monitoring software in real time.

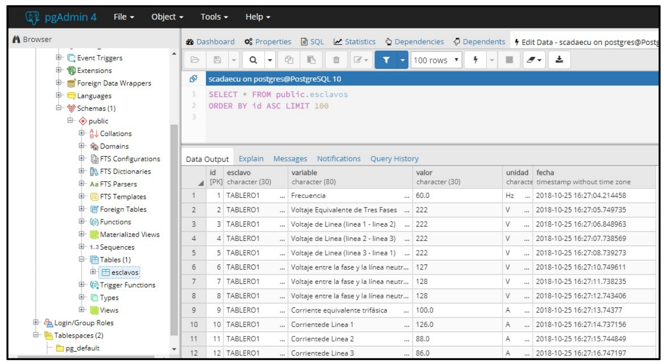


Fig. 20. Data stored in the PostgreSQL database.

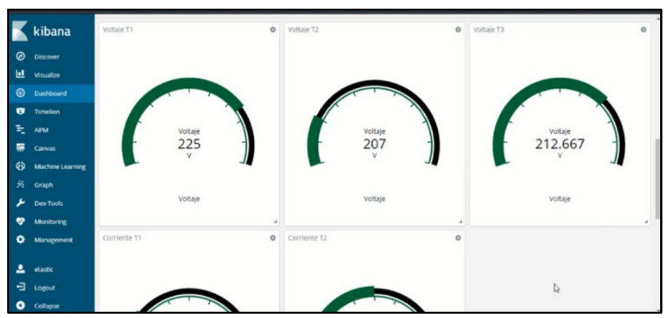


Fig. 21. Web interface developed in Kibana.

VI. Conclusions

A key part of the present investigation was the acquisition of the data of the electro-energetic variables, which were measured by the electric power control and backup equipment, coming from different manufacturers, this was achieved with the analysis of the protocols of industrial communication, taking into account the availability of information of the field devices and their technical specifications, reaching the conclusion that the Modbus protocol has better characteristics for the transmission of information between master and slaves, besides being open source.

An intuitive and user-friendly Human-Machine Interface was designed, which presents the readings of the electro-energetic parameters and alarms established graphically, facilitating the operator to differentiate between the different states of the elements of the system, this with the integration of "Qt designer software" and the "Phyton Language" for programming, thus providing all the necessary information about the process to the user and allowing him to know about the analog and digital variables of all the elements that comprise the electrical control system.

The storage of the data, which allows the protection of the information and the web publication of the readings of the electro-energetic parameters, was carried out in the "slaves" table, created for this specific use in the database, managed by PostgreSQL automatically, making use of a "sequence" to avoid overwriting some data saved previously, avoiding the loss of it.

It was evidenced that the electro-energetic variables measured by each electric power control and backup equipment are stored in a format that is configured by the equipment manufacturer, for example, in the case of the boards the negative values are represented by setting the most significant bit in height and the decimal part is obtained by multiplying by a scale factor, instead the UPS represent these values under the IEEE 754 format, this because the ModBus protocol is not fully developed, therefore, it does not specify in what format to store the information. This was solved by means of an individual programming that incorporates the characteristics of each manufacturer.

The management and presentation of the data in the web interface was developed using the Kibana tool of the ELK stack, obtaining an environment with: detailed, graphic and easily interpreted information; with which, the personnel in charge is allowed to access or consult the state of the equipment and the values of the electro-energetic variables in any part of the building that has access to the internal network of the SIS ECU 911 Loja.

The controllers developed in Python code, which are in charge of establishing communication with the electric power control and backup equipment and transforming the data into congruent values, make use of the MinimalModbus library in its version 7.0 developed by Jonas Berg, this library was the only one that needed to be modified, to make.

REFERENCES

[1] DUCATI Energia SpA. (n.d.). "Analizador de Red DUCA-LCD96". Available: https://www.ducatienergia.com/media/products/140729-1633-duca-lcd96-manual-usuario-v11-es.pdf . (December, 2019).

[2] Tecnoplus. (n.d.). "Tecnoplus". Obtenido de CUADROS DE CONTROL-MONO+TRIFASICO+diferencial. Available: http://www.tecnoplus.es/sites/default/files/Tecnoplus_AMF-DSE7320.pdf . (December, 2018).

[3] Manton, A. (2009). "Modulo de Control Series DSE7200/DSE7300". Mexico: IDIMEX.

[4] EATON. (n.d.). "Eaton 9390 UPS 40-160 kVA". Available: http://powerquality.eaton.com/Products-services/Backup-Power-UPS/9390.aspx?cx=8&GUID=AF07AB25-594F-47CE-B1E7-1B74D8D9CD95 . (December, 2019).

[5] Moya Calderón, C. B. (2009). "Software orientado a sistemas de control HMI/Scada usando recursos libres y de código abierto, desarrollado sobre plataforma linux". Quito: Universidad San Francisco de Quito.

[6] National Instruments. (n.d.). The Modbus Protocol In-Depth. Available: http://www.ni.com/en-us/innovations/white-papers/14/the-modbus-protocol-in-depth.html . (August, 2018).

[7] Company, The Qt. (n.d.). "Complete software development framework | Qt". Available: https://www.qt.io/what-is-qt/. (May, 2019).

[8] Python Software Foundation. (n.d.). "Python". Available: https://www.python.org/. (May, 2019).

[9] Berg, J. (n.d.). "MinimalModbus". Available: https://minimalmodbus.readthedocs.io/en/master/usage.html#using-multiple-instruments. (January, 2019).

[10] Elasticsearch. (n.d.). "Elasticserch - The heart of the Elastic Stack". Available: https://www.elastic.co/es/products/elasticsearch

[11] Modbus-IDA. (n.d.). "Modbus Application Protocol Specification V1.1b". Available: http://www.modbus.org/docs/Modbus_Application_Protocol_V1_1b.pdf. (January, 2019)

[12] Telecommunications Industry Association. (1998). Electrical characteristics of generators and receivers for use in balanced digital multipoint systems. TIA Standard, TIA-485-A (Mar. 1998).

Cosme Xavier Gálvez Sánchez is an Electronics and Telecommunications Engineer, from the National University of Loja (UNL), Ecuador. His research interests are: control and automation systems, monitoring systems, databases, networks. He has participated in network projects in the Department of Telecommunications and Information of UNL.

Ángel José Ordóñez Mendieta, Electronics and Telecommunications Engineer, Master in Communications Networks from the Pontifical Catholic University of Ecuador, PhD(c) in Applied Physics from the University of Salamanca (Spain). Former National Director of Telecommunications and Tics Policies at the Ministry of Telecommunications of Ecuador, currently a professor of the Electronics and Telecommunications career of the National University of Loja in Ecuador. Member of RTC-REDU Ecuadorian Network of Universities and Polytechnic Schools for Research and Postgraduate Studies.