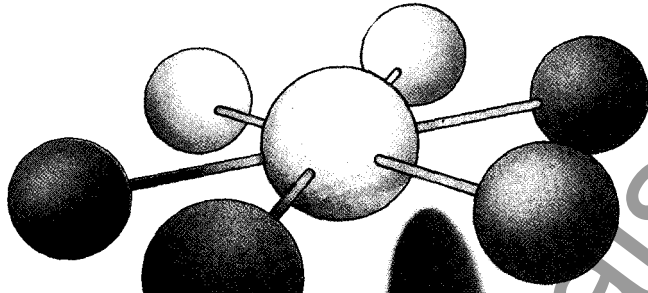


**SF6**

universal technology  
for medium voltage  
3 to 40.5 kV



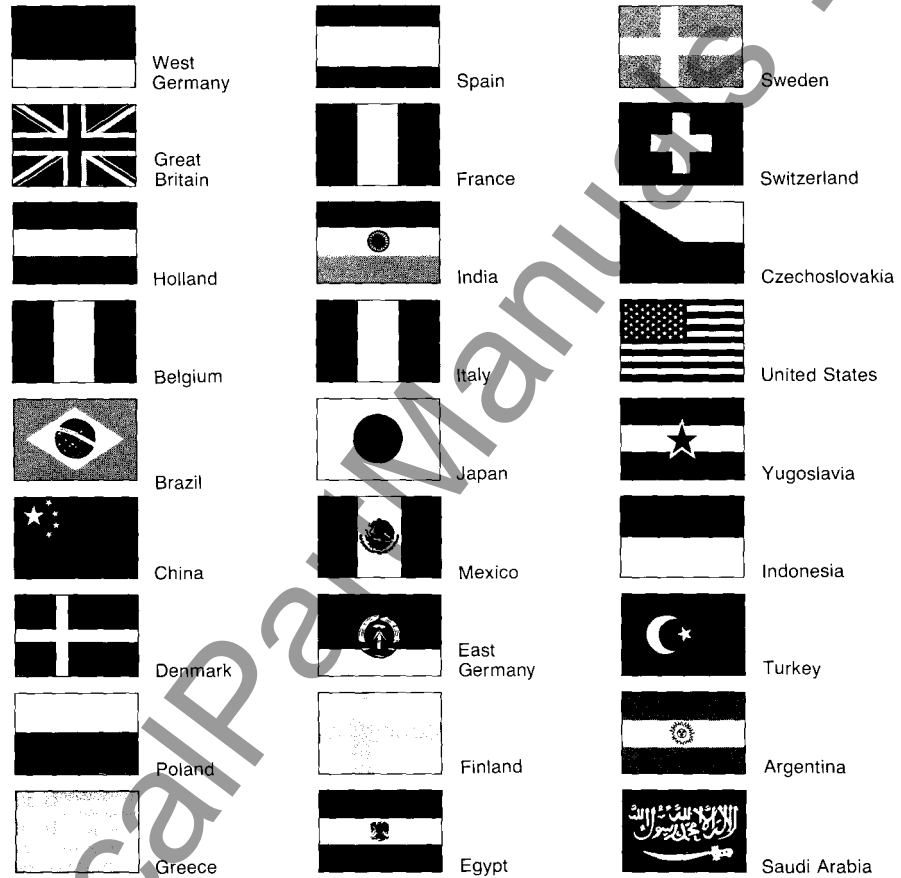
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*mastering electrical power*



all major manufacturers throughout the world have chosen SF6 as an insulating and breaking gas

**countries with manufacturers of SF6 switchgear**



In the high voltage sector, SF6 has become the accepted gas for switchgear manufacturers :

■ which dielectric is used in all extra high voltage metal-clad substations ? SF6.

■ which breaking technique is used almost exclusively today at extra high voltage ?

Breaking by puffer technique in SF6.

■ which inert dielectric is used in compact MV/LV substations ? SF6.

SF6 is approved unanimously. All the major manufacturers in the world - in the United States, Europe and Japan - have chosen SF6 as the preferred insulating and breaking gas.

