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Challenges in Implementing Occupational Safety Standards NR-10 and NR-12 in Brazil

Desafios na Implementação das Normas NR-10 e NR-12 de Segurança do Trabalho no Brasil

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ABSTRACT: This study aims to analyze the main challenges in implementing NR-10 and NR-12 Regulatory Standards within the context of Electrical Engineering, regarding their impact on occupational safety in industrial environments. To this end, a qualitative bibliographic review was conducted, based on scientific articles, technical standards, case studies, and specialized publications, focusing on identifying the technical requirements of these standards, assessing their practical application, and proposing strategies to overcome common obstacles. The results indicate that, despite being well-structured, the application of these standards faces significant challenges, such as the lack of technical training, financial constraints, cultural resistance to change, and limited strategic planning. Companies that adopt integrated approaches, such as safety committees, continuous training, and simplified management systems, tend to achieve higher compliance rates and lower accident rates, establishing safety as a competitive advantage. It is concluded that the effective implementation of these standards requires not only technical compliance but also a broader organizational transformation that prioritizes education, leadership, and a strong commitment to safety.

KEYWORDS: Occupational safety, regulatory standards, electrical engineering.

RESUMO: Este estudo tem como objetivo analisar os principais desafios na implementação das Normas Regulamentadoras NR-10 e NR-12 no contexto da Engenharia Elétrica, enfatizando seus impactos na segurança do trabalho em ambientes industriais. Para tanto, utilizou-se uma revisão bibliográfica qualitativa, baseada em artigos científicos, normas técnicas, estudos de caso e publicações especializadas, com foco em identificar os requisitos técnicos exigidos por essas normas, avaliar seu grau de aplicação prática e propor estratégias para superar os obstáculos mais comuns. Os resultados apontam que, apesar de bem estruturadas, a aplicação dessas normas enfrenta desafios significativos, como a falta de capacitação técnica, limitações financeiras, resistência cultural à mudança e escassez de planejamento estratégico. Empresas que integram abordagens como comitês de segurança, treinamentos contínuos e sistemas simplificados de gestão têm se destacado por registrar menores índices de acidentes e maior conformidade, consolidando a segurança como um diferencial competitivo. Conclui-se que a efetiva implementação dessas normas requer não apenas o

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cumprimento técnico, mas também uma transformação organizacional que priorize educação, liderança e compromisso com a segurança.
PALAVRAS-CHAVE: Segurança do trabalho, normas regulamentadoras, engenharia elétrica.

I. INTRODUCTION

Safety in the electrical sector is a critical issue, given the high risk of accidents involving electricity and industrial machinery. In this context, Regulatory Standards NR-10 and NR-12 were developed to establish guidelines that guarantee the protection of workers who operate in high-voltage environments and use machinery and equipment.

The main objective of these standards is to reduce the risks associated with working with electricity and machinery, promoting safe practices and more protected work environments. However, the implementation of these regulations faces significant challenges, ranging from the technical training of professionals to overcoming cultural and financial barriers within organizations.

Given this scenario, this study seeks to investigate how electrical engineering professionals deal with the difficulties associated with the application of NR-10 and NR-12 in industrial environments. The central question guiding this research is: what are the main challenges faced in the implementation of these standards and how can companies overcome these obstacles to ensure a safe work environment? The hypothesis is that compliance with these standards is often compromised by factors such as lack of adequate training, scarcity of financial resources for investments in safety, and resistance to changes in operational practices.

The main objective of this study is to analyze the challenges encountered in the adoption of standards NR-10 and NR-12, in addition to evaluating the impacts of these regulations on occupational safety in the electrical sector. To this end, the study aims to: identify the technical requirements demanded by these standards, especially in relation to the operation of electrical machines and installations; verify the degree of compliance of companies with these requirements; and propose strategies that can facilitate the process of adaptation to the standards, promoting not only safety, but also operational efficiency.

The importance of this study lies in highlighting the fundamental role of NR-10 and NR-12 as tools to preserve the physical integrity of workers and ensure safer industrial environments. In a context where electrical accidents still represent a significant risk, understanding the challenges that hinder the full adoption of these standards is essential to strengthen the culture of prevention and safety in the workplace. In addition, the research contributes to the training of electrical engineers who are better prepared to face the technical and legal requirements of the profession, promoting an organizational culture focused on responsibility and sustainability.

