AFSEC

GUIDELINES FOR

GRID INTEGRATION OF RENEWABLE ENERGY GENERATION IN AFRICA

AFSEC GUIDE 13: 2026
First edition

AFSEC – 50013-04-01

Acknowledgments

The development of this guide was supported by PTB, Germany.

AFSEC also acknowledges the support of IEC by making available referenced standards and the participation of Leon Drotsche (PTB Expert), AFSEC TC08, AFSEC TC64 and AFSEC TC82 Joint Working Group members.

Project leader Alphonse Voegborlo, supported by Eldad Appiah
Final editing team:

- Alphonse Voegborlo
- Comfort Masike
- Tom Simiyu
- Olivier Mukeshimana
- Cyrus Khwa Khalusi
- Pitso Sekhoto
- Patrick Nzabamwita
- Eldad Appiah
- Kareman Fathy

AFRICAN UNION AFREC ENERGY

german cooperation
DEUTSCHE ZUSAMMENARBEIT

PTB
Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

GUIDELINES FOR
GRID INTEGRATION OF RENEWABLE ENERGY GENERATION IN AFRICA

Contents

AFSEC Foreword

The African Electrotechnical Standardization Commission (AFSEC) has been established by the Association of Power Utilities of Africa (APUA) as subsidiary of AFREC under the auspices of the African Union to provide a collaborative framework for stakeholders in African member states, through their national Electrotechnical committees, with the main mandate to harmonize/ develop Electrotechnical standards, and the associated conformity assessment requirements including assessing conformity to standards, aiming to improve access to electricity and hence the wellbeing of the African population of Africa.

The African Electrotechnical Standardisation Commission (AFSEC) is organised around the Council consisting of Statutory Members representing the National electrotechnical Committees of African countries, the Management Committee; the Executive Secretariat; the Standards Management Committee, the Conformity Assessment Committee and the Technical Committees.

The AFSEC Strategic Goals (2025-2029) were approved at the 9th General Assembly Meeting held in Kigali Rwanda, in September 2024, see Annex C for more details.

AFSEC is cooperating with different International / Regional Institutions through signed MoUs /agreements, or Joint Technical committees, namely APUA, ARSO, IEC, IEEE, CENELEC, SAC to harmonise Regional Standard's for the Africa Continent.

The Agreements with Standards Institutions (IEC or IEEE) allow to AFSEC to adopt the reviewed Standards as African Regional Standards. AFSEC as one of the Pan African Quality Infrastructure PAQI Institutions participated in the development of Africa Quality Policy approved by AUC in 2023, as well as in the implementation of Standards used in the processing machinery of Cassava in Africa.

AFSEC is mentioned in Annex6 of Protocol of Trade and Goods of the African Continental free trade agreement (AfCFTA) for its standards to be adopted by African Countries.

Introduction

The integration of renewable energy (RE) into Africa's electrical grids presents both opportunities and challenges, particularly in managing the variability and uncertainty inherent to sources like wind and solar. To address these challenges, the African Electrotechnical Standardization Commission (AFSEC), has initiated the development of a harmonized Interconnection Guideline. This guideline, led by a Joint Working Group (JWG) comprising members of AFSEC Technical Committees TC 8, TC 82, TC 64, aims to support the reliable integration of RE systems across the continent by aligning with national grid codes and international standards.

With the growth of renewable energy, the electric grid is shifting. To make sure the grid is ready to meet the rising tide of clean energy technologies, advanced integration including grid modernization and visions for future designs is needed.

Grid integration of renewable energy means reimagining operation and planning for a reliable, cost-effective, and efficient electricity system with cleaner new energy generators. This includes where it is built, how it is optimized, and how it is used to power a carbon-free future. It means providing grid operators with the situational awareness and control capabilities they need to plan and manage a rapidly changing energy resource mix. The path forward involves assessing long-range demands and evaluating pathways for efficient performance. For example, projecting atmospheric patterns can help guide and maximize siting of solar or wind power. It also includes evaluating, scheduling, and optimizing future energy market design using advanced modelling and simulation to understand the operational connections to renewable energy availability, generator performance, grid reliability, and electricity delivery to customers.

Grid integration of renewable energy includes building resilience against threats, such as natural disasters and cyberthreats. It also involves overcoming challenges, such as instantaneous to seasonal unavailability of renewable resources. By developing solutions and mitigative measures across both information technology and operational technology systems, we can prepare for a cleaner, greener, and more resilient energy landscape. This guide outlines the criteria that a Renewable Energy Plant must meet for the electrical network operator to approve a safe connection to the utility grid, ensuring that all quality-of-supply requirements are satisfied and the integrity of the grid is not compromised.

As electricity access in Africa is very challenging mini/micro grid solutions are being pursued by Utilities. This guide also addresses this solution as an independent electrical source, supplying customers, that need to meet the associated electrical grid standards to ensure a safe, quality, secured and sustainable electrical system.

The guide structure is based on commonalties identified in AFSEC member countries grid codes – see Annex B.

This guide does not supersede applicable local and/or regional grid codes, where they are in place. Grid code developers and system operators are advised to consider the provisions in this guide when reviewing the grid codes to promote alignment within the continent.

1 SCOPE

Integration of renewable energy sources into the grid is a relatively new advancement for supplying electricity to the distribution network. Since Renewable Energy RE resources such as wind and solar generally increase variability and uncertainty associated with power system operations, reaching high penetrations of these resources on the grid requires an evolution in power system planning, installation, operation and maintenance.

This document provides guidelines on the technical requirements for the integration of renewable energy (RE) plants with utility electrical power systems in Africa. It provides criteria relevant to the performance, operation, testing, safety considerations, and maintenance of RE interconnections. The guideline covers general requirements, power quality, response to abnormal system conditions, active and reactive power control, frequency support, islanding, etc. It also includes provisions for design, testing, installation and commissioning of RE plants and associated equipment, including Battery Energy Storage Systems (BESS).

The requirements apply to renewable energy technologies such as solar photovoltaic (PV), wind, hydro and hybrid systems interconnected to transmission and distribution networks, including microgrids.

2 REFERENCE STANDARDS

The following standards contain provisions which, through reference in this text, constitute provisions of this guide. All normative documents are subject to revision and, since any reference to a normative document is deemed to be a reference to the latest edition of that document, parties to agreements based on this guide are encouraged to take steps to ensure the use of the most recent editions of the normative documents indicated below. Information on currently valid national and international standards and specifications can be obtained from the appropriate national standards organization.

The following referenced documents are required in the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies:

IEC TS 62786-1
Distributed energy resources connection with the grid – Part 1: General requirements

IEC 61000-3-6
EMC – Part 3-6: Limits – Assessment of emission limits for connecting distorting installations to MV, HV and EHV power systems

IEC 61000-3-7
EMC – Part 3-7: Limits – Assessment of emission limits for connecting fluctuating installations to MV, HV and EHV power systems

IEC 61400-21-1
Wind energy generation systems – Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines

IEC 62109-1
Safety of power converters for photovoltaic power systems – Part 1: General requirements

IEC 62109-2
Safety of power converters for photovoltaic power systems – Part 2: Requirements for inverters

IEC 61000 (series)
Electromagnetic compatibility (EMC) – All Parts

IEC 62271 (series)
High-voltage switchgear and controlgear – All Parts

IEC 61850 (series)
Communication networks and systems for power utility automation – All Parts

IEC 60076 (series)
Power Transformers – All Parts

IEC 60255-1
Measuring relays and protection equipment – Part 1: Common requirements

IEC 60909
Short-circuit currents in three-phase a.c. systems – Calculation of currents

IEC 60364-7-712
Low-voltage electrical installations – Part 7-712: Solar photovoltaic (PV) power supply systems

IEC TR 63401-3
Dynamic characteristics of inverter-based resources in bulk power systems – Part 3: Fast frequency response and ride-through

IEC 61936-1
Power installations exceeding 1 kV AC and 1.5 kV DC – Part 1: AC

IEC 60364-5-54
Low-voltage electrical installations – Earthing arrangements and protective conductors

IEC 62446-2
Requirements for testing, documentation and maintenance – Part 2: Grid-connected PV systems

IEC TS 63060
Electric energy supply networks – General aspects and methods for maintenance of installations and equipment

IEC 60364-6
Low-voltage electrical installations – Part 6: Verification

IEC 62548
Photovoltaic (PV) arrays – Design requirements

IEC 61557
Electrical safety in low-voltage distribution systems up to 1,000 V AC / 1,500 V DC – Equipment for testing, measuring or monitoring protection

IEC 61010
Safety requirements for electrical equipment for measurement, control, and laboratory use

IEC 60255-121
Measuring relays and protection equipment – Part 121: Functional requirements for distance protection

IEC 60255-127
Measuring relays and protection equipment – Part 127: Functional requirements for overcurrent protection

IEC 60255-181
Measuring relays and protection equipment – Part 181: Functional requirements for frequency protection

IEC 60255-187
Measuring relays and protection equipment – Part 187: Functional requirements for differential protection

IEC 62934
Grid integration of renewable energy

IEC 62898 (series)
Microgrids – All Parts

IEC TS 62898-1:2023
Microgrids – Part 1: Guidelines for microgrid projects planning and specification

IEC TS 62898-2
Microgrids – Part 2: Operation guidelines

IEC TS 62898-3-1
Microgrids – Part 3-1: Protection and dynamic control

IEC 60364 (series)
Low-voltage electrical installations – All Parts

IEC 61427 (series)
Secondary cells and batteries for renewable energy storage – General requirements and methods of test

IEC 61400 (series)
Wind turbines – All Parts

IEC 61730 (series)
Photovoltaic (PV) module safety qualification

IEC TS 62898-1
Microgrids – Part 1: Guidelines for microgrid projects planning and specification

IEC TS 62898-2
Microgrids – Part 2: Guidelines for operation

IEC TS 62898-3-1
Microgrids – Part 3-1: Technical Requirements – Protection and Dynamic Control

IEC 60050
International Electrotechnical Vocabulary

IEEE Std 1815
IEEE Standard for Electric Power Systems Communication – Distributed Network Protocol (DNP 3)

IEEE C37.94
IEEE Standard for N times 64kps Optical Fibre Interfaces between Teleprotection and Multiplexer Equipment

IEC 62116
Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures

IEC 60870-5-101
Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks

IEC 60870-5-104
Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles

IEC TS 62933-3-1
Electrical energy storage (EES) systems – Part 3-1: Planning and performance assessment of electrical energy storage systems – General specification

IEC 62446-1
Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection

IEC TR 63401-3 Dynamic characteristics of inverter-based resources in bulk power systems – Part 3: Fast frequency response and frequency ride-through from inverter-based resources during severe frequency disturbances

3 TERMS AND DEFINITIONS

For the purpose of this guide, the following terms and definitions apply.

Contingency
Event, usually involving the loss of one or more elements, which affects the Power System at least momentarily.

Demand
The magnitude of an electricity supply, expressed in kilowatts or kilovoltamperes.

Distributed Energy Resource (DER)
Generators (with their unit auxiliaries, protection and connection equipment), including loads having a generating mode (such as electrical energy storage systems), connected to a low voltage or a medium-voltage network.

Droop
The MW/Hz characteristic according to which governing will take place. This is expressed as the percentage increase in frequency that will theoretically cause a unit to go from MCR to zero.

Element of power system
Any electric device with terminals that may be connected to other electric devices. e.g., generator, transformer, circuit breaker, or bus section.

Emergency
A situation where generators, transmission or distribution service providers have an unplanned loss of facilities, or another situation beyond their control, that impairs or jeopardises their ability to supply their system demand.

Fault
An unplanned occurrence or defect in an item which may result in one or more failures of the network.

Fault Current
The current flowing at a given point of a network resulting from a fault at another point of the network.

Generation (of electricity)
A process of producing electrical energy from other forms of energy.
Note 1 to entry: The amount of electric energy produced, usually expressed in kilowatt-hours (kWh) or megawatt hours (MWh).

Interconnected power system (IPS)
Interconnected electrical power system within a wide area, comprised of system elements assigned to different local areas within the same operating authority or a different operating authority (e.g., ISOs) on which faults or disturbances can have a significant adverse impact outside of the local area.

Load
Device intended to absorb power supplied by another device or an electric power system.

Operating limit
The maximum value of the most critical system operation parameter(s) which meets: (a) pre-contingency criteria as determined by equipment loading capability and acceptable voltage conditions, (b) stability criteria, and (c) post-contingency loading and voltage criteria.

Reliability
The ability of an item to perform a required function under given conditions for a given time interval.

Outage
The state of an item of being unable to perform its required function.

