In-Stream Hydrokinetic Turbines

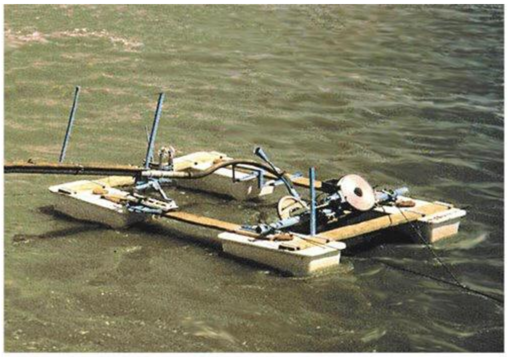
The Electric Power Research Institute conducted a study of Tidal In-Stream Power Production that is one of the best references available and has reports for download. A similar study of River Turbines describes many turbines. The U.S. Department of Energy's Marine and Hydrokinetic Technology Database provides up-to-date information on marine and hydrokinetic renewable energy, both in the U.S. and around the world.

This is the best short Reference Article on In-Stream Turbine Technology we have found:

"State of River Energy Technology"

Jahangir Khan, Powertech Labs, British Columbia, Canada. 2006.

Based on the available formal literature, the very first example of river turbine that was developed and field tested is attributed to Peter Garman. An initiative by the Intermediate Technology Development Group (ITDG) in 1978 resulted in the so-called Garman Turbine specifically meant for water pumping and irrigation. Within a period of four years, a total of nine prototypes were built and tested in Juba, Sudan on the White Nile totaling 15, 500 running hours. Experience gained during this venture indicated favorable technical and economical outcome. Initial designs had a floating pontoon with completely submerged vertical axis turbine, moored to a post on the bank. Later designs consisted of an inclined horizontal axis turbine with almost similar floatation and mooring system. Detailed investigation on a low cost water pumping unit indicated 7% overall efficiency and concluded with emphasis on societal and cost issues. More recent commercial ventures resulting from this work are being pursued by Thropton Energy Services, Marlec Engineering Co. Ltd. , and CADDET Center for Renewable Energy.



(a) Garman Turbine: ITDG,U.K.

(b) Tyson Turbine: Australia

(c) Rutten Company,Belgium

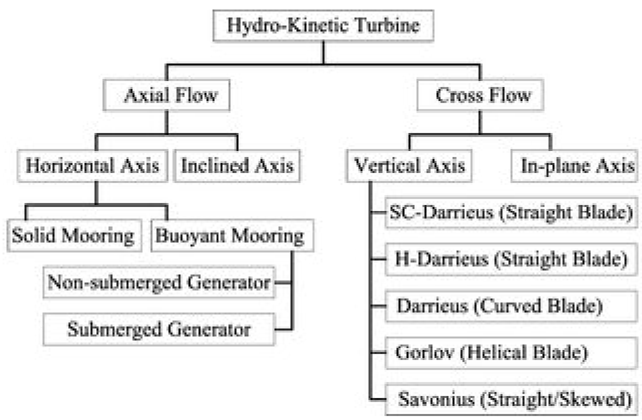
(d) Marlec Engineering Co. UK

Another Australian design (Alternative Way, Nimbin, Australia) known as Tyson Turbine consisted of a horizontal axis rotor with a submerged 90 degree transmission mechanism that powers a generator fitted on a pontoon. A Belgian concept (Rutten Company, Herstal, Belgium) containing a twin tubular pontoon with floating turbine and a straight bladed waterwheel was tested in Zaire, Africa. Information on several similar designs with horizontal and vertical axis rotors that were tested in the Amazon regions of Brazil could be found in. This report emphasizes the success and robustness of the tested hydrokinetic turbine system for use in remote locations. The need for protection mechanisms against debris and severe conditions has also been outlined. However, technical information on these designs and their performance is not available.

