

# How to select isolating spark gaps for use in hazardous explosive environments for protection of insulating pipe joints



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# How to select isolating spark gaps for use in hazardous explosive environments for protection of insulating pipe joints!

Insulating joints (IJ) are used to electrically isolate pipeline systems or to isolate high-voltage-interference on pipelines into sections. Cathodically protected systems are electrically isolated until the dielectric strength of the insulating joint is breached. Surges caused by a lightning strike, into exposed parts of a pipeline system, may lead to the dielectric strength of insulating joints being exceeded. As a result, hazardous sparking may occur or the insulation material may be damaged.

The function of isolating spark gaps (ISG) and connection cables is to protect the insulating piece (insulation) against lightning-induced surges and to discharge the lightning energy without uncontrolled arcing in an explosive environment. During normal operation and after the discharge process, the EXFS isolating spark gaps must ensure safe electrical isolation. Based on practical experience, AfK recommendation No. 5 (1986 edition) was amended in accordance with the latest lightning current parameters according to IEC 62305. The new version, described below, now includes notes on the selection and inspection of isolating spark gaps including their connection elements.



## Field of application of AfK recommendation No. 5

This document describes measures to prevent ignition-related hazards to insulating joints and to ensure cathodic corrosion protection in potentially explosive atmospheres. These recommendations apply to natural gas compressor stations and pipeline systems. In these type of installations, insulated couplings or insulating flanges are used as insulating pieces. Other protection measures may be taken when transporting or handling hazardous liquids in harbours and waterways. Protection measures against other risks such as discharging injected alternating currents or protection measures against electric shock are described in EN 50443 and AS/NZS 4853.

## The need for EXFS-ISG

For explosion protective measures, the primary goal in potentially hazardous explosive atmospheres is to avoid sources of ignitions (e.g. uncontrolled spark-over on insulating pieces).

EXFS type ISG do not have to be used outside of potentially explosive areas (e.g. in case of buried insulating joints); however, faulty insulating joints basically interfere with the cathodic corrosion protection and if pipelines are subjected to external high voltages and electromagnetic interference, human protection against electrical shocks is no longer possible. Faulty insulating joints must therefore be replaced. This involves high repair costs and negatively affects system availability. For these reasons, it may be useful to install EXFS-ISG even outside of potentially explosive areas.

## Selection, installation and testing of EXFS-ISG

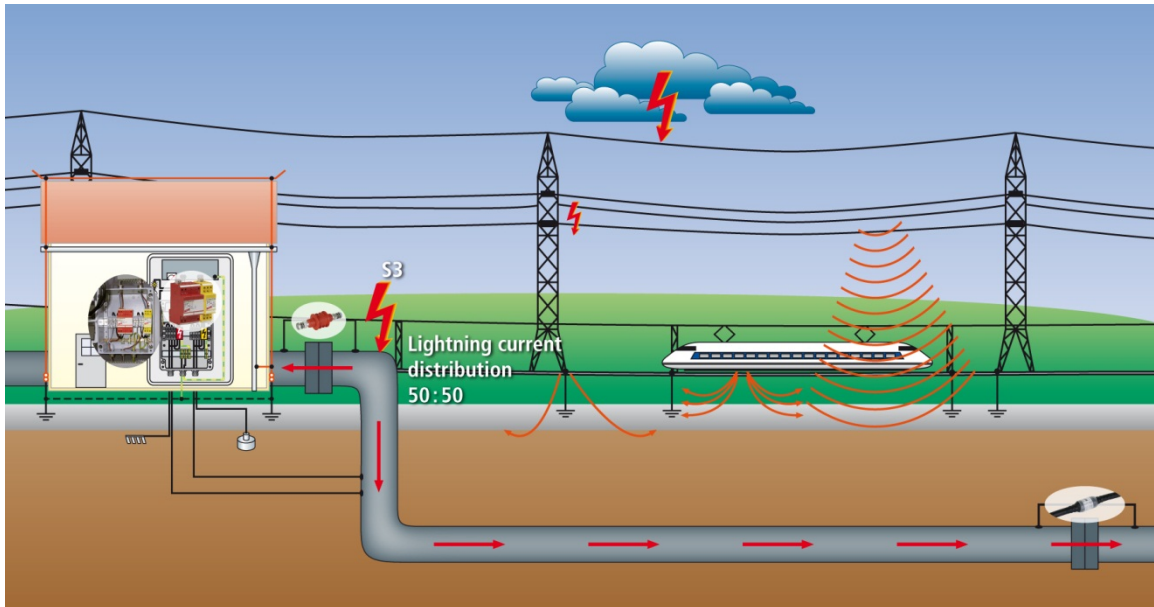
The selection of procedure of EXFS-ISG and their connection elements depends on:

- Lightning protection level (LPL),
- Dielectric strength of the insulating material,
- Distance between the connection points (cable length),
- Technical data of the ISG,
- Place of installation (Ex zone), and

- Insulation coordination (insulating piece with the connected ISG).

### a) Determination of the lightning protection level (LPL)

The lightning protection level (LPL) is determined by means of a risk assessment according to IEC 62305-2. Based on this parameter, the maximum lightning current (lightning current distribution according to IEC 62305-1) flowing through the EXFS-ISG is determined by means of different strike source scenarios (S1 – S4). For example, the maximum lightning current (LPL I) flowing through the EXFS-ISG in the event of a lightning strike into an aboveground pipeline section would be 100 kA (10/350  $\mu$ s) (see Figure 1).



**Figure 1** Lightning current distribution in case of lightning strike source S3

Table 1 of IEC 62561-3 specifies the maximum parameters of the first short stroke depending on the LPL for EXFS-ISG and connection elements. The values for the subsequent negative stroke are not considered.

### b) Dielectric strength of the insulating piece

After insulating joints have been manufactured, they are tested with an a.c. test voltage  $U_{PW}$  of 50 Hz according to the relevant test class. Generally there are two test classes:

Class 1:  $U_{PW} \geq 5 \text{ kV}_{\text{rms}}$

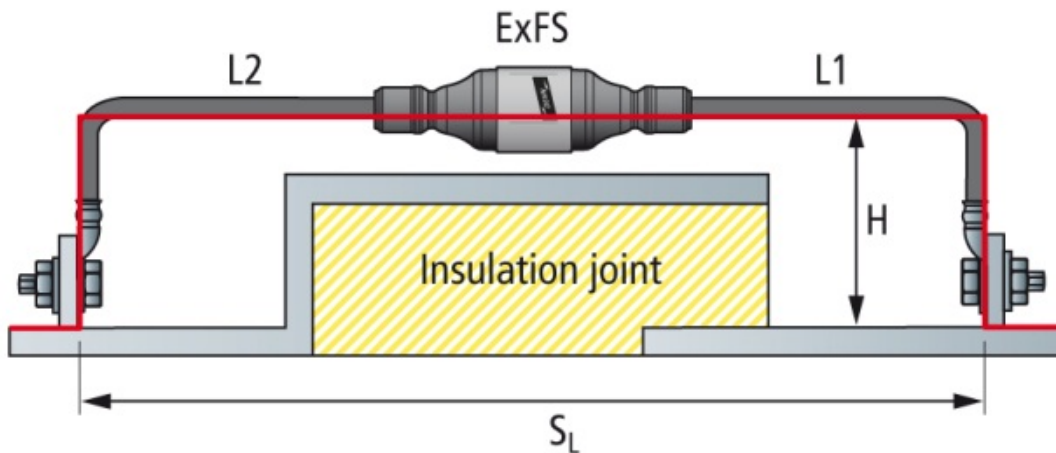
Class 2:  $U_{PW} \geq 2.5 \text{ kV}_{\text{rms}}$

The manufacturer of the insulating joints will provide information on these test classes for the insulating joints. It must be noted that higher test voltages (e.g. 10 kV) may be requested by customers.

### c) Distance between the connection points (length of the connecting cable)

Depending on the maximum current rate of rise of the partial lightning current determined in a) and the length of the connecting cable, the dielectric strength of the insulating piece may be exceeded due to a voltage drop across the connecting cable (during the discharge process).

