# Technical Webinar Series 2021

# "Transformer Protection using Surge Suppressors"

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# Introduction…

- Definition
- Intro to Transients
- Mixed Transients
- Effects of Transient Activity
- Suppression Techniques
- Optimised Surge Suppression
- User benefits
- Installation and Application

# Intro to Transients…

## Energisation Transients

- High frequency oscillatory exchange of current
- 100 kHz to 10 MHz
- Occurs between supply and load capacitances
- Fraction of a milli-second before any load current is established

## De-energisation Transients

- Sudden interruption of 50/60Hz load current
- Finite current is “trapped” in the winding, diverting to the load capacitance
- “Trapped” energy oscillates between winding inductance and load capacitance
- 1 kHz to 10 kHz

In practice, these two transient types often combine during switching operations

# Mixed Transients…

**Prestrike**

Premature ignition across the switch contacts before mechanical closure resulting in up to 30 steep fronted surges being imposed on the machine winding

**Current chopping**

De-energisation of the load at the moment when the finite current is flowing through the switch in the form of an arc

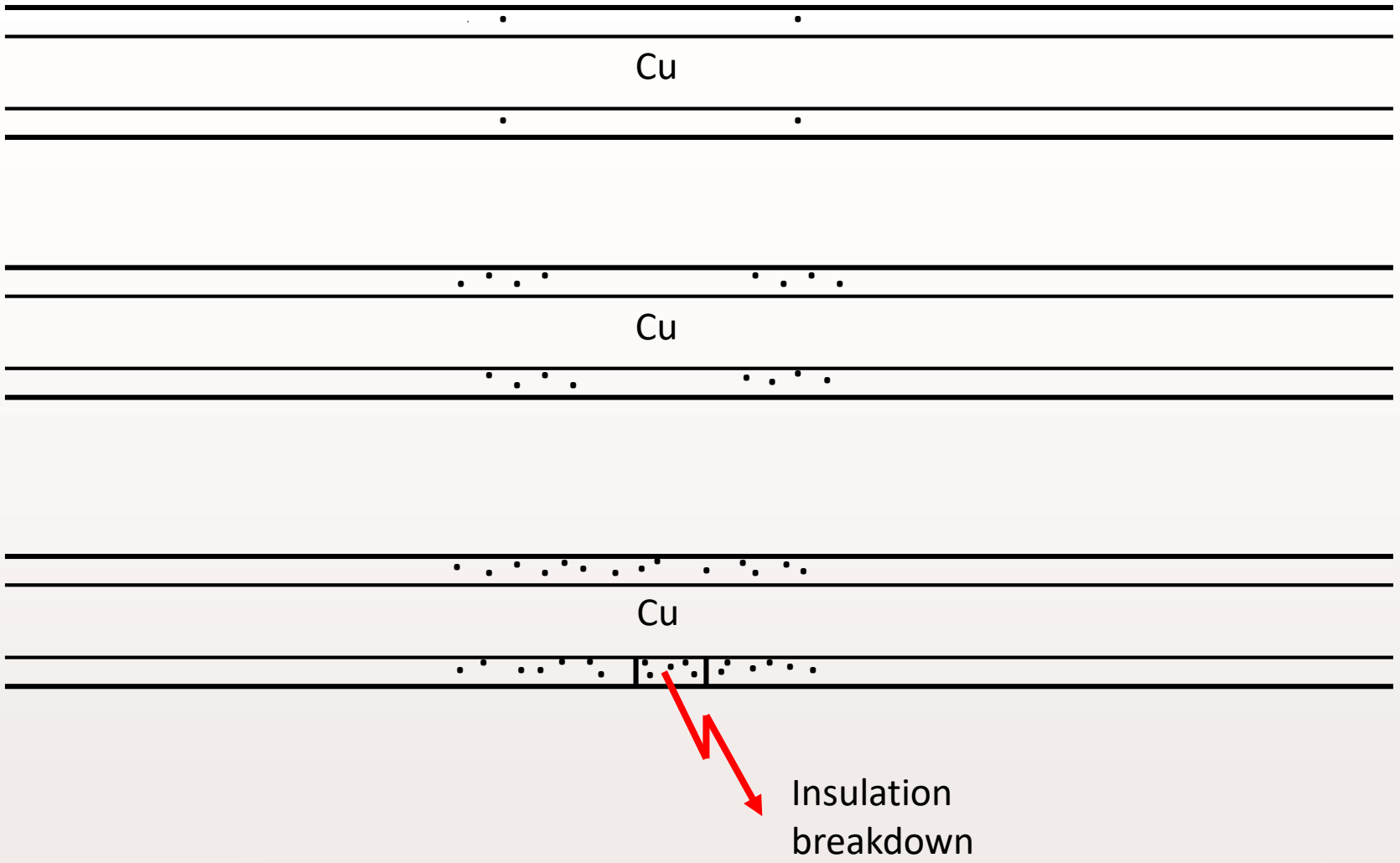
**Restrike**

Re-energisation of the load circuit following de-energisation due to dielectric breakdown across the moving contacts

**Multiple restriking**

A series of sequential current chop and restrike processes. Probability of this is in the order of 30% to 40% with associated surge magnitudes of 4 to 6 pu with rise times of between 0.2µs and 1.0µs

# Effects of Transient Activity…



## Effects of Transient Activity

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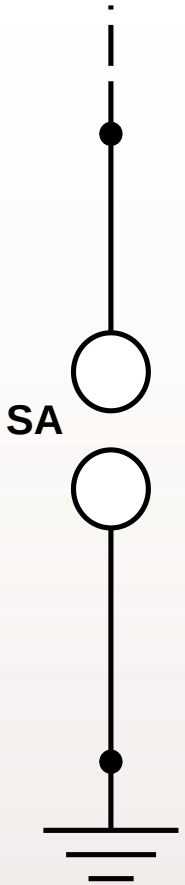
# Effects of Transient Activity

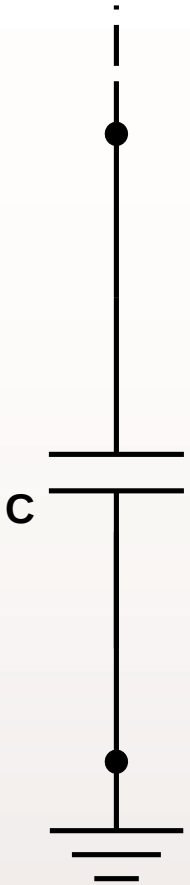
# Insulation Failure Costs…

- Cost of removing failed equipment from service, and for reinstallation after repair.
- Cost of transportation to and from the site.
- Direct repair cost.
- Cost of downtime and lost production (or disruption to production).

