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DRAFT TANZANIA STANDARD
(Draft for comments only)

Mini-Grid System –

Part 6: Aerial Bundled Cables (ABC) (0.6/1kV)

TANZANIA BUREAU OF STANDARDS

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TANZANIA STANDARD

0. Foreword

This Draft Tanzania Standard is part of an integrated set of specifications and standards issued to govern design and construction of mini-grid power systems in Tanzania. The mini-grid standards, have been developed to support improved residential, commercial and public services for rural communities of Tanzania. The mini-grid energy systems, when properly designed, will support affordable and reliable energy supply for remote households, community services, commercial and economic activities including shops, workshops, micro-industry, fresh water pumping, secondary schools, health services, public lighting, places of worship or cultural activities, agro-processing activities and other activities

1. Scope:

1.1 This standard covers minimum technical requirements for the design, manufacture, testing and supply of two, three, and four core twisted unsheathed cable rated 0.6/1 kV (Um=1.2kV) for use on 230/400V, 50 Hertz, three phase four wire multiple neutral grounded overhead line single phase and three phase power distribution networks of mini-grid systems.
1.2 The rated voltage of the cable is 0.6/1.0 kV, whereas 600 volts is the rated power frequency voltage between conductor and earth for which the cable is designed and 1000 volts is the rated power frequency voltage between conductors, for which the cable is designed. This cable is hereinafter referred to as Aerial Bundled Cable or ABC.

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

The ABC cables shall conform to the latest editions of the IEC standards applicable to their construction, including but not limited to those listed below, and to their normative references:

IEC 60104 *Aluminium-magnesium-silicon alloy wire for overhead line conductors*
IEC 61089 *Round wire concentric lay overhead electrical stranded conductors*
IEC 60228 *Conductors of Insulated Cables*
IEC 60502-1 *Cables for Rated Voltages of 1kV (U_m=1.2kV) and 3kV (Um=3.6kV)*
TANESCO Specification S01 *Supply and Installation of Plant and Equipment*
TANESCO engineering manuals.

In the event of conflict between these standards and this standard, this standard shall govern.

3. Quality Control

Aerial Bundled Cable shall be manufactured in a plant that has established a credible past record of production of cables of similar ratings, designs, and characteristics and that holds ISO: 9001 certification for quality management.

4. Service Conditions

Aerial bundled cable (ABC) shall be suitable for outdoor operation under the local service conditions in Tanzania, which are as follows:

a) Altitude above mean sea level (MSL): <3,000 metres

b) Maximum/record yearly high ambient temperature: +40°C

c) High humidity promoting the growth of fungi

d) Extended periods of intense sun exposure

In accordance with the IEC standards, altitudes not exceeding 1000 m are considered as normal service conditions. Altitudes higher than 1000 m are considered as abnormal service conditions, which may require special considerations in the design, manufacture or application of the materials or equipment. It is the responsibility of the proponent to recognize the particular conditions on any site and call them to the attention of the manufacturer.

5. Electrical System Parameters

Mini-grids may be single or three-phase but regardless, system parameters of mini-grids for the low voltage overhead line power distribution network are as follows:

a) Nominal system low voltage (U): 230/400V (±10%)

b) Maximum permissible system low voltage (U_m): 253/440V

c) Minimum permissible system low voltage: 215/374V

d) System frequency: 50 Hz

e) Neutral grounding arrangement: multi- grounded

f) Power frequency withstand voltage for 5 minutes: $3kV_p$

6. Design

6.1 The cable shall be designed for a maximum permissible continuous conductor temperature of 90°C, emergency loading conductor temperature of 105°C and maximum conductor short circuit withstand temperature of 250°C for 5 seconds.

6.2 The insulated conductors and insulated neutral of the ABC shall form a bundle, which shall comprise one or more single core insulated aluminum phase conductor(s) and a street light conductor if so specified, all twisted together with an insulated aluminum alloy conductor to be used as neutral and messenger.

