Product Research, LLC
PO Box 729; Stanwood, WA 98292
360 387 3677; Cell 360 393 0185
prprllc@hotmail.com

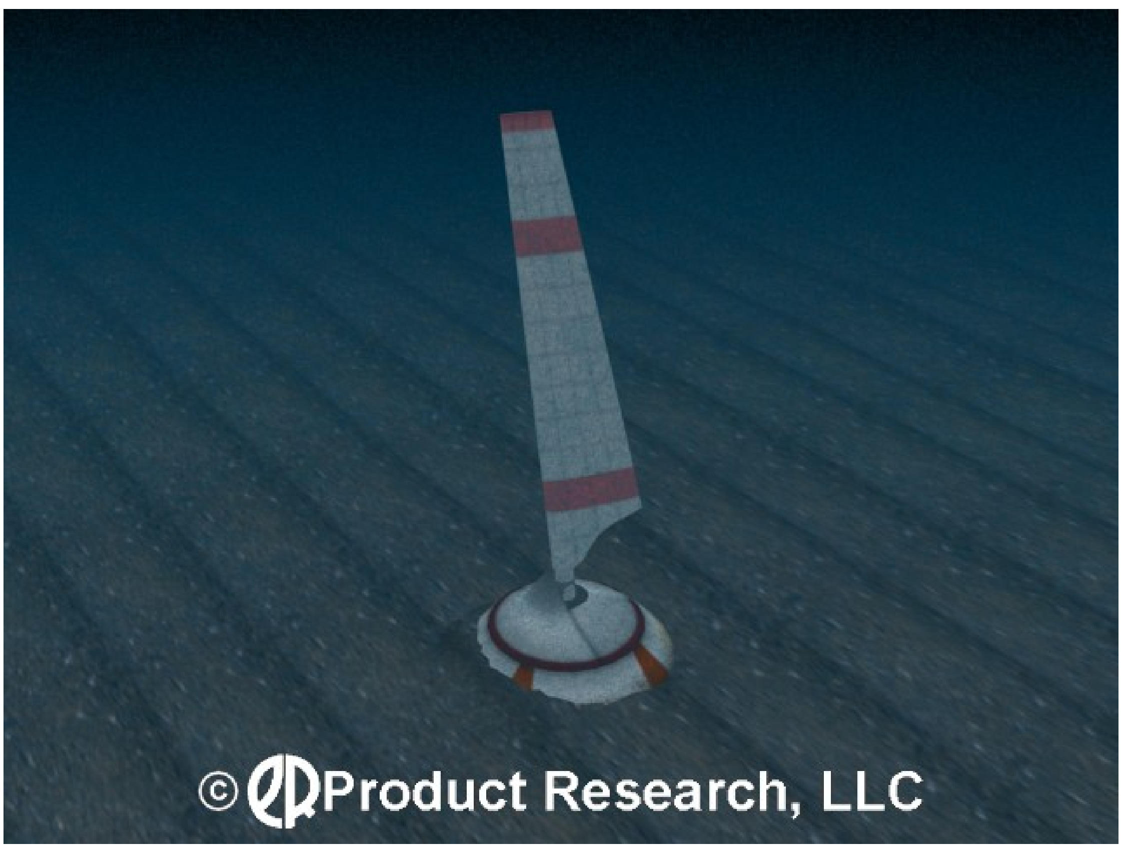
Buoyant Blade Free Stream Tidal Power.

Our patent 7,839,009 is for sale.
Please contact PR Product Research, LLC.

