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Overview and Technical Analysis of the Offshore Wind Turbine Platform Access System

Qihao Ma[1, a], Xusheng Zhang[1, b]

[1]Merchant Marine College, Shanghai Maritime University, Shanghai, 201306, China.

[a]2469376640@qq.com, [b]xszhang@shmtu.edu.cn

Abstract

Offshore wind power has become an important development direction in the world and the number of offshore wind farms is increasing. With the continuous use of offshore wind turbines, offshore operators need to maintain wind turbines on a regular basis. Due to the influence of wind, wave, current and tide, the difficulty and risk of offshore access and landing are increased. In offshore operations, access systems are often used to transfer people and equipment. In order to make offshore transfer operations safer and more reliable, many types of maritime access systems have been built to provide the best possible compensation for movements caused by wind and waves. This paper mainly introduces the different types of access gangway system with different motion compensation techniques, crane systems for offshore access and hydraulic clamping system on ships. In addition, the access methods built on the wind platform is also reviewed. Based on the technical analysis on the primary offshore access methods, three-level compensation is suggested for the domestic offshore access system on operation and maintenance ships, especially for application of wind farm further from shore in the future.

Keywords

Offshore wind power; access system; motion compensation; multi-level compensation.

1. INTRODUCTION

With the development of world economy, energy and environmental issues are paid more attention to by all countries. The new energy, e.g. the wind power industry has been vigorously developed around the world. According to statistics, wind power accounts for 16% of the world's renewable energy generation. In 2017, the total power generation capacity of offshore wind was 18.8MW [1]. In recent years, offshore wind power has developed rapidly in China. According to the project of "Tenth Five-Year Plan for Wind Power Development", offshore wind power will have a total capacity of up to 10,000 MW in China at the end of 2020[2].

The growth of the offshore wind power market requires the necessary maintenance of wind farm, so that safe transfer of technicians and goods by operation and maintenance(O&M) vessels and O&M facilities is of significantly importance. In addition, as the future offshore wind farms is moving away from the coast in order to obtain more favorable wind resources, more O&M vessels need to be deployed and new access devices need to be introduced. During the life of an offshore wind farm, the O&M costs contribute significantly to energy costs. Therefore, it is essential for the maintenance of offshore wind farms.

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2. STATUS OF MAINTENANCE AND DEVELOPMENT OF OFFSHORE WIND FARMS

The location of the wind farm is divided into coastal and oceanic. The further from the shore, the worse the sea conditions are. Therefore, more O&M for wind power equipment are required. Wind, waves, currents, tides, weather and other complex offshore environments could cause offshore wind turbines to malfunction and timely maintenance is necessary for the wind farm. It is inevitable to consider the accessibility of the wind turbine platform by the engineer. The staff can access the offshore wind turbine platform (OWTP) by means of the helicopter or professional O&M vessel. Although the helicopter maintenance is fast and convenient, the working time should not be too long and the carrying capacity is limited. In addition, an additional parking platform is required. In domestic and foreign applications of wind farm maintenance, O&M vessels are primary choices. According to the development of offshore wind power, the O&M vessels are mainly divided into ordinary O&M vessels, professional O&M vessels, O&M mother vessels, and self-lifting O&M vessels. The complicated and rough sea conditions make the O&M ship swing irregularly and never stop. Even the O&M ship with the dynamic positioning system will still have pitch, heave and roll motions. At the same time, there is a height difference between the sea level and the platform, and the operator cannot directly board the platform, which also increases the risk of the operator. In order to safely and reliably transport maintenance person and equipment to the OWTP, it is necessary to equip the O&M vessel with an access system [3] [4] [5].

The maritime boarding system can be divided into the boarding device without any compensation, the active motion compensation system, the passive motion compensation system, the compensation system combining active motion and passive motion, etc. These boarding systems can be installed either on the front deck of the ship or on OWTPs. The OWTP ship characteristics (e.g. length, load) and vessel landing requirements vary with the boarding system and compensation method.

