GAS-INSULATED HVDC WALL BUSHING
Type PWHS 820.1900.2236 - Large
Champa – Kurukshetra bipole

OPERATING
AND
MAINTENANCE INSTRUCTIONS
LIST OF CONTENTS

1. Introduction .................................................................................................................. 3
2. Safety ............................................................................................................................ 3
   2.1 Preliminary operative information .................................................................................. 4
3. Transport lifting and storage conditions ............................................................................. 5
   3.1 Transport conditions ..................................................................................................... 5
   3.2 Lifting conditions ......................................................................................................... 6
   3.3 Storage conditions ....................................................................................................... 6
4. Technical characteristics .................................................................................................. 7
5. Bushing preparation and installation .................................................................................. 8
   5.1 Controls at the arrival .................................................................................................... 8
   5.2 Bushing unpacking ....................................................................................................... 9
   5.3 Transport pressure gauge removal ................................................................................ 10
   5.4 Internal transport supports removal ............................................................................. 11
      5.4.1 Upper transport support removal ........................................................................... 13
      5.4.2 Lower transport support removal .......................................................................... 15
      5.4.3 Internal transport supports re-installation and bushing preparation for shipping or storage ........................................................................................................ 17
   5.5 Bushing lifting and installation on the valve hall wall .................................................... 17
6. Gas filling station ............................................................................................................. 22
7. Gas SF₆ characteristics and gas filling instruction ............................................................... 25
   7.1 Gas first filling operation and control of alarm and tripping signals ................................. 26
   7.2 Gas refilling during the bushing normal operation ........................................................ 27
8. Gas density monitor ......................................................................................................... 28
9. Gas moisture sensor ......................................................................................................... 29
10. Power factor tap .............................................................................................................. 30
11. Composite insulators maintenance .................................................................................. 30
12. General maintenance plan ............................................................................................. 32
13. Disposal at the end of life .............................................................................................. 34

Appendix 1 Calculation formulas for gas moisture content .................................................... 35
Appendix 2 Procedure for gas leakage measurement ............................................................. 37

List of separated documents

Appendix 3 RXF00684-01 – General Arrangement DC Through Wall Bushing.
Appendix 4 RX79A010-03 - HVDC Wall Bushing wiring diagram electrical.
Appendix 5 RX38A518-01 – Support Assembly.
   RX380696-81 – Main assembly.
   RX38A488-01 – Weight steel.
Appendix 6 RX380664-01 – Key assembly (Lower support extraction handle).
Appendix 7 MB2193 rev 4 – General guide for handling and cleaning of composite insulators.
   MB2188 rev 5 – Repair of silicone sheds on composite insulators.
Appendix 8 SF6 Dew point temperature transmitter – Type SGM/DEW
   SF6 Gas Density controller -Type GDC 363
Appendix 9 NOR 508 - Gas insulated wall bushing – Installation check list.
Appendix 10 NOR 509 - Gas insulated wall bushing – Gas flushing check list.
1 Introduction

These instructions are applicable to the gas SF₆ insulated HVDC wall bushings of the series PWHS and provide all information relevant to:

- Safety aspects.
- Transport conditions.
- Technical characteristics.
- Controls at the arrival and preparation activities.
- Lifting and installation operation.
- Gas filling operation.
- Service and maintenance plan and procedures.

The PWHS bushings are manufactured and tested in compliance with the following standards:

- IEC IEEE 65700-19-03 Bushings for DC application.
- IEC 60137 Insulated bushings for alternating voltages above 1000V.

2 Safety

In this document important safety requirements are highlighted by the word **CAUTION** and important operative instructions are evidenced by the word **NOTE**.

This manual must be available to the personnel responsible of the installation, operation and maintenance of the bushings.

The wall bushing is a high voltage DC device, filled under pressure with SF₆ gas, that is installed at relevant height through the wall of the valve building.

The preparation and the installation of the bushing, the gas filling and the periodical maintenance operations must be performed by qualified operators. They must be trained operating in accordance with the guidelines described in this instruction manual.

Every operator must use the prescribed tools and the prescribed safety devices.

Non-compliance with the following procedures and instructions can result in serious and dangerous situations for the personnel and in risks of damages of the equipment and the property.
Main safety risks related to the bushing handling and its operative conditions are:

- Transport and handling of heavy and large parts.
- Lifting and moving of heavy and not well-balanced components.
- Work operations under the crane and suspended materials.
- Work at height. All operation at height must be performed on a suitable certified platform.
- Risk of falling of heavy parts during the installation.
- Risks deriving from un-proper balancing of the masses that can cause un-expected rotation during the installation on the wall.
- Risks due to the use of un-proper tools or wrong operations.
- **Risks of explosion deriving from un-proper installation or operation on the bushing when filled with SF$_6$ gas at rated filling pressure.**
- Environmental risks related to dispersion of SF$_6$ gas in the atmosphere.
- Severe electrical shock risk related to the extremely high voltage DC level of the equipment.
- Severe electrical shock risk due to un-proper realization of the bushing grounding connections.
- Severe electrical shock risks deriving by the fact that the composite insulator and the other main parts of the bushing remain electrically charged at high voltage for a long period of time (hours) after the plant de-energization and the bushing grounding. Before starting any work on the de-energized bushing, check the discharge by touching all surface of both indoor and outdoor side composite insulators and all other parts of the bushing with an insulated grounding rod which length must be ≥ 3m. Operators must wear protective insulating gloves and boots and helmet with protective transparent face shield.

2.1 Preliminary operative information

The following notes are mandatory for personnel involved in wall bushing assembly. All problems detected during the bushing installation must be reported to the Foreman and to GE Grid Solutions RPV Supervisor.

- **The bushing is a pressurized device. Operations on the valves, manholes, pressure gauges, pipes, protective devices must be performed by qualified operators, with the proper equipment and respecting the instructions of this manual. Foreman and operators must take care about handling the pressurized equipment.**
- It is mandatory to use clean safety gloves and protective clothes, helmets and safety shoes during all bushing moving, assembly, hauling and installation operations.
- Work in quote will be done by trained operators on adequate and certified moving platforms. Workers that will operate in quote must use the above prescribed safety devices and in addition they must wear certified safety harnesses.
- Lifting equipment must be adequate and certified.
- Tools and pieces of clothes or no-fibre fabric used during the assembly must be clean.
- The composite insulators sheds are made by silicone that can be mechanically damaged, if not properly handled. Protect the insulators with clean plastic foils during the bushing installation and report to Foreman and to Grid Solutions RPV any event which could have caused a damage of the composite insulators.

**CAUTION:** It is strictly forbidden to move, lift and install equipment that is under pressure. Check through appropriate gauge that the devices are at a pressure less than or equal 0.15 MPa abs (0.5 bar gauge) before operating on them.

**CAUTION:** The bushing is equipped with a safety rupture disk. This is installed on the outdoor side flange and protected by a red metal cover. Do not remove this cover and the relevant mechanical parts. Never touch the safety disk with the bushing filled with gas, as it can break, causing a violent gas explosion. Maintenance operation on the safety disk is allowed only to trained operators and after removing all gas pressure.
3 Transport lifting and storage conditions

The bushing is shipped in a wooden box, suitable for marine transport, designed to provide protection of the bushing in accordance with the specified transport conditions.

For the transportation the bushing is filled with dry Nitrogen (with Dew Point < -50°C) at a pressure of 0.125 MPa abs (0.25 bar gauge).

The complete crate must be lifted, loaded on vehicles and transported with great care to prevent damages of the bushing or its accessories. Stacking of crates is not allowed.

An electronic impact recorder could be installed on the bushing and records all shocks happened during the trip. Additional shock indicators are fixed on the crate walls.

GE Grid Solutions RPV will not respond of any damage due to un-proper operations. Removal or damage of the electronic recorder and or shock indicators will cause the interruption of the warranty.

Centre of gravity and lifting points are painted on the crate walls.

3.1 Transport conditions

The bushing can be transported by truck and ship.

To prevent dangerous movement of the crate during the transport, it’s responsibility of the transport company to carefully fix it on the vehicle by suitable retain systems like ropes, synthetic pulling bands or any other method.

The maximum allowed transport acceleration along the three axis is 6g (58.86 m/s²). In case of transport by truck along very bad roads (‘bumpy roads’), the speed must be adequately reduced to max 30 km/h.

Trucks to be used for road transportation must have a platform of adequate dimensions to accommodate the crate. Crate overhang from the truck platform in both length and width direction and crate towing are not allowed.

As indicated on the information tags on the crate walls, the bushing crate must be positioned on the truck platform respecting the orientation of the packaging with respect to the truck cabin (see Figure 1).

