The Future of Vacuum Switchgear – Pushing the Boundaries

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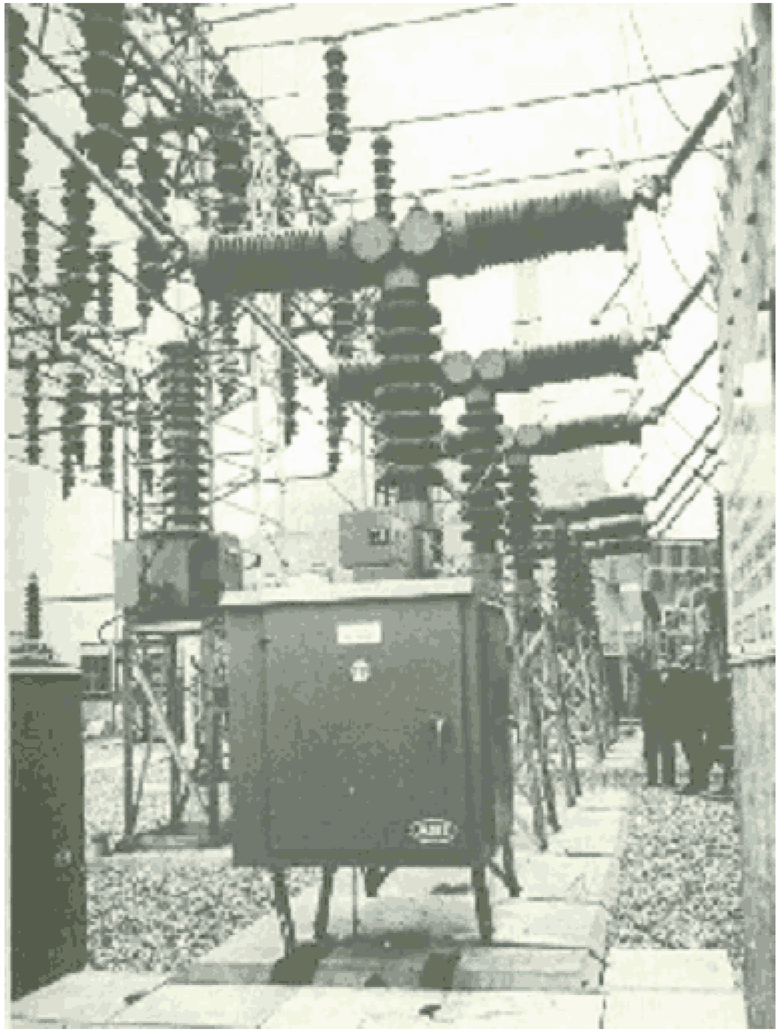
The Problem:

- ***Historically technology in our field has changed quite slowly allowing us to adapt and absorb the changes over an extended period***
- ***Today technology is changing rapidly and the electrical system faces the most radical changes since the 19th century***
- ***Switchgear must change significantly to meet these new challenges and requirements***

Introduction:

- ***Vacuum switchgear has now been commercially available for more than 50 years***
- ***Like most technology Vacuum Interrupters & Circuit Breakers have evolved during that period until we now have an optimised design concept which matches our requirements***

History - Early 132kV Vacuum:

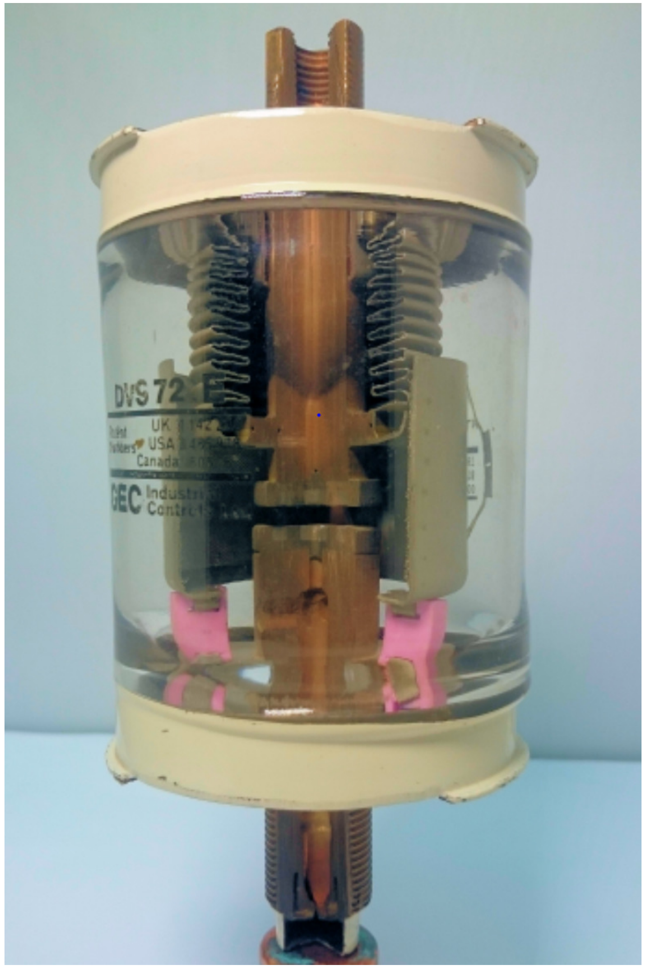


The photo shows two AEI 132kV Vacuum circuit Breakers which went into service in London with the CEGB in 1967 – 50 years ago!

They have six breaks per phase.

Others were installed in the UK. They remained in service until 1999/ 2000.

