Research on the Manufacturing Process of Submarine Cable Joints and Joint Room Design

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Abstract. In this paper, the connection technology of offshore cables is summarized and analyzed in accordance with the requirements of environmental conditions for laying submarine cables in deep water. Then the technical requirements and characteristics of the design, construction and operation of submarine cable joint chamber are studied, and the general manufacturing process of the joint is summarized. Finally, on the basis of the above research results, combined with the research and development of submarine cable joint room in China and other relevant information, a practical design scheme of submarine cable joint room is proposed, and its reliability and practicability are analyzed in terms of service conditions, main equipment and technical characteristics.

Introduction

Cable joints are an important accessory in power cable routing. The installation of cable joints at sea requires professional vessels, equipment, professional operators and suitable weather conditions. Moreover, in the laying of submarine cables, the connection of cables is characterized by high difficulty and high technical content. The basic requirements for cable joints are: The main components of cables, such as conductors, inner shields, insulation, outer shields, waterproof metal sleeves, armoring, etc., must be connected; Cable conductors should have good electrical and mechanical properties at the joints; cable joints should have the same insulation strength and waterproof properties as the cables; the gland should also have corrosion resistance. According to different needs, submarine power cable joints can be roughly divided into two types: flexible joints and rigid joints. The choice of these two types of cable joints needs to be determined according to local sea conditions.

Due to the unfavorable conditions of the marine environment, once a cable fails, it will be very difficult to repair it, so the quality of the cable joint must be guaranteed.

The Manufacturing Process of Submarine Cable Joints

The joints of medium and low voltage submarine cables are mainly flexible joints. This kind of joints has the same material/structure/mechanical properties as the cable, and can withstand tensile, torsional and bending stresses. The flexible joint has a similar shape to the cable and is laid with the same equipment as the cable. It has the advantages of simple design, small size and easy installation.

Because of the stability problems associated with conventional flexible joints, rigid joints can be used for the connection of high voltage or ultrahigh voltage submarine cables. Rigid joints are stiff and have a larger diameter than the cable, so ordinary laying equipment cannot meet the requirements, so the installation must use complex lifting equipment. However, the rigid joint has a
steel protective box to provide good mechanical protection. The rigid joint is mainly composed of an electrical connecting portion and an outer protective box. The electrical connection can be further divided into a connection of the cable conductor and a connection of the insulating part.

Choosing the right process is important to ensure the quality of joints. The method to connecting conductors is usually divided into three types, welding, crimping and mechanical connection. The common mechanical connection method is bolting. For different joints and electrical requirements, it is important to choose the proper conductor connection method, which is related to whether the cable joint can work stably. At the same time, the connection of insulation and shielding layers is also different. In general, the conductors of the flexible cable joints are welded, and the insulation and shielding connections are usually wrapping. The combination of soldering and wrapping can also be used for rigid joints, but the use of prefabricated insulating sleeves for insulated connections is more common, in which case three conductor connections are possible. This method is simpler and faster and is an advantage of rigid joints.

**Joint Room Design**

**The Technical Requirements of the Use Conditions**

Submarine cable joints shall be made in good weather conditions without heavy winds and heavy rain, and the workboat shall be stabilized by mooring to avoid movement. For the sake of safety and efficiency, in the general marine environment, the joint room should meet the following environmental requirements:

1) Applicable to ambient temperature, -10 ~ +60°C; Applicable to relative humidity, 60%
2) The house exposed to the external environment has the ability to resist sea salt spray corrosion;
3) During the joint making process, the rocking angle of the working vessel under extreme working conditions is ±15°;
4) Easy to disassemble and carry;

In addition, the joint room must provide sufficient space for operation of cables, and not exceed the space of the cables’ aisle on ships, so a reasonable and appropriate size should be determined.

**The Main Equipment**

According to the existing relevant information, the structure of the joint room should mainly include the following components: 1) joint room body; 2) environmental control equipment: purification ventilation equipment, temperature control equipment, air cleanliness testing equipment, air shower equipment; 3) Joint making equipment; 4) safety monitoring equipment; 5) power supply and lighting equipment. The joint room body should meet the above technical requirements of use conditions.

The internal environment has a great influence on the joint quality, including the influence of temperature, humidity and cleanliness on the quality of cable joints. The adhesion of trace moisture and impurities may cause the interface defect problem of joints, which leads to the generation of space charge, and when the space charge reaches a certain level, it will discharge and make the joints broken down. In order to ensure a good interface of the cable joint, the environmental control equipment that controls the ambient temperature, humidity and cleanliness is an important part of the equipment.

Each environmental control device first draws in air, and then separates the dust particles, reduces the moisture content, and adjusts the temperature, and finally blows the treated air into the joint room. By performing the above steps cyclically, the air is purified and meets the environmental requirements for joints’ making. At the same time, the environmental control equipment should monitor the changes of temperature, humidity and cleanliness at any time during the joint production to ensure the stability of the joint-making environment.

In addition to environmental control equipment, equipment for monitoring and detecting joints is also required to ensure joint quality. At the same time, it is necessary to equip some related tools for the joint production, which is convenient for cable conductor connection, insulation recovery and
armoring connection. Which tools are selected is determined by the type of cables and the type of the joints selected, but equipment for securing and supporting cables is essential. According to the process of joint making, after the two cables to be connected are placed and fixed, they need to be cut, so an insulation-cutting tool must be provided in the joint room.

Both flexible joints and rigid joints are possible to be made in the joint room, so for the two types of joints, some related equipment can be equipped as appropriate.

