RECOMMENDATIONS FOR ELECTRICAL TESTS (PREQUALIFICATION AND DEVELOPMENT) ON EXTRUDED CABLES AND ACCESSORIES AT VOLTAGES >150 (170) kV AND ≤500 (525) kV

Working Group 21.03[1] and Task Force 21.18 of Study Committee 21

PREQUALIFICATION AND DEVELOPMENTS TESTS

CONTENTS

This paper is a revision to the work of Working Group 21-03 published in Electra No 151 [1]. It was prepared by Task Force 21-18 comprising R.SCHROTH (Germany), E.BERGIN (Ireland), E.FAVRIE (France) and S.FUKUNAGA (Japan).

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1 INTRODUCTION

During the Study Committee 21 Meeting in Paris in 1996 it was decided to form a Task Force, named TF 21.18, to extend the work performed by Working Group 21.03 to 500 (525) kV. The Terms of Reference were as follows:

- **field of activities:**

Extruded cables and accessories for rated voltages above 150 (170) kV up to and including 500 (525) kV. These cables are referred to as being in the E.H.V. range in this document.

- **Scope of work:**

a) To prepare recommendations for electrical type, special and routine tests based on extending the existing IEC 840 [2] standard on so far as is possible

b) To make proposals or guidelines for prequalification/development tests which, as a minimum, should be performed

- **Time schedule**

To present results at CIGRE Study Committee 21 Meeting in Glasgow in 1997.

The results of the deliberations are published in two parts, namely prequalification/development tests and the proposals for the revision of IEC 840. This document addresses the prequalification/development tests; the revisions to IEC addressing type, special and routine testing are the subject of a separate document [3]. The test requirements in the two documents are based on a common test philosophy which covers all tests from development to after laying tests.

The general methodology adopted was to try to extend IEC 840 to E.H.V. cables and, if this was not possible, to clearly state the reasons and the new values that might apply.

The extension of IEC 840 to E.H.V. cables merits extra consideration because of the following factors:

- E.H.V. cables form part of the backbone of a transmission system and, as a result, reliability considerations are of the highest priority.
- E.H.V. cables and accessories operate at higher electrical stresses than cables up to 150 kV and, as a result, have a smaller safety margin with respect to the intrinsic performance boundaries of the cable system.
- E.H.V. cables and accessories have a thicker insulation wall than those below 150 kV and, as a result, will experience greater thermo mechanical effects.
- the design and coordination of the cables and accessories becomes more difficult with increasing system voltage levels.

There is, at this stage, limited experience with extruded E.H.V. cables.

Because of the above factors, the Task Force has not only looked at the extension of IEC 840 to E.H.V. cables and accessories, but has also investigated if any additional testing such as development, prequalification or special tests should be recommended.

This recommendation has been produced on the basis of the current international "state of the art" knowledge in this field and should assist in the development and use of E.H.V. extruded cables and accessories. Nevertheless, it should be noted that the conclusions as outlined below will need to be carefully monitored in line with future experience and should be modified accordingly, as necessary.

2 BACKGROUND

At present cable systems are covered by development tests, type tests, special tests and routine tests. The details and schedules of the development tests, which are not officially specified, are at the discretion of the manufacturer and, as a result, may differ widely between manufacturers. While the type, special and routine tests, which are specified, have been adequate at voltages up to 150 kV, and indeed operating experiences have proven this, they are not adequate on their own to cover the extension to higher voltage cables. It is considered that in order to gain some indication of the long term reliability of the proposed cable system, it is necessary to carry out a long term accelerated ageing test.

The test should be performed on the complete system comprising cable, joints and terminations in order to demonstrate the performance of the system.

The concept of performing such a test is already well established in many countries [4] and [5]. This test shall be called a prequalification test and shall be performed as the final stage of the development process.

The term qualification test is often synonymous to type tests and hence the term prequalification has been used in order to differentiate between short term tests and the long term accelerated ageing test.

In drawing up the guidelines for the prequalification test it was necessary to take into account the possible existence of the "limiting electrical stress" [6][7].

Minimal criteria must be met in terms of components (lengths of cable, number of accessories) and test parameters (voltage level, duration, temperatures etc.) within the prequalification test regime. If these criteria are exceeded, it is acceptable but should not be interpreted as a demonstration of higher quality. The prequalification test is not designed to be used for comparison purposes between different cable systems or between different manufacturers.

