

Regulation-Based Safety Redesign of Electric Forklift Charging Panel

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Abstract— The increasing use of electric vehicles in industrial operations requires charging infrastructure that complies with technical safety regulations. However, many industrial charging panels are installed without systematic evaluation of regulatory compliance, which may increase electrical and fire risks. This study aims to evaluate the compliance level of an existing electric forklift charging power supply panel with Minister of Energy and Mineral Resources Regulation No. 1 of 2023 and to develop a redesigned panel that meets the regulatory requirements. The research used an observational compliance assessment method based on an eleven-item checklist derived from the regulation. Each requirement was scored as compliant or non-compliant, and the compliance percentage was calculated. The existing panel fulfilled only 5 out of 11 requirements (45.45%). Critical deficiencies included the absence of energy metering devices, load monitoring instruments, earth leakage protection, an emergency stop switch, and a single line diagram. A new panel was then designed using PCSHEMATIC Automation software incorporating all required protection and monitoring components. The redesigned panel achieved full compliance with 11 out of 11 requirements (100%). The results indicate that regulation-based redesign significantly improves electrical safety performance and reduces the risk of electric shock and fire incidents in industrial electric forklift charging systems.

Keywords— Charging infrastructure; Earth leakage protection; Electrical safety; Emergency isolation; Energy metering; Industrial sockets; Regulatory assessment; Risk reduction; Single line diagram; Technical standards.

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I. INTRODUCTION

Paper manufacturing company located in Driyorejo District, Gresik Regency, East Java, produces paper rolls and sheets for packaging applications. As part of its environmental commitment, the company participates in the national Green Industry initiative [1]. To improve energy efficiency and reduce greenhouse gas emissions, the company has initiated the replacement of fossil-fuel-based operational vehicles with electric vehicles (EVs) [2]. This transition aligns with broader industrial decarbonization efforts, in which fleet electrification is recognized as an effective approach to lowering fossil energy dependency and reducing emissions [3]. One implementation of this initiative is the deployment of lithium-ion battery-powered electric forklifts for warehouse material handling operations [4].

Compared with residential charging systems, EV charging infrastructure in industrial settings operates under higher load variability and extended duty cycles, thereby requiring more robust electrical protection to ensure safety and reliability [5]. To support forklift charging, portable chargers provided by the manufacturer have been installed [6]. However, the associated power supply panel was implemented without

comprehensive technical planning in accordance with applicable standards or regulatory requirements [7]. The existing configuration is relatively basic, consisting only of a conventional Miniature Circuit Breaker (MCB) and non-industrial-grade socket outlets.

Conventional MCB protection with limited short-circuit response capability may reduce the system's effectiveness in interrupting fault currents and limiting electrical arcing, thereby increasing the risk of overload and thermal incidents [8]. In addition, the panel lacks critical protective features, including an adequate grounding system, residual current protection, and coordinated fault protection mechanisms, which are essential for EV charging operations [9]. The use of non-industrial-rated sockets further increases the potential for overloading, particularly under sustained high-current conditions exceeding their design capacity [10].

Fire incidents related to improper EV charging installations have been reported both nationally and internationally. In Indonesia, a fatal fire in Penjaringan, North Jakarta, was reportedly associated with deficiencies in EV charging installation practices [11]. Similar cases have occurred in Hong Kong, where electrical short circuits originating from charging sockets caused vehicle fires [12]. These incidents highlight the significant safety risks posed by inadequate protection design and non-compliant installation practices, particularly in industrial environments where charging activities are conducted continuously.

To enhance safety regulation, the Indonesian government issued Minister of Energy and Mineral Resources Regulation No. 1 of 2023, which establishes mandatory technical requirements for EV charging infrastructure. The regulation specifies provisions related to panel configuration, grounding systems, protection coordination, and operational safety controls [13]. This regulation serves as a formal technical benchmark to

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ensure the safe, reliable, and sustainable operation of EV charging systems.

