



한국전기안전공사
Korea Electrical Safety Corporation

New and Renewable Energy Safety Management Laws and Technical Standards in the Republic of Korea and ASEAN

Part of Capacity Building in Electrical Safety
Management for New and Renewable Energy
Facilities (Solar, Wind, ESS, etc.) in ASEAN Region

Implemented by
Korea Electrical Safety Cooperation (KESCO)
and ASEAN Centre for Energy (ACE)

Supported by AKFTA



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About ACE



ASEAN Centre for Energy
One Community for Sustainable Energy

Established in 1999, the ASEAN Centre for Energy (ACE) is an intergovernmental organisation within the ASEAN structure that independently represents the interests of the 10 ASEAN countries in the energy sector. The Centre accelerates the integration of energy strategies within ASEAN by providing relevant information and expertise to ensure the necessary energy policies and programmes are in harmony with economic growth and the region's environmental sustainability. It is guided by a Governing Council composed of Senior Officials on Energy, leaders from each ASEAN Member State, and a representative from the ASEAN Secretariat. Hosted by Indonesia's Ministry of Energy and Mineral Resources (MEMR), ACE's office is located in Jakarta, Indonesia.

About KESCO



The Korea Electrical Safety Corporation (KESCO) is a South Korean quasi-governmental organisation dedicated to protecting the public from electrical accidents and ensuring the safe use of electricity. Initially established as a foundation named the Korea Electrical Security Association on 7 June 1974, it was reorganised and renamed KESCO on 1 April 1975. Operating under the supervision of the Ministry of Trade, Industry and Energy (MOTIE), KESCO plays a crucial role in South Korea's electrical safety management system. Its primary mission is to safeguard lives and property by minimising risks associated with electrical installations and equipment through systematic inspection, research, and public awareness initiatives.

KESCO's core activities involve conducting regular safety inspections and diagnostic testing of electrical facilities across various sectors, including residential, commercial, industrial, and public utility installations. Beyond inspections, the corporation is actively involved in research and development to advance electrical safety technologies and standards. It also undertakes extensive public relations and educational campaigns to promote electrical safety awareness among citizens and industry professionals, contributing significantly to a safer electrical environment throughout South Korea.

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From Indonesia: Ms. Andriah Feby Misna (Director of Various New and Renewable Energy, MEMR Indonesia), Mr. Doddy B. Pangaribuan (Executive Vice President HSSE, PT PLN (Persero)), Mr. Wildan Fujiansah (Sub Coordinator of Electrical Technical Feasibility, Directorate General of Electricity, Indonesia), and Mr. Andhy Dharma Setyawan (Vice President K3, PT PLN (Persero)).

Furthermore, we acknowledge the crucial review and endorsement provided by the Renewable Energy Sub-Sector Network (RE-SSN) Focal Points and the Heads of ASEAN Power Utilities/Authorities (HAPUA) delegates who participated in the invitation-only electrical safety training programme held at KESCO headquarters. Their feedback and support were instrumental.

Foreword from ACE



Dato Ir. Ts. Abdul Razib Dawood

Executive Director of ASEAN Centre for Energy (ACE)

Against a backdrop of dynamic economic growth and shifting global priorities, ASEAN is intensifying its focus on accelerating a just and inclusive energy transition. As we shape our regional energy cooperation beyond 2025, the drive to enhance energy security, improve affordability and accessibility, and contribute effectively to global decarbonisation efforts remains central. Key to this vision is significantly increasing the amount of renewable energy (RE) in our power supply – a change that every ASEAN Member State needs to embrace.

Through ACE, we are working on several fronts to support this change. We collaborate with our Dialogue Partners and various International Organisations to create a better investment climate, secure funding, and encourage the use of modern renewable technologies across the region. However, quickly increasing RE use brings its own challenges. While expanding generation capacity and grid infrastructure, including enhancing regional connectivity through initiatives like the ASEAN Power Grid (APG), is very important, we must also pay close attention to the essential aspects of safety and technical quality.

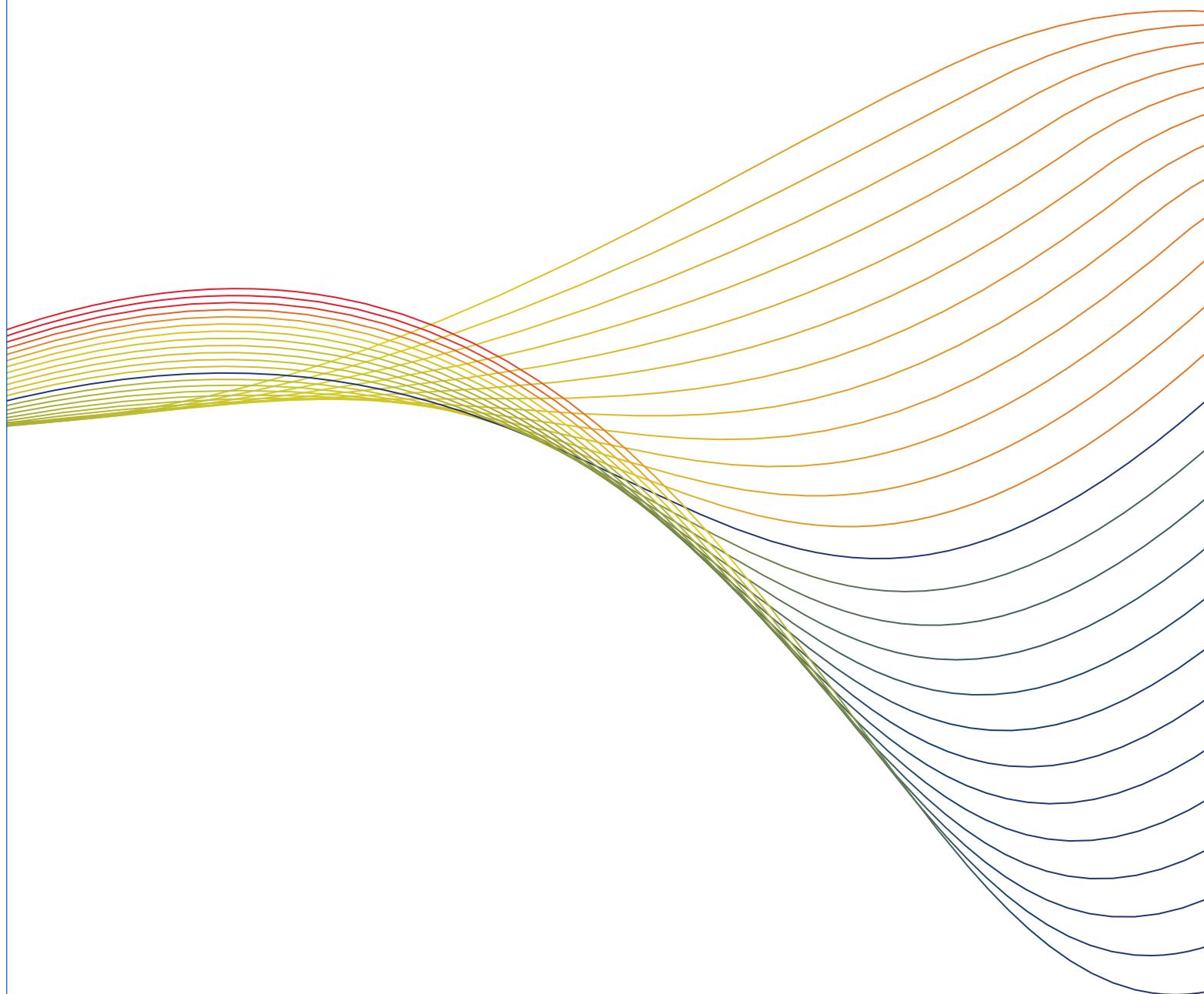
This is the important background for ACE's joint project with KESCO. While our other partnerships focus on enabling RE growth, this study, titled *New and Renewable Energy Safety Management Laws and Technical Standards in the Republic of Korea and ASEAN*, looks into the essential technical requirements needed to add these new energy sources safely and reliably. Strong electrical safety management systems and consistent technical standards are not just about following rules; they are necessary for building public confidence, protecting people and property, and ensuring the long-term successful operation of our growing RE sector.

This publication offers useful information by looking at the comprehensive system used in the Republic of Korea, and describes the varied electrical safety regulations, standards, and practices across the ASEAN region. It explains the specific safety challenges of different RE technologies, such as solar, wind, and energy storage systems, and points out key areas for improvement in ASEAN's current systems.

This study is a result of the strong partnership between ACE and KESCO, and shows our shared commitment to promoting a safe, secure, and sustainable energy future for ASEAN. We believe the findings and analyses in this study will be valuable resources for policymakers, regulators, utilities, industry members, and researchers throughout the region as we work through the complexities of the energy transition together.

Dato Ir. Ts. Abdul Razib Dawood

Executive Director of ASEAN Centre for Energy (ACE)



Foreword from KESCO



Mr. Nam Wha-yeong

The President of Korea Electrical Safety Corporation (KESCO)

Dear ASEAN Member States,

I extend my sincere gratitude and expectations for the joint efforts between the Korea Electrical Safety Corporation (KESCO) and the ASEAN Centre for Energy (ACE) as we strive toward a safer and more sustainable energy transition.

The world today faces significant challenges brought by rapidly changing climate conditions and evolving energy paradigms. In response, ASEAN member countries are proactively working to increase the share of renewable energy, thereby enhancing energy security, and achieving sustainable growth. These transformations present us with important opportunities; however, they also pose essential technical and regulatory safety management challenges.

For the past 50 years, KESCO has dedicated itself to protecting lives and property from electrical disasters through proactive safety management systems and consistent technical standards. Particularly in recent years, as renewable energy sectors such as solar, wind, and energy storage systems (ESS) experience rapid growth, we have established and implemented stringent safety standards.

This report, *New and Renewable Energy Safety Management Laws and Technical Standards in the Republic of Korea and ASEAN*, embodies our commitment to sharing our experiences and expertise with the ASEAN region. The report introduces Korea's comprehensive electrical safety management systems, and provides detailed safety management measures and standards tailored to various renewable energy technologies. Additionally, it reviews the electrical safety regulations, standards, and practical cases related to renewable energy across ASEAN, addressing common challenges and seeking solutions collaboratively.

We firmly believe this report will substantially contribute to strengthening ASEAN countries' capacities in renewable energy safety management, technical standardisation, and building a trusted energy supply foundation. KESCO remains committed to close cooperation with ACE, offering tailored technical support and training programmes that reflect each country's unique characteristics, thereby supporting a safer and more sustainable energy future for ASEAN.

Once again, I sincerely thank everyone who has contributed to the publication of this report and look forward to our continued strong partnership with ACE in promoting sustainable development and strengthening electrical safety in ASEAN.

Mr. Nam Wha-yeong

The President of Korea Electrical Safety Corporation (KESCO)

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Abbreviations

A

A*STAR	Agency for Science, Technology and Research (Singapore)
ACE	ASEAN Centre for Energy
AEC	ASEAN Economic Community
AENBD	Autoriti Elektrik Negara Brunei Darussalam
AEO	ASEAN Energy Outlook
AI	Artificial Intelligence
AIMS	ASEAN Interconnection Masterplan Study
AMS	ASEAN Member States
ANIEM	Algemeene Nederlandsch-Indische Electriciteits-Maatschappij
APAC	Asia Pacific Accreditation Cooperation
APAEC	ASEAN Plan of Action for Energy Cooperation
APG	ASEAN Power Grid
APSA	ASEAN Petroleum Security Agreement
ASNT	American Society for Non-destructive Testing (assumed definition based on context)

B

BEC	Board of Engineers, Cambodia
BFP	Bureau of Fire Protection (Philippines)
BMS	Battery Management System
BNPB	<i>Badan Nasional Penanggulangan Bencana</i> (Indonesia)
BOMBA	Fire and Rescue Department of Malaysia
BPS	Bureau of Philippine Standards
BRIN	<i>Badan Riset dan Inovasi Nasional</i> (Indonesia)
BS	British Standard
BSN	<i>Badan Standardisasi Nasional</i> (Indonesia)

C

CAGR	Compound Annual Growth Rate
CB	Certification Body (IECEE)
CCUS	Carbon Capture, Utilisation, and Storage
CCT	Clean Coal Technology
CEB	Central Electricity Board (Malaysia)
CEO	Chief Executive Officer
CMV	Common Mode Voltage

CNS	Carbon Neutrality Scenario (in AEO)
COP	Conference of the Parties
CS	Cambodian Standards
CSMS	Contractor Safety Management System
CV	Cable type designation (e.g., Cross-linked Polyethylene insulation / Polyvinyl Chloride sheath)

D

DC	Direct Current
DEDE	Department of Alternative Energy Development & Efficiency (Thailand)
DES	Department of Electrical Services (Brunei)
DPs	Dialogue Partners
DR	Demand Response
DRI	Department of Research and Innovation (Myanmar)
DSM	Department of Standards Malaysia

E

EAC	Electricity Authority of Cambodia
EBTKE	<i>Energi Baru, Terbarukan, dan Konservasi Energi</i> (Directorate General, Indonesia)
EDC	<i>Electricite du Cambodge</i>
EDL	<i>Electricite du Laos</i>
EE&C	Energy Efficiency and Conservation
EEI	Electrical and Electronics Institute (Thailand)
EGAT	Electricity Generating Authority of Thailand
EIR	Electrical Installation Requirements (Brunei)
EIT	Engineering Institute of Thailand
EMA	Energy Market Authority of Singapore
EMC	Electromagnetic Compatibility
EOL	End of Life
EPGE	Electric Power Generation Enterprise (Myanmar)
ERC	Energy Regulatory Commission (Philippines)
ERC	Energy Regulatory Commission (Thailand)
ERAV	Electricity Regulatory Authority of Viet Nam
ESB	Electricity Supply Board (Myanmar)
ESDM	<i>Energi Sumber Daya Mineral</i> (Ministry of Energy and Mineral Resources, Indonesia)
ESS	Energy Storage System
EV	Electric Vehicle
EVN	Viet Nam Electricity

F	FATs	Factory Acceptance Tests
	F-CV	Flame Retardant XLPE insulation / PVC sheath (Cable type)
	FDI	Foreign Direct Investment
	FR-CV	Flame Retardant or Fire Resistant XLPE insulation / PVC sheath (Cable type)
G	Gatrik	Directorate General of Electricity (Indonesia)
	GFD	Ground Fault Detector
	GHG	Greenhouse Gas
	GW	Gigawatt
H	HSE	Health, Safety, and Environment
	HV	High Voltage
	Hz	Hertz
I	IAEA	International Atomic Energy Agency
	IAF	International Accreditation Forum
	ICT	Information and Communication Technology
	IDR	Indonesian Rupiah
	IEC	International Electrotechnical Commission
	IECEE	IEC System for Conformity Assessment Schemes for Electrotechnical Equipment and Components
	IEE	Institution of Electrical Engineers
	IES	Institution of Engineers Singapore
	IESR	Institute for Essential Services Reform
	IGCC	Integrated Gasification Combined Cycle
	IIIE	Institute of Integrated Electrical Engineers (Philippines)
	ILAC	International Laboratory Accreditation Cooperation
	IMD	Insulation Monitoring Device
	IOs	International Organisations
	IP	Ingress Protection (Rating)
	IPP	Independent Power Producer
	ISC	Institute of Standards of Cambodia
	ISO	International Organisation for Standardisation
	IUJPTL	<i>Izin Usaha Jasa Penunjang Tenaga Listrik</i> (Electrical Supporting Service Business Permit, Indonesia)

K

KATS	Korean Agency for Technology and Standards
KEC	Korea Electric Code
KESC	Korea Electric Safety Code
KESCO	Korea Electrical Safety Corporation
KOH	Potassium Hydroxide
KOLAS	Korea Laboratory Accreditation Scheme
kW	Kilowatt
kWh	Kilowatt-hour

L

LCOE	Levelised Cost of Electricity
LIT	<i>Lembaga Inspeksi Teknik</i> (Technical Inspection Agency, Indonesia)
LNG	Liquefied Natural Gas
LOTO	Lockout/Tagout
LPG	Liquefied Petroleum Gas
LPZ	Lightning Protection Zone
LS	Lao Standard
LSK	<i>Lembaga Sertifikasi Kompetensi</i> (Competency Certification Agency, Indonesia)
LTMS-PIP	Lao PDR-Thailand-Malaysia-Singapore Power Integration Project
LV	Low Voltage

M

MEM	Ministry of Energy and Mines (Lao PDR)
MEMR	Ministry of Energy and Mineral Resources (Indonesia)
Meralco	Manila Electric Railroad and Light Company
MFSD	Myanmar Fire Services Department
MISTI	Ministry of Industry, Science, Technology & Innovation (Cambodia)
MITI	Ministry of Investment, Trade, and Industry (Malaysia)
MLMUPC	Ministry of Land Management, Urban Planning and Construction (Cambodia)
MME	Ministry of Mines and Energy (Cambodia)
MNE	Multi-National Enterprise
MNSC	Myanmar National Standards Council
MOEE	Ministry of Electricity and Energy (Myanmar)
MOEP	Ministry of Electric Power (Myanmar)
MOI	Ministry of Industry (Thailand)
MOST	Ministry of Science and Technology (Lao PDR, Myanmar, Viet Nam)
MOTIE	Ministry of Trade, Industry and Energy (Korea)

MoU	Memorandum of Understanding
MPPT	Maximum Power Point Tracking
MPT	Multilateral Power Trade
MRA	Mutual Recognition Arrangement
MS	Malaysian Standard
MV	Medium Voltage
MW	Megawatt
MWh	Megawatt-hour

N

NADMA	National Disaster Management Agency (Malaysia)
NCDM	National Committee for Disaster Management (Cambodia)
NDT	Non-Destructive Test
NEC	National Electrical Code (US)
NEDA	New Enhanced Dispatch Arrangement (Malaysia)
NEM	Net Energy Metering (Malaysia)
NEMA	National Electrical Manufacturers Association (US)
NIGM	<i>Nederlandsch Indische Gasmaatschappij</i> (Netherlands Indies Gas Company)
NPC	National Power Corporation (Philippines)
NZE	Net-Zero Emissions

O

O&M	Operational & Maintenance
OGEM	<i>Overzeese Gas- en Electriciteitsmaatschappij</i> (Overseas Gas and Electricity Company)

P

PCS	Power Conversion System
PEC	Philippine Electrical Code
PEA	Provincial Electricity Authority (Thailand)
PLN	<i>Perusahaan Listrik Negara</i> (Indonesia)
PMS	Power Management System
PQR	Procedure Qualification Record (Welding)
PUB	Public Utilities Board (Singapore)
PUIL	<i>Persyaratan Umum Instalasi Listrik</i> (Indonesia)
PV	Photovoltaic
PVC	Polyvinyl Chloride

Q	QCVN	Quy chuẩn Kỹ thuật Quốc gia (National Technical Regulations, Viet Nam)
R	R&D	Research and Development
	RCD	Residual Current Device
	RCM	Residual Current Monitor
	RE	Renewable Energy
	REE	Rural Electricity Enterprise (Cambodia)
	RoK	Republic of Korea
	RT	Radiographic Testing
S	SATs	Site Acceptance Tests
	SBU JPTL	<i>Sertifikat Badan Usaha Jasa Penunjang Tenaga Listrik</i> (Electrical Supporting Service Business Entity Certification, Indonesia)
	SCDF	Singapore Civil Defence Force
	SDAT	Site Delivery Acceptance Tests
	SDG	Sustainable Development Goal
	SELCO	Self-Consumption (Solar scheme, Malaysia)
	SESB	Sabah Electricity Sdn Bhd
	SHENA	Safety, Health, and Environment National Authority (Brunei)
	SIRIM	Standard and Industrial Research Institute of Malaysia
	SKTTK	<i>Sertifikat Kompetensi Tenaga Teknik Ketenagalistrikan</i> (Electrical Engineering Personnel Competency Certificate, Indonesia)
	SLO	<i>Sertifikat Laik Operasi</i> (Operation Worthiness Certificate, Indonesia)
	SMK2	<i>Sistem Manajemen Keselamatan Ketenagalistrikan</i> (Electrical Safety Management System, Indonesia)
	SNI	<i>Standar Nasional Indonesia</i> (Indonesian National Standards)
	SOME	Senior Officials Meeting on Energy (ASEAN)
	SPD	Surge Protection Device
	SPLN	<i>Standar PLN</i> (PLN Standard, Indonesia)
	SRE	Sustainable and Renewable Energy
	SS	Singapore Standard
	SSN	Sub-Sector Network
	STAMEQ	Directorate for Standards, Metrology and Quality (Viet Nam)

T

TAGP	Trans-ASEAN Gas Pipeline
TCVN	<i>Tiêu chuẩn Việt Nam</i> (Viet Namese National Standard)
TCXDVN	<i>Tiêu chuẩn Xây dựng Việt Nam</i> (Viet Namese Construction Standard)
TFR-CV	Tray Flame-Retardant Cross-linked Polyethylene insulation / Polyvinyl Chloride sheath (Cable type)
TFEC	Total Final Energy Consumption
TIS	Thai Industrial Standard
TISI	Thai Industrial Standards Institute
TNB	Tenaga Nasional Berhad (Malaysia)
ToR	Term of Reference
TPES	Total Primary Energy Supply

U

UK	United Kingdom (Implied from British)
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UPS	Uninterruptible Power Supply
US	United States
USD	United States Dollar

V

V	Volt
VDMA	Viet Nam Disaster Management Authority
VRE	Variable Renewable Energy

W

WPS	Welding Procedure Specification
-----	---------------------------------

X

XLPE	Cross-linked Polyethylene
------	---------------------------

Executive Summary

This study examines electrical safety management laws and technical standards pertinent to New and Renewable Energy in the Republic of Korea and ASEAN. It outlines Korea's comprehensive safety system structure and legislative evolution, details specific RE safety challenges and inspection protocols, analyses the diverse ASEAN landscape, with its associated gaps, and proposes ways forward, including potential ACE-KESCO cooperation.

Overview of Electrical Safety System in Korea. Korea's electrical safety system involves multiple entities coordinated to protect the public. Key players include the Electricity Utility (KEPCO, power companies) for supply; the Korea Electric Engineers Association for managing safety personnel; the Ministry of Trade, Industry and Energy (MOTIE) for policy and legislation; the Korean Agency for Technology and Standards for product safety; and KESCO for direct safety control through inspection, investigation, R&D, and promotion. Electrical facilities are classified into Business Use (large-scale/power plants), Private Use (factories/apartments), and General Use (homes/offices), with further sub-categories based on voltage and capacity (e.g., $>75\text{ kW}$, $<75\text{ kW}$) to apply tailored safety standards. Safety control relies on mandatory pre-operation assessments and periodic evaluations, distinguishing between rigorous "Inspections" for large-capacity facilities (every 1-4 years) and "Check-ups" for smaller ones (every 1-3 years), driven by the facility's assessed safety degree. KESCO, established under safety legislation and evolved through key institutional expansions (research/education institutes, specialised centres), plays a central role in implementing these controls, conducting research, promoting a safety culture, and providing public services.

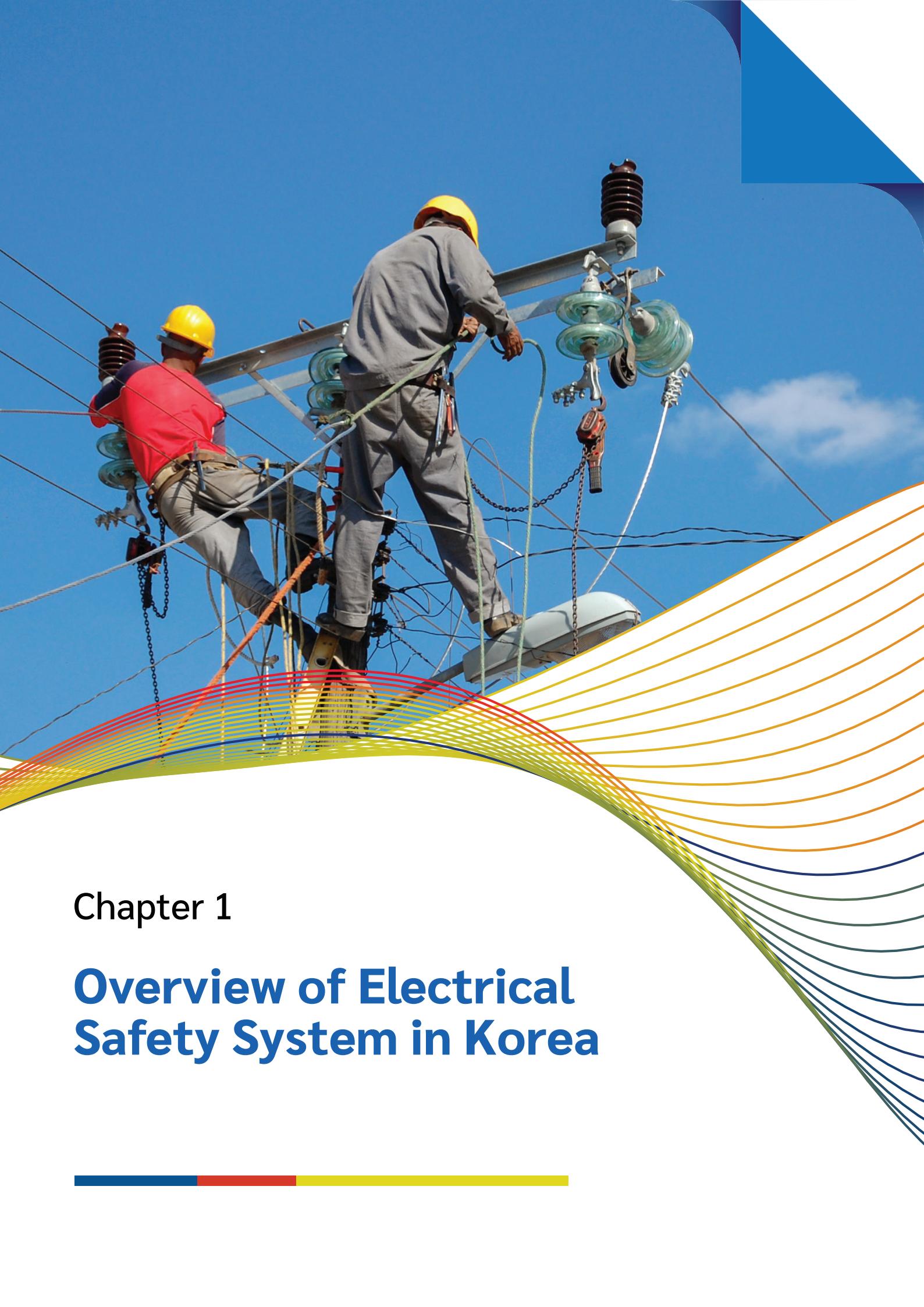
Korea's Electrical Safety Management Act and Master Plans. The Republic of Korea enacted a dedicated Electrical Safety Management Act after 2020, specifically separating safety oversight from the business promotion goals of the older Electric Business Act to provide a clear legal foundation for electrical disaster prevention. This Act mandates the government to create comprehensive 5-year Master Plans directing systematic safety management, including policy improvements, R&D support, and tailored measures for vulnerable facilities and groups. Key elements involve a facility safety grading system, a central information database, expanded safety checks for ageing infrastructure and new technologies like RE and EVs, emergency protocols, and enhanced personnel expertise through education. Korea's future vision aims to strengthen safety-first policies, foster private-sector collaboration, integrate advanced ICT for data-driven oversight, nurture the safety industry, and cultivate a pervasive safety culture.

Inspection and Diagnosis on Renewable Energy Facilities. RE technologies introduce unique safety concerns: wind turbines are prone to structural failures and fire risks; solar PV faces issues from panel damage, installation errors, and fire hazards; Energy Storage Systems (ESS) carry significant risks like thermal runaway and fire suppression difficulties; and water electrolysis and fuel cells require specific hazard management for gases and processes. Korea addresses these through mandated Pre-Operation and Periodic Inspections guided by the Korea Electric Code (KEC) and Korea Electric Safety Code (KESC).

Inspections verify compliance with standards covering electrical systems, structural integrity, site safety, and specific components, utilising various tests (visual, NDT, pressure, functional, monitoring) tailored to each RE type, e.g. PV, Wind, ESS, Electrolysis, and Fuel Cells.

Overview of Electricity Safety System in ASEAN. The ASEAN region is characterised by significant diversity in RE development stages, grid infrastructure quality, economic levels, and institutional capacity. Integrating Variable RE (VRE) safely is challenging, especially on weaker grids, increasing risks of instability and electrical hazards. Safety governance varies, often embedded within multi-functional agencies rather than independent bodies, supported by a complex network of utilities, standards organisations, and ministries. While national laws exist, technical standards show fragmentation, predominantly influenced by IEC, but with varying adoption and legacies from BS and NEC frameworks. RE-specific guidelines are often incomplete or heavily focused on solar PV. Historical colonial influences on foundational electricity systems also impact current standardisation and grid modernisation efforts.

Addressing Gaps in ASEAN's Electricity Management Systems. Compared to Korea's unified approach, ASEAN exhibits gaps in independent safety governance, consistent agency responsibilities (especially disaster management and R&D), standards harmonisation, comprehensive RE safety guidelines, and uniform enforcement rigour. Legacy systems and inadequate grid modernisation further impede safe VRE integration. Lessons from Korea suggest value in dedicated safety legislation, systematic master planning, unified codes, structured lifecycle inspections, and data-driven oversight. Case studies of Indonesia and Cambodia highlight practical enforcement challenges in standards application, inspection protocols, personnel competency verification, and coordination. Recommendations focus on strengthening national frameworks and enhancing regional collaboration through initiatives like the proposed ACE-KESCO cooperation programme.



Chapter 1

Overview of Electrical Safety System in Korea

1.1. Organisational Structure of Electrical Safety in Korea

A comprehensive view of the Electrical Safety Organisation within the Republic of Korea (Korea) is illustrated in Figure 1-1. This system is designed to protect the public, positioned centrally to emphasise that all efforts are ultimately focused on ensuring their safety and well-being. The system is composed of several interconnected entities, each with distinct yet crucial roles:

Electricity Utility: This segment, represented by Korea Electric Power Corporation (KEPCO) and other power companies, forms the foundation of the electrical system. Their primary responsibility is the generation, transmission, and sales of electric power. A stable and reliable power supply is essential, and these entities work to provide that, while also adhering to safety protocols in their operations.

Engineer Management: The Korea Electric Engineers Association plays a vital role in managing the professionals who are directly involved in electrical safety. This includes the education and training of electrical safety managers, as well as their appointment and dismissal. Ensuring that competent and qualified personnel are in charge of electrical safety is paramount to preventing accidents.

Safety Responsibility: The Ministry of Trade, Industry and Energy (MOTIE) is the governmental body that establishes the overarching framework for electrical safety. They are responsible for formulating safety policies, enacting relevant legislation, and enforcing these regulations. This ministry provides the legal and administrative backbone that guides all electrical safety activities in the nation.

Safety Control: The Korea Electrical Safety Corporation (KESCO) is the key player in hands-on safety control. KESCO's activities include inspecting electrical installations to ensure compliance with safety standards, investigating electrical accidents to determine their causes, promoting safety awareness through public campaigns, and conducting research and development to improve safety technologies and practices. KESCO acts as a frontline safety guardian.

Product Safety: The Korean Agency for Technology and Standards focuses specifically on the safety of electrical products. They set standards for these products and ensure that they meet safety requirements. This is crucial because faulty or substandard electrical products can be a significant source of electrical hazards.



Figure 1-1 Electrical Safety Organisation in Korea

1.2. Classification of Electrical Facilities within the Korean System

The classification of electrical facilities is not arbitrary; it's a fundamental step that allows for the application of appropriate safety standards, inspection protocols, and regulatory oversight. By classifying electrical facilities, the system can address the unique risks and characteristics associated with different types of installations. Electrical facilities in Korea are categorised into three groups:

BUSINESS USE: This category encompasses facilities designed for the large-scale generation and distribution of electrical energy to support commercial and industrial activities. These are the powerhouses of the nation's electrical grid. Key examples include:

- ⚡ Power plants, which convert various energy sources into electricity;
- ⚡ Large industrial complexes that require substantial power for their operations;
- ⚡ These facilities are characterised by high voltage and high-power demands, necessitating stringent safety measures to protect both workers and the public.

PRIVATE USE: This category focuses on electrical facilities within privately owned or managed properties, primarily serving industrial or residential purposes. These facilities are essential for supporting production and habitation. Examples include:

- ⚡ Factories utilising electricity to power machinery and production lines;
- ⚡ Complexes that may include a mix of commercial and residential spaces with varying electrical needs;
- ⚡ Apartments, where electricity provides power for lighting, heating, appliances, and other daily necessities;
- ⚡ Safety considerations in this category involve protecting workers in industrial settings and ensuring the safety of residents in living spaces.

GENERAL USE: This category covers facilities that provide electricity for everyday consumption in smaller-scale settings. These are the facilities that directly serve the majority of individual consumers and small businesses. Examples include:

- ⚡ Small houses, where electricity is used for basic needs;
- ⚡ Buildings ranging from small commercial establishments to office buildings;
- ⚡ Offices or Stores, where electricity powers lighting, computers, and other equipment;
- ⚡ Safety in these settings focuses on protecting the general public from electrical hazards in their daily lives.

Figure 1-2 provides an in-depth breakdown of the classification of electrical facilities for business activities in Korea. This deeper elaboration is crucial because it moves beyond the high-level categories to offer specific examples and technical specifications, which dictate the precise safety protocols and regulatory requirements. This granularity ensures that safety measures are appropriately tailored to the unique characteristics of each type of electrical installation.

