MASTER

EVALUATION, DESIGN, DEVELOPMENT AND
DELIVERY OF A 1200-kV PROTOTYPE TERMINATION

Ninth Technical Progress Report

Covering the Period From
December 1, 1980 to February 28, 1981

April 30, 1981

Westinghouse Electric Corporation
Power Circuit Breaker Division
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Contract No. DEAC01-78ET-29068

Sponsored By The U.S. Department of Energy

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of a 1200-kV Prototype Termination

Ninth Technical Progress Report

Reporting Period: December 31, 1980 to February 28, 1981

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Evaluation, Design, Development and Delivery
of a 1200-kV Prototype Termination

Ninth Technical Progress Report

April 30, 1981

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Evaluation, Design, Development and Delivery
of a 1200-kV Prototype Termination

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1.0 ABSTRACT

Tests are continuing on the shatter-resistant weathercase models and small samples. Two epoxy weathercase material samples are still undergoing accelerated tensile creep tests. Progress is reported on the design of the full scale prototype termination.

2.0 INTRODUCTION

This is the Ninth Technical Progress Report on the Evaluation, Design, Development and Delivery of a 1200 kV Prototype Termination. The SF₆ gas bushing termination will be integrated into a gas insulated substation. The produced design will be economically attractive and will exhibit improved electrostatic performance, acceptable temperature gradients, and better mechanical integrity when compared with the gas/air termination of typical ratings built with conventional technology.

The project is divided into nine tasks which include the evaluation of innovative and novel concepts and materials uses, thorough paper and model studies of the electrical, thermal and mechanical characteristics of the most promising configurations, designs, production and testing of a full scale prototype and finally delivery of the prototype termination to an appropriate field site. Tasks one through three are complete.

3.0 TASK 4 - MECHANICAL STUDIES

See section 4 for the report on the mechanical models and section 5 for the application of the mechanical analysis to the full scale prototype design.

4.0 TASK 5 - MODEL STUDIES

Additional hollow insulators are being made and will be hydrostatically burst as described in the previous technical progress report.

Improvements in the assembly of the fiberglass fabric into the mold before casting some of these insulators are expected to improve the static pressure strength of the finished insulators. Glued joints are also expected to be made and tested on some of the insulators.

The reinforced slabs have been prepared to test how well the shatter resistant material responds to temperature cycling. Results should be reported in the next period.

Long term creep testing of small epoxy samples described in the previous Technical Progress Report are continuing. Preliminary conclusions drawn from the testing to date indicate no changes are expected from the earlier reported data.

5.0 TASK 6 - DESIGN OF A PROTOTYPE

5.1 Electrostatic Analysis of Bottom End

The highest dielectric stresses in the prototype are at the bottom end. Care must be taken that the stresses in the gas, along the surface of the lower insulator, and in the volume of the lower insulator are all within acceptable limits. Electrostatic field plots and calculations were made to determine the best configuration.

The Seventh Technical Progress Report, October 17, 1980, Section 6.2-1 states that a practical limit for SF_6 gradient is 216 kV/cm (550 kV/in) for lightning impulses. The inner conductor was sized within the cylindrical portion of the throat shield to meet that limit. (See Figure 5-1).

The highest voltage gradient in gas is expected to appear on the outer surface of the support nut. A bulb shield is shown around the conductor just above the support nut to help limit the voltage gradients on the outer surface of the support nut and the triple points where the inner and the outer edges of the insulator and the nut intersect. Figures 5-2 and 5-3 show the magnitudes, shape and direction of the electrostatic field for that configuration. Figure 5-2 shows that although the stress is acceptable on the support nut, it gets as high as 267 kV/cm on the bulb shield. Examination of Figure 5-3 reveals that the presence of the relatively high dielectric constant insulator near the bulb shield forces the field to be high on the surface of the shield. The shape of the shield must be improved.

For comparison, the electrostatic field was calculated without the bulb shield. Figure 5-4 shows that now the gradient on the conductor does not increase as the support nut is approached. The maximum stress on the support nut as shown in Figure 5-5, is increased slightly but is acceptable. The maximum field along the surface of the insulator is 56 kV/cm which is significantly lower than the 93 kV/cm maximum surface

FIGURE 5-2
Voltage Stresses on
Lower End With
Bulb Shield (kV/cm)

FIGURE 5-3

Electrostatic Fieldplot of
lower end with bulb shield.

