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HARMONISED TECHNICAL STANDARDS: DESIGNS AND MINIMUM SPECIFICATIONS

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This publication presents the Rural Electrification Agency's (REA) technical standards (including designs and minimum specifications) required to implement the agency's rural electrification schemes through grid extension and interconnection, injection substations, solar mini-grids, solar home systems, productive-use systems, e-mobility (EVs, charging infrastructure & solar-assisted electric vehicles), wind and small hydropower systems, energy storage systems, as well as solar street lights. The publication was conceived and produced by REA. All reasonable precautions have been taken by the agency to verify the reliability of the material in this publication.

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Glossary of Terms

AAC	All Aluminium Conductor
AAMAS	Advanced Asset Monitoring and Alert System
AC	Alternating Current
ACSR	Aluminium Conductor Steel Reinforced
AMP	Africa Mini-grids Programme
BEME	Bill of Engineering Measurement and Evaluation
BESS	Battery Energy Storage System
BoS	Balance of System
CDMS	Central Data Management System
COREN	Council for the Regulation of Engineering in Nigeria
CT	Current Transformer
CVT	Capacitor Voltage Transformer
DARES	Distributed Access through Renewable Energy Scale-Up
DER	Distributed Energy Resources
dB	Decibel
DC	Direct Current
DOD	Depth of Discharge
DSM	Demand-Side Management
EAP	Energising Agriculture Programme
EV	Electric Vehicle
EVA	Ethylene Vinyl Acetate
FMEnv	Federal Ministry of Environment
GESI	Gender and Social Inclusion
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
Hz	Hertz
IEC	International Electrotechnical Commission
IEPT	Integrated Energy Planning Tool
IRP	Integrated Resource Plan
IP	Ingress Protection
IT	Information Technology
kV	Kilovolt (1,000 Volts)
kW	Kilowatts
kWh	Kilowatt-hour
kVA	Kilovolt-Ampere
lm	Lumens

M&E	Monitoring & Evaluation
MD	Minor Deviation
MoP	Ministry of Power
MPPT	Maximum Power Point Tracking
MT	Metric Tonnes
MC	Multi-Contact
MW	Megawatts
NEMSA	Nigerian Electricity Management Services Agency
NEP	Nigerian Electrification Project
NERC	Nigerian Electricity Regulatory Commission
NESI	Nigeria Electricity Supply Industry
NESIS	Nigeria Electricity Supply and Installation Standards
NESP	Nigerian Energy Support Programme
NESREA	National Environmental Standards and Regulations Enforcement Agency
NSE	Nigerian Society of Engineers
PRS	Pre-stressed Rectangular Solid
p.u.	Per unit
PUE	Productive Use Equipment/Productive Use Energy
PV	Photovoltaic
RETScreen	Renewable Energy Technology Screen
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SE4ALL	Sustainable Energy for All
SHS	Solar Home System
SLD	Single Line Diagram
SMG	Solar Mini-Grid
SON	Standards Organisation of Nigeria
SR	Safety Relevant
SSL	Solar Street Lighting
STC	Standard Test Conditions
STS	Smart Transformer Stations
TUV	Technischer Überwachungsverein
V	Volt
VIDA	Virtual Integrated Development and Analysis
VD	Voltage Drop
XLPE	Cross-linked polyethene

Definition of Terms

AAMS	Advanced Asset Monitoring and Alert System – A remote monitoring electronic device designed to enhance security, operational efficiency, and preventive maintenance in mini-grid and off-grid energy systems.
Applicant	Mini-grid Owner, also referred to as Owner, who may authorise a third-party that is fully familiar with the Mini-Grid, to apply and procure the Inspection Certificate on its behalf, provided that he is a NEMSA certified Renewable Energy contractor for Electricity Generation.
Back-up Generation	Any firm Generation such as diesel-powered or biomass-powered generator that can operate within seconds of the non-availability of Solar Photovoltaic (PV) Generation.
BoS	Balance of System – All components of a PV system other than the PV panels; including wiring, switches, a mounting system, one or many solar inverters, a battery bank or many battery banks, related electronic battery converters and battery chargers.
BESS	Battery Energy Storage System – A rechargeable battery system that stores energy from renewable sources and releases it when needed to ensure continuous electricity supply.
CDMS	Central Data Management System – A digital platform for managing and analysing mini-grid and renewable energy project data.
Customer	A client of the Owner buying electricity from the Mini-Grid under a domestic, commercial, productive and/or administrative service contract, and maybe a natural person or any other legal entity.
Commissioning	The period when all installations of electrical works have been completed and technically inspected, tested and certified by NEMSA before the start of operations.
DARES	Distributed Access through Renewable Energy Scale-Up – A program aimed at expanding energy access through mini-grid and off-grid solutions.
DER	Distributed Energy Resources – Decentralized energy sources, including solar PV, wind, and storage systems, that contribute to the electricity grid.
Distribution Network	Electric power lines with connections for low voltage (230/400V) and optionally medium voltage (up to 33kV), transformers and other switchgear to distribute electric power (produced by a Generation source) to the Customers.
DSM	Demand-Side Management – A set of strategies used to optimize energy consumption and reduce peak demand in mini-grid systems.

Electrical Installation	The construction or installation of electrical wiring and the permanent attachment or installation of electrical products in or on any structure.
Electrical Safety	Any safety precautions (organisational measures and technical) taken against electricity (electric current, electric arc, electromagnetic field and static electricity) to prevent harmful and dangerous effects on anyone.
EV	Electric Vehicle – A vehicle powered by electricity, typically charged using renewable energy mini-grid systems.
FMEnv	The Federal Ministry of Environment, Nigeria, responsible for environmental policy formulation, regulation, standards and enforcement, including climate change adaptation, environmental impact assessments, waste management, and sustainability initiatives across several economic sectors.
Generation	Solar PV Generation in combination with any Other Generation and Back-up Generation, as well as the land (including the Powerhouse and the Fencing) housing the Generation source
GESI	Gender and Social Inclusion – A framework ensuring equitable energy access, participation, and benefits across all societal groups.
GIS	Geographic Information System – A spatial data tool used for mapping and analysing mini-grid deployment locations.
Inspection	The physical inspection and testing of electrical installations by NEMSA inspectors as per the procedure described in their extant guidelines.
Inspection Certificate	shall mean the Certificate issued by NEMSA to any Owner of a Solar Hybrid Mini-grid having successfully undergone the process of Inspection by NEMSA Inspectors, as defined in these Guidelines, and is valid for 5 years, unless the Electrical Installation requires Significant Modifications before this period, in which case the Owner shall apply for Re-inspection.
Inspection Fee	The fee stipulated for inspection of electrical works/installations as published by NEMSA on www.nemsa.gov.ng.
Inspector	An inspecting Engineer under NEMSA to carry out the functions of inspection, testing and certification of all electrical installations/works.
IRP	Integrated Resource Plan – A planning tool used to optimize energy supply, demand, and infrastructure development.
Meter	As defined under the Nigerian Electricity Regulatory Commission (NERC), Metering Code, V02 and NEMSA Act, 2015.
Mini-grid	Any electricity supply system with its power Generation capacity of up to 1 MW, supplying electricity to more than one customer and which can operate in isolation from or be connected to a Distribution Licensee's network", under NERC's, Mini-grid Regulations, 2023.

Mini-grid Documentation and Inspection Forms	The standardised document to be filled by the Applicant to apply for inspection and shall be subject to changes by NEMSA and for which the latest version can be downloaded from www.nemsa.gov.ng or picked up in any of the NEMSA Inspectorate Field Offices (https://nemsa.gov.ng/field-inspectorate-offices/).
MoP	The Federal Ministry of Power, Nigeria, responsible for policy formulation, regulation, and oversight of the electricity sector, including grid extension, renewable energy initiatives, rural electrification, and infrastructure development.
NEMSA Certified Contractor	Any Contractor duly certified by NEMSA to carry out electrification projects through grid extension, injection substations and solar mini-grids, home systems and street lights.
NEP	Nigerian Electrification Project – A government initiative focused on expanding electricity access through mini-grids and off-grid solutions.
PUE	Productive Use Energy – The application of electricity to enhance income-generating activities, such as agro-processing and refrigeration.
PUE	Productive Use Equipment – Electrical appliances and machinery that utilize energy to support income-generating activities in mini-grid and off-grid systems. Examples include agricultural processing equipment, refrigeration units, water pumps, small-scale manufacturing equipment, etc.
Regulation	Any applicable piece of Regulation, as approved by the NERC or any other statutory regulatory body in Nigeria.
Re-inspection	Inspection after correcting the defects observed during Inspection or upon expiry of the Inspection Certificate for reasons of renewal of the Inspection Certificate or upon significant modifications carried out by the contractor, and shall follow the same procedure as Inspections.
SCADA	Supervisory Control and Data Acquisition – A system used for remote monitoring and control of mini-grid operations.
SE4ALL	Sustainable Energy for All – A global initiative promoting universal access to sustainable energy solutions.
Solar Hybrid Mini-grid	Any Mini-grid that combines Solar PV Generation, other Generation sources (wind, biomass, etc.), Back-up Generation and a Distribution Network, as specified in NERC's Mini-grid Regulations, 2023.
Solar PV Generation	The main Generation source of the Solar Hybrid Mini-grid and comprising the solar modules, the ground-mounted/roof-mounted or building-integrated support structure, the charge controller or grid-tie inverter and the required Balance of Systems (BoS), if not part of the System Controller.

SSL	Solar Street Light – Public lighting systems powered by solar energy.
Standard	Any Standard as recommended and/or approved by NERC, NEMSA, SON, NESREA, IEC or other related bodies.
Storage	Secondary (rechargeable) batteries, including, but not necessarily limited to lead-acid batteries and lithium to store excess electricity produced by the Generation for later use, including power electronic converters or charge controllers and monitoring, if not part of the overall System Controller.
System Controller	The central element that manages all types of Generation and Storage of the Mini-grid and ensures a reliable supply of electricity to the Distribution Network of the Mini-Grid. The System Controller shall comprise of a simple charge controller **for small systems** (i.e., up to 10kW) and dedicated off-grid inverters, or a supervisory controller in combination with dedicated controllers and electronic power inverters **for large systems** (i.e., from 10kW), including all required BoS.
System Stress Testing	Loading the concurrent users over and beyond the level that the system can handle, so it breaks at the weakest link within the entire system.
Technical Documentation	Datasheets, Single Line Diagrams (SLDs), detailed schematics, construction plans, internal test and Commissioning reports/protocols, as well as Operating Procedures.

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Table of Contents

1 SCOPE AND OVERVIEW

1. This publication is an updated version of Version 1.0, originally published in May 2021.
2. The updated publication presents the Rural Electrification Agency's (REA) harmonised technical standard (including designs and minimum specifications) that is required to implement the agency's rural electrification schemes through grid extension and interconnection, injection substations, solar mini-grids, solar home systems, productive-use systems, e-mobility (EVs, charging infrastructure & solar-assisted electric vehicles), wind and (small) hydropower systems, energy storage systems, as well as solar street lights. It also includes standards for system interoperability to ensure seamless integration of hybrid technologies, including solar, wind, storage, and grid extensions.
3. It incorporates previously developed technical standards for the Technical Services (TS) Directorate, Rural Electrification Fund (REF), and Nigerian Electrification Project (NEP). Extant Procurement rules, as well as the Nigerian Electricity Regulatory Commission (NERC), Nigerian Electricity Management Services Agency (NEMSA), Nigerian Electricity Supply and Installation Standards (NESIS), Standards Organisation of Nigeria (SON), International Electrotechnical Commission (IEC) standards[1], the Federal Ministry of Environment (FMEnv) regulatory guidelines for lifecycle management and recycling of solar components, and National Environmental Standards and Regulations Enforcement Agency (NESREA) policies and regulations such as the National Environmental (Battery Control) Regulations 2024, were also considered.
4. A committee was set-up to develop and present this publication to the Executive Management and Board for ratification. The committee consisted of representatives from the following directorates/departments: office of the Managing Director (MD), TS, REF, NEP-DARES, Monitoring & Evaluation (M&E) and Procurement.
5. The publication provides usefulness to state governments, project developers, contractors, power sector Ministries, Departments and Agencies (MDAs), utility companies, investors, equipment manufacturers/suppliers, development partners, local authorities/communities, as well as other stakeholders interested in implementing sustainable rural electrification schemes through grid extension and interconnection, injection substations, solar mini-grids, solar home systems, productive-use systems, e-mobility (EVs, charging infrastructure & solar-assisted electric vehicles), wind and (small) hydropower systems, energy storage systems, as well as solar street lights.
6. Internally, the publication also provides usefulness to REA in carrying out several organisational functions, including procurement, surveys, design, internal control, performance management, M&E, project implementation, project inspection/monitoring and project assessment.
7. The document also includes a framework for monitoring and evaluation (M&E), with clear methodologies for project assessment, compliance audits, and continuous performance improvement.
8. The document also outlines the necessary training and certification requirements for technical personnel involved in system design, installation, and maintenance to ensure quality and safety compliance across REA projects.

[1] Referenced IEC standards in this document that have been formally adopted by the Standards Organisation of Nigeria (SON) are enforced as national standards. This ensures that internationally recognized technical requirements are locally regulated, reinforcing compliance and quality across projects within Nigeria.

All Standards Organisation of Nigeria (SON) standards are mandatory, ensuring that all technical specifications and safety protocols are uniformly applied across national projects to uphold quality, safety, and consistency in compliance with Nigerian regulations.

9. The standards and specifications in this publication are in line with extant laws and regulations, and as such, shall be implemented together with other laws, regulations and standards, including:

a. Laws of the Federal Republic of Nigeria, including (but not limited to) the Electricity Act, 2023 and NEMSA Act, 2015.

b. Regulations from NERC, but not limited to:

i. The Nigerian Electricity Health and Safety Code, 2014.

ii. The Nigerian Electricity Supply and Installation Standards Regulation, 2015.

iii. The Grid Code, 2018

iv. The Distribution Code, 2014

v. The Metering Code (V02), 2014

vi. Nigerian Electricity Smart Metering Regulations, 2015

vii. The Mini-Grid Regulations, 2023

viii. Electrical Installations Regulations S.I.5 and Electricity Supply Regulations S.I.6 of 1996; and

ix. The Nigerian Electrical Installations and Construction Guidelines Manual, Distribution Subsector, Volume 1, 2020.

x. Other technical regulations, guidelines and codes issued occasionally by NERC, NESIS, NEMSA[2], IEC, etc.

c. IEC and other international Standards, specifically for materials and equipment that are not covered under any Nigerian Law, Regulation or Standard. Also, IEC Standards formally adopted by SON. These standards include (but not limited to) the following:

i. IEC 62446-1:2016+A1:2018: PV systems - Requirements for testing, documentation and maintenance - Part 1: Grid-connected systems - Documentation, commissioning tests and inspection.

ii. IEC 62619:2022: Safety requirements for secondary lithium cells and batteries, for use in industrial applications.

iii. IEC 63056:2020: Safety requirements for secondary lithium batteries for stationary energy storage. Applicable to energy storage batteries used in mini-grids and distributed systems.

iv. IEC 62485-1:2015: Safety requirements for secondary batteries and battery installations - Part 1: General safety information.

v. IEC 62619:2017: Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications.

vi. IEC 62620:2014: Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for use in industrial applications.

vii. NIS IEC 61215: Standards for the design and performance testing of Photovoltaic (PV) modules to ensure durability and efficiency in outdoor environments.

viii. IEC 61730: Specifies the safety qualifications for PV modules, including electrical insulation, fire safety, and protection against electric shocks.

ix. NIS IEC 62109: Governs the safety of power converters used in photovoltaic systems, ensuring protection against electric shocks, overcurrent, and overheating.

x. NIS IEC 62257: Comprehensive guidelines for the deployment and operation of off-grid energy systems, including isolated and interconnected mini-grids.

xi. IEC 62619: Focuses on the safety requirements for secondary lithium cells and batteries used in industrial applications, including energy storage systems.

xii. IEC 61851: Governs the safety and operation of electric vehicle (EV) charging stations.

xiii. IEEE 1547: Establishes standards for the interconnection of distributed energy resources (DERs), such as mini-grids, with the grid.

[2] Guidelines for the Inspection of Solar Mini-Grids in Nigeria.

xiv. IEC 61970-301: Lays down the common information model (CIM), representing major objects in an electric utility enterprise involved in operations.
xv. NIS[3] 1209-1-2024: Minimum energy performance standard for lighting products.
xvi. NIS 1209-2-2024: Minimum energy performance standard for luminaires.

10. The necessary cost considerations were taken into account when updating the technical standards (including designs and minimum specifications).

11. The document prioritises the preservation of local content to enhance affordability, promote job creation, and support the local supply chain.

12. Upon ratification by the Executive Management and Board, the document (Version 2.0) will supersede the Version 1.0 Harmonised Technical Standards. The document will take precedence over other technical standards, provided it is in line with extant laws and regulations.

13. The document is also expected to be integrated into REA procurement processes to ensure consistency, enforce compliance, enhance project quality, and drive cost-effective implementation across all REA projects.

14. The document will be periodically revised and updated (as required) to meet international best practices.

[3] Nigerian Industrial Standards (NIS)

2 GRID EXTENSION

2.1 STANDARDS AND SPECIFICATIONS: ELECTRICAL WORKS

This sub-section outlines standards and specifications for electrical works. The distribution network, in this context, includes the following: 33kV networks; 11kV networks; 400V networks and below.

2.1.1. General Guidelines[4]

1. **Material Requirements:** All materials used for electrical works, their components, accessories and support structures are required to ensure safe operational performance within the anticipated life span of the installation in compliance with **IEC 60287** (thermal performance), **IEC 60364** (electrical installations), and **IEC 62271** (switchgear safety). Materials shall be **corrosion-resistant** and suitable for harsh environmental conditions, especially in rural and coastal areas
2. **Thermal Ratings:** The thermal capacity of electrical works shall be sufficient to pass the electrical load for which they are designed, without reduction of electrical and mechanical properties to a level below safe operational performance, in compliance with **IEC 60287 standards, considering ambient temperature variations and solar radiation impacts in tropical climates.**
3. **Short Circuit Ratings:** The electrical works shall be of sufficient capacity to pass short circuit currents and **arc-flash protection tests**, **per IEEE C37,** which will enable the correct operation of protective devices so that a fault is cleared without reduction of electrical and mechanical properties to a level below safe operational performance**.**
4. **Mechanical Loading Conditions:** The electrical works shall have sufficient mechanical and structural strength, in compliance with IEC 60826 for overhead lines to withstand anticipated stresses and strains due to environmental and electrical service conditions.
5. **Electrical Service Conditions and Physical Environment:** In determining the electrical service conditions and the physical environment under which the electrical works will operate, due and reasonable care shall be given to the consideration of extremes that may occur, the likelihood of their occurrence and the associated risks.
6. **Prevention of Unauthorised Access:** All electrical works with exposed live parts shall be designed and constructed in a manner that prevents unauthorised access to any person, as far as is reasonably practicable.

2.1.2 Allowable Voltages and Voltage Control [5]

The distribution network shall be operated on voltages as defined below:

1. **System of Supply:** The following system standards shall apply;
   a. The frequency shall operate within a narrow operating band of 50 Hertz ± 1%) or (49.50 – 50.5 Hz). However, under System Stress Testing, the Frequency on the Power System can experience variations within the limits of 50 Hz ± 2.5% (48.75 – 51.25 Hz).
   b. Standard A.C. voltages shall be 230 V ± 6% between the phase conductor and neutral conductor and 400 Volts ± 6% between phases conductors. Primary distribution high voltage shall be 33,000 Volts ± 6% and secondary distribution high voltage shall be 11,000 Volts ± 6%.

2. **Standard Types of Supply**
   a. Two-wire system (single-phase alternating current) at a nominal voltage not exceeding 230 volts at the user's main switchboard.
   b. Three-phase four-wire alternating current system at a nominal voltage not exceeding 400 volts between phases
   c. The voltage shall be maintained within ±6% of the nominal voltage at the consumer's

[4] Updated to align with IEC 60287, IEC 60364, and IEEE C37 Standards

[5] Updated to align with IEC 61727 for grid interconnection and IEC 60038 standard for voltage stability

main switchboard. In the case of a complaint by any consumer that the variation in voltage exceeds the limits specified, or on the instructions of the Inspecting Engineer, the Distribution licensee shall provide, connect and maintain a portable recording device to record the voltage profile between the service line. If the variation thus recorded are caused within and by the licensee's system and exceed the above limits, the licensee shall take immediate steps to resolve the complaint.

d. However, if the voltage variation is caused by the consumer's own equipment, system or installation, it shall be the consumer's responsibility to take corrective action.

3. Supply Voltage

a. The Supply Voltage shall not exceed 230 ± 6% volts at the user's main switchboard. For supply to services exceeding 10 kilowatts connected load, the nominal voltage shall not exceed 400 ± 6% volts at such switchboard.
b. The Supply Voltage for industrial purposes may be given at high voltages either for transformation or for direct supply to motors or any other agreed voltage between the Distribution Licensee and the user. This shall be subject to the standard voltage in these regulations provided that the transforming apparatus and control gear are so enclosed as to be inaccessible except to authorised persons.

2.1.3 Insulation Requirements, Earthing, and Thermal Performance[6]

Distribution Network shall be appropriately insulated to guarantee the safety of equipment and personnel. Insulation materials used shall be capable of withstanding high insulation value(s) throughout the service life of the equipment or installation. Provisions of **IEC 60502** on the insulation of equipment, materials and installation shall be adhered to.

1. **Earthing:** All electrical installations and network shall be adequately earthed in compliance with IEC 60364-5-54 and the Code of Practice for Earthing (NCP[7] 09) to guarantee operational safety

2. **Earthing of Metal Structures**

a. Where lines are operated at high voltages, all metal structures, other than conductors shall be permanently and effectively connected to earth electrode(s). For this purpose, a continuous earth wire shall be provided and connected to the earth.
b. Where any special equipment on a pole includes a metal structure accessible from ground level which normally has to be handled by an operator when the line is live (e.g., a switch-operating handle), such metal structure shall be connected to an earthing mat, so situated as to include within its area the whole of the ground on which the operator would normally stand to eliminate step-potential hazards.
c. Earthing at Pole-Mounted Substations for Pole-mounted transformer: The electrode used for earthing the steelwork shall be situated outside the resistance area of the earthed electrode connected to the low voltage neutral.
d. Earthing at Plinth-Mounted Substations for Plinth-mounted transformer: The Lightning Arrester, D-fuse and general earthing (Transformer body, Feeder pillar body, channel iron, Transformer neutral etc.) shall have different earth pit respectively. All section poles shall be earthed including angle poles with steel cross arm.

[6] Updated to align with IEC 60502, IEC 60364-5-54, and IEC 60287 standards
[7] National Security Inspectorate (NSI) Code of Practice -NCP

3. **Thermal Performance & Current-Carrying Capacity**

   a. The maximum allowable conductor temperature shall comply with IEC 60287 to prevent overheating under full load conditions.

   b. For underground cables, heat dissipation factors and soil thermal resistivity shall be accounted for to prevent premature degradation.

2.1.4 Equipment and Installation Devices[8]

1. All materials, equipment, devices and accessories used directly in construction, installation and maintenance of distribution network shall constitute electrical network equipment and installation devices. They shall include (but not limited to) the following:

   a. Support structures: metal or reinforced concrete poles, gantry guy, stay assembly
   b. Overhead materials: conductors, insulators, line hardware, accessories
   c. Underground materials: cables, termination kits, lugs
   d. Substation equipment: transformers, shunt capacitors, arresters, feeder pillars.

2.1.5 Overhead Distribution Lines and Conductors[9]

1. Overhead Distribution Lines shall be constructed with non-insulated and insulated conductors on supports designed and constructed to:

   a. Have insulation appropriate for the nominal voltage;
   b. Can carry the maximum electrical load currents for which they are designed without exceeding thermal limits (IEC 60287)
   c. Allow the passage of electrical short circuit currents which will enable the correct operation of protective devices;
   d. Ensure they are structurally secure for the environment and service conditions for which they are designed;
   e. Maintain safe clearances;
   f. Ensure that safe operational performance will occur, under normal and emergency conditions, and
   g. Prevent unauthorised access to electrical works.

2. **Overhead Lines with Bare Conductors:** Overhead lines with bare conductors passing through areas used for public recreation or non-farming work activities shall be equipped with cradle guards or other protective measures to prevent accidental contact. However, if a risk assessment confirms that the minimum clearance heights and alternative safety measures are adequate to eliminate the risk of contact, additional protection may not be required.

3. **Routing Overhead Lines across Farmlands:** A risk assessment shall be carried out and any unacceptable location shall be avoided. Examples include the following:

   a. Locations where regular loading /unloading activities take place.
   b. Fields where potable irrigation pipes are regularly used.
   c. Any location identified as being a potential hazard to farmworkers.

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[8] Updated to align with IEC 60826 (design criteria for overhead lines), IEC 60652 (structural testing for towers and poles), IEC 61442 (test methods for cable accessories), and IEC 60076 (power transformers)

[9] Updated to align with IEC 61089 (conductors for overhead lines), IEC 60826 (design criteria for overhead transmission lines), IEC 61089, IEC 60364, IEEE C2, ISO 1461)

d. If no alternative routes exist, insulated cables (per **IEC 60502**) or underground cabling (per **IEC 60840**) shall be considered.

4. **Space Between Conductors:** The space between conductors in the 33kV line shall be 1.2m while that of the 11kV line shall be 0.9m. The transverse distance between the phase conductor of the 400V line shall be 0.25m.

5. **Crossing of Lines at Different Voltage Levels:** Where two lines with different voltage levels cross each other, the line operating at the higher voltage shall be positioned above the line operating at the lower voltage. A safety net or equivalent protective measure shall also be installed beneath the higher voltage line to enhance operational safety and mitigate risks associated with conductor failure or accidental contact.

6. **Supporting Structures:** The supporting structures shall be selected from concrete poles, steel poles, steel lattice towers, or gantry guy and stay assemblies. These structures shall meet required standards for mechanical strength, corrosion resistance, and environmental durability to ensure long-term reliability and stability in varying operational conditions.

2.1.6 Concrete Poles and Structural Durability

1. The accepted types of concrete poles include the following: Pre-stressed steel-reinforced H section; pre-stressed steel-reinforced spun square section, and pre-stressed steel-reinforced spun circular section.

2. According to BS[10] 607, concrete poles shall have the following classifications:

Table 2.1: Concrete Poles Classifications

Length of Pole		Application
Meter (m)	Feet (ft)	
8.5	28	LV only
10	34	LV and HV
12	39	LV and HV

3. **Pre-Formed Holes:** The holes shall be formed during the manufacturing process and shall be free of obstructions and burrs to prevent cable damage and structural weakness.

4. **Span of High Tension (HT)/Low Tension (LT) Poles:** The span between two intermediate poles in inter-township (between towns) shall be in the range of 50m - 70m while that of intra-township (within towns) shall be 45m.

