CERTIFIED
TEST REPORT

Eaton's Cooper Power Systems

600 Amp - 35 kV Class
Deadbreak Bushing
With Internal Ground Screen

Design Qualification Tests

COOPER POWER SYSTEMS
By Eaton

600 Amp - 35 kV Class
Deadbreak Bushing
With Internal Ground Screen

Voltage Withstand
Qualification Tests

CERTIFICATION

Statements made and data shown are, to the best of our knowledge and belief, correct and within the usual limits of commercial testing practice.

Douglas H. Yute
Director – LIPE Engineering
12/18/13

John M. Makal
Senior Principal Engineer
12/17/13

Eaton's Cooper Power Systems
600 Amp - 35 kV Class Deadbreak Bushing
With Internal Screen

Introduction

Eaton's Cooper Power Systems 600 A 35 kV Class Deadbreak Bushing with internal screen is a one-piece integral apparatus bushing designed to be applied on 21.1 kV phase-to-ground systems and mounted to either mineral oil, Envirotemp™ FR3™ dielectric fluid, or SF_6 filled equipment. This report covers design tests conducted in both mineral oil and Envirotemp™ FR3™ fluid. The bushing interface is designed per the requirements of IEEE Std 386™-2006 standard, Figure 13 – 600 A Deadbreak Interface No. 1, 21.1 kV. The bushing is available in two (2) different continuous current ratings, 600 amps and 900 amps and with either the standard 150 kV BIL or a 200 kV BIL rating. The 600 amp bushing has a tin plated aluminum conductor rod and the 900 amp bushing has a tin plated copper conductor rod. The internal screen molded into the epoxy insulation is connected to ground with three (3) stainless steel clips on the bushing flange. The 150 kV BIL rated bushings are made with black colored epoxy and the 200 kV BIL rated bushings are made with reddish colored epoxy.

Object

To demonstrate that Eaton's Cooper Power Systems 600 Amp 35 kV Class deadbreak bushing with internal screen complies with the 35 kV Class 21.1 kV phase-to-ground design test requirements for non-elastomeric components outlined in the IEEE Standard "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems above 600V" designated as IEEE Std 386™-2006 standard and Eaton's Cooper Power Systems leak rate requirement for apparatus bushings.

Procedure

Design tests per Sequence A of Table 5, "Design Tests", were performed on Eaton's Cooper Power Systems 600 Amp 35 kV Class deadbreak bushings following the test procedures and requirements specified in IEEE Std 386™-2006 standard. Four (4) sets of bushings, 150 kV and 200 kV BIL having both aluminum and copper conductor rods, were tested in mineral oil. Two (2) sets of bushings with aluminum conductor rods were tested in Envirotemp ™ FR3™ fluid. Bushings were also leak tested per Eaton's Cooper Power Systems design test requirements. Sample bushings were randomly selected from finished goods inventory that had been checked for compliance to the dimensional requirements provided in Figure 13 of IEEE Std 386™-2006 standard.

35 kV 600 A Deadbreak Bushing with Internal Screen					
Design Qualification Tests IEEE Std 386™-2006		Number of Bushings Tested & Passed			
	Impulse Rating	150 kV		200 kV	
	Part Number	**DB635B150**	**DB935B150**	**DB635B200**	**DB935B200**
	Load Current	600 A	900 A	600 A	900 A
	Conductor	Aluminum	Copper	Aluminum	Copper
Test	Test Clause #				
A. Thermal Cycle	7.20	12	12	12	12
B. Leak Test	Cooper	12	12	12	12
C. Partial Discharge **26 kV CEV**	7.4				
Mineral Oil		12	12	12	12
FR3™ Fluid		10	-----	10	-----
D. AC Withstand **50 kV**	7.5.1				
Mineral Oil		12	-----	-----	-----
FR3™ Fluid		10	-----	-----	-----
D. AC Withstand **70 kV**	7.5.1				
Mineral Oil		-----	-----	12	-----
FR3™ Fluid		-----	-----	10	-----
E. Impulse Withstand **150 kV**	7.5.3				
Mineral Oil		12	-----	-----	-----
FR3™ Fluid		10	-----	-----	-----
E. Impulse Withstand **200 kV**	7.5.3				
Mineral Oil		-----	-----	12	-----
FR3™ Fluid		-----	-----	10	-----

