Research Journal of Applied Sciences, Engineering and Technology 6(6): 1116-1121, 2013
DOI:10.19026/rjaset.6.4022
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: December 20, 2012 Accepted: January 25, 2013 Published: June 30, 2013

**Research Article**

# Optimal Selection of Floating Platform for Tidal Current Power Station

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**Abstract:** With continuous development of marine engineering, more and more new structures are used in the exploring of tidal current energy. Three are there different kinds of support structures for tidal current power station, which are sea-bed mounted/gravity based system, pile mounted system and floating moored platform. Comparison with them, the floating mooring system is suit for deep water and the application of which will be widely. In this study, catamaran and semi-submersible as floating platform of tidal current power station are studied. And they are compared with its economic, efficiency of turbine and stability of station. It is found that the catamaran is optimal choice. Based on basic ship theory and using software MOSES, the stability of Catamaran tidal current power station is also calculated. The research of this study is significant and it will be as the reference for the future study.

**Keywords:** Catamaran, floating platform, power station, semi-submersible, tidal current

## INTRODUCTION

With dramatically increasing energy consumption, all over world has faced the energy risk. One effective solution is to develop renewable and sustainable energy, such as wind energy, hydropower, solar energy, biofuels and ocean energy (Eyad, 2007; Kaldellis, 2008; Selcuk *et al*., 2008). And Ocean energy is available in many different forms including tide, wave, tidal current, thermal, salinity gradients and biomass (Charles and Roger, 2009). Tidal current energy is regarded as one of the most promising alternative energy resources for its minimal environmental footprint and high-energy density. Among them, tidal current energy was highlighted because of the advantages including the high energy density (approximately 832 times greater than wind) (Charles and Roger, 2009). Therefore, it is receiving more and more attention from politicians, industrialists and academics all over the world and is expected to play a very important role in the future energy supplies (Dong *et al*., 2010).

Available tidal current energy resources are widely distributed all over the world, however, only a few amounts of that are developed. The effect factors for development of tidal current energy can be classified as ocean environment (wind, wave and current), geological condition (rock, soil or clay) and construction condition. The platform of Tidal Current Power Station (TCPS) is used to support turbines, generators and other equipments, where staffs are also working on. Therefore, the selection of support platform for TCPS is significant. According to different types of TCPS, platforms can be classified as sea-bed mounted/gravity based system, pile mounted system and floating moored system.

Fig. 1: WangxiangII-40kW TCPS (HEU, China)

Fig. 2: AK-100TM TCPS (Atlantis Resources Co.UK)

The sea-bed system is suit for shadow water and the effect from wind and wave is minimal. However, the generator is under water which requires high sealing technology and maintenance is not convenience which will increase cost (Yunwu, 2008). The sea-bed TCPS are shown as Fig. 1 and 2.

Pile mounted system applied for deep water (30~60 m) and structure is very firm. This kind of system is limited by geological condition, if the sea-bed is too hard to drill, which would not be used (Yunwu, 2008). And pile mounted TCPS are shown as Fig. 3.

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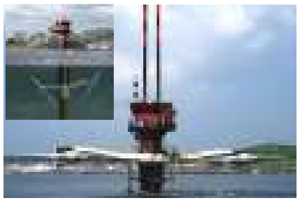
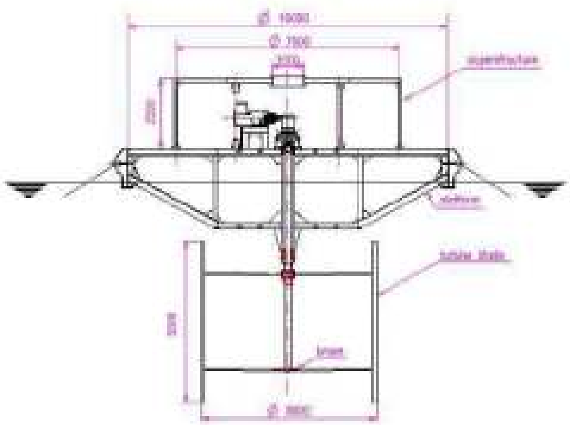


Fig. 3: SeaGen of MCT

(a) (b)

Fig. 4: "WangxiangI"-70kW TCPS and "Haiming I"-2x150kW TCPS (HEU, China)



(a)

(b)

Fig. 5: 150kW Kobold turbine (Ponte di Archimede S.p.A (PDA), Italy)

Comparison with them, advantages of the floating moored system are:

- They may be easily installed. Essentially, they are towed-to and then moored-in site
- They are easier to remove if a major repair task is needed or if relocation is necessary
- Routine maintenance is substantially simpler because it is mostly carried on close-to or over the surface (Shujie *et al*., 2010). In additional, the environment around the site of power station is one of factors which affect the design of platform system. The sites where sea condition is deeper and the sea-bed is mostly stone, the floating system is preferable. The floating moored TCPS can be seen from Fig. 4 and 5. *"Haiming I"* is the prototype of our research which has been working in Zhejiang province from July, 2012.

