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GUIDELINES Nº 02/GL/EL-EWS/RURA/2019 ON MINIMUM TECHNICAL REQUIREMENTS FOR MINI-GRIDS IN RWANDA

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ABBREVIATIONS AND ACRONYMS

AC	alternating current
CE	Conformité Européenne
DC	direct current
DOD	depth of discharge
IEC	International Electrotechnical Commission
IGC	Induction Generator Controller
IP	ingress protection
kV	kilovolt
LV	low voltage
MCB	Miniature Circuit Breaker
MV	medium voltage
O&M	operation and maintenance
PV	photovoltaic
PVC	polyvinyl chloride
STC	standard test conditions (25 degrees C and 1000 watts per m^2)
UL	Underwriters Laboratories
UV	ultra violet
V	volt
W	watt
Wh	watt hour
Wp	watt peak (unit of nominal power of photovoltaic devices)

1 PURPOSE

The purpose of these guidelines is to outline the minimum technical specifications that must be followed in development of mini-grids plants in Rwanda.

These technical specifications are developed with the purpose of ensuring safety and reliability of mini-grids.

2 GENERAL REQUIREMENTS

a) All mini-grids must generate at least 50% of consumed energy on an annual kWh basis from renewable energy.
b) The mini-grid project developer is responsible for on-site warranty, ensuring that failed components are repaired or replaced in case such a claim is required.
c) The installation must include a complete toolbox with all tool necessary for routine maintenance and with a collection of commonly replaced spare parts replacement.
d) Any mini-grid that connects or intends to be connected to the National Grid shall be in compliance with the Main Grid Standards and the Rwanda Grid Code.

2.1 Information

The following information shall be readily available from the Isolated Mini-Grid Operator and provided at the mini-grid site at all times:

a) A complete set of drawings including:

    i) Single-line diagram showing all generation components, conversion components, storage components, monitoring/communication components and isolation and protective devices with Connection Points clearly marked;

    ii) As-built drawings showing the distribution network with pole positions, pole spans, single or three phase network or DC network, conductor size, isolation points/devices, earthing points, major customer locations and protection measures clearly indicated.

    iii) Operation/ Maintenance manuals of major equipment in hardcopy and soft copy if possible.

b) A mini-grid system inventory showing quantities, sizes, manufacturers and technical specifications on:
    i) Civil works
    ii) Generation, storage, energy conversion, monitoring and control systems
    iii) Distribution system
    iv) Metering and vending system
c) A customer database showing the following information:
    i) Customer name, address phone number and date of connection

ii) Type of customer
iii) Connection type
iv) Pole number where customer is connected from
v) Meter number and allocated power (if applicable)

2.2 Nominal voltage and operating voltage range

a) For AC mini-grids, the nominal voltage at customer service drops shall be 400 V line to line or 230 V line to neutral. The operating voltage shall not vary beyond ± 10% of the nominal voltage.
b) For DC mini-grids, the nominal voltage shall be 48 volts or less.

2.3 Nominal frequency and operating frequency range

a) For AC mini-grids, the nominal operating frequency of the mini-grid shall be 50 Hz. The allowed operating range shall be within +6% (53 Hz) and -6% (47 Hz), beyond which the protection relays at generation shall operate to shut down the mini-grid, after a time delay of 500 ms from the time the frequency crosses the allowed boundaries.

3 SOLAR PV GENERATION SYSTEM COMPONENTS

3.1 Photovoltaic (PV) modules

a) Solar modules shall conform to the following standards:
   i) RS IEC 61215 Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval.
   ii) RS IEC 61730 Photovoltaic (PV) modules safety qualification – Requirements for construction and requirement for testing.
b) All PV modules shall have the following product warranty levels:
   i) Manufacturing warranty for material and workmanship: must have at least a ten-year warranty on physical manufacture of module itself, i.e. the frame, encapsulant, glass, module junction box etc.
   ii) Power output performance warranty: ten years 90% rated output and 25 years 80% rated output warranty.
c) Bypass diodes shall be installed in each module to prevent hotspots in modules, which occur often because of partial shading of modules.
d) Solar modules shall have a junction box with ingress rating IP65 or higher mounted at the back of the panel with at least 4 mm^2 cross sectional conductor area output cables.
e) The label of the PV module shall have the following details: Name of the manufacturer, model number, serial number, short-circuit current (I_{sc}), open-circuit voltage (V_{oc}), current at maximum power (I_{mp}), voltage at maximum power (V_{mp}), and power rating of panel at standard test condition (STC).