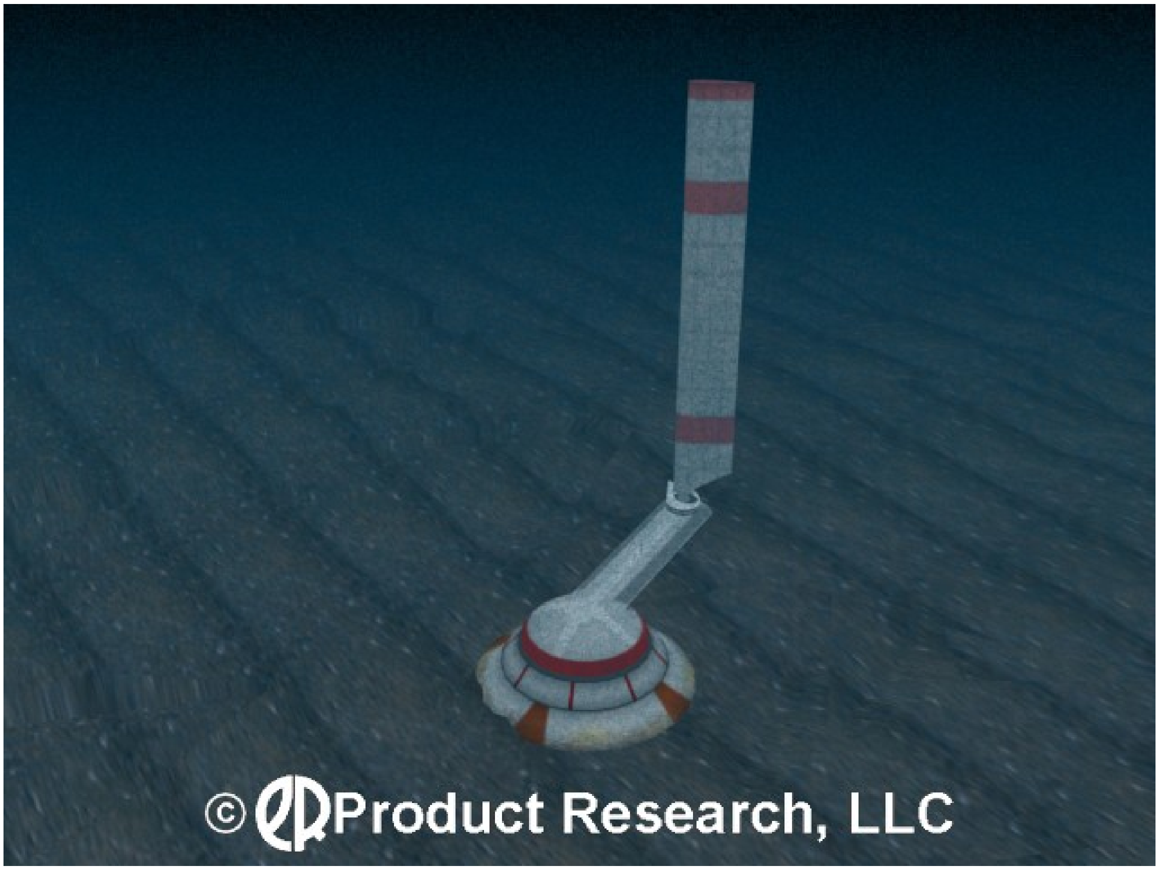
Summary

Free Stream Tidal Power, including the power in river flow, is generating interest as a renewable power source. Current approaches use designs adapted from windmills to harvest the power in the moving water flow. These "water-windmills" are not well adapted to the marine environment and present significant problems once they leave the theoretical world. A better solution is provided, taking two forms.

The first form is similar to a canoeist in a moving boat sticking her paddle straight down into the water. If she twists the handle of her paddle the blade of the paddle is acted on by the moving water, pulling the paddle to one side. By holding her upper hand still and alternately twisting the paddle blade left and right, the paddle will pull from side to side, rotating around her hand. Everyone has performed a similar task by holding their hand out the window of a moving car. As you twist your wrist, your hand is pulled up and down by the actions of the wind stream.



The second form of the new approach is more like a wakeboarder being towed behind a boat. As the wakeboarder changes the angle of his board relative to the water stream, he is alternatively pulled back and forth across the wake. He rotates around the point where the rope attaches to the boat.



In either form, the new approach keeps the single blade vertical in the current stream using the blade's own buoyancy. A hinge at the base allows the blade to deflect and "shrug off" kelp or other debris, eliminating the requirement for a huge foundation, mounting pole, or guy wires. The use of a freely mounted, buoyant blade also allows the blade to pivot and safely unload during extremely high currents, protecting the structure while still generating power.

Background

Please refer to http://en.wikipedia.org/wiki/Tidal_power for a good overview of the current state of the art.

Another excellent industry overview from the Snohomish County (WA) PUD is here:
http://www.snopud.com/Content/External/Documents/tidal/TidalPres11_13_07.pdf

Why is this approach needed?

As seawater sloshes in and out of inlets under the influence of the moon's gravitational pull, currents are created. These water currents contain substantial amounts of kinetic energy that can be harvested at predictable times to provide power, usually in the form of electricity. River flows are also potential sources of “tidal” power.

Tidal or riverine currents are often low-density power sources, flowing at 3-5 knots or less. This makes the power difficult to extract efficiently. Hydroelectric dams and their coastal cousins the barrage plants amplify the energy density of the water and then harvest the energy using high-pressure, high-velocity turbines. In the process they modify the environment they utilize, often displacing or destroying native ecosystems.