When making flexible joints, cable conductors are welded, so a specific conductor-welding bracket and other welding tools, such as welding torches, are required. In addition, cooling fixtures are required to hold the conductors to prevent the insulation quality from being affected by the high soldering temperature. In order to connect insulation or shielding layers, it is necessary to prepare an insulation manufacturing tool, such as wrapping machines, molding machines, and injection molding machines. When the insulation is recovered by the method of wrapping, the wrapping machine can automatically wrap the insulating tape, and the self-adhesive rubber tape can be automatically vulcanized to become a whole by tension, and the molding machine vulcanizes the insulating tape by high temperature and high pressure. Injection molding machines generally include an injection molding device and special molds, which are used when the insulation is connected by the method of injection molding. For the connection of waterproof sleeves or armoring, since the welding is also used, the related welding tools and the cooling device are necessary.

If the electrical part of rigid joints is connected in the same way as flexible joints, the required equipment is identical to that of flexible joints. When a prefabricated insulating sleeve is used, a mounter for prefabricated insulating sleeves should be equipped which provides the functions of expanding and pulling prefabricated insulating sleeves. If cable conductors are crimped, crimping tools, which connects conductors by applying mechanical pressure to cable conductors that are sheathed with a special sleeve, are used. Crimping tools using the principle of leverage are called crimping pliers, and those using the hydraulic principle are called hydraulic pliers. If bolting is used to connect conductors, bolts and connecting tubes are needed. Finally, when installing the external protection box, it is necessary to have welding tools for tightly connecting the protection box to the armoring (to the waterproof metal sleeves). In addition, the protective box and armoring can also be connected using flange clamps. It depends on the structure of the external protective box.

**The Technical Characteristics**

A joint room for the manufacture of submarine cable joints shall be equipped with adequate equipment and tools according to the corresponding submarine cable connection process, and relevant equipment shall be used to control the indoor environment to meet the environmental requirements of the joint fabrication. Overall, the design of the joint room has the following main technical characteristics:

1. The cleanliness and environmental control requirements for the making of submarine cable joints of different voltage levels shall be met;
2. In addition to the functions of maintaining constant temperature, humidity and cleanliness, the joint room can also provide technical equipment for making of submarine cable joints and functions such as electric power, lighting, electrical test, and submarine cable fixing to ensure continuous production of submarine cable joints;
3. The size of joint rooms shall be capable of accommodating a certain length of cables and not exceeding the working space of offshore platforms;
4. A joint room shall be capable of being disassembled and moved, and its size shall not exceed the maximum size limit of road transport;
5. Offshore platforms should provide sufficient space for joint production and other basic functions such as electricity and communication, and submarine cables shall be firmly fixed;
6. A joint room should be able to cope with complex environment of ocean, such as seawater corrosion, ship shaking, etc. It is recommended to obtain approval from the relevant inspection departments.
The Case

According to the above research, this paper independently developed a special offshore joint room equipment system. In this system scheme, the cable guide, the cabling machine, the joint room and the water inlet are arranged on one side of the deck in a longitudinal arrangement. Submarine cables are transported along the longitudinal direction of the ship and, after joint making is completed, finally put in the water.

The structure of the joint room is shown in Figure 1 and Figure 2, where: 1-clean joint room, 2-office, 3-warehouse, 4-submarine cable fixed device with double head, 5- submarine cable bracket, 6-air shower , 7- tool placement area, 8-sealed protective window, 9-dressing room, 10-cable; 401- base of 4, 402-a pair of mouths, 403- position control rod; 501-chassis of 5, 502-horizontal roller, 503- vertical roller.

Figure 1. Top view of the joint room structure.

Figure 2. Side view of the joint room structure.

The main components of the equipment system are the joint room body, the ventilation system for indoor environmental control, the air shower system, the temperature control system ,the air cleanliness detection system, the power supply and lighting system, the submarine cable bracket ,and the submarine cable fixed device with double head. The body of the joint room can be removed and moved, so it can be used at sea or on land. The submarine cable fixed device with double head fixes cables’ position by a pair of mouths that can be closed up and down. There are two submarine cable bracket, which are installed at the front and rear ends of the submarine cable fixed double-head mold base in the direction of the cable. There are two submarine cable brackets, which are placed along the direction of cables’ movement and in front of and behind of the submarine cable fixed device with double head. The submarine cable bracket has horizontal rollers and vertical rollers arranged in a regular manner. When submarine cables slide on the rollers, the rollers can reduce the moving frictional resistance and prevent the lateral slip of cables.
Conclusion

When laying cables at sea, the cables are mainly connected by flexible joints or rigid joints for different sea conditions. The main difference between the two types of joints is the different way of armoring. Whether joints are flexible or rigid, they need to be made in a standard and suitable environment, so a joint room must be placed on the ship. As a facility for the manufacture of submarine cable joints, joint rooms must be designed to take into account the impact of marine environment and the comprehensiveness of performance. Therefore, a qualified joint room should not only have sufficient strength to provide a safe and stable working environment for the staff in the room, but also be easy to manufacture, transport and disassemble. For example, the joint room should be an all-steel frame that is easy to manufacture, equipped with lifting lugs for movement, and can be used both on land and at sea. It should also be durable. All in all, the design of joint rooms should meet some technical requirements in consideration of the use conditions and performance. When preparing equipment in a joint room, except for the basic equipment of power supply and lighting, some environmental control equipment and related equipment for joint production are also essential. For safety reasons, monitoring equipment must be equipped for monitoring at any time, and joint making processes can be recorded to better ensure the quality of cable joints. According to the technical requirements of the use conditions and the main equipment, the main technical characteristics about joint room design can be summarized.

Figure 3. The bracket and the fixed device with double head.
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