Reserved capacity
The contracted amount of capacity, expressed in megavolt-amperes (MVA) or megawatts (MW), that a system operator or service provider allocates to a customer or generating plant at a particular point of supply.

Short circuit.
Accidental or intentional conductive path between two or more conductive parts, whether made accidentally or intentionally, forcing the electric potential differences between these conductive parts to be equal to or close to zero (relatively low impedance). Short circuit current is electric current in a given short circuit.

Stability
Ability of an electric system to maintain a state of equilibrium during normal and abnormal conditions or disturbances.
Note 1 to entry: Power system stability can be classified as voltage, rotor angle and frequency stability.

Network Security
The probability of not having an unwanted operation, or the ability of the power system to continue to operate satisfactorily following a contingency.

Transmission system (TS)
The whole of the means of transmission between two points, comprising the transmission medium, terminal equipment, any necessary intermediate equipment and any equipment provided for such ancillary purposes as power feeding, supervision and testing.

Point of Common Coupling (PCC)
Point of a power supply network, electrically nearest to a particular load, at which other loads are, or may be, connected.
Note 1 to entry: These loads can be either devices, equipment or systems, or distinct network users' installations.

Reactive Power Voltage Control
Voltage control by the adjustment of reactive power generation in a power system.

Flicker
Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.

Voltage Unbalance
In a polyphase system, a condition in which the r.m.s. values of the phase voltages or the phase angles between consecutive phases are not all equal.

Ancillary Services
Services necessary for the operation of an electric power system provided by the system operator and/or by power system users.

Black Start
Start-up of an electric power system from a blackout through internal energy resources.

Microgrid
Group of interconnected loads and distributed energy resources with defined electrical boundaries forming a local electric power system at voltage levels of distribution of electricity, that acts as a single controllable entity and is able to operate in island mode.
Note 1 to entry: This definition covers both (utility) distribution microgrids and (customer owned) facility microgrids.

Battery Energy Storage System (BESS)
Electrical energy storage system with an accumulation subsystem based on batteries fitted with secondary cells.
Note 1 to entry: Battery energy storage systems include flow battery energy systems.

Independent Power Producer (IPP)
Producer whose principal activity is to generate electric energy with the sole intention of its sale to distribution business entities, or, via a third-party electric power system, to customers.

Renewable Energy
Primary energy the source of which is constantly replenished and will not become depleted.
Note 1 to entry: Examples of renewable energy are: wind, solar, geothermal, hydropower.
Note 2 to entry: Fossil fuels are non-renewable.

4 GRID CONNECTION REQUIREMENTS

4.1 Ownership of RE Plants

Ownership of Renewable Energy (RE) plants may reside with a variety of entities, including Independent Power Producers (IPPs), public utilities, government agencies, community-based organizations, or through Public-Private Partnerships (PPPs). The ownership structure must be clearly defined and documented during the project development and grid connection application stages.

All owners of RE plants connected to the grid shall:

- Be responsible for ensuring compliance with applicable grid codes, technical standards, and interconnection requirements.
- Maintain all necessary licenses, permits, and authorizations as required by national regulatory authorities.
- Be accountable for the operational performance, maintenance, and reliability of the facility.
- Facilitate coordination with the System Operator (SO) or relevant Transmission / Distribution System Operator (TSO / DSO), especially regarding operational data exchange, dispatch instructions, and grid support services (e.g., voltage and frequency control).
- Ensure that the RE plant is adequately insured against operational, environmental, and force majeure risks.
- Have in place a duly executed Power Purchase Agreement (PPA) or equivalent contractual arrangement with the designated off-taker, which sets out the commercial and operational obligations of both parties.

For technical compliance, the Point of Connection (POC) and Point of Common Coupling (PCC), as agreed with the relevant Transmission or Distribution System Operator, shall serve as the reference point at which all requirements specified in this guideline are to be measured and enforced.

Where the RE plant is owned by a third party but operated by a different entity e.g., through a Build-Operate-Transfer (BOT) or an Operation & Maintenance (O&M) contract, the ownership entity retains ultimate responsibility for ensuring contractual compliance with all applicable grid and regulatory obligations.

4.2 Voltage and Frequency Tolerance

4.2.1 Normal Voltage and Frequency Operating Ranges

Voltage Tolerance
Renewable Power Plants (RPPs) shall be capable of withstanding voltage deviations at the Point of Connection (POC) under both normal and abnormal system conditions, as defined in this guideline. RPPs must aim to maintain active power output during these deviations as much as possible, in accordance with voltage stability requirements. RPPs shall continue to deliver actual active power as long as the voltage at the POC remains within the permissible operating ranges. Automatic disconnection from the grid shall only occur when voltage conditions fall outside these ranges, and only after specified time delays, unless immediate disconnection is required by the grid operator.

Voltage at POC	RPP requirements
$U_{min1} \leq U \leq U_{max1}$	Operate continuously
$U < U_{min2}$ $U > U_{max2}$	Disconnection allowed after time T_{u2}
$U_{min2} \leq U < U_{min1}$ $U_{max1} < U \leq U_{max2}$	Disconnection allowed after time T_{u1}

Table 1- RPP Voltage and Connection Requirements at POC

Voltage at POC	RPP requirements
U_{min1} in per unit	0.9pu
U_{min2} in per unit	0.85pu -0.9pu
U_{max1} in per unit	1.1 p.u
U_{max2} in per unit	1.1pu – 1.2pu
T_{u1} in seconds	10s – 180s
T_{u2} in second	0 s

Table 2 – Voltage (p.u) and Time values for RPP Connection Requirements in Table 1

If the voltage drops below U_{min2}, undervoltage ride through limits as specified in this guideline shall apply. If voltage exceeds U_{max2}, overvoltage ride through limits as specified in the guidelines shall apply. In the event that the voltage falls below Umin2, undervoltage ride-through (UVRT) requirements specified in this guideline shall apply. Similarly, if the voltage exceeds Umax2, overvoltage ride-through (OVRT) provisions shall be enforced.

Frequency Tolerance
Renewable Power Plants (RPPs) must be capable of withstanding some deviations in system frequency without unnecessary disconnection. RPPs shall maintain active power generation as long as the system frequency remains within the allowed operating ranges. Disconnection shall only occur when frequency deviations fall outside the specified boundaries and in accordance with system operator requirements as specified in the grid codes.

Frequency	RPP action required
$f < f_{min2}$ $f > f_{max2}$	Instantaneous disconnection permitted
$f_{min2} \leq f < f_{min1}$ $f_{max1} < f \leq f_{max2}$	Operate for a minimum time T_{f1}
$f_{min1} \leq f \leq f_{max1}$	Operate continuously

Table 3 – Frequency tolerance requirements for connection at POC

Frequency of power system (Hz)	f_{min1}	f_{max1}
50	48.50 to 49.85	50.15 to 51.00
60	58.00 to 59.90	60.2 to 61.5

Table 4 – f_{min1} and f_{max1} values for frequency tolerances

Frequency of power system (Hz)	f_{min2}	f_{max2}	T_{f1}
50	47.00 to 49.80	50.20 to 52.00	2 s to 90 min
60	56.50 to 59.00	60.30 to 62.50	2 s to 90 min

Table 5 – f_{min2}, f_{max2} and disconnection times for frequency tolerances

Related Standard

IECTS 62786-1 – Distributed energy resources connection with the grid – Part 1: General requirements
This standard, which is a Technical Specification, provides principles and general technical requirements for distributed energy resources (DER) connected to an electric power network. It applies to the planning, design, operation and connection of DER to networks. It includes general requirements, connection scheme, choice of switchgear, normal operating range, immunity to disturbances, active power response to frequency deviations, reactive power response to voltage changes, EMC and power quality, interface protection, connection and start to generate electrical power, active power management, monitoring, control and communication, and conformance tests. It is supplemented by additional parts of IEC 62786 series, covering specific aspects.

This document specifies interface and interoperability requirements for connection of DER to a network operating at a nominal frequency of 50 Hz or 60 Hz. These requirements are intended for application at the point of connection (POC) of the DER to the grid. In some situations, the requirements can be the applied at the AC terminals of the generator. Additional parts of IEC 62786 provide more specific requirements.

4.3 Power Quality Requirements

The power quality requirements specified in this section are to be measured at the Point of Common Coupling (PCC).

4.3.1 Harmonics

The increasing integration of renewable energy (RE) plants in grid networks has introduced new challenges in maintaining power quality. One of such issues is the generation of harmonic distortion. Harmonics are voltage or current waveforms whose frequencies are integer multiples of the fundamental frequency (typically 50 Hz or 60 Hz). These are typically produced by power electronic devices such as inverters, converters, and other non-linear loads which are common in RE systems. When injected into the power grid, harmonics can distort the ideal sinusoidal waveform, leading to a range of technical issues including increased losses, overheating of equipment, mal operation of protective devices, and interference with communication systems.

For the connection of renewable energy (RE) plants to the grid at medium-voltage (MV) and high-voltage (HV) levels, the individual and total harmonic emission limits in the related standard shall apply to maintain voltage distortion levels within acceptable thresholds across the power system. Emission limits must be satisfied to ensure that the RE plant does not degrade the power quality or interfere with the stable operation of the grid.

Related Standard

IEC TR 61000-3-6: Electromagnetic compatibility (EMC) – Limits – Assessment of emission limits for the connection of distorting installations to MV, HV, and EHV power systems
This Technical Report, which is informative in its nature, provides guidance on principles which can be used as the basis for determining the requirements for the connection of distorting installations to MV, HV and EHV public power systems (LV installations are covered in other IEC documents).

For the purposes of this report, a distorting installation means an installation (which may be a load or a generator) that produces harmonics and/or interharmonics. The primary objective is to provide guidance to system operators or owners on engineering practices, which will facilitate the provision of adequate service quality for all connected customers. In addressing installations, this document is not intended to replace equipment standards for emission limits.

The report addresses the allocation of the capacity of the system to absorb disturbances. It does not address how to mitigate disturbances, nor does it address how the capacity of the system can be increased. Since the guidelines outlined in this report are necessarily based on certain simplifying assumptions, there is no guarantee that this approach will always provide the optimum solution for all harmonic situations.

4.3.2 Voltage Fluctuations & Flicker

Renewable Energy (RE) plants shall be designed and operated to minimize rapid voltage variations at the Point of Common Connection (POC) that may affect power quality. These voltage fluctuations often caused by variable generation, switching operations, or control system actions can interfere with end-user devices, even if perceptible flicker is not observed. The assessment

and limitation of voltage fluctuations shall be carried out in accordance with the IEC TR 61000-3-7, which define planning levels and provides methods for evaluating the impact of fluctuating power on the network.

Flicker is a visible consequence of voltage fluctuations, typically resulting from rapid and cyclic changes in active power output such as those seen in wind turbines under gusty conditions or solar PV systems under passing cloud cover. Although RE plants are commonly connected at MV or HV levels, their flicker emissions can propagate through the network and impact low-voltage users, particularly lighting. RE plants shall limit flicker emissions to avoid adverse impacts on power quality and maintain compliance with allowable thresholds at the PCC. Flicker severity shall be evaluated using the following metrics: Short-term severity (Pst) and Long-term severity (Plt). These values shall be measured in accordance with IEC 61000-3-7 (Section 6) and in compliance with the planning limits set in the standard.

For example, IEC 61400-21-1 (Section 8) describes measurement for flicker during normal operation, flicker and voltage change during switching operations for wind energy generation systems.

Where required, the mitigation measures for voltage fluctuations and flicker shall be implemented. These include ramp-rate control of active power output, smoothing algorithms, Reactive power compensation, voltage control, and integration of energy storage systems.

Related Standards

IEC TR 61000-3-7: Electromagnetic compatibility (EMC) – Part 3-7: Limits – Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems
This part of IEC 61000 provides guidance on principles which can be used as the basis for determining the requirements for the connection of fluctuating installations to MV, HV and EHV public power systems (LV installations are covered in other IEC documents). For the purposes of this report, a fluctuating installation means an installation (which may be a load or a generator) that produces voltage flicker and / or rapid voltage changes. The primary objective is to provide guidance to system operators or owners on engineering practices which will facilitate the provision of adequate service quality for all connected customers. In addressing installations, this document is not intended to replace equipment standards for emission limits. This report addresses the allocation of the capacity of the system to absorb disturbances. It does not address how to mitigate disturbances, nor does it address how the capacity of the system can be increased. Since the guidelines outlined in this report are necessarily based on certain simplifying assumptions, there is no guarantee that this approach will always provide the optimum solution for all flicker situations. The recommended approach should be used with flexibility and engineering judgment as far as engineering is concerned, when applying the given assessment procedures in full or in part.