Previous studies on EV charging infrastructure in Indonesia have primarily focused on macro-level aspects, including user adoption behavior, socio-economic factors, regulatory frameworks, and infrastructure development strategies [14]. While these studies provide valuable policy-level insights, limited research has examined equipment-level technical compliance and electrical safety performance in industrial applications [15]. In particular, empirical assessment of charging panel conformity with Ministerial Regulation No. 1 of 2023, as well as quantitative evaluation of safety improvement resulting from regulation-based redesign, remains limited [16].

This study addresses the absence of a structured and measurable framework for evaluating whether existing industrial EV charging power supply panels comply with the mandatory technical provisions of Ministerial Regulation No. 1 of 2023. Although regulatory standards are formally established, their implementation at the equipment level is not always systematically verified, potentially creating discrepancies between regulatory requirements and field conditions [17]. Compliance enhancement within a real industrial setting. This approach contributes to bridging the gap

between regulatory provisions and their technical realization in operational practice [18].

The novelty of this research lies in conducting a clause-based compliance assessment of an operational electric forklift charging power supply panel, followed by a technically justified redesign aligned with regulatory requirements to achieve measurable safety improvement. Unlike prior studies that emphasize policy adoption or infrastructure expansion, this research integrates regulatory clause mapping, component-level conformity evaluation, and quantitative compliance enhancement within an actual industrial setting. This approach aims to bridge the gap between regulatory provisions and their practical technical implementation [19].

Accordingly, this study aims to (1) evaluate the compliance level of the existing electric forklift charging power supply panel with Minister of Energy and Mineral ulatory compliance and reduces potential electrical safety risks. Documentation of the existiResources Regulation No. 1 of 2023, and (2) develop a redesigned panel configuration that satisfies the stipulated technical requirements. Furthermore, this research assesses the extent to which the proposed redesign enhances regng installation, including its physical layout and schematic configuration, is presented in **Figure 1** and **Figure 2**.

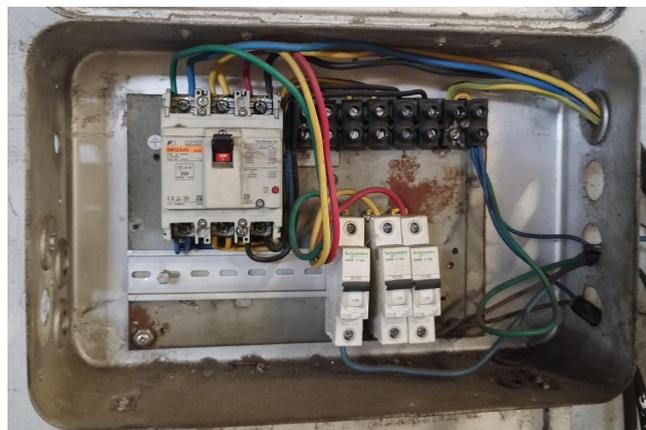


Figure 1. Photo of existing electric panel of charging station

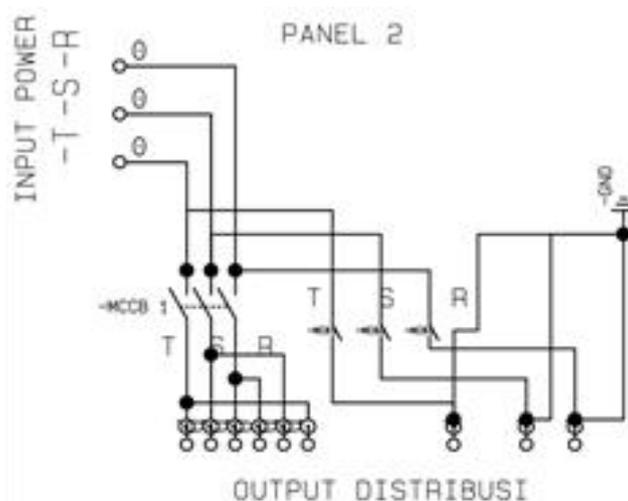


Figure 2. Schematic diagram of existing electric panel of charging station.

II. METHOD

A. Panel Compliance Evaluation

The observation was conducted to evaluate the compliance of the existing power supply panel at the charging station with the technical requirements for power input panels as stipulated in Minister of Energy and Mineral Resources Regulation No. 1 of 2023. The observation method involved visual and technical inspections focusing on the presence, functionality, and adequacy of mandatory protection and metering devices required by the regulation. According to Minister of Energy and Mineral Resources Regulation No. 1 of 2023, several key requirements must be fulfilled in the installation of power input panels for charging stations, including.

- The distribution panel shall be equipped with current-limiting and metering devices (MCB and kWh meter).
- Measuring instruments shall be capable of monitoring both normal and peak load conditions.
- The charging line shall use a single final circuit (dedicated circuit).
- Cable routes shall be provided with mechanical protection (conduit).
- Overcurrent protection shall be installed.
- Earth leakage protection (ELCB/RCCB) shall be provided.
- An emergency stop switch shall be installed.
- All equipment (MCB, panel, cables, and chargers) shall comply with SNI/IEC/NEMA standards.
- The grounding system shall meet standard resistance values ($< 5 \Omega$).
- A clear and updated SLO/SLD diagram shall be available.
- The use of industrial sockets for electrical connections (recommended).

Each compliance item was assigned equal weight and scored as 1 (compliant) or 0 (non-compliant). The overall compliance percentage was calculated as the ratio of fulfilled mandatory requirements to total mandatory requirements. Non-compliant items were qualitatively categorized into high, medium, or low electrical safety risk based on their potential impact on electric shock, fire hazard, and system reliability.

B. Required Component Analysis

Prior to conducting the observation, an identification of essential panel components mandated by Minister of Energy and Mineral Resources Regulation No. 1 of 2023 was performed, as described below.

1) Miniature Circuit Breaker (MCB)

A Miniature Circuit Breaker (MCB) is a low-voltage electrical protection device designed to automatically disconnect electrical circuits under abnormal conditions. The MCB provides protection against overload and short-circuit faults. Unlike fuses, MCBs can be reset after fault conditions are resolved. The primary functions of an MCB include [20].

- Protection against overload conditions.
- Protection against short-circuit faults.
- Switching and isolation of electrical circuits.

2) kWh Meter

kWh meter is an electrical energy measuring instrument used to record the total electrical energy consumed by a load in kilowatt-hours (kWh). In charging station power supply panels, the kWh meter is installed upstream of the charger to ensure accurate measurement of all energy consumed during the charging process. The functions of a kWh meter include [21].

- Measurement of electrical energy consumption.
- Evaluation of energy efficiency.
- Operational load monitoring and control.
- Energy cost calculation.
- Regulatory compliance and audit support.
- Indirect contribution to operational safety.

3) Residual Current Circuit Breaker (RCCB)

RCCB is a protective device designed to disconnect electrical power when earth leakage current is detected. RCCBs operate based on the principle of residual current detection, identifying imbalances between phase and neutral currents. In modern electrical installations, RCCBs are more widely used than conventional ELCBs due to higher reliability and sensitivity. The functions of RCCB include [22].

- Protection against electric shock.
- Prevention of electrical fires caused by leakage currents.
- Additional protection for charging systems.

4) Emergency Stop Switch

Emergency Stop Switch is a safety device intended to rapidly stop system operation during emergency conditions. Its purpose is to minimize the risk of personal injury, equipment damage, and escalation of hazardous events. The functions of an emergency stop switch include [23].

- Immediate shutdown of the system.
- Protection of personnel safety.
- Prevention of equipment damage.
- Energy isolation during emergency situations.

5) Single Line Diagram (SLD)

Single Line Diagram (SLD) is a simplified electrical diagram representing a power distribution system using a single line to depict single-phase or three-phase circuits along with major components. The SLD illustrates power flow, interconnection of equipment, and protection systems within an electrical installation. The functions of an SLD include [24].

