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# FORMULATION OF A NEW ELECTRICAL SAFETY MANAGEMENT SYSTEM AND ASSESSMENT OF ITS IMPACT THROUGHT A CASE STUDY IN CHILEAN LARGE-SCALE MINING

## FORMULACIÓN DE UN NUEVO SISTEMA DE GESTIÓN DE SEGURIDAD ELÉCTRICA Y LA EVALUACIÒN DE SU IMPACTO MEDIANTE UN ESTUDIO DE CASO EN LA GRAN MINERÍA DE CHILE

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**ABSTRACT**

Currently, internationally electrical regulations like, IEEE and NFPA, and legislation in various countries require management of electrical safety, but there is no existing system for its implementation. Therefore, a system for electrical safety management was designed based on the requirements of ISO 45001 standard and technical norms such as NFPA 70E and IEEE 3007.2. First, an investigation of national and international regulations regarding electrical safety was conducted, and the electrical safety management system was designed. Based on the proposed electrical safety management system, diagnostic audits were performed on companies from various economic sectors to assess their electrical safety management. The results of these audits indicated that all the audited companies were taking specific actions, but there was no management of electrical safety. Subsequently, the electrical safety management system was applied to one of the audited companies, and after the system was

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implemented, a follow-up audit was conducted. Finally, an analysis of the obtained data was carried out, which allowed us to demonstrate the positive impact of the system, as it showed benefits such as increasing compliance with legal regulations, reducing accidents involving individuals, lowering costs related to equipment and facility damages, and optimizing operational costs. This was aimed at promoting the safe and efficient use of electrical energy.

**RESUMEN**

**Palabras clave:**
sistema de gestión, seguridad eléctrica, riesgos industriales, indicadores de seguridad, riesgos de accidentes.

Actualmente la normativa eléctrica internacional como, la IEEE y la NFPA, y la legislación de diversos países exigen realizar gestión sobre la seguridad eléctrica, pero no existe un sistema para su implementación. Por ello, se diseñó un sistema de gestión en seguridad eléctrica con base en los requerimientos de la norma ISO 45001 y normas técnicas como la NFPA 70E y la IEEE 3007.2. Primero, se realizó una investigación de las normativas nacionales e internacionales en lo que respecta a la seguridad eléctrica y se diseñó el sistema de gestión de seguridad eléctrica. Con base en el sistema de gestión de seguridad eléctrica propuesto, se realizaron auditorías de diagnóstico a empresas de diversas actividades económicas para evaluar su gestión de seguridad eléctrica. Los resultados de estas auditorías indicaron que todas las empresas auditadas realizaban acciones específicas, pero no se hacía gestión de seguridad eléctrica. Posteriormente se aplicó el sistema de gestión de seguridad eléctrica a una de las empresas auditadas y a la que, después de implementado el sistema se le realiza una auditoria de seguimiento. Finalmente, se realizó un análisis de los datos obtenidos donde se pudo demostrar el impacto positivo del sistema ya que mostró beneficios al aumentar el cumplimiento de la normativa legal, además de reducir los accidentes a las personas, reducir los costos por daños a los equipos e instalaciones y optimizar los costos operacionales, buscando el uso seguro y eficiente de la energía eléctrica.

## Introduction

Currently, international electrical safety standards such as IEEE 3007.3 and NFPA 70E, have been demanding greater awareness of the real cost of electrical injuries and learning to appreciate the risks related to electricity, which is why countries such as the United States, Costa Rica or Colombia have required them in their national standards and countries such as Spain, Australia or Canada have used them as a reference (Crow et al., 2018). Given this, the National Fire Protection Association (NFPA, 2021) and the Institute of Electrical and Electronics Engineers (IEEE, 2012), recommend the employer implement and document an electrical safety program that mandates appropriate activities for risks related to electrical hazards.

In countries such as Costa Rica, Colombia and Mexico, electrical safety and electrical safety programs have already been included as a specific standard based on NFPA 70E criteria. Therefore, although it has become a legal requirement for companies to have an electrical safety program, there is still a general lack of knowledge on how to implement it. Currently, the regulatory bodies of different countries, such as the Superintendency of Electricity and Fuels (SEC) in Chile, through the Regulation of consumer electrical installations DS 8, requires companies that general electrical installations must comply with the basic requirements for operation and maintenance as defined in DS 8 - RIC 17: "Operation and Maintenance. This document establishes that each company must implement and document an electrical safety program (PSE) in accordance with the company's occupational risk management system, either through universally used standards (ISO, OHSAS, ANSI) or through specific risk prevention programs implemented by the company.

Like Chile, other countries such as the U.S. and Canada have also been affected. The US, Colombia, Mexico and Peru, within their legal requirements, demand the incorporation of technical standards such as the National Electrical Code (National Executive Committee), the electrical safety standard in the workplace (NFPA 70E), the National Electrical Safety Code (NESC), among others. There are also other recognized standards and guides that contain electrical safety information that can be referred to in a legal case such as the IEEE and NETA standards, however, the same problem of not having an electrical safety management system in place is present.