Specialising in electrical power distribution since 1920, Merlin Gerin were pioneers.

At extra high voltage, in the early days, Merlin Gerin was first in the world, in 1965, to run successful tests, at the Electricité de France laboratory, on the first bay of 220 kV metalclad equipment insulated by SF6.

The success of SF6 at extra high voltage led Merlin Gerin to develop this same technique at medium voltage. After more than 15 years of industrial experience we offer a wide range of reliable high-performance equipment to meet the requirements of worldwide public and industrial distribution systems from 3 to 40.5 kV.

# SF6 moves into all medium voltage electrical distribution markets

## 1971

First SF6 circuit breaker : the Fluarc F, designed for 24 kV public distribution substations.

## 1974

A world first; for secondary and transformer substations Merlin Gerin offers an SF6 circuit breaker, the Fluarc FB.

## 1975

- this is innovation ; applying the SF6 technique to switches with the Vercors M6 for MV/LV transformer substations.
- the Fluarc FB circuit breaker becomes available for systems with a rated voltage of 36 kV.

## 1977

A new breaking technique, the rotating arc in SF6, gives rise to the Rollarc contactor designed for the control and protection of medium voltage motors.

## 1979

The withdrawable Fluarc FG2 is added to the range of puffer type SF6 circuit breakers at 7.2, 12 and 17.5 kV.

## 1980

Most of the breakers manufactured by Merlin Gerin use the SF6 technique and performances progress rapidly :

- the Fluarc circuit breaker doubles its electrical endurance,
- the Vercors M6 load break switch triples its breaking capacity for highly inductive currents,
- the Rollarc contactor doubles its rated current and breaking capacity.

## 1981

Reliability confirmed with the inspection of the first circuit-breakers delivered : no change in pressure, minimum erosion of arcing contacts.

## 1983

A decisive year :

- the RM6, a unanimously accepted ring main unit, revolutionizes the design and operation of transformer substations,
- the Fluarc FG1, smallest breaker in the world with the use of the rotating arc technique,
- the Fluarc FG2 reaches 50 kA with the same operating mechanism thanks to the thermal expansion effect.

## 1987

Further progress :

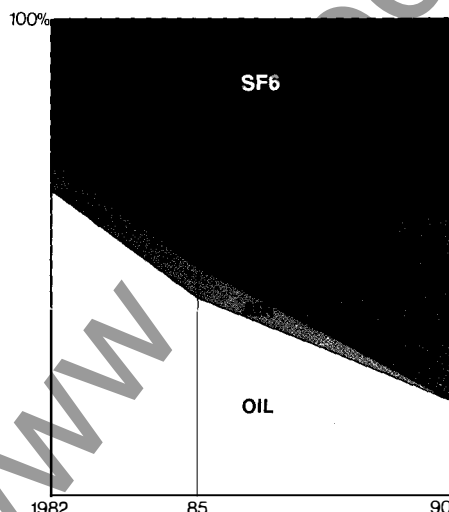
- the Fluarc circuit breaker range extended with the Fluarc FG3 and FG4,
- Merlin Gerin introduces the circuit breaker in MV/LV transformer substations : the RM6 ring main unit is now available with an SF6 circuit breaker specially adapted to the performance requirements of MV/LV transformer protection.

## 1989

Merlin Gerin remains at the forefront :

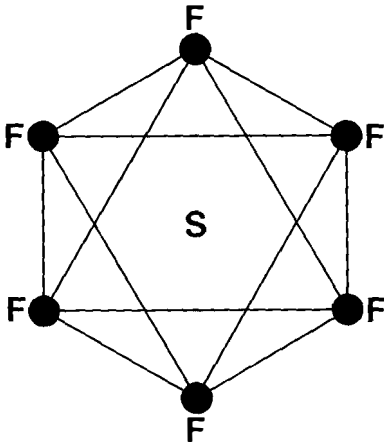
- the SFset, the first autonomous MV circuit breaker with integrated digital protection ; the SFset is specially designed for the protection of MV/LV transformer substations,
- VIP 200, the first microprocessor-based protection unit requiring no auxiliary power source,
- SF6 ring main units - over 50 000 RM6 switch units throughout the world, confirming Merlin Gerin as world leader,
- VM6 modular cubicles : the 200 000 th unit installed.

