LIFETIME PREDICTION BASED on ELECTRO-THERMAL AGING TEST and ELECTRIC FIELD SIMULATION of A NEW AC 500KV SUBMARINE CABLE

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ABSTRACT

This paper studied the XLPE insulation material of the new AC 500kV submarine cable with different aging conditions. The electro-thermal aging test was performed at 25 ℃/40 ℃ /55 ℃/70 ℃ with the time step of 60s, 120s, 240s and 480s.The accelerating thermal aging test was performed under 130℃.

Inverse Power Model (IPM) was used for the lifetime prediction with electro-thermal stress aging under 25 ℃/40 ℃/55 ℃/70 ℃. The lifetime index n and constant C under different tempretures were calculated and IPM under different temperetures were established.

The ε'_r and the $tan\delta$ of different aged samples were measured based on the thermal aged samples under 130 ℃. The ε'_r was used to simulate the changes of electric field of the service submarine cable under different aging conditions and the results of the simulation indicated the electric stress of aged XLPE insulation remain unchanged.

KEYWORDS

cross-linked polyethylene (XLPE), submarine cable, lifetime prediction, Frequency Domain Spectroscopy(FDS), simulation

INTRODUCTION

During the long-term operation of cable,. The 500kV power interconnection project in Zhoushan, Zhejiang province of China is currently the highest voltage and longest routing XLPE cable project throughout the world. The project will promise the reliability and stability of electric power transmission in Zhoushan island of China. However the high electric level and the long-term thermal stress will lead to the insulation deterioration which results in the insulation failure [1]. Aging of insulation materials after operation will be an important factor restricting the safe operation of the XLPE cable [2-3].

Life assessment of materials can effectively judge cable life. The commonly used life models are mainly divided into two types: the thermal stress life model based on the Arrhenius equation and the electrical stress life model based on the Inverse Power Model (IPM)[4-8].

On the other hand, simulation has been used to analog cable operation. Most simulations concentrated on the partial discharge of cables with aritificial defects. Simulation of partial discharge of cable joints and other parts illustrates the formation mechanism of cable interface and branch aging [9]. Literature [10] made a detailed analysis and improvement of the cable simulation method and model, and proposed method of double layered sheath in accurate HV XLPE cable modeling. However, few simulation based on dielectric properties has been reported.

The paper performed the aging experiments of 500 kV AC submarine cable insulation materials by step stress electrical aging under 25 ℃/40 ℃/55 ℃/70 ℃ and thermal aging at 130℃. Lifetime prediction model under different temperatures was obtained according to IPM. The dielectric properties of different thermal aged samples were measured at 25℃，40℃，55℃ and 70℃. COMSOL Multiphysics was used to simulate the electric field of the true cable according to the ε'_r of different aging conditions.

EXPERIMENTS

Sample preparation and aging

Sample preparation

The 500 kV submarine XLPE cable insulation material was provided by Zhoushan Power Supply Company of State Grid Zhejiang Electric Power Supply Company (China). Rectangular pieces (thickness:1mm,0.5mm, respectively) were prepared.

Electro-thermal aging

The electro-thermal aging test performed at 25 ℃/40 ℃/55 ℃ /70 ℃ and the electro-thermal accelerated ageing experiment was conducted for the new 500kV AC XLPE submarine cable insulation. The paper chose step-stress voltage as electrical stress for efficiency. The voltage step is 1kV, and the time step is 60s, 120s, 240s and 480s. The initial voltage is 10kV.The test electrodes were plate-plate electrodes with a diameter of 25 mm. Oil bath was adopted to control temperature. Nine tests were repeated at each temperature. The breakdown voltage and voltage duration of each test were recorded.

Thermal aging

This paper used the 401-C aging oven for accelerated thermal aging, and the aging temperature was controlled at 130 ℃. These samples were taken out according to the color changes of samples which were purple black finally. Samples aged at 130 ℃were taken out at 0-day, 40-day, 95-day, 125-day, 135-day and 160-day. Aged samples were placed in a plastic bag with desiccant and stored away from direct sunlight during the process of 24 h cooling.

FDS test and simulation

The XLPE sample was measured by the Concept80 broadband dielectric spectrometer of NOVOCONTROL Company. The rectangular sample was measured under frequency ranging from10^{-2} Hz to 10^{6} Hz with electrode