

The Use of Vacuum Interruption at Transmission Voltages

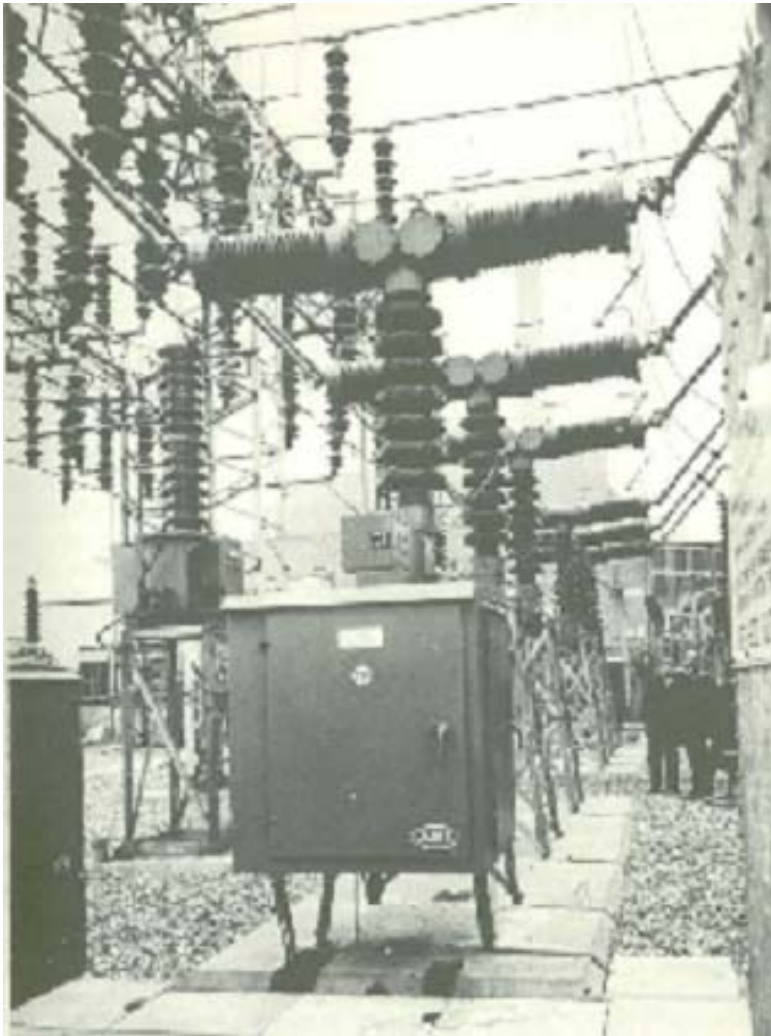
Dr Leslie T Falkingham

Managing Director

Vacuum Interrupters Limited



History: Origins



Serious development of Power Vacuum Interrupters started in England in the 1950's. At the same time GE in the USA also commenced work.

One of the first applications was for transmission circuit breakers!

The photo shows an AEI 132 kV vacuum circuit breaker in service with the CEGB at West Ham in 1967. It remained in service into the 1990's.

Introduction

The Paper covers the following topics:

- 1. Vacuum Interrupter & Switchgear Technology**
- 2. What was the problem with the 1960's Technology?**
- 3. The Situation Today**
- 4. Difficulties Facing Vacuum Interruption at Higher Voltages**
- 5. Modern Vacuum High Voltage Circuit Breakers**



Manufacturing



The Manufacture of vacuum interrupters is performed in special facilities using state of the art technology such as clean rooms and high vacuum furnaces.

Main horizontal laminar flow clean room at VIL, Finchley, 1978.



Manufacturing -One Shot Seal Off



Manufacture of Vacuum Interrupters in South Africa
c1990

Vacuum interrupter manufacture is a Hi-Tech industrial process.

After assembly 32 interrupters are loaded into a vacuum furnace and brazed and sealed at the same time.