6.3 The total horizontal tension of the conductor shall be carried by the aluminum alloy neutral/messenger wire.

7. Phase Conductors

7.1 The phase conductors shall be constructed of round hard drawn electrical grade aluminum wires (61% conductivity per IACS), circular stranded into conductors of diameter and resistance complying with the requirements of this standard

7.2 The outer layer shall have a right-hand direction of lay. The surface of the conductor shall be smooth.

7.3 The insulation shall be XLPE insulation filled with 2.5% carbon black or other certified or approved suitable UV protector extruded over the conductors.

7.4 The XLPE insulation shall comply with the requirements of IEC 60502-1 and this specification, and shall be suitable for continuous operation at a conductor temperature of +90°C.

7.5 The insulation on phase conductors shall be embossed with a raised rib 1mm high on the entire length of each phase conductor as follows:

i) One rib on phase 1
ii) Two ribs on phase 2
iii) Three ribs on phase 3

8. Neutral /Messenger Conductor

8.1 The neutral conductor shall be constructed of round hard drawn aluminum-magnesium-silicon alloy wire conforming to the requirements of Type B of IEC 60104, circular stranded into conductors of diameter and resistance complying with the requirements of this standard.

8.2 Direction of lay shall be right handed.

8.3 The neutral conductor shall be insulated with XLPE insulation filled with 2.5% carbon black or other certified or approved suitable UV protectant.

8.4 The XLPE insulation shall comply with the requirements of IEC 60502-1 and this specification and shall be suitable for continuous operation at a conductor temperature of +90°C**.**

8.5 The insulation of the neutral conductor shall be embossed with eight raised ribs 1mm high on the entire length of each neutral conductor.

8.6 The neutral conductor shall be embossed (matrix print shall not be acceptable) at a regular interval of two metres with the following information:

a) The manufacturer's name
b) Voltage designation
c) Type of insulation
d) Size of the neutral and phase conductors
e) Progressive cumulative length measurement with the highest length mark on the outer end of the cable
f) Year of manufacture

9. Street Light Conductor

9.1 When a street light conductor is specified, it shall be supplied as an additional core bundled with the ABC, consisting of 16mm^2 all aluminum stranded conductor covered with XLPE insulation.

9.2 The XLPE insulation of the street light conductor shall be embossed with word 'SL' at regular intervals of two metres on its entire length.

9.3 The properties of conductor and XLPE shall be equal to those of the phase conductor specified in this standard.

10. Bundling of Cores

The cores shall be bundled into cables by using two or three cores for single phase, four cores for three phase and five cores for three phase with street light facilities. The different combinations of bundles are as indicated:

10.1 For Three Phase Four Wire Systems

(No. of aluminum (Al) phase conductors) x (Al conductor cross section mm^2) + (No. of aluminum alloy conductors) x (Al alloy conductor cross section mm^2) + (No. of aluminum street light conductors) x (Al street light conductor cross section mm^2)

a) Without street light conductor:
- 3×25 + 1x25
- 3×50 + 1×50
- 3x70 + 1x70
- 3×100 + 1×100

b) With street light conductor:

- 3x50 + 1x50 + 1x16
- 3x70 + 1x70+1x16
- 3×100 + 1×100 + 1x16

10.2 For Single Phase Systems

(No. of aluminum phase conductors) × (Al conductor cross section mm^2) + (No. of aluminum alloy conductors) × (Al Alloy conductor cross section mm^2)

- 1x16 + 1x16
- 1×25 + 1×25
- 2x 25 +1x25
- 2×50 + 1×50

11. Lay Pitch of Bundle

The cores of a bundle shall be twisted with a right hand lay, so that the cores conform to the direction of the central part of the letter Z, when the cable is held vertically. The pitch of the bundling specified in Table-1.

Table-I	
Lay pitch of the bundled cores	
Cross-section of phase conductor (mm2)	Assembly pitch (cm)
10	30-50
16	40-70
25	50-80
40	60-90
63	70-100
100	80-110

12. Dimensional Requirements for All-Aluminum Conductors

The dimensions, construction and properties of insulated all aluminum conductors are given in Table-II.