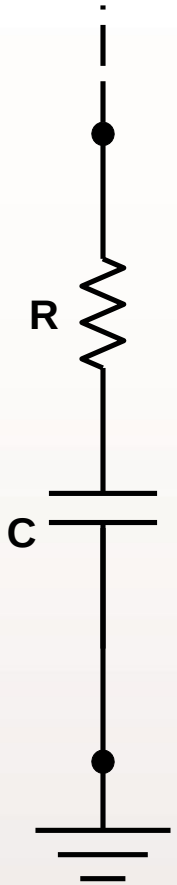
# Suppression Techniques…



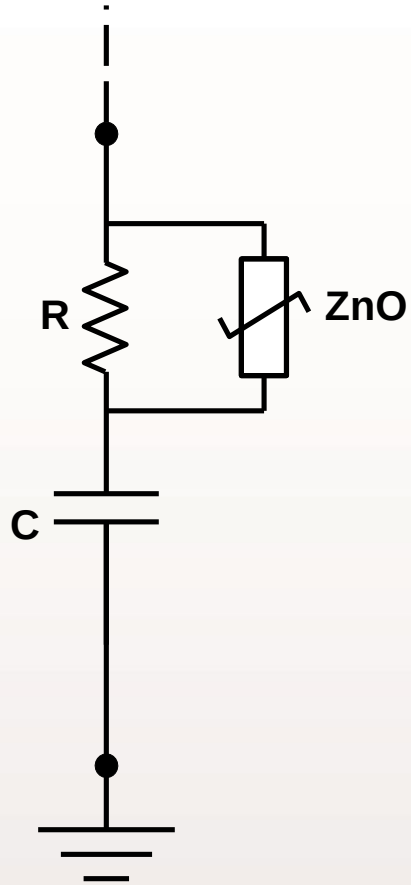

Surge Arrester




Surge Capacitor




RC Suppressor




Optimised Surge Suppressor

# Suppression Techniques…

## Surge Arrestors

- Slight limiting of surge magnitudes to approx. 3pu
- No effect on surge rise times
- Does not limit voltage doubling
- Inadequate surge protection from escalating voltages caused by circuit resonance

✖ Minimum protection

## Surge Capacitors

- Reduces the escalation of peak pre-strike voltage
- Reduces the number of pre-strikes
- Undamped capacitor enhances high frequency capacitive coupling
- Could increase severity of stalled tripping surges

● Medium protection when used with Surge Arrester

# Suppression Techniques…

## RC Suppressors

- Matches surge impedance of load cables
- Reduces re-ignition surge voltages
- Does not limit surge rise times
- Cancels voltage doubling effect
- Best installed at terminals

Better protection

## Optimised Surge Suppression

- Can be installed at either end of load cable
- Both frequency and voltage dependant
- Discharge free at full system voltage
- Elimination of sequential re-ignitioning

Best protection

STRIKE TECHNOLOGIES

# Optimised Surge Suppression…

ZORC®

**Z** - Zinc

**O** - Oxide

**R** - Resistor

**C** - Capacitor

# ZORC Surge Suppressor…

The ZORC is a unique, high frequency transient over voltage surge suppressor for the protection of medium and low voltage motors, transformers and generators from steep wave-front, short rise-time, high magnitude, spikes, surges and other transient over-voltages generated by switching and other sources.

# ZORC User Benefits…

- **ZORC halves the magnitude of steep wave-front surges** impinging on the load terminals by providing a matched cable terminating impedance under transient conditions, thereby eliminating refraction of steep wave-front surges (i.e. eliminates voltage doubling effects).

- **ZORC eliminates multiple pre-striking and re-striking transients** associated with vacuum and other switchgear, by eliminating reflections of the pre-strike and re-strike current wave-fronts, and thus preventing high frequency current zeros in contact gap of the switch.

- **ZORC provides a suitably low absolute limit** to the magnitude of steep wave-fronted surges that may impinge on the load terminals, and slopes that portion of the steep wave-front which exceeds this limit.

# ZORC User Benefits…

- **ZORC provides comprehensive insulation co-ordination**, at all practical steep wave-front surge magnitudes and rise-times, within the motor impulse withstand levels recommended by the IEEE and CIGRë curves

- **ZORC protects new motors and dry-type transformers** throughout their service life by reducing the magnitude, rise-time and frequency of occurrence of steep wave-fronts impinging on the load terminals.

- **ZORC extends the life of motor and dry-type transformer** insulation if retro-fitted to existing motors in service.

- **ZORC saves money by eliminating losses** incurred as a result of insulation failures of motors and dry-type transformers, in terms of both direct repair costs as well as costs of down-time leading to lost or disrupted production.

# Insulation Impulse Withstand Levels…

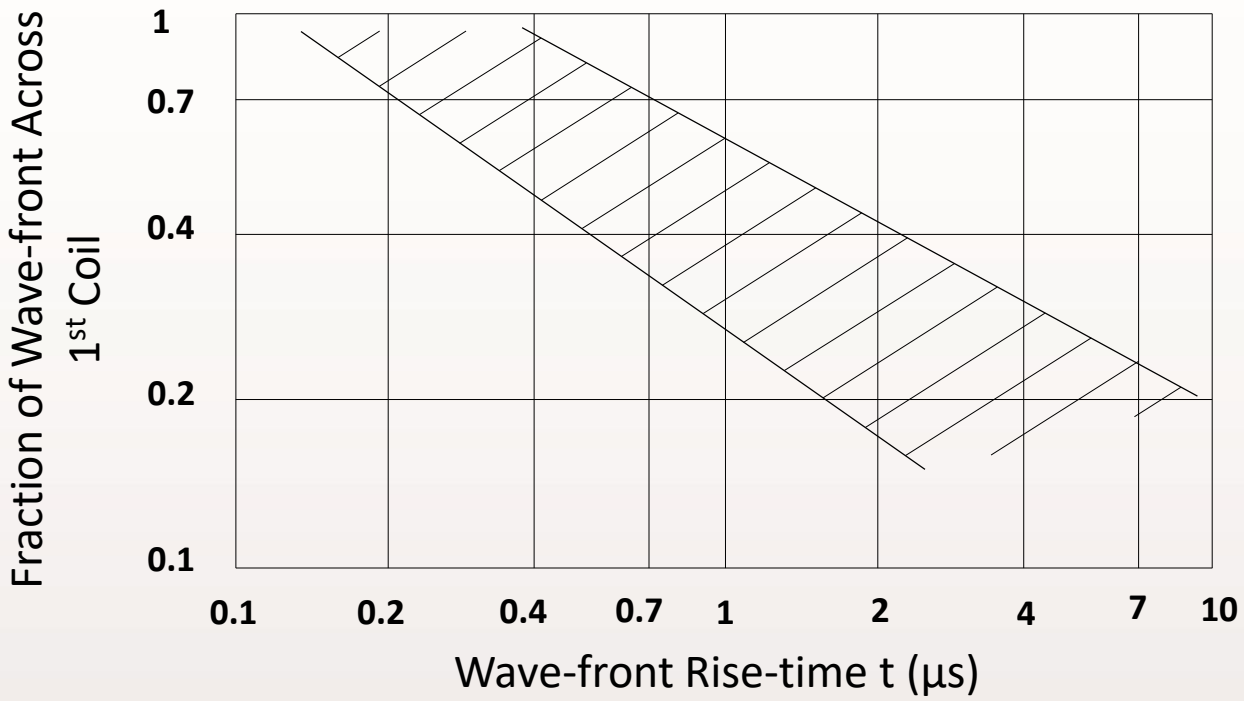
- In service, there is an inevitable and unpredictable degradation of motor and transformer insulation.