3. MARINE BOARDING SYSTEM

3.1. Ordinary Boarding Device

3.1.1 Ordinary boarding devices include detachable hanging ladders, fixed ladders, straight ladders, and software. The ship abuts against the turbine base at the idling condition of the main engine to increase the stability of the ship .This approach is achieved by approaching the OWTP tower base and using the ordinary boarding device to transfer the staff. In addition, this type of device is suitable for sea conditions with little wind and waves and primary application of coastal wind farm. It is difficult for the ordinary boarding device to compensate the ship motions so that potential risk exists in this device. It is gradually replaced by professional O&M vessels or professional O&M facilities. As shown in Fig. 1, the O&M vessel tightly touches on the tower base at the idle speed of the main engine and a fixed boarding device is adopted.

Figure 1. Fixed boarding ladder device

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3.1.2 Concept is from the maintenance mode of the oil platform, and the maintenance of the OWTP is also used. This type of boarding is not based on offshore oil platforms or OWTPs and is a manual boarding method.

(1) A remotely controllable telescopic gangway is installed on the OWTP. When an engineer approaches the platform at the stern the gangway with remote control is placed in a suitable position according to the deck height of the O&M vessel. The staff passes the gangway. (2) During the access, the O&M vessel does not dock without contacting the base. Figure 2 shows the access system including fixed straight ladder and hanging ladder. The ladder absorbs the movement of the ship and reduces the safety risk of the personnel boarding the platform in the poor sea environment. The ladder is placed in the box to avoid freezing in winter[6][7]. This type of boarding is suitable for large OWTP with available platform space to install straight ladders or telescopic gangways by remote control.

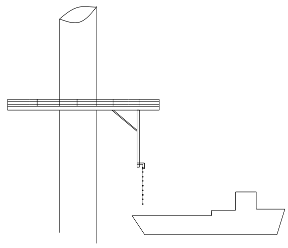

Figure 2. Fixed ladder and hanging ladder system

3.2. Ordinary Motion Compensation Gangway System

3.2.1 A motion compensated gangway system with one degree of freedom (DOF) or two DOF.

Such a motion-compensating gangway system generally does not have good effects on the motion compensation of the ship due to limited DOF. For example: the spring bearing compensation gangway (the gangway is retractable), it only passively compensates for the ship's heave and swaying (two DOF). This type of equipment has large compensation redundancy, poor stability, and low security.

3.2.2 Motion compensation gangway system with three DOF

The motion-compensated gangway can safely and efficiently transfer people and cargo to a fixed OWTP. Three DOF compensation normally is used for the standard gangway. The compensation system includes active, passive or combined control methods.

The ordinary motion compensation gangway system is mainly composed of a rotary base, a telescopic gangway and a pitching mechanism. The pitch is achieved by the expansion and contraction of the hydraulic cylinder connected to the gangway. Rotary motion is controlled by the swivel base. The hydraulic motor is used to realize the telescopic movement by the expansion and contraction of the movable ladder. When the O&M ship has three DOF motions of roll, pitch and heave, the gangway can effectively compensate by telescopic, pitching and rotating movements, so that safe and reliable transportation of workers and goods is obtained.

Working mode of motion compensation gangway: Before landing, the gangway is in "active motion compensation mode". The landing cone is stabilized by the active motion compensation module during deployment. The cushioning device is mounted on the top of the ramp instead of the landing cone and pushed onto the platform to ensure contact. The damping device remains stationary by active motion compensation. The active motion compensation mode allows the gangway to effectively compensate for the movement of the ship, allowing a smooth connection to the landing area; after the connection is completed, the gangway switches to the "passive motion compensation mode" to track the motion of the ship caused by the waves. The passive motion compensation mode allows the gangway to absorb all three axes of motion

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through pitch, swivel and heave, enabling long-term connection. It has proven to be a reliable solution for access and reducing the wear of the gangway components. Multiple redundant real-time sensors work in conjunction with the control system to ensure safety. For example, if a major power failure occurs on board, the emergency function will be activated by the battery of the ramp itself. They provide enough power to lift and retract the ramp to a safe position, which is a redundant feature that further enhances safety. A classic 3DOF compensation gangway is shown in Figure 3.

