The Floating Axis Wind Turbine's Preliminary Study

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Abstract - *Using a tilted cross flow wind turbine that is floating on water, the floating axis wind turbine is a novel idea for lowering the cost of offshore wind energy. The floating axis turbine layout will be an alternate choice for large-capacity offshore wind turbines because building a high tower of a horizontal axis wind turbine in an ocean setting is costly. The description of the concept and an example design are provided in the article.*

***Key Words*: Component; floating axis wind turbine, FAWT, offshore wind turbine, vertical axis wind turbine**

1. INTRODUCTION

Offshore wind turbine is a hopeful renewable energy device because of the steady wind force in offshore environment. Since shallow water region suitable for constructing bottom- fixed offshore wind turbine is limited, we have to consider the further development of floating offshore wind turbines. However, the cost of floating wind turbine is considered to be more expensive than those of offshore wind turbines with foundations on sea bed in shallow water region.

At present, most of offshore wind turbine concepts are conversion of land based horizontal axis wind turbine (HAWT) because of its successful development in these days. However, their high tower for supporting the wind turbine leads to significant increase of cost in ocean environment because keeping the upright position of high tower requires large floating structure. Also, construction and maintenance of wind turbine on the top of tower require specially designed work vessels (crane ships) or calm water condition. Since offshore wind farms will be sited in windy (and rough) sea area, the probability of calm weather for such operations is not high. It leads to the increase of construction period deteriorates the total economy of the project.

There are proposals for floating wind turbines that stand out for their efforts to bring down the overall cost of the plant. In the North Sea off Norway, Hywind [1] is the first large-capacity floating wind turbine. Its 2.3MW turbine is mounted on a straightforward spar buoy that is catenary cable-moored to the ocean floor. HAWT on a tri-column floating platform was the idea put out by Wind Float [2]. In order to reduce the structural weight of the plant, the turbine tower stands on one of three columns. In order to lower the cost of float per turbine, there are designs for many rotors on a huge float. Wind turbines on a float may face aerodynamic interference if they are placed near to one another.

There are vertical axis wind turbine (VAWT) designs for offshore wind generation in order to avoid building tall towers. Large-capacity VAWT provides several advantages in offshore applications while not being widely used in onshore applications. The VAWT's electric generator may be mounted near the base of the rotating axis, allowing for a lower gravity centre height than the HAWT. Additionally, it makes important mechanics that are situated at low altitudes accessible for simple maintenance. Blonk demonstrated that the offshore VAWT ideas' economic performance is on par with that of HAWT [3]. Nenuphar [4] suggested a direct drive electric generator and a straight blade VAWT installed on a tri-column float.

Keeping the tower or vertical axis turbine in an upright posture on a floating platform is difficult. The size of the float and overall cost of the plant rise in order to provide the turbine with enough stability. Sway[5] suggested the inclined floating HAWT as a solution to the problem. The turbine is positioned in the design atop a tower that is tethered to the ocean floor. The suction anchor and ballast weight linked to the bottom end limit the tilt angle of the tower to a few degrees. A Darrieus turbine installed on a rotating spar buoy was suggested by Deepwind [6]. Even at 20MW rated power, it is not necessary to design large-capacity mechanical bearings since the spinning axis is supported by buoyancy. Technical difficulties must be overcome in order to install the electric generator that is intended for the bottom of the spar buoy.

Significant efforts are made to maintain the turbine in an upright position in the ideas mentioned above. Even though Sway and Deepwind's concepts permit their turbine to tilt, the angle's range is constrained. The conceptual drawings for floating wind turbines are shown in Figure 1. The floating concepts of the HAWT, straight blade VAWT, Darrieus blade VAWT, and Deepwind are depicted in Figures 1(a), (b), (c), and (d), respectively. Figure 1 illustrates the notion of a slanted floating turbine that was developed by Akimoto et al. [7] to further reduce the overall cost of offshore wind energy (d). It is the concept of a floating axis wind turbine (FAWT).

Similar to the Deep wind idea, the FAWT turbine is mounted atop a spinning spar buoy. The secondary float limits the turbine's ability to move in a planer motion. The secondary float, which is situated above the water, has electric generators installed.