- There are no international standards which lay down requirements regarding medium voltage motor insulation impulse withstand levels.

- However, the CIGRë Working Group 13.02 and the IEEE working group on the impulse strength of AC rotating machines, give some guidance as to what can be expected in practice. The IEEE curve takes the effects of ageing into account.

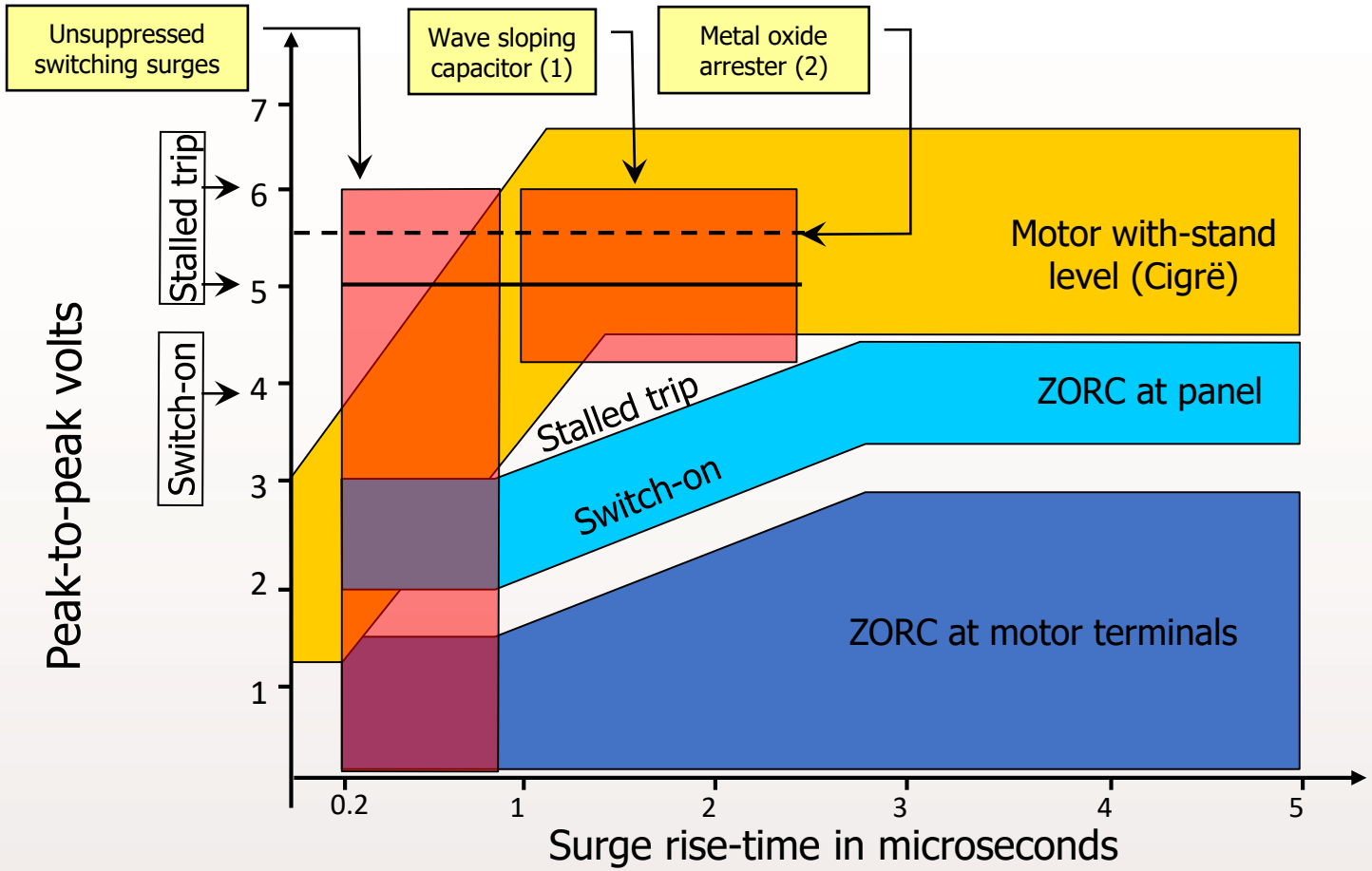
# Insulation Impulse Withstand Levels…

The ability of motors and dry-type transformers to withstand steep wave front switching, lightning and other transient overvoltage phenomena is the lowest of all equipment generally connected to a three-phase power system.



