Switchgear Connecting Technologies

This document has been written by Cable Accessories manufacturers to describe the technologies suitable to connect Switchgears to the electrical networks. It also provides an overview of possible applications, guidance in choosing the right products and applicable tests.

I - Grid Description

In common usage, the voltage range is referred to as “Medium Voltage" although this is not a standardized term. Medium Voltage represents the range between 1 kV and 36 kV according to EN 50160, but the upper limit could change from country to country and harmonization documents like HD629.1 covers up to 20,8/36(42) kV. Medium voltage is primarily used in the distribution network between substation and transformer station applications. Underground cables are increasingly used instead of overhead lines as the means of distribution.

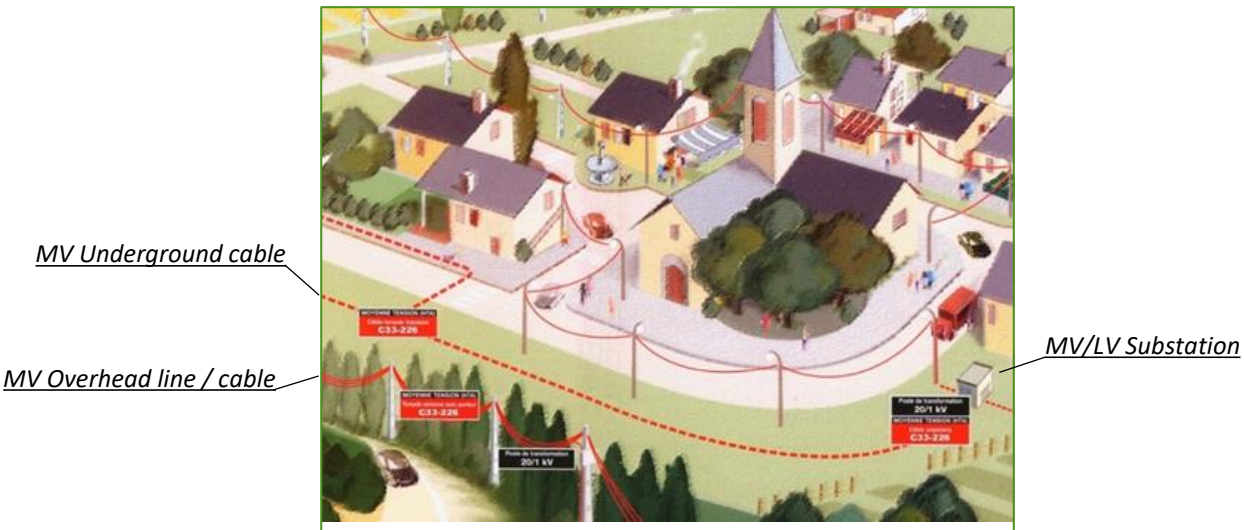


Figure 1: Conventionalized Distribution Grid

Depending on load density, different voltage levels are used (see table below).

Standardized insulation levels U_0/U (U_m)	
3.6/6.0 (7.2) kV	12.7/22.0 (24.0) kV
3.8/6.6 (7.2) kV	18.0/30.0 (36.0) kV
6.0/10.0 (12.0) kV	19.0/33.0 (36.0) kV
6.35/11.0 (12.0) kV	20.8/36.0 (42.0) kV
8.7/15.0 (17.5) kV	26.0/45.0 (52.0) kV
12.0/20.0 (24.0) kV	

The publication “Distribution Grids in Europe – Facts and Figures 2020” from Eurelectric association reports the main voltage classes operated in Europe and listed in the table below:

Middle Europe	Main U voltage classes used by DSOs				
	6/6,6 kV	10/11 kV	15 kV	20/22 kV	30/33 kV
Austria		X		X	X
Baltics	X	X	X	X	
Belgium	X	X	X		X
Czech Republic	X			X	X
Finland				X	X
France				X	
Germany		X	X	X	X
Hungary		X		X	X
Ireland		X		X	
Italy				X	
Luxemburg	X			X	
Netherlands	X	X		X	X
Norway				X	
Poland	X		X	X	X
Portugal	X	X	X		X
Romania	X			X	
Slovakia		X		X	
Spain		X	X	X	X
Sweden		X		X	X
Switzerland		20		80	

