EVALUATION OF PD MEASUREMENTS ON MV CABLE SYSTEMS BY MEANS OF A WEB DATABASE

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ABSTRACT

The medium voltage (MV) cable network is an important asset of a distribution system. It represents a large investment, and it must guarantee a reliable operation and it is from economic point of view essential to extend the life time of the medium voltage power cables as much as possible.

It is known that with increasing age, the number of faults will increase and the power supply reliability might be reduced. Important symptoms of this degradation process can be related to discharging local insulation imperfections or defects which may occur in particular cable sections or cable accessories: joints, terminations. About 50% of failures in medium voltage power cable networks are related to insulation problems.

Insulation problems may have different origins : in new cables in joints and termination due to mounting faults or in aged cables in service due to degradation of cable insulation, or degradation of joints and terminations.

The use of onsite PD measuring systems is more and more common to detect and locate PD faults to prevent service failures and loss of power supply. To perform a PD measurement is today quite easy, but the interpretation of the results rise often more questions and makes the decision for replace or repair difficult.

The increasing number of joint failures prepared in the past 15 years was an initial point to establish a VDE-working group to collect and share experiences of onsite PD measurements. More than 30 German utilities and several manufactures of PD measuring equipment are members of the working group.

The outcome of this work is a WEB database, to collect in a clear structure the most important PD parameter of field measurements and the results of visual inspections of the located PD faults. Because the ignition of PD in a defect depends from the type of excitation voltage the database is structured accordingly.

The data collection in the database should be not limited on German utility and industry networks, but can be also used for worldwide input and use for interpretation of onsite PD measurements.

INTRODUCTION

It has to be pointed out that this paper is published on behalf of a VDE working group, which has discussed the content and structure of the data base in several meetings. The intention of this paper is to make us much as possible international experts aware about this database and motivate them to use it as a source of information for the evaluation of their own partial discharge measurements and hopefully to convince a big community to contribute active for this open knowledge source.

The physics and causes for PD defects in XLPE and PILC cable systems is mainly well known and described in detail in several publications. [1 - 8]

From the view of the network owner it is in the first line important to know, if the cable system is operating with permanent PD activity under normal service conditions or not.

The second important issue is the behaviour of the insulating system in case of over voltages due to earth faults or switching. In networks with resonance grounding a voltage of 1.7 Uo could be applied over some hours to the cables.

If a cable system has during normal operation at Uo continuous PD the question about the risk of these PD is raised.

Basically, three PD parameter are important for the judgement of the PD behaviour of a cable system.

PD Inception Voltage PDIV : The PD inception voltage is determined by a stepwise or continuous increase of the voltage applied to the test object. PDIV is the voltage, where measurable PD start, i.e., the sensitivity of the measuring system and the existing ground noise during the measurement influence the recording of the inception voltage.

PD Extinction Voltage PDEV : Since PD sources often show a hysteresis response regarding the inception and extinction voltage, i.e., the PD in ignited locations are often only extinguished below the PD inception voltage, the value of the extinction voltage is also important for the judgment of the risk factor.

PD Level : Normally, the average impulse charge at Uo is used as assessment criterion. There are some global experiences in order to evaluate the risk factor for the reliability of operation depending on the location of the PD (cable, joint, termination), the type of insulation of the cable and the design of the accessories.

The phase-resolved display of the PD offers for typical types of PD sources the possibility of comparison with so-called “fingerprints“. For GIS systems, there are already relatively exact characterizations. For cable systems, however, fingerprints depend on a number of influencing factors like the type of excitation voltage and nature of defect so that presently significant correlations are only possible in a limited value, but a useful additional information can nevertheless be derived.

For the network operator, the following requirements are important for the assessment of cable systems.

- The cable system should be free from PD at the rated voltage Uo.
- In networks with resonance earthed starpoint , there should not be any PD up to 1.7 Uo. Should this nevertheless be the case, the PD must extinguish again above Uo.
- For the PD diagnosis, a voltage shape should be used, which creates comparable PD parameter (inception and extinction voltage and PD level), such as the 50 Hz service voltage.
- The voltage stress during the PD diagnosis must incite the existing PD faults in order to detect them, determine the intensity and locate the position of the PD.
- The PD diagnosis must to take place non-destructively, i.e., no additional fault locations in the form of electrical trees should be initiated.
- When using power-frequency or similar voltage shapes, the gradual increase in voltage may be limited to levels up to max. 1.7 Uo during the diagnosis. This way, the risk of damage to the insulation is minimized.
- When using distinct different voltage shapes (e.g. 0.1Hz Sinus), there should be knowledge for interpretation how the obtained test readings can be transferred to 50 Hz service conditions.