FIGURE 5-4

Electrostatic fieldplot
of lower end without
bulb shield.

5-6

FIGURE 5-5
Voltage Stresses on
Lower End Without
Bulb Shield (kV/cm)

gradient accepted on the 1200 kV bus support insulator developed by another project.* The 56 kV/cm is also the maximum gradient within the bulk of the insulator. This translates to a steady state 60 hertz stress of 18 kV/cm which is quite acceptable for long term application in epoxy insulators. Since this design adequately limits the stresses in the gas and on the insulator, no further bottom end shielding configurations will be considered.

Additional voltage field calculations will be made in the next period to verify the design of the shielding at the throat and at the top end of the termination.

*Prototype UHV Compressed Gas Insulated Transmission System (DOE Contract #E(49-18)-2061), Seventh Progress Report, May 1978, page 101.

5.2 MECHANICAL ANALYSIS OF TOP END

The detailed mechanical design of the air end of the termination was investigated. Four concepts were considered. Provisions for shielding the top end will be evaluated later.

5.2.1 Description of Design Types

Figure 5-6 shows Type 1. In this design, helical compression springs are used to provide the necessary force to compress the weathercase seals and counter balance the SF_6 gas pressure force on the weathercase. In addition, the springs must provide adequate force to prevent tilting of the weathercase against the forces produced by the wind and cable loads over an ambient temperature range from -40°C to $+40^\circ\text{C}$. A metal bellows provides a flexible SF_6 gas seal between the weathercase and the conductor.

The Type 2 design is shown on Figure 5-7. The springs serve the same function as in Type 1 and in addition then provide the counter balance force to the force produced by the SF_6 gas pressure on the top cover. Sliding fingers are used to provide the conducting path between the top cover and main conductor. The fingers allow for relative motion between the conductor and top cover plate. The motion is due to differences in thermal expansion and contraction of the conductor and weathercase.

Figure 5-8 shows Type 3. In this design the top bushing flange which was a separate aluminum plate in Types 1 and 2 is epoxy and is cast as part of the weathercase. The conductor is supported by this flange through the conductor top plate. No springs are required as a slip joint between the shield and cone at the bottom of the bushing compensate for the differences in relative motion between the conductor and weathercase. For this configuration, the weathercase is in axial tension.

FIGURE 5-6

Type 1 - Spring loaded bushing with bellows

FIGURE 5-7

Type 2 - Spring Loaded Bushing with Sliding Finger Contact Cluster

FIGURE 5-8

Type 3 - Flanged weathercase bushing.

Type 4 shown in Figure 5-9 goes one step further than Type 3. In this concept the conductor is mounted directly to the top flange of the cast epoxy weathercase. This reduces the number of parts needed. Otherwise it is the same as Type 3.

5.2.2 Discussion

Types 1 and 2 have the advantage that the large compressive force exerted on the epoxy weathercase by the springs helps reduce the scatter of the epoxy fragments should the weathercase fracture. Type 2 has the advantage over Type 1 that it does not require a large and rather expensive metal expansion bellows. Type 1 however, has the advantage that the spring force required is 24% lower than for Type 2.

Types 3 and 4 are probably less expensive than Types 1 and 2; however, they require a thicker walled and much more complicated weathercase. Should the weathercase fracture the epoxy fragment scatter would be much greater because the weathercase is in axial tension. The epoxy weathercase would not have the restraining compressive force supplied by the springs present in Types 1 and 2.

5.2.3 Layout Drawings

Because of the superior safety and reasonable cost of the Type 2 design, it was chosen for further study. Stress calculations were made to size the parts. Layout and most of the detail and assembly drawings incorporating these changes will be completed in the next period.

FIGURE 5-9

Type 4 - Flanged Weathercase Bushing with Simplified Top End

6.0 TASK 9 - REPORTING

Under this task the following reports were prepared and submitted to DOE during the reporting period:

<u>Quantity</u>	<u>Report Title</u>
3	Project Status Reports
3	Contract Management Summary Reports
3	Cost Management Reports
1	Conference Record
1	Technical Progress Report

6.1 Program Status

The progress of each individual subtask is shown in the program schedule Figure 6-1. This same schedule is incorporated in each quarterly report as a means of showing clearly the technical progress on the project.