Another difficulty is the tendency of organizations to implement management systems that do not consider the complexities of electrical risks, nor the benefits that their reduction can bring to operational continuity and efficiency. This added to the absence of a clear and consensual definition of what electrical safety implies, which generates confusion by carrying out isolated activities to solve specific problems, but not systematized to be able to make measurements and take actions to improve the independence of electrical safety management of the productive activity where it is implemented, without considering the variables and conditions of each sector or industry.

These factors limit the ability of organizations to ensure effective electrical safety management that protects workers, improves operational performance and contributes to sustainable development. Therefore, there is a need to design and implement a specific management system for electrical safety that considers its particularities and benefits, and that adapts to the characteristics and needs of each organization.

To comply with this, a key requirement for any installation internationally, is that good design practices are followed; that new systems are installed in accordance with NFPA

70E, the NEC and/or other applicable technical codes and standards; and that any changes to the electrical system are properly documented. (Drewiske and Kalcec, 2020). Other countries such as Mexico and Colombia, for example, include in their regulatory requirements that companies engaged in the production, transformation, transmission and distribution of electrical energy must have an asset management system to ensure the integrity of electrical installations, in accordance with the standards of the International Organization for Standardization, specifically ISO 55000.

Despite all these legislative efforts, false safety and worker comfort increase, which transforms into small failures turning into serious accidents (Lee et al, 2019). Electrical hazards are very different from non-electrical hazards, as they are very difficult to deal with. It is apparently very difficult to foresee the level of risk associated with an electrical circuit just by a simple visual inspection of the circuit. It is also noted that, in most cases of dangerous occurrences, the worker who performed an unsafe act was not the victim of the injury, but rather it was a member of his or her team who relied on his or her aptitude and was therefore injured. (Sarkar, 2021).

According to on-site audits conducted as part of this study, there was low compliance with national and international regulations. In this sense, most of the audited companies have electrical safety programs and comply with the recommendations, but they are not systematic or structured processes, rather they are isolated activities that seek to solve a problem or comply with a specific regulation being NFPA standard 70E, which defines electrical safety program as a documented system consisting of electrical safety principles, policies, procedures and processes that governs the activities appropriate to the risk associated with electrical hazards. In other words, the NFPA standard requires the implementation of a safety management system and not a program of isolated activities or activities for a specific circumstance.

In this sense, the problem that emerges from the evaluation of the audits carried out is that programs of activities focused on electrical safety are implemented, but no management is implemented to support electrical safety and allow for the continuous improvement of this management.

In accordance with the stated problem, the objective of this work was to propose an electrical safety management system and to show the benefits of implementing such a system. The system is based on 3 fundamental principles: People, electrical equipment/facilities and operational continuity that allows the company to identify needs, implement controls seeking to reduce incidents, comply with legal and/or corporate regulations and ensure operational continuity, which in turn, reduces harm to people, costs due to damage to equipment and costly operational losses caused by undesired events that cause the use of electricity.

### *Management System*

The term management Lopez Cachero (1998)defined it as the methodical order of interdependent activities and related procedures that make possible the good work of an organization. Therefore, a management system is an integrated set of interacting processes and tools used by an organization to develop a strategy in order to develop operational actions, monitoring and improving the effectiveness of both (Kaplan y Norton, 2008).

If the concept is expanded a little further, a risk management system consists of constructing the minimum information that makes it possible to calculate the risk to be

assumed and to foresee the reserves that would allow survival under appropriate conditions (Lavell, 2001).

The objective of the safety management system is to prevent work-related injuries and health impairment and to provide safe and healthy workplaces; consequently, it is of critical importance for the organization to reduce hazards and eliminate risks by taking effective preventive and protective measures (ISO, 2018).

### *Electrical Safety Program*

Annually, the average number of work-related fatalities in Chile exceeds 200 workers, of which between 10 and 13% are of electrical origin (Electro Industria, 2016). Particularly, the electrical industry presents accident rate indicators below 2%, i.e., 2 workers per 100 are injured, being the country average in 2013 of 4.3%. However, "the Mortality Rate is notoriously higher, being 3.5% in the companies that are members of the Mutual Societies and 6.4% in the total number of companies".

Electro Industria (2016) relates how a report on electrical accidents carried out by the ACHS between 2009 and 2012 found that about 17% of electricity-related work accidents are considered to be serious. Although this figure appears to be low in absolute terms, it is important to note that these few incidents account for almost 80% of the days lost due to medical leave. Of these cases, 72% are related to the electric shock effect, while the remaining 28% are due to electric arc, according to the ACHS expert.

According to NFPA (2021), an electrical safety program is a documented system consisting of electrical safety principles, policies, procedures, and processes governing activities appropriate to the risks associated with electrical hazards.

In this sense, the goal of the PES is to systematically, proactively and preventively address electrical hazards in the workplace, which is a more effective approach than reacting to injuries and fatalities caused by those hazards.