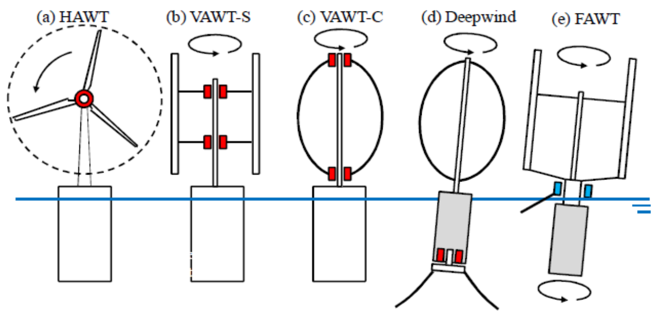

Fig. 1 Variation of floating wind turbine concepts

2. FLOATING AXIS WIND TURBINE

Although the FAWT idea is based on a vertical axis wind turbine, when it is operating, as illustrated in Fig. 2, its rotational axis is inclined. Since a spar buoy's righting moment rises with tilt degree, its size can be decreased by making the slanted position its default working state. The inclination of turbine is in the balance of wind force, gravity and buoyancy of submerged part. The turbine axis has bulged part near the water surface and ballast weight in its bottom to enhance the stability. Merits of this design are summarized as follows.

1. The sweep area of the turbine is reduced when it is tilted in severe winds. Overspeed rotation is avoided.

2. Since the weight of the turbine is directly supported by buoyancy, it does not require large-capacity mechanical bearings.

3. The load of large-capacity turbine will be shared by multiple units of contacting roller and generator installed off axis of the turbine.

4. Solely the thrust of the turbine is supported by the contacting rollers (horizontal component of turbine load).

Although the idea is straightforward, there are new difficulties in the dynamics of a big VAWT turbine exposed to naturally variable wind. Magnus force, wave load, and ocean current will all be present on the spar buoy. The turbine's gyration moment helps to level the power output and keep the spinning axis stable.

The FAWT in Fig. 2 has a 3MW rated power. The primary characteristics of the turbine and its anticipated cost of energy are displayed in Table 1 [7]. At the moment, the impact of tilt is only taken into account when changing the turbine's front projection area. Despite the fact that a VAWT requires a wider sweep area than a HAWT, the system's overall weight and price may be lower. The early projections indicated that the current approach performed economically competitively [7].

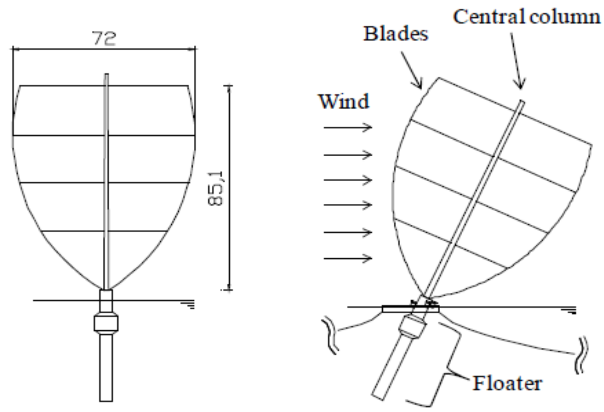

Fig. 2 Floating axis wind turbine concept

Table 1 Cost estimation of 3MW shallow-water HAWT and FAWT (1000USD) [7]

	3MW HAWT	3MW FAWT
Rotor	477	871
Drive train, nacelle	1425	659
Control, Safety Sys., Monitor	60	60
Tower/Central column	415	221
Marinization	321	244
Monopile / Float	1114	1712
Transport, Install	1835	1835
Scour Protection	204	0
Surety Bond	180	168
Offshore Warranty Premium	357	272
(Subtotal: Initial capital cost)	(6386)	(6042)
Replacement Cost (USD/yr)	55	55
O&M (USD/turbine yr)	215	145
Bottom Lease Cost (USD/yr)	12	12
(Subtotal: Annual Operating Expenses [USD/year])	(282)	(212)
Cost of Energy (USD/kWh)	0.095	0.071

3. DESIGN FOR PRACTICAL APPLICATION

For practical realization of the concepts, we have to solve some problems. Some of them are common in VAWT concepts and some are from the new feature of floating turbine configuration. They are discussed in this section.