II. THEORETICAL FRAMEWORK

Regulatory Standards NR-10 and NR-12 are essential to ensure safety in industrial and agricultural environments, defining technical requirements that protect workers and ensure legal compliance by companies. NR-10, which regulates safety in electrical installations, establishes minimum standards for the protection of professionals who deal with electricity, including the use of Personal Protective Equipment (PPE), such as insulating gloves, helmets and safety glasses. In addition, this standard requires the creation of technical procedures for high and low voltage operations, aiming to guarantee worker safety and process traceability (Chaves, 2024).

In addition to PPE, NR-10 requires the development of procedures for the safe disconnection of electrical circuits before interventions and detailed documentation of all steps to ensure traceability and technical accountability. Research indicates that rigorous application of these measures can significantly reduce the frequency of accidents, especially when combined with periodic inspections and risk analyses that consider environmental and operational conditions (Lara et al., 2022).

In contrast, NR-12 focuses on the safety of machinery and equipment, requiring the installation of safety devices, such as fixed barriers, presence sensors and emergency stop systems, to prevent accidental contact with moving parts or dangerous components. This standard also addresses ergonomic aspects, aiming to reduce fatigue and repetitive strain injuries, in addition to requiring clear signage of risk areas and the implementation of power lockout protocols during maintenance (Castro et al., 2023).

The integration between NR-10 and NR-12 is seen as essential for the creation of comprehensive safety management systems that address electrical and mechanical risks in a coordinated manner. Companies that adopt these standards in an integrated manner, including the creation of updated Environmental Risk Prevention

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Programs (PPRAs), record significant reductions in accident rates, in some cases of up to 40% (Monti et al., 2023).

However, the practical implementation of these standards still faces challenges, especially in sectors with high informality or limited financial resources. Among the main obstacles are the lack of technical knowledge on the part of managers and workers, who are often unaware of the detailed requirements of the standards or underestimate their long-term benefits (Castro et al., 2023).

Furthermore, the integration of technologies for continuous monitoring, such as sensors and warning systems, can be a solution to overcome these barriers, as it increases efficiency in risk management and improves operational safety (Silva et al., 2019).

The difficulty in ensuring compliance with standards in small companies or in more remote regions is aggravated by the lack of adequate monitoring, allowing risky practices to continue (Baesso et al., 2024). In this scenario, the digitalization of processes, such as the use of software for risk analysis and real-time monitoring systems, emerges as a viable alternative to improve transparency and efficiency in safety management (Silva et al., 2019).

Furthermore, the adoption of international certifications, such as ISO 45001, can complement the requirements of national standards by integrating occupational safety with environmental and quality management systems. Studies indicate that companies that invest in automation and artificial intelligence can reduce accident-related costs by up to 60%, while strengthening their corporate reputation (Monti et al., 2023).

The practical application of NR-10 and NR-12 in electrical engineering presents significant challenges, as it requires technical flexibility to adapt the regulatory requirements to the operational particularities of each production sector. Santos et al. (2024) emphasize that, although compliance with these standards is essential, many professionals still see them as additional costs, which can limit the effectiveness of their implementation. To overcome this perception, it is crucial to demonstrate the relationship between compliance, accident reduction, and increased productivity over time.

Another critical aspect is the experience of professionals, which directly influences how they interpret and apply standards. Marquezini et al. (2024) highlight that workers with greater exposure to risks tend to value safety measures more, while less experienced professionals may underestimate these dangers. This contrast reveals the importance of continuous training programs that combine normative theory with practical simulations, promoting awareness and the adoption of best practices in daily operations.

The evolution of standards, especially NR-10, reflects a continuous learning process, driven by previous incidents that resulted in stricter rules for activities in electrical installations. Barros and Nascimento (2024) point out that understanding this history is essential for engineers to anticipate risks and avoid repeating past mistakes. In addition, constant updating on legislative changes is essential to ensure compliance and safety in complex industrial environments.

Implementing safety standards in small and medium-sized companies is often hampered by financial and logistical constraints. Nunes et al. (2023) point out that, in sectors such as dairy, the lack of strategic planning and restricted budgets make it difficult to acquire safety equipment and carry out preventive maintenance. To overcome these challenges, it is necessary to adopt creative solutions, such as prioritizing critical risks and using more accessible technologies. In addition, creating realistic schedules that distribute investments over time can facilitate compliance without compromising the financial viability of operations.