This may already be the case (based on Class I insulating joint and LPL I) for a cable length exceeding 300 mm. If the length of the connection elements ( $S_L + 2 \cdot H$  according to Figure 2) can be limited to  $\leq 400$  mm (length of the EXFS-ISG + cable length in case of a Class I insulating piece), a further risk assessment (coordination of the EXFS-ISG with the insulating piece) is not required.



**Figure 2** Length of the connection elements

In addition, all connection elements must

- be capable of carrying lightning currents,
- not produce ignition sparks (in case a potentially hazardous explosive atmosphere is present at the time),
- be installed directly in parallel and close to the insulating joint,
- be connected with the shortest possible distance,
- be protected against accidental bridging (e.g. by tools).

Adequate connection points to pipelines are:

- Welded lugs, studs or earth bosses
- Threaded holes in the flanges for fixing bolts

**Note:** Connection via a clamp is only permitted if it has been verified in tests that no ignition sparks occur in case of lightning currents.

All joints must be prevented from becoming loose, for example, by inserting a spring washer. Serrated washers have not proven very effective in practice (sparking in case of lightning currents).

#### d) Minimum requirements for EXFS-ISG

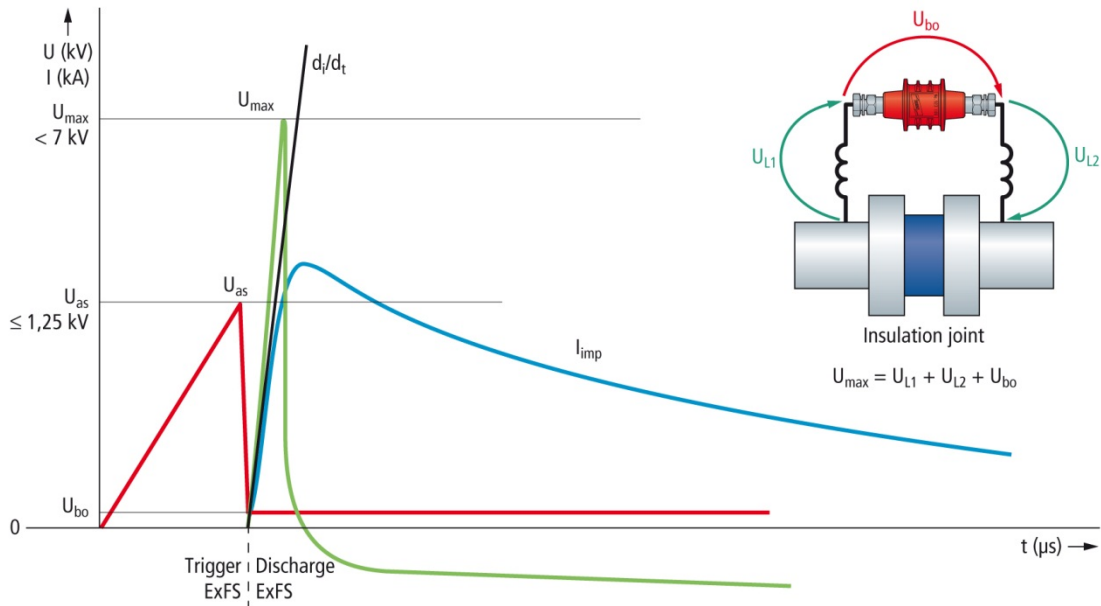
EXFS-ISG should have the following technical data and approvals:

- Tested to IEC 62561-3 [5]
  - Lightning current carrying class: H or N
  - d.c. sparkover voltage:  $> 600 \text{ V}^1$
  - 100 % lightning impulse sparkover voltage (1.2/50  $\mu\text{s}$ ):  $\leq 1.25 \text{ kV}$
  - Nominal discharge current (8/20  $\mu\text{s}$ ): 100 kA
  - Lightning impulse current  $I_{\text{imp}}$  (10/350  $\mu\text{s}$ ): 100 kA (H), 50 kA (N)
  - Rated impulse withstand voltage (50 Hz): 250 V<sup>1</sup>
  - Rated a.c. discharge current (50 Hz): 500 A/0.5s<sup>2</sup>
  - IECEx or ATEX certification of compliance according to the Ex zone at place of installation
- <sup>1</sup>) As a rule  $> \hat{U}$  at the place of installation  
<sup>2</sup>) Max. discharge current due to inductive and capacitive coupling from external high voltage source at place of installation