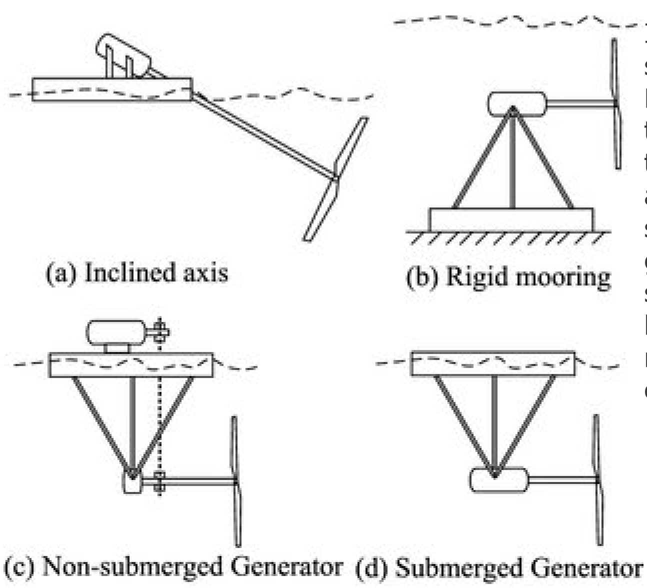
Apart from the axial flow turbines surveyed in the above section, cross flow turbines have also shown good promise. Perhaps the most detailed design, testing and entrepreneurial efforts toward realizing vertical axis turbines for tidal energy conversion was carried out by Barry Davis and his business concern Blue Energy Canada Inc. To date six prototypes including model names such as: 20 kW B1, 100 kW B2, 4 kW VEGA, and 5 kW TOR5 were field tested and results were considered encouraging. The use of augmentation devices (namely, Tidal Fence) was proposed and experiments had indicated nearly 45% system efficiency. Alternative Hydro Solutions Ltd. in Ontario has recently developed vertical axis turbines specifically meant for river applications. Attempts on designing variable pitch vertical turbines, namely, cycloidal turbines have been reported by Verdant Power LLC. and Environmental Turbine Technology development (ETTE Elektro, Norway).

A recent design by Alexander M. Gorlov developed at the Northeastern University, Boston, U.S.A has gained significant attention for both river and tidal applications. The so-called Gorlov Helical Turbine, GHT employs twisted blades with helical curvature. Better modularity, scalability and economics have been claimed in favor of this design.

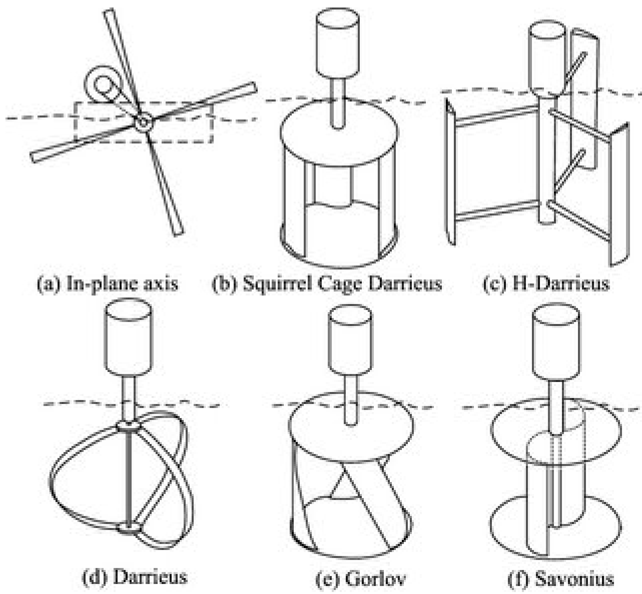
Classifications of turbines and channels



Based on the alignment of the rotor axis with respect to water flow, two generic classes could be formed, namely, the axial and cross flow turbines. The axial turbines have axes parallel to the fluid flow and employ propeller type rotors. On the other hand, the cross flow types encounter water flow orthogonal to the rotor axis and mostly appear as cylindrical rotating structures.



Inclined axis turbines have mostly been studied for small river energy converters. But, horizontal axis turbines are common in tidal energy converters and are very similar to modern day wind turbines from design and structural point of view. Turbines with solid mooring structure require the generator unit to be placed near the river or seabed. Horizontal axis rotors with a buoyant mooring mechanism may allow a non-submerged generator to be placed closer to the water surface.



The cross-flow turbines can rotate unidirectionally even with bi-directional fluid flow. These can also be divided into two groups: vertical axis (axis vertical to water plane) and in-plane axis (axis on the horizontal plane of water surface). In-plane axis turbines are better known as floating waterwheels. These are mainly drag based devices and inherently less efficient than their lift based counterparts. The large amount of material usage is another problem for such turbines. Darrieus turbines with in-plane axes may also fall under this category. But such systems are less common and suffer from bearing and power take-off problems.

In the vertical axis domain, Darrieus turbines are the most prominent options. Even though examples of H-Darrieus or Squirrel Cage Darrieus (straight bladed) are rather common, instances of Darrieus turbines (curved blades) being used in hydro applications are non-existent. The Gorlov turbine is another member of the vertical axis family, where the blades are of helical structure. Savonious turbines are drag type devices, which may consist of straight or skewed blades.

These turbines may also be classified based on their lift/drag type blades, up/down flow orientation of the rotor, and fixed/variable (active/passive) pitching mechanism of the blades. Different types of rotors may also be hybridized (such as, Darrieus-Savonious hybrid) in order to achieve a specific performance feature.