Electric Facility for Business: This category, dedicated to large-scale energy generation and distribution, is further distinguished between different types of high-power facilities:

- ⚡ **Power Plant:** This refers to the core facilities that generate electricity on a massive scale. These can include various types, each with its own safety considerations:
- ⚡ **Independent Power Producer (IPP):** This designates privately owned entities that generate electricity and sell it to the national grid. Safety regulations at this level ensure that private generators comply with national standards and don't compromise grid stability.
- ⚡ **Substation:** These are critical facilities in the power transmission and distribution network. They transform voltage levels to facilitate efficient long-distance transmission and safe local distribution. The slide specifies:
 - 154 kV Substation: Indicating a high-voltage substation, which requires stringent safety measures due to the inherent dangers of high voltage.

Private Use: This category, encompassing facilities within privately owned or managed properties, is further refined to include:

- ⚡ **Substation:** Similar to the “Business Use” category, these substations might be dedicated to supplying power to large factories or residential complexes. Safety protocols focus on protecting on-site workers and residents.
- ⚡ **Large-scale Factory:** These are industrial facilities with substantial electricity consumption to power heavy machinery, production lines, and other operations. Safety is paramount to prevent accidents involving workers and protect equipment.
- ⚡ **Factory, Building, etc.:** This is a broader classification that captures various industrial and commercial facilities with significant electrical installations, each requiring tailored safety plans.
- ⚡ **Facilities Above 1,000 V, or 75 kW:** This specifies larger private use facilities that, due to their higher voltage or power demand, require more robust safety measures than typical residential or small commercial installations.

General Use: This category, serving the everyday electrical needs of homes and businesses, is detailed based on voltage levels and power capacity:

- ⚡ **Pole Transformer:** These are distribution transformers mounted on utility poles, which step down the voltage of distribution lines to the levels used in homes and businesses (e.g., 380 V or 220 V). Safety considerations include preventing public access and ensuring transformer integrity.
- ⚡ **380 V/220 V Distribution Line:** These are the power lines that deliver electricity to consumers. Safety measures involve maintaining safe distances, insulation, and protection against faults.
- ⚡ **1,000 V or Less, under 75 kW:** This covers the majority of standard general-use facilities, including most homes, small shops, and offices. Safety regulations here focus on protecting the general public from common electrical hazards.

- ⚡ **10 kW or Less:** Generator for Emergency: This refers to backup generators designed to provide power during outages. Safety is critical to ensure proper operation and prevent hazards during emergencies.
- ⚡ **Under 20 kW:** Danger or Multi-Use Facilities: This category highlights facilities that, despite being “General Use,” present unique safety challenges due to their nature or intensity of use. Examples include:
 - Facilities with potentially hazardous environments;
 - Multi-use facilities with high occupancy and complex electrical systems

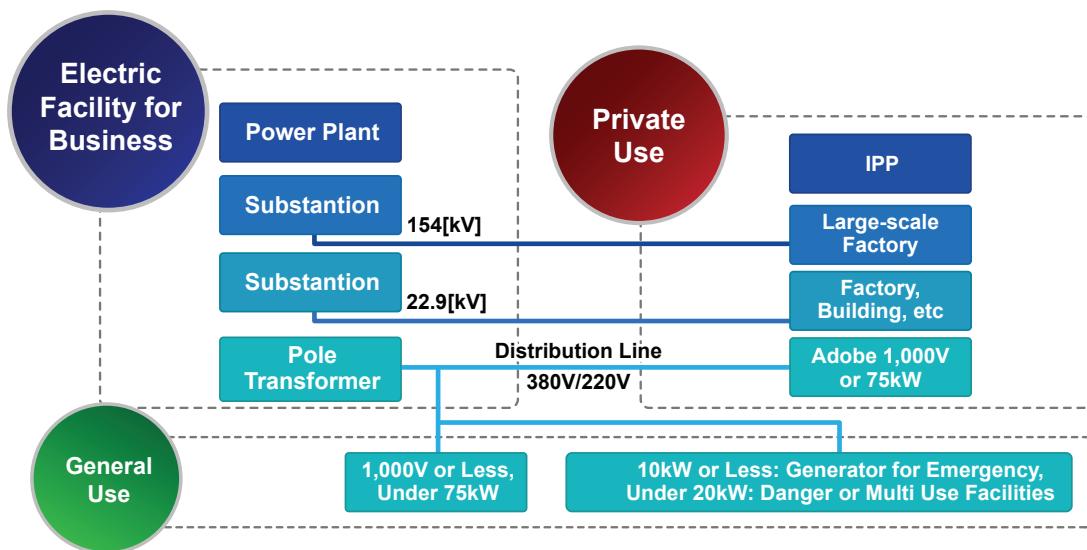


Figure 1-2 Classification of Electrical Facilities for Business

1.3. Safety Control Mechanisms for Electrical Facilities in Korea

The electrical safety control system in Korea comprises two distinct primary activities: Inspection and Check-up.

Inspection is generally a more rigorous and comprehensive evaluation, typically reserved for “large capacity” facilities. These are installations that pose a potentially higher risk due to their size, complexity, or power load. Examples include factories, large buildings, and power plants (facilities “over 75 kW”). Inspections involve a detailed examination to ensure strict adherence to safety standards and regulations.

Check-up, on the other hand, is a less intensive assessment, suitable for “Small Capacity” facilities. These are typically simpler installations with lower risk profiles, such as those found in houses, stores, and involving basic electrical infrastructure like street lamps and traffic lights (facilities “below 75 kW”). Check-ups aim to verify the ongoing safe operation and identify any readily apparent issues.

The decision to conduct an inspection or a check-up is fundamentally driven by the facility’s safety degree. This safety degree isn’t an arbitrary label; it’s a classification meticulously determined by the facility’s conditions. These conditions encompass various factors:

- ⚡ **Capacity:** As highlighted earlier, the electrical load (kW) is a primary determinant. Higher capacity generally translates to higher risk and thus necessitates a more stringent inspection.
- ⚡ **Usage:** The purpose of the facility matters. A hospital, with its critical life-support systems, has a higher safety degree than a small retail shop.
- ⚡ **Complexity:** Intricate electrical systems, like those in a power plant, demand expert inspection.
- ⚡ **Occupancy:** Facilities with a high number of occupants (e.g., apartments and large stores) require stringent safety measures to protect lives.
- ⚡ **Specific Risks:** Some facilities inherently carry higher risks (e.g., those handling hazardous materials).

To enforce these safety measures, the system incorporates a strong regulatory framework:

- ⚡ **Legal Responsibility:** Facility users have a “Legal Obligation for Inspection,” reinforcing the concept that safety is not optional.
- ⚡ **Penalties:** “Punishment or Fine on Violation & Illegal Usage” serve as a deterrent, ensuring compliance.

The frequency of inspections and check-ups is also risk-based:

- ⚡ **Inspection Cycles:** High-risk facilities (e.g., power plants, large factories) undergo more frequent and rigorous inspections. Depending on the specific facility type, inspection cycles vary between 1 year and 4 years.
- ⚡ **Check-up Cycles:** Lower-risk facilities have less frequent check-up schedules. The recommended “self-control” check-up cycles are 1 year, 2 years, and 3 years for different types of occupancies.

Korea’s control system first categorises facilities based on their use and electrical capacity, distinguishing between large-scale electric utility, business/private use, and smaller general use installations to establish a baseline of electrical safety. Before these facilities begin operation or are connected to the power supply, KESCO performs crucial initial assessments—either an “Inspection before Operation” or a “Check-up before Use”—to confirm that the electrical installations meet the required safety and conformity standards as described in Table 1-1.

Electric Utility Facilities: These include power plants, substations, and transformers used for electricity generation and distribution. Before they can operate, KESCO performs an “Inspection before Operation” to confirm the facility’s conformity to safety standards.

Business/Private Use Facilities: These are larger facilities typically found in factories, complexes, and apartments, defined as exceeding 1,000 V, or 75 kW capacity. Similar to utility facilities, KESCO conducts an “Inspection before Operation” to ensure the facility meets requirements.

General Use Facilities: These are smaller installations like those in houses, small buildings, offices, and stores, defined as 1,000 V or lower, and under 75 kW capacity. Before these facilities are supplied with electricity, KESCO performs a “Check-up before Use” to verify conformity.

Beyond the initial setup, continuous electrical safety is maintained through a system of regular, ongoing assessments tailored to the facility's type and potential risk level. This involves periodic "Regular Inspections" for larger capacity facilities used for business or private purposes, which are legally mandated, and "Regular Check-ups" for smaller, general-use facilities, with frequencies for both varying from 1 to 4 years depending on the specific characteristics and usage of the installation.

Business/Private Use Facilities (Large Capacity >75kW): These facilities are subject to mandatory "Regular Inspections" conducted by KESCO every 1 to 4 years. The exact cycle depends on the specific type (e.g., Turbine, Transformer, Wind Blade, ESS, and Fuel Cell), and usage of the facility (e.g., hospitals, hotels, large stores, apartments, factories that might have cycles of 1, 2, 3, or 4 years). This is a legal obligation for the facility users, and violations can lead to penalties. In addition to regular inspections, safety management agents (KESCO or private contractors) perform checks at appropriate intervals.

General Use Facilities (Small Capacity < 75kW): These facilities undergo "Regular Check-ups" by KESCO every 1 to 3 years. The specific cycle depends on the facility type (e.g., facilities for juveniles, kindergartens, traditional markets have 1 or 2-year cycles; schools, single houses, small stores have 3-year cycles). While the check-up cycle is regulated, the emphasis is more on recommending self-control by the owner compared to the strict legal obligation for larger facilities.

Table 1-1 Control System of Electrical Safety in Korea

Electric Utility For Business	Inspection before Operation	Conformity of Power Plant, Substation, Transformer	 KESCO Korea Electrical Safety Corporation
	Regular Inspection	Inspection every 1 ~ 4 Years	 KESCO Korea Electrical Safety Corporation
Private Use (Exceed 1,000V, or over 75kW)	Inspection before Operation	Conformity of Facility	 KESCO Korea Electrical Safety Corporation
	Regular Inspection	Inspection every 1 ~ 4 Years	 KESCO Korea Electrical Safety Corporation
	Safety Management Agent	Check at Appropriate Intervals under a contract with customer	 KESCO + Private Korea Electrical Safety Corporation
General Use (1,000V or Lower, under 75kW)	Check-Up before Use	Check-Up the Conformity before Supply	 KESCO Korea Electrical Safety Corporation
	Regular Check-Up	Check-Up for every 1 ~ 3 Years	 KESCO Korea Electrical Safety Corporation

1.4. KESCO's Role in Korea's Electrical Safety System

The evolution of electrical safety legislation in Korea is driven by the fundamental need to protect citizens and property from electrical hazards, a goal explicitly stated in the purpose of the Electrical Safety Management Act. Historically, electrical safety requirements were likely integrated into broader laws governing the power industry, such as the Electric Business Act, and specific regulations targeting certain products, like the Electric Appliance Safety Control Act (amended in 1999).

Over time, several factors likely pushed toward more comprehensive and dedicated safety legislation:

Industrial Growth and Technological Advancement: As Korea industrialised and technology advanced, the use of electricity became more widespread and complex. This included the rise of power-intensive facilities like data centres, new types of household appliances, and different energy sources (like renewables and energy storage). Increased complexity inherently brings new potential risks and magnifies the potential damage from accidents.

Need for Systematisation: Managing safety across diverse applications—from power generation and transmission, to industrial facilities and everyday appliances—likely necessitated a more systematic and unified approach than scattered regulations might provide. The current Act aims for “systematic electrical safety management”.

Harmonisation with International Standards: There has been a clear effort to align Korean safety requirements with international standards, such as those from the International Electrotechnical Commission (IEC). This harmonisation enhances safety levels and facilitates international trade and recognition.

Focus on Prevention and Public Safety: The core goal shifted towards proactive prevention of electrical disasters and ensuring overall public safety. This involves not just technical standards, but also inspections, research, education, and public awareness campaigns, roles fulfilled by KESCO under the legislative framework.

This historical trajectory, driven by increasing electrical use, technological change, and a desire for systematic, internationally aligned safety practices, culminated in the dedicated Electrical Safety Management Act (enacted 31 March 2020, effective 1 April 2021). KESCO is established under the authority of Korea’s electrical safety legislation. This legal foundation mandates KESCO’s core mission: to safeguard the public and property from the dangers associated with electricity, ensuring electrical safety across the nation.

To achieve its mission, KESCO focuses on two key areas: ensuring the physical integrity of electrical systems and promoting a broader culture of electrical safety.

Inspection & Check: Ensuring Physical Safety. This involves hands-on assessment of electrical installations to ensure they meet safety standards and are operating correctly. This objective translates into specific actions tailored to different types of facilities:

- **Comprehensive Safety Checks:** Performing legally mandated inspections and general safety checks across all types of electrical installations.
- **Business Use Facilities:** Conducting specific inspections for larger facilities that generate or use substantial energy for business purposes (like power plants, substations, large factories). This includes checks before operation and regular inspections during their lifecycle.
- **Private Use Facilities:** Acting as the inspecting body and safety management agency for facilities often found in factories, complexes, and apartments (typically over 75 kW or 1,000 V).

This involves conformity checks before operation, and regular inspections. KESCO may work alongside private agents for ongoing checks under contract.

- **General Use Facilities:** Performing check-ups for smaller installations common in houses, small buildings, and offices (typically under 75 kW and 1,000 V or less). This includes conformity checks before power supply, and regular check-ups (every 1-3 years).

Support & Promotion: Building a Safety Culture & Knowledge Base. This area focuses on activities beyond direct inspection to enhance overall electrical safety awareness, knowledge, and preventative measures:

- **Research & Development (R&D):** Actively engaging in R&D to develop and implement new electrical safety technologies. This includes specialised areas like Energy Storage System (ESS) safety assessments and dedicated research into electrical disasters.
- **Education and Public Relations:** Promoting an “Electrical Safety Culture” through tailored education and public relations programmes designed for different life stages (e.g., infants, seniors). This involves experiential safety programmes and regular campaigns, like the safety campaign held on the 4th of every month.
- **Disaster Investigation and Prevention:** Investigating the root causes of electrical disasters (like fires or shocks) to understand how they happen and develop effective preventative strategies and remedies. This includes sharing know-how and collaborating with other agencies like fire brigades.

KESCO’s journey began with the Association of Korean Electrical Security in 1974, which laid the initial foundation for organised electrical safety efforts. This evolved into the Korea Electrical Safety Corporation (KESCO) in 1990 through a renewal process. Since then, KESCO’s evolution has been marked by strategic expansions of its facilities.

1995: Electrical Safety Research Institute Opened. This coincided with KESCO being designated a responsible entity for disaster investigations. The establishment of the Research Institute was likely driven by the increasing complexity of electrical systems and the need for dedicated, scientific investigation into electrical accidents and safety technologies. It aligns with KESCO’s mandate under safety legislation to conduct surveys, research, and develop technologies related to electrical safety. The institute provides the foundation for developing effective countermeasures and advancing safety protocols.

2000: Electrical Safety Education Institute Opened. Recognising that technical solutions alone are insufficient, this expansion addressed the crucial need for education and awareness. The Electrical Safety Management Act mandates activities related to education, public campaigns, and fostering specialised personnel. The Education Institute provides the necessary infrastructure for specialised training programmes, disseminating safety information to professionals and the public, and cultivating a stronger electrical safety culture nationwide.

2023-2024: Electrical Safety HRDI, ESS Assessment Centre & Electrical Disaster Research Centre Opened. These recent additions reflect KESCO’s adaptation to contemporary challenges.

- **The Human Resources Development Institute (HRDI)** focuses on advanced training and development for the specialised workforce needed to manage modern electrical systems.
- **The Energy Storage System (ESS) Assessment Centre** directly addresses the safety challenges posed by new energy technologies, particularly the rapid growth of RE and associated storage systems, which require specific safety protocols and assessments.
- **The Electrical Disaster Research Centre** is responsible for a further intensification and specialisation of research efforts, focusing specifically on understanding and preventing large-scale or complex electrical disasters.

1.5. Core Components of KESCO's Businesses/Services

The core components of the Korean Electrical Safety System represent the nation's strategic approach to managing electrical risks and ensuring public safety. These components are actively implemented and brought to life through KESCO's main business activities. As the specialised organisation responsible for electrical safety management, KESCO's key operational areas range from preventive management and disaster response, to public services, research, and sustainable practices.

Enforcing Preventive Safety Management. This component emphasises proactive measures to prevent electrical accidents before they happen, going beyond standard inspections.

 **Advanced Analysis & Assessment:** KESCO utilises its “Electrical Disaster Research Centre” to investigate disaster causes and assess/test equipment, including new energy technologies. They also enact and amend the Korea Electrical Safety Code (KESC) based on findings. A notable example is identifying issues with refrigerators leading to a national recall order.

 **Targeted Safety for Vulnerable Facilities:** KESCO identifies and manages risks in facilities deemed vulnerable. This includes assigning “Safety Degrees” (A-E) to places like old apartments (over 25 years), traditional markets, and multi-use venues. Specific standards have been arranged for places like public baths to prevent shock accidents.

 **Proactive Support & Collaboration:** KESCO offers free consulting and supports transformer upgrades for old apartments (over 532 diagnosed). They also implement concrete safety management plans for military facilities and old industrial sites, often collaborating with partners like the Army or the Ministry of Environment.

Social Safety with Developed Disaster Management. This component focuses on a comprehensive disaster management cycle – preparation, response, and recovery – ensuring societal resilience against electrical hazards and related disruptions.

 **Structured Disaster Management Cycle:** KESCO follows a four-stage approach: Precaution (preventive checks in places like cultural heritage sites, traditional markets), Preparation (preparedness training), Response (maintaining business continuity via standards like ISO 22301 and KOSHA-MS), and Restoration (support after events like typhoons, earthquakes, heavy rain).

 **Risk Identification and Mitigation:** KESCO actively discovers “blind spots” for disasters, considering factors like facility aging and social issues. They also arrange legal education for civil engineers to reduce electrical accidents during construction or maintenance.

 **National Support:** KESCO provides crucial electrical safety support during national events (like elections) and vulnerable periods (rainy season, holidays), operating special HQs and dispatching professionals. In 2023, they handled 33,825 such cases according to the data presented, split between governmental orders, special occasions, and vulnerable periods.

Providing the Best Safety Service for People. This aspect highlights KESCO’s commitment to providing accessible, direct safety assistance and welfare services, particularly targeting vulnerable populations.

 **Targeted Welfare Programmes:** KESCO runs initiatives like a 5-year programme (2020-24) improving home electrical conditions for the disabled (618 sites, USD 4.9M budget) and provides free safety checks and improvements for veterans (1,308 houses) and residents in old apartments (6,802 units).

 **Comprehensive Emergency Services:** KESCO offers several 24-hour emergency services:

- *ES-911*: A first-aid service for electrical issues targeted at socially vulnerable groups (handling 26,000 cases mentioned).
- *ES-SOS*: An emergency service for apartments, sharing blackout information with the main utility (KEPCO) and offering free consultations.
- *ES-Sheriff*: Utilises local contractors as “sheriffs” to provide emergency services in isolated areas like remote islands (28 mentioned) and mountainous regions (22 mentioned). They also appoint ‘ES Honor Sheriffs’ in small islands lacking electrical engineers.

Promoting Investigation, R&D, Public Relations, and Education. This component underscores the importance of continuous learning, technological advancement, and public engagement in maintaining electrical safety.

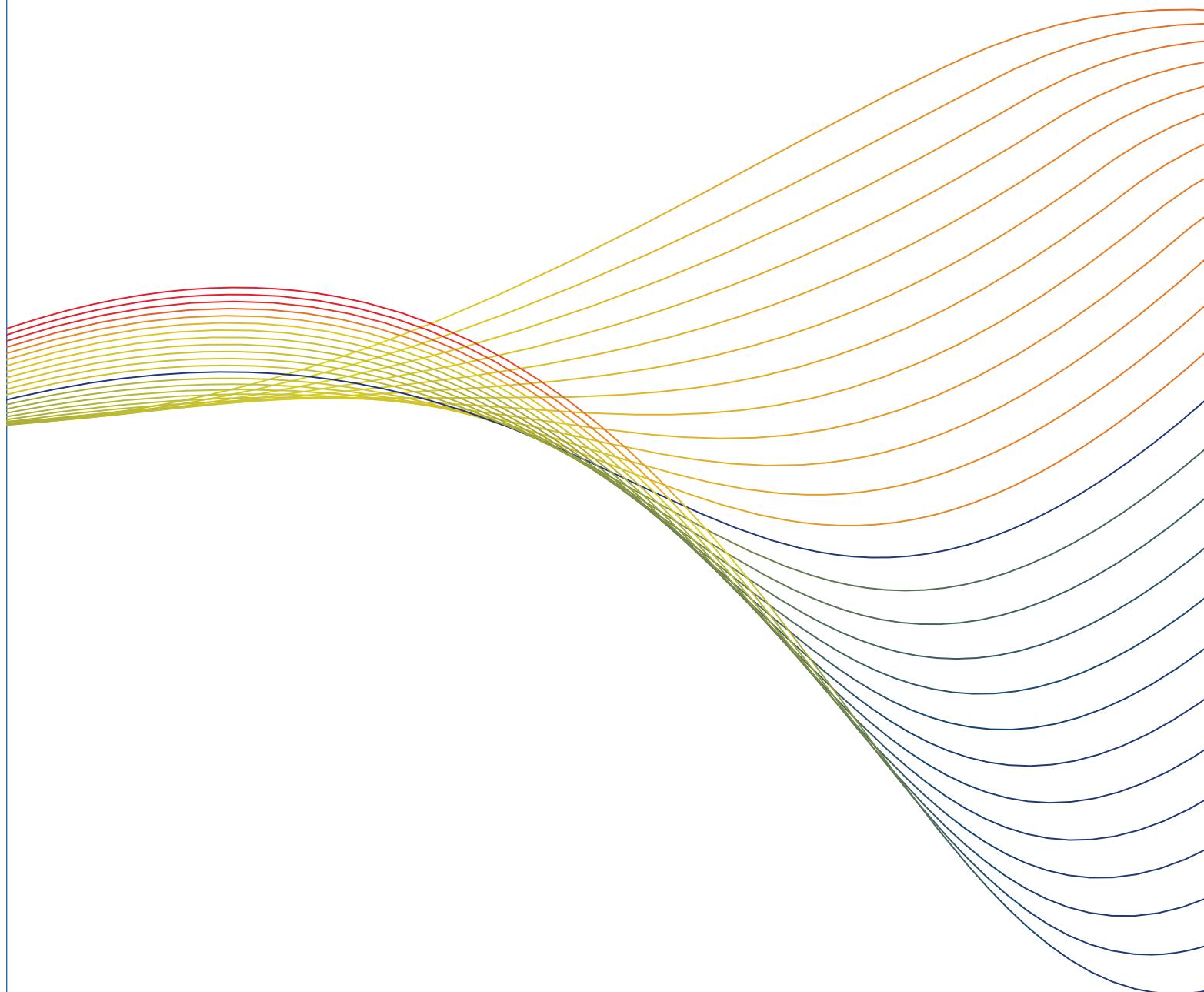
 **Systematic Incident Investigation:** KESCO operates a joint investigation system with 90 investigators across its branches to determine accident causes accurately. They focus on developing know-how and hold seminars and discussions with relevant bodies like fire brigades.

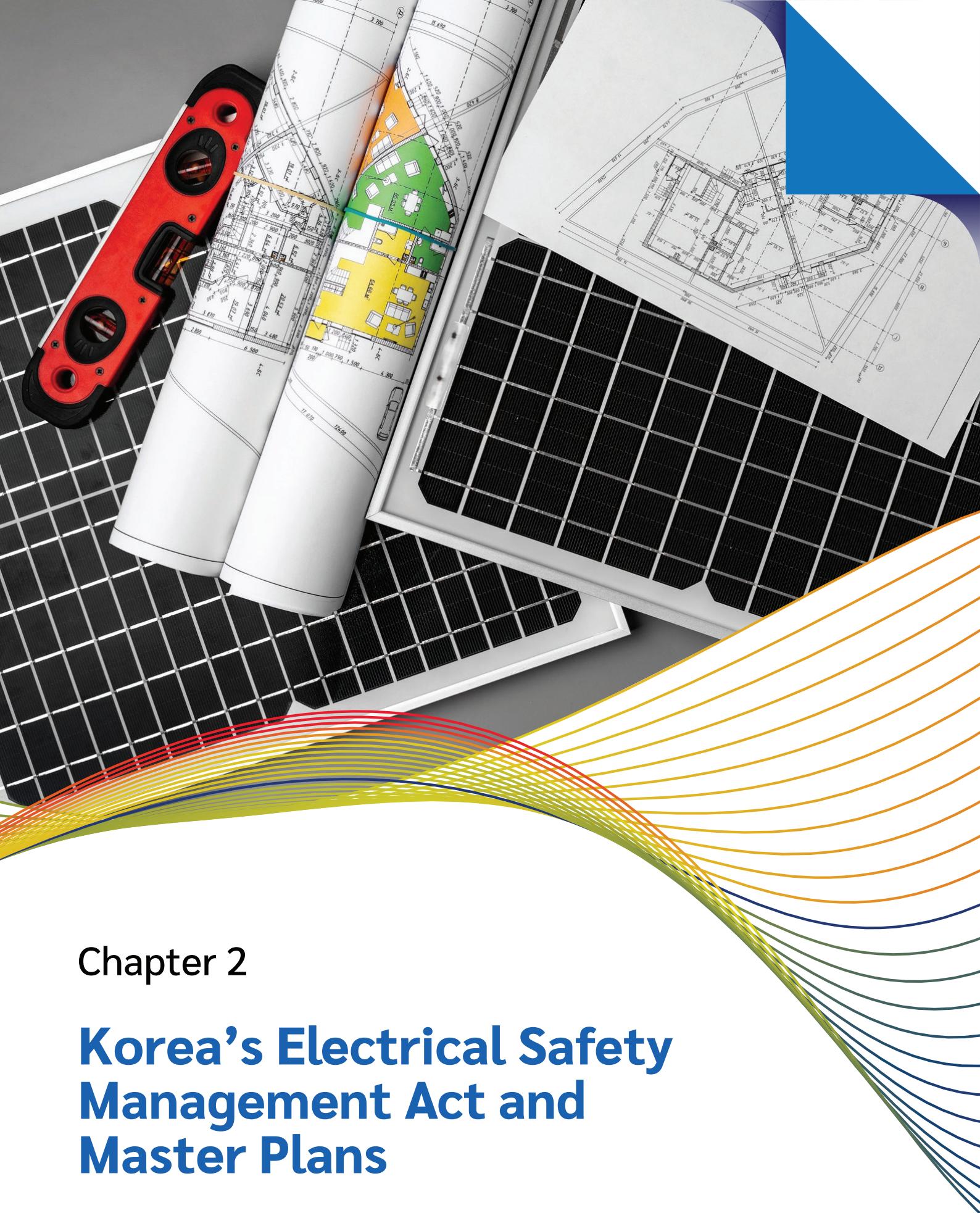
 **Applied Research & Development:** KESCO follows a cycle of developing, demonstrating, and implementing R&D technologies via its Electrical Safety Research Institute. Key focus areas include ESS Safety Assessment, Electrical Disaster Research, and exploring new safety technologies.

 **Targeted Education & Promotion:** KESCO aims to promote an “Electrical Safety Culture” through customised public relations and education programmes designed for different life cycle stages (infants, seniors, etc.). This includes experiential safety programmes to raise awareness and a recurring safety campaign on the 4th of every month.

KESCO’s ESG Initiatives. This shows KESCO integrating broader sustainability and ethical considerations into its core mission and operations.

- ⚡ **Environmental (KESCO Carbon Diet):** Supporting the reuse of waste batteries (e.g., from EVs through a “Regulatory Sandbox,” supporting 36 cases) and introducing measures like virtual corporate cards to reduce carbon footprint.
- ⚡ **Social:** Initiatives include the “Universal Art Troupe” featuring disabled individuals to promote safety culture and create jobs, and the “Dream-ON Project” offering basic life support, mentoring, and employment opportunities for youth needing assistance toward independence.
- ⚡ **Governance:** Implementing ethical business practices with a designated “CEO” (Chief Ethics Officer), promoting an “Ethics & Human Rights Day,” and using a “Conflict of Interest Prevention System” as part of its Corporate Social Responsibility (CSR) efforts.





Chapter 2

Korea's Electrical Safety Management Act and Master Plans

2.1. Introduction to the Electrical Safety Management Act

Republic of Korea (Korea) addressed electrical safety before 2020. The “Electrical Appliances Safety Control Act” was enacted in 1974, focusing on consumer protection from hazards like fires and shocks related to specific appliances. General oversight of the electricity sector, including some safety aspects, fell under the broader “Electric Business Act”.

Over time, it became clear that incorporating comprehensive safety management within the Electric Utility Act had drawbacks. This led to conflicts between promoting the electricity business and ensuring public safety, and the government’s limited ability to implement robust, dedicated safety policies. The Electric Business Act’s primary focus was on the business aspects, licensing, and market structure.

Several major man-made disasters throughout its modern history (e.g., Sampoong Department Store collapse 1995, Daegu subway fire 2003) while not all were electrical, these events significantly increased public awareness and demand for stronger safety regulations and enforcement across all sectors, contributing to the political environment more receptive to specialised safety legislation. The increasing complexity of electrical systems, the rise of new technologies (like renewables and energy storage), and the desire for a more proactive, systematic approach highlighted the inadequacies of the older act.

The Electrical Safety Management Act was enacted with a clear and focused purpose: to protect lives and property and to ensure public safety by establishing comprehensive measures for preventing electrical disasters and effectively managing electrical installations.

A recognised gap in the regulatory framework prompted the need for a separate legal instrument dedicated specifically to electrical disaster prevention—distinct from the existing Electrical Business Act. The earlier law combined both economic objectives (promoting the electricity industry) and social responsibilities (ensuring public safety), which often led to conflicts between commercial interests and regulatory oversight.

The new Act resolved this tension by establishing an independent legal foundation centred exclusively on electrical safety management. Its goal is to prevent electrical disasters—defined as accidents such as fires or electric shocks that pose risks to human life and property—through a regulatory regime that prioritises safety above business interests.

The Electricity Management Act mandates the government to establish and implement policies for electrical safety management. This includes formulating 5-year master plans to systematically manage safety, improve systems, support R&D, and enhance welfare services, particularly for vulnerable groups. The Act’s main contents focus on three core pillars: advancing safety management through systematic planning, grading systems, and integrated data management; strengthening disaster prevention with expanded safety checks for various facilities, including aging infrastructure and new technologies, alongside provisions for emergency measures; and improving the overall safety ecosystem by boosting the expertise of personnel and refining the business conditions for safety management services.

2.1.1. Advancements in Energy Safety Management

A key component of the Electrical Safety Management Act involves modernising the overall approach to safety oversight. This is achieved through several strategic advancements detailed in the legislation,

including the establishment of structured long-term planning, the implementation of a performance-based facility grading system, and the development of a comprehensive national database for safety information.

Master Plans. The Act mandates the MOTIE to formulate and execute a comprehensive master plan for electrical safety management every five years. These plans outline mid-to-long-term policies, system improvements, support for safety services, education, R&D, and welfare for vulnerable groups. The first such plan specifically aims to strengthen tailored safety management for vulnerable areas over five years, like multi-use facilities (including newly added sectors like escape rooms and kids' cafes), industrial complexes, and socially disadvantaged groups. An advisory committee composed of specialised agencies and organisations assists MOTIE in efficiently establishing and promoting these policies.

Safety Grade System: A system grades the safety condition of facilities like traditional markets, district electric businesses, and multi-use facilities on a scale. Facilities achieving a superior grade (e.g., 'A') may benefit from an extended inspection cycle by one year.

Total Information System: The Act requires establishing a comprehensive system to manage electrical safety data. This includes collecting and managing information, such as inspection results, check-up details, electrical safety manager appointments, and disaster statistics. Key information is subject to public disclosure. KESCO plays a role in managing electrical disaster statistics.

2.1.2. Strengthening Electrical Disaster Prevention

Recognising the need for enhanced preventative measures, the Electrical Safety Management Act significantly strengthens proactive efforts to avert electrical disasters. The Act details expanded safety check obligations targeting specific areas of concern, such as aging residential buildings and newer technologies like RE installations and EV charging points. The Act also equips authorities with clear powers for emergency safety interventions when immediate risks are identified.

Expanded Safety Checks: The Act mandates safety checks for various facilities, expanding oversight:

- **Old Apartments:** Regular check-ups are required for apartments over 25 years old.
- **Rural Accommodations & EV Charging Infrastructure:** Safety checks are extended to accommodations in rural areas and EV charging infrastructure.
- **Renewable Energy (RE):** Facilities like ESS require inspection before operation, with specific checks based on the energy source, structure, and system. This aligns with broader national plans addressing the volatility introduced by increased RE.

Emergency Safety Measures: In situations posing a high risk of electrical disaster (shock, fire), authorities can order emergency measures. These measures can include repair, relocation, demolition, or suspension of the facility's use. This complements the national electricity emergency response manual, which outlines broader procedures (like demand restraint and load-shedding) based on supply levels under the Electric Utility Act framework.

2.1.3. Improving Expertise and Business Conditions

Beyond direct facility oversight, the Electrical Safety Management Act also aims to bolster the foundational elements supporting electrical safety nationwide. This involves specific measures designed to improve the expertise of personnel involved in electrical work through mandatory education, alongside initiatives to enhance the operational environment and professional standards for safety managers and specialised safety management businesses.