Collaboration between academia and industry is also essential to prepare engineers for the challenges of applying standards in practice. Castro et al. (2023) highlight that continuing education programs, which include simulations, case studies, and partnerships with companies, increase professionals' critical capacity to interpret and adapt regulations. These experiences reinforce technical knowledge and promote skills to solve complex problems in dynamic industrial environments.

In addition to technical knowledge, the integration of ethical and social responsibility issues into academic curricula contributes to the consolidation of the perception that standards are not just bureaucratic requirements, but tools to protect lives and promote safer work environments (Castro et al., 2023). This approach helps to train professionals who are more aware and prepared to face the challenges of the sector, promoting a culture of safety at all stages of the production process.

SAFETY AND REGULATION: LEVEL OF COMPLIANCE WITH NR-10 AND NR-12

Compliance with Regulatory Standards NR-10 and NR-12, which address safety in electrical installations and in machinery and

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equipment, is essential to ensure the protection of workers in industrial environments. NR-10, for example, establishes strict guidelines to minimize the risks associated with working with electricity, requiring the adoption of safe practices and detailed technical procedures (Barros & Nascimento, 2024). In addition to being a legal requirement, compliance with this standard is considered essential to reduce the likelihood of serious accidents and create safer work environments.

Studies indicate that the correct application of NR-10 not only meets regulatory requirements, but also contributes significantly to the prevention of fatal accidents, promoting a safety culture that prioritizes the protection of human life (Rodrigues et al., 2017). It is of utmost importance to understand the objectives set out in the Standard in question. According to Pereira and Sousa (2010, p. 7):

This Standard provides the basic guidelines for the implementation of control measures and preventive systems, designed to guarantee the safety and health of workers who directly or indirectly interact in electrical installations and services with electricity in its most diverse uses and applications and any work carried out in their vicinity.

Regarding NR-12, which is focused on safety in the use of machinery and equipment, the application and adaptation to this standard are fundamental for reducing work accidents, focusing on the physical integrity of heavy machinery operators (Santos et al., 2024).

Still according to Pereira and Sousa (2010, p 9):

This standard ensures safety at work with machines and equipment. It establishes preventive measures for safety and hygiene at work to be adopted by companies in relation to the installation, operation and maintenance of machines and equipment, aiming at the prevention of accidents at work. These machines and equipment range from elevators, cranes, to table saws, concrete mixers and concrete vibrators, among others.

Adopting the safety measures provided for in NR-12 can result in a significant reduction in the number of accidents, in addition to improving operational efficiency. Santos et al. (2024) observed that, by implementing these guidelines, companies tend to record lower incident rates, directly reflecting increased productivity. However, resistance to the full application of the standards remains a substantial challenge, requiring a cultural change that favors safety as a priority.

This resistance can be attributed, in part, to the lack of awareness among workers about the benefits of the standards. Marquezini et al. (2024) point out that many professionals are still unaware of the detailed requirements of the regulations, which limits their adherence to safe practices. Furthermore, the constant updating of these standards is essential to keep up with technological innovations and new demands in the electricity sector, as emphasized by Neto (2024), who advocates the importance of periodic reviews and ongoing training programs to ensure the effectiveness of the standards.

Compliance with NR-10 and NR-12 requires more than just technical compliance; it is necessary to invest in ongoing education and training so that companies can ensure safer and more efficient work environments (Neto, 2024). Without a clear understanding of the risks and without practical skills to mitigate them, the application of the standards can be superficial, compromising the safety of workers and the sustainability of industrial operations.

Internal training programs are essential for the effective implementation of these standards, especially in sectors that deal directly with electricity and machinery. Marquezini et al. (2024) emphasize that continuous training is essential for professionals to recognize the risks associated with their activities and know how to apply preventive measures appropriately. These programs should include not only technical training, but also the development of an organizational culture that values safety as a central principle.

Furthermore, the effectiveness of training can be increased by using digital platforms and distance learning methods, which increase accessibility and employee engagement. Amaral and Ensslin (2021) highlight that technologies such as Moodle have proven effective in facilitating continuous learning and performance management, especially in companies that face logistical challenges in organizing face-to-face training.

