CONTROLLED SWITCHING

CIRCUIT BREAKER CONSIDERATIONS

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Seminar/Workshop on Controlled Switching
CIGRE WG A3.07
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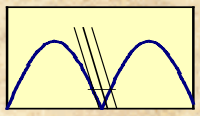


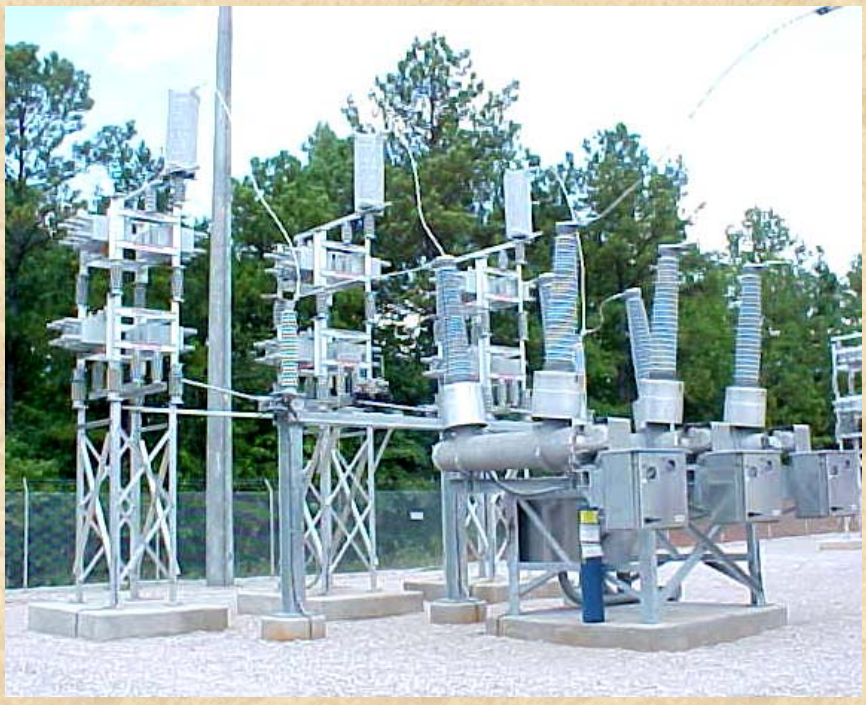
Circuit Breaker Considerations

OUTLINE

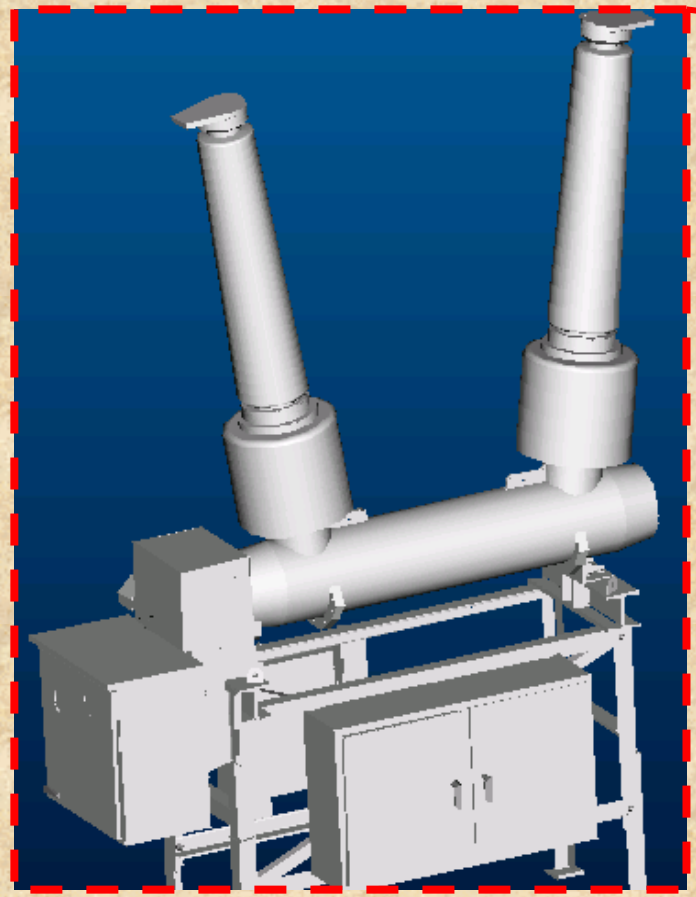
- Circuit breaker characteristics
- Interrupter wear
- Life extension, maintenance intervals
- Circuit breaker performance
- Benefits for switched equipment
- Benefits for the power system & equipment
- Conclusions