- Electrical system planning.
- Protection and safety analysis.
- Official technical documentation.
- Support for operation and maintenance activities.

6) Industrial Socket

Industrial socket is an electrical connection device specifically designed for industrial applications, capable of handling higher current and voltage ratings, enhanced mechanical strength, and improved

environmental protection compared to residential sockets. The functions of industrial sockets include [25].

- High-capacity electrical power delivery.
- Improved electrical safety.
- Protection against harsh working environments.
- Prevention of incorrect connections.
- Enhanced operational reliability.

C. Existing Panel Assessment Results

Based on the observation of the existing power supply panel, the level of compliance with the requirements stipulated in Minister of Energy and Mineral Resources Regulation No. 1 of 2023 is summarized in **Table 1**. The Description column presents the technical requirements applicable to power supply panels as specified in the regulation. The Y (Yes) column indicates requirements that have been fulfilled by the existing installation, whereas the N (No) column denotes requirements that have not yet been satisfied in accordance with the provisions of Minister of Energy and Mineral Resources Regulation No. 1 of 2023.

Table 1 presents the results of the compliance assessment of the existing power supply panel against the technical requirements specified in Minister of Energy and Mineral Resources Regulation No. 1 of 2023. The assessment indicates that while several fundamental electrical safety aspects—such as dedicated circuits, mechanical cable protection, overcurrent protection, equipment certification, and grounding resistance—have been adequately implemented, a number of critical safety and monitoring requirements remain unfulfilled.

Key deficiencies identified include the absence of energy metering and load monitoring devices, lack of earth leakage protection, unavailability of an emergency stop switch, and the absence of an updated single line diagram. Additionally, the use of non-industrial sockets

further increases operational and safety risks. These findings demonstrate that the existing panel does not fully comply with the mandatory provisions of Minister of Energy and Mineral Resources Regulation No. 1 of 2023, thereby justifying the need for a comprehensive redesign of the power supply panel.

D. Single-Line Diagram Redesign

The observation identified several major deficiencies in the existing panel, including.

- Absence of MCB and kWh meter.
- Lack of normal and peak load monitoring capability.
- Absence of ELCB/RCCB protection.
- No emergency stop switch installed.
- No single line diagram available.

To address these deficiencies, a new single line diagram for the power supply panel was designed using PCSCHMATIC Automation software. PCSCHMATIC Automation is a Computer-Aided Design (CAD) software specifically developed for electrical and industrial automation system design, supporting standardized technical documentation. In this study, PCSCHMATIC Automation was utilized to [25].

- Develop electrical schematic diagrams.
- Design power distribution and control panels.
- Generate standardized technical documentation.
- Improve design efficiency and reduce errors.
- Support compliance with international standards (IEC/NFPA).

TABLE 1.
OBSERVATION RESULT OF EXISTING PANEL BASED ON MINISTER OF ENERGY AND MINERAL RESOURCES REGULATION NO. 1 OF 2023

Description	Yes	No
Distribution panel is equipped with current-limiting and metering devices (MCB and kWh meter)		√
Measuring instruments are capable of monitoring both normal and peak load conditions		√
Charging line uses a single final circuit (dedicated circuit)	√	
Cable routes are provided with mechanical protection (conduit)	√	
Overcurrent protection is installed	√	
Earth leakage protection (RCCB) is available		√
Emergency stop switch is installed		√
All equipment (MCB, panel, cables, and charger) complies with SNI/IEC/NEMA standards	√	
Grounding system meets standard resistance requirements (< 5 Ω)	√	
A clear and updated Single Line Diagram (SLO/SLD) is available		√
Use of industrial socket for electrical connection (recommended)		√

The redesigned schematic demonstrates that the new power supply panel fulfills all ten mandatory

presented in **Table 2**.

