Promotion of village grids

Quality and safety guidelines for pico-hydro village grids

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1. Introduction

Promoting private sector-based investments in village mini-grids, EnDev Rwanda aims to leave as much freedom as possible to the project developer in regards to technical design and business model. However, some minimum requirements for the quality and safety of the village grid installation must be fulfilled to ensure:

- a reliable power supply within the village grid,
- the quality of electricity supplied to protect electrical appliances connected, and
- the safety of the customers and staff.

The following document provides guidelines for the development of Small Power Distribution Projects. Only general orientation is provided on issues that EnDev deems critical during the design phase, finally contributing to a sustainable and safe operation of the distribution grid.

We recommend using more detailed technical guidance available (see literature overview in section 6, all publicly available documents can be provided on request).

Beside the distribution network, for which the design standards and guidelines for EARP Rural electrification must be applied, the guidance provided in this document shall be considered as recommendations. More orientation is provided by the EnDev Commissioning Checklist, which represents a binding part of the contract, and describes the detailed checks and measurements conducted by EnDev Rwanda during site commissioning to determine if the village grid meets the required quality and safety level.

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2. Site identification

The design of a hydropower system has to be based on the following information to be gathered during site identification (pre-feasibility study):

- The water flow during the whole year with minimum and maximum flow. Generate a Flow Duration Curve[1] from data obtained. The curve is the most important information that illustrates the availability of water flow over the year. A hydropower scheme operating in an isolated network should be designed on the basis of the "100% flow", meaning a flow which is (statistically) available during 365 days in a year.
- The optimal layout of the whole scheme with the locations of the intake, headrace, forebay, penstock, powerhouse and tailrace. The respective locations have to be clearly marked (using pegs) on site. The available gross head will be measured as the difference in height between the water level at the forebay and the planned level of the turbine shaft.
- The geo-coordinates of the major components using a GPS unit.
- Rough characteristics of proposed turbine, generator and control system.
- Voltage level, estimated total length of the transmission and distribution lines from the power house to the end consumers and number and capacity in case transformers are required.
- The demand forecast of consumers such as productive users of energy, small workshops/industries, social infrastructure facilities (schools, health centre, church etc.) and households, and their expected respective consumption (time and load) to establish a typical load profile over the day. This survey should also gather socio-economic information on the consumer base such as the source of income, income clustering, etc.
- Calculate available power, demand, required investment etc. in the form of a (pre-) feasibility study.

3. Civil Works

3.1. Weir & Intake

A weir and intake structure should meet the following requirements:

- The intake structure should be located at the outer side of a river bend to minimize sediments. It should during all seasons (at any water level) allow diverting sufficient flow into the headrace.
- The weir should be equipped with an overflow spillway and a sluice gate (at the intake side of the weir). The spillway should be able to divert the excess flow during rainy season. The sluice gate should allow to release the residual flow and to flush the sediment when required.
- The weir structure should have wing walls and/or side walls to protect the river banks against erosion.
- The intake itself (can be a simple intake orifice) combined with the spillway of the weir are controlling the flow entering into the headrace. In addition, a sluice gate or grooves for stopping logs allow to completely block the headrace (e.g. for maintenance). A trash rack is required at the intake to retain large debris from entering the headrace.
- The weir and intake should in general be constructed in a way that they can withstand temporary inundation.

3.2. Sand trap – settling basin

The purpose of a settling basin is to slow down the flow velocity to allow settlement of sediments.

- If appropriate space is available, the sand trap should be placed right after the intake to restrain as

[1] Flow Duration Curve, Good and Bad of Mini Hydro Power Vol1, page 5.

much sediment as possible from entering the headrace. However, functions of sand trap can also be adapted to a forebay.

- The width and depth of the settling basin are enlarged compared to the headrace. The basin should be preferably in a V-shape[2].
- The sand trap must be equipped with a flushing gate to remove sediment deposits and a spillway for excess water.

3.3. Headrace (canal)

- Steep and eroding slopes in the channel itself and in the adjacent terrain should be avoided. Properly maintained grass is a good choice to cover the slopes and thus to stabilize the banks and reduce erosion. In sections where flushing out of erosion material (into the channel) cannot be prevented, the channel should be covered.
- The slope of the canal determines the velocity of the flow. The velocity of flow should neither be too fast (to avoid erosion in the canal) nor be too slow (to avoid sedimentation in the canal).
- Depending on the conditions, masonry headrace provides a good quality-cost ratio, preferably with trapezoidal or rectangular shape.
- The depth of the headrace should include a freeboard allowance of a minimum factor of 1.3. For proper sizing of the canal, consult the channel dimensioning table.[3]
- Avoid earth channels if possible because they entail higher maintenance, higher risk of erosion and thus more material/sediment which could reach and damage the turbine.

