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Proposal of a predictive and preventive maintenance plan in electrical substations through the use of thermography

Proposta de um plano de manutenção preditiva e preventiva em subestações elétricas através do uso da termografia

Propuesta de un plan de mantenimiento predictivo y preventivo en subestaciones eléctricas mediante el uso de la termografía

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ABSTRACT

The objective of this study was to make a proposal for a predictive and preventive maintenance plan in the electrical substations La Propicia, Las Palmas, and La Pradera belonging to CNEL-EP Esmeraldas Business Unit through the use of thermography. The methodology was of a qualitative approach, under the type of documentary-bibliographical research. The search for information was carried out online in scientific and academic databases. It was found that the information on the maintenance plans in the subtransmission system of CNEL EP Esmeraldas Business Unit, is meager, preventive and predictive maintenance actions are carried out such as revision, washing, readjustment and replacement of elements in poor condition, but no information was found on the analysis technique used leading to the maintenance activities of electrical equipment and installations. The results of the consulted investigations agree that the thermographic technique and its tools such as drones, infrared cameras and software programs are very useful for the diagnosis, collection and processing of data in electrical systems to determine maintenance requirements. Finally, the investigation yielded substantial information that allowed the preparation of a maintenance plan for the aforementioned La Propicia, Las Palmas and La Pradera electrical substations of CNEL-EP Esmeraldas Business Unit through the use of infrared thermography, to assist in their better operation. and performance by allowing the evaluation of the state of the equipment that makes up the electrical system of the aforementioned substations.

Keywords: Electrical substations, thermography, maintenance, planning.

RESUMO

O objetivo deste estudo foi propor um plano de manutenção preditiva e preventiva nas subestações elétricas La Propicia, Las Palmas e La Pradera pertencentes à Unidade de Negócio CNEL-EP Esmeraldas por meio do uso de termografia. A metodologia foi de abordagem qualitativa, sob o tipo de pesquisa documental-bibliográfica. A busca de informações foi realizada online em bases de dados científicas e acadêmicas. Constatou-se que as informações sobre os planos de manutenção no sistema de subtransmissão da Unidade de Negócio CNEL EP Esmeraldas, são escassas, são realizadas ações de manutenção preventiva e preditiva como revisão, lavagem, readequação e substituição de elementos em mau estado, porém sem informações foi encontrado na técnica de análise utilizada conduzindo às atividades de manutenção de equipamentos e instalações elétricas. Os resultados das investigações consultadas concordam que a técnica termográfica e suas ferramentas como drones, câmeras infravermelhas e programas de software são muito úteis para o diagnóstico, coleta e processamento de dados em sistemas elétricos para determinar requisitos de manutenção. Finalmente, a investigação produziu informações substanciais que permitiram a elaboração de um plano de manutenção para as mencionadas subestações elétricas La Propicia, Las Palmas e La Pradera da Unidade de Negócio CNEL-EP Esmeraldas por meio do uso de termografia infravermelha, para auxiliar em seu melhor funcionamento. desempenho ao permitir a avaliação do estado dos equipamentos que compõem o sistema elétrico das referidas subestações.

Palabras clave: Subestações elétricas, termografia, manutenção, planejamento.

RESUMEN

El objetivo de este estudio fue realizar una propuesta de un plan de mantenimiento predictivo y preventivo en las subestaciones eléctricas La Propicia, Las Palmas, y La Pradera pertenecientes a CNEL- EP Unidad de Negocio Esmeraldas mediante el uso de la termografía. La metodología fue de enfoque cualitativo, bajo el tipo de una investigación documental-bibliográfica. La búsqueda de información se realizó vía online en bases de datos de naturaleza científica y académica. Se encontró que la información sobre los planes de mantenimiento en el sistema de subtransmisión de CNEL EP Unidad de Negocio Esmeraldas, son exiguos, se realizan acciones de mantenimiento preventivo y predictivo como labores de revisión, lavado, reajuste y reemplazo de elementos en mal estado, pero no se encontró información sobre la técnica de análisis empleada conducente a las actividades de conservación de los equipos e instalaciones eléctricas. Los resultados de las investigaciones consultadas coinciden en que la técnica termográfica y sus herramientas como drones, cámaras infrarrojas y programas de software, es muy útil para el diagnóstico, recopilación y procesamiento de datos en los sistemas eléctricos para determinar los requerimientos de mantenimiento. Finalmente, la indagación arrojó información sustancial que permitió la elaboración de un plan de mantenimiento para las referidas subestaciones eléctricas La Propicia, Las Palmas y La Pradera de CNEL- EP Unidad de Negocio Esmeraldas mediante el uso de termografía infrarroja, para coadyuvar en su mejor funcionamiento y rendimiento al permitir evaluar el estado de los equipos que conforman el sistema eléctrico de las referidas subestaciones.

