POLYMER CONDENSER BUSHING WITH COMPOSITE AIR END SILICONE INSULATOR

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ABSTRACT

The use of non-ceramic composite insulators with silicone rubber has been steadily increasing since they were introduced in the 60s. Silicone rubber offers unique properties that make it more suitable for contaminated environment. This material is now being used more and more on different types of insulators and apparatuses. This paper describes the construction, design, and testing of a proposed IEEE Style, oil free polymer condenser bushing with a non-ceramic composite insulator and silicone rubber weathersheds.

INTRODUCTION

Non-ceramic composite insulators with silicone rubber weathersheds were introduced in the 60s and their use for outdoor applications has been steadily increasing since their introduction. The use of silicone rubber for outdoor applications offers unique advantages that make it more suitable for contaminated environments such as coastal and industrial areas. Silicone rubber is now being used more and more on different types of insulators and apparatuses. This paper describes the design, construction, and testing of a proposed IEEE Style oil free, dry polymer condenser bushing with composite insulator and silicone weathersheds for outdoor applications. The bushing is of oil free type and can be used at any angle from vertical to horizontal. The design can be converted from a draw lead application to a bottom end connected split conductor application. A summary of the tests specified in the program is included.

DESIGN AND CONSTRUCTION

Type CORIP bushings have been designed for application on oil filled transformers and reactors and meet or exceed the applicable requirements of IEEE Standards C57.19.00 – 1991 and C57.19.01 – 2000. The design offers a capacitively graded, oil free, dry polymer condenser bushing with a composite air end insulator and silicone rubber weathersheds for outdoor applications. The condenser consists of an electrical grade paper wound over a central winding tube. The condenser design is achieved by inserting aluminum foil layers at predetermined locations for distribution of stresses. The condenser core is then heat and vacuum dried and subsequently impregnated with an electrical grade epoxy. The cured resin paper condenser core has the electrical, mechanical, and thermal properties that make it suitable for application in oil filled transformer and reactors.

The air end insulator consists of a filament-wound glass fiber reinforced composite insulating tube with silicone rubber weathersheds for outdoor application. The lower end of the composite insulating tube is attached to an aluminum-mounting flange. The upper end of the tube is attached to an aluminum cap that enables the assembly of the bushing. The insulator is assembled over the upper part of the condenser in such a way that it makes a seal with the condenser in the mounting flange area as well as at the upper end. The insulator assembly with the mounting flange provides the bushing with mechanical strength as well as means to mount the bushing on the apparatus. The double, oil resistant O-ring seals at the top and bottom ends along with the composite insulator make the bushing design virtually impervious to moisture from the outside. Both the mounting flange and the upper cap are made of corrosion resistant aluminum.

The space between the condenser core and the composite insulator is filled with a specially formulated non-tar polymer compound, which after curing results in a hard rubber like consistency. This filler maintains its rubber-like consistency at temperatures typically encountered in oil filled transformer and reactor applications. The lower end of the resin impregnated condenser core is exposed to transformer oil. Since there is no liquid filler, the bushing is dry in nature and therefore not susceptible to any leaks or fire hazards and can be applied at any angle from vertical to horizontal. See Figures 1 and 2 for constructional features.
Constructional Features of Bushings 69 kV and Below

**FIGURE 1**

Constructional Features of Bushings Above 69 kV

**FIGURE 2**
The composite silicone insulator is designed to meet or exceed the heavy contamination creep distance requirements of the IEEE Standards C57.19.01 – 2000 and C57.19.100 – 1995. The use of non-ceramic composite insulator with silicone rubber weathersheds offers unique features that make this design more suitable for areas with contamination and seismic activity. In the absence of porcelains, the bushing is lighter, easier to handle and install. It is less susceptible to damage from vandalism, shipping, and handling. Because of these unique features, it is virtually maintenance free and its use will result in a cost effective product on an overall basis.

**RATINGS**

Initially, the bushings will be offered in the 34.5 kV, 69 kV, 138 kV, and 230 kV voltage ratings. The current ratings will be as per the table below:

<table>
<thead>
<tr>
<th>Voltage Class</th>
<th>69 kV and Below</th>
<th>Above 69 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw Lead</td>
<td>400 A</td>
<td>800 A</td>
</tr>
<tr>
<td>Split Conductor</td>
<td>1200 A</td>
<td>1200 A</td>
</tr>
</tbody>
</table>

**TEST TAPS**

**Test Tap**

Bushings rated 69 kV and below are provided with a test tap. This tap is connected to the outermost foil/layer of the condenser. It is designed to withstand the 2 kV/60 HZ, 1-minute requirement as per the IEEE Standard C57.19.00 – 1991 and the proposed revision of this standard. Under normal operation, the tap is automatically grounded to the bushing-mounting flange with the help of a spring provided in the tap assembly. This tap can be used for checking the power factor and capacitance of the bushing. See Figure 3a for test tap details.

**Voltage Tap**

Bushings above 69 kV are provided with a Type A (Normally Grounded) voltage tap as per Figure 1 of the IEEE Standard C57.19.01 – 2000. This tap is connected to one of the inner foil/layers of the condenser. It is designed to withstand the 20 kV/60 HZ, 1-minute requirement as per the IEEE Standard C57.19.00 – 1991 and the proposed revision of this standard. Under normal operation, the tap is grounded to the flange with the help of the tap cover. This tap can be used for checking the power factor and capacitance of the bushing. Also, this tap can be used in conjunction with a potential device for drawing a small amount of power for relaying purposes. See Figure 3b for voltage tap details.

![Test Tap Details Figure 3a](image1)

![Voltage Tap Details Figure 3b](image2)

**FIGURE 3**
APPLICATION

Type CORIP bushings are suitable for application in oil filled power transformers and reactors. They can be used in draw lead or bottom end connection split conductor application modes. The bushing can be converted from draw lead mode to a split conductor mode or vice versa by changing the necessary hardware. Both draw lead and the split conductor applications offer the advantage of removing or replacing the bushings without lowering the transformer oil. In the draw lead mode, the transformer current carrying cable is attached to the draw lead connector located near the top end of the bushing. In the split conductor mode, the transformer cable is attached to the lower terminal, which is an integral part of the split conductor. In the split conductor mode, the split conductor carries the current. Since the bushing is of oil free dry type, it can be applied at any angle from vertical to horizontal. The use of non-ceramic composite insulator with hydrophobic silicone rubber weathersheds allows the bushing to be applied in environment where contamination and seismic activity are an issue.

TERMINAL CONNECTIONS

Top End External Connection

Bushings rated 400 and 1200 A, are designed with a standard top end termination of 1.5 – 12 thread class UNF – 2A as per the IEEE Standard C57.19.01 – 2000. See Figures 1 & 2.

Bottom End Internal Connection

The internal connection to the bushing can be made using the following methods.

Draw Lead Application

In the draw lead mode, the transformer cable is brazed to a removable draw lead connector. The upper end of the draw lead connector also serves as the top terminal as shown in Figure 4.

Split Conductor Application

In this application, the bushing is supplied with a two-part split conductor. The two parts are connected together with bolted lap joint located in such a way that the upper part can be removed for transformer shipment without lowering the transformer oil. The top end of the upper split conductor also serves as the top terminal. The bottom end of the lower split conductor serves as the bottom terminal. Bushings, 69 kV and below and rated 1200 A are designed with a bottom end termination of 1.5 – 12 thread class UNF – 2A as per the IEEE Standard C57.19.01 – 2000. Bushings above 69 kV and rated 1200 A, are designed with a bladed bottom end terminal with NEMA 4 - Hole pattern. This type of termination eliminates the need of an external bottom end terminal that is generally required to connect the bushing to the transformer leads. See Figure 5 for more details. Also, split conductor bushings above 69 kV are provided with a bottom terminal shield.
TESTING

The following tests have been specified for these bushings.

