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Design of Offshore Oil and Gas Platform Based on Tidal Energy Turbine Power Generation

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***Abstract:** The development of offshore oil and gas energy has become the focus of production breakthrough in the oil and gas industry. Due to the rich oil and gas resources in the offshore coast, aiming at the problem of maximization the commissioning of offshore operations in shallow, we can learn from the conventional jacket platform and make full use of the rich tidal energy resources in the marine resources and their strong regularity and predictability. A set of offshore oil and gas platform based on tidal current turbine power generation is designed. The reasonable reliability of the platform is verified by simulating the load stress under four typical simulated environments with two working conditions under current load, sea breeze load and sea ice load. The results show that under extreme conditions, the UC value of the jacket platform is between 0.34 and 0.43, far less than 1. It has good stability and bearing capacity.*

***Keywords:** Exploitative of Offshore Petroleum-Gas Reservoir, Tidal Energy, Jacket Platform, Uc Values, Simulation*

1. Introduction

The offshore shallow layer contains abundant oil and gas resources due to the action of waves and inherited anticline structure[1]. Because the convenience and economy of jacket offshore platform in shallow water area, jacket offshore oil and gas platform accounts for a high proportion in shallow water area[2-3]. After the model frame is welded on land, it is directly transported to the offshore site, and the deck is installed after entering the pile, that is, the installation of the platform is completed. At the same time, because the jacket platform has small load under the action of wave and current and is less affected, it can meet the working load requirements on the premise of meeting various design specifications[4-5]. At the same time, considering that there are abundant tidal energy resources around the offshore platform, tidal energy turbine generator[6-7] is introduced to assist the power generation and anti-corrosion of the offshore platform, so as to provide a certain guarantee for the power supply of the offshore platform.

2. Design of Jacket Platform for Tidal Energy Turbine Power Generation

2.1 Jacket Platform

According to the conventional hydrological environment and development scheme of offshore waters, the jacket platform is designed as a 4-leg and 4-pile comprehensive platform. The jacket platform[8] is mainly divided into three parts: deck, jacket and pile foundation. It is designed as a three-layer deck[9], including the lowest deck as the production layer, the middle layer as the treatment layer and the uppermost layer as the living area, The design parameters of each part are shown in Tab. 1. Considering that ships need to be docked on one side of the platform, the apparent inclination of jacket leg is 10:1, the pile leg on one side of the platform is monoclinic and the other side is biclinic. The overall appearance is shown in Fig. 1.

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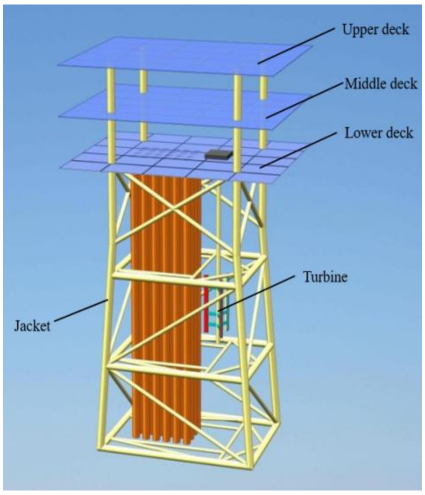

Figure 1: Overall Appearance of the Jacket Platform

2.2 Turbine Design

According to the relationship between the main axis direction and the incoming flow, tidal current turbine can be divided into horizontal axis tidal current turbine parallel to the incoming flow and vertical axis tidal current turbine perpendicular to the incoming flow[10-11]. Among the tidal current energy utilization technologies applied in the market, the most common is H-Darrieus vertical axis turbine, which has the advantages of simple manufacture of straight blades and controllable costs.

Therefore, H-Darrieus ordinary 3-Blade turbine is adopted in the design to obtain smoother fatigue load and effectively reduce the impact of complex dynamic load caused by impeller mass imbalance. The airfoil of blade is NACA 0018. A vertical axis tidal current turbine mainly includes impeller, transmission shaft, speed increasing gearbox, generator and installation platform. When the power flow passes through the impeller, the power flow drives the impeller to rotate to realize the transformation from power flow energy to mechanical energy, and drives the generator to generate electricity through the transmission system to realize the transformation from mechanical energy to electrical energy.