![Figure 1 – Crate on the truck positioning information label](image)

During the transport by road or ship, the good must be protected from rain, sea water and other exceptional environment conditions by tarpaulins, not provided by GE Grid Solutions RPV, suitable to full cover the crate.

Sea transportation on the ship main deck is allowed. Transportation in ship hold is preferred.
3.2 Lifting conditions

The crate can be lifted by one or two cranes. The lifting points are indicated on the crate and are reinforced by steel plates (see Figure 2). Lifting by fork lift is not allowed.

Figure 2 – Example of two crane lifting arrangement

Lifting operation must be done by qualified operators and with suitable certified ropes and equipment.

3.3 Storage conditions

For short period storage, up to 1 month, the package can be stored outside, just protected by a suitable additional tarpaulin. The storage area must have a concrete floor made in such a way to ensure enough drainage of water.

For long-time storage, it is necessary that the whole crate is placed inside a suitable warehouse and that a periodical check, every six months, of the bushing, the gas pressure and of relevant accessories will be activated.

In this case, it is also recommended to increase the gas pressure (dry Nitrogen with DP < -50°C) to 0.15 MPa abs (0.5 bar gauge). GE Grid Solutions RPV must be informed concerning the activation of the long-time storage condition.

The periodical controls must verify the bushing conditions, the gas pressure and its dew point and the overall status of the electric instruments, the accessories and tools. All data must be recorded in a specific check list.

NOTE: Violation of the above prescriptions will cause the immediate termination of the warranty.
4 Technical characteristics

PWHS bushings are based on gas insulated technology. The electric field is controlled by suitable electrodes that are placed inside and outside the bushing. The internal electrical strength capability is ensured by the gas density, while the external withstand capability is ensured by composite insulators of adequate length and creepage distance.

The inner and outer side of the bushing are designed to withstand the various environmental conditions existing inside and outside the valve building.

Bushing is based on:

- Composite insulator with HTV silicone sheds.
- The internal shielding arrangements.
- An aluminium central flange.
- An internal aluminium tube conductor.
- The top flanges with the line terminals.
- The top toroidal electrical shields.

The bushing is filled with SF₆ gas at rated filling pressure of 0.57 MPa abs (4.7 bar gauge).

The bushing is installed on the wall inclined with an angle from the horizontal that is prescribed in the bushing outline drawing (see Appendix 3).
5 Bushing preparation and installation

All operators involved in the unpacking and installation operations must work carefully to avoid damage to the object. During the unpacking operation it is necessary to check that all components supplied by GE Grid Solutions RPV are available and not damaged during the transportation.

All incoming goods must be stored in a covered area and prepared for the installation.

5.1 Controls at the arrival

Before proceeding with the unpacking operation, it is necessary to perform the following controls:

- Check the wooden crate status.
- Check the external visual shock recorder(s) (see next Figure 3).
- Open the crate and inspect packaging and goods inside (see next Paragraph 5.2).
- Check the pressure of the gas inside the bushing from the Transport pressure gauge located on the central flange of the bushing (see Figure 4). The Nitrogen gas pressure must be $\geq 0.11$ MPa abs (0.1 bar gauge).
- Check the composite insulators status, the top terminals and the relevant accessories.
- Check the bushing instruments and the status of the electric wiring.

![Figure 3 – External visual shock recorder](image1)

![Figure 4 – Transport pressure gauge](image2)

**CAUTION**: The transport pressure gauge must be removed from the bushing before the gas filling at rated pressure operation. This instrument must be used only at the transport pressure value. **Values of pressure > 0.2 MPa abs (1 bar gauge) will damage it.**
Any damage of the crate, of the goods inside or lack of gas pressure must be reported to GE Grid Solutions RPV.

The bushing is equipped with an electronic shock recorder type Shocklog 208 (see Figure 5) installed on the central flange.

At the arrival on site, this device must be removed and send back to GE Grid Solutions RPV, Via Mario Villa, 210 - 20099, Sesto San Giovanni (MI), Italy, for data analysis.

![Figure 5 – Example of electronic shock recorder](image)

### 5.2 Bushing unpacking

Unpacking operation and the subsequent activities must be performed when the weather is good and in a windless day. A confined area with a stable, flat and levelled floor and adequate lifting facilities are necessary for all the preparation operation.

Next Figure 6 shows typical bushing arrangement in its transport crate. Inside the crate the bushing stands on wooden supports and it is locked by locking belts.

![Figure 6 – Bushing crate inside view](image)

![Figure 7 – Bushing inside the crate top view](image)
The transport box is closed by a lid in sections. They can be lifted by a suitable crane. After the opening of the crate, the visual inspection of the bushing, the removal of the locking ropes and locking blocks, the bushing can be lifted.

For this purpose, lifting hooks, where foreseen, are placed on the central flange and/or composite insulators extremities closing plates. See Figure 8 for some typical arrangements.

Lifting operation must be performed by qualified operators, by using adequate synthetic lifting ropes and cranes.

**Figure 8 – Example of lifting hooks on main flange and on outdoor and indoor sides extremities**

**CAUTION:** The two composite insulators are protected by a PE plastic foils and a corrugated cardboard cylinder. Remove the protection only after the installation of the bushing on the wall and just before the energization.

**CAUTION:** To lift the bushing do not wrap ropes (i.e. ‘tie’ lifting method) around the silicone sheds. The composite insulators will be seriously damaged.

**CAUTION:** It is not allowed to step on the composite insulators. The silicone sheds can be seriously damaged.

**CAUTION:** The centre of gravity point is not centred with respect to the bushing geometry. Care must be taken to compensate the mass unbalancing before and during the lifting operation.

5.3 Transport pressure gauge removal

The bushing is equipped with a transport pressure gauge installed on the gas filling valve. This pressure gauge **must be removed** before proceeding with the installation operations. If the connecting valve is not used for instruments, it shall be closed with its protective cap (see Figure 9). The Transport pressure gauge must be stored with the transport supports (see **Paragraph 5.4**) for future reuse.

**CAUTION:** The transport pressure gauge must be removed from the bushing before the gas filling operation at rated pressure. It must be used only at the transport pressure value. **Higher pressures will damage it.**
5.4 Internal transport supports removal

The bushing is equipped with two removable supports for the transport. These parts keep centred the internal conductor, preventing excessive deflection or oscillations consequent to transportation shocks. These supports are located on the outdoor side of the bushing under two flanges placed on the top and the bottom of the bushing central flange.

The next Figure 10 shows the arrangement of the two supports. The respective removable masses of the two parts are:

Type a) Lower support mass: 20 kg).
Type b) Upper support mass 4 kg).

![Figure 10 – Transport supports arrangement](image)

When the supports are inserted for transportation, they are protected by a removable cover with a yellow warning tag. See example in Figure 11.

Before operating on the supports, it is mandatory to check that the internal pressure is equal to the atmospheric pressure (0.10 MPa abs, 0 bar gauge). To reduce the gas pressure, it is necessary to act on one of the gas valves installed on the bushing flange.

**CAUTION:** Always reduce the gas pressure to zero before operating on the transport supports. Otherwise there is the risk of a sudden and violent expulsion of the transport support from the flange.
The preferred condition for removal operation is that it will be performed with the bushing installed on the valve hall wall (see next Paragraph 5.5 for the installation details).

The overall operation must be carried out as quickly as possible, to prevent the entry of dust or other foreign materials, minimizing also the risk of entry of air and moisture into the bushing. This activity must be completed without interruption.

**NOTE:** In the event of particular conditions, relating to the building structure, the surrounding areas or to the evidence of possible risks for the safety of workers, the aforementioned preferred requirement on the condition for the removal of transport support is modified and the removal of only the upper support at ground level is allowed.

In this case the bushing lifting operation must be performed with great care to avoid impacts. The maximum acceleration must be <3g. To monitor this limitation, it is recommended to reinstall the shock recorder before performing the operation.

The following conditions are mandatory:

- Do not proceed if the weather conditions are bad (rain, fog, high wind or dusty environment).
- Protect the working zone on the flange from the environment with a provisional clean PE foil.
- Always complete the operative sequence on each support. Do not interrupt it, when it is started.

![Figure 11 – Example of transport support with the yellow warning tag (support type b).](image)

**CAUTION:** The internal transport supports MUST be removed. Missing this operation and leaving the supports installed is extremely dangerous as it will result in a failure at the bushing energization.

The extraction sequence of the two supports is described in the following pages.