Palavras-chave: Subestaciones eléctricas, termográfia, mantenimiento, planificación.

INTRODUCTION

Power generation is a factor considered essential in the scenario of economic growth and the quality of the standard of living of the population in all countries of the world, due to the long list of benefits and services that it makes feasible in terms of convenience, comfort and whose availability is directly interrelated for the access of goods such as optimal health care, education, water, communication, among many others, in this sense it is necessary to have a plan and constant maintenance work techniques to ensure uninterrupted supply of this public good, In this sense, it is necessary to have a plan and work techniques of constant maintenance to ensure the uninterrupted supply of this public good, minimize the rates of electrical failures in the electrical system, in addition to prolonging the life of the equipment over time.

In addition to this, particularly in Ecuador, the normative ordinances indicated in the Organic Law of the Electric Energy Public Service, the applicable regulations, the concession contract and the corresponding regulations, determine the mandatory compliance for the distribution companies to provide the electric service to the consumers located in their concession area within the established efficiency levels, specifically in regulation No. ARCONEL 005/18, which aims to establish the indicators, indexes and limits of the quality of the distribution and commercialization of electric energy service; and, to define the measurement, registration and evaluation procedures to be complied with by the distribution companies. ARCONEL 005/18, which aims to establish the indicators, indexes and quality limits of the service of distribution and commercialization of electric energy; and, to define the measurement, registration and evaluation procedures to be complied with by the electric distribution companies and consumers, as appropriate (ARCONEL, 2018).

It is worth mentioning that this regulation repeals in its entirety, the previous regulation 004/01, which refers to the "Quality of the electric distribution service" approved by the National Electricity Council (CONELEC), currently known as the Electricity Regulation and Control Agency (ARCONEL).

The present regulation is mandatory for electric distribution companies and for regulated and non-regulated consumers connected to the distribution network (ARCONEL, 2018). The quality parameters of the distribution electric service provided by the regulation no. ARCONEL 005/18 consider the following aspects: a) Product Quality; service quality attribute related to the way in which voltage signals are delivered by the distribution electric company; b) Technical Service Quality: service quality attribute related to the continuity with which the electric power service will be provided, and which is characterized by the frequency and duration of supply interruptions and c) Commercial Service Quality: Attribute of the quality of service related to the attention to the final consumer provided by the distributing electric company, also detailing the times of attention to new supplies, resolution of claims, the replenishment of supply and adequate billing. (ARCONEL, 2018).

This refers to the fact that the country's electric service distribution companies must have the capacity to provide and guarantee to all users, whether domestic, business, commercial or other, an excellent electric service in accordance with the requirements issued by the governing body in the matter.

In order to achieve compliance with the requirements suggested in terms of quality electrical energy distribution, the responsible companies must adopt the principles of good maintenance practices for preventive and predictive maintenance in electrical substations. Specifically, preventive maintenance is carried out on a scheduled basis to a good, service or facility, whether it is a medium voltage, low voltage electrical network or distribution transformer, with the purpose of reducing the probability of failure, maintaining safe and pre-established operating conditions, prolonging the useful life and avoiding accidents. (Barreto Sánchez, 2023). As for predictive maintenance, it is based on the performance of tests, reviews and diagnostics to equipment in order to know its current status and predict possible failures that could occur. The result of this maintenance allows taking corrective and/or preventive actions to optimize its operation. (Barreto Sánchez, 2023).

