Proposition of New Diagnostic Features for VLF Tan Delta Measurements in Order to Improve Their Interpretative Value

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ABSTRACT

Diagnostic based on the evaluation of VLF Tan δ are now well established and interpretative criteria in terms of boundaries for overall condition assessment are proposed in IEEE 400.2. One of the main limitation of this diagnostic method, in its current form, is that the user can only obtain a "general" assessment with no interpretation tool available to discriminate the type of problem(s) present on the tested circuit. In cases where the diagnostic outcome calls for an "action", because the circuit is assessed as in "bad condition", the user has no other option than to act on the whole circuit (wholesale replacement or rejuvenation). This paper proposes a preliminary set of new VLF Tan δ "advanced" diagnostic features that could help to provide information's on the type and severity of the aging or anomalous degradation present.

KEYWORDS

Very Low Frequency, Tan delta, Time evolution, Diagnostic Testing, Power Cable, Insulation degradation

INTRODUCTION

Diagnostic based on the evaluation of VLF Tan Delta are now well established and interpretative criteria in terms of boundaries for overall condition assessment are proposed in IEEE 400.2 [1]. The actual proposed criteria are: Mean Tan δ at service voltage (U_0), Voltage dependence (Tip-Up) between 0.5 U_0 and 1.5 U_0 and Time stability (expressed in terms of standard deviation of TD values) at service voltage. As proposed now, condition assessment goes as: "No action", "Further study" and "Action required" (based on the figures of merit presented in the following section [**Table 1**]).

One of the main limitations of the VLF diagnostic, as it is now, resides in the "global" nature of the assessment which leads to the lack of ability to "discriminate" various types of (internal or external) defects from each other. As for example, according to the actual interpretation rules, in cases where the assessment indicate a situation of "Action required", there is no way to know what component(s) of the cable system (cable, splice, termination) is (are) impaired with advanced degradation, nor is there a well-defined means to discriminate what kind of aging (e.g. water-treeing, thermal degradation, shield corrosion) is present within the cable system.

Because of that, according to the current interpretation, in cases of "Action required" the user has practically no other option than to act on the whole circuit (wholesale replacement or rejuvenation), with no means to optimize his repair or refurbishing efforts.

This paper proposes to explore the potential of making use of the currently unexploited information that may lie in the detailed VLF Tan δ numbers recorded during tests. Taking the benefit of cumulated experience of ~8 years of VLF Tan δ measurements in the lab and in the field, the author has been led to believe that some specific "patterns" or "features" could be associated (at least on an empirical basis) to specific situations of aging and degradation.

Such associations would be based on a number of empirical data coming out of experiments carried out on various samples of cable systems with specific and relatively known aging/degradation conditions. The associations could also be achieved through the use of proper understanding of a number of basic concepts of the physics involved in various aging and/or insulation degradation phenomena.

ACTUAL EXISTING CRITERIA & BEYOND

The actual guidance for interpreting VLF Tan δ test results is provided in the guide IEEE 400.2 – 2013 [1]. The figures of merit relating to the current three diagnostic features (described earlier) are summarized in **Table 1**.

Table 1: Figures of Merit for Condition Assessment of Service-aged PE-based Insulations (i.e. PE, XLPE, and TRXLPE) using Tan δ Measured at 0.1 Hz according to IEEE 400.2 [1]

Condition Assessment	STD U_0 [E-3]		TU U_0-0.5 U_0 [E-3]		TD U_0 [E-3]
No Action Required	<0.1	and	<5	and	<4
Further Study Advised	0.1 to 0.5	or	5 to 80	or	4 to 50
Action Required	>0.5	or	>80	or	>50

Since the release of the IEEE guide, the second phase of project CDFI ("Cable Diagnostic Focused Initiative") [2] has proposed an additional diagnostic feature called TUTU ("Tip-up of the Tip-up") which relates to the difference in mean Tan δ evolution from 0.5 U_0 to U_0 vs from U_0 to 1.5 U_0. Accordingly, CDFI proposes the figures of merit described in **Table 2**.

Table 2: Figures of Merit for Condition Assessment of Service-aged PE-based Insulations (i.e. PE, XLPE, and TRXLPE) using Tan δ Measured at 0.1 Hz according to CDFI II [2]

Condition Assessment	STD U_0 [E-3]		TU $1.5U_0$-$0.5U_0$ [E-3]		TUTU $(1.5U_0-U_0)-(U_0-0.5U_0)$ [E-3]		TD U_0 [E-3]
No Action Required	<0.1	and	<5	and	<2	and	<4
Further Study Advised	0.1 to 0.5	or	5 to 80	or	2 to 52	or	4 to 50
Action Required	>0.5	or	>80	or	>52	or	>50

A visual description of these diagnostic features is shown in **Figure 1**. One thing noticeable with the three diagnostic features used in IEEE 400.2 is that they only relate to "calculated" numbers without making any use of the "shape" aspect of the time evolution of measured VLF Tan δ values.

This is especially the case with the "time stability" diagnostic feature for which a roughly same value of standard deviation could actually be associated to very different figure cases of "time evolution" scenarios.