Catamaran or semi-submersible for floating platform – selection of a better design

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Abstract. With nonstop advancement in marine engineering, more and more new structures are being designed and explored for tidal current energy. There are three different kinds of support structures for tidal current power station mostly in use, which are sea-bed mounted/gravity based system, pile mounted system and floating moored platform. Comparing all of them, the floating mooring system is most suitable for deep water systems and the application of this arrangement is widely usable. In this paper, a semi-submersible and a catamaran as floating platforms for tidal current power stations are studied and compared on the basis of its economics, efficiency of turbine and stability of the station. Based on basic ship theory and using software MAXSURF, the stability of Catamaran tidal current power station is also calculated. It is found that the catamaran design is optimal choice.

1. Introduction

With radical and exponential surge in energy consumption all over the world, there is a huge energy risk if not the crisis. With fossil fuel energy becoming extinct and more and more expensive, one effective solution is to create renewable and sustainable energy, such as wind energy, hydropower, solar energy, biofuels and ocean energy (Eyad, 2007[1]; Kaldellis, 2008[2]; Selcuk et al., 2008[3]). It is available in many different forms including tide, wave, tidal current, thermal, salinity gradients and biomass (Charles and Roger, 2009[4]). Tidal current energy is considered as one of the most favorable alternative energy resources for its negligible environmental footprint and high-energy density. Of all the ocean energy options, tidal current energy was highlighted because of the advantages including the high energy density (about 832 times greater than wind energy) (Charles and Roger, 2009[4]). Therefore, it is getting a lot of attention from businessmen, politicians, industrialists and academics all over the world and is projected to play a vital role in the near future for energy supplies (Dong et al., 2010[5]).

Available tidal current energy assets are widely scattered all over the world, however, only a few are developed. There are different factors involved for the effect factors for expansion of tidal current energy and they can be classified as construction conditions, geological conditions (rock, soil or clay) and ocean environments (wind, wave and current). The most important factor is the design of the platform. The Tidal Current Power Platform (TCPP) is used to support turbines, generators and other equipment, where staff works. Therefore, the selection of support platform for TCPP is very significant. According to different types of TCPP, platforms can be classified as floating moored system, pile mounted system and sea-bed mounted/gravity based system. Pile mounted system is useful for deep waters (30–60 m) and the structure is very firm. This kind of system, however, is restricted by geological conditions, if the sea-bed is rocky and too hard to drill, this system of platforms would fail and not be used (Yunwu, 2008[6]). Pile mounted TCPP are shown in figure 1&2.
Figure 1. Pile mounted platforms (from google.com)

Figure 2. Pile mounted platforms (from google.com)

The sea-bed system is suitable for shallow water and the affect from wind and wave is nominal. But, the generator is submerged (under water) which requires high sealing technology and cost of maintenance is very expensive and inconvenient which will increase cost beyond reasonable approach (Renjun, 2003a[7]). The sea-bed TCPPs are shown in figure 3 and figure 4.

Figure 3. Seabed mounted platform (from google.com)

Figure 4. Seabed mounted platform (from google.com)

In comparison with the above mentioned platforms, advantages of the floating moored system are: They are very handy and easy to install. It’s just plug n play, they are towed-to and then moored-in site. They are easily removed if relocation is necessary or if a major repair task is needed0 (Renjun, 2003b[8]). Routine maintenance is substantially simpler because it is mostly carried on close-to or over the surface (Shujie et al., 2010[9]).

Furthermore, the surroundings around the site of platform plays a very important role in designing the platform system. The areas where sea condition is deeper and the sea-bed is mostly rocky, the floating system is desirable. The floating moored TCPP can be seen from figures 5 and 6. In this paper two proposed platforms were compared best suited for the tidal energy generation.

Figure 5. Floating moored platforms (from google.com)
Based on the results of working-ocean environment, Semi-submersible and Catamaran are studied in this study as the floating platforms. The optimization of these platforms will consider aspects that have impact on selection of support structures, from the view of efficiency of turbine, economics and stability of platform during working hours. As we know, if we need tidal energy to be commercial, economic issues should be solved first hand. Support platforms carry the most weight of the platforms, therefore satisfying the strength requirements, weight decrement in platform will be an efficient way to reduce economics of TCPP (Fengmei, 2013 [10]). And it’s evident that greater efficiency means higher power attained. In order for TCPP to work normally, stability is the key.

In this research, the stability is deliberate using MAXSURF software. Both of the two platforms are equated based on the above mentioned factors. And by far, the catamaran is a superior choice as support platform for TCPP.

