JICABLE '95

A.3.2. Extrémités de câbles synthétiques THT avec isolateurs composites

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A.3.2. Composite EHV terminations for extruded cables

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Résumé

L'isolation synthétique est utilisée depuis plus de vingt ans pour les extrémités de cables en moyenne et haute tension.Si des solutions entièrement synthétiques peuvent être proposées en HT,il n'en est pas de même en THT.Les contraintes diélectriques rencontrées ne permettent pas de mettre le bloc répartiteur de champ en contact direct avec le milieu ambiant.Aussi un fluide et une protection externe constituée par un isolateur doivent être employés.Des isolateurs composites destinés à equiper des extrémités 225 kV ont été développés.Les extrémités présentées dans ce rapport répondent aux prescriptions de la Spécification d'Entreprise HN 68 S 23 d'EDF.Leurs performances sont comparées à celles d'extrémités traditionnelles sous porcelaine.Les essais de longue durée sont en cours et confirment l'excellent comportement de ces nouveaux matériels dont on peut dès à présent envisager l'emploi sur des liaisons provisoires.

Abstract

Synthetic insulation for cable terminations has been used for more than twenty years for medium and high voltage systems.If dry HV terminations can be proposed,the dielectric stresses encountered in service are such that it is not possible to let the stress cone without protection.An insulator filled with insulated liquid or gas must be used .Composite insulators have been developed to replace porcelain in 225 kV terminations. The terminations equipped with these insulators comply with EdF Company Specification HN 68 S 23 . The report compares their performances with those of traditional equipment using porcelain. Long term tests are in progress.They confirm the excellent behaviour of these new terminations,which can already be used for temporary links.

1- INTRODUCTION

Synthetic insulation for outdoor applications of cable terminations were first developed more than 20 years ago [1] to replace traditional porcelain terminations for MV and HV levels.

The advantages of those terminations over traditional equipment are well known :

- no risk of explosion or fire in case of internal breakdown,
- simplicity and ease of installation.

In the field of higher voltages,there is a need for terminations without porcelain to reduce the risk of explosion,but at the present time,synthetic terminations are not available and the use of an insulating fluid is required (oil or SF6). Hollow core composite insulators have thus been developed in order to offer a safer behaviour of the termination in case of breakdown.

The basic specification for the development of non-ceramic EHV cable terminations described in this report was the EdF Company Technical Specification HN 68 S 23 in use for cable terminations for 36 kV and above [2] which foresees the use of oil or SF6.

As a first step,225 kV terminations using composite insulators and filled with SF6 gas were developed,referring to IEC 815 [3] for the dimensioning of the insulator,as requested in the Technical Company Specification.

The choice of composite materials,the electrical and the mechanical dimensioning have been made taking into account long term exceptional stresses encountered during the service life of the accessory.

The report briefly recalls the technical requirements for a 225 kV termination as per HN 68 S 23, describes the design criteria and the choice of process and materials used,and compares the electrical performances of the resulting non-ceramic termination with the existing one using porcelain.

2- TECHNICAL REQUIREMENTS

Technical requirements are listed in the EDF Company Technical Specification HN 68 S 23 .

HN 68 S 23 covers outdoor terminations for extruded cables rated 36 kV and above.Main points of this specification taken into account for the development of porcelain-free terminations were:

*2-1 Rated voltages:*Uo/U(Um)=**130/225(245)kV**

2-2Short circuit rating=**31.5kA during 0.5s**

2-3 Construction and main characteristics of components

The insulator shall be dimensioned in accordance with the rules given in IEC 815(3).Maximum internal service pressure in case of use of SF6 gas shall be 3.5 bars gauge at 20°C.The termination shall be equipped with a pressure monitoring system.

2-4Type tests:

Type tests include short-term and long-term tests.

Short-term tests:

- hot impulse test : **10 pulses at + and - 1050 kV**
- power frequency test at room temperature:**350kV 24 hours**

Long-term tests:

6000h at 225kV($\sqrt{3}$ U_o) between conductor and metallic shield.In addition ,**250** thermal cycles are performed while the voltage is applied.