[10] British Standards Institution (BSI)

5. **Pole Identification:** Each pole shall bear legible engraved identification marks to be located 3m from the butt. The length of the pole, type of pole, date of manufacture, manufacturing company's initials, REAs initials shall be clearly shown as in the sample pattern below:

   a. 10.36m/PRS/REA/COMPANY/01-2021, or 10.4m/ PRS/REA/Zampoles/01-2021
   b. The engraving in (a) categorises a 10.36m long Pre-stressed Rectangular Solid (PRS) pole, manufactured for or supplied to REA by Zampoles Company. The pole was produced on 1st January 2021.
   c. Poles without the engraving specified in (a) will be rejected.

6. **Pole Markings:** Each pole shall be marked to guide during the process of erection. The marking which shall be at least 0.15m thick will be at the following height from the butt of the pole and shall be at the topsoil level or casted beam:

Table 2.2: Pole markings for selected reinforced concrete poles

Pole Description	Marking Level from Butt of Pole (m)	Marking Level from Butt of Pole (ft)
8.53m /28ft R.C. Pole	1.52m	5ft
10.36m /34ft R.C. Pole	1.82m	6ft
12.2m /40ft R.C. Pole	2.13m	7ft

2.1.7 Steel Towers/Steel Poles – Design, Load Capacity & Corrosion Resistance

1. **Structural Members of Supporting Structures:** Steel Structural Members of supporting Structures (including flat steel, shaped steel, steel pipes, steel plates, steel bars and bolts) which compose a steel tower or iron pole used for overhead transmission lines shall be appropriate ones as specified by IEC (International Electrotechnical Committee), ISO (International Organisation for Standardisation), and SON (Standards Organisation of Nigeria).

2. **The thickness of Steel Members and Structural Requirements (Updated – IEC 60652):** Shaped steel, steel pipes and steel plates to be used for steel tower or iron pole for overhead transmission lines shall have the thickness and other dimensions as specified below:

   a. Minimum thickness of shaped steel to be used as:

      i. The main post member of an iron pole shall have a thickness of 4mm. The same shall apply where the main member of a cross arm is included.
      ii. The main post member of a steel tower shall have a thickness of 5mm.
      iii. Other structural members shall have a thickness of 3mm.

   b. Minimum thickness of steel pipes to be used as:

      i. The main post member of an iron pole shall have a thickness of 2mm.
      ii. The main post member of a steel tower shall have a thickness of 2.4mm.
      iii. Other structural members shall have a thickness of 1.6mm.

c. Slenderness ratio of steel members: The slenderness ratio of a compression member shall be no more than 200 for those to be used as the main post member and no more than 220 for compression members other than main post members (excluding those used as auxiliary members) and no more than 250 for those used as auxiliary members.

d. Minimum thickness of steel plates: The thickness shall be no less than 1mm.

3. Corrosion Resistance & Surface Protection[11]

a. All steel structural components shall be protected from corrosion through the following:
   i. Hot-dip galvanization in compliance with ISO 1461 to achieve a minimum zinc coating thickness of 85 microns (µm) for outdoor environments.
   ii. For installations in high-humidity, saline, or industrially polluted environments, additional protective measures such as polyurethane or epoxy-based coatings shall be used.
   iii. Protective coatings per ISO 12944 (Paint Systems for Corrosion Protection), if galvanization is not applied.

2.1.8 Steelworks and Structural Integrity

Steelworks entail the channel iron, angle iron, stay rod, stay thimble, stay wire, terminating strap, j-hook, clevis adapter, socket tongue, cross arm (tie) strap, bracket mount, line taps, shackle insulator complete (D-iron, D-iron pin) and bolts, nuts & washers. The steel material for steelworks used in the construction of overhead lines shall be galvanised.

1. General Guidelines

a. The steel used in the manufacture of the items listed is to be Grade 43A, 28/33-ton quality, in compliance with BS EN 10025-2 (Hot-Rolled Structural Steel Grades) or an equivalent specification approved by NEMSA and the sections shall conform with BS. 4848 Part 4, or to an equivalent Standard.
b. Where a tube is used in the manufacture of some of the items, solid drawn seamless to B.S. 980 CDS-2 or equivalent shall be used
c. All drillings, filing and welding shall be carried out before galvanising and such galvanising shall be in accordance with BS 729, i.e., a minimum deposition of 610 grammes/m², in accordance with **BS 729 (Zinc Coatings on Steel Products)**
d. Where nuts, bolts or studs are required, they shall comply with Equipment & Materials Standard 1-250 for fasteners and shall be hot-dip galvanised to **ISO 10684** for corrosion resistance.

2. Stay Rods

a. Rods used in the construction of the stay rod shall be Grade 43A steel complying with BS 4360 **(Structural Steel for Overhead Line Supports)**.
b. Stay Rod could be the tubular type rods for use with High Voltage services and or the Auger type rods for use with Low Voltage service lines

3. Stay Wires

a. All Stay wires shall be galvanised steel and stranded; stay wires shall be galvanised to BS 443 or equivalent
b. Stay wires shall be manufactured from mild steel stay wire of 700N/mm^2 quality in accordance with BS 183 or an equivalent specification approved by NEMSA

[11] Updated to align with ISO 1461, ISO 12944 and IEC 60826 standards

c. The finished strand shall be right-hand lay, except for the 19-wire strand, which shall have an inner layer left hand and outer 12-wire right-hand lay.
d. The lay of the strand of each size of stay wire shall be in accordance with BS 183 or an equivalent specification.
e. Where a stay wire crosses over a road or street, a flying stay shall be adopted.

Table 2.3: Approved size and drawing numbers

Size	Mean Force Level (MFL)
7/3.25mm (7/10 SWG)	40.6kN
7/4.0mm (7/8 SWG)	61.6kN
19/3.55mm (19/10 SWG)	131.6kN

4. **Cross Arm (Tie) Straps:** All cross arm (tie) straps shall be galvanised steel angle bar-shaped. The thickness of the tie strap will be 6mm.

5. **Bracket Mount:** All bracket mount shall be of galvanised steel with a thickness of 4mm-6mm.
6. **Line Taps**
a. Line taps (either bi-metal line taps or aluminium line taps) shall be used for joining conductors.
b. Where copper conductors are jointed with aluminium conductors, bi-metal couplers or bi-metal line tap shall be used so as not to generate electrochemical corrosion in the joint.
c. Where Aluminium conductors are to be joined as in a section or on an intermediate span aluminium line shall be used.

2.1.9 Overhead Line Insulators and Performance Criteria

1. This Standard specifies line insulators for general use on current designs of overhead lines having phase-to-phase system voltages of up to and including 33kV.
2. The mechanical failing load of 10kN (pin insulator) in a transverse direction and strain insulators shall be suitable for a minimum failing load of 70kN, in alignment with **IEC 61109** standards.
3. HV insulator shall be either ceramic (porcelain glazed or glass type) or silicon rubber type, complying with **IEC 60383 and IEC 61109** for performance under various environmental conditions. LV insulator shall be ceramic “porcelain glaze” in accordance with **BS 3288 and IEC 60168**. Stay insulators for both HV and LV shall be ceramic “porcelain glaze”.

2.1.10 Cross Arms – Materials, Design & Stress Testing

1. Fibre cross arm shall be used for intermediate single poles.
2. Cross arms for terminal and section poles shall be galvanised steel angle iron of appropriate length depending on the line deviation.
3. The cross arms shall be made from high-quality fiberglass-reinforced polymer (FRP) composite material. The specification shall be as follows:

Table 2.4: Cross arm specifications (voltage rating, length and thickness)

Voltage Rating	Length (mm)	Length (ft)	Thickness (mm)
11kV	2438.4	8	6.35
33kV	2743.2	9	6.35

2.1.11 Line Conductors – Sizing, Performance & Testing[12]

1. The conductors used on overhead lines shall be limited to aluminium and alloys of aluminium material, essentially All Aluminium Conductor (AAC) and Aluminium Conductor Steel Reinforced (ACSR).
2. Classes and qualities of aluminium conductors applicable in distribution overhead network shall comply with the provisions of IEC 61089.
3. For 33kV and 11kV transmission lines, 150mm² ACSR conductors shall be used for long spans requiring higher mechanical strength, while 100mm² ACSR conductors shall be applied for shorter spans in inter-township connections across the far north. In the south, 150mm² AAC conductors shall be used under normal wind conditions, whereas 100mm² ACSR conductors shall be deployed in areas with strong wind conditions, except where additional reinforcement is necessary.
4. For 400V medium voltage lines, conductors of 100mm² AAC shall be used.
5. All Aluminium conductor shall be manufactured in Nigeria.
6. The recommended conductors are shown in the table below.

Table 2.5: Recommended line conductors

AAC to IEC 61089, BS 215, Part 1		ACSR Stranding		
Metric (mm²)	Current Rating (Amperes)	Area (mm²)	Aluminium (mm)	Steel (mm)
100	290	50	6/3.35	1/3.35
150	346	100	6/4.72	7/1.57

2.1.12 Installation of Transformers – Guidelines & Compliance

1. All Transformers shall be new
2. The minimum standard RATING for all distribution transformers shall be 200kVA
3. Distribution Transformer can either be of single-phase type or three-phase type.
4. A three-phase Distribution Transformer with a vector group Dyn11 shall be used.
5. Standard protection for distribution transformers shall be D-Type fuse at the Transformer Primary and HRC fuse at the secondary. The insulation for the D-Type fuse shall be porcelain or silicon type.

[12] Updated to align with IEC 61089 and NEMSA Standards

6. Transformer windings shall be copper bars.
7. All Transformers shall be approved ISO compliance.
8. All transformer substations shall be accompanied by a Ganged Isolator.
9. All substations are to be protected with the voltage rated Lightning Arrester. The insulation shall be porcelain or silicon type.
10. 70mm^2 Bare copper shall be used for transformer substation earthing; 50mm^2 Bare copper conductor shall be used for line earthing.
11. The earth resistance for a substation shall be <10 ohms.

2.1.13 Feeder Pillars – Safety & Operational Efficiency

1. Feeder Pillars shall be installed on a plinth of not less than 600 mm from the ground furnished with a tamper-proof lock and appropriate cable clamp.
2. The feeder pillar shall conform to NERC standards and other standards not stated in this document for acceptance.
3. The following instruments shall be installed for the measuring of LV feeder pillar parameters:

   a. Ammeter: At least one ammeter shall be installed on a feeder pillar incomer bus bar.
   b. Voltmeter: Voltmeter shall be installed on a feeder pillar to show line-to-line and line-to-neutral voltages.
   c. Energy Meter: Energy Meter for low voltage distribution feeder pillar panels shall be installed according to the requirements of the Nigerian Metering Code.

4. The approved feeder pillars shall be 800A, 4ways, copper Bars for all transformer substations.

2.1.14 Transformer Incomer Cables – Updated Safety & Insulation Standards

1. **11kV/400V Transformer Substations:** Transformer Incomer cables shall be 45m (15mx3) of 35mm^2 Cross-linked polyethylene (XLPE) Nigerian Cable[13].
   a. However, XLPE shall not be used as a down drop cable due to their limited flexibility, reduced mechanical strength under vertical stress, and higher risk of insulation degradation from bending and movement.
   b. Flexible cables (such as PVC insulated copper cables, EPR insulated cables, or HO7RN-F rubber flexible cables) with appropriate outdoor-rated insulation shall be preferred for such installations[14].
2. **33kV/400V Transformer Substations:** Transformer Incomers cable shall be 18m (6mx3) of 95mm^2 single core (copper) Nigerian Cable[15].

[13] 30m is not sufficient to allow for maintenance requirements.
[14] **PVC – Polyvinyl Chloride:** A widely used thermoplastic insulation material known for good flexibility, durability, and cost-effectiveness. **EPR – Ethylene Propylene Rubber:** A type of synthetic rubber insulation offering excellent flexibility, heat resistance, and moisture resistance. **HO7RN-F – Harmonized code cable:** A heavy-duty, flexible rubber-insulated and sheathed cable designed for industrial and outdoor use, offering high resistance to abrasion, water, oils, and UV radiation.
[15] 10m length would result in excessive sagging at an almost 30° angle.

2.1.15 Transformer to Feeder Pillar Incomer Cable: Sizing and Installation Requirements

1. **200kVA transformers:** The feeder pillar Incomer cable shall be 6m of 150mm^2 x4 Core Nigerian Cable.
2. **300kVA transformers:** The Feeder Pillar Incomer cable shall be 24m (4x6m) of 300mm^2 x 1 Core Nigerian Cable.
3. **500kVA transformers:** The Feeder Pillar Incomer cable shall be 24m (4x6m) of 500mm^2 x 1 Core Nigerian Cable

2.1.16 Substation Upriser: Voltage Control & Power Quality Standards

1. 200kVA transformers Up riser cable shall be 15m of 95mm^2 x4Core Nigerian Cable.
2. 300kVA transformers Up riser cable shall be 15m of 120mm^2 x4Core Nigerian Cable.
3. 500kVA transformers Up riser cable shall be 15m of 150mm^2 x4Core Nigerian Cable[16].
4. To avoid vandalization, uprisers shall be incorporated into PVC pipes and concreted.

2.1.17 Ganged Isolators and Anti-climb Guards: Security & Protection Measures

1. Ganged Isolator shall be either Silicon type or Porcelain depending on the requirements of the Distribution Company (DisCo).
2. Anti-climbing guards shall be fitted at a minimum height of **2.5 meters from the ground** or at suitable positions where climbing may be possible.

2.1.18 Tree Cutting & Right-of-Way Clearance

1. All trees within the line right of way (ROW) which does not exceed 3 meters in height and are within the location of the poles shall be cut down.
2. Also, all other trees on the ROW that are considered to interfere with the stringing of the line shall be cut down.
3. Tree trimming and ROW maintenance shall be the responsibility of the Distribution Licensee, as per regulatory guidelines.
4. Other trees outside the line ROW considered as a threat to the power line during operations shall be cut or trimmed.
5. For high-voltage (33kV and above), a minimum clearance of 10 meters from the conductors shall be maintained. For medium-voltage (11kV), a minimum clearance of 5 meters shall be maintained.

2.1.19 Danger Plates & Signage

1. Conspicuous "DANGER" plates shall be provided and fixed on all poles at approximately 2m above ground.
2. The danger plate shall be fixed at substations and positioned at the base of the transformer.

2.1.20 Tension Sets

1. Conforming to IEC-60120 for strain insulator fittings and IEC 61109 for composite insulators, the fittings shall consist of a cross arm strap and forged steel ball eye to attach the socket end of the strain insulator to the cross-arm strap.
2. Fittings for strain insulators with conventional dead-end clamps are to be used with tongue & clevis or ball & socket type insulators.

[16] 240mm² would be too heavy to work with, impracticable, and result in material wastage.

2.1.21 Bolts, Nuts and Threads

1. Bolts shall comply with BS 4190, grade 4.6; Nuts shall comply with BS 4190, grade 4.
2. Each bolt shall be supplied with one nut.
3. Threads shall be in accordance with BS 3643.
4. the thread shall be related to the bolt or stud lengths as follows:

Table 2.6: Thread lengths and respective bolt lengths

Length of Bolt	Length of Thread
Up to 180mm	Standard BS 4190
Over 180mm	150mm

2.1.22 Washers

1. **Washer – Round (Flat):** Round mild steel washers (flat) shall be in accordance with BS 4320.
2. The washers shall accommodate either M12, M16 or M20 bolts.
3. Square Curved and Flat washers shall be of mild steel and shall be in accordance with BS 3410.

2.1.23 Surge Arresters

1. Surge arresters shall be gapless Metal-Oxide type made of Zinc-Oxide polycrystalline element, housed in polymer insulating materials and suitable for the pole-top mounting arrangement
2. Surge arresters shall comply with the IEC 60099-4 standards.
3. The surge arresters shall protect power equipment (like transformers) from system overvoltage and lightning surges.
4. The surge arrester shall be suitable for satisfactory and continuous operation under a moderately hot and humid tropical climate, including maximum wind loading of 570N/m^2 and minimum ambient air temperatures of 50ºC (degree Celsius) and 5ºC respectively.

2.2 Integration of Distributed Energy Resources (DERs)[17]

2.2.1 Solar, Wind, Biomass & Hybrid Systems

1. **General Requirements:**
   a. All DERs shall comply with IEC 61727 (PV Grid Interface Standard) and IEEE 1547 (DER Grid Interconnection Standard).
   b. DERs shall incorporate anti-islanding protection in line with IEC 62116.
   c. System components shall meet local NEMSA and SON certification requirements.
   d. DER control systems shall comply with IEC 61850 (Communication Networks and Systems for Power Utility Automation).

2. **Solar PV Systems:**

   a. Modules shall comply with IEC 61215 (Performance Testing) and IEC 61730 (Safety Standards).
   b. Inverters shall conform to IEC 62109-1 & 2 for electrical safety.
   c. Energy storage systems shall meet IEC 62619 (Lithium Batteries Safety) and any other relevant standards specified in the Standards Codes document.
   d. Grid-connected PV systems shall adhere to IEC 62817 (Tracking PV Systems) for system performance.

3. **Wind Energy Systems:**
   a. Wind turbines shall comply with IEC 61400 (Design & Performance for Small Wind Turbines).
   b. Structural integrity shall meet IEC 61400-2 for wind turbines operating in remote locations.
   c. Turbine inverters shall be certified under IEEE 1547 for grid interconnection.
   d. Power quality assessment shall be carried out in line with IEC 61400-21 (Wind Turbine Power Quality Testing).

4. **Biomass & Hybrid Energy Systems:**
   a. Biomass power plants shall adhere to IEC 62282-3 for fuel cell safety and performance.
   b. Hybrid systems shall integrate load management as per IEC 62257-9.
   c. Waste-to-energy systems shall meet ISO 50001 (Energy Management).
   d. Emissions from biomass plants shall comply with IEC 61427 (Environmental Impact Standards).

2.2.2 General Guidelines: Interfacing DERs with Rural Grid Extension Projects

1. **Grid Interconnection & Synchronization:**
   a. DERs shall comply with IEEE 1547 for synchronization, power quality, and frequency regulation.
   b. Voltage regulation shall be within IEC 60038 (Standard Voltages) limits.

[17] Distributed Energy Resources (DERs) refer to decentralised energy systems that generate, store, or manage electricity close to where it is used. They include (but not limited to) solar panels, wind turbines, biomass systems, battery storage systems, conventional energy systems, hybrid systems, etc. DERs can operate independently in off-grid settings or be integrated into the main grid to improve energy reliability, efficiency, and resilience. They vary in scale, from small residential systems to larger commercial and industrial installations that contribute to grid stability and energy diversification.

c. DER integration with smart grids shall comply with IEC 61850 (Substation Communication Standards).

2. **Load Flow & Demand Management:**
   a. Smart grid integration with IEC 61850 (Substation Automation Protocols) shall be included for efficient load balancing.
   b. Rural grids shall integrate demand-side management (DSM) as per IEEE 2030.7.
   c. Battery Energy Storage Systems (BESS) shall be managed per IEC 62933 (Electrical Energy Storage Systems).

3. **Safety & Protection Measures:**
   a. Anti-islanding protection is required as per IEC 62116, ensuring DERs disconnect within 2 seconds of grid loss. Reconnection shall follow a 5-minute delay per IEEE 1547.
   b. Overvoltage, overcurrent, and fault tolerance shall be designed in accordance with IEEE C37.
   c. Safety compliance shall include IEC 60269 (Low-voltage Fuses) for DER protection.

2.2.3 Voltage Stability, Power Quality & Load Balancing

1. **Voltage Regulation Requirements:**
   a. Shall adhere to IEC 60038 for voltage tolerances within ±6% of nominal voltage.
   b. Power factor correction shall be included, meeting IEC 61000-3-2.
   c. Voltage flicker limits shall align with IEC 61000-3-3.

2. **Power Quality & Harmonic Distortion:**
   a. Total Harmonic Distortion (THD) shall not exceed IEEE 519 limits of 5%.
   b. DER inverters shall meet IEC 61000-3-12 for current harmonics.
   c. Three-phase DER systems shall maintain a voltage imbalance of less than 3% as per IEC 61000-3-13 and IEEE 1547.

3. **Load Balancing Requirements:**
   a. Three-phase DER systems shall maintain a load imbalance of less than 10%, as per IEC 61850
   b. Reactive power compensation shall be implemented in line with IEC 60909.

2.2.4 Reliability Metrics & Performance Testing for DERs

1. **Performance Metrics:**
   a. Reliability benchmarks shall meet IEEE 1366 (Electric Power Reliability Indices).
   b. Energy availability factor shall be at least 95% uptime annually.
   c. DERs shall be tested under IEC 60076 (Power Transformer Testing) for grid reliability.

2. **DER Fault Tolerance Testing:**
   a. DERs shall undergo IEEE C37 testing protocols for circuit breakers and relay coordination.
   b. Power system stability shall be tested under IEC 60255 (Protective Relay Standards).
   c. Microgrid stability testing shall be conducted in compliance with IEEE 2030.8.

2.3 Circuit Protection & Fault Tolerance

2.3.1 High Voltage Switchgear Compliance

1. **Minimum Safety Requirements:**

   a. Switchgear shall comply with IEC 62271 (HV Switchgear & Control gear).
   b. Protection relays shall meet IEC 60255 (Protection & Control Devices).
   c. Gas-insulated switchgear shall be tested under IEC 62271-203.

2.3.2 Relay Coordination & Fault Protection Mechanisms

1. **Relay Coordination for Rural Networks:**
   a. Relays shall be tested as per IEC 60255.
   b. Coordination study required for minimization of tripping errors.
   c. Distance protection relays shall conform to IEC 60255-121, ensuring accurate fault detection within a 5% error margin, operation within 40-100ms for high-speed protection, and proper coordination across multiple fault detection zones.

2.3.3 Circuit Breakers and Surge Protection

1. **Breaker Selection Criteria:**

   a. Breakers shall meet IEEE C37.04 (Ratings for Circuit Breakers).
   b. High-voltage breakers shall conform to IEC 62271-100.
   c. Medium-voltage circuit breakers shall comply with IEC 62271-200[18], ensuring safe operation, fault tolerance, and proper coordination with protection relays.

2. **Surge Protection Standards:**

   a. Surge arresters shall comply with IEC 60099-4 (Metal-Oxide Surge Arresters).
   b. Lightning protection to be implemented per IEC 62305.
   c. Voltage transients shall be managed in compliance with IEC 61000-4-5.

2.3.4 Grounding & Earthing Protocols

1. **General Earthing Requirements:**

   a. Compliance with IEC 60364-5-54 (Earthing & Protective Conductors).
   b. Resistance shall be <10 ohms for substation grounding.
   c. Soil resistivity testing shall be performed as per IEEE 81.

[18] IEC 62271-200 defines arc fault containment, insulation performance, and dielectric withstand strength, which are critical for maintaining system reliability in rural distribution networks.

3 INJECTION SUBSTATIONS

3.1 STANDARDS AND SPECIFICATIONS: ELECTRICAL WORKS

3.1.1 Switchgear and Fuse Gear Assemblies (IEC 62271)

1. The Scope includes low-voltage switchgear and control gear assemblies (Type-Tested Assemblies – TTA) or Partially Type-Tested Assemblies – PTTA) whose rated voltages are ≤ 1,000 VAC or 1,500 VDC.
2. The new IEC 61439 standard applies to enclosures where the rated voltage is under 1,000V AC (at frequencies not exceeding 1,000 Hz) or 1,500 V DC.
3. **Switch Gears**
   a. The design, manufacture, assemblage, installation, testing and commissioning of all 33kV and 11kV switch gears in an Injection Substation shall conform to the requirements of IEC 62271.
   b. Also, they shall be capable of continuous operation under a daily average ambient temperature range from 25°C to 50°C.
4. **Indoor Switchgears**
   a. Indoor switchgears shall be housed in well laid-out buildings.
   b. Materials, equipment and methods used in the manufacture of indoor switchgears shall conform to the requirements of the following standards:
      i. Switchgear and control gear – IEC 60694, IEC 60298, IEC 62271-200, IEC 60529.
      ii. Circuit Breaker – IEC 62271 – 100
      iii. Isolating and earthing switches – IEC 62271-102
      iv. Current Transformer – IEC 60185
      v. Voltage Transformer – IEC 60186
      vi. Relays – IEC 60215
   c. The LV and HV switchgear shall be located near the door.
   d. A clear passageway of at least 1m wide shall be allowed from each item of switchgear to the access door.

3.1.2 Voltage Transformers (VTs) and Current Transformers (CTs)

1. Voltage Transformers (VTs) shall conform to the following Standards: NIS/IEC 60186, 60694 and 60947-1.
2. The number of secondary cores (protection or metering), accuracy class and burden shall be according to the requirements of the protection system.
3. The accuracy class for metering core shall be equal to or better than the accuracy class of the meter specified in the Metering Code.
4. Current Transformers used for instrumentation and protection of power system equipment shall conform to the following Standards: NIS/IEC60186, 60694 and 60947.
5. The rated currents and ratios, the number of secondary cores (protection or metering), accuracy class, burden, secondary winding resistance, knee point voltage and excitation current shall be in accordance with the requirements of the protection system.
6. The accuracy class for the metering core shall be equal to or better than the accuracy class of the meter specified in the Metering Code.

3.1.3 Station Service Transformers – Integration & Load Handling

1. The 33 kV substation service transformers will be supplying the substation auxiliary services loads from the main substation through a 33 kV busbar (where available).
2. In substations without a 33kV busbar, other means of supplying the auxiliary station loads shall be used. This includes (but not restricted to) earthing transformers, station battery systems, or dedicated auxiliary transformers to ensure reliability.
3. Combined CTs and Voltage Transformers (VTs), in compliance with IEC 61869 (Instrument Transformers) shall be deployed where there is a constraint of space and shall conform to the applicable standards for Current and Voltage Transformers.

3.1.4 Lightning Arresters[19]

1. Every electric equipment or any support exposed to liability or injury from lightning shall be effectively protected against such liability by lightning or surge arresters.
2. These shall be fitted with pressure relief devices and diverting ports suitable for preventing shattering of porcelain housing providing a path for the flow of rated currents in the event of failure of the surge arrester.
3. A leakage current monitor with a surge counter shall be provided with each lightning arrester.
4. All such Surge Arresters to be deployed shall comply with the provisions of IEC 60099-4 (Metal-Oxide Surge Arresters for AC Systems) on Surge Arresters, and IEEE C62.11 (Guide for Metal-Oxide Surge Arresters) for power system protection standards.
5. The design and dimensioning of the surge arresters shall take cognisance of the energisation of the different lines as well as the lightning protection of the substation equipment.