IEEE 3007.3 (2012), for its part, indicates that an electrical safety program is a plan designed so that neither workplace conditions nor the actions of individuals expose personnel unnecessarily to electrical hazards. Establishing an electrical safety program and making sure employees follow it can be a great tool against accidental injury or death due to electrical incidents.

If one considers the requirements and definitions given to the concept of electrical safety program in the various standards, what the standards require is an electrical safety management system, even though the term used does not explicitly define it. Since companies are unfamiliar with the concept and there is no defined electrical safety management system that they can implement, in the best of cases, they apply isolated actions to try to comply with the requirements of these regulations.

When implementing an electrical safety management system, the principles of the system should be identified and taught to employees as a key component of improving the electrical safety culture (Eastwood et al., 2002)as a key component of improving the electrical safety culture. This is achieved by aligning the objectives of the electrical safety program with the organizational objectives of each company.

The goal of electrical safety programs was established to address unsafe work practices and unsafe installations (Becker y Davis, 2015)it is easy to focus on the technical aspects of the program (Crow et al., 2018), such as facility maintenance, leaving aside the document management, which is what demonstrates that the planned actions have been

carried out. However, electrical safety has not been well defined (Liggett, 2006). Identifying incidents that can cause injury to electrical workers helps prevent these types of injuries from occurring (Anderson, 2019).

Those responsible for implementing and monitoring the electrical safety program should be informed about the evolving knowledge of leading indicators and assist those responsible for training management in establishing a balanced scorecard of metrics that can more effectively serve the organization in identifying and controlling the risk of electrical hazards. The main indicators should be closely related to electrical safety. For example, an organization with a leading indicator that measures overall safety and health management/leadership needs to add a metric that measures electrical safety management/leadership (Landis, 2022). Electrical injuries, compared to other types of industrial injuries, represent a relatively small percentage, however, in terms of the number of injuries with serious and fatal results it ranks first. Therefore, the utmost attention should be paid to the indications of the technical regulations with regard to electrical safety (Lebedev, 2021).

## Method

The research approach was based on a methodology of documentary analysis of information and statistical analysis, where the identification and compilation of documentation was carried out through the analysis of available information. For confidentiality reasons, this article reserves the right to name and/or identify the audited companies, due to the possibility of non-compliance with national or international regulations, otherwise company 1 (E1), company 2 (E2) and so on are named.

### *Data Collection*

In the first instance, research was carried out on current national and international standards, such as ISO 45001; ISO 31001, NFPA 70E (NFPA, 2021) and IEEE 3007.2. As a result of this research, checklists were prepared and used to collect data for diagnostic audits or gap verification.

Subsequent to this, an electrical safety audit was designed based on ISO 19011 (ISO, 2018). The audit evaluated 7 topics which are: general installations, electrical rooms, fire fighting system, safety equipment and PPE, safety procedures, documentation and electrical training. Details of each of these topics are included in the checklists used for data collection. The data collected from these audits were evaluated on a scale ranging from 0 to 5, with 0 being total non-compliance with regulations, 3 being minimum compliance with regulations and 5 being full compliance with regulations, best practices and innovation in implementing electrical safety management. For this purpose, matrices were developed that incorporate specific indicators applicable to each situation. These indicators cover all stages of the electrical safety management process, and are detailed in Table 1 and Table 2. The purpose of these indicators is to accurately measure each of the topics to be audited, which allows for a subsequent impartial and objective analysis of the results obtained in the audit.

**Table 1**
*Acceptance criteria for operational variables*

| | | Does not comply | Does not comply | Does not comply (by very little) | Minimum compliance | Complies with best practices | World Standard |
|---|---|---|---|---|---|---|---|
| **Variables** | **Standard** | **0** | **1** | **2** | **3** | **4** | **5** |
| General electrical installations | ▪ SD 132<br>▪ DS 08<br>▪ NFPA 70E<br>▪ IEEE 3007.3 | No type of control is defined | Significant shortcomings with respect to expectations | Minor shortcomings compared to expectations | Updated without implementing recommendations | Updated and systematized studies | Practices above expectations |
| Maintenance management | ▪ SD 132<br>▪ DS 08<br>▪ NFPA 70B | No type of control is defined | Significant shortcomings with respect to expectations | Minor shortcomings compared to expectations | The requirement is effectively fulfilled | Effective and systematized compliance | Practices above expectations |
| Equipment and PPE | ▪ SD 132<br>▪ DS 08<br>▪ DS 40<br>▪ NFPA 70E | No PPE for electrical use is defined | Electrical PPE is not enough | Shock PPE is delivered, but not arc PPE | It is available for arc and electric shock and is monitored and reset | It is effectively complied with. Systematized delivery and replenishment | Practices above expectations |
| Fire protection systems | ▪ SD 109<br>▪ SD 132 | No fire protection systems | Do not comply with legal requirements | They exist, but there is no control of periodic inspections and maintenance | They exist and are inspected and maintained periodically. | It is effectively complied with. Systematic testing and inspection | Practices above expectations |