3.4. Forebay

The forebay slows down the water to allow sediments to settle down and allows transition and regulation of flow pressure and velocity before entering the penstock. It ensures permanent submergence of the penstock entrance (prevents air from entering).

- The forebay should be equipped with a flushing gate to flush out sediment deposits.
- A spillway (with a respective channel back to the river) allows excess flow and flood flows to be safely channelled back to the river without causing any erosion.
- Using a trash rack placed right before the entrance to the penstock blocks debris from entering the penstock. The spacing width of the trash rack bars should follow the recommendations of the turbine manufacturer.
- The forebay should have a safe and accessible service area bridge for maintenance and operation (especially regular cleaning of the trash rack).
- The forebay must be wider and deeper than the headrace[4]. It should be equipped with an inlet gate to the penstock.

3.5. Penstock and support

- While determining the routing of the penstock, look for straightness and safe underground. Avoid crossings and inaccessible terrain.
- Provide for an anchor block at each change of direction – horizontal and vertical – of the penstock.
- Expansion joints have to be placed between two anchor blocks.
- A thrust block should be placed right before the entrance to the powerhouse to absorb all dynamic water forces in the pipe.

[2] Cross section of a sand trap, “Good and Bad of Mini Hydro Power Vol1”, page 53.
[3] The channel dimensioning table, “Micro Hydro Power Scout Guide”, page 41.
[4] Forebay with sedimentation basin, “Good and Bad of Mini Hydro Power Vol1”, page 73.

- The penstock material is mainly motivated by the cost, the availability on the market and the required resistance to pressure. The materials for penstock mainly available are steel, ductile iron, PVC and GRP (glass fibre reinforced plastic).
- Main characteristics of a penstock are its cross-sectional diameter and wall thickness (determining the pressure that the pipe can withstand). The required diameter (DN) and pressure class (PN) should be determined with all due care.
- The penstock requires a ventilation pipe.

3.6. Powerhouse

- The floor space of the powerhouse as well as the layout of main and auxiliary equipment should take into account convenience during installation, operation and maintenance work, and the floor area should be effectively utilized.
- Clear demarcation on the floor has to show ways and clear warning signals have to be placed on machineries.
- The powerhouse as such and especially its floor have to be clean. A clean floor allows detection of water leakages and other irregularities. A sealed ground allows dust to be easily removed.
- The powerhouse has to be built in a flood-proof area.
- The powerhouse should be well lit and ventilated. It should protect the equipment against adverse weather conditions, dust and any damage.

4. Electromechanical equipment

4.1. Turbine-generator unit

Turbine and generator have to be selected to

- Suit the design specifications (mainly depending on the range of flow and the net head),
- Guarantee stable operation for a long time,
- Be easy to handle and to maintain by a skilled operator, and
- Have acceptable technical guarantees.

Turbine and generator have to be perfectly parallel to the horizontal and to the vertical plane; parallel alignment is crucial for smooth transmission. Vibrations must be limited to a minimum.

In isolated mode, it is recommended to opt for synchronous generator with an AVR (Automatic Voltage Regulator). An AVR has to be selected which is suitable for operation in isolated mode. The AVR controls the generator voltage.

- Live electrical cables should always be protected by a flexible pipe
- All equipment has to be connected to the earthing system
- All rotating parts have to be well protected.
- All connections must be properly made (terminal strips) and protected by a lockable box (preferably plastic or metal).
- The electro-mechanical components and their base frame should sit on a solid and stable foundation.

4.2. Control and protection

- There must be a mechanism to control the rotational speed of the turbine, for example by adjusting the flow of water entering the turbine. The control can be done by manual operation of the valve or automatically with the use of a speed governor.