Organizational support also plays a crucial role in the effectiveness of training programs. Campos and Lima (2023) argue that workplaces that encourage active employee participation in safety initiatives tend to record better results in terms of regulatory compliance and accident reduction. To achieve these goals, companies need to promote open communication and encourage the continuous exchange of information on safe practices.

Continuous evaluation of training programs is essential to ensure their effectiveness. Monitoring tools should be used to measure the impact of training on operational safety, allowing for regular adjustments as new demands arise. This process of continuous review is essential to consolidate a safety

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culture that prioritizes worker protection and the efficiency of industrial operations.

INTEGRATING SAFETY AND PRODUCTIVITY: PROPOSALS FOR EFFICIENT IMPLEMENTATION OF STANDARDS

Compliance with Regulatory Standards NR-10 and NR-12 represents a significant challenge for companies in the electrical and industrial sectors, as it requires constant adaptation to strict technical requirements and varied operational contexts. To overcome these challenges, it is necessary to adopt integrated strategies that combine strategic planning, technical training, and organizational strengthening. These initiatives not only ensure legal compliance but also promote safer and more efficient work environments, reducing risks and improving productivity (Lombardi & Trindade, 2021).

In small and medium-sized enterprises (SMEs), where financial and human resources are often more limited, implementing simplified management systems is a priority. Lombardi and Trindade (2021) suggest that practical materials, such as guidance manuals, can help managers implement security measures more efficiently, reducing the administrative burden and allowing them to focus on operational priorities. In addition, the use of tools such as checklists and flowcharts helps to standardize procedures and maintain compliance, even in environments with high employee turnover.

Building a safety-focused organizational culture also depends on the creation of collaborative structures, such as safety committees, that promote the exchange of experiences between managers and workers. Potascheff et al. (2023) point out that these groups facilitate the identification of specific problems and the formulation of collective solutions, strengthening commitment to standards. In addition, active employee participation in regular meetings and transparent communication about risks are essential to consolidate a safety culture throughout the organization.

Technical training for workers is another essential pillar to ensure compliance with standards. Lima et al. (2023) point out that structured training programs, which include simulations of risk situations and case studies, increase the effectiveness of learning and make professionals better prepared to deal with day-to-day challenges. In addition, training internal multipliers can help disseminate knowledge and ensure that safety practices are maintained even in high-turnover environments.

Integrating systematic risk analysis into operational planning is crucial to identify and mitigate threats before they materialize. Neto et al. (2015) suggest that small and medium-sized companies can benefit from adaptive models that combine periodic assessments with protocol updates based on historical incident data. Cechin et al. (2016) add that the use of monitoring technologies, such as real-time sensors and automated alert systems, can increase the accuracy of fault detection, improving emergency response and reducing corrective maintenance costs.

The effective implementation of Regulatory Standards NR-10 and NR-12 requires an integrated approach that combines structural, educational, and technological strategies. Simplified management systems, safety committees, regular training, and risk analyses form the basis for ensuring legal compliance and consolidating safety as an organizational value. Studies indicate that companies that adopt these practices are able to significantly reduce accident rates and improve their corporate reputation, in addition to increasing employee satisfaction (Lima et al., 2023).

To overcome resistance to the application of these standards, it is essential to adapt them to the practical realities of companies, considering their financial and cultural limitations. Serralheiro et al. (2018) highlight that the perception of rigidity of standards can hinder their adoption, especially in smaller organizations. To face this challenge, it is necessary to establish constant communication between operators, managers and safety technicians, allowing for adjustments that balance worker protection with the economic viability of operations.

Furthermore, practical examples demonstrate that the creation of internal safety committees is an effective strategy for strengthening a culture of prevention. Potascheff et al. (2023) observe that companies that actively involve their employees in frequent training and awareness campaigns can significantly reduce accident rates. This integration of standards into the management system ensures that safety guidelines are treated as a continuous part of the production process, and not just as isolated requirements.

The integration of management systems, such as the combination of ISO 9001 with safety standards, also proves advantageous for optimizing resources without compromising worker protection. Serralheiro et al. (2018) emphasize that this approach allows aligning quality, health, and safety requirements, eliminating redundancies and promoting improvements in production processes. In addition, this integration strengthens corporate

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governance, positioning safety as a strategic pillar for corporate sustainability.