Vacuum Interrupter Technology

There are three key areas of technology in the design of Vacuum Interrupters:

- 1. Overall Electrical and Vacuum Design.**
- 2. Arc Control System**
- 3. Contact Materials.**



Classic Vacuum Interrupter Design

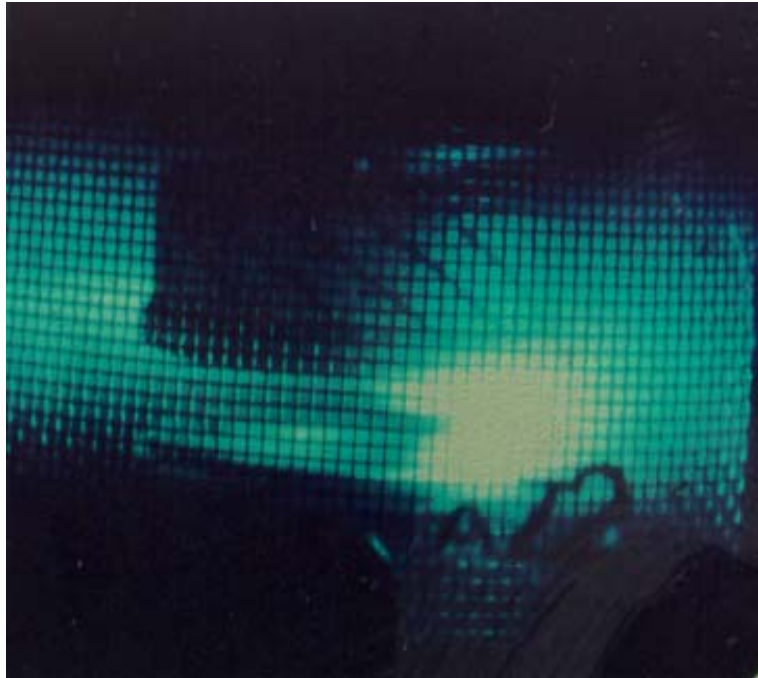


The photo shows a V8 interrupter from the 1970's.

This shows the basic design and main components of a Vacuum Interrupter.

V8 1213, VIL Finchley 1970's.

Arc Control: Radial Magnetic Field (RMF) Contact Geometry

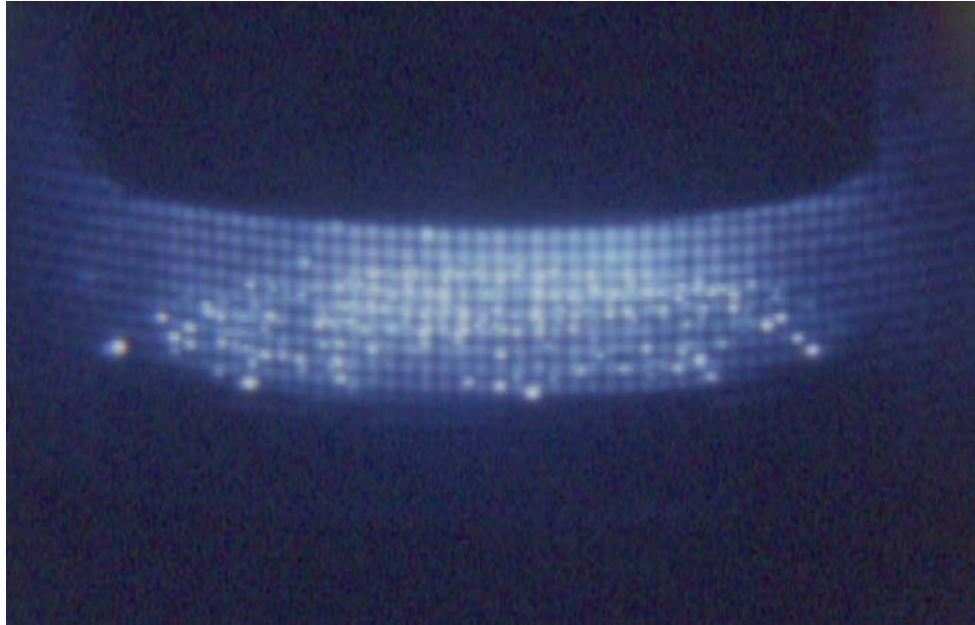


This works by using a self induced Radial Magnetic Field to make the arc move over the contact surface, reducing local heating.