Today, it has become possible to integrate technology as a support tool to undertake better preventive and predictive maintenance work in electrical systems, thus, progress in this field has allowed to have tools such as thermography, a heat detection technique that helps to discover anomalies that can be corrected in a timely manner before they cause a severe failure in the electrical system. It is worth saying that when electrical equipment has a defect, it usually manifests itself by an elevation of its temperature, for this reason, the technique of infrared thermography is increasingly used, as it provides a new vision in predictive and preventive studies becoming a technique that provides valuable information on the state of operation of machinery and electrical equipment. (Olarte, Botero, & Cañon, 2011)..

Infrared thermography is a very useful technique based on the analysis of the surface of a body or components of a company's facilities, without the need to interrupt its operations, it is a minimally invasive technology because it allows measurements without contact. (Torres Leones, 2021). The devices used for predictive maintenance through thermography are thermal cameras capable of detecting different atmospheric conditions (humidity, path, wind, temperature and radiation) by means of infrared irradiation, these data are necessary for the definition of the temperature at a certain distance without physical treatment with the factor or object of analysis. (Molina Quiroz, 2023)..

Now, contextualizing this research, according to the National Electricity Corporation (CNEL EP), the substations La Propicia, Las Palmas, and La Pradera belonging to CNEL- EP Esmeraldas Business Unit, currently lack a maintenance plan, and there are high rates of out of service affecting the quality of service, for these reasons arises the need to propose a predictive and preventive maintenance plan using infrared thermography as an alternative to reduce the frequency and duration of interruptions improving the quality of service and thus comply with the regulations established in Resolution No. arconel 005/18. ARCONEL 005/18.

Overall objective

Propose a predictive and preventive maintenance plan using thermography techniques to improve the quality of the electrical service provided by the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit.

Specific objectives

To review the maintenance plan carried out in the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit by means of a bibliographic analysis of the documentation and the frequency and duration indexes of failures in order to determine the strengths and weaknesses of the current maintenance plan.

Describe the techniques and procedures for the application of predictive and preventive maintenance through the use of thermography, according to the characteristics of the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit.

3. Elaborate a predictive and preventive maintenance plan through the use of thermography in the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit, with the purpose of adapting the frequency and duration indexes of electrical failures to what is established in Resolution No. ARCONEL 005/18.

Literature Review. Conceptual Aspects

Maintenance

Maintenance can be defined as the interventions carried out on equipment and facilities to keep them in optimal operating and safety conditions (Risueño, 2019). The main objectives of performing maintenance on equipment and facilities would be: 1) To keep them in good working order, resulting in optimal productivity; 2) To reduce direct and indirect costs caused by lack of maintenance; 3) To keep them in ideal conditions regarding the safety of technicians and users; 4) To eliminate or reduce environmental pollution caused by equipment; 5) To try to reduce unscheduled shutdowns or breakdowns as much as possible; 6) Reduce anomalies, deficiencies or irregularities during equipment operation, whose increase is usually a symptom of lack of maintenance; 7) Maximize the useful life of equipment and facilities; 8) Improve the quality of the product or service; 9) Analysis of continuous improvements, innovating and automating processes and 10) Maintain equipment and facilities in regulatory and legal situation. (Risueño, 2019).

The function of maintenance is the task of the maintenance department is to safeguard the operability of the main elements that make up the subsystems and systems in high standards of operation by mixing different techniques, technology and administrative management, appealing to reduce breakdowns. (Zavaleta, 2021). The complexity of today, the great technological development involved in production equipment and service facilities, make that maintenance should be studied and applied with greater scientific content, analytical rigor and depth, if you want to achieve its main objective under the current and future conditions of the customers. (Bermúdez, 2007).

Types of Maintenance

Depending on the complexity of the maintenance to be performed or the needs of the company, we speak of preventive maintenance, predictive maintenance, among others.

Preventive Maintenance

Preventive maintenance can be defined as the set of periodic actions previously scheduled for each specific machine or installation, necessary to ensure reliable operation, reducing the deviations produced during normal use, in order to keep the installation in optimal conditions of safety, functionality and energy efficiency throughout its life. (Risueño, 2019). On the other hand, (Poma, 2012) refers that preventive maintenance is that which is carried out through the previous programming of activities, in order to avoid as much unforeseen damage as possible, and above all to contribute to the reduction of production downtime due to failures, thus contributing to the reduction of costs due to them. The aforementioned author also notes that the objective of preventive maintenance is to prevent interruptions and failures, while at the same time prolonging operating times by means of scheduled inspections and periodic reviews of the equipment.

