

## Village Hydro Specifications

## Line Distribution

Description of Item	Requirement	Recommendation
L.1 Voltages	<ol style="list-style-type: none"><li>1. The <b>consumer voltage</b> must be between +10% and -10% of the nominal national voltage (nnv.)</li><li>2. <b>Reduced specification contract clauses.</b> Scheme designers are reminded that the warranties affecting some electrical appliances may be invalid in schemes not in accordance with a conventional -6% nnv. Nevertheless the cost savings of the reduced specification can be significant and disbenefits will usually be insignificant in the context of village electrification. It is recommended that the purchaser take responsibility in the main contract for the reduced specification; he may defer this responsibility to consumers in consumer contracts.</li><li>3. <b>Powerhouse voltage</b> must not exceed nnv +10%. In the exceptional case where the controller is distant from the generator and no consumer or other loads will be attached to the connecting cable, the power house voltage can be between nnv and nnv +15%.</li><li>4. Powerhouse <b>voltage</b> must be <b>adjustable</b> by tuning of the voltage potentiometer on the controller (induction generator systems) or on the AVR (automatic voltage regulator) on synchronous generator systems.</li></ol>	
L.2 Distribution plan	<ol style="list-style-type: none"><li>1. A distribution diagram must be provided for schemes over 5kW capacity which shows <b>key line distribution information</b> including:<ul style="list-style-type: none"><li>▪ voltage at power house</li><li>▪ cable lengths</li><li>▪ conductor cross-sectional areas and materials</li><li>▪ max demands at load centres (in amps)</li><li>▪ min expected voltages at all nodes and load centres</li><li>▪ number of phases for each section</li><li>▪ positions of lightning arrestors</li><li>▪ positions of isolation switches and ELCBs</li></ul><p>This information must be relevant to operation of the plant at full capacity for maximum loading as expected after some years of demand growth.</p></li><li>2. In <b>3-phase</b> systems design the load distribution so that the phases will be sufficiently <b>balanced</b> at all hours of the day.</li></ol>	
L.3 Power factor	<ol style="list-style-type: none"><li>1. In <b>synchronous generator systems</b>, the power factor should not drop below 0.8.</li><li>2. In <b>induction generator systems</b>, the consumer power factor should not drop below 0.95 in order to retain frequency control.</li><li>3. <b>Correction</b> must be added to achieve the limits specified above.</li></ol>	
L.4 Earthing	<ol style="list-style-type: none"><li>1. <b>TT</b> system will be adopted.</li></ol>	

	<ol style="list-style-type: none"> <li>2. <b>Earthing</b> in the powerhouse will be in accordance with the specifications of the ELCB. It is not compulsory to draw an earth line in the distribution circuit.</li> <li>3. Where consumer loads are simple appliances such as lights and double insulated non-metal items like radios, no earthing is required other than the powerhouse earth. Where consumer loads may include metal appliances such as irons, water heaters, an earth connection must be installed for each consumer likely to use such loads.</li> </ol>	
L.5 Isolators, Fuses, ELCBs	<ol style="list-style-type: none"> <li>1. <b>All consumer circuits</b> must have isolation switches and fuses or MCBs fitted at entry point and these must be clearly labelled in the local language. An well-illustrated electrical safety booklet should be provided for each household.</li> <li>2. <b>Clusters.</b> If the number of consumers is large, it is recommended that isolation switches be also fitted to clusters of consumers. This will allow a speedier location of earth faults.</li> <li>3. <b>ELCBs.</b> It is usually not cost-effective to fit ELCBs to individual consumer points, but where the number of consumers is large and spurious triggering of a single 30mA ELCB in the power house poses a problem, it is recommended that clusters (typically of around 15 houses or 1.5kW) are protected by 30mA ELCBs. These can be located inside the powerhouse or outside in weatherproof housing: If located outside, it is recommended that the powerhouse is also fitted with an ELCB the sensitivity and response time of which is reduced.</li> </ol> <p>When visiting the site, verify the above and in addition:</p> <ol style="list-style-type: none"> <li>4. check whether <b>earth faults</b> can be <b>found without</b> undue <b>delay</b>. If the powerhouse ELCB trips the first step is to isolate the powerhouse and then restart the generator. If the ELCB stays untripped the fault is in the distribution system, and the next step is to isolate clusters of consumers or all individual consumers. Progressive switching in of consumers will reveal the location of the fault.</li> <li>5. It is recommended to install a single 150 mA or less ELCB at the powerhouse to protect each circuit drawn from the powerhouse. A single 30 mA ELCB is recommended to install at the load points, which uses loads more than 1kW. Wherever only class 2 insulation is ensured for equipment used ELCB s are not required.</li> </ol>	
L.6 Load Limiters	<ol style="list-style-type: none"> <li>1. Appropriate <b>MCBs</b> (0.5 A for 100W and 1A for 200W) are recommended to install at the load points. 1mm<sup>2</sup> size PVC insulated cables are recommended for house wiring if the maximum load used by the house is less than 200 W.</li> </ol>	
L.7 Cables	<ol style="list-style-type: none"> <li>1. <b>Material and Strength:</b> Aluminium, copper, ACSR and high strength aluminium alloy cables are recommended. <b>Underground cables are not</b> recommended due to cost of its construction and safety.</li> <li>2. <b>Insulation and Clearance:</b> For Overhead lines (OH) the minimum ground clearances are 5.8m across motorable roads, 5.5m beside motorable roads and 3m over open ground. The minimum horizontal and top clearance is 1.5m. It is recommended that insulated cables be always used in heavily</li> </ol>	

