Condition based maintenance of HV cable line using damped AC technique - a case study

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ABSTRACT

In this paper a case study is presented about a 27 years HV cable line which has been tested 5 times between 2012 - 2019. During this relatively long period the cable has been refurbished by the replacement of the outdoor terminations based on the diagnostic test results. Later, due to moving of the cable root and GIS switchgear replacement combined acceptance and diagnostic tests have been carried out. This case study emphasizes the effectiveness of the condition based maintenance by the regular diagnostic measurement. Moreover, it highlights that the weakest points of a cable line are the accessories.

KEYWORDS

high voltage cable termination, partial discharge, damped AC, onsite testing, weak spot analysis, voltage withstand test, condition monitoring, off-line test, condition based maintenance

INTRODUCTION

The cable networks play an important role in energy distribution however most of the cable lines have been in operation for 20 - 30 years. The safe future operation of the transmission, distribution grids requires the condition monitoring of cable lines, therefore the reliable diagnosis of this cable networks is a key question

The cable accessories are very complex components, and they are likely responsible for about half part of the unexpected cable outages. The most common condition monitoring techniques for examination of cable accessories are based on partial discharge (PD) measurement, because this method is feasible to locate the source of PDs. The damped AC (DAC) technique is one of the several diagnostic methods which is designed for detecting PDs. The DAC technique as a diagnostic tool for HV cable lines has already been used for ten years. This method provides several diagnostic factors such as PD inception (PDIV), and extinction (PDEV) voltage, phase resolved pattern (PRPD), PD map, loss factor, therefore it is an effective tool for cable diagnosis. Since, the DAC technique is able to generate test voltage above the nominal voltage, this test method can be considered as an acceptance test for the cable to be taken into operation.

HISTORY OF THE MEASURING SERIES

The 3542 m service aged 64/110 kV cable line has operated since 1992 to supply the customers of electricity company at residential area. During the entire lifetime it has operated reliably without any outages. Considering its age (more than 20 years), the operator decided to investigate insulation condition of the line. Initially the cable was mounted by the porcelain outdoor terminations at the near end where the tests have been carried out, and by the indoor plug-in terminations at the opposite site, where it is connected to a GIS switchgear. The cable line contains 4 straight joints and 1 screen grounded joint in each phase. Based on the first measurement results - as part of the refurbishment of the line - the porcelain terminations were replaced. After that due to cable trace replacement - as part of the reconstruction of the substation – cable sections and GIS plug-in sealing ends were replaced also. For condition monitoring DAC technique was used. The PD evaluation was carried out simultaneously according to both, conventional PD detection (IEC 60270) and time domain reflectometry (TDR) analyses for the localization of PD pulses. The diagnostic tests were complemented with the acceptance tests. The applied range of test voltage was up to 1.7U_0

The tests were carried out 5 times. The first measurement was carried out in 2012 and the last in 2019. The purpose of the tests during this 7 year period were different: eg. condition monitoring, trending the PDs in the joint and testing the quality of workmanship in case of termination replacement.

RESULTS OF THE MEASUREMENTS

First measurement

The first measurement was carried out in 2012. The results of tests can be seen on Table 1

	L1	L2	L3
Groundnoise [pC]	58	47	63
PDIV [kV RMS]	76.4	75.7	76.4
PDEV [kV RMS]	64.3	66.9	64.1
PD level [pC] (PDIV)	106	102	83
PD level [pC] (Uo)	74	58	88
PD level [pC] (1.7Uo)	627	227	137
Capacitance [µF]	0.72	0.73	0.73
Frequency [Hz]	62.4	62.2	62.2
Diel losses [%] (Uo)	0.1	0.1	0.1
Diel losses [%] (1.7Uo)	0.1	0.1	0.1

Table 1

The Table 1 shows that the level of the background noise was quite low.

Fig. 1, 2 show the PRPD, PD amplitude of single sine wave and the pattern characteristic of multiple sine wave at 1.7U_0. in phase L1. The Fig. 3 shows the same measuring parameters at phase L2 also.