ANNEX 7

RECOMMENDED TECHNICAL GUIDES FOR REGISTERED MINI-GRIDS

While Mini-Grids of up to 100 kW are excluded from regulation, it has been observed that for such type of systems mistakes in sizing and design of technical components have caused accidents and poor performance of systems. This applies particularly to developers and operators of small Mini-Grids, as these are often not aware of the existence of or cannot access technical standards and guidelines. They also often lack or cannot access the necessary practical experience/training. The desire to cut down on costs of lead to systems that fall short of basic technical standards. Therefore, this Annex 7 summarizes some basic design criteria in terms of "rules of thumb" that should be used by small Mini-Grid Developers and Registered Mini-Grid Operators with low voltage mini-grids wherever the national and international technical standards are not at hand or cannot be understood, in order to improve the safety and reliability of their systems.

In all cases, NERC requires the application of the relevant technical standards and guidelines as set; for example in NERC's Distribution Code as well as the respective manufacturers' rules. Where this is not possible, the following rule-of-thumb standards/guidelines may be applied. As these requirements are scientifically not 100% correct, but are just an indication, NERC does not assume any liability for failures or accidents resulting from the application of the rules mentioned below.

1 DIMENSIONING OF CABLES

There are three design criteria for cable and conductor dimensioning:

1) The heat that is produced by the current flowing through the resistance of the cable must be dissipated without risk of melting the insulation and without risk of causing fire.

2) The voltage drops along the cable must result in a voltage at the last customer which is high enough for appliances to work. For most appliances it is recommended that voltage losses not exceed 10% of the nominal grid voltage.

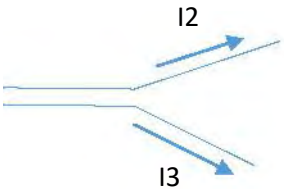
- The resistance of the cable must be low enough so that a short circuit current at all customer connections causes circuit breakers or fuses to trip reliably. This, together with criterion 1 (above) protects from fire and electrocution from bare cables with molten insulation.

In small Mini-Grid systems, distribution of electricity is sometimes done on a house-to-house wiring basis by looping from one house to another. The use of such type of distribution system is not recommended for safety reasons. However, where Distribution Code compliant distribution grids are not financially viable and house-to-house wiring or similar approaches are required for

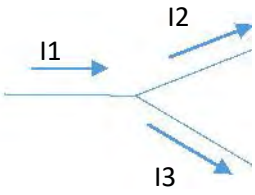
financial feasibility, the following dimensioning of cables can be used for alternating current (AC) and direct current

(DC) electricity supplies together with circuit breakers of B10 characteristic (see chapter "Circuit breakers and fuses" below) typical for a household or shop at the end customer connection. The max current values are meant to be continuous currents for 30 minutes or more on a specific line. In three phase systems, the current indicates the current over one of the line-conductors in the three phase system.

In radial distribution systems, currents of lines which split into more lines to connect more customers are larger than the currents in the split lines. In order to design the cross sections of lines that split



Assume that line 2 and line 3 are connected to the source individually and identify the right cross-section of line 2 and line 3 from the tables below.



Then add the cross-sections of line 2 and line 3 to calculate the proposed cross-section for line 1.

Cross-sections of conductors in copper cables

The following table indicates recommended conductor cross-sections for certain currents and cable lengths of a copper conductor. Below 0.75 mm^2 of conductor cross-section, the mechanical strength of the cable is rather low and the cable may break easily causing the risk of electrocution and fire. Therefore, it is not recommended to use these low diameters. As in very small Mini-Grid systems, these small cross sections are sometimes the only economically feasible option, they are indicated in the table below anyway but marked red. Special attention should be given to safe installation of these thin conductors..

Max continuous current (for 30 min or more)	Up to 100 m distance between source and load	Up to 200 m distance between source and load	Up to 300 m distance between source and load	Up to 400 m distance between source and load
<1.5 A rms	0.15 mm^2	0.5 mm	1.5 mm	2.5 mm
<5 A rms	0.5 mm	1.5 mm	2.5 mm	4 mm

<10 A rms	1.5 mm	2.5 mm	4 mm	6 mm
<16 A rms	2.5 mm	4 mm	6 mm	10 mm
<25 A rms	4 mm	6 mm	10 mm	16 mm
<40 A rms	6 mm	10 mm	16 mm	25 mm
<60 A rms	10 mm	16 mm	25 mm	35 mm
<100 A rms	16 mm	25 mm	35 mm	50 mm

It is a requirement to attach cables to guy wires where cables are connected from one house to the other and no fixed attachment to walls can be made. Where cables are moved during operation, flexible (stranded) cables are required.

Cross sections of conductors in aluminium cables

The following table indicates required conductor cross-sections for certain currents and cable lengths of an aluminium cable assuming a B10 circuit breaker at the last customer's connection and a maximum of 10% voltage drop at the customer's connection.