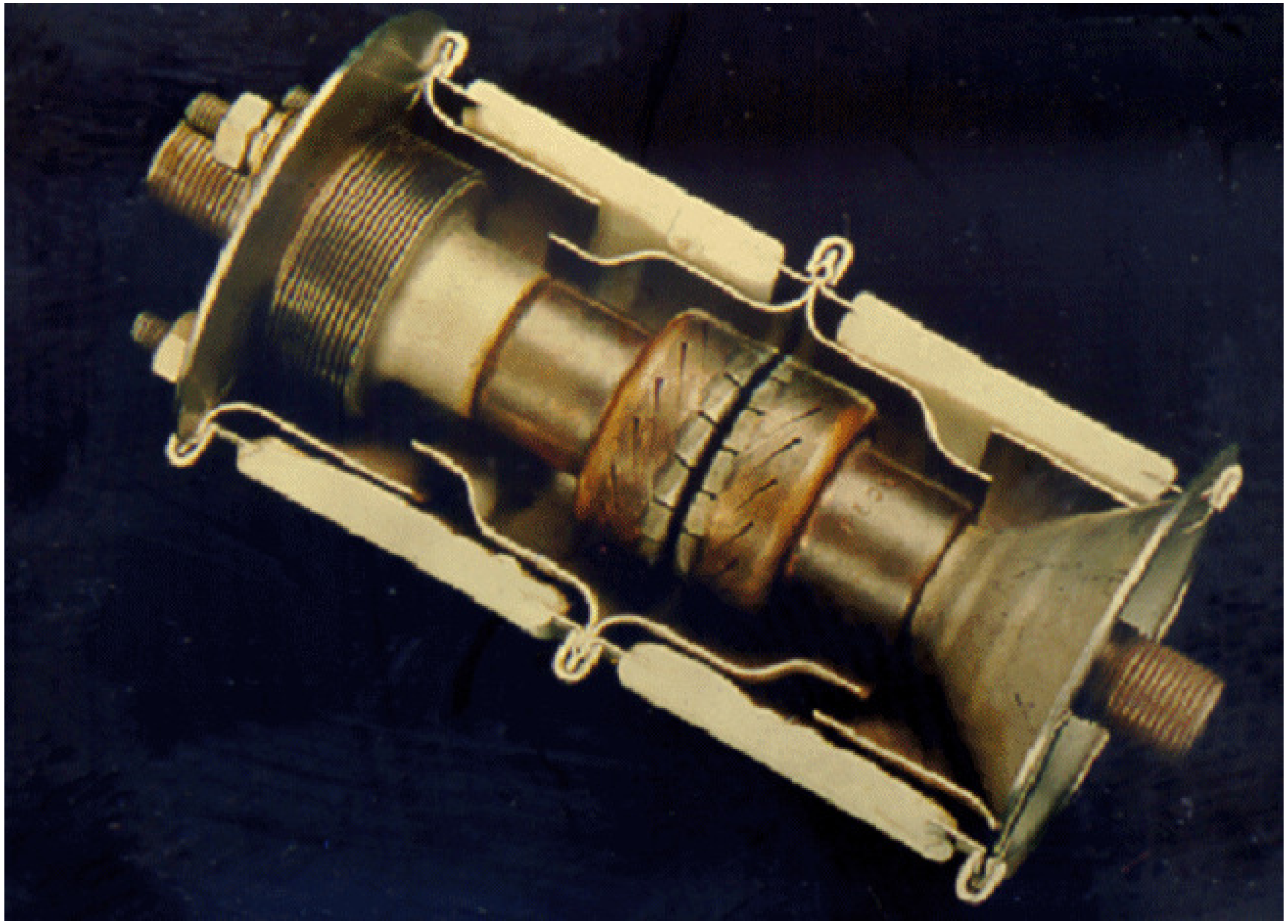
History - Vacuum: 1960's



This is a vacuum interrupter of the 1960's

They are characterised by a Glass insulator, large contacts and manufactured by welding and individual vacuum pump tubes

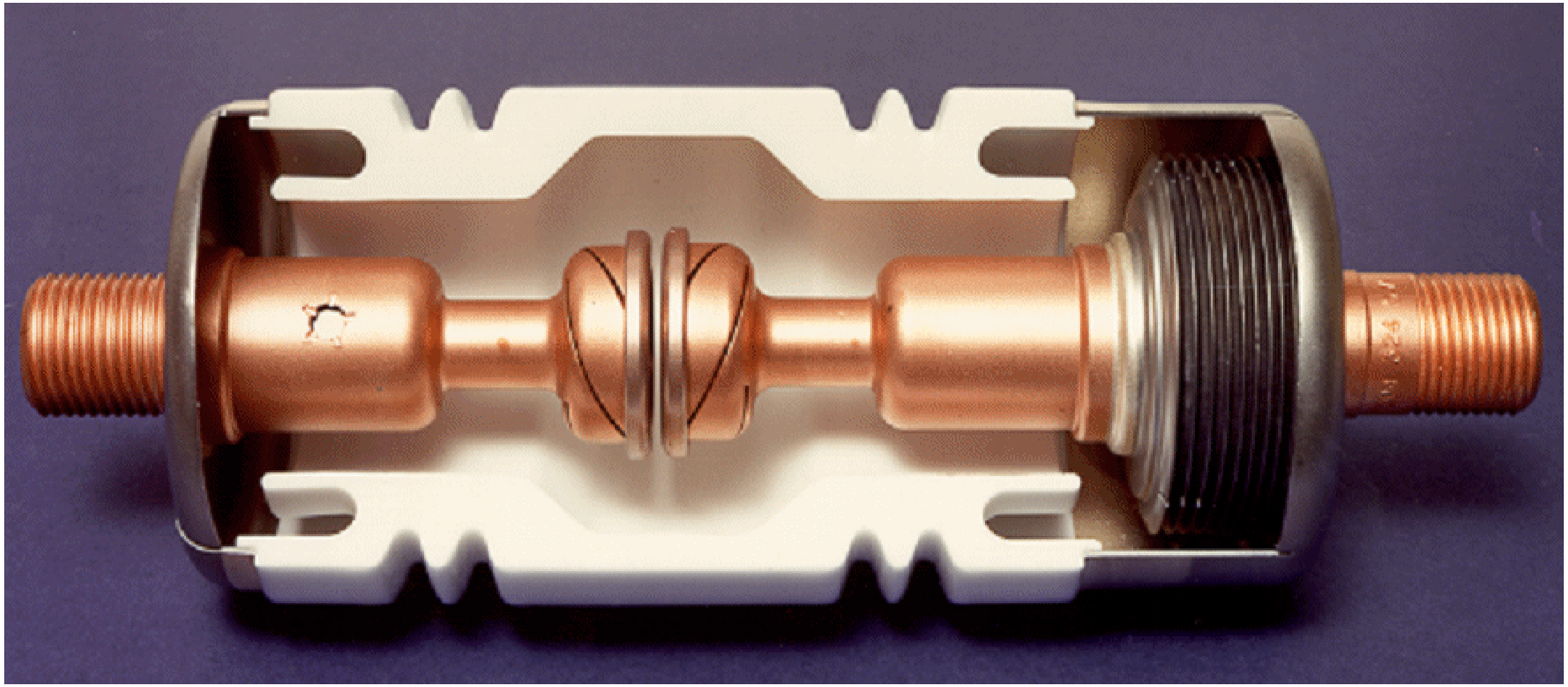
History - Early Vacuum: 1970‘s



This is a vacuum interrupter of the 1970‘s

They are characterised by a Glass-Ceramic insulator, smaller contacts and ware manufactured by multiple vacuum furnace brazing snd Vacuum furnace seal off

