Experience Report

About 10 years

”Voltage on-site Test on Medium Voltage Cable Networks by means of 0.1 Hz Cosine Square Wave Voltage” in the 10 kV network in the City of Dortmund

Introduction

Since 1987 the on-site voltage test on plastic insulated medium voltage cables on the 10 kV network in the city area of Dortmund has been provided by means of one of the first 0.1 Hz Cosine Square Wave Test Set (VLF Test Set) that was sold in Germany. Until end of 1997 3237 tests have been carried out. The experience and evaluation of the test results are given in this report.

0.1 Hz Test Voltage with square wave shape

The principle of the 0.1 Hz Cosine Square Wave AC Voltage enables the generation of the test voltage with less losses. The VLF Test Supplement transforms the DC voltage of the DC Test Set into the 0.1 Hz Cosine Square AC Voltage. Both weight and dimensions are much smaller than those of a 50 Hz AC Test Equipment. Beside ths the DC Test Generator that is installed into the Test Van is used as DC Source. This way the VLF Test supplement can be integrated into a Cable Test van without difficulties. The test power is sufficient for cable capacities up to 5 µF, this corresponds to a one phase cable length up to 25 km or a system length of 8 km. For cable networks inside the city almost all voltage tests are three phase tests.

Demands to the VLF Test as on-site testing on cables

- Suitability for paper and plastic insulated cables

  Cables are tested on-site to check the voltage strength of newly installed equipment, e. g. joints and terminations or of newly laid cables. ... In many cases of laying of new cables in the DEW 10 kV network plastic insulated cables must be connected with existing paper insulated ones. These ”mixed” cable lengths are tested by means of 0.1 Hz Cosine Square Wave Voltage because the DC test is not applicable to plastic insulated medium voltage cables. Even high DC test voltage levels do not show even very weak points caused by cable ageing or bad mounting. However, pure paper insulated cable lengths can be tested successfully by means of 0.1 Hz Cosine Square Wave Voltage as an alternative to the DC test.

- Low Test Voltage and short Test Time

  DC tests on paper insulated 10 kV cables are carried out by means of 36 kV (this is 6 x Uo). This test voltage level shows the cable faults within a test time of 30 min. The experience shows that this test does not cause new weak points that later in service appear as a breakdown. So as not to damage plastic insulated 10 kV cables during testing the VLF test is provided with 18 kV (this is 3 x Uo). Existing faults come to break at this test voltage and a test duration of 60 min.

- No additional damage of service aged cables

  It must be ruled out that after testing new faults are generated in the cable. The VLF Test meets this requirement for newly laid and normal service aged cables with solid welded outer conduct layer and PE sheath. Very service aged cables on which tests already have led to breakdowns of faults are tested with 10 kV. This way one ensures that until the replacement of this cable the remaining voltage strength is sufficient in case of a possible earth fault.

- Discovery of existing faults during the test

  All voltage tests for the discovery of existing faults are ”damaging” tests because in this cases a breakdown appears between core and sheath. Such faults must be detected within the test time of one hour.
  The experience shows that this test time is sufficient to bring the electrical trees to break down at the faults (=water trees) because of the high growing velocity that is typical for the 0.1 Hz Cosine Square Wave Voltage. Only in a very few cases other faults led to breakdown in service after the test was completed.
  The experience of VLF tests shows that the demands to a voltage tests are fully met. The experience provided below will confirm that.

<u>Experience with VLF voltage tests</u>

- Cable Test Procedure

  In 1988 – 1991 plastic insulated cables were tested by means of DC or VLF voltage. This was because on the one hand there was no knowledge about suitability of DC test on plastic insulated 10 kV cables and on the other hand both our Cable Test Vans were measuring equipment for a complete cable fault location were not installed into the. Thus the necessary tests after fault location were carried out by means of the installed into the test vans DC test sets. Since middle of 1991 all plastic insulated 10 kV cables including the mixed cable lengths were tested by means of 0.1 Hz Cosine Square Wave Voltage only. Also more and more paper insulated cables are tested with 0.1 Hz cosine square wave voltage.

  Voltage tests are provided:

  - After installation of a new cable as commissioning test (VBG 4 § 5)
  - After fault location
  - After network extensions and repairs as test before putting in service
  - After reconnection of cables in construction areas before putting in service

We do not test cables periodically or occasionally in sense of prophylactic maintenance or for evaluation of the ageing. In a few cases a voltage test of a cable can make sense for evaluation of the service reliability if a fault is supposed.