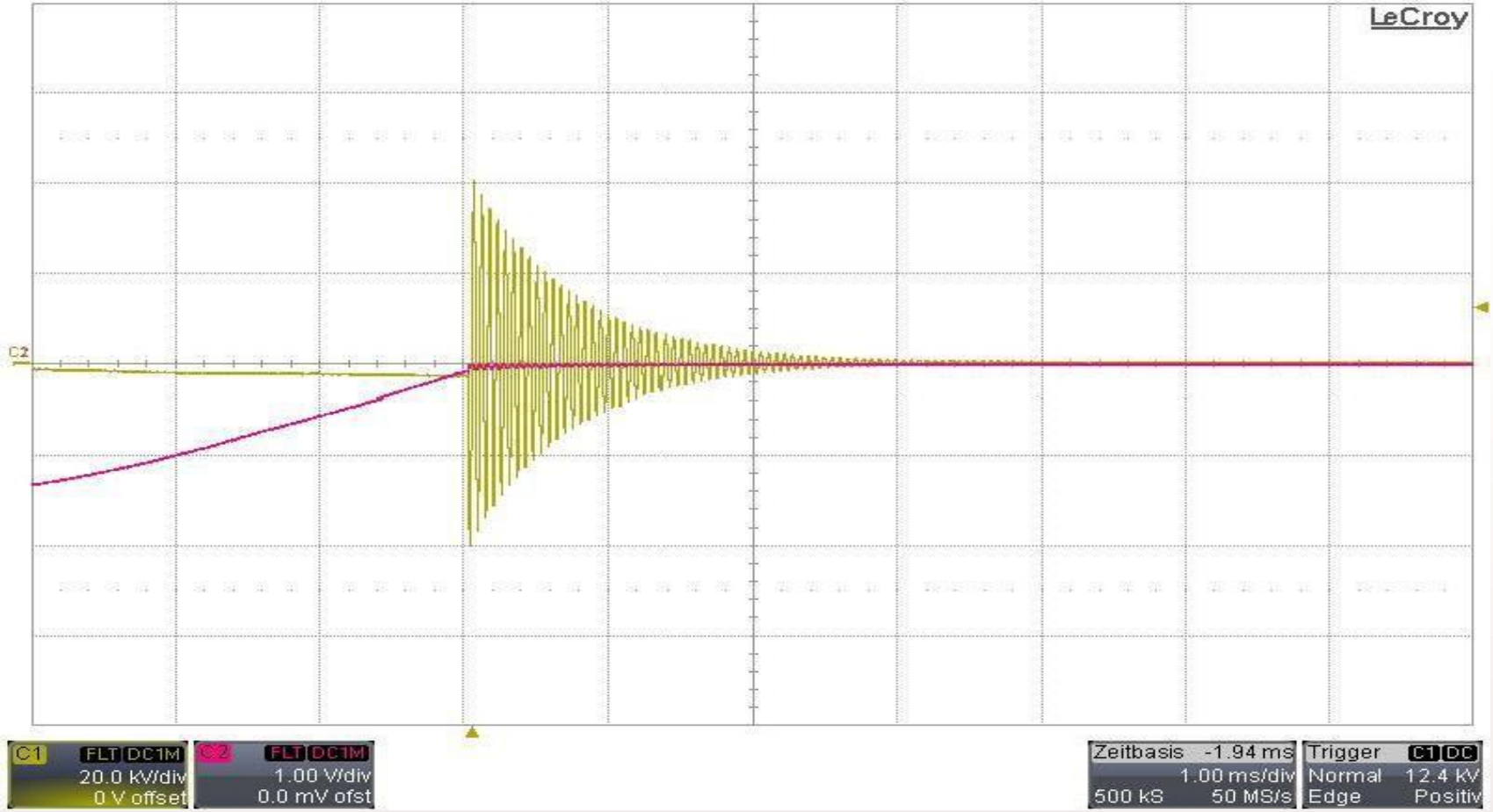

The surge withstand ability of motors and dry-type transformers decreases with decreasing impulse wave-front rise-times (i.e. with steeper wave-fronts)

# Insulation Impulse Withstand Levels…




Notes: (1) Normally fitted with parallel metal oxide power arresters.
(2) Clamping voltage: peak-to-peak = 2 x peak-to-earth volts.

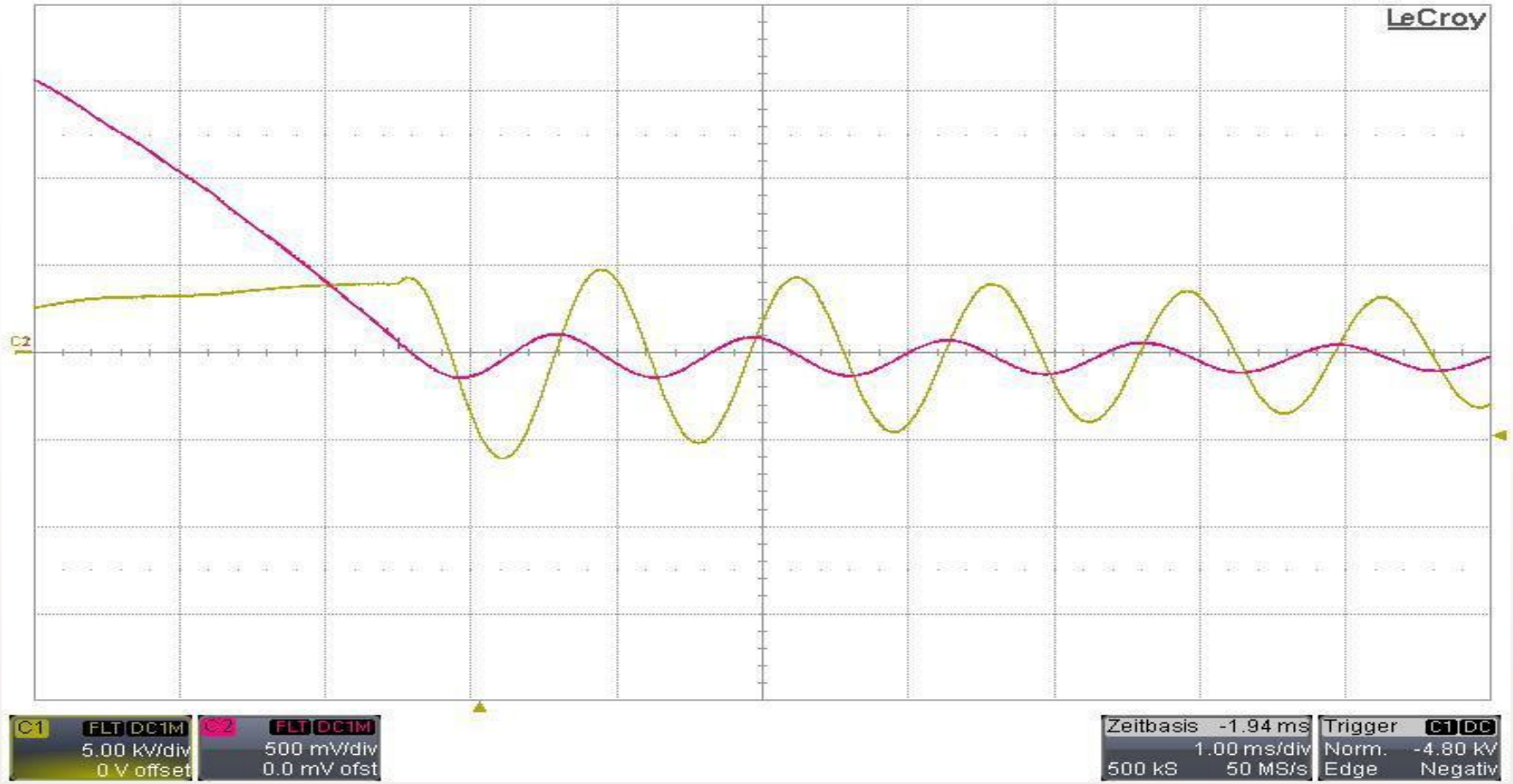
# Transient without ZORC…




**Without ZORC:**

Voltage scale factor = **20 kV/div.** Time base = 1 ms/div **40 kV peak TRV** at 50 A switching current