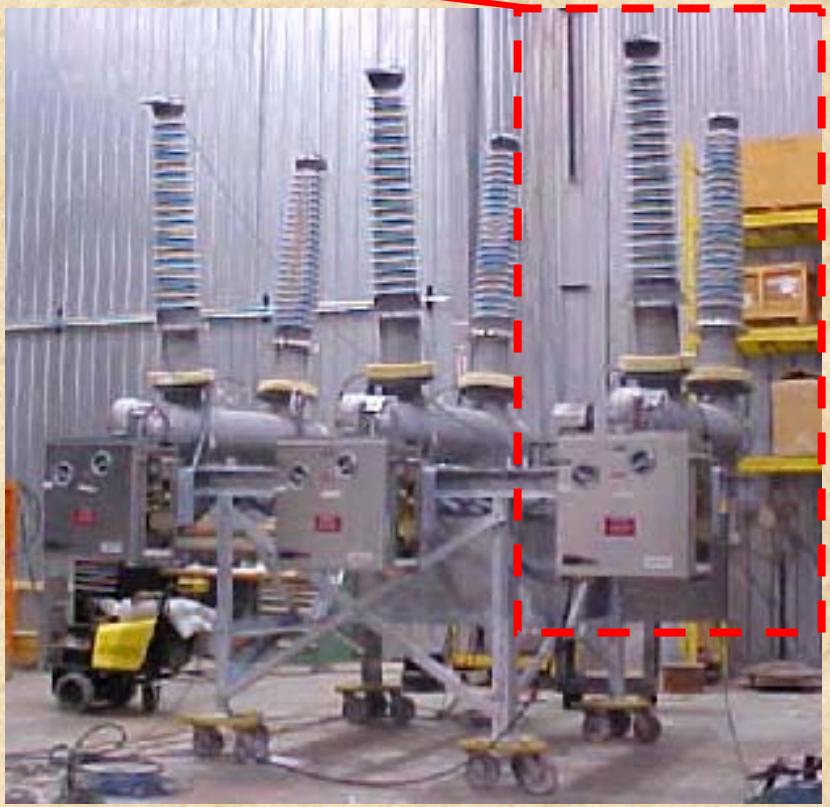
Circuit Breaker Characteristics

Independent-Pole Operated



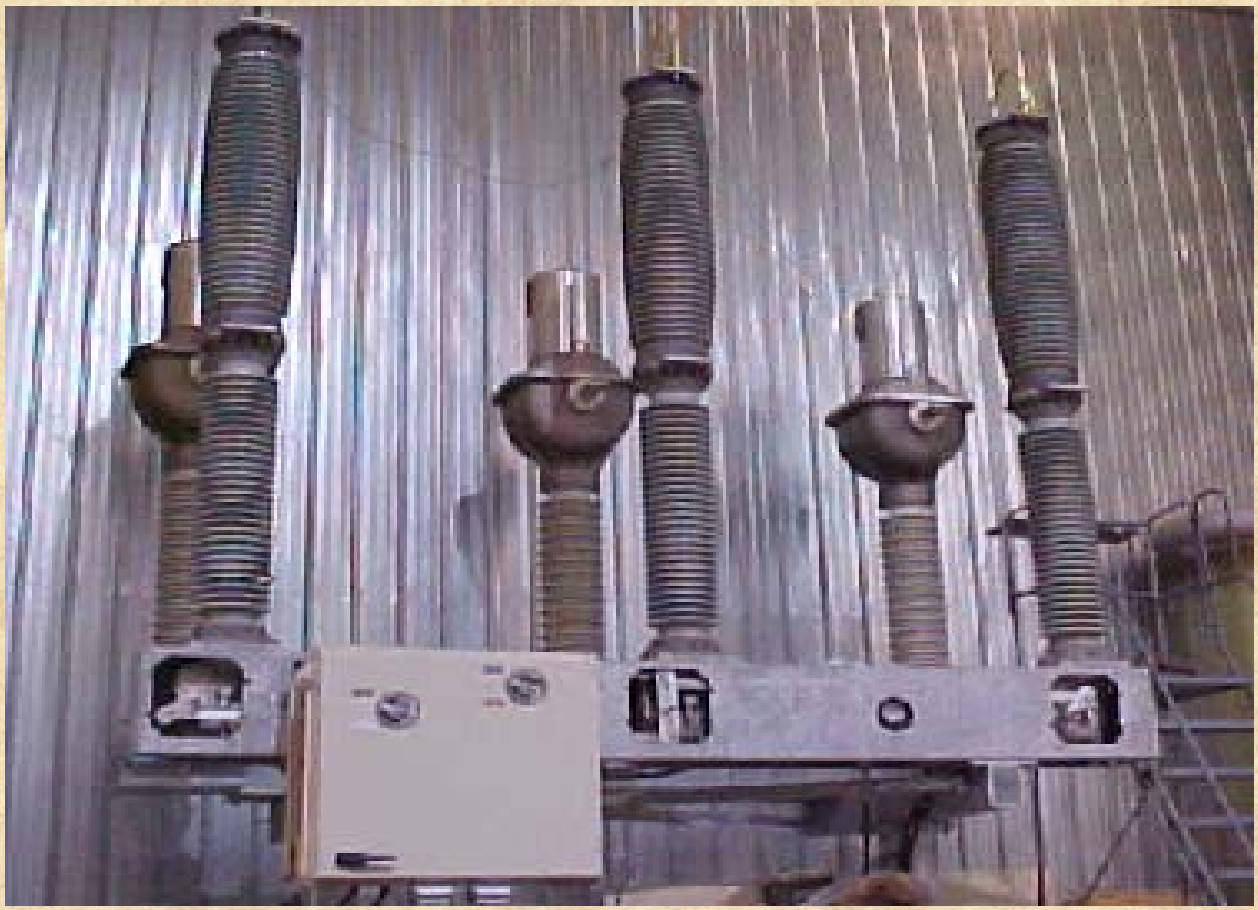
Independent-Pole Operated



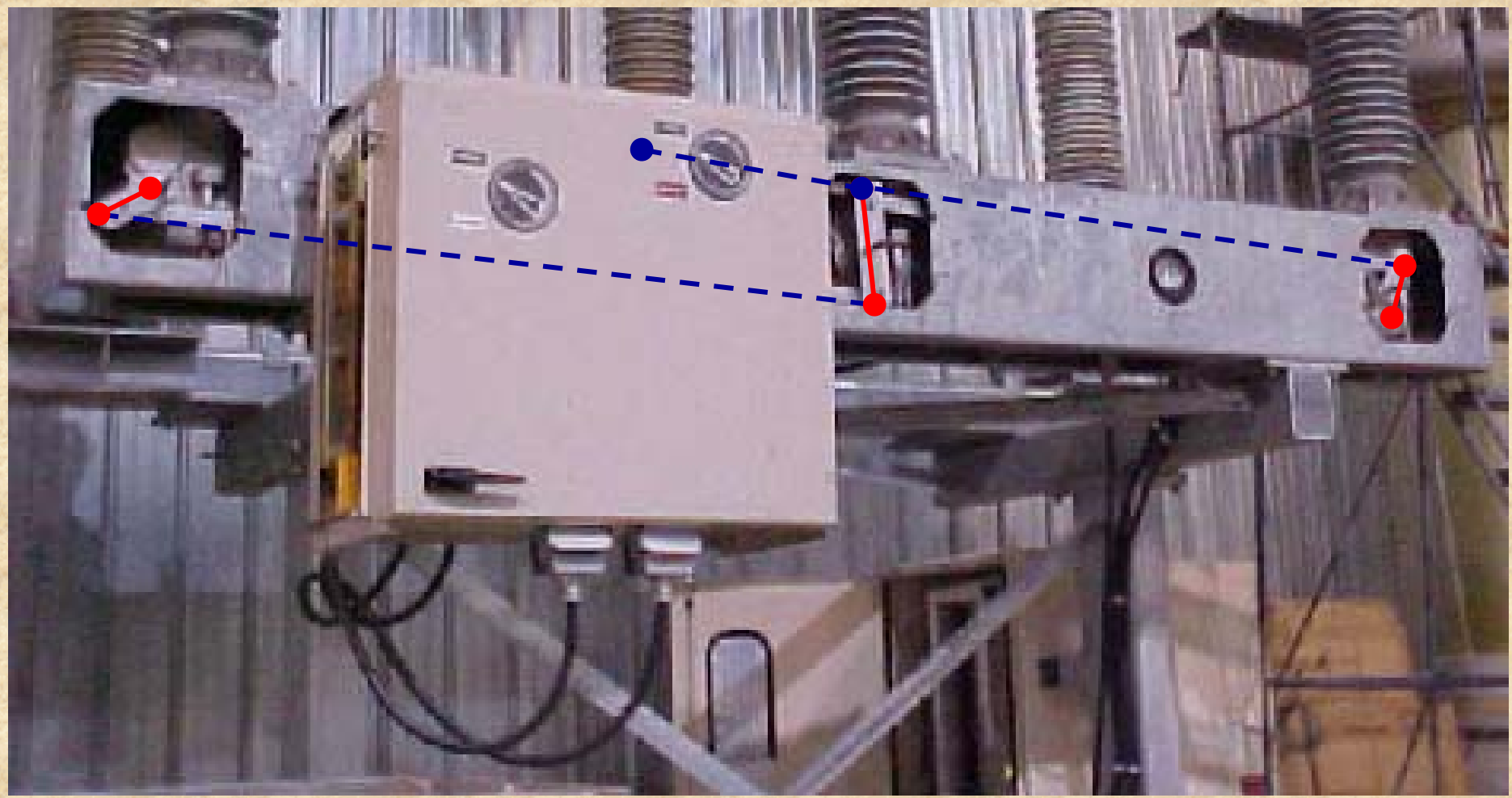


Circuit Breaker Characteristics

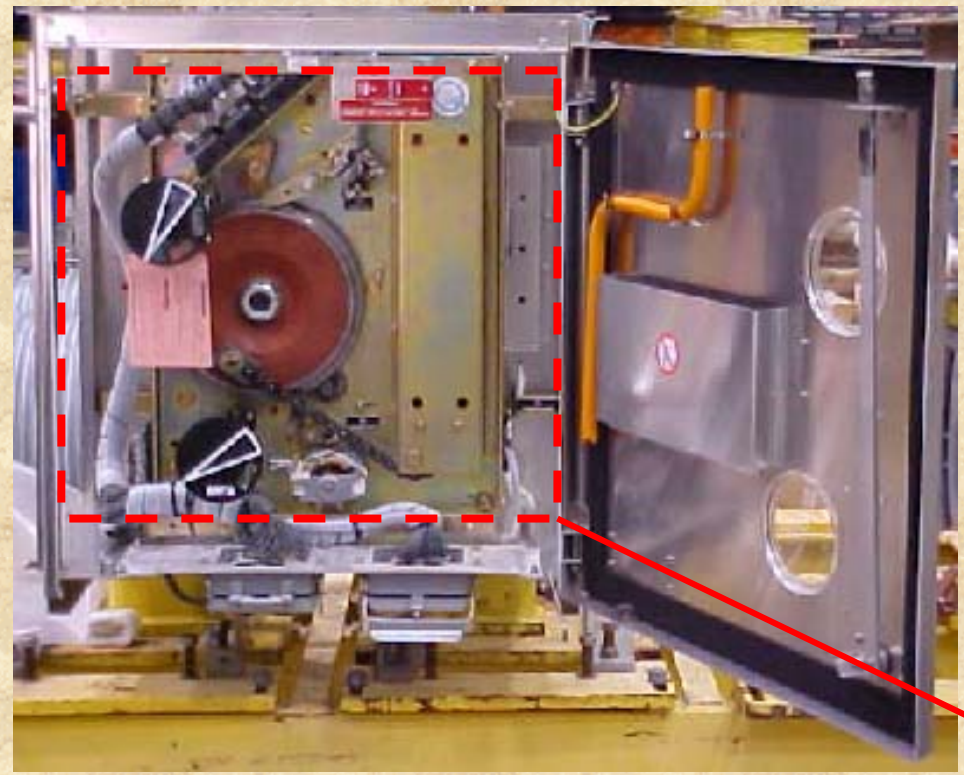