3.1.5 Control Panels & Protection Panels

1. Control panels, including the frames to which they are attached, shall be made of fireproof material.
2. All types of boxes, cabinets, etc., shall generally conform to and be tested in accordance with IEC-60439, as applicable.
3. All Control cabinets, junction boxes, marshalling boxes & terminal boxes shall be dust, water & vermin proof.
4. Other safety requirements can be seen in annexe C2.
5. The fabricated protection panel shall be of adequate dimensions (height, width, and depth) with sufficient working space to accommodate all protective relays, control devices, and auxiliary protection equipment in compliance with IEC 61439 (Low Voltage Switchgear & Control gear Assemblies).
6. All panels shall be constructed using fire-resistant and corrosion-proof materials, ensuring durability and compliance with IEC 62271-200 (Metal-Enclosed Switchgear).
7. The protection panel shall be properly earthed, either by direct grounding of a reference point at lower system voltage or through an earthing bar, in accordance with IEC 60364-5-54 (Earthing & Protective Conductors) to prevent electrical hazards and ensure personnel safety.
8. Ingress Protection (IP) Rating shall be IP54 or higher to ensure dust, water, and vermin resistance per IEC 60529 (Degree of Protection by Enclosures - IP Code).

[19] Updated to ensure compliance with IEC and IEEE

3.1.6 Underground Transmission Line Cables – Thermal & Performance Standards

1. The cables shall have the electric resistance specified in IEC 60228 (Conductors for Cables & Flexible Cords).
2. The cables shall be stranded wires composed of solid wires, such as annealed copper wire, annealed aluminium wire, hard-drawn aluminium wire and semi hard-drawn aluminium wire that satisfy the mechanical characteristics specified in annexe C3.
3. **Insulators and Shields**
   a. A cable shall have an insulator that is a butyl rubber compound, an ethylene-propylene rubber compound or a polyethene compound
   b. Also, have an electric shielding layer made of metal provided on the insulated conductor, or shall be a lead-covered cable, aluminium-covered cable or a cable with some other metal cover.
4. Deviation from the above shall be subject to written approval from NERC or the appropriate state electricity regulatory authority, in accordance with the Electricity Act 2023.
5. **Joint Boxes:** Cables shall be jointed using a joint box that conforms to the following requirements:
   a. The joint box shall not increase the electric resistance of cables.
   b. The joint box shall have the dielectric strength equal to or higher than that of cables.
   c. The joint box shall have sufficient mechanical strength.
   d. The joint box shall have a corrosion-free structure.
6. **Earthing of Underground Cables and Joint Boxes:** Class D earthing work shall be provided on metallic members used for covering cables for underground transmission lines
7. Where cables enter or leave the ground, they shall be protected from a point at least 0.5m below the ground level to a height above ground as may be considered necessary.

3.1.7 Battery Banks – Safety & Efficiency Standards

1. Distribution substation batteries shall be installed in a separate room provided to house the Battery Banks and a charger.to provide DC supply and protection for the system.
2. Distribution substation batteries shall be placed on metal racks suitably constructed for the purpose and on acid and chemical proof tile.
3. Every battery shall be arranged such that a potential difference exceeding 50V does not exist between adjacent cells without adequate protections against electrical hazards. Also, each cell shall be readily accessible from the top of the battery bank and from at least one side.
4. **Safety Measures**
   a. The room where batteries are placed shall be effectively ventilated to prevent the accumulation of dangerous and flammable battery fumes.
   b. Extractor fans shall be provided at every battery room.
   c. Persons entering the room shall be provided with personal protective equipment including nose mask, safety goggles, and hand gloves.
   d. Generating Set
   There shall be a generator set of capacity capable of charging the battery bank in the event of Grid failure.

3.2 STANDARDS AND SPECIFICATIONS: CIVIL WORKS

3.2.1 Civil Works: Design, Site Preparation and Installation

1. **General Guidelines:** The design, site preparation and installation of civil works for Injection Substations shall be in accordance with the following guidelines:
   a. All materials used shall be in accordance with approved engineering designs and specifications in conformity with relevant extant Nigerian Industrial Standards and Codes.
   b. Geotechnical Investigations shall be carried out on all Injection Substation sites to assess soil load-bearing capacity, groundwater levels, and seismic considerations.
   c. The report of the soil tests shall form the basis for all related civil design works for Injection Substation construction. These soil tests shall be carried out under the supervision of a COREN certified Civil Engineer from REA.
   d. Earthworks shall include (but not limited to) the clearing of the site, the supply and compaction of fill materials, excavation and compaction of backfill materials for foundation, access road construction, drainage, trenches and final gravelling as specified in the National Building Code (NBC) in line with IEC 60364-5-52 (Cable Routing & Civil Work Guidelines).
2. **Foundations:** The design and construction of Injection Substation foundations shall be in accordance with BS 8004 specifications, based on the results of geotechnical investigations.
3. **Concrete Structures:** concrete structural works shall be in accordance with BS 8110.
4. **Structural Steel Works:** The design, fabrication and erection of structural steelworks shall be in accordance with BS 5950.
5. **Water Retaining Structures (Embankment):** The Design and construction of water retaining Structures/embankments shall be in accordance with BS 8007.
6. **Block Work/Brickwork:** The design and Construction of blockwork/brickwork shall be in accordance with the requirements of BS 5628.
7. **Sound Insulation:** All roof and wall cladding systems, including ventilators, openings, windows, doors, etc., shall be designed and constructed such that the noise level emissions at the site boundary do not exceed 60 dB in compliance with WHO Environmental Noise Guidelines.

3.2.2 Access Roads

1. Access roads to Injection Substation sites shall measure, and not be less than 7.3 m wide from any adjoining/existing public road with adequate clearance for manoeuvring of heavy-duty vehicles.
2. Within substation fencing, roads to be provided for access along with car parking lot shall have the capacity to accommodate a minimum of five vehicles with adequate clearance from installed equipment and building.
3. The layout of the roads shall be based on layout drawings for the substation.
4. Parking areas shall be provided for site personnel and visitors as per layout drawing.
5. Adequate turning space for vehicles shall be provided for vehicles, with the bend radius appropriately designed to accommodate the maneuvering of transformers and mobile cranes.
6. All access roads, up to the control room building, shall be constructed to have a minimum load-bearing capacity that will support the transportation of heavy-duty equipment up to 100 Metric Tonnes (MT).
7. All access roads shall be provided with paving stones and demarcated with side kerbs.
8. The roadside kerbs used for the construction of all access roads shall be of a minimum thickness of 80 mm with compressive strength of not less than 450 kg/cm^2.

3.2.3 Property Fencing

1. All Injection Substations shall be fenced to prevent unauthorised access.
2. The fence shall be constructed using either galvanised steel chain link or vibrated blockwork.
3. To withstand the prevailing wind speed within the environment, all perimeter fencing shall be designed to meet critical loading conditions that are peculiar to the site under consideration.
4. Where Electric Fencing is installed as part of security measures to prevent unauthorised entry and access into substation premises, it shall be mandatory that marked Warning Signs be displayed within visible range of not more than six meters apart on all sides of the perimeter fencing.
5. The installation of electric fencing shall be in accordance with guidelines on electric fencing issued by NERC Guidelines on Electric Fences (Version 1).

3.2.4 Galvanised Steel Chain Link

1. Where the perimeter fence and the entrance gates are made of galvanised steel chain-link fencing and galvanised steel pipes (as may be specified in the General Specification for materials and workmanship), they shall comply with the provisions of this regulation.
2. The height of the fence and the gates shall not be less than 2.5m vertical with a further 0.5m extended outwards from the site at 45º on which three rows of barbed wire shall be fixed.
3. The mid-sections of the fence shall be kept taut by the introduction of steel stiffeners.
4. Fence posts shall be of galvanised tubular steel of 50 mm diameter for intermediate posts and 75mm for angle and tensioned posts, 3.0 m apart on the average centre.
5. The fence posts shall have a concrete foundation projecting 100 mm above the finished laterite level, but flushing with the top level of the crushed rock.
6. The top of the concrete foundation of the steel pipes shall be cambered to prevent water stagnations that might lead to rusting.
7. The vehicular and pedestrian gates shall be plastic coated chain link with galvanised steel frames/posts.
8. The widths of the vehicular and pedestrian gates in a fully opened position shall be 5.0 m and 1.0 m respectively.

3.2.5 Vibrated Block Wall

1. Where the perimeter fence and the entrance gates are made of vibrated blocks, 228.6 mm vibrated blocks shall be used for fenced work.
2. The height of the fence and the gates shall not be less than 1.90 m vertical with a capping and fence wire finishing.
3. The mid-sections of the fence shall be maintained with concrete reinforcement 3.0 m apart on the average centres.
4. The vehicular and pedestrian gates shall be of plastic-coated, galvanised or enamelled-steel sheet with galvanised steel frames/posts.
5. The widths of the vehicular and pedestrian gates in a fully opened position shall be 5.0 m and 1.0 m wide respectively.

3.2.6 Control Room Building

1. The control room building design shall consider the following specifications:
   a. The suitability of the structure to withstand possible major hazard events as defined in the NERC Health & Safety Code.
   b. The layout and the arrangement of switchgears, tripping units, etc., to ensure effective ergonomic operation of the indoors and outdoors equipment for normal operations and emergencies, including the provision of emergency exits.

c. More than one emergency exit shall be provided for a control room exceeding 10m in length.

2. The construction of the control room building shall conform to the requirements of the National Building Code. The structural design and details of the control room building shall be able to guarantee the following stability conditions:

a. All possible combination of dead and service loads
b. Wind loads
c. Natural hazards due to seismic activities and flooding
d. Fire and thermal loading

3. The minimum floor area for the control room building shall not be less than 200m^2, which may be increased at the time of detailed engineering design to meet project requirements.

4. An open workspace of a minimum of 1.2 m shall be provided between the wall and the switchgear to allow for movement and access as well as maintenance.

5. The building design shall also meet the following requirements:

a. Provide for easy access and maintenance of the equipment with, wherever required, fire-resisting and/or retarding materials for walls, ceilings and doors.
b. Adopt the use of materials that shall prevent dust accumulation.
c. Individual structural members of the building frames shall be designed for the worst combination of forces, such as bending moments, axial force, shear force and torsion.
d. Permissible building loading stress shall be in accordance with the National Building Code.
e. The Control Room building lighting shall be designed in accordance with IEC 60364 and NIS 1209-1-2024 MEPS for lighting.
f. The Control Room building auxiliary services such as Heating, Ventilation and Air Conditioning Systems, fire prevention, detection and control systems and all other miscellaneous services shall be designed in accordance with the NBC.

3.2.7 Equipment Plinth and Oil Sump

1. The construction of the equipment plinths shall take into consideration the site geotechnical investigation report and shall be designed to meet the load-bearing capacity that adequately supports the weight of the intended equipment to be installed in the substation.

2. Also, the reinforced concrete design and construction of the equipment plinth shall accommodate the equipment manufacturer’s specifications.

3. The power transformer plinth shall be of a minimum horizontal distance of 11.2 m from the control room.

4. The oil sump provided shall be of a minimum depth of 1 m and a width of 0.6m.

3.2.8 Drainage

1. The entire substation area shall be provided with adequate drainage facilities to prevent flooding and accumulation of water.

2. Building drains shall be provided for the collection and evacuation of stormwater from the roof and the adjoining facilities.

3. The design of drain collectors shall be adequate to effectively evacuate stormwater from the substation.

4. Drainage systems shall comply with, ISO 4355 (Precipitation & Drainage) and IEC 60364-5-52 (Drainage for Underground Cabling).

3.2.9 Cable Trenches

1. Cable trenches shall be constructed for use in Injection Substations.
2. The separation between cables and their depths shall depend on the following factors: Operating Voltages; Ambient temperature; Cable design temperature; Soil Resistivity; Heat sources in the vicinity of cables; Cable type; Method of earthing, and Load cycle
3. Cable trenches shall be of a minimum depth of 1m, except under the switchgear where the trench shall be of a depth of 1.2m and a minimum width of 800mm, for cable trench and switchgear panels.
4. Manhole capable of permitting bending radius of 3m shall be provided along the trench route before cable entry into the control room.
5. Trenches shall be watertight and shall not be connected to the outside drainage system.
6. Trench covers shall be suitably constructed to support pedestrian traffic.
7. The covers shall be divided into sections of a maximum of 1m lengths, each weighing no more than 20 kg.
8. The trench cover when laid across the trench shall be flush with the surrounding floor level.

3.2.10 Gravelling and Landscaping

1. The Injection Substation active switchyard area shall be demarcated using roadside Kerbs and gravelled with 25mm aggregate chippings to a minimum depth of 150mm.
2. Landscaping shall be carried out in non-active areas of the Injection Substation. Non-active areas within the Injection Substation shall be landscaped for proper levelling; paving, sloping, consolidation and grassing.

4 SOLAR MINI-GRIDS

4.1 STANDARDS AND SPECIFICATIONS: SOLAR MINI-GRIDS

4.1.1 General Guidelines & Technical Framework

1. The service standards and technical specifications listed below are complementary to the NERC Mini-Grid Regulations and the NEMSA regulations but do not replace them.
2. Applicants applying for Mini-grid projects in REA shall comply with the technical specifications set out below, as well as the Mini-Grid Regulations and the NEMSA regulations (Section 5 and Section 10), International Standards, including IEC, IEEE, and ISO best practices
3. Also, applicants applying for REA Mini-grids projects shall meet the service standards listed in Table 4.2.
4. These service standards are differentiated based on the size of the mini-grid, based on the same categorisation found in the NERC Mini-Grid Regulations
5. Mini-grids rated above 100kW (of distributed electricity) are subject to stricter voltage, frequency, and reliability standards compared to mini-grids rated below 100kW
6. Service standards are measured at the point of customer connection.

Table 4.1: Eligibility requirements for mini-grids[20]

SIZE OF MINIGRID	NERC REQUIREMENT	REMARKS
≤100KW	REGISTRATION[21] OR PERMIT	For mini-grids under 100kW, developers may either register or apply for a permit. However, unlike the 2016 regulation, developers cannot commence operations until authorisation is received. Obtaining a permit provides added protection for a developer's assets in the event of a DisCo's emergence and subsequent acquisition.
≤1MW	PERMIT	Requires the use of the mini-grid MYTO methodology to determine customer tariffs. The permit provides transparency, protects the developer's investments and ensures cost-reflective tariffs for customers. This applies to both Isolated and Interconnected mini-grids.
>1MW	LICENSE	Various licenses include: Embedded Generation, Off-Grid Electricity Generation, and Distribution Licence. Note: The 2023 Regulations and the Electricity Act now recognise that States may allow >1MW mini-grids within their boundaries under State law, but interstate or transnational operations still require a license from NERC.

[20] Where a Mini-Grid Developer desires to operate an interconnected Mini-Grid, the regulation requires that the Mini-Grid Developer enter a tripartite contract with a community and Distribution Licensee to construct, operate and/or maintain an interconnected Mini-Grid in an underserved area. The tripartite contract only becomes binding on all parties upon the approval of NERC.

[21] However, unlike the 2016 regulation, developers cannot commence operations until authorisation is received from NERC.

Table 4.2: Service standards for mini-grids

Service Standards	<100kW (small mini-grids)	100kW-1MW (large mini-grids)
Power quality		
Voltage imbalance	≤3%	≤5%
Long duration voltage variation	≤1 per week	
Short duration voltage variation	≤60 per day	
Frequency range (Hz)	49Hz<f<51Hz	49.5Hz<f<50.5Hz
Power reliability		
Unplanned SAIFI[22]	≤2 per year	
Unplanned SAIDI[23]	≤240 hours per year	≤120 hours per year
Planned SAIFI	≤2 per year	
Planned SAIDI	≤24 hours	≤12 hours
Power availability		
The planned duration of daily service	24 hours	

4.1.2 System Design and Requirements

1. Mini-grid systems proposed by the Applicant will fall in one of the four system configurations listed in Table 4.3, based on the predicted load.
2. Some minimum technical requirements listed in the sections below differ between system types.
3. The system shall be designed so that the battery inverter continuous output is at least 50W per customer at commissioning in consistent with Tier 2 energy access under ESMAP Multi-Tier Framework (MTF).
4. The REA reserves the right (if reasonably justified by the Applicant) to approve Site-Specific Technical Applications where the battery inverter's continuous output is lower than 50W per customer
5. **Renewable Energy Fraction:** The system shall be designed to meet a minimum of 60% renewable energy fraction, as calculated by any reputable renewable energy simulation software (e.g., HOMER, RETScreen, PVSyst, etc.).
6. Table 4.4 presents the design margins that Applicants shall comply with. The REA reserves the right to approve Site-Specific Technical Applications where these design margins are not met if this is reasonably justified by the Applicant.

Table 4.3: Overview of system configurations

Type	System Description	Power Architecture	Battery Inverter Continuous Output
Type 1	Small DC-coupled systems using PV generation with a Maximum Power Point Tracking (MPPT) charge controller. A single grid-forming inverter produces single-phase AC.	DC Coupled	Single small inverter <10kW

[22] System Average Interruption Frequency Index – total number of interruptions
[23] System Average Interruption Duration Index – total duration of interruptions

Type 2-A	Multiple bi-directional single-phase inverters connected in parallel, creating a single-phase output.	AC Coupled (Modular)	10kW – 300kW (single-phase/three-phase)
Type 2-B	Multiple bi-directional three-phase inverters connected in parallel, creating a three-phase output. Solar PV is coupled to the AC bus using PV inverters and/or MPPT charge controllers.	Hybrid (AC & DC Coupled)	150kW – 1MW (three-phase)
Type 3	Large AC-coupled mini-grids using central three-phase battery inverters with high-power modules (≥100kVA per module).	Large-Scale AC Coupled	Central inverters >1MW (three-phase)

Table 4.4: Design requirements for mini-grids

System component/aspect	Formula	Nomenclature
Grid-Tie Inverter	$P_{INV} = \frac{P_{PV}}{ILR \times \eta}$	• P_{INV}, = Grid-Tie inverter capacity • P_{PV}, = PV nominal capacity connected to the inverter • ILR, = Inverter loading ratio also known as DC/AC ratio. *ILR* can be a maximum of 2. The recommended value is 1.25 • η, = Efficiency of the inverter at rated power
Battery Inverter	$P_B = DF \times P_{peak}$	• P_B, = Battery inverter capacity under continuous load at 25°C ambient temperature • P_{peak}, = Peak-load from demand assessment • DF = is a design factor, the allowable range is 1.2 – 1.6
Grid-Tie Inverter and Battery Inverter capacity ratio	$1.8P_B < P_{INV} < 2P_B$ $P_{INV} \geq P_B + P_{peak}$	• Refer to row 1 and 2 of this table.
Battery	$n = \frac{Q_U \times DOD \times \eta}{E_{night}}$	• n is the number of autonomy days for the designed battery capacity • Q_U, = Total nominal battery capacity in kWh • DOD, = maximum allowable depth of discharge • η, = round-trip efficiency for the proposed battery • For designing the mini-grid, recommended autonomy value is 1≤n≤2

Generator: (Diesel, Gas and Biomass)	$P_{gen} = DF \times P_{peak}$ $0.8P_B < P_{gen} < 1.2P_B$	• P_{gen}, = General capacity in kW • P_{peak}, = Peak-load from demand assessment • P_B, = Battery inverter capacity • DF, = Design factor for generator set is 1.2-1.4
Charge controller[24]	$I_{CC} = DF \times I_{PV}$	• I_{CC}, = the nominal current handling capacity of the charge controller • I_{PV}, = Maximum current from PV string that the charge controller will have to face • DF, = design factor should be between 1.2-1.3

4.1.3 Compliance with the Manufacturers' Requirements

1. Applicants shall meet the following requirements:
   a. All installation and system design requirements of the respective component manufacturers shall be met.
   b. For AC-coupled systems, battery inverter manufacturers may require the system designed to limit the PV output capacity compared to the battery inverter capacity to avoid overloading of the battery inverter caused by rapid irradiance fluctuations caused by the cloud moving[25] over the PV generation plant.
   c. Documentation proving compliance with manufacturers' specifications shall be provided as part of the application.

4.1.4 Compliance with Service Standards (Reliability & Availability)

1. The system shall meet the required power reliability and power availability service standards.
2. The system shall be designed to meet a minimum of 98% annual availability, as may be calculated by any reputable renewable energy simulation software.
3. The Applicant shall show how it plans to achieve that, using one of the two following options:
   a. The system design shows full redundancy, for instance by including a combustion-based generator with a prime power rating at power factor 1, large enough to cover the complete electric power demand and being capable of continuous operation with a fuel storage to cover at least **7 days of autonomous operation**
   b. A stock of critical spare parts comprising inverters, charge controllers, battery cells, fuses, breakers, etc., is available on site or within a distance from the site that enables shipment to the site within less than two calendar days.

[24] A charge controller will not be required if the system is not either DC or AC-DC coupled.

[25] This cloud movement and subsequent overloading can create spikes in PV power output before the frequency shift control can de-rate the PV power output.

4.1.5 Capacity Shortage and PV Modules

1. Any reputable renewable energy simulation software shall show a capacity shortage of less than 3% of the total annual electricity demand (kWh).
2. The Applicant shall declare and present evidence that all the solar PV modules comply with the minimum specifications in table 4.5:

Table 4.5: Standards and specifications for PV modules

Property Description	Required Standard
Type of solar cells	Polycrystalline/Monocrystalline[26]
	Solar cells embedded in EVA-layer (ethylene vinyl acetate)
Number of modules	Provide the number of rows mounted on the support structure
	An equal number of modules per row
	The requirement of voltage, power, and current per input of the charge controller or grid-tie inverter specified below for the climatic conditions in Nigeria
Standards	IEC 61215 defines the requirements for the design qualification and type approval of crystalline silicon and thin-film PV modules. EC 61730 specifies the safety requirements for PV modules
Type of Frame	Anodised aluminium frame
Nominal power per module of solar cells	>300W at Standard Test Conditions (STC).
Power tolerance of individual module	±3% from nominal power capacity
Junction box	Weatherproof, IP 65 with bypass diodes and pre-configured cables
Output cables	According to TUV or equivalent of 4.0 mm², symmetrical lengths and suitable for installation on the support structure, MC4-compatible connectors.
Product Warranty	>10 years
Performance Warranty	Minimum of 10 years for 90%
	Minimum of 80% of rated capacity after 25 years per IEC 61215.
Temperature coefficient	-0.46%/^{0}C ±0.05
The efficiency of PV modules	≥16% at Standard Test Conditions (STC)
Equipotential bonding	16mm² copper conductor to be used.
Grounding	<5Ω earth resistance of support structure

[26] Polycrystalline PV modules are recommended in temperate regions of Nigeria

4.1.6 PV Mounting

Table 4.6: Standards and specifications for PV mounting

Description	Required Standard
Slope	Between 10° to 15°
Height clearance	0.5m minimum clearance
Support structure	Open area support for all photovoltaic solar modules supplied
Depth of planting the PV structure	Not <1.5m
Protection against corrosion	Metal parts of the structure in-ground and near the ground shall be protected against corrosion for 20 years.
Surface	Photovoltaic solar modules shall be fixed on an even surface, with no more than 20mm difference from the ideal plane
Gravelling	150mm thick
Material for bolts and nuts	For structures in aluminium: all bolts and nuts made of stainless steel
	For steel structures: all bolts and nuts made of hot-dip galvanised steel
Static calculation	In accordance with ground conditions in considering wind speed and other risks

4.1.7 Batteries/Energy Storage Devices

1. All stationary lithium-ion battery systems proposed for Type 1 mini-grids shall comply with applicable standards and REA performance requirements. Site-specific configurations may be subject to additional review by REA, where necessary, to ensure safety, durability, and interoperability.

Table 4.7: Standards and specifications for batteries/energy storage devices

Property Description	Required Standard
Lithium-ion batteries	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for large format secondary lithium cells and batteries for use in industrial applications (IEC 62619, UN 38.3)
Battery charge controllers for photovoltaic systems	Performance and functioning (IEC 62509)
Safety requirements for secondary batteries and battery installations	Part 1: General safety information and Part 2: stationary batteries (IEC 62485-1 and 62485-2).
Battery Rack	Battery support structure/cabinet made of steel and insulated to ground
	Floor bearing capacity shall allow carrying the weight of the battery
Battery cabling	Battery cables to be made of copper ($16mm^2$ and $25mm^2$), preconfigured with terminals according to the requirement of the battery quoted
	Cable length and cross-section should limit DC voltage drop to less than 1%
	Appropriate cable termination with lugs.

Reference battery life cycle	For lithium-ion or other technologies: ≥5,000 cycles at 80% depth of discharge and end of life 80% of nominal capacity
Paralleling of cells to get the requested capacity	For lithium batteries and others: paralleling of cells only allowed if explicitly specified by the manufacturer and if an adequate battery management system is installed
Operating temperature range in the battery room	5°C to 35°C, air conditioning is required for systems with more than 30 kW rated battery inverter power
Battery management	The algorithm calculating the switch-off point needs to consider the measured battery temperature to prevent deep-discharge and overcharging (low voltage disconnect)

Table 4.8: Minimum Technical Requirements for batteries/energy storage devices based on mini-grid system configurations

Type of requirement	Type 1	Type 2-A	Type 2-B	Type 3
The nominal voltage of battery strings	40-100 VDC			300-1,200 VDC

4.1.8 Electronics and Balance of the System

1. Electronics and balance of the system shall comply with the following IEC norms and standards: Safety of power converters for use in photovoltaic power systems (IEC 62109).
2. The electronics and balance of the system shall comply with the following specifications according to the type of the system in table 4.9.
3. Table 4.9 shows the requirements for the electronics and balance of the following components: Solar Inverter/Grid-Tie Inverter; Battery Inverters; DC& AC Combiner Boxes for PV Strings, Power Station Monitoring Systems.