# Transient with ZORC…

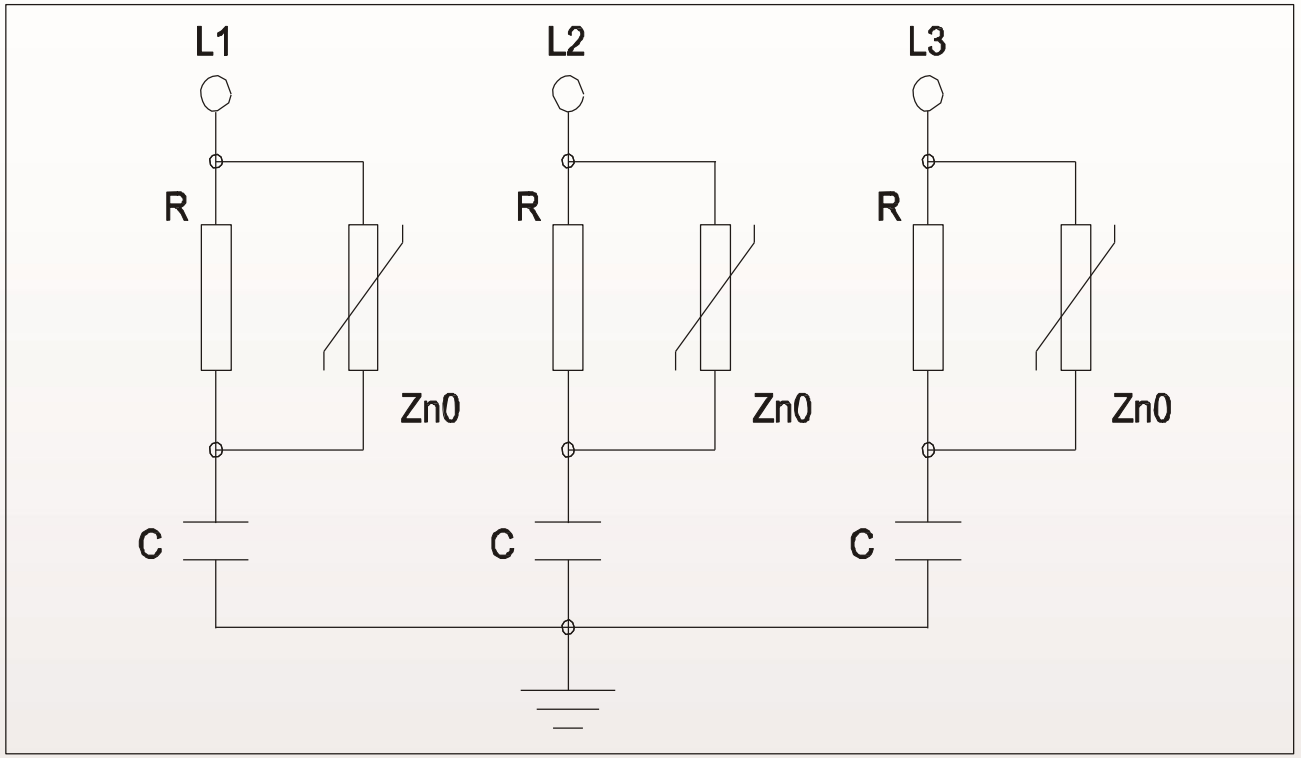



**With ZORC:**

Voltage scale factor = **5 kV/div.** Time base = 1 ms/div **6.2 kV peak TRV** at 50 A switching current

# How ZORC Works…

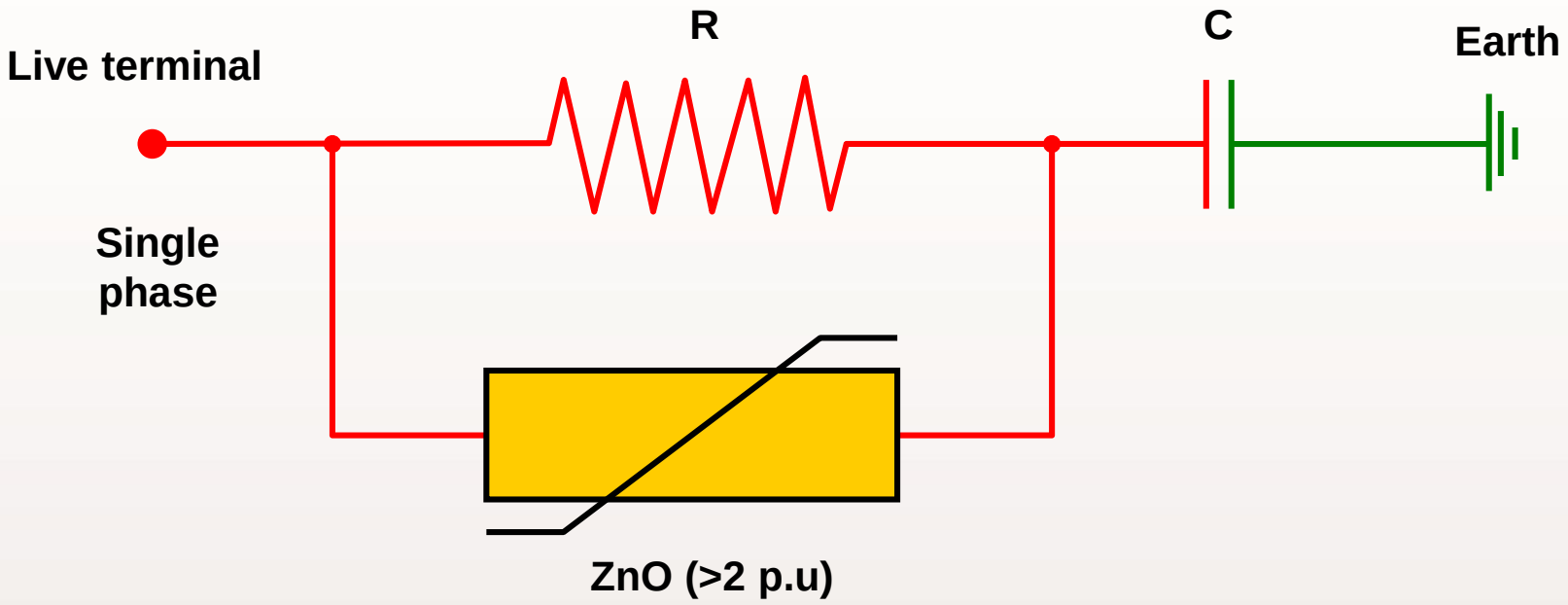
The ZORC surge suppressor is a unique voltage and frequency dependent (50Hz/60Hz) cable-terminating network comprising of capacitors, resistors and Zinc Oxide (ZnO) non-linear arresters.