Similarly, within the main objectives of preventive maintenance the author. (Risueño, 2019) highlights the following:

1) Ensure the safety conditions of equipment, facilities, operators and users; 2) Reduce the number and severity of equipment breakdowns, which would have as direct consequences, among others, production stoppages; 3) Reduction of operating costs of the service with process automation; 4) Reduction of operating and response times; 5) Increase the useful life of equipment and facilities; 6) Improve energy efficiency by reducing or optimizing energy consumption and 7) Reduce environmental pollution, including noise pollution. (Risueño, 2019).

Predictive Maintenance

It is intended to combine the advantages of all types of maintenance to achieve maximum equipment uptime and eliminate unnecessary work. This requires more advanced review and testing techniques to determine with certainty the condition of the equipment and a more rigorous control to achieve the correct planning and make the truly necessary revisions. (Poma, 2012). Predictive maintenance is intended to anticipate a breakdown or anomaly in the operation of equipment before it occurs. For this purpose, periodical revisions will be scheduled with special equipment measuring specific equipment parameters, subsequently analyzing their evolution over time. This type of maintenance relates a physical parameter to the wear or abnormal operation of a piece of equipment. It measures, monitors and tracks parameters and service conditions of an equipment or facility. (Risueño, 2019).

Among the objectives of predictive maintenance (Poma, 2012) points out: 1) Preventive protection of people and vital physical resources; 2) Maximization of machine effectiveness; 3) Reduction of the combined cost (maintenance plus stoppages) and 4) Obtaining information for statistics. Additionally, this same author indicates that the implementation of this type of maintenance is costly, but its operation is economical and the highest degree of reliability is obtained. Therefore, its use is ideal for vital parts, machines and systems.

Maintenance Plan

The maintenance plan according to Heredia (2013) cited by. (Lombana & Zarante, 2018) is a management model that contains the set of scheduled maintenance tasks to be performed in a plant to ensure the availability levels that have been established (p. 20). These authors also highlight that the elaboration of the Maintenance Plan requires the following phases: 1) Perform an equipment analysis, a phase in which it is sought to draw up an ordered list of the equipment therein; 2) Break down the plant into equipment or sub-processes and each of them into basic elements; 3) Make a record of each of the equipment that make up the process; 4) Determination of the functional failures of the systems that make up each of the equipment and for each of them identify the potential and actual failure modes; 5) Study of the consequences of a failure: Classification of failures, into failures to avoid and failures to cushion; 6) Determination of preventive measures that avoid or cushion the effects of failures; 7) Selection of the maintenance tasks that fit the maintenance model determined for each system; 8) Determination of the optimal frequencies for each task; 9) Grouping of the tasks in maintenance routes and ranges; elaboration of the initial maintenance plan; 10) Implementation of the routes and ranges; corrections to the initial plan and 11) Drafting of procedures to carry out the routes and ranges. (Lombana & Zarante, 2018)..

Thermography in Electrical Distribution Systems

The increase in demand for a higher quality and availability of electricity supply is a current requirement of the companies that distribute this service. A key element to achieve these objectives is the predictive-preventive maintenance of electrical distribution lines and systems, which requires the use of maintenance procedures and equipment in line with current needs. In this sense, thermography emerges as a technology whose application to the inspection of electrical distribution systems will help to detect possible failures in advance, thus reducing the probability of failure of the installation in the future. (Poyato, 2009).