**Required Tools:** Allen keys Nr. 6 and 8, extraction handle RX380664-01, silicone grease Molykote 111, SF6 grease Klubertemp UT 18, no-fibres fabrics, isopropyl alcohol, rubber protective gloves (surgical type) and plastic bags for the storage of the removed supports and parts.
5.4.1 Upper transport support removal

This paragraph describes the upper transport support extraction procedure.

This picture shows the transport conditions arrangement with the upper supports inserted inside the flange.

In this condition the assembly is closed with a protective cap provided with a yellow warning tag.

**CAUTION:** Before proceeding, check the gas pressure and reduce it to 0.10 MPa abs (0 bar gauge).

![Arrangement with the transport support inside](image)

To disassemble the complete transport support assembly, unscrew the 6 Allen screws on the locking flange by using the Allen key Nr. 6.

It is not necessary to remove the protective cover with the yellow tag.

![n°6 Allen screws](image)

Carefully extract the support, taking care to prevent foreign bodies from falling into the bushing.

The sealing surface of the flanges and the gasket are greased with Molykote 111 silicone grease.

**NOTE:** Do not pollute the gasket and the sealing greased surfaces with foreign materials. This could compromise the gas tightness. Protect all parts from pollution by properly storing them during the overall operation.

**CAUTION:** In case of evidence of heavy damages of the support, complete all the operations, close the bushing and immediately report the problem to GE Grid Solutions RPV.
Lubricate the gaskets, the Teflon ring and the flange surfaces before installing the closure flange:

**Type 1) Teflon ring located inside the bushing flange in contact with SF6:**
Apply with a greased cloth a thin layer of Klubertemp UT 18, special for SF6 applications.

**Type 2) External gaskets in contact with air:**
Apply a thin layer of silicone grease Molykote 111.

**Type 3) Metal flanges contact surfaces:**
Apply a thin layer of Molykote 111 with a greased roll painter.

*CAUTION: For the lubrication always use thin rubber protective gloves (surgical type).*

Re-assemble the Teflon ring inside the flange.
Install the closure flange with the red warning tag and carefully lock the Allen screws in cross-sequence (torque value: 17.2 Nm).

Seal the complete support and relevant parts in a plastic bag and store them for a possible future reuse.
### 5.4.2 Lower transport support removal

This paragraph describes the lower transport support extraction procedure.

<table>
<thead>
<tr>
<th><img src="image1.png" alt="Diagram" /></th>
<th><img src="image2.png" alt="Diagram" /></th>
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</thead>
<tbody>
<tr>
<td><strong>CAUTION:</strong> Before proceeding, check the gas pressure and reduce it to 0.10 MPa abs (0 bar gauge).</td>
<td></td>
</tr>
<tr>
<td>To disassemble the transport support assembly, unscrew the 8 Allen screws on the locking flange by using the Allen key Nr. 8. <strong>NOTE:</strong> Do not pollute the gasket and the sealing greased surfaces with foreign materials. This could compromise the gas tightness. Protect all parts from pollution by properly storing them during the overall operation.</td>
<td></td>
</tr>
<tr>
<td>Remove three screws at 120° from the locking plate and remove the central support locking nut.</td>
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</table>
Install on the plate the three guiding rods of the extraction tool and the three safety nuts.

Install the extraction handle tool (drawing Nr. RX380664-01) on the central support and regulate the three nuts on the guiding rods to keep the three safety nuts in contact to the locking plate.

Remove the remaining locking screws from the locking plate then slowly pull the handle and simultaneously release the three safety nuts until the support is extracted from the bushing flange.

Complete the extraction of the support.

Control the status of the Conductor saddle on the top of the support. The saddle must not show any significant damage such as cracks, dents or scratches.

Remove the three Guiding rods and from the flange hole check the status of the bushing conductor which surface must not show any damage such as cracks, dents or scratches.

**CAUTION:** In case of evidence of heavy damages on the support or the conductor, complete all the operations, close the bushing and immediately report the problem to GE Grid Solutions RPV.
Clean the parts with isopropyl alcohol and lubricate the gaskets, the Teflon ring and the flange surfaces before installing the closure flange:

**Type 1)** Gaskets and Teflon ring located inside the bushing flange in contact with SF6:
Apply with one finger a thin layer of Klubertemp UT 18 special for SF6 applications.

**Type 2)** External gaskets in contact with air:
Apply a thin layer of silicone grease Molykote 111.

**Type 3)** Metal flanges contact surfaces:
Apply a thin layer of Molykote 111 with a greased roll painter.

**CAUTION:** For the lubrication always use thin rubber protective gloves (surgical type).

Re-assemble the Teflon ring inside the flange.

Install the closure flange with the red warning tag and the DILO Type valve and carefully lock the Allen screws in cross-sequence (torque value: 34.3 Nm).

Seal the complete support and relevant parts in a plastic bag and store them for a possible future reuse.

### 5.4.3 Internal transport supports re-installation and bushing preparation for shipping or storage

To re-install the transport supports after the removal from the wall, it is necessary to remove under vacuum the residual SF6 gas from the bushing with a DILO machine and then fill it with dry Nitrogen up to the atmospheric pressure (0.10 MPa abs, 0 bar gauge).

After this operation to proceed with the supports re-installation operation, it is necessary to follow the previous described disassembly sequence in reverse. When correctly inserted, all parts fit without any interference.

**NOTE:** In case of evidence of insertion problems do not force the insertion of the supports. This can damage the internal bushing conductor. Contact GE Grid Solutions RPV for instructions.

Re-install the Transport pressure gauge (see Figure 4) and increase the Nitrogen gas pressure up to the transport pressure value (0.125 MPa abs, 0.25 bar rel) for shipping or to the storage pressure value (0.15 MPa abs, 0.5 bar gauge) for storage conditions. After this the bushing can be packed.

### 5.5 Bushing lifting and installation on the valve hall wall

This paragraph describes the procedure to be followed for the installation of the wall bushing on the valve hall by using the special lifting tool supplied as separate accessory (see Appendix 5).

The complete operative sequence is described in the following pages.

**CAUTION:** All operation must be performed only if operating and weather conditions are satisfactory. Especially the absence of wind and rain is a mandatory condition. 
In case of worsening of the weather conditions, the operation must be stopped and the bushing must be re-located on its wooden platform.
Preparation for the bushing installation

- Place the crate close to the installation position and prepare the cranes.
- Take care of the identification and correct position, respect the valve wall, of the Outdoor and Indoor sides.
- Open the crate by removing the top lid sections.
- Perform the prescribed inspection controls.
- Prepare and control all the lifting tools:
  a) Lifting frame and screws,
  b) ropes and relevant hooks,
  c) counter-weight and fixing plate tools.

Reference Drawings:
RX38A518-01 – Support Assembly.
RX380696-81 – Main assembly.
RX38A488-01 – Weight steel.

Crate wall removal and bushing preparation

- Remove the fixing ropes and the crate walls.
- Position the two cranes.
- Install the lifting tool on the bushing flange.

CAUTION: Carefully remove all the nails and dispose them in a safe way.

Lifting frame installation
(refer to lifting tool outlines: RX38A518-01 and RX380696-81).

Install the lifting frame on the bushing flange on the outdoor side.

Carefully place in position the frame, control that it fits with the holes on the two supporting bars welded on the bushing flange.

The frame must be fixed on the bushing flange by 8 screws M20x80 and relevant nuts and locked at 380 Nm (Allen key Nr. 17 and spanner Nr. 30).

The crane hook must be connected to the rotating type hook on the lifting frame.
Counter-weight preparation
Refer to counter-weight mass drawing: RX38A488-01.
The counter-weight mass is composed by the following parts:

1) 2 Guiding rods M30 x 200.
2) 2 Locking nuts M30 + 2 washers D30.
3) Assembled counterweight.

- Install the two guiding rods on the outdoor side flange.
- Install the required counter-weight disks by centring the two guiding rods.
- Lock the disks with the two locking nuts.

**CAUTION:** Perform this operation with the necessary precautions to avoid damages of the rupture disk protective cap, the gas desiccant unit and the bushing terminal.

The counterweight total mass necessary to ensure the proper inclination is:

- For 20° inclination the total mass is 304 kg (17 disks of 17 kg + 1 disk of 15 kg).

Complete the preparation by tying the guiding ropes around each end of the bushing.

**CAUTION:** The installation operation requires a strong coordination among the workers. Walkie talkie radios are strongly recommended.

Bushing lifting procedure
The first operation is to lift the bushing in horizontal.
This operation is done by using two cranes:
The Main crane, connected to the lifting tool and the Secondary crane, connected to the indoor side extremity of the bushing.

