TI-UP Enquiry: Micro-Hydropower - Low Head Turbines

Prepared by Frauke Urban, Climate Change and Development Centre, Institute of Development Studies IDS (f.urban@ids.ac.uk) for the TI-UP Resource Centre

Contents:

1. Definition Low Head turbines

Low Head turbines are hydropower turbines which have been developed for small-scale exploitation of rivers or irrigation canals. (Practical Action, 2006). These turbines have been developed for low water heads - below 10 metres- but large flows of water (Sanchez, 2009). Turbines are low-cost and easy to install. Maintenance is usually simple and does not require special tools (The Gold Standard Foundation, 2009). Low Head turbines need to be carefully custom designed for the site (All Energies, 2009; Pico Hydro, 2003).

2. Examples

Low Head turbines are mainly used in Europe, Asia and South America (Pico Hydro, 2003).

South America: Practical Action developed a Low Head turbine project with the support of DFID during 1996-1999. Practical Action designed a Low Head turbine model based on a propeller turbine which was used for large flows of water and high water speeds. This turbine was installed in 2001 in Peru and is still running. Adjustments were made to the turbine design for other locations, both downsizing and upsizing the design. Another Low Head turbine developed by Practical Action is the 'river current turbine' installed in Peru in the Amazon area (Sanchez, 2009). In 2004-2007, a joint project between Nottingham Trent University and Practical Action Peru was funded by the Leverhulme Trust for developing a closed volute design for Low Head turbines. This design can reach efficiencies of up to 70% and can be manufactured locally using inexpensive material and manufacturing processes. The turbines are currently in operation in Peru (Williams and Simpson, 2009; Pico Hydro, 2003; Sanchez, 2009). It is reported that Low Head turbines are also installed at Magdalena in northern Peru (HEDON , 2007).

Asia: Practical Action installed Low Head turbines in Sri Lanka (Sanchez, 2009). The Kathmandu University in Nepal is currently also involved in the design of Low Head turbines with a specific design called 'open flume design' (Williams and Simpson, 2009). The Gold Standard Foundation -which evaluates Clean Development Mechanism (CDM) projects according to their environmental, social and economic sustainability- supports a pico-hydro project in the Philippines developed by the Northelbian Missionary Centre and the Renewable Energy Association of the Philippines. Low Head turbines of 200W to 1,000W capacity will be installed as ‘family hydro systems’ in remote and un-electrified rural communities in the Philippines to help overcome energy poverty. These turbines will be installed in small streams and irrigation canals (The Gold Standard Foundation, 2009). There is an indication that Low Head turbines are also used in China, Thailand, Vietnam, Lao and Burma (MHyLab, 2005).

Europe: Low Head turbines are also used in Europe and the UK, for example turbines manufactured by NHT Engineering which are used in the Manchester Shipping Canal. These turbines have an installed generation capacity of 750kW. (NHT Engineering, 2008).

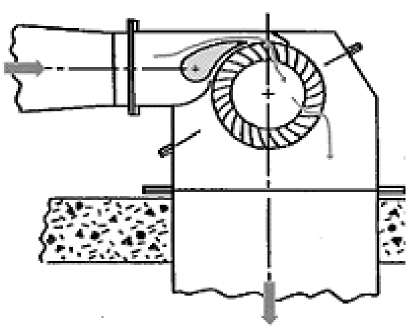
3. Applications

Hydropower turbines are usually divided into three groups: high, medium and low head pressure. Table 1 below shows a classification of turbine types according to these groups. The categories ‘impulse’ and ‘reaction’ refer to the type of turbine construction[1]. There are three types of Low Head turbines: Crossflow, Propeller and Kaplan turbines (Practical Action,2006).

	Head pressure		
Turbine Runner	**High**	**Medium**	**Low**
Impulse	Pelton Turgo Multi-jet Pelton	Crossflow Turgo Multi-jet Pelton	Crossflow
Reaction		Francis Pump-as-turbine (PAT)	Propeller Kaplan

Table 1: Classification of turbine types (Practical Action, 2006: 4)

Crossflow turbines are simple impulse turbines with rather low costs compared to other turbine types. The turbines are called Crossflow, because the water flows through the runner transversely. “Water enters a Crossflow in a flat section striking the flat blades of the runner before passing through and meeting the blades a second time as it leaves.” (NHT Engineering, 2008:1). “The shape of the blades is such that on each passage through the periphery of the rotor the water transfers some of its momentum, before falling away with little residual energy.” (British Hydro Association, 2004:1).