Manager and Contractor Expertise: Mandatory safety education is required for electrical contractors to prevent accidents during construction. KESCO is involved in providing specialised education concerning electrical safety.

Facility Management Businesses: New registration standards covering capital, engineers, and tools are established to enhance the expertise of businesses specialising in electrical safety management.

- **Safety Agents:** The scope of business for safety agents is expanded, for example, to include remote monitoring and control of PV systems up to a certain capacity (e.g., 3 MW).
- **Safety Manager Protections:** The Act aims to improve conditions for electrical safety managers by establishing standards for facility improvement costs and prohibiting unfair treatment like termination or salary suspension related to their safety duties. This is managed within the broader context of the Electric Business Act, which governs the licensing and structure of electricity-related businesses.

2.1.4. Broader Scope

The Electrical Safety Management Act provides a far-reaching and integrated legal framework for electrical safety in Korea, extending well beyond the previous three key functions. It depicts the Act as a central governing structure that encompasses the entire lifecycle and administration of electrical safety. This broad scope as presented in Figure 2-1 includes:

Strategic Direction: This aspect underscores the Act's role in setting the long-term vision and policy for electrical safety nationwide. It is primarily embodied by the mandatory formulation of Electrical Safety Master Plans.

Comprehensive Oversight: The Act establishes a multi-layered system for monitoring and verifying the safety of electrical installations throughout their lifecycle. This includes mandatory **Inspections** (both pre-use before operation, and regular periodic inspections) and various **Check-Ups** (pre-use, regular, and specific checks for public utilities). Oversight is further enhanced by embracing technology through **Remote Check-ups** linked to control centres, and conducting targeted **Safety Check-Ups** for specific high-risk or public locations like markets and apartment complexes, or during specific vulnerable times.

Performance and Risk Management: The Act moves beyond simple compliance checks toward managing safety performance and risks. This is evident in the implementation of a **Safety Grade system** for key facilities like power plants and public utilities, allowing for differentiated management based on assessed risk or performance. It also explicitly includes **Precautions**, which involves proactive measures and defining procedures for **Emergency Precautions** to be taken in the event of electrical accidents, aiming to mitigate potential harm.

Human Element Management: Recognising the critical role of people in ensuring electrical safety, the Act addresses the management and qualification of personnel involved. This includes regulations concerning **Manager Appointment**, outlining requirements for facilities to designate responsible individuals (either their own staff or through **Management Delegation** to specialised firms). Crucially, it mandates specific **Education** for Electrical Safety Managers to ensure they possess the necessary knowledge and competence.

Information and Accountability: The Act establishes mechanisms for transparency, learning from incidents, and enforcing compliance. It mandates Investigations into the causes and details of electrical disasters and accidents. It also requires the creation of a **Total Safety Data Centre** to systematically collect, manage, and analyse data regarding accidents, statistics, and the status of electrical safety nationwide. Finally, the Act provides the legal basis for **Punishment & Fines**, ensuring accountability for violations of safety regulations and standards.

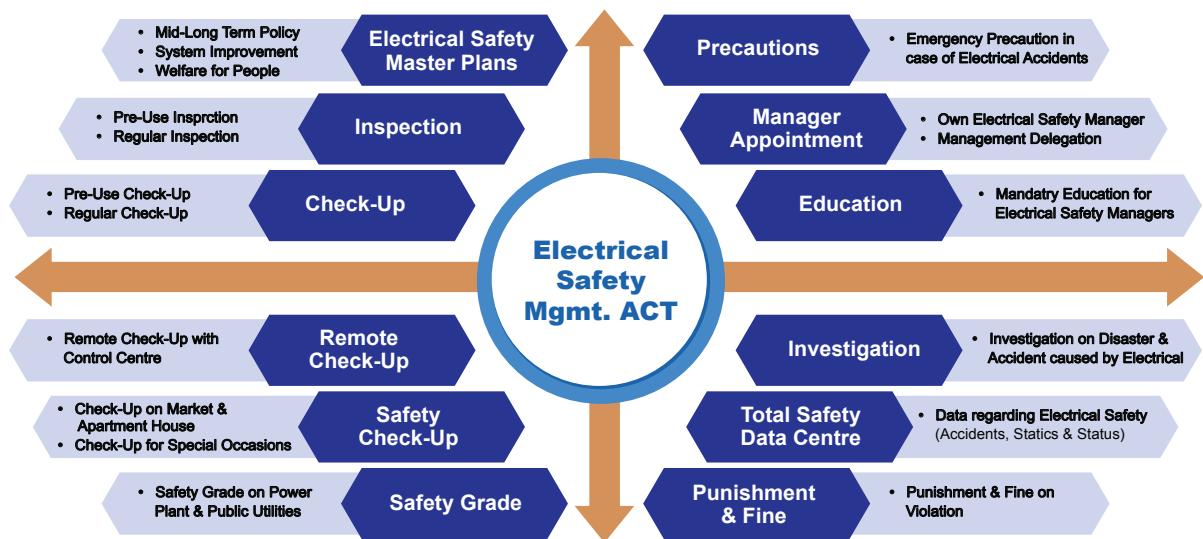


Figure 2-1 Core Components of the Electrical Safety Management Act

2.2. Master Plans of Electrical Safety Management

The current Master Plans provide a legal and integrated framework for enhancing electrical safety across the board. Encompassing everything from residential homes to large-scale power generation facilities, these pan-governmental plans are developed through a consultative process involving the Energy Committee, public hearings, and relevant stakeholders. Their purpose is to define the mid-to-long term direction, drive policy improvements, foster necessary R&D and public awareness, and ensure safety considerations extend even to the most vulnerable populations.

With the framework established, the Master Plans articulate a clear mission: to cultivate a safe society through dedicated and effective electrical safety management. This broad mission is distilled into four core, interconnected objectives, forming the strategic pillars of the plan:

Strengthening Customised Electrical Safety for Vulnerable Sectors: Establishing robust preventative safety management by reinforcing vulnerable multi-use facilities, creating customised safety systems

tailored to different energy sources, actively identifying and eliminating safety blind spots, and implementing optimal and rigorous safety quality control.

Flexible Electrical Safety based on sites: Introducing inspection & management methods based on risk level, Real-time response on electrical disasters, and Advancing safety management system.

Innovating Safety Tech with High-Tech: Embracing digitalisation as a key enabler, leveraging AI and advanced technologies for smarter safety management, adapting systems to counter climate change impacts, and significantly expanding R&D efforts.

Foundation of Electrical Safety by Civil-Driven: Actively cultivating a mature safety culture through targeted education for professionals and the public, promoting proactive safety practices, and using diverse channels to embed safety awareness deeply within the community.

Translating the mission and objectives into tangible outcomes, the Master Plans detail a wide array of specific initiatives across multiple fronts:

- ⚡ **Closing Safety Gaps:** Aggressively eliminating blind spots by intensifying checks on older infrastructure like aging apartments (including checks during property transactions and support for transformer upgrades), extending oversight to previously less-regulated areas like rural accommodations and EV charging stations, and providing enhanced safety support for vulnerable groups. Precise inspections for large facilities and tailored policies for EV charging infrastructure types are also considered.
- ⚡ **Enhancing Management Quality and Adapting to Renewables:** The plans improve the quality of safety management services through provider assessments and ensure safety regulations are actively reviewed during inspections. Critically, they establish dedicated safety systems for RE facilities, coordinate institutional efforts, and develop specific standards for new energy sources, such as hydrogen and floating wind, throughout their lifecycle.
- ⚡ **Leveraging Technology and Building Resilience:** Implementing digitalisation across safety management through expanded remote monitoring, smart systems, such as always-on monitoring and condition-based risk management for equipment, and big data analytics for risk prediction. Simultaneously, the plans address climate change adaptation by developing specific prevention systems, improving disaster response coordination, and building overall response capacity.

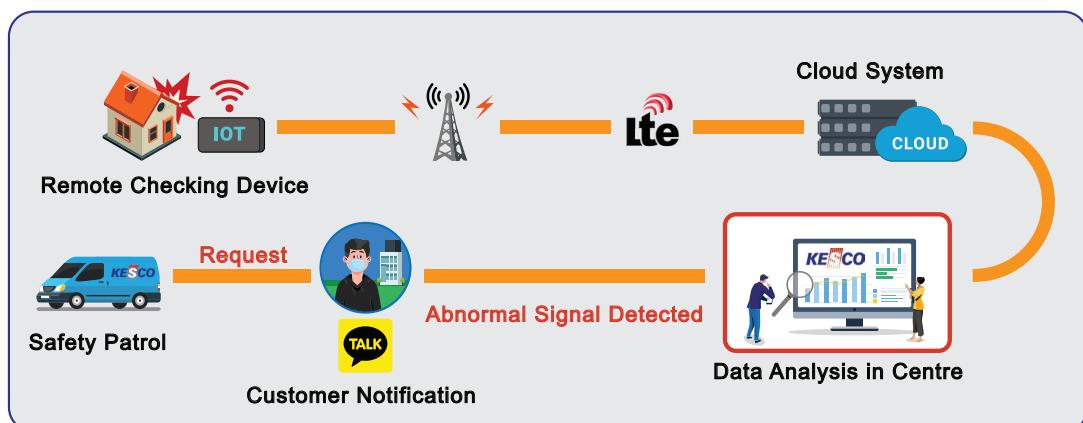


Figure 2-2 Remote Checking System on Electrical Facilities

Investing in Future Capabilities: Significantly investing in R&D and demonstration infrastructure, including facilities for disaster cause analysis, testing transmission/distribution tech, and assessing new ESS solutions. This commitment extends to human resources, with programmes for educating officials and managers, engaging youth, and utilising modern educational tools like virtual reality.

Broadening Impact through Cooperation and Culture: Fostering international cooperation to share knowledge and adopt best practices, developing local safety clusters to support key industries, improving data collection on electrical disasters, and potentially linking safety grades to insurance. Foundational to all this is a concerted effort to cultivate a pervasive safety culture through targeted awareness campaigns, educational events, and broad public relations efforts using diverse media channels.

Looking beyond the current implementation of the Electrical Safety Management Act and its associated Master Plans, the vision for the future entails a significant transformation in Korea's approach to electrical safety. This future concept, outlined as a shift from the present state, envisions fundamental changes concerning how safety is managed, how the related industry develops, and how safety culture permeates society.

Evolution in Safety Management: The future vision for safety management involves a fundamental shift towards clearer, safety-first policies, moving away from potential legal ambiguities of the past. It emphasises a transition from top-down government control to a collaborative approach, fostering partnerships with the private sector and adopting a two-way communication style for promoting safety initiatives. Furthermore, management practices are set to evolve significantly through the comprehensive integration of Information and Communication Technology (ICT), enabling more dynamic, data-driven oversight beyond traditional on-site inspections.

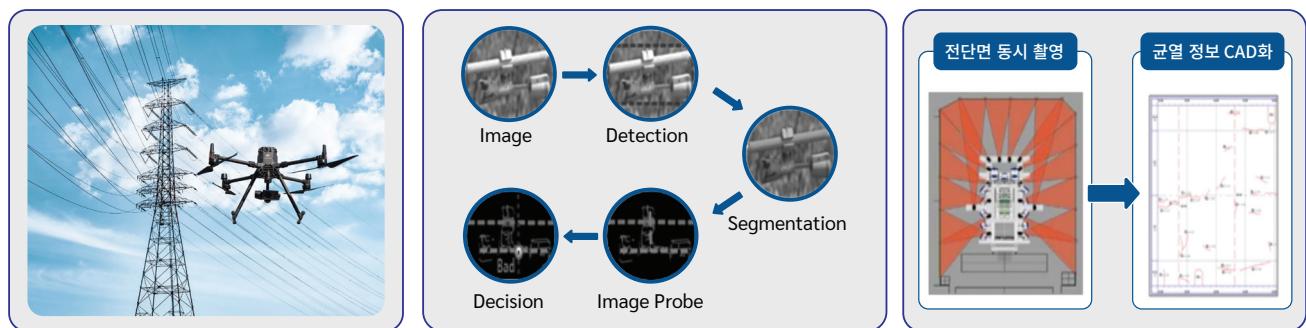
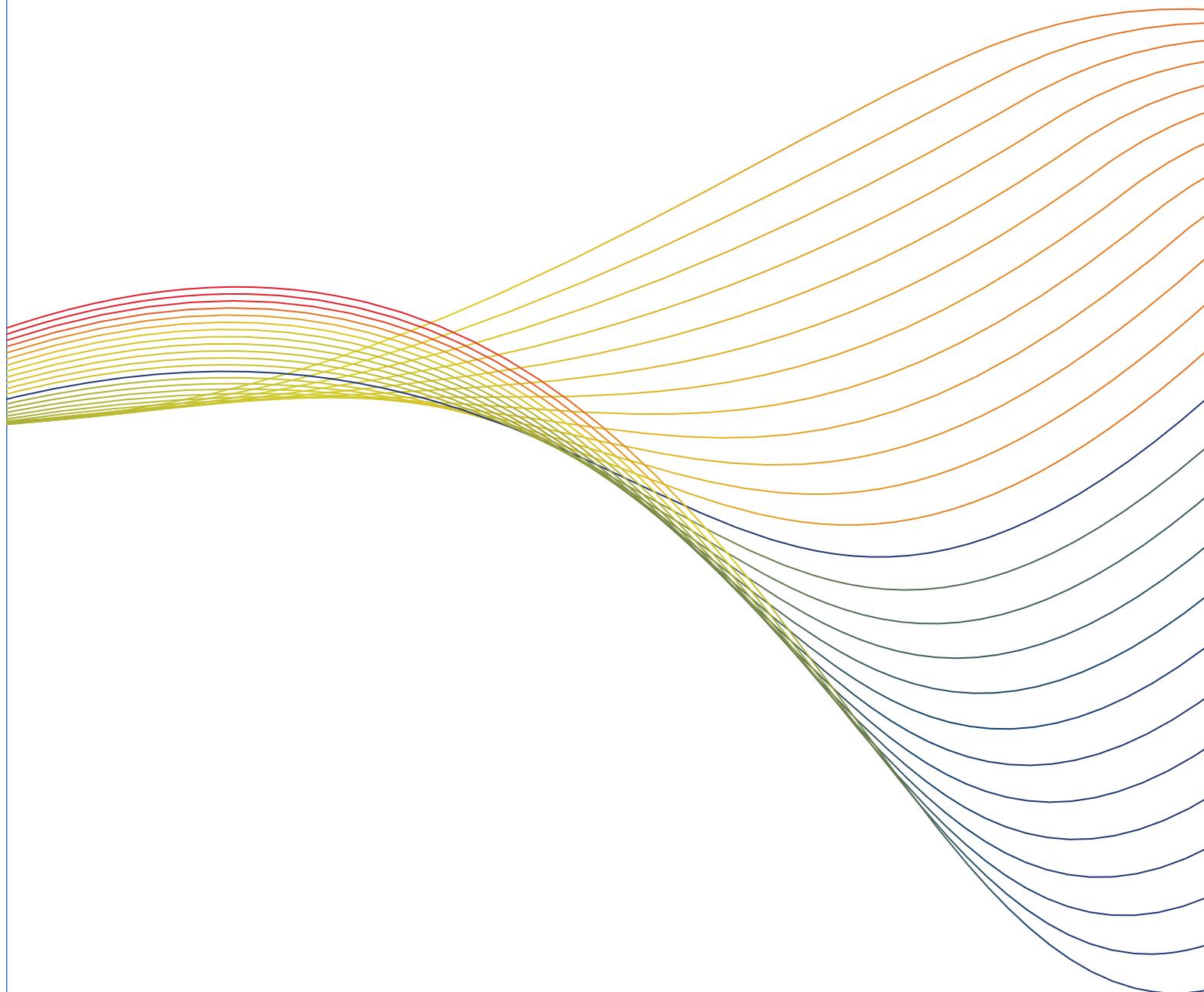


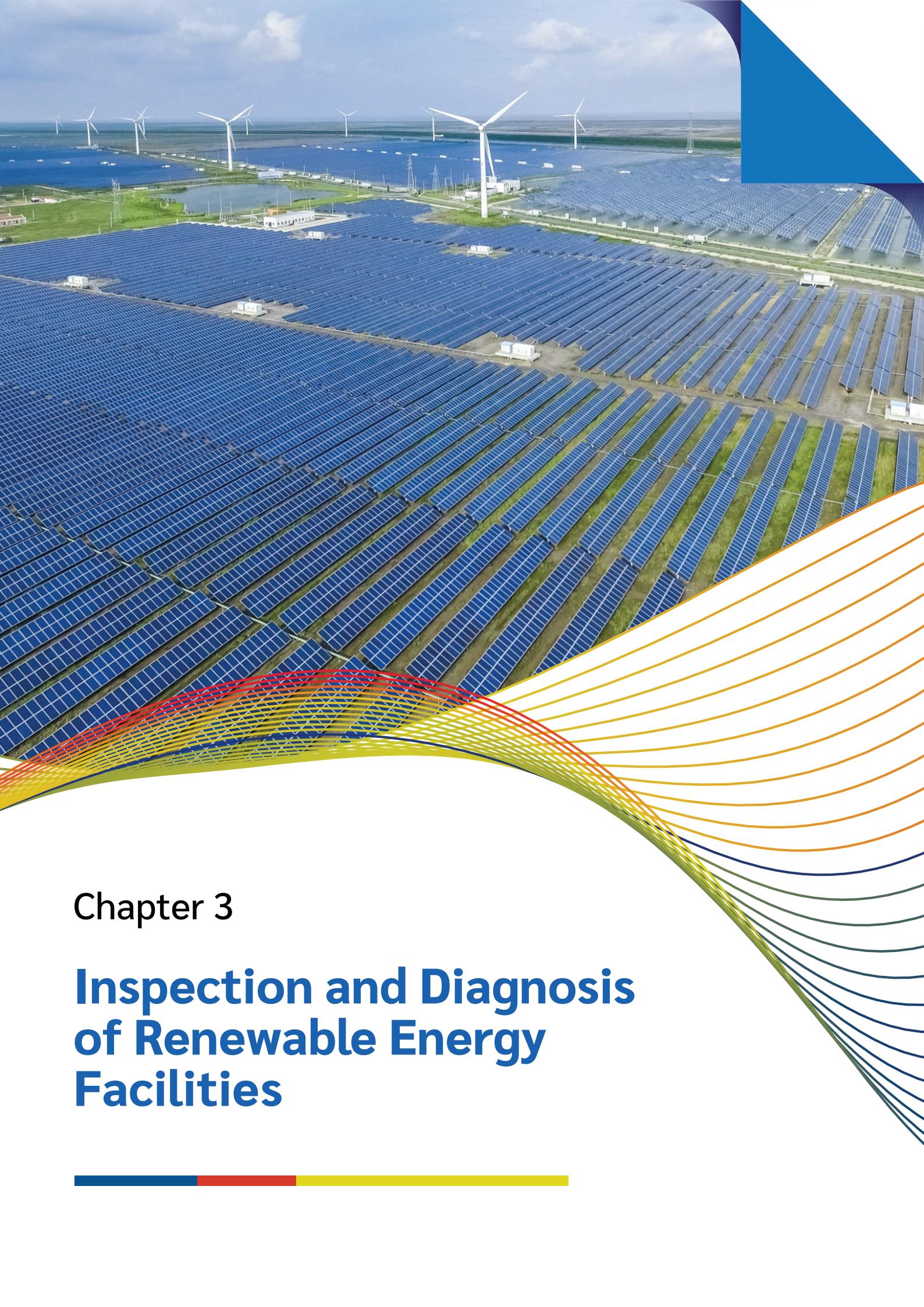
Figure 2-3 Promising Safety Tech in Future

(a) Inspection by Self-flying Drone; (b) Judgement with Image Recognition; (c) Tunnel Scanning Tech

Advancement in the Safety Industry: Looking ahead, the plan focuses on actively developing the electrical safety industry to drive growth and foster the emergence of specialised companies capable of creating and deploying advanced safety solutions. Central to this effort is the systematic development of human resources, aimed at cultivating deeper expertise and technical skills, thereby overcoming the limitations of previous training systems. To support this evolution, the strategy also emphasises building a strong technological foundation through targeted investment in infrastructure essential for the development and adoption of next-generation safety technologies.

Cultivating a Stronger Safety Culture: A core aspect of the future concept is the deliberate cultivation of a pervasive and participatory electrical safety culture throughout society. This means moving beyond a baseline level of awareness to instil safety as a shared value and priority for all citizens and organisations. Public engagement strategies will also transform, shifting from one-way government pronouncements toward interactive, two-way communication methods that encourage active civil participation, feedback, and shared responsibility in maintaining electrical safety.





Chapter 3

Inspection and Diagnosis of Renewable Energy Facilities

3.1. Safety Failures in Renewable Energy Facilities

Renewable energy facilities, while crucial for a sustainable future, present unique electrical safety challenges. These range from structural failures due to environmental stress, to complex fire risks inherent in energy generation and storage technologies. Understanding these problems is vital for ensuring the safe deployment and operation of these systems. This section highlights key issues like collapses and fires across different renewable technologies.

3.1.1. Wind Turbine Safety Problems

Wind turbines, often large structures placed in exposed locations, face significant safety challenges related to both mechanical stress and complex electrical systems. Failures can be dramatic and hazardous, involving component breakdown, structural collapse, and fire risks within the nacelle (the housing at the top of the tower).

Structural and Mechanical Failures: Turbines can collapse, and catastrophic failures can occur in various components. Blades are subject to immense stress and can fail due to fatigue or extreme weather. Gearboxes, operating under high loads, are prone to wear and failure. Generators can fail due to overheating or electrical faults. Even the tower structure itself can fail due to fatigue, corrosion, or foundation issues.

Electrical Hazards: Key electrical risks include:

- **Arc Flash:** A dangerous release of energy caused by an electrical fault, posing severe burn and blast risks.
- **Electric Shock:** Risk from contact with energised components, exacerbated by potentially wet environments inside or outside the turbine.
- **Component Failures:** Overloaded circuits, defective insulation, and worn or damaged equipment increase the risk of electrical faults, shock, and fire.
- **Lightning Strikes:** Due to their height, turbines are vulnerable to lightning, which can damage electrical systems, control systems, and blades, potentially causing fires.
- **Fire Risks:** Fires can ignite within the nacelle due to electrical faults, overheating components, or flammable materials like lubricants and insulation. Fire suppression is challenging, and fighting fires can expose responders to toxic gases and oxygen depletion in the confined space of the nacelle.

3.1.2. Solar Panel / Solar Plant Safety Problems

Solar installations, from rooftop systems to large-scale plants, involve risks primarily associated with panel damage, installation quality, and the inherent electrical nature of the components. While generally safe when installed correctly, failures can lead to reduced efficiency, electrical shock, and fire hazards.

Panel Damage: Panels can be damaged physically (e.g., cracked glass from hail or impact, damaged frames) or electrically, e.g. internal cell damage, 'hotspots' where a damaged cell overheats. Environmental factors like high winds and lightning also pose risks.

Installation and Component Issues: Faulty installation is a significant concern, especially with DIY systems. Improper wiring, loose connections, incorrect earthing, and the use of substandard components (like inverters or connectors) can lead to overheating, electrical arcs, reduced system lifespan, and increased fire risk.

Electrical Hazards:

- ⚡ **Shock Risk:** Damaged panels with exposed wiring or components, especially if moisture enters, create a risk of potentially lethal electric shock. Panels generate DC electricity in daylight even when disconnected.
- ⚡ **Fire Risk:** Hotspots, electrical arcs from poor connections or faults, and malfunctioning components like bypass diodes or inverters can lead to overheating and potentially ignite surrounding materials.

3.1.3. Energy Storage System Safety Problems

Energy Storage Systems, often utilising lithium-ion batteries, are increasingly paired with renewables, but introduce specific and significant safety concerns, predominantly related to fire and explosion risks stemming from the battery technology itself.

Thermal Runaway: This is a critical hazard in battery systems. It's an uncontrolled chain reaction where increasing temperature causes a cell to release more heat, which can propagate to neighbouring cells. This rapid energy release can result in fire, smoke, and potentially explosion. It can be initiated by various 'abuse' factors:

- **Mechanical Abuse:** Physical damage like crushing or penetration.
- **Thermal Abuse:** Exposure to external heat sources.
- **Electrical Abuse:** Overcharging, charging too rapidly, or discharging too rapidly.
- **Internal Defects/Aging:** Manufacturing flaws or degradation over time.
- **Environmental Factors:** Flooding, seismic activity, extreme heat.

Stranded Energy: A unique hazard where batteries involved in a fire can retain a significant electrical charge even after the event. This poses a shock risk during overhaul and clean-up, and the stored energy can potentially cause the fire to reignite hours, days, or even weeks later.

Toxic and Flammable Gas Generation: Batteries release hazardous gases during thermal runaway or fire. If these flammable gases accumulate within an enclosure without igniting immediately, they can form an explosive atmosphere.

Difficult Fire Suppression: ESS fires are often deep-seated within protective casings and battery modules. This makes it challenging for extinguishing agents like water to reach the core of the fire and effectively cool the batteries, often requiring very large volumes of water.

3.2. Safety Management of Renewable Energy Facilities in Korea

Effective safety management is crucial for mitigating the risks associated with RE facilities. The systematic approach within the Korean regulatory context involves governing laws, technical codes, and detailed inspection procedures.

National legislation, which empowers regulatory bodies and defines the requirements for different inspection stages, is the foundation of mandatory safety inspections. The safety management process is mandated by specific laws. These laws are the Electric Utility Act (Article 63) and its Enforcement Regulations (Article 31), which specifically govern the Pre-Operation Inspection phase, and Electric Safety Management Act (Article 18) which mandates the requirements for ongoing Periodic Inspections during the facility's operational life.

To ensure consistency and technical rigour, inspections are performed against standardised codes that detail the specific safety requirements for electrical installations. Compliance is measured against established technical codes:

- ⚡ **Korea Electric Code (KEC):** This serves as the foundational set of safety standards for electrical installations, covering requirements for design, installation, earthing, protection against hazards (like overcurrent, surges), and maintenance. It ensures a baseline level of safety and electrical integrity.
- ⚡ **Korea Electric Safety Code (KESC):** This provides the detailed, specific inspection criteria and procedures used for conducting both Pre-Operation and Periodic inspections, ensuring consistent and thorough safety evaluations based on the KEC framework. KESCO maintains and applies these detailed codes during inspections.

Safety oversight is implemented through distinct inspection phases that cover the entire lifecycle of a RE facility, from initial design through to its ongoing operation. These phases ensure safety is considered and verified at critical points, which comprise three main stages.

Construction Plan Approval/Notification: The safety process begins even before construction, with an essential review of the facility's design. This initial stage involves reviewing the facility's design plans before construction begins to ensure they comply with relevant codes and safety standards.

Pre-Operation Inspection: Following construction, a comprehensive inspection is mandated to confirm that the installation meets all safety requirements before it can be energised and connected. This is a mandatory and detailed inspection conducted after construction but before the facility begins commercial operation. Its purpose is to verify that the actual installation conforms to the approved plans and meets all safety requirements stipulated by KEC and KESC.

Periodic Inspection: Safety management does not end at commissioning; regular checks are necessary throughout the facility's operational life to address degradation and ensure continued compliance. These are recurring inspections conducted throughout the facility's operational life, mandated by law. They are essential for ensuring long-term safety, detecting degradation or potential faults, maintaining efficiency, and verifying ongoing compliance with safety codes.

The Pre-Operation Inspection represents a critical gateway check before a new RE facility can commence operation. KESCO's meticulous workflow emphasises thorough preparation by the applicant and a comprehensive review process by the inspecting authority.

Application for Inspection: The formal inspection process is initiated by the facility owner or operator through the submission of a defined set of application documents. The process formally starts when the applicant submits the request along with a specific list of required documents:

- Application Form
- Construction Plan (Approval) Notification
- Repair Certificate (if applicable)
- Supervisor Assignment Confirmation
- Electric Safety Manager Appointment Notification

Examinee Preparation (Applicant's Duties): Significant responsibility rests with the applicant to prepare thoroughly before the inspection authority's technical review, including gathering data, performing initial checks, and preparing documentation. Before KESCO's review, the applicant must undertake significant preparation:

- **Compile Equipment Information:** Gather detailed data for: Solar Cells, Secondary Batteries, Power Conversion Devices, Grid Integration Equipment, and Battery Management System.
- **Perform Initial Inspection/Testing:** Conduct and record results for: Solar Cells, Secondary Batteries, Power Conversion Devices, Transformers, Circuit Breakers, and Power Lines.
- **Prepare Documentation:** Ready the Inspection Record and Field Test Report based on the initial tests conducted.
- **Prepare Checklist Items:** Ensure aspects relevant to the KESCO checklist are ready for inspection, covering: Solar Cells, Secondary Batteries, Power Conversion Devices, Mounting Structures, Power Lines, and the Surrounding Environment.

Technical Review (KESCO's Assessment): Prior to the physical site inspection, the inspecting authority conducts a detailed review of the submitted materials to assess compliance on paper and identify areas for focus. KESCO performs a detailed technical assessment before the site visit:

- Review the submitted application documents and the applicant's preparation materials (Inspection Record, Field Test Report).
- Develop an understanding of the key equipment information provided.
- Review diagnostic records, inspection records, and measurement values specifically by section of the facility.

- Assess the validity of product test reports (from manufacturers) and the field test reports (from the applicant's initial testing).
- Utilise a “Pre-Commissioning Inspection Preparation and Review Checklist” covering the items mentioned above (Cells, Batteries, PCS, Structures, Lines, Environment).

Conduct Pre-Operation Inspection: The culmination of the preparation and review process is the final on-site inspection, where the physical installation is verified against the documentation and standards. Following a satisfactory technical review, KESCO conducts the final on-site inspection. This involves physical verification against the reviewed documents and checklists, ensuring the facility is built as planned and meets all KEC/KESC safety standards before receiving the judgment and approval to operate. Typical checks include visual inspection for defects, electrical testing, verification of earthing and connections, and ensuring safety systems function correctly.

3.3. Principles of RE Facilities Inspection

The principles of RE facilities inspection emphasise ensuring electrical and structural safety through compliance verification, specific tests, and adherence to procedural requirements.

Compliance Verification: Inspections serve to confirm that every aspect of the RE facility meets the specific technical and safety standards detailed in the KESC document and related codes (like KEC). This is a broad principle encompassing many checks:

- ⚡ **Electrical Systems:** Verifying adherence to standards for wiring methods (e.g., using specified cable types for PV systems), insulation resistance, earthing (including specific requirements for PV module frames and integrated earthing for wind turbines), lightning protection (including specifics for PV and Wind), overcurrent and fault protection devices (installation and function), and electrical connections (secureness, polarity markings).
- ⚡ **Structural Integrity:** Checking that foundations and support structures are designed and installed to safely withstand all anticipated loads, including self-weight, operational loads (like wind turbine rotation), and environmental loads (wind pressure, snow, seismic activity, wave loads for offshore). This includes verifying materials used and protective measures like corrosion prevention (coatings, galvanisation, cathodic protection for offshore wind).
- ⚡ **Installation Site & Layout:** Confirming facilities meet location requirements, such as adequate spacing for operation and maintenance (e.g., 0.8 m for ESS components, 1 m/0.8 m for ESS racks), clearance from other structures or hazards (e.g., 1.5 m/3 m for ESS, 3 m for portable ESS), flood prevention measures (e.g., minimum height above ground), appropriate ventilation (e.g., for ESS battery rooms, PV inverter spaces), and access control (fences, warning signs, locks).
- ⚡ **Safety Devices:** Ensuring the presence and functionality of safety mechanisms like emergency stop systems (manual and automatic for ESS, Fuel Cells, and Wind), fault detection systems (e.g., ground fault detectors for ESS, gas leak detection for Fuel Cells, abnormal vibration detection for Wind), and fire protection systems (e.g., for large wind turbines).

Procedural Adherence: This principle focuses on ensuring the correct processes and documentation are followed throughout the facility's lifecycle. Inspections verify the existence and adequacy of required documents before and during inspection. This includes:

- Design documents (signed by qualified engineers).
- Construction Plans (checking submitted documents like single-line diagrams, capacity calculations, structural plans, etc., to align with standards).
- Material Certifications (Mill Certificates) to verify material properties.
- Welding Documentation (WPS, PQR) to ensure welding is performed according to qualified procedures.
- Test Reports and Calibration Certificates for equipment used in tests.
- Manufacturer's manuals and specifications.

Following the document check, the procedure is followed with the approvals and reviews, which check that necessary approvals for construction plans or modifications have been obtained and confirm that a Preliminary Technical Review by KESCO was conducted for applicable facilities, as well as the review of personnel qualification to ensure tasks are performed by qualified individuals, particularly for specialised work like Non-Destructive Test (NDT), where specific certification levels (e.g., ISO 9712, ASNT Level 2 or equivalent) are required for inspectors

Specific Tests and Examinations: KESC mandates various physical tests and examinations, often detailed with specific procedures and acceptance criteria:

 **Visual Inspections:** A common requirement across components. For example, Fuel Cell and Wind Tower welding involve checking for cracks, alignment issues (misalignment limits), correct weld profiles (reinforcement limits), undercut limits, surface cleanliness, and the absence of spatter or harmful defects. Illumination levels (min. 500 lux) and access requirements are also specified.

 **Mechanical Inspections (Primarily Welding):** Involves testing specimens taken from test plates welded alongside the main component (e.g., pressure vessels in Fuel Cells).