3.2 PV array rack (mounting structure)

a) The mounting structure used for the solar panels shall be made of corrosion-resistant material such as aluminium alloy or hot dip galvanized steels. If hot dip galvanized, thickness of galvanization shall exceed 80 microns.
b) The array rack shall be constructed as earth mounted, top-of-pole, or roof-mounted type.
c) The minimum thickness of the structural material used for mounting structure shall be 2 mm.
d) Bolts, nuts, fasteners, panel mounting clamps including joining the sections of structure shall be with galvanized or stainless-steel fasteners or by welding. Bolts shall be secured with locking washers or locknuts.
e) In case of a welding structure, galvanization shall be done after the fabrication work.
f) Any contact between unlike materials shall be avoided by using insulation between any aluminium and galvanized sections.

3.3 Inverters

3.3.1 Standards and certifications

Inverters, whether PV inverters or battery inverters used for mini-grids are required to meet the following standards:

a) RS IEC 62109-1 (Safety of Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements)
b) RS IEC 62109-2 (Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
c) CE or UL 1741

3.3.2 Inverter labelling

Each inverter device must be labelled with at least the following information:

a) Manufacturer name and model
b) Serial number
c) Frequency
d) Input and output voltage and rated power

3.3.3 Inverter warranty

Inverters must be warranted against manufacturing defects for at least five years.

3.3.4 Inverter efficiency

The PV inverters efficiency shall be equal to or greater than 95% over 75% of the inverter's power range. The efficiency of battery inverters if used shall be equal to or greater than 90% over 75% of the power range.

3.3.5 Inverter protection

a) Inverters shall have protection for over-temperature and excessive DC voltage.
b) Inverters shall have an ingress protection rating at a minimum of IP 54 if installed outdoors.

3.4 PV charge controllers

PV charge controllers, if present, shall have the following characteristics:

a) Maximum Power Point Tracking (MPPT) or Pulse Width Modulated (PWM)
b) PV charging efficiency at least 90% based on IEC 61683: Photovoltaic System-Power Conditioners - Procedure for Measuring Efficiency
c) Rated current at 50^{o} C must be at minimum 120% of peak array current (Isc)
d) Protected from dust ingress (IP54 or higher).
e) Controllers to be certified to meet at least one of the following standards:
   i) CE or UL 1741 Marking
   ii) RS IEC 62509
   iii) RS IEC 62093

3.5 Batteries

3.5.1 Cycle life and warranty

a) The battery's manufacturer-rated cycle life shall be not less 1,000 cycles when discharged to 50% DOD.
b) All batteries to be warranted to at least 2 years under the operational conditions on site, to 80% of original rated capacity.

3.5.2 Battery labelling

a) Each battery/cell shall be engraved with the date of manufacture.
b) For each battery type, the battery must be labelled indicating at minimum: the manufacturer, model number, voltage and capacity (Ah).

3.5.3 Overcurrent protection and disconnects

Positive cables between batteries and inverters shall be protected with DC-rated over-current protection and disconnect (either circuit breaker or fused disconnect) of appropriate rating to protect cables in the event of a short circuit.

4 HYDROPOWER

The requirements listed below apply to hydropower facilities that employ a weir, canal and penstock.

If the developer choses to employ technologies that do not require these structures, the Regulatory Authority shall apply an appropriate subset of requirements listed below and may impose other requirements that pertain to the proposed configuration and equipment employed.