TABLE-II
Stranded Phase Conductor (Aluminum)

Nominal Cross Section of Conductor	No. Of Strands Nominal dia. of each	Nominal diameter of Conductor	Maximum DC Resistance at 20°C*	Rated Strength	Nominal Thickness of XLPE Insulating sheath*	Minimum Thickness of XLPE insulating sheath **
(mm^2)	Strand (mm)	(mm)	(Ohms/km)	(kN)	(mm)	(mm)
16	7/1.71	5.1	1.80	2.8	1.1	1.0
25	7/2.21	6.6	1.07	4.6	1.2	1.1
50	7/3.1	9.3	0.542	8.3	1.5	1.4
70	7/3.66	11.0	0.389	11.3	1.5	1.4
100	7/4.39	13.2	0.27	16.00	1.5	1.4

* Note that these values exceed the requirements of IEC 60502-1
** Minimum requirement at any point of cable circumference-this is a governing requirement and exceeds the requirements of IEC 60502-1

13. Dimensional Requirements for Aluminum Alloy Neutral Conductors

The dimensions, constructions and properties of aluminum alloy conductors standardized for use are given in Table-III.

Table-III

Nominal cross section	Actual conductor cross section	No. of strands/ Nominal dia. of each strand	Overall diameter of conductor	Maximum DC resistance at 20˚C	Minimum breaking strength	Nominal thickness of XLPE insulation*	Minimum thickness of XLPE insulation **
$(mm)^2$	$(mm)^2$	(mm)	(mm)	(Ohm/km)	(kN)	(mm)	
16	18.8	7/1.85	5.49	1.75	5.43	1.1	1.0
25	30.1	7/2.34	7.02	1.094	8.44	1.2	1.1
50	59.9	7/3.3	9.9	0.5498	16.8	1.5	1.4
70	84.0	7/3.91	11.7	0.3917	23.56	1.5	1.4
100	118.9	7/4.65	13.95	0.2769	33.3	1.5	1.4

* Note that these values exceed the requirements of IEC 60502-1
** Minimum requirement at any point of cable circumference-this is a governing requirement and exceeds the requirements of IEC 60502-1

14. Joints

a) There shall be no joints in any wire of stranded conductor containing seven wires, except those made in the base rod or wire before final drawing.

b) In stranded conductor containing more than seven wires, joints in individual wires are permitted, in addition to those made in the base rod or wires before final drawing, but no two such joints shall be less than 15m apart in the complete stranded conductor. Such joints shall be made by resistance butt welding, fuse welding or cold pressure welding. Joints made by resistance butt welding shall, subsequent to welding, be annealed over a distance of at least 250mm on each side of the joint.

15. Requirements for XLPE Insulation

15.1 General

The insulation of all insulated conductors shall consist of cross linked polyethylene filled with 2.5% carbon black or other equally effective UV protectant, suitable for use in outdoor wet and dry locations at a continuous conductor operating temperature of 90^{o}C throughout its life and for service under the conditions described in this standard. The XLPE insulation shall comply with the requirements of IEC 60502-1.

15.2 Physical Requirements

15.2.1 Original Physical Properties

a) Tensile strength, min. kg/cm^2:127
b) Elongation at rupture minimum percent (%):200

15.2.2 Physical Properties after Accelerated Aging

After air oven exposure at 135± 3^{o}C for 168 hours:

a) Tensile strength minimum percent (%) of un-aged value: 75
b) Maximum percent (%) of un-aged value:125
c) Elongation, minimum percent (%) of un-aged value:75
d) Elongation maximum percent (%) of un-aged value:125

15.2.3 Water Absorption

When tested by the gravimetric method the insulation shall show a maximum increase in mass of 1mg/cm^2 following immersion in water at 85^{0}C, ±2^{0}C for 336 hours.

15.2.4 Insulation Resistance

When tested in accordance with IEC 60502-1 clause 17, insulation resistance at maximum conductor temperature of 90^{0}C shall not be less than 10^{12} ohm-cm and the insulation resistance constant K_i shall not be less than 3.67.

