Automation of the electrical power distribution network applying SCADA and GPRS to enhance remote activities in rural areas due to the COVID-19 pandemic in PERU.

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Abstract*– The research describes the automation of the distribution network in order to provide a reliable electrical energy system for the development of the activities generated during the COVID-19 pandemic in rural areas in Peru. The proposed objective is to implement the communications architecture using equipment with General Package Radio Service (GPRS) technology and interconnect it with a relational database and a Supervisory Control and Data Acquisition (SCADA) graphical interface. The system made it possible to monitor the status signals in real time, as well as to achieve precise and rapid control of the protection and reconnection equipment responsible for the automatic correction of faults in the distribution network. Regarding the maximum demand for energy during the 2020 period, the billing statistics showed a significant reduction due to the cessation of activities in a large part of the industrial, commercial and services sector, caused by the declaration of a state of emergency for management of the health crisis caused by COVID-19; This atypical behavior caused power outages due to system failures, such as short circuits and overloads, determining a series of problems for users as they were affected in their remote work activities, virtual classes and telehealth, among others. It is concluded that the equipment used in automation allows recording the failure reasons, the protection functions used, the phase in which the failure occurred, among other parameters without the presence of maintenance personnel, as well as supplying energy continuously. to meet remote activities in this pandemic.

***Keywords*- Electrical distribution network, electrical protection, GPRS, SCADA, maximum demand, COVID-19**

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I. INTRODUCTIÓN

The current health crisis represents a socio-economic challenge without precedent in the history of humanity, but in this technological and industrial era where data, statistics and energy consumption reflect the behavior of people and their habits, it is possible to know the customs of a society through its electricity consumption. The intelligent and automated systems of the electrical installations instantly collect all the data of the system, these are processed in control centers to be able to react to any unforeseen event and manage the entire network much more efficiently. This situation does not happen in rural areas because the substations are far from the control base, taking time to restore service until after several days, time that allows maintenance personnel to travel to the network point where the failure occurred. time in which the user is left without power supply.

Considering that today the market offers a diverse range of protection equipment in different brands and capacities, the challenge of this research will be to be able to adapt a variety of equipment from different manufacturers and with different configuration methods for its integration into a SCADA system. that will fulfill the tasks of universal manager of the entire network.

It should be considered mandatory isolation measures did not affect equally to all sectors that require electricity. The residential sector increased its electricity demand. This increase is due to both teleworking and more intensive home use of devices, throughout the day. Likewise, many businesses, when they were closed, stopped demanding electricity, and the industries, mostly closed or operating in a limited regime, reduced it significant [1].

During the pandemic Hidrandina S.A suspended commercial activities such as attention to new connections, cuts, reading shots, distribution of receipts, or others that are not essential in this emergency. The group indicated that preventive maintenance work was interrupted, however, they allowed themselves to deploy an operational force oriented to attend contingencies that restrict access to connectivity in the development of remote activities, however [2] it argues that in rural areas the lack of energy has caused delays in activities even more so in the development of virtual classes for young people and health care in remote areas.

As support for the research, theses, articles and scientific journals have been reviewed, we have [3] who explains that the automation of distribution networks automatically and quickly performs the maneuvers previously executed manually, also [4] describes how the design and implementation of a pilot system for the automation of feeders of the distribution network of the regional electric company Centro Sur SA, improves the quality of the service in the management of interruptions, as well as [5] maintains that a system of telemetry and telecontrol regulates the speed of an electric motor using GPRS technology and finally [6] presents a projection study regarding the behavior of the operation of Post COVID-19 electrical systems.

The results obtained in the various stages of implementation and tests were carried out using the existing equipment in the distribution network of the company Hidrandina S.A. in the city of Trujillo, where GPRS modems and multiband antennas were installed in a group of 05 reclosers. Likewise, the protection equipment was configured in such a way that they can establish a link with a Hidrandina master server, using the standard DNP 3.0 protocol. for the reading of signals and the execution of commands from the control center in Trujillo, from where the maneuvers were carried out.

II. ESTATE OF THE ART

Electricity distribution companies currently face typical problems of a distribution network, commonly called electrical failures. These faults involve a danger for people, for the devices and for the equipment of the distribution companies, since very high electrical currents can be produced with a severe destructive capacity. Likewise, these failures cause interruptions in the electric power supply causing economic losses by not selling energy, if the interruption time is long, the distribution company may suffer penalties for power cuts to users.

In Hidrandina's electrical systems there are various types of faults, such as ground faults, overload faults in the network, overcurrent fault, etc. Protective and reconnection equipment, better known as reclosers, are used to prevent these faults from causing prolonged interruptions.

Reclosers are devices with the ability to stop a failure in the network by detecting a current or voltage value above the configured nominal by their sensors. This action is achieved by opening its switch, which prevents the supply of energy, thus preventing the fault from spreading to larger sectors of the distribution network. In this way, a greater number of users are prevented from being affected, that is, the electrical failure is isolated to the fewest possible customers.

On electrical energy [7] he describes it as an essential ingredient for the industrial and general development of any country. It is a sought-after form of energy, as it can be centrally generated in bulk and economically transmitted over long distances. Furthermore, it can be easily and efficiently adapted to various applications in both industrial and domestic fields. The system that generates controls, transmits and ultimately consumes electrical energy is called the electrical energy system.