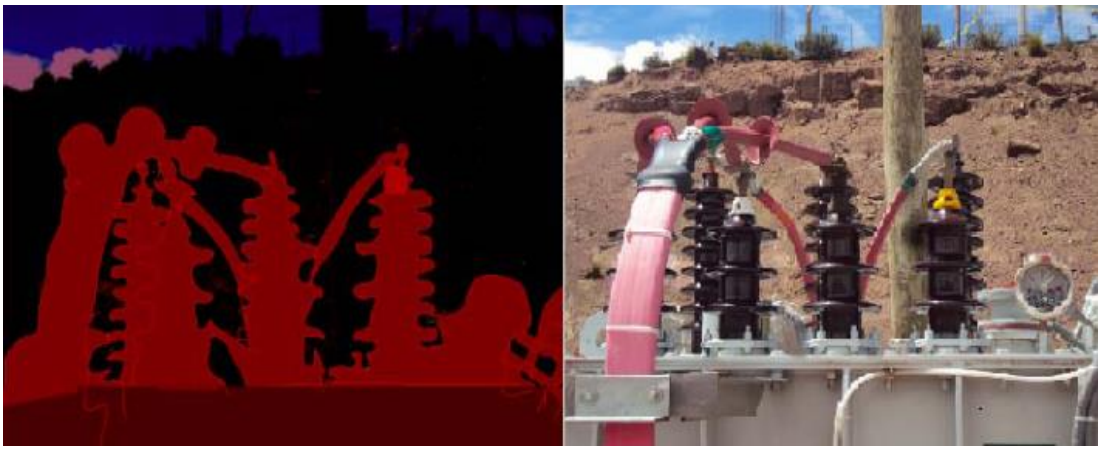
Thermography is an imaging procedure that makes visible the heat radiation (infrared light) of an object or body that is invisible to the human eye (Poma, 2012). Infrared thermometers have the ability to measure temperatures without physical contact with the object. This feature is based on the fact that all objects emit radiant energy, whose wavelength is located in the infrared spectrum, and the intensity of the radiation is a function of temperature (Yoc de la Cruz, 2005).

In particular, according to (Poyato, 2009) In the inspection of electrical distribution systems At a technical level, the application of thermography makes it possible to visualize the temperature patterns of electrical systems and installations. In this sense, it must be taken into account that a cause of failure in electrical systems is an excess of temperature caused by different reasons: a) increase of resistance in connection points, which results, under normal conditions, in an increase of its temperature giving rise to a "hot spot", which can be detected accurately with a thermographic camera; b) Failures in cooling systems and c) Leakage currents in insulating systems.

The basis for infrared imaging technology is that any body whose temperature is above 0 [ºK] radiates infrared energy. The amount of energy radiated is a function of the body's temperature and its relative radiation efficiency, a property known as emittance (Poma, 2012). The aforementioned author emphasizes that the amount of radiated thermal power and the specific characteristics of the radiation spectrum are governed by the laws of thermal radiation. Therefore, infrared

thermography is a technique that allows, at a distance and without contact, to measure the temperature distribution on the surface of a body accurately. For this purpose, infrared detectors are used to extract a quantifiable image in temperature through calculations, called thermogram. (Poma, 2012).

Figure 1. *Digital image with its respective thermogram.*



Note. Source. (Poma, 2012)

Description of Infrared Thermography Technique in Electrical Systems

Through the thermographic camera, the maintenance technician can examine each of the elements that make up the electrical distribution system in search of heating patterns, which will allow him to detect and solve a possible problem before it leads to a failure or interruption in the line. (Poyato, 2009).

If a region of high resistance is located, formed by corrosion or a poor connection, it will produce an undesired effect commonly known as a "Hot Spot", which can be detected by a thermographic camera, and through measurements and analysis the degree of severity of the problem in question can be quantified. (Poma, 2012). The increase of electric current flow in an equipment due to overloads, deterioration due to aging, insulation breakdown or load imbalances results in an increase of heat, which causes a malfunction in the equipment. (Poma, 2012).

Infrared sensors register electromagnetic energy invisible to the human eye. The heat of objects can be measured by the infrared energy they radiate. Infrared sensors create images that show temperature variations in a given area. (Yoc de la Cruz, 2005).

The equipment and elements connected in a substation that can be analyzed by infrared thermography are: Feeders and joints connected at 69KV; 13.8KV busbars.

Disconnecting blades; Connectivity points; Power circuit breaker; Power transformer; Recloser; Voltage regulator. (Yoc de la Cruz, 2005). Below are some images obtained from electrical distribution systems using the infrared thermography technique.

Figure 2. Review of a transformer body and its ventilation systems. Thermography with IR technology Fusion of a capacitor bank.