	<p>vegetated or forested areas. Twin sheathed cables are recommended for use as service wires. Recommended sags and tensions of the cables, size of the poles, Insulator types, etc., are given in the annexed document: <u>Village Hydro Specifications – Notes on line distribution</u>. (hereinafter referred to as Notes)</p> <p>3. <b>Conductor Sizing:</b> Details pertaining to the selection of conductors are provided in the Notes. Different sizes of conductors could be used for a single project.</p> <p>4. <b>Conductor Spacing:</b> The spacing should be 300mm between conductors for a vertical arrangement of OH conductors with the neutral lowest.</p> <p>5. <b>Joints:</b> All joints must be durable, adequate for their purpose, mechanically strong and visible. Bi-metallic clamps are recommended for joint, which connects dissimilar metals.</p>	
L.8 Type of poles	<p>1. <b>Materials.</b> Distribution cable should be drawn on poles made from hardwood, reinforced or pre-stressed concrete, galvanised steel pipes. Also trees are recommended to use as poles, where care is taken to ensure safety.</p> <p>2. Steel and wooden poles should be <b>treated or painted</b> for longer life.</p> <p>3. <b>Dimension and spans:</b> 7m high poles for insulated cable network, up to 10mm<sup>2</sup> cable size. Above 10mm<sup>2</sup> and up to 35mm<sup>2</sup> size cables, 9m poles are used. For un-insulated cables and bundled cables 9m and 13m poles are used.</p> <p>4. <b>Span of the poles - Single Phase system:</b> Span of the poles will depend on the terrain. Up to 16mm<sup>2</sup> insulated wire- 2 core, maximum span of 30m. Above 16mm<sup>2</sup> and up to 35mm<sup>2</sup>, max. Span of 25m. More details for the span is given in the Notes.</p> <p>5. <b>Span of the poles –Three Phase system:</b> GANT conductor to FLY conductor and bundled conductors of 50mm<sup>2</sup> – 4 core, max. 30m span.</p> <p>6. <b>Type of Insulators:</b> For insulated cables Nylon bobbins or telecom insulators as partial insulation. For bare cables, LT insulators are recommended. For the connection of those insulators, refer the Notes.</p> <p>7. <b>Stays:</b> Stays must be used at the first and last pole of straight line and at any turns.</p> <p>8. <b>Span and Sag:</b> See Notes for details.</p>	
L9. Lightning protection	<p>1. <b>Arrestors</b>, as described in the specifications for electrical components.</p> <p>2. The lightning arrestor is connected to the neutral earth of the generator set. It is recommended that the earth electrode resistance to be less than 1 Ω. However up to 5 Ωs shall be acceptable.</p>	
L10 House Wiring	<p>1. Load limiter of 0.5 A <b>MCB</b> should be installed as the incoming protection device for the installations of 100 W. For 200 W 1 A <b>MCB</b> should be used. For other loading appropriate MCB to be installed as the main incomer.</p>	

	<ol style="list-style-type: none"><li>2. In installations up to 1 kW, 1 circuit with 1 mm<sup>2</sup> cable can be used. The wire shall be of 600 V grade insulation.</li><li>3. Conduits shall be used wherever the mechanical protection is needed -- running on the roof section the wires can be clipped on to the wooden parts.</li><li>4. Switches shall be standard switch, which is designed for 230 volts.</li></ol>	
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**L4 TT System**

Generator neutral is earthed, and all the exposed metal bodies of the installation are earthed at the installation.