2-5 Special requirements for insulators

The insulator equipped with its metallic fittings shall be dimensioned according to the following table :

Height	2200/2800 mm
Leakage path	5450mm/6950mm/8200mm
Max.Horizontal Bending Force on top	200 daN
Internal diameter (Bottom)	320 mm
Internal dia (top)	166 mm
Bottom fitting	12 M 14/480 mm
Top fitting	8M 12/285 mm

Table 1 : 225 kV insulator dimensions as per HN 68 S 23

3 - CHOICE OF MATERIALS

The composite insulator designed to replace the ceramic insulator is composed of:

- a rigid fibreglass core equipped with its fittings
- a housing which protects the fibreglass core and provides the required leakage path.

The fibreglass core is made from E glass fibre impregnated with epoxy resin wound onto cylindrical or conical mandrel, at a specific fibre angle.

Silicon rubber is the prefered material for the housing, based on the experience gathered with the composite suspension insulators used for years on overhead lines.

This silicon rubber is optimised to obtain:

- a good ageing performance in severe conditions of pollution and UV[4][5]due to the high capability to recover hydrophobicity.The specific formulation of the silicon rubber has been adapted to the intended application which includes erosion resistance under high levels of surface activity in very severe pollution conditions.
- a high reliability of all the interfaces with the fibreglass core,the fittings and the sheds to guarantee a perfect impenetrability.
- a good mechanical resistance to take into account the accidental stresses during transportation and installation of the accessory.

4 - DESIGN AND DIMENSIONING

The termination is of the "stress cone and insulator "type,as described in the CIGRE Technical Brochure No 89[6](see fig 1).

The factory premoulded stress cone allows the electrical field control at the lower part of the termination and specially at the base of the insulator.

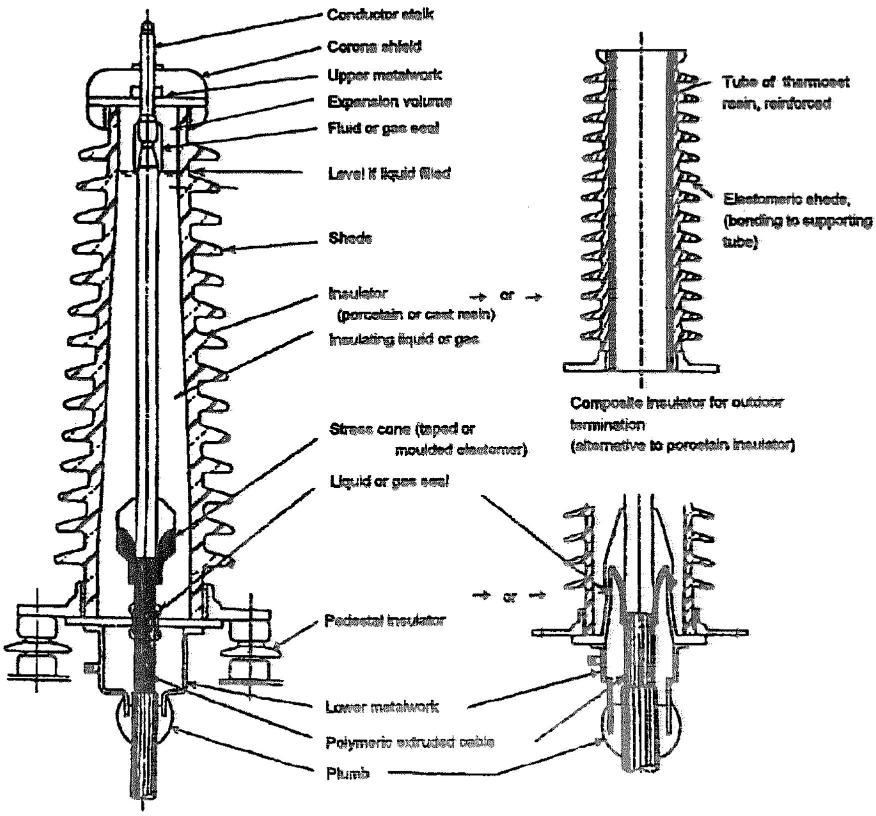

Figure 1. 'Stress cone and insulator ' outdoor termination

3-1 Electrical field calculation

The field calculation has been made in both types of construction,with composite and porcelain insulators,and with two different software packages (Electro and Flux 2D),with the same limits at the domain boundary.The equipotential lines given by Flux2D are shown in figure 2.