Table 4.9: Technical requirements for the electronics and balance of the system (solar charge controller)

Type of Requirement	Type 1	Type 2-A	Type 2-B	Type 3
Solar charge controller (if part of the system)				
Minimum rated power per charge controller	> 4.5kW			>100kW
Maximum Power Point Tracking (MPPT) type	Yes			Yes
PV array operating voltage range	100-600VDC			600-1200VDC
Maximum efficiency	>95%			>95%
DC disconnect device	Yes			Yes
DC surge arrester	Type I + II for each DC string			Type I + II for each DC string; and PV modules; and

		PV inverters shall each have surge arrestors installed if more than 20m cable length in between PV modules and the inverter
The minimum degree of protection	IP20 or better if not installed outside or	
	IP54 or better for outside installation	
Worldwide warranty and service of the manufacturer	Shall be available	Yes
Warranty	Minimum of 5 years	Minimum of 5 years

Table 4.10: Technical requirements for the electronics and balance of the several components

Type of requirement	Type 1	Type 2-A	Type 2-B	Type 3
Solar Inverter/Grid-Tie Inverter				
Total solar inverter capacity	Not Applicable (N/A)	≥5kW	≥10kW	≥100kW
Type of inverter	N/A	Transformer-less / Transformer[27]		
Nominal AC line to neutral voltage range for inverters	N/A	180–280 VAC		
AC power frequency range for inverters	N/A	50Hz ± 5Hz		
Maximum efficiency	N/A	>96%		
DC disconnect device (integrated or separate)	N/A	Yes		

[27] Transformer-less or Transformer can be used where necessary and applicable

PV inverters shall be able to limit their output power based on the state of charge of batteries to prevent overcharging (through the battery inverters); and	N/A	Yes		
Charge controllers connected to the same battery string have to coordinate their charging algorithms				
DC surge arrester	• Type I + II for each DC string; and PV modules; and • PV inverter shall each have surge arrestors installed if more than 20m cable length in between PV modules and the inverter			
The minimum degree of protection	IP65			IP20 if installed inside a building or container, if outside IP65
Worldwide warranty and service of the manufacturer	Yes			
Warranty period	Minimum of 5 years			
Type of requirement	**Type 1**	**Type 2-A**	**Type 2-B**	**Type 3**
Battery Inverters				
Inverter system minimum rated power	≥6 kVA continuous N/A output at 25°C (nominal power)			≥100 kVA continuous output at 25°C (nominal power)
Nominal AC voltage	230 V		230/400 V	230/400 V

Nominal frequency	50Hz		
Continuous AC output at 25°C / Continuous AC output at 45°C	100% of nominal value / 80% of nominal value		
AC output power for 30 min at	nominal power + 30% / nominal		
25°C/ AC output power for 3 seconds at 25°C	value + 80%		
Efficiency	> 90% at 10 to 120% continuous output	> 90% at 10 to 90% continuous output and >95% peak efficiency	
Device protection	Protection against: short-circuit, overload, over temperature		
Standards and Specifications of Power Conditioning Systems (PCS)	a. 50kW PCS, 100kW PCS, 150kW PCS, 200kW PCS and above: Standards shall comply with IEC 62477-1 for power electronics safety. b. Efficiency Requirements: Minimum 96% efficiency at full load. c. Grid Integration: Compatibility with IEC 61727 for PV grid-connected systems		
Ambient temperature:	0°C to 50°C		
Display	Yes, or other ways of displaying inverter parameters		
Multi-function relays	Not required	Required	
Warranty	Minimum of 5 years		
DC Combiner Box for PV Strings			
Box cabinet material	Powder-coated steel		
DC fuse or DC-rated breaker	Required if string configuration of more than 2 strings in parallel		
Internal powerhouse cables pre-configured for plug and play installation and testing	Yes		
AC Combiner Box			
Box cabinet material	Powder-coated steel		
Overvoltage arrestors	Integrated combined Type I and II		
Circuit breakers	Sized according to battery inverter, self-consumption of the power plant and the peak current		

Internal powerhouse cables and cables to all components inside of the power station pre-configured for plug and play installation, and tested	Yes	
Power Station Monitoring Systems		
Data storage	N/A	The monitoring system shall have a local data storage option (if possible, with remote data retrieval via GSM network)
Minimum recorded data Storage on SD cards or internal storage.	N/A	Time series of state of charge of each battery, and
		Power in and power out of each battery, and
		Solar power produced per inverter/charger and total generation
Minimum data resolution	N/A	Every 15 minutes

4.1.9 Generators: Diesel, Gas and Biomass

1. The Applicant shall declare and present evidence that all the diesel generators comply with the following specifications: Rotating electrical machines – Part 1- Rating and performance (IEC 60034-1)
2. The standards for diesel generators apply only to the relevant system type as indicated in Table 4.10 for diesel generators.
3. The diesel generators may be installed inside the powerhouse, or under a suitable massive shelter, or outside with a canopy.
4. Each Generator shall be supplied complete with all installation drawings and documentation, warranty, operation and maintenance manuals.
5. The diesel generators shall be prime rated with an electrical output from each diesel generator as given below:
   a. 5kVA (single phase)
   b. 10kVA (Single phase)
   c. 16kVA (single-phase and three-phase options)
   d. 25kVA, 40kVA, 60Kva, 80kVA, 100kVA, 150kVA, 200kVA, 500KVA, 1MVA.
6. The diesel generator set shall achieve the rated values and performance under the following specified conditions and shall deliver power within the following requirements:
   a. Nominal Voltage: 415/240 V at alternator terminals.
   b. Nominal Frequency: 50 Hz.
   c. Power Factor: Rated 0.8 lagging.
   d. Overload greater than 1.5 p.u. for 10 seconds, with less than ≤20% voltage dip.

Table 4.11: Minimum Technical Requirements for batteries/energy storage devices based on mini-grid system configurations

Type of Requirement	Type 1	Type 2-A	Type 2-B	Type 3
Nominal capacity	No diesel generator	kVA prime power rating		
Nominal AC voltage range	N/A	220V- 240 V	220V-240V and 380V-415V	
Nominal frequency	N/A	50Hz		
Cable to connect the diesel generator to the AC combiner box	N/A	Armoured AC cable, unless the cable is installed inside a building		
Cable length and cross-section	N/A	Shall limit AC voltage drop to less than 1%		
Bypass switch (to switch between diesel generator only and battery inverter to supply power to the network)	N/A	Yes		
The generator should include a canopy	N/A	Yes		
Day tank fuel capacity	N/A	80 litres or above	200 litres or above	200 litres or above

4.1.10 Accessories and Spare Parts

1. The Applicant shall declare and present evidence that all the accessories and spare parts comply with the following specifications:
   a. All tools for installation and maintenance of the components specified in a toolbox, including 2 pieces of 1,000 V isolated screwdrivers and spanners for the terminals of the distribution, power lines
   b. For the building installations, 2 pieces of large side cutters with 1,000 V isolated handles, 2 pieces of electrician's knife, 2 sets of basic spanners, hammer, small handsaw, set of terminal strips, electrical tape, cable ties, 10 pcs of MC4 connectors, spare DC fuses, two hard hats, and electrical gloves.
   c. Cleaning equipment, including 2 quality soft brooms for cleaning of solar modules, 2 squeegees with extra-long handle, 2 buckets for wet cleaning of the PV modules, soft cloth for wiping of inverters and other cloth for wiping of batteries, one aluminium ladder with 2m length.
   d. One complete first aid box, including bandages, antiseptic, sterile pads, burn treatment and an adhesive bandage.

4.1.11 Metering and Distribution

The standards for metering and distribution apply only to the relevant system type as indicated in the table below.

Table 4.12: Technical requirements for metering and distribution based on system type/configuration

Type of requirement	Type 1	Type 2-A	Type 2-B	Type 3
Energy meters	Prepaid meters and in accordance with the Nigeria metering code (version 2)			
Distribution system	230 V (±6%), single-phase as per the distribution code of Nigeria		230/400 V (±6%), three phases as per the distribution code of Nigeria	
Voltage Drop (VD)	±5% drop from nominal voltage level at the end of the feeders			

Applicable distribution code	The company installing the distribution code shall follow the guidelines of the Distribution Code and Grid Code of NERC, Nigeria
Distribution line design, planning and installation guideline	The distribution network can either be overhead or underground and according to "Nigerian Electricity Supply and Installation Standards Regulations 2015"

4.1.12 Installation

1. The minimum requirements for electric installation inside customer premises are as follows:

   a. Protection against overcurrent (IEC 60364-4-43) shall be installed with a miniature circuit breaker (MCB). Rating of the breakers shall ensure instantaneous release considering the loop impedance of the network and the rated and short-term overcurrent of the appliances.
   b. Earthing Requirement: a protective conductor (PE) is required for all British standard sockets, other 3 and 5 pole sockets and directly connected appliances of protection class 1, in accordance with IEC 61140.
   c. Residual Current Device (RCD) protection is required for customers with loads exceeding 10kW. It is accepted if all customers have it installed at the service drop.

4.2 INTERCONNECTED MINI-GRIDS: SYNCHRONISATION, FAULT PROTECTION & LOAD MANAGEMENT

1. Interconnected mini-grids play a significant role in expanding rural electrification by allowing for the integration of multiple energy sources, ensuring reliability, scalability, and optimized energy management.
2. However, effective synchronization, fault protection, and load management strategies are essential to ensure seamless operation and grid stability.

4.2.1 General Requirements: Voltage and Frequency Synchronization

1. Synchronization of voltage and frequency is a key requirement for interconnected mini-grids to ensure a stable power supply and seamless integration with the main grid or other mini-grids.
2. The IEC 62116 standard provides a framework for anti-islanding protection and synchronization requirements for grid-tied distributed energy resources.
3. **Voltage Regulation:** Mini-grid inverters shall operate within acceptable voltage ranges to prevent instability when connected to a central grid. Adherence to IEC 61727 ensures that photovoltaic (PV) systems maintain voltage stability.
4. **Frequency Control:** Mini-grids shall maintain a frequency range within 49.5Hz - 50.5Hz for compatibility with the main grid. Dynamic frequency regulation mechanisms, such as droop control, shall be implemented to manage fluctuations.
5. **Synchronization Protocols:**

   a. Grid-forming inverters shall manage synchronization when the mini-grid operates in isolation.
   b. Grid-following inverters shall be used when interconnecting with a central power grid.
   c. Automatic synchronization relays shall be installed to prevent voltage or frequency mismatches before reconnection.

6. **Phase Matching:** Systems shall ensure that phase angles between interconnected mini-grids and the grid network align to prevent circulating currents.
7. **Testing and Commissioning:** Before synchronization, mini-grids shall undergo dynamic testing using a phasor measurement unit (PMU) to verify that voltage and frequency remain within the set limits.

4.2.2 Anti-Islanding Protection & Fault-Tolerant Operations

1. Anti-islanding protection is essential for preventing safety hazards and ensuring that distributed energy resources (DERs) disconnect from the main grid when necessary.
2. IEC 62116 establishes test procedures to evaluate the anti-islanding performance of PV systems.
3. **Anti-Islanding Protection Mechanisms:**

   a. Passive Methods:
      i. Voltage and frequency relays detect deviations from the normal operating range.
      ii. Harmonic distortion monitoring ensures that unintentional islanding does not cause network instability.

   b. Active Methods:
      i. Inverter-based anti-islanding techniques, such as impedance measurement and reactive power shifting, help detect grid disconnection more effectively.
      ii. Phase-jump detection ensures that microgrids do not continue supplying power to disconnected sections.

   c. Communication-Based Methods:
      i. Supervisory Control and Data Acquisition (SCADA) systems detect grid faults and provide rapid disconnection capabilities.
      ii. Smart meters with real-time power flow monitoring help ensure compliance with interconnection standards.

4. **Fault-Tolerant Mini-Grid Operations:**

   a. Advanced Protection Mechanisms: Adaptive relay coordination and circuit breakers shall be designed to detect and isolate faults dynamically.
   b. Load Shedding Strategies: Automatic load management shall prioritize critical infrastructure (e.g., hospitals, water pumps) in case of power shortages.
   c. Battery Energy Storage Systems (BESS) Integration: BESS shall be designed to provide backup power and frequency stabilization in case of transient disturbances.

4.2.3 Grid-Connected Photovoltaic (PV) Systems: Technical Requirements for LV and MV Interconnection

1. The technical requirements shall apply to all mini-grids, embedded generation systems, and distributed energy resources that connect at 230V, 400V, 11kV, or 33kV levels.
2. PV systems may be connected to the LV distribution network through either 230V single-phase or 400V three-phase configurations.
3. Similarly, MV interconnections may occur at 11kV or 33kV levels, depending on the Disco's distribution network topology and availability.
4. At the point of common coupling (PCC), the PV system shall operate within the normal voltage range specified by the Distribution Code for both LV and MV levels. The system must maintain acceptable limits of voltage fluctuation and shall be designed to mitigate both short-term and long-term flicker in compliance with IEC 61000-3-3.

5. The total harmonic current distortion at the inverter output, particularly at the cable connected to the PCC, shall remain within acceptable thresholds for both even and odd harmonics, as defined in IEC 61000-3-2 and related standards.
6. The power factor for PV systems connected at LV or MV shall comply with the minimum threshold stipulated by the Nigerian Distribution Code, ensuring minimal reactive power burden on the network.
7. DC injection into the AC network shall be actively limited by the inverter or control system in accordance with IEC 62116, to prevent saturation or operational disturbances in upstream transformers and metering devices.
8. Voltage unbalance across phases must not exceed 2% under steady-state conditions and shall be addressed through appropriate inverter configuration or phase balancing techniques.
9. Interconnection methods, whether for LV or MV systems, shall be clearly specified and agreed with the Distribution Licensee. These shall include both direct and indirect feed options[28].
10. Short-circuit current contributions from PV systems must be assessed and documented, ensuring compatibility with the protection ratings and fault withstand capacity of equipment on the Disco's network.
11. For planning and operational purposes, recommended PV penetration limits shall be defined for LV and MV feeders to prevent reverse power flow, protection miscoordination, and system instability.
12. Standard connection schemes for PV systems shall be categorized as follows:
    a. Type 1 - LV single-phase (230V)
    b. Type 2 - LV three-phase (400V)
    c. Type 3 - MV 11kV (protected earth configuration)
    d. Type 4 - MV 11kV (direct connection)
    e. Type 5 - MV 33kV (direct connection)
13. The chosen feeding method shall either be through a direct feed at the Distribution Licensee's side or through an indirect feed at the customer's side, where technically and commercially feasible.
14. Renewable energy (RE) connections shall adhere to all technical interconnection requirements and should be coordinated with the relevant DisCo to ensure network compatibility.
15. Metering for MV-connected PV systems shall comply with NEMSA and NERC-approved standards, with appropriate metering class, CT/VT accuracy, and communication capability for remote monitoring and settlement purposes.

[28] Direct feed refers to connection at the utility side, while indirect feed refers to connections on the customer side (only applicable for LV systems).

4.3 SMART GRID & ENERGY MANAGEMENT SYSTEMS

1. Smart grids enhance the reliability and efficiency of interconnected mini-grids by enabling real-time monitoring, demand response, and intelligent load balancing.
2. They also leverage SCADA systems and demand-side management (DSM) strategies to optimise power distribution and consumption.

4.3.1 General Requirements: SCADA Systems for Mini-Grids

1. SCADA (Supervisory Control and Data Acquisition) systems facilitate the remote monitoring and control of mini-grids, improving operational efficiency and fault detection.
2. **Key Features of SCADA Systems in Mini-Grids:**
   a. Real-Time Data Acquisition: Sensors and smart meters collect data on voltage, frequency, load demand, and system performance.
   b. Fault Detection and Rapid Response:
      a. Automated alerts notify operators of system failures or outages.
      b. Remote disconnect and reconnection capabilities improve network resilience.
   c. Grid Interoperability: SCADA systems shall comply with IEC 61850, which standardizes communication protocols for seamless integration with utility networks.
   d. Cybersecurity Measures: SCADA systems shall implement encrypted communication channels, access control, and tamper-detection mechanisms to prevent cyber threats.
   e. Cloud-Based Data Analytics: Mini-grid operators shall use cloud-based SCADA platforms for predictive maintenance and performance optimization.

4.3.2 Demand-Side Management (DSM) Strategies

1. DSM strategies are essential for balancing supply and demand in interconnected mini-grids, reducing power shortages, and improving grid stability.
2. **Key DSM Techniques:**
   a. Time-of-Use (ToU) Tariffs: Encourage users to shift energy consumption to off-peak hours by adjusting pricing based on demand.
   b. Load Forecasting and Demand Response: AI-based load prediction models shall be used to optimize power allocation based on historical consumption patterns.
3. **Smart Meters & Load Control:**
   a. Smart meters provide real-time power usage data, enabling consumers to adjust their consumption behaviour.
4. **Integration of Energy Storage:** Deploy Battery Energy Storage Systems (BESS) to store excess energy during off-peak hours and discharge during peak periods.
5. **Incentivizing Energy Efficiency:** Implement energy-efficient lighting, cooling, and appliances to lower peak loads.

5 ENERGY STORAGE SYSTEMS

5.1 BATTERY STANDARDS & SAFETY REQUIREMENTS

1. All energy storage systems deployed shall comply with IEC 62933-5-2, which establishes performance, safety, and operational standards for battery energy storage in power applications.
2. **General Safety Requirements:**

a. Battery Technology: Approved technology shall be limited to Lithium-ion (Li-ion) batteries that meet performance and durability criteria[29].

b. Thermal Runaway Protection:
   i. Batteries shall have an integrated Battery Management System (BMS) with temperature monitoring, overvoltage protection, and automatic shut-off.
   ii. Compliance with IEC 62619 (for industrial lithium-ion batteries) and IEC 62133-2 (for portable lithium batteries).

c. Fire Resistance & Explosion Prevention:
   i. Compliance with IEC 60730 for temperature control and NFPA 855 for fire safety of battery storage.
   ii. Battery enclosures shall meet IP65 or higher (for outdoor applications).

d. Electrical Performance & Protection:
   i. *Depth of Discharge (DoD):* Battery systems shall allow a minimum of 80% DoD while maintaining ≥ 4000 cycles at rated capacity.
   ii. *Round-Trip Efficiency:* The battery energy storage system shall achieve a minimum efficiency of 90% under IEC 62933 test conditions.
   iii. *State of Charge (SoC) Monitoring:* Batteries shall have real-time SoC monitoring with remote diagnostics.
   iv. *Short Circuit & Overcurrent Protection:* Battery systems shall comply with IEC 60269 (Fuses for Low-Voltage Circuits).

e. Environmental & Structural Compliance:
   i. Battery enclosures shall comply with IEC 62208 (General requirements for enclosures).
   ii. Seismic resistance per IEC 60068-3-3 for earthquake-prone regions.
   iii. Salt-mist corrosion testing per IEC 61701 for installations in coastal environments.

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[29] Lithium-ion batteries (such as LFP – Lithium Iron Phosphate) now offer the best balance of energy density, safety, cycle life (≥6,000 cycles), and cost-performance ratio. They are supported by global warranties, Tier 1 manufacturers, and compatibility with digital asset monitoring and remote maintenance platforms. These are key to REA's performance-based contracting approach. Other battery chemistries such as Lead-Acid, Flow Batteries, and Solid-State Batteries are not approved for REA projects at this time, based on the following factors:
Environmental Impact of Lead-Acid Batteries: Lead-acid batteries pose significant environmental and health risks due to lead contamination and improper recycling practices. In Sub-Saharan Africa, only ~5% of used lead-acid batteries are recycled in environmentally sound facilities, with most ending up in informal recycling that pollutes soil, air, and water. This contradicts Nigeria's Battery Control Regulations (2024) and NESREA guidelines.
Technological Limitations of Flow Batteries: While promising in stationary large-scale grid applications, flow batteries (e.g., vanadium redox) are technologically immature for rural mini-grids and require large tanks and complex management systems, making them unsuitable for decentralised or containerised deployment.
Unproven Nature of Solid-State Batteries: Solid-state batteries remain largely in R&D and early-stage commercialisation. They currently lack proven large-scale deployment data and reliable supply chains, making them inappropriate for performance-guaranteed electrification projects.

iv. Battery storage rooms shall comply with ventilation and gas detection standards as per IEC 62485-2 for large stationary battery installations.

5.2 LIFECYCLE MANAGEMENT, RECYCLING & DISPOSAL STANDARDS

1. To ensure sustainable energy storage adoption, all battery systems shall comply with circular economy principles and environmentally responsible disposal methods.
2. **Lifecycle Performance & Monitoring:**

a. End-of-Life (EoL) Assessment:
   i. A minimum of 80% capacity retention after 10 years of operation under standard cycling conditions.
   ii. Batteries shall feature predictive maintenance algorithms to estimate lifespan degradation.

b. Second-Life Battery Applications:
   i. Used lithium-ion batteries shall be evaluated for repurposing in secondary applications such as backup power or stationary storage.
   ii. Compliance with IEC 62933-4-1 (Re-use of Second-Life Batteries).

3. **Recycling & Safe Disposal of Batteries:**

a. Hazardous Material Management:
   i. Disposal and recycling shall comply with Basel Convention regulations for transboundary movement of hazardous waste, as well as national environmental and battery lifecycle policies.
   ii. Battery recycling shall also meet ISO 14001 environmental standards.

b. Battery Collection & Take-Back Schemes:
   i. Manufacturers shall implement Extended Producer Responsibility (EPR) programmes for battery collection and disposal.
   ii. Compliance with EU Battery Directive (2013/56/EU) for lithium-ion recycling efficiency of ≥50%.

c. Material Recovery & Reuse:
   i. Critical battery materials (Lithium, Cobalt, Nickel) shall be recovered with a minimum efficiency of ≥70% through certified recycling facilities.
   ii. Adherence to IEC 62576 (Reuse of Lithium-Ion Batteries in Renewable Energy Systems).

4. **Environmental & Social Responsibility:**

a. GHG Emission Reduction Targets:
   i. Battery storage systems shall meet lifecycle carbon footprint limits as per ISO 14064 (GHG Emissions Accounting).

b. Worker Safety & Compliance:
   i. Recycling facilities shall comply with ISO 45001 (Occupational Health & Safety Management System).

c. Safe Handling & Transportation:
   i. Compliance with UN38.3 (Lithium Battery Transport Safety) for international shipping and handling.
   ii. Storage and handling regulations as per IEC 60086-4 for primary lithium batteries.

5. **Implementation & Compliance Monitoring:**

a. Mandatory certification of all energy storage products under SON-MANCAP and NEMSA regulations.
b. Periodic inspections every 3 years to ensure compliance with battery safety, performance, and disposal standards.
c. Penalties for non-compliance with hazardous waste disposal laws according to Nigeria's Environmental Impact Assessment (EIA) Act.

6 SOLAR HOME SYSTEMS

6.1 GENERAL REQUIREMENTS FOR SOLAR HOME SYSTEMS

1. Solar Home Systems (SHS) provide decentralised renewable energy solutions for individual households, particularly in rural and off-grid areas.
2. **Standards for System Components:** To ensure the quality, durability, reliability, performance, and user safety of SHS components, all SHS shall comply with the following standards:

a. IEC 62257-9-5 – Guidelines for selection, design, and testing of standalone lighting kits, including PV modules, batteries, charge controllers, and lamps.
b. IEC 62257-9-8 – Quality assurance guidelines for off-grid renewable energy products, ensuring reliability and performance.
c. IEC 62109 – Safety standard for power converters (inverters and charge controllers) used in SHS to prevent electric shocks, overcurrent, and overheating.
d. IEC 61730 & IEC 61215 – Performance and safety standards for PV modules, ensuring module reliability under real-world conditions.
e. IEC 62619, UN38.3, IEC 62133-2, IEC 62933-5-2 – Safety, transport, and performance guidelines for lithium-ion batteries and energy storage systems.
f. IEC 62257 – Standards for rural electrification deployment, including Battery Management Systems (BMS) for optimized performance.

6.2 SYSTEM DESIGN AND PERFORMANCE CRITERIA

To ensure sustainable energy delivery, SHS shall meet the following key technical criteria:

1. **Power Supply & Load Management:**

a. SHS shall supply reliable and continuous power for lighting, phone charging, and small appliances such as fans, radios, and TVs.
b. Power output shall be designed for at least 24-hour operation under normal conditions.
c. The system shall provide a minimum of 60% renewable energy fraction, calculated using reputable renewable energy simulation software.

2. **Battery Storage & Management:**

a. <u>Battery Storage Standards:</u>
   i. All SHS batteries shall comply with IEC 62619, UN38.3, IEC 62133-2, IEC 62933-5-2, ensuring safe lithium-ion battery use.
   ii. Battery cycle life shall be ≥ 4000 cycles at 80% depth of discharge.
   iii. Storage efficiency shall be ≥ 90% round-trip efficiency.
b. <u>Battery Management System (BMS):</u>
   i. Real-time monitoring and control of charge/discharge cycles.
   ii. Temperature monitoring and overload protection.
   iii. Smart BMS with remote monitoring capabilities for SHS efficiency optimization.

3. Energy Conversion & Inverters

a. DC Power Systems:
   i. DC-coupled SHS shall follow IEC 62257-9-5, IEC 62257-9-8.
   ii. PV module and charge controllers shall meet IEC 62109.

b. AC Power Systems:
   i. AC-coupled systems shall comply with IEC 62109 for inverters & charge controllers.
   ii. Smart meters shall support remote monitoring and automated billing.

4. Smart Metering & Remote Monitoring

a. Smart Meters:
   i. Shall comply with IEC 62053 series for energy measurement.
   ii. Shall support real-time monitoring & data logging.

b. Remote Monitoring & IoT Integration:
   i. Smart SHS systems shall support IoT-enabled remote tracking.
   ii. Automated billing & fault detection through cloud-based analytics.

6.3 PRODUCT TIERS & PERFORMANCE REQUIREMENTS

The table below defines the product tiers for SHS based on PV capacity, daily energy output, battery storage, and minimum service level.

Table 5.1: Product tiers and performance requirements[30] for solar home systems

Product Tiers	Units	Tier 2	Tier 3	Tier 4	Tier 5
PV Type	Polycrystalline/Monocrystalline with Aluminium frame encapsulated in EVA Having				
Nominal Capacity	W_P	At least 50	At least 200	At least 800	At least 2000
Daily Capacity	Wh	200	1000	3400	8200
Nominal Voltage	V	12	12	12/24	24
Minimum service		Electrical Lighting, air circulation, DC LED TV, phone charging, DC fan,	LED lamp, phone charging, DC fan, DC LED TV (20W), Fridge (≤30W)	LED lamp, phone charging, fan, LED TV (20W), Fridge (≤30W)	LED TV, Radio, LED lamp, phone charging, fan, laptop, Fridge (≤30W)
Availability (day)	Hrs	4	8	16	23
Availability (evening)	Hrs	2	3	4	4
Warranty	Yrs	2	2	2	2
DC/DC		YES	YES	NO	NO
DC/AC		NO	YES	YES	YES

6.4 LIFECYCLE MANAGEMENT & END-OF-LIFE PROTOCOLS

SHS components shall comply with international best practices for recycling and disposal:

1. **Battery Disposal & Recycling:**
   a. SHS batteries shall follow IEC 62933-5-2 for energy storage lifecycle management.
   b. Lithium-ion batteries shall be disposed of per UN38.3 transport safety regulations.
2. **PV Module Recycling:**
   a. Solar panels shall comply with IEC 61730 and IEC 61215 for durability & efficiency.
   b. Decommissioned panels shall be collected and recycled in compliance with ISO 14001 environmental guidelines.

[30] Due to capacity limitations, Tier 1 products and services do not adequately support productive use activities. Therefore, Tier 2 and above products/services are recommended for SHS standards and specifications. However, a derogation or exemption may apply to existing and ongoing REA contracts or grant agreements requiring the supply of Tier 1 products/services. Moving forward, all future contracts shall align with the agency's agreed, approved, and updated standards for the use of Tier 2 and above products/services.

3. **Inverter & BMS Maintenance:**
   a. SHS inverters & charge controllers shall comply with IEC 62109 for long-term safety.
   b. Systems shall include a maintenance schedule with predictive analytics for failure prevention.