II – Definitions

A. General

Termination	A device **fitted to the end of a cable** to ensure electrical connection with other parts of the system and to **maintain the insulation** up to the point of connection
Separable Connector	A **fully insulated termination** permitting the **connection and disconnection** of the cable to and from **the mating bushing**.
Bushing	A **bushing** allows an electrical connection to **penetrate the metallic casing of switchgear, transformers, or other equipment** (e.g., electric motors). One end of the bushing is immersed in an **insulating medium** (gas or oil) inside the casing and the other end has a **standardized interface** for a separable connector.

Figure 2: Separable Connector mated to a bushing

B. Separable Connectors

There are two main separable connector families.

Dead Break separable connector	A separable connector which can be connected / disconnected only when **the system is not energized**.
Load Break separable connector	A separable connector which can be connected/disconnected under **voltage and load**.

The Dead Break system is the only one used in Europe. The Load Break system is mainly used in North America.

C. Dead Break Separable Connectors

Within the family of Dead Break separable connectors there are two basic designs.

Screened Separable Connector: A separable connector which has a fully screened external surface ("safe to touch" under normal service conditions).

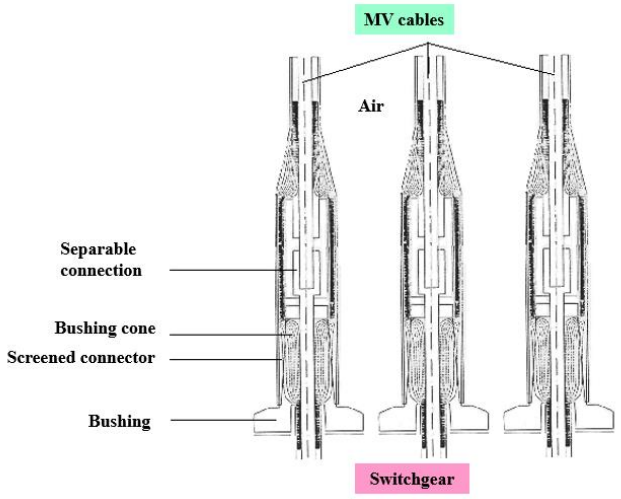


Figure 3: Screened Separable Connector Electrical Field

Unscreened Separable Connector: A separable connector which does not have an external screen (not "safe to touch").

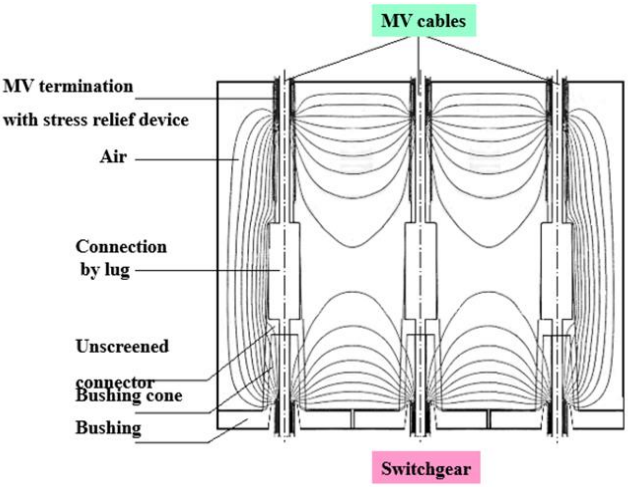


Figure 4: Unscreened Separable Connector Electrical Field

Screened separable connectors are more popular: their screened design makes them safer and more suitable for applications with reduced clearance or compact compartments.

III – Bushing Interface description

The bushings are usually pre-installed and delivered with the equipment (switchgear, transformer, etc…). Separable connectors are usually provided via a different supply-chain and need to be correctly specified to ensure compatibility with the bushing interface and cable to be connected.