**Three phase configuration in one container**

# ZORC Internal Configuration…

**Internal Connections**

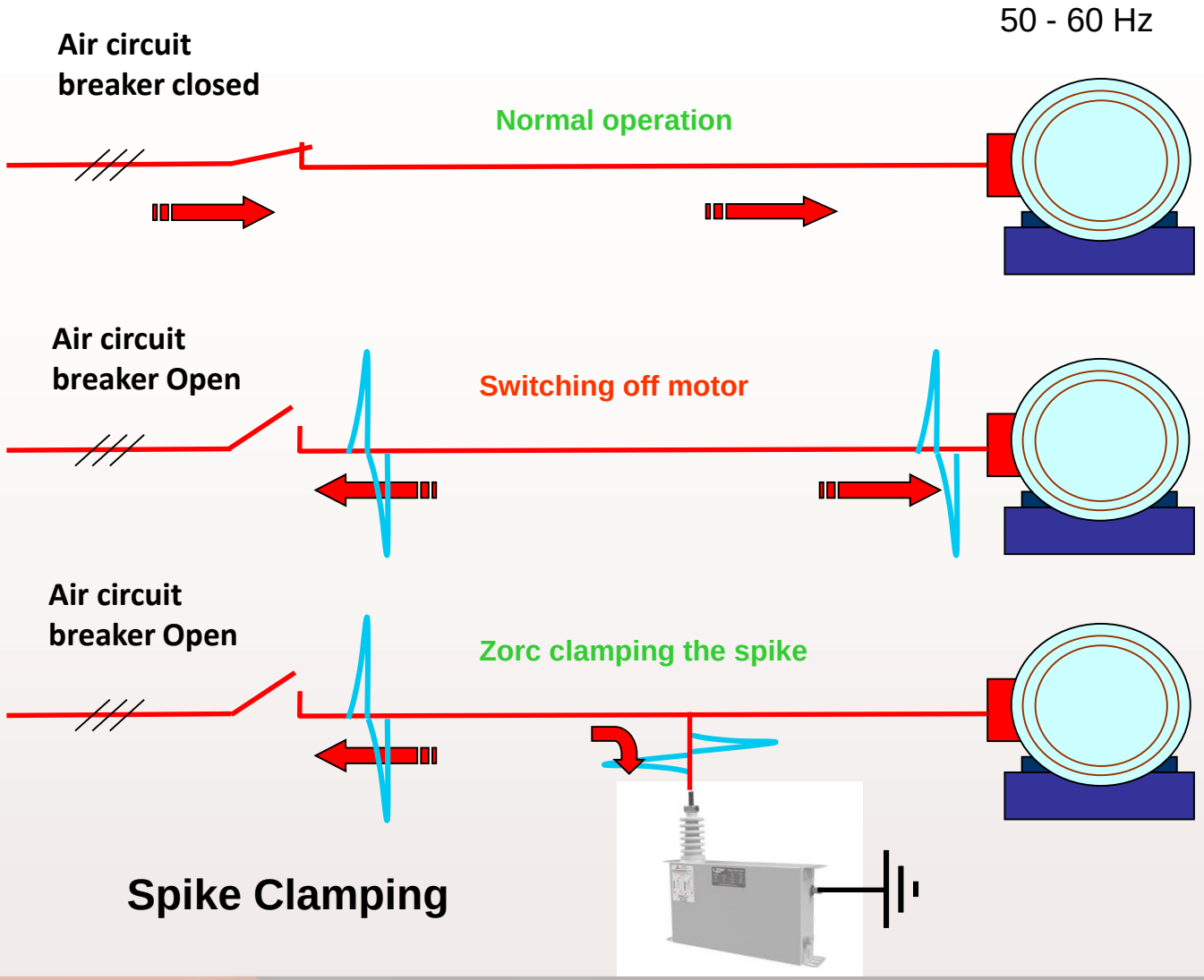



**Single phase configuration in one container**

# How ZORC Works…

- Under normal mains frequency conditions the impedance of the capacitive elements is very high
- Under high frequency transient conditions the impedance of the capacitive elements is low with respect to the resistive elements
- Voltage refraction and reflection of steep wave fronts is minimised, voltage doubling is avoided and high frequency re-strike current zeros in the switch are eliminated
- This eliminates multiple pre-striking transients associated with vacuum and other switchgear
- Under high magnitude steep wave-front conditions, the ZnO arrestors ‘trigger’
- The cable surge impedance is independent of cable length. Therefore a resistance of 30Ω for the ZORC is suitable and is independent of cable length, motor size and voltage.
- The value of the capacitive elements is optimised to minimise the heat dissipation and stressing of the resistive elements
- ZnO gapless non-linear arrestors are used because the voltage across the ZnO is negligible

# How ZORC Works…




Spike Clamping

**Spike description**

- amplitude 1-6 pu
- rise time 0.1- 0.2µ sec

# ZORC Features…

**Compact**

ZORC is compact enough to be fitted within most motor/transformer terminal enclosures or switchgear panels.

**Low Cost**

ZORC offers an unparalleled price/performance ratio.

**Easy to apply**

ZORC suppressors may be selected from a catalog with no detailed engineering required.

**Motor/transformer mounting and switchgear panel Mounting versions**

ZORC versions are available for both motor/ transformer mounting (M-type) and panel mounting (P-type)

**Single phase and three phase versions**

ZORC suppressors are available as both single phase or three phase versions. Single phase versions are suitable for installing in phase segregated terminal enclosures.