2. Two types of floating platforms of TCPP

In this study, two kinds of floating platforms are deliberated, Catamaran and Semi-submersible. Catamaran is designed on twin-hull engineering ship, which is a special ship. Two hulls are linked together by a boxed structure and the turbine being between them and the turbine is reinforced by one point, shown as figure 7.

Some of the advantages for a Semi-submersible floating platform are wide deck, better hydrodynamics and easier mooring/ anchorage. And two support reinforcements make the turbine work more stably. Semi-submersible power platform is built with four columns, like one box, where the turbine is inside and braced by two points, shown as figure 8. Factors for considering the floating platform are:

- Economics/ Finances of the power platform.
- Efficiency of the turbine in working conditions.
- Stability of the platform in working conditions.

The finances/ economics of the station is mainly related to machinery and platform structure, while the machinery mainly include turbine, electricity controlled apparatus, generator, gear box, etc. Whereas, the platform is mainly about the construction procedures and the total steel usage. Because the construction of platform is too complex to estimate, steel usage will be considered as the key to evaluate the economics of power station.
The platform has a direct effect on the effectiveness of the turbine. As for semi-submersible platforms, the water is approaching around the supports; the supports must have effect on the fluid field. The vertical-axis turbine is installed in the center of platform and one or two supporting points are given.

The stability is considered the critical parameter to the performance of the platform. The platform must have sufficient stability to support all the machinery and the turbine. Software MAXSURF is used to calculate the stability of platforms.

### Table 1. Parameters of semi-submersible.

| Items                  | Unit | Data |
|------------------------|------|------|
| Length (L)             | m    | 44.2 |
| Breadth (B)            | m    | 20.6 |
| Depth (D)              | m    | 8.50 |
| Space b/w two Columns  | m    | 12.1 |

### Table 2. Parameters of catamaran.

| Items                  | Unit | Data |
|------------------------|------|------|
| Total length (L)       | m    | 45   |
| Total Breadth (B)      | m    | 18.2 |
| Depth (D)              | m    | 5    |
| Design depth           | m    | 1.60 |
| Breadth of body        | m    | 3.60 |
| Space b/w two bodies   | m    | 11.0 |

Method of stability calculation: The stability calculation has two parts: Initial stability (static stability), it is the stability when heeling angle is smaller than 10° or before the immersion deck edge. Complete stability, it is the stability when heeling angle is greater than 10° or after immersion of deck edge (Rawson and Tupper, 2001 [11]).

Following are the checks for stability calculations:

- The area under the righting moment curve will attain a ratio with the area under the wind heeling moment curve of at least xxx, with both measured at the lesser of the down flooding angle or second intercept.
- The maximum righting arm will attain a ratio with the wind arm of at least xxx, with both measured at the angle of maximum righting arm.
- The area under the righting moment curve will be at least xxx ft-degree or m = degree.
- The second intercept will be at xxx degree.
- The first zero crossing will be at most xxx degree, here, the first zero crossing is the equilibrium heel without wind acting.
- The first intercept, or equilibrium heel dues to wind, will be at most xxx degree, here, the first zero intercept is the equilibrium position including wind.
- The second intercept will be at xxx degrees.
- The minimum height of the down flooding point must be greater than xxx feet or meters at the first intercept (equilibrium position including wind).
- The down flooding angle will be greater than the first intercept.

Here, the values xxx depend on the specific rule being applied. This offers a general outline for all the rules. If a rule does not require something, then it is satisfied if xxx is a value which will always be satisfied (0 for minima or 90 for maxima). To make matters more confusing, the values change between damaged and intact conditions and for types of vessel. (xxx is the generic value)

Dimensions of the platform: In order to fulfill the design necessities, diameter of turbine and power output of the turbine is 8m and 150kW respectively. Measurements of platforms are shown in tables 1 and 2.