Note: Source: (Poyato, 2009)

Figure 3. Transformer thermography

Note: Source: (Poma, 2012)

Figure 4. Infrared Thermography of a Recloser

Note: Source: (Yoc de la Cruz, 2005)

In substations, the aspects to be examined are those already mentioned: mainly points of bad contact both between fixed elements and between moving elements, and to a lesser extent insulation failures. However, given the great wealth of equipment, it is also possible to talk about failures in capacitor banks, motors, cooling systems, among others. (Poyato, 2009). In this sense, two types of inspections can be differentiated: on the one hand, qualitative inspections and on the other hand, quantitative inspections. In the first case, the aim is to make a comparison of the temperature patterns of the elements working under the same conditions. In the second instance, the temperature of the elements is measured precisely, for which several aspects must be taken into account, including: a) Emissivity of the surface under study; b) Wind speed; c) Spatial resolution and optical resolution; d) Background temperature

METHODOLOGY

This research assumed the qualitative approach, under a bibliographic documentary type of inquiry, in considerations of (Tamayo & Tamayo, 2006). All of which allowed describing the key elements to make a proposal for a predictive and preventive maintenance plan in the electrical substations La Propicia, Las Palmas, and La Pradera belonging to CNEL- EP Esmeraldas Business Unit through the use of thermography. The population according to the estimates of (Arias, 2006)(Arias, 2006), was made up of documentary information gathered from different sources such as indexed journals, research papers, articles, books, etc., which according to (Rojas, 2011) are the sources of information used in the research and are people, institutions, documents, things, bibliographies, publications, states of the art, states of knowledge, theses, databases, electronic sources located on the Web, etcetera. The data collection techniques and instruments, according to the criteria of (Tamayo & Tamayo, 2006) were based on documentary observation and content analysis. Thus, data collection was carried out through the documentary analysis matrix, which is a research technique for the systematic and quantitative objective description of the content of publications in order to interpret them. (Sierra Bravo, 2007).

RESULTS

In response to specific objective number 1, which contemplates reviewing the maintenance plan carried out in the

electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit by means of a bibliographic analysis of the documentation and the frequency and duration indexes of failures to determine the strengths and weaknesses of the current maintenance plan. The research to access documentary information on the preventive and predictive maintenance plans carried out in the aforementioned electrical substations, carried out online, yielded the following data:

Table 1. Results of the documentary information collected on preventive and predictive maintenance plans.

Author	Results/conclusions
(Quiñónez, Ordoñez, Quiñónez, Sánchez, Hidalgo, & Mercado, 2017).	During the visits to the Subtransmission System of CNEL EP Esmeraldas Business Unit, it was discovered that not all the systems are in optimal conditions, which reflects the absence of an adequate maintenance plan, since it does not comply with all the activities that should be carried out in such system.
(Garcia, 2021)	As part of the preventive and predictive maintenance actions, CNEL EP Esmeraldas Business Unit executes the integral maintenance plan at the sub-transmission level. The 69kV Santas Vainas-Las Palmas and Las Palmas - Tachina sub-transmission lines in the Esmeraldas canton underwent revision, washing, readjustment and replacement of elements in poor condition.

Note: Prepared by the authors. Data collection instrument

Interpretation: It is found in the first document collected that not all systems are in optimal conditions, which reflects the absence of an adequate maintenance plan, since it does not comply with all the activities that should be carried out in such a system. (Quiñónez, Ordoñez, Quiñónez, Sánchez, Hidalgo, & Mercado, 2017).. However, the second bibliographic source refers to preventive and predictive maintenance actions carried out by CNEL EP Esmeraldas Business Unit in the 69kV Santas Vainas-Las Palmas and Las Palmas - Tachina subtransmission lines, in the Esmeraldas canton. (Garcia, 2021). It can be deduced that over time the maintenance parameters in the CNEL EP Esmeraldas Business Unit have evolved favorably.

In order to fulfill the specific objective number 2, corresponding to describe the techniques and procedures for the application of predictive and preventive maintenance through the use of thermography, according to the characteristics of the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit. A search was carried out in academic web pages in order to determine the use of thermography as a maintenance technique that can be applied in the referred electrical distribution substations, this search yielded the following results (see table 2).

Results of the information collected on predictive and preventive maintenance using thermography.