IEC 61400-21-1: Wind Energy Generation systems – Part 21-1: Measurement and assessment of power quality characteristics of grid-connected wind turbines

- This standard includes:
- definition and specification of the quantities to be determined for characterizing the electrical characteristics of a grid-connected wind turbine.
- measurement procedures for quantifying the electrical characteristics.
- procedures for assessing compliance with electrical connection requirements, including estimation of the power quality expected from the wind turbine type when deployed at a specific site.

The measurement procedures are valid for single wind turbines with a three-phase grid connection. The measurement procedures are valid for any size of wind turbine, though this part of IEC 61400 only requires wind turbine types intended for connection to an electricity supply network to be tested and characterized as specified in this part of IEC 61400.

4.3.3 Voltage Unbalance

Renewable Energy (RE) plants shall be capable of operating within acceptable limits of voltage unbalance at the Point of Common Coupling (PCC) and shall not introduce excessive unbalance into the network. Voltage unbalance is typically caused by uneven phase loading, asymmetrical faults, or single-phase inverter configurations.

Voltage unbalance can have significant negative effects on Renewable Energy (RE) plants. It reduces the efficiency of inverters, increases thermal stress on transformers and motors, and may cause malfunction of protection systems. Persistent unbalance can also accelerate equipment wear, disrupt control systems, and impair the plant's ability to meet grid code requirements for voltage quality and stability.

At the system level, voltage unbalance increases line losses, causes overheating and derating of three-phase motors, and introduces negative sequence currents that can damage rotating generators. It also degrades overall power quality and reliability, especially in weak or rural networks, where unbalance from one source can propagate and affect other users and grid-connected equipment.

The RE plant shall remain connected to the grid during voltage unbalance conditions where the negative phase sequence component does not exceed 2%, and in accordance with IEC/TR 61000 3-13. Beyond these limits, the plant may disconnect in coordination with the system operator. For example, voltage unbalance and limits for wind turbines is described in IEC 61400-21-1.

4.4 EMC Compatibility

Renewable Energy (RE) plants shall be designed and operated to ensure full electromagnetic compatibility (EMC) with the power system and nearby communication infrastructure. While harmonics are a primary EMC concern and are addressed separately in this guideline (section 4), broader EMC requirements must also be met to prevent electromagnetic interference and ensure the proper functioning of electrical and electronic systems.

All RE plant equipment including inverters, controllers, transformers, SCADA devices, and communication systems shall comply with the relevant parts of the IEC 61000 series, which define limits emissions as well as immunity to external electromagnetic disturbances. Where necessary, EMC mitigation measures should be implemented. Special attention shall be given to preventing interference with nearby substations, telecommunication lines, and sensitive electronic equipment. The RE plant operator shall ensure that the cumulative EMC impact of the plant remains within acceptable planning limits and does not impair grid reliability or communication system performance.

Related Standard

IEC TR 61000 series – Electromagnetic Compatibility
The IEC 61000 series provide guidelines for ensuring electromagnetic compatibility (EMC) among electrical and electronic equipment and systems. It defines the limits, test methods, and performance criteria necessary to control electromagnetic disturbances and ensure that devices can operate reliably in shared electrical environments without causing interference. The provisions cover both emission i.e. the unwanted generation of electromagnetic energy and immunity i.e. the ability of equipment to function correctly in the presence of such disturbances.

4.5 Studies Required for RE Integration

Renewable Energy (RE) plants shall be supported by comprehensive power system studies to ensure stable and reliable integration into the transmission or distribution network. These studies shall evaluate plant performance under normal and disturbed operating conditions and confirm compliance with applicable grid code requirements.

At minimum, the following studies shall be undertaken: load flow, voltage stability, frequency stability, transient stability, short-circuit analysis, protection coordination and power quality assessment. It is also recommended that Electro-Magnetic Transient (EMT) studies be done to ensure most risks are identified and adequately mitigated. Representative models, specific or generic as the case may be, may be used for this purpose.

Related Standards / Codes:

- National Grid Code Requirements for RE Integration
- Utility-specific protection and system planning standards

IEC 60909-0: Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents
This standard is applicable to the calculation of short-circuit currents in low-voltage three-phase AC systems, and in high-voltage three-phase AC systems, operating at a nominal frequency of 50 Hz or 60 Hz. It establishes a general, practicable and concise procedure leading to results which are generally of acceptable accuracy and deals with the calculation of short-circuit currents in the case of balanced or unbalanced short circuits.

IEC 61850-7-420: Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources and distribution automation logical nodes
This standard defines the IEC 61850 information models to be used in the exchange of information with distributed energy resources (DER) and Distribution Automation (DA) systems. DERs include distribution-connected generation systems, energy storage systems, and controllable loads, as well as facility DER management systems, including aggregated DER, such as plant control systems, facility DER energy management systems (EMS), building EMS, campus EMS, community EMS, microgrid EMS, etc. DA equipment includes equipment used to manage distribution circuits, including automated switches, fault indicators, capacitor banks, voltage regulators, and other power management devices.

The IEC 61850 DER information model standard utilizes existing IEC 61850-7-4 logical nodes where possible, while defining DER and DA specific logical nodes to provide the necessary data objects for DER and DA functions, including for the DER interconnection grid codes specified by various countries and regions. This document also includes generic approach of modelling to support any kinds of DER including generation, storage and controllable loads.

4.6 General technical requirements for components

The design and integration of the various system components e.g. PV modules, inverters, protections systems etc., into a Renewable Power Plant shall ensure reliability and safe operation.

All major components of renewable energy (RE) installations such as inverters, transformers, switchgear, protection devices, and cables shall conform to applicable IEC standards to ensure safety, interoperability, and grid compatibility.

Inverters shall comply with IEC 62109-1 and IEC 62109-2 for safety. Power transformers shall be designed in accordance with IEC 60076 series, to ensure thermal, dielectric, and short-circuit performance under variable RE output. Switchgear and circuit breakers shall meet the requirements of IEC 62271 series for medium- and high-voltage applications. All protection relays and control systems shall comply with IEC 60255 series. IEC 61850 ensures effective communication systems and SCADA system integration. Use of components tested and certified to these standards is highly recommended to ensure operational reliability and grid code compliance.

Related Standards

IEC TR 61000: Electromagnetic compatibility (EMC) – All Parts

See Section 4.4 of this guide for the abstract.

IEC TR 61850: Communication networks and systems for power utility automation – All Parts
The IEC 61850 series provides guidelines for communication networks and systems in power utility automation. It establishes a unified framework for data exchange, system modelling, and interoperability among intelligent electronic devices (IEDs) within substations and across power system domains. This Technical Report enables real-time, high-reliability communication for protection, control, monitoring, and automation functions, using modern networking technologies such as Ethernet, TCP/IP, and MMS.

Beyond conventional substation automation, IEC TR 61850 supports scalable architectures that extend to distributed energy resources (DERs), wind and solar plants, and wide-area control applications. It defines common data models, communication services, and engineering configuration methods that ensures vendor-independent interoperability, reduces integration complexity and enhances system reliability.

IEC 62109-1: Safety of power converters for use in photovoltaic power systems – Part 1: General requirements
This standard applies to the power conversion equipment (PCE) for use in photovoltaic systems where a uniform technical level with respect to safety is necessary. Defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards. Provides general requirements applicable to all types of PV PCE.

IEC 62109-2: Safety of power converters for use in photovoltaic power systems – Part 2: Requirements for inverters
This standard covers the particular safety requirements relevant to d.c. to a.c. inverter products as well as products that have or perform inverter functions in addition to other functions, where the inverter is intended for use in photovoltaic power systems. Inverters covered by this standard may be grid-interactive, stand-alone, or multiple mode inverters, may be supplied by single or multiple photovoltaic modules grouped in various array configurations, and may be intended for use in conjunction with batteries or other forms of energy storage. This standard must be used jointly with IEC 62109-1.

IEC 62271: High-voltage switchgear and controlgear – All Parts
The IEC 62271 series specifies the design, performance, testing, and safe operation of high-

voltage switchgear and controlgear for AC and DC systems above 1 kV. It covers indoor and outdoor equipment operating up to 60 Hz for AC applications and at 100 kV and above for HVDC systems.

Part 62271-1 provides the common specifications for all high-voltage AC switchgear, while 62271-3 addresses digitally integrated equipment and its conformity with IEC 61850 communication requirements. Part 62271-4 defines procedures for the safe and environmentally responsible handling of insulating and switching gases, and TS 62271-5 specifies common requirements for HVDC switchgear. Product-specific standards such as 62271-100 further detail performance and testing requirements for equipment like high-voltage circuit-breakers.

IEC 60076: Power Transformers – All Parts
The IEC 60076 series specify the design, performance, testing, and safe operation of power transformers used across transmission and distribution networks. Part 60076-1 defines the general requirements for ratings, insulation levels, temperature rise, dielectric performance, and short-circuit withstand capability.

Complementing the general standard, 60076-2 covers temperature-rise limits, 60076-3 defines dielectric test methods, and 60076-4 provides guidance for lightning and switching impulse tests. Part 60076-5 specifies the short-circuit strength requirements, while 60076-7 gives the loading guide for oil-immersed transformers and 60076-10 covers sound level measurements. Specialized parts address specific technologies and applications, including dry-type transformers (60076-11), among others.

IEC 60255: Measuring Relays and Protection Equipment – All Parts
The IEC 60255 series defines the common requirements, performance criteria, testing methods, and safety rules for measuring relays and protection equipment used in power system protection, control, monitoring, and automation. Part 60255-1 establishes the general rules and uniform test requirements applicable to modern protection relays, including distributed protection schemes and emerging technologies. Specific functional standards include 60255-12 for directional and power relays and 60255-13 for biased differential relays, each defining detailed performance requirements for their respective subfamilies. The series also includes supporting standards such as 60255-24, which specifies the COMTRADE format for exchanging transient and event data across power systems and simulation environments.

IEC 60255-26 defines EMC emission and immunity requirements, while 60255-27 specifies essential electrical safety requirements for relays and associated auxiliary devices up to 1,000 V AC or 1,500 V DC.

5 SYSTEM PLANNING FOR RE INTEGRATION

Effective system planning is essential for integrating variable renewable energy (VRE) sources like wind and solar into Africa's power grids. Given the continent's growing energy demand, aging infrastructure, and high RE potential, strategic planning ensures reliability, cost-effectiveness, and sustainability.

Integrating renewable energy (RE) into Africa's power grids requires adherence to internationally recognized standards to ensure reliability, interoperability, and safety. Below are key guidelines for system planning in RE integration.

5.1 Impact Assessment of High RE Penetration – Grid Capacity Evaluation

Grid capacity evaluation is a critical step in ensuring that the power system can safely, reliably, and efficiently accommodate additional renewable energy (RE) sources such as solar PV and wind. To a chieve the above-mentioned objectives, there's need to; Conduct load flow studies, transient stability studies and short-circuit analyses to determine the grid's ability to handle RE integration. In the assessment of grid connection capacity, the impact of rooftop PV systems connected to the grid must be properly considered by system planners. In addition, investment in smart grid technologies (e.g., advanced sensors, automation) for real-time monitoring is also recommended.

Short-circuit analysis and calculations should be done in accordance with IEC 60909, while Assessment of grid stability with high RE penetration should be done in accordance with IEC 61000 to ensure RE plants do not cause harmful harmonics or voltage fluctuations

5.2 Network Planning Requirements

Network planning for the integration of Renewable Energy (RE) plants shall ensure that the transmission and distribution systems can accommodate new generation without compromising security, reliability, power quality, or operational flexibility. Planners shall evaluate the long-term impact of RE connections on system loading, voltage profiles, short-circuit levels, stability margins, protection coordination, and congestion risk. Studies shall consider both normal and contingency conditions, seasonal demand variations, and the evolving characteristics of inverter-based resources.

5.3 Coordination with Transmission and Distribution Operators

Coordination between Transmission System Operators (TSOs) and Distribution System Operators (DSOs) is crucial for successfully integrating renewable energy (RE) sources into the grid. This cooperation helps maximize the utilization of Distributed Energy Resources (DER), increases system flexibility, reduces grid congestion, improves system reliability and stability and optimizes infrastructure investments.

Key enablers for this coordination include data exchange platforms, digitalization, and clearly defined roles for TSOs and DSOs.

5.4 Long-Term Planning and Forecasting

5.4.1 Long-term planning

Long-term planning is crucial for successful renewable energy (RE) integration and considers the overall power system's needs, including electricity demand projections and grid infrastructure. Planning must consider grid stability, ensuring sufficient reserve capacity and balancing services to handle VRE fluctuations.