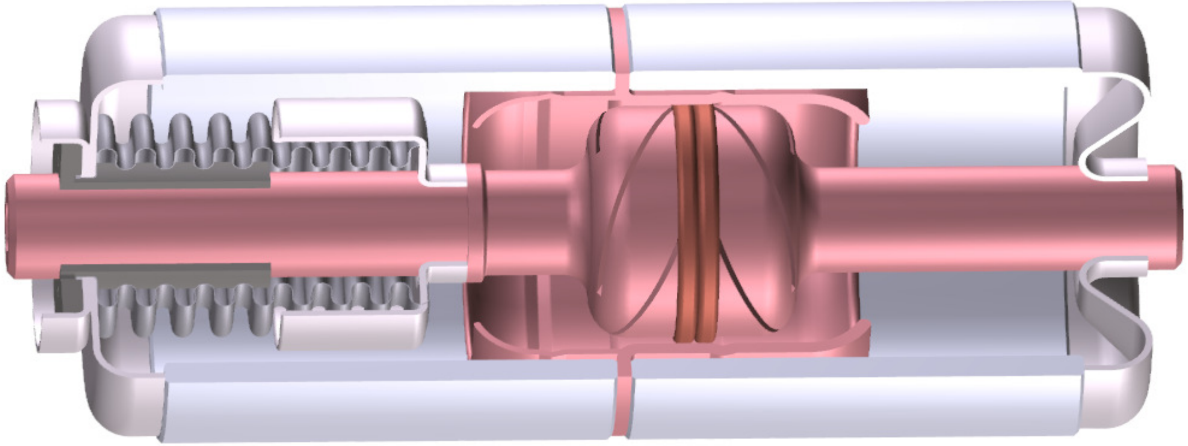
History - Vacuum: 1980's



This is a " shieldless" vacuum interrupter of the 1980's onwards

They are characterised by a Ceramic insulator, no shields, smaller contacts and were manufactured using One Shot Seal Off, with one furnace run performing all brazing and sealing in one operation

History - Vacuum: 1980's



This is a vacuum interrupter of the 1980's up to today

They are characterised by a metallized Alumina ceramic insulator, smaller contacts and the manufacture uses multiple vacuum furnace brazing or One Shot Seal Off

The Problem:

Obvious technical limits or boundaries of VCB technology are:

- High Voltage (>72.5kV)
- High Current (>3150A)
- AC Interruption only
- Low Voltage (<1kV)

The State of the Art Today:

Vacuum interrupter technology has been stable for over 25 years, with little innovation (smaller size, slightly higher ratings).

The present situation today generally is;

- ***AC Interruption only***
- ***Medium Voltage (3kV – 50kV)***
- ***Interruption Current (< 80kA)***
- ***Load Current (< 4000A)***

Vacuum completely dominates the Medium Voltage (MV) market worldwide.

But for Low Voltage (LV) and High Voltage (HV), vacuum is not really present in large numbers. Why?

The State of the Art Today:

For Low Voltage and High Voltage, vacuum is not really present in large numbers. Why?

This limitation is caused in two ways;

Cost: ***For LV it is very difficult to compete with Air breaking on cost except in special markets***

Technology: ***Particularly for HV, vacuum technology finds it difficult to meet the technical requirements***

The Problem:

The world of electrical switchgear is changing;

- ***Today environmental issues are making SF_6 and Solid State switching much less attractive***

- ***There is a move towards DC distribution & Transmission, off-shore windfarms particularly need high voltage DC switchgear, but no technical solution yet***

- ***You can't have a Smart Grid with Dumb Switchgear! We need new switchgear and protection that is intelligent and self diagnostic***

The Problem:

Obvious technical limits or boundaries of VCB technology are:

Requirement	Existing Technology?	Limit
High Voltage (>72.5kV)	SF_6	Technical/Environmental
High Current (>3150A)	SF_6	Technical/Environmental
DC Interruption (>6kV)	?	Technical/Environmental
Low Voltage (<1kV)	Air	Cost
Low Voltage (< 3kV)	Solid state	Environmental
Smart Grid (smart devices)	?	Technical

The Problem:

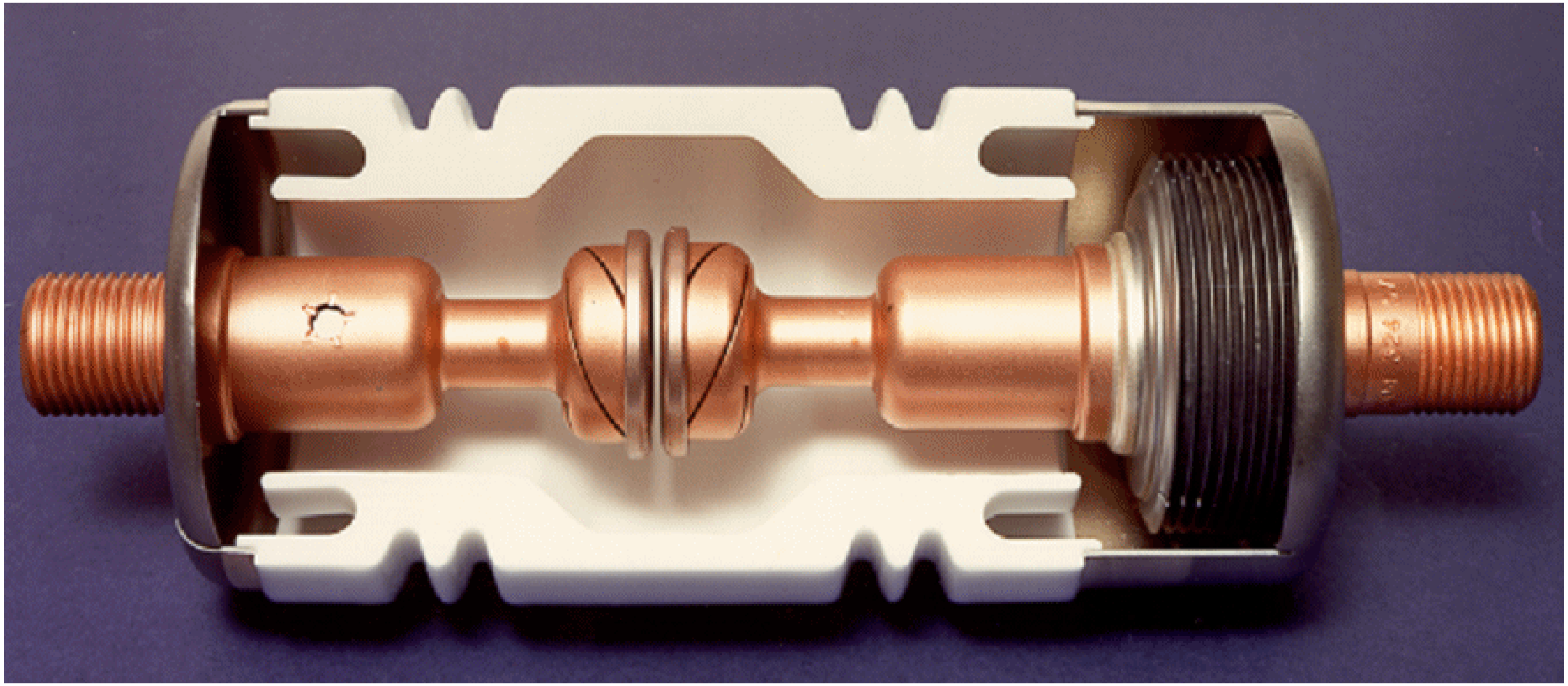
All of the Problems faced can be met by technical innovation;

Technical targets for VCB technology are:

	Achievable?	Prototype	Market
• High Voltage (245kV)	Yes	2-3 years	4-7 years
• High Current (>6300A)	Yes	1-2 years	4 years
• DC Interruption (<30kV	Yes	2-3 years	5 years
• LV (<1kV)Low cost	Yes	2-3 years	5 years
• Smart Grid (smart devices)	Yes	2-5 years	6 years
• MV Low cost & size	Yes	1-2 years	3-4 years

The Problem:

- ***Historically technology in our field has changed quite slowly allowing us to adapt and absorb the changes over an extended period***



The Solution:

Work is now being carried out round the world to meet the challenges of a true 21st century power system

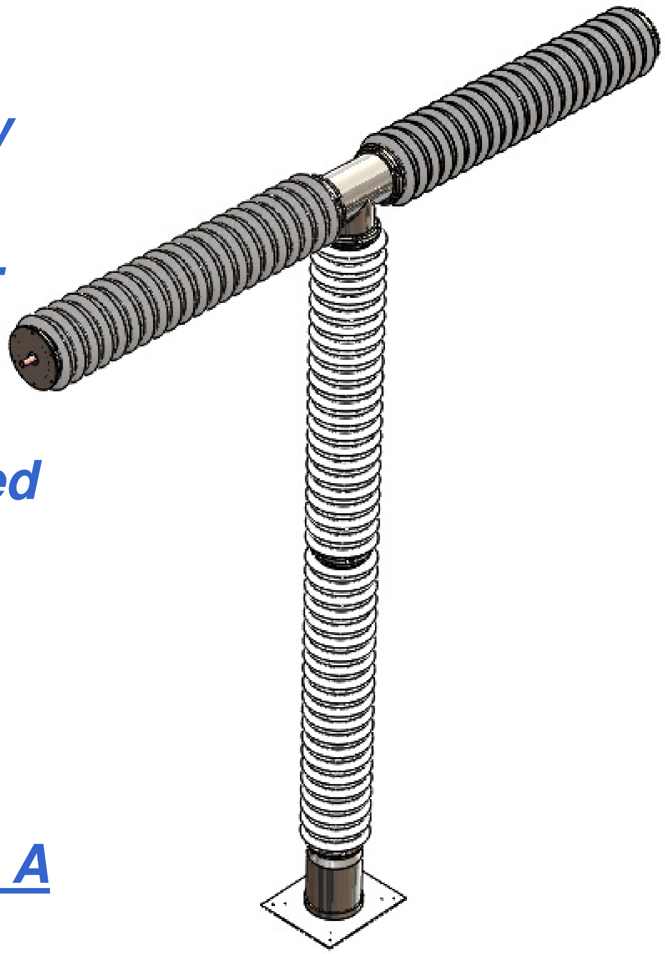
What follows are a few examples of the work being carried out by our R&D group. Other research groups are also working on these problems, and other solutions will certainly also appear in the near future

Example 1: 245kV vacuum circuit breaker

Existing Technology

This is a design study for a 245kV transmission breaker.

This is completely feasible with today's technology, but limited in performance by existing technology



Near Future

However, it is possible to overcome the technical limitations on Normal Current and Interruption Capability with innovative new designs. These are being worked on now, and in the next few years should become available