In our reality, electrical energy reaches end users through distribution lines, which have protection and reconnection equipment that protect the system from failures; the scheme is shown in Figure 1.

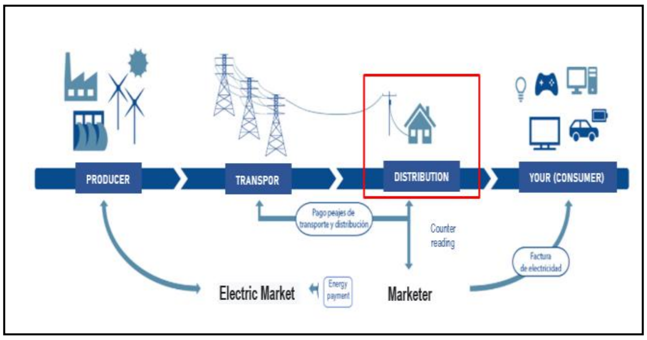

Figure 1. Stages of the electrical system. [7]

In this regard [7] they allow us to infer that to achieve the objectives of this research we must improve the indicators of the electrical system by automating this protection equipment. However, before entering the field of automation, it is necessary to delve into the electrical system, its processes, and its stages to have a better understanding of its operation from a global perspective.

Electric power today plays an extremely important role in the life of the community and in the development of various sectors of the economy. In fact, the modern economy is totally dependent on electricity as its basic input. This in turn has led to an increase in the number of power transmission lines connecting generating stations to load centers. Interconnections between systems are also on the rise to improve reliability and economy. The transmission voltage, while dependent on the amount of transmitted power, should accommodate long-term system requirements and provide flexibility in system operation.

Currently, he explains [8] there is no conception of a society without access to energy. There are constant efforts and measures to increase access to electricity, and numerous studies support the benefits it brings. However, more than one billion people in the world (17% of the world's population) lack access to modern energy services and use candles and batteries to meet their energy needs.

In many countries, lack of access to adequate levels of energy services is highly correlated with high levels of poverty. This situation is not alien to Peru, where although there has been a significant growth in energy consumption, the incidence of poverty in rural areas highlights the importance of including investment in the provision of electrical infrastructure within the national agenda.

Also, [7] explains that most of the electrical energy is transferred from the transmission or sub-transmission network to the high and medium voltage networks to take it directly to the consumer. The distribution network is generally connected in a radial structure as opposed to the mesh structure used in the transmission system, Figure 2.

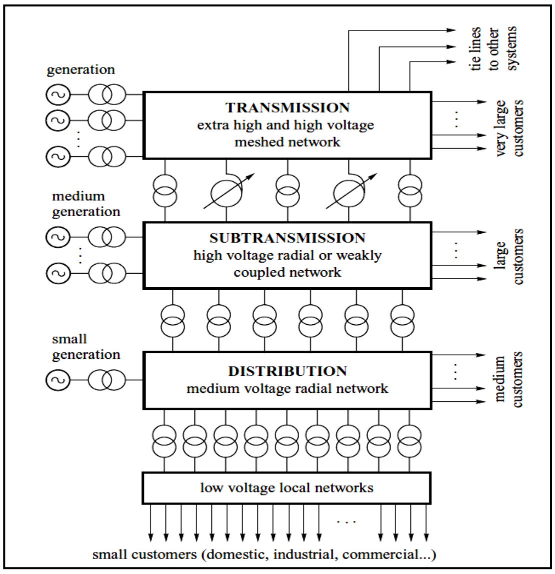

Figure 2. Structure of an electrical power system. [9]

For [9] large consumers can be supplied with a week coupled and meshed distribution network or, alternatively, they can be supplied from two radial feeders with the possibility of automatic switching between feeders in case of power failure.

The MV levels are three-phase regulated according to the CNE: Line 1 - Phase R, line 2 - Phase S and line 3-Phase T.

The distribution substations have the function of transforming medium voltage (MV) levels to low voltage (LV) levels. [10] defines the term failure as any unplanned change in the operating variables of a power system, it is also called disturbance and is caused by: failure in the power system (Short-circuit), foreign failure to the power system (In protective equipment), network failure (Overload, load fluctuation, lightning, pollution, sabotage, damage). When changing the operating conditions of an electrical system, unwanted consequences appear that alter the expected balance, they are: Short-circuit currents cause overheating and burning of conductors and associated equipment, increased deflection of conductors (Thermal effects), movement in conductors, insulator strings and equipment (Dynamic effects), severe voltage fluctuations, unbalance causing improper operation of equipment, Power fluctuations, instability of the power system.

In this context [11] it put into effect the procedure "Supervision of the Operation of Electrical Systems", approved with OSINERG Resolution No. 074-2004-OS / CD for distribution concessionaires to report information on interruptions occurred in all its electrical systems, in addition to establishing performance indicators. In Table I we can see the considerations that apply in the standard.

TABLE I
COMPENSATION FOR POOR QUALITY OF SUPPLY. PERIOD 2008-2011.