15.2.5 Hot Set Test (in accordance with the IEC 60811 standard)

- Temperature: 200^{0}C
- Duration: 15 Minutes
- Mechanical stress: 20 N/cm^2
- Elongation under load: 175% Maximum
- Permanent elongation: 15% Maximum

14.2.6 Shrinkage Test (in accordance with the IEC-60811-1-3 standard)

- Distance- between mark: 200mm
- Temperature: 130 ± 3 ^{0}C
- Shrinkage test: 4% Maximum
- Duration: 1 hour

14.3. UV Resistance Test

Retention of 80% of tensile and elongation properties following exposure of samples of XLPE insulation to either a carbon arc or a Zenon arc lamp in accordance with ISO 4892-3 for a period of 720 hours.

16. Tests

a) Cables shall be tested as specified in this section. Except as noted, testing procedure and pass/fail requirements shall be as specified in IEC 60502-1 for XLPE insulated cables.

b) Type tests shall be carried out in an accredited independent testing laboratory on cables and materials of equivalent design and material characteristics to those proposed for delivery under this order.

c) Sample and routine tests shall be carried out in the manufacturer's laboratory.

17. Type Test

Both electrical and non-electrical type tests shall have been completed on ABC cables of similar design in accordance with IEC referenced standards and evidence of successful completion of such tests shall be provided with the tender.

17.1 Electrical Type Tests

ABC cables shall have successfully passed the electrical type tests in accordance with the reference IEC standard for the following parameters:

a) Insulation resistance test at ambient temperature

b) Insulation resistance measurement at maximum conductor temperature in normal operation

c) Voltage test for four hours

17.2 Non-Electrical Type Tests

ABC cables shall have successfully passed the non-electrical type tests in accordance with the reference IEC standard for the following parameters:

a) Dimension test - measurement of thickness and uniformity
   The results of the dimension tests shall meet the minimum insulation thickness requirements of Tables II and III of this standard, which exceed the requirements of IEC 60502-1.
b) Mechanical properties-tensile strength and elongation at break.
   i) Without Ageing
   ii) After ageing in an air oven
   iii) After ageing of pieces of complete cable

c) Hot set test
d) Water absorption

e) Shrinkage test
f) Sunlight Resistance test on the XLPE insulation consisting of exposure to either a carbon arc or a Xenon arc lamp in accordance with ISO 4892-3 for a period of 720 hours while retaining 80% of the sample's tensile and elongation properties

18. Sample Tests

18.1 Sample tests shall be carried out during production of cables in accordance with IEC 60502-1 for XLPE insulated cables.

18.2 The number of samples taken for physical tests shall be as determined by the ISO 9001 procedure in place at the manufacturer, but not less than the number of samples required by application of Table 12 of IEC 60502-1 for multicore cables, that is 1 sample for every 10km of cable produced under the purchase order. Sample tests shall include as follows:

a) Conductor examination for compliance with the requirements of this standard.

b) Check of insulation thickness in accordance with IEC 60502-1, except that the minimum allowable insulation thickness shall comply with the requirements of Tables II and III of this standard.

c) Hot set test in accordance with IEC 60502-1

19. Routine Tests

19.1 Routine tests shall be carried out on every manufactured length of cable without exception. No reduction in the number of lengths to be tested is allowable, regardless of any quality control procedure that may have been instituted by the manufacturer.

19.2 Routine tests shall be carried out in accordance with IEC 60502-1 and shall include:

a) Measurement of electrical resistance of conductors except that the values of conductor resistance shall be those in Tables II and III of this standard.

b) AC voltage test for multicore cables without individually screened cores.

20. Test Reports

20.1 Certified type test reports shall be provided for all specified tests in accordance with IEC 60502-1. Type test reports or certificates of qualification shall be provided at the time of tender from Tanzania Bureau of Standards or an independent accredited testing laboratory.

20.2 Certified test reports for sample tests and for routine tests shall be submitted upon completion of production and prior to release for shipment.