A. Self-Starting Capability

Self-starting of the turbine is difficult since the VAWT's initial torque is low. Some large-scale VAWTs have an extra Savonius turbine for the assistance of beginning torque in addition to the primary turbine. Even though the Savonius turbine exhibits considerable torque at low rotation speeds, the system's overall performance suffers at the intended operating state. Another option is to adopt helical blade design, as seen in Fig. 3, to lessen the pulsing of turbine torque. It is well known that helical blade design enhances self-starting capabilities. Since the helical shape's curvature is quite mild in the current design, it has little impact on the price of the blades.

Reduced necessary torque and loss of drive train at low rotation speeds are further self-starting remedies. Since viscous drag on the submerged turbine axis is inversely related to rotation speed, drag is absent during initiation. As a result, the floating axis design significantly adds to the system's self-star properties.

Although the difficulty of self-starting is considered to be one of major problems of VAWT, it does not matter in large-scale applications. Since offshore wind turbines have to be connected to onshore power grids by undersea cables, it is easy to borrow electricity from the grids for start-up and to use the generator as a starter motor.

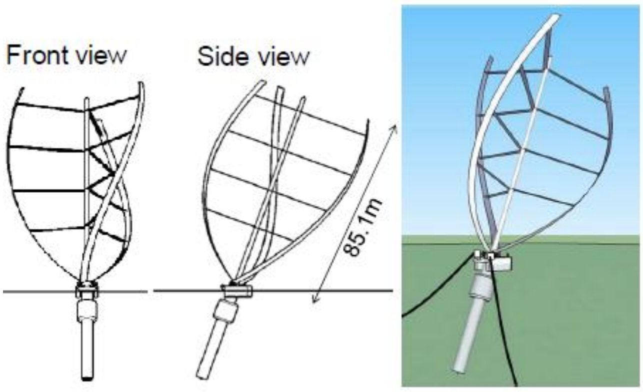

Fig. 3 Helical blade design of FAWT

B. Treatment of reaction torque

In floating wind turbine, we have to manage the reaction torque of the electric generators. A simple solution is absorbing the torque by mooring cables attached on the secondary float. However, it leads to the complexity of mooring system and needs additional consideration in the design of secondary float. Our alternative solution is twin-turbine configuration where two counter rotating turbines are connected by a bridge as shown in Fig. 4.

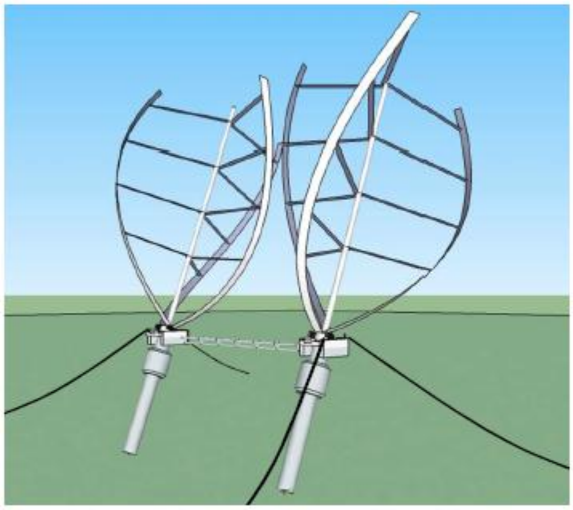

Fig. 4 Twin turbine configuration of FAWT

The mooring method may be made simpler since reaction torque between the two turbines will be neutralised. In order to reduce the overall system structure, the bridge connecting the two floats restricts just their yaw movements. There can be interference between the turbines because of their near proximity. For the selection of response torque therapy, more research will be needed.

B. Structural Requirement

The current design suggests that blades encounter compression in the direction of the span. It is necessary to adjust the construction such that the compression load and structural weight of the turbine are reduced by the centrifugal force operating on it. The problem is not much worse than in HAWT designs, though.