Table 1 shows the acceptance criteria for operational variables, where the variables considered and the associated score are shown. The variables consider several aspects based on legal regulations, which are explained in more detail below:

- General electrical installations: Seeks to provide safe working environments with no or minimal exposure to electrical hazards, while complying with current legislation, technical regulations and manufacturer's guidelines. The design should consider aspects such as electric shock and arc flash protection, fire protection measures, adequate lighting, workspace layout and design considerations.
- Maintenance management: Seeks to carry out proper maintenance of electrical systems to preserve their original condition. This is done through measurement (predictive maintenance) and scheduled maintenance (preventive maintenance) programs to avoid unexpected failures. Pre-planning, detailed documentation, and implementation by qualified personnel are essential to achieve this objective.

- Equipment and PPE: It includes the selection of elements and personal protective equipment (PPE) for people exposed to electrical hazards. This is verified by reviewing the electric shock PPE, which must be insulating, considering the voltage to which people will be exposed, and for the electric arc PPE, which must be flameproof, taking into account the incident energy that could be generated in the event of an electric arc.
- Firefighting systems: It focuses on the existence and maintenance of fire protection systems in electrical installations.

**Table 2**

*Acceptance criteria for documentary variables*

| | | **Does not comply** | **Does not comply** | **Does not comply (by very little)** | **Minimum compliance** | **Complies with best practices** | **World Standard** |
|---|---|---|---|---|---|---|---|
| **Variables** | **Standard** | **0** | **1** | **2** | **3** | **4** | **5** |
| Projects and Technical Documents | ■ SD 132<br>■ DS 08 | They do not have any type of document | The documents submitted are outdated | Minor shortcomings compared to expectations | The requirement is effectively fulfilled | Effective and systematized compliance | Practices above expectations |
| Security documents | ■ SD 132<br>■ DS 08<br>■ NFPA 70E<br>■ IEEE 3007.3 | No document backup | Procedure does not meet all requirements | Procedure is delivered, but comprehension is not evaluated | Procedures are provided and understanding is evaluated, but it is not systematized | Monitoring and measurement of document compliance is systematized | Practices above expectations |
| Training and qualification | ■ SD 132<br>■ DS 08<br>■ NFPA 70E | No training | Only occasional training is provided | Training is provided and on-site training is conducted | It is delivered, trained and authorized, but the process is not systematized | Monitoring and measurement of compliance with qualifications. It is systematized | Practices above expectations |

Similarly, variables were defined for the acceptance criteria for documentary variables as follows:

- Projects and technical documents: Verify the projects and technical documents, which are tools that detail the technical specifications of the electrical installations. These consist of drawings and descriptive memories that are created for the purpose of illustrating the design of the electrical installation and the amount of materials required.
- Security documents: Reference is made to various documents, such as work authorizations, inspections, audits, hazard identification, risk assessment, procedures, regulations, talks, checklists, guidelines and action plans for non-conformities.

- Training and qualification: Training is essential to protect all personnel, including contractors, who face electrical hazards. This verifies that an effective strategy is in place to ensure the safety of workers and also to raise awareness of electrical safety. Its objective is to enable workers to identify electrical hazards and reduce their exposure to them.

Finally, on-site audits were carried out at various mining companies in Chile and a surface graph was made with the data obtained, which facilitated the analysis of the data to justify the problem for this stage.

### *Population and sample*

For this research, electrical safety audits were carried out on a sample of 15 large mining companies in Chile, since this is one of the most developed and regulated areas with respect to electrical safety. This is due to the fact that the companies selected for this study are international corporations, which means that not only the national regulations must be complied with, but also those of their country of origin, making them more demanding. Among these, one of them was selected as a case study for analysis. The case study data are as follows:

- Economic Activity: Large copper mining. Chile.
- Number of workers: 900 of our own and an average of 3,100 contractor workers.
- Electrical workers: 60 of our own and an average of 250 contractor workers.

### *Formulation of the System*

This system was developed based on the structure of the Deming cycle (Fisher et al., 2005), with a theoretical basis extracted from the ISO 45000 standard (ISO, 2018) and the recommendations of the NFPA 70E (NFPA, 2021) and IEEE 3007, highlighting the addition of a context evaluation to the cycle and the continuous improvement applied transversally throughout the system.

It began with an assessment of the context of the organization. This was aimed at identifying internal and external factors that could influence the achievement of the objectives and the attainment of the desired results for the system. The context assessment addressed both internal company information and external information affecting its implementation.

The planning design then proceeded. In this phase, the complete structure for the management of the proposed system was created. This involved conducting an analysis of the safety and maintenance aspects that would be relevant, as well as establishing organizational aspects such as the scope and responsibilities of the roles. The design and creation of specific documented procedures for the proposed system was carried out, and the activities and requirements to be fulfilled were established.