Free-stream turbines have been proposed or deployed that are designed using modern windmill concepts. These “water-windmills” are installed in high-current areas to take advantage of the higher energy density. High current areas are typically “choke points” with lots of marine/riverine mammal, fish, and boat traffic. They are also, in the case of tidal power, highly variable, with reversing currents running from zero to 15 knots or more. It is very difficult to design a turbine to be efficient or even effective in such a variable environment.

In many areas water flows carry debris such as fishing nets and fishing lines, kelp fronds or stalks (which can be extremely tough and entangling), boat anchors and anchor lines, and deadheads and other floating wood. This debris can not only clog or jam the mechanism of a water-windmill, but can build up on the structure or anchoring system significantly increasing the load on the foundation and requiring complicated intervention using divers or underwater vehicles to correct. It is even conceivable that a large water-windmill could snag a small boat’s anchor line or fishing nets and pull it under the water.

Water-windmills are usually designed with high Reynolds number, high-efficiency blades. The blades are long and thin, with sharp leading edges. They rotate at fairly high speeds[1] with high tip velocities causing damage to either the turbine blade or the struck object in the event of a collision. If the struck object is a small tree (deadhead), only monetary damage is sustained. If the struck object is a whale or a school of migrating salmon, the carnage and subsequent adverse publicity could easily destroy the local tidal power industry.

If a free-stream tidal plant were to cause significant ecological damage, even perceived damage, it would be subject to eco-terrorism and “monkey-wrenching”. Water-windmills would be extremely easy to damage or destroy. Buoy-hung chains launched elsewhere that follow the current into the turbine area will become entangled, requiring difficult servicing or equipment replacement.

Even if a site is chosen that has little or no existing marine life, the very existence of the power plant will create an artificial reef. Various installations[2] around the world have shown that artificial structure in a “desolate” underwater location soon creates its own local ecosystem. Filter feeders growing on the foundation and moving parts attract small predatory fish and crabs, eddies and current upsets attract migratory animals, and larger species will soon follow. Power generation installations must be sensitive to all affected marine life, even attracted by the system itself.

A solution is proposed that provides for the extraction of power from flows away from choke points that is not overly susceptible to fouling from debris and that minimizes damage or deleterious effects to the surrounding environment and ecosystem. In addition, the “normal” requirements for low maintenance in an extremely hostile environment and overall cost effectiveness still apply and are addressed.

Key Concept: Impedance Matching

Impedance Matching is an involved design approach that comes from electrical engineering. In very simple form, it says that if you have a small load you get the most efficiency using a small *matched* power source.

[1] High speeds relative to the marine environment and the animals that live there.
[2] Offshore oil rigs, for example.