[1] “Impulse turbines convert the kinetic energy of a jet of water in air into movement by striking turbine buckets or blades - there is no pressure reduction as the water pressure is atmospheric on both sides of the impeller . The blades of a reaction turbine, on the other hand, are totally immersed in the flow of water, and the angular as well as linear momentum of the water is converted into shaft power - the pressure of water leaving the runner is reduced to atmospheric or lower.” (Practical Action , 2006:4)

Figure 1: Small Crossflow turbine (British Hydro Association, 2004).

Figure 2 shows the efficiency curve of a Crossflow turbine.

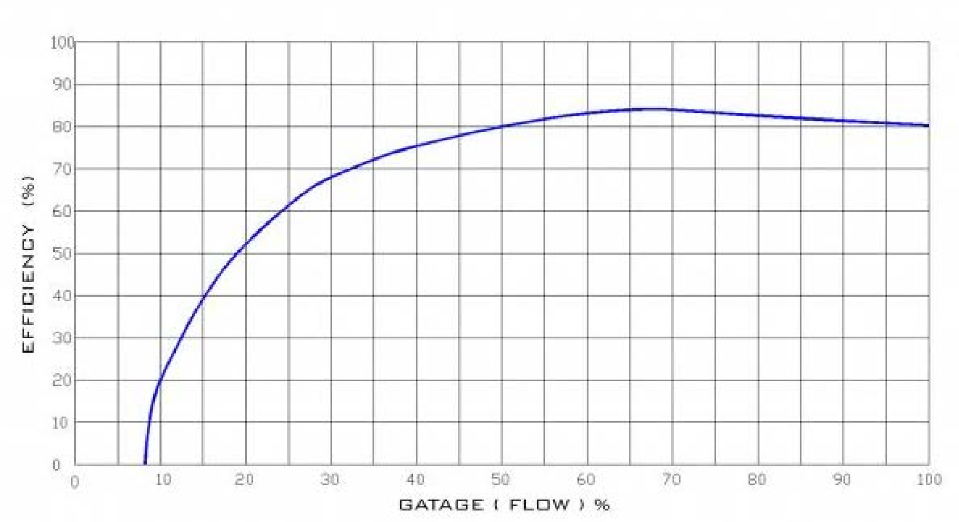


Figure 2: Efficiency curve for Low Head Crossflow turbine (NHT Engineering, 2008).

Kaplan turbines are inward radial flow type reaction turbines. “The turbine is usually placed in a spiral volute. […] [T]he Kaplan has a series of adjustable wicket gates. […] [T]he turbine runner […] has adjustable blades. By changing the angle of the blades in tandem with the angle of the turbines the Kaplan can maintain a high efficiency even at very low flows. Reaction Turbines like the Kaplan have a change in water pressure as the water passes through the turbine. There is pressure on the upstream side of the turbine runner and suction on the downstream side. On the downstream or outlet side of the turbine is the draft-tube which slows the water as it exits the turbine. The draft-tube has a unique curved horn like shape” (NHT Engineering, 2008:1). Kaplan turbines are particularly used for sites where there is a high variation in the amount of available water (NHT Engineering, 2008). Figure 1 below shows the design of a Crossflow turbine.

Figure 3 below shows the design of a Kaplan turbine.

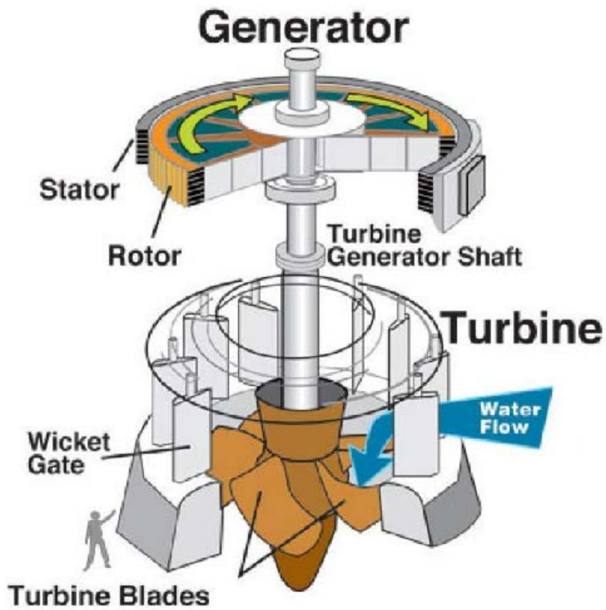


Figure 3: Kaplan turbine design (NHT Engineering, 2008)