7 SOLAR STREET LIGHTS

7.1 STANDARDS AND SPECIFICATIONS: SOLAR STREET LIGHTS

Table 6.1: Standards and specifications for solar street lights

S/N	PROPERTY DESCRIPTION	RANGE
1	LED POWER	60W-120W
2	MINIMUM LUMEN EFFICACY	105 lm/W
3	SYSTEM LUMENS (LM)	6,000-16,000LM
4	COLOUR TEMPERATURE	3000K-7000K
5	BATTERY SPEC	Lithium Iron Phosphate Battery ($LiFePO_4$)12.8Vdc TO 25.6Vdc
		9AH TO 100AH
6	SOLAR MODULE	MONOCRYSTALLINE
		18Vdc TO 36Vdc
		50Wp TO 150Wp
7	CHARGING TIME	4H TO 10H
8	OPERATION RAINY DAYS (AFTER FULLY CHARGED)	3 TO 7 RAINY DAYS
9	INSTALLATION HEIGHT	6 TO 12m DEPENDING ON LED POWER
10	CONTROL TYPE	REMOTE CONTROL (OPTIONAL)
11	OPERATING TEMPERATURE	$+10^0$C TO $+50^0$C
12	MINIMUM IP RATING	IP65
13	BODY MATERIAL	ALUMINIUM ALLOY
14	FINISH	POWDER COATING
15	POLE FITTER DIAMETER (ϕ)	76mm TO 100mm
16	MOUNTING TYPE	BRACKET / ADJUSTABLE BRACKET
17	FOUNDATION DEPTH	Not <1.28m

Table 6.2: Solar Street Light Installation: Height and Spans Between Poles

S/N	LED Power (Watts)	Height of Pole (m)	Distance Between Poles (m)
1	40	7 to 8	19 to 23
2	50	7 to 9	23 to 27
3	60	7 to 9	27 to 31
4	80	8 to 10	31 to 35
5	100	8 to 10	30 to 35
6	120	9 to 12	30 to 35
7	150	10 to 12	35 to 45

7.2 DURABILITY, ENVIRONMENTAL TESTING & PERFORMANCE BENCHMARKS

To ensure long-term performance, solar street lighting systems shall comply with the following durability and performance standards:

1. **Ingress Protection (IP) & Impact Resistance (IK) Standards:**
   a. Minimum IP65 (IEC 60529) for protection against dust and heavy rainfall.
   b. Impact Resistance: IK08 – IK10 for protection against physical damage and vandalism.

2. **Wind Load & Structural Stability:**
   a. Poles and fixtures shall withstand wind speeds of ≥ 160 km/h, tested according to IEC 61400-2 (Small Wind Turbines).
   b. The foundation depth shall be ≥1.28m with reinforced concrete to improve pole stability.

3. **LED & Photometric Standards:**
   a. Luminous efficacy shall be ≥105 lm/W based on NIS 1209-2-2024 MEPS for lighting
   b. Colour Rendering Index (CRI) ≥70 to ensure good visibility and colour recognition.
   c. Minimum lifetime: 50,000 hours (L70 at 25°C ambient temperature).

4. **Battery Life & Performance Requirements:**
   a. Lithium-ion (LiFePO4) batteries shall meet IEC 62619, UN38.3, and IEC 62133-2 for safety and transport.
   b. Battery cycle life: ≥4000 cycles at 80% depth of discharge.
   c. Temperature range: 10°C to 50°C, with BMS (Battery Management System) for overcharge protection.

7.3 REMOTE MONITORING FOR OPERATIONAL EFFICIENCY

Solar street lights may[31] integrate remote monitoring capabilities for real-time tracking of system performance, failures, and maintenance needs.

1. **Remote Monitoring Features:**
   a. Cloud-Based Monitoring:
      i. GSM / LoRa / Zigbee / Wi-Fi communication for remote control.
      ii. GPS tracking for pole location and theft prevention.
      iii. Data logging of battery charge levels, LED health, and solar efficiency.

2. **Automated Maintenance Alerts:**
   a. Predictive maintenance using AI-based analytics.
   b. Remote fault diagnosis with failure alerts via SMS & email.
   c. Automatic switching to low-power mode when battery SOC (State of Charge) falls below 20%.

[31] The applicability of this requirement is subject to the discretion of the project implementing entity (Capital Projects, REF, NEP-DARES, AMP, EAP, etc.) under REA.

3. **Adaptive Lighting Control:**
   a. Motion-sensing technology for automatic brightness adjustment.
   b. Dimming schedules based on time and ambient light sensors.

8 E-MOBILITY (ELECTRIC VEHICLES, CHARGING INFRASTRUCTURE & SOLAR-ASSISTED EVs)

8.1 STANDARDS AND SPECIFICATIONS FOR EV CHARGING INFRASTRUCTURE

Electric Vehicle Supply Equipment (EVSE) and charging stations shall adhere to international standards to ensure compatibility, operational safety, and seamless integration with renewable energy sources, particularly solar mini-grids.

The following international standards and technical guidelines are required for compliance:

1. **IEC 61851 for EV Charging Stations:** This standard establishes the fundamental requirements for electric vehicle charging infrastructure, covering aspects such as:

   a. Charging modes: AC slow charging (Mode 1 and Mode 2), AC fast charging (Mode 3), and DC rapid charging (Mode 4).
   b. Communication protocols: Ensuring interaction between the charging station, the vehicle, and the power grid.
   c. Safety protections: Overvoltage, overcurrent, earth fault detection, and insulation monitoring.
   d. Power quality considerations: Ensuring minimal interference with mini-grid and off-grid power networks.

2. **IEC 62196 – Charging Connector Standards for Mini-Grid Applications:**
   a. This standard defines charging connectors, plugs, and inlets for EVs, ensuring cross-compatibility across manufacturers.
   b. It includes the following key classifications:

      i. Type 1 (J1772): Common in North America and Japan.
      ii. Type 2 (Mennekes): Standard in Europe and widely adopted in Africa.
      iii. CCS (Combined Charging System): Enables both AC and DC fast charging.

   c. For mini-grid applications, IEC 62196 also ensures compatibility between EVs and renewable-powered charging stations, preventing inefficiencies in charging infrastructure deployment.

3. **Technical Guidelines for EV Charging**
   The following technical guidelines are required for sustainable and efficient operations:
   a. Mini-Grid Integration:

      i. Smart load balancing mechanisms to prevent overloading mini-grid systems.
      ii. Energy storage solutions to buffer charging demand during peak hours.
      iii. Prioritisation of charging schedules based on renewable energy availability.

b. Off-Grid Solar-Powered Charging Stations:

i. Use of solar photovoltaic (PV) microgrids to power charging infrastructure.
ii. Incorporation of battery energy storage systems (BESS) to enable charging even during low solar radiation periods.
iii. DC-to-DC fast charging models to minimize conversion losses.

c. Renewable Energy Utilization:

i. Direct coupling of EV chargers to solar PV arrays where feasible.
ii. Ensuring that EV charging infrastructure complies with ISO 15118, which governs smart charging and load management strategies.

d. Safety and Compliance Considerations:

i. Compliance with IEC 60364-7-722 for safe installation of EV chargers in mini-grid settings.
ii. Protection mechanisms such as residual current devices (RCDs) and surge protection to mitigate electrical faults.

8.2 RENEWABLE ENERGY-BASED CHARGING & RURAL APPLICATIONS

8.2.1 General Requirements: Solar-Powered EV Charging Stations for Mini-Grids

1. Solar-powered EV charging stations shall comply with IEC 61851 for charging infrastructure and IEC 62196 for charging connector standards.
2. All solar PV modules used in EV charging stations shall meet IEC 61215 and IEC 61730 standards to ensure long-term performance and reliability.
3. Battery Energy Storage Systems (BESS) for EV charging stations shall comply with IEC 62933-5-2 to enable safe energy storage and distribution.
4. Charge controllers and inverters used in solar-powered EV charging stations shall conform to IEC 62109 for safety in power conversion systems.
5. EV charging stations in mini-grid environments shall be integrated with smart Energy Management Systems (EMS) compliant with IEC 61850 for grid interoperability.
6. Direct DC charging shall be prioritized for solar-powered EV stations to minimize energy losses associated with multiple conversion stages.
7. Hybrid solar-diesel setups may be implemented in locations with extended cloudy periods, ensuring continuous EV charging reliability.
8. Solar-powered EV charging infrastructure shall include real-time monitoring and remote-control functionalities to optimize energy distribution and reduce peak loads on mini-grids.

8.2.2 General Requirements: Battery Swapping and Decentralized Charging Models for Rural Areas

1. Battery swapping stations shall be designed and operated in compliance with IEC 62933-5-2 to ensure safety and efficiency in battery energy storage.
2. Standardized battery pack sizes and connectors shall be mandated to ensure interoperability across different EV models.
3. All battery swapping stations shall include safety mechanisms such as temperature monitoring, overcurrent protection, and fire suppression systems.
4. Decentralized charging models shall be implemented to allow multiple small-scale charging hubs instead of centralized stations, ensuring accessibility in rural areas.

5. Battery swapping hubs shall integrate smart payment and mobile money solutions to facilitate cashless transactions for end-users.
6. All off-grid and mini-grid battery swapping systems shall be optimized for local renewable energy integration to minimize reliance on fossil fuel-based generators.
7. Swappable battery packs shall have a minimum cycle life of 4,000 cycles at 80% depth of discharge, in accordance with IEC 62619 and IEC 62133-2.
8. Fast-charging protocols used in battery swapping hubs shall comply with IEC 61851-23 for DC fast-charging infrastructure.

8.2.3 General Requirements: Integrating EV Charging into Mini-Grid Energy Management Systems

1. All mini-grid EV charging systems shall include demand-side management (DSM) mechanisms, ensuring that vehicle charging does not negatively impact local power availability.
2. Vehicle-to-Grid (V2G) and Vehicle-to-Home (V2H) capabilities shall be implemented in compliance with ISO 15118, allowing EVs to supply power back to the grid when needed.
3. Load management strategies shall be integrated into EV charging operations, ensuring that the system prevents overloading of mini-grids during peak demand hours.
4. EV chargers connected to mini-grids shall comply with IEC 61850, enabling real-time communication with substation automation and grid management systems.
5. Charging stations connected to mini-grids shall include intelligent scheduling mechanisms to distribute loads dynamically based on real-time power availability.
6. Power converters and inverters used in mini-grid-connected EV charging shall comply with IEC 62109, ensuring safety and reliability in conversion processes.
7. Rural EV charging infrastructure shall align with IEC 60364-7-722, defining safety measures for EV supply equipment installations in remote and off-grid locations.

8.3 SOLAR-ASSISTED ELECTRIC VEHICLES (SAEVS): TWO- AND THREE-WHEELED EVS

8.3.1 Standards for Solar-Powered Electric Motorcycles, Mopeds & Tricycles

1. All solar-assisted electric vehicles (SAEVs), including motorcycles, mopeds, and tricycles, shall comply with ISO 13063, ensuring safety and operational efficiency.
2. Battery energy storage systems used in SAEVs shall adhere to IEC 62933-5-2, ensuring safe and efficient storage capacity for solar-powered light EVs.
3. The electrical components of SAEVs shall be designed to withstand rural conditions, including dust, vibration, and high-temperature variations.
4. SAEVs shall integrate MPPT (Maximum Power Point Tracking) charge controllers to optimize solar energy harvesting efficiency.
5. The solar PV panels used in SAEVs shall be compliant with IEC 61215 and IEC 61730, ensuring high durability and performance under extended exposure to sunlight and weather conditions.

8.3.2 Structural Design and Efficiency Optimization of Mounted Solar Panels

1. Solar panels mounted on electric motorcycles, mopeds, and tricycles shall be designed for maximum aerodynamics and weight efficiency, ensuring minimal impact on vehicle performance.
2. Solar panel weight shall be optimized to prevent excessive load strain on the vehicle frame, while ensuring maximum energy capture efficiency.
3. Flexible and lightweight solar panels may be used where applicable, provided they conform to IEC 61215 for durability and IEC 61730 for safety.

4. The structural mounting design of solar panels on SAEVs shall withstand vibrations, shocks, and varying weather conditions without compromising efficiency.
5. Electrical wiring and connections between solar panels and battery management systems (BMS) shall conform to IEC 62109 for safety in power electronics.

8.3.3 Safety and Performance Requirements for Two- and Three-Wheeled EVs

1. **General Safety Requirements:**

   a. All two- and three-wheeled electric vehicles (EVs) shall comply with ISO 13063, ensuring safe design, operation, and maintenance.
   b. SAEVs (Solar-Assisted Electric Vehicles) shall undergo rigorous safety testing, including mechanical stability, electrical insulation, thermal protection, and vibration resistance.
   c. Electrical systems shall be designed to prevent electric shocks, short circuits, and battery over-discharge, in compliance with IEC 62133-2 and ISO 13063.
   d. High-voltage components shall be properly insulated, and protective barriers shall be in place to prevent accidental contact.

2. **Battery System Safety:**

   a. Lithium-ion batteries used in two- and three-wheeled EVs shall comply with ISO 13063-2 for thermal stability, overcurrent protection, and safety against mechanical impact.
   b. Battery packs shall include Battery Management Systems (BMS) that regulate charge-discharge cycles, thermal protection, and state-of-health monitoring, ensuring operational safety.
   c. Battery enclosures shall meet IP65 or higher rating to protect against dust, water ingress, and mechanical damage.

3. **Vehicle Performance Standards:**

   a. SAEVs shall have efficient regenerative braking systems, ensuring compliance with ISO 13063-3 for braking safety and efficiency.
   b. Vehicles shall comply with weight distribution guidelines to optimize stability and manoeuvrability while supporting solar panel integration.
   c. All electrical wiring shall adhere to ISO 16750, ensuring vibration resistance and long-term durability in rural and high-temperature environments.

4. **Crash and Impact Protection:**

   a. All structural components shall undergo impact testing in accordance with ISO 13063, ensuring chassis rigidity and occupant protection.
   b. The seating and frame design shall include shock-absorbing materials to reduce the risk of injury in case of a collision.
   c. Helmets and protective gear shall meet ISO 62262 for personal safety in high-risk driving conditions.

5. **Charging and Energy Efficiency:**

   a. Charging interfaces shall comply with IEC 61851-24 to ensure compatibility with mini-grid and standalone solar charging stations.
   b. SAEVs shall be designed to operate efficiently in off-grid and rural environments, ensuring long-term durability and performance reliability.

6. **Fire and Thermal Management:**

a. Fire suppression mechanisms shall be integrated into SAEVs, ensuring compliance with ISO 13063-2 and IEC 62619 for battery safety.
b. Vehicles shall include temperature monitoring systems, ensuring batteries do not exceed maximum operational limits in high-temperature conditions.

8.3.4 Solar-Powered Light EVs[32]

1. **General Battery Storage Requirements:**

a. All energy storage systems (ESS) used in solar-powered light EVs shall comply with IEC 62933-5-2, ensuring safe operation, energy efficiency, and long-term durability.
b. Lithium-ion battery packs shall be designed for 4,000+ cycles at 80% depth of discharge (DoD), as required by IEC 62619.
c. Batteries shall include integrated overcharge, over-discharge, and short-circuit protection, ensuring compliance with IEC 62133-2.

2. **Thermal Management and Fire Safety:**

a. Battery packs shall feature active and passive cooling systems, ensuring they remain within safe operating temperatures during high energy demand.
b. Battery enclosures shall meet IP67 rating for protection against dust, water, and environmental contaminants in off-grid applications.
c. Fire suppression mechanisms shall comply with IEC 62619, preventing thermal runaway and ensuring safe disposal of hazardous materials.

3. **Energy Management and Smart Charging:**

a. Battery packs shall be integrated with smart energy management systems (EMS) to optimize charging efficiency and extend battery lifespan.
b. Charging interfaces shall comply with IEC 61851-23, ensuring compatibility with solar-powered EV charging stations.
c. Energy storage systems shall be capable of bidirectional energy flow, allowing integration with vehicle-to-grid (V2G) and vehicle-to-home (V2H) applications.

4. **Structural Integrity and Vibration Resistance:**

a. Battery enclosures shall be designed to withstand high-impact forces and vibrations, in compliance with IEC 62933-5-2.
b. Structural mounting of battery packs shall be reinforced to prevent dislodgment during rough terrain travel and high-speed operation.

5. **Sustainability and Recycling:**

a. End-of-life (EOL) battery management shall comply with IEC 62933-5-2, ensuring safe disposal, second-life applications, and recycling strategies.
b. Solar-powered light EV batteries shall include state-of-health (SoH) monitoring, ensuring operators can track performance degradation and plan replacements accordingly.

6. **Integration with Mini-Grid and Off-Grid Systems:**

a. Battery storage systems for solar-powered light EVs shall be designed for seamless integration with standalone solar charging stations and mini-grid networks.
b. Energy storage solutions shall support modular scalability, allowing for future expansion and adaptability based on demand fluctuations.

[32] Lightweight electric vehicles equipped with integrated solar panels to supplement battery charging, enhancing energy efficiency and reducing reliance on external power sources.

8.3.5 SAEV Integration with Mini-Grid and Standalone Solar Charging Systems

1. SAEVs shall be capable of charging directly from mini-grid solar charging stations that comply with IEC 61851.
2. Standalone solar charging stations for SAEVs shall be designed to operate independently using battery storage systems compliant with IEC 62933-5-2.
3. Charging systems for SAEVs shall include bidirectional energy flow capabilities, allowing for V2G and V2H applications in alignment with ISO 15118.
4. SAEV charging infrastructure in rural areas shall incorporate IEC 60364-7-722 safety standards to ensure secure installation in off-grid environments.
5. Smart controllers shall be integrated into SAEVs to dynamically adjust solar power usage and optimize energy consumption.
6. **Batteries:** Compliance with IEC 62933-5-2 for battery energy storage in EV battery swapping systems.
7. **Chargers:** Adherence to IEC 61851-23 for DC fast charging and battery swapping infrastructure.
8. **Connectors:** Standardization under IEC 62196 to ensure interoperability.
9. Cabinets (5-Slots BSS, 12-Slots BSS): Modular designs to optimize space utilization and battery swapping efficiency.
10. **EV Categories:** Support for 2-wheelers (2W), 3-wheelers (3W), and 4-wheelers (4W), ensuring inclusivity for diverse transport applications.

9. SOLAR-POWERED PRODUCTIVE USE EQUIPMENT FOR AGRICULTURE & RURAL ENTERPRISES

9.1 GENERAL REQUIREMENTS AND STANDARDS: SOLAR-POWERED APPLICATIONS FOR AGRICULTURE & OTHER PRODUCTIVE USES

1. The integration of solar-powered applications for agriculture and other productive uses[33] is required to improve productivity, sustainability, and rural economic growth.
2. To ensure safety, efficiency, and long-term viability, compliance with internationally recognized standards is required.
3. **Applicable Standards:** The following standards shall be met for solar-powered productive use applications in agriculture & rural enterprises
   a. IEC 62253: Photovoltaic pumping systems – Design qualification and performance testing to ensure reliability and efficiency in agricultural applications.
   b. ISO 50001: Energy management systems – Requirements with guidance for energy efficiency in solar-powered irrigation and other agricultural applications.
   c. IEC 61701: Salt mist corrosion testing of photovoltaic (PV) modules – Ensuring durability in high-humidity and coastal environments.
   d. VeraSol Quality Assurance Programme: For ensuring efficiency and durability of productive-use appliances, particularly solar-powered irrigation, refrigeration, and milling.
   e. SON-MANCAP Certification: Mandatory Conformity Assessment Programme (MANCAP) certification for locally manufactured solar components and agricultural appliances to ensure compliance with Nigerian Industrial Standards (NIS).

[33] Where applicable, these requirements and standards may also extend to other productive use applications, such as irrigation, cold storage, agro-processing, water pumping, fish farming, textile production, small-scale manufacturing equipment, etc., which rely on solar-powered solutions for enhanced efficiency and sustainability.

4. **Technical Requirements:**

a. Energy Efficiency: All solar-powered irrigation systems shall achieve a minimum of 60% efficiency under standard test conditions as per IEC 62253.
b. Water and Energy Management: Integration of Maximum Power Point Tracking (MPPT) controllers and automated water-level monitoring to prevent excessive energy consumption and optimize irrigation scheduling.
c. Product Durability: All components, including PV modules, pumps, and controllers, shall be tested under IEC 61701 corrosion resistance standards, especially in high-humidity and saline environments.
d. Integration with Mini-Grids: Systems may[34] be compatible with mini-grid networks, enabling effective energy distribution for productive use.
e. Support Structure:
   i. PV panel support structures (rooftop, pole-mounted, or ground-mounted) shall be made of aluminium or galvanized steel, capable of withstanding high wind velocities up to 150 km/h.
   ii. Anti-rust protection and cathodic protection shall be applied where necessary.
   iii. The design must prevent theft and allow easy maintenance access

f. Specifications for Solar-Powered Irrigation Pumps (SPIP): All-in-One solar-powered water pump with a standard flywheel, RPM range of no less than 50–100 RPM, and a minimum flow rate of 0.5 litres per second. Performance benchmarks:
   i. At 1-meter lift: 3,600 litres per hour
   ii. At 6-meter lift: 2,500 litres per hour
   iii. Equipped with 120W solar panels and backed by a 10-year warranty.

5. **Compliance and Quality Assurance (QA):**

a. Testing and Certification: All products shall be tested and certified under SON MANCAP for Nigerian markets, alongside international certifications such as IEC 62253.
b. Local Manufacturing and Assembly: Preference shall be given to systems that incorporate locally manufactured or assembled components, provided they meet performance and durability standards.

10 HYDROGEN ENERGY SYSTEMS

10.1 STANDARDS AND SPECIFICATIONS: GREEN HYDROGEN SYSTEMS

1. **General Guidelines:** Safety, efficiency, and sustainability principles for green hydrogen generation.
2. **System Design and Requirements:** Compliance with ISO 22734 for hydrogen generators.
3. **Manufacturer's Compliance:** Equipment shall meet IEC 62282-3 for fuel cell safety and performance.
4. **Reliability and Availability:** Systems shall maintain at least 98% uptime, with redundancy provisions
5. **System Components for Hydrogen Production, Storage and Transport**
   a. Water Sources: Quality and purification standards per ISO 3696.
   b. Renewable Energy Sources: Integration with solar, wind, hydroelectric power for sustainable hydrogen production.

[34] The applicability of this requirement is subject to the discretion of the project implementing entity under REA.

c. Electrolyser: Compliance with IEC 62282-4 for proton exchange membrane (PEM) electrolysers.
d. Fuel Cell: Standards for hydrogen fuel cell performance under IEC 62282-2.
e. Hydrogen Storage Tanks: Adherence to ISO 14687 and IEC 62282-6-1 for hydrogen storage and transport safety.
f. Infrastructure and Distribution: Adopting best practices from ISO 19880-1.

11 WIND & SMALL HYDRO POWER SYSTEMS

11.1 GENERAL REQUIREMENTS

1. To ensure the safe and reliable deployment of wind and hydro power systems, compliance with internationally recognized standards is required.
2. These standards cover design, performance, safety, and maintenance aspects for small- and medium-scale renewable energy projects.

11.1.1 Wind Energy Systems

1. **IEC 61400 for Wind Turbine Performance & Safety:** All wind energy systems deployed under this regulation shall comply with IEC 61400, which establishes requirements for design, performance, safety, and testing of wind turbines.
2. The following criteria shall be adhered to:

a. Wind Resource Assessment:
   i. Developers shall conduct a detailed wind resource assessment for at least 12 months, in compliance with IEC 61400-12.
   ii. Minimum capacity factor of ≥25% under standard wind conditions (≥6m/s wind speed).

b. Turbine Certification:
   i. Wind turbines shall be certified according to IEC 61400-1 for design load cases and safety requirements.
   ii. Small wind turbines (<100 kW) shall comply with IEC 61400-2, which addresses distributed and off-grid wind energy applications.

c. Structural Integrity & Safety:
   i. Wind turbine tower structures, blades, and nacelles shall be designed for a minimum lifespan of 20 years under standard wind conditions.
   ii. Lightning protection shall be implemented per IEC 61400-24.
   iii. Anti-corrosion measures shall meet ISO 12944 for extreme weather conditions.

d. Power Quality & Grid Compliance:
   i. Wind turbine output voltage and frequency shall adhere to IEC 61400-21 for power quality and grid integration.
   ii. Harmonic distortion shall be ≤5%, complying with IEEE 519.
   iii. Wind farms shall feature fault ride-through (FRT) capabilities, per IEC 61400-27.

11.1.2 Small Hydroelectric Power Systems

1. Compliance with IEC 62006 is required for ensuring safety and performance verification.
2. **System Design & Site Selection:**

   a. Hydroelectric systems shall meet IEC 62006 requirements for performance, efficiency, and safety.
   b. Site feasibility studies shall be conducted using flow duration curves and hydrological data for a minimum of 5 years.
   c. Minimum plant efficiency of ≥85% under rated operating conditions.

3. **Turbine & Generator Specifications:**
   a. Turbines shall comply with IEC 60041 (Field Acceptance Tests).
   b. Generators shall meet IEC 60034-1 standards for rotating electrical machines.
   c. Protection against cavitation and sedimentation shall be implemented.

4. **Grid Connectivity & Load Balancing:**
   a. Small hydro systems feeding into mini-grids shall meet IEC 60034-7 (Grid Synchronization).
   b. Voltage and frequency regulation shall align with IEC 60038.
   c. Transformer and switchgear protections shall comply with IEC 62271.

5. **Environmental & Safety Considerations:**
   a. Fish-friendly turbines and flow diversion structures shall comply with EU Water Framework Directive.
   b. Structural safety shall meet IEC 62305 for lightning protection.

12 RELIABILITY STANDARDS FOR MINI-GRIDS, STANDALONE SYSTEMS, SMART TRANSFORMER STATIONS (STS) AND DISTRIBUTED ENERGY RESOURCES (DERS)

1. To ensure consistent power quality and system stability, reliability standards shall be established for voltage imbalance, frequency range, and harmonic distortion in mini-grids, standalone power systems, Smart Transformer Stations (STS) and distributed energy resources (DERs).
2. Compliance with international standards is mandatory to maintain efficiency and protect electrical equipment.
3. **Voltage Imbalance, Frequency Range & Harmonic Distortion:**

   a. <u>Voltage Imbalance (IEC 61439, IEC 61000-3-3):</u>
      i. Single-phase loads: Maximum voltage imbalance shall not exceed 3%.
      ii. Three-phase systems: Maximum voltage imbalance shall not exceed 5%.
      iii. Systems with higher unbalance shall include voltage regulation and load balancing mechanisms.

   b. <u>Frequency Stability (IEC 60038, IEEE 1547):</u>
      i. The system frequency shall remain between 49.5Hz – 50.5Hz under normal conditions.
      ii. Allowable deviation under fault conditions: 48Hz – 52Hz, with automatic recovery within 2 seconds.

c. Harmonic Distortion (IEEE 519, IEC 61000-3-2):
   i. Total Harmonic Distortion (THD) for voltage shall be ≤5%.
   ii. Sensitive loads shall comply with IEC 61000-3-2 for electromagnetic interference (EMI) and harmonic distortion mitigation.
   iii. Power electronics (e.g., inverters, converters) shall include active harmonic filtering.

