International Conference on Hydropower for Sustainable Development
Feb 05-07, 2015, Dehradun

ULTRA-LOW HEAD TECHNOLOGIES FOR MICRO HYDRO POWER GENERATION: SCOPE AND COMPARISON

Anubhuti Agarwal
Micro Hydro System Expert, United Nations Industrial Development Organization, Project Execution Unit, Dehradun

ABSTRACT

Hydropower is known as renewable source of power, which when generated through large dams has voiced social and environmental concerns. It has been recognized that hydroelectric power doesn't necessarily require a large dam and there are available technologies those use a small canal to channel the river water through a turbine. Therefore, as an alternate to this Micro Hydro Power comes as a solution providing green energy to meet local needs in an environment friendly manner. Various low head (up to 3 m fall) based technologies provide a more acceptable perspective to the potential that has not yet been utilized in an efficient way. A wide range of Ultra Low Head to Low head based technologies are available worldwide and many of them are successfully supplying energy in decentralized manner, while their wider availability needs to be propagated. The paper aims at comparing the various low head based technologies available for canal based application and exploring what makes them unique in terms of decentralized power generation. It will also explore the usefulness, reasons of popularity, commercial availability and non-availability of the Ultra low head technologies and their scope.

INTRODUCTION

Hydropower is the most traditional and clean renewable energy technology. It converts the potential of water into througha turbine (potential and kinetic energy into mechanical energy by rotation) and a generator (rotation into electrical energy). The output of a hydropower plant is given in terms of power (kW) and electricity production (kWh). In India, the definition of small hydro covers any generation upto 25 MW while micro hydro is till 100 kW. The classification of hydropower generation based on head is given in the table below. Thus the range currently under discussion is upto 3 m head and called Ultra Low Head range.

S. N.	**Category**	**Head Range**
1	High head	75 m and above
2	Medium head	30-100 m
3	Low head	3-30 m
4	Ultra Low head	<3 m

The total installed capacity of India is 211, 766 MW as on Jan 2013 [1]. The potential of Small Hydro Power has been estimated to be 20,000 MW while installed capacity is 3, 496 MW as on Dec 2012.

Large hydropower projects are surrounded by environmental impacts related to environment flow, submergence, impact on flora & fauna, rehabilitation and resettlement, reservoir rim treatment, catchment area treatment, compensatory afforestation, muck disposal plan, etc. and the proper implementation of the environment management plan.

With such concerns, solutions for decentralized generation have been provided in the Ultra Low Head range.Such technologiescan be deployed to develop untapped potential at man-made water channels for irrigation, water supply, sewage, outfall structures, power station waterways, drainage from factories and habitat, agricultural watercourse; require no diversion, penstock or powerhouse building for installation. This eliminates major cost of civil works, land acquisition and has minimal impact on environment. Due to compact nature of the unit, installation is easy, quick and suitable for de-centralized power generation. The current paper limits to canal based low-head innovative technologies only.

VARIOUS AVAILABLE TECHNOLOGY

As per the SHAPES (SMALL HYDRO ACTION FOR THE PROMOTION OF EFFICIENT SOLUTIONS) project [2], there are four main types of turbines shown in the table below with Kaplan turbines most suitable for low head range of operation.

Turbine type	**Operation range**	**Multipurpose schemes**									
		Drinking water network	**Irrigation network**	**Raw waster water network**	**Treated wastewater network**	**Runoff collection system**	**Reserved flows and compensation discharge**	**Fish bypass system**	**Navigation locks and dams**	**Desalination plants**	**Cooling/ heating system**
Pelton	60 – 1000 meters	X	X	X	X	X				X	
Francis	20 –100 meters	X	X	X	X	X	X	X		X	
Kaplan	1.5 – 30 meters	X	X	X	X	X	X	X	X		X
Revers e pumps	Output <30 kW	X	X	X	X	X	X	X	X	X	X

This section explores the variousUltra Low Head micro hydropower generation technologies that can be procured worldwide.

Seabell International Co. Japan [3] has produced a compact version of vertical cross-flow turbineswith operating head range from 0.5 to 3 m and corresponding discharge ranges from 0.3 cumecs to 5 cumecs**.**The output capacity ranges from 0.5 to 50 kW.

Ossberger, Canada [4] have introduced movable power house using double regulated bulb type Kaplan turbine with operating range of 1.5 to 5 m head and output of 100 to 900 kW.