Mechanically-Staggered Linkage

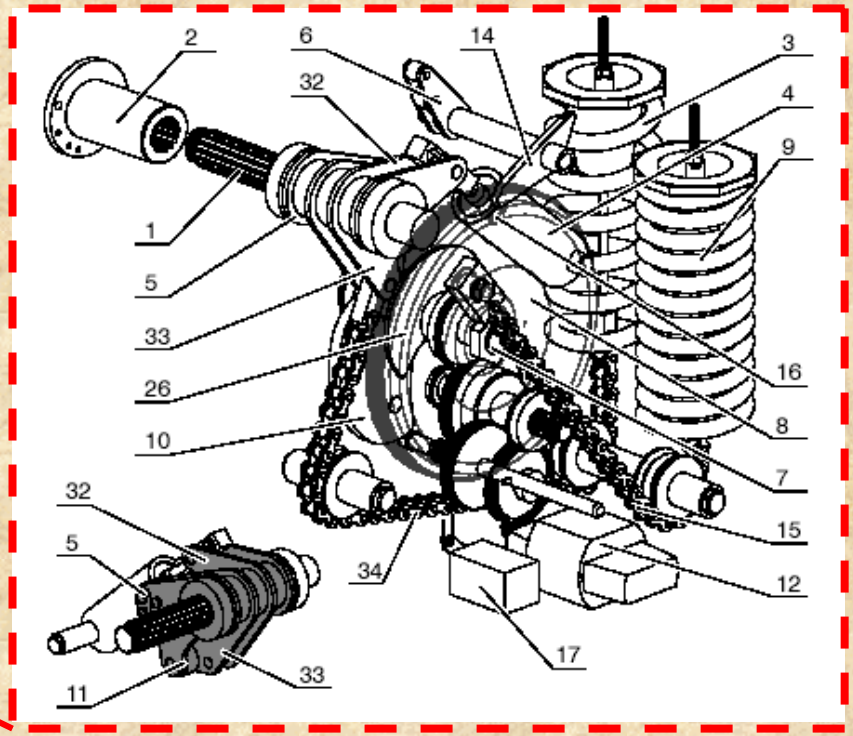


Mechanically-Staggered Linkage

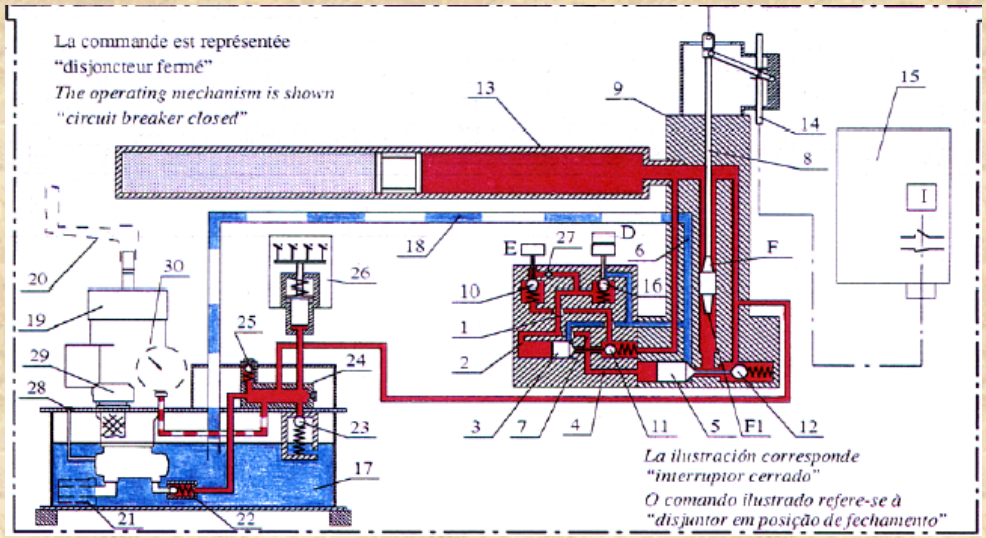


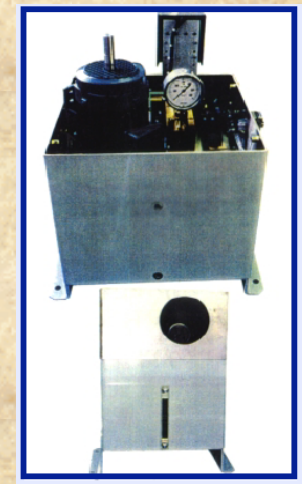
Spring Mechanism

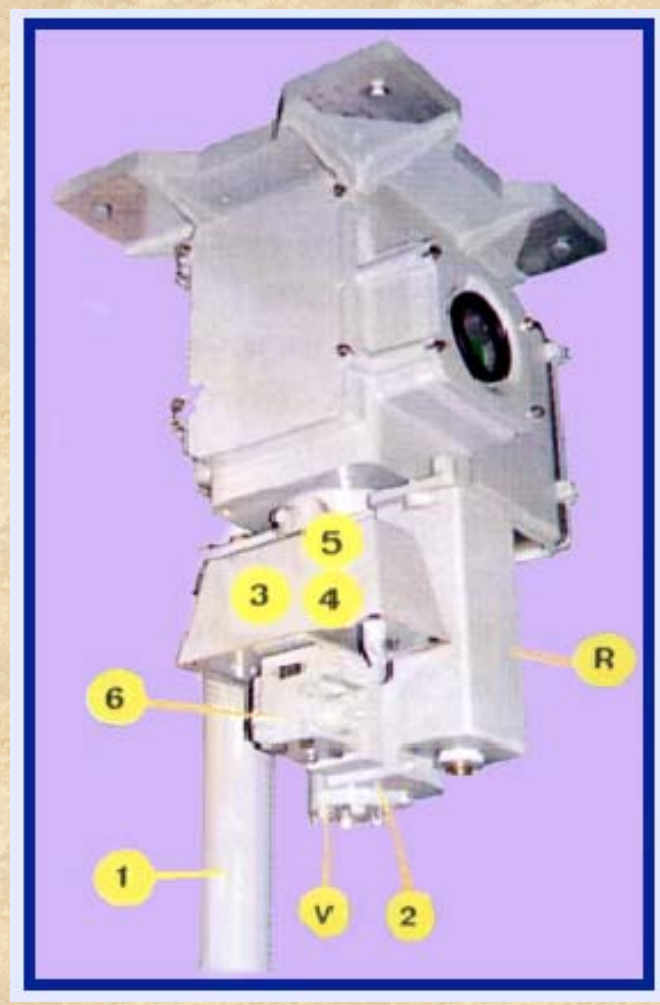




Hydraulic Mechanism

