Online monitoring of the cross-linking process of XLPE-insulated power cables during cable production using ultrasound

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ABSTRACT

Due to its excellent thermal and electrical properties, the insulation system of modern power cables is mainly made of crosslinked polyethylene (XLPE). By cross-linking the PE-material the thermal rating and therefore transmission capacity can be increased. Today's quality control of the complex cross-linking process is limited to sample tests. A detection of process faults is therefore delayed or impossible. In material investigations, the relationship between the degree of cross-linking and the sound velocity of the XLPE has already been demonstrated. Based on this, a demonstrator is constructed which simulates the motion sequences and conditions in the production line. On the basis of specially manufactured cable samples with different degrees of cross-linking, the evaluation procedure is transferred from the preliminary investigations to real cable geometries. The cable samples are scanned with ultrasound. From the determined wall thicknesses and the measured sound propagation time, the sound velocities of the different cable core samples are calculated. As a result, the cross-linking of a cable insulation system can be evaluated by focusing the sound velocity. The increasing trend of the sound velocity with decreasing cross-linking goes with the results of the material investigations.

KEYWORDS

Cross-Linking, Production-Process, Online-Monitoring, Ultrasound, Sound velocity, Defects, Eccentricity

INTRODUCTION

The current situation of energy policy poses new challenges to the transmission grid**.** Due to the increase in decentralized energy generation, it is necessary to reinforce existing transmission lines and to build further new power transmission systems.

Motivation

Modern power cables are predominantly made from polymer plastics. Regarding the insulation system, cross-linked poly ethylene has replaced oil and mass insulated cables [1]. The advantage of polymer insulated cables lies in the comparatively simple installation of the cable system, the increased transmission power due to optimized thermal characteristics and a long life time. So, the high quality of the cable insulation is fundamental. For achieving better thermal stability the poly ethylene is cross-linked during the production process. The cross-linking itself is a very complex process which depends on multiple parameters. The degree of cross-linking is usually controlled in a Hot-Set-Test at the beginning and the end of a production length. At present, a continuous monitoring of the degree of cross-linking is not established, although it is useful to achieve optimal cross-linking and to minimize rejects.

Preliminary Investigations

In power cable production the state of cure is assured by performing a Hot-Set-Test. Cutting the necessary samples out of the insulation destroys the cable core. Therefore, a check of the curing quality is only possible at the beginning, after few meters of produced length, and at the end of the production [2]. Fluctuations of the cross-linking process in the CV line over the full production length cannot be detected.

Past investigations show that there is a measurable relationship between the state of cure and the sound velocity of an ultrasonic signal [3,4,5,6]. Special XLPE block samples of different curing (Table 1) show a decreasing sound velocity with increasing degree of cross-linking.

Type	Class of cross-linking	Hot-Set-Result
A	Uncured	Ripping
B	Insufficient	225 %
C	Threshold	Ca. 173 %
D	Complete	77 %

Tab.1: Classification of block samples

Figure 1 shows the results of the preliminary investigations as a function of the degree of cross-linking at a usual CV-outlet temperature of 45 ° C.

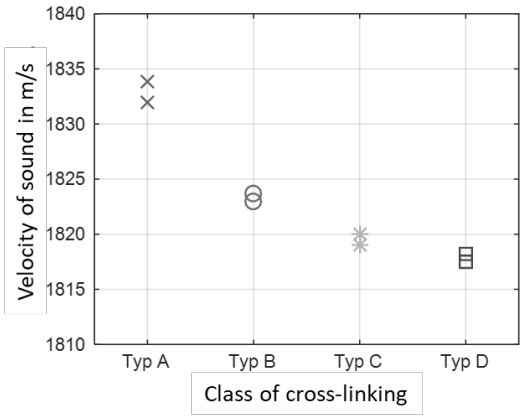

Fig. 1: Sound Velocity dependent on degree of cross-linking at 45 °C [6]

Further acoustic parameters such as sound attenuation and specific characteristics of the measured frequency spectrum were found to be unstable during the preliminary investigations, so it is not suitable for consideration. Focusing the velocity of sound, investigations on real 245-kV cable cores, which were especially produced with different degrees of cross-linking, will be presented below.