- There must be a mechanism to stop the turbine manually, e.g. by means of a valve.
- Control of current flowing into the distribution network has to be assured. In case of low load, a load controller should instantly divert electricity to the ballast load, installed at the powerhouse and, if applicable, the turbine discharge has to be reduced. The system must be able to shut down automatically in case of technical problems.
- Pressure, Voltage, Current, Power, Frequency, Hour-meter, energy (kWh and kVA) should be measured at the power plant.
- Protection of the LV distribution line should be provided against: Over frequency, under and over voltage, and over current.

5. Power distribution and consumer installation

5.1. AC/DC distribution

- The design voltage will be 230/400 Volt. To supply household users with energy for lighting, TVs and other domestic appliances a 1-phase system is generally sufficient. However, 3-phase connections should be considered for larger costumers.
- The maximum permitted voltage drop at the end of the LV service connection (customer supply point) shall not be more than ±5% for single phase and ±10% for three phase of nominal voltage with the calculated saturation load.
- The network's design shall be overhead bundle conductor radial systems with Areal Bundled Cables (ABC). The covered neutral carrier system is to be used.
- Requirements for the construction of LV distribution network applicable in Rwanda are detailed in the EARP construction standards. The standards provide minimum ground clearances and acceptable line spans.
- The grounding scheme for the power distribution (IT/TN/TT) must comply with the EARP guidelines. Inverters and AC main cabinets must be designed to comply with local requirements regarding the grounding scheme.

5.2. Consumer interfaces and installations

- Service connections are of the overhead type, connecting directly from the pole to the house and fixed onto the house's roof structure or the wall by means of a suitable tension clamp with eye bolt or pigtail bolt.
- Metering and/or load limitation shall be done through energy meters or current limiting devices such as MCB. Energy limitation devices or prepayment management system can also be implemented in case of many customers.
- Appropriate cables with correct size and insulation shall be used depending on the required current of the consumer.
- All power sockets must have a protective earth that is connected to the grounding scheme.
- Distribution boxes installed between the distribution grid and the house inner cabling must fulfill safety requirements, and comply with the grounding scheme.
- The project developers must think about their ownership and responsibility: (i) inner/household wiring, including bulbs, can be provided, owned and maintained by the company (this enables to better control energy use and demand), or (ii) the company only provides service connections and meters or power/energy limiter.

6. Selection of recommended manuals and guides on Pico Hydro

Technical guidance is provided by the following standards and guidelines (RS standards to be purchased):

1. EWSA (2013): Design standards and guidelines for EARP Rural electrification
2. RS 116 – 2011 Electrical wiring of premises – Part I: Low Voltage installations
3. RS EAS 811-1 to 5: 2014 Code of practice for safety of electrical installations

A selection of MHP Manuals is available on ENERGYPEDIA or in the internet

(https://energypedia.info/wiki/Micro_Hydro_Power_%28MHP%29_Manuals)

1. ACE (2009): Good and bad of mini hydro power, Vol 1 & 2 (English & French).
2. GTZ (2009): Micro Hydro Power Scout Guide.
3. JICA (2009): Manuals and Guidelines for Micro-hydropower Development in Rural Electrification, Volume I.
4. JICA (2009): Micro-hydropower Plant Site Completion Test Manual.
5. ESHA (2004): Guide on How to Develop a Small Hydropower Plant, Part 1&2.
6. NRECA (2009): Guides for Electric Cooperative Development and Rural Electrification. https://www.nreca.coop/wp-content/uploads/2013/07/GuidesforDevelopment.pdf
7. SERC (2013): Review of Strategies and Technologies for Demand-Side Management on Isolated Mini-Grids. http://www.cleanenergyministerial.org/Portals/2/pdfs/Review_of_Strategies_and_Technologies_for_DSM_on_MiniGrids.pdf
8. SERC (2013): A Guidebook on Grid Interconnection and Islanded Operation of Mini-Grid Power Systems up to 200 kW. http://www.cleanenergyministerial.org/Portals/2/pdfs/A_Guidebook_for_Minigrids-SERC_LBNL_March_2013.pdf
9. ARE (2015): Risk Management for Mini-Grids. http://ruralelec.org/fileadmin/DATA/Documents/06_Publications/RISK_Management_for_Mini-Grids_2015_Final_web.pdf

Published practical MHP handbooks (to be purchased):

1. Harvey Adam (1993): Micro Hydro Design Manual - A guide to small-scale water power schemes
2. Inversin Allen R. (1986): Micro-Hydropower Sourcebook - A Practical Guide to Design and Implementation in Developing Countries

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