4.1 Powerhouse

a) The mini-grid powerhouse shall be located above the maximum 25-year flood levels as observed by local residents near the site.
b) The floor area of the powerhouse shall be sufficient to safely place the equipment and carry out routine maintenance work conveniently. Adequate spacing and easy access to the

electrical and electromechanical equipment from all sides shall be maintained for ease operation and maintenance.

c) Window areas of the powerhouse shall be equivalent to at least 10% of the powerhouse floor area to ensure adequate passive ventilation in the absence or failure of automatic temperature control equipment.
d) The minimum height between floor and ceiling shall be 3 meters.
e) Roofing material shall be made of fire-resistant materials such as tile or corrugated sheets. In case of corrugated sheets, the minimum thickness shall be 0.47mm. The roof shall be watertight and shall extend at least 1 meter over walls to prevent water for entering through window portals.
f) The power-house door shall be designed with adequate spacing for easy installation and removal of equipment. For safety reasons, the door shall be outward-opening.
g) Workers' quarters or rest house with basic facilities such as bathroom/washroom and essential living furniture shall accompany the powerhouse design as it is necessary for an operator to be present all the times during normal system operation.

4.2 Civil works – concrete and steel

Concrete mixtures in hydropower civil works structures shall follow the ratios of cement, sand, and gravel as described below:

- For base (screed) concretes: 1:2:4 (Grade 15)
- For foundations and other structures: 1:1.5:3 (Grade 20)
- For water-bearing structures such as the forebay tank, weir and channel of a hydropower facility:1:1:2 (Grade 25)
- Tor steel or rebar and bends used for construction shall comply with standards adopted by the Competent Authority.

4.3 Weir & intake

a) The weir should be located at a river section with an exposed bedrock or where depth to the bedrock is minimum, along with considerable upstream storage in the case that flows are restricted during the dry season.
b) Intake shall be selected such that minimum debris will enter the system during flooding period.
c) Intake shall be equipped with a trash rack to prevent clogging; a control gate to control the water flow to the channel and flood barrier wall to make the control gate operations possible during high flow periods.
d) Trash rack shall have preferably iron rods or flat iron; welded with a gap decided based on the turbine supplier's recommendation; rod orienting upward (vertical) direction without cross bars, making it easy for the plant personnel to clean efficiently with a rake.
e) The intake shall be located such that it can be accessed during high flood period.

f) The sluice or flush gate shall be designed based on the maximum silt load of the stream. The sluice gate shall be located at the lowest point of the weir with a proper controlling mechanism.
g) Erosion and deepening of downstream riverbed, due to scouring action, of weir and spillways shall be considered in design phase and shall be protected with suitable mechanism/ structures incorporated in weir design.

4.4 Channel

a) Freeboard allowance of 30% shall be kept when designing the channel dimensions.
b) To limit erosion in the channel, maximum channel velocity shall conform to the specifications below. In case of silty water, channel velocity shall be maintained at the minimum velocity of 0.3 m/s to prevent clogging of the channel.

Table 1- Maximum channel velocity of different types of hydro channels

Type of channel	**Maximum velocity (m/s)**
Concrete channels with no internal plaster	2
Rubble and masonry channel with smooth plaster	1.8
Clay channel	1.5
Earth Channel	0.7

4.5 Forebay

a) The settling tank section shall settle and filter particles above 0.3 mm in diameter.
b) A manually operated sluice or flush gate and spillway shall be incorporated to the settling section to flush the silt collected from time to time.
c) A second trash rack shall be included in the in the forebay section with rod spacing at similar proportions to the weir intake trash rack.
d) The penstock penetration through the forebay shall be deep enough to avoid vortex formation, yet be positioned at least 150 mm above the forebay tank floor to prevent silt and small stones from entering the penstock.
e) A vent pipe with a sufficient diameter shall be fixed to the penstock or bell mouth section to prevent implosion of the penstock due to surge pressure.

4.6 Penstock and supports

a) Penstock shall ideally have constant gradient in each section; i.e. straight from one anchor to the next.
b) An air release valve shall be fitted to highest point if air is likely to be trapped due to the layout of the penstock.