- *Tensile Tests:* Specimens must meet minimum strength requirements, often compared to the base material's strength. Failure criteria and retest procedures are defined.
- *Bend Tests:* Specimens are bent, and the convex surface is checked for cracks, with specific allowances for edge cracks or minor imperfections.
- *Impact Tests:* Required for some fuel gas equipment components to assess toughness, with exemptions based on material, thickness, and temperature.

 **NDT:** Used extensively for verifying weld integrity in critical components like Fuel Cell pressure vessels/piping and Wind Towers.

- *Scope:* Defined based on component type, weld classification (e.g., A, B, C, D joints), material (P-numbers), thickness (specific thresholds trigger full radiographic testing/RT), and pressure/

temperature conditions. Fuel gas piping often requires 100% RT. Wind towers have specific NDT scopes outlined in KESC.

- **Methods:** Detailed procedures and acceptance criteria are provided for RT (ISO 17636-1), density requirements, image quality indicator usage, acceptance levels based on ISO 10675-1), ultrasonic testing (ISO 17640, equipment/probe specs, sensitivity setting methods, acceptance levels based on ISO 11666), magnetic particle testing (ISO 17638, yoke requirements, procedures, acceptance levels), and penetrant testing (ISO 3452-1, material requirements, procedures, acceptance levels based on ISO 23277).

⚡ **Pressure Testing:** Critical for Fuel Cell and Water Electrolysis pressure vessels and piping.

- **Hydrostatic Tests:** Typically, 1.3 or 1.5 times the maximum allowable/design working pressure, adjusted for temperature. Requires leak checks after applying pressure. Procedures for venting and isolating components are specified.
- **Pneumatic Tests:** Used when hydrostatic testing is impractical. Typically, 1.1 or 1.2 times the design pressure. Requires specific procedures for gradual pressurisation, temperature control (to avoid brittle fracture), use of non-flammable gas, and installation of relief devices.

⚡ **Product Inspections (Pre-shipment):** Mandated for Fuel Cells >100 kW and Wind Turbines >100 kW (Blades, Nacelles, Towers). Involves verifying manufacturing facilities and quality systems, conducting type tests (based on standards like IEC 62282-3-100 for Fuel Cells) and acceptance/shipping tests. Specific tests for wind blades include static load, fatigue load, and mass/centre of gravity checks. Nacelle inspections verify major components against design documents. Tower inspections focus heavily on material verification and extensive NDT of welds. Passed products require specific approval markings.

⚡ **Functional Tests:** Verify the correct operation of control and safety systems, such as emergency stops, interlocks, alarms, and monitoring devices. For ESS, charge/discharge functionality tests are also recommended in KESC.

Operational Monitoring (Especially ESS): For ESS, especially Lithium/Sodium-based types, KESC mandates ongoing monitoring and specific routine inspections based on operational data:

⚡ **Online Uninterrupted Routine Inspections:** Businesses can apply for these inspections, which rely on analysing operational data transmitted to the KESCO ESS Safety Information System. Key criteria include:

- **Connectivity Rate:** Ensuring data is consistently transmitted (e.g., $\geq 90\%$ rate).
- **Alert Handling:** Documenting actions taken in response to system-generated abnormal alerts (overcharge, temperature rise, ground fault, etc.) within specified timeframes.
- **Safety Device Function:** Verifying emergency stop device reaction times (e.g., within 5 seconds).
- **Operational Limits:** Checking adherence to mandated charge rate limits (e.g., 80% indoor, 90% outdoor) and operation below-rated discharge capacity (end-of-life capacity check).

- ⚡ **System Health:** Monitoring insulation resistance values and ensuring battery room temperature/humidity stays within manufacturer recommendations.
- ⚡ **CCTV Monitoring:** Continuous surveillance inside and outside secondary battery locations is required, with footage stored for a minimum period (e.g., 7 days).

3.4. Electrical Safety Inspection in Solar PV

This section explores the practical application of these inspections specifically for PV facilities, starting from schematic and corresponding photos of the key electrical and structural components within a typical PV system that KESCO usually examines during processes. Figure 3-1 shows the components of PV facilities that are identified as subject to inspection, ranging from the grid interface down to the site level, including: (1) incoming line, (2) high-voltage switch, (3) high-voltage circuit breaker, (4) relay, (5) transformer, (6) low-voltage circuit breaker, (7) power conversion unit, (8) connection box/junction Box, (9) wiring, (10) solar module, (11) site (the overall installation area), and (12) structure (the mounting framework).

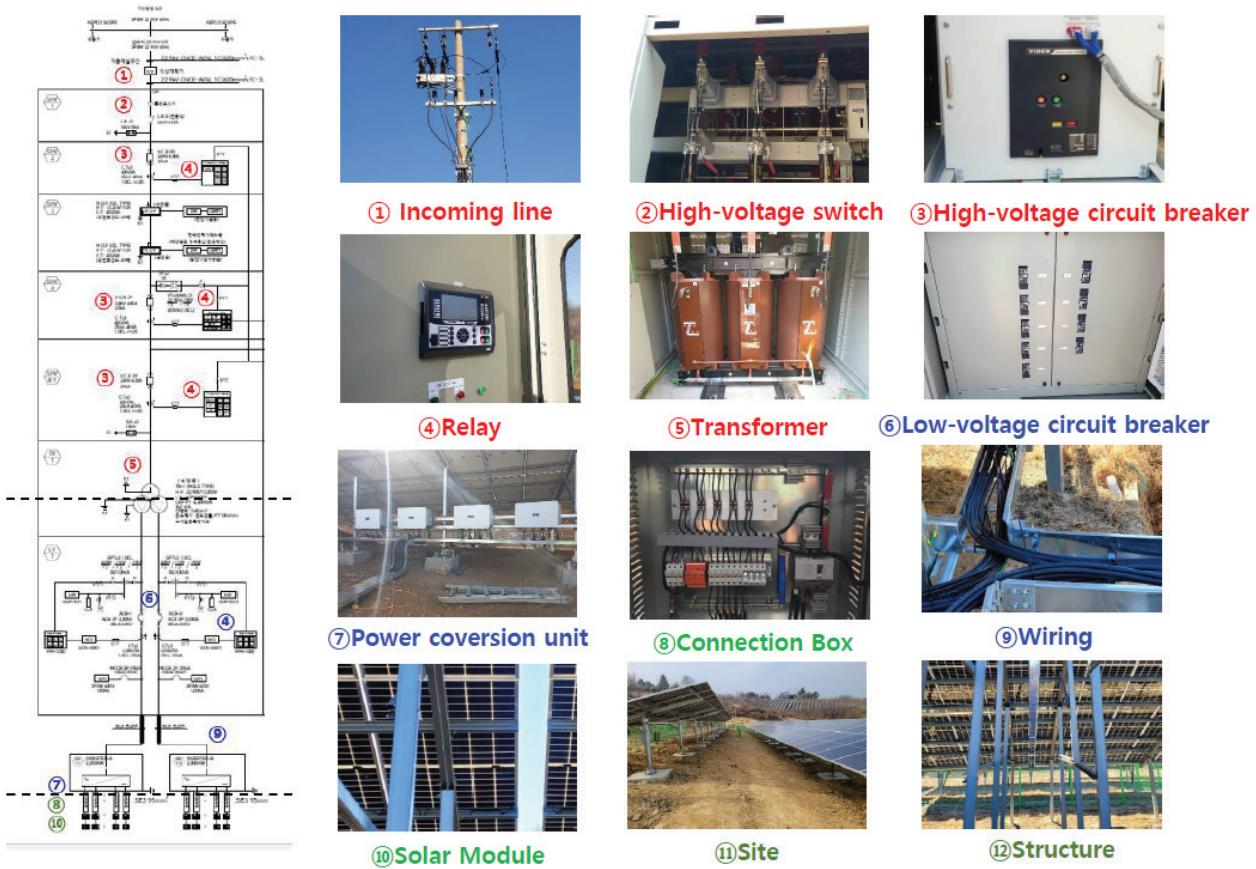


Figure 3-1 Typical Components of PV Facilities

Foundational safety rules applied across distributed energy systems are **human electrocution protection, insulation, and earthing**. Facilities must strictly adhere to the specified safety standards to prevent electric shock hazards to personnel. Electrical circuits must meet the required insulation resistance and dielectric strength. All metal enclosures (like inverter casings and junction boxes) and

support structures must be properly earthed according to the relevant earthing system guidelines. Specifically, for PV, module frames must be electrically bonded to their supports. Floating PV installations also require earthing, with earthing electrodes installed such that they are not floating or left exposed on the underwater ground. General earthing practices must follow the applicable standards. The visual inspection of solar modules is the basic to-do-list as illustrated in Figure 3-2.

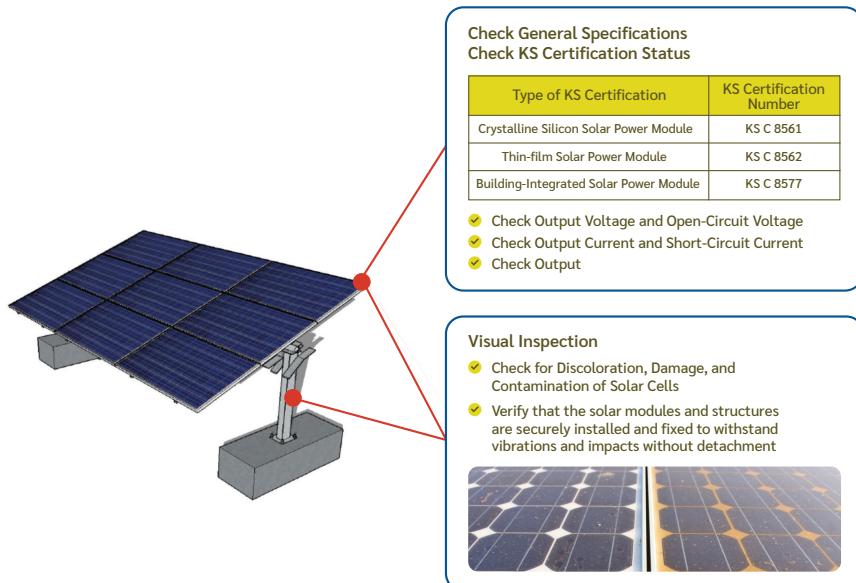


Figure 3-2 Visual Inspection of Solar Modules

Measures must comply with the specified regulations for **lightning protection**. If an external lightning protection system is installed specifically for the PV facility, it must meet the detailed requirements for such systems. PV systems, as distributed power sources, must implement protective measures as detailed in the applicable **protection standards (device level)** for low-voltage electrical facility installations.

Furthermore, facilities must have clear **warning (hazard) signs and access** by unauthorised personnel must be restricted. Fences or barriers may be required according to substation facility standards. For PV systems where the maximum open-circuit voltage of a series string exceeds 750 V DC (up to 1,500 V DC): specific safety measures like fencing or hazard markings are required depending on the location (ground-mounted, publicly accessible rooftop, non-easily accessible rooftop, parking lot, or floating structure).

System Interconnection Electrical Safety: The PV system's electrical supply characteristics must align with the interconnected system or have **electrical consistency**. Systems over 250 kVA need devices to monitor connection status and measure active power, reactive power, and voltage at the interconnection point. Besides this general requirement, certain other criteria need to be assessed:

⚡ DC Leakage Prevention (Low Voltage Grid): To prevent DC injection into the AC grid, a commercial frequency isolation transformer (not a single-winding type) must typically be installed between the inverter and connection point. Exceptions apply if: (1) the PV DC circuit is unearthed or the inverter uses a high-frequency transformer, or (2) the inverter has a DC detector on its AC output and can automatically stop output upon detection.

⚡ **Short Circuit Current Limitation:** If the PV system's fault contribution could exceed the ratings of existing equipment, current-limiting devices (e.g., reactors) or other measures must be implemented.

⚡ **Protection Devices and Coordination:**

- Automatic disconnection devices are mandatory to separate the PV system during internal faults/abnormalities, grid faults/abnormalities, or islanding.
- Protection must coordinate with the grid. Disconnection during grid faults must occur *before* grid re-closure, and the PV system must remain disconnected until grid voltage/frequency normalises.

⚡ **Reverse Power Flow (Simple Parallel):** Systems designed only for onsite consumption generally require reverse power relays. Exception: Relays may be omitted for PV systems ≤ 50 kW using new/renewable energy if connected at the same usage location, the location's contracted load exceeds PV capacity, and the system has an islanding prevention function.

⚡ **Control Devices (High Voltage):** PV systems connecting to high-voltage transmission may need control devices installed for grid stability or current flow suppression if required.

⚡ **Transformer Earthing (High Voltage Grid):** Interconnection transformer neutral earthing must not cause overvoltage or hinder grid ground fault protection coordination.

⚡ **General Electrical Standards Compliance:** Associated electrical facility installations must comply with the relevant provisions for Cables, Earthing systems, Lightning protection systems, Transmission lines, High/Extra-High Voltage facilities, Low Voltage facilities, Power Station/Substation facilities, and Wiring facility construction.

Specific Electrical Safety for PV Installation: These requirements apply directly to the PV components and their assembly:

⚡ **Charged Part Protection:** Installation must prevent exposure of live parts. Junction boxes need warnings about potential residual charge after inverter disconnection. Components need adequate heat resistance.

⚡ **Earth Voltage Limit (Indoor Wiring):** In residential settings, DC wiring voltage-to-ground is limited to 600 V DC provided: (1) An automatic ground fault circuit-disconnecting device is installed, and (2) Wiring is concealed using specified methods (synthetic resin duct, metal duct, or protected cable work in inaccessible locations; appropriate protection needed if using cable work in accessible concealed spots).

⚡ **Wiring Installation:**

- **Conductors:** Use flexible conductors, nominal cross-section ≥ 2.5 mm². Module-to-inverter cables should be module-specific or specific single-core flame-retardant types (TFR-CV, F-CV, FR-CV,¹ etc., floating PV excepted).

¹ TFR-CV - Tray Flame-Retardant Cross-linked Polyethylene (XLPE) insulation/Polyvinyl Chloride (PVC) sheath. This is a power cable with XLPE insulation and a flame-retardant PVC sheath, specifically designated as suitable for installation in cable trays. F-CV - Flame Retardant XLPE insulation/PVC sheath. This is described as a Flame Retardant power cable with XLPE insulation and a PVC sheath. FR-CV - Flame Retardant or Fire Resistant (Enhanced type meeting standards like IEC 60331 or CNS 11174) XLPE insulation/PVC sheath. A power cable with XLPE insulation and PVC sheath designed for enhanced flame retardancy or fire resistance, potentially meeting specific fire survival standards.

- **Installation Practices:** Follow general wiring facility standards. Secure connections (screws/ equivalent) without tension. Protect from environmental factors (wind, ice, temperature, sun). Use clear polarity markings. Minimise induction loops. Install away from sharp edges/damage sources. Protect ground-level cables. Install in the shade, prevent water pooling, and keep away from lightning conductors. Use poles for overhead lines.

⚡ **Terminals:** Ensure mechanical/electrical safety. Use nuts/screws with anti-loosening features. Maintain contact pressure over time. Fasten without damaging the conductor surface.

⚡ **Component Installation:**

- **Modules:** Securely install against all loads (weight, snow, wind, seismic, etc.). Parallel strings connected to one inverter/maximum power point tracking (MPPT)² must use modules with identical short-circuit current ratings for uniform output.
- **Inverters:** Must meet IP ratings (min. IP20 indoor/IP44 outdoor). Install where they are not continuously touched, or obstructed by movement. Module capacity $\leq 105\%$ of inverter capacity. The module must be within the inverter's input voltage range. Must display: Input (V, I, P), Output (V, I, P, F)³, Cumulative Generation, Max Output. Figure 3-3 demonstrates the inspection list of typical inverters.

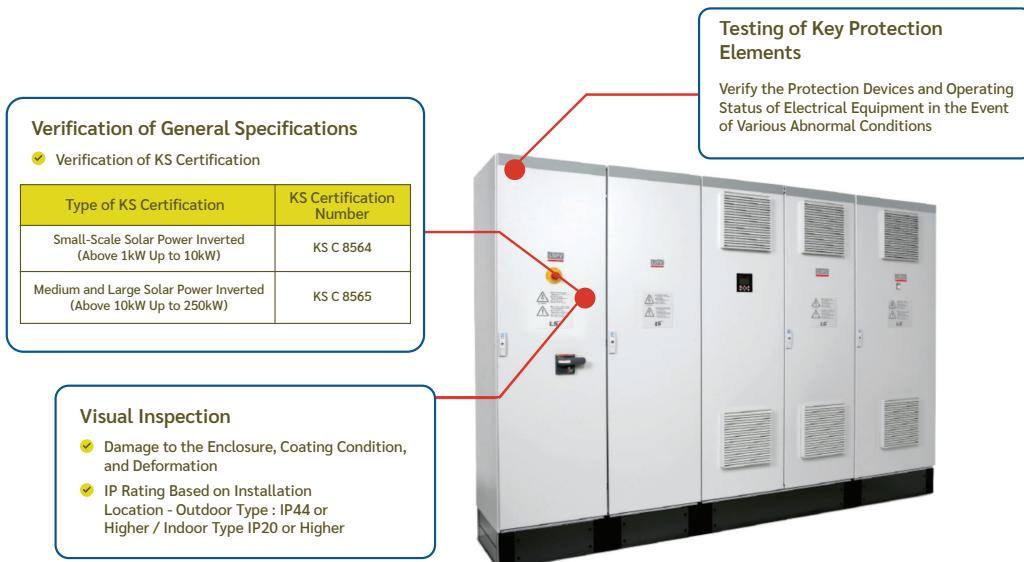


Figure 3-3 Inspection of Solar Power Inverter

⚡ **Junction Boxes:** Install in easily accessible locations. Use enclosure materials like cold-rolled steel, aluminium, polycarbonate, or equivalent heat-resistant material; seal against rain (min. IP54 outdoor). If using backflow diodes, capacity must be $\geq 1.4x$ rated current and $\geq 1.2x$ rated voltage. Install separately from the inverter; use heat dissipation if needed. Surge Protection Devices (SPDs) are required inside if ≥ 4 strings are connected, or in lightning-prone areas. Figure 3-4 indicates the locations of overcurrent protection devices in a junction box.

2 MPPT is a function that adjusts the voltage or rotation speed of a power source, such as solar or wind power, using power converter control, to produce the maximum power possible under current conditions.

3 Input (V, I, P) refers to the DC power coming into the inverter from the solar modules. Output (V, I, P, F): This refers to the AC power going out of the inverter to the grid or loads. V: Voltage (in Volts); I: Current (in Amperes); P: Power (in Watts or Kilowatts); F: Frequency (in Hertz).

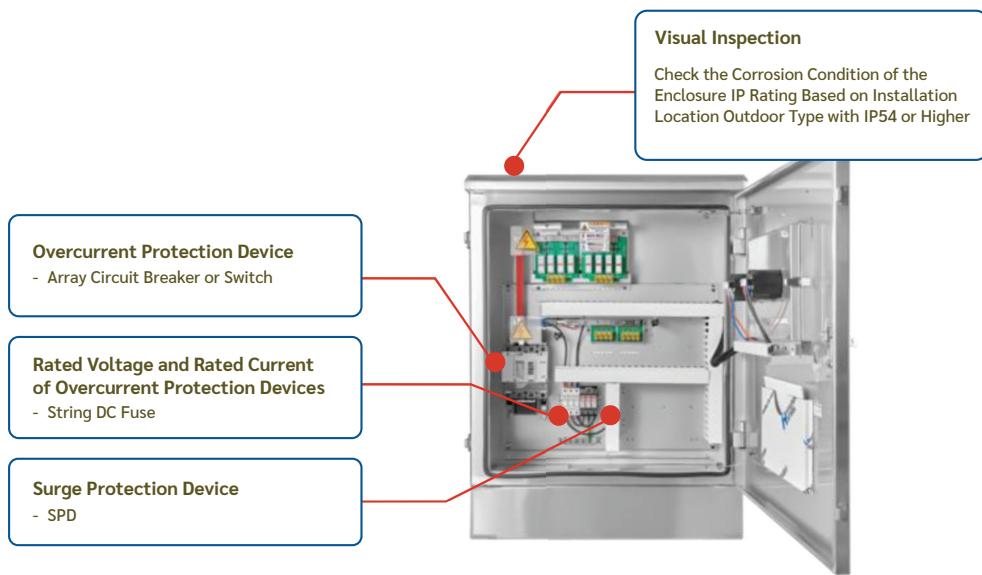


Figure 3-4 Check the Overcurrent Protection Devices in Solar Junction Box

⚡ Protection Devices:

- **Array Output Switch:** Install an accessible switch near the array-inverter connection, capable of opening/closing the DC load current.
- **Overcurrent Protection:** Parallel module circuits need breakers/fuses, unless the wiring itself can handle the max short-circuit current.
- **Ground Fault Protection:** Mandatory installation of a ground fault interrupter (inverter either integrated or separate) in the DC circuit path. This device needs KOLAS, ILAC, or APAC accredited performance certificates.⁴

⚡ **Measurement:** Instruments must be installed to measure voltage and current, or voltage and power for both the PV facility circuits and the associated AC electrical system circuits. Real-time monitoring system displays can fulfil this.

⚡ **Safety of PV Structure and Foundation:** KESC place significant emphasis on ensuring the structural and mechanical integrity of PV supports and foundations, but key electrical safety requirements are also integrated, primarily focusing on earthing and bonding:

⚡ **Mandatory Earthing of Metal Supports:** Metal support structures used for PV modules must be properly earthed. This establishes the structure as part of the facility's overall earthing system.

⁴ KOLAS - Korea Laboratory Accreditation Scheme. A governmental body in South Korea, established by the Korean Agency for Technology and Standards (KATS), responsible for accrediting the competence of calibration laboratories, testing laboratories, and inspection bodies according to international standards (like ISO/IEC 17025 and 17020).

ILAC - International Laboratory Accreditation Cooperation. ILAC is the global association for accreditation bodies operating in the field of laboratory testing, calibration, and inspection accreditation. It manages a mutual recognition arrangement (MRA), often called the ILAC Arrangement, where signatory accreditation bodies agree to recognise the equivalence of results from facilities accredited by other signatories. KOLAS is a participant in ILAC.

APAC - Stands for Asia Pacific Accreditation Cooperation. This is the regional accreditation cooperation for the Asia Pacific region, formed by the amalgamation of Asia Pacific Laboratory Accreditation Cooperation (APLAC) and Pacific Accreditation Cooperation (PAC). Like ILAC, APAC manages a mutual recognition arrangement among its member accreditation bodies within the region. APAC is recognised by ILAC and International Accreditation Forum (IAF). KOLAS also participates in APAC (formerly APLAC).

- ⚡ **Mandatory Bonding of Module Frames to Supports:** The metallic frames surrounding the solar modules must be electrically connected (bonded) to the support structures they are mounted on. This connection ensures that should a module frame become unintentionally energised, the fault current has a safe path to ground via the earthed structure, minimising electric shock risk.
- ⚡ **Compliance with General Earthing Standards:** The specific methods, materials (like conductor types and sizes), and installation details for earthing the supports and the overall system must adhere to the comprehensive earthing standards.
- ⚡ **Specific Earthing for Floating PV Foundations:** Earthing is mandatory for PV systems installed on water. Furthermore, the earthing electrodes associated with these floating structures must be installed so that they do not float or become exposed on the underwater ground. Compliance can be verified through methods like a supervisory report.
- ⚡ **Interaction with Lightning Protection Systems:** Should an external lightning protection system be installed for the PV facility, its design and installation must comply with the relevant detailed regulations for such systems. This system will typically utilise the main facility earthing, including the earthed structures.
- ⚡ **Indirect Safety Contributions via Structural Requirements:**
 - **Material Integrity:** The requirement to use corrosion-resistant materials for structures (like hot-dip galvanised steel, stainless steel, aluminium alloys, or materials proven equivalent through tests like salt spray tests for floating systems) indirectly supports electrical safety. By preventing degradation, these materials help ensure the long-term reliability and low resistance of the earthing path through the structure.
 - **Secure Fixing:** Requirements ensuring supports are securely fixed to foundations or buildings, and that bolt assemblies (using features like spring washers or anti-loosening nuts) are firmly tightened, prevent components from becoming loose or detached. This structural stability is crucial to maintaining the integrity of the necessary electrical bonding and earthing connections throughout the system's life.

3.5. Electrical Safety Inspection in Wind Farm

Fundamental safety rules of wind power facilities are intended to ensure a baseline level of safety in their design and operation. These include measures for personnel protection, system integrity, and hazard mitigation. Facilities must strictly implement the specified safety standards to prevent electric shock hazards to personnel. This includes ensuring **adequate access control and warnings**; safety signage must be provided, access by non-operators restricted, and specific measures like warning signs for live electrical states and means to discharge stored electricity safely must be available for personnel working on the turbine. Additionally, a disconnecting device must be present at the tower base for maintenance power cut-offs.

System integrity relies on several key electrical safety measures. Circuits must comply with regulations for **insulation** resistance and dielectric strength. Proper **earthing** is mandated for metal enclosures and support structures like the tower. The guidelines specifically require integrated earthing works using the tower base, along with equipotential bonding to eliminate potential differences between components. General earthing practices must follow the applicable standards. Furthermore, wind facilities must adhere to comprehensive regulations for **lightning protection**, detailed elsewhere in the standards. As distributed power sources, wind turbines must also implement the necessary protective measures detailed in the general standards for low-voltage facilities.

Beyond these core electrical safety requirements, other critical considerations include **aviation safety and fire protection**. Wind turbines reaching 60 m or more in height must be equipped with aviation obstruction lights and daytime obstruction markings, complying with relevant aviation laws and standards. For fire safety, turbines with a rated output of 500 kW or more require fire protection facilities installed within the nacelle that are capable of both detecting and automatically extinguishing fires.

System Interconnection Electrical Safety: Safely connecting the wind power system to the electrical grid involves several key requirements:

- ⚡ **Electrical Consistency:** The system's electrical supply characteristics must match the grid it connects to. For facilities >250 kVA, devices monitoring connection status or measuring active power, reactive power, and voltage at the interconnection point are needed.
- ⚡ **DC Leakage Prevention:** If applicable (though less common for wind than PV), rules for preventing DC leakage into low-voltage grids apply, potentially requiring transformers or specific inverter functions.
- ⚡ **Short Circuit Current Limitation:** If the wind system's fault contribution could exceed the ratings of existing grid equipment, current-limiting devices (e.g., reactors) or other measures must be implemented.
- ⚡ **Protection Devices and Coordination:** Automatic disconnection devices are required to separate the wind system during internal faults/abnormalities, grid faults/abnormalities, or islanding. Protection settings must coordinate with the grid, including timings relative to grid re-closure procedures.
- ⚡ **Control Devices (High Voltage):** Systems connecting to high-voltage transmission systems must install control devices if needed for grid stability or current flow suppression.
- ⚡ **Transformer Earthing (High Voltage):** Interconnection transformer neutral earthing must not cause overvoltage or impede grid protection coordination.
- ⚡ **General Standards Compliance:** Associated electrical systems must comply fully with the relevant provisions for Cables, Earthing systems, Lightning protection systems, Transmission lines, High/Extra-High Voltage facilities, Low Voltage facilities, Power Station/Substation facilities, and Wiring facility construction.

Specific Electrical Safety for Wind Turbine Installation and Operation: Numerous specific requirements for the safe installation and operation of the wind turbine's electrical components and control systems:

⚡ Control and Protective Devices:

- Turbines need control and protection systems to maintain operation within normal limits.
- Required measuring devices include tachometers, nacelle vibration meters, anemometers, pressure gauges, and thermometers. (Small systems <100 kW using certified products may omit these).
- Control system functions must cover output regulation by wind speed, output limitation, rotational speed control, grid integration, starting/stopping, stopping on grid failure or load loss, and limiting cable twisting via yawing.
- Protective system functions must activate under conditions like: High winds, generator issues (overproduction/failure), abnormal vibrations, grid failures/accidents, and cable twisting limits.

⚡ Automatic Stopping Devices: Turbines must automatically stop under specific trigger conditions, including:

- Unusual increase in rotational speed.
- Reaching the cut-out wind speed.
- Manual emergency stop-test activation.
- Excessive rise in bearing temperature (Applies to turbines ≥ 500 kW, or ≥ 100 kW in densely populated areas).
- Excessive increase in nacelle vibration during operation (Applies to turbines ≥ 10 kW installed in densely populated urban areas).
- Excessive decrease in control hydraulic pressure (Applies to plants ≥ 100 kVA).
- Excessive decrease in compressed air device pressure (Applies to plants ≥ 100 kVA).
- Excessive decrease in electric control device power voltage (Applies to plants ≥ 100 kVA).

⚡ Wiring (Small Systems ≤ 100 kW):

- Use specified cable types (CV, TFR-CV or equivalent) from the generator to output wiring. Wires passing through the ground require sheath damage prevention.
- Conductors must have a nominal cross-sectional area of ≥ 2.5 mm² or equivalent strength/thickness.
- Terminal connections must ensure mechanical and electrical safety, use nuts/screws with anti-loosening features, maintain contact pressure, and fasten securely without damaging conductors. General wiring rules from referenced standards apply.

⚡ Component Standards (Small Systems ≤ 100 kW):

- Wind turbines and their inverters must comply with recognised national industrial standards, or provide equivalent test reports if such standards are unavailable.

- Inverter-rated capacity must be equal to or greater than the connected generator's rated output. Generator output voltage must fall within the inverter's input voltage range.
- Inverter IP ratings must be at least IP20 for indoor types and IP44 or higher for outdoor types.

Lightning Protection Electrical Safety: Protecting wind turbines from lightning strikes is a critical electrical safety concern:

⚡ Standard Compliance: Protection must comply with recognised international standards (IEC 61400-24). Unless specified otherwise, the highest protection level should be applied, designed to handle high peak currents (e.g., 200 kA). Small systems (<100 kW) might be exempt only if fully shielded by other nearby structures' lightning protection systems.

⚡ External Protection Components:

- *Air Terminals:* Must be installed at blade tips and edges, and on the nacelle top to shield sensors like anemometers/wind vanes. They must be made of materials that resist melting from lightning currents, considering material type, size, thickness, shape, and weld quality per manufacturer specifications. Nacelle rods should connect to the nacelle frame.
- *Down Conductors:* Must be a corrosion-resistant metal wire, sufficiently thick for safe current conduction, and installed as straight as possible. Their installation and function must not impair other systems.

⚡ Internal Protection Measures:

- *Sensor Cables:* Internal measurement sensor cables require protection from induced overvoltage using metal conduits or shielded cables.
- *Power Equipment:* Protection involves using metal-sheathed cables, lightning-proof transformers, and SPDs.
- *Control Equipment:* Protection typically involves using optical cables and photocouplers.

⚡ Earthing and Bonding: Lightning protection requires integrated earthing works utilising the tower base. Equipotential bonding is essential to eliminate potential differences between components (should be visually verified or have resistance $\leq 0.2 \Omega$). General earthing must comply with the applicable standards.

⚡ Protection Zones: The design must consider the defined Lightning Protection Zones (LPZs) as illustrated in Figure 3-5 to ensure appropriate protection levels for different areas of the turbine.

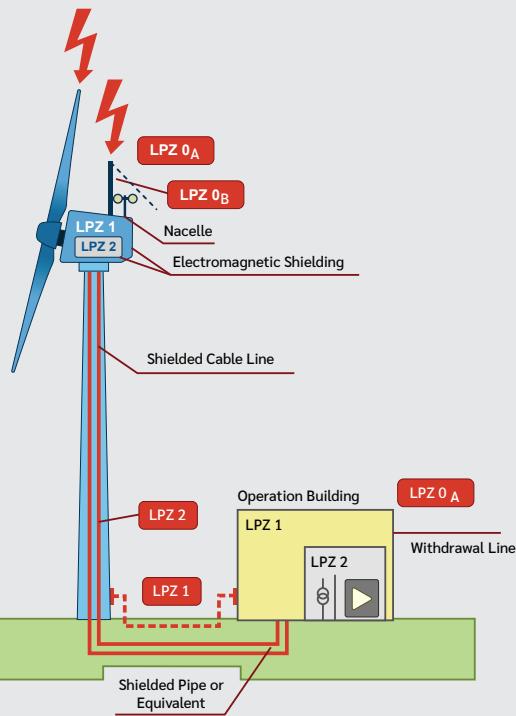


Figure 3-5 Classification of Lightning Protection Zones in Wind Farm

Offshore Wind Power Electrical Safety: For wind turbines installed offshore, additional electrical safety considerations apply:

- ⚡ **Subsea Cables:** Electrical connections must be secure, not increase resistance, and have insulation covering equivalent or superior to the original cable insulation. Cable laying procedures must prevent damage to the protective outer layer and avoid twisting. Cable location indicators must be attached.
- ⚡ **Floating Systems Electrical Power:** These installations must have a reliable power supply for essential systems like pumps and controls. If using batteries instead of an emergency generator, the battery capacity must be sufficient to last longer than the maximum expected power interruption duration for that marine area, and suitable battery charging devices must be provided.

Safety of Wind Structures and Foundations: Structural and mechanical requirements for towers and foundations (e.g., ability to withstand wind loads, seismic activity, material strength, fatigue life, etc.) are intended to ensure the tower can physically perform its electrical safety roles.

- ⚡ **Mandatory Earthing:** Proper earthing of metallic support structures, including the wind turbine tower.
- ⚡ **Integrated Earthing System:** Wind turbine earthing systems should utilise integrated earthing works that incorporate the tower base as a fundamental part of the facility's connection to earth potential.
- ⚡ **Equipotential Bonding:** Bonding must connect the tower structure with other conductive equipment to eliminate hazardous potential differences. The effectiveness of this bonding requires verification, either visually or by ensuring electrical resistance is very low (specified as 0.2Ω or less).

