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Time and frequency domain based non-destructive diagnosis in comparison to destructive diagnosis of service-aged PE/XLPE insulated cables

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Résumé

L'état de vieillissement de 50 câbles à isolation polyéthylène et polyéthylène réticulé (PR) vieillis en service est examiné par le mesurage de la réponse électrique en domaine du temps de la fréquence. Les résultats sont comparés avec des essais destructifs, notamment l'essais de tension de claquage et l'examen microscopique.

Il est montré que les dégradations de type arborescence peuvent être révélées par la valeur du facteur de dissipation (tg S à 0.1 Hz) et par la valeur absolue du courant de dépolarisation (id (t=10s). Cependant, le facteur de dissipation est un meilleur indicateur que le courant de dépolarisation.

Abstract

The ageing state of approximately 50 different service-aged (partly water treed) PE/XLPE insulated medium voltage cables is investigated by dielectric response measurements in the time- as well as in the frequency domain. The results are compared to results of destructive tests, namely voltage breakdown tests and microscopical investigation.

It is shown that the water tree deterioration can be determined by the dissipation factor (e.g. tanδ at 0.1Hz) and by the absolute value of the depolarisation current (e.g. i_d(t=10s)). However, the dissipation factor is more sensitive to water trees than the depolarisation current.

1 Introduction

On-site diagnosis of e.g. water tree aged PE/XLPE medium voltage cables is one of the interests of power utilities. Reliable and economic electrical power distribution and the possibility of better investment planning are the main reasons for this interest.

The ageing of electrical insulation systems changes the so called dielectric response which can be obtained by capacitance and dissipation factor (tan δ) measurements in the frequency domain and/or by depolarisation or polarisation current respectively recovery voltage measurements in the time domain [1-15].

The dielectric response is evoked by well described dielectric and electrical processes (e.g. [2]), (i) fast and slow dipole orientation, (ii) electrode polarisation; (iii) charge injection leading to trapped space charge effects; (iv) tunnelling of charge carriers from electrodes to empty traps and (v) hopping of charge carriers from one localised state to another. Water trees increase the number of polarisable particles and traps due to newly formed interfaces. These interfaces (water trees PE) are the main contributions to the dielectric response [4, 5]. Note, the permeability inside water trees is higher than that of PE leading to charges at this interface (also known as interface polarisation).

The mentioned processes respectively the dielectric response can be described by several mathematical and physical models, as represented and discussed in detail in [2, 3]. The main purpose of this paper is, however, to study the relations between the different diagnostic methods and to correlate these results to the residual ac breakdown strength and the degree of water tree deterioration. Both are methods which are applied frequently to evaluate water tree aged cables in the laboratory.

Results of dielectric response measurements and destructive tests of approximately 50 different service-aged (partly water treed) PE/XLPE insulated medium voltage cables are presented and compared. Possible diagnosis criteria are discussed and recommended.

2 Experimental technique

Test objects

Table 1 gives an overview of the investigated PE/XLPE medium voltage cable samples and shows the huge variance with respect to different cable age, manufacturers, utilities etc. Each cable sample was prepared with a guard-ring arrangement as described in [1] to assure that no terminations respectively creepage currents over the terminations could influence the measurements.

No.	utility	pro-ducer	prod. year	insu-lation	V [kV]	triple ex-truded	no. sam-ples
S1	U1	A	1979	XLPE	12/20	no	11
S2	U1	B	1975	PE	12/20	no	4
S3	U1	C	1978	XLPE	12/20	no	3
S4	U2	B	1972	PE	12/20	no	8
S5	U3	C	1979	PE	12/20	no	5
S6	U4	C	1975	PE	12/20	no	4
S7	U5	C	1978	XLPE	12/20	no	2
S6	U6	C	1980	XLPE	12/20	no	5
S9	U7	B	1978	XLPE	6/10	no	4
S10	U8	B	1985	XLPE	6/10	yes	2
S11	U9	D	1980	XLPE	12/20	yes	2
S12	U10	E	1978	PE	12/20	no	3

Table 1: *Investigated service-aged cable samples*