The contact material must allow the arc to move freely over the surface.

Still from HS film @ 5,000 pps showing 55mm diameter RMF contact interrupting 31.5kArms @12kVrms.

Arc Control: Axial Magnetic Field (AMF) Geometry

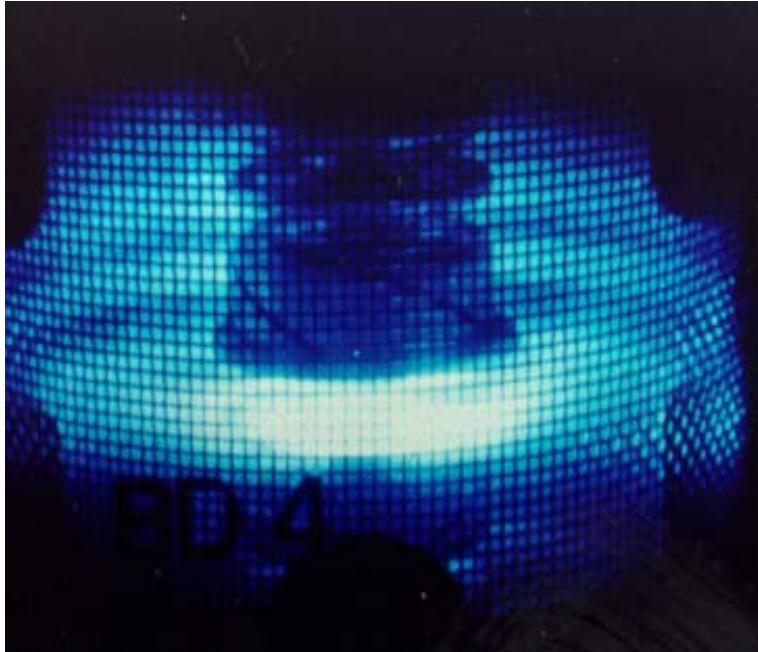


Still from HS film @ 9,000pps showing an AMF contact interrupting 40kArms @12kVrms.

This works by using a self induced magnetic field in the axis of the arc which prevents the arc from constricting and reduces local heating by spreading the energy over the surface.

The contact material does not have to allow the arc to move freely.

The Vacuum Arc – Contact Material



Still from HS film @ 5,000 pps showing 35mm diameter RMF contact interrupting 20kArms @ 12kVrms.

The term Vacuum Arc is a misnomer. What we have is really a metal vapour arc in vacuum.

The metal composing the arc gives the arc many of its properties.

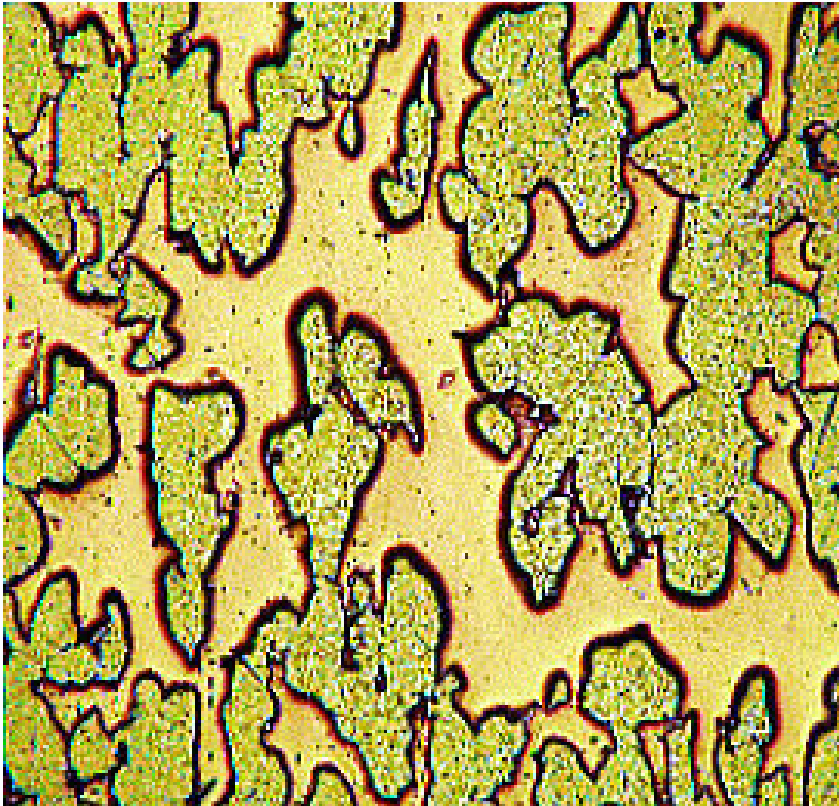
Changing the material of the contact can fundamentally change the properties of the arc.