- ⚡ **Compliance with Earthing Standards:** The implementation specifics (methods, materials) for earthing the structure must follow the general earthing standards referenced within the guidelines.
- ⚡ **Lightning Protection System Pathway:** The tower structure is designated as the primary pathway for safely conducting lightning currents via down conductors. These conductors connect air terminals (often via the nacelle frame) down to the integrated earthing system at the base.
- ⚡ **Down Conductor Specifications:** The down conductors installed on the structure must meet specific criteria: they should be made of corrosion-resistant metal wires with sufficient thickness to conduct lightning currents safely and should be installed as straight as possible.
- ⚡ **Lightning Protection System Standard Compliance:** The entire lightning protection system, including its integration with the tower and earthing, must adhere to the relevant technical standards for wind turbine lightning protection.
- ⚡ **Corrosion Prevention for Electrical Integrity:** Preventing abnormal corrosion is required. Specific measures include hot-dip galvanising or similarly treating bolts, nuts, and washers used in tower joints and foundations for rust prevention and appropriately coating welded areas.

3.6. Electrical Safety Inspection in Energy Storage System

Many foundational electrical safety principles and standard interconnection requirements apply broadly to various distributed energy resources, including PV, wind farms, and ESS. These common aspects cover fundamental personnel safety against electric shock, basic requirements for earthing metallic enclosures and support structures, general compliance with lightning protection standards, standard wiring practices, and rules for safely interconnecting with the power grid (such as ensuring electrical characteristic consistency, coordinating protection with grid devices for faults and islanding, and managing fault currents).

However, electrical safety aspects specifically related to the technologies and potential hazards inherent in ESS are elaborated below:

Battery-Specific Safety Measures & Installation Constraints: Recognising the unique characteristics of battery energy storage, specific precautions are:

- ⚡ **Thermal Runaway & Hazard Prevention (esp. Lithium/Sodium-based):** Facilities must incorporate measures to prevent thermal runaway and explosion. This includes *installing rapid exhaust devices* in battery rooms to vent flammable gases or internal pressure if they exceed manufacturer-set limits. Battery modules or racks must be *constructed to prevent the spread of fire between units or be equipped with fire-extinguishing devices*. Secondary batteries themselves (unless covered by other specific safety acts) must *comply with national standards* or equivalent performance levels.
- ⚡ **Specific Installation Requirements:** Strict rules govern the location and construction of ESS enclosures, often requiring dedicated *fire-resistant rooms or buildings*, especially for Lithium/Sodium types. *Mandatory separation distances* are specified between the ESS and surrounding

facilities, buildings, combustible materials, entrances, and evacuation routes. Specific internal spacing between racks and from walls is also required. *Adequate ventilation* is crucial to prevent explosive gas accumulation and manage temperature/humidity according to manufacturer recommendations. Ventilation might be omitted only if the manufacturer proves that no hazardous gases will accumulate.

- ⚡ **Battery Management:** Battery output wiring must be clearly *marked for polarity*. Reused secondary batteries require specific *marking* ('*Reused Secondary Battery*'), the indication of initial and remaining capacity, and must meet manufacturer compatibility requirements.
- ⚡ **Flow Battery Specifics:** Require minimum circuit insulation resistance (100 Ω/V relative to nominal voltage) and mandatory systems for electrolyte leakage control, detection, collection, and neutralisation (to pH 5.0-9.0).

Enhanced Control & Protection Systems: ESS require highly specific and sensitive control and protection systems beyond general requirements:

- ⚡ **Mandatory Automatic Disconnection/Alert Triggers:** Protective devices must automatically disconnect power lines or alert operators upon detecting a wide range of ESS-specific conditions, including (1) overvoltage, undervoltage, or overcurrent in the batteries, (2) overcharging or over-discharging (for Li/Na systems), (3) control device faults, (4) rising internal temperature of secondary battery modules, (5) ground faults on the DC power line, (6) cooling system failure (for Li/Na systems), (7) communication failures between control systems (for Li/Na systems), and (8) presence of flammable or inflammable gases (for Li/Na systems).
- ⚡ **DC Line Ground Fault Protection:** This is mandatory. An automatic disconnection device is required. For IT (unearthed) systems, an Insulation Monitoring Device (IMD) must continuously monitor insulation resistance, provide alerts, and automatically trigger disconnection if resistance drops below the manufacturer's specified threshold. Accepted device types include IMD, Ground Fault Detector (GFD), Residual Current Monitor (RCM), or B-type Residual Current Device (RCD).
- ⚡ **Emergency Stop:** Systems require emergency stop switches/devices. For Li/Na (>20 kWh) and portable systems, these must allow automatic and manual activation within 5 seconds, with the manual stop being easily accessible.
- ⚡ **DC Surge Protection:** Specific requirements exist for installing DC SPDs on DC circuitry (PCS side and control circuits) for Li/Na and portable systems. Selection criteria consider impulse withstand voltage (Up), maximum continuous operating voltage (Uc), and nominal discharge current (In).
- ⚡ **Power Conversion System (PCS) Considerations:** PCS must comply with national standards. Importantly, insulation measures considering potential Common Mode Voltage (CMV) must be implemented to prevent insulation breakdown in the connected batteries.
- ⚡ **DC Breakers:** If DC circuit breakers are used, they must be rated to interrupt DC short-circuit currents and be explicitly marked "For DC Use".

- ⚡ **Power Management System (PMS):** A PMS is required to display the operating status of the PCS, communication status with the Battery Management System (BMS), and measurements of power, current, and voltage.

Operational Safety, Monitoring & Data Logging: Strict operational controls and monitoring are mandated:

- ⚡ **Charging Limits (Li/Na >20 kWh):** Specific state of charge limits must be adhered to: a maximum of 80% for indoor/attached facilities and a maximum of 90% for outdoor dedicated buildings. Charging beyond the battery's rated capacity or attempting further charging after reaching full charge is prohibited. Operation must remain below the rated discharge capacity, considering end of life guarantees.
- ⚡ **Central Safety System Integration:** Safety information, particularly charge level, must be integrated with the central ESS Safety Information System operated by the safety authority. Failure affects routine inspections.
- ⚡ **CCTV Monitoring:** Continuous CCTV surveillance is required inside and outside secondary battery locations (also for large Lead/Ni/V and Flow Battery systems).
- ⚡ **Data Logging:** Real-time operational data, emergency event data and CCTV footage must be synchronised, securely transmitted outside the battery room, and stored (minimum 1 month for operational/event data, minimum 7 days for CCTV).
- ⚡ **Instrumentation:** Requires devices to measure key parameters: battery voltage, current, power, temperature, state; main transformer voltage, current, power; battery room ambient temperature and humidity.
- ⚡ **Online Inspections:** Checks include verification of emergency stop reaction time, charge rate compliance, operation within EOL capacity, insulation resistance monitoring, electrical parameter checks via PMS, and temperature/humidity monitoring against manufacturer standards.

Portable ESS Specifics:

- ⚡ **Location:** Strict rules apply – outdoors only, minimum distances (3 m) from roads/buildings/combustibles, and requirement for restricted access signage/locks with 1.5 m clearance.
- ⚡ **Transport:** Must meet specific mechanical impact/vibration standards and include vibration monitoring devices during transport.
- ⚡ **Safety Features:** Follow many of the same detailed control, protection, monitoring, and charging limit rules as stationary Li/Na systems.

Safety of ESS Structures and Foundations: While the fundamental requirement to properly earth metallic support structures and enclosures according to general earthing standards applies to ESS, similar to PV and Wind facilities, the unique safety considerations for ESS focus on the surrounding

structure's role in providing fire containment, physical protection, and environmental protection (like flood prevention). This section covers the structural integrity, fire safety, and location requirements of the building or enclosure that houses the ESS components that are critical for containing potential electrical hazards specific to energy storage, particularly battery fires or thermal runaway.

- » **Fire-Resistant Construction:** For certain battery types, such as Lithium (Li) and Sodium (Na)-based systems, the building or room housing the ESS requires specific fire safety construction. Floors, ceilings (or roofs), and walls must often be made of specified non-combustible materials, with internal insulation materials needing to meet at least semi-non-combustible standards. Installations within public buildings may require even stricter fire-resistant structures conforming to detailed building regulations.
- » **Fire Compartmentation:** Measures are required to limit fire spread. This includes potentially installing firewalls within the battery room based on the total energy capacity and ensuring that any penetrations through walls (e.g., for wiring) are sealed in a way that does not compromise the compartment's fire resistance. For Li/Na systems, batteries should generally be installed in a compartment separate from other electrical facilities, such as power conversion devices.
- » **Foundation Height/Flood Prevention:** Outdoor dedicated buildings or enclosures housing ESS components must be installed with their base significantly above ground level (e.g., at least 30 cm generally, and 60 cm in salt farms or reclaimed land areas) to prevent flooding. Installation locations must be free from flooding and leakage risks.
- » **Structural Load Capacity (Flow Batteries):** For ESS using flow batteries installed in locations other than dedicated buildings, the installation site structure must be capable of withstanding the loads according to specified structural load design standards.
- » **Collision Protection:** In locations vulnerable to vehicle impacts, physical protection devices like collision barriers must be installed around the ESS structure.
- » **Support Structure Integrity:** Supports specifically for the secondary batteries must be corrosion-resistant and structurally safe against anticipated loads, seismic activity, vibrations, and impacts to ensure the batteries remain secure and their electrical connections intact.

3.7. Electrical Safety Inspection in Power Generation with Water Electrolysis System

Foundational electrical safety practices, such as personnel protection from shock, basic equipment earthing, ensuring adequate insulation, standard wiring techniques, and the use of SPD, generally apply as described for other earlier facilities. The water electrolysis systems introduce numerous specific requirements focused on managing hydrogen/oxygen hazards, ensuring the safety of the high-current DC systems, and implementing robust control logic for the electrical safety of water electrolysis facilities.

Hydrogen and Oxygen Hazard Management:

- **Ventilation and Atmosphere Control:** Ventilation is critical. If forced ventilation is the sole method for the room, it must interlock with the electrolysis equipment—operation must stop if ventilation fails. Specific requirements exist for natural ventilation openings (size relative to floor area, location near ceiling). Indoor oxygen concentration must be kept $\leq 23.5\%$. Enclosure tops must be designed to prevent hydrogen accumulation.
- **Gas Detection:** Hydrogen detection alarm devices are mandatory in locations where leaked gas may accumulate. These detectors must meet specific performance criteria: use certified explosion-proof detection units, alarm at $\leq 25\%$ of the lower explosive limit, meet accuracy ($\pm 25\%$ of the set point) and response time (typically < 30 sec at $1.6x$ alarm level) standards, provide a clear indication, and maintain the alarm until addressed. Detectors must be strategically placed (e.g., on top of enclosed spaces, away from heat/vibration). Emergency stops are triggered if hydrogen concentration inside an enclosure exceeds 1%.
- **Gas Purity Monitoring & Control:** Systems require emergency stops if the oxygen concentration in the hydrogen produced exceeds 3%, or if the hydrogen in the produced oxygen exceeds 2%.
- **Venting:** Vent pipe outlets for hydrogen and oxygen must be in safe, well-ventilated locations away from ignition sources. Specific height requirements apply (e.g., H_2 outlet ≥ 5 m above the ground, or ≥ 2 m above equipment top, whichever is higher, and ≥ 6 m from fire hazards; O_2 outlet lower than H_2). Oxygen released must be diluted (e.g., with air) to keep concentration $< 23.5\%$. Overpressure safety device discharge pipes must also vent safely, potentially with flow limiters.
- **Purging & Static Electricity:** Enclosures must be purged (e.g., with air or nitrogen) before startup to remove flammable gases. Static electricity elimination equipment must be installed on components like tanks, heat exchangers, and vent stacks to prevent ignition; bonding may be used for connected piping.

Electrolysis Process & Component Safety:

- **Cell/Stack Electrical Safety:** The facility must have an insulating case to prevent short circuits and must include a membrane to prevent H_2/O_2 mixing. It also requires emergency stops based on specific cell/stack parameters, such as abnormal supply voltage, significant temperature rise, overcurrent, or differential pressure changes affecting safety.
- **Electrolyte & Water System Safety:** If hazardous electrolytes (like KOH) are used, the enclosure needs safe containment measures. Emergency stops are triggered by significantly high/low electrolyte levels or significantly low water/electrolyte flow. Check valves must be installed at water supply connections to prevent backflow. Water supply purity below manufacturer-set minimum levels must trigger a shutdown.
- **Hydrogen Purification Devices:** The facility must include equipment (e.g., catalysts, adsorbers) to remove oxygen and moisture. Monitoring (temperature, pressure) and specific shutdown interlocks are

required for the purification system itself. Compressors must not be installed between the electrolysis stack and the hydrogen purification unit.

DC Power Supply (Rectifier) Safety:

- **Rectifier Insulation and Verification:** Rectifiers (converters) must withstand specified insulation strength tests based on their operating voltage. Verification requires appropriate test reports or certifications.
- **Low Voltage DC Circuit Rules:** For indoor DC circuits up to 1,500 V supplied by rectifiers, the charged parts must not be exposed. Earth voltage limit is 600 V DC under specific conditions (ground fault protection + concealed/protected wiring). DC quality requirements apply (ripple-free, harmonic limits). DC-rated overcurrent breakers and switches are required. DC ground fault protection (e.g., IMD) is mandatory. Measures are needed to prevent electrical corrosion due to DC leakage currents, especially in the earthing system. DC earthing must bond with AC earthing.

Control System & Power Failure Logic:

- **Control System Safety:** Must operate safely under normal use and potential fault conditions, using principles like defect avoidance, fault tolerance, and fail-safe design, particularly for software controls. Emergency stop controls must have priority and require manual reset (lockout).
- **Power Failure Performance:** Specific requirements dictate safe shutdown (blocking water/electrolyte paths) upon power loss and ensure the system remains stopped until manually restarted after power returns. Behaviour, when powered by UPS during grid loss, is also defined.

Safety of Structures and Foundations: Beyond the standard requirement for earthing metallic structures, the unique electrical safety focus for water electrolysis structures and foundations relies heavily on the design of the enclosure or building itself to actively manage and mitigate the risks associated with hydrogen and oxygen gas through specialised ventilation, gas dispersion features, spark prevention, and static control measures.

Integrated Ventilation for Gas Management: The structure or enclosure must incorporate specific ventilation designs (natural or forced) to prevent the accumulation of potentially explosive hydrogen or oxygen-enriched atmospheres. Detailed requirements are provided for ventilation openings, including minimum size relative to floor area and placement near the ceiling to facilitate hydrogen removal. If forced ventilation is the sole method, it must be interlocked with the electrolysis equipment's operation, forcing a shutdown if ventilation fails. Indoor installations require maintaining the room's oxygen concentration at or below 23.5%.

Structural Design for Gas Dispersion: The top of the equipment enclosure must be designed to prevent the retention or trapping of leaked hydrogen. Vent pipe outlets, which are part of the overall structural installation, have specific location and height requirements to ensure safe gas dispersion away from personnel and ignition sources.

Spark Prevention from Structure: The enclosure structure itself, including components like access panels, covers, and doors, must be designed and constructed such that opening or closing them does not produce sparks, which could ignite hydrogen.

Static Electricity Control for Structural Components: Specific measures are required to eliminate static electricity on equipment often integral to the structure, such as storage tanks and vent stacks, to prevent static discharge from becoming an ignition source. This includes requirements for isolating or bonding these components.

Installation Site and Foundation Safety: The immediate surroundings and walls where the equipment is installed must be fire-safe. Foundations and installation sites must be free from flooding risks. The electrolysis system must be securely anchored to its foundation or structure to prevent movement or toppling.

Earthing Implementation Details: While the principle of earthing is common, specific details for earthing conductors used with water electrolysis systems are mentioned, including minimum cross-sectional areas (e.g., 16 mm² or 6 mm² for low-voltage neutrals) and the need for associated resistors/reactors to handle fault current safely. The installation must also ensure earthing components are placed where they are not hazardous or accessible to unauthorised personnel.

3.8. Electrical Safety Inspection in Fuel Cell Power Generation

Specific electrical safety focus for fuel centred on managing fuel gas hazards, ensuring the safe operation of the stack and reformer through dedicated controls and interlocks, and implementing a thorough product inspection process for larger systems.

Fuel Gas Management & Process Safety: Given that fuel cells utilise various fuels (hydrogen, LPG, LNG, methane, biogas, etc.) and involve processes such as reforming, specific safety measures are mandated:

- ⚡ **Gas Handling Materials and Design:** Parts carrying fuel gas or reformed gas must use non-combustible materials, with exceptions only for necessary seals/packing. Structures must be designed to prevent the accumulation of leaked gas.
- ⚡ **Gas Leak Detection and Ventilation:** Facilities must have devices to detect and alarm gas leaks in areas where accumulation is possible. Adequate ventilation (natural or forced with interlocks) is critical. The flammable gas detection system must trigger a systemwide shutdown if the concentration exceeds 25% of the lower flammability limit. Consideration must be given to Hazardous Area Classification based on the potential for explosive gas atmospheres.
- ⚡ **Purging and Isolation:** A “Gas Purge” function is required to remove process gases safely. Safe procedures for replacing fuel gas with inert gas must be possible. Fuel gas pipelines require clear external markings indicating the gas type, maximum pressure, and flow direction.
- ⚡ **Burner and Ignition Safety:** These rules govern burners used (e.g., for reformers): (1) they require stable mounting and design to prevent backfire, (2) automatic air purge (minimum 4x housing

volume) is needed before ignition attempts, (3) reliable flame monitoring devices are mandatory, (4) automatic fuel supply cut-off must occur rapidly (e.g., within 3 seconds, unless safety analysis justifies longer) upon flame failure or flame monitoring device fault, followed by a lockout requiring manual reset, and (5) specific requirements apply to electrical ignition devices (spark gaps, insulation, heater mounting).

- ⚡ **Fuel Supply Control:** The main fuel supply must pass through at least two serially connected automatic shut-off valves. Measures must prevent air backflow into fuel pipes or fuel gas into air supplies. The backflow of treated fuel gas into the fuel source must also be prevented.

Fuel Cell Stack/Module Electrical Safety: Specific protections are tied directly to the fuel cell's electrochemical operation:

- ⚡ **Emergency Shutdown Triggers:** The system must automatically disconnect from the circuit, cut off gas supply, and safely vent internal gas upon detecting conditions specific to fuel cell operation, including: (1) overcurrent within the fuel cell stack, (2) abnormalities in the generated voltage of the fuel cell stack, (3) significant rise in oxygen concentration at the fuel gas outlet or fuel gas concentration at the air outlet, and (4) significant temperature rise within the fuel cell stack.
- ⚡ **Reformer Safety Interlocks:** An emergency stop must be triggered if the reformer burner flame goes out.

Control System Electrical Safety:

- ⚡ **Fail-Safe Operation:** Electronic control devices must be designed such that malfunctions (like partial short-circuits or disconnections) or state changes (like switching from open to closed) do not cause overheating or unintended gas release affecting safety.
- ⚡ **Control Power Monitoring:** An emergency stop must occur upon significant drops in control power voltage or malfunctions in the control devices themselves.

Product Inspection Regime (for Systems >100 kW): Unique to larger fuel cell (and wind) systems is a detailed pre-use product inspection process:

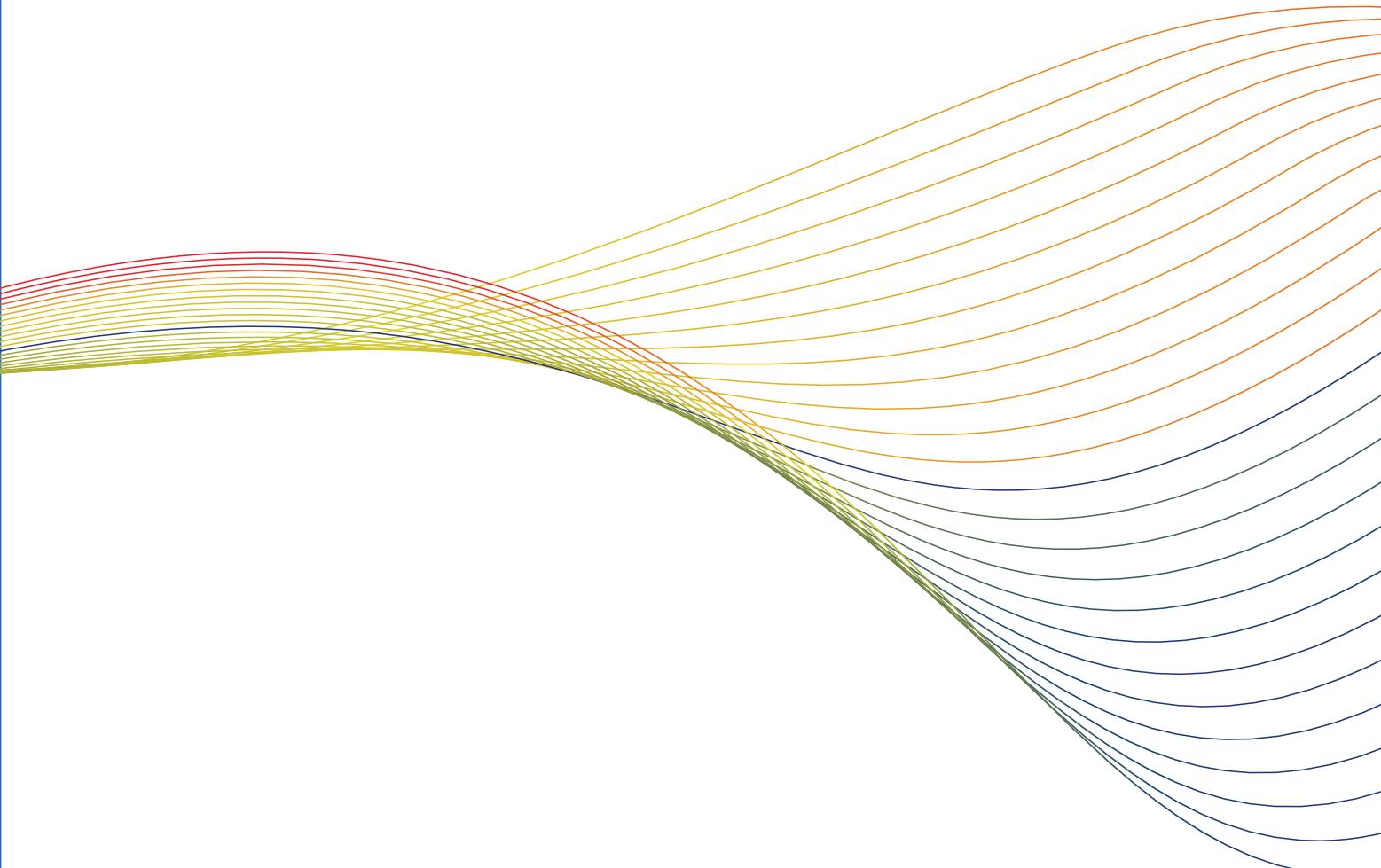
- ⚡ **Manufacturing Facility Standards:** Manufacturers require specific manufacturing and testing facilities and must maintain a quality management system, subject to initial and periodic inspections.
- ⚡ **Product Testing:** Products undergo rigorous initial (type) testing and subsequent shipping inspections covering safety requirements based on referenced international standards (like IEC 62282-3-100). This includes tests for leakage, strength, normal operation, electrical overload, shutdown parameters, burner characteristics, emissions, electrical safety, and EMC.
- ⚡ **Certification and Marking:** Passed products receive specific approval markings for traceability and confirmation of compliance.

Safety of Structures and Foundations: Beyond the standard earthing requirements for metallic structures, the unique electrical safety emphasis for fuel cell structures and foundations lies in how the physical design, layout, and ventilation features of the building or enclosure directly impact the management of flammable gas hazards and the subsequent classification of hazardous locations, which in turn dictates requirements for electrical equipment installed within that structure.

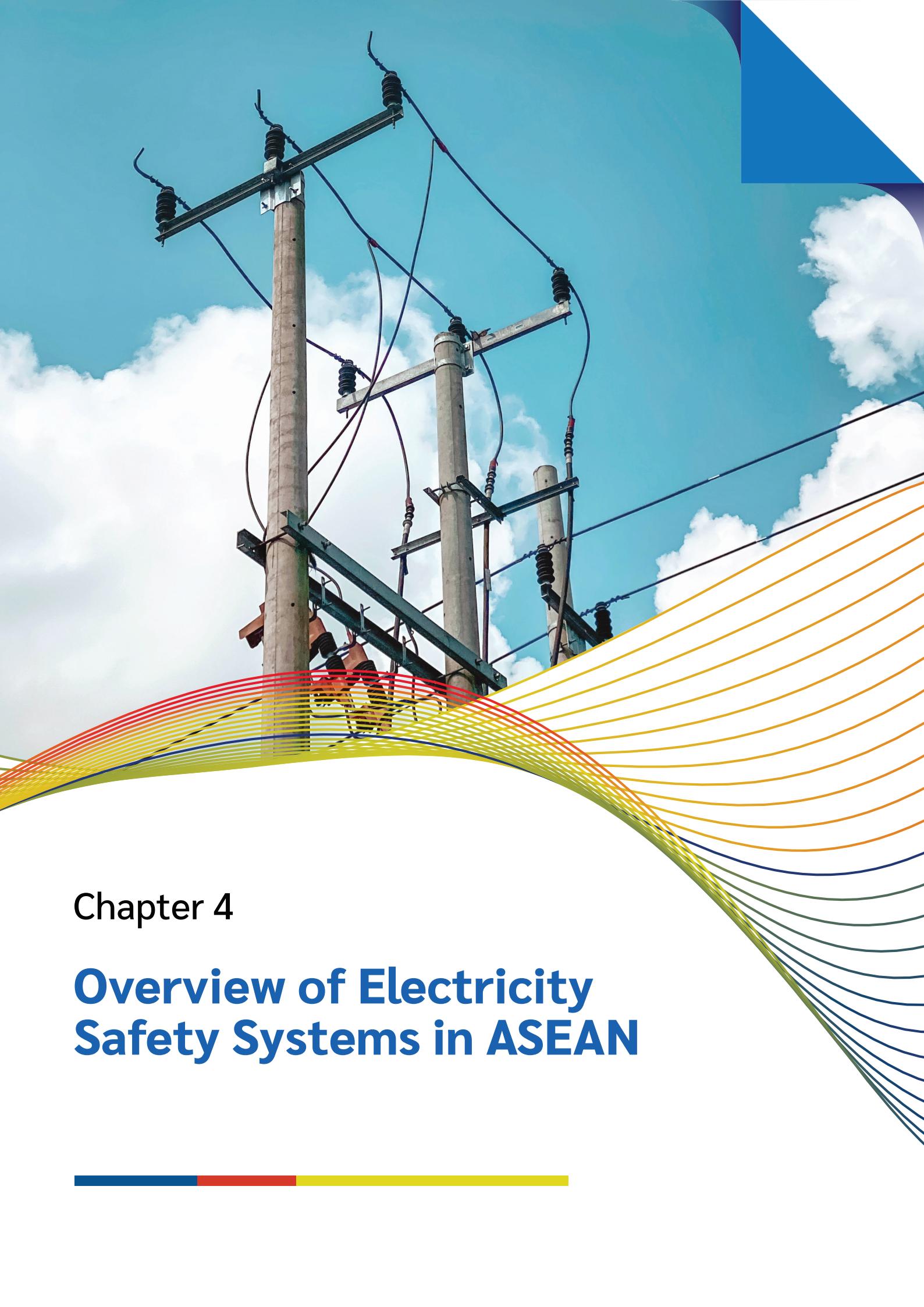
Structural Design Influence on Hazardous Area Classification: The design of the building, enclosure, or structure housing the fuel cell equipment plays a critical role in electrical safety by influencing the classification of hazardous areas. The structure's layout and integrated ventilation systems must be designed to minimise the frequency, duration, and volume of potential flammable gas leaks and, consequently, limit the extent of classified hazardous zones (like Zone 0 or Zone 1). This structural design directly dictates where specific types of electrical equipment (e.g., explosion-proof rated) must be installed to prevent ignition sources in potentially flammable atmospheres.

Gas Accumulation Prevention via Structure: The installation site and structure must be configured to prevent the accumulation of leaked fuel gas. This structural consideration works in conjunction with required gas detection and alarm systems, which must be placed in locations within the structure where gas could potentially accumulate.

Electrical Corrosion Prevention for Associated Buried Piping: For buried steel pipes carrying fuel (which are often installed in or near the foundation), measures must be taken for electrical corrosion prevention to maintain pipeline integrity.







Chapter 4

Overview of Electricity Safety Systems in ASEAN

Building on the analysis of the Republic of Korea's unified and systematically implemented electrical safety framework, this chapter turns to the markedly different—and significantly more complex—landscape of the ASEAN region.

Unlike Korea's relatively homogeneous, centralised system, ASEAN comprises a highly diverse set of Member States, each with distinct levels of economic development, technological priorities, energy resources, grid reliability, infrastructure maturity, and institutional capacity. This diversity fundamentally shapes the region's fragmented approaches to electrical safety management.

The complexity is further intensified by ASEAN's collective pursuit of ambitious renewable energy (RE) targets. While this energy transition presents major opportunities, it also introduces a range of safety challenges that vary widely across national contexts. As a result, ASEAN cannot adopt a single, uniform model like Korea's KEC and KESCO system; instead, it requires differentiated, context-specific solutions.

To comprehensively understand this multifaceted environment, this chapter systematically dissects the key dimensions influencing electrical safety in ASEAN, starting from mapping the heterogeneity in RE development itself and the wide spectrum of grid infrastructure quality, and the consequent safety risks arising from integrating intermittent technologies into systems with vastly different capabilities and resilience levels. Then this chapter examines the diverse governance structures responsible for electrical safety.

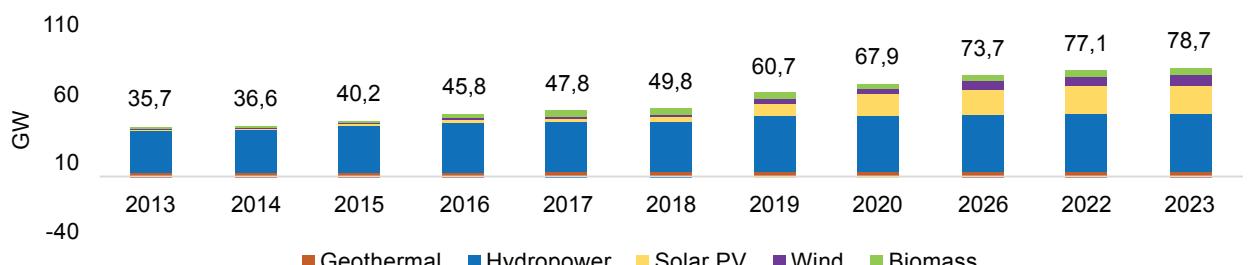
The effectiveness of these agencies is intrinsically linked to the regulatory tools, legal frameworks, technical codes, and standards adopted nationally. Lastly, the evaluation of grid modernisation challenges (essential for RE penetration) is explored by investigating the legacy electricity system and its impact on standards adoption.

4.1. Heterogeneity of Renewable Electricity Development in ASEAN

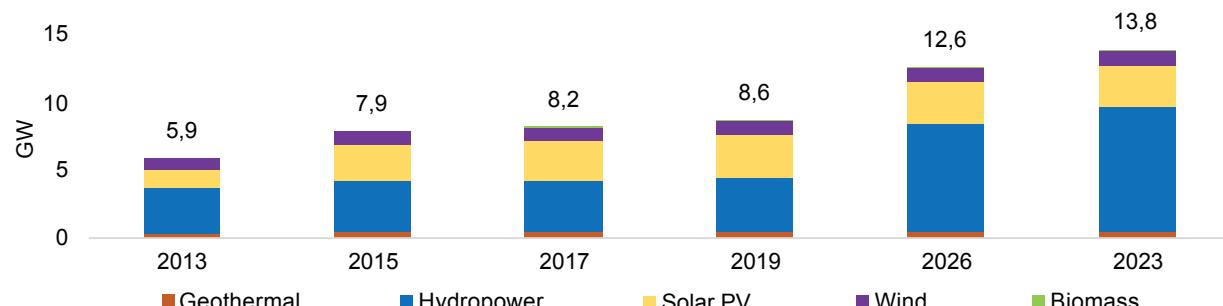
ASEAN presents a highly diverse picture regarding both the pace and focus of RE development and the underlying quality of its electrical infrastructure. ASEAN countries collectively work towards regional targets under the ASEAN Plan of Action for Energy Cooperation (APAEC) Phase II, aiming for a 23% RE share in Total Primary Energy Supply (TPES) and 35% RE share in installed power capacity by 2025. However, as of 2022, the RE share in TPES stood at 15.6%, with fossil fuels still dominating.

The region possesses vast RE potential, estimated by IRENA at over 17,000 GW total, overwhelmingly led by solar PV potential (around 15,600 GW) and followed by offshore wind (around 1,150 GW).^[1] As indicated in Figure 4-1, current operational RE capacity shows hydropower leading (approx. 44.6 GW), followed by solar PV (approx. 20.2 GW), wind (approx. 9.4 GW), bioenergy (approx. 5.3 GW), and geothermal (approx. 4.1 GW).

