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# Literature Review on Blade Design of Hydro-Microturbines

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**Abstract:** Microturbines have wide range of applications in power generation for domestic purpose like lighting, battery charging, for a small scale fridge etc. Large amount of research is in progress for improvement in design of Microturbine in terms of efficiency, self-starting ability and torque. This paper discuss the various types of traditional and hybrid Microturbine. It was found from the review that Darrieus and Savonius hybrid Microturbines removed most of the problem faced by traditional Microturbines.

**Key words:** Microturbines, Darrieus, Savonius, Efficiency, Torque.

## INTRODUCTION

The natural power of a running river or a stream has been of interest for electricity production for many years. The technology of small scale hydro power is diverse and different concepts have been developed and tried out. These turbines are supposed to be used for domestic electric applications such as lighting, battery charging, or for a small scale fridge. The units are small and cheap. Water current turbines are also called as Hydro-kinetic or In-stream turbines. Water current turbines can be installed in any flow with velocity greater than 0.5 m/s. Several hydro-kinetic conversion concepts have been developed through the years [1]. Hence various researchers have done efforts to improve the design of the Hydro-Microturbines blades and to increase their efficiency and overcome the design difficulties.

## VARIOUS DESIGNS OF HYDRO- MICROTURBINES

K. Sornes [2] in his paper have discussed about various types of blade design used in Hydro-Microturbines. The two most common small scale hydro-kinetic turbine concepts are axial flow turbine and cross flow turbines. The axial concept has a rotational axis of rotor which is parallel to the incoming water stream. The cross flow concept on the other hand, has a rotational axis of rotor which is parallel to water surface. The advantage of cross flow turbines over axial flow turbine is that they can rotate uni-directional even with bi-directional flow. Cross flow turbine can be divided into two groups, namely Vertical axis (Axis vertical to water plane) and In-plane axis (Axis on the horizontal plane of water surface). From which we are going to discuss namely six traditional types of blade design.

## CROSS FLOW TURBINES

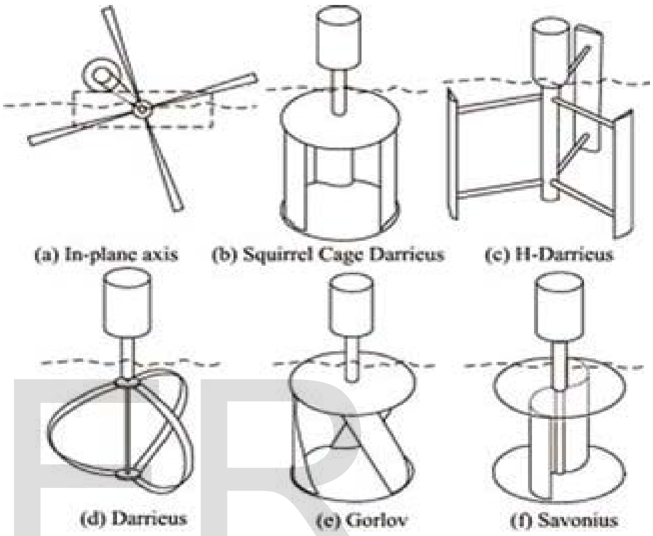


**Fig 1:** Cross-flow Turbine [2]

In cross flow turbine the water passes through the turbine transversely, or across the turbine blade. It provides additional efficiency. Cross flow turbines are often constructed as two turbines of different capacity that share the same shaft [2]. The different types of Cross-flow turbines are explained below.

### In-plane axis

J. Khan [3] in his research paper have discussed about In-plane axis. In-plane axis is better known as floating water wheels. These are mainly drag based devices and inherently less efficient than their lift based counter parts. The large amount of material usage is another problem for such turbines. Darrieus turbines with In-plane axis may also fall under this category. But such systems are left common and suffer from bearing and power take off problems.

### Squirrel cage Darrieus

G. J. M. Darrieus [4] has presented two major types of Darrieus mechanisms. They differ on how they handle the centrifugal force impose on the blade of the turbine, one is called Squirrel cage variant which consists of two disks at top and bottom with the airfoil running straight up and down between their rims. This allows the centrifugal force to be handled by the relatively sturdy construction of the disks. The advantage of turbine is to be able to progressively get into rotation. The disadvantage of it is the low reynold number.

**H-Darrieus**

S. Roy et al [5] in his work have described about H-darrieus turbine. H-Darrieus are breed of vertical axis wind turbine designed by George Darrieus in 1920's. They are capable of producing much power than most typical wind turbine. H-Darrieus rotor is a lift type device having two or three blades designed as airfoils. The blades are attached vertically to centre shaft through support arms. The support to vertical axis helps rotor to maintain its shape. One major disadvantage of H-type Darrieus turbine is that since lift forces drives them that must be brought to a minimum speed before the forces generated as sufficient to propel the turbine. The starting torque coefficient is zero and at low tip speed ratio it is even negative. Therefore, a special motor is required to start the rotor. With increase of height to diameter ratio, velocity magnitude difference from inlet up to rotor increases up to height to diameter ratio 1.0 and then decreases loss of performance for turbine with increases of height to diameter ratio. It can be concluded that velocity difference from inlet up to rotor is responsible for power stroke of blades during its clockwise direction. The Tip Speed Ratio of H-Darrieus turbine is high, hence, it rotate faster [6].