Desirable Material Properties

| Voltage | Application | Key Features |
|-----------|-------------|--|
| 1.2-12kV | Contactor | Low Current Chopping (<0.5A) High Electrical Life (>500,000) Anti Weld (low strength mechanism) |
| 12-40.5kV | C/B | High Dielectric Strength (<200kV in 12mm) High Breaking Capacity (<63kArms) High Making Capacity (<160kApk) Anti-Weld (medium strength mechanism) |
| 132kV+ | C/B | Very High Dielectric Strength (<800kV in 50mm?) High Breaking Capacity (<63kArms) High Making Capacity (<160kApk) Anti-Weld (medium strength mechanism) |



Contact Material



Photomicrograph of Chromium Copper (CrCu) contact material which was originally developed and patented by English Electric in the 1960's.

This is now the most popular material for MV Vacuum Interrupters in manufacture today.

Mechanisms

Vacuum Interrupters do not need very high energies for operation – the mechanism energy plays no part in the interruption process, it merely moves the contacts apart.

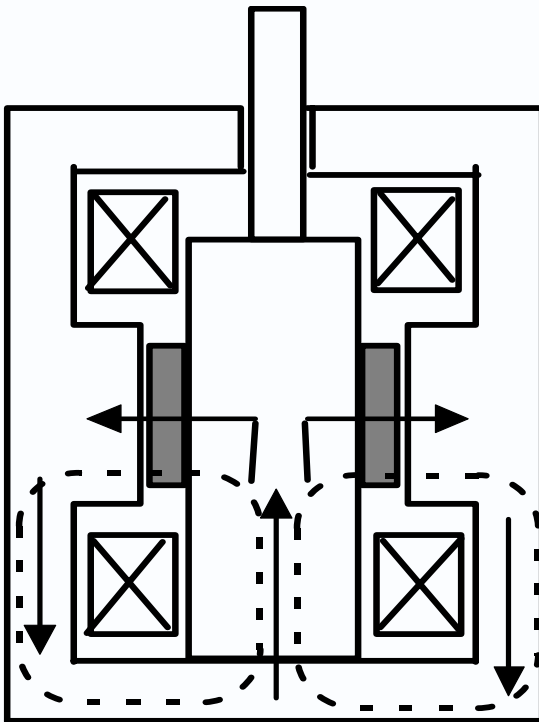
A typical 38kV recloser will use only 150 – 200 Joules of energy to operate as opposed to the 18,000 - 24,000 Joules typically needed for a 400kV SF6 Puffer circuit breaker!

This has allowed the use of a very special very low energy technology – The Permanent Magnet Magnetic Actuator.