Accurate long-term planning will allow system planners to determine whether energy storage systems will be required to minimize the risk of energy curtailment. These energy storage systems can then be optimally deployed at strategic locations in the network.

5.4.2 Forecasting

Forecasting helps manage the variability of RE sources like wind and solar, while planning considers the overall grid's needs, including grid stability and balancing. Accurate forecasting of VRE production is essential for managing the intermittency of wind and solar power, which can fluctuate based on weather conditions.

Forecasting techniques use both physical models (like weather forecasting) and statistical models based on historical data to predict generation output. Centralized forecasting provides an overall view of regional or state-level VRE generation, while decentralized forecasting focuses on plant-level information.

Forecasting helps generators plan to improve their production plans. It also helps grid operators to estimate the expected load and secure the necessary generation resources to meet the load demands whiles providing adequate reserve margins. It also allows the system operator to predict, plan for and manage energy curtailment.

RE Generators shall provide daily forecast of production to the system operator.

Related Standard

IEC TR 63043 : Renewable Energy Power Forecasting Technology
This technical report, describes common practices and state of the art for renewable energy power forecasting technology, including general data demands, renewable energy power forecasting methods and forecasting error evaluation. For the purposes of this document, renewable energy refers to variable renewable energy, which mainly comprises wind power and photovoltaic (PV) power – these are the focus of the document. Other variable renewable energies, like concentrating solar power, wave power and tidal power, etc., are not presented in this document, since their capacity is small, while hydro power forecasting is a significantly different field, and so not covered here.

The objects of renewable energy power forecasting can be wind turbines, or a wind farm, or a region with lots of wind farms (respectively PV systems, PV power stations and regions with high PV penetration). This document focuses on providing technical guidance concerning forecasting technologies of multiple spatial and temporal scales, probabilistic forecasting, and ramp event forecasting for wind power and PV power.

This document outlines the basic aspects of renewable energy power forecasting technology. This is the first IEC document related to renewable energy power forecasting.

6 WHEELING OF RENEWABLE ENERGY

Wheeling is vital for renewable energy as it links generation with demand, enhances the commercial viability of clean power, and drives the energy transition by enabling broader access to the grid and electricity markets. This facilitates enhanced uptake and optimal usage of renewable energy.

6.1 Guidelines for participation in wheeling agreements

Wheeling is the financial transactions representing the delivery of electrical energy over a network. In a wheeling arrangement there are at least three (3) groups of participants, that is the Suppliers of power, the network services providers and the off takers as indicated in figure 1 below.

Different countries generally have their own wheeling frameworks and rules. Also, cross-border wheeling arrangements are governed by regional frameworks which set out principles and rules to be followed by participants. In general, it is recommended that interconnection codes and standard wheeling agreements should consider the underlisted aspects:

a. Regulatory and Policy Framework

b. Technical and Operational Requirements

c. Metering, Data Management, and Settlement

d. Economic and Financial Considerations

e. Contractual and Legal Framework

f. System Operation and Coordination

g. Renewable Integration and Grid Stability

h. Regional and Cross- Border Wheeling

i. Digitalization and Innovation

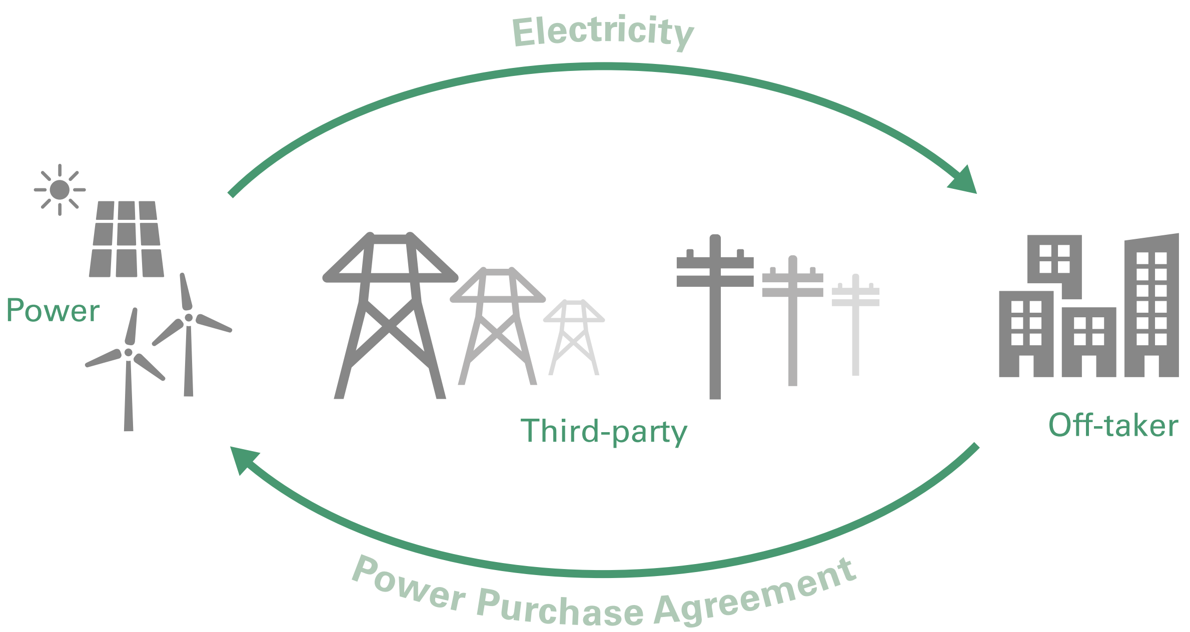

Figure 1: Schematic view of a wheeling transaction

Source: SALGA wheeling report,2023

7 PERFORMANCE MONITORING & COMPLIANCE

Ability of the electric power system to collect, assess, and report on the performance and compliance of grid-connected renewable energy (RE) systems under operational conditions, using defined data standards and system metrics. This ensures grid stability, facilitates planning, and enables continual performance improvement of integrated RE technologies.

7.1 Data Collection and Reporting Standards

Data collection and reporting shall be conducted in accordance with national, regional and internationally recognized standards, policies and regulations to ensure consistency, comparability, and traceability of performance metrics across RE installations. Systems shall be designed to acquire time-synchronized and high-resolution data related to active power, reactive power, voltage, frequency, and power quality. This is necessary for operational analysis, grid planning, and compliance assessment. Records of system performance during disturbances should be used to verify the accuracy of network models used for system studies.

According to IEC TS 62933-3-1:2018, electrical energy storage (EES) systems of category 3 must be monitored with clear parameters for charge/discharge efficiency, capacity retention, State of Charge (SOC), voltage, frequency and operational availability. Collected data shall be aggregated, reported, and archived following standard reporting formats to facilitate regulatory compliance and benchmarking. According to IEC TS 62933-3-1:2018 common standards for communication involving control centres include IEC 60870-5-101, IEC 60870-5-104, IEC 60870-6, IEEE Std 1815.

For example, in wind generation, IEC 61400-21-1 specifies the methodology for measuring and assessing power quality characteristics of grid-connected wind turbines categorized into five aspects, Power Quality, Steady State Operation, Control Performance, Dynamic Performance and Disconnection from the Grid. Compliance reporting must include both real-time data feeds and periodic reports submitted to regulatory bodies and system operators, with automated alarms for non-conformities.

Related Standard

IEEE Std 1815 – Electric Power Systems Communication – Distributed Network Protocol (DNP 3)

The purpose of this standard is to document and make available the specifications for the DNP3 protocol. While a primary focus of this protocol is the Electric Utility Industry, other industries that deliver Energy and Water are also using DNP3. The intent of this DNP3 standard is to meet the goal established by the National Institute of Standards and Technology (NIST) for a Smart Grid protocol:

- Provides a protocol standard from a recognized standard institution
- Provides interoperability with hundreds of operational systems and thousands of devices
- Provides cyber security based on IEC/TS 62351-5
- Provides Device data profiles in a format that can be mapped to IEC 61850 Object Models.

Vendors may use this standard to implement and test the protocol in their products and be assured of interoperability.

7.2 Metrics for Evaluating System Performance and Stability

Standardized metrics shall be defined and implemented to evaluate the performance and stability of RE systems within the grid. These include power output consistency, energy yield, voltage regulation, frequency response, ramp rates, and contribution to system inertia. For energy storage systems, key performance indicators include round-trip efficiency, response time, system availability, and degradation rate, as defined in IEC TS 62933-3-1. These metrics are critical for determining system readiness and lifecycle performance.

For example, wind turbines shall be assessed using power quality metrics outlined in IEC 61400-21-1, ensuring minimal adverse impact on grid stability through proper control of harmonics, flicker, and voltage deviations. All performance metrics must be evaluated under both normal and dynamic grid conditions, using validated models and field measurements.

For photovoltaic systems, power performance verification shall be conducted in accordance with IEC TS 61724-2. The Power Performance Index (PPI), defined as the ratio of measured AC power to the expected power of a system's measured power output under test conditions to its expected output at those conditions based on the system's design, is recommended as the primary metric for capacity validation and contractual acceptance.

Measurement systems must ensure high accuracy and resolution, with quality assurance processes in place to validate data integrity. By applying these standards and performance indicators, utilities and operators can ensure that RE systems contribute reliably to the African power grid, support stability objectives, and comply with technical regulatory frameworks.

Related Standards

IEC TS 62933-3-1 – Electrical energy storage (EES) systems – Part 3-1: Planning and performance assessment of electrical energy storage systems – General specification
This document is applicable to EES systems designed for grid-connected indoor or outdoor installation and operation. This document considers necessary functions and capabilities of EES systems test items and performance assessment methods for EES systems requirements for monitoring and acquisition of EES system operating parameters exchange of system information and control capabilities required.

IEC TS 61724-2 – Photovoltaic system performance – Part 2: Power performance index and capacity evaluation method
This document applies to grid-connected PV systems comprising at least one inverter. The test evaluates the PV system only in conditions where output is unconstrained by limitations in AC power output from the inverters. This document defines a test of a PV system's power performance index (PPI). PPI, defined in IEC 61724-1, is the ratio of a system's measured power output under test conditions to its expected output at those conditions based on the system's design. The test is intended to be performed over a short period of typically three to five days and is typically used to satisfy a contractual performance guarantee as part of the final completion of a PV power plant.

IEC TS 61724-3 – Photovoltaic system performance – Part 3: Energy evaluation method
This document defines a procedure for measuring and analyzing the energy production of a specific photovoltaic system relative to expected electrical energy production for the same system from actual weather conditions as defined by the stakeholders of the test.

The energy production is characterized specifically for times when the system is operating (available); times when the system is not operating (unavailable) are quantified as part of an availability metric. The aim of this technical specification is to define a procedure for comparing the measured electrical energy with the expected electrical energy of the PV system.

IEC 60870-5-101 – Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks
This standard applies to telecontrol equipment and systems with coded bit serial data transmission for monitoring and controlling geographically widespread processes. Defines a telecontrol companion standard that enables interoperability among compatible telecontrol equipment. The defined telecontrol companion standard utilizes standards of the IEC 60870-5 series of documents. This publication is of high relevance for Smart Grid.

IEC 60870-5-104 – Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles
This standard a telecontrol companion standard that enables interoperability among compatible telecontrol equipment. Applies to telecontrol equipment and systems with coded bit serial data transmission for monitoring and controlling geographically widespread processes.This publication is of high relevance for Smart Grid.

IEC 61400-21-1 – Wind energy generation systems – Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines
Refer to Section 4.3.2 of this guide for the abstract.

8 PROTECTION, AUTOMATION AND CONTROL

The integration of renewable energy (RE) into African power systems requires a robust framework for plant control, communication, and protection.

Protection schemes for RE plants must be engineered to ensure safe operation, reliable fault detection, and proper coordination with the wider grid. Inverter-based resources produce lower and controlled fault currents, which affects traditional protection philosophies; therefore, appropriate relays, settings, and communication-assisted schemes must be applied. The design must also address anti-islanding, grid code compliance, and system stability during disturbances. Overall, protection should be optimized to ensure personnel safety, equipment protection, and secure grid integration of RE generation.

The System Operator (SO) must ensure that all RE plants comply with the following specifications in section 8.1 to 8.4 of this guide.

8.1 Control and Communication

RE plants shall implement telecommunication and metering infrastructure to enable secure, real-time monitoring, control, and data exchange with substations and SO control centres. Communication systems shall conform to the IEC 61850 series for interoperability and support standardized data models (e.g., IEC 61850-90-7 for solar and wind). SCADA systems shall be implemented to provide centralised visibility, event logging, alarm handling, and remote-control functions.