In the implementation, the decision was made to establish a system based on process management. This involved defining the necessary management, complying with the essential requirements of reference standards (ISO 45000, ISO 31000) and widely recognized technical standards, such as NFPA 70E and IEEE 3007.1. Management focused on areas such as work authorization, inspection, maintenance, hazard identification and risk assessment, as well as the creation of procedures, among other aspects.

The system verification stage was based on the objectives and goals previously defined during the planning phase. To carry out this verification, the actions and processes

requiring monitoring and measurement were established, which included legal aspects and other requirements, activities related to electrical hazards and risks, progress towards the achievement of objectives, effectiveness of controls, among others.

The evaluation and follow-up of the proposed system involved comparing the information gathered in the initial evaluation with the results obtained after the implementation phase. This was proposed to be achieved by conducting an audit or applying other management indicators.

### *Application of the Electrical Safety Management System*

Based on the diagnostic audits, one of the initially audited companies, which provided the facilities to carry out the study, was taken and a process of implementation of the proposed electrical safety management system was developed. Subsequently, a second audit was carried out to evaluate the improvement in security management.

An analysis was also made of the incidents, caused by electrical energy, that occurred in this same company before and after the implementation of the electrical safety management system.

### *Analysis of Results and Profitability*

The information from the initial audit is presented in an area graph. Subsequently, the implementation and actions taken by the company to improve its processes. And then, a surface graph corresponding to a final audit is presented, showing the progress made in implementing the management system.

Finally, the diagnostic audit versus the follow-up audit was compared and a comparative table was made with the initial evaluation versus the final evaluation of the case study, showing how much the evaluation improved and how this affects the company.

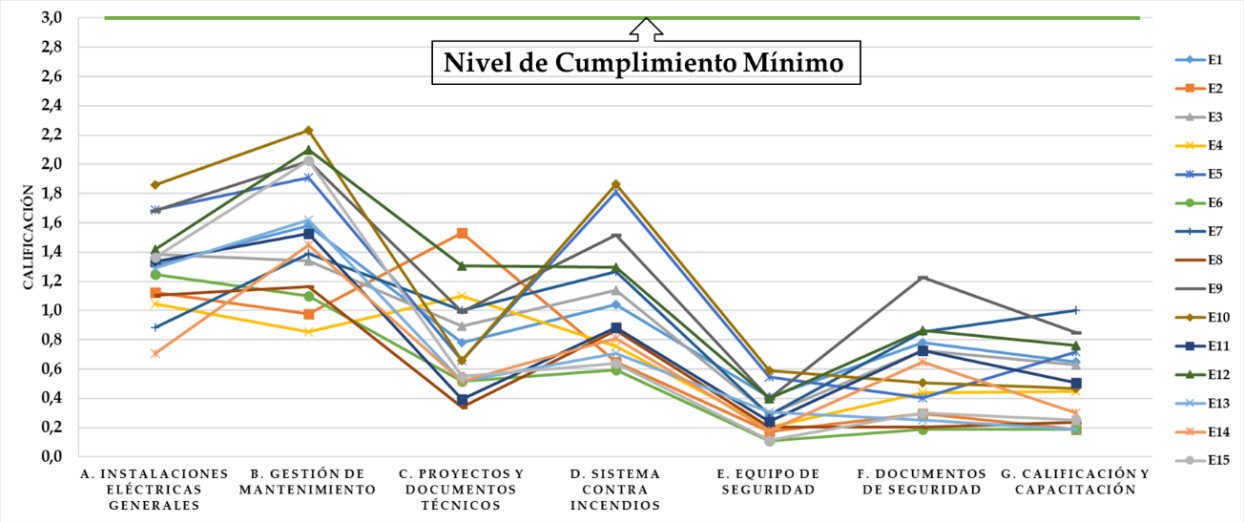
## Results

### *Data collection Analysis*

The audits carried out in different mining companies were grouped in Figure 1, which shows the similarities in the shortcomings and their best evaluated points.

Through the audits it was possible to detect legal non-compliance, loss of resources, incidents caused by electricity, among other undesirable findings resulting from lack of knowledge of the regulations and/or poor application of electrical safety management. Of the 15 companies audited, all were engaged in electrical safety activities. However, none of them had an electrical safety management system in place. It was also found that management depended solely and exclusively on the leadership of the person in charge, which is exactly what a management system tries to avoid. What is even worse, in several of these companies, the entire management was the responsibility of the superintendence or electrical department, and these programs were not included in the company's OHS management.

**Figure 1**
*Results of diagnostic audits*




***Management System***

By analyzing the problem, the most common shortcomings among all the companies were identified and an electrical safety management system was developed to improve the poorly evaluated processes. The proposed system was developed based on the Deming cycle, which is a method of proven effectiveness worldwide in most organizations (Azadeh et al., 2014; Roldán-Molina et al., 2021; Rungtusanatham et al., 2003). It is composed of five major stages (Figure 2), which are planning, implementation, verification, evaluation and continuous improvement, which can be carried out at each stage of the cycle.