Breakdown of interrupting techniques in the EEC\* : MV circuit breakers



\* EEC : European Economic Community

# the switchgear manufacturers' gas



SF6 : sulphur hexafluoride

## a widely available gas

Like all gases in current use, SF6 is available in cylinders in all countries of the world. Among many applications, SF6 is used as a tracer gas for leakage tests in the petrochemical and nuclear industries. It is also used for very diverse applications: electron microscopy, particle acceleration, etc. SF6 is non-toxic. The use of this gas in electrical switchgear assures the safety of the personnel and the installations. Dozens of thousands of SF6 switchgear units in service throughout the world have proved this under severe operating conditions.

## a non-inflammable gas

SF6 is an inert gas and does not sustain combustion.

## a very stable gas

The high stability of the SF6 gas is due to the 6 covalent bonds of its molecule.

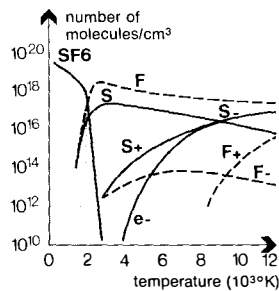
## an insulating gas

The dielectric strength of SF6 is superior to that of most known media, reaching 5 times that of air at a pressure of a few bars.

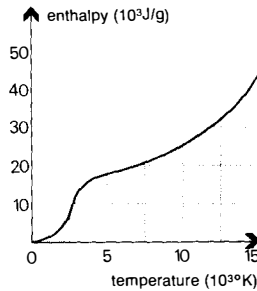
## a breaking gas

SF6 is "the" breaking gas, combining the most properties :

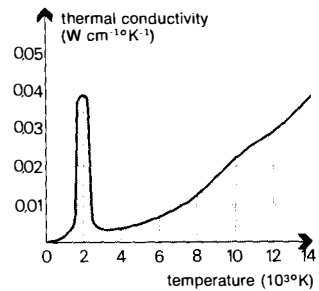
- high capacity for carrying the heat produced by the arc. The latter is strongly cooled by convection during arcing.
  - high radial thermal conduction and high electron capturing capacity. When the current passes through zero, the arc is extinguished by the combination of these two phenomena :
    - SF6 permits rapid heat exchange from the centre of the arc towards the exterior,
    - fluorine atoms, which are highly electro-negative, act as veritable "traps" for electrons.
- Since it is the electrons which are mainly responsible for electric conduction in the gas, the gap between the contacts recovers its initial dielectric strength through this electron capture phenomenon at current zero.
- the decomposition of the SF6 molecule is reversible. The same mass of gas is therefore always available, making the device self-sustained throughout its operating life.



At high temperature, the decomposition of the SF6 molecule is reversible, therefore the gas does not wear down.



One gramme of SF6 can carry 30,000 Joules at 12,000°K (breaking at 25 kA)



The arc is surrounded by a column of hot gas, extremely effective in carrying away the heat (thermal conductivity peak at 2000°K) without conducting the electric current.

... allows scope for a variety of techniques

to remove the heat produced by the electric arc, relative movement must be created between the arc and the SF6 gas or the heat produced by the arc must be used to create a pressure difference.

Two solutions are possible :

- displacing the gas by forced convection (puffer technique),
- displacing the arc by magnetic blowout (rotating arc technique).