Table 1: Design Parameters of the Jacket Platform

Deck			
Design Location	Design height(m)	Design Specifications(m)	Material
Lower deck	16.0	20*25	Q355HYD
Middle deck	19.8	20*25	Q355HYD
Upper deck	25.2	20*25	Q355HYD
Jacket			
Design Location	Design length(m)	Design Specifications(m)	Material
Jacket under water	8.08	900*25	Q355HYD
Jacket above water (vertical)	8.8	900*25	Q355HYD
Jacket above water (curved)	3.5	900*25	Q355HYD
Deck column	5.5, 5.4	700*25	Q355HYD
Pile foundation			
Seabed mudline	Design length(m)	Design Specifications(m)	Material
	55	4*OD1100	Q355HYD

3. Theoretical Calculation of Environmental Load

3.1 Sea Breeze Load

The wind load[12] refers to the load generated by the wind acting on the part above the water surface of the offshore platform. When the air is at a certain speed, the theoretical wind pressure acting on the plane and curved surface is the kinetic energy function of the air. The total wind force is expressed as equation (1), and the wind pressure is equation (2).

$$F = KK_Z p_0 A \tag{1}$$

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$$P_0 = \alpha v_t^2 \tag{2}$$

Where: K -- wind load shape factor; K_Z -- height variation coefficient of offshore wind pressure (selected according to the regional class); A -- wind exposed area, m2; p_0 -- basic wind pressure, Pa; α -- wind pressure coefficient，taken as 0.613 $N \cdot s^2/m^4$; v_t -- design wind speed, m/s.

3.2 Ocean Current Load

In the design of offshore platform, the ocean current motion is relatively stable, and its impact on the platform is usually simplified as only drag force[13]. Due to different platform structures, there will be different blocking effects, resulting in lower current speed. Generally, according to different structural shapes, certain drag force coefficients should be selected for correction. The calculation formula is as equation (3).

$$f_d = \frac{1}{2} C_d \rho A U_C^2 \tag{3}$$

Where: f_d -- current load, N/m; C_d -- drag force coefficient; ρ – density, kg/m^3; A -- projected area, m^2; U_C -- flow velocity, m/s.

3.3 Sea Ice Load

The core issues of the research on the interaction between platform structure and sea ice are mainly the maximum static ice force and dynamic ice force acting on the platform structure and the structural vibration caused by seawater[14]. Ice can exist in the form of single layer ice, overlapping ice, ice ridge or iceberg. The calculated ice load can be divided into two cases: extrusion and blockage and are judged on the following basis:

$$\begin{cases} SP < \dfrac{3.5(D_1 + D_2)}{2} & \textit{Blocking} \\ SP \geq \dfrac{3.5(D_1 + D_2)}{2} & \textit{Squeezing} \end{cases}$$

Where: D_1, D_2 -- diameter of components, m; SP -- distance of components, m.

In case of extrusion, the ice load is calculated according to equation (4).

$$F = mIf_c Dh\sigma_c \tag{4}$$

Where: F -- horizontal force of the ice, N; m -- structure shape coefficient; I -- embedding coefficient; f_c -- contact condition coefficient; D -- width of squeezing surface, cm; h -- ice thickness, cm; σ_c -- uniaxial compressive strength of ice, kg/cm^2.

The structure shape coefficient (m) is taken as follows: circular section, m=0.9; square section, m=1.0 (positive action), m=0.7 (oblique action). For a cylinder, the embedding and contact condition coefficients are determined by the empirical equation (5).

$$If_c = 3.57\, h^{0.1} / D^{0.5} \tag{5}$$

In case of blockage, the ice load is calculated according to equation (6).

$$F_c = CWh\sigma_c \tag{6}$$

Where: F_c -- blocking force of ice, N; C -- blocking coefficient; W -- structure width, cm.

4. Numerical Simulation

4.1 Simulated Condition

In this paper, the operating conditions and extreme conditions of the designed offshore platform are analyzed respectively. The environmental conditions are shown in Tab. 2.

Operating condition refers to the most unfavorable load combination that the platform may bear

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under normal operation. It is generally defined as the operating condition that the platform bears fixed load and the maximum (or minimum) live load combination corresponding to the normal operation of the platform. For China's offshore oil fields, the operation conditions are generally based on the one-year environmental conditions. Extreme condition refers to the most unfavorable load combination under the worst environmental conditions that the platform may encounter during the service period. It is generally defined as the design environmental conditions under which the platform bears fixed load and the maximum (or minimum) live load combination corresponding to the extreme conditions.

