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Relevance of Dam-less power generation

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Abstract—Ocean/River currents are often described as a cradle of renewable energy, similar to wind and solar energy. This unexploited energy could be extractable using underwater turbines capable of transforming water power into mechanical energy. A turbine with a low cut-in speed and enhanced torque is desirable to get concentrated energy from the marine current. In this paper, relevance of dam-less power generation using vertical axis hybrid turbine based on the Darrieus and Savonius are discussed.

Index Terms—GHT, CFX.

I. INTRODUCTION

Ocean currents can be categorized into three: 1) Gradient currents mainly due to seawater density variations; 2) Wind-driven currents produced by the forces exerted by the wind on the ocean surface; and 3) Currents produced by long-wave motions. The latter are primarily tidal currents, but may include currents associated with internal waves, tsunamis and seiches. The major ocean currents are of continuous, stream-flow character, and are of first-order importance in the maintenance of the Earth's thermodynamic balance. Such currents are a significant and untapped renewable resource of energy [1].

The turbines for rivers and canals allow for the introduction of a base load supply, providing a complete renewable energy solution for the best cost-benefit possible. This exclusive technology is standardized and easily scalable. Although succeeding as “green”, these products are positioned as the best alternative for decentralized electrification along rivers. The best example of river/canal turbines is the "Smart Hydro Power turbine"[2] developed to produce a maximum amount of electrical power with the kinetic energy of flowing waters. Because it is powered by kinetic energy instead of potential energy, it is known as a so-called “zero-head” or “in-stream” turbine. As such, no dams and/or head differential are necessary for the operation of this device; the course of a river remains in its natural state and no high investments in infrastructure are required. Because the amount of kinetic energy (velocity) varies from river to river, a greater amount of energy is generated with a higher velocity of water flow.

II. COMPARITIVE STUDY OF VARIOUS CLASSES OF TURBINE

Savonius type vertical axis turbine produces higher torque at lower cut-in speed. A lift type Darrieus turbine (classified as vertical axis) can have a blade tip speed many times the speed of the water current (i.e. the Tip Speed Ratio (TSR) is greater than 1). Hence, a Darrieus turbine generates less torque than a Savonius but it rotates much faster. This makes Darrieus turbines much better suited to electricity generation, regardless of the direction of flow of the flowing bodies like water or wind. The Darrieus type turbine has weak self-starting characteristics and higher cut-in speed. This problem was

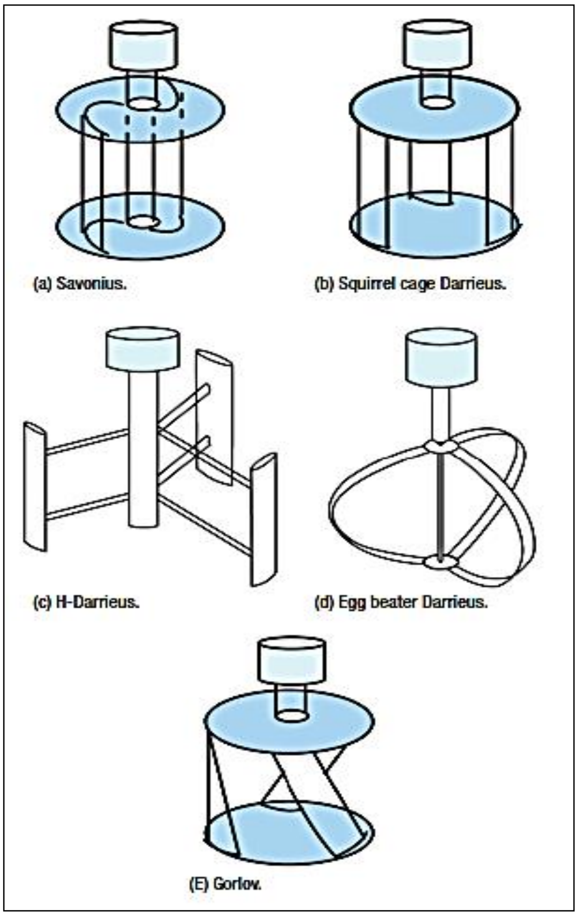

Figure 1: Evolution of Vertical axis water turbines

solved using helical blades, which paved way for the birth of Gorlov's turbine. A Savonius drag type turbine can be combined with a Darrieus turbine to overcome its weak self-starting characteristics [3].

