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Electric Energy Transmission Processes and the  
Importance of Integrated System Management and  
Operation

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# Electric energy transmission processes and the importance of integrated system management and operation

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**Abstract.** Electric energy is fundamental in different sectors of a society's development; electric energy is used in all types of industries and economic sectors and is essential in people's homes, so access to a quality electric energy service in the city or in rural areas provides a reference index of a territory's level of development. For this reason, electricity transmission is considered one of the most relevant factors for improving the quality of life of the inhabitants of a country with a high poverty index. Electric power is a service that must be transmitted in a guaranteed manner with high standards of quality, reliability, and availability. This supports the economic development of a nation. This research focused on studying the efficiency of an organization that provides the service of transformation and transportation of electrical energy in Colombia and through this study to impact professionals, higher education institutions and companies to ensure their presence in the market, improving the quality of their graduates in different areas of knowledge such as physics and engineering and in parallel to provide companies with a guide that allows organizations dedicated to the electricity sector in Colombia to comply with existing regulations. This work highlights the need to perform mechanical, electrical, instrumental, operational and management processes with high standards for companies that provide electric power transmission service with equipment operating at voltages above 220 kV. Additionally, this research aims to establish a guide that allows organizations dedicated to the electric sector in Colombia to comply with current regulations.

## 1. Introduction

Electric power is essential in different sectors of a society's development; electric power is used in all types of industries and economic sectors and is essential in the homes where people live; therefore, access to a quality electric power service in the city or in rural areas provides a reference index of the level of development of a territory [1,2]. For this reason, electric power transmission is considered one of the most relevant factors to improve the quality of life of the inhabitants of a country with high poverty rates. Electric power is a service that must be transmitted in a guaranteed manner with high standards of quality, reliability, and availability. This supports the economic development of a nation [3]. To guarantee a service with high quality levels, it is necessary to establish a model that allows planning, reviewing, and evidencing all the processes involved in guaranteeing this service.

The audit is a mechanism that allows verifying the correct operation and execution of the processes that are part of the transformation and transportation of electric energy, which include, among others, the physical processes of transformation and transportation of energy, the operation of these mechanical, electrical, and electronic systems and their maintenance. The audits also allow to identify the tasks and



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processes that are executed correctly to consolidate them as a good practice in the operation, these audits also allow to define the great distances that exist between the management of integrated systems and a quality service of electric energy transmission, these distances must be minimum so that the society enjoys an optimal service.

Additionally, this work aims to impact professionals, higher education institutions and companies so that each of them, from their position in the country's economy, can ensure their presence in the market, as would the education institutions with competent graduates and qualified in different areas of knowledge such as physics and engineering, it also allows companies to establish a guide that allows organizations dedicated to the electricity sector in Colombia to comply with the existing Regulation different areas of knowledge such as physics and [4], and to companies it allows them to establish a guide that allows organizations dedicated to the electricity sector in Colombia to comply with the "Resolution 023 of 2016 of the Commission for the Regulation of Energy and Gas in Colombia (CREG)" [5] and the "Resolution 177 of 2016 of the CREG [6].

This work obtained results that have made it possible to establish that the nature, content and scope of the integrated audit, applied to different areas of knowledge, will be evaluated by a multidisciplinary and interdisciplinary team: academics or teachers, public accountants, engineers, sociologists, business administrators, mathematicians, chemists, physicists, lawyers, economists that show that this type of research can be carried out in companies that provide services to other economic sectors of the country, not applicable exclusively to the electricity sector; this, considering that we are talking about services of primary need for any type of society or community and the impact that these services have of direct inference in the economic development of a territory. Considering that the regulations of electric power systems are of great importance to improve the energy supply in a territory [7], benefiting the quality of distribution in application sectors such as transportation [8,9], manufacturing [10], health, education, among others.

## 2. Development of the methodology

This work seeks to provide guidance to Colombian organizations that provide electric energy transformation and transportation services, so that they can comply with the regulations in force in the country and provide a quality service throughout the territory, thus providing the population with a better quality of life. The following is a timeline of the evolution of certifiable management systems, including those based on ISO 9001:2015 [11], ISO 14001:2015 [12], OHSAS 18001:2007 [13], ISO 27001:2013 [14], ISO 45001:2018 [15] and ISO 55001:2014 [16], and their integration for a company in the electric power transmission sector, as shown in Figure 1.