Max continuous current (for 30 min or more)	Up to 100 m distance between source and load	Up to 200 m distance between source and load	Up to 300 m distance between source and load	Up to 400 m distance between source and load
<1.5 A rms	4 mm	6 mm	10 mm	16 mm
<5 A rms	6 mm	10 mm	16 mm	25 mm
<10 A rms	10 mm	16 mm	25 mm	35 mm
<16 A rms	16 mm	25 mm	35 mm	50 mm
<25 A rms	25 mm	35 mm	50 mm	70 mm
<40 A rms	35 mm	50 mm	70 mm	95 mm
<60 A rms	50 mm	70 mm	95 mm	120 mm
<100 A rms	70 mm	95 mm	120 mm	150 mm

Aluminium cables with the dimensions mentioned above may be used without a guy wire carrying the cable. Distance between poles carrying the cables should not be more than 50 m.

1 CIRCUIT BREAKERS AND FUSES

Circuit breakers switch off short circuits and overloads. They protect the lines from getting too hot and therefore prevent fire or electrocution from bare cables with molten insulation. Circuit breakers have a rated current and an instantaneous tripping current. If the actual current is larger than the rated current, the circuit breaker will trip with a delay. If the actual

current is larger than the instantaneous tripping current, the circuit breaker will trip immediately within 100 milliseconds.

There are circuit breakers with rated currents of 6A \ 10A \ 13A \ 16A \ 20A \ 25A \ 32A \ 40A \ 50A \ 63A \ 80A \ 100A available on the market. The immediate tripping current is determined by the letter in front of the number indicating the rated current. Breakers can have B characteristic (immediate tripping at 3 to 5 times the rated current) for usual household and shop loads, C characteristic (immediate tripping at 5 to 10 times the rated current) for machines and a larger number of lamps and D characteristic (immediate tripping at 10 to 20 times the rated current) for heavy machines and transformers.

Each connection to the distribution grid should be protected using the smallest circuit breaker possible. Households in rural villages typically need B6, B10 or sometimes B16 circuit breakers single phase. Mills, wood, metal and welding workshops may require three phase C20 or similar.

The line dimensioning in the tables above was prepared for B10 circuit breakers. If the rated current of the circuit breakers is higher or the characteristic of the circuit breaker is C or D cross-sections of cables need to be larger. Please consult an electrician in this case.

Fuses are available in the ratings of 3A \ 5A \ 10A \ 15A \ 20A \ 25A \ 30A \ 45A \ 60A \ 80A \ 100A. The fuse is a slow disconnector. If the actual current is higher than the rated current for a certain time, the fuse trips. The fuse rating should be the same as the maximum continuous current used for line dimensioning.

2 GROUNDING

Mini-Grids for village electrification are typically TN-C-Systems or TN-C-S-Systems. This means that there needs to be grounding of the PE and N conductor or the combined PEN conductor in order to operate the system safely. Grounding takes place at the generator, in the distribution grid, at the end of each line of the distribution grid and at the customers' buildings.

Depending on the conditions of the ground and the ground water level, different methods of grounding can be applied. In predominantly wet soil, grounding can be performed through ground rods that are driven into the ground. In dry areas, a conductor with a large surface needs to be dug in. After installation of the grounding equipment contact between the conductor and the soil can be established by pouring large amounts of water on the surface to be soaked up by the soil around the grounding material.

The ground resistance should preferably be smaller than 2 Ohm but in any case smaller than 10 Ohm. To measure this resistance value, special measuring equipment is required.

3 IP Ratings

Ingress Protection (IP) refers to the ability of an electrical device's covering to protect against dust and water ingress. All electric equipment exposed to a voltage should be covered by a box with adequate protection class, or the device itself should have adequate protection class. IP 42 or higher numbers should be printed on the boxes containing electrical equipment which are installed outside of buildings and only exposed to rain but no water from below the box. In some cases higher IP classes are required to cater for adequate protection.

IP Ratings			
Level of Protection against solid objects, materials, or dust		**Level of protection against water or liquids**	
0	No Protection	0	No Protection
1	Protected against solid objects down to 50 mm	1	Protection against vertically falling drops of water (e.g. condensation)
2	Protected against solid objects down to 12 mm	2	Protection against direct sprays of water up to 15 degrees from vertical
3	Protected against solid objects down to 2.5 mm	3	Protection against direct sprays of water up to 60 degrees from vertical
4	Protected against solid objects down to 1 mm	4	Protection against water sprayed from all directions – limited ingress permitted
5	Protected against dust, limited ingress (no harmful deposit)	5	Protected against low pressure jets of water from all directions – limited ingress permitted
6	Totally protected against dust	5	Protected against low pressure jets of water from all directions – limited ingress permitted

Moving parts of machinery must be designed and constructed in such a way as to prevent risks of contact which could lead to accidents or must, where risks persist, be fitted with guards or protective devices. All necessary steps must be taken to prevent accidental blockage of moving parts involved in the work. In cases where, despite the precautions taken, a blockage is likely to occur, the necessary specific protective devices and tools must, when appropriate, be provided to enable the equipment to be safely unblocked. The instructions and, where possible, a sign on the machinery shall identify these specific protective devices and how they are to be used.

5 FREQUENCY AND VOLTAGE

For quality and safety reasons, the generator should be operated to maintain a stable voltage and frequency at the electricity consumer. The voltage shall not deviate more than +-10% from its nominal value at the consumer's site. The grid frequency shall not vary more than 20% from its nominal value.