4. **Power Quality Monitoring:**

a. Mini-grids and DERs shall have continuous power quality monitoring with real-time analytics.
b. Grid operators shall log and report any deviations beyond permissible limits and implement corrective actions.

5. **Smart Transformer Stations (STS):**

a. Applicable for transformers rated 1MVA, 0.8 power factor at 33kV/50Hz and 1MVA, 0.8 power factor at 11kV/50Hz, or higher.
b. Voltage Regulation: Compliance with IEC 60076 for transformer design and performance.
c. Grid Stability: Compliance with IEC 61850 for communication and automation of substations.
d. Harmonic Distortion Control: Compliance with IEEE 519 to ensure clean power delivery.

13 INSTALLER CERTIFICATION AND COMPETENCY REQUIREMENTS FOR RENEWABLE ENERGY SYSTEMS

1. All installers of mini-grid, solar, wind, hydro, and storage systems shall meet competency, training, and certification requirements according to IEC 63049.
2. These requirements ensure proper installation, maintenance, and safety compliance in alignment with both national and international standards.
3. **IEC 63049 Certification & Training Standards:** Installer shall have any of these mandatory certifications which apply to the installation of solar PV systems, battery storage, wind turbines, and hydroelectric systems:

a. NEMSA Certification of Installers for grid-connected and off-grid systems.
b. NAPTIN (National Power Training Institute of Nigeria) Certification for electrical installations related to renewable energy.
c. Economic Community of West African States (ECOWAS) Certification Scheme for renewable energy professionals
d. Other approved certification schemes by REA (Rural Electrification Agency) or related regulatory authorities (NERC, SON, etc.).

4. **Technical Skills & Safety Requirements:** Installers shall demonstrate competency in the following:

a. System sizing, grounding, fault diagnostics, and protective devices.
b. Safe handling and installation of lithium-ion and other advanced battery storage systems as per IEC 62619.
c. Arc fault detection (IEC 63024) and insulation resistance testing (IEC 61557-2).
d. Surge protection and lightning protection design based on IEC 62305.

5. **Periodic Re-certification & Professional Development:**
    a. Certification shall be renewed every three years to ensure continuous compliance.
    b. Installers shall complete Continuing Professional Development (CPD) focusing on emerging technologies such as:
        i. BESS (Battery Energy Storage Systems)
        ii. Smart grids & demand-side management
        iii. Hybrid energy systems

6. **Workplace Safety & Compliance:**
    a. Installers shall comply with occupational health and safety standards (ISO 45001).
    b. All installations shall strictly follow:
        i. National electrical wiring codes and building safety regulations.
        ii. Nigerian Electricity Supply and Installation Standards (NESIS).
        iii. ECOWAS Regional Code for Renewable Energy Systems.
        iv. REA-approved safety and technical guidelines.

7. **Compliance Audits & Penalties:**
    a. Regulatory bodies (NEMSA, REA, and other relevant authorities) shall periodically audit renewable energy installations for compliance.
    b. Non-compliant installations shall be subject to penalties, mandatory re-certifications, or revocation of installation licenses.

14 OPERATION & MAINTENANCE REQUIREMENTS

14.1 Standardized Maintenance Protocols

1. To enhance the longevity and reliability of renewable energy projects, standardized maintenance protocols shall be implemented in accordance with IEC 62246-2.
2. **Standardized Maintenance Protocols (IEC 62246-2):**
    a. Preventive & Predictive Maintenance:
        i. Scheduled visual inspections, testing, and servicing shall occur every six months.
        ii. Battery energy storage systems (BESS) shall be tested for state-of-charge accuracy and thermal performance.
        iii. Wind turbines and hydro turbines shall undergo structural inspections and lubrication maintenance.
    b. Fault Diagnostics & Remote Monitoring:
        i. Systems shall include remote monitoring and SCADA integration (IEC 61850).
        ii. Real-time fault prediction using AI-based analytics is recommended.
    c. Emergency Repair & Response Time:
        i. Critical failures shall be diagnosed within 24 hours.
        ii. Spare parts inventory shall be maintained for essential components.
    d. Regulatory Compliance & Record Keeping:
        i. Maintenance logs shall be digitally recorded and stored for 5 years.
        ii. In addition to routine audits, third-party audits and inspections shall be conducted every 3 years, in line with international best practices for infrastructure governance.

14.2 O&M for Project Sustainability

1. To ensure sustainable operations during and after the liability period post-commissioning, the following O&M measures shall be implemented.

2. **Reference Guidelines and Templates:**
   a. All O&M activities shall be aligned with the following:
      i. Updated REA guidelines, models and frameworks for O&M
      ii. REA-approved standardised financial model spreadsheets and transaction templates
      iii. Community governance bylaws and REUCS structures.

3. **Development and Implementation of an O&M Framework:**
   a. A detailed Operation & Maintenance Framework shall be developed for each mini-grid project to cover:
      i. Roles and responsibilities of the Developer, REA, and Community;
      ii. Provision of technical O&M services;
      iii. Measures to recover variable O&M costs only;
      iv. Asset lifecycle planning and component replacement timelines;
      v. Integration with performance audits and monitoring protocols.

4. **Community Ownership through REUCS:**
   a. Rural Electricity Users Cooperative Societies (REUCS), Farmers' Cooperatives, or other related Cooperatives shall be established and formally registered to drive community ownership and oversight.
   b. Communities shall be sensitised and trained on the following:
      i. The importance of local ownership and governance;
      ii. Productive and efficient use of electricity;
      iii. O&M fee contributions and reporting mechanisms;
      iv. Safeguarding infrastructure and security arrangements.

5. **Tripartite O&M Agreement Execution:**
   a. A Tripartite Operation & Maintenance Agreement shall be executed among the following parties:
      i. Rural Electrification Agency (REA),
      ii. The selected O&M Developer or Contractor,
      iii. The REUCS or designated Community Representative.
   b. The agreement shall outline service expectations, asset handover conditions, reporting responsibilities, escalation procedures, and dispute resolution protocols.

6. **Sustainability and Oversight Mechanisms:**
   a. Routine technical audits and performance reviews shall be conducted by REA and/or third-party experts every six months.
   b. Where applicable, integration with Distribution Companies (DisCos) and State Electrification Agencies shall be included for interconnected mini-grids, especially in States with functional electricity markets.
   c. Steering Committees made up of REA, Developer, and Community Leadership shall oversee project governance, long-term planning, and performance feedback loops.

15 ENERGY AUDITS, DESIGN TOOLS AND CAPACITY BUILDING FOR RENEWABLE ENERGY SYSTEMS

1. To enhance multi-technology integration, system performance assessment, and workforce capacity, renewable energy audits and standardized design tools shall be adopted.
2. **Tools for Multi-Technology Integration:**

a. Energy System Simulation & Sizing Tools:

i. HOMER Pro and PVsyst for off-grid and grid-tied hybrid system modelling.
ii. RETScreen for financial viability and impact analysis.
iii. ETAP for grid impact and load flow analysis.

b. Geospatial & Remote Sensing Tools:

i. GIS-based tools such as QGIS and ArcGIS for site selection and resource mapping.
ii. NASA's POWER API and Global Solar Atlas for solar irradiation and wind resource assessments.
iii. Nigeria SE4ALL Central Data Management System (CDMS), Integrated Energy Planning Tool (IEPT), and Energy Access Explorer (EAE) for national geospatial energy access planning and decision-making.
iv. VIDA for spatial analysis and mapping of decentralized energy access solutions.

c. Performance Benchmarking & Compliance Testing Tools:

i. IEC 61724 for Photovoltaic System Performance Monitoring.
ii. IEC 61400-12 for Wind Turbine Power Performance Measurement.
iii. IEC 60034-2 for Efficiency Testing for Generators and Motors.

d. Standardized Planning Frameworks & Design Templates:

i. Use of digital twins and AI-driven simulations for grid stability studies or ETAP.
ii. Standardized electrical single-line diagrams (SLDs) for regulatory approvals.
iii. The United Kingdom Nigeria Infrastructure Advisory Facility's (UKNIAF) Integrated Resource Plan (IRP) for structured energy infrastructure planning and optimization.
iv. Odyssey Energy Solutions for data-driven mini-grid development, performance tracking, and financial analytics.

3. **Capacity Development for Engineers and Project Developers:**

a. Training Programmes & Workshops:
i. Engineers and project developers shall complete training in IEC 63049 (Installer Competency Standards).
ii. Technical workshops on emerging technologies such as BESS, microgrid controls, and SCADA integration.

b. Certification & Accreditation:

i. Project teams shall include certified professionals with recognized industry certifications.
ii. Engineers working on mini-grid and utility-scale projects shall be certified in IEC 60287 (Cable Sizing) and IEC 60826 (Structural Design for Overhead Lines).

c. Knowledge Sharing & Research Collaboration:
i. Partnership with universities, research centres, and international energy agencies.
ii. Development of an open-access renewable energy knowledge platform.

d. On-Site Practical Training & Apprenticeship Programmes:
i. Practical training sessions shall be included in mini-grid pilot projects.
ii. Apprenticeship programmes shall be endorsed by regulatory bodies to improve workforce readiness.

16 ADVANCED ASSET MONITORING AND ALERT SYSTEMS (AAMAS)

1. The Advanced Asset Monitoring and Alert System (AAMAS) is a Remote Monitoring Electronic Device (RMED) designed to enhance security, operational efficiency, and preventive maintenance in mini-grid and off-grid energy systems.
2. The system ensures real-time tracking, predictive maintenance, and secure communication, integrating seamlessly with existing rural electrification installations.
3. **General Requirements:** The AAMAS shall comply with global best practices and national regulations for remote monitoring in renewable energy asset management. Key requirements shall include:

a. Integration with all Rural Electrification Installations, including (but not limited to):
i. Solar Home Systems (SHS)
ii. Standalone Mini-Grids (SMG)
iii. Solar Street Lighting (SSL)
iv. Productive Use Equipment/Energy (PUE) systems
v. Battery Energy Storage Systems (BESS)
vi. Transformers and Substations
vii. Other related rural electrification installations

b. Remote Monitoring and Security Features:
i. Continuous surveillance and tracking of critical energy assets.
ii. Real-time data logging and transmission to a centralized control centre.
iii. Protection against unauthorized access, tampering, or theft.

c. Automated Alerts and Predictive Maintenance:
i. Real-time anomaly detection for voltage fluctuations, load imbalances, and thermal stress.
ii. Smart diagnostics using machine learning-based predictive analytics.
iii. Instant fault notifications via SMS, email, and web dashboards.

d. Cloud-Based Data Hosting and Control Room Integration:
i. Remote access through a secure web-based dashboard and mobile application.
ii. Secure cloud storage with historical performance tracking.
iii. Redundancy mechanisms to ensure zero data loss.

4. **Device Specifications:**
   a. The AAMAS hardware shall be rugged, weatherproof, and highly accurate, meeting the minimum technical specifications and requirements in the table below:

Table 15.2: AAMAS Device Specifications

Specification	Requirements
GNSS Type	All-in-One GNSS Receiver
Constellation Support	GPS, Glonass, Galileo, Beidou
Position Accuracy (CEP)	< 2.0m (Autonomous Mode)
Tamper and Motion Detection	Internal 3-axis Accelerometer
Waterproof Rating	IP67 (Suitable for outdoor installation)
Operating Temperature	-20°C to +60°C
Power Saving Mode	Standby Time up to 3 years

5. **Communication and Security Protocols:** To ensure data integrity, security, and real-time monitoring, the AAMAS shall include the following:
   a. Encrypted Communication Channels for Secure Data Transmission:
      i. AES-256 encryption to prevent data breaches.
      ii. Secure wireless and wired data transmission via LoRaWAN, GSM, LTE, or Satellite Networks.
      iii. MQTT and HTTPS-based data exchange to ensure real-time, secure communication.
   b. Real-Time Asset Tracking and Location Alerts:
      i. GPS-based tracking with real-time geolocation mapping.
      ii. Instant alerts for unauthorized asset displacement or energy theft.
   c. Geo-Fencing Capabilities (Internal & External Geo-Fences):
      i. Customizable virtual boundaries for high-value assets.
      ii. Automatic notification of entry and exit from designated locations.
6. **Remote Monitoring and Control Room Integration:**
   a. The AAMAS shall be seamlessly integrated with control room operations for continuous oversight of energy assets.
   b. Secure Server Hosting for Data Storage and Retrieval:
      i. Encrypted cloud and on-premise storage for asset data.
      ii. ISO 27001-compliant cybersecurity measures.
   c. Automated Alerts for Asset Movement and Unauthorized Access:
      i. Real-time push notifications for unauthorized tampering.
      ii. Instant reports on energy theft and equipment failures.
   d. Real-Time Performance Analysis for Preventive Maintenance:
      i. ETAP or AI-driven performance tracking for proactive fault detection.
      ii. Predictive analytics to reduce system downtime and maintenance costs.
7. **Application in Mini-Grid and Utility Asset Protection:** The AAMAS shall be capable of tracking, monitoring, and securing energy assets across diverse mini-grid and off-grid applications, including:

a. Tracking and Protection of Mini-Grid Infrastructure:
   i. Monitoring of transformers, battery storage, solar panels, and EV chargers.
   ii. Remote shut-down capability for emergency scenarios.

b. Remote Monitoring of Mini-Grid Control Centres and Distribution Networks:
   i. Oversight of energy distribution lines and substations.
   ii. Load balancing analysis for system stability.

c. Operational Monitoring for Renewable Energy Installations and Off-Grid Power Systems:
   i. Live tracking of performance metrics across multiple remote site
   ii. Trend analysis to optimize system efficiency.

d. Preventive Maintenance Alerts to Reduce System Downtime:
   i. Automated fault detection and self-diagnosis capabilities.
   ii. Data-driven maintenance scheduling to minimize operational disruptions.

ANNEXES

Annexe A: Applicable National and International Standards

Table A1: IEC, ISO, BS, IEEE and Other Applicable Standards and Codes

CODE	DESCRIPTION
IEC 60364-7-711	Electrical installations of buildings - Part 7-711: Requirements for special installations or locations - Exhibitions, shows and stands
IEC 60364-7-701	Low-voltage electrical installations - Part 7-701: Requirements for special installations or locations - Locations containing a bath or shower
IEC 60364-7-705	Low-voltage electrical installations - Part 7-705: Requirements for special installations or locations - Agricultural and horticultural premises
IEC 60364-7-704	Low-voltage electrical installations - Part 7-704: Requirements for special installations or locations - Construction and demolition site installations
IEC 60092-306	Electrical installations in ships - Part 306: Equipment - Luminaires and lighting accessories
IEC 60598-2-3	Luminaires - Part 2-3: Particular requirements - Luminaires for road and street lighting
NIS IEC 61000-3-11	Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current ≤ 75 A and subject to conditional connection
NIS IEC 60081	Double-capped fluorescent lamps - Performance specifications
NIS IEC 60974-9	Arc welding equipment - Part 9: Installation and use
NIS IEC 60335	Household and similar electrical appliances
IEC 60335-2-75	Households and similar electrical appliances, with a particular requirement for commercial dispensing appliances and bending machines
IEC 60099-8	Surge arresters - Part 8: Metal-oxide surge arresters with an external series gap (EGLA) for overhead transmission and distribution lines of a.c. systems above 1 kV
IEC 61850	Communication networks and systems in substations - ALL PARTS
IEC 608-70-104	Communication between Substation Automation System (SAS) and power plant devices
NIS IEC 60557	Dissolved gas analysis carried out on all transformers periodically
IEC 60726	Dry-type power transformers
IEC 60044	Instrument transformers
IEC60044-2 (2000-1)	Instrument transformers - Part 2: Inductive voltage transformers
IEC 60502-2	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (*U*m =1,2 kV) up to 30 kV (*U*m = 36 kV) – Part 2: Cables for rated voltages from 6 kV (*U*m = 7,2 kV) up to 30 kV (*U*m = 36 kV)
IEC 60060	High-voltage test techniques - ALL PARTS
IEC 60947-1	Low-voltage switchgear and control gear - Part 1: General rules
IEC 60947-2	Low-voltage switchgear and control gear - Part 2: Circuit-breakers
IEC 60898	Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations
IEC 62271-100	High-voltage switchgear and control gear - Part 100: Alternating current circuit-breakers
IEC 62271-200	High-voltage switchgear and control gear - Part 200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV

IEC 60099-5	Surge arresters - Part 5: Selection and application recommendations
IEC 60099 -6	Surge arresters - Part 6: Surge arresters containing both series and parallel gapped structures - Rated 52 kV and less
IEC 60099 -8	Surge arresters - Part 8: Metal-oxide surge arresters with an external series gap (EGLA) for overhead transmission and distribution lines of A.C. systems above 1 kV
IEC 62305-1	Protection against lightning - Part 1: General principles2, 3 & 4-for the design, selection and specification of lightning arresters for use in distribution networks
IEC 60255-1	Measuring relays and protection equipment - Part 1: Common requirements
IEC 61810-1	The electromechanical relay used on distribution substation switchgears
IEC 60255	An electrostatic relay, which are relays that do not have and use moving parts
IEC 61810-7	Electromechanical elementary relays - Part 7: Test and measurement procedures
IEC 60364-5-54	Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors
IEE 519	Guide-for-Harmonic-Control-and-Reactive-Compensation-of-Static-Power-ConvertersBS
7671-2008	Every means of earthing to be selected and erected
IEC 60076 – 1	Power transformers - Part 1 General
IEC 60076 – 2	Power transformers – Part 2: Temperature rise for liquid-immersed transformers
IEC 60076 – 3	Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076 – 4	Power transformers - Part 4: Guide to the lightning impulse and switching impulse testing-power transformers and reactors
IEC 60076 – 5	Power transformers: Ability to withstand short circuit
IEC 60076 – 6	Power transformers – Part 6: Reactors
IEC 60076 – 7	Power transformers – Part 7: Loading guide for oil-immersed power transformers
IEC 60076 – 8	Power transformers – Application guide
IEC 60076 – 10	Power transformers – Part 10-1: Determination of sound levels – Application guide
IEC 60076 – 13	Power transformers – Part 13: Self-protected liquid-filled transformers
IEC 60076 – 14	Power transformers – Part 14: Design and application of liquid-immersed power transformers using high-temperature insulation materials
NIS IEC 60186	Inductive voltage dividers
IEC60947-1	Low-voltage switchgear and control gear - Part 1: General rules
IEC 60099-4	Surge Arresters
IEC 60296	Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear
IEC 60044-1	Instrument transformers - Part 1: Current transformer
IEC 60044-2	Instrument transformers - Part 2: Inductive voltage transformers
IEC 60273	Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000 V
IEC 60282-2	High-voltage fuses - Part 2: Expulsion fuses
IEC 60289	Reactors
IEC 60947	Shunt Reactor
IEEE 1031 -2011	Reactive Power Compensator
IEC 60255	Electrical relay
IEC 60255	Measuring relays and protection equipment
NIS IEC 61850	Communication networks and systems in substations - ALL PARTS

IEC 61089	Round wire concentric lay overhead electrical stranded conductors
IEC 60028	International standard of resistance for copper
IEC 60889	Hard-drawn aluminium wire for overhead line conductors
IEC 60888	Zinc-coated steel wires for stranded conductors
IEC 61232	Aluminium-clad steel wires for electrical purposes
IEC 60104	Aluminium-magnesium-silicon alloy wire for overhead line conductors IEC 60383-1: Insulators for overhead lines with a nominal voltage above 1000 V - Part 1: Ceramic or glass insulator units for A.C. systems - Definitions, test methods and acceptance criteria
IEC 60038	IEC standard voltages
IEC 60840	Power cables with extruded insulation and their accessories for rated voltages above 30 kV (*U*m = 36 kV) up to 150 kV (*U*m = 170 kV) - Test methods and requirements
IEC 60502-2	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (*U*m = 1,2 kV) up to 30 kV (*U*m = 36 kV) – Part 2: Cables for rated voltages from 6 kV (*U*m = 7,2 kV) up to 30 kV (*U*m = 36 kV)
IEC 60228	Conductors of insulated cables
NCP 9	National Code of Practice on Earthing
IEC 60364-5-54	Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective BS 8004: Foundations for the Design and construction of Injection Substation foundations
BS 8110	Concrete Structural works
BS 5950	Structural use of steelwork in buildings, providing guidelines for the design of rolled and welded steel sections to ensure structural integrity, safety, and compliance with engineering standards.
BS 8007	Code of practice for the design of concrete structures for retaining aqueous liquids
BS 5628	Block Work/Brickwork for the design and construction of blockwork/brickwork
IEC 60335-2-76	Household and similar electrical appliances - Safety - Part 2-76: Particular requirements for electric fence energisers
IEC 60694	Common clauses for high-voltage switchgear and control
IEC 60298	High-voltage metal-enclosed switchgear and control gear
IEC 62271-200	High-voltage switchgear and control gear - Part 200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to 52 kV
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 62271-100	High-voltage switchgear and control gear - Part 100: Alternating current circuit-breakers
IEC 60185	Current Transformer
IEC 60186	Voltage Transformer
IEC 60215	Relays
IEC 62271-4	High-voltage switchgear and control gear - Part 4: Handling procedures for Sulphur hexafluoride (SF_6) and its mixtures
IEC 62128-1, 2, 3	Bypass Isolators-Protective device for electrical safety
IEC 60099	Lightning or surge arrester devices for protection of all substations, the intersection of overhead lines and underground cables from lightning and switching surges
IEC 61954	Static VAr Compensator installed on medium voltage distribution for power quality improvement of the network
IEC 61400	Dynamic Voltage Restorers or Series Voltage Booster devices, installed to mitigate against voltage sags, spikes, harmonics and in-voltage variations

IEC 60871	Shunt capacitors installed in the Injection Substations-Each capacitor unit is designed, rated, manufactured, and tested
IEC 60143-1	Series capacitors for power systems - Part 1: General
IEC 62068	Electrical insulating materials and systems - General method of evaluation of electrical endurance under repetitive voltage impulses
IEC 61089	Classes and qualities of aluminium conductors applicable in distribution overhead network
B.S. 125, 1970	For Copper or Copper Equivalent
B.S. 215 Part 1 197	for Aluminium
IEC 60173	Colours of the cores of flexible cables and cords: High-voltage switchgear and control gear - Part 202: High-voltage/ low-voltage prefabricated substation
NIS IEC 60228	Conductors of insulated cables
IEC 60079-0	Explosive atmospheres - Part 0: Equipment - General requirements
IEC 60227	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 1: General requirements
IEC 60502	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (*U*m = 1,2 kV) up to 30 kV (*U*m = 36 kV) - ALL PARTS
NIS IEC 60204	Safety of machinery - Electrical equipment of machines - ALL PARTS
NIS IEC 60884	Plugs and socket-outlets for household and similar purposes - Part 1: General requirements
BS5266-1	Where indoor lighting is designated for emergency purposes in such places as hospitals, entertainment venues, schools, industrial premises, hotels amongst others

Annexe B: Guidelines for Grid Extension and Engineering Design

1 Environmental Requirements and Conditions: Electrical Works

The design, construction and installation of electrical works shall take into consideration environmental issues and concerns, which include (but not limited to) the following:

1. Promotion of energy efficiency
2. Social impact of new projects and community concerns
3. Minimisation of environmental damage, including visual impacts, tree and forestry management programmes
4. Considerations for electromagnetic radiation
5. Erosion prone environment
6. Equipment and materials that are exposed due to outdoor installations shall be able to withstand the environmental conditions shown below in table B1.

Table B1: Environmental conditions for Electrical works

Humidity	Extended periods of relative humidity, ranging from 10% to 90%
Solar Radiation Level	1,100 W/m^2 with high ultraviolet content
Ambient Temperature Range	45°C summer daytime (maximum) and - 5°C winter night time (minimum)
Precipitation	Annual rainfall above 1500mm (Bureau of Meteorology)
Wind Speed	Tropical summer storms with gust wind speeds above 160 km/h
Isokeraunic Level	35-40 (Bureau of Meteorology)
Pollution	Level IV – Very heavy (for installation in polluted ambient air with areas of coastal salt spray and industrial pollution

2 Guide to Conduct Electrical Load Surveys

1. Identify a contact person for the survey exercise.
2. Identify any obstacles at the T-off, including buildings, shrines, markets, etc.
3. Set up measuring instrument and record all possible landmarks (big lines, convert, rivers bridges, etc.) along survey route and the angles of the route.
4. Identify the feeder which is the source of electricity supply.
5. Identify the bulk source of electricity supply. For 33kv feeders, identify the transmission station. for the 11kV feeder, identify the primary injection substation.
6. Record the capacity of the transformer (including the loading percentage) and its approximate distance from the T-off point to the proposed network.
7. Mark out the boundaries within inter-town distribution networks. These indicated boundaries shall be shown in the Legend of your drawings.
8. Sketch out all existing electrical networks along the survey route
9. Enumerate all physical structures (schools, churches, mosques, and other household categories) in the community for Energy Audit.
10. Produce a design based on collected information, taking into consideration the load diversity and growth plan at an optimum cost.
11. Develop the BEME using computer software or other spreadsheet applications.

3 Route Surveys

1. Pole line surveys shall produce a plan and profile of the surveyed route. The plan shall show the route the line will follow and the significant topography adjacent to the route.
2. Poles for distribution lines shall be placed on the side of the streets that is freest of other lines and trees.
3. Poles shall be erected 10m away from the road edge where practicable, else the poles shall be erected at a safe distance such that its collapse will not result in traffic jam or destruction of properties.