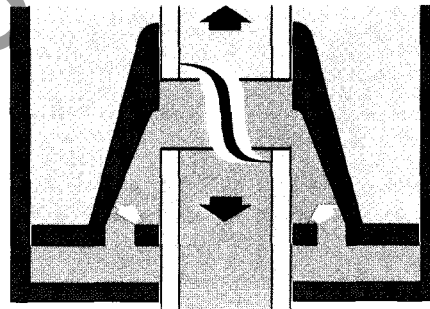
### puffer technique

#### Simplicity

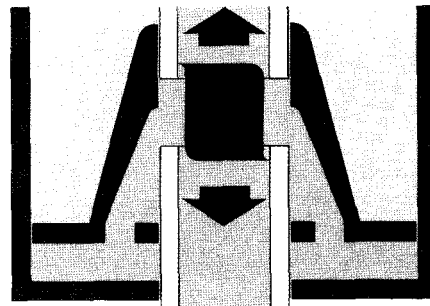
The arcing contacts, when they separate, drive a piston. The SF6 thus compressed is channelled by an insulating nozzle between the arcing contacts. These contacts are tubular and can evacuate the hot gas through their interior by forced convection.

#### Efficiency

Half a litre of gas is sufficient for breaking. With this technique, low load currents can be interrupted as efficiently as heavy currents even at 50 kA, as the natural auto-expansion of hot gasses towards the colder areas of the bottle result in a rapid dissipation of the gas.



Forced injection of a small quantity of cold gas (breaking of a low current)



Natural thermal expansion effect downstream of the tubular contacts (breaking of heavy currents)

#### Clogging effect

When breaking heavy currents, the arc occupies the whole of the space available between the arcing contacts. Gas flow is thus impeded : this is the clogging effect. This natural phenomenon has two beneficial results :

- storage, before the current passes through zero, of almost all the gas compressed by the piston,
- arcing energy limited by the braking of the moving parts, which limits the length of the arc.

#### Longer life

Wear on the arcing contacts is very low on account of the instability of the roots of the arc inside the tubular contacts.

### rotating arc technique

#### A sound method

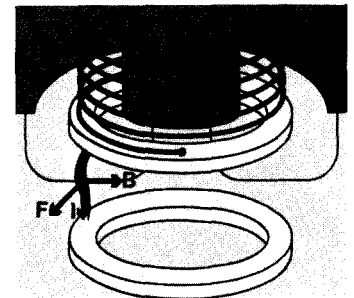
Rotation of the arc between the circular arcing contacts is caused by an intense electromagnetic field. This field is produced by a solenoid through which the current to be interrupted flows at the moment of opening.

#### Efficiency

The power required to blow out the arc is supplied by the system. Control is thus simple and economical.

#### Longer life

The rapid movement of the arc roots over the contacts substantially limits erosion of the contacts.



Rotating arc technique

## decisive advantages

1  
at least 20 years life

2  
zero maintenance

3  
sealed-for-life bottles

4  
insensitive to the environment

5  
simple technology

6  
smooth breaking technique :  
no overvoltages

7  
switchgear to meet individual requirements

8  
competitive technology,  
economy-wise

9  
confirmed experience

10  
technique of the future

The mechanical and electrical endurance of SF6 switchgear is far above that recommended by the IEC.

Its life is estimated at a minimum of 20 years even on systems where the switchgear is very much in demand. This level of performance is particularly appreciated in public distribution substations.

SF6 switchgear requires neither inspection nor special maintenance :

- the gas does not wear down as molecule decomposition is reversible ;

- wear on arcing contacts is very slight ;

- the operating mechanism needs little or no maintenance depending on its use.

The moving parts of contactors, breakers and switches are enclosed in a sealed-for-life bottle (type 3 - IEC). A rotary system assures tightness around movement transmission shaft.

The switchgear is designed with the key parts **inside** this sealed vessel, the full assembly constituting a **total insulation** system.

This sealed design makes the switchgear totally insensitive to the environment (pollution, weather, etc.).

The technology implemented by SF6 switchgear is temptingly simple :

- unsophisticated contacts

with customary alloys ;

- strong moulded resin or metal casings.

Their design allows optimization of form (complete poles, three-pole casings or enclosures).

This simplicity also facilitates technology transfer for local manufacture of switchgear units.

With puffer or rotating arc type SF6 switchgear, there is no need for any device to reduce switching surges.