With the continuous development of marine engineering, more and more new structures are used in the exploring of tidal current energy. Based on measurement results on the working ocean environment, Catamaran and Semi-submersible as floating platforms of TCPS are studied in this study. The optimization will consider factors that affect selection of support platform, from the view of economics, efficiency of turbine and stability of power station during working conditions. As we all know, if we want tidal current energy to be commercial, economic issue should be the first problem to solve. Weight of TCPS are mostly concentrated in support platform, thus satisfied with strength requirement, decreasing of platform weight is an efficient way to reduce cost of TCPS. And it's obvious that higher efficiency means more power obtained, so the influence on power efficiency from support platform should be as little as possible. Stability is necessary to guarantee TCPS working normally.

In this study, based on basic ship theory, the stability is calculated using software MOSES. Two types of floating platforms are compared based on three factors mentioned above. And catamaran is a better choice as support platform for TCPS. This research is very important for the design and application of vertical axis turbine of ocean currents.

## TWO TYPES OF FLOATING PLATFORMS OF TCPS

The ship used as platform of TCPS has special characteristics, where does no need speed to sail (Renjun and Zhongyun, 2003a). Two types of floating platforms are discussed in this study, which are Catamaran and Semi-submersible. Catamaran is designed based one twin-hull engineering ship, which is a special ship (Renjun and Anxi, 2003b). Two bodies are connected by box structure and the turbine is between of them, where the turbine is supported by one point, shown as Fig. 6.

Advantages of Semi-submersible floating platform are width deck, better hydrodynamics and easier mooring. And two support points will make the turbine working at more stable situation. Semi-submersible power station is composed with four columns, which is like one box, where the turbine is inside and the turbine is supported by two points, shown as Fig. 7. Factors considered for the floating platform option:

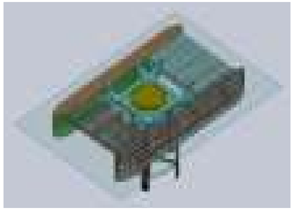


Fig. 6: Catamaran as floating platform

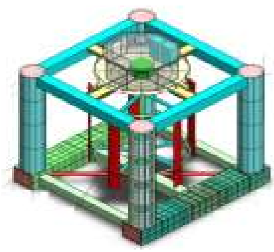


Fig. 7: Semi-submersible as floating platform

- Economics of the power station
- Efficiency of the turbine during it working condition
- Stability of the power station during its working condition

The economics of the power station is mainly related to equipments and platform, while the equipments mainly include turbine, electricity controlled equipments, generator, gear box, etc. and the platform of TCPS are mainly considering construction techniques and the total steel consumption. Because the construction techniques are too complex to evaluate, steel consumption is considered as the index to judge the economics of floating platform.

The platform has an influence on the efficiency of the turbine. As for semi-submersible platform, the water is coming around the columns; the columns must have influence on the fluid field. The turbine is a vertical-axis turbine which is installed in the middle of power station and one or two support points are used.

The stability is a most important index to evaluate the performance of platform. The platform must have enough stability to support all the equipments and turbine. Software MOSES is used to calculate the stability of platforms.

- **Method of stability calculation:** The stability includes two parts: Initial stability (static stability), it is the stability when angle of heeling is smaller than 10° or before the edge of deck immersing. Complete stability, it is the stability when angle of heeling is larger than 10° or after edge of deck immersing (Rawson and Tupper, 2001).

The following checks are stability rules:

- 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,
- 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 particular rule being used. This provides a general framework for all 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.
- **Dimensions of the platform:** In order to satisfy the design requirements that are diameter of turbine is 8m and output power should be 150kW. Dimensions of platforms are shown as Table 1 and 2.

Table 1: Parameters of semi-submersible floating platform

| Items | Unit | Data |
|---|---|---|
| Length (L) | m | 14.2 |
| Breadth (B) | m | 2.1 |
| Depth (D) | m | 1.6 |
| Space between two columns (l) | m | 12.1 |

Table 2: Parameters of catamaran floating platform

| Items | Unit | Data |
|---|---|---|
| Total length (L) | m | 24 |
| Total Breadth (B) | m | 13.9 |
| Depth (D) | m | 3 |
| Design depth | m | 1.2 |
| Breadth of body | m | 2 |
| Depth of body | m | 3 |
| Space between two bodies | m | 11.7 |

## COMPARISON WITH TWO TYPES OF PLATFORMS

- **Weights of TCPS:** Semi-submersible TCPS are mainly consistent with floating platform, turbine and generator etc. weigh of each part is evaluated by distribution method and data are in Table 3, where basic line of Semi-submersible platform is considered as reference line of center of gravity.