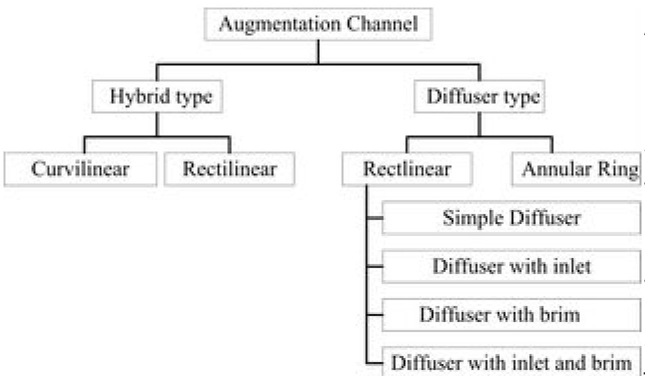
From applications point of view, hydrokinetic turbines can be used both in rivers or oceans (for tidal or marine current energy conversion). However, there are some subtle differences amongst these two fields of application. Tidal turbines are typically larger in size (> 100 kW), whereas river turbines are generally in the range of 1 kW to 10 kW. Most marine turbines use horizontal axis rigid mooring/submerged generator configurations. On the other hand, inclined horizontal axis or Darrieus type turbines are common in river energy applications. Tidal and marine current turbines work under the natural events of daily tide flow and seasonal ocean current variations, respectively.

River turbines operate under the influence of varying volumetric water flow through a river channel subject to various external factors such as, channel crosssection, rainfall, and artificial incidences (such as, transportation, upstream dam opening etc.). River water is less dense than seawater and therefore it has lower energy density. Siting is more stringent in river channels as the usable space is limited and river transportation may further constrain the usability of the sites. There could also be varying types of suspended particles and materials (fish, debris, rock, ice etc.) in river and sea channels depending on the geography of a site.

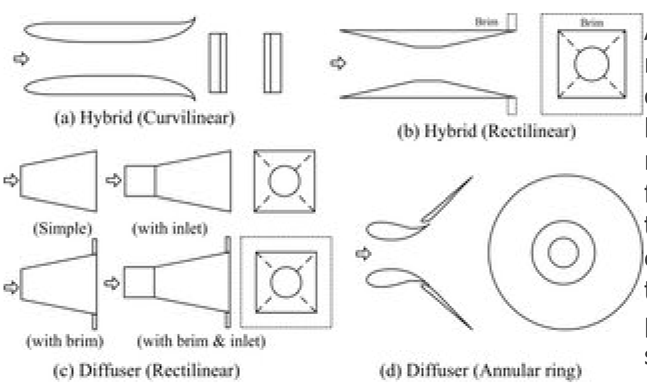
Based on this overview and underlying pros and cons of various turbine topologies, straight bladed Darrieus turbines (H-type or Squirrel Cage type) might be considered as a viable option for hydro applications. Several advantages that may affirm this choice are:

- Design Simplicity
- Design Symmetry
- Generator Coupling
- Directional and Augmentation Equipment

The disadvantages associated with vertical axis turbines are: low starting torque, torque ripple, and lower efficiency. These turbines may not be self-starting and therefore external electrical, mechanical or electromechanical starting mechanisms need to be adopted. In such turbines, the blades facing the water flow appear in a periodic manner causing significant torque ripple in the output. Efficiency is another concern for such turbines, where there are many claims that these turbines are of lesser efficiency.



Augmentation channels induce a sub-atmospheric pressure within a constrained area and thereby increase the flow velocity. If a turbine is placed in such a channel, the velocity around the rotor would be higher than that of a free rotor. This increases the possible total power capture significantly. In addition, it may aid regulate the speed of the rotor and reduce low-speed drive train design problems. Such devices have been widely tested in the wind energy domain. Terms such as, duct, shroud, wind-lens, nozzle, concentrator, diffuser, and augmentation channel are used synonymously with regard to this arrangement.



A simple channel may consist of a single nozzle, cylinder (or straight path) with brim or diffuser. In a hybrid design, all three may be incorporated in one unit. Each of these models come with unique set of performance features and design limitations. For instance, the hybrid types perform better at an expense of bigger size (as high as 6 times the rotor diameter). The annular shapes also perform very well when hydrodynamic shapes are optimally designed.

A complete hydrokinetic system for use in river environment may consist of units such as augmentation channel, rotor-blade assembly, electrical generator, flotation device, mooring, control system, protection screen, etc. Based on these observations, the straight bladed Darrieus type turbine has been selected as the rotor of choice and a simple diffuser model has been identified as the solution for augmentation.

****

The article above provides a fine overview of the many technology possibilities. Hydrovolts has developed a new turbine that is an improvement over all existing designs.