#### e) Coordination of the EXFS-ISG with the insulating joint

Coordination between the dielectric strength of the insulating joint and the associated spark gap is ensured if during a lightning discharge the sparkover is via the EXFS-ISG and not through the insulating material of the insulating joint! The EXFS-ISG thus represents a defined flashover point which prevents uncontrolled sparkovers, and at the same time must prevent ignition of the explosive atmosphere!

Coordination during lightning discharge conditions is ensured if the total voltage rise during the discharge process does not reach the peak break-down voltage of the dielectric material used in the manufacture of the insulated joint.



**Figure 3** Schematic voltage characteristic of the insulating joint in case of a lightning strike

As can be seen from Figure 3, behaviour of the EXFS-ISG before and after it's triggered, plus the voltage drop across the connecting cable must be compared with the dielectric strength of the insulating material for coordination.

#### f) Impulse sparkover of the EXFS-ISG

The impulse sparkover voltage  $U_{as}$  (1.2/50  $\mu s$ ) of an EXFS-ISG must be 50% less than the rms value of the a.c. test voltage  $U_{PW}$  of the insulating material (according to AfK 5).

Requirement:  $U_{as} \leq U_{PW}/2$

e.g. Class 2 insulating joint:  $U_{PW} = 2.5$  kV

Impulse sparkover voltage of the isolating spark gap:  $U_{as} \leq 1.25$  kV

**Note:** When using EXFS-ISG with  $U_{as} \leq 1.25$  kV all (Class 1 and 2) insulating joints can be protected by the EXFS-ISG.

#### g) Discharge of the EXFS

The electric voltage stress on an insulating material does not only depend on the impulse sparkover voltage of an isolating spark gap connected in parallel with the insulating piece. After the isolating spark gap has ignited, impulse current flows, causing a voltage drop on all connection elements. The voltage drop is significantly influenced by the impedance of the connection elements and may reach values which could exceed the dielectric strength of the insulating material (greater than the impulse sparkover voltage  $U_{as}$ ).

The maximum volt rise on all connection elements ( $U_{max}$ ) of the spark gap arrangement during the lightning current discharge process must be less than the peak value of the test voltage of the insulating piece  $\hat{U}_{PW}$ .

Requirement:  $U_{max} < \hat{U}_{PW}$

e.g. Class 1 insulating piece:  $U_{PW} = 5$  kV

peak value of  $U_{PW}$ :  $\hat{U} = U_{PW} * \sqrt{2} = 5 \text{ kV} * \sqrt{2} \Rightarrow \hat{U}_{PW} = 7 \text{ kV}$ .

The maximum volt drop  $U_{max}$  can be determined using the following formula:

$$U_{max} = U_{bo} + I_{imp} * R_L + L * di/dt$$

$U_{bo}$ : Arc voltage of the EXFS-ISG, depending on the type of spark gap!

## h) Case study

The following parameters are used in our case study for an isolating spark gap installed across an insulated pipe joint, subjected to all relevant expected lightning discharge phases! (Please refer to Figure 2.)

H = Average height of the EXFS-ISG: 10 cm

$S_L$  = Spacing between connection points: 80 cm

$U_{bo} = 30$  V; Spark gap arc voltage

$U_{as} \leq 1.25$  kV; Impulse sparkover voltage

Connecting cable: 25 mm<sup>2</sup>, Cu, round;

$$\rho = 0.0178 \Omega \text{ mm}^2/\text{m}$$

$$R_L = 0.712 \text{ m}\Omega/\text{m}$$

$$L = 1 \mu\text{H}/\text{m}$$

$$l = S_L + 2H = 1 \text{ m}$$

Insulating piece: Class 1 ( $U_{PW} \geq 5$  kV;  $\hat{U}_{PW} = 7$  kV)