Table 3: Total weight of semi-submersible TCPS

| Items | Weight [t] | Center of gravity [m] |
|---|---|---|
| Body | 27.20 | |
| Columns | 43.30 | |
| Generator | 10.00 | |
| Turbine | 16.00 | |
| Anchor-machine | 2.00 | |
| Others | 10.00 | |
| Main desk | 14.58 | |
| Support of body | 15.18 | |
| Total weight | 138.26 | 6.67 |

Table 4: Total weight of catamaran TCPS

| Items | Weight [t] | Center of gravity [m] |
|---|---|---|
| Body | 31.99 | |
| Connection parts | 20.67 | |
| Generator | 10.00 | |
| Turbine | 16.00 | |
| Anchor-machine | 2.00 | |
| Others | 10.00 | |
| # Bracket | 16.00 | |
| Total weight | 106.66 | 1.08 |

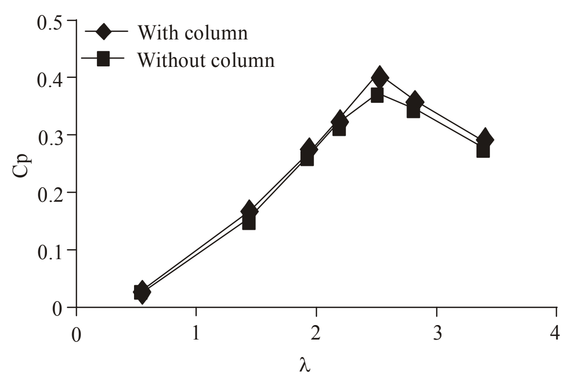



Fig. 8: Power coefficient of floating platform to speed ratio λ

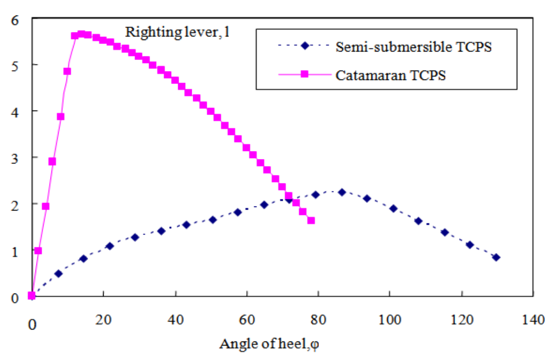



Fig. 9: Righting lever of TCPS

Main parts of Catamaran TCPS are catamaran bodies, Connection Bridge, supporting structure of turbine and generation etc. Weights are evaluated as the same method and shown as Table 4, where basic line of catamaran platform is considered as reference line of center of gravity.

The total weight of Semi-submersible TCPS is about 138.26 ton and that of Catamaran TCPS is about 106.66ton, thus the weight of latter will be reduced about 23%, which economics will be better.

- **Efficiency of turbine:** The supporting platform has influence on the efficiency of turbine. When fluid is coming around column, the column will change the fluid field so that has affect on the efficiency of turbine and this phenomena obviously exists in Semi-submersible TCPS. Using software CFX to calculate the power coefficient of them, results are drawn as Fig. 8.

It is obvious that power coefficient of Semi-submersible TCPS is smaller than that of Catamaran TCPS and the decreasing amount is about 0.3%. Thus, the latter choice will be better.

- **Stability of TCPS:** According to stability standard of multi-hull established by International Marine Organization (IMO), complete stability of multi-hull is weighed by the biggest value of righting lever, area under curve of righting lever and angle of heel. Based on basic ship theory, bigger area means larger righting moment so that the stability of the ship will be better. The biggest value of righting lever means the ship is suffered to biggest moment, when the ship itself has biggest righting moment, where biggest value of righting lever is constant with biggest angle of heel.

Another standard referred is "Criterion of Building and Classing Mobile Offshore Units" (CCS, 2005) and complete stability of offshore platform is weighed by the capability it resists applied moment of outside through its self righting moment. Actually, we mainly focus on curves of righting lever. Therefore, in this study, the curves of righting lever are adopted to do the research on complete stability. Both curves of righting lever calculated are shown as Fig. 9.

Seen from above figure, the red line is the righting lever of Catamaran TCPS while the blue line is the righting lever of Semi-submersible TCPS. Maximum value of righting lever of the former is bigger than that of the latter. And area under righting lever curve of the former is also larger than that of the latter. Therefore, catamaran is the better choice as floating platform of TCPS.

## STABILITY CACULATION FOR CATAMARAN

Software MOSES is used to compute stability of Catamaran TCPS. Wind heeling arm are ignored, because there is no superstructure. Due to the ratio of length to breath is smaller, seven rotation degrees (they are rolling angles) are considered during computing process which are 0, 15, 30, 45, 60, 75 and 90°, respectively. Comparison with the calculation results, it is found that when rolling angle is 0°, the arm of static stability is smallest. In this case, Fig. 10 gives the righting arm to rolling angle with different depths.