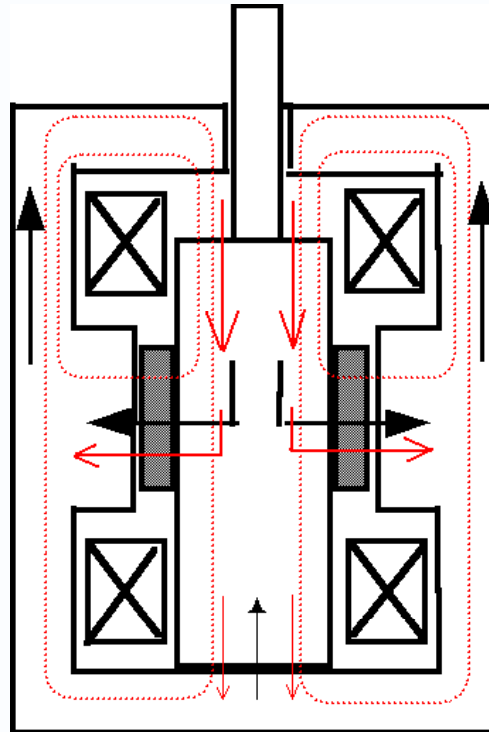


Mechanisms –Magnetic Actuator*

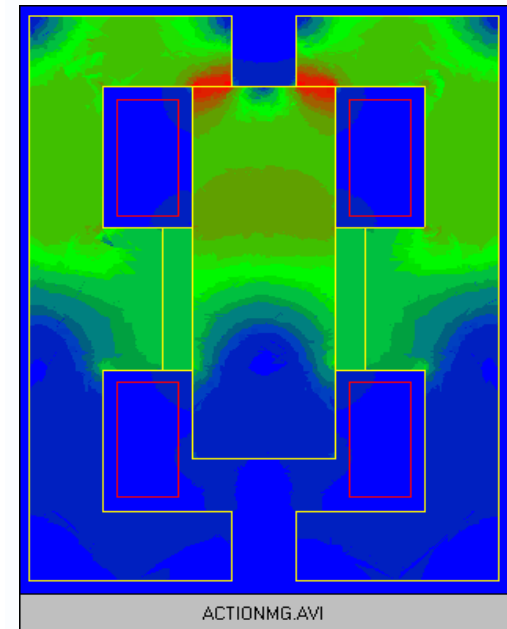
**Static
Condition**



**Dynamic
Condition**



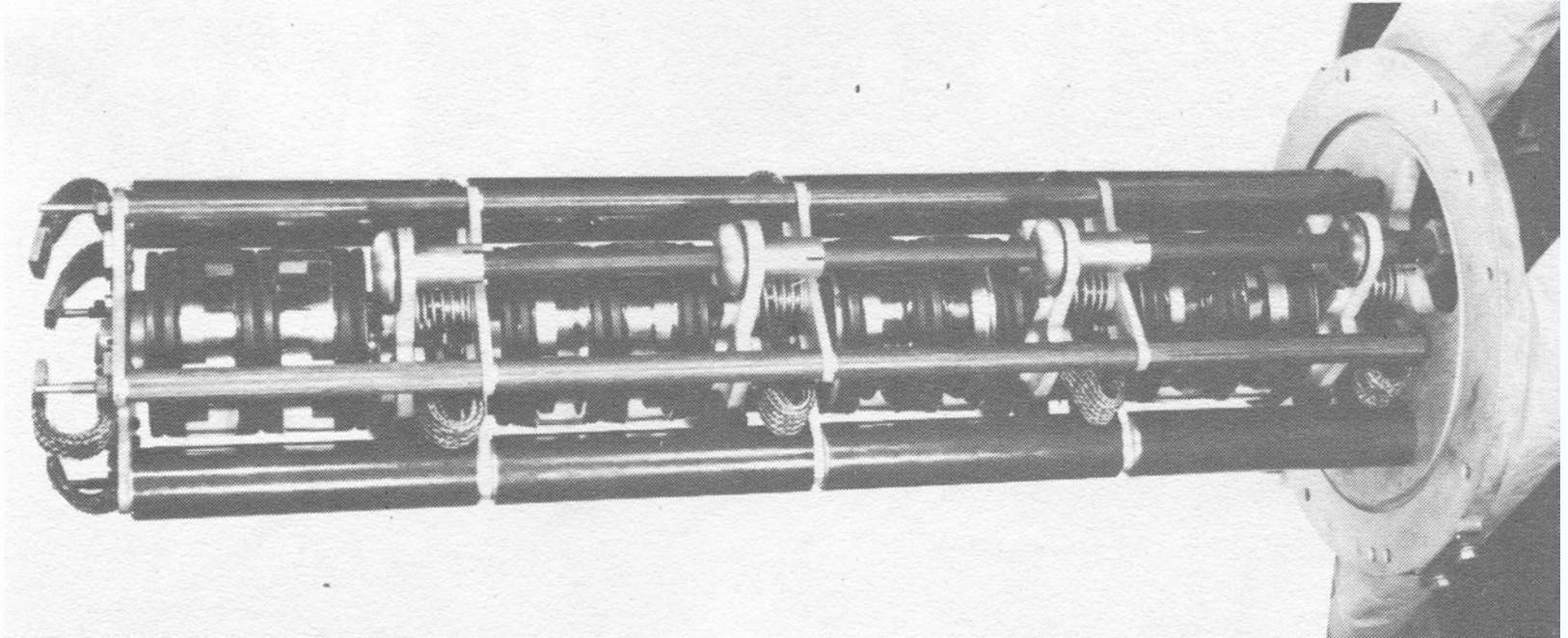
**Dynamic
Model**



What was the problem in the 1960s?

- **In the early days of Vacuum single interrupters could only interrupt voltages up to 17.5 or 24kV.**
- **As a result a large number of interrupters in series were needed to achieve the voltage rating.**
- **In turn this resulted in complex and expensive operating mechanisms**
- **The interrupters used were optimised for the Distribution market where large sales volumes were possible. It was not economically justifiable to develop special interrupters for the relatively small Transmission Switchgear market**

The AEI 132kV Vacuum Circuit breaker



One arm of one phase of the AEI 132kV circuit breaker. Each arm had four vacuum interrupters in series, giving a total of eight interrupters in series per phase!

What is the Situation Today?

- **Advances in interrupter design over the past forty years mean that single interrupters for 36kV, and 72/84kV are now common.**
- **Higher ratings are now becoming available with single interrupters rated at up to 145kV.**
- **This increase in voltage rating together with the low operating energy requirement allows simple, reliable low cost mechanisms to be used.**
- **The environmental problems with using SF6, and the need for an SF6 free alternative is driving research to investigate the use of Vacuum Interruption up to the highest levels.**



Difficulties Facing Vacuum Interruption at Higher Voltages