This feature is particularly useful for the control of motors, as their insulation levels are much lower than those of the rest of the circuit. Current chopping is perhaps the best known phenomenon, but it is not the most dangerous for a motor. The surges produced by successive re-ignitions on opening or successive pre-strikes on closing are much more harmful, due either to the amplitude of the overvoltage or to its rate of rise. These surges are likely to take place in vacuum circuit-breakers having an extremely high rate of rise of dielectric recovery. They do not occur in SF6 switchgear.

This is particularly of interest for contactors.

The Rollarc contactor can be used whatever the rating of the motors, their method of starting, the length of the leads, and so forth. This contactor also has a very high breaking capacity which is essential to achieve a proper fuse-contactor combination for motor protection.

To meet all installation requirements, SF6 switchgear offers many solutions :

- single or three-pole housing ;
- fixed or withdrawable switchgear ,
- compact apparatus ;
- indoor or outdoor equipment, fully insensitive to the environment.

Simple design, universal parts and materials, tested production and inspection processes...

the reasons behind the low manufacturing costs of SF6 switchgear. Prices are sure to remain competitive.

Experience based on **400,000** SF6 switchgear units :

- 100,000 Fluarc circuit breakers since **1971**,
- 300,000 load break switches since **1975**.

Installed the world over, this apparatus is tested daily and the confidence shown by the users is fully justified.

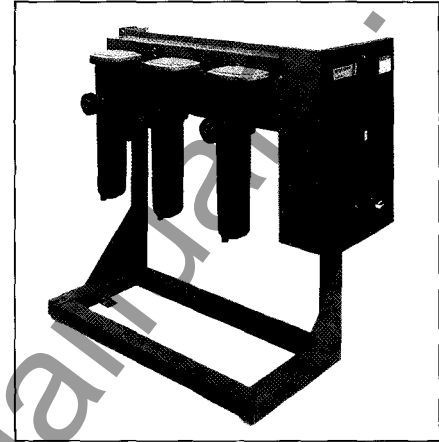
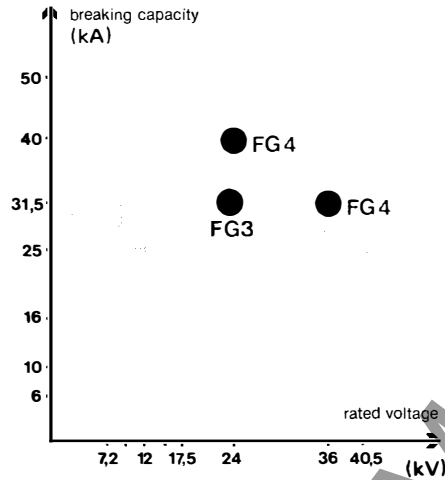
The SF6 breaking technique allows the design to develop along several lines which have not all yet been

explored.

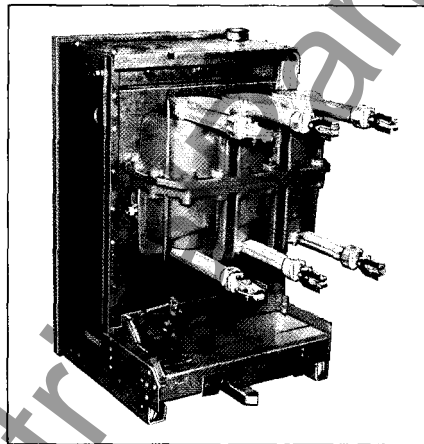
The considerable evolutionary potential is one with prospects for the future.