Continuous training of workers is another essential factor for the effectiveness of standards. Lima et al. (2023) emphasize that dynamic training, based on real risk scenarios, is essential for employees to understand and practice safety measures on a daily basis. In addition, the training of internal multipliers, who disseminate knowledge and supervise the application of standards, expands the reach of these initiatives, reducing the occurrence of incidents and promoting a culture of safety in the workplace.

Creating an organizational culture focused on safety is essential to strengthen risk perception and promote adherence to safety standards. Cruz et al. (2020) highlight that collaborative environments, where employees feel encouraged to report problems and suggest improvements, tend to be more effective in identifying risks early. Practices such as open communication between departments and valuing feedback from operators are essential to building this culture. Examples include creating anonymous channels for reporting risks and reward programs for safety initiatives, which encourage active employee participation and significantly reduce accident rates.

Leadership support is equally crucial to ensure the effective implementation of NR-10 and NR-12 standards. Potascheff et al. (2023) emphasize that cultural resistance and financial limitations can only be overcome with the direct involvement of senior management. This includes prioritizing investments in protective equipment, preventive maintenance, and monitoring technologies. In addition, linking safety goals to managers' key performance indicators (KPIs) helps align the organization's strategic interests with worker protection, promoting a more robust and transparent safety culture.

Studies show that companies that adopt a holistic approach, combining integrated management systems, ongoing training and a strong safety culture, are able to transform NR-10 and NR-12 standards into competitive advantages. This integration not only reduces accident costs, but also improves productivity and strengthens the corporate image. To achieve these results, organizations need to see standards as allies in the process of continuous improvement, and not as mere bureaucratic requirements, promoting safer and more efficient work environments.

Success Stories in the Application of Regulatory Standards in Industrial Environments

The proper application of Regulatory Standards NR-10 and NR-12 is essential to ensure the safety and health of workers in industrial environments, consolidating itself as a strategic pillar for organizational sustainability. Research indicates that companies that integrate these standards into their operational practices not only reduce the occurrence of accidents, but also strengthen their reputation and increase productivity (Potascheff et al., 2023). These success stories show that compliance is not only a legal requirement, but also an opportunity to improve operational efficiency and market competitiveness.

A significant example is Usiminas, which incorporated NR-10 and NR-12 into its management system through a collaborative approach. The creation of safety committees, composed of representatives from different hierarchical levels, facilitated the identification of risks and the implementation of solutions adapted to the company's operational context (Lima et al., 2023). In addition, regular training focused on real risk scenarios and the promotion of internal awareness campaigns were essential to reduce accident rates by 40% over a five-year period (Serralheiro et al., 2018).

Another example is Recrusul, a construction company that prioritized compliance with NR-12 by modernizing its equipment and providing technical training to its operators. The installation of safety devices, such as proximity sensors and emergency stop systems, was complemented by specific training on the safe use of heavy machinery (Cruz et al., 2020). This strategy not only reduced accident rates by 60%, but also increased productivity, as workers felt safer and more engaged.

The use of safety checklists also stands out as an effective tool for ensuring compliance with standards. Companies that adopt this practice systematize the verification of equipment, procedures and environmental conditions, reducing the risk of operational failures. Neto et al. (2015) point out that the continuous analysis of data collected in these checklists allows the identification of risk patterns and the implementation of preventive measures, reducing non-conformities by up to 35%.

The integration of digital technologies, such as IoT sensors, real-time monitoring systems, and artificial intelligence, also plays an important role in risk management. Barros and Nascimento (2024) emphasize that these systems allow early detection

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of anomalies, such as overheating in electrical installations, enabling immediate corrective actions and avoiding catastrophic failures. In addition, digital platforms that centralize safety data facilitate evidence-based decision-making, aligning risk management with companies' strategic goals (Nunes et al., 2023).

The combination of factors such as the creation of safety committees, ongoing training, the use of structured checklists and the adoption of advanced technologies are essential for the effective application of NR-10 and NR-12. These practices not only reduce accidents but also increase operational efficiency and employee satisfaction, consolidating safety as a core value in the organizational culture (Lima et al., 2023).

The success stories analyzed indicate that consistent application of Regulatory Standards NR-10 and NR-12 requires a comprehensive approach that integrates technical aspects, employee involvement, and the adoption of innovative technologies. Elements such as the formation of safety committees, the promotion of regular training, the use of checklists, and the implementation of digital tools are essential to ensure compliance and create safer work environments.

