Measurement of the conductor temperature in power cable production

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ABSTRACT

In this article a method for the non-destructive measurement of the conductor temperature during power cable production is presented and optimized regarding different power cable designs. In the water cooling bath after the continuous vulcanization line the reflection of ultrasonic impulses at the interface between the XLPE insulation layer and the inner semiconductive layer is evaluated. Using the temperature dependency of the acoustic material characteristics a method for the estimation of the conductor temperature which was developed in previous works is presented. The method is refined in this article to take different cable and conductor geometries into account. Their influence on the measurement results is shown.

KEYWORDS

Power cable production, insulation system, temperature monitoring, ultrasonic testing

INTRODUCTION

In state of the art power cables polymeric insulation systems are used, with cross-linked polyethylene (XLPE) being the most common material. The insulation system, which consists of an XLPE insulation layer and an inner and outer semiconductive layer (short: semicon), is produced in two immediately consecutive steps. At first the raw plastic materials with incorporated cross-linking agents are extruded onto the metallic conductor. Subsequently, the cable core is fed into the continuous vulcanization line (CV-line), where the cross-linking is performed by first heating the cable core to activate the cross-linking agents. After cross-linking, the cable core has to be cooled down to stop the cross-linking process before the core leaves the CV-line.

Furthermore, a sufficient mechanical stability of the plastic insulation system has to be ensured, which is critical for the spooling of the core onto the drum for storage and degassing. Due to the high thermal capacity of the metallic conductor, the cable core may be reheated from the inside during cooling in the water bath from outside. This reheating process can lead to a degradation of the mechanical stability and to a reactivation of the crosslinking process, which produces gaseous byproducts that can lead to the formation of electrically critical voids in the insulation system. Hence, the production speed has to be reduced to ensure sufficient cooling and to eliminate the appearance of critical temperatures. Therefore, the temperature inside the cable core during cooling is a key parameter for the production of the insulation system. The knowledge of the conductor temperature would be helpful for a continuous optimization and control of the production process. Previous works have shown that the ultrasonic measurement technique can be a suitable tool for the measurement of the conductor temperature [2-4].

METHODICAL APPROACH

The measurement of the conductor temperature in power cable production relies on the evaluation of ultrasonic measurement data on the power cable core. In general, acoustical properties of polymeric materials show a dependency on temperature [2-4]. Therefore, ultrasonic measurements are performed on power cable cores with variation of the conductor temperature to verify the dependency of measured ultrasonic amplitude on temperature. Additionally, different cable core designs with varying insulation thickness as well as conductor designs are investigated to assess the influence of the design onto the measurement method. In particular, the influence of the movement of the power cable core during production is examined. Based on the amplitude of the reflected impulses in the cable core and simultaneous temperature measurement using thermocouples, a measurement method for the conductor temperature is developed and discussed.

ULTRASONIC MEASUREMENT TECHNIQUE

Ultrasonic measurement technique uses acoustical waves with frequencies in the kHz to MHz range, which are generated in an ultrasonic transducer using the piezoelectric effect, for the examination of materials. The excitation of the piezoceramic is achieved by voltage impulses in the range of 100 to 400 V. In principal, two different wave types can be created, which are longitudinal and shear waves. For the application of ultrasound measurements in cable production, water of the cooling pipe is used for acoustic coupling between the transducer and the cable surface. Shear waves cannot propagate in water and are therefore neglected in the further elaboration [1]. In Figure 1 a typical ultrasonic impulse with a center frequency of 2 MHz is shown.

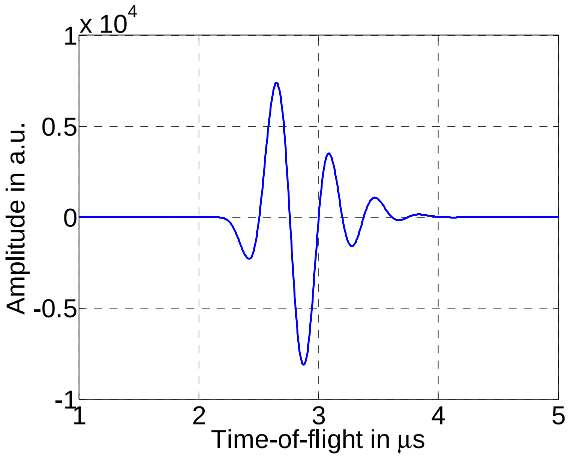

Fig. 1: Typical ultrasonic impulse