The compliance assessment results of the

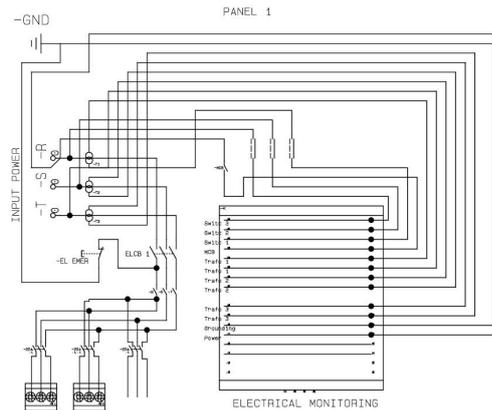


Figure 3. Single line diagram of new design electric panel of charging station.

TABLE 2.
 OBSERVATION RESULT OF EXISTING PANEL BASED ON MINISTER OF ENERGY AND MINERAL RESOURCES REGULATION No. 1 OF 2023

Description	Yes	No
Distribution panel is equipped with current-limiting and metering devices (MCB and kWh meter)	√	
Measuring instruments are capable of monitoring both normal and peak load conditions	√	
Charging line uses a single final circuit (dedicated circuit)	√	
Cable routes are provided with mechanical protection (conduit)	√	
Overcurrent protection is installed	√	
Earth leakage protection (RCCB) is available	√	
Emergency stop switch is installed	√	
All equipment (MCB, panel, cables, and charger) complies with SNI/IEC/NEMA standards	√	
Grounding system meets standard resistance requirements (< 5 Ω)	√	
A clear and updated Single Line Diagram (SLO/SLD) is available	√	
Use of industrial socket for electrical connection (recommended)	√	

requirements and one recommended criterion stipulated in Minister of Energy and Mineral Resources Regulation No. 1 of 2023, which were previously unmet by the existing panel. Therefore, it can be concluded that the newly designed power supply panel complies with Minister of Energy and Mineral Resources Regulation No. 1 of 2023 at **Figure 3**. To verify whether the single line diagram of the newly designed power supply panel complies with the applicable standards, a re-evaluation was conducted on the single line diagram of the redesigned panel. The assessment employed the same observation checklist used in the compliance evaluation of the existing power supply panel. The results of this observation for the single line diagram of the newly designed power supply panel are

redesigned power supply panel, as summarized in **Table 2**, indicate a substantial improvement compared to the existing panel. The evaluation demonstrates that all mandatory technical requirements stipulated in Minister of Energy and Mineral Resources Regulation No. 1 of 2023 have been fully satisfied.

The redesigned panel is equipped with current-limiting and energy metering devices, including Miniature Circuit Breakers (MCB) and a kWh meter, enabling accurate measurement and control of electrical energy consumption. In addition, the inclusion of monitoring instruments allows effective supervision of both normal and peak load conditions, thereby enhancing operational reliability and preventing overload scenarios.

The charging system utilizes a dedicated final circuit, which minimizes electrical interference and reduces the risk of overloading shared circuits. Mechanical protection of cable routes using conduits or trunking has been implemented to protect conductors from physical damage and environmental exposure. Furthermore, overcurrent protection and earth leakage protection RCCB are installed, significantly improving electrical safety by mitigating risks of short circuits, leakage currents, and potential electrical fires.

The integration of an emergency stop switch provides an additional layer of safety, allowing immediate isolation of electrical energy during emergency situations. All electrical components used in the redesigned panel, including MCBs, panel enclosures, cables, and chargers, comply with recognized national and international standards (SNI/IEC/NEMA), ensuring reliability and regulatory conformity.

Moreover, the grounding system of the redesigned panel meets the standard resistance requirement of less than 5Ω , thereby ensuring effective fault current dissipation. The availability of a clear and updated Single Line Diagram (SLD) further supports safe operation, maintenance, and inspection activities. Although the use of industrial sockets is categorized as a recommendation, its implementation in the redesigned panel enhances connection reliability and operational safety.