Lightning protection level (LPL) II

Max. Lightning current  $I_{imp}$ : 75 kA (10/350  $\mu\text{s}$ )

### i. Sparkover voltage

Requirement:  $U_{as} \leq U_{PW}/2$ ;

$$\Rightarrow 1.25 \text{ kV} \leq 5 \text{ kV}/2$$

$$1.25 \text{ kV} \leq 2.5 \text{ kV} \text{ (requirement fulfilled)}$$

### ii. Maximum voltage

Requirement:  $U_{max} < \hat{U}_{PW}$

$$U_{max} = U_{bo} + I_{imp} * R_L + L * di/dt$$

$$= 30 \text{ V} + (75 \text{ kA} * 0.712 \text{ m}\Omega) + (1 \mu\text{H} * 7.5 \text{ kA}/\mu\text{s}) = 30 \text{ V} + 53.4 \text{ V} + 7.5 \text{ kV} = \underline{7.50834 \text{ kV}}$$

$$\underline{7.50834 \text{ kV} < 7 \text{ kV} \text{ (requirement not fulfilled!)}$$

Additional measures must be taken since the goal of protecting the insulating joint has not been achieved during all phases of the discharge process.

### Possible measures:

- Parallel connection of another EXFS-ISG (type test recommended)
- Increase the dielectric strength of the insulating joint
- Reduction of the inductance L of the connecting cable
- Detailed assessment of the current distribution according to IEC 62305-1 or risk analysis according to IEC 62305-2

### i) Testing of EXFS-ISG

If EXFS-ISG are to be used in potentially hazardous explosive environments, they must be tested at least every three years according to IEC 60079-17 [6]. Testing an EXFS-ISG and its connecting cables always requires visual inspection and measurements.

The EXFS and its connection elements are visually inspected for

- damage of the EXFS housing
- installation position according to the manufacturer's installation instructions
- insulation integrity of the connecting cables
- tightness of the connecting cable
- contact stability
- pollution of the EXFS installation
- suitability for installation in potentially explosive environments
- connecting cable length > 300 mm → proof that the EXFS is coordinated with the insulating joint
- other test criteria (see c)

Short-circuits and sufficient insulation strength must be measured according to the relevant manufacturer's test instructions. Electrical tests may only be carried out on disconnected and removed EXFS-ISG outside of potentially explosive areas. If an electrical test is to be carried out in a potentially explosive area, close consultation with the operator is required.

## Conclusion

Based on the above recommendation it is possible to evaluate the installation of the EXFS isolating spark gap to achieve the correct protection requirements. The starting point must be to know the electrical properties of the insulated joint material! (Peak voltage.) Establish the correct lightning protection level (LPL) by conducting a lightning risk assessment – this will determine the required lightning discharge current rating of the spark gap (type of ISG, either H or N) and the inductive volt-drop contributed by the connecting cables!

Insist on getting copies of the spark gap IECEx certificates – the IECEx approval must be clearly and permanently visible on the actual spark gap! You have to know the possible max. temperature of the environment at the place of installation during normal conditions and make sure what the IP rating of the spark gap device is, not all spark gaps are rated suitable for burial below ground!

## References

AfK recommendation No. 5, February 1986 (replacement for AfK recommendation No. 5 of November 1973): “Kathodischer Korrosionsschutz in Verbindung mit explosionsgefährdeten Bereichen” [Cathodic corrosion protection in potentially explosive atmospheres]

IEC 62305-1: 2011; Protection against lightning – Part 1: General principles

IEC 62305-2 : 2011; Protection against lightning – Part 2: Risk management

IEC 62305-3 : 2011; Protection against lightning – Part 3: Physical damage to structures and life hazard

IEC 62305-4 : 2011; Protection against lightning – Part 4: Electrical and electronic systems within structures

AfK recommendation No. 5, July 2010 (replacement for recommendation No. 5 of February 1986): “Kathodischer Korrosionsschutz in Verbindung mit explosionsgefährdeten Bereichen” [Cathodic corrosion protection in potentially explosive atmospheres]

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