Study on Design and Constructure of Offshore Substation

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Abstract: In recently years, there are more than 70% of power generated by coal station. Based on this, it can be shown that fossil fuels are the main consumption for generating energy. Burning fossil fuels will produce a lot of carbon dioxide and other harmful gas. Moreover, fossil fuels are unsustainable energy, which means it will run out in the future. For avoiding this situation, sustainable energy need to be exploited so that can replace fossil fuels. Currently, there are wind power, solar power, nuclear power in China. Some wind farms already built in different place of China. Due to high advantages of sea, China is paying attention to develop offshore wind farm. This essay introduces details of offshore wind farm including rules of designing facilities and outlook of each level in China.

1. Introduction

Wind energy is a kind of clean energy, which can be found in any area of the world. Since BC, wind power has been used to carry water, grinding wheat and other activities. With time goes by, clean energy developed very fast. Wind power is one of a typical example\cite{1}. There are two types of wind farms. One type is onshore wind farm and the other is offshore wind farm. Onshore wind farm are relative easy to operate and maintenance. However, Offshore wind farm can provide more wind energy. Offshore wind farm is becoming more and more important, because it not only supply a huge amount of electricity, it is also a kind of sustainable energy. Although there are some difficulties about designing and construction of offshore wind farm, these difficulties can be solved with development of technology. This paper introduces the design of offshore wind farm and facilities in the offshore wind farm.

2. The overview of Chinese wind industry

Due to overuse of fossil fuels, worldwide happened oil crisis. Based on this, developed countries started to develop sustainable energy. Wind energy is recognized as one of best clean energy in the world. Since 21 century, the capacity of wind power increased rapidly. Total capacity of world has become 94.112MW, when in 2007. the capacity of wind power is 6.05MW in China, which is fifth biggest country in the world.

3. Construction and function of offshore wind farm station

Offshore substation is an extremely important part for offshore wind farm. It is used for transferring and transmitting electricity There are two parts for offshore wind farm. One part is wind turbines and the other is offshore substation. The main part is offshore substation. According to
location of wind farm and environmental conditions of sea, it forms two kinds of offshore substations. The first is module offshore substation. The second one is Integrated offshore substation.

3.1. Module offshore substation

Modules offshore substation is divided into several parts including transformer module, medium voltage module, backing power module, auxiliary system module, control module, etc. Each module is firstly installed on land and then transported to destination by ship. Finally all modules is installed and connected to become a offshore substation.

3.2. Integrated offshore substation

Whole part of Integrated offshore substation is installed on land. It requires more time and more money to transport the whole substation to destination. However it saves installing time and has less install mistakes comparing with module offshore substation. Therefore it is better to choose Integrated offshore substation. Integrated offshore substation can be divided into two parts include upper construction and undersea construction.

3.3. Upper construction

There are four layers for upper construction. First layer consists of oil pool, the lifesaving device, the connector and so on. It is mainly used for cable layer and connection layer. Second layer consists of transformer, switch room, low voltage distribution room, GIS room and so on. Third layer consists of center transformer, battery room, communication relay room, refuge room, diesel engine room, etc. The top layer is arranged with air conditioning outside machine, communication antenna lightning rod and helicopter hover area.

3.4. Undersea construction

Undersea construction is built for supporting upper construction. There are two types including single pile foundation and multiple pile foundation.

4. electrical design of substation

Electrical design consists of high voltage part and protection part. high voltage part includes main transformer, electrical wire connection, electrical equipment, emergency power supply, lighting and navigation.

4.1. Main transformer

Due to the variety of changes for offshore environment, it is hard for wind turbines to become full load. when the output power of the wind turbine is large, the wind force is large. Therefore requirement for heat dissipation is low. When transformer running, it produces no-load loss and load loss. No-load loss is also called iron loss and load loss is called copper loss. The specific calculation is as follows:

\[ \Delta P = P_0 + K_T \beta P_k \]  
\[ \Delta Q = Q_0 + K_T \beta Q_k \]  
\[ \Delta P_t = \Delta P + K_q \Delta Q \]  
\[ Q_0 = I_0 S_N \]  
\[ Q_k = U_k S_N \]  

\( \Delta P \) is Active power loss, \( \Delta Q \) is Reactive power loss \( \Delta P_t \) is total active power loss \( Q_0 \) is No-load reactive loss, kvar; \( P_0 \) is no load active loss; \( P_k \) is Rated load loss; \( S_N \) Transformer rated capacity; \( I_0 \) No-load current; \( U_k \) is Short circuit voltage \( \beta \) is Average load factor; \( Q_k \) is Magnetic flux leakage power for rated load.
As no load current is very small and can be ignored, so the transformer loss is basically iron loss. The iron loss of the transformer is constant, while the copper loss varies with the load. The larger the capacity of the transformer, the greater the iron loss. Therefore, the selection of transformers should take copper loss and iron loss into consideration. In general, the capacity of the main transformer should be the same as the installed capacity of the wind power plant.