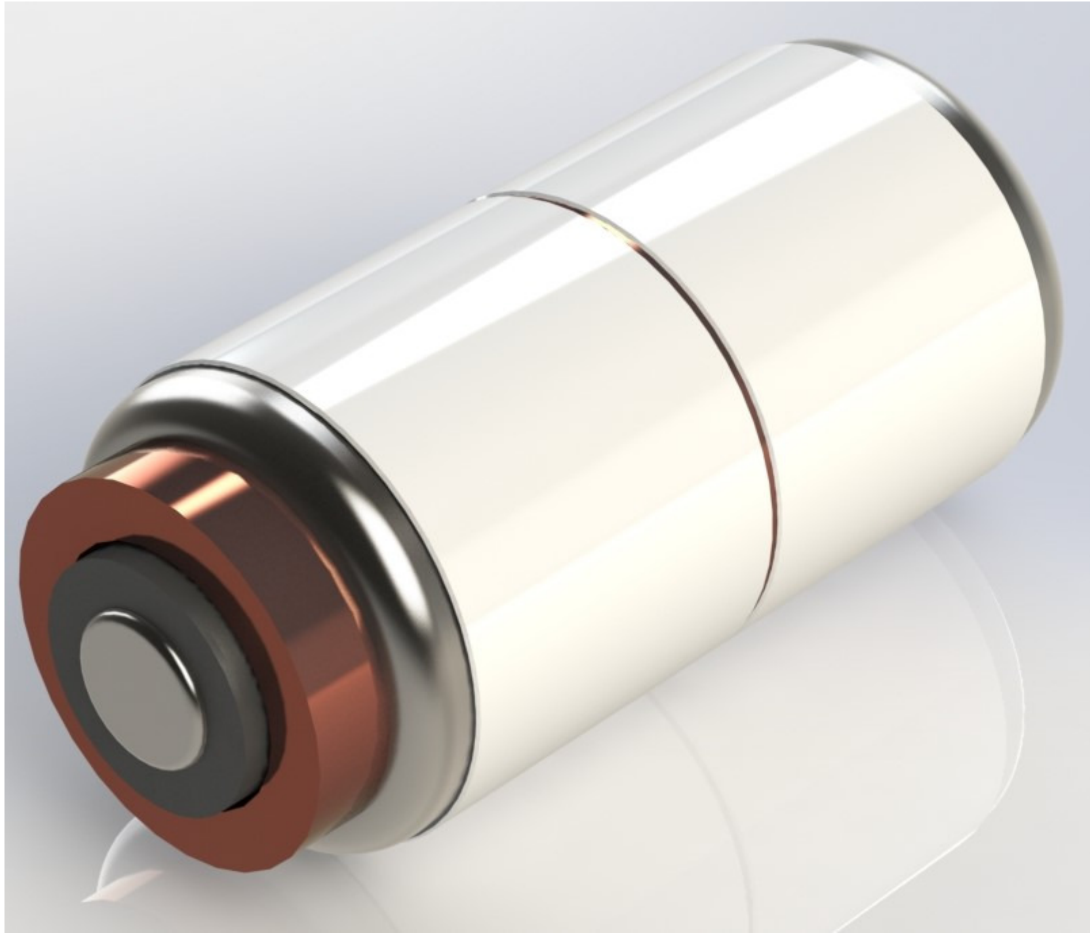
Normal Current: 3150 A

Interruption: 31.5kA

Normal Current 8000A

Interruption 60kA

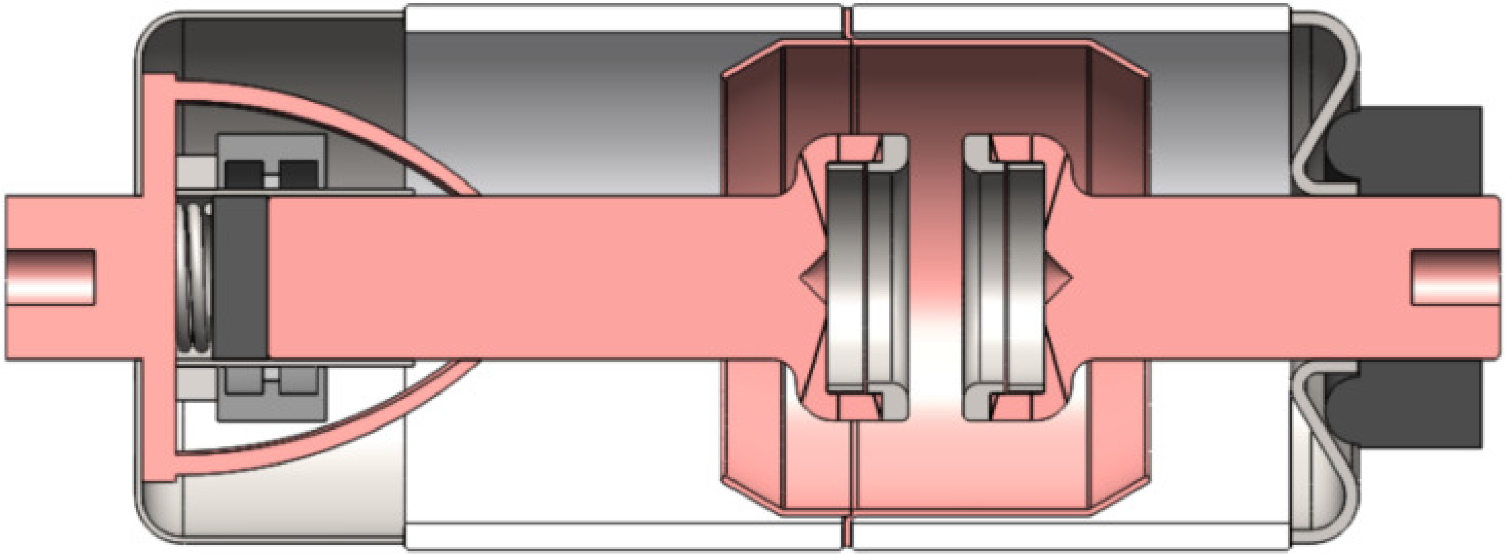
Example 2: Self Actuating Vacuum Interrupter (SAVI)



This is a Vacuum Interrupter which has no external mechanism.