**Figure 2**
*Graphical representation of the proposed electrical safety management system*


In addition, to start the cycle proposed by the system, the context assessment is considered, in which an analysis of the internal and external context of the organization is

carried out, and the policies and objectives concerning electrical safety are established, thus starting the planning stage.

The first stage of the system is planning, where all the schematization and structuring of the management system is developed. For this purpose, an analysis of occupational safety and maintenance aspects is performed, organizational aspects such as scope, roles and responsibilities are also established, and then the identification of hazards and electrical risk assessment is performed in order to establish preventive and mitigating control measures for the associated risks.

Next, in the implementation stage, the documentation of the proposed system is prepared. This documentation must be prepared based on compliance with the basic requirements demanded by the reference standards (ISO 31000, ISO 45000), also considering the applicable legal and technical regulations. As a minimum, an electrical safety management manual should be prepared, which contains all the general, technical, electrical risk prevention and maintenance management documentation, in the form of procedures and instructions, focused on the operation of the electrical safety management system. In addition, it considers all actions arising from the planning.

In the verification stage, the actions implemented are followed up at a frequency established in the planning. This is done through the execution of a specific audit for the electrical safety management system, which focuses on several objectives, including verification of compliance with legal and regulatory requirements, evaluation of the effectiveness of the electrical safety management system, identification of risks and prevention measures, promotion of continuous improvement and promotion of an electrical safety culture. This audit covers seven key aspects: electrical safety management, design and engineering of safe work areas, maintenance of electrical installations, condition of electrical enclosures, regulatory documentation and procedures, electrical-related fire systems, training and qualification of personnel exposed to electrical hazards, as well as the condition of personal protective equipment and available electrical protection systems.

The evaluation establishes the level of compliance with the planned actions versus the implemented actions, being able to determine the gaps and good practices through the analysis of the results of the verifications carried out; finally, at this point, recommendations are given on the findings and the new cycle begins, planning the actions to correct the gaps detected.

Continuous improvement is placed at the center of the cycle, to demonstrate that this improvement can be made at any stage of the cycle, where the deviation is detected, and not having to wait until the verification and evaluation stages to make a new planning. On the contrary, at the stage where the deviation is detected, we return to planning and then correctly implement and, consequently, verify and evaluate the proposed improvement.

### *Case Study*

From Figure 1, company N°8 (E8) was selected for an implementation and follow-up study to evaluate the impact of the implementation of an electrical risk management system.

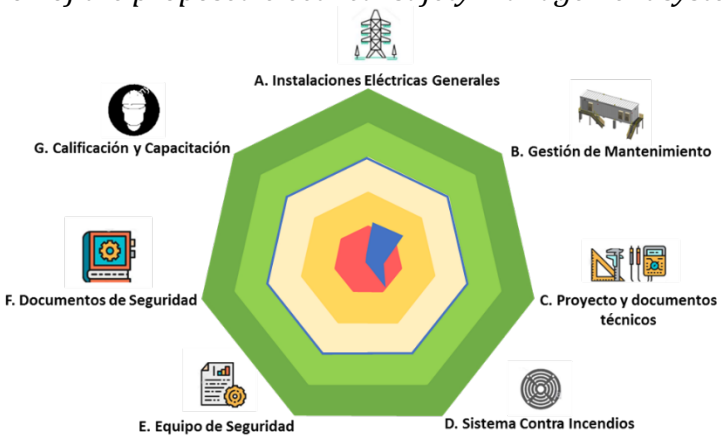
### *Context Evaluation*

The initial audit (Figure 3) shows the results of the evaluation of the different topics prior to the implementation of the management system developed in the case study. Such is the case of extreme topics, such as the best evaluated topic, which is the electrical rooms.

Here it shows an evaluation of 1.2 pts. In contrast, the worst evaluated point is the documentation of the electrical system, with an evaluation of 0.2 points, not to mention that it shows the minimum legal compliance level indicated with the green line.

**Figure 3**

*Graphical representation of the proposed electrical safety management system*




On the other hand, through the initial audit, conducted in 2019, in the documentary analysis it was established that there have been 3 accidents and 5 incidents without harm to people. Subsequently, the case study (the company E8 shown in Figure 1), provided the facilities to implement the electrical safety management system and set up an electrical safety committee that will be responsible for implementing the different stages defined in the management system, which also defined: objectives, scope and plans of the working groups, meeting schedules, work plans, methods for evaluating the results of the management system, among others.

### *Planning*

The key factors for the success of this implementation is the support of senior management and the support of experienced personnel with up-to-date knowledge. According to electrical safety standards, the minimum requirements to be met are:

- Establishment of roles and responsibilities of those in charge of managing and implementing the system such as representatives, an electrical safety committee or coordinators.
- Design and maintenance of installations by means of a procedure for the engineering and construction conditions of electrical installations and a standard for the maintenance of electrical equipment and installations was developed.
- Identification of hazards and evaluation of electrical risks based on the activities present in the tasks of the organization's personnel, both specialists and users of electrical energy.
- Inspection and evaluation of electrical equipment through documentary reviews and field inspections.
- Elaboration of general and specific procedures and work permits required for electrical safety. This may include manuals, audits, procedures for performing specific tasks, among others.