Control period	Biannual
Quality indicators	*Number of interruptions per customer (N)*
	** Total weighted duration of interruptions per customer (D)*
	In addition, interruptions due to load rejections are independently evaluated.
Control	By supply
Tolerances	Limits *N* and D according to supply voltage levels
	MAT/AT: N=2, D=4 hs
	MT: N=4, D=7 hrs
	BT: N= 6, D=10hs
	Typical distribution sector 2 and 3: additional 30%
	In the case of load rejection, there is no tolerance

For the evaluation of the quality of the electricity supply, 2 indicators of international use are used as defined below [11]:

System Average Interruption Frequency Index (**SAIFI**) such as the one that measures the frequency of occurrence of interruptions in electrical installations of electrical systems, in the face of component failures, maneuvers and unavailability that affect electrical systems, these may be their own (protection systems, network design, state of the facilities) and external (environment and third parties).

System Average Interruption Duration Index (**SAIDI**), the one that measures the time of the duration of the interruption, is related to the location of the fault, with the intensity of the fault and the resources available for replacement such as: crews, vehicles, materials, media, as well as access roads, the length of networks, etc. The following formulas allow us to evaluate the corresponding SAIFI and SAIDI:

$$SAIFI = \frac{\sum_{i=1}^{n} u_i}{N} \quad \text{.... (1)}$$

$$SAIDI = \frac{\sum_{i=1}^{n} t_i x u_i}{N} \quad \text{.... (2)}$$

Where:
Ti: Duration of each interruption
Ui: Number of users affected in each interruption.
n: Number of newspaper interruptions
N: Number of users of the electrical system

When companies incur low levels of quality in the electricity supply, expressed in their SAIFI and SAIDI indicators, they are obliged to issue compensation to their customers, in Figure 3 we can see the compensation incurred by distribution companies between the years 2008 and 2011.

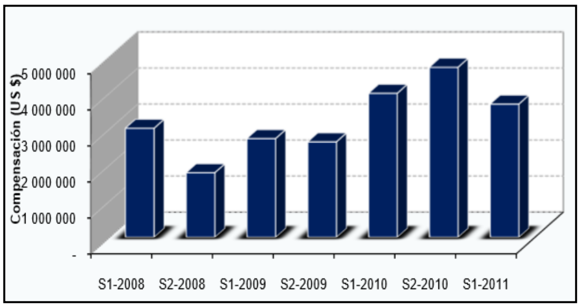

Figure 3. Evolution of compensation for poor quality of supply, period 2008-2011 [11]

This behavior continued in the years after the standard, [11] explains that the percentage of clients that distributors had to compensate increased slightly.

Regarding protection and reconnection equipment (Reclosers), according to [12] Most failures (80 to 85%) in distribution / transmission lines are temporary, lasting only a few cycles. Reclosers are self-monitoring devices that automatically cut off overloads, but they are not serious faults. after a predetermined number of operations, the lock remains open, Figure 4.

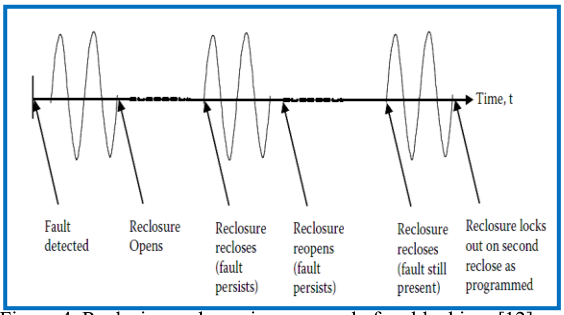

Figure 4. Reclosing and opening process before blocking. [12]

Reclosers are used to protect feeders leaving power substations and to minimize service interruption, [12] explains that reclosers are rated to carry a particular voltage, direct current rating, and minimum fault current in the protected zone, and can coordinate with other protection devices such as relays, Figure 5.

Figure 5. Recloser with its controller relay. [12]

Control Levels in Electrical Substations - From the point of view of the control and automation of substations; 4 levels are defined, considering level 0 as the lowest and 3 as the highest, Figure 6.

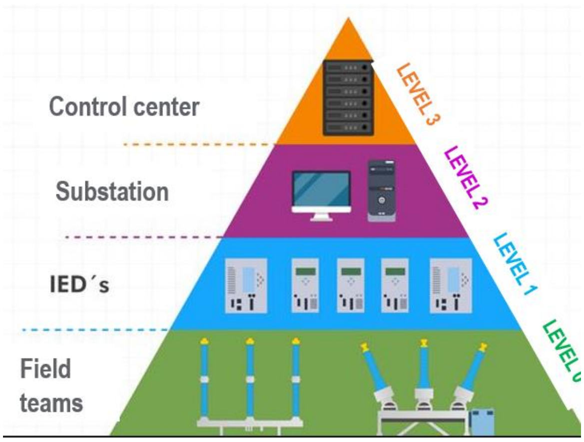

Figure 6. Control levels in electrical substations. [12]

- The first level (level 0) is the Patio level or Process level, in which the field equipment is located, such as switches and disconnectors.
- The second level (level 1) is the Bahia level or IEDs, it is made up of teams specialized in controlling and protecting the operation of field teams.
- The third level (level 2) is the Substation level, in which from a SCADA HMI system, the control, supervision and data acquisition functions of the entire Substation are performed.
- The fourth level (level 3) is the level of Control Center - SCADA, in this level the information of the SCADA HMI systems implemented in the third level is concentrated.