8.1.1 Teleprotection Communications

Teleprotection systems shall ensure high-speed and highly reliable signal exchange between protection relays located at different substations or plant connection points. The required end-to-end transmission time for teleprotection signals must typically be less than 10 ms to support fast fault clearance and system stability. Teleprotection channels shall support redundancy (dual communication paths) to mitigate single point of failure risks. Protocols such as IEEE C37.94 (optical interface for protection relays) and IEC 60834-1 (performance and testing of teleprotection equipment) should be applied.

8.1.2 Communication Media

The choice of communication media shall consider latency, availability, security, and environmental conditions:

- **Optical Fibre:** The preferred medium for teleprotection and SCADA due to its low latency, high bandwidth, immunity to electromagnetic interference, and long-distance capability.
- **Microwave Radio Links:** Used as backup or in areas where fibre deployment is not feasible; must provide sufficient bandwidth and latency performance for protection signals.
- **Power Line Carrier (PLC):** May be used for legacy or rural systems, but limited bandwidth and susceptibility to noise restricts its application to backup channels.
- **Satellite Communications:** Generally avoided for teleprotection due to latency but may serve as emergency backup for SCADA or monitoring in remote locations.

8.1.3 Cybersecurity and Reliability

- All communication channels shall implement **encryption, authentication, and access control** to prevent cyber intrusions into protection and control systems (aligned with IEC 62351). Systems must be designed for **high availability (>99.99%)**, with redundant paths, automatic failover, and continuous monitoring. Environmental conditions in Africa (heat, dust, humidity, lightning exposure) require robust outdoor-rated communication equipment and surge protection.

8.2 Protection Philosophy

Protection shall ensure selectivity, sensitivity, speed, and security while accounting for the limited fault current contribution of inverter-based resources. Adaptive protection schemes are required to accommodate bi-directional power flows and dynamic grid conditions. Anti-islanding protection is mandatory at all interconnection points.

8.3 Grid Code and Standards Compliance

Plants shall support Low Voltage Ride Through (LVRT), Frequency Ride Through (FRT), and ramp-rate control in accordance with national grid codes. Protection and automation equipment must conform to the IEC 60255 series (general coordination, overcurrent, frequency, differential, and distance protection).

Renewable installations shall comply with IEC 62934 for grid integration requirements. In addition, in respect of the various RE systems, the following requirements shall apply:

a) Solar Photovoltaic Systems
PV inverters shall provide undervoltage, overvoltage, frequency, and phase protection functionalities. Anti-islanding schemes shall be implemented to disconnect isolated sections safely. For distributed PV in microgrids, protection shall coordinate between solar arrays, storage, and loads (IEC 62898 series).

b) Wind Generation Systems
Protection shall address turbine-specific technologies (DFIG or direct-drive synchronous). Coordination is required between turbine-level, collector system, and transmission protection. Power quality protection shall mitigate flicker and harmonics (IEC 61400 series, IEC 60255-1). Lightning protection systems are mandatory.

c) Hydroelectric Installations
Large hydro units with synchronous generators provide inertia and support traditional protection. Run-of-river or small hydro with converters require inverter-based protection principles. All hydro units shall coordinate with grid-level protection zones.

d) Microgrid Systems
Microgrid protection shall cover grid-connected and islanded modes with automatic reconfiguration. Energy storage must be integrated with protective functions for both charging and discharging states (IEC 61427). Synchronization protection is required for reconnection to the main grid.

e) Communication and Automation
Protection schemes shall use high-availability communication media (optical fibre preferred; wireless as backup). Wide Area Monitoring Systems (WAMS) with Phasor Measurement Units (PMUs) shall provide real-time visibility across regions. Communication-enabled differential protection and adaptive relaying should be applied (IEC 61850, IEC 60255-187).

8.4 Compliance Verification

Compliance will be demonstrated through testing, commissioning, and ongoing audits as follows:

a) Factory and Site Testing
Factory Acceptance Tests (FAT) and pre-commissioning tests / Site Acceptance Tests (SAT) shall validate equipment performance per IEC 60255 requirements. Dynamic testing (hardware-in-the-loop or simulation) shall confirm ride-through, coordination, and fault detection capabilities.

b) Commissioning
Verification of protection coordination under varying renewable generation levels. Communication protocol conformance testing per IEC 61850. Anti-islanding and synchronization checks.

c) Ongoing Compliance
Periodic protection coordination studies shall be performed to reflect evolving system conditions. SCADA and WAMS data shall be retained for compliance monitoring and incident investigation. Maintenance and training programs must ensure local technical capability for long-term sustainability.

Related standards (grouped):

COMMUNICATION & AUTOMATION

IEC TR 61850 series: Communication networks and systems for power utility automation
Refer to Section 4.6 of this guide for the abstract.

IEC 61869 series: Instrument Transformers
The IEC 61869 series defines the general and product-specific requirements for instrument transformers used for measurement, protection, and control in AC and DC power systems.

Part 61869-1 establishes the common rules applicable to all instrument transformers above 1 kV AC or 1.5 kV DC, forming the base standard for the series. Subsequent parts provide additional requirements for specific transformer types, including current transformers (61869-2), inductive voltage transformers (61869-3), and combined transformers (61869-4), as well as capacitor voltage transformers (61869-5) for high-voltage systems. The series also includes standards for low-power passive CTs and VTs (61869-10 and 61869-11), digital interface and communication requirements (61869-9), and stand-alone merging units (61869-13) used to convert analogue signals to IEC 61850-compliant digital outputs.

For DC applications, the series specifies dedicated requirements for DC current transformers (61869-14) and DC voltage transformers (61869-15) used in HVDC and converter-based systems, addressing the unique demands of DC measurement, harmonic content, polarity, and withstand capability.

PROTECTION EQUIPMENT

IEC 60255: Measuring relays and protection equipment
See Section 4.6 of this guide for the abstract

RENEWABLE INTEGRATION

IEC 62934: Grid integration of renewable energy generation – Terms and definitions
This standard provides terms and definitions in the subject area of grid integration of renewable energy generation. The technical issues of grid integration mainly focus on the issues caused by renewable energy generation with variable sources and/or converter-based technology, such as wind power and photovoltaic power generation.

Some renewable energy generations such as hydro power and biomass power with a relatively continuously available primary energy source and a rotating generator are conventional sources of generation and are therefore not covered in this document. The intention of this document is to answer the question “what do the words mean” and not “under what conditions do the terms apply”.

MICROGRIDS

IEC 62898 series: Microgrids
The IEC 62898 series provide comprehensive technical guidelines and requirements for the planning, specification, operation, protection, and control of AC microgrids at low- and medium-voltage levels.

Part 62898-1 addresses project planning and system specification, including microgrid applications, DER and load forecasting, system design, and high-level requirements for DER, interconnection, control, protection, and communication systems. Microgrids are classified as isolated or non-isolated, with non-isolated microgrids capable of operating in grid-connected and islanded modes.

Part 62898-2 defines operational and control guidelines, covering mode transitions, energy management systems, monitoring and communication procedures, storage integration, protection principles for both isolated and non-isolated microgrids, and requirements for commissioning, maintenance, and testing. Part 62898-3-1 provides the technical requirements for fault protection and dynamic control, focusing on the unique protection challenges of microgrids and disturbance-handling strategies to ensure safe and stable operation. Complementing this, Part 62898-3-2 specifies requirements for microgrid energy management systems (MEMS), detailing performance expectations, key functional blocks, information exchange protocols, power and energy balancing, forecasting, optimization, and ancillary-service capabilities.

Part 62898-3-3 defines the requirements for autonomous self-regulation of dispatchable loads to support frequency and voltage stability through load modulation and synthetic inertia.

ENERGY STORAGE

IEC 61427 – All Parts: Secondary cells and batteries for renewable energy storage – General requirements and methods of test
The 61427 series specify the general requirements and test methods for secondary batteries used in renewable energy storage systems, providing chemistry-neutral procedures to evaluate endurance, performance, and suitability in real operating conditions. Part 61427-1 covers batteries used in off-grid photovoltaic (PV) systems, detailing performance verification methods for batteries operating in standalone PV applications.

Part 61427-2 addresses batteries used in on-grid electrical energy storage (EES), where storage systems interface with regional or national grids via power conversion equipment and function as fast energy sources or sinks to support grid stability under variable renewable generation.

PV SAFETY

IEC 61730: Photovoltaic (PV) module safety qualification
The 61730 series define the safety requirements for photovoltaic (PV) modules. Part 61730-1 specifies the construction criteria needed to prevent electrical shock, fire hazards, and mechanical injury for terrestrial flat-plate PV modules operating in outdoor environments.

Part 61730-2 provides the corresponding safety test sequences used to verify compliance with these construction requirements, identifying failures that could compromise electrical or mechanical safety

EMC

IEC 61000 – All Parts: Electromagnetic compatibility (EMC)
The 61000 series provide the framework for managing electromagnetic compatibility (EMC) across electrical and electronic equipment, power systems, and installation environments. It establishes fundamental EMC principles, defines disturbance environments, sets emission and immunity limits, and specifies standardized testing and measurement techniques. The series also includes guidance on installation, mitigation, and power quality assessment to ensure reliable operation in the presence of electromagnetic disturbances

Each Part in this series has several subparts. Part 1 provides fundamental definitions, concepts, and general EMC principles. Part 2 characterizes electromagnetic environments and establishes compatibility levels in different system contexts. Part 3 sets emission and immunity limits, primarily addressing power quality issues such as harmonics, flicker, and voltage unbalance. Part 4 defines standardized testing and measurement techniques used to evaluate equipment EMC performance. Part 5 offers installation and mitigation guidelines, covering grounding, shielding, cabling, and surge protection practices. Part 6 includes generic emission and immunity standards for various environments (industrial, residential, substations).

9 PLANT SAFE OPERATING REQUIREMENTS

9.1 Safety Systems for RE Plants.

Safety systems for renewable energy (RE) plants, such as solar and wind farms, are crucial for ensuring safe and reliable operation. These systems encompass various aspects, including electrical, physical, and environmental protection measures, designed to mitigate risks and maintain operational efficiency.

The specific systems required for a RE plant will depend on its size, location, and the specific types of technologies used. A comprehensive approach, combining electrical, physical, and environmental protection measures, is necessary to ensure the safe and reliable operation of RE facilities

Protection settings must be calculated such that the protection system is sensitive, dependable, secure, and fast for all possible short circuits. To aid with speed of operation, distance protection applications must be equipped with tele-protection facilities.

To aid with both speed and security, differential protection applications must be equipped with dedicated fibre tele-protection facilities. This is to ensure correct protection operation that will clear faults in protection time, limit the impact to the faulted area and allow for stable, safe, and secure operation of the IPS.

Backup Direct Current (DC) systems with appropriate capacity and standby time isare required to sustain the substation plant and equipment.

At the points of connection there shall also be synch check facilities to ensure that voltage and frequency measurements are within acceptable range whenever the systems are being connected. Incorrect protection operation as a result of incorrect setting or relay maloperation can be the cause or contributing factor to a major network outage incident.

Therefore, protection systems should be tested and maintained regularly. Testing of interconnector protection equipment should be coordinated between the two areas. Test reports should be made available to relevant stakeholders.

To improve the protection performance, the KPIs which looks at the security and dependability of the protection schemes should be formulated, monitored, trended, and benchmarked against international practices.

9.1.1 Electrical Protection

a) Lightning Protection:
RE plants, especially solar farms, are vulnerable to lightning strikes. Lightning protection systems are essential to minimize damage to equipment and personnel. These systems typically involve lightning rods, grounding systems, and surge arresters to safely dissipate lightning energy.

b) Surge Protection Devices (SPDs)
SPDs protect against voltage surges and spikes caused by lightning, switching, and other electrical disturbances. They are crucial for safeguarding inverters and other electrical equipment.

c) Overload Protection:
Overload protection, including instantaneous overcurrent (IOC) and time overcurrent (TOC) protection, prevents equipment damage and system instability due to excessive currents.

d) Differential Protection
This scheme detects faults in specific areas of the system, like generators or transformers, and isolates them quickly, limiting damage and preventing the fault from spreading.

e) Distance Protection
This method protects transmission lines and other long-distance equipment by measuring impedance and distance from a fault, allowing for fast and selective fault clearing.

f) Protective Relays and Relay Coordination
Protective relays detect abnormal conditions like faults and automatically isolate faulty equipment, preventing wider system damage. Relay coordination ensures the relays work together effectively, preventing cascading failures.

g) Fire Protection
Fire suppression systems, including sprinklers and fire-resistant materials, are essential for protecting power plants, including RE facilities, from fire hazards.