Overall, the findings confirm that the redesigned power supply panel achieves full compliance with all mandatory requirements and recommended practices outlined in Minister of Energy and Mineral Resources Regulation No. 1 of 2023. This improvement is expected to significantly reduce electrical and fire-related risks associated with forklift battery charging operations.

III. RESULTS AND DISCUSSION

A. Compliance Assessment of the Existing Power Supply Panel

The first research objective was to evaluate the compliance level of the existing electric forklift charging panel with the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 1 of 2023. The empirical findings indicate that the panel met only fundamental electrical protection criteria, such as overcurrent protection (MCB), mechanical cable protection, grounding resistance below 5Ω , and the use of a dedicated circuit. These elements represent conventional electrical safety practices commonly applied in industrial distribution panels.

However, the assessment revealed significant regulatory gaps. The absence of energy metering devices, load monitoring instruments, earth leakage protection (ELCB/RCCB), emergency stop mechanisms, and updated single line documentation indicates that the panel was not designed to function as a regulated electric vehicle (EV) charging infrastructure.

This finding supports previous studies on EV charging safety, which emphasize that EV charging

systems require layered protection mechanisms due to continuous high-current loads and human interaction risks. Unlike traditional industrial loads, EV charging introduces prolonged electrical stress and potential leakage current hazards. Therefore, compliance with general electrical standards alone is insufficient for EV applications.

Compared with public EV charging infrastructure studies, which typically focus on grid impact and load management, this study positions itself within the industrial context, where retrofit adaptation of existing panels is common. The results highlight a critical gap in industrial electrification practice: many facilities assume conventional panels are adequate for EV charging without comprehensive regulatory verification. Thus, the empirical findings demonstrate that partial compliance does not ensure functional safety adequacy in industrial EV charging systems.

B. Regulation-Based Redesign and Technical Implementation

The second research objective was to develop and verify a redesigned panel that fully complies with the regulation. The redesigned panel integrates.

- kWh meter for energy measurement.
- Load monitoring instruments for normal and peak conditions.
- MCB for overcurrent protection.
- RCCB for earth leakage protection.
- Emergency stop switch.
- Updated single line diagram.
- Components compliant with SNI, IEC, and NEMA standards.

Verification results show full compliance with all mandatory and recommended criteria stipulated in the regulation. From an engineering perspective, the redesign introduces a structural shift from passive protection to active monitoring and layered risk mitigation. While the existing panel relied primarily on overcurrent protection, the redesigned system applies a multi-layered safety architecture consisting of.

- Overcurrent protection.
- Leakage current detection.
- Emergency isolation capability.
- Operational monitoring and traceability.

This layered approach aligns with modern electrical safety engineering principles and is consistent with international best practices for EV infrastructure. When compared with prior studies on EV charging systems, most literature emphasizes smart charging algorithms, grid stability, and renewable integration. However, fewer studies focus on regulation-driven compliance engineering in industrial settings.

Therefore, the novelty of this study lies not in introducing new hardware technologies, but in demonstrating a structured method of translating regulatory clauses into concrete engineering specifications and validating them empirically in a real industrial case. This positions the research within the compliance engineering and industrial electrification

discourse rather than purely technological EV innovation research.

C. *Comparative Analysis and Risk Reduction*

The third objective was to analyze the safety and operational improvement achieved through redesign. The comparison between the existing and redesigned panels reveals a qualitative transformation in safety performance. The introduction of earth leakage protection significantly reduces the probability of electric shock incidents, especially in environments where operators physically connect charging cables. Previous electrical safety research confirms that residual current devices substantially reduce fatal shock risks in industrial environments.

The installation of an emergency stop switch enhances system controllability during abnormal events, enabling rapid power isolation. This adds an additional safety barrier absent in the original design. Furthermore, the integration of energy metering and load monitoring improves operational transparency. Unlike the existing panel, which operated without measurable consumption data, the redesigned system enables.