Conclusion

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class deadbreak bushing with internal screen installed on mineral oil and Envirotemp™ FR3™ fluid-filled equipment met and exceeded the applicable 35 kV Class 21.1 kV phase-to-ground design test requirements for non-elastomeric components as outlined in IEEE Std 386™-2006 standard and Eaton's Cooper Power Systems leak rate design specifications. Representative samples of the 200 kV BIL rated bushings passed a 70 kV 1-minute ac withstand test and three (3) negative and three (3) positive impulse shots at 200 kV.

TEST - A
THERMAL CYCLE WITHSTAND TEST
Section 7.20

Object

To demonstrate that Eaton's Cooper Power Systems 600 Amp 35 kV deadbreak bushings having an internal screen with both copper and aluminum conductor rods meet the 35 kV Class IEEE Std 386™-2006 standard thermal cycle requirement of withstanding ten (10) -40 °C to +130 °C thermal cycles without damage and without impairing the bushing's ability to meet 35 kV Class partial discharge, ac withstand and impulse withstand requirements.

Procedure

Twelve (12) each of the internally screened 150 kV BIL rated and 200 kV BIL rated bushings in both the 600 A aluminum and 900 A copper styles were subjected to ten (10) -40 °C to +130 °C thermal cycles. The cycles consisted of a 1-hour dwell at the temperature extremes with 2-hour ramp times between extremes. After thermal cycling, each bushing was inspected for physical changes and damage.

Results

All 150 kV BIL rated and 200 kV BIL rated bushings in both the 600 A aluminum and 900 A copper styles tested withstood the ten (10) thermal cycles without any physical damage.

Conclusion

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class deadbreak bushings with internal screen withstood ten (10) -40 °C to +130 °C thermal cycles without any damage.

TEST - B
LEAK TEST
COOPER POWER SYSTEMS DESIGN TEST

Object

To demonstrate that Eaton's Cooper Power Systems 600 Amp 35 kV Class deadbreak bushings with internal screen meet Eaton's Cooper Power Systems maximum leak rate requirement for apparatus bushings of 1×10^{-6} cc/sec of helium gas after thermal cycling.

Procedure

After thermal cycling, twelve (12) each of the internally screened 150 kV BIL rated and 200 kV BIL rated bushings in both the 600 A aluminum and 900 A copper styles were fitted with a mating gasket and mounted to a pressure vessel. The shank end of the bushing was pressurized with a nitrogen / helium gas mixture to a minimum of 7 psig for twenty (20) minutes. The interface end of the bushing was then fitted with a cap having a leak detector probe that was connected to a helium mass spectrometer type leak tester.

Results

All 150 kV BIL rated and 200 kV BIL rated bushings in both the 600 A aluminum and 900 A copper styles tested had a leak rate less than $1 \times {}^{10\text{-}7}$ cc/sec. of helium, at least 1-order of magnitude less than the maximum limit of 1×10^{-6} cc/sec.

Conclusion

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class deadbreak bushings with internal screen met and exceeded Eaton's Cooper Power Systems maximum leak rate requirement for apparatus bushings of 1×10^{-6} cc/sec of helium gas after ten (10) thermal cycles.

TEST - C
PARTIAL DISCHARGE TEST
Section 7.4 (part of 7.20)

Object

To demonstrate that Eaton's Cooper Power Systems 600 Amp 35 kV Class deadbreak bushings with internal screen meet 35 kV Class IEEE Std 386™-2006 standard minimum partial discharge extinction voltage of 26.0 kV rms after thermal cycling.