The test time of one hour is approved, it was fixed in the DEW standard.

Those cables that are aged heavily because of water-trees and that are supposed to show less voltage strength are tested with max. 10 kV for 30 min. In the 10 kV DEW network this concerns only the XLPE insulated cables with outer graphite conduct layer manufactured in 1977 to 1979.

All voltage tests are recorded. Beside all data of the tested cable all test parameters including the breakdown moment in case of faults are stored. All data recorded in these test protocols will be stored from 1999 in a data bank that is under development now. Also all sheath tests are registered in these protocols and the data bank.

- Evaluation of the VLF tests provided in 1998 to 1997

Within this period 3237 VLF voltage tests were provided on the 3184 km long 10 kV cable network.
2364 VLF Test were made on mixed (paper and plastic insulated) cable with a system length of 2425 km. There are 536 VLF voltage tests on plastic insulated cables with a system length of 536 km. Because of the good results of the VLF voltage tests mentioned above paper insulated cables with a system length of 305 km were tested in 337 VLF tests. For better comparison of the VLF voltage tests on mixed as well as on pure paper and plastic insulated cables these were separated accordingly. The following list shows the number of breakdowns per 100 km for the different cable insulation.

Table 1: Tested cables with different core insulation

Tests	Mixed insulation	Plastic insulation	Paper insulation
Number	2364	536	337
Tested system length (km)	2425	454	305

Table 2: Breakdowns during test

Test results	Plastic insulation	Paper insulation
Tested system length (km)	2149	999
Breakdowns	91	29
Breakdowns per 100 km	4.2	2.9

The test results show that existing faults during the VLF test come to breakdowns within the test duration is interesting, too. It shows whether the

test duration should be one hour as before or whether a shorter test time makes sense. The table 3 gives the information.

Table 3: Breakdowns over the test time

Period (min)	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60
Breakdowns	79	6	5	11	6	13
Result	90 = 75 %			30 = 25 %		

66 % of all breakdowns appear within the first 10 minutes of the VLF test and 75 % within the first 30 minutes. Not all faults grow so fast to breakdown that they appear within 30 minutes. However, these faults show themselves within the second half of the test time. The evaluation of the table 3 confirms that a test duration of 60 minutes is necessary to bring all faults in the cable, in joints and terminations to break. Besides it became clear that new inner faults on the tested cables leading to supply failures during the following at least 2 ... 4 years appeared only on cables with outer graphite conductive layer manufactured in 1977 to 1979. These heavily water tree damaged cables more often fail after the first inner faults. The experience shows that the VLF voltage test does not cause new faults in service aged cables and their equipment and the time when it came to breakdown during test.

Table 4: Analysis of faults

Breakdown within minutes	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 – 60
XLPE cable with outer graphite conductive layer	57	3	3	10	6	11
Paper insulated cable NAKBA	6	1	-	1	-	1
Paper insulated cable DNAKBA	2	-	2	-	-	1
Casted joint for paper insulated cables NAKBA	7	2	-	-	-	-
Wrapped joint for single core plastic insulated cables	1	-	-	-	-	-
Transition joint	6	-	-	-	-	-

The evaluation of the faults in combination with the breakdown period shows:

- All faults in joints, independent on their design, lead to breakdown within the first 20 minutes; most of them (88 %) even within the first then minutes.

- The breakdown properties of plastic insulated and paper insulated cables is comparable. 70 % of all faults com to breakdown within the first 30 minutes, most of them (63 %) within the first 10 minutes.

- Despite of the lower VLF test voltage in comparison to the DC test voltage faults in paper insulated cables come to breakdown within short time, so that this voltage test is well suited for paper insulated cables.

- Existing water trees in the XLPE insulation in a significant number of cases lead to breakdown only shortly before the completion of the one hour test time. That means that the test duration of one hour is correct.

- No one VLF voltage test led to a breakdown on terminations.

Conclusion

The demands to an on-site test of cable installations as described above are completely met by the VLF voltage test. The VLF voltage test has proven itself as useful toll of the preventive maintenance on cable installations. In combination with an as useful cable diagnosis an economical and effective cable maintenance that meets the demand of the power utilities could become possible in the future.

Source: DEW note
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