Scope of the Secondary crane is to compensate the mass unbalancing of the overall system that will push the indoor side down.

Bushing horizontal lifting will be done by simultaneously acting on the two cranes up to a distance from the floor ≥ 8 - 9 m.

**CAUTION:** All operations must be performed only if operating and weather conditions are satisfactory. Especially the absence of wind and rain is a mandatory condition. In case of worsening of the weather conditions, the operation must be stopped, and the bushing must be re-located on its wooden platform.
After reaching the horizontal position of the bushing, start to lift the Main crane and simultaneously to lower the Secondary crane until the bushing will achieve the requested inclination (20°).

**CAUTION:** During the overall operation pay great care that the indoor side of the bushing does not crash on the floor and always maintain a minimum safe distance (>2 m) of the indoor side respect the floor.

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Check the correct inclination angle by an inclinometer or by an electronic inclination gauge (not supplied) on the Indoor or Outdoor side of the bushing.

Adjust the counterweight mass to correct the inclination angle by adding or removing disks.

**CAUTION:** To perform this operation the bushing must be relocated on its wooden platform.

After the control disconnect the Secondary crane from the bushing.

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Carefully lift the bushing up to the correct quote and position it on the wall.

Use the guiding ropes to align the bushing in the correct position.

Insert the bushing in the wall hole taking care that the composite insulator and the lifting frame do not hit the wall structure.

During this operation pull the two guiding ropes at the extremities to guide the bushing in the correct position.

Before completely closing the gap between the bushing flange and the supporting structure on the wall, apply a layer of acrylic silicone to seal the joint between the two parts.

Fix the bushing flange on the wall structure by the appropriate bolts (not included).

With the bushing fixed on the wall, remove the counter-weight masses, the lifting tool and the guiding ropes.

**NOTE:** During the removal of the lifting tool and of the counter-weight pay attention that they do not hit and damage the composite insulator or the bushing accessories (valves, rupture disk, dehydrating units, instruments).
Bushing installation completion

Complete the bushing installation with the following activities:

- **Remove the upper and lower transport supports (see Paragraph 5.4).**
- **Install the two corona shields (toroids) on the two extremities of the bushing.**
- **Install the grounding connections from the bushing flange to the system ground.** The bushing flange has 2 grounding points (item 4 of the outline drawing) suitable for the connection of copper braids. The required total cross section of grounding conductors must be ≥ 400mm².
- **Check that the instrumentation, the electrical wiring and the gas device have not been damaged during the bushing installation operation.**
- **Connect the line cable to the two bushing terminals.** Use contact grease Burndy Penetrox A-13 to improve the electrical contact and tighten the line terminal clamp at the prescribed torque (line clamps not included).
- **Remove the protecting corrugated cardboard and PE foils from the indoor composite insulator.**

**NOTE:** Pay attention in preventing damages to the air rings (toroids). Electrical performances of the bushing are strongly influenced by the perfect status of these components. Immediately report to GE Grid Solutions RPV any damage to these components.
6 Gas filling station

The gas filling station is a device that gives the possibility to control the gas parameters and fill the bushing with gas by operating at man height. The device is installed in a stainless-steel cubicle, that centralizes also the electrical connecting boards for the bushing instrumentation and controls systems wiring. All relevant drawings and the electrical circuit diagram of the bushing and of the gas filling station are enclosed in Appendix 4.

Figure 12 – Gas filling station with DP and Pressure displays
The gas filling station is equipped with two digital meters that are connected to sensors that provide a continuous monitoring of the moisture level of the gas and simultaneously the value of the operative gas pressure. Each display is equipped with a 4-20 mA analogue output for remote monitoring.

The moisture content is indicated as ‘Dew Point in °C @ operative gas pressure’. While the operative gas pressure is expressed in MPa abs.

From these two parameters it is possible to convert by calculation the measured values in other moisture typical parameters (Dew point @ atmospheric pressure, ppm v, ppm w). See Appendix 1 for more details.

The gas filling station can be installed either on bushings already filled at low or high pressure of SF6 gas or on bushings filled at low pressure of Nitrogen gas. Before proceeding it is necessary to check that the wall bushing is de-energized and grounded. The procedure for both cases is described here:

To install the gas filling station on the valve hall wall, proceed in accordance to the following instructions (see HVDC Wall Bushing Electrical Scheme in Appendix 4).

- Install the galvanized cable tray and the gas filling station cabinet on the valve hall wall. The cabinet should be fixed at man height.
- Install and connect the multicore shielded electrical cables between the junction box on the bushing and the gas filling station. Cables can be locked inside the cable tray with the provided cable clamps.
- Install the gas hose inside the cable tray and connect it to the gas filling station side only. Connect the 6 mm² grounding braids to the tube valves at the two extremities of the tube and connect them to the gas filling station grounding plate and to the grounding point located on the bushing flange.
- Place and install the 16 mm² grounding braid inside the cable tray and connect it to the gas filling station grounding plate and to the grounding point located on the bushing flange.

All the above actions must be performed independently from the situation of the wall bushing (SF6 or Nitrogen filled). To fill with gas the gas filling station and complete the installation, follow the specific instructions for the two cases:

**Gas filling station to be installed on a SF6 gas filled wall bushing**

This part applies to installed bushings that are already filled with SF6 gas (new or existent), either at transport pressure or at its rated filling pressure. In this case it is necessary to ensure that the gas filling station and its relevant gas equipment will be pre-filled with SF6 gas before connecting it to the installed wall bushing:

Here below the procedure to be followed:

- Connect the DILO gas filling machine to the gas filling station DILO Type valve and put under vacuum the gas hose and the gas filling station equipment. Vacuum level ≤ 20 Pa abs (0.2 mbar abs) must be maintained for at least 1 hour.
- Fill with SF6 gas at 0.25 MPa abs (1.5 bar gauge).
- Check for gas leakages the gas hose and the gas equipment inside the gas filling station by a suitable leak-meter device. Total measured gas leakages must be less than 1 ppm v. After the leakage test, reduce the gas pressure to 0.12 MPa abs (0.2 bar gauge).

At this point the gas filling station system is ready and can be connected to the SF6 filled wall bushing.

- Connect the gas hose top valve to the DILO Type valve on the bushing flange.
- After the pressure stabilization, control the value of the gas pressure on the gas density monitor device(s) installed on the bushing flange.
- Follow the procedure for gas refilling described in Paragraph 7.2 and refill the bushing at its rated filling pressure value.
After the gas filling operation completion, continue with the following actions:

- Keep the bushing at the rated filling pressure for 4 hours, the purpose of this standing time is to allow the gas temperature stabilization, then make the final adjustment of the gas pressure.
- Control the gas purity and Dew point directly at the bushing flange DILO Type valve.
- Perform the final control of the electrical wiring and gas hose.
- Close the junction box on the bushing and the cable tray cover.
- Check the functionality of the moisture and pressure sensors.

Gas filling station to be installed on a Nitrogen gas filled wall bushing

This part applies to installed bushings that are filled with Nitrogen gas at transport pressure. In this case it is necessary to evacuate under vacuum the Nitrogen gas from the bushing and the gas filling station.

Proceed as follow:

- Connect the gas filling station hose top valve to the DILO Type valve on the bushing flange.
- Follow the procedure indicated in Paragraph 7.1.
- During the vacuum stage, control on the Pressure gauge located inside the gas filling station that the gas filling station and relevant gas equipment are effectively put under vacuum.
- During the SF6 gas filling operation, control on the Pressure gauge located inside the gas filling station that the all the gas filling station and relevant gas equipment are effectively filled with SF6 gas.

After the gas filling operation completion, continue with the following actions:

- Keep the bushing at the rated filling pressure for 4 hours, the purpose of this standing time is to allow the gas temperature stabilization, then make the final adjustment of the gas pressure.
- Perform the gas leakage test on the bushing, the valves, the connecting hose and the gas filling station (see Appendix 2).
- Control the gas purity and Dew point at the bushing flange DILO Type valve.
- Perform the final control of the electrical wiring and gas hose.
- Close the junction box on the bushing and the cable tray cover.
- Check the functionality of the moisture and pressure sensors.