Procedure

After thermal cycling, twelve (12) each of the internally screened 150 kV BIL rated and 200 kV BIL rated bushings in both the 600 A aluminum and 900 A copper styles were installed on a mineral oil filled tank and mated with a 200 kV BIL 600 Amp deadbreak insulated protective cap, DPC638.

Ten (10) of the internally screened 200 kV BIL rated bushings of the 600 A aluminum style were installed on an Envirotemp™ FR3™ fluid-filled tank and mated with a 200 kV BIL 600 Amp deadbreak insulated protective cap, DPC638.

Each bushing was tested for a minimum partial discharge extinction voltage of 26.0 kV rms. The partial discharge test was conducted by increasing the test voltage to 20% above the 26.0 kV rms partial discharge minimum extinction voltage or higher, until corona exceeded 3pC. Once partial discharge exceeded 3pC, the test voltage was lowered until the partial discharge dropped below 3 pC for a period of 3 to 60 seconds.

Results

All 150 kV BIL rated and 200 kV BIL rated bushings in both the 600 A aluminum and 900 A copper styles tested met or exceeded a minimum partial discharge extinction voltage of 26.0 kV rms in mineral oil. All 600 A 200 kV BIL rated bushings with aluminum conductor rods tested met or exceeded a minimum partial discharge extinction voltage of 26.0 kV rms in Envirotemp™ FR3™ fluid.

Conclusion

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class deadbreak bushings with internal screen met or exceeded the 35 kV Class IEEE Std 386™-2006 standard minimum partial discharge extinction voltage level of 26.0 kV rms in mineral oil after ten (10) thermal cycles. The representative samples of the 200 kV BIL rated version of the bushing also met or exceeded the minimum partial discharge extinction voltage level of 26.0 kV rms in Envirotemp™ FR3™ fluid.

TEST - D
ALTERNATING CURRENT WITHSTAND VOLTAGE TEST
Section 7.5.1 (part of 7.20)

Object

To demonstrate that Eaton's Cooper Power Systems 600 Amp 35 kV Class 150 kV BIL deadbreak bushings with internal screen meet the 35 kV Class IEEE Std 386™-2006 standard, 60 Hz, 1-minute voltage withstand requirement of 50 kV rms after thermal cycles. And to demonstrate that the 200 kV BIL rated bushings meet a 60 Hz, 1-minute voltage withstand test of 70 kV rms after thermal cycling.

Procedure

After thermal cycling twelve (12) each of 150 kV BIL rated and 200 kV BIL rated bushings with internal screen in both the 600 A aluminum and 900 A copper styles were installed on a mineral oil filled tank and mated with a 200 kV BIL 600 Amp deadbreak insulated protective cap, DPC638.

Ten (10) of the internally screened 200 kV BIL rated bushings of the 600 A aluminum style were installed on an Envirotemp™ FR3™ fluid-filled tank and mated with a 200 kV BIL 600 Amp deadbreak insulated protective cap, DPC638.

Each bushing was subjected to a 60 Hz, 1-minute ac withstand of 50 kV rms and higher for the 150 kV BIL bushings and 70 kV rms and higher for the 200 kV BIL rated bushings. The bushing assemblies were tested by raising the applied 60 Hz test voltage to the test level in less than 30 seconds and holding the voltage for one (1) minute.

Results

All 24, 150 kV BIL rated bushings (12 aluminum and 12 copper) tested in mineral oil, withstood 50 kV rms and higher for one (1) minute without a puncture or flashover.

All 24, 200 kV BIL rated bushings (12 aluminum and 12 copper) tested in mineral oil, withstood 70 kV rms and higher for one (1) minute without a puncture or flashover.

All 10, 200 kV BIL rated 600 A bushings with aluminum conductor rod tested in Envirotemp™ FR3™ fluid, withstood 70 kV rms for one (1) minute without a puncture or flashover.

Conclusion

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class deadbreak bushings with internal screen exceeded the 35 kV Class IEEE Std 386™-2006 standard, 60 Hz, one-minute ac voltage withstand level of 50 kV rms in mineral oil without a flashover or puncture after ten (10) thermal cycles.