9.1.2 Physical Protection

a) Perimeter Security
Solar farms and other RE facilities require robust perimeter security to deter theft, vandalism, and unauthorized access. This includes fencing, CCTV monitoring, and potentially security personnel.

b) Security Systems
CCTV cameras, including PTZ and thermal cameras, can monitor large areas and provide real-time security.

c) Access Control
Implementing access control measures, such as key cards or biometric systems, can help restrict access to sensitive areas.

d) Fencing
Barbed wire and other fencing materials can be used to deter intruders and create a physical barrier.

9.1.3 Environmental Protection

a) Irrigation Systems:
In some cases, irrigation systems may be used to control dust and maintain the environment around the RE plant.

b) Contaminant Control:
Measures to control dust and other contaminants can be implemented to protect the environment and equipment.

9.2 Safety Standards for Operators and Equipment

Safety standards in renewable energy (RE) integration for operators and equipment are crucial for preventing accidents and ensuring a safe working environment. These standards encompass various aspects, including operator training, equipment maintenance, hazard identification, and control measures. Safety standards for operators and equipment involve ensuring a safe working environment by requiring pre-operation checks, regular maintenance, proper use of personal protective equipment (PPE), and effective communication. The related standards below apply.

Related Standards

IEC 62109-1: Safety of power converters for use in photovoltaic power systems – Part 1: General requirements
Refer to Section 4.6 of this guide for the abstract.

IEC 62109-2: Safety of power converters for use in photovoltaic power systems – Part 2: Requirements for inverters
Refer to Section 4.6 of this for the abstract.

IEC 62116: Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measure
This standard provides a test procedure to evaluate the performance of islanding prevention measures used with utility-interconnected PV systems. This standard describes a guideline for testing the performance of automatic islanding prevention measures installed in or with single or multi-phase utility interactive PV inverters connected to the utility grid. The test procedure and criteria described are minimum requirements that will allow repeatability.

10 TESTING AND COMMISSIONING

It is important to define a structure that will ensure that all RE plants comply to the testing requirements below, before they are connected to the grid. This structure will be accountable for the safe integration of the RE Plant into the grid.

Compliance tests must be conducted on RE Plants to verify adherence to the grid connection requirements outlined in Section 4 of this guideline. In addition, RE Plants must also meet the testing requirements specified in applicable national and/or regional grid codes.

Measuring instruments and monitoring equipment and methods shall be chosen in accordance with the relevant parts of IEC 61557. Additional tests may be conducted, on a case-by-case basis, as determined by the requirements of national and/or regional codes and regulations.

10.1 PV Plant

Testing and commissioning of PV plants shall verify the safety, performance, and grid-compliance of all modules, inverters, array wiring, and protection systems. This includes confirming that module construction and performance meet internationally accepted design-qualification and safety requirements, and that the complete PV system satisfies the documentation, inspection, and functional test expectations prescribed for grid-connected installations. Anti-islanding response, inverter behaviour, grounding integrity, insulation resistance, and system performance indicators must be validated in accordance with related IEC PV safety, performance, and system commissioning standards as specified in the related standards.

Related Standards

IEC 62446-1 Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection
This standard defines the information and documentation required to be handed over to a customer following the installation of a grid connected PV system. It also describes the commissioning tests, inspection criteria and documentation expected to verify the safe installation and correct operation of the system. It is for use by system designers and installers of grid connected solar PV systems as a template to provide effective documentation to a customer.

IEC 61215- 1: Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements
This standard lays down requirements for the design qualification of terrestrial photovoltaic modules suitable for long-term operation in open-air climates. The useful service life of modules so qualified will depend on their design, their environment and the conditions under which they are operated. Test results are not construed as a quantitative prediction of module lifetime. This document is intended to apply to all terrestrial flat plate module materials such as crystalline silicon module types as well as thin-film modules. It does not apply to systems that are not long-term applications, such as flexible modules installed in awnings or tenting.

IEC 61730 -2 : Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing
This standard lists the tests a PV module is required to fulfil for safety qualification. This document applies for safety qualification only in conjunction with IEC 61730-1. The objective of this document is to provide the testing sequence intended to verify the safety of PV modules whose construction has been assessed by IEC 61730-1. The test sequence and pass criteria are designed to detect the potential breakdown of internal and external components of PV modules that would result in fire, electric shock, and/or personal injury.

This document defines the basic safety test requirements and additional tests that are a function of the PV module end-use applications. The additional testing requirements outlined in relevant ISO documents, or the national or local codes which govern the installation and use of these PV modules in their intended locations, are considered in addition to the requirements contained within this document.

IEC 62116 – Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures
This standard provides a test procedure to evaluate the performance of islanding prevention measures used with utility-interconnected PV systems. This standard describes a guideline for testing the performance of automatic islanding prevention measures installed in or with single or multi-phase utility interactive PV inverters connected to the utility grid. The test procedure and criteria described are minimum requirements that will allow repeatability.

10.2 Wind Plant

The testing & commissioning of wind power plants shall demonstrate that mechanical, electrical, and control systems operate safely and reliably and that the plant meets grid-connection and performance obligations. This involves verifying power performance, electrical characteristics, power-quality behaviour, mechanical loads, and acoustic requirements, together with validation of turbine models used for grid studies. Compliance shall be based on the relevant IEC wind turbine performance, electrical behaviour and protection standards that define the required tests and acceptance criteria.

Related Standards

IEC 61400-12-1: Wind energy generation systems – Part 12-1: Power performance measurements of electricity producing wind turbines
This standard specifies a procedure for measuring the power performance characteristics of a single wind turbine and applies to the testing of wind turbines of all types and sizes connected to the electrical power network. In addition, this document defines a procedure to be used to determine the power performance characteristics of small wind turbines (as defined in IEC 61400-2) when connected to either the electric power network or a battery bank. This document defines a measurement methodology that requires the measured power curve and derived energy production figures to be supplemented by an assessment of uncertainty sources and their combined effects.

IEC 61400-21-1: Wind energy generation systems – Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines
Refer to Section 4.3.2 of this guide for the abstract.

IEC 61400-27-1 Wind energy generation systems – Part 27-1: Electrical simulation models – Generic models
This standard defines standard electrical simulation models for wind turbines and wind power plants. The specified models are time domain positive sequence simulation models, intended to be used in power system and grid stability analyses. The models are applicable for dynamic simulations of short-term stability in power systems. This document defines the generic terms and parameters for the electrical simulation models.

This document specifies electrical simulation models for the generic wind power plant topologies / configurations currently on the market. The wind power plant models include wind turbines, wind power plant control and auxiliary equipment. The wind power plant models are described in a modular way which can be applied for future wind power plant concepts and with different wind turbine concepts.

10.3 Hydro Plant

Hydropower plant commissioning shall verify that turbines, generators, governors, and all auxiliary systems operate safely and perform as designed under expected hydraulic and electrical conditions. Performance testing, including hydraulic efficiency checks, mechanical integrity assessments, and electrical verification of generators, shall follow internationally recognised procedures. Commissioning of control, protection, and balance-of-plant equipment shall also comply with the relevant IEC standards for turbine testing, generator performance, switchgear, transformers, and protection systems to ensure reliable and coordinated plant operation.

Related Standards

IEC 60041 – Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines
This standard specifies methods for any size and type of impulse or reaction turbine, storage pump or pump turbine. Determines whether the contract guarantees have been fulfilled and deals with the rules governing these tests as well as the methods of computing the results and the content and style of the final report.

IEC 60034 -1 Rotating electrical machines – Part 1: Rating and performance
This standard is applicable to all rotating electrical machines, except rotating electrical machines for rail and road vehicles, which are covered by the IEC 60349 series of standards. Machines within the scope of this document may also be subject to superseding, modifying or additional requirements in other standards, for example, IEC 60079 and IEC 60092.

IEC 60034-2-1 – Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)
This standard is intended to establish methods of determining efficiencies from tests, and also to specify methods of obtaining specific losses. This document applies to DC machines and to AC synchronous and induction machines of all sizes within the scope of IEC 60034-1 rated for mains operation. These methods may be applied to other types of machines such as rotary converters, AC commutator motors and single-phase induction motors.

IEC 60034-14 : Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity
This standard specifies the factory acceptance vibration test procedures and vibration limits for certain electrical machines under specified conditions, when uncoupled from any load or prime mover. It is applicable to DC and three-phase AC machines, with shaft heights 56 mm and higher and a rated output up to 50 MW, at operational speeds from 120 min–1 up to and including 15 000 min–1.

IEC 60034-27-1 : Rotating electrical machines – Part 27-1: Off-line partial discharge measurements on the winding insulation
This standard provides a common basis for:

- measuring techniques and instruments.
- the arrangement of test circuits.
- normalization and testing procedures.
- noise reduction.
- the documentation of test results.
- the interpretation of test results,

with respect to partial discharge off-line measurements on the winding insulation of rotating electrical machines.

This standard cancels and replaces IEC TS 60034-27 (2006). It constitutes a technical revision and reflects numerous improvements and corrections with respect to the previous publication.

10.4 BESS Plant

As the demand for renewable energy grows, the role of Battery Energy Storage Systems (BESS) becomes increasingly critical. A fully integrated BESS is a complex system that combines batteries, power electronics, thermal management, and control systems into a single, cohesive unit.

To ensure the reliability, efficiency, and safety of these systems, regular inspections are essential:

a) Visual Inspection
The first step in any BESS inspection is a thorough visual examination. Inspectors should check for any obvious signs of wear and tear, such as corrosion, damaged wiring, or loose connections. Special attention should be given to the enclosure, ensuring it is intact and free from any breaches that could expose internal components to the elements. Additionally, all labels and warning signs should be clearly visible and legible.

b) Electrical System Evaluation
The electrical components of a fully integrated BESS are its lifeblood. Inspectors should verify that all electrical connections are secure and free from damage. This includes checking the integrity of the busbars, circuit breakers, and fuses. The inspection should also involve testing the system's grounding to ensure it meets safety standards. Any signs of overheating, such as discoloration or burnt smells, should be addressed immediately.

c) Battery Health Assessment
The batteries are the core of any BESS, making their inspection crucial. Inspectors should check for any signs of swelling, leaking, or corrosion on the battery terminals. The state of charge (SOC) and state of health (SOH) of the batteries should be monitored regularly to ensure they are within optimal ranges. Any significant deviations may indicate underlying issues that need to be addressed. Additionally, the battery management system (BMS) should be inspected for proper functionality.

d) Thermal Management System Check
A fully integrated BESS relies on an effective thermal management system to maintain optimal operating temperatures. Inspectors should check the cooling systems, including fans, heat exchangers, and coolant levels, to ensure they are functioning correctly. Any blockages or leaks should be promptly repaired to prevent overheating, which can lead to reduced efficiency and potential safety hazards.

e) Control System Verification
The control system is responsible for managing the operation of the BESS, making its inspection vital. Inspectors should ensure that all control systems, including software and hardware components, are functioning as intended. This includes verifying the accuracy of sensors, the responsiveness of control algorithms, and the reliability of communication between different system components. Regular software updates and system recalibrations may be necessary to maintain optimal performance.

f) Safety Systems Evaluation
Safety is paramount in any energy storage system. Inspectors should verify that all safety systems, such as fire suppression, emergency shut-off mechanisms, and alarms, are fully operational. Regular testing of these systems is essential to ensure they will function correctly in the event of an emergency. Any deficiencies should be addressed immediately to maintain the highest level of safety.

g) Documentation and Reporting
Finally, all inspection findings should be thoroughly documented. This includes recording any issues identified, actions taken, and recommendations for future maintenance. Comprehensive documentation not only helps in tracking the system's condition over time but also provides valuable information for future inspections and maintenance efforts.

Related Standards

IECTS 62786 3 – "Distributed energy resources connection with the grid – Part 3: Additional requirements for stationary battery energy storage system
This Technical Specification provides principles and technical requirements for interconnection of distributed Battery Energy Storage System (BESS) to the distribution network. It applies to the design, operation and testing of BESS interconnected to distribution networks. It includes the additional requirements for BESS, such as connection scheme, choice of switchgear, normal operating range, immunity to disturbance, active power response to frequency deviation, reactive power response to voltage variations and voltage changes, EMC and power quality, interface protection, connection and start to generate electric power, active power management, monitoring, control and communication, and grid-connected tests.