**NOTE:** Do not perform the 2 kV 1 min AC withstand test or the DC insulation resistance by Megger on the gas moisture and the pressure sensors, the relevant wiring, displays and 4-20 mA terminals as the electronic sensors will be immediately damaged.
7 Gas SF₆ characteristics and gas filling instruction

The SF₆ gas to be used to fill the bushing must comply with the data shown in the following Table 1. This table shows the limits stated by GE Grid Solutions RPV specification and the characteristics of a premium Supplier:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Unit</th>
<th>GE Grid Solutions RPV limits</th>
<th>Premium Supplier’s limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min SF₆</td>
<td>% by weight</td>
<td>≥99.9%</td>
<td>≥99.993%</td>
</tr>
<tr>
<td>Air</td>
<td>ppm by weight</td>
<td>≤500 ppm w</td>
<td>≤50 ppm w</td>
</tr>
<tr>
<td>CF₄</td>
<td>ppm by weight</td>
<td>≤500 ppm w</td>
<td>≤10 ppm w</td>
</tr>
<tr>
<td>H₂O</td>
<td>ppm by weight</td>
<td>≤15 ppm w</td>
<td>≤0.65 ppm w</td>
</tr>
<tr>
<td>Dew point @ atmospheric pressure</td>
<td>°C</td>
<td>≤-40°C</td>
<td>≤-65°C</td>
</tr>
<tr>
<td>Mineral oil</td>
<td>ppm by weight</td>
<td>≤10 ppm w</td>
<td>≤1 ppm w</td>
</tr>
<tr>
<td>Total acidity expressed in HF</td>
<td>ppm by weight</td>
<td>≤0.3 ppm w</td>
<td>≤0.3 ppm w</td>
</tr>
<tr>
<td>Hydrolizable fluorides in terms of HF</td>
<td>ppm by weight</td>
<td>≤1 ppm w</td>
<td>≤1 ppm w</td>
</tr>
</tbody>
</table>

Table 1 - Characteristics of new SF₆ gas according GE Grid Solutions RPV and premium Supplier

The minimum requirement is that the characteristics will be in accordance with the data listed in the GE Grid Solutions RPV column. The gas filling must be performed with an equipment that prevents dispersion of the SF₆ gas in the atmosphere. As an example, next Figure 13 shows a gas plant manufactured by the German company DILO GmbH.

Figure 13 – Vacuum filling gas plant DILO and connecting valves

NOTE: This bushing is operated with pure SF₆. In case of need of replacement of SF₆ gas with a mixture SF₆ N₂, before proceeding, please contact GE Grid Solutions RPV for instructions and approval.

CAUTION: The following safety notes are mandatory.

- The bushing can be filled at the rated filling pressure of 0.57 MPa abs (4.7 bar gauge). @ 20°C, only when installed on the valve hall wall.
- If, for any reason, the bushing must be removed from the wall, it is mandatory to reduce the gas pressure to 0.125 MPa abs (0.25 bar gauge) before proceeding with the operation.
- All gas filling and gas recovering operations must be performed by a gas plant device (example a DILO machine).
7.1 Gas first filling operation and control of alarm and tripping signals

A new bushing is shipped in slight overpressure of Nitrogen gas (see Paragraph 5.1). If the pressure is positive proceed with the operation as follows, otherwise contact GE Grid Solutions RPV for additional instructions.

If the bushing is equipped with the gas filling station, it is necessary to install it before the gas filling, see Chapter 6.

**NOTE:** Before proceeding with the gas SF6 filling, check that the internal transport supports have been removed (see Paragraph 5.4).

The following operations must be performed with the bushing installed on the wall (see Paragraph 5.5).

**Bushing preparation and Nitrogen flushing operation.**

- Install a calibrated vacuum / pressure digital gauge to one DILO Type valve on the bushing flange.
- Connect the vacuum pump to a DILO Type valve on the bushing, or to the gas filling station DILO Type valve, if provided.
- Start the vacuum pump and set a vacuum level ≤1 mbar residual pressure at the bushing level; keep it for 24 hours. Check also that the gas filling station, if provided, is under vacuum.
- Stop the vacuum and connect a dry Nitrogen bottles pack (DP ≤-50°C at atmospheric pressure, 39 ppm v) to another DILO Type valve on the bushing flange, or to the gas filling station DILO Type valve, if provided.
- Fill the bushing at 0.25 MPa abs (1.5 bar gauge) and maintain the pressure for 12 hours.
- Check and record the dew point of the gas and the pressure. The dew point of the Nitrogen gas inside the bushing should be ≤-40°C at atmospheric pressure (-31.6°C at 1.5 bar gauge, 127 ppm v).
- If gas moisture parameters are correct, continue as follows. Unless repeat the Nitrogen flushing cycle.
- Carefully install the density meter(s) on the bushing flange and the other relevant accessories.

At the end of this phase the bushing is filled with dry Nitrogen and it is ready for the gas filling operation.

**SF6 Filling operation and control of Alarm &Tripping contacts**

Before to proceed with the gas filling operation, it is necessary to control the SF6 gas parameters in the bottles. SF6 must be of the quality indicated in Table 1. Gas parameters must be recorded in the gas check list.

- Install a calibrated vacuum / pressure digital gauge to one DILO Type valve on the bushing flange.
- Connect the vacuum pump to a DILO Type valve on the bushing, or to the gas filling station DILO Type valve, if provided.
- Start the vacuum pump and set a vacuum level ≤0.5 mbar residual pressure at the bushing level; keep it for 24 hours. Check also that the gas filling station, if provided, is under vacuum.
- Fill the bushing with SF6 at 0.25 MPa abs (1.5 bar gauge) and wait for 24 hours.
- Check the gas parameters inside the bushing. The moisture content must be ≤ 25 ppm w (DP < -36°C at atmospheric pressure corresponding to 200 ppm v). If gas parameters are correct, continue with the SF6 filling operation, unless contact GE Grid Solutions RPV for additional instructions.
- Gradually increase the gas pressure up to 0.20 MPa abs (1 bar gauge). Pressure must be directly measured on the gas density monitors installed on the bushing flange.
- Perform a preliminary check of all gas seals for leakages with a suitable SF6 leak-meter device (see Appendix 2 for more details). In case of significant leakages mark the area of leaking, stop the activities and contact GE Grid Solutions RPV.
• If the bushing does not show any leakage, gradually increase the pressure up to the rated filling pressure value of 0.57 MPa abs (4.7 bar gauge). The pressure must be directly measured on the compensated gas density monitors installed on the bushing flange.
• During the pressure rising, check the functionality of the Tripping (0.48 MPa abs), Alarm 2 (0.50 MPa abs) and Alarm 1 (0.52 MPa abs) contacts and record the respective operating pressures on the bushing check list. In case of malfunction, check the wiring and inform GE Grid Solutions RPV.
• During the alarm / tripping functionality test, record on the bushing check list the readings on the gas density monitors.
• Keep the bushing at the rated filling pressure for 4 hours, the purpose of this standing time is to allow the gas temperature stabilization, then make the final adjustment of the gas pressure.
• Check the gas parameters inside the bushing. The moisture content must be ≤ 25 ppm w (DP < -36°C at atmospheric pressure and 200 ppm v). If gas parameters are correct, continue with the SF6 filling operation, otherwise contact GE Grid Solutions RPV for additional instructions.
• Perform the gas leakage test (see Appendix 2 for more details).
• Remove the calibrated vacuum / pressure digital gauge from the DILO Type valve on the bushing flange and close the valve with its protective cap.
• Disconnect the gas plant from the DILO Type gas filling valve and close it with its closure cap.

NOTE: The gas density monitors installed on the wall bushing are fully thermally compensated devices that indicate the pressure independently from the effective gas temperature. Whatever the temperature of the gas, the instrument indicates a pressure equivalent to an average gas temperature of 20°C. This condition is related with the gas density inside the bushing.

7.2 Gas refilling during the bushing normal operation

CAUTION: The gas refilling operations must be done with the bushing de-energized. This is recommended also when the bushing is equipped with the gas filling station.

The bushing is a fully sealed unit and its leakage rate is <0.5% x year. Anyway, after many years of operation, it could be necessary to refill it. The refilling operation should be done within 7 – 10 days after Alarm 1 intervention and it is mandatory to perform it within 1 – 2 days after the Alarm 2 intervention.

Gas refilling can be done from the DN 20 DILO Type valve located on the bushing flange or from the DN 20 DILO Type valve located inside the gas filling station, if provided.

The operation can be done by a gas plant or directly from a SF6 bottle, equipped with an appropriate pressure reduction equipment equipped with a DILO Type connecting plug (contact DILO GmbH for information on the equipment for direct bottle filling).