Author	Results/conclusions
(Varas Alava, 2022)	Electrical system inspections are performed both visually and thermally through the use of a drone. This provides an accurate inspection with information on the condition of the structures, insulators and network. By means of software in charge of evaluating the shot and videos that the drone captures in real time and evaluates them according to the resistance of each material.
(Llosas, 2022)	In the search for affectations by the operators, the FLUKE TiS65 thermographic camera is used, which has great advantages and benefits when performing thermographic studies, since real data is obtained in conjunction with its Smart View software. Where it was found that there are hot spots that may eventually cause a distribution failure. The study made it possible to verify the general condition and the type of maintenance that should be applied according to the NETA (International Electrical Testing Association) standard.
(Loor, Quiroz, & Llosas, 2021)	Thermographic analysis identified the areas with the highest incidence of hot spots. The thermographic sweep found thermal anomalies with varying degrees of severity. It was possible to establish a database that allowed the development of a failure history for the substation's component systems. The technical sheet obtained was focused on preventive maintenance activities oriented to the analysis with thermography techniques as a contribution to the maintenance that guarantees the operational availability of the system components with a readjustment of the maintenance activities in the elements that present a higher incidence of hot spots within the substation analyzed.
(Cruz Loya & Yugcha Quinatoa, 2021)	The infrared thermography method studied and analyzed can be applicable to any alternating current electrical system, regardless of the voltage level and as long as there is a load on the system and the established inspection procedures are complied with. Additionally, it is theoretically proven that infrared thermography only depends on the system load regardless of the voltage level. Additionally, it is possible to observe heating in insulators, which defines that infrared thermography should be applied to all insulators, both in poles or pylons and retention towers. Once the existence of anomalies is determined, maintenance priorities are established through quantitative analysis for the infrared thermography technique.
(López Ortiz, 2019)	It is recommended that electric distribution companies implement a Maintenance Management System, which is a computerized tool that allows the planning, coordination and execution of maintenance carried out in the transmission and distribution systems, respectively.

Note: Prepared by the authors. Data collection instrument

According to the data collected from the literature review, it can be observed that it is feasible to implement infrared thermographic technology to diagnose the operating status of the equipment that make up the electrical substations, which can be applicable in the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit. This technology can be implemented through various tools such as the use of drones; from thermographic cameras such as the FLUKE TiS65 model. The data collected through these artifacts are processed through the software program, whose results are the basis for decision making for the implementation of the maintenance management system, whether preventive or predictive, in order to provide the community with a quality service.

In response to the specific objective number concerning the development of a predictive and preventive maintenance plan through the use of thermography in the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit, in order to adapt the frequency and duration indexes of electrical failures to the provisions of Resolution No. ARCONEL 005/18.

As can be seen from the data provided by the empirical works consulted, the infrared thermography technique constitutes a way to detect through temperature fluctuations a series of internal failures in the equipment that constitute the electrical system, thus, such evaluation and interpretation based on statistics has been used for some time to know about what to take into account to establish preventive and predictive maintenance plans with effective results in the key aspects involved that allow increasing reliability and efficiency in an electric power distribution system.

In this sense, an outline of a preventive and predictive maintenance plan is presented for the La Propicia, Las Palmas and La Pradera substations of CNEL- EP Esmeraldas Business Unit, as a way to contribute to a more effective service, to reduce the occurrence of possible failures, thus increasing the useful life of the equipment and consequently reducing economic costs to the entity for the constant repair of the equipment.

Results of the information collected for the development of a predictive and preventive maintenance plan using thermography.

General Objective: Predictive and preventive maintenance plan using thermography techniques to improve the quality of the electrical service provided by the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit.			
Scope: A one-year period is foreseen, during which preventive and predictive maintenance activities will be developed based on the analysis of data obtained from infrared thermography in the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit.			
Specific objectives	**Activity**	**Periodicity**	**Responsible**
Diagnosis by infrared thermography of the condition of the distribution system equipment.	Equipment inspection Electrical for hot spot detection: -Search for critical and/or less critical areas.	Critical assets (every 6 months) Less critical assets (annual)	Distribution Management Technical and technological assistant manager
Analyze historical data from previous years (2 years) of maintenance related to frequency, time and activities that have been performed. Analyze recent data obtained by processing the data in the software program.	Review of the information with the specialized technical team: -Measurement and analysis -Quantification of the degree of severity	Every 6 months and/or annually	Distribution Management Technical and technological assistant manager
Locate critical and less critical structures involved in maintenance.	Review of the information with the specialized technical team: Geo-referencing	Every 6 months and/or annually	Distribution Management Technical and technological assistant manager
Make joint decisions between the administrative and technical areas on preventive and predictive maintenance actions in electrical substations.	Technical and administrative team meeting. Discussions to define the maintenance plan to be implemented. Establishment of the investment costs required by the technical team to undertake the required maintenance. Allocation of resources	Every 6 months and/or annually	Distribution Management Technical and technological assistant manager. Financial Sub-Management
Execute the preventive and predictive maintenance plan.	Maintenance and/or replacement of broken equipment: Power transformer cooling systems. Isolation systems -Connecting rods and substation connections	Every 6 months and/or annually	Distribution management. Technical and technological assistant manager.