SCADA system for autonomous supervision of the distribution network. For [13] the automation of power systems is defined as automation of substations, the term "substation" being used to refer to the accommodation of protection and maneuvering equipment in a location, cabinet, or control room.

Data communication according to [13] is the core of any power system automation system and is practically the glue that holds the system together. Without communication, the functions of electrical protection and local control will continue, and the local device can store some data, but the power system automation system cannot work. The form of communication will depend on the architecture used, and the architecture may, in turn, depend on the form of communication chosen.

SCADA software, according to [14], can be divided into two types, proprietary or open. Companies develop proprietary software to communicate with their hardware. These systems are sold as "turnkey" solutions.

DNP3 or Distributed Network Protocol Version 3.3 is a telecommunications standard that defines communications between master stations, remote telemetry units (RTU) and other intelligent electronic devices (IEDs), [15].

Electric utilities, especially in urban areas, face the challenge of providing reliable power to end users at competitive prices. Equipment failures, lightning strikes, accidents, and natural catastrophes all cause power disruptions and power outages and often result in prolonged service interruptions.

The automation of electrical systems sustains [16] that is the creation of a reliable and self-repairing electrical system that responds quickly to events in real time with actions, its objective is to maintain an uninterrupted power service.

It is important to highlight that, among the accessories, the antenna is the one with the greatest relevance since it will be responsible for establishing a connection between the modem and the mobile operator's GPRS network. Antennas are the ears of electromagnetic waves and can capture and transmit signals thousands of kilometers away.

III. METHODOLOGY

The Regional Public Electricity Service Electro Norte Medio S.A. Known as Hidrandina, it is a Peruvian company that carries out activities of the public electricity service, mainly in the distribution and commercialization of electricity, in the concession area, in accordance with the provisions of the Electricity Concessions Law No. 25844 and its Regulation Supreme Decree No. 009-93 EM and amendments, is the company that provided its infrastructure for the development of research, Figure 7.

Hidrandina's electrical systems present various types of failure, such as ground faults, network overload faults, overcurrent fault, etc. Protective and reconnection equipment, better known as reclosers, are used to prevent these faults from causing prolonged interruptions.

Currently, the problem is that the supervision and conventional operation of these recloser equipment is carried out manually by sending people to the location of the recloser to operate, which normally implies long trips and consequently a slow replacement of electrical service.

These long times for operation also apply to the execution of other tasks typical of a distribution company, such as the recording of parameters in the recloser equipment, recording of maneuvers, transfer of loads, disconnections for maintenance, scheduled cuts, etc.

On the other hand, the execution of these conventional works is also the cause of high operating costs that include the payment of personnel, vehicle, fuel, travel expenses, among others.

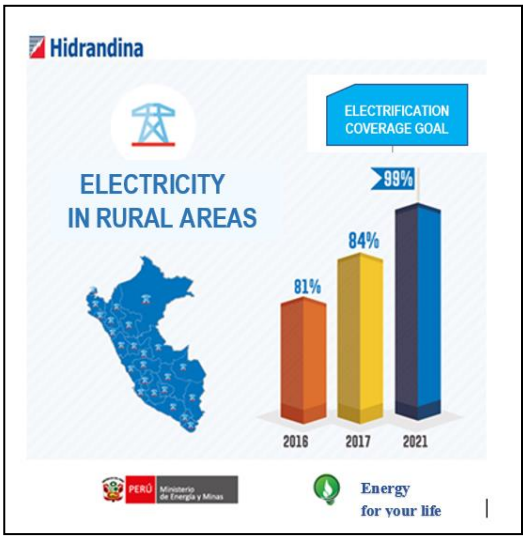

Figure 7. Electrification coverage- Hidrandina. [11]

However, the continuous expansion of electricity companies makes this less and less real, since the greater the territorial extension it is more difficult to manage the correct electricity supply since the execution of routine operations, problem solving, and replacement of services take more time in be affected. On the other hand, the longer the time it takes to replace the electrical service or the execution of operational tasks, the greater the cost assumed by the electrical company and the loss due to unsold energy.

Material and method:

The research is a field study with a quantitative approach, whose objective is to automate distribution equipment, for which 5 substations of the electrical distribution network were considered in different geographical locations in the rural areas of Hidrandina's concession, to minimize cuts electric power failures happening permanently coming and with greater impact in the stage of pandemic COVID-19. The results in the short time showed a continuous service as faults are automatically repaired in real time.

The activities carried out considered, in the first place, to manage the permits corresponding to the Hidrandina company, analyze the regulations in force, carry out field work to obtain relevant information on the implementation areas, verify the equipment and technologies for automation, as well as reviewing statistical information on the types of network failures and interruptions level court users, showing the critical paths for research.

In addition to the technical data obtained, the investigation considered the data provided by the Ministry of Energy and Mines regarding the limited access to electricity on a continuous basis to many users in rural areas, hindering the development of remote activities imposed against to Covid-19. Table II shows a high percentage with problems for the continuous access of the electric power service.