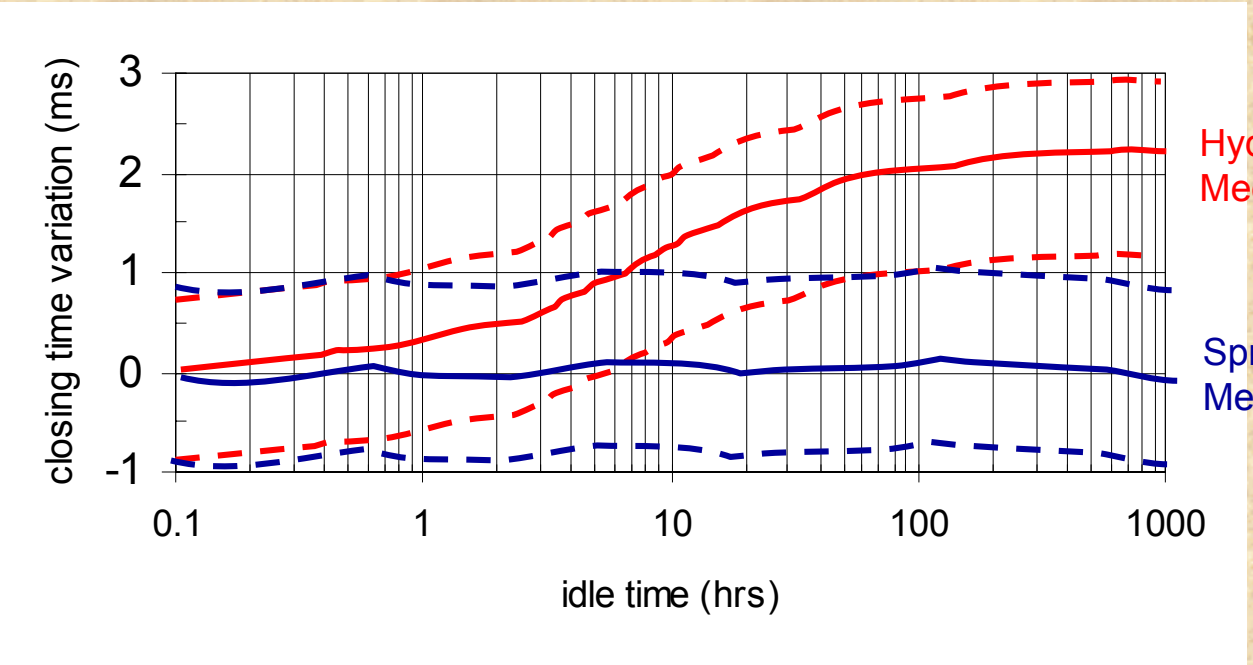




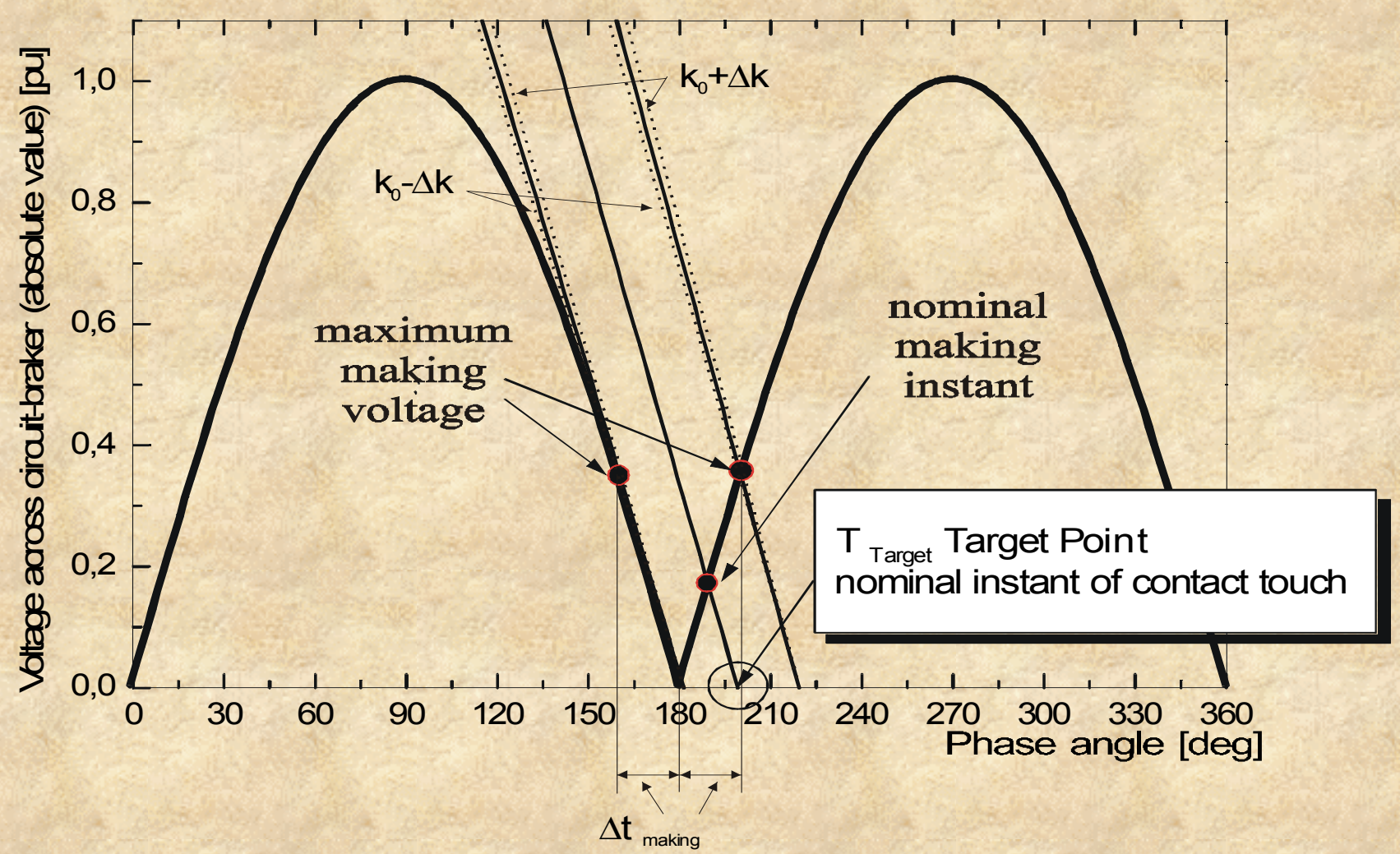


Timing Characteristics

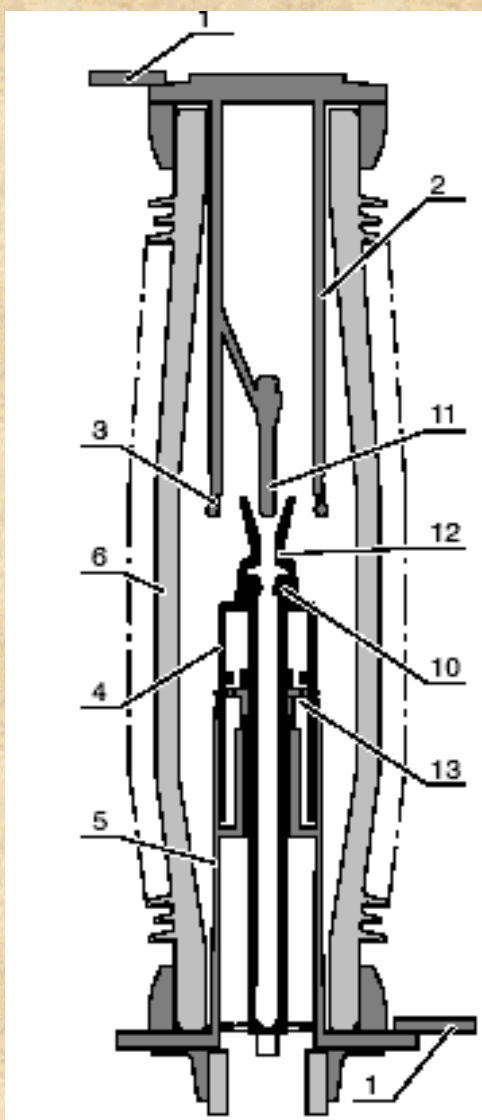
- Effect of idle time
- Influence of ambient temperature on operating time
- Hydraulic pressure - Spring constant



Controlled Closing - RDDS