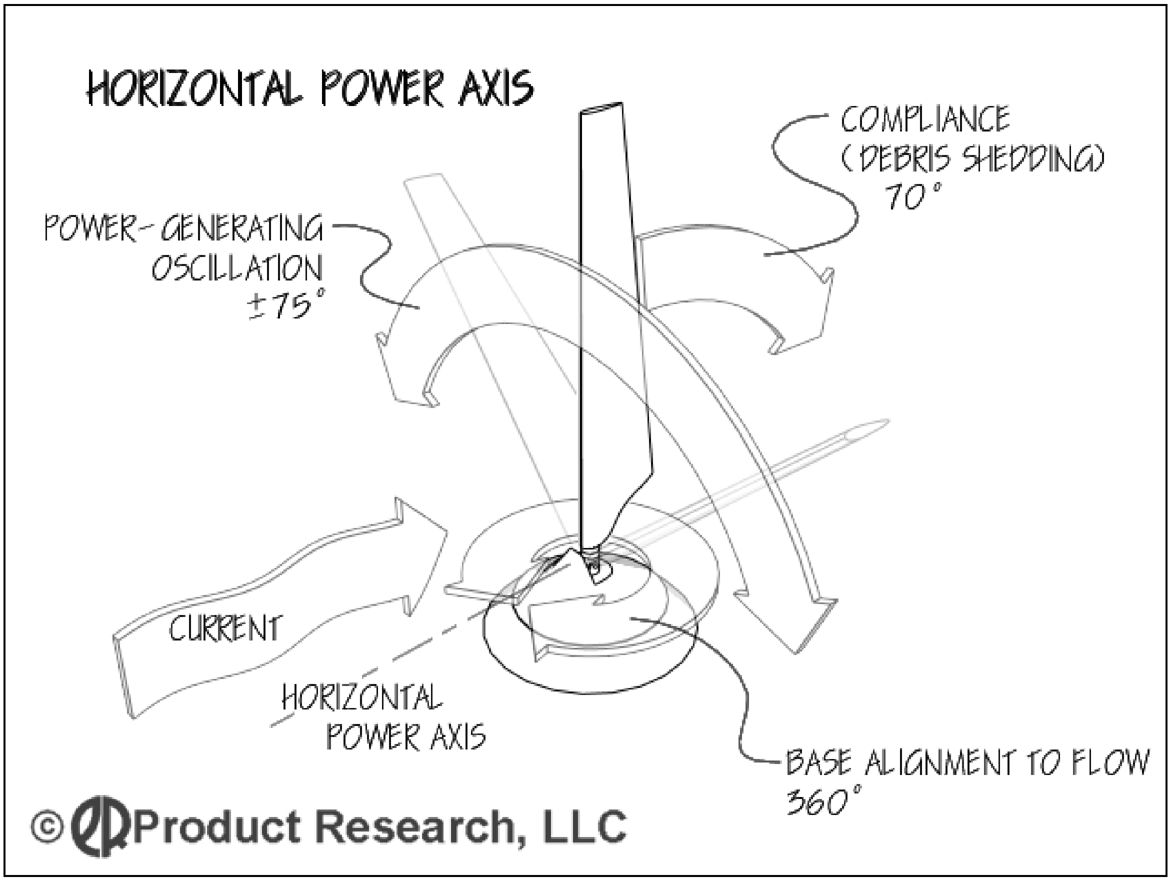
In our case, it means that if you have a large, slow moving stream of dense fluid, the best way to extract energy is to use a large, slow moving device that exploits the density of the fluid.

Another use of the concept is that if you must coexist and interact with large, slow moving marine mammals your device should be of a similar scale and speed to minimize damage to the animals or your device.

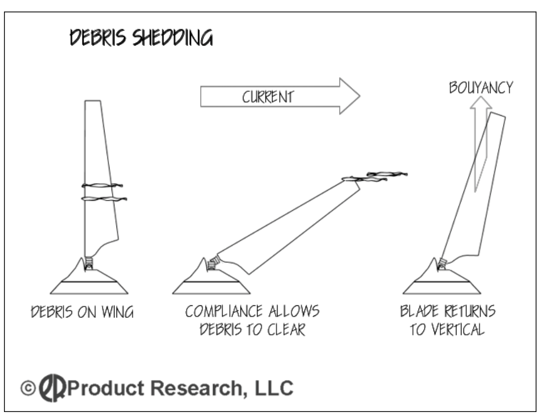
PO Box 729; Stanwood, WA; 98292
prprllc@hotmail.com

What is the New Approach?

Horizontal Power Axis Parallel to Flow Stream.

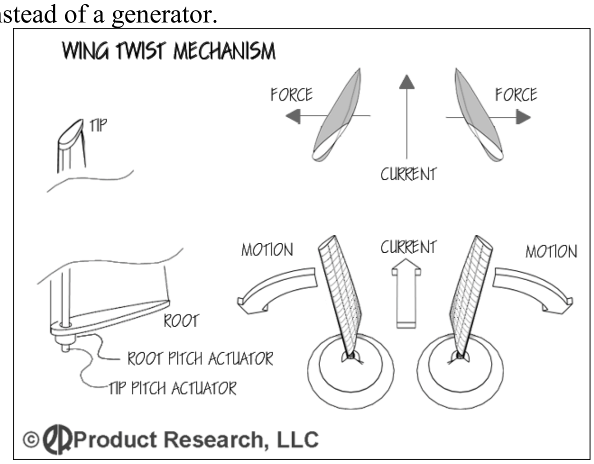


In its first form, the new system is a single blade or wing that projects upward from a base or foundation on or in the sea floor. The blade is oriented to the prevailing current flow, and its pitch is controlled to make the blade swing to and fro across the current. Power is extracted by resisting the torque created by the blade where it attaches to the base.