Propeller turbines have propeller-like runners with three to six runner blades. They operate similar to boat propellers, but in a reverse mode. “Propeller turbines are usually applied in systems with water heads between 2 metres and 30 metres”. (Electrical and Mechanical Services Department Hong Kong, 2007).

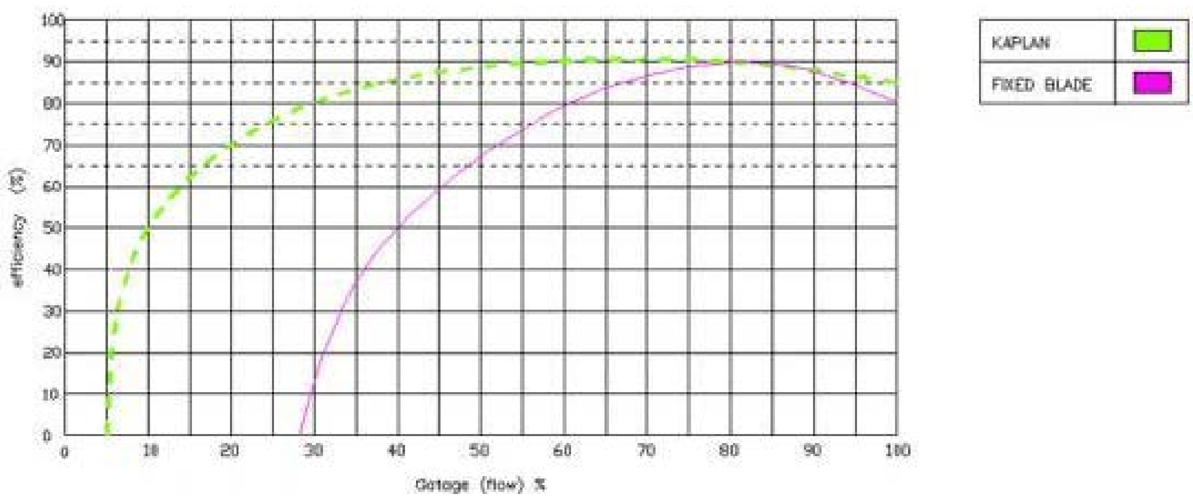


Figure 4: Efficiency curve for Low Head fixed blade Propeller (purple line) and a Kaplan turbine (green line) (NHT Engineering, 2008).

Figure 4 above shows the efficiency curve of a Kaplan turbine and a propeller turbine. It can be seen from figures 2 and 4 that the Propeller and Kaplan turbines have a slightly higher maximum efficiency than the Crossflow turbine. It can also be seen that the Propeller turbine has a rather restricted efficiency, whereas the Kaplan turbine has a rather stable efficiency and can be also be used where there is relatively little water flow. Figure 5 below shows the design of a propeller turbine.

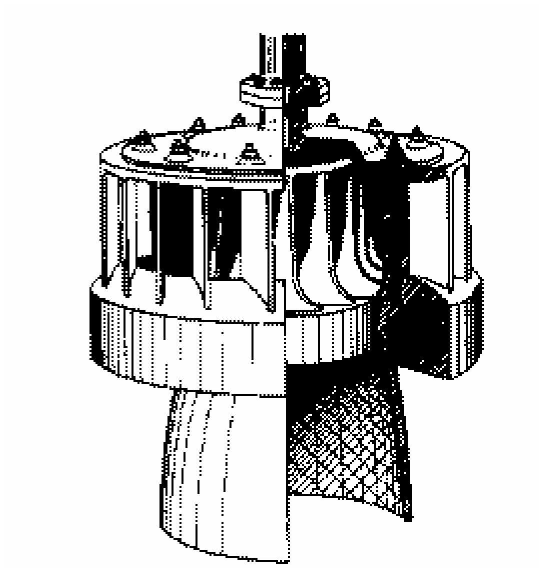


Figure 5: Propeller turbine design (JFCCivilEngineer, 2009)