c) Penstock material and thickness shall take into account pressure due to normal operation as well as any surge that might occur do to blockage, with a safety factor of at least 2.
d) Penstocks laid above ground shall be supported at 6m intervals with a slide block or support block. In the event of support blocks, minimum of 120 degrees of the penstock circumference shall be firmly in contact to the support block. These supports and slide blocks can be made with concrete, rubble and masonry
e) In all bends, an anchor block made of reinforced concrete shall be constructed to counterbalance the forces occurs due to cause by change of momentum of water. Possible penstock failing scenarios like toppling, sliding, sinking/lifting forces shall be considered when sizing the anchor blocks
f) Underground steel and PVC penstocks shall be buried at least 300 mm beneath the ground and shall be on a sand bed. No slide or support blocks apart from anchor blocks at the bends are required in underground penstocks.
g) Rubber sheets or tar sheets (graphite asbestos sheet) of minimum thickness of 3 mm must be placed between a steel penstock and supports to prevent abrasion due to thermal expansion and contraction.
h) Expansion joints are required in steel penstocks to minimize the stress created due to thermal expansion and contraction.
i) A tailrace shall be constructed with reinforced concrete and shall create a safe passage of water back to the stream downstream of the power-house. Steps or rock protuberance shall be incorporated to break the water speed and to minimize erosion.

4.7 Micro-hydropower generators and controls

4.8 Turbine

a) The turbine shall be able to operate at runaway speed or loss of load condition for two hours without mechanical failure.
b) Water flow must be able to be fully stopped by a valve or guide vanes to allow for turbine maintenance. The valve shall be slow closing with at least 10 seconds to prevent a pressure wave in the penstock pipe.
c) The turbine shall have a sealing mechanism to prevent water from flowing along the shaft and entering the generator.
d) In configurations where the turbine is coupled directly to the generator, a flexible coupling is advised to protect against bearing failure from misalignment.

4.9 Generator

a) Generators must have means of controlling voltage and frequency that are within limits specified in these guidelines under all conditions from 0% to 100% load.
b) If the generator type is induction, excitation capacitor banks shall have an over-current device to stop the generation of excessive voltage and damage to the alternator in the case of turbine overspeed / runaway speed.

5 ELECTRICITY SUPPLY STATIONS

5.1 Protective arrangements

a) Spaces in which electric supply conductors or equipment are installed shall be protected from entrance of unauthorized persons.
b) Floors shall have even surfaces and secure footing.
c) Each room with working electrical equipment shall have means of exit that is kept clear of obstructions.
d) Mechanical parts such as pulleys, belts, or other parts that transmit mechanical power shall have guards installed to prevent injury.
e) Suddenly moving parts of equipment that operate in such a way that persons in the vicinity are likely to be injured by such movement shall be guarded or isolated.
f) Electrical Danger warning signs must be installed at all access points to the yard and building.
g) Fire extinguishers of appropriate type must be installed and maintained in the building.
h) The name of the plant must be displayed clearly on the front of the building.
i) Sufficient lighting must be installed to do safe work on any equipment by day or night.

5.2 Battery installations (where applicable)

a) Space shall be provided around batteries to allow for safe maintenance, testing, battery replacement, and inspection. Space shall also be provided above the cells to allow for operation, taking measurements, adding water (if cells are flooded type), and for lifting equipment when required.
b) Storage batteries shall be located in an area accessible only to qualified persons or within a protective enclosure such as a fence, battery room, case, or cage that limits the chances of contact with energized parts.
c) To limit hydrogen accumulation and explosion risk in flooded lead-acid batteries, the battery area shall be ventilated either by a fan or by a natural ventilation system.
d) Racks that support battery cells shall be firmly anchored, preferably to the floor. Racks made of metal shall be earthed.
e) The floor material in battery areas shall be of a material that resists corrosion from electrolyte. Provision shall be made to keep spilled electrolyte from leaking to areas where it can cause damage.
f) Battery areas shall be provided with goggles or face shield, acid-resistant gloves, protective aprons, first aid kit and water to use to rinse skin in case of contact with electrolyte.

5.3 On-site fuel storage

a) All tanks, pipes, valves and pipe fittings shall be designed and built in accordance with an approved standard and shall have a safety factor that is adequate for the conditions of service.
b) The storage facility shall incorporate spillage control such as remote impounding, impounding around tanks, bunding or by a combination. In both types of impounding, the

impoundment area shall be protected by adequately designed systems to prevent the contamination of ground water if such a risk exists.