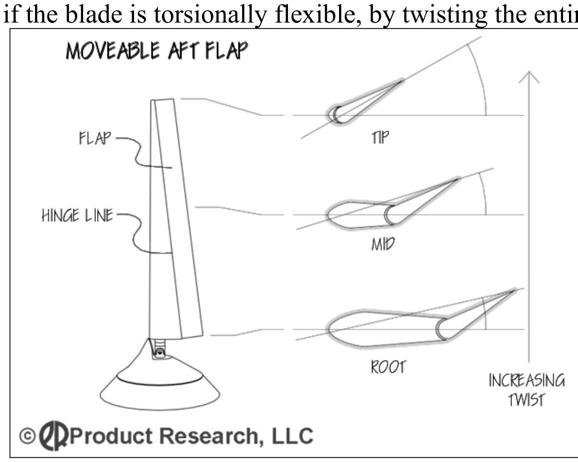


A key feature of the new system is that the blade is buoyant and is mounted compliantly in the current-flow axis. Kelp or debris that entangles the blade will increase drag on the blade, causing it to lean back until the debris clears itself. The blade will also lean back in very high-current events, unloading the blade and preventing structural damage. In addition, the loads on the system's base or foundation are greatly reduced since buoyancy keeps the blade in the current stream, not a force imposed through the foundation. Variable-buoyancy can be employed[3] to make the blade more buoyant to generate power, but less buoyant if fouling is detected to allow the systems to quickly “shrug-off” the fouling material.

The blade is more of an oscillating wing than a propeller blade. It moves slowly, generating little parasitic drag but huge amounts of torque. That torque is harvested at the root of the blade using conventional means such as a directly coupled generator, a gearbox/generator or hydraulic motor/generator. Of course, an alternator could be used instead of a generator.



Operating each portion of the blade at an optimal angle of attack (affected by blade velocity at a point plus stream velocity, added as vectors) increases the hydrodynamic efficacy. Multiple actuators can twist the blade either piece-wise or, if the blade is torsionally flexible, by twisting the entire blade.



Another approach to address the requirement for “twist” in the single blade is to use an axially fixed tapered forward section together with a moveable aft flap. As the flap alternates from side-to-side, the entire blade acts as a variable-camber wing maintaining a roughly constant angle-of-attack along its length.

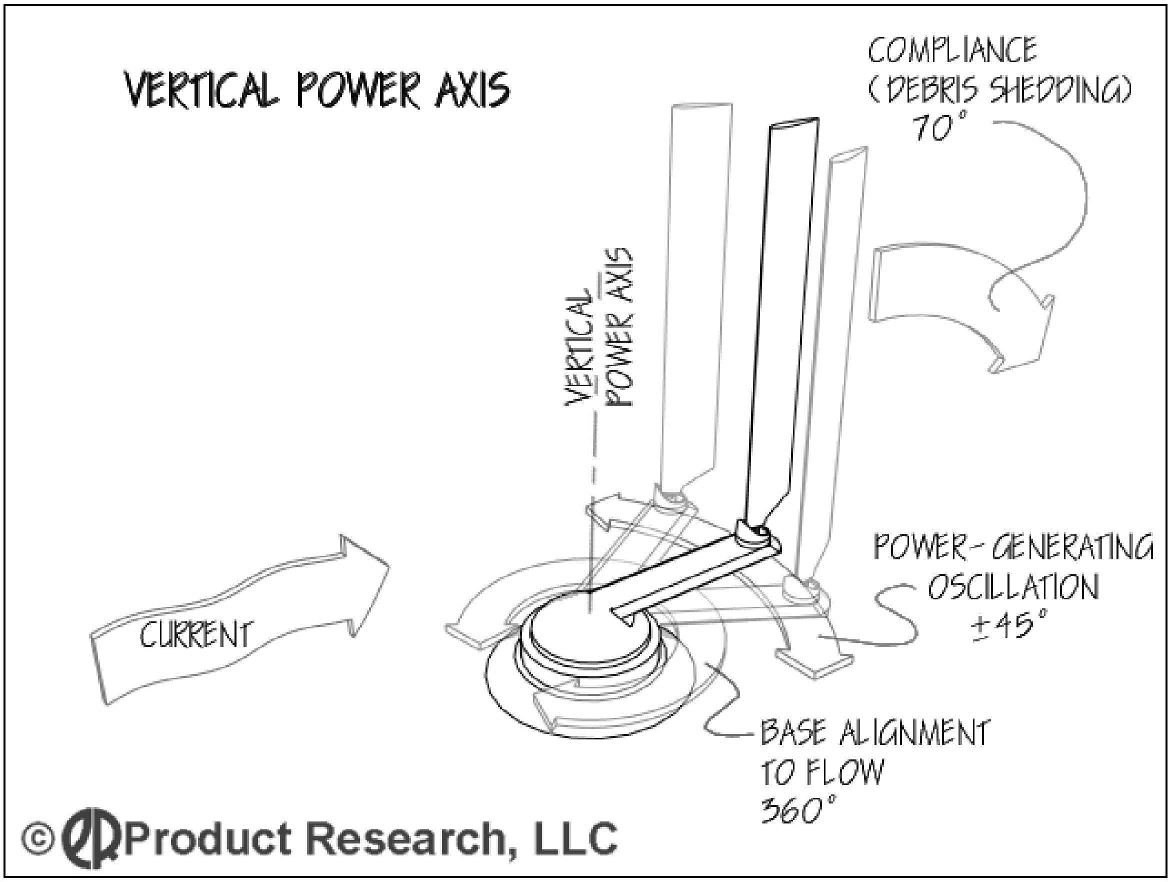
The blade’s buoyancy opposes torque once the blade passes vertical and heads down toward the sea floor, but that torque returns to the system as the twist in the blade is reversed and the blade heads back to again pass through vertical. In fact, the buoyancy force helps slow the blade as it approaches reversal and also helps accelerate the blade as it begins moving in the opposite direction.