# ZORC Features…

**Hazardous environment application**

As an option ZORC surge suppressors may be ordered certified for use in potentially flammable atmospheres (Class 1 Division 2 locations), temperature classes T1 to T5

**Easy to install**

ZORC suppressors may be mounted in any orientation and convenient mounting brackets or clamps are provided.  (See dimension drawings)

**Well proven**

Many thousands of ZORC surge suppressors have been installed over the past 35 years, on motors, generators and transformers, solving the pressing problem of insulation failures and attendant repair and downtime costs

# ZORC Types & Voltage Ranges…

## Low Voltage ZORC

- 400V to 1100V
- 3 phase only
- Machine mount only


## Compact ZORC

- 3.3kV, 4.16kV and 6.6kV
- 3 phase only
- Machine mount only

# ZORC Types & Voltage Ranges…

**Standard Single Phase ZORC**

- 3.3kV, 6.6kV, 11kV, 12.5kV, 13.8kV and 15kV
- Machine mount only

**Standard Three Phase ZORC**

- 3.3kV, 4.16kV, 6.6kV, 7.2kV, 11kV, 12.5kV and 13.8kV
- Machine and panel mount

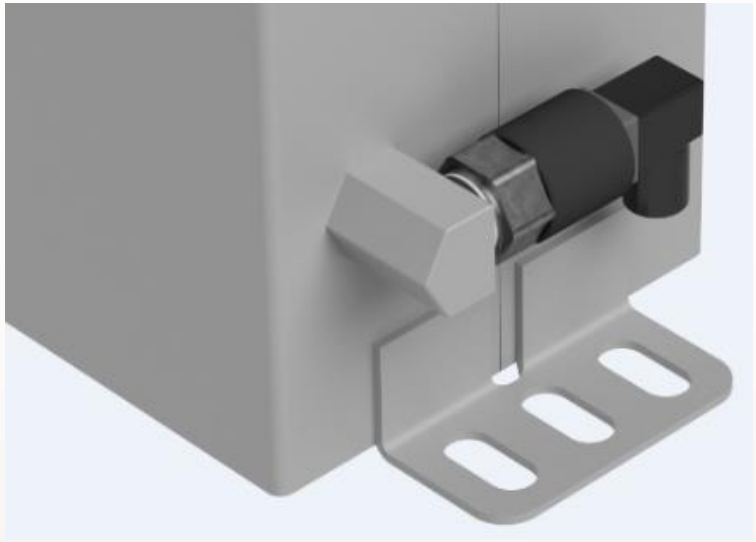
# ZORC Types & Ranges…

**ZORC – RC Suppressors**

- 22kV, 25kV, 33kV, 36kV and 40kV
- Single phase only
- 22kV has single container with no insulator plinth
- 25kV to 40kV has double container configuration with insulator plinth
- 25kV to 40kV containers are ‘live’

# ZORC Types & Ranges…

## ZORC with Pressure Sensor



**Provides an additional safety feature when:**

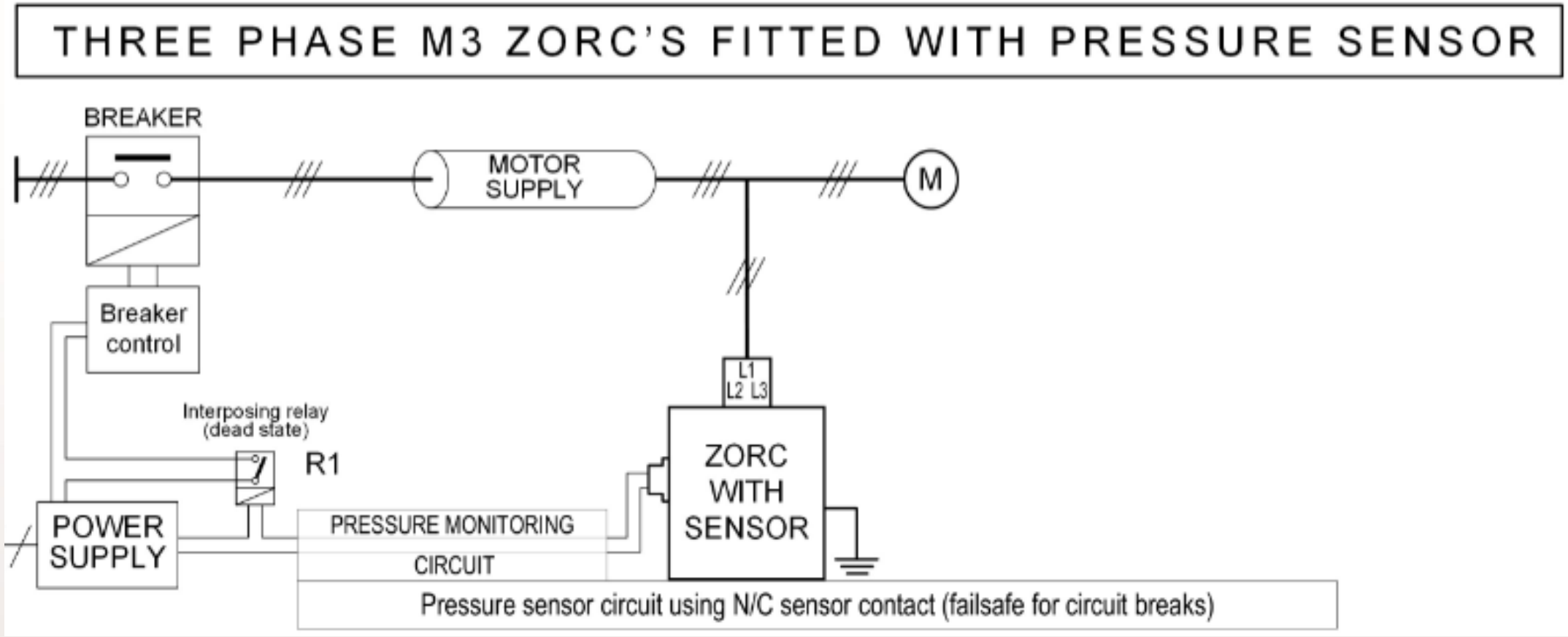
- there is evidence of TH(V)D being higher than 8%
- ambient temperatures are constantly high, ie. >56°C (133°F)
- additional general safe practice is required

**Features:**

- Detects and reacts to internal pressure build-up due to electrical anomalies
- Set to 0.8 Bar (11,6psi)  (factory pre-set)
- IP 65 rated
- Can be rated for hazardous environments

**Available for voltage range 3.3kV to 22kV**

# ZORC Types & Ranges…



# ZORC Installation…

**Installation**

- At motor
- At panel
- Compact version (smaller bushings) in terminal box
- Select correct ZORC for operating voltage
- Any orientation with proper clearance consideration
- 2,5mm² (0.003875in²) flexible lead
- 16 – 25mm² (0.0248in²) earth cable
- Surge arrestors where required
- Watch vibration, water ingress and  moisture, excessive dust and vermin
- Unit should be properly bolted down with minimal stress on bushings
- No more than 20Nm for tightening of bushing nuts
- Ambient temperatures from -40°C to +55°C (-40°F to 131°F)

# ZORC Additional Considerations…

## Maintenance and Visual inspection:

The ZORC is maintenance-free requiring only periodic cleaning of bushings in contaminated areas.