In addition to reducing risks, these practices also strengthen the competitiveness of organizations, consolidating their reputation for social responsibility and operational excellence. To achieve sustainable results, it is essential that companies treat safety as a strategic priority, combining compliance with legal standards with worker protection and continuous improvement of production efficiency.

III. METHODOLOGY

This study adopted a qualitative literature review as its methodology, with the objective of exploring the main concepts, challenges and solutions related to the implementation of Regulatory Standards NR-10 and NR-12 in the context of Electrical Engineering. This type of approach was chosen because it allows a detailed analysis of the technical requirements, normative demands and practical challenges that directly affect the safety of work with electricity and machinery.

Data collection was carried out from publications indexed in widely recognized scientific databases, such as SciELO (Scientific Electronic Library Online), Google Scholar and ResearchGate. These platforms were selected because they bring together highly relevant and peer-reviewed journals, in addition to offering broad access to technical studies, systematic reviews and specialized documents that reflect contemporary practices and challenges in the application of standards. The time frame included publications from the last five years, from 2020 to 2024, in order to ensure that the information analyzed was up-to-date and aligned with recent changes in safety regulations.

To increase the accuracy and scope of the research, several terms and combinations of keywords were used, such as "NR-10 + electrical safety", "NR-12 + machine safety", "implementation of regulatory standards", "occupational safety + electrical engineering", "regulatory compliance + industrial accidents", "risk analysis + occupational safety", "technical training + accident prevention" and "training programs + electrical safety". These expressions were applied in isolation and in combination, allowing the identification of studies that directly addressed the technical requirements of the standards and the challenges of their practical application.

The inclusion criteria for the selected materials considered their relevance to the topic, their focus on technical and regulatory aspects of NR-10 and NR-12 standards, and the academic quality of the studies, prioritizing peer-reviewed articles with a significant impact on the field. On the other hand, texts that did not directly address the aforementioned standards, that focused exclusively on other regulations unrelated to electrical safety, or that did not contain concrete data for critical analysis were excluded.

The extracted data were organized into thematic categories that included technical requirements, compliance analysis, implementation challenges, capacity building strategies, and case studies. This categorization allowed for a comprehensive view of the key factors influencing the application of standards, as well as facilitating the identification of knowledge gaps that can be explored in future research.

The analysis of the collected material was conducted through content analysis, a technique that enables the qualitative interpretation of texts based on criteria such as frequency of terms, identification of patterns and critical evaluation of the results presented. This approach allowed us to summarize the main theoretical and practical contributions to the topic, establishing the basis for the discussions and conclusions of this study.

Using this methodology, the study sought not only to understand the technical requirements of standards NR-10 and NR-12, but also to assess the challenges faced by companies in their

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implementation, proposing viable solutions to improve workplace safety and operational efficiency.

IV. ANALYSIS AND DISCUSSION OF RESULTS

The application of Regulatory Standards NR-10 and NR-12 is widely recognized as essential to ensure safety in industrial environments, but it faces considerable challenges in terms of compliance, technical qualification of professionals and strengthening of organizational culture. These standards, aimed at safety in electrical installations and in the use of machinery and equipment, respectively, are essential to reduce the risk of accidents and create safer and more productive work environments.

NR-10 establishes basic requirements for safety in electrical installations, including the mandatory use of Personal Protective Equipment (PPE), such as insulating gloves, helmets with protection against electric shocks and safety glasses, in addition to the need for specific training to recognize risks and respond to emergency situations (Chaves, 2024; Lara et al., 2022). It also requires the creation of technical procedures for activities involving high and low voltage, aiming to ensure that professionals understand preventive measures, such as disconnecting electrical circuits before interventions and adequate documentation of processes, ensuring traceability and accountability (Lara et al., 2022). The rigorous implementation of these procedures has been associated with a significant reduction in accidents, especially when combined with periodic inspections and risk analyses that consider environmental and operational variables.

NR-12 focuses on safety in the use of machinery and equipment, requiring protective devices, such as fixed barriers, presence sensors, and emergency stop systems, to prevent accidental contact with moving parts or dangerous components (Castro et al., 2023; Baesso et al., 2024). In addition, this standard includes ergonomic requirements for the design of machinery, seeking to reduce workers' exposure to physical risks, such as fatigue and repetitive strain injuries, and requires adequate signage of risk areas and the implementation of power lockout procedures during maintenance (Lima et al., 2023). In sectors such as agriculture, where the use of heavy machinery is frequent, the lack of preventive maintenance and the inappropriate use of equipment are factors that increase the likelihood of serious accidents (Sousa et al., 2022).