- Development of a personnel training and qualification model for implementation in organizations.
- Design of electrical safety emergency procedures for operational emergencies. This was developed in conjunction with emergency, medical, electrical and SSO personnel, an electrical emergency procedure, as well as training on the rescue of victims related to electrical accidents.

***Implementation***

Some of the actions implemented to reinforce and improve the processes were as follows:

- Senior management considered the integration of OHS requirements into the electrical safety management system processes, in addition to the mission, vision and electrical safety policy.
- Elaboration of an electrical safety regulation in accordance with the legal regulations and technical standards applicable to electrical safety.
- Implementation of maintenance plans which contain the actions, procedures, resources, methods and time necessary for the development and systematization of tasks through software such as SAP.
- Studies of electrical systems such as power, short circuit, protection coordination and incident energy.
- Electrical risk assessment through the development of a specific method that includes probability, consequence and human factor, as well as the appropriate control measures respecting the hierarchy of controls.
- Application of qualification and authorization processes for electrical personnel and training of electrical energy users regarding the electrical risks to which they are exposed by developing a model which includes general and specific inductions, training and training related to electrical safety and evaluations.

***Verification and Evaluation***

A follow-up audit was conducted to verify the implementation process. This audit provided results of the implementation of the electrical safety management system (Figure 4). In this case, although the values obtained do not reach legal compliance (green line marked in note 3), all the topics evaluated are very close to achieving it. The gap decreased considerably, with documentation increasing from 0.2 to 2.8.

A comparative table (Table 3) was made between the results of the initial audit versus the results of the follow-up audit. This table shows the decrease in the gaps in each of the evaluated topics, as opposed to the low evaluation obtained in the initial audit.

**Figure 4**

*Surface chart showing the results of the monitoring and evaluation audit of the implementation of the electrical safety management system*

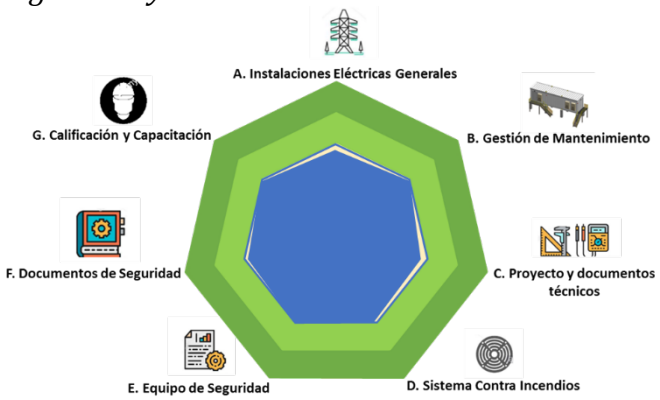



**Table 3**

*Comparative table between the results of the initial audit vs. the final audit*

| Topics evaluated in the audits | Initial | Final |
|---|---|---|
| General electrical installations | 1.1 | 2.8 |
| Maintenance management | 1.2 | 3.0 |
| Project and technical documents | 0.3 | 2.8 |
| Fire protection system | 0.9 | 2.9 |
| Safety equipment | 0.2 | 2.9 |
| Security documents | 0.2 | 2.8 |
| Qualification and training | 0.2 | 3.0 |

## Discussion and Conclusions

### *Data Interpretation*

In Figure 1, it can be seen how the different audits show a negative trend in the evaluation, which allowed to determine management failures or vulnerabilities existing in the organization (Biler, 2017)the best evaluated points are always the general installations, the electrical rooms and the electrical equipment , and even so, their evaluations do not achieve the minimum requirements to comply with the regulations. On the other hand, the worst evaluated points are safety procedures, documentation and electrical training, which do not achieve a score of 1, which means that the performance in these areas was more than deficient, demonstrating administrative shortcomings, failure in follow-up, lack of systematization of processes in risk assessments and lack of knowledge of the minimum requirements of the regulations in force, due to the lack of an electrical safety management system.

A management system provides efficient solutions to solve the problems of organizations through dynamic, forward-looking, holistic and contingent principles, in addition to giving them the opportunity to develop better strategies for the survival of organizations by taking advantage of more regular and logical methods (Gholizadeh et al., 2021). Therefore, to solve the problems raised in the study , a management system was

developed to solve the problems identified (Figure 2), which consists of a series of steps that after an initial action of context evaluation corresponding to the analysis of the initial state of the company, proceeds to follow a cycle of stages, which consists of planning the necessary measures to improve the shortcomings, the implementation of these measures, the verification of the effectiveness of the system and the final evaluation and taking contingency actions if these were necessary.