From the field calculation,it appears that the maximum electrical field calculated in the air under service conditions(Uo=130 kV),at the surface of the composite insulator is equal to 0.4 kV/mm which is far below the maximal electrical stress encountered in the case of overhead line composite insulators.

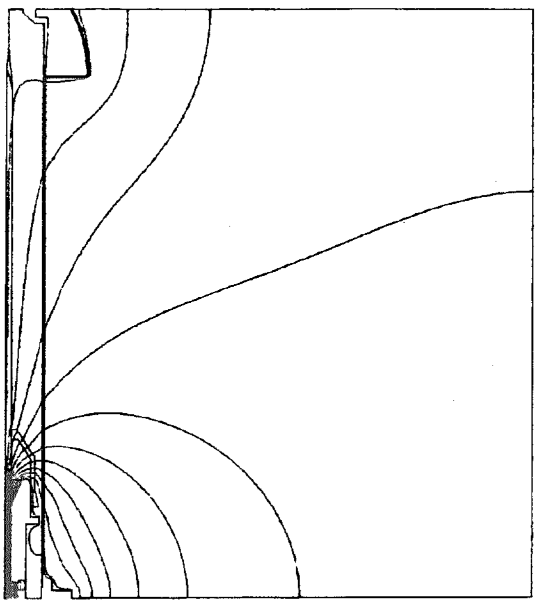

Fig 2: equipotential lines(flux 2 D)

3 -2 Mechanical dimensioning

General overall dimensions of the insulator required in the specification are given in table 1.
Mechanical performance of the insulator depends on the thickness and the winding angle of the fibreglass rigid core and on the dimensioning of the aluminium fittings.
To optimise this mechanical performance,finite elements mechanical calculation software has been used.
This calculation takes into account:
- the percentage of glass in the matrix
- the mechanical characteristics of the resin/fibre system using the local co-ordinates of each layer
- the maximum local stresses that can be supported in each direction
- the different winding angle of each layer
- the number of layers.

Previous SEE report [7] shows the calculated stresses in a composite cylindrical core and in the bottom metal fitting under internal pressure.

5 - PERFORMANCE

5-1 Mechanical performance

The composite insulator has been tested with an internal pressure of 23 bars during 5 minutes without any failure or leakage.
A top deflexion of 17mm under a load of 500 daN was measured.
These results were in good correlation with the calculations made with the finite element modelisation.

5-2 Electrical performance

Short time tests included in HN68S23 were carried out on two terminations using composite insulators.The short time test sequence was repeated four times and followed by investigation tests at higher voltages levels.

In addition,comparative electrical tests have been made on the same termination,successively equipped with composite and porcelain insulator.The following tests were performed:

1)Dry lightning impulse test
2)Wet switching impulse test
3)Dry power frequency test
4)Wet power frequency test
5)Pollution test

The comparatives electrical results of these tests are given in table.2

		Porcelain termination	**Composite termination**
Dry lightning impulse voltage	U50+	1250 kV	1205kV
	U50-	1307kV	1323kV
Wet switching impulse voltage	U50+	744kV	913kV
	U50-	857kV	931kV
Pollution flashover voltage	U50	166kV	>250kV
Wet power frequency flashover voltage	U50	387kV	560kV

Table 2:comparative results of electrical tests on porcelain and composite terminations.

Solid layer pollution tests which are very long and delicate have been made for high degrees of pollution,in order to obtain flashovers in a range compatible with the performance of the testing equipment.The ESDD of the layer was 0.4 ± 0.1 mg/cm² which is an exceptionally heavy pollution.
With the same dimensioning (height,leakage distance),the performance of the composite insulator under severe pollution appears to be 56% higher than the one of the traditional porcelain insulator.This result would have been even higher if the delay between the application of the pollution layer and the electrical tests had been long enough to allow total hydrophobicity recovery of the housing of the composite insulator.