**L5 Requirement of ELCBs**

For TT system, as per the regulations (IEE 16<sup>th</sup> Edition), the Residual Current Devices (RCD) are required. However this may be avoided if the installation uses only class 2 insulation.

**L6 Wire Size for the Installation**

Installation class of wire is 600V grade. These wires are freely available in the market. Considering the voltage drop by the regulations (4% from the origin of the installation) and assuming a maximum length of the circuit as 30 m, 1 mm<sup>2</sup> cable has been recommended.

**L7 Cable Selection for Distribution System**

Considering the basic requirements, cost effectiveness and environmental aspects the village hydro plants are categorised into **three** main groups. The standards applied for these systems differ as appropriate. By studying the existing plants it was noticed that 5 kW plants are very popular and feasible in many cases in remote Sri Lankan villages.

- System up to 5 kW** - **Category A** (single phase generators)
- System between 5 kW and 15 kW** - **Category B** (either single phase or 3 phase generators)
- System between 15 kW and 50 kW** - **Category C.**

It is evident that overhead lines are the cheapest option. The standard of overhead line depends heavily on the construction method. When compared with the total project cost, the electrical distribution always accounts for a sizeable part of the scheme. These divisions would reduce the cost incurred in the construction of the line. These lines are also considered expensive compared to cost of generating set made for 5 kW capacity. Therefore cheaper version of distribution of power is necessary.

Distribution of power along various distances is given in the Table 1. After simplification of the cases, assumptions given below are made to fix the insulated wire sizes. Tables 2 & 3 give cable sizes for longer distribution lengths for various loads using bundled cables and all aluminium bare conductors.

*Cable Sizing Procedure*

Category A

Table 1 shows the cable size of twin copper cable as shown in Annex 2 sheet 1. Select the cable according to the load and distance with load density increasing by 800 W for every 0.5 km.

Assumptions made to prepare the Table 1 are:

- a) Each house is allowed to use 200W supply.
- b) Density of power demand is taken as 800W per 0.5km
- c) PVC Insulated and sheathed cables are used for the distribution



- c) PVC bundled cables shall be used for distances over 500 Mts. Cables given in table 3 is 3 phase 4 wire bundle cables. Wherever needed PVC cables are used as guided by the Table 1 or 2.
- d) Voltage drop allowable for the supplier's works (distribution net work) is  $\pm 10\%$ . i.e. The voltage variation on the network is set to +10% to - 10 % overall drop from the origin allowed as 20%.

(Even though the category A refers to 5 kW capacity power plants, the same tables could be used for higher capacity plants provided the line loads do not exceed those referred to in the tables.)

Table showing distance Vs the bundle cable size for village hydro systems above 5 kW up to 50 kW is shown in the Table 3 below

Table 3

Distance	Power Distributed	A/ phase	Voltage. Drop	Cable Size mm	Install. Method
1.5	7.5kW	10.8	8%	16	A/B
2	10 kW	14.4	11%	25	A/B
2.5	12.5 kW	18.0	12%	35	A/B
3	15 kW	21.6	15%	35	A/B
4	20 kW	28.8	15%	50	A/B

In case the load and distances differ from above values, Table 4 can be used to size the cables. It is assumed that the load is distributed at the last 500 Mt. spans and the voltage variations are kept at  $\pm 10\%$  at full load.

Table 4

Distance Km	Cable Size For 5000 W	Cable Size For 7500 W	Cable Size For 10000 W	Cable Size For 15000 W
1	16 mm <sup>2</sup>	16 mm <sup>2</sup>	16 mm <sup>2</sup>	16 mm <sup>2</sup>
2	16 mm <sup>2</sup>	16 mm <sup>2</sup>	16 mm <sup>2</sup>	35 mm <sup>2</sup>
3	16 mm <sup>2</sup>	25 mm <sup>2</sup>	35 mm <sup>2</sup>	50 mm <sup>2</sup>
4	25 mm <sup>2</sup>	35 mm <sup>2</sup>	35 mm <sup>2</sup>	95 mm <sup>2</sup>

#### Distribution lines with bare conductors

These are constructed to standards of CEB to cater the loads up to 30A single phase and 30 A 3 phase as required. However the requirements may vary according to the consumer load variation from 200W & 7000W per consumer.