For all the above mentioned topics the database www.vde-kabeldatenbank.de should provide information about PD parameter and the related nature of PD-defects. Exclusively data from PD measurements were implemented which are validated by visual inspections of the located PD faults. The nature of PD defect strongly determines the risk for a final breakdown in service and the reliability of the cable system. The documentation of PD parameter, typical PD pattern and pictures from dissection of located terminations, joints or cable segments (PILC) should help all users of PD measurement equipment for evaluation of their own measurements and decision support for maintenance or replacement activities.

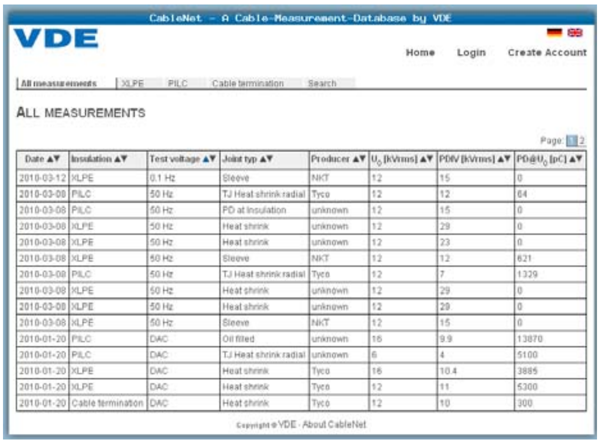
GENERAL STRUCTURE

PD diagnosis is preferably used for quality control of new installed cable circuits and to assess the condition of service aged systems. A typical demand for PD diagnosis is the investigation of serious failure occurrences in accessories after a certain time of operation.
For on site PD measurements at cable systems the following excitation voltages are commonly used.

- 50/60 Hz resonance technique (ACR)
- 50 – 500 Hz damped AC voltage (DAC)
- 0,1 Hz sinusoidal voltage (VLF)

Due to the physics of ignition of PD in voids, gaps or interfacial defects, the PD results of the different test voltages, especially ACR/DAC and VLF, are not directly comparable. Therefore the results in the database must be first sorted according the used type of test voltage.
The overview page displays the most important information on one view Fig.1 :

- type of cable
- type of test voltage
- type of joint or insulation failure
- nominal voltage Uo
- partial discharge inception voltage PDIV
- PD level at Uo



Date ▲▼	Insulation ▲▼	Test voltage ▲▼	Joint typ ▲▼	Producer ▲▼	U_0 [kVrms] ▲▼	PDIV [kVrms] ▲▼	PD@U_0 [pC] ▲▼
2010-03-12	XLPE	0.1 Hz	Sleeve	NKT	12	15	0
2010-03-08	PILC	50 Hz	TJ Heat shrink radial	Tyco	12	12	64
2010-03-08	PILC	50 Hz	PD at insulation	unknown	12	15	0
2010-03-08	XLPE	50 Hz	Heat shrink	unknown	12	29	0
2010-03-08	XLPE	50 Hz	Heat shrink	unknown	12	23	0
2010-03-08	XLPE	50 Hz	Sleeve	NKT	12	12	621
2010-03-08	PILC	50 Hz	TJ Heat shrink radial	Tyco	12	7	1329
2010-03-08	XLPE	50 Hz	Heat shrink	unknown	12	29	0
2010-03-08	XLPE	50 Hz	Heat shrink	unknown	12	29	0
2010-03-08	XLPE	50 Hz	Sleeve	NKT	12	15	0
2010-01-20	PILC	DAC	Oil filled	unknown	16	9.9	13870
2010-01-20	PILC	DAC	TJ Heat shrink radial	unknown	6	4	5100
2010-01-20	XLPE	DAC	Heat shrink	Tyco	16	10.4	3885
2010-01-20	XLPE	DAC	Heat shrink	Tyco	12	11	5300
2010-01-20	Cable termination	DAC	Heat shrink	Tyco	12	10	300

Figure 1. Overview page

By selecting one data set the detailed results of the PD measurement are shown and the related PD-pattern und pictures of the visual inspection can be examined Fig.2 ; 3.

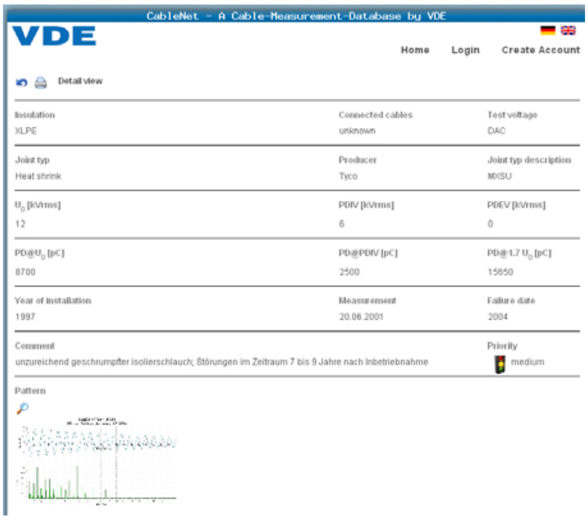


Figure 2. Detailed view of one data set

Figure 3. Image Viewer – pattern and pictures of visual inspection

Because PD defects in cable systems are mainly located in accessories the database is structured for the different type of accessory design.