- Inspect the ZORC for dirty, broken or chipped bushings.
- Physical damage to the casing.
- Earth cable and terminal cable. The casing earth and terminal cable should not be corroded.
- Inspect casing for any bulging. (Needs to be removed from service immediately).
- Inspect very carefully for oil leaks, especially as a result of hair-line cracks on the bushing. (Needs to be removed from service immediately).

# ZORC Additional Considerations…

## Life Expectancy

- With the variable operating and environmental conditions that can affect the operating life of the ZORC we can only give a guideline for life expectancy of the unit.
- In an ideal environment where the ZORC is installed correctly, the internal capacitor is the most vulnerable component in the ZORC
- Certain conditions that the ZORC unit might be exposed to, such as very high ambient and internal temperatures, could accelerate the degradation of the internal capacitor. For this reason the expected life span of the ZORC has been conservatively set at 20 years
- The life expectancy on standard capacitor banks is typically set at approximately 30 to 40 years

# ZORC Application…

**Application examples:**

- Fans
- Pumps
- Compressors
- Mills
- Crushers
- Refrigeration machines
- Motor-generator sets
- Mine winders
- Conveyors
- Mini and mobile substations
- Generators
- Power station auxiliaries
- Induction and arc furnaces
- Dry type transformers

# ZORC Cost Benefit…

Cost of a transformer could be from $2k to a few million and excludes down time and labour.

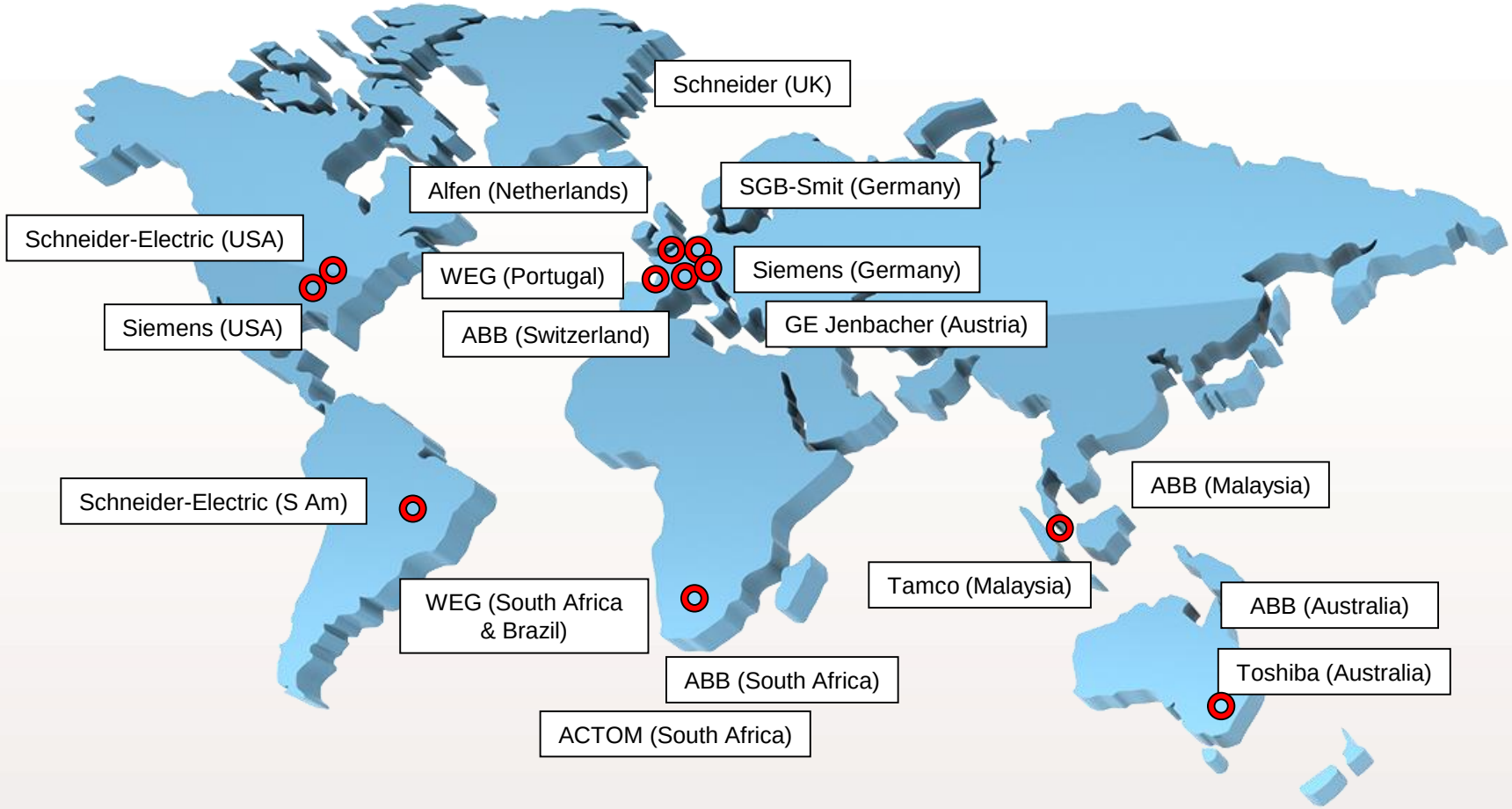
ZORC costs range from approx. $ 1 000 to $ 3 500 and therefore the cost benefit is evident.


**Benefit Cost Ratio**

| | | |
|---|---|---|
| **Eg1.** | BCR for 13,8kV ZORC on 13,8kV, 2MVA Transformer | = **12.8** |
| **Eg2.** | BCR for 33Kv ZORC on 33kV, 30MVA Transformer | = **16.3** |

If costs are amortised over 20 year lifespan of ZORC, then BCR is even better.

# ZORC – Typical Customers…



# ZORC Interesting Facts…

**Supplied to approx. 34 countries across the globe**

STRIKE TECHNOLOGIES

GARD
Unparalleled Protection

# *Thanks for your attention*

## Stay connected for our upcoming webinars

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