EDC 5 (5236) P3

DRAFT TANZANIA STANDARD

(Draft for comments only)

Mini-Grid Systems –

Part 9: Interconnection of less than 1MW of Generation with the National Grid

TANZANIA BUREAU OF STANDARDS

TBS 2017 First Edition 2017

Table of contents

TANZANIA STANDARD

0 Forward

This Standard specify requirements for interconnection of mini-grids with the national grid, including voltage levels, frequency, maximum harmonic contents, synchronization, monitoring, metering, protection system and continuity of service to the customers.

The aim of this Tanzania standard is to provide a framework within which mini-grid operators can be assured of their rights and obligations in the event they wish to interconnect the mini-grid with the national grid operator.

Considerations include:

Interconnection of mini-grid generation to the national grid for generation in excess of 1MW is covered by the existing requirements that govern the interconnection of SPPs

Mini-grids in the size range considered here have economic limitations that make compliance with the standards intended for larger system excessively burdensome.

The presumption is that the size of the mini-grid generation covered by this standard is small enough that it cannot affect system frequency and makes a negligible contribution to system fault conditions. It is the responsibility of the grid operator to clearly and objectively demonstrate that this is not the case before imposing any additional requirements.

While several parameters of an electricity supply such as frequency, continuity of supply, voltage level, etc. must be within allowable limits to ensure that the consumer obtains satisfactory performance for their electrical equipment while ensuring that the demands of the consumer continue to be met, the capital and operating costs of doing so should be held to the minimum possible.

EWURA is considering a distribution grid code at the present time and it may be that, if the grid code can be adjusted to apply to mini-grids, there may not be a need for an additional mini-grid code.

This standard focuses on the specifications for performance, operation and maintenance, safety considerations, stability, synchronization, protection, metering, testing and interconnection requirements. It will lay general requirements of power quality, islandin g and evaluation and periodic tests. This document will apply to aggregate capacity less than 1MW and more than 10kW. This Standard is derived from EWURA guidelines for grid interconnections and various IEC Standards.

Regulatory framework allows small power producers to supply electricity from both grid-connected and off-grid power supply systems. Small Power Producers (SPPs) with generation capacity of less than 1MW are exempted from obtaining a license but are required to register with EWURA.

1 Scope

This standard provides a framework within which consumers and mini-grid developers know what the minimum requirements are for service quality including service voltage level ranges at the consumer premises, maximum harmonic levels in the wave shape, and continuity of service as specified in IEC Standards EWURA Distribution and Grid Codes.

This standard provides minimum interconnection requirements for mini-grid generation and associated distribution network with national utility (TANESCO) and specifies performance, operation, testing, protection, metering and testing procedures. The requirements shall be met at the point of common coupling (PCC). The equipment, hardware and software shall meet the specified requirements and standards and shall be technically qualified to operate under the local service conditions.

Note 1 This standard shall be read in conjunction with other relevant – Tanzania Standards, applicable standards and specifications to have uniformity, compatibility and standardization in the distribution system.

2 Normative references

For the purpose of this Tanzania Standard, the following references shall apply:

EWURA draft Distribution Grid Code, June 2016

Guidelines for Developers of Small Power Projects in Tanzania

Standardized Small Power Purchase Agreement (SPPA) for the Purchase of Grid-Connected Capacity and Associated Energy

Standardized Small Power Purchase Agreement (SPPA) for the Purchase of Capacity and Associated Energy to Mini-grids

TANESCO Grid Code for Embedded Generation

Guidelines for Grid Interconnection of Small Power Projects in Tanzania, Parts A, B, and C, 2011

EN 61000-3-2, Electromagnetic Compatibility - Part 3: Limits - Section 2: Limits for harmonic currents emissions (Equipment input current up to and including 16A per phase)

EN 61000-3-3, Electromagnetic Compatibility - Part 3: Limits - Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current =< 16A

IEC TS 61000-3-4:1998 Electromagnetic compatibility (EMC) - Part 3-4: Limits - Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A

EN 61000-4-2, Electromagnetic compatibility (EMC) - Part 4: Testing and measuring techniques — Section 2: Electrostatic discharge requirements

EN 61000-4-5, Electromagnetic compatibility (EMC) - Part 4: Testing and measuring techniques - Section 5: Surge immunity tests

IEC 61727:2004 Photovoltaic (PV) systems - Characteristics of the utility interface

IEC 62116:2014 Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures

3 Conditions of Interconnection with National Grid

Mini-grids involve small-scale electricity generation (10kW to 1MW), which serves a limited number of consumers on distribution grid that can operate in isolation from national grid system. Requirements specified in these guidelines are applicable to all mini-grids between 10kW and 1MW, where the mini-grids are to be interconnected with the national grid. It is the objective of these guidelines that such interconnections appropriately protect the service quality and facilities of both the mini-grid operator and the national grid operator at a cost that is not an excessive burden to either.

a) All mini-grids considered here are assumed to have loads that are low enough that they can be served for short periods by the interconnection with the national grid. Such mini-grids can be provided with simplified interconnections. In the event this is not the case, either because the load of the mini-grid is high or because the capability of the interconnection is low, the interconnection will be deemed to be subject to the requirements of Guidelines for Grid Interconnection of Small Power Projects in Tanzania, Parts A, B, and C, 2011.
b) Mini-grids with generation up to 100kW shall interconnect at low voltage (400V) unless otherwise agreed by the parties.