6 WIRING

6.1 General

a) All outdoor exposed wiring and junction boxes must be protected from UV radiation and terminals protected against dust and moisture. The wiring installation shall be both physically robust against bumping and tugging, and electrically robust.
b) Outdoor wiring shall have UV resistant insulation or be protected by UV-resistant plastic or metal conduit.

6.2 Wiring losses

a) PV array to battery circuit(s) shall be sized for maximum 5% voltage drop at rated array current.
b) Wire shall be derated for climatic conditions.

6.3 Wiring standards

a) Cables may be copper or aluminum.
b) Cables shall comply with RS IEC 60227: Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V or appropriate standard.

6.4 Wiring installation

a) Cables terminations shall be identifiable by color and/or lettering/numbering unless there is no possibility of confusion.
b) All wiring must be neatly installed and secured by means of appropriate fasteners at regular intervals.
c) Wiring lengths shall be sufficiently looped to allow ease of connection and disconnection in the case of component replacement or maintenance.

6.5 Earthing

6.5.1 Equipment earthing, including PV array frame

a) Exposed metal parts such as metallic module frames, electrical equipment, and conductor enclosures must be bonded through an equipment earthing conductor, connected to an earth rod sized sufficiently to ensure that the earth loop impedance is less than 25 Ohms.
b) Earthing conductors for equipment, raceways, cable, and other metal enclosures for wires shall have ampacities adequate for the available fault current over the operating time of the fault-protective device.
c) If the circuit has no overcurrent or fault protection, the earthing conductor ampacity shall be determined by the design and operating conditions of the circuit. If the conductor enclosures and attachments to equipment enclosures are continuous and adequate, the circuit path formed by these metallic surfaces may constitute the equipment earthing conductor.

d) Earthing conductor wires shall be connected via a suitable lug, terminal, or device that is not disturbed in the course of normal operation, inspection, or maintenance.

6.5.2 AC conductor earthing

a) System electrical earthing shall only occur on the AC side of a system, where the AC neutral conductor is connected to the consumer earth conductor, at a single location at the generation facility site.
b) The site of the neutral/earth bonding shall be clearly labelled and indicated on the installations' single line diagram.
c) Alternating current conductors shall be earthed in accordance with Main Grid standards.

6.5.3 DC conductor earthing

DC systems, or the DC portion of mini-grids with AC may remain unearthed.

6.6 Lightning protection

Mini-grids in lightning-prone areas shall be protected against lightning through the installation of a surge protection device that can provide protection for least 100 kA surge current (8/20 μs). If the mini-grid has both an AC and DC sides, each side shall be protected with a separate surge protection device.

7 DISTRIBUTION LINE

a) MV lines and LV lines that the developer intends to possibly interconnect at a later time with the national grid shall be built in accordance with Main Grid standards and Rwanda Grid Code.
b) LV lines that are not built with the intention of being eligible for interconnection with the national grid shall meet the following basic safety and performance requirements:
    i) The maximum permitted voltage fluctuation at the customer supply point shall not be more than +10% and -10% of nominal voltage with the calculated saturation load.
    ii) Poles supporting wires must be either rot resistant wood, concrete or metal. Live trees shall not be permitted.
    iii) The minimum distance of service cable to the ground shall not be lower than 3 meters on normal terrain and 6 meters crossing a road.
    iv) Service connections must be attached to the house's roof structure or walls by means of a suitable tension clamp that provides strain relief in the event that the wire is pulled.
    v) Service connections shall include a drip loop that prevents water from dripping onto the meter.
    vi) Overhead conductors shall feature suitable insulation rated to withstand UV degradation and contact with water.
    vii) All network wiring including service connections shall be built in such a way that protects against accidental contact with energized conductors.
    viii) Each LV feeder shall be protected with a circuit breaker rated for protection of the LV cable.

8 METERING

a) Meters used in Mini-Grids that the developer intends to possibly interconnect at a later time with the national grid shall be in compliance with the Metering Code of the Rwanda Grid Code.

b) Meters used in mini-grids that the developer has no intention of connecting at a later time with the national grid need not to follow the metering requirements of the Rwanda Grid Code, but must use meters that have at least 2% accuracy at full load (class 2).

Kigali, on 27 /06/2019

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Dr. Ignace GATARE

CHAIRPERSON OF THE REGULATORY BOARD