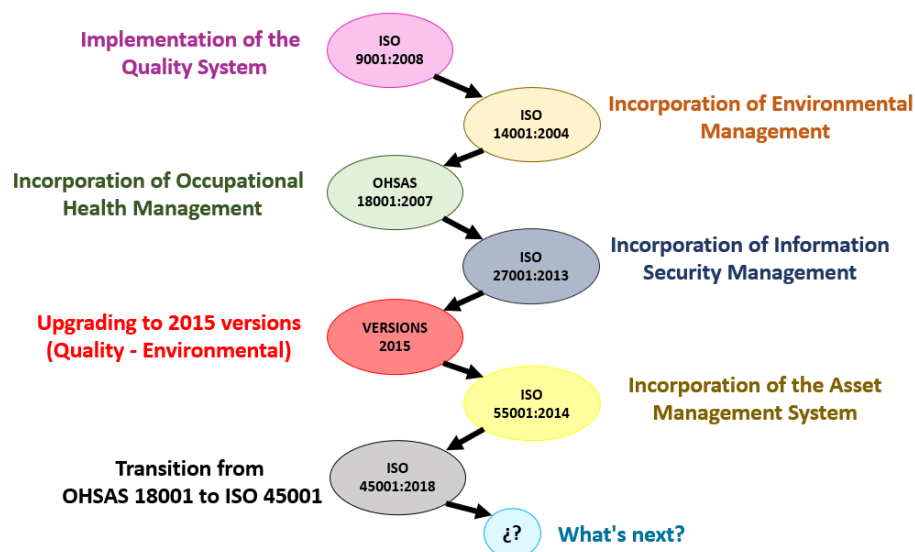
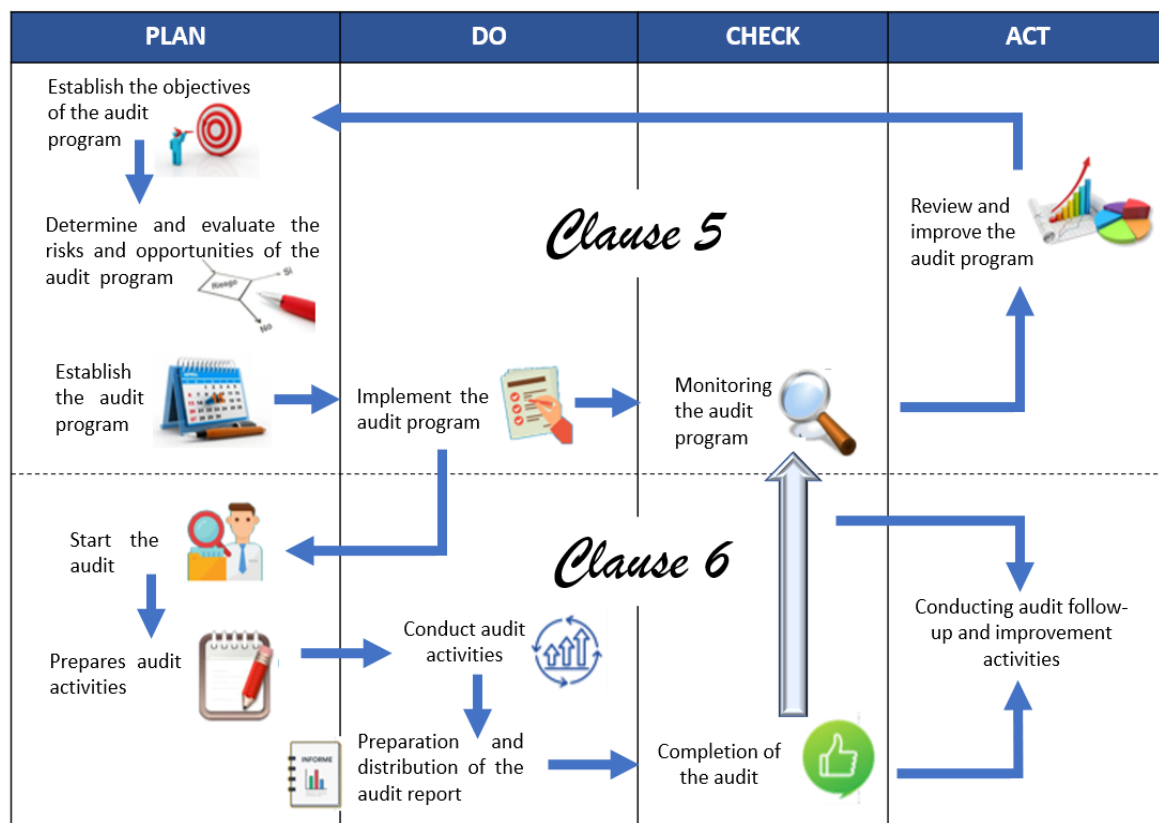


Figure 1. Integrated management systems integration timeline.

The principle of continuous improvement of management systems based on ISO standards specifies that such improvement should be in the sense of relevance/convenience, adequacy, and effectiveness (Section 10.3 of the standards) [11-16]. In this intention, the internal audit program should allow these conclusions to be reached, based on the results obtained from the exercise.