Table 5

Distance	Power of Distributed	A/phase	Voltage drop	Conductor Type
1.5	15 kW to 50 kW	72.17	6%	Gnat
2	15 kW to 50 kW	72.17	7%	Lady Bird
2.5	15 kW to 50 kW	72.17	8%	Fly
3	15 kW to 50 kW	72.17	8.5%	Dog
4	15 kW to 50 kW	72.17	10%	Dog

Line configurations

*Category A (5kW)*

Conductors used are given in Sheet 1 and Sheet 2 of Annex 2, which are PVC/PVC cable with or without neutral insulation but with sheath. The characteristics of cables are given in Table 6 below.

Table 6. Technical Details PVC /PVC Cables

	Units	4mm <sup>2</sup> Twin	6mm <sup>2</sup> Twin	10mm <sup>2</sup> Twin	16mm <sup>2</sup> Twin	25mm <sup>2</sup> Twin	35mm <sup>2</sup> Twin	10mm <sup>2</sup> 2 x Twin	16mm <sup>2</sup> 2 x Twin
Number of Cores and Diameter		2	2	2	2	2	2	4	4
Approximate Mass	Kg /m	.06	0.85	.14	0.2	0.36	0.51	0.28	0.4
Max. AC Resistance	Ω /km	7.1	5.6	4.2	2.7	1.8	1.3	3.7	2.3
Max. Continuos. Current	A	32	44	53	70	79	98	49	62
Min. breaking load	KN	20	50	61	75	110	132	4.8	7.9
Working Tension	KN	3.6	9	11	13.5	19.8	23.4	1.37	2.25
Every Day Tension	kN								

*Category B (5 kW to 15 kW)*

Conductors used for this shall be mainly bundled cables drawn from tree to tree and the characteristics of cables is given in Table 7. Sheets 8 to 11 of Annex 2 gives the Installation details.

Table 7. Technical details of Bundled Conductors

	Units	16mm <sup>2</sup> Twin	25mm <sup>2</sup> Twin	35mm <sup>2</sup> Twin	50mm <sup>2</sup> Twin
Number of Cores and Diameter		2	2	2	2
Approximate Mass	Kg /m	.06		.14	0.2
Max. AC Resistance	Ω /km	7.1		4.2	2.7
Max. Continuos. Current	A	32		53	70
Min. breaking load	KN	1.5		2.8	3.2
Working Tension	KN	0.4		0.8	1.25
Every Day Tension	kN				

*Category C (15 kW to 50 kW)*

Bare all aluminium conductors shall be used for this purpose. Sheet 4 and Table 8 below shows the conductors and the characteristics of the conductors respectively.

Table 8. Technical details of All Aluminium Conductors

	Units	Gnat	Lady Bird	Fly
Approximate Mass	Kg /m	0.0734	0.1173	0.174
Max. AC Resistance	$\Omega$ /km	0.012	0.0066	0.0044
Max. Continuous Current	A	85	120	155
Min. breaking load	KN	0.49	0.74	1.05
Working Tension	KN	0.196	0.296	0.42
Every Day Tension	kN	0.08	0.13	0.189

Sag tension of line

For 5 kW systems in villages present systems are used to distribute 200W for lighting and for TV among the villagers. The access roads in these places are with grown up trees. The present systems are wired using insulated cables from tree to tree or otherwise. Sag Tension Charts are given Annex 1.

The proposed method of construction of the system is given in drawings in Annex 2. The system proposed is drawing insulated wire directly from tree to tree with tension points as wooden poles, or concrete poles, used as tension points. Flexibility is maintained to allow swing of trees to minimise the stresses to the conductors details of constriction.

Insulator Types

For insulated cables, Nylon bobbins or telecom. Insulators could be used as partial insulation. For un-insulated cables, LT insulators are recommended. For the connection of those insulators, refer the Annexe 2 sheet 12 &13.

**L8. Types of Poles**

For insulated cable networks up to 10mm<sup>2</sup> size cables, 7m height poles could be used. Above 10mm<sup>2</sup> and up to 35mm<sup>2</sup> size cables, 9m poles could be used. For un-insulated cables and bundled cables 9m and 13m poles could be used.