The blade sweeps through approximately 90-160 degrees.

[3] For instance, by pumping air or other gas or buoyant medium in and out of a hollow blade.

PO Box 729; Stanwood, WA; 98292
prprllc@hotmail.com

Vertical Power Axis at Right Angles to Flow Stream.



Placing the power axis vertically, normal to the current flow, and having the vertical blade oscillate in an arc behind and around the power axis creates interesting opportunities worth investigating. The blade will still shed debris and excess load though the same buoyancy/passive hinge approach, but the blade can now be constant cross section. The angle of attack is constant, so provisions are not required to twist the blade. The anchor/base needs to be tall enough to get most of the blade out of the seafloor boundary layer, but the loads on the base will be limited to reacting the torque and keeping the entire system from washing downstream. The blade will keep itself vertical using its buoyancy. The orientation axis will now be either the same as or parallel to the power axis. The arm will sweep through approximately 90-110 degrees.

This configuration is similar to the BioPower Systems bioSTREAM approach[4], but our buoyant blade and associated features greatly reduce the structural requirements on the foundation. Debris buildup and fouling is reduced or eliminated by removing the mounting pole.

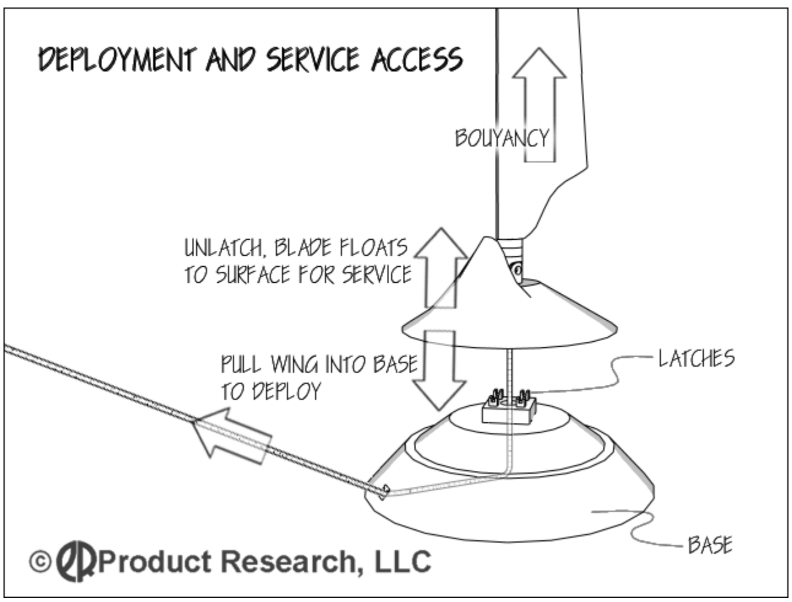
[4] http://www.biopowersystems.com/briefs/bioSTREAM_Technology_Brief.pdf

System Deployment and Maintenance

In single units, or in small installations such as cabin power from a stream or small river, a system is "installed" by dropping a complete unit into a suitable spot and running the electrical cables or hydraulic tether to shore where the power would be used. The system will land on its base, self-orient, and begin producing power immediately. Retrieving the same smaller system for re-deployment or servicing would be as easy as lifting it by its power tether.