4 Technical Requirements

4.1 Existing Guidelines of Interconnection with National Grid

There are existing requirements used to govern the interconnection of small power plants with the national grid, but these guidelines are burdensome for small systems in the 10kW - 1MW range and this standard addresses the technical requirements for interconnection of such systems.

4.2 Requirements for Interconnection

4.2.1 Interconnection voltage

a) Mini-grids with 100kW or more of installed generation shall be connected at medium voltage which may be an 11kV or 33kV, three phase three wire system. The choice of interconnection voltage depends on the voltage level and carrying capacity of the facilities in the area and will be chosen to match the voltage of the mini-grid distribution system, if available.

b) Mini-grids with less than 100kW of installed generation shall be connected at low voltage, 400/230V, three phase four wire system. It may be necessary to install a transformer if the available national grid line is 11kV or 33kV.

c) Equipment requirements for the mini-grid are the same regardless of voltage of interconnection.

4.2.2 Point of Common Coupling

The Point of Common Coupling (PCC) is the point of interconnection between the mini-grid and the main grid. The location of this point shall be chosen carefully to allow for access and installation of necessary equipment.

4.2.3 Equipment at the Point of Common Coupling

The following equipment shall, at a minimum be located at the PCC:

a) Fault interrupting equipment designed to ensure that a fault on the mini-grid does not interrupt service on the main grid. Appropriately sized fuses fulfill this requirement.

b) A utility grade meter installation with associated voltage and current transformers capable of metering real and reactive power both into and out of the mini-grid. Such a meter is commonly referred to as a four-quadrant meter

c) A manually operated, lockable disconnect means providing a visible open between the mini-grid and the main grid.

d) Additional equipment may be installed at the PCC upon mutual agreement.

4.2.4 Integration of Mini-grid Grounding System with National Grid Grounding System

The grounding scheme of the mini-grid system shall be integrated with that of the national grid, in case the two grids utilize different approaches to grounding, then grounding transformer may be required to prevent over voltages that exceed the rating of the equipment connected to the national grid or that disrupt the ground fault protection system of the national grid. This might occur if the mini-grid uses a four wire multi-grounded MV system while the national grid does not.

4.2.5 Synchronization

a) The Mini-grid system shall be synchronized to the national grid at the mini-grid generator locations unless otherwise agreed between the parties.

b) Synchronization of synchronous rotating machines may be manual or automatic, except that all schemes shall contain permissive synch check relays that inhibit synchronization until voltage, frequency, and phasing are within acceptable limits.

c) Rotating non-synchronous machines shall be brought up to synchronous speed by auxiliary means before being connected to the grid.

d) Power electronics inverters designed and programed for grid tied operation are an acceptable means of synchronization.

e) Synchronization of the mini-grid with the National Grid system shall not cause a voltage fluctuation at the PCC greater than +/-5% of the prevailing voltage level of the Nation Grid at the PCC and shall meet the specified flicker requirements.

4.2.6 Real Time Metering

There is no requirement that real-time metering be installed at the PCC unless agreed upon by both parties.

5 Response to Local Area Abnormal Conditions

Abnormal conditions can arise on the national grid electric power system that requires a response from the connected mini-grid. The required response is a separation of the mini-grid generation from the system. This response contributes to the safety of utility maintenance personnel and the general public, as well as the avoidance of damage to connected equipment, including the mini-grid. All voltage and frequency parameters specified in this standard shall be met at the mini-grid generator location, unless otherwise stated.

There are three cases for responses to abnormal conditions:

a) The mini-grid generators disconnect from the main grid, cease generation and wait for the grid to become stable, then reconnect after a time delay.
b) The mini-grid generating system disconnects from the main grid and continues to operate as an islanded grid. Reconnection is automatic once the grid becomes stable. Executing this option will require additional equipment at the PCC than that specified in 4.2.3.
c) In the event of an extended outage, the mini-grid generators would open the disconnect switch from the main grid and the mini-grid would then be manually isolated from the main grid at the PCC. The mini-grid generators are then restarted to supply the islanded grid, but must continue to respond to local disturbances. When the main grid outage has been resolved, the mini-grid generators would be turned off, the distribution component of the mini-grid system manually reconnected and then the mini-grid generators turned back on and resynchronized.