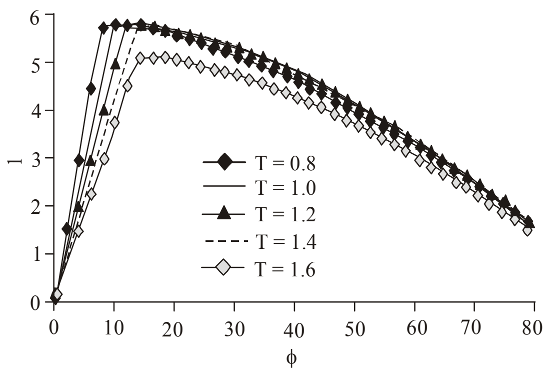



Fig. 10: Righting armof Ctamaran TCPS with different depths

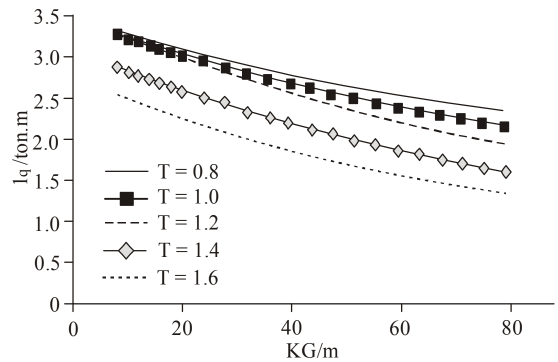



Fig. 11: Maximum dynamic heeling arm with different KG

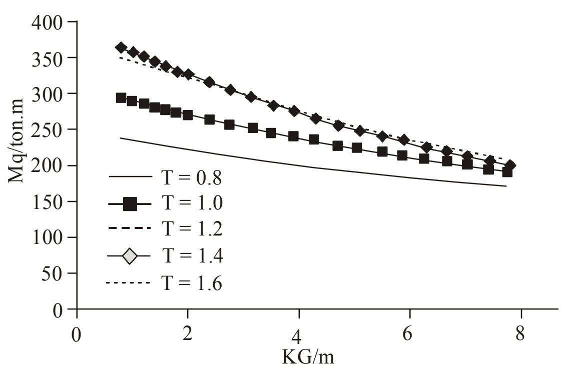



Fig. 12: Maximum heeling moment with different depths

The biggest static stability arm is 5.8 m. And when the depth is 1.6 m and rolling angle is 6°, the righting moment can satisfy.

According to offshore platform standard, in case of without considering initial angle of heeling, from zero degree to the second intercept point of heeling arm and righting arm, the ratio of the area under the righting arm curve to the area under the heeling arm curve is bigger than 1.4, the stability is satisfied criterion requirement.

Based on basic ship theory, curve of dynamic stability is integral from curve of static stability. When ship is heeling, increasing mount of centre of gravity and that of buoyancy is considered as arm of dynamic stability, $l_q$. In the limit situation, maximum dynamic heeling arm $l_q$ and maximum dynamic heeling moment $M_q$ response to different heights of gravity center (KG) are calculated using MOSES. And the relation of $l_q$ and $M_q$ is as following:

$$M_q = l_q \Delta \tag{1}$$

Seen from calculation results as Fig. 11 and 12, we know that when depth of catamaran is constant, center of gravity should be to the water level as closer as possible. In this study, the reference gravity center of catamaran is Zg = 1.08 m and when the range of depth is from 0.8 m to1.6 m, extreme arm of dynamic stability is from 2.5 m~3.2 m, while extreme moment of dynamic stability is from 240 kNm to 370 kNm.

## CONCLUSION

Two types of floating platform are proposed for tidal current power energy. They are compared in three aspects of economics, efficiency of turbine and stability.

In order to satisfy design requirement, total weight of catamaran TCPS is about 107 ton and that of Semi-submersible is about 138 ton, so that the economic of the former will be better than that of the latter. After calculation using CFX, power coefficient of turbine of Semi-submersible TCPS is 0.3% lower than that of catamaran TCPS. The last index compared is stability and catamaran's stability is better than Semi-submersible's. Therefore, catamaran is a better choice as floating platform for tidal current power station.

## ACKNOWLEDGMENT

This study is financially supported by 2010 Ocean Special Funds (Grant No. GHME2010GC02, ZJME2010GC01 & No. ZJME2010CY01), and it is supported by the Fundamental Research Funds for the Universities (No.HEUCF130105). And it is supported by "111 project" foundation (Grant No. B07019) from State Administration of Foreign Experts Affairs of China and Ministry of Education of China.

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