Two EN standards describe the existing interfaces:

- EN 50180: Bushings above 1 kV up to 52 kV and from 250 A to 3.15 kA for liquid-filled transformers.
- EN 50181: Plug-in type bushings above 1 kV up to 52 kV and from 250 A to 2.50 kA for equipment other than liquid filled transformers (e.g., switchgear, motors, etc).

There are two basic types of bushing interface:

- Outside Cone
- Inside Cone

A. Outside Cone Bushings

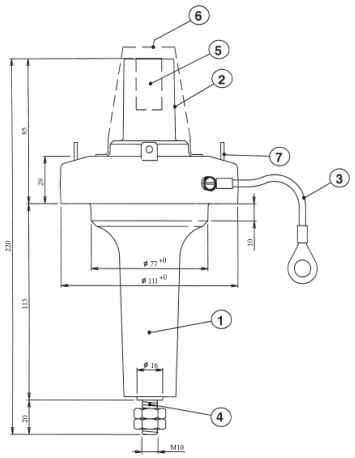
Each interface has differing dimensions of the bushing cone and is rated for a range of currents. A voltage class is defined for each interface type. The following table describes the standardized interfaces:

Interface type	U_m (kV)	I_r (A)	Contact type
A	12 – 24	250	Sliding
B	12 – 24 – 36	250 – 400	Sliding
C	12 – 24 – 36	630 – 1250	Bolted
D	12 – 24	800 – 1250	Bolted
E	36		Bolted
F	12 – 24 – 36	630 – 1250 – 2500	Bolted
	12 – 24 – 36 – 52	630 – 1250	Bolted

Sliding contact types (cf. Fig 6) are limited up to 400A rating.

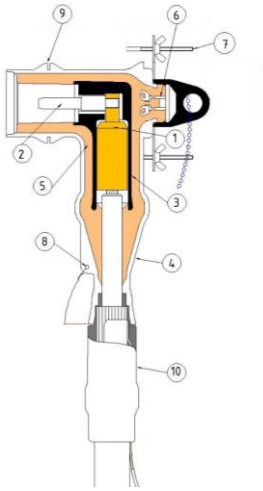
For rating starting from 630A, the contact is bolted (cf. Fig 7).

Figure 5: Bushing Interface A - 250A / 24kV



1. Bushing body
2. Bushing interface with separable connector
3. Earthing
4. Bushing rod
5. Bushing contact: sliding or bolted
6. Protective cap
7. Bail holder (for sliding contact interface)

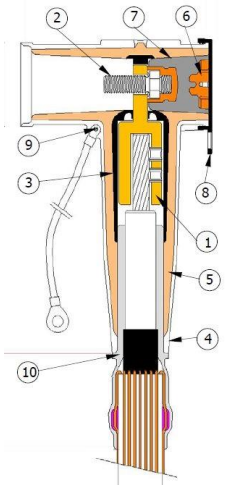
Figure 6: Elbow Separable Connector Interface A - 250A / 24kV



1. Cable conductor lug
2. Pin finger for **sliding contact**
3. Separable connector electrode
4. Separable connector outer semiconductive screen
5. Separable connector insulation
6. Separable connector voltage test point
7. Bail holders
8. Earthing eye
9. Groove for locking ring
10. Earth cover

Diagram above shows main parts of a separable connector with sliding contact

Figure 7: Asymmetric Separable Connector Interface C – 630A / 36kV



1. Cable conductor lug
2. Clamping screw for bolted contact
3. Separable connector electrode
4. Separable connector outer semiconductive screen
5. Separable connector insulation
6. Separable connector voltage test point
7. Insulated tap
8. Semiconductive cap
9. Earthing eye for ground connection
10. Cable adapter