Live-Tank Circuit Breaker

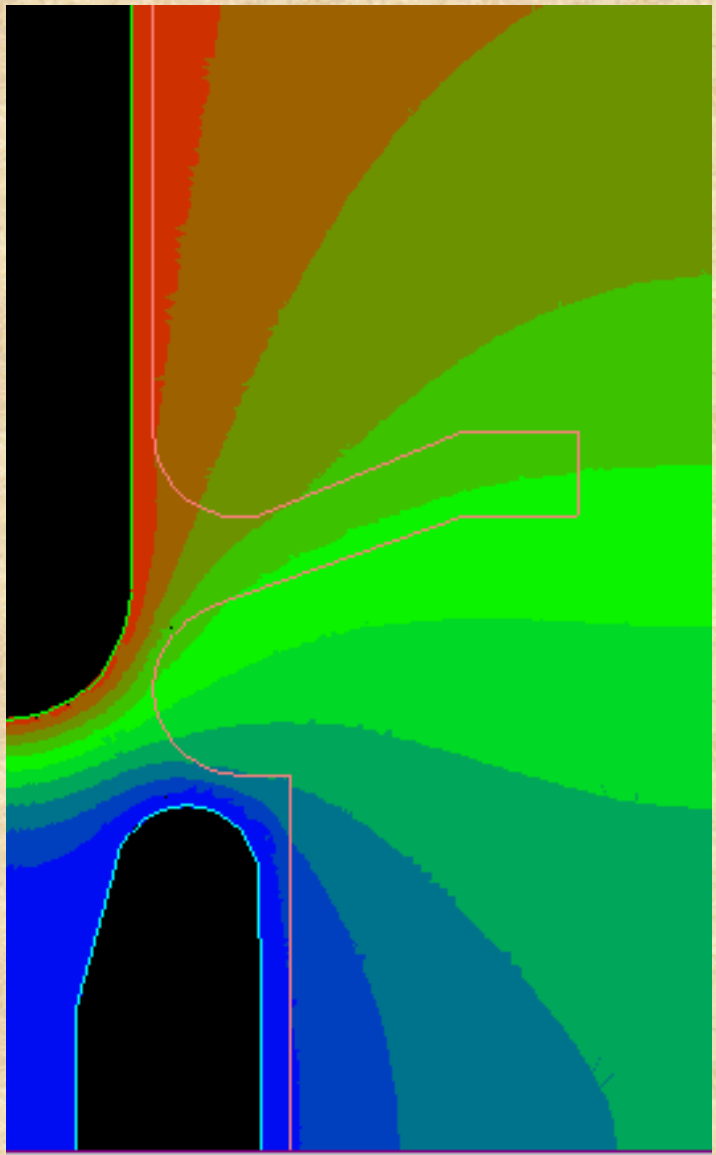


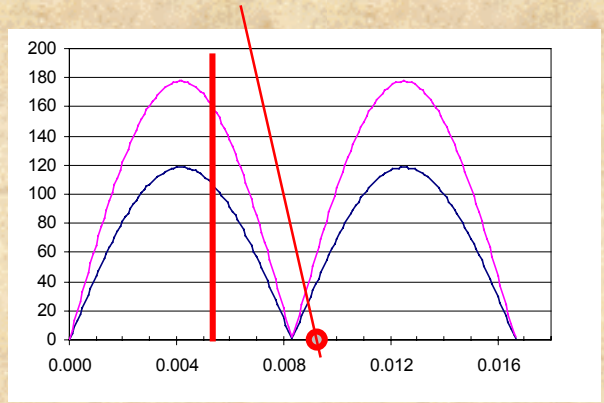
Mark	Component
1	Terminal
2	Fixed contact support
3	Main contacts
4	Moving contact
5	Moving contact support
6	Envelope
10	Arcing contacts
11	Fixed contact rod
12	Insulating nozzle
13	Valve