4.2. Distribution equipment
Taking 35KV distribution equipment as an example, it includes 40.5kv switch gear and grounding transformer. Transmission line need to use special cable which can undertake corrosion and wet. 35KV system should adopt small resistance grounding model and each bus should equip with a grounding transformer. According to technical guidelines for substation of offshore wind farms, distribution equipment should follow the following principles:
1. The equipment should be able to operate reliably under unattended conditions.
2. Can adapt to the operation environment of offshore substation (high reliability, long service life).
3. Main electrical equipment is arranged indoors.
4. The size and weight of the equipment should be as small as possible.

4.3. Reactive power compensation devices (svg)
The function of the reactive compensation device is to reduce the power loss of the equipment and improve the quality of power supply. Due to the limitation of conditions of the offshore substation, it is difficult for the reactive power device to completely meet the reactive power capacity requirement. Therefore, it is necessary to make a scheme to demand reactive power. At present, the reactive compensation equipment mainly includes 220KV high voltage reactor and 35kv dynamic reactive compensation device. The common devices are SVG (STATCOM) compensation device, TCR type SVC compensation device and MCR type SVC compensation device.

4.4. Collecting line and emergency power supply
The capacity of most offshore wind farms are 300MW. For example and the offshore substation is usually set about 15KM from land. Collecting lines are 220kv sea cable in China. Two wiring modes can be seen as below:

![Figure 1: One-line diagram](image)
From graph 1, it can be easily seen that the power loss of single line is smaller than that of double line. But the reliability of lower that of double line. Moreover, price of single line cable is lower than double line. Taking all these reasons as consideration, single line is usually used. The following principles be followed:

1. Reliability: the wiring should be reliable and should have back up.
2. Flexibility: system can undertake different situations and be able to shut down without conditions.
3. Economy: cost-effective
4. Protection part

   Protection part consists of substation computer monitoring system, relay protection and safety automatic device, dc power supply and ac power supply video monitoring and environmental security, communication system, etc. Here is an introduction to each system:

   Regulation system of substation

   Because substation is operating automatically, so the substation computer monitoring system is in the centralized control center. In order to ensure safe and stable operation, the substation is equipped with the anti-error-operation latching function and monitored by the computer, which can also reduce the workload in operation.

   Protection relay and safety automatic device

   Different system need to match with different protection configurations. By comprehensive analysis and calculation, the most reasonable protection relay configuration scheme can be worked out based on principles of rapidity, selectivity, reliability and sensitivity. For example, for the main electrical connection, the most common protection in the circuit is the instantaneous current cut off and the time-limited current cut off together constitute the main protection. When the protection area and sensitivity cannot meet requirements, it should be considered to design the voltage interlock speed break as main protection. For the power transformers, it includes: 1. Protection of acceleration measures for protection transformers with short circuit fault between phases--differential speed break protection; Protection of asymmetric short circuit faults in and out of the transformer - negative sequence over current protection.

   Dc power supply and UPS

   Due to the importance of high voltage electrical equipment in the offshore substation, there is always a back-up protection system. Each protection system needs to set up independent dc power supply, using two battery banks and two sets of charging device scheme. The rated voltage of dc power supply is 220V, and the connection is single bus connection.

   Video surveillance and environmental security

   Video monitoring system includes video monitoring system of offshore and video monitoring system of onshore centralized control center. The offshore substation is equipped with video control station, while the onshore center is equipped with main control station. The video monitoring system should satisfy the requirement of monitoring, record and replay around substation platform and the sea area. In addition, the video surveillance system should be linked with the automatic fire alarm system, and the scene switching can be achieved in the land centralized control center. These are the main components of substation.

5. Conclusion

   Currently, offshore wind power industry has a broad prospect. According to the needs of offshore wind power market, a large number of professional teams focusing on operation and maintenance will emerge in the future to provide comprehensive and professional services for investment enterprises. In addition, offshore wind power equipment standards, product testing and certification systems will be gradually established and improved.
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