The advantages of offshore wind turbine ideas include stable offshore winds and the availability of wide areas. However, it is currently difficult to build a large-capacity floating wind turbine. The challenge of building tall structures on a floating platform, as previously mentioned, is one factor. The second reason is that huge capacity bearing, drive train, and generator development is challenging. Their R&D is more challenging due to the unsteady motion of the mechanism in an ocean environment. From this vantage point, the current FAWT idea is a good contender for a huge offshore wind turbine in the future. Small-capacity units can split the load of the floating turbine since it will be supported by several contacting roller and generator units. The challenge of scaling up is greatly lessened. Because they must be installed inside the tiny nacelle at the top of the tower, the HAWT's drive train and generator must be small and lightweight. The mechanisms of the FAWT concept are off the axis of the primary rotor and have no installation space restrictions.

Additionally, because the spinning spar buoy's buoyancy supports the weight of the turbine, the roller units only need to carry the horizontal portion of the load. In comparison to HAWT and VAWT designs, the authors believe that FAWT is more likely to succeed as a large-scale offshore wind turbine.

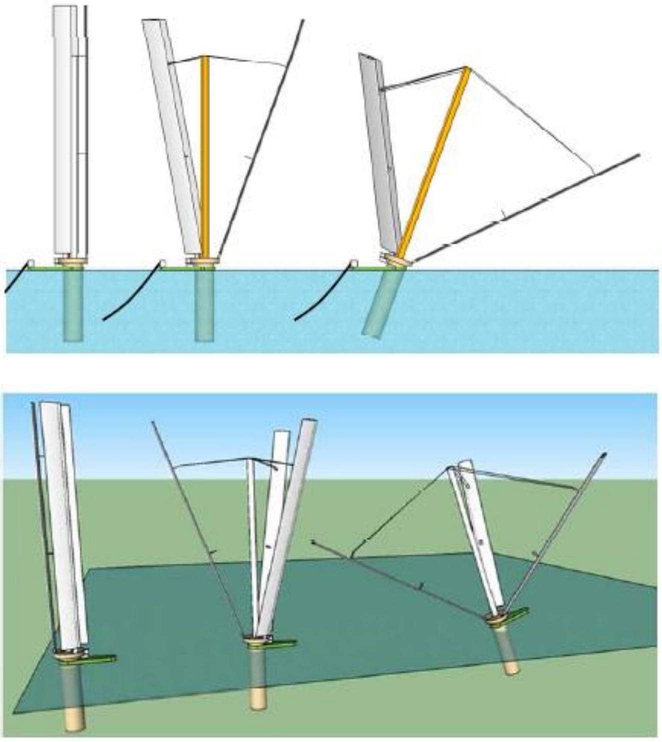

Fig. 5 Experminetal small plant of FAWT

C. Pilot Plant Configuration

We must begin from scratch because the current notion is new. tiny pilot plant, and then gradually improve the concept's scale-ups. We offer the design for a small experimental FAWT plant for this purpose, as illustrated in Fig. 5.

The design of the FAWT has been simplified since the major goal of the plan is to comprehend the dynamics of a floating turbine in real offshore conditions. The capacity to convey and maintain durability in strong winds comes from the turbine blades. On offshore platforms or tiny islands that are not linked to onshore power systems, the turbine can be moved and utilised to generate electricity. Additionally, wind turbines of this kind can be placed close to the disaster region to provide energy in the event of a large-scale ocean-side calamity, such as an earthquake or tsunami. If it is possible to lessen the amount of work required to get gasoline to the disaster region, the limited transport capacity to the location might be utilised for further rescue efforts.

5. CONCLUSION

The notion of a floating axis wind turbine can produce inexpensive offshore wind energy. There are several issues we need to resolve before the concept can be implemented commercially because it is still in the conceptual study stage. The design has a few expected qualities that make it appropriate for huge offshore wind turbines. The authors believe that the current concept is a promising option for a large-capacity offshore wind turbine design in deep water regions where sea-bed mounted wind turbines are not economically feasible.

6. REFERENCES

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