The refilling procedure is described here below:

• Connect the gas filling equipment (gas plant or system for direct filling from gas bottles) to the filling valve of the bushing flange or the filling valve located in the gas filling station, if provided.
• Gradually and slowly increase the gas pressure up to the rated filling pressure value of 0.57 MPa (4.7 bar gauge). Pressure must be directly measured on the temperature compensated pressure gauge installed on the bushing from the thermally compensated pressure gauge located inside the gas filling station. Do not follow the indications of the digital display located in the gas filling station because this instrument is not thermally compensated, and it shows the real pressure inside the bushing.
• Check that all alarm contacts are re-set.
• Stop the gas filling equipment, shut the bottle valves.
• Disconnect the gas plant from the DILO Type gas filling valve and close it with its closure cap.
NOTE: In case of use of the DILO machine, check that the machine set-up is for gas filling and that the connecting pipe is full of $\text{SF}_6$. In the case of direct filling from the bottle, check that the bottle is effectively charged with $\text{SF}_6$, that the gas quantity is sufficient for the re-filling, the gas quality is in accordance with the prescription of Table 1 and that the pressure reduction unit and the pipe are compatible with the DILO filling system and filled with $\text{SF}_6$. All equipment must be specific for $\text{SF}_6$ filling application and certified for a safe use.

CAUTION: The refilling action must be performed by qualified operators. Safety prescriptions of Chapter 2 must be followed.

CAUTION: Always use equipment certified for $\text{SF}_6$ gas. This will avoid mistakes, safety issues and risk for the environment and the equipment.

8 Gas density monitor

The bushing is equipped with one or more gas density monitors.

This device ensures a great accuracy in the measurement, as it is based on the continuous and direct comparison between the gas density inside the bushing and the gas density of a built-in reference chamber filled with the same gas. This system is different and more accurate respect to the normal gas density monitors that estimate the gas density through the pressure measurement corrected by a bi-metal element that considers the ambient temperature.

The next Figure 14 shows the instruments and their graduated scale.

![Gas density monitor](image)

**Figure 14 – Example of gas density monitor**

The indication on the scale is expressed in MPa absolute, referred to a gas temperature of 20°C. This means that the instrument converts the gas density into a value of pressure referred to 20°C, independently from the effective temperature of the gas.

With this system the instrument reading practically does not change with the gas temperature, that is a function of the bushing loading condition and ambient temperature.

Changing of reading during the bushing normal operation is an indication of gas leakages, that reduce the gas density inside the bushing, or malfunction of the instrument.

NOTE: Due to the instrument principle of operation, the replacement of bushing gas from $\text{SF}_6$ to a gas mixture $\text{SF}_6 \, \text{N}_2$ is not allowed without replacing the gas density monitors with the proper type. In this case contact GE Grid Solutions RPV for support, instructions and approval.
Each gas monitoring device is equipped with three change-over micro switches for alarm and tripping signals, **Table 2** shows the micro switches purpose and the pressure set up.

<table>
<thead>
<tr>
<th>Micro switch</th>
<th>Description</th>
<th>Pressure set up [MPa abs]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarm 1</td>
<td>Low pressure level 1</td>
<td>0.52</td>
</tr>
<tr>
<td>Alarm 2</td>
<td>Low pressure level 2</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Minimum operating pressure</td>
<td></td>
</tr>
<tr>
<td>Tripping</td>
<td>Too low pressure for operation</td>
<td>0.48</td>
</tr>
</tbody>
</table>

**Table 2 – Alarm and tripping micro switches**

Each gas density monitor device is installed on a DILO Type valve for easy disassembly without the need to completely empty the bushing from the gas. See **Appendix 8** for technical characteristics and maintenance instructions.

In addition, the electrical cables of all devices are wired in a junction box provided with DIN type terminal boards for easy assembly and maintenance (see **Appendix 4**).

### 9 Gas moisture sensor

The bushing is equipped with a gas moisture sensor that continuously measures the humidity level of the SF6. This instrument provides a 4-20 mA analogue output, proportional to the Dew Point value at the Operative gas pressure. The instrument Dew Point operative range is from -60°C to +20°C.

![SF6 moisture sensor](image)

**Figure 15 – SF6 moisture sensor**

The sensor is provided with a DILO Type valve for easy installation on the bushing central flange. See **Appendix 8** for technical characteristics and maintenance instructions.

**NOTE:** Do not perform the 2 kV 1 min AC withstand test or the DC insulation resistance by Megger on the gas moisture and the pressure sensors, the relevant wiring, displays and 4-20 mA terminals as the electronic sensors will be immediately damaged.
10  Power factor tap

The bushing is equipped with one PF tap. This tap is used for capacitance, tan-delta and partial discharge measurements during the tests. In operation it must be accurately closed with its metal cap that ensures also the grounding connection.

![Power factor tap](image)

**Figure 16 – Power factor tap**

*CAUTION: PF tap cap MUST be accurately closed. Missing the cap could be dangerous and it can cause an electrical discharge at bushing energization.*

11  Composite insulators maintenance

Composite insulators, manufactured by qualified and experienced Suppliers, require very limited maintenance. The silicone used for the sheds is highly hydrophobic and it has the property to transfer this characteristic to the pollution layer. For this reason, it is not necessary to proceed with frequent washing operation which may progressively weaken the ability of silicone to regenerate its hydrophobicity. Washing must be done only when strictly necessary, i.e. in case of a heavy pollution of the composite insulator. Keep in mind that after washing, the silicone recovers its hydrophobicity in one or two days.

The preferred method for cleaning is manual wiping of de-energized insulators by using water or Iso-propyl alcohol, see Appendix 7 (document MB2193).

Use of pressure water washing is at the Customer own responsibility so it is Customer responsibility to perform preliminary verifications that the equipment and method used do not cause any damage to the composite insulators.

To proceed in the water pressure washing, the recommendation described in CIGRE Brochure 455 paragraph 9.6.1 can be used:

“High pressure water washing (live or de-energized) can be used with a maximum nozzle pressure of 70 bars. Differences between pump types will result in inconsistent nozzle pressures and therefore, it is important to know the nozzle pressure prior to power washing.

It is recommended that pressure be limited to the minimum pressure that provides acceptable cleaning. A minimum distance of 0.5 m should be maintained between the nozzle and the insulator whilst the maximum effective distance has been shown to be 0.7m. Spraying should be done in a continuous up & down motion and it is important not to focus the spray on a localized area during cleaning.

Using a "sweeping" motion will provide adequate cleaning without overstressing the polymer sheds."

*CAUTION: Severe electrical shock risks are due by the fact that the composite insulator and the other main parts of the bushing remain electrically charged at high voltage for a long period of time after the plant de-energization and the bushing grounding. Before starting any work on the de-energized bushing, check the discharge by touching all surface of both indoor and outdoor side composite insulators and all other parts of the bushing with an insulated grounding rod which length must be ≥ 3m. Operators must wear protective insulating gloves and boots and helmet with protective transparent face shield.*
CAUTION: Bushing washing must be performed only with the bushing de-energized. Live washing is not allowed due to the high risk of fatal electrical shocks and dangerous flashovers across the composite insulator.

CAUTION: Inspection of indoor side of the bushing with the plant de-energized must be done by qualified technicians, fully in accordance with the safety rules specific for the access to the valve hall.

In case of accidental damage of silicone sheds, the repairing procedure is illustrated in Appendix 7 (document MB2188). The composite manufacturer can provide a repairing kit and technical support for the repairing activity.

Useful indications about the composite insulator maintenance plan main actions are shown in Table 3. It is recommended to perform all Table 3 listed actions, as a reference starting point, at the first bushing energization.

<table>
<thead>
<tr>
<th>Time base</th>
<th>Visual inspection</th>
<th>UV camera and infrared examination</th>
<th>Wettability</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 Months</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Year</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>When plant is off</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 – Composite insulator maintenance plan

Visual inspection:
Carefully check that the composite insulators sheds do not show any mechanical damages and significant tracking or erosion due to electrical stress.
Visually evaluate also the pollution status and identify the areas of concentrated contamination.
Take note of the position of the areas of evidences, to be carefully analysed and taken under control during future inspections. In case of evidence of incipient erosion / tracking, plan an immediate cleaning or washing action.

UV camera and infrared examination:
Scan all the surface of the composite insulators with an UV camera to identify possible areas of intense UV emissions on the sheds, on the toroids and the incoming cables. To perform this test, the camera must be properly set to avoid false signals and background noise.
In addition, an infrared scan on the line terminal and the incoming cables can reveal incipient hot spots phenomenon that can evolve into a serious damage on the electrical connection and then of the bushing itself.
In case of significant variation of the UV and IR emission, plan the following actions:
UV emission: Immediate cleaning or washing action on the interested part, in the meanwhile control all electrical connections.
IR emission: Immediate control of all electrical connections.