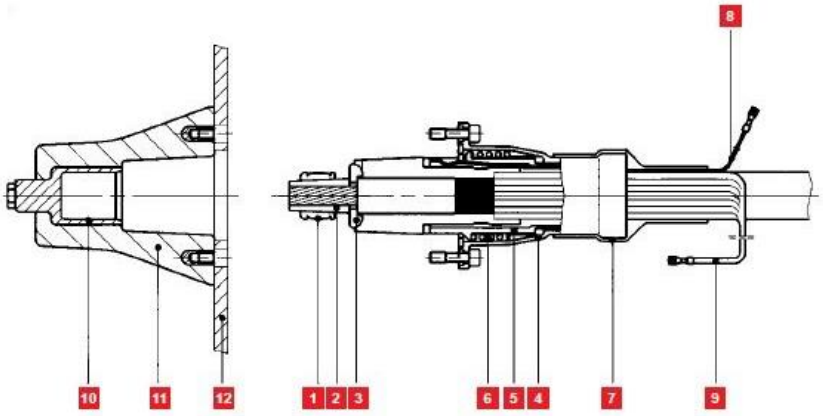
Diagram above shows main parts of a separable connector with bolted contact

B. Inside Cone Bushings

Each interface has differing dimensions of the bushing cone and is rated for a range of currents. A voltage class is defined for each interface type. The following table describes the standardized interfaces:

Interface type	U_m (kV)	I_r (A)	Contact type
0	12 – 24	250	Sliding
1	12 – 24 – 36	400 – 630	Sliding
2	12 – 24 – 36	800	Sliding
3	12 – 24 – 36 – 52	1250	Sliding

The diagram below shows the main parts of an inside cone connection:



1. Contact ring
2. Tension cone
3. Thrust piece
4. Bell flange
5. Pressure sleeve
6. Pressure spring
7. Heat-shrink sleeve
8. Test point
9. Cable metallic screen bushing:
10. Female contact part
11. Bushing insulation
12. Bushing flange

Figure 8: Straight Inside Cone Separable Connector

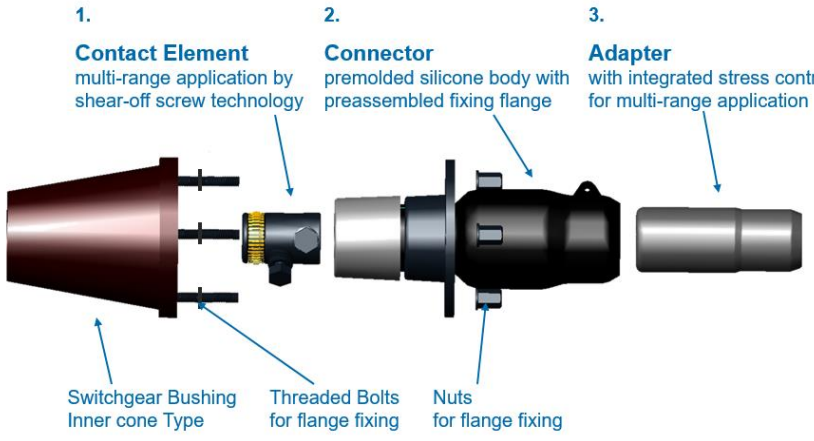


Figure 9: Straight Inside Cone Separable Connector

C. Guidelines for choosing the right separable connector

In order to choose the right separable connector and ensure its compatibility with:

The Bushing - The requested information is:

- **The bushing interface:** letters A, B, C, etc… for Outside Cone / numbers 0, 1, 2, etc … for Inside Cone
- **The bushing rating:** 250A, 400A, 630A, etc…
- **The bushing voltage class:** 12kV, 24kV, 36kV, etc…

The Cable - The requested information is:

- **The cable design:** one core or three-core
- **The cable conductor cross-section and nature**
- **The cable layers** (insulation, outer sheath) **outer diameters**
- **The cable metallic screen design** (Cu wire, Cu Tape, Polylam, etc..)

IV – Comparison of separable connector with other cable/equipment connections:

Air-insulated switchgear is often used in walk-in transformer stations and represents approximately 30% of applications. Indoor terminations are used in this kind of switchgear.