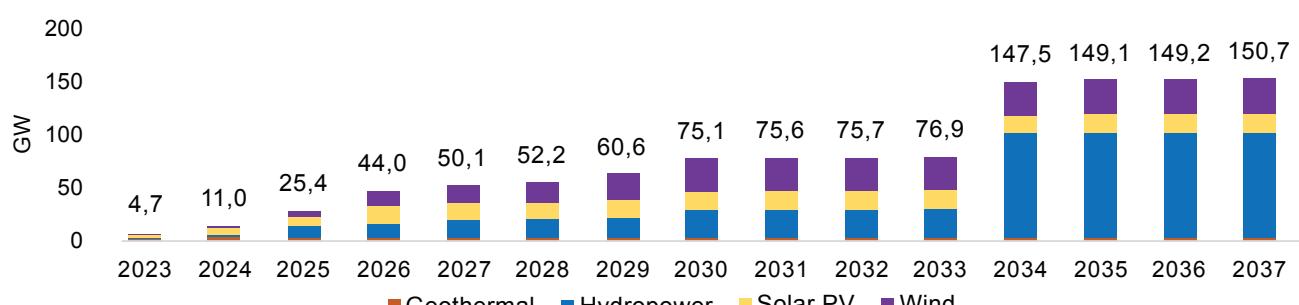
Future development trends indicate a major shift towards variable renewables. While hydropower continues to grow (over 38 GW planned pre-construction, nearly 12 GW under construction), planned pre-construction capacity is dominated by wind (over 111 GW) and solar PV (over 35 GW). Solar also has significant capacity under construction (over 4 GW). This signifies transitioning from current hydropower dominance towards wind and solar as key future players in ASEAN's energy. [2]



(a)



(b)



(c)

Figure 4-1 Current and Future Trends of RE Sources in ASEAN
(a) Operational; (b) Under Construction; (c) Pre-construction

Economic growth across the region is a fundamental driver of increasing energy demand, necessitating diverse supply options including renewables. Enhancing national and regional energy security by diversifying energy sources and reducing reliance on volatile global fossil fuel markets remains a primary motivator. Regional cooperation frameworks, like APAEC and broader ASEAN Economic Community integration goals provide platforms for coordinated action and knowledge sharing. Facilitating technology transfer and developing a skilled workforce are recognised as vital for building and maintaining modern and safe RE infrastructure.

Grid infrastructure quality and stability differ dramatically across ASEAN. Some nations boast modern, highly reliable networks. In contrast, others and particularly archipelagic states, or less developed areas, contend with challenges like ageing infrastructure, limited connectivity, high transmission losses, and grid instability (voltage/frequency fluctuations). Integrating large shares of VRE like solar and wind into grids, especially those less robust or originally designed for predictable fossil fuel generation, introduces significant technical complexities and may heighten electrical safety risks [3].

Weak or unstable grids are inherently less resilient to VRE power fluctuations, increasing the likelihood of disturbances that can cascade into electrical faults, equipment damage, or service interruptions. Grid limitations magnify specific safety hazards tied to VRE integration. These include electrical fires and system failures stemming from improper installations (e.g., poor connections, inadequate wiring), component malfunctions (especially inverters), system overloading, and insufficient protective systems. The high humidity of the ASEAN climate potentially causes short circuits, heavy rains affecting hydropower operations, coastal salinity impacting wind turbines, and high ambient temperatures leading to overheating—further stressing electrical systems and exacerbating these safety risks.

The deployment of ESS, often vital for managing VRE on less stable grids, introduces specific risks like thermal runaway or fires if not implemented with rigorous safety management, monitoring, and control systems appropriate for the grid environment. Ultimately, managing the increased complexity of safe VRE integration, particularly on grids with varying quality, demands substantial grid modernisation. This must be done alongside the critical implementation and strict enforcement of updated, comprehensive electrical safety standards and practices for all aspects of generation, transmission, distribution, and end-use equipment.

4.2. Electricity Safety Management in ASEAN

Most AMS have established national legal frameworks governing electrical safety, often rooted in broader electricity laws, specific safety acts, or regulations issued under relevant ministries (e.g., Energy, Industry, Works). These frameworks typically empower government bodies to set standards, regulate installations, and control the sale and use of electrical equipment. The structure commonly involves ministerial agencies as indicated in Table 4-1, where electrical safety oversight is embedded within a government ministry, often alongside other energy market or industrial policy responsibilities. Some countries utilise non-ministerial agencies, but these may also handle commercial aspects (e.g., pricing, market competition), potentially diluting the focus on safety, indicating the need for truly independent agencies focused solely on electrical safety across ASEAN. [4]

Table 4-1 Compilation of Agencies Responsible for Electrical Safety Management for RE Facilities in ASEAN Countries

Countries	Main agency responsible for electrical safety	Structure	Responsible on Electrical Safety			Others
			Certification & Inspection	Disaster Management	Research & Development	
Brunei Darussalam	Autoriti Elektrik Negara Brunei Darussalam (AENBD)	Ministerial agency	✓	✓	✗	Administrative, operational, and financial aspects.
Cambodia	Electricity Authority of Cambodia (EAC)	Non-ministerial agency	✓	✗	✗	Economic and operational regulations
Indonesia	Directorate General of Electricity and EBTKE	Ministerial agency	✓	✓	✗	Regulate the business framework, including licensing, pricing, and land use

Countries	Main agency responsible for electrical safety	Structure	Responsible on Electrical Safety			Others
			Certification & Inspection	Disaster Management	Research & Development	
Lao PDR	Ministry of Energy and Mines (MEM)	Ministerial agency	✓	✓	✗	Pricing, Investment, Service, Consumer Rights
Malaysia	Suruhanjaya Tenaga-Peninsular	Non-ministerial agency	✓	✓	✓	Economic, environmental, and market dynamics of energy supply
	Electricity Supply Division-Sarawak					
	Energy Commission of Sabah (ECoS)-Sabah					
Myanmar	Ministry of Electric Power (MOEP)	Ministerial agency	✓	✓	✗	Administrative, economic, and operational regulations
Philippines	The Energy Regulatory Commission (ERC)	Non-ministerial agency	✓	✗	✗	Fostering a competitive electricity market
Singapore	Energy Market Authority of Singapore (EMA)	Non-ministerial agency	✓	✓	✓	Market Competition and Fairness
Thailand	Energy Regulatory Commission (ERC)	Non-ministerial agency	✓	✓	✓	Tariff and market regulation
Viet Nam	Electricity Regulatory Authority of Viet Nam (ERA) V	Ministerial agency	✓	✗	✗	Power market, power planning, tariff regulation

Source: Authors' compilations

The governance structure for electrical safety in ASEAN countries shows distinct patterns. Ministerial structures are prevalent in Brunei Darussalam, Indonesia, Lao PDR, Myanmar, Thailand, and Viet Nam, alongside several Non-ministerial bodies in Cambodia, Malaysia, the Philippines, and Singapore. Notably, no country features a truly independent agency focused solely on electrical safety, separate from governmental or commercial/market oversight functions.

Regarding the scope of responsibilities held by these main agencies, Certification & Inspection is consistently marked as a function covered by all listed bodies across ASEAN. However, coverage for other key safety functions varies. Disaster Management is indicated as a responsibility of the main safety agencies in Brunei, Indonesia, Lao PDR, Malaysia, Myanmar, Singapore, and Thailand, but not in Cambodia, the Philippines, or Viet Nam. R&D appears to be the least integrated function within these primary agencies, with only Malaysia, Singapore, and Thailand showing coverage; the agencies listed for the other seven countries do not include R&D within their scope. Consequently, the agencies in Cambodia, the Philippines, and Viet Nam are shown as lacking direct responsibility for both Disaster Management and R&D.

Several other significant trends include the extensive list of “Other” responsibilities assigned to nearly all these agencies, regardless of their structure. These often encompass economic regulation, market

functions (pricing, competition), licensing, and broader administrative or operational duties for the electricity sector, highlighting a potential dilution of focus away from purely safety-related tasks. The limited inclusion of R&D within these primary agencies suggests that this function is frequently managed by separate entities, or may receive less emphasis within the primary safety governance structure.

Furthermore, Figure 4-2 reveals a diverse mix of organisations supporting the main regulatory agencies in Certification and Inspection activities across ASEAN. A prominent trend is the significant involvement of national electricity utilities. Examples identified include *Electricite du Cambodge* (EDC), Indonesia's *Perusahaan Listrik Negara* (PLN), *Electricite du Laos* (EDL), Malaysia's *Tenaga Nasional Berhad* (TNB), Sabah Electricity Sdn Bhd (SESB), and Sarawak Energy, the Philippines' National Power Corporation (NPC), Singapore's SP Group, Thailand's EGAT, MEA, and PEA, and Viet Nam Electricity (EVN). Their involvement likely pertains to grid connection standards, inspection of installations connected to their network, or certification of utility-specific equipment.

National Standards Bodies also play a crucial role, such as Indonesia's *Badan Standardisasi Nasional* (BSN), the Philippines' Bureau of Philippine Standards (BPS), Thailand's Industrial Standards Institute (TISI), and Viet Nam's Directorate for Standards, Metrology and Quality (STAMEQ). A unique case in Thailand also involves the professional engineering association – the Engineering Institute of Thailand (EIT).

Various Government Ministries or Departments contribute, including those responsible for Energy (Indonesia), Science & Technology (Lao PDR, Viet Nam, Myanmar), Trade & Industry (Malaysia, Philippines), and specific bodies like Brunei's Department of Electrical Services (DES) or Thailand's Department of Alternative Energy Development & Efficiency (DEDE).

In Thailand, additional agencies such as the Department of Industrial Works under the Ministry of Industry, and the Department of Labour Protection and Welfare under the Ministry of Labour also play key roles in ensuring electrical safety in industrial and occupational settings. Agencies focused on Safety or Enterprise Development, like Singapore's Enterprise Singapore and Brunei's Safety, Health, and Environment National Authority (SHENA), are also involved.

Other Related Agencies	Best Practice	ASEAN Countries										
		Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam	
Certification and Inspection		 AENBD DES SHENA	 ISC EDC	 MME EAC	 KESDM	 UNIVERSITAS TEKNOLOGI ENERGI DAN MINERAL	 ST EDL	 SESA TBN	 DISI	 BUREAU OF PHILIPPINE STANDARDS	 OPEA EGAT nnw PTEC	 KSP MOST
Disaster Management		 AENBD SHENA		 KESDM	 UNIVERSITAS TEKNOLOGI ENERGI DAN MINERAL	 BOMBA ST MMUT	 ST SIRIM	 SHOEP	 MFSD	 BPPF	 nnw PTEC	
Research and Development				 TECHNICAL INSTITUTE		 ST SIRIM	 IEE	 IEE	 nnw PTEC	 MOI ECA NSTDA	 MOST	

Figure 4-2 Other Related Agencies Responsible for Electrical Safety in ASEAN

For Disaster Management related to electrical safety incidents, the trend clearly points towards the involvement of specialised national emergency response agencies. This includes dedicated national disaster management agencies, such as Cambodia's National Committee for Disaster Management (NCDM), Indonesia's *Badan Nasional Penanggulangan Bencana* (BNPB), Malaysia's National Disaster Management Agency (NADMA), Thailand's Department of Disaster Prevention and Mitigation (DDPM), and the Viet Nam Disaster Management Authority (VDMA).

Equally prominent is the role of Fire and Rescue Services or Civil Defence Forces, including Malaysia's firefighters (BOMBA), Myanmar's Fire Services Department (MFSD), the Philippines' Bureau of Fire Protection (BFP), and the Singapore Civil Defence Force (SCDF). These organisations are primarily responsible for the immediate response to emergencies, including electrical fires, rescues, and managing the aftermath of incidents affecting electrical infrastructure. The safety authority SHENA in Brunei is also listed, potentially indicating a coordinating or preventive role.

The agencies involved in R&D related to electrical safety show a different pattern, featuring a mix of government research institutions, ministries, standards bodies with research functions, and professional associations. National research agencies—such as Indonesia's *Badan Riset dan Inovasi Nasional* (BRIN), Singapore's Agency for Science, Technology and Research (A*STAR), and Thailand's National Science and Technology Development Agency (NSTDA)—play a direct role. Relevant government ministries, particularly those overseeing Science, Technology, and Innovation (like in Cambodia – MISTI, Lao PDR – MOST, Thailand – MHESI, Myanmar – DRI under MOST) or Industry (Thailand - MOI), are also involved. Standards and industrial research institutes, such as Malaysia's SIRIM and Thailand's Electrical and Electronics Institute (EEI) and TISI, contribute by linking standardisation with research efforts. A unique aspect is the involvement of professional engineering bodies, like the Institute of Integrated Electrical Engineers (IIEE) in the Philippines and the Institution of Engineers Singapore (IES), suggesting a role for professional expertise and collaboration in advancing safety-related knowledge and practices.

4.3. Regulatory Frameworks of Electrical Safety in ASEAN

The foundation for electrical safety in most AMS rests upon national-level legislation. This often takes the form of a comprehensive electricity law or act (relevant examples exist in Brunei, Cambodia, Indonesia, Lao PDR, Myanmar, Philippines, Singapore, and Viet Nam), or specific regulations issued by relevant ministries (often Energy, Industry, or Works). These primary laws establish the regulatory authority, define the scope of regulation – covering everything from power generation and transmission, to distribution and end-user installations, and safety mandate compliance. Implementation is overseen by designated national bodies as described in the previous section.

Supporting these laws are detailed technical regulations and national installation codes. These are critical documents providing prescriptive rules for safe electrical design and installation work. Prominent examples include the Philippines Electrical Code (PEC), extensively based on the US National Electrical Code (NEC), while also considering IEC standards; Singapore Standard SS 638, based on British Standard BS 7671 (aligned with IEC 60364) with local adaptations; and Indonesia's *Persyaratan Umum Instalasi Listrik* (PUIL), which is adopted as the national standard SNI 0225, and based on the IEC 60364 series.

These codes detail essential requirements for wiring systems, earthing, overcurrent protection, equipment selection, and special installations. [5]

Adherence to the established national electrical safety laws, technical regulations, and specified standards (especially for installations and specific product categories) is generally mandatory across ASEAN. This is typically enforced through licensing requirements for workers and installations, mandatory product certification before sale, and inspections. Regulators employ various tools, including mandatory licensing, site inspections (though scope and rigour vary widely), verification of product certifications at import/sale points, and legal penalties for violations stipulated within the national legislative framework.

For instance, some countries require an Operation Worthiness Certificate (e.g., Indonesia's SLO) for grid-connected Solar PV installations. Table 4-2 compiles the primary electricity safety laws and relevant standards/guidelines in each ASEAN country.

Table 4-2 Electrical Safety-Related Laws and Standards/Guidelines in ASEAN

Country	Primary Law	Guidelines/Codes/ Technical Standards	RE Specific Guidelines (may cover Electrical Safety aspects too)
Brunei Darussalam	Electricity Order 2017	Electrical Installation Requirements (adopted 17 th edition IEE Wiring Regulations – BS 7671) Guidelines and Best Practices for Low Voltage Wiring and Electrical Appliance Safety; Guidelines and Best Practices for Construction Power; Guidelines and Best Practices for Public Lighting; Electrical Appliances and Product (Safety Requirement) Guideline	Guidebook for Solar PV Rooftop and Net-metering Programme; Code of Practice for Large-Scale Solar PV Connection to Distribution Grid; Code of Practice for Small Scale Solar PV System Connection to Low Voltage Network (capacity below 0.9 MWac connecting to 400V/230V network)
Cambodia	Electricity Law (2001)	Prakas on Establishment of Specific Requirement of Electric Power Technical Standards (No. 796 of 2007 – amended Prakas No. 470 of 2004, referencing international standards)	Prakas on Updated Principles for Permitting the Use of Rooftop Solar Power in Cambodia (No. 0312 of 2024 – replaced No. 0159 of 2023). This Prakas mandates compliance with technical and safety standards; Grid Connection Technical Requirements by EAC specified certain technical limits that installations must adhere to in connecting solar PV to national grid

Indonesia	<p>Electricity Law (No. 30 of 2009, amended);</p> <p>Ministry Regulation – Permen ESDM No. 10 of 2021 about Electrical Safety;</p> <p>Permen ESDM No. 38 of 2018 requirements for obtaining SLO;</p> <p>Permen ESDM No. 2 of 2024 mentions the need for safety check in solar rooftop installations</p>	<p><i>Persyaratan Umum Instalasi Listrik</i> (PUIL), currently SNI 0225:2020 series (based on IEC 60364)</p>	<p>Mandatory certification standard SNI IEC 61215 for PV modules;</p> <p>Operation Worthiness Certificate (SLO) required for grid-connected PV;</p> <p>PUIL 2020 includes Section 7-712 for Solar PV systems</p>
Lao PDR	Law on Electricity (2017 Edition)	<p>Lao Electric Power Technical Standard (adapts international standards, esp. IEC): electrical installations (e.g., LS 245-2016 based on IEC 60364-7-717 for mobile units) and electrical products</p>	<p>Not available, but adopting IEC 61730 for PV safety (for example) is encouraged</p>
Malaysia	<p>Electricity Supply Act 1990 (Act 447);</p> <p>Electricity Regulations 1994 (include technical rules and safety requirements);</p> <p>Energy Commission Act 2001 established Energy Commission (<i>Suruhanjaya Tenaga</i>) to enforce the Electricity Supply Act 1990 and Electricity Regulations 1994</p>	<p>Primarily uses Malaysian Standards (MS) referencing IEC, particularly the MS IEC 60364 series for electrical installations of buildings;</p> <p>MS 1979:2015 (Code of practice) also relevant</p>	<p>Guidelines for Solar Photovoltaic Installation under Net Energy Metering (NEM) Scheme (e.g., GP/ST/No.4/2016, amended 2019);</p> <p>Guidelines for Solar Photovoltaic Installation for Self-Consumption (SELCO) (e.g., GP/ST/No.51/2024);</p> <p>Grid Code and New Enhanced Dispatch Arrangement (NEDA) compliance is required for larger RE installations or specific schemes like the Corporate Renewable Energy Supply Scheme (CRESS)</p>
Myanmar	National Electricity Law (2014)	Myanmar National Building Code 2012 (updated 2020) contains provisions for electrical installations	<p>Not available, but adopting IEC 61730 for PV safety (for example) is encouraged</p>
Philippines	<p>Republic Act No. 7920 (New Electrical Engineering Law of 1995);</p> <p>Republic Act No. 9513 (RE Act of 2008)</p>	<p>Philippine Electrical Code (PEC) Part 1 (2017 Edition is the key version referenced, based on US NEC with IEC considerations);</p> <p>Occupational Safety and Health Standards Rule 1210 (Electrical Safety) and Rule 1211 that explicitly adopts PEC as the safety standard for electrical installations in workplace</p>	<p>PEC 2017 includes Article 6.91 (Large-Scale Solar PV) and Article 7.6 (Energy Storage Systems)</p>

Singapore	<p>Electricity Act 2001 (Chapter 89A);</p> <p>Electricity Regulations made under the Electricity Act, especially the part about Electrical Installations and Electrical Workers;</p> <p>The Energy Market Authority of Singapore Act 2001 established EMA as a statutory board that is mandated to enforce the Electricity Act and its subsidiary regulations.</p>	<p>Singapore Standard SS 638:2018 (Code of practice for electrical installations, based on BS 7671/ IEC 60364);</p> <p>SS 650 (Temporary Electrical Installations);</p> <p>SS 551 (Earthing)</p>	<p>EMA provides consumer guide outlining the following steps for solar rooftop installation include,</p> <p>Engaging a Qualified Person (registered Architect or Professional Engineer) for design and regulatory compliance and;</p> <p>Engaging a Licensed Electrical Worker for the actual installation, connection, and handling of relevant electrical licenses</p> <p>Fire safety requirements are provided in SCDF Fire Code 2023 - clause 10.2 for solar PV (class C rating based on IEC 61730-2 tests) and clause 10.3 for ESS</p>
Thailand	<p>Energy Industry Act 2007;</p> <p>Industrial Product Standards Act 1968 (governs the TISI *under Ministry of Industry);</p> <p>Building Control Act 1979 (regulates building construction);</p> <p>Ministry of Labour/ Occupational Safety and Health Regulations (ensuring safe electrical practices within workplace)</p>	<p>EIT Standard 022001-22: Thai Electrical Code 2021, based on IEC 60364</p>	<p>Standards for Solar Power Installation: EIT Standard 022013-22 (covering arc-fault circuit interrupter, PV rapid shutdown, and ESS)</p> <p>Standards for Products of Solar PV Generation System: TIS 61215 Part 1-1 and TIS 2580 Part 2 (PV Module); TIS 2603 Part 1 and 2, TIS 2606, TIS 2607 (Power Conversion Equipment)</p> <p>ERC Code of Practice for electricity generator from solar PV technology</p> <p>MEA and PEA Grid Codes (Service, Connection, Operation)</p>
Viet Nam	<p>Electricity Law 2024 (Law No. 61/2024/QH15) effective from 1 February 2024, replacing 2004 version – Article 4 mandates electrical safety and Article 9 prohibits violation of electrical safety regulations;</p> <p>MOIT Circulars</p>	<p><i>Tiêu chuẩn Việt Nam</i> (TCVN) – Vietnamese National Standards;</p> <p><i>Quy chuẩn Kỹ thuật Quốc gia</i> (QCVN) – National Technical Regulations;</p> <p>TCVN 7447 series (based on IEC 60364) covers fundamental principles, protection for safety, selection, and installation of equipment, etc.;</p> <p>TCVN 9206:2012 covers the design requirements for installing electrical equipment in dwellings and public buildings;</p> <p>QCVN QTD 8:2010/BCT setting technical standards related to electrical safety;</p> <p>Other specific TCVN standards apply to earthing (e.g., TCXDVN 319:2004), equipment safety (e.g., TCVN 5699-1:2010), lighting, etc.</p>	<p>Standards for PV/BESS installation and standards noted as being under development</p>

The prevailing trend across ASEAN countries is the establishment of a primary law specifically dedicated to governing the electricity or energy sector. These often take the form of an “Electricity Law” (seen in Cambodia, Indonesia, Lao PDR, Myanmar, Philippines, Singapore, Viet Nam), an “Electricity Order” (Brunei), an “Electricity Supply Act” (Malaysia), or an “Energy Industry Act” (Thailand). A significant number of these laws have been enacted or substantially updated in the 21st century, indicating a regional move towards modernising the legal frameworks governing electrical safety, often incorporating provisions for RE and evolving market structures.

While a single primary law is common, some countries supplement this with other relevant legislation, such as acts covering industrial product standards or building control (like Thailand), or specific laws addressing RE (like the Philippines) or establishing the regulator (like Malaysia and Singapore).

ASEAN nations employ diverse instruments, including comprehensive national standards issued by standards bodies (like SNI in Indonesia, MS in Malaysia, SS in Singapore, TCVN/QCVN in Viet Nam), specific electrical codes developed by professional institutes or authorities (such as the PEC in the Philippines or the EIT Standard in Thailand), dedicated requirements documents (like the EIR in Brunei or the Lao Electric Power Technical Standard), ministerial regulations (Prakas in Cambodia), and codes of practice. In some cases, electrical safety requirements are integrated into broader regulations like national building codes (Myanmar). The mandatory status of these documents also differs; some are legally binding by default or specific regulation (e.g., SNI PUIL, SS 638), while others, particularly those from professional bodies, often become mandatory through reference in laws or other enforceable regulations like building codes.

IEC standards, especially the IEC 60364 series for low-voltage installations, are the most commonly cited foundation, noted explicitly or implicitly for Indonesia, Malaysia, Singapore, Thailand, Viet Nam, and Laos. Influence from British Standards (BS), specifically BS 7671 is also evident, being directly referenced by Brunei’s EIR and forming a basis for Singapore’s SS 638. The Philippines stands apart by primarily basing its PEC on the US NEC, although it incorporates IEC considerations as well.

Regarding RE-specific guidelines, the coverage currently focuses heavily on Solar PV technology across many ASEAN nations, including Brunei, Cambodia, Indonesia, Malaysia, Philippines, Singapore, and Thailand. These guidelines address various aspects like rooftop installations, grid connection rules for different scales, and specific programmes like net-metering or self-consumption. ESS are also gaining specific attention, being mentioned within the primary codes or guidelines of the Philippines, Thailand, Singapore, and Malaysia, and likely covered in Indonesia via its IEC-based PUIL. However, Table 4-2 indicates a gap in explicitly listed guidelines covering the specific electrical safety aspects of other RE technologies (e.g., wind, power generation with water electrolysis facility, and fuel cell). Furthermore, for Lao PDR and Myanmar, specific RE guidelines are marked as “Not available,” while Viet Nam notes that relevant standards are still under development.

4.4. Legacy Electricity Systems and Impact on Standards Adoption

The development of electricity infrastructure in Southeast Asia was significantly shaped by the colonial powers present in the region during the late 19th and early 20th centuries. This historical context established foundational systems, including voltage levels, frequencies, and initial technical standards, which have influenced the subsequent evolution and adoption of international standards like IEC or BS. Table 4-3 summarises the legacy electricity system, its implications for standards adoption, and RE penetration/infrastructure modernisation.

Table 4-3 Legacy Electricity Systems, Standards, and Impacts on Renewable Energy Adoption in ASEAN

Country	Primary Historical Influence	Legacy Voltage/ Frequency Standard	Current Standards Body/ Approach	Key Impacts on RE/ Modernisation
Malaysia	British	240 V, 50 Hz, BS Standards	DSM (national body), SIRIM (testing/cert); Actively adopt IEC as MS, but legacy persists (e.g., BS 1363 plugs).	Legacy BS grid challenges RE (bidirectional flow), needs upgrades, IEC codes, and smart grids.
Singapore	British	230/240 V, 50 Hz, BS Standards & practices	Enterprise Singapore (standards - SS), EMA (regulation); Actively adopts IEC directly or with minimal amendments (e.g., SS CP 5 based on IEC 60364).	Land scarcity drives rooftop RE; Dense grid requires advanced smart grid capabilities (storage, DR) based on IEC for stability.
Brunei	British	240 V, 50 Hz, BS Standards	No fully independent standards body; References IEC & regional (MY/SG) practices; Regulations often require IEC/BS 1363 compliance.	Small grid size impacts stability with intermittent RE; it requires IEC grid codes and upgrades for bidirectional flow/power quality.
Myanmar	British	230/240 V, 50 Hz, BS-compliant equipment	MNSC is developing standards, heavily relying on IEC. Practical adherence is inconsistent due to the ageing grid. Major projects typically follow IEC.	Poor grid quality and reliability hinder RE integration and automation. Utility-scale RE often needs upgraded IEC segments (foreign-funded).
Indonesia	Dutch	~110 V/220 V -> 220V/230V, 50Hz (European)	BSN (national body); Predominantly adopts IEC as SNI (e.g., PUIL based on IEC 60364); Mandatory SNI mark often signifies IEC compliance.	Archipelago/island grids challenge RE stability (need storage/controls); IEC-based RE grid codes are developing; and low voltage upgrades are needed for PV.
Viet Nam	French	220 V, 50 Hz (French/European)	STAMEQ (standards), EVN (utility), and TCVN standards have increasingly harmonised/adopted IEC.	Rapid RE growth outpaced grid upgrades (legacy capacity limits), causing curtailment; Needs massive investment, modernisation (IEC) & flexibility.

Lao PDR	French	220 V, 50 Hz (French/European)	Less developed national standardisation; Relies heavily on IEC & neighbour practices (TH/VN); Major projects follow IEC (developer/financier driven).	The hydro-export grid challenges domestic intermittent RE (stability/flexibility) and needs operational adaptation (IEC/Thai), upgrades, and forecasting.
Cambodia	French	220 V, 50 Hz (French/European)	ISC established; heavily relies on adopting IEC, influenced by neighbours and aid/investment; IEC is the default for major projects.	Developing/unreliable grids create stability risks for RE; may require batteries and robust, evolving IEC grid codes.
Philippines	Spanish, then American	110 V -> 230 V, 60Hz (US Standard)	BPS (national body) but PEC (based on US NEC) is dominant electrical code; ERC regulates. Standards reflect US practices, adapted for 60Hz/NEC.	Unique 60 Hz challenges RE (equipment, stability); Codes adapt IEC to NEC/PEC framework.
Thailand	Independent (but early foreign influence)	220/230 V, 50 Hz (European/Global)	TISI (national body); Proactive adoption/harmonisation of IEC standards as TIS; TISI participates in IEC committees.	High RE penetration challenges an extensive/legacy grid (MEA/PEA); it needs accelerated IEC-based smart grids, upgrades, and flexibility (EGAT planning).

4.4.1. Malaysia – British

The first public electricity supply was initiated in Penang in 1904 and Kuala Lumpur in 1905, primarily driven by the needs of tin mining dredges, ports, railway workshops, and colonial administration. Early systems were often localised diesel generators or small hydro plants. The British established the Central Electricity Board (CEB) in 1949 (predecessor to TNB), standardising generation and distribution based firmly on British practices: 240 V (phase-to-neutral), 50 Hz frequency, and BS standards for equipment, installation (wiring), and safety.[6]

Department of Standards Malaysia (DSM) is the national body, with SIRIM Berhad providing testing and certification. While Malaysia actively adopts IEC standards as Malaysian Standards (MS), significant legacy remains:

- **MS IEC 60364 (Wiring Regulations):** While based on IEC 60364, specific national practices influenced by older BS 7671 persist, particularly in domestic installations.
- **Plug and Socket:** The MS 589 standard mandates the BS 1363 plug and socket system for domestic use, a very direct and enforced British legacy for safety reasons (fused plugs, shuttered sockets).
- **Equipment Certification:** SIRIM certification is mandatory for many electrical products. While the underlying safety standards are often IEC-based, compliance checks ensure compatibility with the Malaysian 240 V/50 Hz system and plug requirements.

The 50 Hz legacy simplifies the integration of modern IEC-based industrial automation compared to 60 Hz systems, although interfacing with legacy BS-influenced wiring in older facilities might still pose

challenges. However, older parts of the distribution network, designed under historical BS-influenced radial principles, struggle with the bidirectional power flow required by high penetrations of distributed solar PV. This often necessitates costly upgrades, and the deployment of smart grid solutions aligned with newer IEC standards to manage voltage rise and reverse power flow. Furthermore, integrating large-scale RE requires robust grid codes based on IEC standards to manage intermittency and ensure stability, demanding modern grid management systems that can operate effectively alongside legacy infrastructure. [7]

4.4.2. Singapore – British

Similar timeline to Malaysia, with early electricity supply for port operations, administration, and commercial centres established by the Municipal Commissioners, later consolidated under the Public Utilities Board (PUB) in 1963. [8] The system was built entirely on British standards: 230/240 V, 50 Hz, and BS specifications for equipment and wiring (e.g., armoured cables and conduit systems reflecting BS practices).

Enterprise Singapore oversees standards (Singapore Standards - SS), often adopting IEC standards directly or with minimal amendments. EMA regulates the electricity industry and technical codes.

- » **SS CP 5 (Code of Practice for Electrical Installations):** This is Singapore's wiring code, heavily based on IEC 60364, but retaining references and practices compatible with the BS 1363 plugs/sockets and historical installation methods where deemed necessary for safety or practicality.
- » **Consumer Protection (Safety Requirements) Regulations:** Managed by Enterprise Singapore, this mandates the SAFETY Mark for specific electrical appliances. While testing is based on relevant IEC standards, it critically enforces the use of BS 1363 plugs for appliances sold locally. [9]

Singapore's strong adherence to IEC standards and high grid quality facilitates seamless industrial automation integration. The primary RE challenge stems not from standards conflicts (though the legacy BS 1363 plug remains mandatory for appliances), but from land scarcity, pushing focus towards rooftop and building-integrated PV. Managing potentially millions of small, distributed RE sources on a dense, highly optimised urban grid requires advanced smart grid capabilities (demand response, storage) far beyond the original legacy system's design, in order to maintain grid stability. [10] EMA actively manages this through clear IEC-based interconnection guidelines and the promotion of smart grid technologies, addressing the cumulative impact of massive distributed RE on a grid initially built for centralised generation.

4.4.3. Brunei Darussalam – British

Electrification started later and on a smaller scale than in Malaysia/Singapore, often linked to the oil and gas industry (Brunei Shell Petroleum) and government centres. The development followed British standards (240 V, 50 Hz, BS specifications) due to political ties, proximity, and the use of British consultants and equipment suppliers. [11] DES manages the grid. Brunei largely references international standards (IEC) and often follows practices in Malaysia and Singapore due to regional proximity and trade. There isn't a fully independent, comprehensive set of national electrical standards diverging significantly from

IEC/BS norms. Regulations often implicitly or explicitly require adherence to IEC standards for major equipment and BS 1363 for domestic plugs/sockets.

Integration of IEC-based industrial automation is generally straightforward. However, Brunei's small grid means even moderate amounts of intermittent RE, like planned solar farms, can significantly impact system stability. [12] Effectively integrating RE necessitates adopting modern IEC-based grid codes and potentially upgrading older distribution circuits built on BS principles to handle bidirectional flows and maintain power quality.

4.4.4. Myanmar – British

The Rangoon Electric Tramway and Supply Company started supply in 1905. Early development under the British established the 240/230 V, 50 Hz standard and utilised BS-compliant equipment. Post-independence, the Electricity Supply Board (ESB), now the Ministry of Electric Power (MOEP) overseeing entities like the Electric Power Generation Enterprise (EPGE),[13] faced significant challenges. Decades of conflict and underinvestment severely hampered grid expansion and modernisation, leaving a patchwork of aging infrastructure.

Myanmar is actively working on developing and adopting national standards, heavily leaning on IEC. The Myanmar National Standards Council (MNSC) is involved in this process. However, the practical application faces hurdles. New large-scale generation and transmission projects, such as with China, India, or funded by World Bank (often foreign funded) [14] typically specify and adhere to modern IEC standards. Older distribution networks and building wiring may still reflect outdated BS practices or lack adherence to any formal standard due to age and lack of upgrades.