- **Physically large interrupters are heavy and generally use more components, this in turn affects the Plant's capability to manufacture and handle such large devices.**
- **Large devices tend to have many more components and vacuum seals than is normal today leading to manufacturing and quality control difficulties.**
- **A long (larger than 24mm) contact gap affects the capability of the RMF and AMF arc control systems and may reduce interruption capability.**
- **Current Contact Materials are optimised for the MV ratings. It may be necessary to develop new materials which are more suited to these large contact gaps.**
- **X-ray emission at system voltages becomes possible and needs to be taken into consideration.**



Modern Vacuum High Voltage Circuit Breakers



**JAEPS Vacuum Circuit Breaker rated at 145kV
(Courtesy JAEPS)**

Modern Vacuum High Voltage Circuit Breakers



The development of a single 145 kV vacuum interrupter makes the development of a two break per phase 300kV class Vacuum Circuit Breaker quite simple.

Higher voltage Single and Two break circuit breakers will however require more work on the vacuum interrupter design.

Conclusions

- **Vacuum circuit breakers up to 145kV are already available.**
- **It is possible with existing technology to foresee relatively low risk vacuum circuit breaker development up to 400kV.**
- **Above 400kV serious difficulties will need to be overcome. However there are projects currently in progress to address these difficulties, targeting vacuum circuit breakers rated up to 750kV.**
- **There is no inherent problem with using vacuum interruption for these applications. Vacuum circuit breakers have been successfully used at transmission voltages (132kV) for almost 40 years.**

Questions?