Figure 3. Three DOF motion compensation gangway system

3.3. Six-Degree-of-Freedom Motion Compensation Gangway System

The Ampelmann system is a successful six DOF motion-compensated gangway system. This basic concept was invented during the 2002 Wind Energy Conference in Berlin. The Ampelmann system installs the transport platform on top of the Stewart platform (6 DOF hydraulic compensation platform). In addition, the transmission platform can select a common boarding device or an ordinary motion compensation gangway system with three degrees of freedom compensation motion.

The gangway system is mounted on the top of the Stewart platform on board, using six hydraulic cylinders to provide all motions of six DOF and the motion of the vessel can be compensated. The transport platform is rest relative to the OWTP, and then the engineer could access the OWTP across the gangway. A prerequisite for motion compensation is the continuous provision of accurate real-time measurement of ship motions which is the basic data for the control systems to adjust the Stewart platform. Therefore, by combining Stewart platform technology and motion sensor data, active motion compensation can be achieved in all six DOF [8] [9].

Ship motion compensation can be effectively conducted on the Stewart platform in Hs = 2.5m sea conditions. The Stewart parallel mechanism includes three rotational DOF and three translational DOF. It consists of two platforms and six linear actuators. The lower platform is fixed to the ship's deck and the upper platform is connected to the transport gangway. The servo oil drives the hydraulic cylinders, which cooperate with each other to compensate the movement of the ship in any direction. In addition, the axial forces in the hydraulic cylinders caused by the transfer gangway should be minimized to optimize power requirements and costs. [10].

The Ampelmann system is the most advanced type of maritime boarding device on the market with the best compensation by far as shown in Figure 4.

Figure 4. Six DOF motion compensation gangway system

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3.4. "Elevator Lift" Motion Compensation Gangway System

The motion-compensating gangway is mounted on a height-adjustable pedestal with an integrated elevator for continuous workflow. In addition, the pedestal allows the gangway to land at any height. The movement of the elevator varies according to the height of the OWTP, so that the engineer can be transferred safely with additional DOF compensation. Personnel and cargo can be transported from the ship's main deck to the wind turbine platform through the gangway.

The gangway system includes a channel tower with an elevator installed. The adjustable base provides the flexibility for landing height. This is a unique system that enables reliable and efficient personnel and cargo transfer regardless of the harsh weather conditions, as shown in Figure 5.

Figure 5. 'Elevator lift' motion compensation gangway system

3.5. Motion Compensation Crane

As the weight of the load increases or the height of the platform increases, goods transfer can become a serious problem in an offshore environment. Therefore, compensating cranes have been introduced to the market, as shown in Figure 6.

Motion-compensated cranes are reliable and rigid cranes that can be used to transfer goods and people from ship to ship or from ship to offshore platform by connecting rope baskets. Because the motion-compensated crane has advanced sensor signals and a compensating hydraulic system, It can keep the movable arm stationary for safe and precise operation. The crane base compensates the ship motions and ensure the smooth transfer of offshore workers and cargo. Additional cantilever controls include radar collision detection, cantilever camera imaging, manual overload protection on the system and automatic overload protection system. The market can be customized to the specifications, different boom lengths and lifting capabilities under different sea conditions.

Figure 6. Motion compensated crane

3.6. Hydraulic Clamping System

Installation of a hydraulic and pressure clamping system on the deck of the O&M vessel can increase the stability of the vessel. Staff can reach the platform directly from the bow through the vertical ladder of the offshore base [11].

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The hydraulic clamping system consists of two hydraulic arms that rotate around the vertical axis. A hydraulic clamp is mounted on their front end that swings around the vertical ladder welded by the offshore wind turbine base and clamps the vertical ladder steel frame of the base. By activating two hydraulic cylinders, the hull is pulled to the vertical ladder steel frame with a preset force, and the resulting friction stabilizes the position of the O&M vessel in all directions, completing the fixed connection of the ship and the offshore wind turbine tower base. The constant tension system guarantees a fixed clamping force under the condition of the pitch and heave movement of the vessel.

In addition, the front end of the O&M ship deck is equipped with shock absorbing equipment, which cushions the collision between the O&M hull and the offshore wind turbine base, and reduces the irregular movement of the O&M vessel. Depending on the size of the ship and the structure of the ship, the capacity of the different clamping systems can be selected, As shown in Figure 7.

