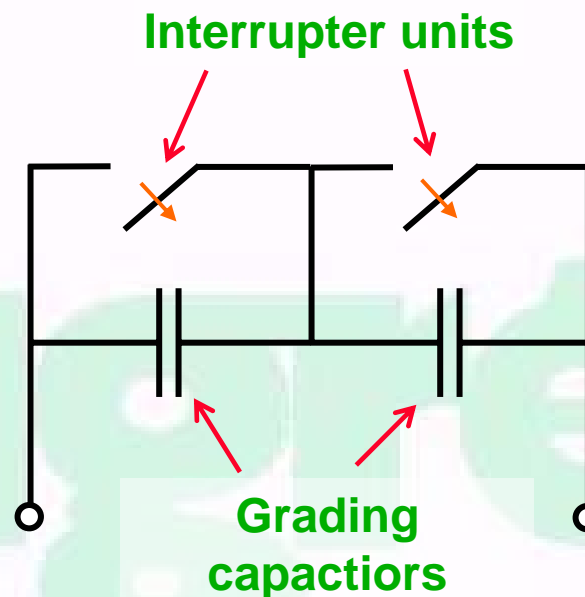


Grading capacitors for circuit breakers

Service experience and failure mechanisms

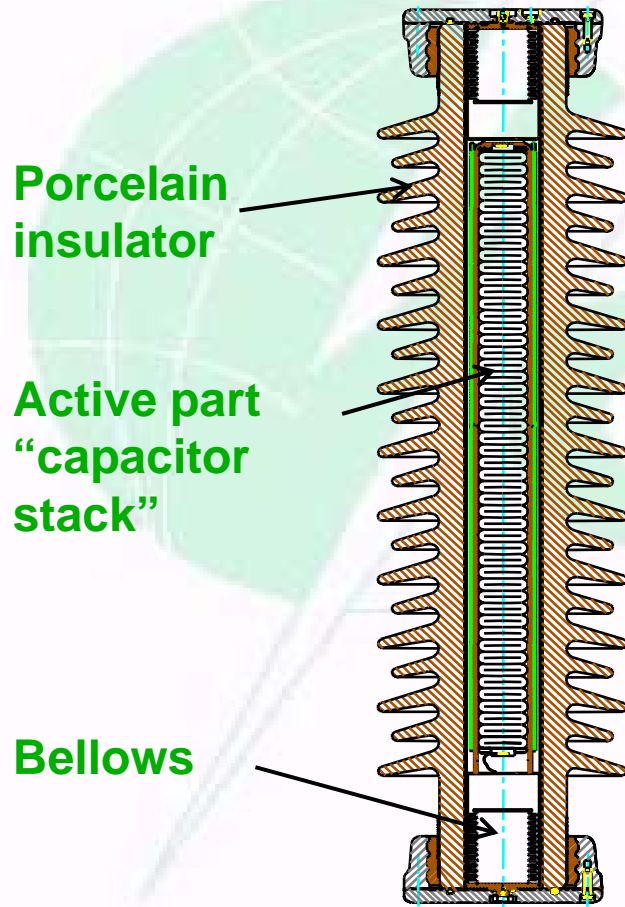
Contribution from Cigré WG A3.18 (M. Runde, A. Bosma, P. Coventry, S. Dick, P. Gramaglia, H. Jahn, N. Koch, E. Kynast, M. Predovan, A. Ribeiro, E. Savary, B. R. Sunga, D. Yoshida)

Grading capacitors control the voltage distribution in multi-unit circuit breakers



Capacitive voltage division equalizes the dielectric stress both in open position and during switching

A stack of capacitor elements made of foils is placed inside a hollow insulator



- Paper or polypropylene or "mixed" dielectric with metal film electrodes
- Foils of dielectric and metal are wound on a mandrel and flattened
- 100 - 200 capacitor elements connected in series
- Impregnated / insulated with oil, or sometimes SF₆

CIGRÉ SC A3 established a WG on grading capacitors in 2003

Background:

- **A number of disturbing incidents (violent failures, comprehensive leak problems, etc.) in recent years**
- **Little qualitative knowledge concerning the stresses grading capacitors are subjected to in service exists**
- **No international standards for testing grading capacitors are available**

Tasks for WG A3.18:

- **Collect information about service experience and failure history**
- **Quantify the electrical, mechanical and environmental stresses experienced in service**
- **Give recommendations for test procedures**

Leak is the most common problem type

Problem:

- Oil leaking out (both AIS and GIS)
- SF₆ leaking in (in GIS)
- Moisture ingress (in AIS)



Extent:

- Predominantly on old (> 20 years) units
- Very common; one utility reported replacement of 5.000 or 20 % of their grading capacitors
- In some GIS the majority of the grading capacitors leaked