Larger systems are installed by locating and placing the base/foundations on the sea floor, then running power and communication infrastructure to each location. Base/foundations contain docking station(s) for the power generating equipment. "Powerheads" containing all the moving and service parts are then winched down to each base/foundation, where they self-orient and are available for power generation.

A variable-buoyancy feature would also be useful in this operation. For servicing, the blade/powerhead could be simply released from the base. It would float to the surface for retrieval. For installation, its buoyancy would be minimized so that it would naturally sink or be only slightly buoyant, so a light tether would be enough to lead it into its base.



Although it is possible for the larger units to be self-contained and "dumb", it's more likely that larger installations will be fully instrumented for both data gathering purposes as well as constant operational optimization[5]. The data gathering parts and pieces may be contained in the power heads, but communicate through the base infrastructure.

Blade/powerheads connect to the base using wet contacts, hydraulic fittings, or inductive couplings in the case of direct electrical generation. Base connections can be back-purged with fresh water or benign protective fluids after coupling.

It may be possible to use the immersive fluid as the working fluid in a hydraulic/electric system. For instance, in a river installation, river water can be pumped by the system to a shore-based power station. In seawater, corrosion and biofouling can cause many problems. It may be possible to eliminate bio-fouling

[5] For instance, measure torque as the blade moves one way, and then compare it to the torque as the blade moves the other way. If they are not equal, re-orient the device to balance the torques. Other process variables such as blade twist and pitch can also be varied continuously to insure that we are operating at the maximum power generation level for the highly variable conditions as tide changes or river current eddies.

PO Box 729; Stanwood, WA; 98292
prprllc@hotmail.com

issues by treating (sterilizing) the seawater working fluid stream before use with an electrolytic cell. Corrosion concerns would remain. The working fluid would be simply returned to the body of water or used for a secondary use such as irrigation. In some instances the device may be more useful as an irrigation pump, with electrical power generation a secondary benefit.

Efficiency?

Is this new configuration efficient? What portion of the energy in the current stream does the device harvest? At this point, we don't know. However, these are not the right questions.

There are many more low-current, large-area tidal or riverine current sites than there are high current "choke points". It is important to find a way to tap into the flow energy of these low-impact areas so that the existing activities (human and otherwise) in the choke points are not degraded. A successful tidal power solution must minimize risk to the overall environment, the local ecosystem, the installed equipment, the managing entity, and the general public.

Tidal power cannot extract a significant portion of the energy of the current stream without changing the nature of the current. More efficient single devices will simply have to be more widely spaced. Highly efficient power extractors, closely placed, will simply block or divert current flow and destroy the resource they are trying to exploit.

Ultimately, return-on-investment and power cost compared to alternatives is the correct evaluation criteria. Assigning environmental and sociological costs to all power options to allow for a complete comparison is the most complex part of this analysis.

Tidal or current power is a young industry. Pilot plants, temporary installations and simulations will be required to evaluate the resource and the potential ways to exploit that resource. However, even the industries first "baby steps" must be taken with great care to protect both the environment and the future of the industry.