Table 2: Operation and extreme environmental conditions

environment condition	Sea breeze		Sea wave		Sea current			
	direction	speed	cycle	height	direction	Surface velocity	Middle velocity	Bottom velocity
Operation conditions	NNE	35.2m/s	6.5s	6.4m	NNE,SSW	1.12m/s	0.88m/s	0.63m/s
Extreme conditions	NNE	60.2m/s	8.6s	14.3m	NNE,SSW	1.90m/s	1.44m/s	1.11m/s

4.2 Simulation Results of Pile-Soil Interaction

Since the platform is regular and symmetrical, set 2 working conditions (operation and extreme), 2 load directions (0 °, 45 °) for a total of 4 cases for simulation. By analyzing the stress load on the four pile legs (pl1-4) of the platform at the incident angle of 0 ° and 45 °, the data through the offshore platform SACS simulation software and SACS FILE text results. The load and displacement obtained are shown in Fig. 2.

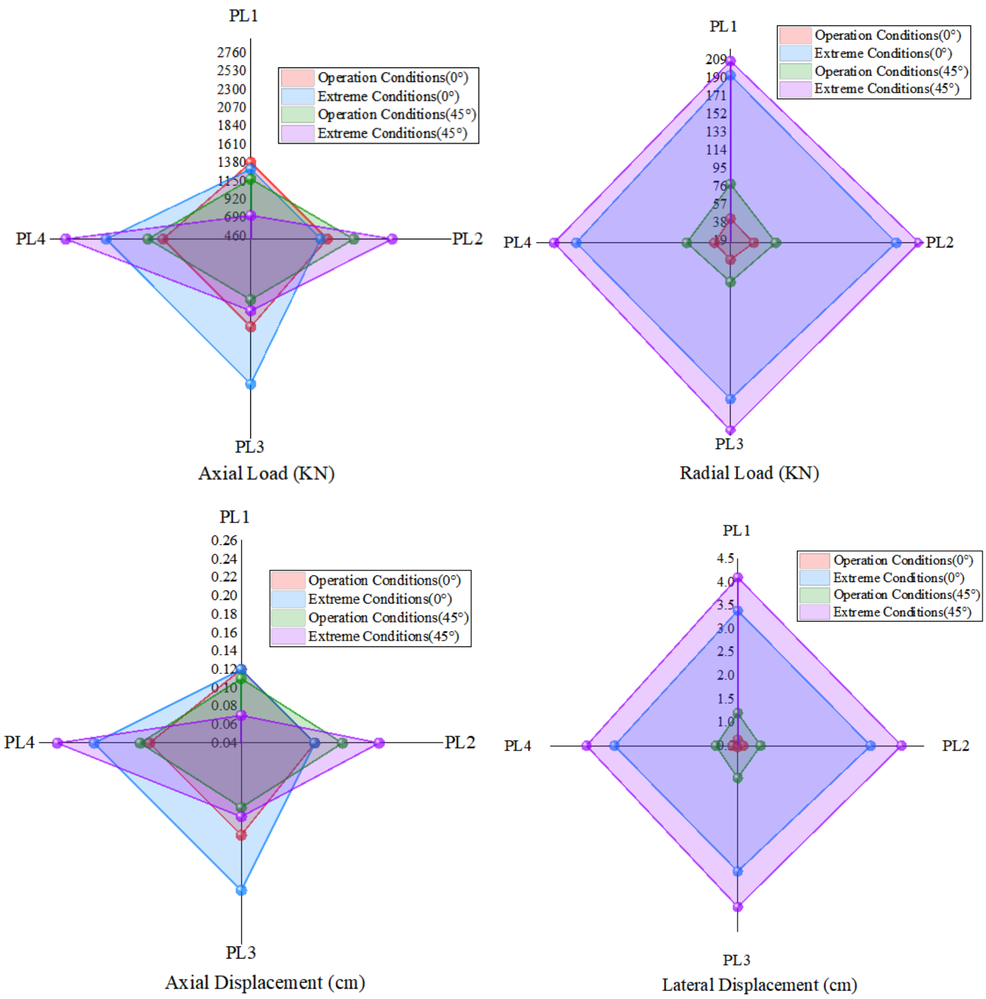

Figure 2: Load and Displacement of Platform 4 Pile Legs

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It can be seen from Fig. 2 that the displacement of leg pile is directly proportional to its load. Under the same incident angle, the load of leg pile under extreme working conditions is greater than that under operating conditions. Under the operating condition, when the incident angle is 0 °, the maximum axial load of 4-leg pile is 1523.66KN; the maximum radial load is 42.21KN, and resulting in the maximum axial displacement of 0.14cm; the maximum lateral displacement of 0.63cm. When the incident angle is 45 °, the maximum axial load of 4-leg pile is 1713.42KN; the maximum radial load is 78.79KN, and resulting in the maximum axial displacement of 0.15cm; the maximum lateral displacement of 1.2cm.

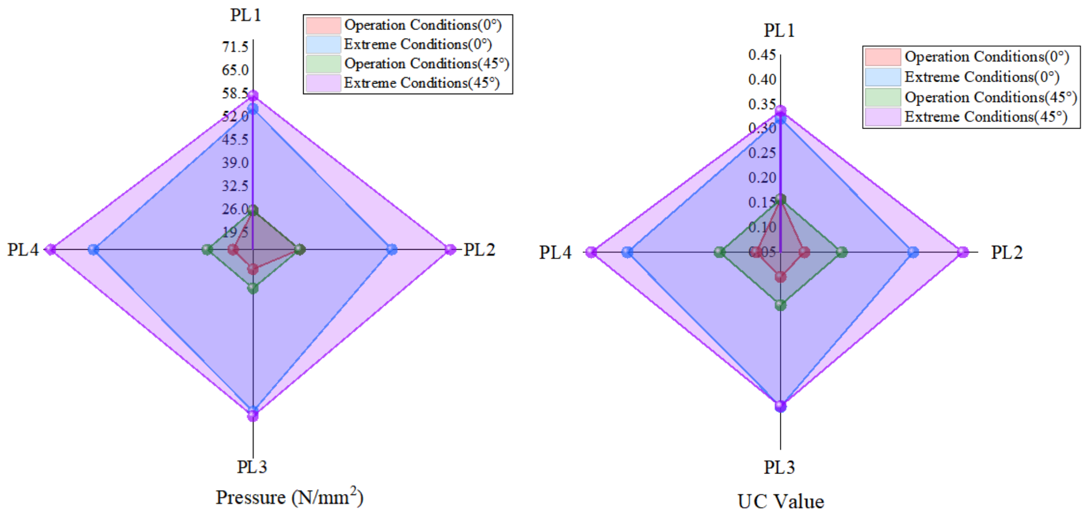

Figure 3: Pressure and UC Value of Platform 4 Pile Legs