The general construction of an air-insulated walk-in transformer space is simple, but the overall space requirement is high due to the necessary space to accommodate clearance distances.

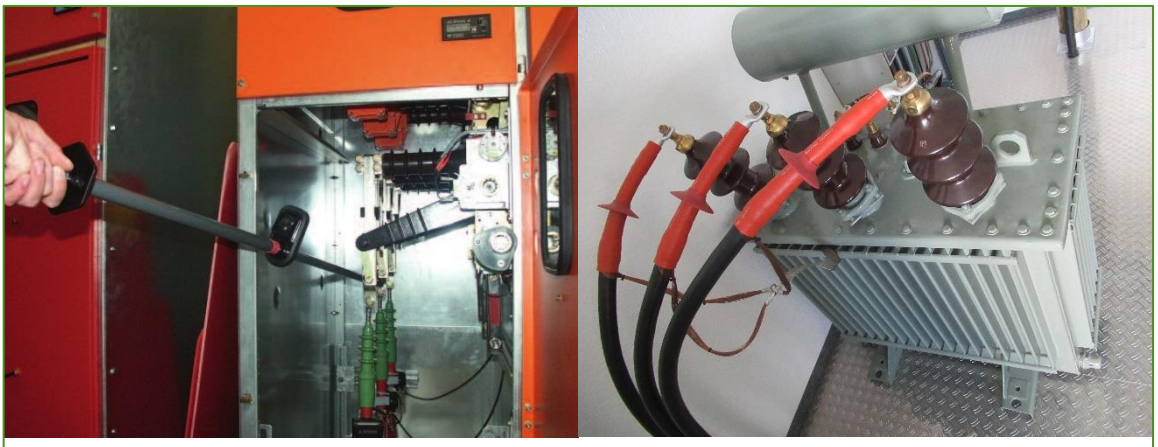


Figure 10: Indoor terminations set-up

Modern medium-voltage switchgear is designed to be fully enclosed.

All active parts such as bus ducts and switching devices are inaccessible during normal operation. **This requires an extended maintenance-free** design of the bus duct connections and the switching devices. In gas-insulated switchgear SF6 gas is used (prior art). In state-of-the-art switchgear a solid insulation of various casting resins is used for insulation means. Alternative gases (based on fluor ketones) are also used. The use of a vacuum as an insulation medium is also possible. Depending on the rated voltage and short-circuit breaking capacity, switching devices are designed as vacuum switching devices or gas insulated devices.

Separable connectors are used in these switching devices, in which the bushings are in accordance with EN 50180, 50181 and DIN 47637.

Compared with Indoor Terminations, **Separable connectors** can be used independently of the insulation type (SF6, vacuum, air, oil) used in the equipment and:

- are **maintenance free**
- can be **temporarily immersed in water**
- can be **easily connected and disconnected**
- are **suitable for outdoor and indoor applications**
- their **insulation withstand is not related to the air environment**

Screened separable connectors are suitable for **more compact equipment.**

Separable connectors are removable, and usually consist of a prefabricated body with prefabricated and specially designed electrodes. The design in general **makes the handling very easy** compared to conventional solutions used for some indoor terminations. Installation does not require special tools. The most common materials are EPDM-rubber and silicone rubber, these materials in combination with the special design makes the bodies very compact.

Outside cone technology is widely used as it is simple and relatively inexpensive.

Figure 11: T-shape Separable connector for Outside cone bushing

Figure 12: T-shape Separable connector for Outside cone

Figure 13: Straight separable connectors for Inside cone without metal housing

Figure 14: Straight separable connectors for Inside cone with metal housing

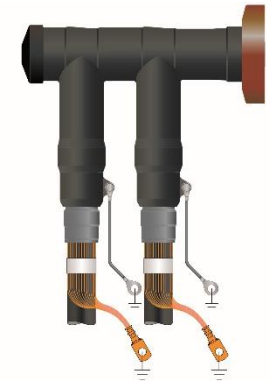
250 A connector installed on a voltage transformer in a gas insulated switchgear

Figure 15: Separable elbow connector for Outside cone bushing

There are different types of T-shaped separable connectors with an outer semi-conductive layer. Due to the design the fault current test is necessary but exposed electrical parts are “safe to touch” under normal service conditions.