a complete range  
of circuit-breakers  
from 7.2 to 40.5 kV

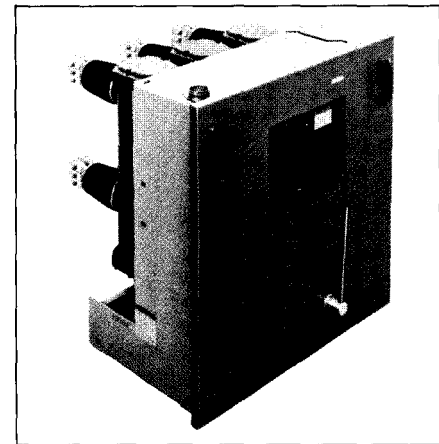
**Fluarc**



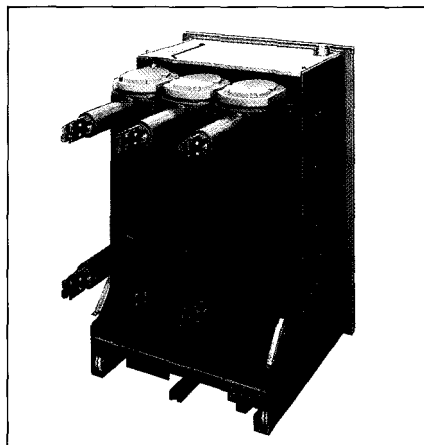
Fluarc FB 4  
With side-mounted operating mechanism  
(front operating mechanism also available)



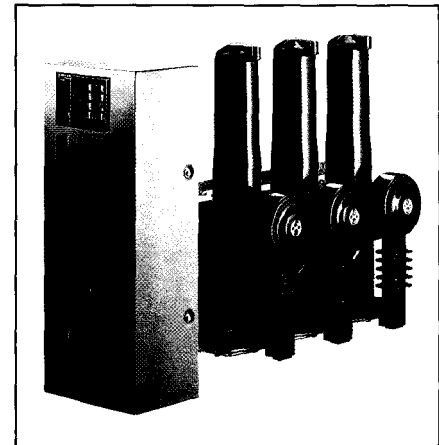
Fluarc FG 1 (1250A)  
Drawout model



Fluarc FG 2 (3150A)  
Drawout model



Fluarc FG 3 (1250A)  
Drawout model



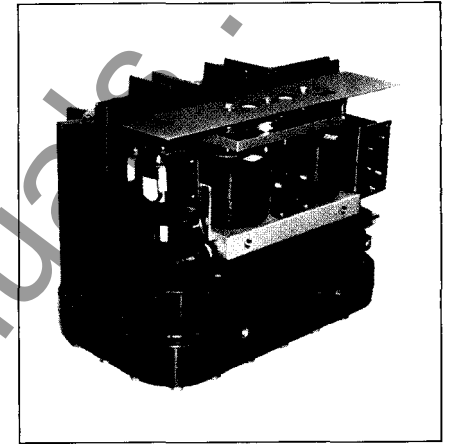
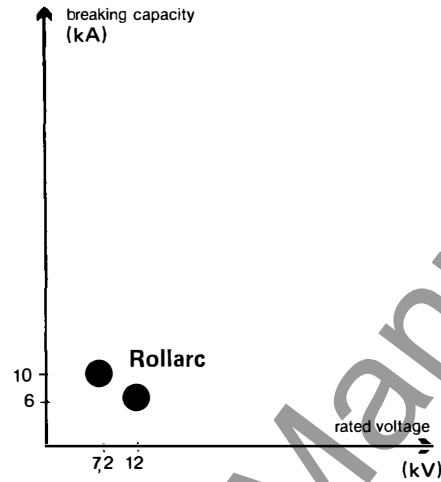
SFset (630 A)  
With autonomous integrated  
electronic protection

www.ElectrArt.com



... a contactor,

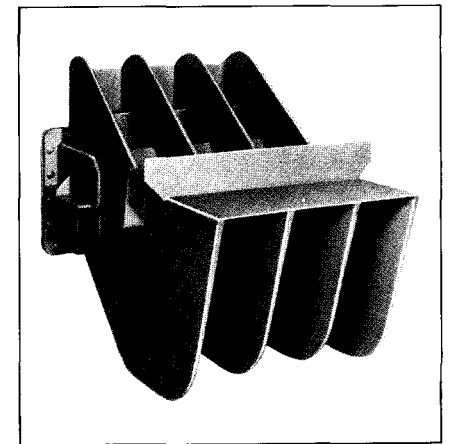
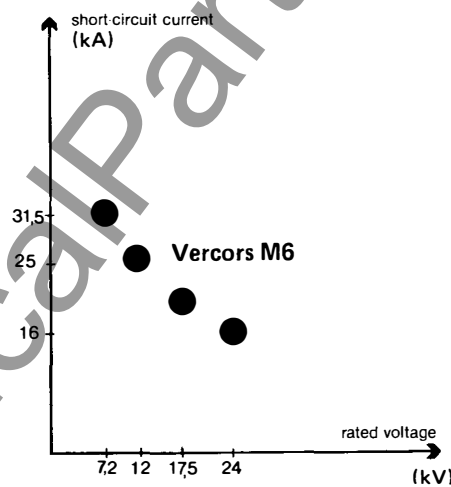
### Rollarc 400A