6.2 Manpower Status

With regard to the manpower utilization in the project, the following key personnel have been committed to carrying out this project in an efficient and timely manner:

SCHEDULE FOR 1200 kV TERMINATION

TASK 1 - CONCEPTUAL DESIGN AND MATERIAL STUDY

- 1.1 PROBLEM DEFINITION
- 1.2 INNOVATIVE CONCEPTS
- 1.3 MATERIALS INVESTIGATION
- 1.4 FABRICATION TECHNIQUES

TASK 2 - ELECTROSTATIC STUDIES

- 2.1 SHIELD EFFECTIVENESS
 - 2.1.1 CONCEPT STUDY AND MODEL DESIGN
 - 2.1.2 ESTABLISH TEST OBJECTIVES
 - 2.1.3 DATA EVALUATIONS & RECOMMENDATIONS
- 2.2 RESISTIVE GRADING
 - 2.2.1 GRADING OBJECTIVES & CRITERIA
 - 2.2.2 DESIGN MODELS
 - 2.2.3 ESTABLISH TEST OBJECTIVES
 - 2.2.4 DATA EVALUATIONS & RECOMMENDATIONS
- 2.3 FIELD PLOTTING

TASK 3 - THERMAL STUDIES

- 3.1 THERMAL TRANSPORT STUDY
- 3.2 HEAT PIPE STUDY

TASK 4 - MECHANICAL STUDIES

- 4.1 SHATTER-RESISTANT WEATHERCASE
 - 4.1.1 CONCEPT STUDY, MODEL DESIGN, AND TEST CRITERIA
 - 4.1.2 DATA EVALUATIONS & RECOMMENDATIONS
- 4.2 REINFORCING LINERS
 - 4.2.1 CONCEPT STUDY, MODEL DESIGN, AND TEST CRITERIA
 - 4.2.2 DATA EVALUATIONS & RECOMMENDATIONS
- 4.3 CLAMPING AND FASTENING

TASK 5 - MODEL STUDIES

- 5.1 SHIELD EFFECTIVENESS
- 5.2 RESISTIVE GRADING
- 5.3 SHATTER RESISTANT WEATHERCASE
- 5.4 REINFORCING LINER

TASK 6 - DESIGN OF A PROTOTYPE

- 6.1 FINALIZE DESIGN PARAMETERS
- 6.2 MAKE ENGINEERING DRAWINGS
- 6.3 REVIEW AND EVALUATE

TASK 7 - PRODUCTION AND THE TESTING OF A PROTOTYPE

- 7.1 QUALITY ASSURANCE & PREPARATIONS FOR TEST
- 7.2 PROCUREMENT OF SPECIAL TOOLING AND COMPONENT PARTS
- 7.3 FABRICATING THE WEATHERCASE AND ASSEMBLING THE PROTOTYPE
- 7.4 ELECTRICAL DESIGN TESTS
- 7.5 OTHER DESIGN TESTS
- 7.6 REVISE & FINALIZE DRAWINGS
- 7.7 DISASSEMBLY PROTOTYPE
- 7.8 MODIFY PROTOTYPE
- 7.9 REASSEMBLE PROTOTYPE
- 7.10 COMPLETE TESTS

TASK 8 - DELIVERY OF THE PROTOTYPE AND MONITORING PERFORMANCE

TASK 9 - REPORTS & RECOMMENDATIONS

Figure 6-1

Key Personnel

Hours Worked During
Reporting Period
(Ninth Quarter)

J. S. Billings

232 Hours

Z. Neri

24 Hours

C. F. Hofmann

0 Hours

R. W. Crookston

0 Hours

Total manhours worked during the reporting period (including Key Personnel).

TASK 1 11 Manhours

TASK 4 72 Manhours

TASK 2 24 Manhours

TASK 5 44 Manhours

TASK 3 0 Manhours

TASK 6 412 Manhours

TASK 7 225 Manhours

7.0 SUMMARY

Additional models are being fabricated to prove that the addition of glass reinforcing fabric to cast epoxy weathercases has an insignificant effect on their mechanical strength. Long term mechanical creep tests are also continuing.

Rationale was given for choosing a springloaded double-ended bushing for the 1200 kV termination. Safety is the primary consideration.

Detailed dielectric stress calculations show that acceptable voltage gradients may be obtained. Further field studies are, however, still required.

The mechanical model studies, and most of the full scale design work is expected to be completed in the next quarter; ordering of parts and tooling for the prototype will soon commence.