Screened Separable connector with metal housing	Screened Separable connector
Inner semi-con Outer semi-con Additional metal encapsulated system No residual potential on the outer surface 	Inner semi-con Outer semi-con Outer semi-con with functional dimension No residual potential on the outer surface 

Separable connectors with outer semi conductive layer are the most common design for safety reasons.

Interface A 250A	Interface B 400A	Interface C 630/1250A	Interface C Coupling 630/1250A
Straight connector Elbow connector 	Elbow connector Straight Connector 	T-form connector 	T-form connector with coupling connector 

Some separable connectors still exist with metal housing design. The presence of the metal housing removes the necessity to perform the fault current test according to standard HD 629.1.

Interface A 250A	Interface B 400A	Interface C 630/1250A
Straight connector Elbow connector	Elbow connector	T-form connector
		

V – Examples of connections configurations:

Separable connectors are used to connect equipment such as switchgear, transformers, or motors.

Figure 16: Cable connection in the cable compartment of a gas insulated switchgear

Figure 17: Double cable connection: Screened separable connectors on Interface C bushing and coupling connector in switchgear with 2 bushings for each phase, cable fixing beneath the compartment

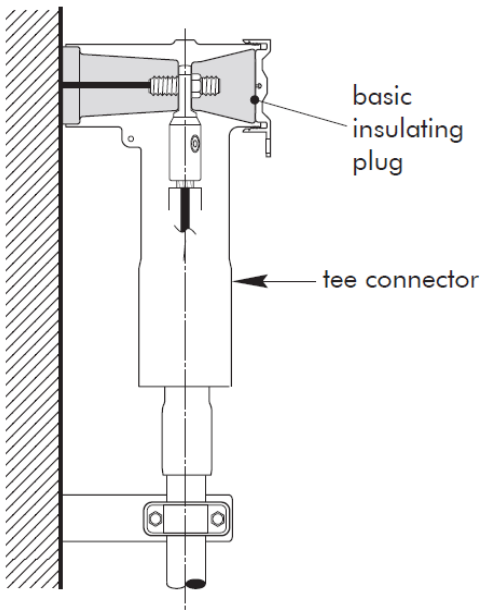


Figure 18: Single Cable

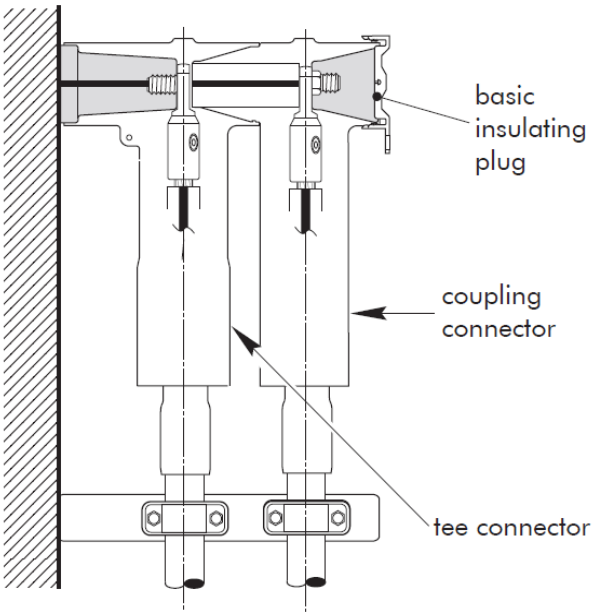


Figure 19: Dual Cables

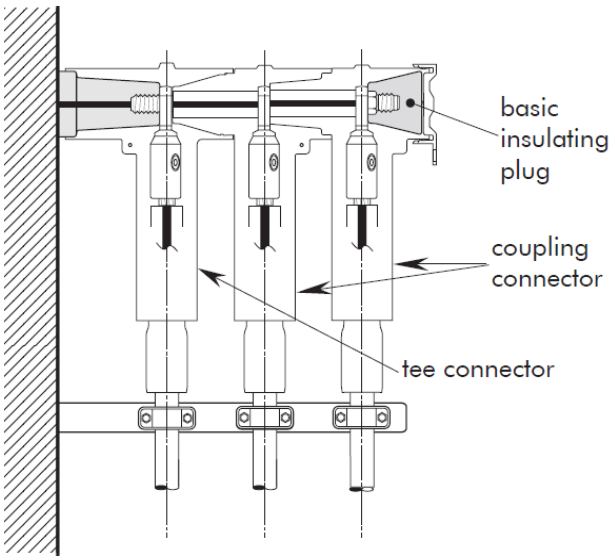


Figure 20: Triple Cables

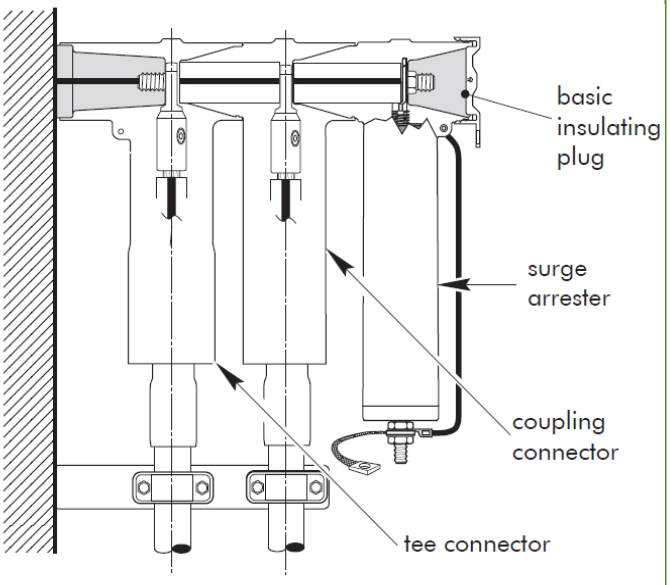


Figure 21: Dual Cables + Surge arrestor

VI –Separable Connector Tests:

The cable cross-section and the conductor material choices for tests are driven by the current rating of the separable connector and are detailed in the following table:

Rating of separable connector	Cable conductor cross section (mm²)			