Rollarc (400 A)

... a load break switch  
7.2 to 24 kV  
400 to 630A

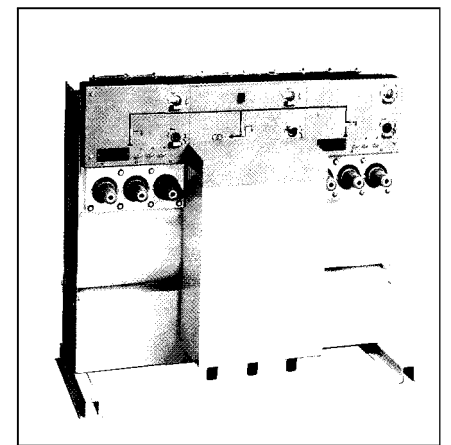
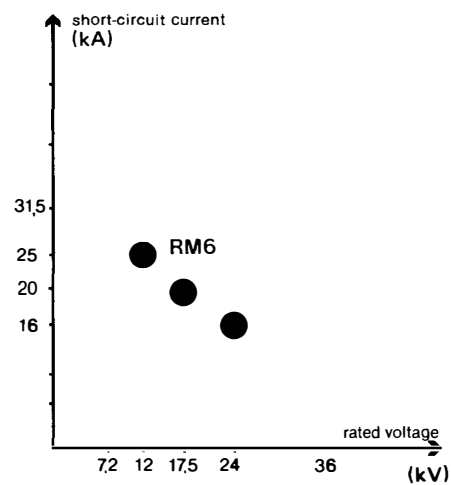
### Vercors M6



Vercors M6 (400 and 630 A)

... a ring main unit  
3 to 24 kV  
400 to 630A

### RM6



RM6

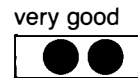
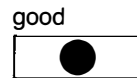
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# SF6: the right choice

## comparative table of the different breaking techniques

technology	oil	air	vacuum	SF6
fire-explosion		● ●	● ●	● ● ● ●
inspection of the dielectric		● ● ●	○	● ● ● ●
reliability in the event of leakage		● ● ●	○	● ● ● ●
range of voltages		●	● ●	● ● ● ●
endurance		● ●	● ● ●	● ● ● ●
range of breaking capacities		● ● ●	● ● ●	● ● ● ●
switching surges		● ● ●	○	● ● ● ●
rapid reclosing		●	● ● ●	● ● ● ●
dimensions		●	● ● ●	● ● ● ●
ease of installation		●	● ●	● ● ● ●
possibility of local manufacture		● ●	○	● ● ● ●
cost of maintenance		● ●	● ● ●	● ● ● ●

### Performance



Merlin Gerin's experience in the field of SF6 switchgear is reflected by the great number of units operating throughout the world for many years now.

Much further progress is still possible. Thanks to the development of various SF6 breaking techniques and their combination tomorrow's switchgear will be even smaller, more efficient and more economical.

Far from having reached its peak, SF6 can look forward to wide-ranging technical and technological advances.

Through a substantial Research and Development programme and major investment in human and material resources for its laboratories and engineering departments, Merlin Gerin strives to continue providing each user with the solution best suited to his needs.