### *Implementation of the Management System*

A case study was conducted to implement and demonstrate the effectiveness of the electrical safety management system. The study reviewed in this section provides an overview of some aspects of the integration of the proposed management system into the occupational health and safety management of the company where it was implemented and, more specifically, the benefits and difficulties of having it in place (Simon et al., 2012). According to the electrical safety management system developed, in the first instance a context assessment is carried out; an initial audit was performed at this stage (Figure 3), which shows deficiencies of the company studied, and as shown in Figura 1, is not very far from the deficiencies shown by most of the companies previously audited.

Continuing with the stages of the electrical safety management system, we proceeded to the planning stage where we formulated an implementation plan with actions such as improving the electrical infrastructure, maintenance plans, systematization of documentation systems, safety procedures, electrical training, among others, since the electrical safety management system is based on a comprehensive approach that covers all the factors that influence safety, not only administrative controls and PPE. If it is limited to just that, then the electrical safety effort will not see a significant change (Liggett, 2006). Subsequently, we proceed to implement what was proposed in the previous stage.

The effectiveness of management systems can be evaluated and measured by analyzing a wide variety of factors that together constitute the input to electrical safety management (Acosta-Palmer and Troncoso-Fleitas, 2011). Therefore, in order to verify the effectiveness of the proposed management system, a second audit was carried out to collect progress data and thus quantify the improvement achieved (Figure 4).

### *Recognition of Benefits*

The implementation of electrical safety management benefits all employees and, above all, the company that implements it (Lavell, 2001). This is demonstrated in the comparative table between the initial audit versus the follow-up audit (Table 3), which shows an improvement in all the topics evaluated, but despite these great results, the minimum compliance evaluation is still not achieved. Even so, among the numerous advantages provided by the implementation of an electrical safety management system, we were able to recognize:

- Potential reduction in the number of accidents and incidents in the workplace.
- Potential reduction of downtime and associated costs.
- Demonstration to all stakeholders of commitment to occupational health and safety. Stakeholders include workers, personnel and prevention delegates, labor authorities, etc.
- Potential reduction of costs associated with medical expenses.

- It allows to obtain a privileged position in front of the competent authority by demonstrating compliance with the legislation and regulations in force and the commitments acquired.
- Ensures credibility focused on electrical safety control. Greater bargaining power is obtained with insurance companies thanks to the reliable backing of the company's risk management.
- Better management of electrical safety risks now and in the future.

### *Limitation of the Method*

Although the positive results are evident, it is still not possible to meet all the requirements for compliance with current regulations, since the implementation time of an electrical safety management system such as this one requires at least 3 years to meet the planned objectives. While administrative controls are possible to implement in the short term, actions such as standardization of facilities, formulation of maintenance plans, electrical studies and others will require more time because long-term investment plans may even have to be formulated.

Another important limitation is the current safety culture, that of evaluating electrical safety in a similar way to how all safety processes are evaluated, given that electrical safety is regulated by legal and technical standards, which according to the evaluations carried out in most cases are not taken into account.

### *Recommendations*

Given that the results obtained are consistently positive, the implementation of the proposed electrical safety system integrated to the safety and occupational health management system of the company that implements it is recommended, since the benefits that the proposed system provides have been demonstrated. In addition, the systematization of management increases the efficiency and effectiveness of the processes considered in the electrical safety management system.

### *Projections*

Although the results are based on a single company, the electrical safety management system is being implemented in 5 companies included in the initial audits. The results of the implementation processes are not included in this study because it was not possible to perform the follow-up audit, due to the restrictions of the current COVID-19 pandemic, the implementation has been delayed. It is expected that from the publication of the results of the implementation processes of this and the other companies that are implementing it, more companies will be interested in implementing it, since electrical safety in the different countries is one of the most regulated safety processes, both by legal regulations and technical standards. Precisely, one of the objectives of the proposed management system is to comply with both legal and technical regulations, depending on the company that implements it and the country where it is implemented, especially if it is considered that all the proposed practices are easily integrated into the usual Occupational Health and Safety management.

The main conclusions derived from this research are as follows:

- In conclusion, based on the results obtained from the initial audits, the problem raised in this study has been demonstrated. In other words, the companies

analyzed do not apply an electrical safety management system, mainly due to a lack of knowledge of this concept or because there is no system to implement.

- With the implementation of the proposed management system, the electrical safety standards necessary to comply with current regulations are achievable, since there is an improvement in the culture and education about electrical safety, the facilities are improved, maintenance becomes a preventive and efficient control, a systematization of document management also facilitates the qualification and authorization, which translates into better and specific procedures, training and training, which ultimately improves the protection systems and prevention of electrical incidents in the company that implements the system.
- These improvements mean a series of tangible benefits such as the protection of electrical equipment, reduction of costs caused by operational interruption and reduction of incidents, not to mention the intangible benefits such as an increase in the workers' sense of security, better training, etc.
- Finally, it was demonstrated that the proposed system is based on the principles of electrical safety, which translates into reducing accidents to people, reducing costs due to damage to equipment and facilities, and optimizing operational continuity by seeking the safe and efficient use of electrical energy.

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