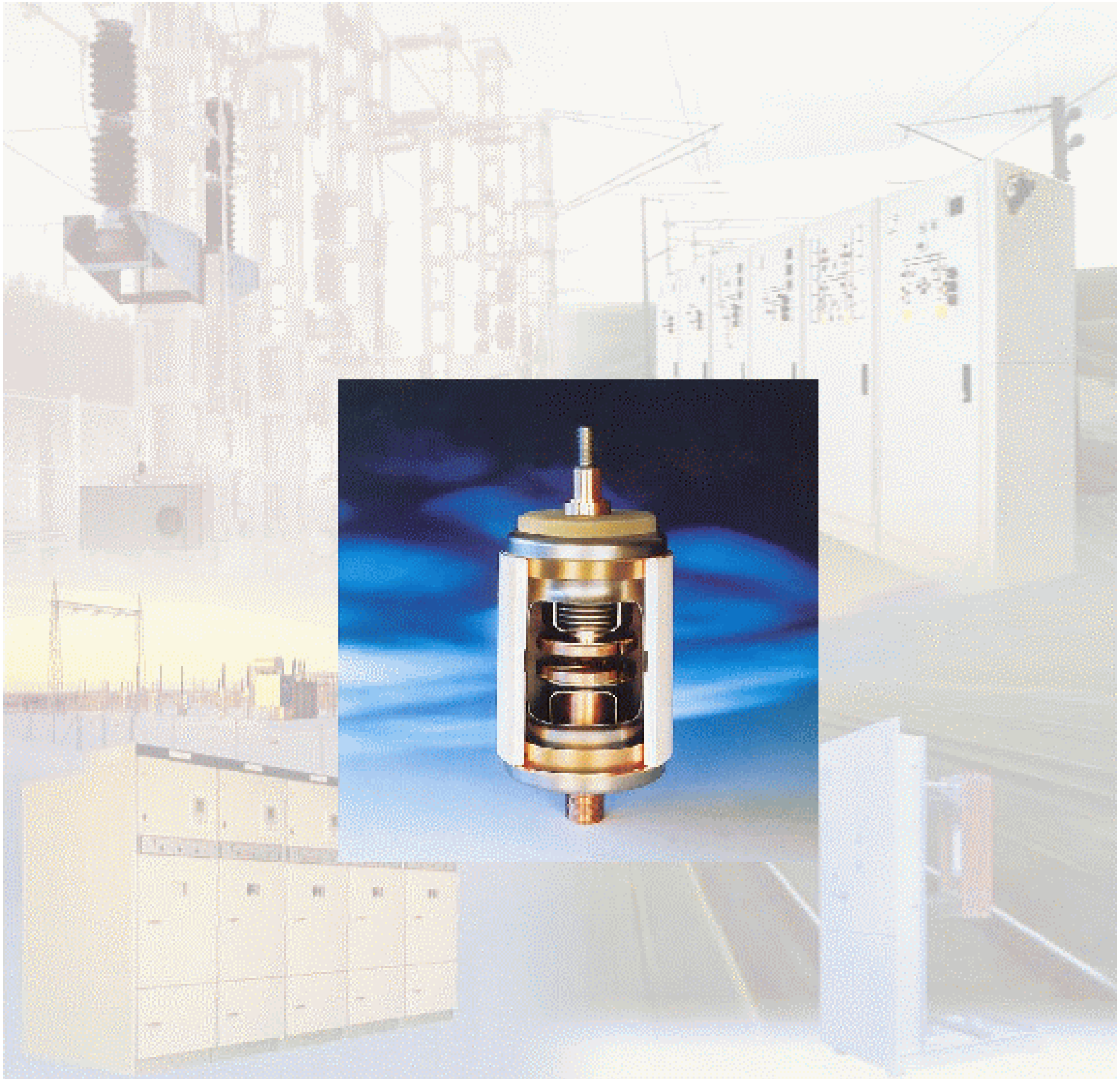
Use of vacuum interrupters in railway applications



Introduction

This document aims to summarise the current situation with respect to the use of vacuum interrupters in switching devices intended for the railway power supply.