The stationary BESSs considered within the scope of this document include electrical forms such as lead-acid, lithium-ion, liquid flow and sodium-sulfur batteries, interconnected to medium voltage (MV) or low voltage (LV) distribution networks via bidirectional DC to AC power converters. This document will specify active and reactive power response and grid-connected testing for distributed BESS, as a supplement for IEC TS 62786-1. This document specifies interface requirements for connection of distributed BESS with the distribution network operating at a nominal frequency of 50 Hz or 60 Hz.

IEC 62933 2 1 – "Electrical energy storage (EES) systems – Part 2-1: Unit parameters and testing methods – General specification"
This standard focuses on unit parameters and testing methods of EES systems. The energy storage devices and technologies are outside the scope of this document. This document deals with EES system performance defining unit parameters and testing methods.

IEC TR 62933 2 201 – Electrical energy storage (EES) systems – Part 2-201: Unit parameters and testing methods – Review of testing for battery energy storage systems (BESS) for the purpose of implementing repurpose and reuse batteries
This technical report focuses on the necessity of using repurpose and reuse batteries in BESS. This document also illustrates, through case studies from various countries, how repurpose and reuse batteries are regulated as per legislation. Furthermore, business examples of BESS using repurpose and reuse batteries are investigated and issues derived in terms of both the design, manufacturing, testing, operation, and maintenance of BESS, considering the anticipated future deployment of BESS

IEC 62485 2 – Safety requirements for secondary batteries and battery installations
Part 2: Stationary Batteries
This standard applies to stationary secondary batteries and battery installations with a maximum voltage of DC 1 500 V (nominal) and describes the principal measures for protections against hazards generated from electricity, gas emission, and electrolyte.

This International Standard provides requirements on safety aspects associated with the erection, use, inspection, maintenance and disposal. It covers lead-acid and NiCd/NiMH batteries.

IEC 62619 – Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications
This standard specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications, including stationary applications. When there exists an IEC International Standard specifying test conditions and requirements for cells used in special applications and which is in conflict with this document, the former takes precedence (e.g., IEC 62660

series on road vehicles). Examples of applications that utilize cells and batteries under the scope of this document include those for stationary applications such as telecom, uninterruptible power supplies (UPS), electrical energy storage system, utility switching, emergency power etc.

IEC 62933 4 3 – Electrical energy storage (EES) systems – Part 4-3: Protection requirements of battery-based energy storage systems (BESS) according to environmental conditions
This standard applies to the effects of the environmental conditions on Battery Energy Storage Systems (BESS). This document addresses these effects and identifies causes, chain of events and final effects on the BESS. Based on those effects, preventative or mitigating measures are described. Typical environmental effects on the BESS include, but are not limited to, the effects of lightning, seismic activities, water, air, flora, fauna, and humans. The described measures focus as a guideline on the entire BESS including all power and communication connections and its Point of Connections (POCs). The scope of this document is limited to BESS specific requirements and operating conditions. Specific design or safety requirements of individual BESS subsystems are excluded from this document.

IEC 62933 4 2 – Electric energy storage (EES) systems – Part 4-2: Guidance on environmental issues – Assessment of the environmental impact of battery failure in an electrochemical based storage system
This standard defines the requirements for evaluating and reporting the negative impact on the environment caused by the failure of a cell, flow cell, battery or flow battery in the accumulation subsystem of a battery energy storage system (BESS).

The batteries within this scope used in a BESS are classified according to the type of their electrolyte. These electrolyte types are aqueous, non-aqueous or solid. The environmental impacts directly caused by the failure of other components of the BESS are not within the scope of this document.

IEC 63056 – Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems
This standard specifies requirements and tests for the product safety of secondary lithium cells and batteries used in electrical energy storage systems with a maximum DC voltage of 1500 V (nominal). Basic safety requirements for the secondary lithium cells and batteries used in industrial applications are included in IEC 62619. This document provides additional or specific requirements for electrical energy storage systems.

Since this document covers batteries for various electrical energy storage systems, it includes those requirements which are common and minimum to the electrical energy storage systems. Examples of appliances that are within the scope of this document are: telecommunications, photovoltaic systems, home (residential) energy storage systems (HESS), and large energy storage: on-grid/off-grid. This document also applies to cells and batteries for uninterruptible power supplies (UPS). This document does not apply to portable systems 500 Wh or below, which are covered by IEC 61960-3.

11 OPERATIONS & MAINTENANCE REQUIREMENTS

'Renewable Energy (RE) plants shall be operated and maintained in a manner that ensures long-term reliability, safety, and compliance with grid performance expectations. Effective operations and maintenance (O&M) practices are essential for sustaining plant availability, supporting real-time grid needs, and ensuring that Renewable Power Plants (RPPs) continue to meet functional, regulatory, and technical requirements throughout their lifecycle. The following subsections outline the minimum operational capabilities including ancillary service functions, earthing practices, maintenance obligations, and coordination protocols expected of RE plant operators, with reference to relevant international standards and best practices.

11.1 Ancillary Services

Renewable Power Plants (RPPs) may be required to provide ancillary services to support the stability and reliability of the power system. Ancillary services include, but are not limited to, active power control, reactive power and voltage control, frequency response, fault ride-through capabilities, and, where technically feasible, additional services such as black start capability. Subsections (11.2–11.4) outline the minimum functional requirements for ancillary services expected from RPPs.

11.2 Active Power Control

Larger Renewable Power Plants (RPPs) should be capable of managing their active power output in a controlled and predictable manner to support the stability and reliability of the power system, including interconnected power systems. This includes the ability to limit, ramp, curtail, and increase active power in response to system operator commands or real-time grid conditions. RPPs should be able to limit output below the available generation capacity when requested by the system operator, and to increase output when permitted by operating conditions and control signals. The plant should also support active power ramp rate control, with ramp rates configurable as required by the system operator to avoid sudden fluctuations.

Where active power dispatchability is required, RPPs shall be capable of accurately tracking active power setpoints provided by the control center. The plant shall respond to setpoint changes within the specified time frames and maintain continuous real-time communication with the system operator to ensure coordinated dispatch and grid reliability.

Related IEC Standard

IEC TS 62786-1 – Distributed energy resources connection with the grid – Part 1: General requirements
Refer to Section 4.2 of this guide for the abstract.

11.3 Reactive Power and Voltage Control

Larger Renewable Power Plants (RPPs) should also be capable of providing voltage support and reactive power control at the Point of Connection (POC), as required to maintain system voltage within acceptable limits and contribute to overall power system stability. These capabilities are especially important in networks with high penetration of inverter-based generation. RPPs should be able to generate or absorb reactive power over a defined power factor range as specified by the system operator and specified time frames.

The System Operator will specify the required accuracy of the adjustment required. This reactive power support capability must be maintained dynamically across varying levels of active power output, using plant-level controllers, inverter functions, or external reactive compensation devices, if required.

Where voltage regulation is required, RPPs shall support one or more of the following control modes, as specified by the system operator including constant power factor mode, Voltage-reactive power (V-Q) droop control, reactive power setpoint control etc. Should the voltage reach the RPPs dynamic design limits even after all control attempts, the control function shall await possible overall control from the tap changer or other voltage control methods.

Related IEC Standard

IEC TS 62786-1 – Distributed energy resources connection with the grid – Part 1: General requirements
Refer to Section 4.2 of this guide for the abstract.

11.4 Frequency Control and Response Mechanisms

Larger Renewable Power Plants (RPPs) shall support system frequency stability by remaining connected during short-term frequency deviations and, where required, participating in active frequency response. RPPs must not disconnect unnecessarily during frequency excursions but shall maintain active power output within their technical limits. The plant shall reduce output in over-frequency conditions and, where feasible, increase output during under-frequency events, following predefined response characteristics as specified by the system operator.

In systems where it is required by the system operator, RPPs shall also provide frequency droop response and, if technically capable, deliver fast frequency response based on the rate of change of frequency (ROCOF). In addition, RPPs shall be capable of withstanding rates of change of frequency (ROCOF) without disconnection, as defined by the system operator. These functions shall be implemented in accordance with IEC TS 62786-1 and applicable national grid code provisions.

Related IEC Standards

IEC TR 63401-3 – Dynamic characteristics of inverter-based resources in bulk power systems–Part 3: Fast frequency response and frequency ride-through from inverter-based resources during severe frequency disturbances.
This Technical Report, provides an insight into the various forms of fast frequency response and frequency ride-through techniques that involve inverter-based generation sources (mainly wind and PV) in a bulk electrical system.

This document first focuses on extracting the clear definition of FFR from different references around the world, while studying the mechanism of FFR acting on system frequency and the unique features of FFR. It then compares various kinds of frequency response and demonstrates the relationship among synchronous inertia response, fast frequency response, and primary frequency response. Several system needs and conditions where FFR is suitable are identified. This document also focuses on the performance objectives, practicality and capabilities of various non-synchronous resources, and discusses the test methods for verifying FFR capability at different levels. Finally, it focuses on the ROCOF issues and on the robust performances of FFR.

IEC TS 62786-1 – Distributed energy resources connection with the grid – Part 1: General requirements
Refer to Section 4.2 of this guide for the abstract.

11.5 Fault Ride-Through Capabilities

Renewable Power Plants (RPPs) shall be equipped with Fault Ride-Through (FRT) capabilities to maintain connection and support grid stability during short-term disturbances on the transmission or distribution network. This includes the ability to remain operational during voltage and frequency deviations, as defined by the system operator. RPPs shall not disconnect immediately upon detection of abnormal voltage or frequency conditions but must be capable of riding through such disturbances for specified durations. Full autonomous recovery is expected once normal grid conditions are restored.

Undervoltage and Overvoltage Ride Through capability for DER shall be in accordance with the provisions specified in Annexes C & D of IEC TS 62786-1.

Related IEC Standards

IEC TR 63401-3 – Dynamic characteristics of inverter-based resources in bulk power systems–Part 3: Fast frequency response and frequency ride-through from inverter-based resources during severe frequency disturbances.
Refer to Section 11.4 of thus guide for the abstract.

IEC TS 62786-1 – Distributed energy resources connection with the grid – Part 1: General requirements
Refer to Section 4.2 of this guide for the abstract.

11.6 Neutral earthing

Renewable Energy (RE) plants shall be equipped with neutral earthing systems that ensure personnel safety, support effective fault detection, and maintain compatibility with the grounding philosophy of the power system. The earthing arrangement shall align with applicable utility requirements and must enable proper functioning of protection and control systems under both normal and fault conditions.

The design of the earthing system shall consider the configuration of step-up transformers, auxiliary supplies, and power electronic interfaces. Depending on the system topology, solid, resistive, impedance, or isolated (in special cases) neutral schemes may be used, subject to grid operator approval and coordination. The chosen grounding method shall prevent issues such as circulating currents, neutral shift, or maloperation of protection systems.

Routine inspection and testing of the grounding system shall be conducted to ensure continuity, detect degradation, and maintain operational integrity throughout the plant's lifecycle.

Related Standards

IEC 61936-1: Power Installations exceeding 1kV AC and 1.5kV DC Part 1: AC
This standard provides requirements for the design and the erection of electrical power installations in systems with nominal voltages exceeding 1 kV AC and nominal frequency up to and including 60 Hz, so as to provide safety and proper functioning for the use intended.

IEC 60364-5-54: Low Voltage Electrical Installations, Selection and Erection of electrical equipment, Earthing arrangements and protective conductors
This standard addresses the earthing arrangements and protective conductors including protective bonding conductors in order to satisfy the safety of the electrical installation.

11.7 Maintenance of RE systems

Renewable Energy (RE) plants must be maintained to ensure sustained performance, safety, and compliance with applicable grid codes throughout their operational lifespan. All RE plant owners and operators shall implement structured maintenance programmes to reduce equipment failure, extend asset life, and uphold grid reliability. Maintenance practices shall include preventive, predictive, and corrective strategies, in line with manufacturer recommendations and applicable industry standards. Maintenance of PV systems shall follow the baseline procedures defined in IEC 62446-2. Where RE plants form part of a larger hybrid or utility-integrated system, it is important to ensure maintenance coordination with the grid operator to avoid service disruption or grid instability during equipment downtime.

Related Standards

IEC 62446-2: Requirements for testing, documentation, and maintenance – Part 2 Grid Connected Systems – Maintenance of PV systems
This standard describes the basic preventive, corrective, and performance related maintenance requirements and recommendations for grid-connected PV systems.