PO Box 729; Stanwood, WA; 98292
prprllc@hotmail.com

Areas of Concern

Concern	Discussion	Action Required
Foundation Size	Torque generated by the system must be reacted by the foundation to generate power. In addition, the foundation must keep the system from tipping over or washing downstream (not so much a problem in a reversing tidal situation) or downhill.	Consider issues during design and testing. This is a "normal" design trade-off issue. The use of a buoyant blade greatly decreases the load on the foundation compared to other approaches.
"Scouring" of the sea floor.	While the blade is extracting energy from the tidal flow, it actually increases the fluid energy in local areas. For instance, tip vortices coming off the ends of the blade may have much higher velocities than the mean stream. Also, the base/foundation may create a wake. If these locally increased flow fields contact the bottom, they may scour or dig up the seabed, causing environmental damage and possibly undermining the base/foundation.	This problem occurs in all systems, except perhaps floating anchored systems that have their own problems with fouling and shipping interference. Attention during design and testing should mitigate this issue.
Bio fouling, corrosion and other environmental concerns.	Water, and especially the ocean, is a hostile place for most materials and equipment.	Again, this is the same problem for all systems. However, this system uses simple mechanisms and simpler, less critical low-speed foil shapes, so that naturally fouling-resistant materials such as foam-filled UHMW[6] may be used for blade construction, as opposed to the FRP[7] construction of water-windmills. In addition, this approach is extremely easy to service when required.
Legal and ethical liability.	Will the system harm the ecosystem? Will the system endanger the operators or the general public? Is the system welcome in new areas or will permitting be problematic?	All good questions, all need to be constantly re-visited during system design and deployment. This system shows the most promise for low-impact of any known system. The approach of "best available solution" is always good.
Scale Issues.	What happens as the systems get bigger? <u>Roughly</u>: As a blade gets twice as long: • Spar thickness goes up 2X, • Tip Speed for a given rotation speed goes up 2X, • Area (Drag, Lift) goes up 4X, and • Volume (Buoyancy force) goes up 8X	Of course, it's not that straightforward. Tip speed is probably the limiting factor, so rotational speed may be reduced, so thickness and lift will be increased, so torque will increase and the blade will be made stronger. All to be addressed in design. At first estimation, everything gets better as the machine gets bigger, although there are undoubtedly limits.
Advanced issues.	What about variable camber foil shapes, flaps, slots, tip plates, axial flow dams, vortex generators and other fancy fluid dynamics stuff?	These are all important concepts involving trade-offs that will be constantly evaluated during design. However, most planes take off with little or no flaps and a clean airfoil to maximize lift/drag. Most of the fancy peices apply in steady-state cruise.
Multiple Blades (separate bases).	It may make sense to combine, for instance, two blades on one power axis acting in opposition so that their net torque on the base/foundation is zero.	This might be a good idea, but the introduced complexity may make it not worthwhile. For instance, synchronizing the blades and keeping them from hitting or fouling each other may be a problem. Multiple (many) blades operating on a single base would be unlikely to synchronize and cause torques large enough to upset the very wide base.
Multiple Blades acting together.	Many insects and model ornithopters use two pairs of wings operating in tandem to create increase efficiencies. The wings can either be combined axially, where one operates in and exploits the other's wake, or side-by-side, where they momentarily come together in the middle.	A very interesting concept, this will be evaluated in testing and simulation to see if the increased complexity and decreased base stresses are worthwhile from an operation standpoint.

[6] UHMW stands for Ultra High Molecular Weight Polyethylene. It is commonly used to make fish farm pens and docks. It is chemically inert, strong, naturally bio-fouling resistant, and extremely tough. Lighter polyethylenes, such as those used to make roto-molded kayaks, are also good blade materials candidates.

[7] FRP stands for Fiber Reinforced Plastic and includes fiberglass, Spectra and graphite reinforced polyester and epoxy. These materials are strong and easy to make into complex shapes but require periodic coating with anti-fouling materials, and must be repaired if damaged by impact.

PO Box 729; Stanwood, WA; 98292
prprllc@hotmail.com

What's Next?

A small-scale physical prototype and a CFD[8] model of the prototype are being developed. Once these are completed, the physical prototype will validate and adjust the CFD model, which will then be used to design and guide the building of a demonstration/pilot plant to meet customer requirements. We are also looking for specialty applications that can be addressed directly.

PR Product Research, LLC is looking for business and customer partners to proceed with the development of these ideas. Please contact us at prprllc@hotmail.com.

Who

PR Product Research, LLC is a family owned product development firm created in 1999.

Phil Rink, the principal of the company, is a Washington State Professional Engineer with ten patents and many other inventions in fields from water purification to aerospace assembly tooling to underwater video equipment to computer games. He is an expert in automated equipment design and once worked for an underwater robotics firm on Vancouver Island in BC, Canada.

Nancy Rink, the other partner in the company, is a mechanical engineer experienced in aerospace manufacturing engineering and process control as well as business management. She was once an employee of the month for the Boeing Everett division and was also on the board of the Northwest Marine Trade Association.

Both Nancy and Phil draw from extensive contacts in many industries. Both are SCUBA divers and experienced boaters, and Phil is a licensed Marine Captain and private pilot. They live overlooking the tidal power resources of Saratoga Passage in Washington State.

Intellectual Property

Our patent 7,839,009 is for sale. Please contact PR Product Research, LLC.

Credits

Our illustrations and animations were created by Bill Nary at www.bladesim.com. Please contact Bill if you need similar work done. He is an experienced mechanical engineer with an artistic streak that can help you bring your ideas to life through realistic presentation.

[8] CFD stands for Computational Fluid Dynamics where a computer program simulates fluid flow and machine movement to investigate performance of the theoretical machine. It is easy to change parameters within the computer model to simulate design and site variable changes.

PO Box 729; Stanwood, WA; 98292
prprllc@hotmail.com