ONLINE-MONITORING OF THE CONDUCTOR TEMPERATURE IN MV POWER CABLE PRODUCTION USING ULTRASONIC DIAGNOSIS

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ABSTRACT

In this article a new method is developed which can be used to monitor the temperature at the conductor inside of the insulation system after cooling. Therefore ultrasonic impulses are sent into the insulation material, which are reflected at the conductor. The received ultrasonic signals are analyzed regarding amplitude and frequency behavior. A correlation between conductor temperature and ultrasonic signal is evaluated and compared with look-up table figures which have been developed in synthetic test arrangements before. Due to the significant temperature dependency of the acoustical properties of XLPE the ultrasonic amplitudes show huge dependency on the conductor temperature.

Using this method the inner temperature can be monitored and controlled online during the production process. Based on a critical ultrasonic amplitude threshold, which is directly connected to the critical conductor temperature, the cross linking process can be optimized in speed as long as the amplitude is below this critical threshold.

KEYWORDS

MV power cables, insulation system, cross linking process, heat transfer in cable core, ultrasonic testing, reflection coefficients, signal correlation.

INTRODUCTION

The main part of a power cable is the insulation system. Modern power cables consist of cross linked poly ethylene (XLPE) as a standard insulation material. The polyethylene is extruded on a metallic conductor and afterwards cross linked in the cross linking line (CV-line). Due to the high temperature in the CV-line the conductor is heated up. After the cross linking process the cable core is cooled down to room temperature by a water bath to stop the chemical cross linking process and to enhance mechanical stability to the cable core, which is spooled up on a drum for storage and degassing. Due to the high heat capacity of the metal conductor the time between cooling and spooling the cable core is a critical aspect. The cable core will be re-heated by the conductor especially at inner parts of the insulation system which degrades the mechanical stability and can restart a cross linking process due to the high temperature. Cross linking – usually done by adding peroxide – produces gas during the chemical process, so void accumulations inside the insulation system will be the consequence if there is no external pressure around the cable core. Additionally, the insulation material becomes weak under higher temperatures. In combination with external mechanical stress due to the guiding and the spooling of the cable core delaminations at inner parts of the core can occur.

To avoid critical temperatures inside the cable insulation and to secure the quality of the insulation system, the production speed of the cross linking line has to be reduced to ensure an adequate cooling of the core. Hence, the inner conductor temperature is an important process parameter to increase the speed and to ensure optimal quality of the produced insulation system.

BASICS OF ULTRASONIC TECHNIQUE

Acoustical waves with frequencies above 22 kHz are classified as ultrasonic waves (ultrasound). Those mechanical waves can propagate in materials due to the mechanical coupling of the molecules. There are two different types of waves: transversal and longitudinal waves. Transversal waves are not considered anymore because only longitudinal waves propagate in water, which is used as coupling liquid between ultrasonic transducer and test sample. Ultrasonic waves are generated by using a piezo ceramic which is triggered by a voltage impulse in the range of usual 100 to 400 Volts {1}. Figure 1 shows a typical ultrasonic impulse.

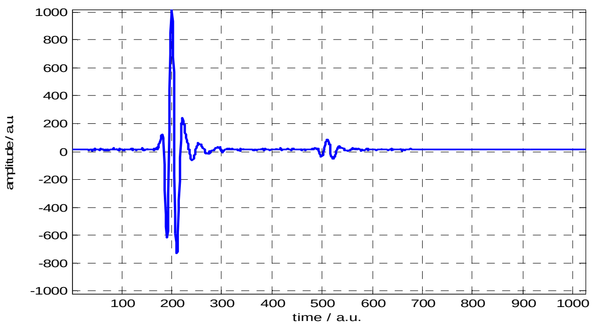

Fig. 1: typical ultrasonic impulse

This generated impulse is propagating in materials with a certain sound velocity *c* which can be calculated by

$$c = \frac{2s}{t} \qquad [1]$$

where *s* is the propagation distance inside the material and *t* the time of flight (TOF) which is needed by the impulse to propagate through the material {1}. Factor *2* results from reflection and the way back to the transducer. So, distance *d* is passed twice. In general, the sound velocity of polymer materials shows a certain dependency on temperature. So, the velocity c changes to a function of the temperature θ, $c(\theta)$ {3,4,5}.

Sound impulses propagating from the transducer through the sample are reflected at inner interfaces of two materials and propagate back to the transducer which receives the impulse. The reflection itself is caused by differences in the sound impedances *Z* of materials. The sound impedance is defined as product of density ρ and sound velocity *c* of the material: