HVDC bushing without oil side porcelain
Type GOF, for outdoor mounting

Installation and maintenance guide
Safety information

Keep this instruction available to those responsible for the installation, maintenance, and operation of the bushing.

The installation, operation, and maintenance of a bushing present numerous potential unsafe conditions, including, but not limited to, the following:

- High pressures
- Lethal voltages
- Moving machinery
- Heavy components
- Slip, stumble or fall

Specialized procedures and instructions are required and must be adhered to when working on such apparatus. Failure to follow the instructions could result in severe personal injury, death, and/or product or property damage.

Additionally, all applicable safety procedures such as regional or local safety rules and regulations, safe working practices, and good judgement must be used by the personnel when installing, operating, maintaining and/or disposing such equipment.

Safety, as defined in this instruction, involves two conditions:
1. Personal injury or death.
2. Product or property damage (includes damage to the bushing or other property, and reduced bushing life).

Safety notations are intended to alert personnel of possible personal injury, death or property damage. They have been inserted in the instructional text prior to the step in which the condition is cited.

The safety conditions are headed by one of the three hazard intensity levels which are defined as follows:

_________________________ DANGER __________________________
Immediate hazard which will result in severe personal injury, death, or property damage.

_________________________ WARNING __________________________
Hazard or unsafe practice which could result in severe personal injury, death, or property damage.

CAUTION: Hazard or unsafe practice which could result in minor personal injury, or property damage.
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1 Description

1.1 Design

The dimensions of the bushing are given in the project specific dimension drawings. The design principle is shown in Fig. 1.

The bushing is built without insulator on the oil side, which means that the bushing shares the oil with the transformer/reactor. The oil conservator of the transformer shall be placed so that the oil level in the conservator is above the top end of the bushing. The air side insulator can be made either by porcelain or by a glass fibre reinforced epoxy tube, fitted with silicone rubber sheds (composite insulator). The air side insulator has flanges of cast iron in the top and bottom ends that are cemented to the porcelain. The respective connections to the top cover and the fastening flange are of aluminium for the composite insulator. The condenser body is wound on its own tube, concentrically mounted to the conductor tube and fixed by means of a clamping device that is bolted to the fastening flange.

The centre tube is made of aluminium or copper. This tube is used as the current conductor. The transformer leads are bolted by means of cable lugs to a bottom contact, made of copper. This contact is drawn against the lower end of the bushing tube by an aluminium/steel rod. See Fig. 7 for the design of the draw rod for aluminium conductors. If the conductor is made of copper, the draw rod has additional bolts of steel. This combination of steel and aluminium have approximately the same linear expansion due to the operating temperature as the copper conductor. The draw rod is connected to a spring device and bolted to the top of the bushing. This system gives the required contact pressure between the bottom contact and the conductor tube at all expected service conditions. The outer terminal may be of aluminium or copper.

During transport and storing the bottom part of the bushing is protected by a transport container.

To prevent gas bubbles from entering the bushing, the flange has a ring-shaped trap. See Fig. 1. The ring shaped trap, when turned 180°, serves together with a sealing ring of steel as a temporary seal during electrical test of the bushing. This temporary seal keeps the oil level correct during electrical test of the bushing. Before delivery from ABB Components the seal is removed and the trap is turned.

The GOF bushing is equipped with a tap connected to the outer layer of the condenser core. The maximum test voltage for this tap is 20 kV, one minute at 50 or 60 Hz. It serves as a test tap, and in connection with an external impedance it can be used as a voltage tap. The operation voltage is limited to 6 kV. The tap has dimensions according to IEEE, Potential tap type A, see Fig. 2a. For continuous measuring it can be furnished with a terminal box according to Fig. 2b.

The bushing is intended primarily as an outdoor bushing for DC smoothing reactors. It may however also be used on a transformer, and whenever transformers or reactors are referred to in the text, it should be read as either of the two types of equipment.
Fig. 1. Design principle. The figure shows a bushing with a composite insulator.
1.2 Voltage tap

In the mounting flange, a voltage tap is mounted that is insulated from the flange and connected to the outermost layer of the condenser body.

CAUTION: The voltage tap must always be earthed or connected to an impedance.

The voltage tap is shown in Fig. 2a.

Fig. 2a. Test tap, 2769 522-T, and test tap cover, 2769 522-M.
1. Cover, 2749 515-2
2. Cylindrical head screw, 2121 2459-220
3. Earthing spring, 9580 148-1
4. Gasket (O-ring) 64.5 x 3
5. Sealing plug, 2522 731-A, for oil filling, when use of potential device. Remove 15% of the total oil volume before sealing.
6. Bushing, 2769 522-N
7. Press screw, 2129 713-3
8. Disc spring, 2195 703-1
9. Gasket (O-ring) 24.2 x 3
10. Cable
11. Stud, 2769 517-6
12. Sealing washer 4.5 x 7
13. Stud, 2769 517-7

Fig. 2b. Terminal box for permanent connection to measuring circuits, 2769 522-C.

The terminal box shall be equipped with a suitable over-voltage protection in order to prevent damages during service. The cable gland shall be oriented downwards in order to prevent water from penetrating the equipment.

1.3 Spare parts

In case of major damage to the bushing we recommend that it is sent back to ABB Components for possible repair and re-testing. Certain parts, which may be damaged or lost during transport or installation, can be ordered from ABB Components. The article numbers or the dimensions are given in the figures.
1.4 Operating conditions

The table below show the standard technical specifications for the GOF HVDC bushings. For conditions exceeding the values below, please contact ABB Components.

**Common specifications:**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>DC-smoothing reactors. May also be used outdoor on transformers.</td>
</tr>
<tr>
<td>Classification</td>
<td>Oil impregnated paper, capacitance graded, outdoor-immersed bushing</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>+40 to -40 °C, minimum value as per temperature class 2 of IEC 137</td>
</tr>
<tr>
<td>Altitude of site</td>
<td>&lt; 1 000 m</td>
</tr>
<tr>
<td>Level of rain and humidity</td>
<td>1-2 mm rain/min horizontally and vertically, as per IEC 60-1</td>
</tr>
<tr>
<td>Pollution level</td>
<td>According to specified creepage distance and IEC815¹</td>
</tr>
<tr>
<td>Type of immersion medium</td>
<td>Transformer oil. Maximum daily mean oil temperature 90 °C, Maximum temporary oil temperature 115 °C</td>
</tr>
<tr>
<td>Mounting angle</td>
<td>0-15° from the vertical</td>
</tr>
<tr>
<td>Max. pressure of medium</td>
<td>100 kPa overpressure</td>
</tr>
<tr>
<td>Markings</td>
<td>Conforming to IEC/ IEEE</td>
</tr>
</tbody>
</table>

¹IEC815 “Guide for the selection of insulators in respect of polluted conditions”.

1.5 Mechanical loading

The bushings are designed for the following cantilever loads applied to the midpoint of the top terminal, perpendicularly to the bushing axis. In axial direction the GOF bushing can withstand 3.6 kN continuously. The maximum torque on the outer terminal stud is 250 Nm.

**Table 1. Mechanical loading**

<table>
<thead>
<tr>
<th>Bushing</th>
<th>Max. test load 1 minute (N)</th>
<th>Max. permissible load (N) in operation at mounting angle 0-15°</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF 141 002-G</td>
<td>5000</td>
<td>2500</td>
</tr>
</tbody>
</table>
2 Installation

2.1 Tools

- Soft slings
- Pull-through cord with M8 swivel 9760 669-A, see Fig. 3b
- Lifting gear, 9769 699-A, see Fig. 3a
- Jack (12 tons) with accessories (Manometer class 2.5) 9769 897-A, shown in Fig. 6
- Box spanner 9760 699-B, see Fig. 3c
- Tackle for mounting the bushing at a certain angle
- Torque wrench key for hexagon head screws, head width 16 mm (M10) and 13 mm (M8)
- Shackles, for hole Ø 28 mm, for connection of soft slings to the bushing flange

Fig. 3a. Lifting gear, 9769 699-A.

Fig. 3b. Flexible pull-through cord, 9760 669-A.

Fig. 3c. Box spanner, 9760 669-B.
2.2 Consumables
- Loctite 242
- Activator T 747

2.3 Transport and handling

CAUTION: The bushing may be transported and stored horizontally up to 6 months. For storing over 6 months it is recommended to raise the bushing to vertical position with the top end upwards, or leaned with the top end upwards at an angle of at least 5°. Keep the bushings dry and clean and protected against mechanical damage.

Keep the bushings protected from penetrating water when stored outdoors. This means that the case must not be stored in areas where it can be foreseen that the ground will be wet and muddy during heavy rains. Shelter the case from rain and snow with a tarpaulin or roofing.

Carefully inspect the bushing on receiving with regard to shipping damage.

The bushings are normally delivered from ABB Components in boxes with the bushing supported by cellular plastic or wooden blocks and fibre boards. The boxes are marked with "Top End".

2.4 Lifting from the box

WARNING
For lifting the bushing from the box, apply two clean lifting slings as shown in the figure below. Slings shall not be applied around the insulator as the sheds may be damaged. When placed on the ground, the bushing shall be supported at the same points as in the box or blocked under the top housing and the fixing flange.

The oil drain plug in the transport container shall be placed upwards.

Fig. 4a. Lifting from the box. (Bushing with procelain insulator).
2.5 Mounting

**CAUTION:** The bushing shall be completely drained from oil before mounting in the transformer.

With the bushing in horizontal position, hoses are connected through the drain hole in the transport container (max. diameter 30) and in the hole in the top cover of the bushing (one valve has to be removed) (max. diameter 13) so that the oil can be sucked out from the lowest level in each part of the bushing.

**CAUTION:** Always use clean and undamaged hoses.

The lower part of the draw rod, that shall be mounted in the bushing turret, is usually mounted inside the transformer and is held during transportation by a special bracket in the transport cover. Before mounting of the bushing, this cover shall be opened and the bracket loosened after which the bracket and the cover are removed.

When the bushing is placed on ground and the oil has been removed, remove the transport container as well as the outer terminal and the seal shown in Fig. 8.

Place the box spanner over the flexible pull through lead, Fig. 7, after which the lead is connected to the upper part of the draw rod. The draw rod is then inserted in the bushing centre tube. Mount the lifting tool, shown in Fig. 3a, and lift the bushing to vertical position according to Fig. 5. Lean the bushing to the mounting angle. Lower the draw rod so that the connection of upper- and lower part can be done. The bushing is now ready to be mounted in the transformer. The draw rod is mounted according to Figs. 6 and 7. The threads in the rods shall be cleaned and the joint locked with locking fluid 1269 0014-410 (Loctite) and activator Loctite T 747. When the draw rod is assembled, the bushing can be inserted in the transformer. Approximately 120 mm before final position the guiding cone at the bottom contact enters the bushing tube.
**CAUTION:** Be careful so that the connection in the transformer is not damaged.

Instructions for assembling the shielding system of the transformer is given in the product information for the transformer.

**CAUTION:** Check that the valves in top of the bushing are closed.

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**WARNING**

The condenser body must not be exposed to open air for more than 2 hours. However, the bushing is allowed to be without oil up to one week if it is mounted in the reactor or in the transport container. If it is necessary, this time may be prolonged up to maximum tree weeks provided that the vacuum time for the transformer is increased with additional 24 hours. and to have at least 5 days from the impregnation is complete (the oil level is above the bushings) to service voltage is applied.

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After bolting the bushing to the reactor, the draw rod is finally mounted according to Fig. 7.

**CAUTION:** The threads and the nut shall be lightly oiled before assembly. Try the nut on the rod to be sure that it can be threaded on easily.

The jack is then connected and a tensile force of 40 kN is applied. Tighten the nut by hand with the box spanner. The jack is then released and removed.
2 Installation

Hexagon nut M16
Box spanner ABB Art.No.9760 669-B
Conical washer 17x39x4
Washer 17x45x3
Washer of insulating material 16x76x3
draw rod, upper part

Hydraulic pump with manometer
The nut shall be mounted so that the free thread above it is > 10 mm

Jack (12 tons) with accessories (Manometer class 2,5)
ABB Art.No. 9769 897-A
The applied tensile force on the draw rod with the jack shall be 40 kN. Tighten the nut just by hand with the box spanner. The jack is then released and removed. Note that the sealing plug, figure page 8, shall be mounted.

Clean the threads from oil and lock the joint with Loctite 242 and activator T 747.
draw rod, lower part

Guide cone ABB Art. No. 4649 134-3 for aluminium conductor max. diameter 74 mm
ABB Art. No. 4649 134-6 for copper conductor max. diameter 68 mm
Bottom contact
Clean the threads from oil. Lock the joint with Loctite 242 and activator T 747.

Fig. 6.
Fig. 7. Mounting of draw rod.
2.6 Mounting of outer terminal

**CAUTION:** First mount the sealing plug LF 170 049-B according to Fig. 8.

**CAUTION:** Before connection of the conductor clamps to the outdoor side of the bushing, the outer terminal made of aluminium or copper must be carefully brushed and greased with a contact compound or vaseline. The inner contact surface on aluminium outer terminals and the contact surface on the bushing cap are tin-zink plated, and wire brushing must thus not be carried out.

Fig. 8 shows a standard current connection.

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![Diagram of outer terminal mounting](image)

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**Fig. 8. Mounting of outer terminal.**

In order to obtain the correct contact pressure and a low contact resistance, the following must be carried out:

1. Clean the contact and gasket surfaces carefully.
2. Lubricate the O-ring with Mobilgrease 28.
3. Assemble the tightening ring, the O-ring and the outer terminal stud and push them over the inner terminal.
4. Grease all bolts on the thread and underneath the head with Molykote 1000, or other suitable compound.
5. Insert and tighten the M10 screws with plane washers, which press the stud against the inner terminal. Tighten stepwise to a final torque of 40 ±4 Nm.
6. Insert the M8 screws with conical spring washers and plane washers, which hold the tightening ring. Tighten them to press the gasket into place. Tighten cross-wise to a final torque of 20 ±2 Nm.

**CAUTION:** It is extremely important in both cases to tighten evenly. The bolts shall thus be tightened in steps, alternately on both sides.
2.7 Flange earthing

The bushing flange is provided with a tapped hole M12. After tightening the bolts fixing the bushing to the bushing turret, the flange should be earthed. This prevents electrical discharges between bushing flange and transformer turret under normal service conditions.

**Alternative 1**

Insert a heavily greased (Mobilgrease 28 recommended) pointed set screw M12 (stainless steel A4+80 preferably). Tighten to 40 Nm, penetrating the paint of the bushing turret down to the metal underneath. This makes an electrical connection between the bushing and the transformer tank keeping them at the same voltage.

**Alternative 2**

Apply a flexible cable between the M12 earthing hole in the bushing flange and a corresponding connection point in the transformer. Grease the screw (Mobilgrease 28 recommended) and tighten the M12 in the bushing to 40 Nm. Connect the other end of the cable to the transformer.

2.8 Oil filling

Before oil filling of bushings and transformer, hoses are connected to the oil filling valves in top of the bushings and to the vacuum/oil filling equipment. When the bushing is completely oil filled, the valves are closed and the hoses removed. The hole in the valves shall be plugged with sealing plug 2522 2028-4 and thread tape.

2.9 Dismounting of bushing from transformer

After dismounting of the bushing from the transformer the transport container shall be mounted. The bushing and the transport container are then filled with dry clean transformer oil after which the expansion volume according to Table 2 is removed from the top of the bushing. The valves in the top of the bushing are then closed and plugged. The sealing plug and the outer terminal must be mounted.

The bushing is then stored leaned with the top cover upwards in an angle $>5^\circ$. If your bushing is not in the table below contact ABB Component for correct information

<table>
<thead>
<tr>
<th>Type of bushing</th>
<th>Drawing no. see rating plate</th>
<th>Oil volume to be removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOF 1550</td>
<td>LF 141 002-4</td>
<td>130 litres</td>
</tr>
</tbody>
</table>

2.10 Recommended tests before energizing

The following tests may be performed to check the insulation, sealing and current path of the bushing. The tests should be made after mounting, but before connecting the outer terminal of the bushing to the rest of the switchyard power circuit.

1. Tightness test between transformer and bushing flange.
2. Measurement of capacitance and tan $\delta$. 
2.10.1 **Tightness test between transformer and bushing flange**

Several different methods may be used and we thus refer to instructions given by the company responsible for the field erection. As a simple example, the tightness of the seal between transformer and bushing flange may be checked when the transformer is oil-filled by using chalk or, perhaps easier, with paper strips.

2.10.2 **Measurement of capacitance and tan δ**

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**WARNING**

Since \( C_2 \) usually is relatively small, the test tap must never be open-circuited when applying a voltage to the bushing. It must always be earthed or connected to an external impedance.

After testing, check that the test tap cover is mounted correctly on the bushing.

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After mounting, a capacitance measurement is recommended. A measuring bridge is connected between the outer terminal and the test tap. This is possible without removing the bushing from the transformer as the bushing has an insulated test tap, see Fig. 2a. More details can be found in ABB Components’ product information 2750 515E-56, “Capacitance and dissipation factor (tan \( \delta \)) test on condenser bushings in the field”.

With the transformer de-energized and the bushing outer terminal disconnected, the test tap cover is removed. The measuring equipment is connected to the test tap and the measuring voltage source is connected to the bushing terminal.

The capacitance \( C_1 \) between the bushing conductor and the tap is marked on the nameplate.

*Table 3. Dissipation factor variations as a function of temperature.*

<table>
<thead>
<tr>
<th>Bushing body temperature °C</th>
<th>Multiplier to 20 °C (IEC)</th>
<th>Multiplier to 25 °C (USA and Canada)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-7</td>
<td>0.85</td>
<td>0.80</td>
</tr>
<tr>
<td>8-12</td>
<td>0.90</td>
<td>0.85</td>
</tr>
<tr>
<td>13-17</td>
<td>0.95</td>
<td>0.90</td>
</tr>
<tr>
<td>18-22</td>
<td>1.00</td>
<td>0.95</td>
</tr>
<tr>
<td>23-27</td>
<td>1.05</td>
<td>1.00</td>
</tr>
<tr>
<td>28-32</td>
<td>1.10</td>
<td>1.05</td>
</tr>
<tr>
<td>33-37</td>
<td>1.15</td>
<td>1.10</td>
</tr>
<tr>
<td>38-42</td>
<td>1.20</td>
<td>1.15</td>
</tr>
<tr>
<td>43-47</td>
<td>1.25</td>
<td>1.20</td>
</tr>
<tr>
<td>48-52</td>
<td>1.30</td>
<td>1.25</td>
</tr>
</tbody>
</table>
3 Maintenance

The GOF bushings normally require no maintenance. The maintenance described below cover aspects of bushing supervision to be carried out, for example, on the occasion of station overhauls or normal scheduled maintenance.

**WARNING**

No work at all can be performed on the bushing while it is energised or not earthed.

3.1 Recommended maintenance and supervision

1. Cleaning of insulator surface
2. Measurement of capacitance and tan δ
3. Thermovision (infrared camera) check for local overheating on connectors
4. Check for leakage
5. Checking and adjustment of the oil level

3.1.1 Cleaning of porcelain insulator surface

*CAUTION: Avoid having solvent on the bushing gasket and porcelain joints.*

Under conditions of extreme pollution it may be necessary to clean the porcelain insulator surface. This should be done by water-jet or by wiping with a moist cloth. If necessary, ethyl-alcohol or ethyl-acetate may be used.

Composite insulators need no cleaning.

3.1.2 Measurement of capacitance and tan δ

Please refer to Chapter 2 Installation.

3.1.3 Thermovision (infrared camera) check for local overheating on connectors

At maximum rated current, the bushing outer terminal normally takes a temperature of about 35 to 45 °C above the ambient air. Significantly higher temperatures, especially at lower current loading, can be a sign of bad connections.

3.1.4 Check for leakage

Make a visual inspection for oil leakage during normal station supervision.
3.1.5 **Hydrophobicity check**

The hydrophobicity of the silicone rubber may be checked as directed in STRI Guide 1, 92/1 "Hydrophobicity Classification Guide". This check is less relevant for indoor applications.

3.2 **Disposal after end of service life**

The bushing consists of the following material:

- Conductor tube of copper or low-alloy aluminium.
- Terminals of copper, brass or low-alloy aluminium may be plated with for instance silver, tin, gold or nickel in layer thickness up to 20 µm.
- Transformer oil as per IEC 296, class 2.
- Transformer oil impregnated condenser body consists of paper and 1% Al foils.
- Top housing, top end nut, test tap and flexible connection consist of Al alloys.
- Flange may be designed of aluminium or welded steel.
- Insulator fittings are made of Al alloy or cast iron.
- Press ring for oil level glass consists of plated brass.
- Insulators consist of quartz or alumino silicate based porcelain or glass fibre reinforced epoxy with silicone sheds.