Turbi watt[5] (Fig 1), France are offering three turbines (Lynx, Leopard and Lion) which utilizes flow from 0.05 cumecs to 1.5 cumecs and taps head from 1.2 m to 8.5 m to generated output from 0.8 kW upto 60 kW. It uses constant speed and direct drive synchronous permanent magnet generator. The turbine has adjustable blades with efficiency. Bulb generator is watertight and ultra-compact providing installation flexibility (horizontal, inclined, vertical, in series, or parallel). Energy production can be in240 V single phase or 400 V three phase and the output can be used for home consumption or connected to the grid. The installation is simple and it can be positioned either vertically, horizontally or inclined. A screen cleaning system, upstream of the water chamber, filters the incoming water. The surplus water flows over the chamber, ensuring the cleaning of the screen cleaner.

Andritz Hydro, Austria has developed a bulb type Hydro matrix turbines [6] with an operating head range of 2 to 20 m, corresponding discharge of 5 to 12 cumecs which would provide an electrical output in range of mini hydro (100 kW to 1500 kW).

Archimedes Screw [7] and propeller type turbines [8] are used in USA for micro hydropower generation. While Archimedes screw principle is being utilized in Germany and Canada [9] too, with German version available in India through a technology transfer to local counterpart. Water enters the top of the screw, filling it to about the midpoint of the diameter. As the water flows downhill it creates torque on the screw and causes it to turn. The screw is connected to a gearbox to step up the rotation speed and turn the generator. Archimedes Screw type turbines are especially suited to sites with high flows. They are technically very simple with significantly lower installed and operational costs. Because of the design of the screws and their operation, all sorts of trash and debris can travel through them without any ill effects. These have robust design, low maintenance costs and don’t require any complex control system as speed is regulated by available flow.

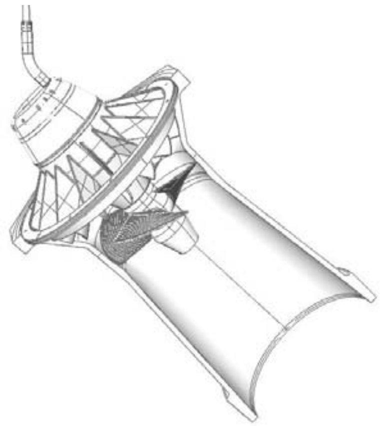

Fig. 1: Turbiwatt Turbine

Rehart GmbH [10], Germany is using the Archimedes Screw principle, for generation of energy with headsrange of 1 to 10 m and flow range of 1 to 10 cumecs from the outlets of Effluent Treatment Plants (ETP)/ Sewage Treatment Plants (STP) and fresh water falls of 1 m to 10 mproducing 500 kW at max flow and head.This technology is available in India through Jash Engineering Limited who have entered into Technical collaboration with Rehart GmbH, Germany.

Propeller type turbines are being used in USA, Japan, Canada and China while screw type turbines are also used in Canada. Smart hydro [11] introduced a hydro kinetic principle turbine. It is a “zero-head” or “in-stream” turbine since it is powered by kinetic energy and not with potential energy. No dams and/or head differential are necessary for the operation of this device. It consists of a horizontal-axis turbine, a permanent magnet underwater generator.

VLH turbines, France [12] have modified the Kaplan turbines to work under a head range of 1.4 m to 3.2 m and produce an output of 100 to 500 kW by varying the discharge from 10 to 26 cumecs. Such Kaplan machines are available in five different sizes.

Stream Diver [13](Fig2) has a concept of using in existing submersible design of using the turbines in the existing dams. It uses a water-floated permanent magnet generator, water lubricated thrust and guide bearings, water-filled turbine bulb with propeller runner and fixed guide vanes inside the turbine housing. Its special feature includes high availability, low maintenance and no peripheral systems, and installation in existing dams, easy retrieval of a single turbine too. Modular concept with 5 different runner diameter. Output range 50 to 550 kW and head range 2 to 5 m, discharge rate 2 to 12 cumecs.