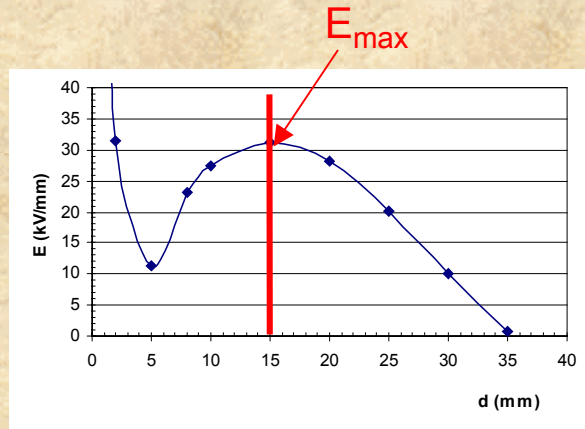
Controlled Closing - RDDS

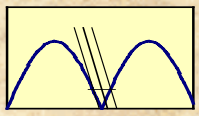
Field Simulation

15 mm and 4.0 ms
from contact touch





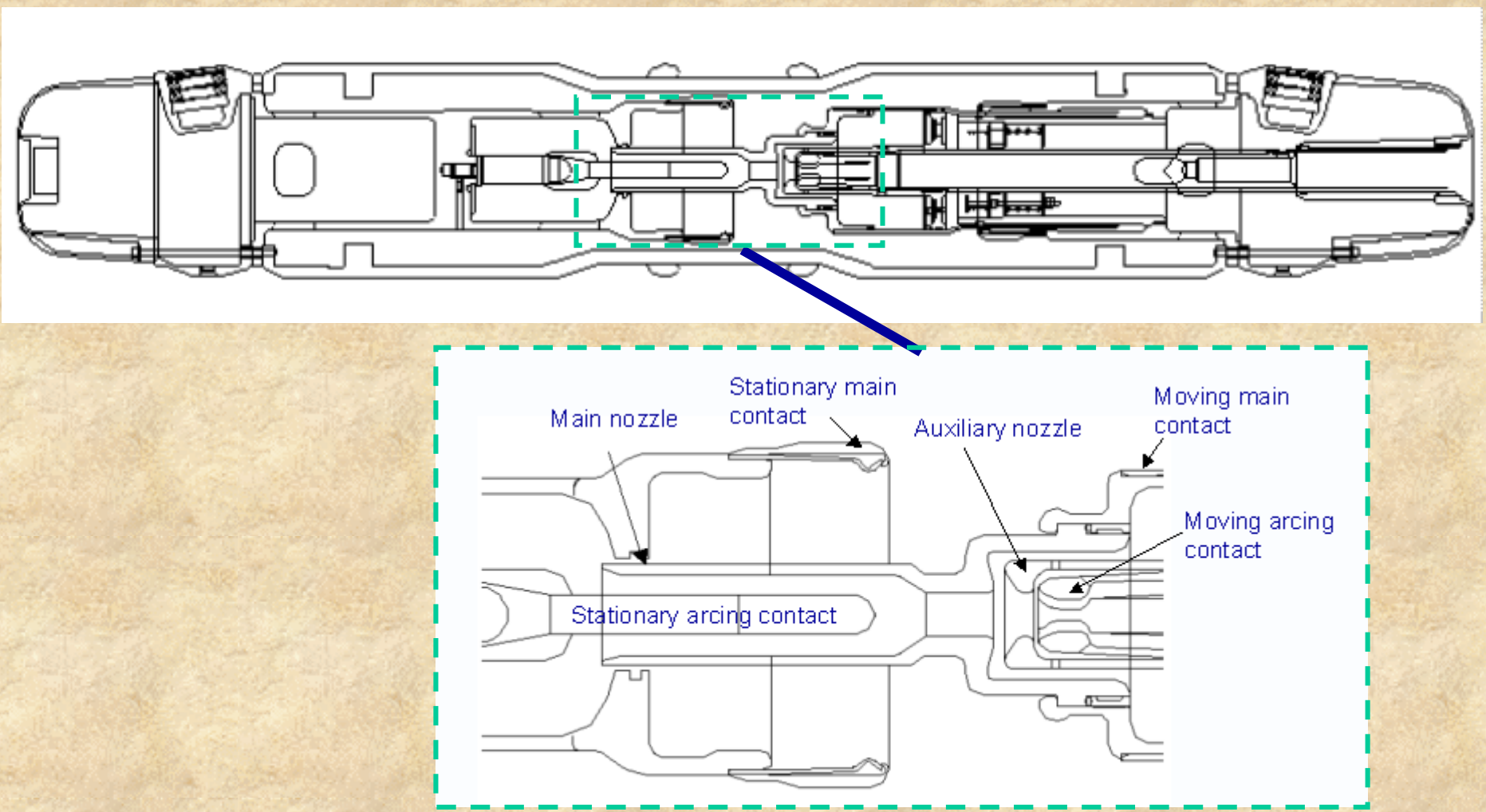


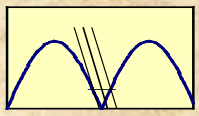


Benefits for the Circuit Breaker

- Extension of circuit breaker life,
- Increase in time intervals between interrupter maintenance or retrofit,
- Added value associated with circuit breaker performance enhancement during current interruption in the thermal or in the dielectric region.

Interrupter Wear

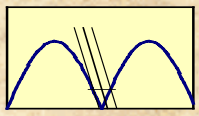




Interrupter Wear

Benefits of controlled switching for the purposes of life extension, reduction of maintenance cost:

- Decrease in magnitude of energization currents.
- Reduce associated interrupter wear.
- Lower probability of occurrence of damaging restrikes.



Interrupter Wear

- Arcing contact wear
  - Source is burning arc across the gap.
  - Loss of material caused by vaporization, melting and burnoff.
  - Consequences are contact shape distortion and increase in surface roughness.