Wettability:
The hydrophobicity of the composite insulator can be checked by following the methodology described in IEC TS 62073 – 2016 Guidance on the measurement of wettability on insulator surfaces.
The simplest way to assess the wettability is the Method C - Spray method.
Wettability level up to HC4 is acceptable for normal operation. In case of further degradation of wettability level (HC5 and HC6) proceed with an accurate washing and drying and then repeat the test.
If wettability remains low but there are no evidences of tracking or erosion keep the bushing in operation but follows the intensive maintenance plan of Table 4.
HVDC WALL BUSHING  
Type PWHS 820.1900.2236 - Large  
Project: Champa – Kurukshetra bipole  

<table>
<thead>
<tr>
<th>Time base</th>
<th>Visual inspection</th>
<th>UV camera and infrared examination</th>
<th>Wettability</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Months</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>When plant is off</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 4 – Composite insulator intensive maintenance plan

12 General maintenance plan

The general maintenance plan is described in the next Table 5.

<table>
<thead>
<tr>
<th>Component</th>
<th>Time base</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite insulators</td>
<td>See Table 3 and Table 4</td>
<td>Inspection and maintenance</td>
<td>See Chapter 11</td>
</tr>
<tr>
<td>Gas SF₆ and Moisture</td>
<td>Monthly</td>
<td>Check the gas density, the gas operative pressure and the gas Dew Point at the gas filling station</td>
<td>Record the data, calculate the ppm v value of the gas.</td>
</tr>
<tr>
<td>Toroids</td>
<td>When plant is off</td>
<td>Clean the surface and check for scratches or deformation.</td>
<td>Anticipate the controls if UV camera reveals corona inception.</td>
</tr>
<tr>
<td>Gas valves, electrical equipment and connecting cables and gas hose to the gas filling station</td>
<td>When plant is off</td>
<td>Clean the gas filling station cubicle. Check for gas leaks.</td>
<td>Check all gas joints from the cubicle to the DILO valves on the bushing. Check the cables and the cable tray to the bushing. Report the evidence of gas leaks.</td>
</tr>
<tr>
<td>Current terminals</td>
<td>When plant is off</td>
<td>Check for evidence of hot spots. Check the terminals and tighten the connecting bolts to the bushing top plates. Check the cable clamps and the bolting to the terminal.</td>
<td>Anticipate the controls if IR camera reveals hot spots. Contact GE Grid Solutions RPV in case of evidence of hot spots during the inspection.</td>
</tr>
<tr>
<td>Grounding terminals</td>
<td>When plant is off</td>
<td>Check for evidence of hot spots. Check the connection integrity and the bolt locking. Verify the effectiveness of the grounding.</td>
<td>Contact GE Grid Solutions RPV in case of evidence of hot spots.</td>
</tr>
<tr>
<td>Component</td>
<td>Time base</td>
<td>Description</td>
<td>Notes</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-----------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Bushing locking to the wall</td>
<td>When plant is off</td>
<td>Check that all bolts are properly locked to the wall support.</td>
<td></td>
</tr>
<tr>
<td>Power factor tap(s)</td>
<td>When plant is off</td>
<td>Open the tap and clean inside. Check the internal spring-loaded contact and clean it. Perform a Megger 1 kV insulation test ( R_{\text{ins}} &gt; 1 , \text{MOhm} ). Check for gas leakages by sniffing the tap insulator area. Carefully close and tighten the cap.</td>
<td><strong>CAUTION:</strong> PF tap cap MUST be accurately closed. Missing the cap could be dangerous and it can cause an electrical discharge at bushing energization.</td>
</tr>
<tr>
<td>Rupture disk red protection cover</td>
<td>When plant is off</td>
<td>Inspect the rupture disk red protection cover, check that the fixing screws are properly locked and that the air breather bolt placed on it is clean and in good conditions.</td>
<td><strong>CAUTION:</strong> Do not remove the protection cover and do not touch the disk when the bushing is filled with gas. An explosion of the disk will be very dangerous.</td>
</tr>
<tr>
<td>Gas density monitors</td>
<td>5 years</td>
<td>Check calibration and operation of micro switches.</td>
<td>Check the effective and correct operation of the alarms &amp; tripping signal chain from the instruments to the substation systems.</td>
</tr>
<tr>
<td>Bushing overall gas leakage</td>
<td>5 years</td>
<td>Check with SF₆ leak-meter device all the flanges joints and the DILO Type valves.</td>
<td>Anticipate the control if the leakage rate is excessive and gas re-filling is frequent. Identify the leakage areas. In case of frequent re-filling, plan for the replacement of the bushing and contact GE Grid Solutions RPV.</td>
</tr>
<tr>
<td>Gas quality</td>
<td>5 years</td>
<td>Check the moisture content and the gas composition in accordance to IEC 60480.</td>
<td>Regenerate / replace the gas if moisture exceeds the maximum limit (&gt;62 ppm w - 500 ppm v) and if there is evidence of SF₆ decomposition by-products. In this case contact GE Grid Solution RPV.</td>
</tr>
</tbody>
</table>

**Table 5 – Bushing general maintenance plan**
## 13 Disposal at the end of life

At the end of the bushing operative life all parts can be recycled or disposed as follows:

<table>
<thead>
<tr>
<th>Part</th>
<th>Material</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF₆ gas</td>
<td>SF₆</td>
<td>Remove by DILO machine, recycle or thermo-destruction</td>
</tr>
<tr>
<td>Main central flanges</td>
<td>Aluminium</td>
<td>Dismount and recycle.</td>
</tr>
<tr>
<td>Central conductor</td>
<td>Aluminium</td>
<td>Dismount and recycle.</td>
</tr>
<tr>
<td>Indoor and outdoor side flanges</td>
<td>Aluminium</td>
<td>Dismount and recycle.</td>
</tr>
<tr>
<td>Top electric terminals</td>
<td>Aluminium</td>
<td>Dismount and recycle.</td>
</tr>
<tr>
<td>Toroids</td>
<td>Aluminium</td>
<td>Dismount and recycle.</td>
</tr>
<tr>
<td>Internal electrostatic shields</td>
<td>Aluminium</td>
<td>Dismount and recycle.</td>
</tr>
<tr>
<td>Transport supports</td>
<td>Aluminium</td>
<td>Recycle the aluminium</td>
</tr>
<tr>
<td>PET</td>
<td></td>
<td>Dispose or thermo-destruction</td>
</tr>
<tr>
<td>Composite insulators with flanges</td>
<td>Fibreglass</td>
<td>Dispose or thermo-destruction</td>
</tr>
<tr>
<td></td>
<td>Silicone</td>
<td>Dispose or thermo-destruction</td>
</tr>
<tr>
<td></td>
<td>Aluminium</td>
<td>Dismount and recycle.</td>
</tr>
<tr>
<td>Electrical wiring</td>
<td>Aluminium</td>
<td>Recycle</td>
</tr>
<tr>
<td></td>
<td>Copper</td>
<td>Recycle</td>
</tr>
<tr>
<td></td>
<td>Plastic</td>
<td>Dispose or thermo-destruction</td>
</tr>
<tr>
<td></td>
<td>Galvanized steel</td>
<td>Recycle</td>
</tr>
<tr>
<td>DILO Type valves</td>
<td>Stainless steel or Aluminium</td>
<td>Recycle</td>
</tr>
<tr>
<td>Pressure gauges, moisture sensors, digital displays</td>
<td>Various</td>
<td>Recycle as electronic products</td>
</tr>
<tr>
<td>Gaskets</td>
<td>EPDM rubber</td>
<td>Recycle or dispose or thermo-destruction</td>
</tr>
</tbody>
</table>

Table 6 – Bushing end of life management
Appendix 1 Calculation formulas for gas moisture content

This Appendix provides the calculation formulas to convert the Operative SF6 gas pressure and the Dew point measured by the sensors located on the bushings, in values of moisture content in the SF6 gas expressed in ppm v (parts per million in volume) or in ppm w (parts per million in weight).

These formulas are based on the IEEE Std C37.122.5-2013 - IEEE Guide for Moisture Measurement and Control in SF6 Gas-Insulated Equipment.

Introduction

Several physical quantities and measurement units are used to indicate the amount of humidity in a gas filled device. They are:

- Water vapour partial pressure generally expressed in Pascal (Pa).
- Volume ratio usually expressed in parts per million by volume (µl / l or ppm v).
- Mass ratio usually expressed in parts per million by mass (mg / kg or ppm w).
- Dew or Frost point temperature usually expressed in degrees Celsius (°C)
- Relative humidity usually expressed in percentage (%RH).