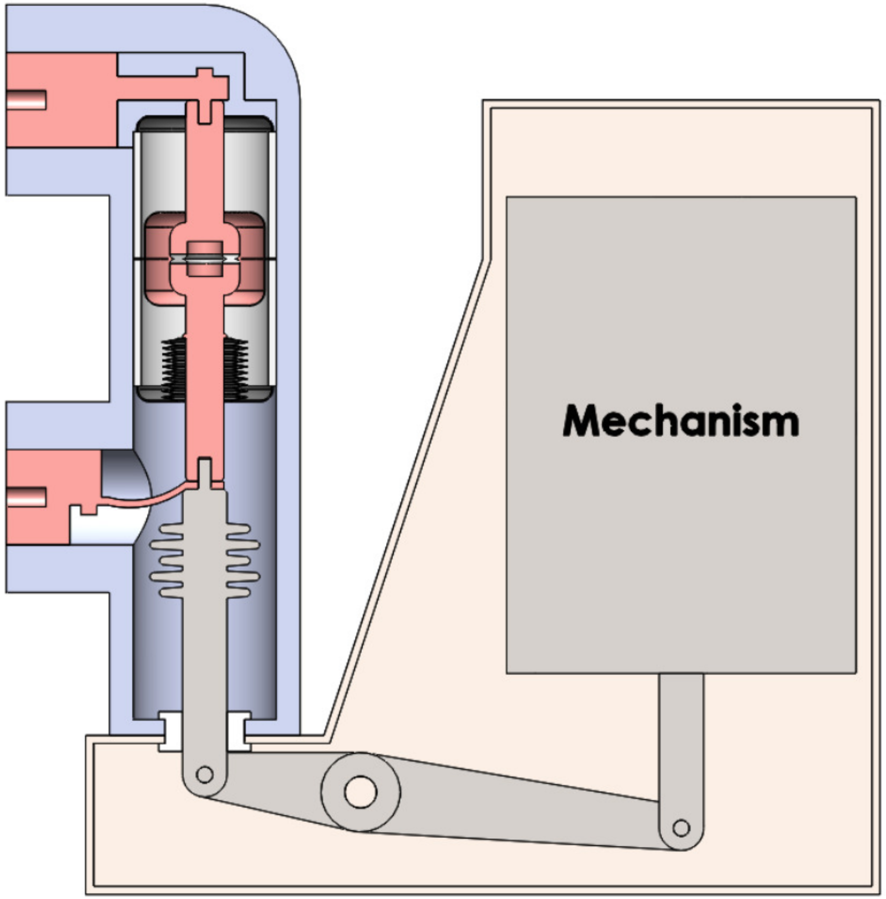
Instead the only movement is of the contacts within the device. This significantly changes the design of the switchgear, and can radically change the design of a substation

Example 2: Self Actuating Vacuum Interrupter (SAVI)



This is a " SAVI" Vacuum Interrupter with an internal magnetic actuator built into the device. It does not require any external mechanism and has no bellows, or externa lmoving parts. This means that, for example it can be completely encapsulated without difficulty

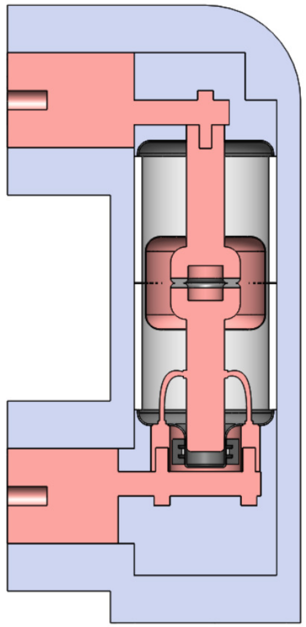
Example 2: Indoor Vacuum Circuit Breaker - Today



This is a conventionl truck mounted MV switchgear truck designed for cubicle use.

The VI is encapsulated in a moulding, with a drive insulator below and linkages to a spring or magnetic mechanism

Example 2: Indoor Vacuum Circuit Breaker (SAVI)



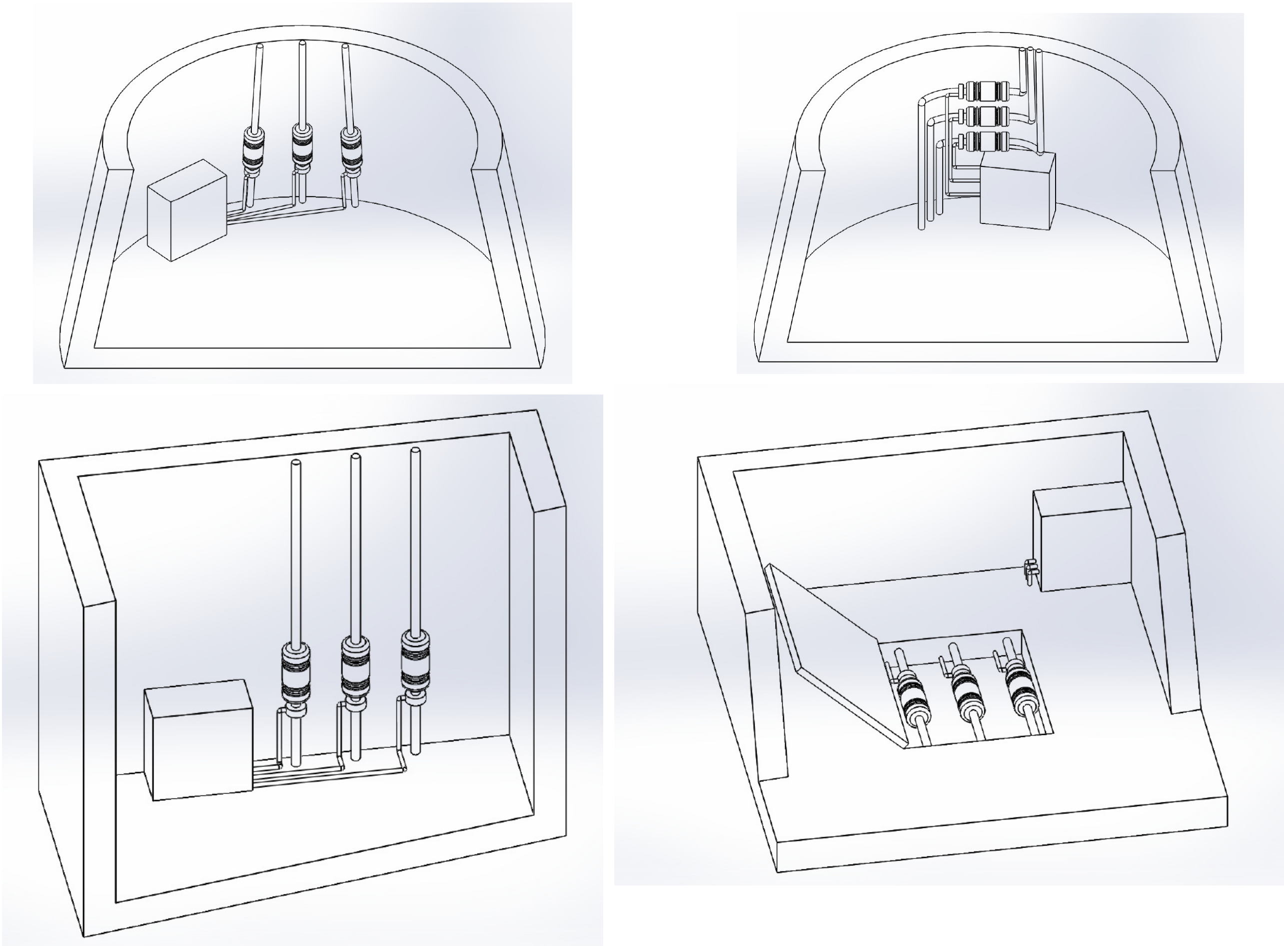
This is the same unit but with a SAVI Vacuum Interrupter fitted.