Electrical Wear of an Interrupter

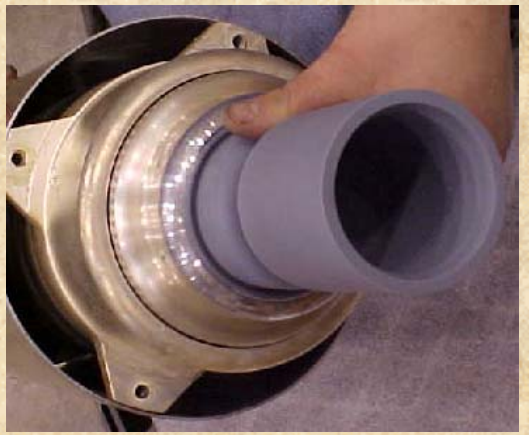
Arcing Contact Wear

- Depends on:
  - contact material composition and micro-structure
  - contact surface porosity
  - initial contact shape
  - manufacturing process
  - arc current duration, amplitude, shape
- Implications
  - erosion, burnoff, vaporization
  - change in shape, surface

Electrical Wear of an Interrupter

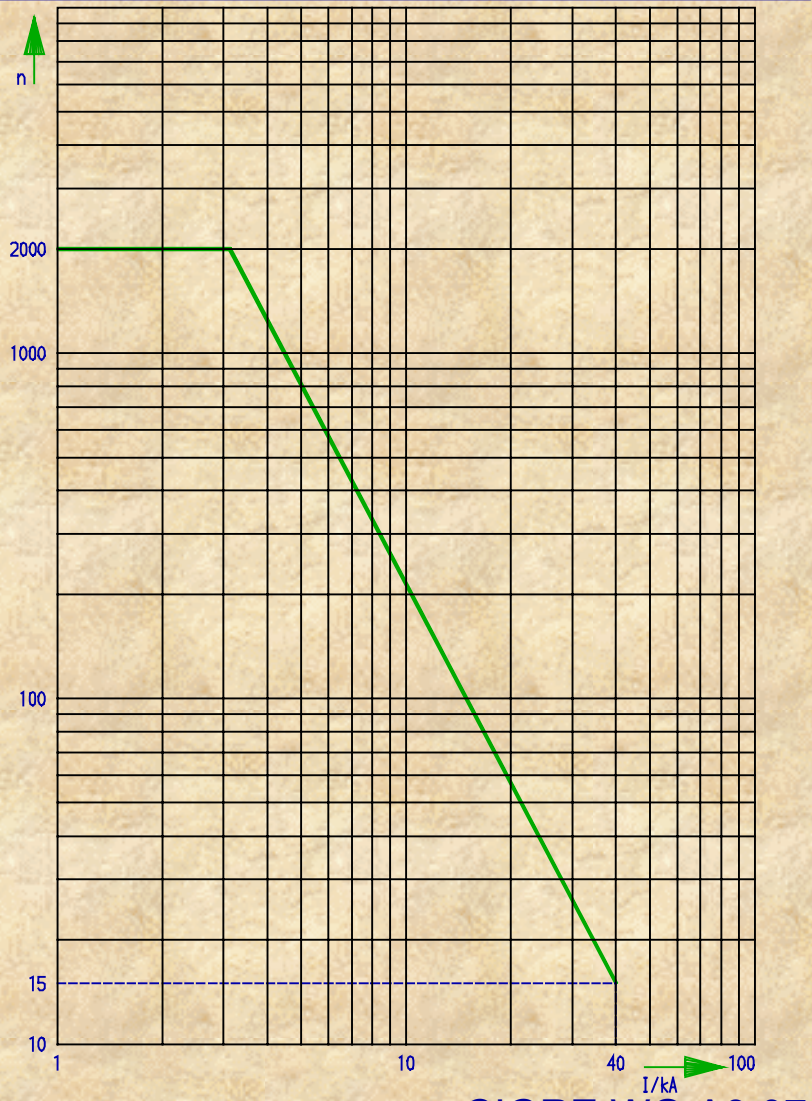
Teflon Nozzle Ablation

- Depends on:
  - nozzle geometry
  - material (teflon) and fillers
- Implications:
  - increase in diameter of throat
  - flake-off, erosion, vaporization of inside surface
  - changes to the dynamic gas flow during interruption
  - degradation of breaker performance (thermal region)



Interrupter Wear

- Definition of maintenance interval
- Number of allowable operations between maintenance/refurbishment
- Simple relation between the interrupted current and a maximum number of operations