TABLE II
USERS WITH LIMITATIONS TO THE DEVELOPMENT OF THEIR REMOTE ACTIVITIES

REGIÓN	ACQUISITION OF SERVICES	DEFICIENCY			OBSERVATIONS
		ENERGY	INTERNET	EQUIPMENT	
Trujillo	35%	X			Energy - Frequency of supply cuts, high costs of Kw / h in the electricity bill, areas without access to electricity. Internet- Bad connectivity - low bandwidth, plans with high rates for data usage. Equipment- Lack of computers, latest generation cell phones and tablets.
	40%		X		
	25%		X	X	
Ancash	45%	x			
	30%		x		
	30%			x	
Cajamarca	50%	x			
	30%		x		
	20%			x	

Source: The Ministry of Energy and Mines (Minem) (2020)

For the design of the automation of the protection and reconnection equipment, it was first necessary to carry out an on-site inspection, which allows us to obtain the necessary information to achieve an adequate design according to the proposed solution.

Based on the data and information obtained from the inspections, it was possible to design a hardware and software configuration model that meets the objective of the investigation.

Developing:

1. **Protection and reconnection equipment control configuration.**

For the design of the recloser configuration, it was determined which would be applied in the investigation and based on this information, the on-site visit was carried out to collect relevant information for the design of the proposed solution, such as: type of ports, connectors, protocols enabled, signals available to enter the SCADA, parameters and attributes of these signals, type of software required for configuration, among other data.

As a result of the information obtained, 25 reclosers were available for configuration and automation, these belonged to 3 different brands: Entec, Noja and ABB. Being from different brands, it was also found that it would be necessary to use 03 different software, one for each brand. The softwares used were the following: AFSuite (ABB), ETIMS (Entec) and CMS (Noja).

The configuration of these reclosers required to be configured in all the protection and reconnection equipment to be integrated into the SCADA supervision and control system. These 03 sections are the following: Port configuration, SCADA protocol configuration and signal map configuration.

The first section responds to enabling the physical port and its characteristics, its type (Serial or Ethernet), transmission speed, link times, maximum response times, data types, among other parameters. After conducting internal tests, it was determined that for the Ethernet ports no further configuration was required in this regard, while for the serial ports it would be required to select certain parameters, Figure 8.

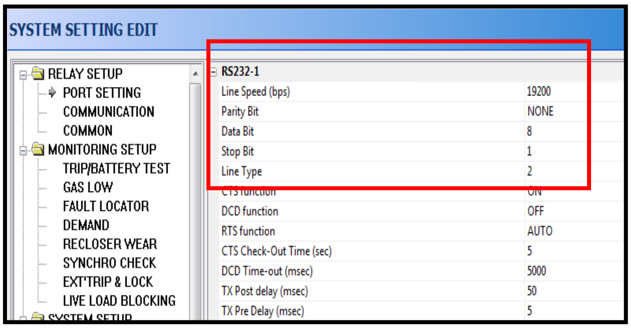

Figure 8. Parameters for configuring a serial port Recloser RS-232 in ETIMS software

The second section responds to the communication parameters for the specific protocol (DNP 3.0.) And according to the medium (Serial or Ethernet). This configuration carried out in one of the reclosers had to be replicated in the rest of the equipment, regardless of its brand or software.

Finally, the configuration of the signal map depended on the capabilities of each recloser, since there will be equipment with one or more protection functions than others, giving rise to a different number of signals available in each recloser.

2. Design of the SCADA system for autonomous supervision. Interaction between applications and programs to configure.

For the implementation of the SCADA system, Survalent software was used, whose license has been acquired by Hidrandina for previous applications. This software is made up of various server and client installers, the ADMS Manager being the general engine.

For the design of the SCADA database, it was important to define a coherent and ordered structure that allows the required variables to be found quickly and intuitively. Likewise, with the communication parameters found in the reclosers, it was necessary to identify those required on the SCADA side to establish communication with the IEDs.

The first step of the design was to define the structure, for this, 02 main logic stations that functioned as mother stations were considered, these are visible in Figure 9 and are:

- SCADA MASTER: Contains all the variables referred to the SCADA master.
- SYS $: Contains the internal variables of the system.

Additionally, to ensure the correct reception of data, it was required to secure the communication link, by configuring the communications in the SCADA. For this, the SCADA creates two internal figures that allow it to establish communication with remote equipment, the so-called Communication lines and virtual RTUs.

For the design of the SCADA graphical interface, it was important to define an ordered structure that allows the required views to be found quickly and intuitively. Likewise, create the necessary links to access the requested information in a practical way.

With this information, the views were developed using actual information from Hidrandina. The first view designed was the general view that allows to appreciate the states of all the local / remote selectors and switches of the reclosers. Likewise, it allows us to go to the general map of reclosers through a general central button.

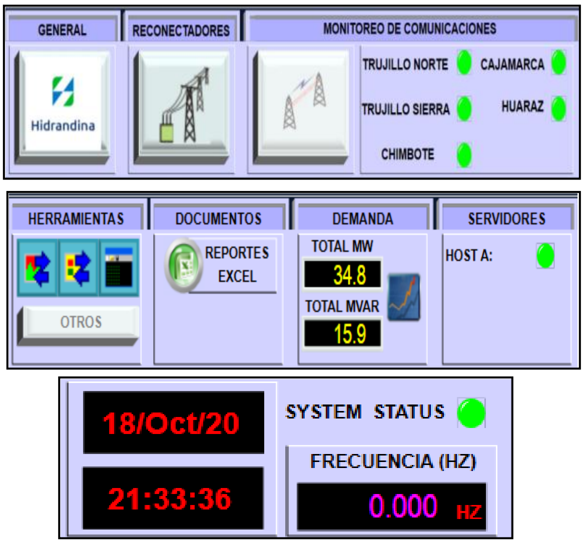

Figure 9. SCADA software: General buttons and monitor's section.