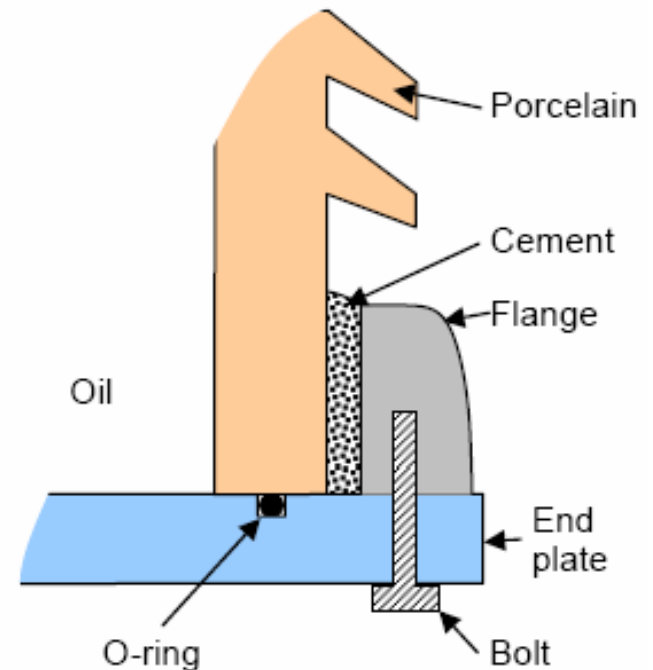
Leaks are predominantly an insulator / housing problem

Causes:

- **Crevice corrosion at flange - end plate interface**
- **Pitting corrosion in o-ring groove**
- **Cracking of cement**
- **For GIS capacitors: Poor workmanship during capacitor assembly**

Consequences and actions taken:

- **A few cases of disruptive failures**
- **Replacement of grading capacitors**
- **Just a few utilities reported repairing capacitors**



A few dozens of disruptive dielectric breakdowns were reported

Problem:

- **Dielectric breakdown in capacitor**
- **Usually a very violent incident**

Extent:

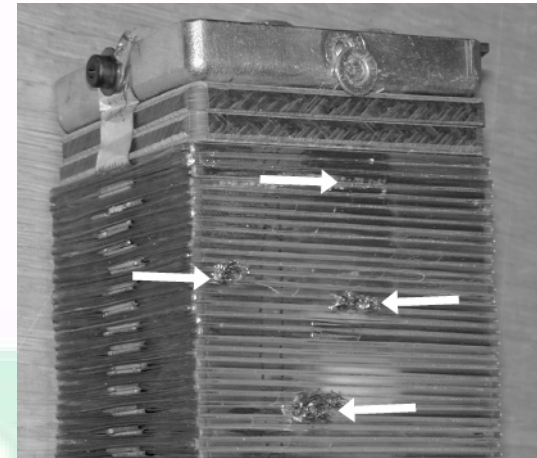
- **Not very common; a few dozens cases only**
- **Both in AIS and GIS**
- **In most cases on reactor breakers**
- **Occurs after opening operation**



Apparently some very large overvoltages may occur during reactor switching

Causes:

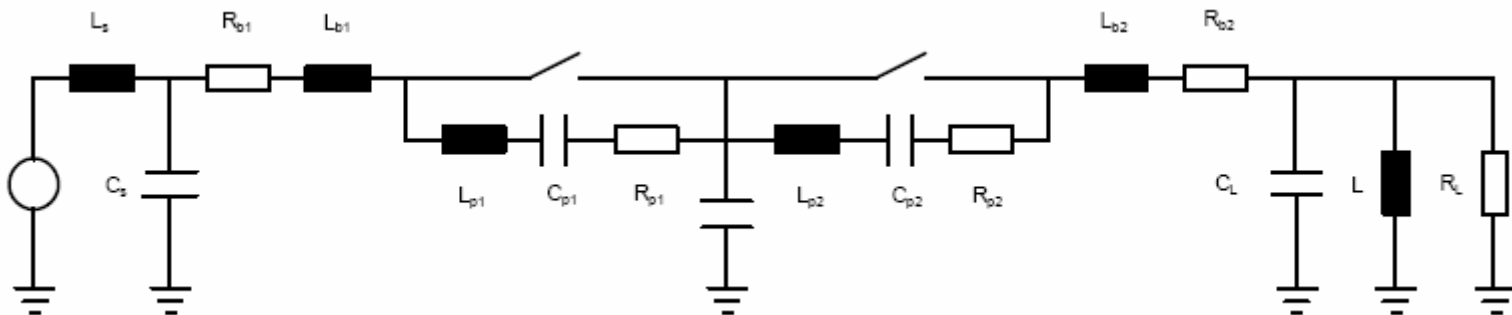
- The dielectric stress during reactor switching appears in some cases to exceed the strength of the capacitor elements
- Hence, internal breakdowns occur



The origin/cause of the dielectric failures have not been understood

Origin:

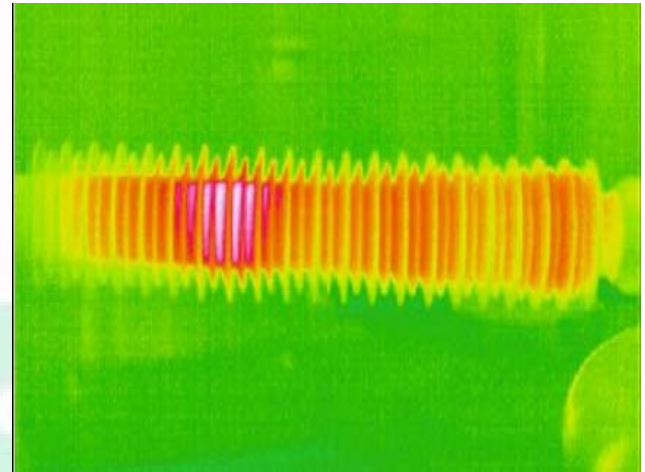
- Simulations and measurements have not been able to explain the phenomenon
- Modeling these phenomena is by no means straightforward, but we are working on it
- What happens inside the first parallel circuit remains the crucial and elusive question.
- Uneven voltage sharing between the grading capacitors may play an important role



As long as the cause of the dielectric failures is elusive, it is difficult to prescribe countermeasures

Actions (on reactor breakers):

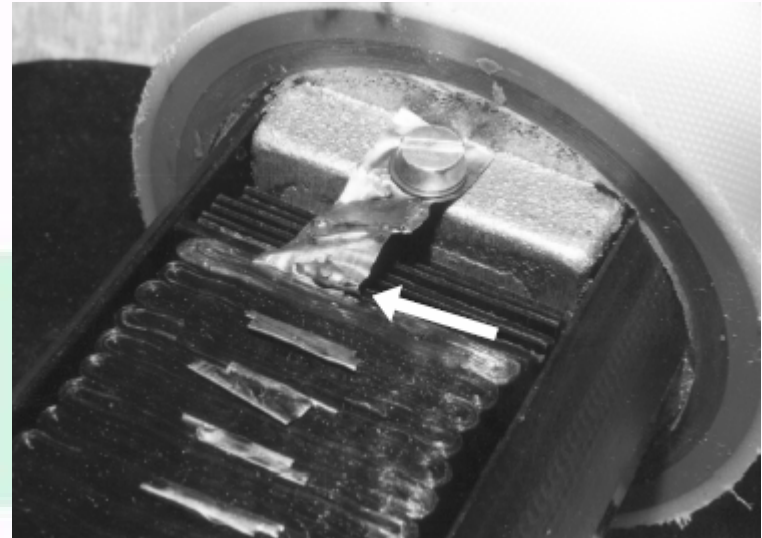
- **Some utilities have installed controlled switching units to eliminate re-ignitions and thereby try to avoid these failures**
- **However, at least one reactor breaker with controlled switching has also experienced dielectric failure**
- **Infrared imaging surveillance may reveal internal failures, but at a very late stage**



Some cases of damaged internal conductors were reported

Problem:

- **Metal foil conductors connecting capacitor elements break off**
- **Open circuit causes arcing and fast deterioration**
- **Indications of mechanical fatigue have been found**



Extent:

- **Several cases found on a few rather old capacitor designs**

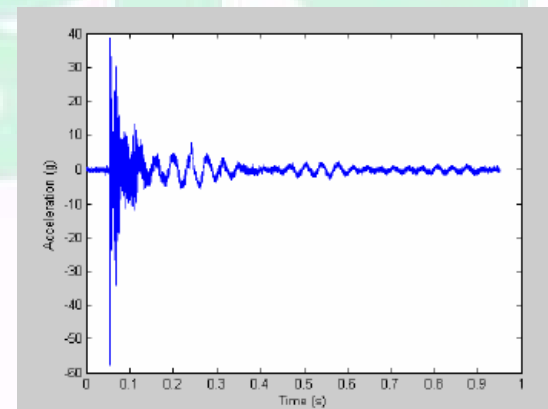
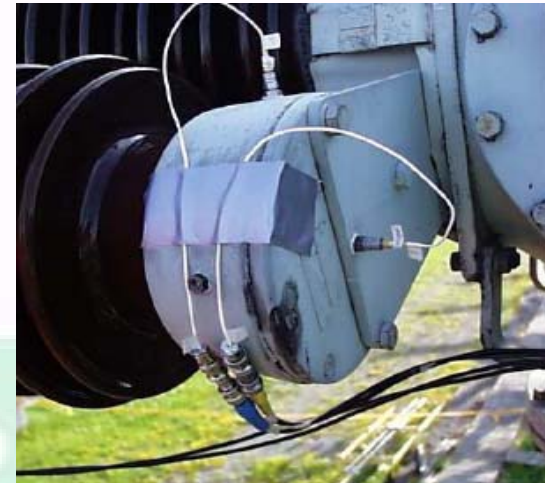
Circuit breaker operations stress the grading capacitors mechanically

Causes:

- **Circuit breaker operation introduces mechanical shocks and vibrations**
- **In some old and poor designs these stresses appear to have caused the damage**

Consequences / countermeasures:

- **Newer designs appear to be much more mechanically robust, and virtually no problems have been reported**



Grading capacitor problems are likely to occur for quite some time yet

- **Many old design grading capacitors appear to last considerably shorter than the rest of the circuit breaker**
- **An increasing number of leaks are expected as the circuit breaker populations get older**
- **Newer grading capacitor designs appear to be more reliable**
- **Understanding the mechanisms behind the dielectric failures associated with switching of small inductive currents is a priority target**