3 DEVELOPMENT TESTS

Development tests shall be completed by the manufacturer before prequalification tests. The details of the tests shall be at the discretion of the manufacturer but should preferably include the following:

- Evaluation of material and processes, e.g. level of voids, contaminants, projections, etc.
- Evaluation of Weibull parameters [8]
- Determination of "*n*" - the long term life factor
- The tests could be initially based on model cables, but should be proven on full sized cables.

4 PREQUALIFICATION TEST

The prequalification test is to indicate the long term performance of the complete cable system and should be completed after the development tests have been carried out. The test need only be carried out once unless there was a substantial change in the cable system with respect to material, processing, design and design levels. Substantial change is defined as that which might adversely affect the performance of the cable system. In view of the importance of the prequalification test in indicating the reliability of the cable system the tests could be carried out with the involvement of an external competent witness.

In conclusion it is considered that long term performances can be best indicated by a long term AC test with heat cycles applied to the cable system.

4.1 TEST ARRANGEMENTS

Approximately 100 m of full sized cable including accessories (at least one of each type) should be tested. The test should be completed with the minimum of interruptions, bearing in mind the practicality of devoting one HV transformer for continuous voltage application over a long period.

It is considered important that the test arrangement should be representative of the associated installation design conditions, e.g. rigidly fixed, flexible system etc.. In particular special attention should be paid to thermo mechanical aspects of accessories.

4.2 TEST SCHEDULE

The level of test voltage and the associated test duration must be sufficient to verify the life expectancy of the system and to reveal the relatively slow ageing process including insulation shrinkage, corrosion, oxidation etc.. In addition a certain flexibility in defining the test parameters is necessary, in order to accommodate practical limitation and constraints with respect to test voltage, power availability, time and economic factors.

Having also considered the implications of the existence of threshold stress level, a test voltage of 1.7 U_o phase to earth voltage should be considered as being the upper limit with a corresponding test duration of not less than one year. If for practical reasons the test level must be lower, a corresponding increase in test duration is necessary (e.g. 2 years at 1.5 U_0).

The test assembly shall be subjected to repeated thermal cycles where the cable conductor temperature is raised to its maximum operating temperature and maintained at that temperature for 2 to 4 hours before being allowed to cool. It should be noted that it will probably be impractical to cool to ambient temperature within a reasonable time period. This cycle should be repeated for the duration of the test.

No failure shall occur.

4.3 PROVING OF TESTS

An impulse test shall be performed on completion of the long term AC test. The number of samples to be subjected to the test shall be three minimum, cut from the circuit (with an "active length" of a least 10 metres). Accessories should be excluded as they may be damaged or disturbed during the movement from the field test area to the laboratory.

The tests shall be completed in accordance with the revised IEC 840 specification with the exception that no AC test is required. The philosophy for the type test is that an AC test is carried out after the impulse test as a proving test, *i.e.* to prove the impulses have caused no damage. In the case of the prequalification test impulse voltage testing is carried out after the long term AC test to prove that the AC test caused no damage. In both cases the test is a combination of AC testing and impulse testing though to different test schedules.

5 REFERENCES

[1] Electra No. 151 (December 1993), p. 14-29.

[2] IEC 840 (1988) issue including amendment 1-1991-11 and Corrigendum of November 1988: Tests for Power Cables with extruded insulation for rated voltages above 30 kV (U_m = 36 kV) up to 150 kV (U_m = 170 kV).

[3] Recommendations for electrical tests (type, special and routine) on extruded cables and accessories at voltages >150 (170) kV and ≤500 (525) kV. / ***Recommandations pour les essais électriques des type, les essais sur échantillons et les essais de routine sur les câbles extrudes et leurs accessoires de tension >150 (170) kV et ≤500 (525) kV.***

[4] EDF spec HN 33-S-54 single core cables with polymeric insulation for 230/400/420 kV.

[5] Development and installation of 138 kV cable system at EEI Waltz Mill Station - G.Bahder et al., IEEE Trans PAS-91 July/August 1972.

[6] Research and Development in France in the field of Extruded Polyethylene Insulated High Voltage Cables / ***Recherche et développement en France dans le domaine des câbles haute tension isoles au polyéthylène extrude - R. Jocteur et al.,*** 1972 Report/***Rapport*** 21-07.[2]

[7] Influence of Surface and Internal Defects of Polyethylene Electrical Routine Test on VHV Cables - R.Jocteur et al., IEEE Trans, PAS, Vol. PAS-96 No. 2, March/April 1977.

[8] Application of Weibull Distribution to the Study of Power Cables Insulation / ***Application de las distribution de Weibull a l'étude de l'isolation des câbles électriques.*** Electra No. 127, 1989.

[2] Disponible au Bureau Central / Available at the Central Office.