Similarly, for the general view and the rest of the specific views, a tool bar or menu was developed that allows linking the current view with any other existing view, as well as executing SCADA client applications or viewing the communication states by zones. By sections, the components of the toolbar or menu that were used to mobilize the user to any point in the graphical interface or to use any of the available functionalities, Figure 9.

On the other hand, a geographic map view was developed that allows directing the user to specific maps of 5 zones by using buttons.

While on the general map only the buttons for each zone and the geographical location of the reclosers are visible through indicators, on the specific map's buttons were created for each recloser in the zone. These buttons link the current specific map view to the specific internal view of each recloser Figure 10.

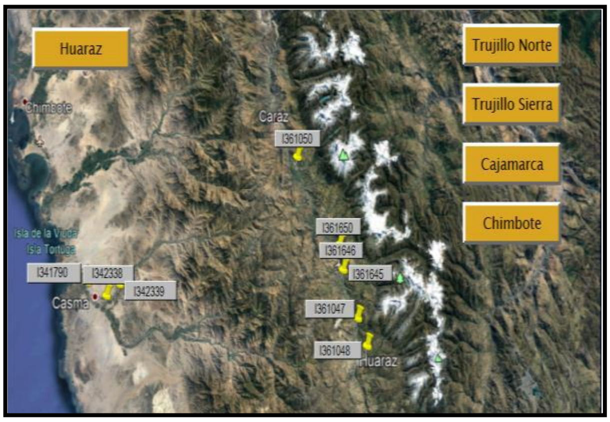

Figure 10. SCADA software: View of specific maps. Huaraz área MAP

Furthermore, specific internal views were designed for each recloser and predefined reports, Figure 11.

Figure 11. SCADA: Internal view of recloser

3. Design of communications using GPRS technology.

Mechanical and electrical design for the installation of GPRS modems. The mechanical design for the installation of the modems constitutes the dimensioning and distribution of the recloser relay and GPRS slave modem equipment within a recloser cabinet. Since the recloser cabinet is an existing structure already installed on the distribution network poles, it would correspond to be coupled to this existing installation.

Many modern reclosers have within their analog output's module, direct and alternating voltage outputs, which facilitates the energization of external equipment using this source from the same relay.

Regarding the design of the communications connection for the second stage of the architecture, this basically included the connection of the computer used in the master SCADA system and the master GPRS modem.

This is a connection that can be of a serial or Ethernet type, however, to standardize a single connection criterion, the Ethernet connection was used.

Design for GPRS modem configuration

For the configuration of the GPRS modem, it was necessary to determine the local network segment to be used for the communication of the modem with the recloser to which it would be connected (in the case of the slave modem) and with the SCADA computer (in the case of the master modem). Then it was necessary to determine what parameters of the cellular network and firewall characteristics were required for the free transit of data between the connection points, to later identify the ports and addresses to be used that needed to be configured together with the physical ports of the modem and function of the communication parameters of the recloser ports and SCADA computer.

For ease of configuration, this same address was determined as the local address of the modem, which consequently implied using, for the peripheral equipment that had to connect with the modem, different IP addresses within the same network 192.168.20.x. The possibility of being able to configure a subnet mask and an exit gateway is also visible.

In the case of Hidrandina, it managed its private network with the company CLARO, so it is necessary to use the APN code provided by CLARO to access the private network. The APN supplied was energiahdna.claro.pe. Placing this APN code and leaving the rest of the parameters in their default values was enough to achieve a link with the rest of the equipment within that private network.

Once the connection with the provider's network was verified and having an acceptable intensity level within the available coverage, the ports and internal addresses had to be configured or designated according to the services or protocols to be used. In this case, the internal SCADA ports (1024), relay configuration software for remote management (5000) and ports for the DNP 3.0 protocol were added. (20000 or 20001).

Finally, in terms of security rules, it was necessary that within the firewall functionalities that the GPRS modem has, a rule can be created that allows data traffic from the LAN network to the WAN network.

4. Implementation

The field implementation included the installation of the GPRS modem, configuration of the recloser and modem, and internal testing prior to testing with the master SCADA system. In Figure 12 you can see the first ENTEC brand recloser visited for its automation, to which a GPRS modem was installed inside its cabinet.

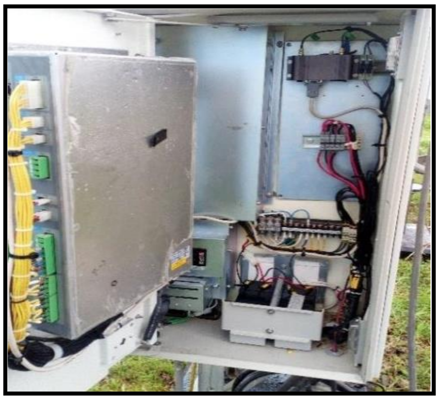

Figure 12. Recloser Configuration for Automation

Regarding the ABB and ENTEC reclosers, a GPRS modem and its corresponding connections were installed. This modem ensured communication by connecting serial cables to the recloser ports.