Long terms tests on two terminations equipped with composite insulators are nearly finished.No problem occured so far.The test set up is shown in fig 3.

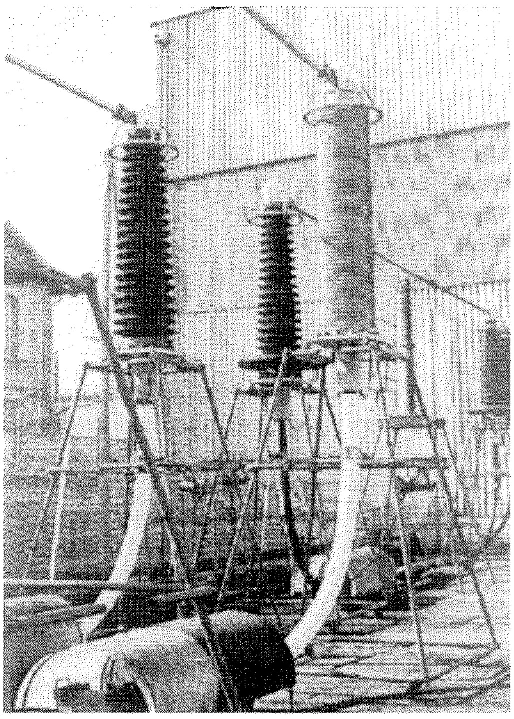

Fig 3: long-term test set-up

Other tests are scheduled to check the behaviour of the composite insulator in case of internal breakdown of the termination with full short circuit current.

6 - CONCLUSION

Hollow composite insulators designed to replace porcelain insulators for 245 kV SF6 cable terminations are more performant than porcelain insulators,with regard to test sequences in current specifications.

- All the short term tests given in HN68S23 specification are satisfied.
- Long term test is in progress and will be soon finished.
- Wet tests and artificial pollution tests (IEC 507 method) show a better performance with the composite insulator than with the porcelain insulator.

In addition,a short-circuit test with a pre-established internal fault is sheduled in the near future.

The use of composite insulators for 245 kV cable terminations is now envisageable.First immediate use will be to replace porcelain insulators for temporary terminations (with a total interchangeability). In the near future,composite terminations could also be used for permanent applications ,once their ability to withstand tests with combined climatic constraints has been demonstrated.

With a cost still higher than porcelain terminations,they provide a number of advantages :

- they increase the safety for persons and property near the equipment,
- they are much lighter and easier to handle:less damages during transportation or installation can be expected.,
- they offer better resistance to shocks and earthquakes.

Taking into account the advantages described above,the generalisation of composite terminations for permanent applications at 245 kV (and above)implies progress in cost reduction.

Regarding the real function and stresses encountered in service, constructive measures to optimise the design and the cost of the whole termination are being developed in parallel with the industrialisation of manufacturing cycles and process.

Development of oil-filled composite termination is part of this program. Studies have been initiated for 225 and 400 kV level.

7- REFERENCES

[1]S.Le Peurian,P.Dejean,P.Argaut:"Synthetic Terminations for High Voltage Cables.Assessment of service life" CIGRE Report 21-201 ,1992 SESSION

[2]Spécification Technique E.D.F. HN 68 S 23:"Extrémités de type extérieur pour cables unipolaires à isolation synthétique de tensions maximales égales ou supérieures à 36 kV"

[3]IEC 815 1986:"Guide for the selection of insulators in respect of polluted conditions"

[4]WB.Freeman,T.Orbeck,E.Moal:"Development of conical silicone rubber bushing to replace porcelain on SF6 circuit breaker " IEEE T & D,April 10-15 1994

[5]R.Parraud,R.Joulie:"Multistress testing of composite insulation" IEEE/PES T& D Polymer Material Pannel April 10-15 1994

[6]CIGRE WG 21-06:"Accessories for HV extruded cables" CIGRE Technical Brochure No 89,1995

[7]P.Argaut,M.H. Luton,R.Parraud,R.Joulie:"Non-Ceramic Terminations for Extra-High Voltage Polymeric Cables" SEE Conference June 7-8 1994