There is no need for mechanism, or linkages for movement.

Also the interrupter is completely encapsulated.

It only needs a control unit to provide the pulse to cause it to operate.

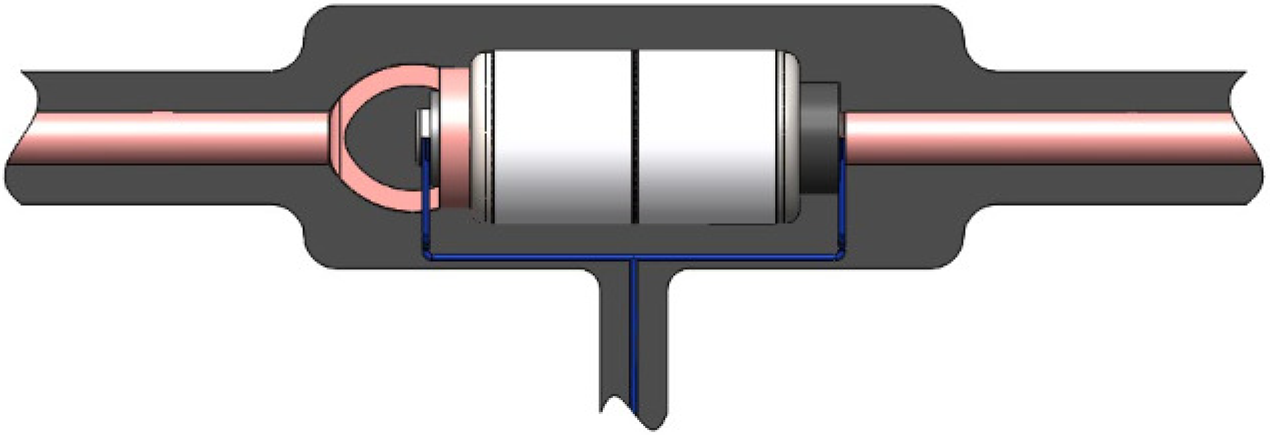
Example 2: Indoor Vacuum Circuit Breaker (SAVI)



These are possible SAVI configurations for switchgear installations.

As each phase is operated independently they do not have to be together and can be mounted virtually anywhere.

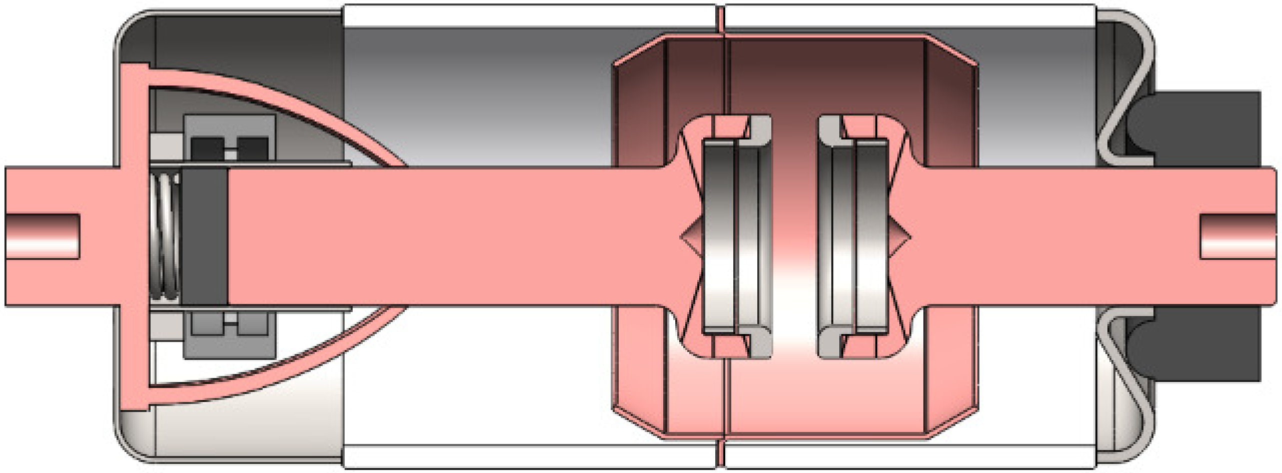
Example 2: Indoor Vacuum Circuit Breaker (SAVI)



This is a " SAVI" Vacuum Interrupter which is mounted as a cable joint.