Significant challenges exist for integrating modern industrial automation due to power quality issues and inconsistent standards adherence in areas with older infrastructure. The poor state, low capacity, and unreliability of large parts of the legacy grid are the primary barriers to RE integration.[14] Utility-scale RE connections are often only feasible in recently upgraded grid segments adhering to IEC standards, typically linked to foreign-funded projects. Integrating RE into weaker grid sections is technically difficult without major reinforcement. Consequently, off-grid and mini-grid RE solutions (usually using IEC-compliant components) are vital for energy access, though they present future standardisation and integration challenges if the main grid expands.

4.4.5. Indonesia – Dutch

Several private Dutch companies (like ANIEM, OGEM) [5] established electricity supply in major cities (e.g., Batavia/Jakarta, Surabaya) starting in the late 19th/early 20th century. These likely followed prevailing continental European practices, standardising for 50 Hz, and voltages around 110 V or 220 V. Post-independence, these were nationalised into the state utility PLN (*Perusahaan Listrik Negara*) in 1961[15], which is standardised on 220V (now often stated as 230 V nominal), 50 Hz through Ministry Regulation in 2005 [16].

⁵ ANIEM - *Algemeene Nederlandsch-Indische Electriciteits-Maatschappij* (General Dutch East Indies Electricity Company) was a major private electricity company operating during the Dutch colonial era in the Dutch East Indies (now Indonesia). Founded in 1909, it established power plants (both diesel and hydro) and distribution networks, particularly in Central and East Java, eventually becoming the largest private electricity supplier in the colony. OGEM - *Overzeese Gas- en Electriciteitsmaatschappij* (Overseas Gas and Electricity Company) was the successor company to the *Nederlandsch Indische Gasmetschappij* (NIGM), which was the state gas company established in the Dutch East Indies in 1862. Its Indonesian assets related to gas likely formed part of the basis for the later state gas company, PGN (*Perusahaan Gas Negara*)

The National Standardisation Agency of Indonesia (BSN) sets SNI. For electrical standards, BSN predominantly adopts IEC standards.

- » SNI IEC 60364 series (PUIL): The “*Persyaratan Umum Instalasi Listrik*” (General Requirements for Electrical Installations) is based on IEC 60364.
- » Mandatory SNI: Many electrical products require mandatory SNI certification (marked with SNI logo), which generally signifies compliance with the relevant IEC standard adopted as SNI.

While IEC integration for industrial automation is generally smooth on the main Java-Bali grid, it can be challenging on less developed island grids. Managing grid stability across a vast archipelago with varying legacy infrastructure quality is inherently complex. Integrating high levels of variable RE is especially difficult on smaller island grids lacking inertia and interconnection, requiring localised solutions like battery storage and advanced controls beyond legacy capabilities. Grid Code Management Committee, which includes the Ministry of Energy and PLN, among others, is developing specific IEC-based grid codes for RE. [17] Furthermore, rolling out distributed rooftop PV necessitates upgrades to legacy low-voltage networks to handle reverse power flow and voltage issues, alongside deploying smart meters and updated systems based on modern standards.

4.4.6. Viet Nam – French

French companies established the first power plants in major cities like Saigon, Hanoi, and Haiphong in the early 20th century. These systems adopted French/European standards: 220 V, 50 Hz. Infrastructure development was concentrated in urban centres and was heavily disrupted by decades of war. Post-reunification (1975), the grid required extensive rebuilding and unification (North/South systems). [18]

The Directorate for STAMEQ under the Ministry of Science and Technology oversees national standards (TCVN). EVN, the state utility, plays a key role. TCVN standards for electrical systems and equipment are increasingly harmonised with or directly adopted IEC standards, driven by the need for modernisation, foreign investment, and participation in regional projects. The legacy 220 V, 50 Hz system provides a compatible base for IEC adoption.

Integration of IEC-based industrial automation is generally smooth, particularly in modern industrial zones. However, the rapid growth of RE, especially solar, has outpaced grid upgrades in certain regions, leading to significant curtailment because legacy transmission lines and substations lack sufficient capacity. Addressing this requires massive investment in grid expansion and modernisation [19] adhering to the latest IEC standards. Additionally, integrating large amounts of intermittent RE demands greater grid flexibility through faster ramping generation, storage, and advanced IEC-standard control systems, which need implementation across the entire EVN system, including areas with older infrastructure.

4.4.7. Lao PDR – French

Electrification under French rule was minimal, confined to a few administrative centres, and based on 220 V, 50 Hz [20]. Significant development is much more recent, largely driven by the state utility EDL and focused on leveraging vast hydropower potential for domestic use and export (especially to Thailand and Viet Nam). [21]

Due to grid interconnections and technology imports, the Lao PDR relies heavily on international standards (IEC) and practices from its neighbours, particularly Thailand. The Ministry of Energy and Mines sets policy. Formal national standardisation is less developed than in larger ASEAN economies. Major power projects almost universally follow IEC standards, often specified by international developers or financiers (ADB, World Bank). Distribution and domestic wiring standards tend to follow Thai or Vietnamese practices, which are themselves increasingly IEC-based.

Industrial automation integration depends on local supply quality, but is generally IEC-compatible. The grid, largely developed for stable hydropower exports, faces challenges integrating significant intermittent domestic RE like solar or wind. [22] This requires adapting grid operations (likely based on IEC/Thai standards) to manage frequency and voltage stability with less system inertia, demanding new forecasting capabilities and potentially storage or flexible backup. Furthermore, the weaker domestic distribution network, especially in rural areas with legacy lines, needs localised studies and potential upgrades following IEC guidelines to safely integrate distributed or medium-scale RE without compromising power quality.

4.4.8. Cambodia – French

Similar to Lao PDR, French-era electrification was very limited (Phnom Penh, a few other towns), using 220 V, 50 Hz. The Khmer Rouge era destroyed much of this nascent infrastructure. Rebuilding the grid, managed primarily by EDC, has been a major focus since the 1990s.

Cambodia established the Institute of Standards of Cambodia (ISC). Like Lao PDR, it heavily relies on adopting international standards (IEC) for rebuilding and new development, often influenced by neighbouring countries (Thailand, Viet Nam) and international aid/investment requirements. IEC standards are the default for generation, transmission, and major distribution projects. Domestic wiring standards are evolving towards IEC, but may show influences from Thai/Vietnamese practices in border areas.

Industrial automation is feasible in areas with new, stable, IEC-compliant supply. However, integrating RE faces hurdles as the grid is still under development and has varying reliability. Connecting utility-scale RE to weaker parts of the grid poses significant stability risks, [23] potentially requiring RE projects to include stabilisation solutions like batteries, and adhere to robust, evolving IEC-based grid codes.

4.4.9. Philippines – Spanish then American

While Spain introduced some very early local generations, the American period established the modern foundation. Manila Electric Railroad and Light Company (Meralco), founded in 1903, was key. [24] The US introduced 110 V (later evolving to the current 230 V standard residential voltage) but crucially standardised on 60 Hz. They also brought American engineering practices and standards.

The BPS is the national body. However, the dominant force in electrical installations is the PEC, which is mandated by law (RA 7920). The PEC is explicitly based on the US NEC, updated periodically following NEC

revisions. [25] It dictates wiring methods, materials (often using NEMA⁶ specs), and safety requirements reflecting US practice. The ERC regulates the power industry. Equipment often needs BPS certification and testing against Philippine National Standards, which may be based on IEC, but must be compatible with the 60 Hz/NEC environment.

The unique 60 Hz legacy requires compatible industrial automation equipment, often following NEC/NEMA practices. This frequency difference from the 50 Hz ASEAN standard presents fundamental RE integration challenges. RE equipment must be 60 Hz compatible, potentially limiting procurement options or affecting costs. More significantly, grid codes (Philippine Grid Code/Distribution Code) must address stability issues within the 60 Hz context, often requiring careful adaptation of IEC concepts into the NEC/PEC framework. Integrating distributed PV according to PEC rules often necessitates substantial upgrades to older distribution networks designed under earlier NEC versions to handle back-feed and maintain voltage stability, a potentially more complex task than in standardised IEC environments.

4.4.10. Thailand – Independent

Early ventures involved Danish, British, and American companies. The Thai government gradually consolidated electricity supply under state entities, now primarily the Electricity Generating Authority of Thailand (EGAT), Metropolitan Electricity Authority (MEA - Bangkok area), and Provincial Electricity Authority (PEA - rest of country).[26] Thailand pragmatically standardised on 220 V (now nominal 230 V), 50 Hz early on, aligning with the dominant European/global trend.

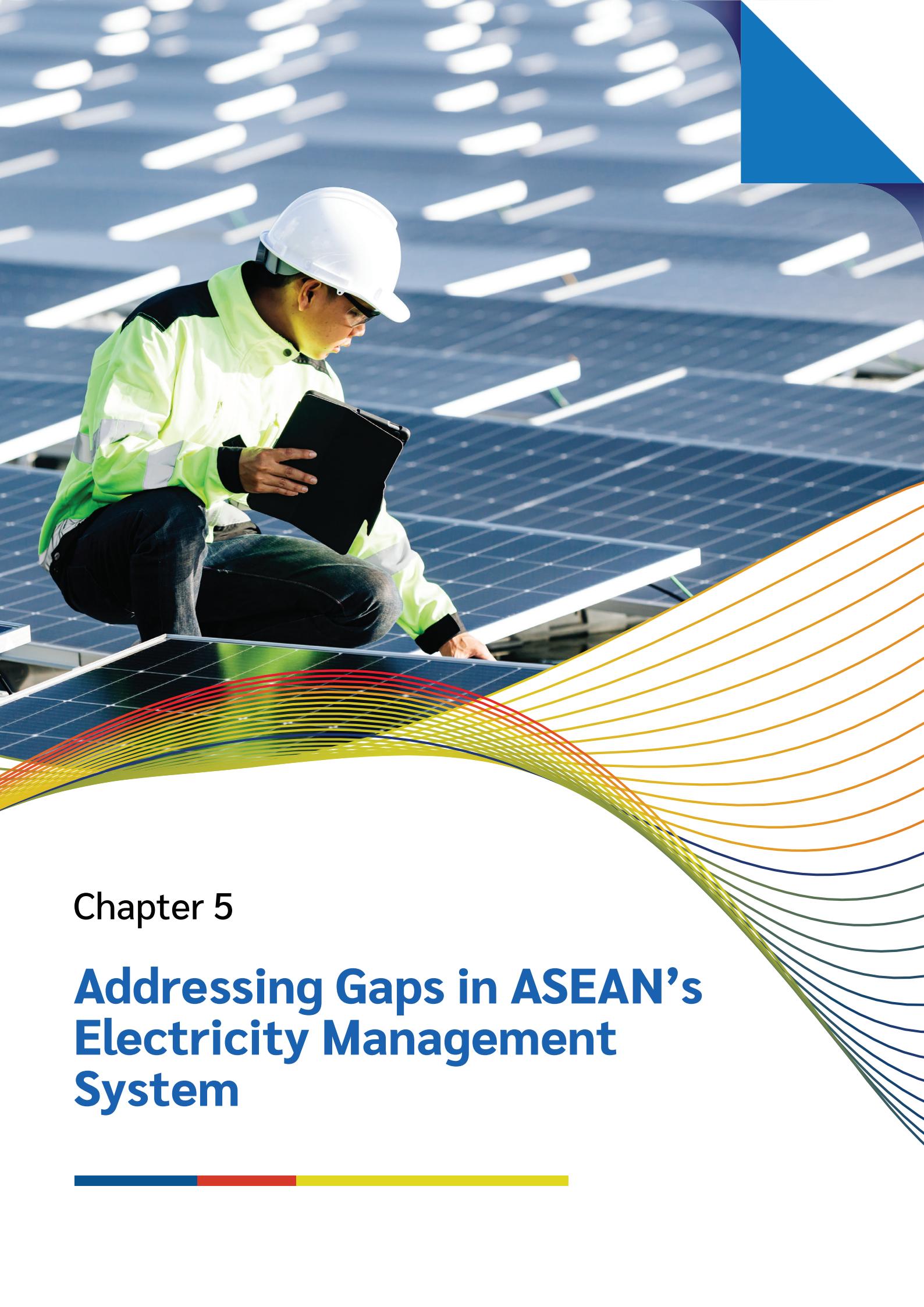
TISI sets standards (TIS). Thailand has been proactive in adopting IEC standards. Many TIS standards for electrical equipment and installations are identical or closely harmonised with IEC standards. TISI often participates directly in IEC technical committees.[27] [28] Wiring regulations generally follow IEC 60364 principles. Mandatory TISI certification for many electrical products ensures compliance, typically with IEC-based TIS standards.

Thailand's proactive IEC adoption facilitates straightforward industrial automation integration. However, managing high RE penetration across the extensive grid, parts of which include older legacy infrastructure under PEA and MEA, requires accelerating smart grid deployment based on IEC standards for better visibility and control of intermittency and voltage fluctuations. Ensuring streamlined, standardised grid connection processes for RE (especially distributed PV) under TISI/IEC guidelines is ongoing. Managing local congestion and minimising curtailment in high RE areas necessitates continuous grid planning and investment in network upgrades and flexibility solutions, with EGAT actively developing advanced RE forecasting and integration strategies.[29]

⁶ NEMA - National Electrical Manufacturers Association, a US-based organisation that sets standards for electrical equipment, primarily for the North American market.







Chapter 5

Addressing Gaps in ASEAN's Electricity Management System

5.1. Gaps in Governance, Regulatory Frameworks, and Grid Modernisation

5.1.1. Variations in Regional Level

Several critical gaps persist concerning electrical safety governance and regulatory frameworks within the diverse ASEAN countries, particularly in the context of the ongoing RE transition. Infrastructure varies immensely, from modern networks in some nations to others grappling with ageing infrastructure, limited connectivity (archipelagic states), high losses, and significant grid instability (voltage/frequency fluctuations). Additionally, the profound heterogeneity in RE development pace, technological focus, resource availability, grid reliability, and infrastructure maturity mean unifying effort on a regional scale like the Republic of Korea's approach is quite far-reaching.

In the *governance* context, a fundamental gap exists across ASEAN: no country features a truly independent agency focused solely on electrical safety. Oversight is typically embedded within Government Ministries or Non-ministerial agencies that often handle broad commercial/market functions. These extensive “Other” responsibilities (economic regulation, pricing, market competition, licensing, administrative duties) risk diluting the focus, resources, and potentially the stringency applied to purely technical safety matters.

The absence of independent agencies implies a complex web of supporting organisations. This includes national utilities involved in grid connection standards and inspections, National Standards Bodies, various Government Ministries, professional bodies, specialised disaster agencies, and research institutions. While necessary, this complexity presents a gap in ensuring seamless coordination, consistent application of standards, and clear lines of accountability, particularly without a strong, independent lead safety agency.

While all primary agencies handle Certification & Inspection, significant gaps exist in other areas. Disaster Management related to electrical incidents is explicitly not listed as a responsibility for the main agencies in Cambodia, the Philippines, and Viet Nam. R&D in electrical safety receives even less attention, formally included only in the mandates of Malaysia's ST, Singapore's EMA, and Thailand's ERC. This points to potential under-resourcing or fragmentation of crucial disaster preparedness/response coordination and future safety innovation within the primary governance structures.

Regarding *the regulatory framework*, fragmentation in standards adoption is observed. While national legislation forms the foundation, the technical standards and codes exhibit divergence. IEC standards, particularly IEC 60364 (the basis for Indonesia's SNI 0225 PUIL, Malaysia's MS IEC 60364, Singapore's SS 638, Thailand's EIT Standard, and Viet Nam's TCVN 7447), are the dominant influence. However, direct BS 7671 adoption (Brunei's EIR) or strong basis (Singapore's SS 638) and the Philippines' reliance on the US NEC framework (PEC 2017) create significant inconsistencies.

Existing RE-specific guidelines demonstrate a strong bias towards solar PV technology. While ESS is increasingly mentioned (in Philippines, Thailand, Singapore, Malaysia, and Indonesia), there is a significant gap in detailed, specific electrical safety guidelines for other technologies like wind power installations, biomass/biogas generation safety, geothermal specifics, and emerging areas like hydrogen production (electrolysis) and fuel cell power systems.

Some nations (Lao PDR, Myanmar) are explicitly noted as lacking specific RE guidelines, while Viet Nam is still developing relevant standards. Beyond the written rules, a likely gap exists in the uniformity and strictness of enforcement mechanisms like site inspections (scope and rigour vary), verification of product certifications (e.g., Indonesia's mandatory SNI IEC 61215 for PV modules, Thailand's TIS marks), and the application of penalties. The mandatory nature of specific certifications like Indonesia's SLO for grid-connected PV is not a universal requirement across ASEAN.

Considering *the legacy electricity system and grid modernisation progress*, the historical influences (British, Dutch, French, and American) set foundational V/Hz standards and technical practices. Legacy infrastructure built on these, often reflecting older design philosophies (e.g., radial networks influenced by BS practices, US NEC-based wiring methods in the Philippines), frequently lacks the inherent capacity and technical features (like managing bidirectional power flow from distributed PV) needed for high VRE penetration.

The rapid RE growth witnessed in countries like Viet Nam has outpaced the necessary grid expansion and modernisation, leading to practical gaps like generation curtailment due to insufficient transmission capacity. This highlights a critical need for better-integrated planning and accelerated investment in modernisation (following IEC standards) to ensure the grid can safely and reliably accommodate the influx of renewables, incorporating flexible solutions like storage and advanced control systems managed by entities like EVN, EGAT, PLN, and so forth.

For countries like Myanmar, Cambodia, Lao PDR, and parts of Indonesia (especially remote islands), the legacy grid's low capacity, unreliability, or underdeveloped nature constitutes the most significant gap, acting as a fundamental barrier to safe and reliable RE deployment. Utility-scale RE often requires dedicated grid reinforcement adhering to modern IEC standards (often driven by foreign investment), while integrating RE into weaker segments poses substantial technical and safety challenges without major upgrades or localised solutions (e.g., storage, microgrids).

5.1.2. Closing ASEAN's Electrical Safety Gaps

Addressing the significant electrical safety gaps observed across the diverse ASEAN region necessitates exploring established best practices from other countries with more developed management systems, even while acknowledging the need for nationally tailored solutions. The Republic of Korea offers a valuable case study with its unified Electrical Safety Management Act and systematic, long-term master planning, presenting a clear contrast to the heterogeneity often found within ASEAN. Recognising this, the following Table 5-1 compares the specific challenges identified in ASEAN's electrical safety landscape—covering governance structures, regulatory frameworks, legacy system limitations, and grid modernisation efforts—with corresponding elements and principles from the Korean system. This comparison aims to provide actionable insights and highlight potential learning points that AMS could consider adapting to enhance its own electrical safety performance.

Table 5-1 Opportunities to Address ASEAN's Electrical Safety Gaps

Gap Area	Specific ASEAN Gap	Potential Adoption/Lesson from Korea's Electrical Safety Approach
Overarching Heterogeneity	Vast differences in infrastructure quality, RE development pace, and institutional capacity across ASEAN countries.	<p>While direct replication is difficult, Korea's model demonstrates the value of:</p> <p>Systematic Long-Term Planning: Establishing 5-year Master Plans to set direction, improve systems, support R&D, and address vulnerable groups, providing a framework adaptable to different starting points.</p> <p>Tailored Safety Management: Plans specifically aim to strengthen management for vulnerable areas (e.g., multi-use facilities, industrial complexes, ageing infrastructure)</p>
Governance #1	Lack of independent agencies solely focused on electrical safety; oversight often embedded in multi-functional bodies.	<p>Dedicated Legal Framework: Enactment of the standalone "Electrical Safety Management Act" specifically to prevent electrical disasters, separating safety regulation from potentially conflicting economic/business promotion goals of the "Electric Business Act"</p>
Governance #2	Potential dilution of safety focus due to agencies' broad commercial/market responsibilities.	<p>Clear Safety Mandate: The Act's core purpose is explicitly protecting life/property and ensuring public safety through dedicated safety management.</p>
Governance #3	Complex coordination needed among multiple supporting agencies (utilities, standards bodies, etc.) without a clear, independent lead.	<p>Centralised Act & Planning: A single governing Act and mandated Master Plans provide a central strategic direction. The future vision includes fostering collaborative partnerships with the private sector</p>
Governance #4	Inconsistent functional scope of primary agencies (esp. regarding Disaster Management and R&D).	<p>Comprehensive Scope Defined by Law: The Act mandates government policy formulation and Master Plans cover system improvements, R&D support, education, etc. The Act structure includes investigation, data centres, and emergency precautions. Master Plans specifically target R&D investment and disaster response coordination.</p>
Regulatory Frameworks #1	Fragmentation in technical standards adoption (IEC dominance mixed with BS, NEC influences).	<p>Unified National Codes: Implementation of standardised national technical codes (KEC - foundational safety standards; KESC - detailed inspection criteria) applied consistently nationwide, which potentially could be adopted at the regional level for the ASEAN context.</p>
Regulatory Frameworks #2	RE guideline gaps: Strong bias towards Solar PV, lack of detail for Wind, Biomass, Geothermal, H ₂ /Fuel Cells, and emerging ESS details.	<p>Technology-Specific Requirements: The Act mandates checks for new technologies. Master Plans aim for customised safety systems for different energy sources. Detailed inspection criteria (KESC) exist for various RE types including Solar PV, Wind, ESS, Water Electrolysis, and Fuel Cells.</p>

Regulatory Frameworks #3	Incomplete RE guideline coverage (some countries lack guidelines or are developing them).	<p>Systematic Development & Updates: Master Plans drive policy and system improvements. The existence of detailed KEC/KESC codes provides comprehensive coverage, presumably updated periodically.</p>
Regulatory Frameworks #4	Variable enforcement rigour (inspections, certifications, penalties).	<p>Mandatory & Structured Inspections: Legal mandates for Pre-Operation and Periodic Inspections based on detailed KESC criteria.</p> <p>Performance-Based Regulation: Safety Grade system allows differentiated inspection frequency based on performance.</p> <p>Data-Driven Oversight: Total Information System collects inspection results and disaster stats.</p> <p>Accountability: Act provides basis for Punishment & Fines.</p>
Legacy Systems & Grid Modernisation #1	Legacy infrastructure (designs, V/Hz) often lacks capacity/features for high VRE integration (e.g., bidirectional flow).	<p>Targeted Checks & Modernisation Focus: Act mandates checks for ageing infrastructure. Master Plans include intensifying checks on older infrastructure (e.g., ageing apartments) and leveraging technology/digitalisation for smarter management and modernisation</p>
Legacy Systems & Grid Modernisation #2	Grid modernisation lagging behind rapid RE deployment in some areas.	<p>Proactive Planning & Tech Adoption: 5-year Master Plans facilitate proactive, mid-to-long term planning. Strong emphasis in plans and future vision on adopting ICT, remote monitoring, big data, and AI for advanced safety management and grid integration.</p>
Legacy Systems & Grid Modernisation #3	Poor grid condition is a fundamental barrier to safe RE deployment in several countries.	<p>Focus on Foundational Safety & Resilience: Korea's system builds on a generally more robust grid, but principles like rigorous Pre-Operation Inspections, detailed KEC/KESC standards, and focus on R&D/technology aim to ensure safety even as new tech is added. Master plans address climate adaptation and disaster response</p>

The gap comparison matrix suggests several critical areas where national electrical safety systems commonly exhibit weaknesses as compared to more unified approaches like Korea's. *Addressing these fundamental gaps at the national level* appears most crucial for tangible safety improvements.

⚡ **Strengthening Governance Focus & Clarity:** Given the lack of fully independent safety agencies and the dilution of focus within multi-functional bodies across ASEAN, adopting the principle of a dedicated legal framework for electrical safety (like Korea's Electrical Safety Management Act) could be highly beneficial. Even without creating entirely new agencies, clarifying mandates and potentially separating safety oversight more distinctly from economic promotion within existing structures (countering identified issues) could improve focus and effectiveness. Enhanced coordination mechanisms among the various involved agencies are also vital.

⚡ **Implementing Structured Lifecycle Inspections & Enforcement:** Mandatory, structured inspection regimes covering the full lifecycle (like Korea's Pre-Operation and periodic inspections based on detailed codes) could significantly improve safety compliance. This includes robust verification of installations against standards before operation.

⚡ **Addressing Legacy System Risks & Planning Modernisation:** For countries with ageing infrastructure or weak grids, systematically identifying risks (similar to Korea's checks on old apartments) and integrating grid modernisation needs with RE deployment plans (reflecting Korea's Master Plan approach) is crucial for enabling safe RE integration.

Beyond individual national efforts, certain electrical safety challenges within the heterogeneous ASEAN region lend *the region opportunities for collaborative, regional approaches*. Drawing inspiration from Korea's integrated system, several principles could be adapted for implementation at the ASEAN level to foster harmonisation, knowledge sharing, and collective capacity building.

- » **Standards Harmonisation Framework:** Facilitating regional convergence towards internationally recognised standards (primarily IEC, which Korea also heavily references). This could involve sharing best practices for national standard development, establishing common minimum requirements for RE installations, or developing regional guidelines based on IEC.
- » **Regional Information Sharing Platform:** Creating a mechanism for sharing anonymised data on electrical accidents, statistics, and potential near-misses, inspired by Korea's Total Information System concept. This could enhance regional understanding of common risks and effective mitigation strategies.
- » **Collaborative R&D Initiatives:** Given that R&D is often under-resourced within primary safety agencies in ASEAN, regional collaboration on safety research (especially for new RE technologies, ESS safety, grid integration challenges, and climate adaptation measures), mirroring the R&D focus in Korea's Master Plans, could pool resources and expertise.
- » **Framework for Personnel Competency & Training:** Developing regional competency standards or mutual recognition agreements for electrical safety professionals and technicians, inspired by Korea's emphasis on mandatory education and expertise enhancement, could uplift workforce capabilities across the region.

Recognising that comprehensive reforms take time, particularly in diverse contexts, certain strategic actions inspired by the Korean model appear potentially more feasible for immediate-term implementation by individual ASEAN countries. The '*low-hanging fruit*' focus on *foundational improvements* that can yield significant safety benefits relatively quickly and build a stronger base for future enhancements.

- **Systematic Accident Data Collection:** Establishing or improving national systems for collecting and analysing data on electrical accidents and their causes, potentially drawing from Korea's data centre concept. This provides immediate empirical earthing for policy and enforcement priorities without initially and necessarily requiring a fully integrated digital platform.
- **Targeted Inspection Programmes:** Launching focused safety inspection campaigns on identified high-risk areas, such as ageing residential or industrial electrical installations, common RE installations like rooftop solar PV, or rapidly deployed technologies like EV chargers, adapting Korea's expanded safety check concept.

- **Enhanced Worker Training Requirements:** Implementing or strengthening mandatory safety training and certification requirements for electrical workers, particularly those involved in RE installations, leveraging principles from Korea's mandatory education focus.
- **Develop Foundational RE Guidelines:** Drafting initial national safety guidelines specifically for the most common RE technologies (Solar PV, ESS) for nations lacking them, and for other RE technologies (wind, hydrogen/electrolysis, fuel cell), potentially adapting frameworks from established international standards, or referencing detailed criteria like those in Korea's KESC.
- **Public Safety Awareness Campaigns:** Initiating targeted campaigns to raise public and industry awareness about common electrical hazards (especially related to new technologies or ageing infrastructure), drawing from Korea's focus on cultivating a safety culture.

5.2. Gaps in Electricity Safety Enforcement

A primary challenge in understanding gaps in electrical safety enforcement in participating AMS is that granular, quantitative data detailing enforcement activities—such as comprehensive inspection rates, violation statistics, or penalties issued—is often not publicly available or readily accessible within the scope and timeframe of this collaborative project. However, the project's activities involve two integrated workshop consultations conducted in Indonesia and Cambodia. This methodology provides a unique opportunity to gather qualitative data and gain deeper insights directly from stakeholders involved in the respective countries' electrical safety management systems.

This section aims to intuitively assess the nature and potential root causes of gaps in electrical safety enforcement in Indonesia and Cambodia. The primary objective is to understand the practical effectiveness and challenges of the enforcement process itself. This involves analysing the underlying systems, capabilities, and implementation practices that enable or hinder effective enforcement activities within these specific national contexts.

The core analysis involves a granular examination of key enforcement-related activities and processes in these two countries. This includes scrutinising how standards are applied, inspection protocols are executed, personnel capacity impacts oversight, compliance verification steps are managed, and coordination occurs between relevant bodies. Findings regarding these processes will be comparatively assessed with the Korean system as a reference point to identify specific weaknesses, bottlenecks, or deviations that constitute gaps in the practical capability and execution of electrical safety enforcement in the Indonesian and Cambodian contexts.

5.2.1. Case Study of Indonesia

This section delves into the specific context of electrical safety enforcement in Indonesia, providing a case study that examines the practical application of the national framework. Drawing upon insights from key stakeholders, including the Directorate General of Electricity (Gatrik) representing the Ministry of Energy and Mineral Resources (MEMR) as the regulator, and PT PLN (Persero) as the primary state-owned utility, supplemented by broader industry observations, this analysis explores the effectiveness and challenges associated with enforcing electrical safety standards and procedures.

How Standards are Applied: A hierarchical system of standards governs the sector, ranging from national laws and ministerial regulations down to specific technical standards like the SNI for equipment and internal standards developed by key players like PLN (SPLN).

- ⚡ **Regulatory Foundation:** The core requirement stems from Electricity Law No. 30 of 2009, as amended by Job Creation Law No. 6 of 2023, which mandates that all electricity business activities must meet electrical safety provisions. This is further detailed in government regulations (like No. 14 of 2012, No. 62 of 2012, No. 25 of 2021) and MEMR regulations, such as Permen ESDM No. 10 of 2021 on Electrical Safety, and No. 7 of 2021 on Standardisation.
- ⚡ **SNI Mandate, Scope, and Purpose:** Any electrical tools or equipment must minimally meet SNI requirements. Permen ESDM No. 7 of 2021 specifically addresses SNI standardisation and safety marks. Where SNI is not available, applicable international or other standards can be used. SNI is mandatory for products impacting health, safety, or environmental sustainability; trading non-compliant items is prohibited. For certain electrical products (cables, breakers, switches, panels, etc.), SNI compliance is crucial for market access.
- ⚡ **PLN Internal Standards:** PLN operates within a hierarchy starting from national law, down through Government and Ministry Regulations, to PLN CEO Policies, and finally specific PLN Standards (SPLN). Examples: PLN implements standards like SPLN U2.008:2024 (Standard of Electricity Safety Management System) and SPLN U2.009-1:2024 (Occupational Safety and Health for Transmission Substations) to operationalise safety requirements within its organisation.
- ⚡ **Practical Application & Challenges:** While the framework exists, the practical application involves ensuring manufacturers and importers undergo the certification process correctly. Harmonising SNI with international standards (IEC), ensuring standards keep pace with technological advancements (e.g., EV battery safety) and are adapted to local conditions (e.g., tropical climates), and ensuring consistent application and verification across the vast range of products in the market remain practical enforcement tasks.

How Inspection Protocols are Executed: The primary mechanism for verifying the safety and operational readiness of electrical installations is the mandatory SLO.

- **SLO:** Mandated by Electricity Law No. 30 of 2009 (Article 44), every electrical installation must possess an SLO before operation. This serves as a formal recognition of compliance and operational readiness. Operating without it carries penalties (fines up to IDR 500 million – equal to around USD 30 thousand), and PLN can be held liable for damages from household installations it supplies without a valid SLO. SLO validity varies - 5 years for power plants, 10 years for transmission/distribution and High Volt-HV/Medium Volt-MV utilisation, and 15 years for low volt (LV) utilisation. SLOs become invalid upon changes in capacity, installation modifications, reconditioning, or relocation, and require recertification upon expiry.
- **Inspection Bodies (LIT):** Accredited LITs are responsible for conducting the technical inspections and testing required for SLO certification. As of December 2024 (when the workshop was conducted),

there were 104 accredited LITs for supply and HV/MV utilisation installations, and 19 LIT entities for low-voltage utilisation installations.

- » **SLO Issuance Process:** An SLO application is submitted online, followed by inspection and testing by the appropriate LIT. After evaluation and report preparation, the SLO is registered and issued. Timelines vary for accredited LITs/appointed LITs, inspection/testing takes ~15 working days (depending on installation conditions); inspection/testing for LIT for LV takes ~2 working days. Registration and issuance take a few additional days.
- » **Inspection Scope:** Inspections are comprehensive, covering (1) documentation - checking relevant permits and technical documents; (2) design conformity - ensuring the installation matches the approved design; (3) visual inspection - physical checks of the installation components, and (4) equipment and system testing - functional tests of individual components and the overall system. Examples are unit testing, environmental impact inspection (for generation/transmission), and corrosive protection checks (generation).
- » **PLN Internal Protocols:** PLN's Contractor Safety Management System involves rigorous checks including document and site verification during pre-qualification, HSE plan verification at kick-off, and performance evaluations during/after work. For new technologies like Floating PV, specific construction and in-service inspections are planned, considering unique access requirements (e.g., gangways for maintenance). For Hydrogen Refuelling Stations, specific safety guidelines are integral to design, construction, and operation.
- » **Practical Effectiveness & Challenges:** The SLO system, executed by LITs, forms the backbone of installation safety verification. Its effectiveness relies heavily on the competency and independence of the LITs and the thoroughness of their inspections. Ensuring timely inspections and SLO renewals across millions of installations nationwide, including ageing infrastructure, is a significant logistical and enforcement challenge. The process, while structured, requires diligent follow-up by installation owners and oversight by authorities.