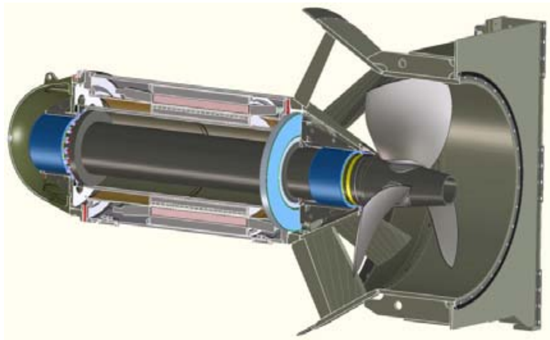

Fig. 2: Stream Diver

Mobile Hydro [14] (Fig 3) is a unique technology using a rotor inside a floating tube to generate electricity in running streams. The floating tube is tied to the banks or available support.

A Hydrokinetic hydrofoil turbine [15] has been conceptualized by the Norta University of Luxembourg which is a horizontally oscillating device used for power generation in rivers.

Fig. 3: Mobile Hydro (concept and installation)

Examples have been demonstrated in South India by using small turbines with water being fed through pipes. Such installation examples have been used for local power requirements.

COMPARISON OF FEATURES

A good number of technologies are available worldwide with generic features listed in the table below:

S. No.	Company (country)	Turbine name	Type	Head range (m)	Discharge (cumecs)	Output range (kW)
1.	Seabell lnt. Co. Ltd. (Japan)	Stream Turbine	Vertical cross flow	0.5 to 3	0.3 to 5	0.5 to 50
2.	VLH (France)	VLH	Kaplan	1.4 to 3.2	10 to 26	100 to 500
3.	Ossberger(Canada)	Movable power house	Double regulated Kaplan Bulb	1.5 to 5	5 to 25	100 to 900
4.	ANDRITZ Hydro (Austria)	Hydromatrix	Bulb type	2 to 20	5 to 12	100 to 1500
5.	Mavel- Micro turbine (USA)	MT-3	Propeller	1.5 to 6	0.14 - 0.4	0.7 to 13
		MT-5	Propeller	1.5 to 6	0.7 - 1.4	2 to 50
6.	3 Helix Power (USA)	Archimedes Screw	Screw	1 to 10	0.2 to 10	2 to 500
7.	Ritz Atro (Germany)	Hydrodynamic Screw	Screw	1 to 10	0.25 to 5.5	2 to 300
8.	Toshiba Power Systems and Services (Japan)	e-kids S-type	Propeller	3.5 to 15	0.1- 0.3	5 to 25
		L- type	Propeller	2 to 15	0.1 - 1.4	5 to 100
		M- type	Propeller	2 to 15	0.1- 3.5	10 to 200
9.	Niade (USA)	Niade water turbine	Propeller	0.6 to 1.2	0.04 to 0.11	0.125 to 0.7
10.	Energy system & design (Canada)	LH-1000	Propeller	0.5 to 3	0.02 to 0.063	0.25 to 1
11.	Power Pal (Canada)	MGH-200LH	Propeller	1.5	0.035	0.2
		MGH-500LH	Propeller	1.5	0.07	0.5
		MGH-1000LH	Propeller	1.5	0.13	1
12.	Exmork (China)	LH-300W	Propeller	1.8	0.04	0.3
		LH-500W	Propeller	2	0.045	0.5
		LH-700W	Propeller	2.2	0.05	0.7
		LH-1KW	Propeller	2.5	0.1	1
13.	Rehart GmbH/ Jash (Germany/ India)	Screw	Screw	1 to 10	1 to 10	upto 500
14.	Greeenbug Energy Inc (Canada)		Screw			
15.	Smart Hydro (Germany)	Smart Hydro	Kinetic turbine	0	-	Upto 6
16.	University of Luxembourg	Hydrofoil-River-Turbine	Horizontally oscillating			

S. No.	Company (country)	Turbine name	Type	Head range (m)	Discharge (cumecs)	Output range (kW)
			Hydrofoil-River-Turbine			
17.	Turbiwatt (France)	Lynx Leopard Lion	Kaplan bulb	1.2 to 2 1.2 to 5.5 1.4 to 8	.05 to .07 .090 to.25 0.25 to 1.4	0.6 to 0.8 3 to 9 6 to 60
18.	Verde Group (Switzerland)		Vortex	1.5 to 2.5	1 or more	5 to 50
19.	Voith (Germany)	StreamDiver	Kinetic turbine	2 to 5	2 to 12	50-550

USEFULNESS AND REASONS OF POPULARITY

Micro Hydro technologies are clean and green source of energywith no requirement of environment clearance in India. The benefits of the micro hydro technologies are listed below:

- It is a solution to the needs of decentralized generation by exploiting untapped potential.
- The technologies are generally simple, reliable, provide installation flexibility and can provide electricity for local load as well as grid connectivity.
- They are ideal for low water heads and low fluctuating flow condition. No extensive civil engineering works required.
- Negligible maintenance due to low rotation speed.
- Good operative life
- Diversity in application; develop untapped potential at man-made water channels for irrigation, water supply, sewage, outfall structures, power station waterways, drainage from factories and habitat, agricultural watercourse;
- Requires no diversion, penstock or powerhouse building for installation. This eliminates major cost of civil works and land acquisition
- Has minimal impact on environment.
- Due to compact nature of the unit, installation is easy, quick and suitable for de-centralized power generation.
- The units can be cascaded

USEFULNESS: AN EXPERIENCE WITH ONE SUCH TECHNOLOGY

The experience in the current UNIDO project "*Promoting Ultra Low-Head Micro Hydropower Technology To Increase Access To Renewable Energy For Productive Uses In Rural India*"has been that the technology needs to be adapted to suit the local conditions.

An assessment is to be made regarding the difference in the working atmosphere of the existing and new proposed locations. Based on such an assessment, suitable mechanical, electrical and electronics circuitry update would be carried out, as required and as per the availability in the country.

In the current case, due to the heavy silt load the bush bearings have been replaced with ball bearings and the same were water sealed. The power evacuation voltage and frequency was different in the parent country and demonstration location, hence the control panel had to be made indigenously.

As per the IEA Small Scale Hydropower Report summary on “Innovative Technologies for Small-Scale Hydro” [16], future development of small-scale hydropower should seek to make advancements related to cost reduction, increased efficiency, improved reliability, and expansion of applicability to exploit previously undeveloped resources. These advancements are required as there is generally no scale advantage to be gained over larger developments. Also, it will be necessary to simplify operations and maintenance to foster new hydropower development and to reduce potential environmental impacts in order to gain public acceptance. In order to make effective use of non-traditional and previously un-utilized hydropower potential in existing facilities, further ingenuity will be required.

COMMERCIAL AVAILABILITY OF TECHNOLOGIES

Out of the 19 canal based technologies searched, the commercial availability is limited geographically. During the search, it was observed that thewidespread use of the technologies and its implementation is missing. The link between the availability, its usage and awareness is yet to be firmed up. Though the usage of each technology is in widespread locations, an overall support from government is required to create awareness and to accept it widely.

Moreover, another obstacle [2] can be the lack of simple administrative procedures adapted to small hydropower. For example, the doubts on the quality of the turbine water outlet notably during and after a maintenance operation have slowed down the SHP development on drinking water networks in France. On the contrary, the procedure in Switzerland is simple, mainly because the water network and the SHP plant are generally owned and operated by the water office of the commune or city.

CONCLUSION

A wide range of technologies is available worldwide in the ultra low head range of micro hydro power generation. However, the availability of the technology is limited in geographical widespread. A technology available in one part of the world is not available on a common platform. Required are policy interventions for promotion and awareness of the technologies. In addition, localized adaptation of the technology by analyzing the difference in the operating parameters of the system needs to be promoted.

REFERENCES

1. http://www.smallhydroworld.org/fileadmin/user_upload/pdf/WSHPDR_2013_Final_Report-updated_version.pdf
2. http://www.esha.be/fileadmin/esha_files/documents/SHAPES/Multipurpose%20schemes%20brochure%20SHAPES.pdf

3. http://seabell-i.com/
4. http://ossberger.ca/
5. http://www.turbiwatt.com
6. http://www.andritz.com/hy-hydromatrix-en.pdf
7. http://www.3helixpower.com/archimedes-screws/
8. http://www.nwhydro.org/events_committees/Docs/2011_Small_Hydro/Technology%20-%20Mavel.pdf
9. http://greenbugenergy.com/get-inspired/micro-hydro-projects
10. http://rehart.de/en/rehart-gmbh.html
11. http://www.smart-hydro.de
12. http://www.vlh-turbine.com
13. http://www.voith.com/en/insights/innovationspreis-stream-diver-56717.html
14. www.mobilehydro.com/
15. https://www.alaska.edu/files/.../all.../Han.pptx
16. http://www.small-hydro.com/Public-Files/101012_Annex-2_Subtask-B2_Summary-Report-(Final-Ve.aspx