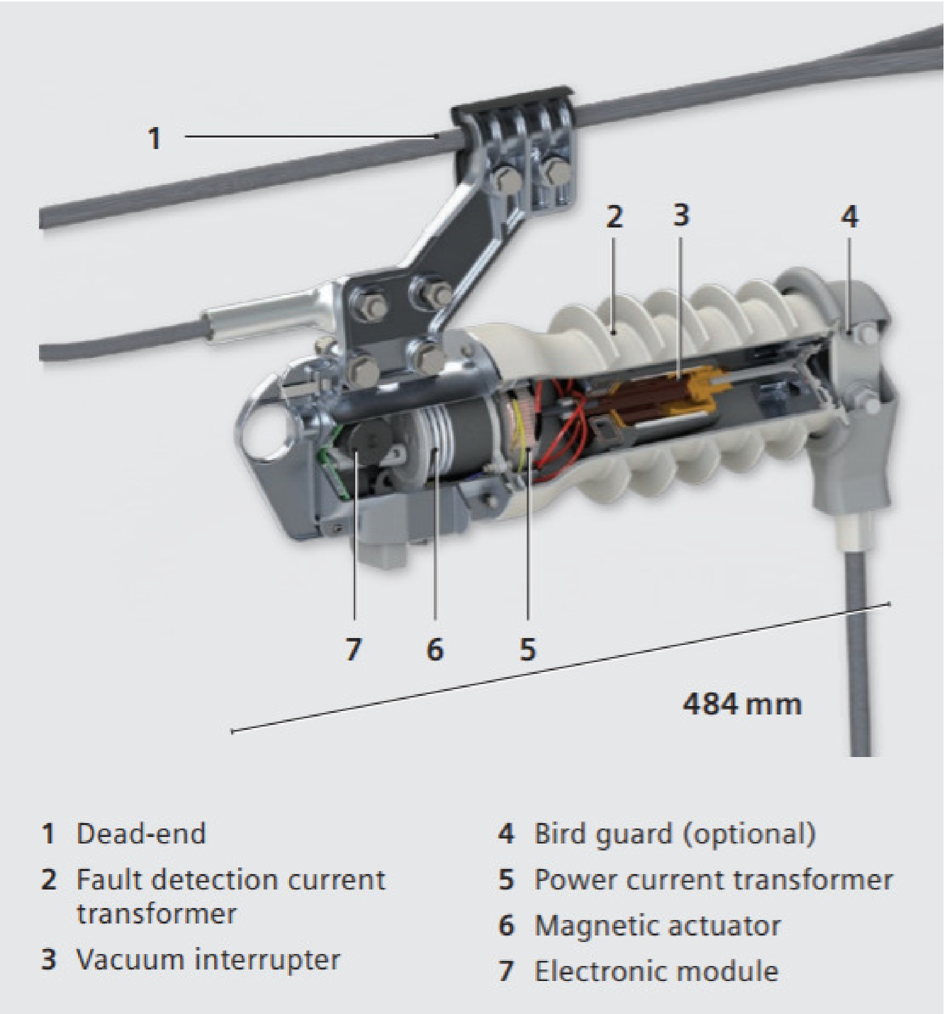
It only needs the control and sensor connections to come out to a control panel. It could be buried in the cable trench, removing the need for a substation completely.

Example 3: Smart Vacuum Circuit Breaker



This is a " SAVI" Vacuum Interrupter with a combined Rogowsi Coil and Voltage Sensor fitted to the conductor. It also has a vacuum measurement device fitted to allow present status and prediction of vacuum life to be assessed during the service life of the Interrupter

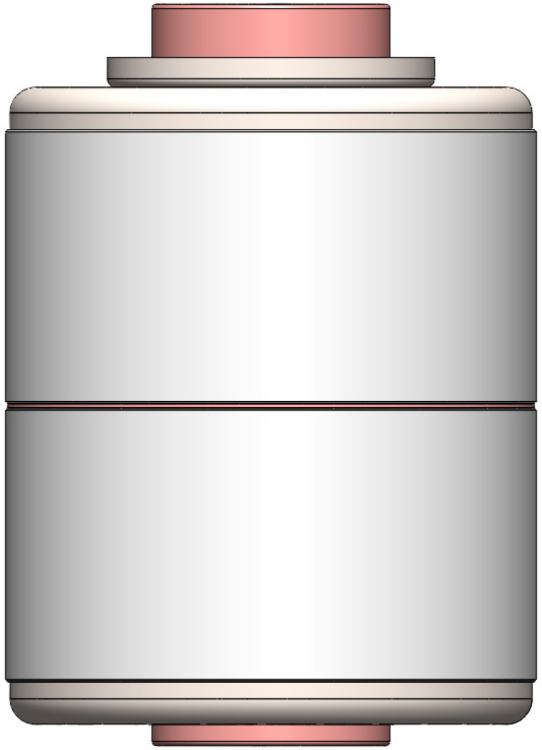
Example 3: Smart Vacuum Circuit Breaker -Fusesaver



This is a " Fusesaver" from Siemens. It combines most of the components and functions of Smart switchgear for a particular application – that of overhead line fuse protection.

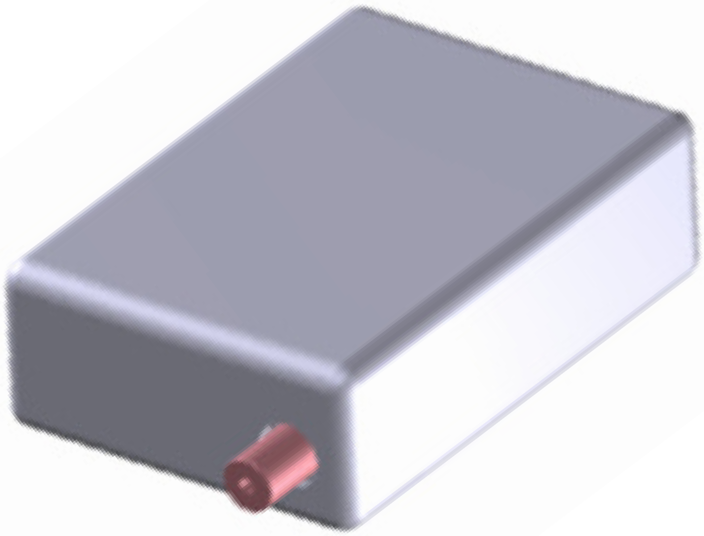
It is available today and gives some indication of what the future holds. All major manufacturers are working in a similar direction.

Example 4: DC Interruption up to 30kV



This is a concept Vacuum Interrupter with a special arc control device which can interrupt DC of 31.5kA at Medium voltages (12kV). It is a concept at present, and will be tested early next year. If successful then scaling up to 30kV and beyond should be possible.

Example 4: DC Interruption up to 30kV



This is a concept Vacuum Interrupter with a special arc control device for Low Voltage use. It is a concept at present, and will be tested next year. It is designed for high volume low cost manufacture in a Robotized factory, and if successful will challenge Air for the LV market

Conclusions:

Vacuum Switchgear has been with us for over 50 years, and today it dominates MV switchgear world wide

During the first 25 years the technology evolved into the classic VI and VCB designs we see today

After a long period of stability, the requirements for switchgear are now changing rapidly with environmental, cost and "Smart Grid" issues making very different requirements

Medium Voltage DC switching is needed to meet the new grids of the future with embedded generation

Conclusions:

Research groups around the world are working on solutions to these problems, and I believe that Vacuum will continue to dominate MV, and will now also move into HV, LV, and DC markets

Conclusions:

Questions?