4. Costs

There are a number of suppliers of Low Head turbines. Costs for Low Head turbines usually tend to be in the range of $350 to $3,250 (approximately £220 to £2,050), depending on their size and power output. Costs for turbines of up to 1kW tend to cost about $1,500 to $3,000, whereas costs for turbines of 200W tend to be about $350 and 500W tend to cost about $650. These costs are based on the models LH1000 (1kW) and PowerPal Low Head Turbine (200W - 1kW), both of which are propeller turbines (Sustainable Village, 2009a; 2009b). Costs for other turbines are only available upon request and depend upon the size.

In general, the investment costs for new small hydropower plants in Europe are about 1,200-3,500 Euros/kW (1,500-4,500 US$/kW) (ESHA, 2009) and the operating costs for small hydropower are between 0.02 US$/kWh and 0.06 US$/kWh with the lowest costs occurring in areas with good hydroelectric resources (IEA, 2007). Micro hydropower usually has investment costs of about 2,500-3,000 US$/kW (Paish, 2002a; Paish, 2002b). Costs for micro hydro can vary depending on the site and the country and have been reported to sometimes even exceed 10,000 US$/kW (Paish, 2002a; Paish, 2002b). On the other hand, costs can also be minimized to 1,000 US$/kW for micro hydro when local resources and indigenous expertise and technology is used (Paish, 2002a; Paish, 2002b). Costs in developing countries are often cheaper than in developed countries, especially for large hydropower (Paish 2002a; Paish, 2002b). Particularly operating costs tend to be lower. See table 2 for details. The lifetime of a hydro power plant can be up to 50 years and once investment costs are paid off, plants can operate at even lower cost levels (IEA, 2007).

Size	Investment costs	Operating costs	References
Large hydropower	2,400 US$/MW	0.03 US$/kWh – 0.04 US$/kWh	IEA, 2007
Small hydropower	1,500 – 4,500 US$/kW	0.02 US$/kWh – 0.06 US$/kWh	ESHA, 2009; IEA, 2007
Mini hydropower	1,500 – 4,500	0.02 US$/kWh –	ESHA, 2009; IEA,

	US$/kW	0.06 US$/kWh	2007
Micro hydropower	2,500-3,000 US$/kW*	Unknown	Paish, 2002a; Paish, 2002b
Pico hydropower	2,500-3,000 US$/kW*	Unknown	Paish, 2002a; Paish, 2002b

Table 2: Costs for different sizes of hydropower plants. *Investment costs for micro and pico hydropower can vary from between 1,000 US$/kW to 10,000 US$/kW depending on site and local resources.

5. Locations

Low Head turbines are suited for low water heads (usually below 10 metres) and large flows of water. They can be installed in rivers, small streams, irrigation canals or small waterfalls. Regarding the two commercially available Low Head Turbine models LH1000 and PowerPal Low Head Turbine, the location requirements are the following:

LH1000: The LH1000 Turbine produces power from water heads of 0.5 meters up to 3 meters, with a maximum output of 1 kW at 3 meters (Sustainable Village, 2009a).

PowerPal Low Head Turbine: The PowerPal Low Head Turbine produces power from water heads of 1.5 meters. The turbine requires a vertical water drop and sufficient water flow. These turbines are therefore mostly installed on small waterfalls, dams or diversion trenches (Sustainable Village, 2009b).

6. Power generated

Low Head Turbines are small hydropower turbines. The Low Head Turbines usually have a power generation capacity of a few hundred Watts to several Kilowatts. The turbine type LH1000 produces 1kW, the PowerPal turbine produces between 200W to 1kW (Sustainable Village, 2009). Larger-scale turbines are also used such as the Axial Flow Propeller Turbine in the Manchester Ship Canal which has a generating capacity of 750kW (NHT Engineering, 2008). The Low Head Turbines have efficiencies of up to 90% as figures 2 and 4 show, thus making it possible to harness close to the full potential of the installed generating capacity.