5.1 Voltage

The protection functions of the mini-grid generation system shall detect the effective (rms) or fundamental frequency value of each phase-to-phase voltage, except where the transformer connecting the local utility electric power system is a grounded wye-wye configuration, or single-phase installation, the phase-to-neutral voltage shall be detected. When any voltage is in a range given below, the mini-grid generators shall cease to energize the utility electric power system within the clearing time as indicated. Clearing time is the time between the start of the abnormal condition and the mini-grid ceasing to energize the national grid. For mini-grid generating equipment less than or equal to 30kW in peak capacity, the voltage set points and clearing times shall be either fixed or field adjustable. For mini-grid generating equipment greater than 30 kW, the voltage set points shall be field adjustable.

Table 1

Parameter	Magnitude	Timing (s)
Over voltage	115 % of nominal voltage	2
Under voltage	70 % of nominal voltage	2

Note that operation of the mini-grid generators in islanded mode may have different disconnect levels and timing (seconds) than those specified table 1. The modified schedule may be applied when the mini-grid is connected to the national grid upon acceptance by both parties

5.2 Frequency

a) When the system frequency is in range given below, the mini-grid generators shall cease to energize the national grid within the clearing time as indicated. For mini-grid generating equipment less than or equal to 30kW in peak capacity, the fre quency set points and clearing times shall be fixed or field adjustable. For mini-grid generating equipment greater than 30kW, the frequency set points shall be field adjustable.

b) Adjustable under frequency trip settings shall be coordinated with the area electric power system operations.

Table 2

Parameter	Magnitude	Timing (s)
Over frequency	1,5 Hz above nominal frequency	1
Under frequency	1,5 Hz below nominal frequency	1

c) Note that operation of the mini-grid generators in islanded mode may have different disconnect levels and timing (s) than those specified here. The modified schedule may be applied when the mini-grid is connected to the national grid upon acceptance by both parties

5.3 Reconnection to National Grid

After a national grid power disturbance, no mini-grid generation reconnection shall take place until the measured voltage is within +/- 10% of nominal voltage (per IEC 60038) and frequency range of 49.0 Hz to 51.0 Hz. The mini-grid interconnection system shall include a function that will delay reconnection for a minimum of five minutes after the area steady-state voltage and frequency are restored to the ranges identified above.

6 Power Quality

6.1 Limitation of dc injection

a) The direct-current injection shall be in accordance with IEC 61727.

b) The PV system or other solid state generator shall not inject dc current greater than 1% of the rated inverter output current into the utility ac interface.

6.2 Voltage Regulation and Reactive Power Exchange

The mini-grid operator shall not regulate the voltage at the point of common coupling (PCC) unless specifically coordinated between the mini-grid and the national grid operating companies, but shall have the ability to present and m aintain a unity power factor at the PCC.

6.3 Limitation of flicker induced by the Mini-grid

The mini-grid shall not create objectionable flicker for other customers on the national grid, defined as compliance with EN 61000-6-1.

6.4 Harmonics

a) The harmonic current emission shall be in compliance with IEC TS 61000-3-4 and IEC 61727.

b) Even harmonics shall be less than 25% of the next higher odd harmonics listed in the IEC 61727.

c) Total voltage harmonic distortion shall be less than 5% at the rated inverter output. Each individual harmonic shall be limited to the percentage listed in the following table:

Table 3

Odd harmonics	Distortion limit
3rd through 9th	Less than 4.0%
11th through 15th	Less than 2.0%
17th through 21st	Less than 1.5%
23rd through 33rd	Less than 0.6%

7 Islanding Interconnection Test specifications and Requirements

a) This clause provides the test requirements to demonstrate that the interconnection system meets the IEC specified requirements (IEC 62116). The applicable tests are required for all interconnection systems. The results of these tests shall be formally documented.

b) The stated test specifications and requirements are universally needed for interconnection of mini-grid including synchronous machines, induction machines, or static power inverters/converters, and will be sufficient for most installations.

7.1 Design Tests Protocol

a) This design test shall be performed as applicable to the specific interconnection system technology. The test shall be performed on a representative sample, either in the factory, at a testing laboratory, or on equipment in the field.
b) This test applies to a packaged interconnection system using embedded components or to an interconnection system that uses an assembly of discrete components.
c) It shall interconnect after five minutes of stable power within 0.3 Hz of 50 Hz, but disconnection is triggered at 48.5 Hz (1.5 Hz difference)

Table 4

Synchronization parameter limits for synchronous interconnection to the system,			
Aggregate rating of mini-grid	Frequency difference	Voltage difference	Phase angle difference
Units (kVA)	(Δf, Hz)	(ΔV, %)	(ΔΦ, °)
10 – 500	0.3	10	20
501 – 1 000	0.2	5	15

7.2 Surge Withstand Performance

The interconnection system shall be tested for the specified requirement in all normal operating modes in accordance with EN 61000-4-5 for all voltages less than 4 kV.