**Darrieus**

L. J. Hagen et al [7] in his research paper has summarized about Darries turbine. This design of turbine was patented by Georges Jean Marie Darrieus, a French aeronautical engineer in 1931. Darrieus turbine is a vertical axis turbine. It has streamlined blades turning around an axis perpendicular to the flow. The turbine consists of number of curved airfoil blades mounted on a vertical rotating shaft or framework. The curvature of the blade allows the blade to be stressed only in tension at high rotating speeds. It is powered by the phenomenon of lift. There are major difficulties in protecting the Darrieus turbine from extreme speed of fluid and in making it self-starting. In Darrieus blades the airfoils are arranged so that they are symmetrical and have zero rigging angle, that is, the angle that the airfoil are set relative to the structure on which they are mounted. This arrangement is equally effective no matter which direction the flow of fluid is flowing in contrast to the conventional type, which must be rotated to face into the fluid. One problem with the design is that the angle of attack changes as the turbine spins, so each blade generates its maximum torque at two points on its cycle, that is, at front and back of the turbine. The Tip Speed Ratio of Darrieus turbine is high approximately same as H-Darrieus, hence, it rotate faster. Its self-starting capabilities are low.

**Gorlov**

A. M. Gorlov [8] have patented information about Gorlov turbine. The Gorlov turbine was invented by Alexander Gorlov in 1995. This turbine is also known as 'Cross flow helical turbine'. It is similar to Darrieus straight blade style turbine, except airfoil blade profile is swept in a helical profile along its span. One of the advantage of helical blade is that it improves self-starting of Gorlov turbine compared to Darrieus turbine. As helical blade sweeps along circumference of rotation of turbine some portion of blade profile is located at optimum angle of attack even in static or slowly rotating conditions, which allows for more uniform starting torque that depend upon turbine azimuthal position. Also owing to helical blade shape is reduction of torque oscillation during rotation. A Darrieus turbine tends to experience torque oscillation resulting from circumferential void space between discrete blade positions. On the other hand Helical turbine with full blade wrap around its circumference does not experience this problem. Uniform blade coverage, neglecting end effects and wake dynamics, ideally give the turbine torque, although in reality some variations are likely to occur. Gorlov reported from experimental testing that maximum efficiency for Gorlov turbine is around 35%.

**Savonius**

I. Dobreva et al [9] in his paper have briefed about Savonius turbine. Savonius rotor was invented by Finnish Engineer S. J. Savonius. It was a primarily drag style rotor. It generates high torque at low speed, making it desirable for application such as water pumping and low wind speed application. The rotation of the rotor is due to drag difference between the advancing blade and returning blades. Design of conventional Savonius rotor is simple and cheap to build. Two half cylinders are set with their concave sides facing each other and then offset with a smaller overlap. The power coefficient of Savonius rotor used for micro-hydraulic turbine is affected by varying the clearance ratio. The maximum power coefficient, is larger when rotation direction is counter clockwise for clearance ratio less than 0.73 while power coefficient is larger when rotation of direction is clockwise for clearance ratio greater than 0.73. The drawbacks of Savonius rotor are that it has low efficiency and that it operates at low tip speed ratio which made it difficult to integrate with generator. Several individuals have tested models to optimize performance and altered its conventional design to improve performance. The highest efficiency of all configurations tested was 24% of two stage, two bucket rotor.

## RECENT TREND IN HYDRO-MICROTURBINES

### Darrieus and Savonius Hybrid Turbine

There are various modification done in Hydro-microturbines to improve certain parameters such as efficiency, tip speed ratio, self-starting ability, torque etc. For example, hybrid of Darrieus and Savonius turbines are available. Double Savonius which is recently been developed have greater efficiency than Savonius turbines.

Darrieus turbine, which is the typical lift-type vertical axis wind turbine, has many advantages over horizontal axis types. In particular, this turbine is suitable for stand-alone power systems on isolated islands and in mountainous regions where the power supply using utility grids is very difficult. Thus, this paper discusses the suitable hybrid configuration of Darrieus lift-type rotor and Savonius drag-type rotor for stand-alone wind turbine-generator systems using our dynamic simulation model [10].