The integration between NR-10 and NR-12 is seen as crucial for the creation of more robust safety management systems, as both standards address complementary aspects that, when applied together, can significantly reduce occupational risks (Lima et al., 2023). Companies that adopt these regulations in an integrated manner, including the creation of Environmental Risk Prevention Programs (PPRAs) updated annually, have recorded substantial reductions in accident rates, with studies indicating drops of up to 40% in incidents (Monti et al., 2023). This effectiveness is increased when associated with the use of real-time monitoring technologies, such as sensors and automated alert systems, which allow rapid responses to risk situations (Silva et al., 2019).

However, despite these advances, the full implementation of these standards still faces obstacles, especially in small and medium-sized enterprises (SMEs), where the scarcity of technical and financial resources makes it difficult to adapt to regulatory requirements (Baesso et al., 2024). In sectors such as dairy, for example, the lack of strategic planning and the absence of regular training programs are factors that increase non-compliance rates and the risk of accidents (Nunes et al., 2023). In addition, many professionals still see these standards as an additional cost, without fully understanding the long-term economic benefits, such as reduced absences due to accidents and increased productivity (Santos et al., 2024).

Another critical challenge is raising awareness among workers about the importance of compliance with standards. Marquezini et al. (2024) point out that professionals with more practical experience tend to value safety measures more, while recent graduates may underestimate risks, reinforcing the need for training programs that combine theory and practice. Collaboration between experienced and novice professionals is also essential to strengthen the collective safety culture and reduce resistance to change (Campos & Lima, 2023).

Furthermore, the evolution of these standards, especially NR-10, reflects a continuous process of learning and adaptation to previous incidents, requiring professionals to stay up to date to avoid repeating errors (Barros & Nascimento, 2024). This context demands not only the technical application of normative requirements, but also a broader understanding of the motivations that led to regulatory changes, integrating aspects of safety, quality, and sustainability. Professionals who adopt

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a proactive stance, anticipating risks and investing in continuous training, are better prepared to ensure safe and competitive industrial environments (Castro et al., 2023).

The effective implementation of Regulatory Standards NR-10 and NR-12 depends not only on technical compliance with legal requirements, but also on the ability of organizations to adapt these standards to their operational and cultural realities. To transform these guidelines into effective prevention tools, an ongoing commitment to education, technological innovation and organizational leadership is required, consolidating safety as a strategic value for corporate sustainability.

V. FINAL CONSIDERATIONS

Based on the in-depth analysis carried out throughout this study, it is concluded that the application of regulatory standards NR-10 and NR-12 represents not only a legal requirement, but an essential strategy for promoting occupational safety in the context of Electrical Engineering.

The research clearly answered the proposed problem question, by highlighting how professionals in the area face significant challenges in implementing these standards, including lack of technical training, financial limitations and organizational resistance to change.

Furthermore, the specific objectives were fully met: the technical requirements of the standards were identified, the level of compliance and practical application in different sectors were assessed, and viable strategies were proposed to overcome the main obstacles encountered, such as the adoption of simplified management systems, ongoing training and the creation of an organizational culture focused on safety.

The analysis also showed that the synergy between NR-10 and NR-12 standards strengthens integrated risk management in industrial environments, contributing to the reduction of accidents and increased operational efficiency. Companies that adopt these standards strategically and with institutional support show not only greater legal compliance, but also gains in productivity, organizational climate and institutional image.

As a suggestion for future work, we recommend further investigation into specific case studies that analyze the practical application of standards in different industrial sectors, such as civil construction, agribusiness, and automated industries. In addition, it would be pertinent to investigate the impact of digitalization and Industry 4.0 on the reinterpretation of safety standards, considering the growing presence of autonomous systems and artificial intelligence in work environments.

Another promising field is the analysis of performance indicators related to occupational safety, linking the effectiveness of the application of standards to concrete metrics, such as reduction of absences, productivity and return on investment in safety. In short, this study contributes significantly to the understanding of the challenges and possibilities in the implementation of standards NR-10 and NR-12, while opening avenues for complementary research that deepens the relationship between safety, technology and strategic management in Electrical Engineering.

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