### 3. Comparison with two types of floating platforms of TCPP

Weights of TCPP: Key parts of the Catamaran are body, connecting bridge, ancillary structure for turbine and generator. Weights are calculated by the distribution method and shown as table 3.
Table 3. Total weight of Catamaran TCPP

| Items          | Weight (t) | Center of Gravity (m) |
|----------------|------------|-----------------------|
| Body           | 110.00     |                       |
| Connection Parts | 60.50     |                       |
| Generator      | 30.50      |                       |
| Turbine        | 20.00      |                       |
| Anchor Machine | 5.00       |                       |
| Others         | 15.00      |                       |
| # Bracket      | 26.00      | 1.2                   |
| Total Weight   | 267        | 1.2                   |

Table 4. Total weight of Semi-Submersible TCPP

| Items          | Weight (t) | Center of Gravity (m) |
|----------------|------------|-----------------------|
| Body           | 87.20      |                       |
| Columns        | 123.30     |                       |
| Generator      | 30.50      |                       |
| Turbine        | 20.00      |                       |
| Anchor Machine | 5.00       |                       |
| Others         | 15.00      |                       |
| Main desk      | 34.58      |                       |
| Support of body | 25.18     |                       |
| Total Weight   | 340        | 7.67                  |

Figure 9. Power coefficient to speed ratio $\lambda$

Semi-submersible TCPP are primarily constant with floating platforms, turbine and generator etc. weight of every part is calculated by distribution method and data collected is recorded in table 4, where base line of Semi-submersible is considered as line of reference of center of gravity.

The total weight of semi-submersible and catamaran is about 340 ton and 267 ton respectively, thus the weight of the former will be reduced about 22%, in order to make the economics better.

Efficiency of the turbine: The ancillary platform can affect the efficiency and therefore has influence on the efficiency of turbine. The phenomena exists in Semi-submersible when fluid is flowing around columns, it changes the fluid field and affects the efficiency of turbine. Software CFX was used to calculate the power coefficient and the results are drawn in figure 9.

It was calculated that power coefficient of Catamaran was greater than the semi-submersible by 0.5%. Therefore, the former choice will be better.

Stability of TCP: International Marine Organization (IMO) has established stability standards for multi-hull platforms. According to these rules, stability of multi-hull is defined by the highest value of righting lever. Larger righting moment confirms that stability of the ship will be better according to the basic ship theory. Highest value of the righting moment means the platform undergoes the highest moment.

“Criterion of Building and Classing Mobile Offshore Units” (Chinese Classification Society, 2005) is an additional standard and complete stability of offshore platform is evaluated by its competency to resist to the moment applied through its self-righting moment.

4. Stability calculation for catamaran

Software MAXSURF is used to compute stability of Catamaran TCPP. Since there is no superstructure, we can ignore the wind heeling arm. In this paper, the curves of righting lever are assumed to do the study on overall stability because we mainly focus on curves of righting lever. Therefore, both curves of righting lever are deliberated and shown in figures 10 and 11. Shown in the figures 10 and 11, maximum value of righting lever of the catamaran is bigger than that of the semi-submersible. Furthermore, the area under the righting lever curve is also larger for catamaran than that of the semi-submersible. Therefore, it is very safe to say that the catamaran is a better choice as floating platform of TCPP.
Figure 10. Stability curve of Catamaran (Figure 7).

Figure 11. Stability curve of Semi-Submersible (Figure 8).

Figure 12. Maximum heeling moment with different depth.
When ship is heeling, increasing amount of center of gravity and that of buoyancy is deliberated as arm of dynamic stability, \( l_q \). In the limit situation, max dynamic heeling arm \( l_q \) and max dynamic heeling moment \( M_q \) respond to dissimilar heights of center of gravity (KG) and are calculated using MAXSURF. And the relation of \( l_q \) and \( M_q \) is as follows:

\[
M_q = l_q \Delta \quad (1)
\]

Looking at the results from figure 12 we observe the center of gravity of Catamaran must be as close to the water level as possible when its depth is constant. In this research, the reference center of gravity for catamaran is \( Z_g = 1.2 \) m when the depth range is from 0.6 m to 1.8 m, whereas moment of dynamic stability is from 150 kNm to 390 kNm.

5. Conclusions
In this paper two types of floating platforms are proposed for generation of tidal current power energy. Three aspects were chosen and the platforms were compared according to them. The three aspects are economics, efficiency of turbine and stability of the platform. Total weight of the Semisubmersible is about 340 ton and that of Catamaran TCP is about 267 ton, in order to satisfy design requirement, so that the economics of the latter will be better than that of the former. After calculation using CFX, power coefficient of turbine of Catamaran TCP is 0.5% higher than that of Semi-submersible TCP. The last aspect compared is stability and catamaran’s stability is better than Semisubmersible’s. MAXSURF software was used in order to calculate the stability of the both platforms. The results coincide with the data from other author (Fengmei et al 2013) who worked on MOSES for the stability analysis. Therefore, all the chosen aspects clearly suggest that the catamaran is a better choice as floating platform for tidal current power platform.

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