- Monitoring of charging efficiency.
- Detection of abnormal peak demand.
- Prevention of overload conditions.
- Data-driven maintenance planning.

This aligns with industrial energy management frameworks, where measurement is the first step toward optimization. Compared with earlier EV charging studies that focus on smart-grid coordination, this study emphasizes internal industrial load governance, thereby expanding the scope of EV charging research into facility-level compliance and control. The findings demonstrate that regulatory compliance functions not only as a legal obligation but also as a risk-reduction and performance-enhancement mechanism.

D. *Positioning of the Study within the Existing Discourse*

Within the broader academic discussion, EV charging research can generally be categorized into.

- Grid integration and load balancing.
- Renewable energy coupling.
- Smart charging algorithms.
- Public charging infrastructure planning.

This study contributes to a less explored domain industrial compliance-based EV charging redesign. By providing an empirical case of regulation-to-design translation, the research bridges regulatory policy and engineering implementation. Therefore, its novelty lies in.

- Applying a systematic compliance audit methodology.

IV. CONCLUSION

This study aimed to evaluate the compliance level of an existing electric forklift charging power supply panel with the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 1 of

- Converting regulatory requirements into measurable design variables.
- Demonstrating full regulatory verification through redesign.
- Providing a replicable model for industrial facilities transitioning to electric fleets.

This strengthens the manuscript's contribution beyond a simple case study.

E. *Managerial Implications for Industrial Operators*

The findings provide several important managerial implications, particularly for the business and industrial sector.

First, industrial companies adopting electric forklifts should not assume that existing distribution panels are inherently suitable for charging operations. A structured regulatory compliance assessment is necessary before integration.

Second, investment in energy metering and monitoring instruments should be viewed not merely as regulatory compliance costs, but as strategic assets supporting energy efficiency, cost control, and sustainability reporting.

Third, implementing layered protection systems (overcurrent, leakage, emergency isolation) reduces operational risk exposure and potential liability associated with electrical accidents.

Fourth, companies participating in government green industry initiatives can leverage compliant charging infrastructure as part of their sustainability performance documentation.

In managerial terms, regulation-based engineering redesign supports:

- Risk mitigation
- Operational transparency
- Energy cost control
- Long-term infrastructure scalability
- Corporate sustainability alignment

Thus, compliance-driven redesign creates both safety value and strategic business value.

F. *Concluding Interpretation of Results and Discussion*

Overall, the empirical findings and comparative analysis confirm that regulation-based redesign significantly enhances safety architecture, operational control, and sustainability alignment of industrial EV charging systems.

The study demonstrates that regulatory compliance should be treated as an engineering design framework rather than an administrative checklist. This conceptual shift represents the primary scientific and practical contribution of the research.

2023 and to develop a redesigned panel that fulfills all regulatory requirements.

Using an observational compliance assessment method based on an eleven-item checklist derived from the regulation, the existing panel was found to comply with only 5 out of 11 requirements (45.45%). Major

deficiencies were identified in energy metering, load monitoring, earth leakage protection, emergency isolation, and system documentation. These findings confirm that partial compliance with conventional electrical practices does not ensure regulatory adequacy for industrial EV charging systems.

A redesigned panel was subsequently developed incorporating all mandatory protection and monitoring components. Verification results demonstrated full compliance (11 out of 11 requirements, 100%), indicating that a regulation-based design approach effectively closes identified safety gaps. The comparative improvement from 45.45% to 100% compliance confirms that structured compliance assessment combined with systematic redesign significantly enhances electrical safety performance and mitigates electric shock and fire risks in industrial electric forklift charging operations.

Therefore, this study demonstrates that regulation-driven engineering redesign provides a practical and replicable framework for improving safety, reliability, and regulatory conformity of industrial EV charging infrastructure. Future research is recommended to validate the long-term operational performance of the redesigned system through real-time monitoring and quantitative risk assessment methods to further substantiate measurable risk reduction outcomes.

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