	Test sequence D1/E1 [a]		Test sequence D2/E2 [c], [d]	
Conductor --->	Cu	Al	Cu	Al
250 A	50	70	50	70
400 A	95	150	95	120
630 A	185	300	120	185
800 A	300	400	150	240
1250 A	500	630	240	400
2500 A [b]	2x500	2x630	500	800

Qualification test sequences are described in the Cenelec HD629.1S3 document:

- Sequence D1/E1 checks, after thermal ageing due to the current load, the electrical characteristics of the separable connector, its watertightness, and its ability to disconnect and reconnect.
- Sequence D2/E2 checks its ability to withstand short-circuit on the cable conductor and on the cable metallic screen.
- Additional specific tests for separable connectors are performed.

The purpose of some of these additional tests is to ensure the safety of the jointer when working with a separable connector:

- **Capacitive test point performances**: allow the check the presence/absence of voltage before disconnection.
- **Screen resistance measurement** and **Leakage current measurement**: ensure that no electric shock is received if a separable connector is touched by hand when it is in service.
- **Screen fault current initiation:** to demonstrate the ability of the separable connector screen to initiate a fault to earth which produces sufficient current to operate the circuit protection, should its insulation fail. Test conditions are according to the grid earth system (solidly earthed, resistance earthed, impedance earthed or unearthed systems).

Other tests are used to verify the mechanical operation of the separable connector:

- **Operating force**: Measure that disconnection and connection force at -20°C for sliding contact separable connectors is acceptable.
- **Operating eye test**: It is applied on sliding contact separable connectors equipped with operating eye. It is inherited from load break design separable connectors. An operating eye is not a mandatory component for dead break applications.