The maintenance procedures cover:

- Basic maintenance of the system components and connections for reliability, safety and fire prevention
- Measures for corrective maintenance and troubleshooting
- Worker safety

This document also addresses maintenance activities for maximizing anticipated performance such as module cleaning and upkeep of vegetation. Special considerations unique to rooftop or ground-mounted systems are summarized

11.8 Coordination Between Grid Operators and RE plant Providers

Effective coordination between Renewable Energy (RE) plant providers and grid operators is essential to support smooth integration of variable renewable generation and also enhance overall system resilience. It is important for RE plant operators to engage with the System Operator throughout all project stages, including planning, commissioning, operation, and maintenance. This includes sharing real-time and forecasted generation data, outage schedules, and providing telemetry and SCADA connectivity in accordance with grid operator protocols.

RE plants must also coordinate on grid support services such as voltage regulation, frequency response, and protection settings to ensure system stability. Communication channels should be established for operational dispatch and emergency events. Also, compliance with operational standards and reporting obligations shall be maintained at all times.

12 MICROGRIDS

Microgrids are increasingly being deployed across Africa to extend electricity access, integrate renewable energy resources, and improve resilience in areas where the main grid is weak or absent. Microgrid projects shall be planned and specified in accordance with IEC TS 62898-1, ensuring that the generation mix, load characteristics, and control strategies are suited to local conditions and will ensure the stability of the microgrid.

Storage systems, including batteries and hybrid storage technologies, are recommended to enhance reliability and manage the variability of solar and wind generation. Microgrid operation shall follow the guidance of IEC TS 62898-2, ensuring stable transitions between islanded and grid-connected modes. System operators must establish clear operating protocols for synchronization, resynchronization, and black start procedures.

IEC TS 62898-3-1 provides guidance on requirements for microgrid protection, dynamic control for transient and dynamic disturbances in microgrids, including technical requirements of fault protection. Protection schemes for microgrids must account for bidirectional power flows, inverter-based generation, and storage units. Anti-islanding protection is mandatory for all distributed generators to safeguard both personnel and equipment. In addition, appropriate lightning, surge, overload, and fire protection measures shall be incorporated, taking into account environmental and rural deployment conditions that are common across African microgrid projects.

Microgrids, even when off grid, constitute a form of public electricity supply and shall adhere to minimum power quality and safety requirements, including voltage tolerance, harmonics, flicker, and unbalance, as specified in IEC 61000-3-6, IEC 61000-3-7, and IEC 61400-21-1. Where microgrids are interconnected with the utility grid, they may also be required to provide ancillary services such as frequency support, reactive power, and voltage regulation, in line with system operator requirements.

Figure 2: A 54kW microgrid facility in Kudorkope, Ghana.
Source: Volta River Authority, Ghana.

Relevant IEC Standards

IEC TS 62898-1: Microgrids –
Part 1: Guidelines for microgrid projects planning and specification
This standard provides guidelines for microgrid projects planning and specification. Microgrids considered in this document are alternating current (AC) electrical systems with loads and distributed energy resources (DER) at low or medium voltage level. This document does not cover direct current (DC) microgrids. Microgrids are classified into isolated microgrids and non-isolated microgrids. Isolated microgrids have no electrical connection to a wider electric power system. Non-isolated microgrids can act as controllable units to the electric power system and can operate in the following two modes:

- grid-connected mode;
- island mode.

This document covers the following areas:

- microgrid application, resource analysis, generation forecast, and load forecast;
- DER planning and microgrid power system planning;

- high level technical requirements for DER in microgrids, for microgrid connection to the distribution system, and for control, protection and communication systems;
- evaluation of microgrid projects.

IEC TS 62898-2: Microgrids – Part 2: Guidelines for operation
This standard provides guidelines for operation of microgrids. Microgrids considered in this document are alternating current (AC) electrical systems with loads and distributed energy resources (DER) at low or medium voltage level. This document does not cover direct current (DC) microgrids.

IEC TS 62898-2 applies to operation and control of microgrids, including:

- operation modes and mode transfer;
- energy management system (EMS) and control of microgrids;
- communication and monitoring procedures;
- electrical energy storage;
- protection principle covering: principle for non-isolated microgrid, isolated microgrid, anti-islanding, synchronization and reclosing, power quality;
- commissioning, maintenance and test.

IEC TS 62898-3-1: Microgrids – Part 3-1: Technical Requirements – Protection and Dynamic Control
This standard provides guidelines for the specification of fault protection and dynamic control in microgrids. Protection and dynamic control in a microgrid are intended to ensure safe and stable operation of the microgrid under fault and disturbance conditions.

This document applies to AC microgrids comprising single or three-phase networks or both. It includes both isolated microgrids and non-isolated microgrids with a single point of connection (POC) to the upstream distribution network. It does not apply to microgrids with two or more points of connection to the upstream distribution network, although such systems can follow the guidelines given in this document. This document applies to microgrids operating at LV or MV or both. DC and hybrid AC/DC microgrids are excluded from the scope, due to the particular characteristics of DC systems (extremely large fault currents and the absence of naturally occurring current zero crossings).

This document defines the principles of protection and dynamic control for microgrids, general technical requirements, and specific technical requirements of fault protection and dynamic control. It addresses new challenges in microgrid protection requirements, transient disturbance control and dynamic disturbance control requirements for microgrids. It focuses on the differences between conventional power system protection and new possible solutions for microgrid protection functions.

Depending on specific situations, additional or stricter requirements can be defined by the microgrid operator in coordination with the distribution system operator (DSO).

This document does not cover protection and dynamic control of active distribution systems. This document does not cover product requirements for measuring relays and protection equipment.

This document does not cover safety aspects in low voltage electrical installations, which are covered by IEC 60364 (all parts and amendments related to low-voltage electrical installations). Requirements relating to low voltage microgrids can be found in IEC 60364-8-2.

13 ANNEXES

13.1 Annex A – List of Other Useful Standards

IEC 60227-1
Polyvinyl Chloride Insulated Cables

IEC TR 63282
LVDC systems – Low – voltage DC electric island power supply systems

IEC 60050-151
International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices

IEC 60050-603
International Electrotechnical Vocabulary (IEV) – Part 603: Generation, transmission and distribution of electricity – Power systems planning and management

IEC 60050-601
Amendment 2 – International Electrotechnical Vocabulary (IEV) – Part 601: Generation, transmission and distribution of electricity – General

IEC 60050-704
Amendment 4 – International Electrotechnical Vocabulary (IEV) – Part 704: Transmission

IEC 61000-3-3
Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection

IEC TR 61000-3-13
Electromagnetic compatibility (EMC) – Part 3-13: Limits – Assessment of emission limits for the connection of unbalanced installations to MV, HV and EHV power systems

IEC 60870-6-502
Telecontrol equipment and systems – Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations – Section 502: TASE.1 Protocol definitions

IEC TS 62933-1
Electrical energy storage (EES) systems – Part 1: Vocabulary

IEC TS 62933-3-2
Electrical energy storage (EES) systems – Part 3-2: Planning and performance assessment of electrical energy storage systems – Additional requirements for power intensive and renewable energy sources integration related applications

IEC TR 63401-1
Dynamic characteristics of inverter-based resources in bulk power systems – Part 1: Interconnecting inverter-based resources to low short circuit ratio AC networks

IEC TR 63401-2
Dynamic characteristics of inverter-based resources in bulk power systems – Part 2: Sub- and Super-synchronous control Interactions

IEC TS 63102
Grid code compliance assessment methods for grid connection of wind and PV power plants

IEC TS 62910
Utility-interconnected photovoltaic inverters – Test procedure for under voltage ride-through measurements

IEC TS 63217
Utility-interconnected photovoltaic inverters – Test procedure for over voltage ride-through measurements

IEC TS 63222-1
Power quality management – Part 1: General guidelines

13.2 Annex B – Bibliography

The following grid codes were reviewed to identify the key aspects of renewable energy integration into the grid that should be considered in the development of the guidelines:

Country	Grid Code
South Africa	Grid connection code for Renewable Power Plants (RPPS) connected to the electricity Transmission System (TS) or the Distribution System (DS) in South Africa (South Africa)
South Africa	Grid Connection for Battery Energy Storage Facilities (South Africa)
Ghana	National Electricity Grid Code (Ghana)
Ghana	Renewable Energy Sub-Code for Transmission System (Ghana)
Ghana	Renewable Energy Sub-Code for Distribution System (Ghana)
Egypt	Solar Energy Plants Grid Connection Code (Egypt)
Egypt	Technical Requirements for Connecting Small Scale PV (ssPV) Systems to Low Voltage Distribution Networks (Egypt)
Kenya	Draft Kenya Electricity Grid Code – Part I: Kenya National Transmission Grid Code (Kenya)
Kenya	Draft Kenya Electricity Grid Code – Part II: Kenya National Distribution Grid Code (Kenya)
Nigeria	The Grid Code for the Nigeria Electricity Transmission System (Nigeria)
Malawi	Malawi Grid Code
Ivory Coast	Grid Connection Code of Côte d'Ivoire
Rwanda	Rwanda Grid Code

13.3 Annex C – AFSEC Strategic Goals.

The AFSEC Strategic Goals (2025-2029) were approved at the 9th General Assembly Meeting held in Kigali Rwanda, in September 2024, as follow:

1. To deliver outputs that are relevant to and **support the objectives of the AU Agenda 2063** and its programs; and to respond to the needs of the Regional economic Communities and the African Union Commission, through relevant and effective electrotechnical standardization and Conformity Assessment, as they are the main drivers to ensure access to reliable, sustainable and modern energy in Africa

2. To provide a framework of **cooperation with the African Continental Free Trade Agreement AfCFTA** towards excellence in electrotechnical standardization and Conformity Assessment, and to cooperate with related parties in the development and effective implementation of obligations under Technical Barriers to Trade (TBT) and annex 6 of the Protocol of Trade and Goods aiming to facilitate trade by removing different technical obstacles and opening new markets.

3. To **collaborate** with **partners and stakeholders** To identify related standards that can be harmonized, and generate necessary interest among African countries to utilize the standards, after reviewing them for adoption as AFSEC Harmonized African standards, aiming to enhance sustainable trade in electrotechnology in Africa, to have one approach on standardization and aligning with the African Continental Free Trade Area (AfCFTA)

4. To enhance **the competence of the National Electro Technical Committees** by improving the systems and structures necessary for harmonization of Standards and to foster the proactive **involvement of** all **stakeholders** by creating a system which can attract Industry, academia (or research institutions) and power utilities, grooming technical expertise

to participate through Technical committees, in the development of globally accepted standards and coping with new technology trends.

5. **To establish a sustainable database** to enable complete information of adopted standards by AFSEC member states, as well as for **Testing Laboratories** in Africa.

6. **To build capacit**y and provide opportunities for career and professional development., especially in new technologies (AI, E-mobility, Green Hydrogen....). **Members could recommend identified opportunities for AFSEC consideration.**

Within AFSEC Strategic Goals (2025-2029) and the main mandate of AFSEC, Standards covering various Electrotechnical aspects are being harmonized/ developed by its Technical Committees. The initial selection of the AFSEC Technical Committees TCs (IEC based) were in support of electricity access, and involve renewable energy:

- ATC8 (System aspects of electrical energy supply) – Micro-grids & grid interconnection,
- ATC13(Electrical energy measurement and control) – metering,
- ATC64 (Electrical installations and protection against electric shock) – safe electrical regulations,
- ATC57 (Power systems management and associated information exchange) – Information management protocol,
- ATC77 (Electromagnetic compatibility) – EMC (product focused),
- ATC 82 (Solar PV Energy Systems) – to support electricity access concentrating on remote areas.
- A E-Mobility for Electric Vehicles- for analysing and adoption of international and/or regional standards of electric vehicles, e-bikes and charging infrastructure.
- AGH2 for Green Hydrogen for analysing and adoption of international and/or regional standards for green hydrogen and associated technologies

13.4 Annex D – AFSEC Published Technical Guides

AFSEC Technical Guides have been developed to interpret Standards into Use Cases to be useful for Investors, Installers and other stakeholders.

They include guides no:

1. Rural Electrification in Africa.
2. Application of Standards for Smart Metering Systems in Africa.
3. Smart Meters requirements for electrification projects in Africa
4. Technical Guidelines for Low Voltage Electrical Installations.
5. Guidelines for the Installation of Photovoltaic Mini-Grids.
6. Electromagnetic Compatibility for Medical Devices.
7. Electromagnetic Compatibility of Power Quality.
8. Electromagnetic Field Exposure.
9. Conformity Assessment in the African Electrotechnical Sector.
10. Electrotechnical Conformance Test Laboratories.
11. Interconnection of Electrical Grids in Africa.
12. Power Systems Automation Standards.

www.afsec-africa.org