Hydrokinetic turbines are designed to be installed in a stream or current, extracting kinetic energy from the flow of water to power an electric generator without possessing or diverting the flow of the water. Conceptually, this is similar to the way wind energy conversion devices work. Considering that hydrokinetic turbines can be deployed in any water resource having sufficient velocity to drive them (between 1 and 2 m/s or even less [4]), their energy generation potential is massive. Water resources that could be yoked include natural streams, tidal currents, ocean currents and constructed waterways such as channels. Installation of such systems is much simpler, because they do not need dams and they can be easily moved to another location or entirely removed from the waterway. During their operation or at rest, they also do not prevent the movement of water.

III. CFD AND COURSE DRIVEN MOTION

In order to learn about the performance of the Darrieus turbine computationally, the numerical model has to account for the flow phenomena in the fluid and the hydrodynamic load on the turbine blades. To obtain the flow dependent rotation of the turbine, a physically correct coupling algorithm between the fluid motion and the solid body motion has to be applied. From the physical viewpoint, the equations describing fluid flows and heat and mass transfer are simply versions of the conservation laws of physics, namely: conservation of mass in Eq. (1) and conservation of momentum in Eq. (2) [5]:

$$\vec{\nabla} \bullet \vec{v} = 0 \text{........}(1)$$

$$\rho \frac{D\vec{v}}{Dt} = -\vec{\nabla} p + \mu \vec{\nabla}^2 \vec{v} + \vec{S}_M \text{.............}(2)$$

Simulations with flow driven approaches can be performed on the drafted models of turbine in Ansys-CFX 13 [6] or Solid works. The model of the Darrieus turbine with horizontal axis having three blades with the length of 0.2 and 0.3 m in diameter and corresponds to the experimental model used by Shiono et al. [7] are available in literature. It is usually modelled in a non-structured manner with 5,100,000 plus elements, which was determined by a preliminary mesh independence study. While modelling the upper and lower blade surfaces special emphasis should be given, with the smallest positioned around the leading and trailing edge.

IV. CONCEPT OF FLEXIBLE BARRIER

The higher power of the constrained flow is reflected in efficiency of the helical turbines. For example, in the experiments conducted by Alexander M. Gorlov and his team, with vertical triple-helix turbine of 20"diameter by 28.5" height confirmed a whopping 70% efficiency in constrained water channel. While with ultra-low-head, it was just 35% efficiency with the same turbine in free flow devoid of the barrier. The testing was conducted in the Circulating Water Channel facility at the U.S. Coast Guard Academy (New London, Connecticut, 1996).

To relax the clash between higher water head with more power on the one hand, and fish safety concern, research suggests using kinetic helical turbines combined with a low-head hydraulic dam. These turbines provide sufficient and rather safe space for fish, even for its swimming between moving blades.

The possible approach is using a flexible barrier with helical turbines (water sail, Figure 2). Such barriers for low-head hydropower have advantages while evaluating conventional dams. Primarily, the barrier can be easily adjusted to develop any low-head without concerns with safer fish passage through turbines in the powerhouse. The point is that the upper edge of the flexible barrier in contrast to rigid conventional dams would fluctuate up and down correspondingly to such oscillation of the water surface. The water head in this case might be adjusted and maintained on a constant level of, say, three meters or less depending on the requirements for the power plant operation. Thus, the flexible barrier with helical turbine might be especially advantageous for tidal power applications because this design allows generation of much more power from tides than the power from the same turbines in kinetic scheme.

Figure 2: Flexible Dam

V CONCLUSION

The structural benefit of the water sail is its ability to repel tensile strains since it is always a stretched structure. All parts of this barrier are in tension, utilizing completely the tensile strength of the structural elements. One of the advantages of the barrier is its compactness. The prefabricated structure can be installed along any shallow shore location. It can also be easily removed for repair or for renovation of surrounding ecology and other environmental purposes, and then reinstalled again.

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