4 Engineering Design

1. All engineering designs shall be carried out, certified and approved by qualified COREN Registered Engineer(s).
2. Engineering designs of overhead distribution lines shall also take into consideration the following:

   a. Compliance with Statutory Regulations
   b. Safety of equipment, employees and the general public
   c. Economic utilisation of materials
   d. Conformity with international best practices that meet the need of users with minimum environmental impact
   e. To conform to acceptable standards, both from an engineering point of view and aesthetics

5 Pole Markings

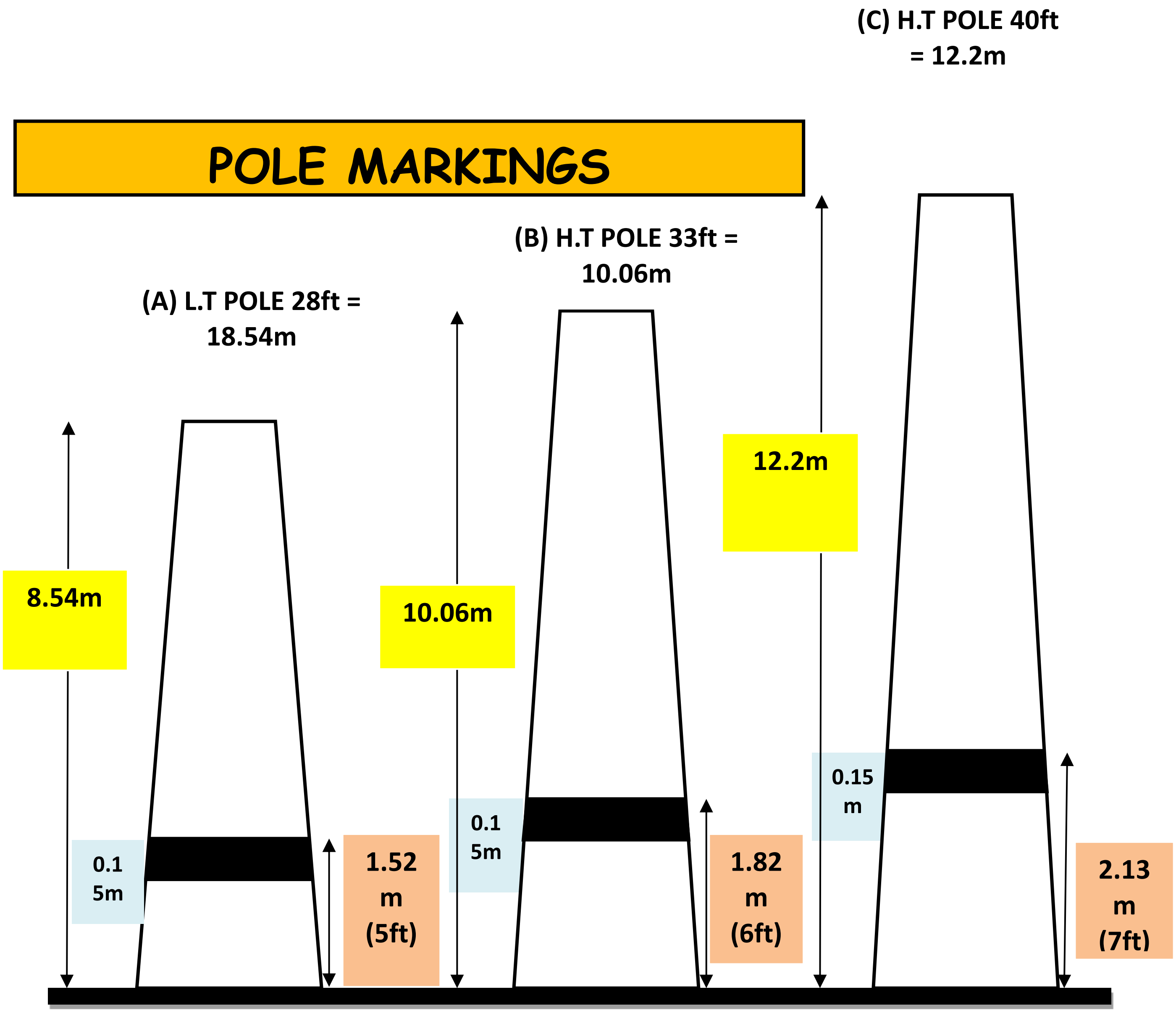


Figure B1: Standard Pole Markings for Low- and High-Tension Poles

6 High Tension Dressed Poles

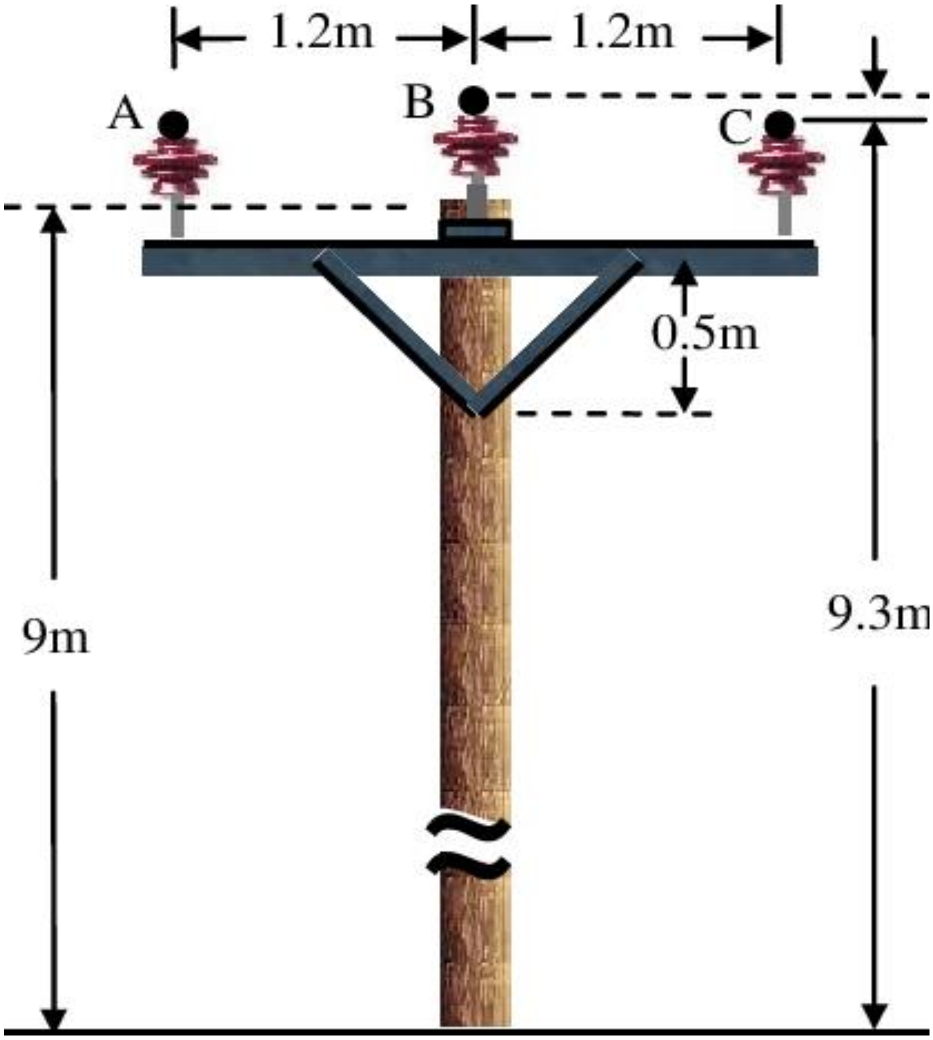


Figure B2: Dimensions of a Typical High-Tension Dressed Pole

Annexe C: Design and Safety Standards for Injection Substations

1 Substation Designs

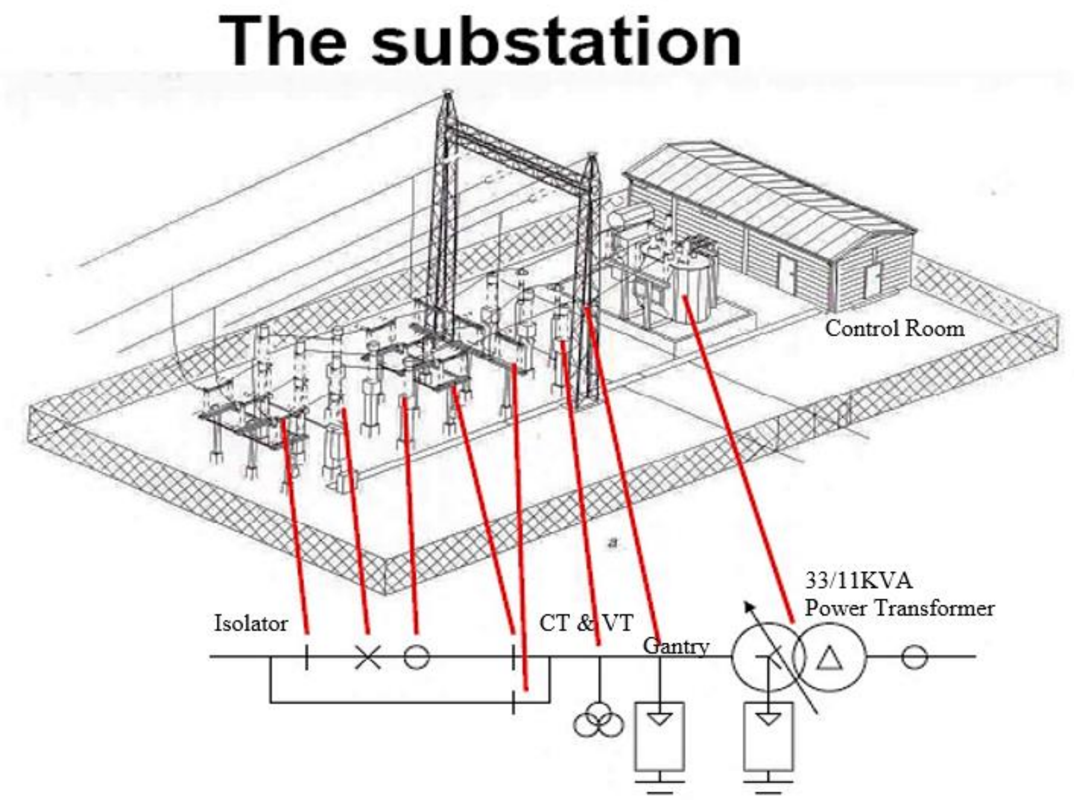


Figure C1: Standard Layout of an Injection Substation

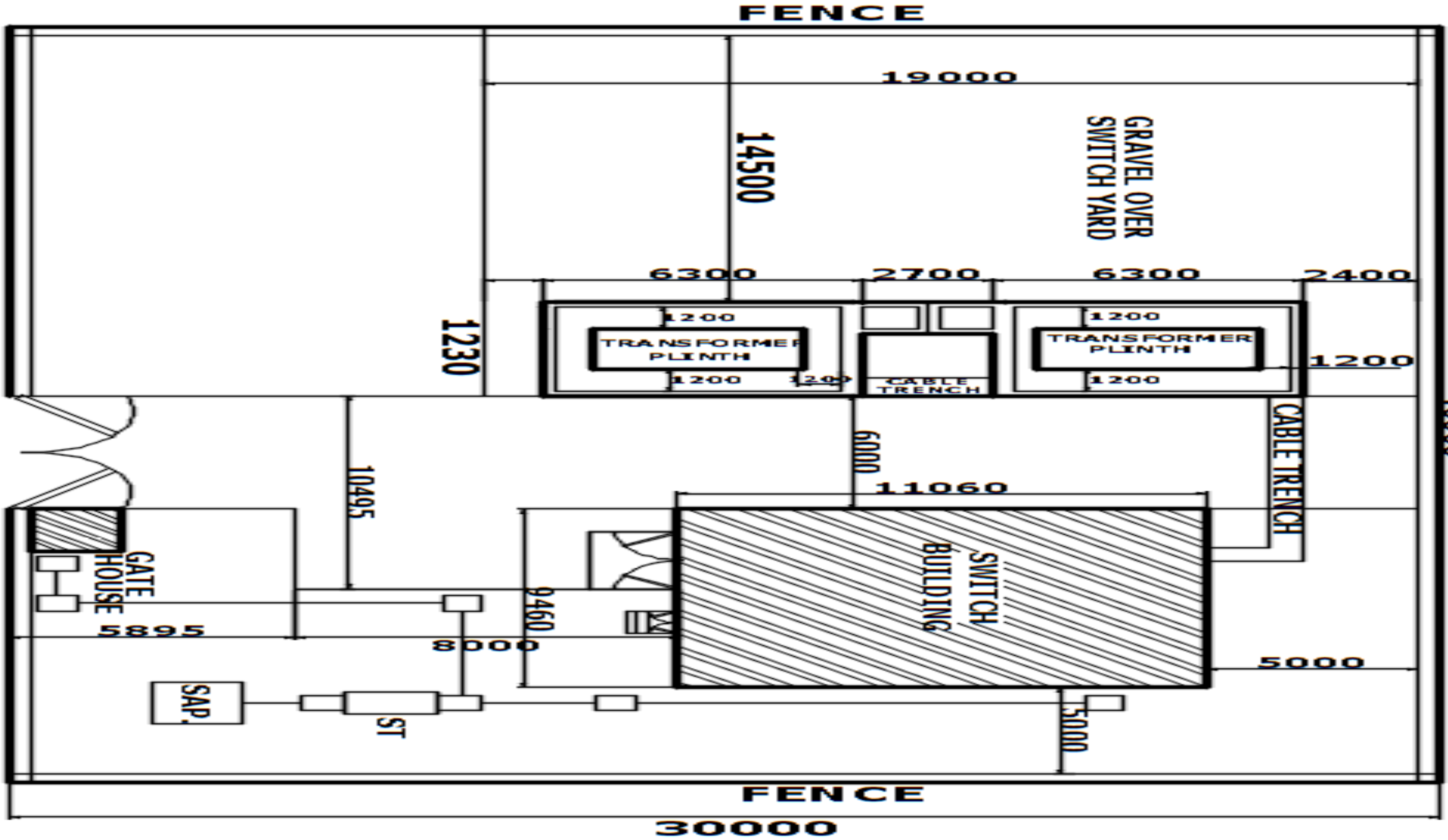


Figure C2: Top-Down View of a Substation Site (All Dimensions in mm)

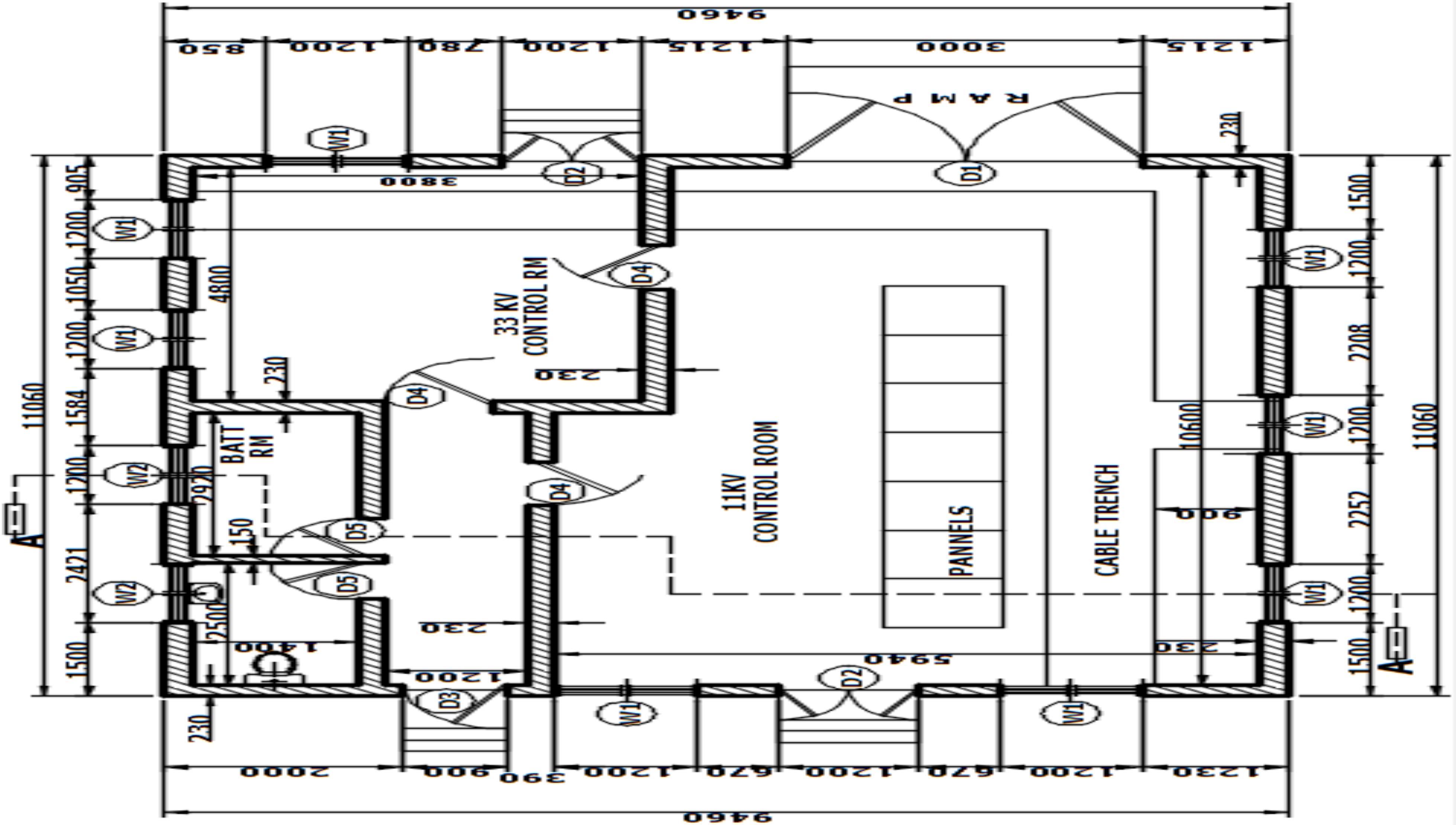


Figure C3: Floor Plan of a Substation Control Room (All Dimensions in mm)

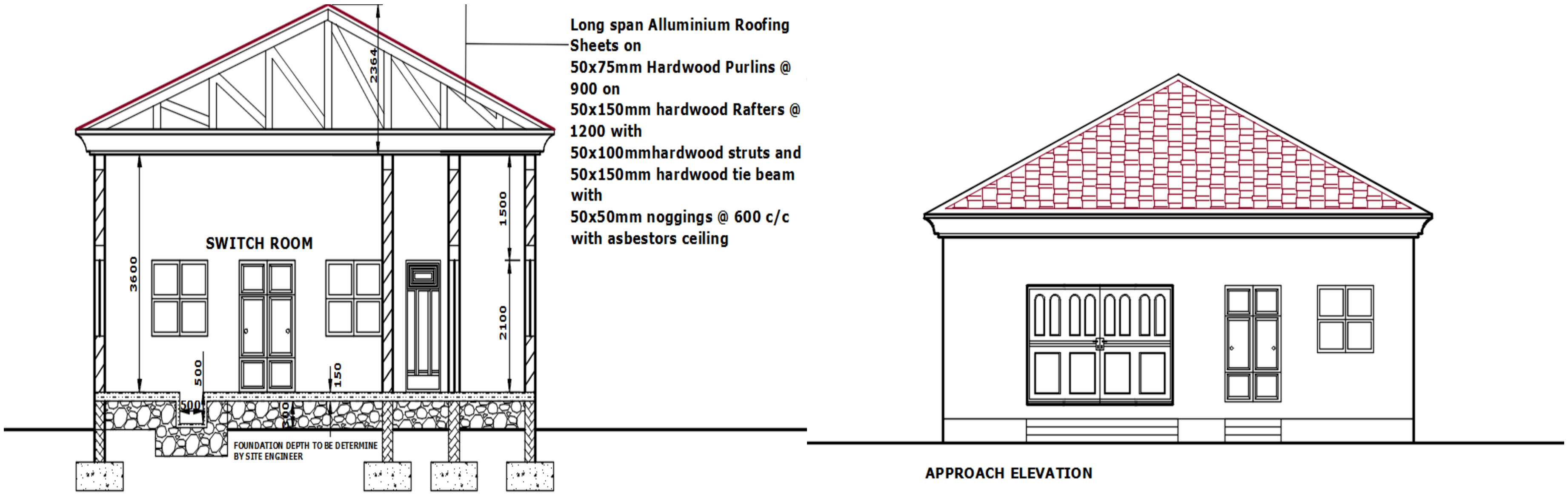
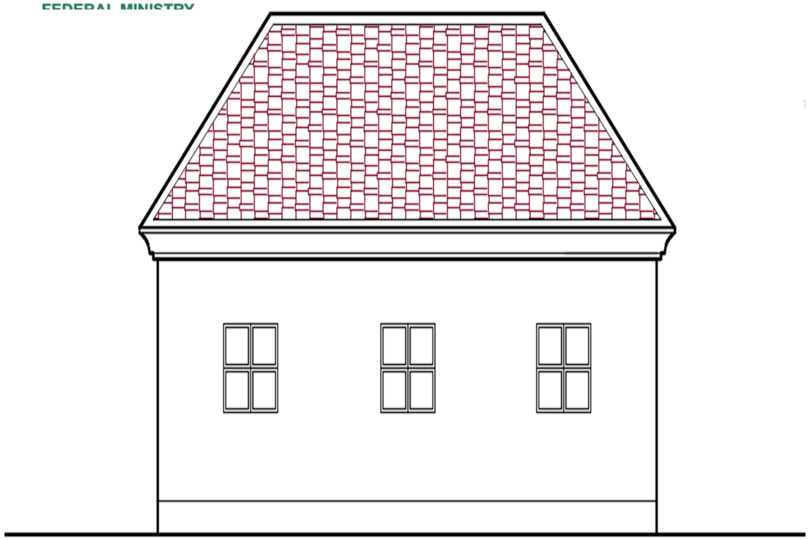
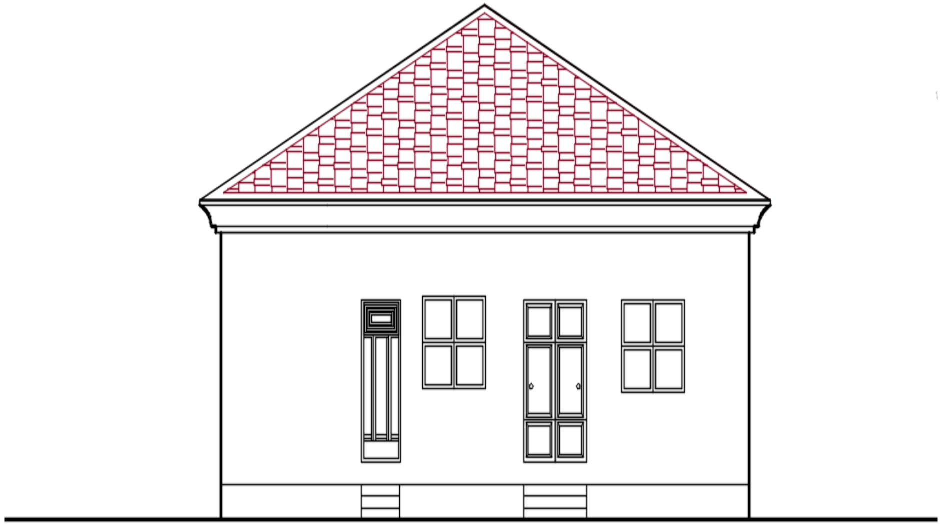


Figure C4: Switch Room Design – Approach Elevation (All Dimensions in mm)



LEFT SIDE ELEVATION



REAR ELEVATION

Figure C5: Switch Room Design – Left and Rear Elevations (All Dimensions in mm)

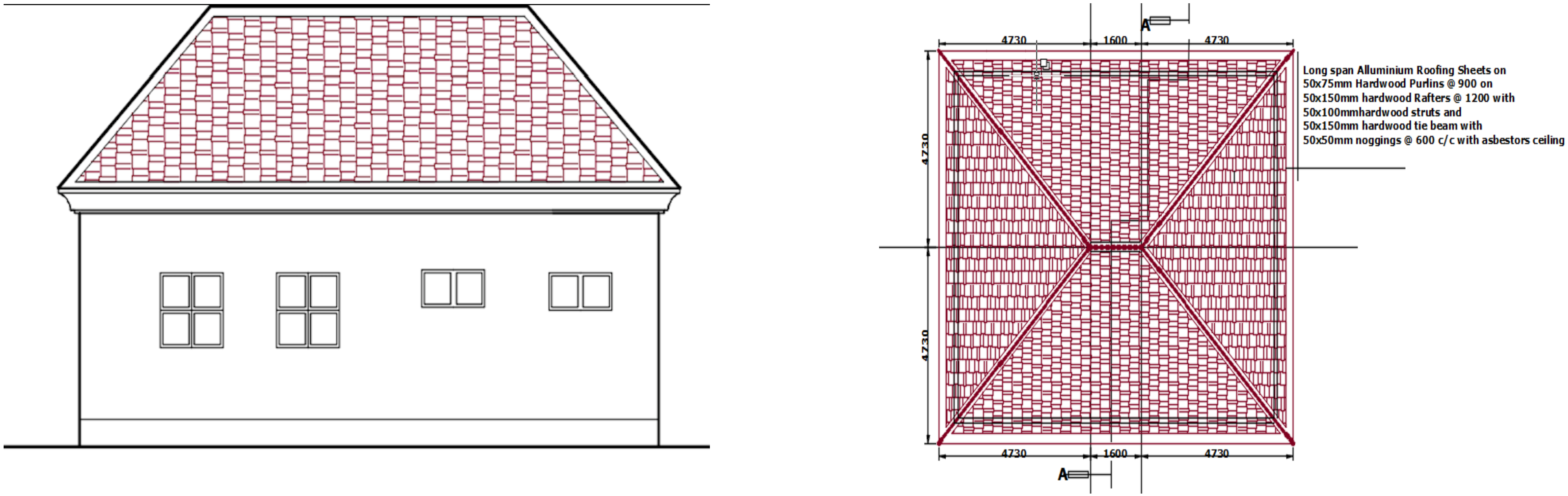


Figure C6: Switch Room Design – Right and Top Elevations (All Dimensions in mm)

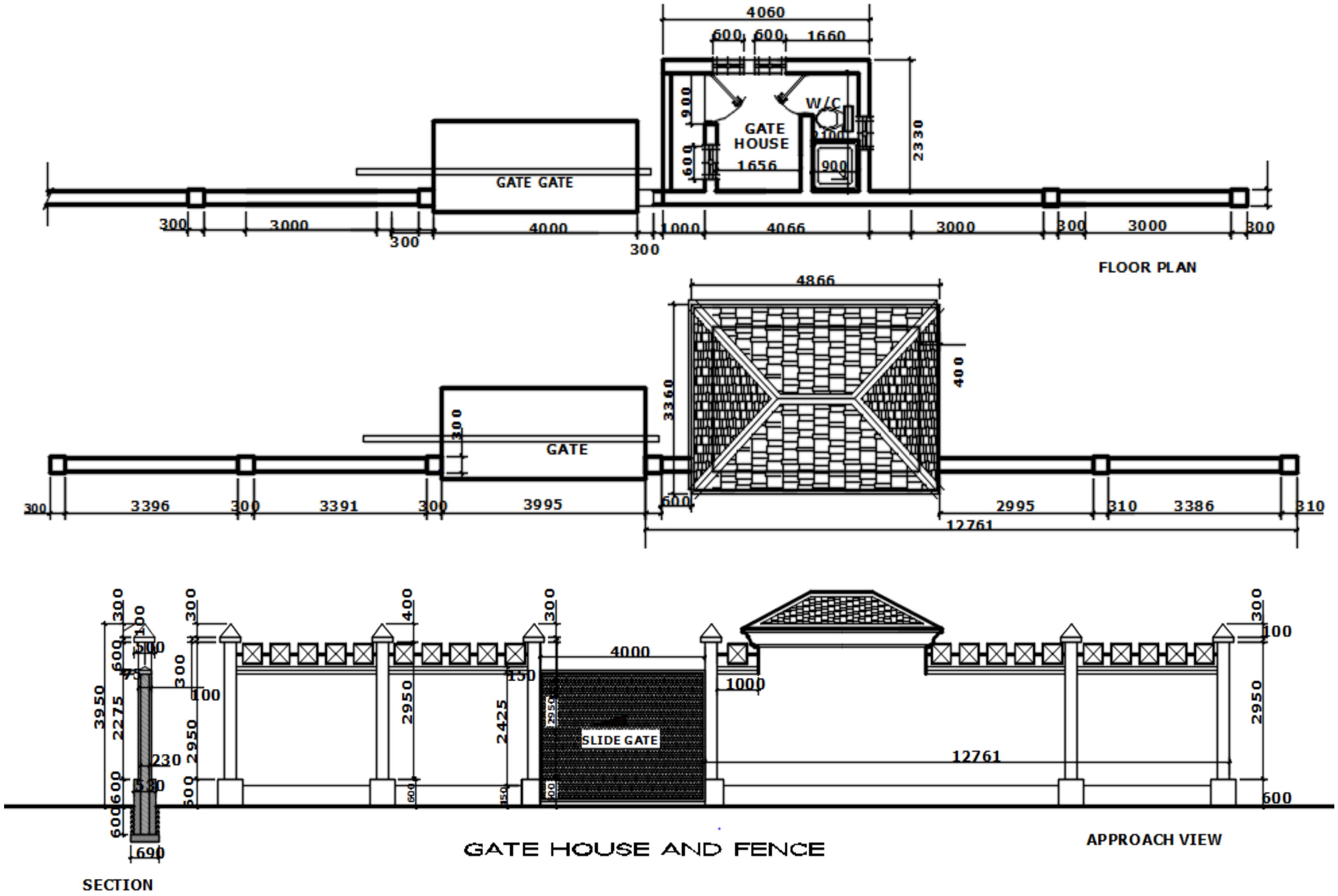


Figure C7: Layout of Substation Gatehouse and Fence (All Dimensions in mm)