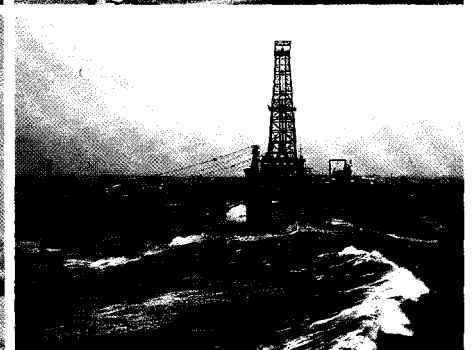
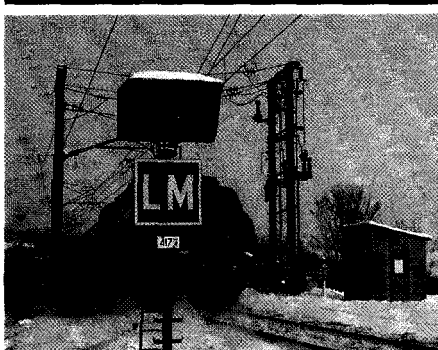
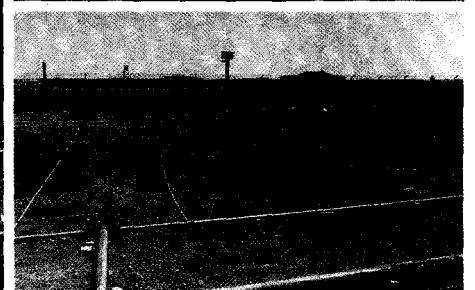
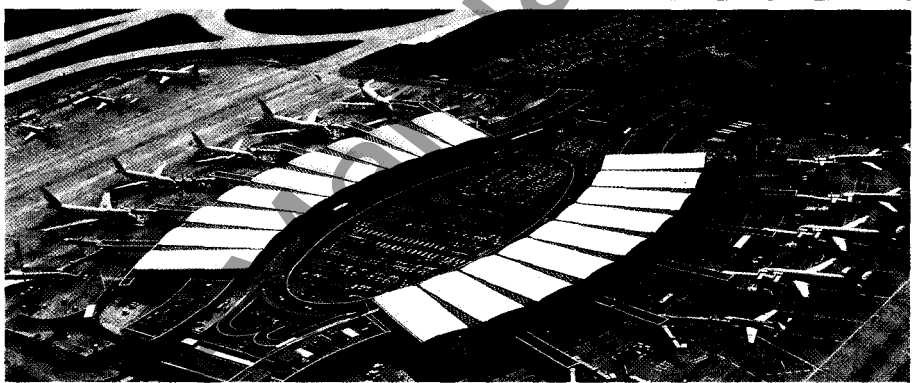
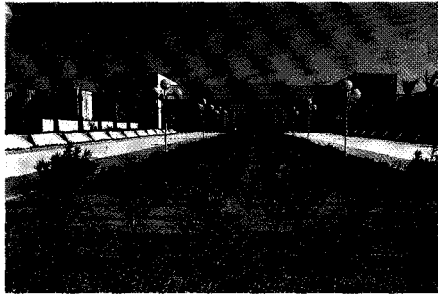
Merlin Gerin  
experience :

400,000 SF6  
medium voltage  
switchgear units

... on all 5 continents,

... in all sectors of  
activity,

... and in all climates



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for more  
information  
concerning SF6...

### Merlin Gerin "cahiers techniques" reports

**E/CT 78**

SF6, the dielectric gas.  
M. Dubois, 10 pp.

**E/CT 79**

SF6 physical and chemical data.  
A. Fihman, 9 pp.

**E/CT 86**

Review of the main current interruption  
techniques.  
Y. Pelenc, 20 pp.

**E/CT 121**

New techniques for medium voltage  
SF6 circuit-breaker.  
J. Hennebert, 8 pp.

**E/CT 122**

The breaking process with Fluarc SF6  
puffer and rotating arc circuit-breakers  
and Rollarc contactors.  
C. Duplay, J. Hennebert, 16 pp.

**E/CT 125**

Mastering switching voltage transients  
with SF6 switchgear  
O. Bouillez 12 pp.

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