How Personnel Capacity Impacts Oversight: Indonesia mandates specific competency certifications (SKTTK, or *Sertifikat Kompetensi Tenaga Teknik Ketenagalistrikan*) for technical personnel working in the electricity sector.

- ⚡ **Competency Certification (SKTTK):** Permen ESDM No. 06 of 2021 governs competency standardisation. Electricity Law No. 30 of 2009 requires any technician working in the electricity sector to hold a relevant SKTTK. It serves as formal recognition of a person's competence level and field.
- ⚡ **Requirement for Businesses:** SKTTK is essential for personnel within companies seeking Electrical Supporting Service Business Entity Certification (SBU JPTL, or *Sertifikat Badan Usaha Jasa Penunjang Tenaga Listrik*) and permits (IUJPTL - *Izin Usaha Jasa Penunjang Tenaga Listrik*). The number and level of certified personnel required depend on the business entity's qualification.

- ⚡ **Process & Validity:** Obtaining SKTTK involves competency testing conducted by an accredited Competency Certification Agency (LSK, or *Lembaga Sertifikasi Kompetensi*), often preceded by training/preparation. Certificates are typically valid for 3 years.
- ⚡ **PLN's Approach:** PLN explicitly states “Only Competent Persons Can Work” as one of its supplementary Life-Saving Rules. They also emphasise building safety behaviour and culture through assessments and regular safety briefings.
- ⚡ **Practical Effectiveness & Challenges:** SKTTK aims to ensure a skilled and safety-aware workforce. However, challenges include ensuring broad compliance (that all personnel undertaking technical work are certified), maintaining the quality and consistency of training and assessment across different LSKs, and potentially addressing a broader national issue of workforce skill levels and safety culture deficiencies. Ensuring technicians keep their certifications current through renewals adds another layer to enforcement oversight. The system relies on accredited LSKs, whose own competence and adherence to standards are vital.

How Compliance Verification Steps are Managed: Verifying compliance within Indonesia’s electrical safety framework involves verifying the conformity of equipment (via SNI), the competence of personnel (via SKTTK), the operational readiness of installations (via SLO), and the implementation of safety management systems within business entities (via SMK2, or *Sistem Manajemen Keselamatan Ketenagalistrikan*, and SBU).

- » **Multi-layered System:** Compliance verification operates at several levels: equipment (SNI), personnel (SKTTK), installation (SLO), and business entity systems (SBU, SMK2).
- » **Business Systems (SMK2):** For larger entities (Generation ≥ 5 MW, Transmission, Distribution, Utilisation >200 kVA), Permen ESDM No. 10 of 2021 requires implementation of SMK2. This involves having safety policies, planning, organisation, implementation, and evaluation/follow-up, with reporting potentially via online systems like SIMATRIK. Gatrik monitors the status of SMK2 reporting.
- » **Practical Effectiveness & Challenges:** This system provides multiple checkpoints. The SLO is crucial for operational permits. SMK2 aims to embed safety within larger organisations’ management structures. CSMS helps manage risks associated with third-party work. Online sources emphasise SLO’s role in ensuring legal compliance and operational safety, potentially improving company image, and reducing risks. However, true effectiveness relies on the integrity of each certification/inspection step, consistent enforcement of penalties for non-compliance (e.g., operating without SLO), and the resources available for oversight and audits by regulatory bodies like Gatrik. The cost and complexity of obtaining certifications (SNI, SLO, SKTTK) can also be a barrier, especially for smaller entities.

How Coordination Occurs Between Relevant Bodies: Key players include the MEMR via Gatrik, PLN, accredited LITs, LSKs, and BSN.

- ⚡ **Coordination Mechanisms:** The SLO, SKTTK, and SNI processes inherently require interaction (e.g., installation owner applies to LIT, LIT inspects based on standards, Gatrik/LIT issues SLO; technician

applies to LSK, LSK tests based on standards). Gatrik oversees LITs and LSKs through accreditation, and monitors SMK2 compliance reporting from entities like PLN. Online portals like SI UJANG Gatrik likely facilitate processes such as SLO applications or information dissemination. PLN also maintains internal systems (e.g., for CSMS).

- ⚡ **Socialisation & Policy Updates:** Gatrik engages with stakeholders (PLN, LITs, business entities) to socialise regulations and safety awareness. PLN needs to synchronise its internal systems (e.g., applications), when MEMR issues new regulations, such as adjustments to SLO fees.
- ⚡ **Practical Effectiveness & Challenges:** While roles are defined, effective national electrical safety critically depends on seamless communication, data sharing, and consistent application of rules among these bodies. General challenges in inter-agency coordination and jurisdictional complexity in Indonesia could potentially impact the electricity safety management. Ensuring that inspections by numerous different LITs are uniformly rigorous, that competency assessments by various LSKs meet consistent standards, and that feedback on practical implementation challenges flows back to regulators (Gatrik/MEMR) requires robust coordination mechanisms. Synchronising databases (e.g., ensuring SLO status is readily available to PLN for connection decisions) is also vital for smooth operation.

5.2.2. Case Study of Cambodia

This case study uses information provided by the Ministry of Mines and Energy (MME) and the state utility EDC, supplemented by external data, to assess the application of standards, inspection methods, personnel requirements, compliance checks, and institutional coordination. The aim is to understand the practical effectiveness of the current system and identify the challenges faced in ensuring electrical safety amidst rapid energy infrastructure expansion and transition.

How Standards are Applied: MEM is responsible for setting technical standards, while EAC is tasked with enforcing them. However, the practical application involves nuances, including the use of international standards by operators like EDC and potential inconsistencies across different power producers.

- ⚡ **National Framework:** The Electricity Law stipulates that the EAC should ensure licensees use technical, safety, and environmental standards issued by MME. Specific technical standards, such as the “Electric Power Technical Standards of Cambodia,” and detailed requirements like Prakas 701 for Transmission and Distribution Facilities, exist to regulate facilities. Cambodia also has a Law on Standards (2007) overseen by MISTI via ISC, which handles industrial standards and certifications, including for electrical and electronic products.
- ⚡ **EDC’s Practical Approach:** EDC acknowledges adopting international standards like ISO (e.g., ISO 45001 for Occupational Health Safety management systems) and IEC for its internal guidelines.
- ⚡ **Product Standards:** Cambodia has established mandatory standards for specific electrical and electronic products, often identical to IEC standards (e.g., IEC 60335 series for household appliances, IEC 60884 for plugs/sockets, IEC 60227 for cables). These require registration and marking via ISC before being placed on the market.

⚡ **Challenges:** A key challenge highlighted by EDC is the potential for an insufficient regulatory framework with a lack of clear and detailed guidelines, and potentially inconsistent regulation application across the country, especially among diverse IPPs, who may have their own differing internal guidelines. Keeping standards updated with new technologies (renewables, smart grids) is another challenge.

How Inspection Protocols are Executed: Unlike the formalised SLO system detailed for Indonesia, the specific national protocols for systematic installation inspection in Cambodia is less defined.

» **Commissioning Tests (EDC):** EDC's process for new facilities involves several testing stages: (1) Factory Acceptance Tests (FATs) - verifying the equipment meets specifications before shipping; (2) Site Delivery Acceptance Tests (SDAT) - checking equipment upon arrival, (3) Site Acceptance Tests (SATs) - ensuring correct installation, integration, functionality, and usability after construction; and (4) Specific Equipment Tests - detailed routine and type tests are performed on equipment like SF6 switchgear (dielectric tests, resistance measurement, tightness tests, mechanical operation tests) and prefabricated substations (dielectric, temperature rise, earthing, functional, mechanical, internal arc tests etc.).

» **Product Inspection/Testing:** For regulated electrical and electronic products, compliance verification before market entry involves conformity assessment. This can include factory assessment and product testing for domestic goods, or presentation of recognised test reports/certificates (e.g., IEC/IEC CB - IEC System for Conformity Assessment Schemes for Electrotechnical Equipment and Components Certification Body, reports from Conformity Assessment Body recognised by ISC/ASEAN Mutual Recognition Arrangement) for imports.

» **Challenges:** The apparent lack of a widely documented, standardised national inspection protocols for operational installations (beyond initial commissioning tests and product certification) could pose a challenge to ensuring long-term safety and compliance across all types of facilities and licensees (EDC, IPPs, REEs – Rural Electricity Enterprises). Reliance on potentially varied internal guidelines among operators might lead to inconsistencies.

How Personnel Capacity Impacts Oversight: Efforts are made to ensure personnel involved in the electricity sector are adequately trained and aware of safety procedures, although a specific national certification system equivalent to Indonesia's SKTTK is not yet available.

⚡ **EDC Training Requirements:** All employees receive initial training on safety procedures before starting work. Monthly awareness training is scheduled by the HSE Section, competency/authorisation training is provided upon request, and refresher training is required when procedures change. EDC utilises an internal system of permits and certificates for specific tasks (e.g., Permit to Work, LOTO, Confined Space Entry, Hot Work, Scaffolding/Working at Height, Hoisting) which likely requires associated competency verification.

⚡ **National Requirements:** The Electricity Law implies the need for qualified personnel. The “Electric Power Technical Standards of Cambodia” reportedly include provisions to prohibit electrical work by unqualified persons to reduce accidents and losses. A system for registering professional engineers

(requiring degrees and experience) exists under the Board of Engineers, Cambodia (BEC). Specific licenses related to mechanics, electricity, and plumbing for construction certification also exist, requiring qualified professionals.

⚡ **Challenges:** EDC identifies a potentially low safety awareness culture within the industry and possible resistance to change regarding stricter safety standards as significant challenges. Ensuring consistent competency and safety adherence across EDC staff, contractors, and personnel working for numerous IPPs and REEs requires continuous effort in training and oversight. The lack of a clearly defined, universally required technician-level competency certification could be a gap.

How Compliance Verification Steps are Managed: Unlike the explicit multi-layered certification system seen in Indonesia (SNI, SKTTK, SLO, SBU), the verification mechanisms in Cambodia appear more focused on licensing conditions and operator-level implementation.

- **Licensing by EAC:** EAC issues licenses for electricity supply services (to EDC, IPPs, REEs). Licensees are required to abide by the Electricity Law, license conditions, EAC regulations (e.g., General Conditions of Supply), and technical standards issued by MEM. This licensing regime is a core compliance tool.
- **EDC Internal Verification:** EDC relies on its internal guidelines and adherence to international standards. Promoting safety as a culture with targets like “Zero Injuries, Zero Property Damage, Zero Environmental Incident”. Use of safety signs (prohibition, mandatory, danger, warning, etc.), barricades, tags, risk assessments, and a system of work permits. Mandatory requirement and provision of Personal Protective Equipment (basic and job-specific). Conducting safety meetings/sharing after injuries or near misses.
- **Product Compliance:** Mandatory adherence to Cambodian Standards CS, often based on IEC standards, for specified electrical and electronic products, verified through testing and registration with the ISC.
- **Installation Verification:** Primarily through commissioning tests (FAT, SAT) conducted by the operator (like EDC) for new installations/equipment. Less evidence was found for a standardised, nationwide system for periodic inspection and certification of operational installations.
- **Challenges:** The main challenge identified is the potential inconsistency in standards and practices between different operators (EDC vs. IPPs vs. REEs). Effective verification relies heavily on the enforcement capacity of EAC regarding license conditions and the diligence of operators in implementing their internal safety systems.

How Coordination Occurs Between Relevant Bodies: The institutional framework assigns specific roles to MEM, EAC, and EDC, amongst- others.

- **Coordination Mechanisms:** The Electricity Law and associated regulations define the powers and duties of MEM and EAC, creating a formal structure for interaction. EAC's licensing of EDC, IPPs, and REEs establishes a direct regulatory link and mechanism for imposing safety and technical standard requirements. MEM sets technical standards, and EAC is responsible for ensuring licensees adhere to them.

➤ **Challenges:** EDC explicitly notes the diversity of IPPs leads to differing adaptations and implementations of safety standards, implying coordination challenges or inconsistencies. Ensuring that standards set by MEM are effectively communicated, understood, and implemented consistently by all licensees (EDC, IPPs, REEs) and uniformly enforced by EAC represents a significant coordination challenge. Coordination with other bodies like ISC (for product standards) and MLMUPC (Ministry of Land Management, Urban Planning and Construction - for construction-related electrical certification) adds further complexity.

5.2.3. Closing Electricity Safety Enforcement Gaps

Table 5-2 synthesises the key observations and challenges identified within each country across five critical areas: standards application, inspection protocols, personnel capacity, compliance verification, and coordination. This comparative summary facilitates an intuitive assessment of specific gaps by implicitly referencing the structured approach found in Korea's electricity management system.

Table 5-2 Opportunities to Address ASEAN's Electrical Safety Enforcement Gaps

Area/Activity	Indonesia	Cambodia	Potential Adoption from Korea's Approach (Suggestions)
1. Standards Application	<p>Hierarchical system (Laws, Regulations, SNI, SPLN). SNI mandatory for key products.</p> <p><i>Challenge:</i> SNI consistency, tech updates, harmonisation, local adaptation.</p>	<p>MEM sets standards, EAC enforces. EDC uses ISO, IEC. Mandatory certification (IEC-based) for products via ISC.</p> <p><i>Challenge:</i> Lack of detailed national standards, inconsistent application (EDC, IPP, REE), lagging standard development vs tech updates.</p>	<p>Provide technical assistance for developing detailed national technical standards (esp. Cambodia) aligned with international norms (IEC).</p> <p>Establish/strengthen processes for rapid standard updates reflecting new technologies (renewables, smart grids, EVs).</p> <p>Support capacity building for standard testing & certification bodies (BSN in Indonesia, ISC in Cambodia).</p> <p>Facilitate sharing of best practices in applying standards between utilities (PLN/ EDC) and IPPs.</p>
2. Inspection Protocols	<p>Mandatory SLO via accredited LITs; defined scope/process. PLN internal checks (CSMS). <i>Challenge:</i> LIT competency/ thoroughness; nationwide SLO renewal logistics; enforcement consistency.</p>	<p>No defined national system like SLO. EDC uses commissioning tests (FAT/SAT). Product conformity via ISC</p> <p><i>Challenge:</i> Lack of standardised operational inspections; potential inconsistencies; ensuring long-term safety.</p>	<p>Support development/strengthening of a nationwide, periodic inspection & certification system for operational installations (esp. Cambodia, potentially enhancing Indonesia's SLO).</p> <p>Capacity building programmes for inspection bodies (LITs in Indonesia, potentially developing similar capacity in Cambodia).</p> <p>Introduce risk-based inspection methodologies.</p> <p>Explore digital platforms for managing inspection schedules, reporting, and certification (SLO/equivalent) tracking.</p>

Area/ Activity	Indonesia	Cambodia	Potential Adoption from Korea's Approach (Suggestions)
3. Personnel Capacity	<p>Mandatory SKTTK via LSKs (3-yr validity); needed for SBU/IUJPTL. PLN emphasises competency.</p> <p><i>Challenge:</i> Broad compliance; LSK quality/consistency; workforce skills/culture; renewals.</p>	<p>EDC internal training/permits. National engineer registration (BEC). Law implies qualified personnel needed.</p> <p><i>Challenge:</i> Lack of specific technician certification (like SKTTK); consistency across operators.</p>	<p>Support establishment/enhancement of a mandatory national competency certification system for electrical technicians (esp. Cambodia), potentially tiered by skill level.</p> <p>Develop standardised, high-quality training modules & assessment methods for certification bodies (LSKs in Indonesia, potential future bodies in Cambodia).</p> <p>Implement programmes for continuous professional development and safety culture promotion targeting technicians and engineers.</p>
4. Compliance Verification	<p>Multi-layered (SNI, SKTTK, SLO, SBU/SMK2). SMK2 for larger entities (SIMATRIK reporting). PLN uses CSMS.</p> <p><i>Challenge:</i> Integrity of checks; enforcement consistency; oversight resources; cost/complexity barrier.</p>	<p>Mainly via EAC licensing. EDC internal verification (guidelines, targets, controls). Product compliance via ISC. Installation checks via commissioning tests.</p> <p><i>Challenge:</i> Reliance on operator systems; inconsistency (EDC vs IPPs/REEs); EAC enforcement capacity.</p>	<p>Strengthen regulatory oversight and enforcement mechanisms for existing certifications (Indonesia) and license conditions (Cambodia).</p> <p>Support implementation of robust Electrical Safety Management Systems (SMK2) for key entities, potentially providing templates or guidance.</p> <p>Develop digital tools for compliance tracking and reporting that are accessible to regulators.</p> <p>Simplify compliance processes for smaller entities where appropriate without compromising safety.</p>
5. Coordination	<p>Defined roles (Gatrik, PLN, LIT, LSK, BSN). Coordination via certification processes, accreditation, reporting.</p> <p><i>Challenge:</i> Communication/data sharing; LIT/LSK uniformity; feedback loops; inter-agency complexity; database sync.</p>	<p>Defined roles (MEM, EAC, EDC). Coordination via laws, licenses, and standard setting (MEM->EAC).</p> <p><i>Challenge:</i> Inconsistency (EDC vs IPPs); MEM->EAC->Licensee chain effectiveness; coordination with other bodies (ISC, MLMUPC).</p>	<p>Establish formal platforms or committees for regular coordination and information sharing between key stakeholders (Regulator, Utility, Inspection Bodies, Certification Bodies, Standards Body).</p> <p>Develop mechanisms for sharing best practices and addressing common challenges between the main utility and IPPs/REEs.</p> <p>Support the development of integrated digital databases for licenses, certifications (SLO, SKTTK, SNI/CS), and inspection results to improve data access and coordination.</p>

Enhancing electrical safety requires addressing fundamental aspects within a country's own regulatory and operational sphere. The case studies highlight *several critical areas where focused national efforts can yield significant improvements* by strengthening the core components of the safety framework, addressing institutional capacity, and ensuring effective implementation on the ground.

- ⚡ **Foundational Framework:** Establish a clear, mandatory national certification system for electrical technicians to ensure baseline competency; develop and enforce more detailed national technical and safety standards for installations and operations, moving beyond reliance on international standards or operator-specific guidelines; and implement a standardised, nationwide periodic inspection system for operational electrical installations to ensure ongoing safety beyond initial commissioning.
- ⚡ **System Enhancement & Enforcement:** Strengthen the oversight, quality control, and consistency of accredited bodies responsible for inspections and personnel certification; improve the practical enforcement of existing regulations, including consistent application of penalties for non-compliance and diligent follow-up on certification renewals; and enhance formal inter-agency coordination mechanisms to improve data sharing and operational alignment between regulators, utilities, and certification/inspection bodies.
- ⚡ **Safety Culture & Modernisation:** Implement targeted programmes to foster a stronger safety culture amongst electrical workers, companies, and potentially the public; develop robust processes to ensure that national standards and safety protocols effectively address new technologies (e.g., renewables, smart grids, EVs, and energy storage).

Drawing lessons from the challenges identified in Indonesia and Cambodia, the following areas represent *opportunities for collaborative action at the ASEAN level* to foster harmonisation, share knowledge, and build collective capacity.

- » **Actionable Harmonisation & Knowledge Exchange:** Promote greater alignment of key national standards (products, codes), and strengthen MRAs informed by observed inconsistencies; explore developing regional competency guidelines/benchmarks for technicians, addressing differing national approaches; establish a platform for sharing practical best practices and challenges regarding safety systems (SMK2), inspection protocols (SLO), and enforcement strategies identified in case studies.
- » **Targeted Regional Capacity Building:** Develop specific regional training-of-trainers or capacity-building initiatives for regulatory staff, inspectors, and certification personnel, focusing on addressing the advanced safety topics (e.g., RE integration, ESS safety) and regulatory/enforcement weaknesses observed in the case studies.

5.3. Policy Recommendations and Way Forward

ASEAN faces significant challenges in ensuring electrical safety, particularly with the increasing share of RE. Key gaps identified across the region include:

Fragmented Governance: Responsibilities for electrical safety are often dispersed across multiple agencies, leading to a lack of clear focus, potential dilution of safety oversight, and insufficient inter-agency coordination.

- ⚡ **Learning from Korea:** Establishing clearer mandates, potentially through dedicated legal frameworks or distinct safety oversight roles within existing structures and improving coordination mechanisms are crucial.

Inconsistent Regulatory Frameworks & Standards: There is a need for greater harmonisation of standards (often based on IEC), development of more detailed national technical/safety standards beyond broad international ones, and specific foundational guidelines for prevalent RE technologies (like Solar PV, ESS).

 **Learning from Korea:** Adopting principles of detailed, nationally enforced standards (like KESC) and aligning regional efforts toward internationally recognised benchmarks.

Challenges in Grid Modernisation & RE Integration: Safely integrating RE requires addressing risks associated with ageing infrastructure and weak grids, necessitating systematic risk identification and planning that coordinates grid modernisation with RE deployment.

 **Learning from Korea:** Integrating safety considerations into master plans for RE deployment and grid upgrades, similar to Korea's approach, is vital.

Weak Enforcement & Lifecycle Management: Deficiencies exist in implementing structured, mandatory inspection regimes covering the full lifecycle (pre-operation, periodic checks), robustly verifying installations, ensuring consistent quality from inspection/certification bodies, and applying practical enforcement. Systematic data collection on accidents is also often lacking.

 **Learning from Korea:** Implementing structured, mandatory lifecycle inspections based on detailed codes, enhancing worker training, and utilising comprehensive data systems (like Korea's Total Information System concept) can significantly improve compliance and safety outcomes.

To address these gaps and leverage successful strategies, a structured, multi-year cooperation between ACE and KESCO is being discussed. This programme serves as a key mechanism for implementing solutions and strengthening regional capacity.

Core Objectives:

- **Enhance Knowledge Transfer:** Share KESCO's expertise in electrical safety management, particularly for RE facilities, through targeted workshops.
- **Facilitate Regional Collaboration:** Create a platform connecting relevant ASEAN agencies and stakeholders for direct dialogue and cooperation on electrical safety matters.
- **Promote Standardisation:** Work towards developing specific ASEAN electrical safety standards and promoting harmonisation across the AMS.
- **Establish Institutional Framework:** Explore forming an ASEAN Electrical Safety Task Force focused on RE facilities and related technologies.

Programme Structure & Gap Alignment: The proposed programme features a series of workshops designed to tackle specific gaps. The topics are:

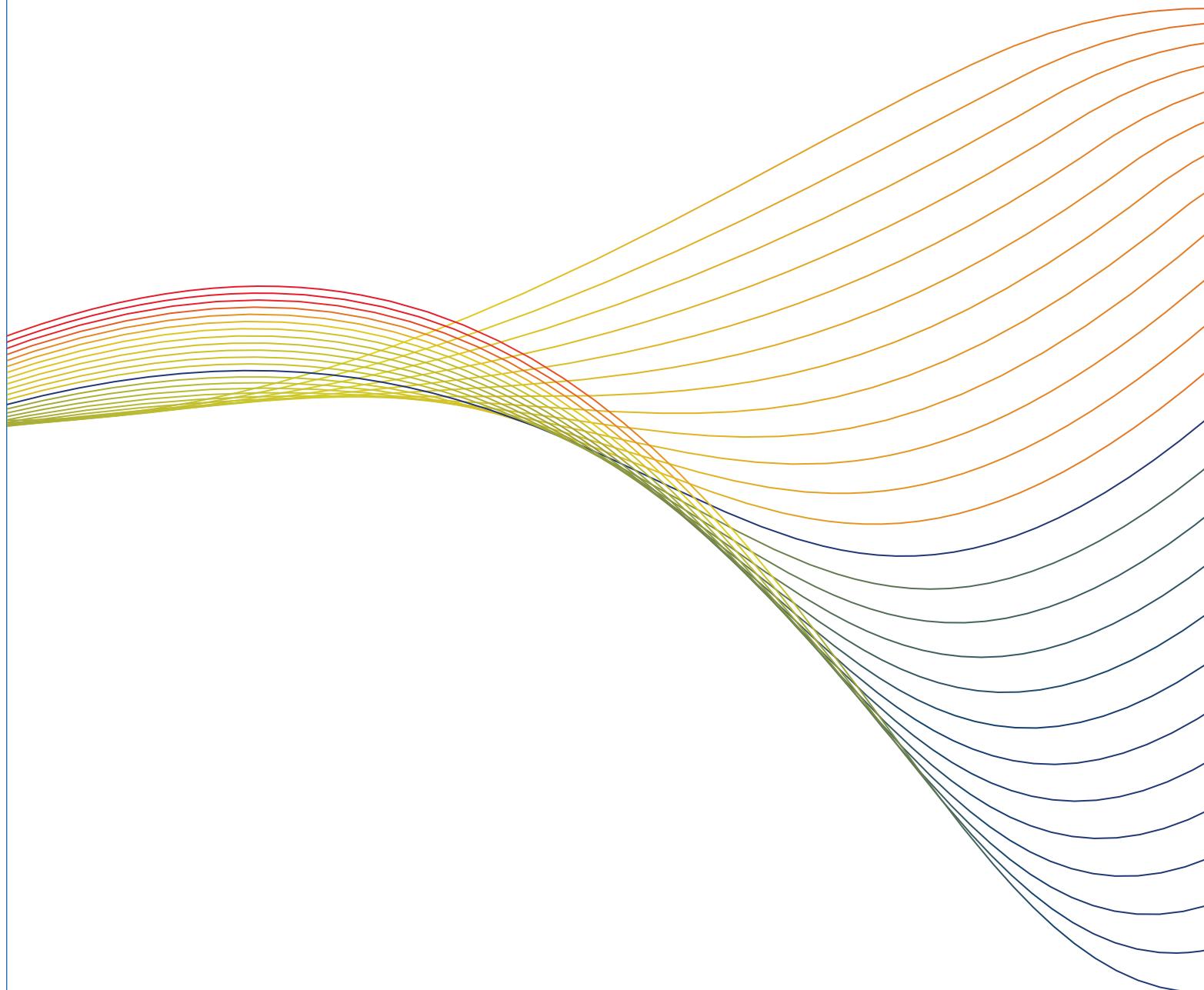
Certification & Inspection: Addresses enforcement and regulatory/standards gaps by focusing on best practices for inspection regimes and application of standards, involving policymakers, regulators, and service providers.

Operational & Maintenance: Targets enforcement and grid modernisation/RE integration gaps by sharing knowledge on safe O&M practices for NRE facilities.

Disaster Management: Connects to grid modernisation and enforcement by addressing safety protocols during emergencies, relevant for grid resilience.

R&D Development: Addresses regulation/standards and grid modernisation needs by fostering collaboration on safety research for new technologies and grid integration challenges.

Task Force Discussion: Directly addresses governance gaps by culminating in discussions on establishing a dedicated regional Task Force.

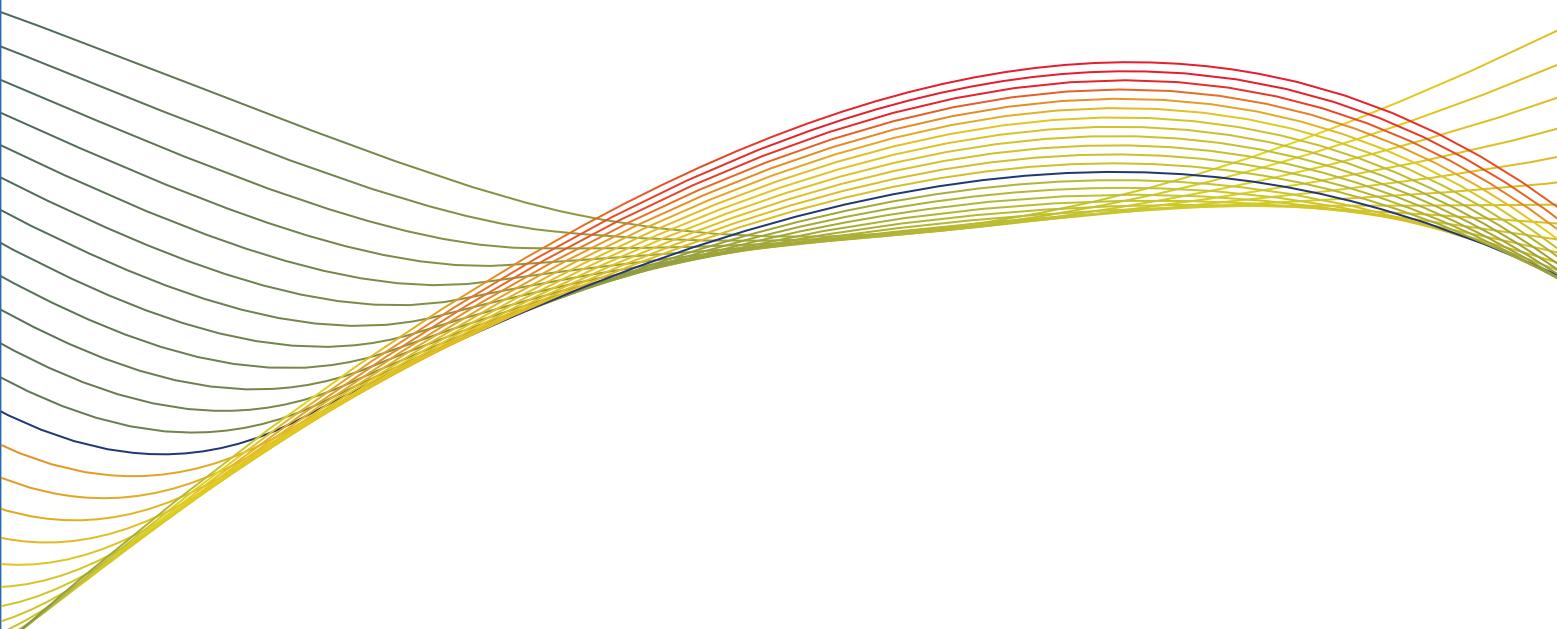


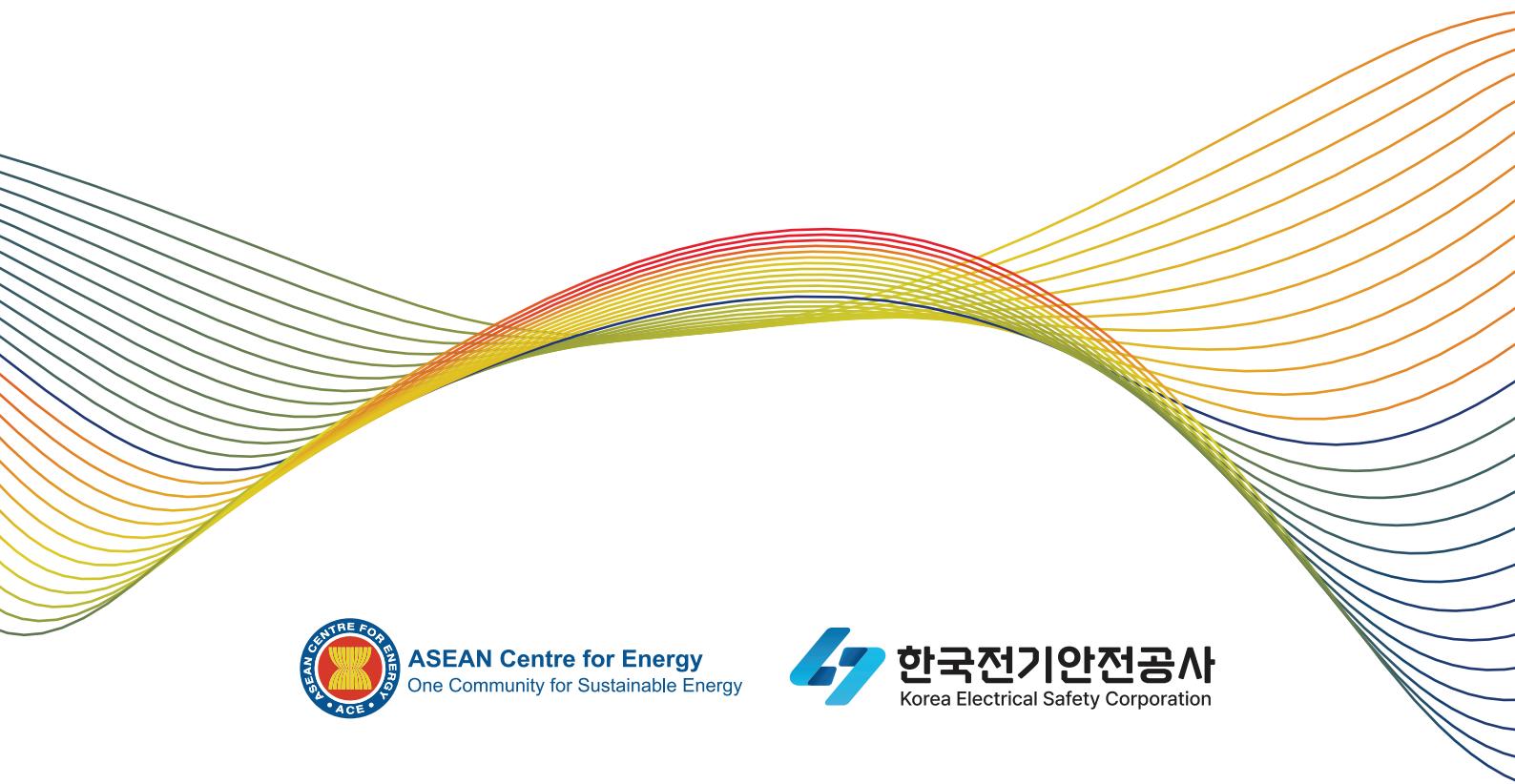
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