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class 200 kV BIL rated deadbreak bushings with internal screen withstood a 60 Hz, 1-minute ac voltage withstand level of 70 kV rms in mineral oil without a flashover or puncture after ten (10) thermal cycles.

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class 200 kV BIL rated deadbreak bushings with internal screen withstood a 60 Hz, 1-minute ac voltage withstand level of 70 kV rms in Envirotemp™ FR3™ fluid without a flashover or puncture.

TEST - E
IMPULSE WITHSTAND AND VOLTAGE TEST
Section 7.5.3 (part of 7.20)

Object

To demonstrate that Eaton's Cooper Power Systems 600 Amp, 35 kV Class 150 kV BIL deadbreak bushings with internal screen meet the IEEE Std 386™-2006 standard 35 kV Class impulse voltage withstand requirement of 150 kV without puncturing or flashing over after thermal cycling. And to demonstrate that the 200 kV BIL rated bushing with internal screen can meet an impulse voltage withstand test of 200 kV without puncturing or flashing over after thermal cycling.

Procedure

After thermal cycling twelve (12) each of 150 kV BIL rated and 200 kV BIL rated bushings with internal screen in both the 600 A aluminum and 900 A copper styles were installed on a mineral oil filled tank and mated with a 200 kV BIL 600 Amp deadbreak insulated protective cap, DPC638.

Ten (10) of the internally screened 200 kV BIL rated bushings of the 600 A aluminum style were installed on an Envirotemp™ FR3™ fluid-filled tank and mated with a 200 kV BIL 600 Amp deadbreak insulated protective cap, DPC638.

Each bushing was subjected to three (3) positive and three (3) negative full wave impulses having a 1.2 x 50-microsec. wave and crest value of 150 kV for the 150 kV BIL rated bushings and crest value of 200 kV for the 200 kV BIL rated bushings. The bushings were energized under oil with a cable fitted with a ring tongue terminal that was seated flush to the end of the bushing rod. The cable was aligned at 90° to the bushing axis.

WAVE SHAPE

Measured Quantity	Tolerance +/-%
Crest Value	3
Front Time	30
Time to Half Wave	20
Nominal Rate of Rise of Wave Front	20

Results

All 24 150 kV BIL rated bushings (12 aluminum and 12 copper) tested in mineral oil withstood three (3) positive and three (3) negative 150 kV impulses and higher without a puncture or flashover.

All 24 200 kV BIL rated bushings (12 aluminum and 12 copper) tested in mineral oil withstood three (3) positive and three (3) negative 200 kV impulses and higher without a puncture or flashover.

All 10, 200 kV BIL rated 600 A bushings with aluminum conductor rod tested in Envirotemp™ FR3™ fluid withstood three (3) positive and three (3) negative 200 kV impulses and higher without a puncture or flashover.

Conclusion

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class 150 kV BIL rated deadbreak bushings with internal screen meet the IEEE Std 386™-2006 standard 35 kV Class impulse withstand voltage level of 150 kV and higher in mineral oil without flashover or puncture after ten (10) thermal cycles.

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class 200 kV BIL rated deadbreak bushings with internal screen withstood an impulse voltage level of 200 kV and higher in mineral oil without flashover or puncture after ten (10) thermal cycles.

The representative samples of Eaton's Cooper Power Systems 600 Amp 35 kV Class 200 kV BIL rated deadbreak bushings with internal screen withstood an impulse voltage level of 200 kV and higher in Envirotemp™ FR3™ fluid without flashover or puncture.

REVISION TABLE

REVISION NO.	DATE	*WHAT WAS ADDED/CHANGED*
1	3/15/2013	Added 200kV BIL rated bushing
2	12/17/2013	Added test results in Envirotemp™ FR3™ fluid

Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

Eaton's Cooper Power Systems Business
2300 Badger Drive
Waukesha, WI 53188
United States
Cooperpower.com

Printed in USA
Publication No.CP1214
December 2013

Cooper Power Systems
by EATON