This project evaluates a case study of a Colombian organization that provides electric energy service and considered the order of investment strategies in technology that seek to improve the efficiency of production processes of industries in Colombia [17]; structuring and implementing the internal audit program shall ensure compliance with the provisions of paragraph 9.2 of each of the standards that are part of the integrated management system.

The case study company has ensured that its internal audit program not only promotes continuous improvement in terms of suitability, adequacy, and effectiveness, but also maintains its scheme in compliance with the provisions of paragraph 9.2, basing this management on the guidelines of the Colombian Technical Guide GTC-ISO 19011:2018 [18], which describes the steps to be considered in the management of an audit program (see Figure 2).



**Figure 2.** Process flow for the management of an audit program [18].

### 3. Results and discussions

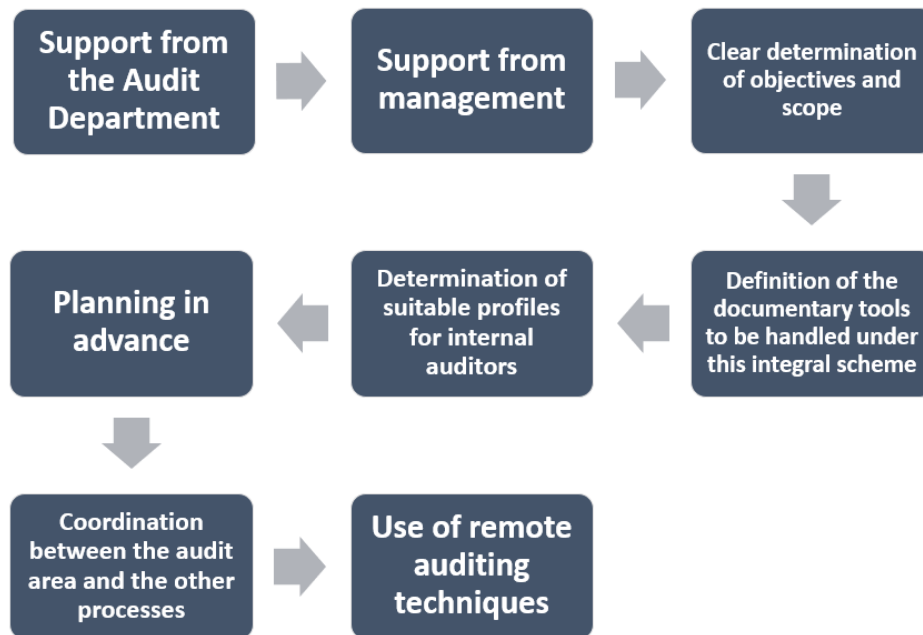
The results of this research show the roadmap that should be followed by organizations dedicated to the transformation and transportation of electric energy in Colombia and that can be used in other types of industries.

This methodology is the sum of several factors that must be executed in a precise manner to achieve high quality standards. Next, we describe the Equation (1) which synthesizes the strategy that was executed in this process such as Compliance with Service Quality Levels (SWQL) Optimization of Economic Resources (OER) Optimization of Human Resources (OHR) Optimization of Time (OT) Improvement in the Management of Action Plans (MAP) Maintenance of the Integrity look in the Management (MIM).

$$\text{Process optimization} = \text{SWQL} + \text{OER} + \text{OHR} + \text{OT} + \text{MAP} + \text{MIM} \quad (1)$$

### 3.1. Key aspects for process optimization

The first important aspect that was obtained because of this research in the aspect that considers maintaining the clarity of the organization's guidelines and the support provided by senior management for the performance of all activities is shown in Figure 3, which lists the steps to follow in this point.



**Figure 3.** Steps to follow to maintain the clarity of the organization's guidelines.

### 3.2. Benefits obtained

Other research has been able to lay the foundations for the evaluation or comprehensive audit of companies or educational institutions, directed, above all, to the heart of the business, in a highly competitive environment. and managed to identify that in the subject of auditing in the academic area as in other areas, there are no works of this nature and in Latin America are scarce. It is an important problem for the academic field, the universities of the country include in the curriculum or study plan, the Audit as a tool to deal with the physics, nature, characteristics, and objectives, as a field of integrated auditing [4].

Other research in auditing has sought the transformation of education in other countries, both at the administrative or organizational level, as well as at the curricular or academic level; thinking about the much-desired quality in the training and execution processes [19], these investigations implemented in other sectors such as academia support the idea that integrated auditing can be a tool that can contribute to professionals in any area, including physicists dedicated to research and science, as well as applied physicists who support all engineering processes in which the processes of transformation and transport of electrical energy are included.

In this research we are achieving the impulse oriented to the implementation and subsequent application of integrated audits, not only directed to the common fields of its application, but also to other professionals; the main benefits obtained from the different variables of the roadmap are shown in Table 1.

