Research on improving the ampacity of high voltage single core submarine cable

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ABSTRACT

Due to the unique structure and complex laying environment of submarine cable, its ampacity is always the difficulty of research, especially for the high voltage single-core submarine cable, the type-selection of armor has a great influence on the submarine cable's ampacity. In this article, the theoretical calculation and experimental study of the effect of armoring type selection on the ampacity of high voltage single-core submarine cable are carried out, according to the research, it is found that the ampacity of single core submarine cable could be increased by replacing part of the galvanized steel wires with copper wires in armor layer, furthermore, as the proportion of copper wire increasing, the ampacity will also increase. The method can be applied to the whole submarine cable or only to the loading end of submarine cable with bottleneck section on ampacity,etc, to achieve the optimum design of the cable ampacity, mechanical performance and material cost, reduce investment cost on submarine cable, obtain certain economic and exemplary effect.

KEYWORDS

High voltage; Single core submarine cable; Ampacity; Armor; Mechanical performance.

INTRODUCTION

With the global growing investment in renewable energy power, especially the offshore wind power industry, market demand for submarine power cable is rising. As the critical equipment for offshore wind farm access, grid interconnection, island power supply, power transmission across the rivers and oceans an offshore oil and gas platform, submarine power cable is an important foundation for building up a global energy internet. Submarine power projects are recognized as the most complicated and tough power transmission project. Therefore, the selection of the submarine cable is of particular importance

ARMORED DESIGN

Submarine power cable is generally constructed of water-blocking conductor, conductor screen, insulation, insulation screen, longitudinal water tightness layers and metallic sheath (typically lead sheath), polymeric inner sheath, armor bedding, armor and armor serving. Armor is one of the critical components in the submarine cable, which primarily provides the mechanical protection and stable tensile strength. Armor also has impact on the cable ampacity and its loss shall be taken into account to evaluate the influence [1].

During installation, submarine cable is subjected to the tensional forces contributed by static weight of the cable between the laying ship and the seafloor and dynamic forces when the laying wheel is moving up and down. The resultant force during installation is usually much larger than the static force when cable lays vertically toward seabed. The armor must also provide sufficient mechanical protection to avoid the threaten caused by the installation toos, fishing gears and anchors. In addition, for extra high voltage submarine cable, single-core design is normally employed for high capacity transmission on account of the limitation of manufacturing and installation.

In case of magnetic material applied as the armor in single-core submarine cable, hysteresis loss and eddy current loss will be generated in addition to the circulating current loss that occurs when armor is grounded at both ends. The total armor loss is comparable to the conductor loss, and even higher. As such, both armor loss and mechanical performance are important aspects to be taken into consideration for single-core submarine cable design [1]. Currently, magnetic galvanized steel wire and non-magnetic copper wire are typical armor types for single-core submarine cable. Galvanized steel wire, as magnetic material concentrates the magnetic field around the conductor generating loss and heat. Though pure copper wire has an advantage of low electrical resistance and high corrosion resistance, its high price leads to the increasing investment cost.

AMPACITY CALCULATION

The main basis of ampacity calculation of submarine cable is IEC 60287 and there are also other relevant international standards, such as IEC 60853, IEC 1042 and IEEE 835. The factors influencing the cable ampacity includes the conductor structure, maximum permissible operation temperature of conductor, insulation material, armor type and submarine cable installation conditions[5].

Principle of Ampacity Calculation

The permissible continuous ampacity of AC power cable can be calculated pursuant to the empirical equations in IEC 60287-1-1. See equation (1)

$$I = \left\{ \frac{\theta_c - \theta_a - W_d\left[\frac{T_1}{2} + n(T_2+T_3+T_4)\right]}{RT_1 + nR(1+\lambda_1)T_2 + nR(1+\lambda_1+\lambda_2)(T_3+T_4)} \right\}^{\frac{1}{2}} \quad (1)$$

Where:

I: conductor current, A;

θ_c: conductor temperature, ℃;

θ_a: ambient temperature, ℃;

W_d: dielectric losses per unit length per phase, W/m;

T_1: thermal resistance between per core between conductor sheath, K·m/W;

T_2: thermal resistance between sheath and armor, K·m/W;

T_3: thermal resistance of external serving, K·m/W;