History of the vacuum interrupting technique

A vacuum interrupter comprises two contacts contained in a sealed vacuum enclosure. Vacuum is an insulating medium; therefore the current can flow through the interrupter only when contacts are closed.

On the other hand, when the contacts are open, the circuit is isolated.

The very first vacuum interrupters were developed during the 1940's.

In the early days, a certain number of problems were found by users related to the use of vacuum interrupters and particularly over voltages.

Paradoxically, over voltages were due to a too perfect switching. Indeed, due to material of the contacts, the current was forced to zero immediately after the separation of the contacts and in few microseconds.

This huge dI/dt is obviously not a problem for capacitive circuits but is a constraint for inductive circuits.

Indeed, by nature, the inductance of a circuit tries to avoid any rapid change of the current in generating a voltage proportional to the dI/dt.

The result is a fast voltage rise with the generation of transients high enough to exceed the insulation level of the circuit.

In the 1960's, major improvements have been made in the technology of vacuum interrupters.

Originally, contacts were made of tungsten, the only available material matching the technological requirements of vacuum interrupters.

Then a sinter having the designed characteristics of smooth switching of interrupter current replaced this material.

Effectively, during contact separation, the switched current creates an arc that melts a microscopic superficial layer of alloy on the surface of the contacts.

This vapour of metal supplies the ions needed to carry the current between the open contacts, without alteration of the sine waveform of the signal.

The arc burns in the metal vapor evaporated from hot spots on the contact surfaces. This metal vapor continuously leaves the contact region and re-condenses on the contact surfaces.

At current zero, the arc extinguishes, contact vapor production stops, and the original vacuum condition is restored. Indeed, more precisely, close to the zero current, the arc is very unstable and may self extinguish short before the exact zero current. The resulting current drop ("Chopping current"), is however limited to few amps.

This new generation had a main characteristic to always interrupt the current at zero current or very close to it, without significant induced over voltage, therefore solving the main disadvantage of vacuum interrupters.

One must note, that the metal vapour has a high conductivity and that the arc voltage is low.

Vacuum is a natural dielectric therefore the gap between contacts is small. This small gap provides fast breaking time and limited operating forces requirement.

Short switching times and reduced energy dissipated during the arcing time explain the long electrical life span of vacuum interrupters.

Although further improvements have been achieved in the field of the metallurgy, the principle of using contacts made in composite materials remains for today's vacuum interrupters.

In parallel with the development of the contact, major improvements were also made in the sealing process.

Nowadays manufacturing and testing processes of vacuum interrupter guarantee the vacuum degree for several years, typically above 20 years for the more advanced manufacturers.

Use of vacuum technology in railway applications

The table below, established according to our best knowledge, summarises the technology used in Europe, for 15 kV and 25 kV fixed installations, account taken of all known suppliers.

	Vacuum	Vacuum & SF6	SF6
SBB, Switzerland	X		
DB, Germany	X		
OSE, Greece	X		
Railtrack, United Kingdom	X		
LES, United Kingdom	X		
BAA, United Kingdom	X		
NL, Netherlands	X		
SNCB, Belgium		X	
CFL, Luxemburg		X	
Jernbanverket, Norway	X		
OBB, Austria	X		
SNCF, France		X	
TCDD, Turkey	X		
CP, Portugal			X
FS, Italy			X
SJ, Sweden	X		

Conclusions

For many decades, vacuum interrupters have been used in switching devices with a nominal voltage above 1 kV.

Vacuum interrupters are now available for nominal voltages up to 72 kV and ensure a reliable interruption, for all types of loads, this including highly capacitive or inductive loads.

The improvements of the contacts have solved the major weakness of possible over-voltages in switching highly inductive loads.

Nowadays, vacuum interrupters have an extremely long life span and can switch a nominal current up to 50'000 times, without exceeding the permitted contact wear.

The use of vacuum interrupters allows the manufacturing of switching devices with a simple design, able to carry out many operations even under short circuit conditions.

High electrical life span is particularly appreciated in networks where the occurrence of short circuits is high; railway networks are typical examples of such networks.

Most of the railway administrations in Europe have chosen the vacuum technology for 15 kV and 25 kV devices, even in 16.7 Hz railway networks where tripping times required are extremely fast and short circuit level very high.

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