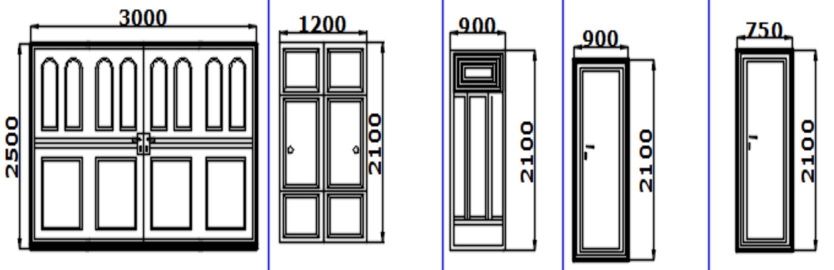
DOOR SCHEDULE					
PROFILES					
SYMBOL	D1	D2	D3	D4	D5
DIMENSION	3000X2500	1200X2100	900X2100	900X2100	750X2100
DESCRIPTION	PURPOSE MADE STEEL DOOR	CRITAL DOOR	CRITAL DOOR	PURPOSE MADE FLUSH DOOR	PURPOSE MADE FLUSH DOOR
LOCATION	MAIN ENTRANCE	ENTRANCE TO 11KV & 33KV CONTROL	CORRIDOR ENTRANCE	CONTROL ROOM	BATTERY ROOM & TOILETS
NO. REQD.	1	2	1	3	2

Figure C8: Substation Site – Door Schedule Design

2 Safety Requirements: Control Panels

1. Safety requirements of Control Panels include the following:
   a. No live conductor shall be exposed on the front of any control panel and the back of any control panel of which bare live metal is mounted shall be made inaccessible (except to authorised persons) using earthed screens or otherwise.
   b. Every door leading to the back of a control panel shall be provided with a spring or other approved device which shall ensure that the door remains open when not properly shut or locked.
   c. An appropriately rated insulating mat or insulating stand shall be provided for the protection of operators in front of control panels of every control room and substation. A similar arrangement shall also be provided in the screened-in space at the rear of every control room and substation control panel (not being of the enclosed iron-clad cubicle type).
   d. All panels shall have marked thereon, near each switch, the name of the feeder controlled by such switch.
   e. All control room and substation control panels shall be provided with at least two different and independent earth connections, connected in parallel, to which all metal frames, all metal instrument cases (unless otherwise protected) and other metal parts thereof shall be connected. Means shall be provided to test the earth electrode resistance of these earth connections individually.
   f. The terminal blocks shall be of extendable design, 650 V category, rated to carry the maximum expected current on the terminals continuously, provided with test links and isolating facilities wherever required and suitable for connecting the designed size of conductors on each side.
   g. Control and instrument lead from the switchboards or other equipment will be brought to terminal boxes or control cabinets in conduits. All interphase and external connections to equipment or to control cubicles will be made through terminal blocks having a locking characteristic to prevent the cable from escaping from the terminal clamp.

3 Cables

Table C2: Mechanical Properties of Selected Cables

Wire Type	The diameter of Solid Wire (mm)	Tensile Stress (N/mm^2)	Elongation (%)
Annealed copper wire	No less than 0.10, no more than 0.28		No less than 15.0
	More than 0.28, no more than 0.29		No less than 20.0
	More than 0.29, no more than 0.45		No less than 20.0
	More than 0.45, no more than 0.70		No less than 20.0
	More than 0.70, no more than 1.6	No less than 196, below (462 - 10.8d)	No less than 25.0

	More than 1.6, no more than 7.0		No less than 30.0
	More than 7.0, no more than 16.0		No less than 35.0
Annealed aluminium wire	No less than 2.0, no more than 5.2	No less than 59, below 98	No less than 10.0
	More than 5.2, no more than 7.0		No less than 20.0
Hard-drawn aluminium wire	No less than 1.2, no more than 1.3	No less than 159	No less than 1.2
	More than 1.3, no more than 1.5	No less than 186	No less than 1.2
	More than 1.5, no more than 1.7	No less than 186	No less than 1.3
	More than 1.7, no more than 2.1	No less than 182	No less than 1.4
	More than 2.1, no more than 2.4	No less than 176	No less than 1.5
	More than 2.4, no more than 2.7	No less than 169	No less than 1.5
	More than 2.7, no more than 3.0	No less than 166	No less than 1.6
	More than 3.0, no more than 3.5	No less than 162	No less than 1.7
	More than 3.5, no more than 3.8	No less than 162	No less than 1.8
	More than 3.8, no more than 4.1	No less than 159	No less than 1.9
	More than 4.1, no more than 5.2	No less than 159	No less than 2.0
	More than 5.2, no more than 6.6	No less than 155	No less than 2.2
Semi hard-drawn aluminium wire	No less than 1.2, no more than 1.3	No less than 98, below 159	No less than 1.2
	More than 1.3, no more than 1.5	No less than 98, below 186	No less than 1.2
	More than 1.5, no more than 1.7	No less than 98, below 186	No less than 1.3
	More than 1.7, no more than 2.1	No less than 98, below 183	No less than 1.4
	More than 2.1, no more than 2.4	No less than 98, below 176	No less than 1.5
	More than 2.4, no more than 2.7	No less than 98, below 169	No less than 1.5
	More than 2.7, no more than 3.0	No less than 98, below 166	No less than 1.6
	More than 3.0, no more than 3.5	No less than 98, below 162	No less than 1.7

	More than 3.5, no more than 3.8	No less than 98, below 162	No less than 1.8
	More than 3.8, no more than 4.1	No less than 98, below 159	No less than 1.9
	More than 4.1, no more than 5.2	No less than 98, below 159	No less than 2.0
	More than 5.2, no more than 6.6	No less than 98, below 155	No less than 2.2

Annexe D: Design and Implementation Guidelines for Solar Mini-Grids

1 Technical Schedule Guarantees

1. Specific fuel consumption (g/kWe) and power output (kWe) shall be quoted at standard (ISO) ambient conditions and 45°C. Although, it's not the highest possible ambient this temperature will be used for assessment of the equipment performance in hot conditions.
2. There shall be adherence to the de-rating curves or correction curves or formulae or calculations applicable to the particular diesel generator for the power de-ration or fuel consumption for the ambient conditions.

2 Diesel Generators: Operating Concept

1. **General Guidelines:**
   a. The diesel engine, alternator, generator control panel, fuel delivery system and fuel storage system shall comply with the current versions of the following applicable standards or equivalent standards.
   b. To provide optimal fuel efficiency and maximum machine life, several generators in series to match the load profile provided in each order shall be provided, instead of one large generator which would run at high inefficiency.
   c. In cases where the load grows beyond the capacity of the installed diesel generator(s), it shall be possible to increase load capacity following a modular concept, adding multiple units to form a single combined source of electricity or mini-grid.
   d. The operation concept also considers the future connection of PV modules or other RE sources (supplied by others; either with or without batteries) to the generation units.
   e. Each diesel generator unit shall be able to operate as stand-alone within the mini-grid.
   f. Manual switchover control panel, automatic switchover control panel for single machine control, and also, panels for full synchronisation control shall be provided separately. The synchronisation control in each case shall be designed for the following modes of operation:
2. **Diesel Only:**
   a. The first diesel unit initially supplies all loads. When the load demand approaches a pre-set threshold (e.g., 70% of the unit's nominal capacity), the second unit is automatically activated and synchronized to share the load.
   b. Switching off and disconnecting the second unit from the grid will take place when the load is below a certain threshold (e.g., 60% of unit capacity).
   c. The diesel gen-sets are running in isochronous or baseload control mode and are adjusted to an internal speed drop.
3. **PV-diesel Hybrid:**
   a. For PV-diesel hybrid generation, the diesel units operate as stand-by systems on the main AC bus together with the PV modules.

b. Diesel gen-sets are operated if the load exceeds a certain threshold (e.g., 70% of module or battery capacity) or the Depth of Discharge (DOD) of the battery is below a preset threshold (e.g., 50%).

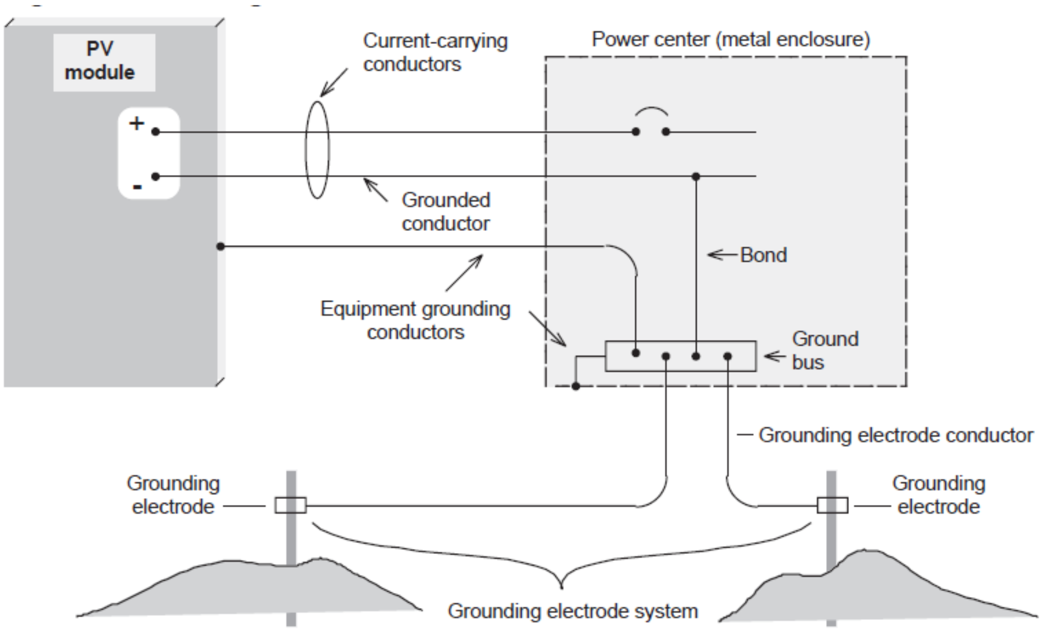
4. **Base Load / Isochronous Load Control**:

a. In all operation modes (automatic, semi-automatic and manual), it shall be possible to select between Base Load / Isochronous Load Control.
b. Baseload control is by operator set point for fixed kW and power factor output.
c. Isochronous Load Control is by automatic load sharing control.

5. **Local Test**:

a. When initiated exclusively from the diesel generator control panel, the diesel generator and its ancillary components will operate at full speed to verify mechanical and electrical excitation.
b. However, synchronization to the load will not occur.

3 PV Module Designs: Grounding and Equipotential Bonding



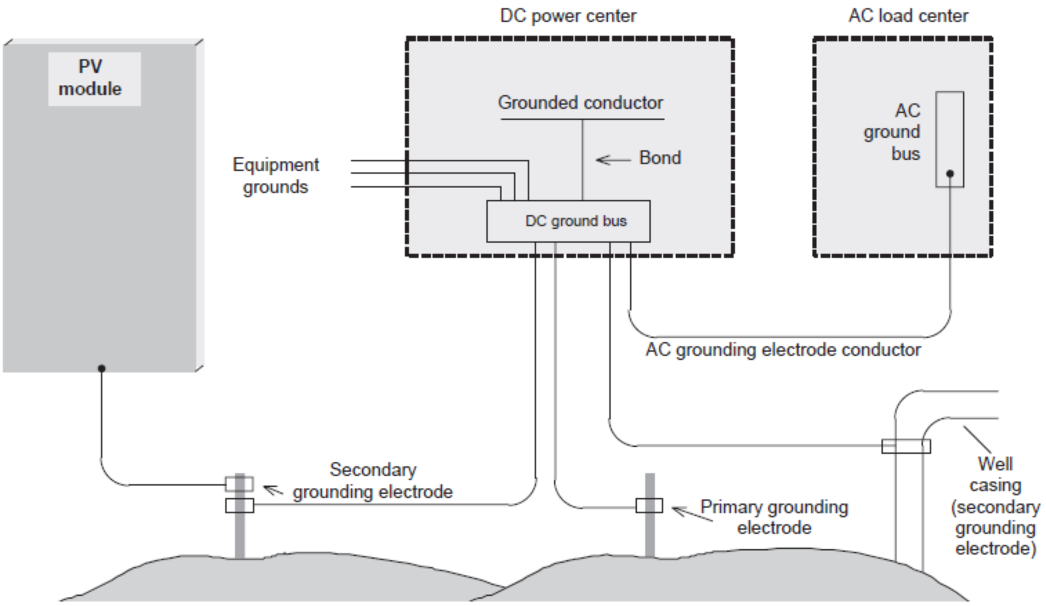


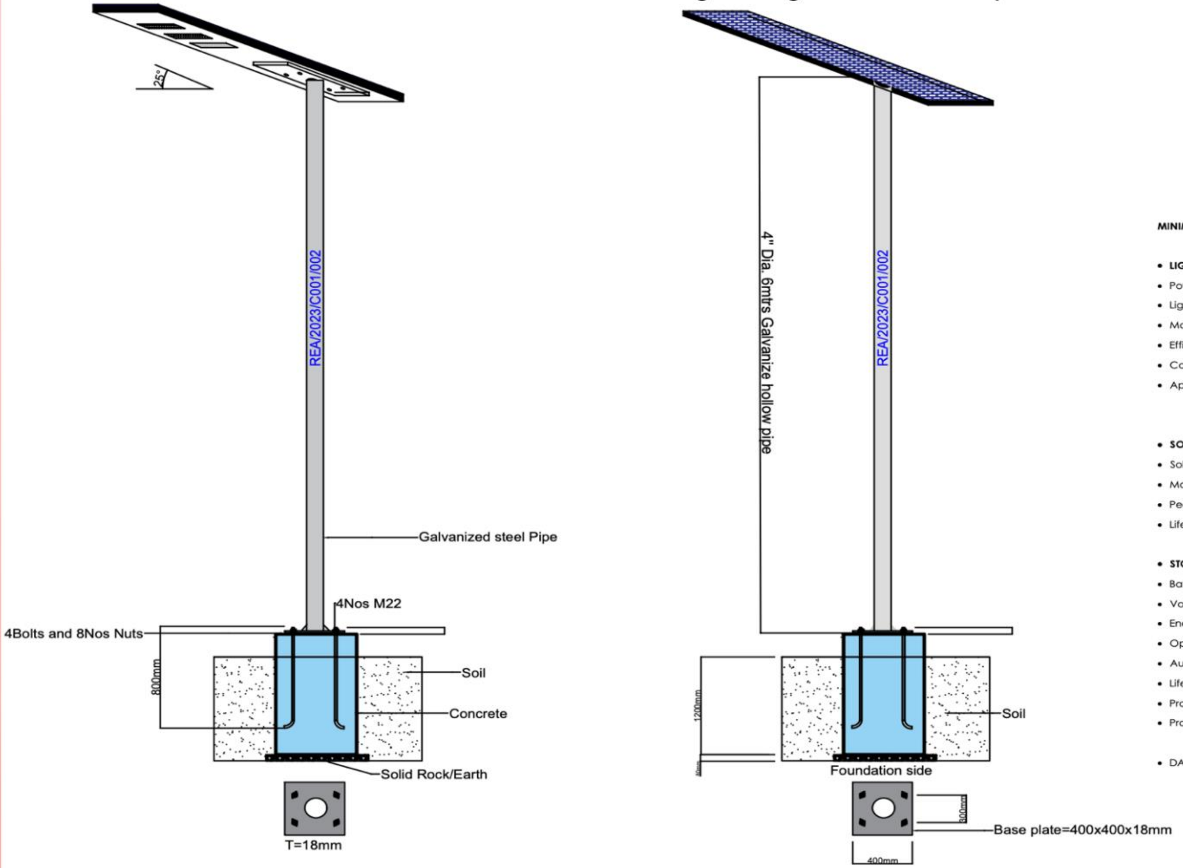
Figure D1: Grounding and Equipotential Bonding Guidelines for PV Modules

1 Solar Street Lights Design

RURAL ELECTRIFICATION AGENCY
ENERGY=EMPOWERMENT=EFFICIENCY

FEDERAL MINISTRY OF POWER

60W Solar Street Light Design and Minimum Specification



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MINIMUM SPECIFICATION OR ITS EQUIVALENT SOLAR STREET LIGHT DESIGN

- **LIGHTING**
- Power consume by Lamp >60W
- Light output(System Lumen) >6000lm
- Maximum light efficiency(im/w) >160lm/W
- Efficiency of LED controller circuit 85%
- Colour of LEDs White(3,000k-7,000k))
- Application Road Square lighting with motion sensor
- **SOLAR PANEL**
- Solar Panel type MONO-Crystalline Horizontal
- Maximum rated power 80Wp
- Peak Power voltage 36.0V
- Lifespan 80% power after 25years
- **STORAGE**
- Battery type Lithium Battery
- Voltage 24V
- Energy Stock 480Wh
- Operating temperature range 20°C to +70°C
- Autonomy up to 5days
- Lifespan 10years
- Product certification EC
- Product warranty 3years

- DAILY BATTERY STORAGE CAPACITY SHOULD SUSTAIN MINIMUM OF 20HOURS.

Head Project Design
Tech. Service Directorate

TITLE: DEPLOYMENT OF SOLAR STREET LIGHT	PREPARED 2023 / SUBMITTED 2023	PROJECT NAME & LOCATION:	SHEET CONTENT:	DESIGN BY:	DRAWING BY:	CHECKED BY:	APPROVE BY:	SHEET NO:
		PROPOSED 60W AIO SOLAR STREET LIGHT	LAYOUT OF SSL	PROJECT DESIGN UNIT	PROJECT DESIGN UNIT	DIRECTOR PROJECTS	ED TECHNICAL SERVICES	60W SSL-001

Figure E1: Design and Minimum Specifications for 60W Solar Street Light

60W, 80W AND 120W Solar Street Light Design and Minimum Specification

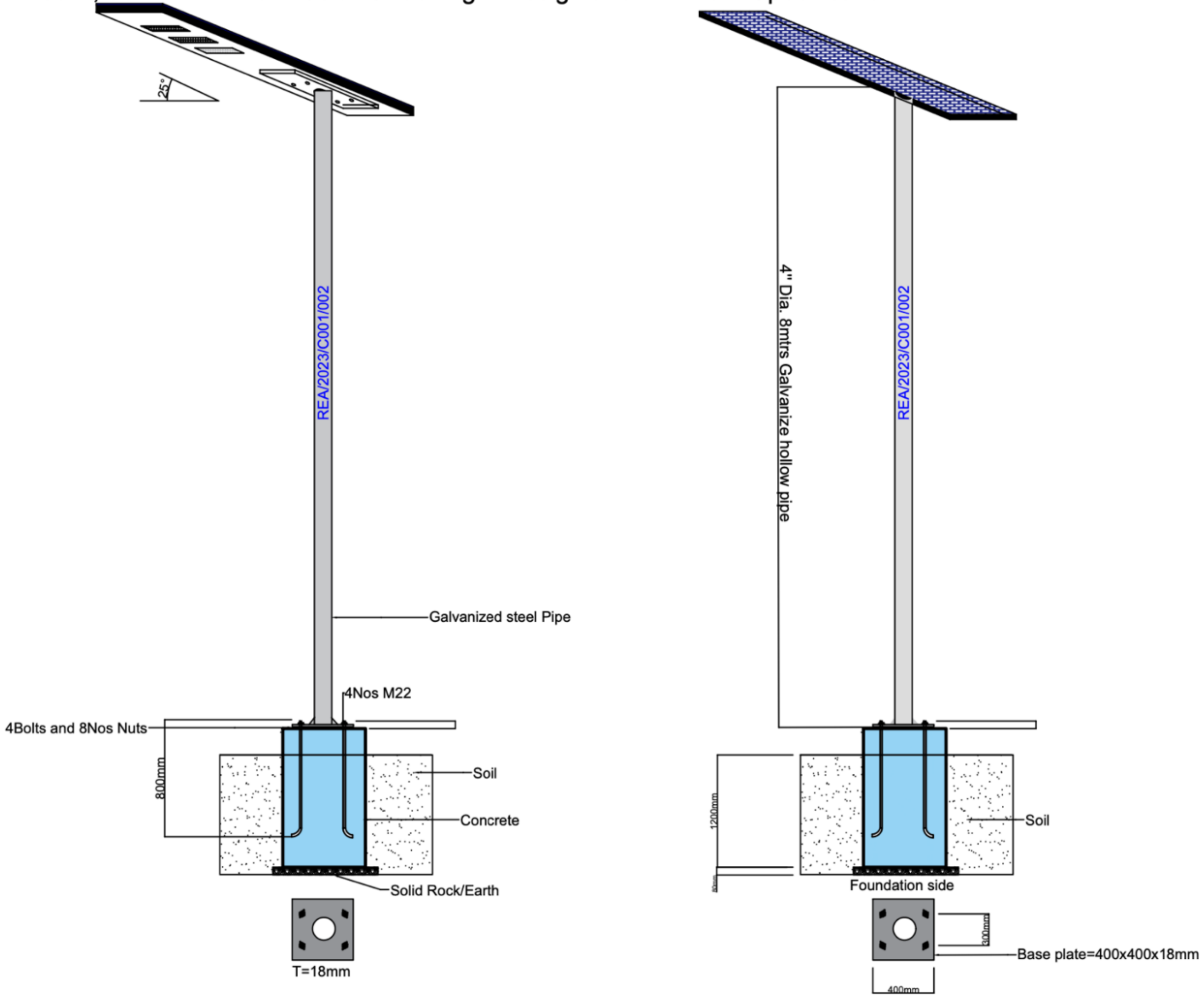

Figure E2: Design and Minimum Specifications for 60W, 80W, and 120W Solar Street Lights

Annexe F: Gender and Social Inclusion (GESI) Requirements and Strategies for Mini-Grid Development and Rural Electrification

1 GESI-Specific Requirements for Mini-Grid Projects

1. This annex outlines specific GESI-related requirements to be embedded in mini-grid project design, execution, and monitoring.
2. The objective is to ensure equitable energy access, representation, and leadership opportunities for women, persons with disabilities (PWDs), and other marginalized groups.

2 GESI-Specific Targets and Objectives in Project Planning & Design

1. **GESI Targets in Mini-Grid Projects:**

   a. At least 33% of electrified households and businesses shall be headed by women or PWDs.
   b. GESI-focused indicators shall be embedded in project design, implementation, and monitoring.
   c. Policies shall explicitly address energy access barriers for marginalized groups.
   d. Electrification plans and designs shall prioritize women-led businesses, community centres, and facilities serving marginalized groups.

3 GESI-Specific Language in Project Documentation

1. Project proposals, funding agreements, and monitoring frameworks shall include GESI-related commitments.
2. Mini-grid projects shall clearly define beneficiary demographics, ensuring inclusive outreach.

4 Women's and PWDs' Participation in Decision-Making

1. **Leadership Representation in Energy Governance:**

   a. At least 30% of leadership roles in mini-grid management bodies and community electricity cooperatives shall be held by women and PWDs.
   b. Community advisory committees shall be gender-balanced and include representatives of marginalized groups.
   c. Mini-grid project consultations shall be conducted at times and locations accessible to women and PWDs.

5 Capacity Building for Women and PWDs

1. Leadership and financial literacy training shall be provided to women and marginalized groups to support active participation.
2. Community energy education programmes shall be tailored for women and PWDs to ensure informed engagement.

6 Economic Participation Through Productive Use of Energy

1. **Women and PWDs in Energy-Based Enterprises:**

   a. Dedicated funding, grants, or micro-loans shall be allocated to women and PWD-led businesses.
   b. Business development training shall be provided to women and marginalized groups, covering financial management and energy-efficient technologies.

7 Women's Participation in High-Value Sectors

1. Mini-grid projects shall increase energy access for agro-processing, refrigeration, ICT, and manufacturing businesses run by women and marginalized groups.
2. Vocational training in solar installation, energy system maintenance, and appliance repair shall be accessible to women and PWDs.

8 Data Collection and Use of GESI-Specific Indicators

1. **GESI Data Collection:**
   a. Project data shall be disaggregated by gender, disability status, age, and income level.
   b. Mini-grid developers shall report on the number of women and PWD beneficiaries.
2. **Key GESI Performance Indicators:**
   a. Women's and PWDs' participation in leadership roles within community energy governance.
   b. Incomes generated through energy-powered activities among women and marginalized groups.
   c. Affordability and willingness-to-pay metrics for women-headed households and PWD-led businesses.
3. **Annual GESI Impact Reporting:**
   a. Mini-grid projects shall submit annual reports highlighting GESI impact.
   b. Third-party GESI audits shall be conducted to evaluate implementation and effectiveness.

9 Addressing GESI Gaps in Mini-Grid Implementation

1. **GESI Targets in Electrification Programmes:**
   a. Projects shall define a minimum percentage of women- and PWD-led households/businesses to be connected.
   b. Gender-balanced representation shall be institutionalized in all community energy cooperatives.
2. **Training Programmes for Women and PWDs:**
   a. At least 40% of participants in mini-grid technical and operational training shall be women.
   b. Specialized training and certification pathways shall be provided for PWDs in renewable energy sectors.
3. **Data Collection and GESI Monitoring:**
   a. All mini-grid projects shall report on GESI-disaggregated beneficiary data.
   b. GESI impact assessments shall be a prerequisite for project approvals and funding.
   c. A monitoring framework shall be established to track compliance with these GESI requirements in rural electrification initiatives.