In the case of the NOJA reclosers, they also required the recloser configuration, the installation of a new GPRS modem and the respective cabling to ensure the future communication link.

Implementation of the GPRS communication link

Finally, regarding communications, it was necessary to configure the master and slave GPRS modems. The master in front of the SCADA would fulfill the function of a gateway to the GPRS network, to finally connect with the reclosers of the same private network contracted by Hidrandina, while the slaves would provide the output to the GPRS network to all protection equipment and remote reconnection.

IV. RESULTS

This section presents the analysis of the results of the automation of the electrical power distribution network through a SCADA and GPRS system to improve remote activities in rural areas in the face of the COVID -19 pandemic.

1. Laboratory tests:

The possibility of making a variation in the SCADA database was validated by receiving a command order from the graphical interface and then sent out of the SCADA to the remote recloser equipment, it was simulated, obtaining a good response.

Chimbote recloser I341786 was chosen for remote control simulated test issues.

Having selected the option to carry out the manual control, it was required to choose the state to which the signal was to be changed, in this first case the "Inoperative" option was selected. In Figure 13 the action and the result can be verified.

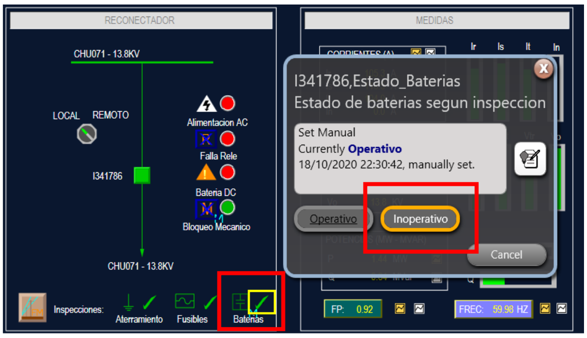

Figure 13. Selection of control for inoperative state, to be carried out from SCADA software.

This test was repeated for the "Operational" option. to verify the action and the result. In both tests the results are favorable.

From these tests, a successful result was obtained, with 3 attempts to achieve this result. The reason why the results were not favorable in the first test was due to errors in the configuration of the SCADA database.

The simulated test of autonomous supervision from the SCADA: It was possible to verify, from a specific recloser view of the graphical interface, that the variables changed and showed different values, like those of the real behavior of an electrical distribution network.

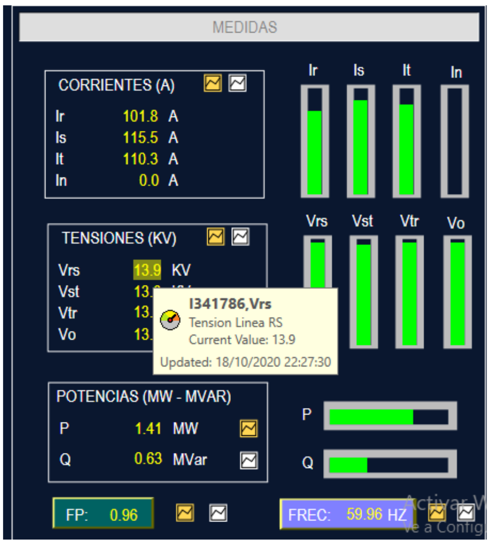

Figure 14. Signals monitored from the graphical interface of the SCADA software:

These results allowed us to conclude that it is possible to have an autonomous supervision of the electrical distribution system with changing values of phase currents and biphasic voltages shown from a graphical interface, Figure 14.

In this laboratory test it was verified that the designed system allows the autonomous supervision of the recloser equipment integrated into the SCADA system, managing to provide valuable information to the operator, such as alarm states, analog signal values, switch status, among others.

For the last laboratory test, we proceeded to search and establish a link between a SCADA system, a signal generator and two GPRS modems in such a way as to simulate the behavior that the elements of the communications architecture would have prior to being carried out in the field.

2. Field tests

Remote control tests of 25 Hidrandina S.A. reclosers.

The first field test aimed to confirm the remote opening and closing function of reclosers from the SCADA system. Likewise, the execution of these maneuvers brought with it the activation of other alarms related to the opening and closing of recloser switches, so in this test it is feasible to validate both functionalities: The control of the recloser switch and the recloser switches. fault alarms.

The list and information of the 25 reclosers are integrated into this system. For this test it was necessary to previously position the verification personnel on site.

This person validated the operation of the remote control and its successful execution, confirmed the activation of the alarms corresponding to a switch operation, both for the opening and closing of the switch, Figures 15.

Figure 15. Personnel in the field for the test of control

Also, it was verified with field personnel that the state of the field breaker has changed. This is not visible, but it is detectable thanks to the sound identified by the field personnel. The last validation was carried out by analyzing the alarms thrown by the SCADA system, these gave us clear evidence that the opening has been carried out and that the alarms caused by an opening have been properly activated.

Testing autonomous monitoring from SCADA

The second field test consisted of validating the autonomous supervision of the network through the real-time variation of the signals arriving from the field, Figure 16.

This was confirmed from the specific views of each recloser equipment or from the trend and historical graphs that were generated in the SCADA graphical interface.