7. Special requirements, canal constraints and other options

Regarding the two commercially available Low Head Turbine models LH1000 and PowerPal Low Head Turbine, the special requirements and constraints are the following:

LH1000: "To gain enough head to operate the LH1000, water is channeled into a sluiceway. The turbine is mounted in a 18cm diameter opening in the sluice bottom, with the draft tube extending to the tailwater below. The water turns the propeller, creating shaft power. This, in turn, powers the generator, producing electricity" (Sustainable Village, 2009a:1). "If there is not enough water volume for the available head, the head can be reduced to match the available volume of water. The head can be reduced by adjusting the vertical drop for the diversion inlet and/or the length of the draft tube. If the site cannot produce the water volume necessary for the head, the turbine will not have enough water to operate, causing air to be sucked into the machine. This situation will reduce the power output considerably. If the water flow exceeds what is required to operate the machine, consider adding additional turbines" (Sustainable Village, 2009a:1). Storage is possible with the LH1000 as it can operate in conjunction with a battery system (Sustainable Village, 2009a).

PowerPal Low HeadTurbine: The producer claims that the installation is simple, there are no running costs and maintenance costs are low (Sustainable Village, 2009b). The turbines are usually installed on small waterfalls. “Electricity passes along a wire and into a house, where an electronic load controller stabilizes the voltage […] to protect electrical appliances during use.” (Sustainable Village, 2009b:1). The water flow needs to be at least 35 litres per second for this type of turbine. The PowerPal turbine requires a pipe and canal to be installed in addition to the turbine, which costs between $150 and $250 (Sustainable Village, 2009b).

References

All Energies, 2009. Hydroelectricity.
http://www.allenergies.net/hydro/background.html
Accessed: 6th October 2009

British Hydro Association, 2004. A guide to UK mini hydro developments.
http://www.british-hydro.co.uk/infopage.asp?infoid=363
Accessed: 6th October 2009

Electrical and Mechanical Services Department Hong Kong, 2007. Hydropower.
http://re.emsd.gov.hk/english/other/hydroelectric/hyd_tech.html
Accessed: 7th October 2009

European Small Hydropower Association ESHA, 2009. Small Hydro Power.
http://www.esha.be/index.php?id=44.
Accessed: 6th October 2009

Household Energy Network HEDON, 2007. Technologies that really work. Boiling Point Nr 53. http://www.hedon.info/docs/BP53_Masterweblayout.pdf
Accessed: 7th October 2009

International Energy Agency IEA, 2007. Renewables in Global Energy Supply. IEA/OECD, Paris.

JFCCivilEngineer, 2009. Propeller turbine design.
http://www.jfccivilengineer.com/turbines.htm.
Accessed: 7th October 2009

MhyLab Mini-Hydrolics Laboratory, 2005. Laboratory development for very low heads.
http://www.esha.be/fileadmin/esha_files/documents/workshops/Lausanne/2L_Denis_1_.pdf.Accessed: 7th October 2009

NHT Engineering, 2008. Crossflow Turbines.
http://www.newmillshydro.com/products
Accessed: 6th October 2009

Paish, O., 2002a. Micro hydro: status and prospects. Special Issues Paper 31, IMechE.
http://josiah.berkeley.edu/2007Fall/ER200N/Readings/Paish_2002.pdf.

Accessed: 7th October 2009.

Paish, O., 2002b. Small hydro power: technology and current status. Renewable and Sustainable Energy Reviews, Vol. 6: 537–556.

Pico Hydro, 2003. Low HeadTurbines. http://www.picohydro.org.uk/ Accessed: 5th October 2009

Practical Action, 2006. Micro-Hydro Power. Technical Brief. Practical Action, Rugby.

Sanchez, T., 2009. Personal communication between with Teodoro Sanchez from Practical Action.

Sustainable Village, 2009a. LH 1000 Low HeadMicrohydro Turbines PowerPal Low HeadTurbines. http://www.sustainablevillage.com/servlet/display/product/detail/36415 Accessed: 7th October 2009.

Sustainable Village, 2009b. LH 1000 Low HeadMicrohydro Turbines http://www.sustainablevillage.com/servlet/display/product/detail/37349. Accessed: 7th October 2009.

The Gold Standard Foundation, 2009. Newsletter May 2009.Case Study: Pico Hydro. http://www.cdmgoldstandard.org/fileadmin/editors/files/2_news/newsletter/GS_Newsletter_May09.pdf. Accessed: 7th October 2009.

Williams, A.A. and Simpson, R., 2009. Pico hydro – Reducing technical risks for rural electrification. Renewable Energy, Vol. 34:1986–1991.