**Design Tests**

Design tests are done as per the requirements specified in the IEEE Standards C57.19.00 – 1991 and C57.19.01 – 2000. These tests include Dielectric, Mechanical, and Thermal.

**Special Tests**

In addition to the above, the bushings / insulators/samples were subjected to the following tests.

- Front of Wave Test as per the proposed revision of IEEE Standard C57.19.00-1991 and C57.12.00-2000
- Tracking and Erosion Test as per IEC 61462
- Water Immersion Test
- Mechanical tests on insulators as per IEC 61462
- Tests on basic samples as per IEC 61462 which include dielectric, mechanical, and thermal tests

ADVANTAGES OF POLYMER BUSHING WITH SILICONE RUBBER OUTDOOR WEATHERSHEDS

The resin impregnated paper condenser core in combination with the non-ceramic non-brittle composite insulator with silicone rubber weathersheds provides the CORIP design with unique features. These features offer the following benefits to the users.

- Dry RIP condenser design with no liquid filler makes the bushing leak free and no risk of fire
- Silicone rubber has sustained hydophobicity, resulting in little or no washing, lower leakage current, reduced dry band arcing, and fewer chances of external flashovers in contaminated environment
- Silicone rubber is resistant to atmospheric degradation
- Non ceramic composite insulator with silicone rubber weathersheds is less susceptible to damage from vandalism, shipping, handling, and installation
- Proven performance in seismic and contaminated environment
- Absence of porcelains make the bushing lighter and safer to handle, transport, store, and install
- Absence of liquid filler enables the installation at any angle from vertical to horizontal
- Little or no wait time before energization due to absence of oil
- Split conductor/Draw lead designs allow easy removal/installation without lowering of transformer oil
- Does not require lowering of oil prior to shipment of transformer
- Convertible between draw lead and split conductor application modes
- Fewer maintenance checks due to absence of oil and porcelain
Overall, more cost effective due to fewer maintenance checks, little or no washing, and resistance to vandalism, shipping, and handling damage

Shorter lead times due to absence of porcelain

**SUMMARY**

Type CORIP polymer condenser bushing design, basically consists of an oil-free resin impregnated condenser core combined with a composite insulator with silicone rubber weathershed for outdoor applications. Being dry type, the bushing is leak free and has no risk of fire. The non ceramic composite insulator along with its end fittings, provide the bushing with the mechanical strength to withstand the design test and operating stresses and make it more suitable for areas with seismic activity. The silicone rubber insulator provides the bushing with features that make the bushing more suitable for areas with contamination. The bushing design can be applied either in a draw lead or a bottom end connected split conductor application mode. The design can be converted from a draw lead to a split conductor application mode or vice versa. The top end of draw lead and the split conductor also serve as the top terminal. The bottom end of the split conductor serves as the bottom terminal. The design offers unique features that make the bushing user friendly. In the absence of porcelain and oil, the bushing will require fewer maintenance checks and will be more cost effective on an overall basis. In the absence of porcelains, the design offers the advantage of a shorter lead-time.

**BIOGRAPHY**

Pritpal Singh is a Fellow Engineer with ABB Inc. in Alamo, TN and is engaged in business/product development activity. In the past 41 years, he has been involved in the design, development, and testing of transformers and bushings. He has held different technical and management positions in BHEL (India), General Electric (Pittsfield, MA), Westinghouse (Alamo, TN), and now with ABB Inc. (Alamo, TN). He has been an active member of the IEEE Transformer Committee for the past 20 years and was the Chair of the WG for the revision of IEEE Std. C57.19.01 – 2000. Presently, he is the Secretary of Bushing Subcommittee. He is a native of India and graduated in 1962 with a Bachelor of Science degree in Electrical Engineering from Aligarh University.

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