7.3 Commissioning Tests

All commissioning tests shall be performed based on written test procedure jointly agreed between mini-grid operator and national grid representatives. The forms and formats must be developed for testing listed below or followed as given in EWURA draft Distribution Grid Code, June 2016:

a) Visual inspection to ensure grounding requirements have been implemented
b) Visual inspection to ensure isolation equipment has been placed and operating
c) Visual inspection of all equipment and devices that necessary equipment has been installed.
d) Operability tests on the isolation equipment as specified
e) Unintentional islanding functionality test as specified
f) Cease to energize functionality tests as specified
g) Monitoring devices testing
h) Metering devices testing
i) System protection relays and devices testing
j) Harmonics, surge withstand, EMI testing
k) Hardware and software used in the interconnection testing
l) Grounding integration with national grid operator
m) Design verifications to verify BIL of equipment and standards certifications
n) Verification of all system parameters to be within specified range
o) Other tests which falls under the provision of testing

Annex A
(informative)
Addendum 1 - Business Requirements

Note: In addition to technical requirements it is to be noted that mini-grids are business enterprises which made a good faith effort to supply electricity to the rural area in support of national objectives. Such an effort can be successful only when the investors in the enterprise can be reasonably assured of recovering their investment. It is therefore important for this standard to consider conditions under which such investors should be compensated for loss of the utility of such as asset, as might occur if the national grid were to take over the service area and supplant at lower cost the service supplied by the mini-grid. Such compensation would be limited to the cost of assets as provided elsewhere in this standard and would not include loss of projected business value. EWURA, as the statutory regulator of the sector would be empowered to approve each transaction individually.

A.1 Business Models

In addition to technical requirements there are different business models, which should be considered by the mini-grid operators, when the service areas of the mini-grid are approached by the national grid. In the event that the national grid operator proposed to serve the same consumers as were currently being served by the mini-grid, it is expected that the national grid operator and the mini-grid operator would enter into discussions about the take-over of the mini-grid assets and that a mutually acceptable arrangement along the lines of one of the business models indicated would be reached.

Case-1: Continuity in operation of the mini-grid by the current mini-grid operator, as viable and sustainable option without interconnection with the national grid

Case-2: Continuity in operation of the mini-grid by the current operator, with interconnection to the national grid

Case-3: Continuity in operation of the mini-grid generation as a power supplier, but sale of the mini-grid distribution network to the national grid operator

Case 4: Sale of generation equipment/assets and distribution system both to the national grid operator

Case-5: Sale of distribution system to the national grid operator and removal of generation system/equipment by the mini-grid operator for use elsewhere

Case-6: Removal of mini-grid assets (both generation and distribution) altogether by the mini-grid operator for use elsewhere.

A.2 Compensation of Assets to Mini-grid Operators by Business Model:

Compensation of mini-grid assets is the subject of EWURA SPP Rule 36.

Compensation would be available to a mini-grid operator whose system was constructed to the requirements of TBS standards as listed below:

TZS (XXX) – Part 1: Standard for Uniform Mini-grid Project Planning

TZS (XXX) – Part 2: Standard for Utility Interactive Inverters for Mini-grids

TZS (XXX) – Part 3: Standard for Distribution Systems for Mini-grids

TZS (XXX) – Part 4: Standard for Wood Poles for Mini-grids

TZS (XXX) – Part 5: Standard for Aerial Bundled Cable for Mini-grids

TZS (XXX) – Part 6: Standard for Low Voltage Underground Distribution Systems for Mini-grids

TZS (XXX) - Part 7: Standard for Cables for Low Voltage Underground Distribution for Mini-grids

TZS (XXX) – Part 8: Standard for Consumer Electric Metering for Mini-grids

TZS (XXX) – Part 9: Grid Interconnection Standard for Mini-grids

Compensation for the value of the assets, but not for lost business revenues, would be available from the national grid operator by business model as follows:

Case-1: No compensation

Case-2: No compensation

Case-3: Compensation for the asset value of the distribution system

Case 4: Compensation for the asset value of the generation and distribution system

Case-5: Compensation for the asset value of the distribution system only.

Case-6: No compensation

Compensation would be paid on the basis of the depreciated original installed value of the asset, with such original installed value determined by audited records from the time of the installation. Depreciation would be taken in accordance with standard utility accounting practice.