Under extreme working conditions, when the incident angle is 0 °, the maximum axial load of 4-leg pile is 2244.73KN; the maximum radial load is 193.22KN, and resulting in the maximum axial displacement of 0.2cm; the maximum lateral displacement of 3.39cm. When the incident angle is 45 °, the maximum axial load of 4-leg pile is 2743.23KN; the maximum radial load is 215.53KN, and resulting in the maximum axial displacement of 0.24cm; the maximum lateral displacement of 4.1cm.

The ratio of applied stress and permissible stress (UC value) of leg pile is used to directly represent the safety of pile leg. Generally, if the UC value is less than 1, the engineering structure is considered safe. The pressure and UC value of 4 pile legs are shown in Fig.3. Under extreme working conditions, when the incident angle of environmental load is 45 °, the bearing capacity of pile leg is the largest; the combined pressure is 57 ~ 72n / mm2; and the UC value is 0.34 ~ 0.43, which is much less than 1, meeting the safety requirements.

5. Conclusions

Combining offshore oil jacket platform with vertical axis tidal turbine generator, an offshore oil and gas platform based on Tidal Turbine is designed to make full use of the rich tidal energy resources in China's coastal areas.

Sea current, sea breeze and sea ice loads are simulated for the design platform, and axial, radial loads and displacements of the platform were obtained under four typical environments with two load directions under operating conditions and extreme conditions.

According to the simulation, when the incident angle of environmental load is 45 °, the bearing capacity of the pile leg is the largest, the UC value is between 0.34 and 0.43, which is far less than 1. And the UC value is less than 1 under all environmental conditions, which is within the safety range. It is proved that the jacket platform has good stability and bearing capacity. It can be put into practical engineering application.

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