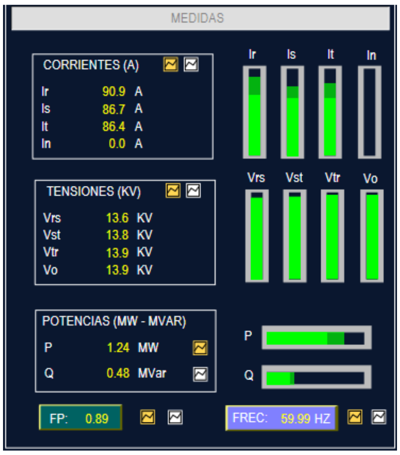

Figure 16. Generation of graphs in the SCADA software

On the other hand, in Figure 17 we visualize the changing values of the field signals, but through trend graphs in real time and with historical variables. With this we confirm that the system designed for this research meets the objective of allowing remote supervision, autonomously and in real time, of the most important variables of the Hidrandina S.A. electrical distribution network.

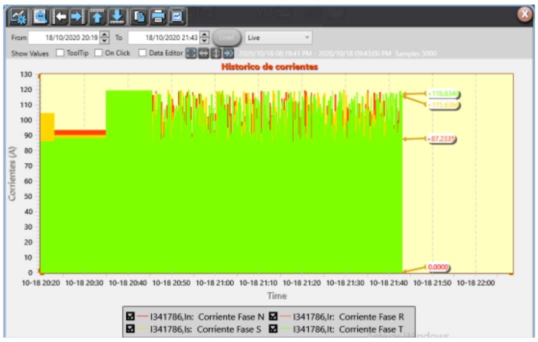

Figure 17. Graph of historical data of the currents generated from the SCADA software.

The final test regarding autonomous supervision consisted in generating reports from the graphical interface with the data obtained from the field. This was obtained by selecting any of the predefined reports in the report view.

The second stage consisted of generating a communication failure, to verify the behavior of the system in the event of a communication drop. We do this by disconnecting the communication cable from the modem, Figure 18.

On the graphical interface side, this test shows an alarmed led (red) that warns the operator that in a zone there are one or more reclosers with communication problems. Likewise, the reestablishment of communication deactivated the zone monitoring led and the communication alarms, Figure 19.

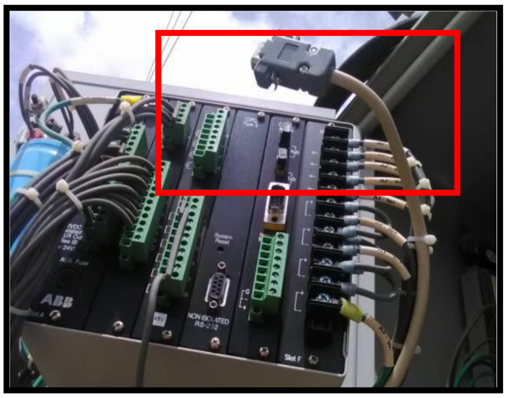

Figure 18. Disconnection of the serial cable at the recloser to generate a communication fault.

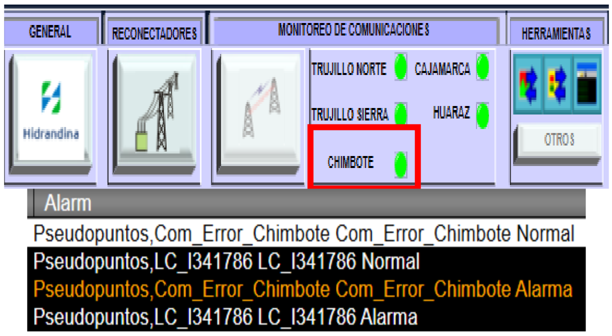

Figure 19. Alarm of communication failure activated of a Chimbote zone recloser shown in the graphical interface of the SCADA software.

V. CONCLUSIONS

The results obtained from the automation in the software reports indicate that the improvements to the failures of the Hidrandina SA distribution network are significant since the response is in real time, thus achieving an advantage at the operating cost level. , optimization of resources, speed of execution and customer satisfaction when receiving an electric power quality service, contributing from engineering with remote activities in rural areas in the face of the COVID-19 pandemic.

The SCADA system is viable for applications that require constant updating of values that change over time and that consequently allow more information about the real state of the electrical distribution network to be obtained.

The software developed made it possible to manage the SAIFI and SAIDI parameters in order to reduce failures and system failure intervals.

The system implemented for the company Hidrandina S.A. it will allow a general improvement in the management of your electrical system in the short term, thus achieving a more precise and faster diagnosis, a much shorter response time during failure events and a better strategy for restoring services, this thanks to the greater amount of information and data available for analysis.

Regarding GPRS communication, the link tests carried out lead us to confirm that this system complies with ensuring the connectivity and exchange of data packets in real time and reliably between the end points of the link, which are: the SCADA system in the control center of

Hidrandina SA and remote equipment installed in the distribution network in rural areas.

In this second phase of Covid-19 that we must live, we must maintain social isolation more than ever, but also develop remote activities, be it work, study and / or health, with continuous access to electricity service.

It is intended that the cut-off percentages due to failures in the Hidrandina distribution system will decrease significantly in 2021, allowing more users in rural areas to access connectivity and the use of technological equipment thanks to a continuous electric power service.

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