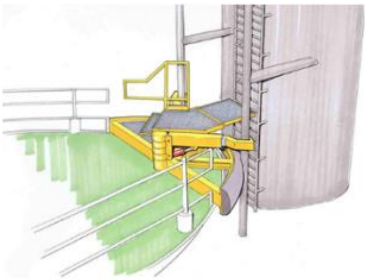
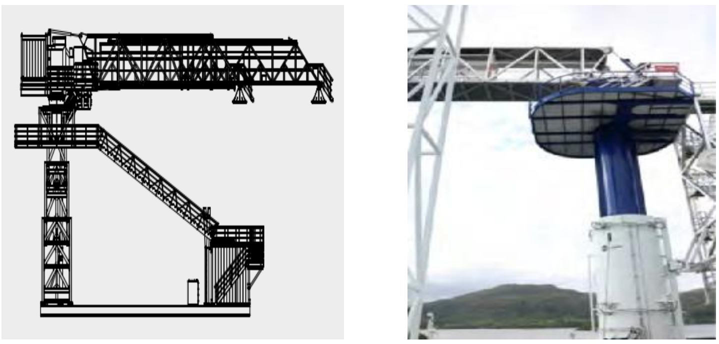


Figure 7. Hydraulic clamping system

3.7. Pedestal Height Adjustable Gangway System

This system consists of a gangway and a height-adjustable pedestal that is mounted on the deck. The gangway system with adjustable height of the pedestal is installed on the special O&M vessel, which enables the gangway working system to land at different heights. The personnel and cargo are transferred through the gangway under different sea conditions. This type of base can be lifted and lowered at different heights and continuously adjustable so that the gangway can be lowered to exact height of OWTPs. Two types are introduced here: as shown in Figure 8a, a height-adjustable steel frame base is mounted above the deck; Figure 8b shows a large hydraulic lifting device is mounted on the deck, and the height of the base can be varied within a certain range.



(a) (b)

Figure 8. Height-adjustable gangway system for steel frame base(a) and hydraulic lift base(b)

3.8. Collapsible Remote Operating Stair System(Access System Based on the OWTP)

The Offshore Transfer System is a collapsible remote operating staircase that can be lowered directly from the OWTP to the ship's deck or sea level for safe and efficient personnel transfer.

The system is deployed by gravity and only needs power to fold the stairs. Anti-slip aluminum steps, platforms, handrails, safety nets, etc. are installed around the stairs to protect workers.

All components of the system are stored in a container that can be moved from one place to another. In addition, the system can be lowered from one deck to another, making it ideal for deck-to-deck transfers. The system does not take up valuable deck space compared to conventional stairs or ladders. When not in use, the stairs are stored in the container to protect the system from the harsh environment and easy to maintain.

The system can be remotely controlled and quickly deployed to install a multi-function access control system, eliminating the threat of unauthorized access. It is therefore a safe and optimal solution for unrestricted access platforms [12].

The biggest feature of the system is that the complete collapsible remote operating stair system is installed on an OWTP or other offshore work platform, as shown in Figure 9.

Figure 9. Collapsible remote operating stair system

3.9. Wind Lift System (System for Lifting and Lowering the Fan Platform)

A wind lift system developed by Fassmer is a height-adjustable platform for accessing offshore wind turbines from ships, driven by wind energy (batteries can be used in standby) for remote control. The platform installed around the turbine foundation is raised or lowered to the deck of the O&M vessel. The platform and the O&M vessel deck maintain the same height, and personnel and equipment on the cabin deck can be smoothly transferred to the platform. It can prevent technicians from climbing on external ladders to reduce safety hazards. As shown in Figure 10, the platform descends to the deck height of the O&M vessel and is diverted through the gangway, staff and equipment. The wind turbine tower is fitted with slide rails on which the fan platform is raised and lowered at the desired height [13].

Figure 10. System for lifting and lowering the fan platform

3.10. Advanced Transfer Basket

The advanced transfer basket is the product of offshore maintenance personnel transfer technology to protect workers. It can replace rope frames or as a backup device. It provides very secure protection against the four major risks of worker movement: fall, heavy landing, collision, and immersion.