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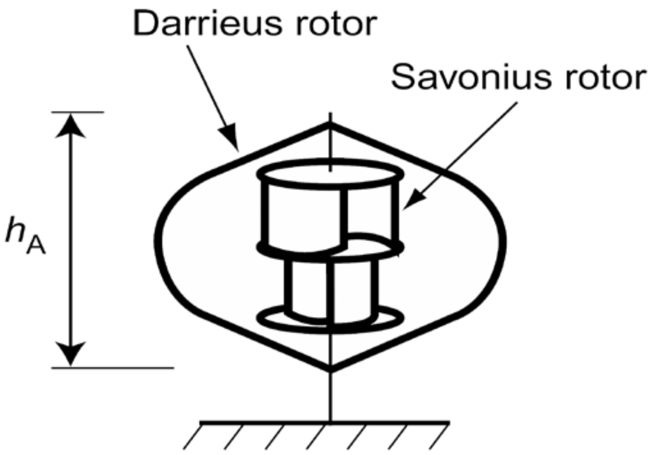


**Fig 2:** Darrieus and Savonius Hybrid

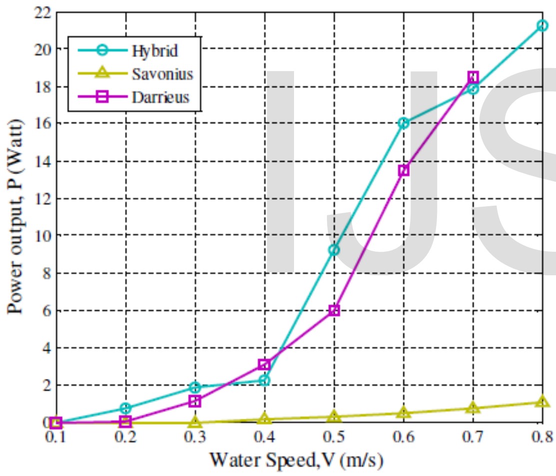


**Fig 3:** Power vs. Water Speed for Hybrid Turbine

### Double stage and Triple stage Savonius Turbine

**Fig 4:** Double Stage Savonius Rotor [11].

**Fig 5**: Three Stage Savonius Rotor [11].

Double stage Savonius rotor is shown in fig where the upper and the lower paddles pairs are set at 90° to each other. Three stage Savonius rotor is shown in fig each of its stages is phase shifted 60° relative to each other. The torque variation in both this designs is less as compared to the traditional design. Test was carried with the help of this three turbines and the results of this turbine stated that the torque fluctuation in double stage is minimum and then followed by the triple stage and the fluctuation in traditional Savonius is maximum. Also the power output of the double stage Savonius rotor is highest amongst the three followed by the triple stage and minimum output is given by traditional Savonius turbine.

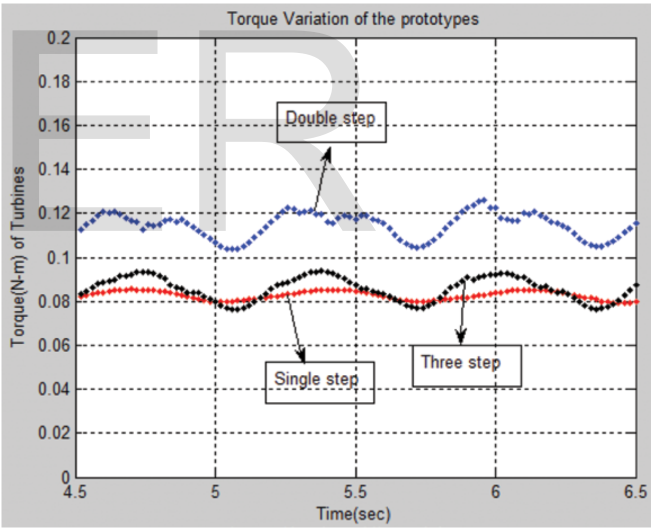


**Fig 6:** Torque variations of three prototypes at 0.8 m/s water current [11].

## CONCLUSION

As an emerging renewable energy solution, comparative information on River Current Turbine systems is invaluable. This work attempts to summarize the state-of-the-art of hydrokinetic turbine technology. Advantages and disadvantages of various turbine rotor models have been discussed. From the survey it is evident that the hybrids made for increasing the performance of traditional turbines can give better output as compared to traditional turbines. From the entire traditional microturbine the Gorlov microturbine has the maximum efficiency which is around 35% and In-plane axis have the minimum efficiency.

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Hybrids are made to improve the efficiency of traditional microturbines and to overcome the disadvantages of the same. As studied from this literature paper it is clear that the Savonius turbine have high starting torque but low efficiency on the other hand Darrieus have high efficiency but low starting torque. Thus hybrid turbine is designed to overcome the disadvantages of both the traditional turbine, that is, it have high efficiency and starting torque as compared to traditional turbines. Also, the traditional Savonius rotor have fluctuating toques at output which is overcome by Double Stage Savonius turbine which can be put into hybrid category.

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