Combined VLF Withstand Testing and Cable Fault Pre-Location – A Field Study

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ABSTRACT

To ensure reliable operation of power cables, they need to be tested. While cable testing, pre-damaged cable insulation may break down, resulting in an arc, which enables to locate and repair the damaged cable section. For this purpose, various cable fault location methods have been established. After an arc occurs these methods are applied with an additional cable fault location equipment. This paper introduces a new approach, where cable testing and cable fault pre-location are combined in one device. To test the device's feasibility a field study was conducted, which is presented in this paper.

KEYWORDS

VLF cable testing, cable fault pre-location, arc pre-location, APL, simultaneous cable testing and fault pre-location

INTRODUCTION

Secure supply of electricity and a reliable operation of the power system can only be guaranteed if the transmission cables are in a sound state. Therefore, regular or condition-based cable testing should be performed. Various test methods have been established to examine the condition of power cables [1-3]. A precise, reliable and commonly used test method is very low frequency (VLF) cable testing. VLF testing is an offline voltage withstand test and is described and recommended in standards such as IEEE 400.2 or CENELEC HD 620 S2 as well as CENELEC HD 621 S1. The target of the voltage withstand test is to detect weaknesses in the cable insulation, when the cable is offline, to avoid a cable insulation breakdown during operation. While a healthy cable is passing the voltage withstand test unharmed, a cable with already damaged insulation will break down during this test, resulting in an arc [3].

In case of a fault, it is of great importance that the fault is located rapidly. Fast fault location can accelerate cable repair, reduce outage durations and avert economic losses [4]. VLF test sets generally show the voltage value at which the cable breakdown occurred as well as the elapsed test time, but they do not provide any information about the fault location. For the localization of the breakdown further tests and equipment are needed - typically carried out by a specially trained testing team with a cable fault location van. Cable fault location vans may not always be available when they are needed, because they are often a limited resource of distribution network operators (DNO). With such vehicles a driver's license for a gross vehicle weight over 3.5 tons might be required. Additionally, equipment within a test van is usually permanently fixed and cannot be used externally. If the vehicle breaks down, the equipment becomes useless. This can lead to longer downtimes of the cable. On the contrary, portable devices are not dependent on the availability of test vans.

This paper introduces an approach, where the functions of VLF testing and cable fault pre-location are combined in one portable device, including an automatic fault pre-location evaluation algorithm only requiring personnel with basic VLF testing training. The aim of this paper is to assess if this approach generally works and if so, how accurate the fault pre-location can be. To answer this question, a prototype was built, where an arc pre-location function was integrated into an existing VLF tester. With this device in-house measurements were conducted, which proved that this approach works under laboratory conditions. In a subsequent field study this device was used to test several service aged cables. In the case of an arc, this device also pre-located the distance to the arc. The results show that within this field study a combined VLF withstand testing and arc pre-location with only one device was possible and provided useful distance information.

CABLE FAULT LOCATION

Since there are several types of faults in underground cable systems, cable fault location depends to a great extent on applying the appropriate technique or a combination of techniques. With no less importance, competent engineers and service providers (mainly for the guidance) are required in order to provide the accurate method [5].

Fault location methods can be categorized into following principles: impedance based, traveling wave based and learning based [4]. Furthermore, the fault location methods can be divided into single ended and multiple ended methods [4]. Here measurements are performed at one or respectively multiple terminals. Various traveling wave pre-location methods have been established. They can be categorized in pulse reflection-based methods and transient methods [6]. In this paper we present a single ended transient based fault location method.

This method is based on an effect that appears when a cable insulation breaks down, due to stress induced by an electrical field. If an insulation breakdown occurs during high voltage testing, this will result in an arc. Such an arc has usually a very low impedance which will burn for a short period of time and discharge the cable capacitance. Furthermore, it initiates a high frequency wave which travels from the arc position into both directions towards the cable ends. These transient waves are then reflected with the same or inverted polarity, depending on the impedance at the cable ends and return to the arc location [7]. If the arc is still present, the transient wave will be inverted and travels again to the cable ends and so forth until the pulse amplitude decays due to damping within the cable [5,8].

The waves hereby propagate with a velocity typical to the cable. The propagation velocity is dependent on various variables like the cable's insulation type, age and temperature [5]. Furthermore it is also frequency dependent [8,9] which adds an uncertainty factor since the frequency spectrum of the traveling wave may not match the frequency spectrum the cable velocity was measured with.