It must be noted that the designation Dew point is applicable for temperatures > 0°C. For lower temperatures the measured data should be referred as Frost point. The normal practice designates as ‘Dew point’ also the measurements below 0°C.

The Dew point value is dependent from the gas pressure. Therefore, every measurement expressed in terms of Dew point must be completed with the indication of the reference pressure.

The normal industrial practice refers the Dew point to the atmospheric pressure.

The instruments installed in the gas filling station provide the value of the Dew point at the Operative pressure of the bushing (in °C) and the value of the absolute Operative pressure (in MPa abs).

From these two values it is possible to calculate the moisture content, expressed in ppm v and ppm w.

Calculation routines

The next Table 7 shows the symbols and the relevant measuring units and values.

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Measuring unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative pressure (absolute value)</td>
<td>$p_{op}$</td>
<td>Pa, kPa</td>
<td></td>
</tr>
<tr>
<td>Standard reference pressure (atmospheric pressure)</td>
<td>$p$</td>
<td>kPa</td>
<td>100</td>
</tr>
<tr>
<td>Temperature</td>
<td>$t$, $T$</td>
<td>°C, K</td>
<td></td>
</tr>
<tr>
<td>Water vapour partial pressure</td>
<td>$p_{wpp}$</td>
<td>Pa</td>
<td></td>
</tr>
<tr>
<td>Dew / Frost point temperature at Operative pressure</td>
<td>$t_d / t_f$</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Volume ratio, parts per million by volume</td>
<td>$ppm_{v}$</td>
<td>µl/l</td>
<td></td>
</tr>
<tr>
<td>Mass ratio, parts per million by weight</td>
<td>$ppm_{w}$</td>
<td>mg/kg</td>
<td></td>
</tr>
<tr>
<td>Molecular weight of SF6</td>
<td>$M_g$</td>
<td>g/mol</td>
<td>146.06</td>
</tr>
<tr>
<td>Molecular weight of water vapour (H2O)</td>
<td>$M_v$</td>
<td>g/mol</td>
<td>18.02</td>
</tr>
</tbody>
</table>

Table 7 – Symbols, units and values
The first step of the calculation routine is to evaluate the Water vapour partial pressure, as function of the measured Dew point temperature.

If the measured Dew point temperature is $< 0^\circ C$, i.e. the Frost point $t_f$, the calculation is done with the following formula:

$$p_{wpp} = 611.2 \times e^{\frac{22.46 \times t_f}{272.62+t_f}}$$

On the contrary, if the measured Dew point temperature is $\geq 0^\circ C$ (from 0 to 50°C), the water vapour partial pressure is calculated with this formula:

$$p_{wpp} = 611.2 \times e^{\frac{17.62 \times t_d}{243.12+t_d}}$$

Based on the measured Operative pressure, the value of moisture expressed in ppm v is:

$$ppm_v = \frac{p_{wpp}}{p_{op} - p_{wpp}} \times 10^6$$

The moisture content expressed in ppm w can be calculated with the following formula:

$$ppm_w = \frac{M_v}{M_g} \times ppm_v$$

**Example of calculation**

<table>
<thead>
<tr>
<th>Operative pressure (absolute value)</th>
<th>$p_{op}$</th>
<th>0.65 MPa abs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dew / Frost point temperature at the Operative pressure</td>
<td>$t_f$</td>
<td>-30°C</td>
</tr>
</tbody>
</table>

$$p_{wpp} = 611.2 \times e^{\frac{22.46 \times (-30)}{272.62+(-30)}} = 38.02 \text{ Pa}$$

$$ppm_v = \frac{38.02}{650000 - 38.02} \times 10^6 = 58.5 \text{ ppm}_v$$

$$ppm_w = \frac{18.02}{146.06} \times 58.5 = 7.21 \text{ ppm}_w$$
Appendix 2 Procedure for gas leakage measurement

This Appendix describes the procedure to be followed to check and measure the gas leakages and to evaluate the Maximum total cumulated relative leakage in one year by direct measurement with a portable gas leak-meter (sniffer).

Technical characteristics of the leak-meter

The next Table 8 shows the typical technical characteristics of a gas leak meter.

<table>
<thead>
<tr>
<th>Measuring principle</th>
<th>Non-dispersive infrared sensor (NDIR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring range</td>
<td>0 – 2000 ppm v SF6</td>
</tr>
<tr>
<td>Detection limit</td>
<td>3 ppm v</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>3.43 g / year</td>
</tr>
<tr>
<td>Accuracy</td>
<td>&lt;50 ppm v</td>
</tr>
<tr>
<td></td>
<td>≥50..&lt;100 ppm v</td>
</tr>
<tr>
<td></td>
<td>≥100..&lt;2000 ppm v</td>
</tr>
<tr>
<td></td>
<td>±2 ppm v</td>
</tr>
<tr>
<td></td>
<td>±5 ppm v</td>
</tr>
<tr>
<td></td>
<td>±2%</td>
</tr>
<tr>
<td>No cross sensitivity to moisture (0 - 100% relative moisture, not condensing) and volatile organic compounds</td>
<td></td>
</tr>
<tr>
<td>Indication accuracy</td>
<td>1 ppm v</td>
</tr>
<tr>
<td>Indication unit</td>
<td>ppm v, g/year, bar x cm³/s</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>0°C to + 50°C</td>
</tr>
<tr>
<td>Response time T90</td>
<td>&lt;1s</td>
</tr>
<tr>
<td>Indication</td>
<td>graphic display + audible signal</td>
</tr>
<tr>
<td>Cumulative calculation</td>
<td>automatic cumulative sum of leaks measurement</td>
</tr>
</tbody>
</table>

Table 8 – Leak-meter typical technical characteristics

Bushing conditions

The bushing and its gas accessories must be filled with SF6 at the rated filling pressure. The test can be performed only after the gas stabilization inside the bushing; that means at least 4 hours after the filling operation.

Test procedure

The direct sniffing leak test will be performed in accordance to the following steps:

- Carefully clean the parts of the bushing that will be subject to the leak test.
- Set the instrument on the bar x cm³/s measuring unit.
- Calibrate the leak-meter with a SF6 calibrated leak test.
- Start from the topmost part of the bushing and the equipment.
- Slowly move (≈5 mm/sec) the sensing probe of the leak-meter around the junction points of the bolted flanges, the welding points of the metallic parts, the gas valves, the tubes and the installed gas instruments at a distance from 2 to 5 mm.
- In case of evidence of gas leak, mark the leaking zone and record the amount of the leakage.
- Sum-up all the measured leaks. If the leak-meter is equipped with cumulative leaks sum feature, activate it before starting.
- Calculate the maximum total cumulated relative leakage in one year (F%)

The maximum acceptable limit for GE Grid Solutions must be < 0.1% per year.
Calculation routine

The maximum total cumulated relative leakage in one year is calculated with the following formula:

\[ F_r \% = \frac{F \times t}{p \times V} \times 100 \]

Where:

<table>
<thead>
<tr>
<th>Maximum total cumulated relative leakage in one year</th>
<th>Fr%</th>
<th>%</th>
<th>&lt; 0.1% x year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cumulated leakages</td>
<td>F</td>
<td>bar x cm³/s</td>
<td>( F = \sum_{i=1}^{n} F_i )</td>
</tr>
<tr>
<td>Operative pressure (absolute value)</td>
<td>p</td>
<td>bar abs</td>
<td>Specific data of the bushing</td>
</tr>
<tr>
<td>Gas volume of the bushing</td>
<td>V</td>
<td>cm³</td>
<td></td>
</tr>
<tr>
<td>Reference time (1 year)</td>
<td>t</td>
<td>s</td>
<td>31.536 x 10⁶s</td>
</tr>
</tbody>
</table>

Example of calculation

Data referred to Champa Kurukshetra 820 kV Large wall bushing:

<table>
<thead>
<tr>
<th>Operative pressure (absolute value)</th>
<th>p</th>
<th>5.7</th>
<th>bar abs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas volume</td>
<td>V</td>
<td>12.7 x 10⁶</td>
<td>cm³</td>
</tr>
<tr>
<td>Total cumulated measured leakage</td>
<td>( F = \sum_{i=1}^{n} F_i )</td>
<td>5.5 x 10⁻⁴</td>
<td>bar x cm³/s</td>
</tr>
</tbody>
</table>

\[ F_r \% = \frac{F \times t}{p \times V} \times 100 = \frac{5.5 \times 10^{-4} \times 31.536 \times 10^6}{5.7 \times 12.7 \times 10^6} \times 100 = 0.024\% \]

The \( F_r \% \) is less than 0.1% \( \rightarrow \) OK.