Note: Prepared by the authors. Data collection instrument

The proposed plan for preventive and predictive maintenance in the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit through bibliographic analysis, aims to contribute to ensure the quality of service at all times, as established in Resolution No. ARCONEL 005/18, and is also aimed at safeguarding the operability and life of the main equipment that make up the electrical subsystems, also tends to achieve the reduction of failures and economic costs for the entity.

CONCLUSIONS

After the systematization of the data collected in the literature consulted, in relation to the first objective, the information available about the maintenance plan carried out in the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit, is very scarce, however, in the documentary sources consulted for this purpose, it was found that there is a need for maintenance activities on an ongoing basis, since according to the following study (Quiñónez, Ordoñez, Quiñónez, Sánchez, Hidalgo, & Mercado, 2017) in the Subtransmission System of CNEL EP Esmeraldas Business Unit, not all the equipment is in ideal conditions, which evidences the absence of a maintenance plan, which by extrapolation includes the electrical substations La Propicia, Las Palmas and La Pradera, since they are part of the CNEL- EP Esmeraldas Business Unit.

It was also found that as part of the preventive and predictive maintenance actions carried out in the CNEL EP Esmeraldas Business Unit, the CNEL EP Esmeraldas Business Unit has developed revision, washing, readjustment and replacement of elements in poor condition in some sections of the power lines of Las Palmas in the canton of Esmeraldas, however, no information was found about the method used to diagnose failures that eventually allow planning ongoing maintenance activities in this entity.

With respect to the results of the second objective, referred to describe the techniques and procedures for the application of predictive and preventive maintenance through the use of thermography, there are several works that report the use of this technique in national and international instances with favorable derivations, in this way, (Varas Alava, 2022) highlights the use of drones for an accurate thermal inspection with information on the condition of structures, insulators, network, whose video data that the drone captures in real time and is evaluated by the respective software.

On the other hand, (Llosas, 2022) mentions the use of the FLUKE TiS65 thermographic camera when carrying out thermographic studies, since they obtain real data in conjunction with their Smart View software. Likewise, (Loor, Quiroz, & Llosas, 2021) indicate that through the thermographic sweep, thermal anomalies with different degrees of severity are found, which is important to establish a database that allowed the development of a failure history for the substation's component systems, which allowed focusing preventive maintenance activities.

In the research work developed by the authors (Cruz Loya & Yugcha Quinatoa, 2021) (Cruz Loya & Yugcha Quinatoa, 2021) denote that the infrared thermography method studied and analyzed, can be applicable to any alternating current electrical system, regardless of the voltage level and as long as there is a load on the system, and the established inspection procedures are complied with. Once the existence of anomalies is determined, maintenance priorities are established through quantitative analysis. In line with these guidelines (López Ortiz, 2019) recommend distribution utilities to implement a Maintenance Management System that a computer tool that allows the planning, coordination and execution of maintenance in transmission and distribution systems respectively. Here it can be added that the infrared thermography technique describes the key aspects involved in the condition of the equipment analyzed, whose specifications are very useful to support maintenance in these companies and consequently the provision of a better service to the community, all of which can be used to plan preventive and predictive maintenance work in electrical substations such as the one referred to in the case of this study.

Finally, the information obtained from the previous empirical reports allowed to establish some guidelines to develop a preventive and predictive maintenance plan in the electrical substations La Propicia, Las Palmas and La Pradera of CNEL- EP Esmeraldas Business Unit through the use of infrared thermography, in order to contribute to their better operation and performance by evaluating the condition of the equipment that make up the electrical system of these substations

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