Joint types for XLPE cable:

- heat shrink
- cold shrink
- slip on sleeve

Joint types for PILC and mixed cable:

- oil filled taped joint
- cast resin
- transition joint (TJ) cast resin
- TJ heat shrink (belted cable / radial field cable)
- TJ cold shrink (belted cable / radial field cable)
- TJ slip on sleeve (radial field cable)

Termination type:

- heat shrink
- cold shrink
- slip on termination
- elbow type
- oil filled

Results from PD in the insulation of PILC or in other type of accessory can entered as well, by creating new default descriptions. For search purposes various categories can be selected to obtain the best fitting data set for the comparison to an actual PD measurement Fig.4.

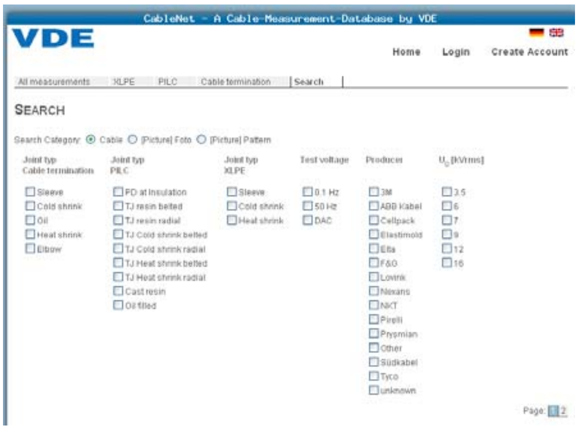


Figure 4. Search function with various categories

Additional filter functions in each column of the displayed spreadsheets help to find similar data for PDIV, PD level at Uo or other values of interest Fig 5.

Date ▲▼	Picture	Insulation ▲▼	Test voltage ▲▼	Joint typ ▲▼	Producer ▲▼
2010-03-11		XLPE	0.1 Hz	Sleeve	NKT
2010-01-20		XLPE	DAC	Sleeve	NKT
2010-01-20		XLPE	DAC	Heat shrink	Tyco
2010-01-20		XLPE	DAC	Sleeve	F&O
2010-01-20		XLPE	DAC	Heat shrink	Tyco
2010-01-20		XLPE	DAC	Heat shrink	Tyco
2010-01-20		XLPE	DAC	Heat shrink	Tyco
2010-01-20		XLPE	DAC	Heat shrink	Tyco

Figure 5. Example of search result

PARTICIPANTS AND HOW TO USE THE DATABASE

The use of the database is free of charge for all passive users and active participants. A registration is only necessary for new participants, which want to contribute with their own results to build up the knowledge base for all users. For searching or browsing in the database it is not necessary to register and login.

The entered data are anonymous and protected. The data can be modified or deleted only by the person who inserted the data set himself.

The major benefit of this database is the possibility to estimate the risk of the different types of PD faults. Most of the PD faults in accessories are caused by workmanship failures. The nature of these defects is often typical for the specific design of the different type of accessory. The severity of such defects depends strongly from the position and character of the fault.

For example a void between field stress tube and insulation tube of a heat shrink joint can “survive” over 8 to 10 years with a PD level at Uo of several thousand pC.

A much higher risk is caused by an interfacial defect underneath the field stress element, which can fail after some month of operation at 200 - 500 pC.

These typical PD defects can be identified by comparing PDIV; PD level at Uo , pattern and visible type of defect in the database.

The criticality assessment can be made on the bases of the pd parameter, the visible deterioration signs and the time frame between installation and date of replacement or failure.

To assess the results of an actual PD measurement the type

of cable as well as the location and type of accessories must be known.
In case of a single PD source the PD parameter can directly compared with results in the database.
Multiple PD faults in the test object must be differentiated by considering the local PDIV of the certain fault locations.

For this purpose the evaluation software of the PD measuring equipment should have the functionality to verify in the PD mapping not only the locations and PD values, but also the related voltage levels.

CONCLUSIONS

Currently the database can be used for the pragmatic comparison of PD results from similar test objects to get an idea how the nature and severity of the certain PD defect can be estimated.
Contributions to the database from a large number of participants should build up a comprehensive knowledge base in the medium term.
When sufficient data are available statistical approaches can be developed to create generic values for the risk assessment of specific PD faults in the several type of accessory. Interested Universities or other scientific institutions are highly welcome to support this work.
Thanks to all present members of the community related with the hope of further enthusiastic and qualified data input from worldwide participants.

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