The advanced transfer basket has a small footprint and easy to land. It has a small storage space and easy to transport. The device includes a spring and hydraulic damping system to

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reduce heavy vertical shocks. The stainless steel frame and buoyancy plate prevent side impacts and provide protection. Reasonable seating and space layout provide passengers with comfort and safety. It can automatically center and float, protecting passengers in the event of possible sinking [14] [15], as shown in Figure 11.

Figure 11. Advanced transfer basket

3.11. Jack-Up Platform(Self-Elevating O&M Ship and Floating Jack-Up Platform)

Self-elevating O&M ship (Figure 12a) belongs to a multi-purpose ship, which can realize the lifting and lowering of the whole hull. The support of the column is stably standing in the air, higher than the sea level. It is mainly used for the replacement and maintenance of large parts of offshore wind farms. The ship is equipped with a motion-compensated crane and has a self-elevating platform for

maintenance work in the waters of about 40 meters in depth and away from the coast. It has the characteristics of high safety, strong endurance, wide working range and superior comfort at sea [16], as shown in Figure 12a.

(a)

(b)

Figure 12. Self-elevating O&M ship(a) and Floating jack-up platform(b)

The floating jack-up platform (Figure12b) is assembled from standard pontoon assemblies, jack-up columns and mud well accessories. With modular components, these components are easy to transport by truck and are quickly assembled on site using a small number of workers and common lifting equipment. The lifting system is hydraulically actuated and manually controlled, allowing the platform to move up and down. Each lifting device includes a rotary lifting and locking mechanism that mounts external lugs on their respective lifting columns and allows the lifting platform to be secured at any height. In addition, the floating jack-up platform is a barge type and has no self-propelled capability.

The use of a floating jack-up platform is economically flexible. Applications include foundations, hook operations, offshore work platform installation and maintenance, and other offshore construction operations. This modular "lift-up" barge is easy to carry and provides a stable working platform that effectively eliminates downtime due to waves, currents and tides.

The floating jack-up platform is safe and convenient for installation and maintenance of OWTP. When offshore workers install and repair OWTPs, the floating jack-up platform rises to the same height as the fan platform and smoothly runs through ordinary ramps. The disadvantage is high cost.

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4. CONCLUSION

Based on the analysis of several types of boarding systems, the key technology is the multi-DOF compensation of vessel motions and the reliable access methods. The foreign companies provide the main products of offshore access systems because of earlier application of offshore wind energy. However, due to heavy influence from wind and waves further from the coast, there is a big challenge for the access system taking into account the development of wind farm. Only one system with several motion compensation is not sufficient and more precise motion compensation is necessary. Therefore, a concept of "three levels of compensation and even multiple levels of compensation" is proposed based on the previous analysis. In the first stage, the ship's dynamic positioning (DP) function controls the ship in a range of small amplitude swings and rotations in three degrees of freedom; the second stage, by relying on motion compensation of six DOF Stewart platform to solve the six DOF swinging motion of the ship under the action of wind, waves and current; the third level, the three DOF compensation function of the gangway itself ensures the long-term stability of the front end of the bridge ladder and the OWTP contact. Or on the third-level platform, add more DOF compensation to obtain more accurate motion control. How to miniaturize and lighten each compensation platform and achieve complete stability and safety is the development direction of the future compensation and boarding system.

Considering the significant development of the wind power market in China, the offshore wind farms will move further from the shore, higher requirements for the O&M of ships and O&M facilities is necessary. The domestic research and development of the O&M vessels and the boarding system should be intensified to fill the various types of boarding systems in China. The development gap is based on the mature technology of the foreign boarding system and domestic technology is vigorously innovated. It is necessary to develop O&M vessels and O&M facilities to cope with the maintenance of large-scale offshore wind farms in the future. For the characteristics of each type of boarding system, the selection of the boarding system should focus on the following aspects: (1) good stability, fast and convenient and safe; (2) light weight, large load, small footprint; (3) According to the sea conditions of the offshore wind farms in the area, the boarding system is selected to achieve optimal resource allocation and save resources; (4) to choose a boarding system with good compensation effect and strong endurance away from the coast; (5) according to the use Select the boarding system.

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