**Table 1.** Benefits of integrated internal audits.

SWQL	With the external view that can be obtained by carrying out evaluations of the energy transmission processes in an integrated manner, it is possible to contribute to the achievement of service quality levels and other commitments with different agents and companies in the sector with which service level agreements (SLAs) have been defined.
OER	The exercise in an integrated manner avoids having to repeat internal audits of the integrated management system at several different times during the same period, which represents more costs in its execution.
OHR	To achieve a competent audit team that covers all the standards in an integral manner, allowing to reduce the number of people necessary for the development of the audits, as well as facilitating the consolidation of findings and the generation of conclusions.
MAP	Performing a single integrated, unified audit exercise avoids the same process having to be audited several times to respond to different management models. An integrated approach makes it possible to approach a process by validating the requirements of the standards that are relevant to its management.
Improvement in the management of action plans	As a result of an integrated audit program is the generation of unified, consolidated results that will facilitate the process leaders, the proper formulation of improvement plans.
MIM	To maintain the integrated management approach, it is necessary for the internal audit area to ensure that the audit program fully responds to this approach, thus demonstrating to the entire organization that integrated management can take place at all levels, areas, and processes, without losing sight of the contribution to the Company's strategic vision.
Weighted average requirement (WAR) [20]	It is necessary to identify the quality metrics with which the audits are performed to determine the credibility of the information that was analyzed, as shown in Equation (2) [20]; where W is the weighting made by the auditor CA is the number of complaints related to the attitude of the audit team overall or individually, CF is the number of complaints related to the audit findings, CNC is the number of complaints related to non-compliance with the audit plan activities for reasons beyond the auditee, and CR is the number of complaints related to the results of the audit.
Risk weighted level (RWL) [19]	A quantitative expression is the result of measuring the quality of the process from the risk perspective, as shown in Equation (3) [20]; where W is the auditor's weighting according to the importance he/she gives to each type of risk based on the particularities of the audit and the organization, RI is the total risks inherent to the management system, RD is the total risks of detection, CR is the total control risks, and TRD is the total risks detected

$$\frac{W_1(CA)+W_2(CF)+W_3(CNC)+W_4(CR)}{\sum_{i=1}^4 W_i}, \quad (2)$$

$$\frac{\sum_{k=0}^p \sum_{j=0}^m \sum_{i=0}^n w_1(RI_i)+w_2(RD_j)+w_3(RC_k)}{TRD*100}. \quad (3)$$

Achieving the development of internal audits in an integral manner has allowed the improvement in the quality indicators of the energy transmission and transportation service for the case study company, which in turn has a positive impact on the Colombian society. Regulatory and strategic changes around optimized asset management have a significant impact on the operation of a transmission system.

Resolution CREG 023 of 2016 [5] and CREG 177 of 2016 [6], which deals with the remuneration of the business, requires the implementation and certification in an asset management system according to ISO55001 [16] within 5 years, but managing to integrate this standard to the management system and develop it in an integrated manner with the other management systems certified by the case study

company has put the organization in a great challenge of integration, so that these management systems do not operate independently, and that their integration is not only focused on the merger of documentation but also on the identification of those common elements (requirements) to simplify their implementation in a cross-cutting manner according to the level of integration established by the organization.

#### 4. Conclusions

Approaching the audit program in an integrated manner has generated gains for the organization from different perspectives: economic, management, impact and, above all, improvement. Moving forward to an integrated audit program that covers all the management approaches established in the organization and that is based on the asset management platform has resulted in optimizing the use of resources by covering all the certified standards in a joint exercise. In addition, the results obtained in this type of exercise make it easier for those responsible for the processes, the proper management, and the maintenance of a view of improvement that projects the globality of the system.

Enabling a comprehensive approach through the audit exercise contributes to maintaining the stability of the integrated management system by ensuring that management and results are verified in a comprehensive manner within the processes, avoiding the detection of isolated situations that will ultimately generate isolated findings that do not have a greater impact on the management system.

Maintaining the comprehensive approach in the internal audit exercise allows all those responsible and other actors in the system to maintain the unified and transversal language of the integrated management system. This contributes to the consolidation of the culture of the management system in the daily activities, since the collaborators, when going through these auditing exercises, will evidence that they are responsible for the integrality of the approaches and not for a particular subject, improving the state of awareness and level of responsibility.

Developing the audit program in a comprehensive manner guarantees the generation of unified, robust findings with real impact for the processes, thus facilitating the management to be carried out by those responsible for the formulation and implementation of improvement plans and, consequently, generating a contribution real. to the continuous improvement of the management system, in any area of knowledge, where it is applied as a quality management tool for scientific, industrial and research processes.

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