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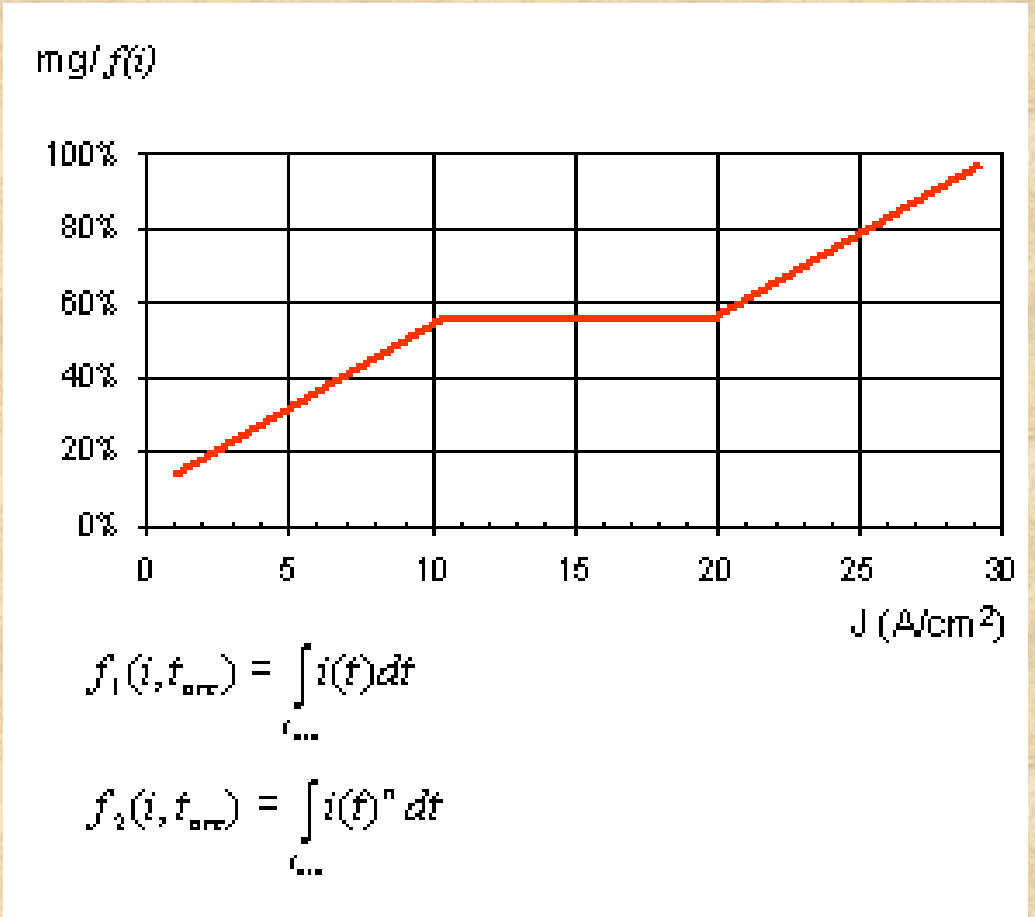
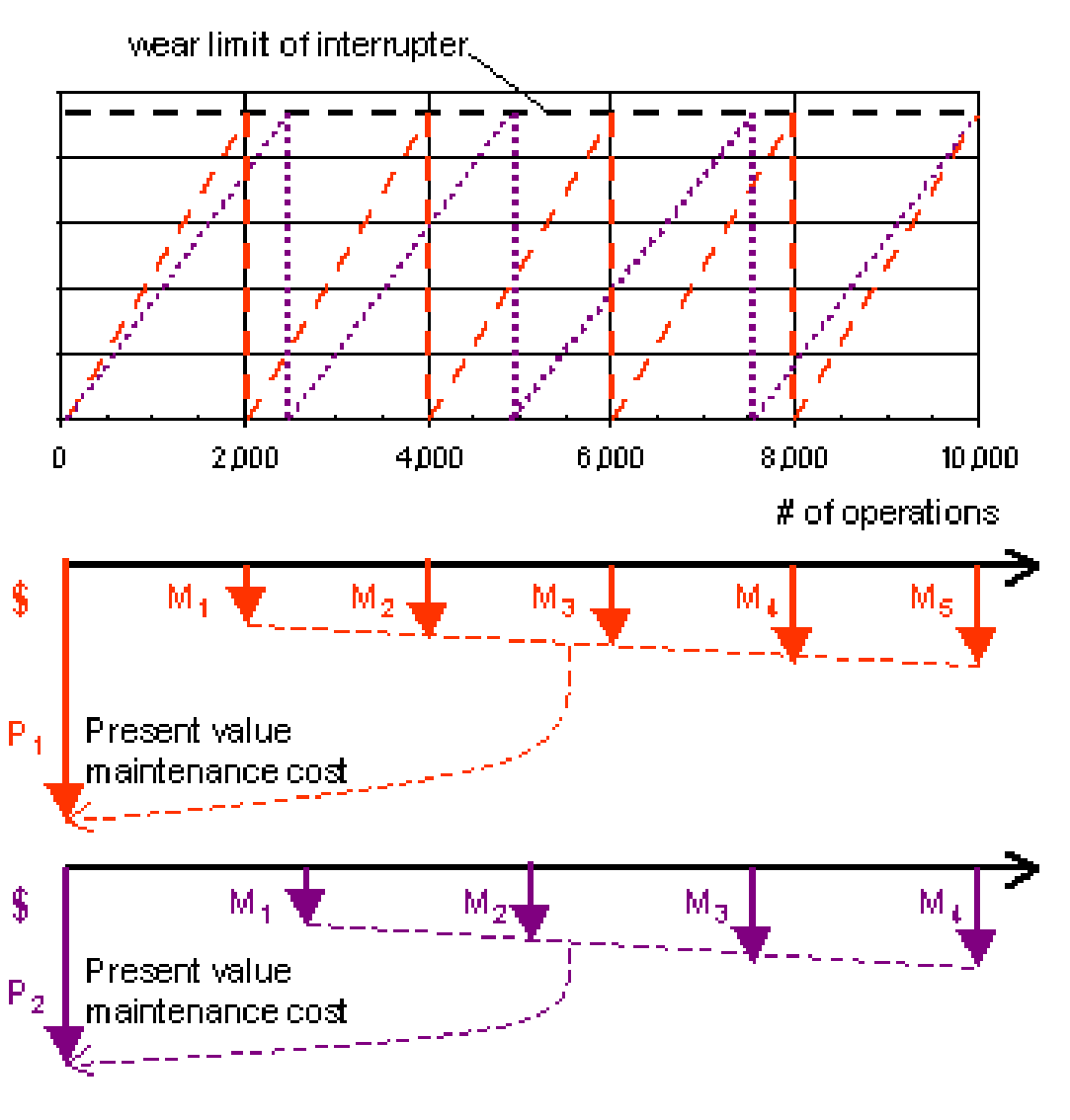
Improved Assessment of Interrupter Wear

- Separate limits for arcing contact wear and nozzle ablation
- Specific to interrupter design
- Can be implemented together with electronic monitoring



Maintenance Intervals and Costs



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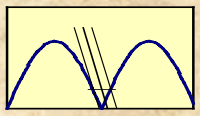


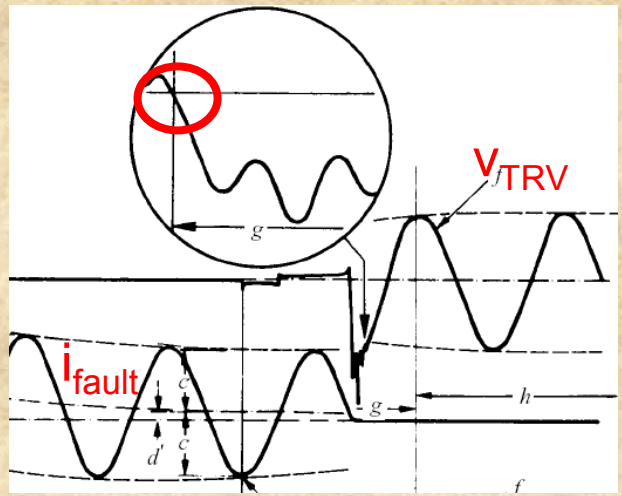
Circuit Breaker Performance Enhancement

- Improve performance during interruption
  - Thermal region of interruption
  - Dielectric region of interruption
- Increase or decrease arcing time
  - Life extension
  - Unusual system voltages (25 Hz rail system)
  - Higher X/R ratios
  - Further reduce restrike probability for severe TRV applications

Circuit Breaker Performance Enhancement

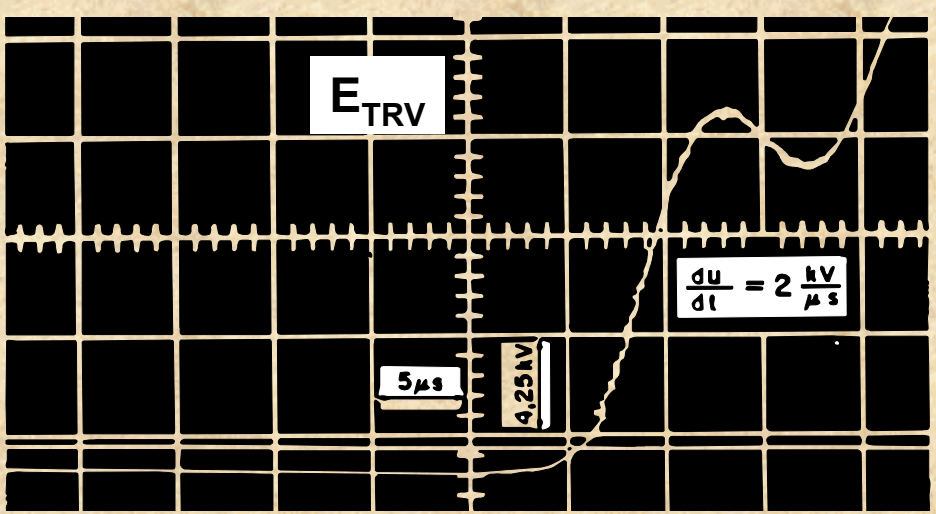
Thermal (Energy Balance) Region

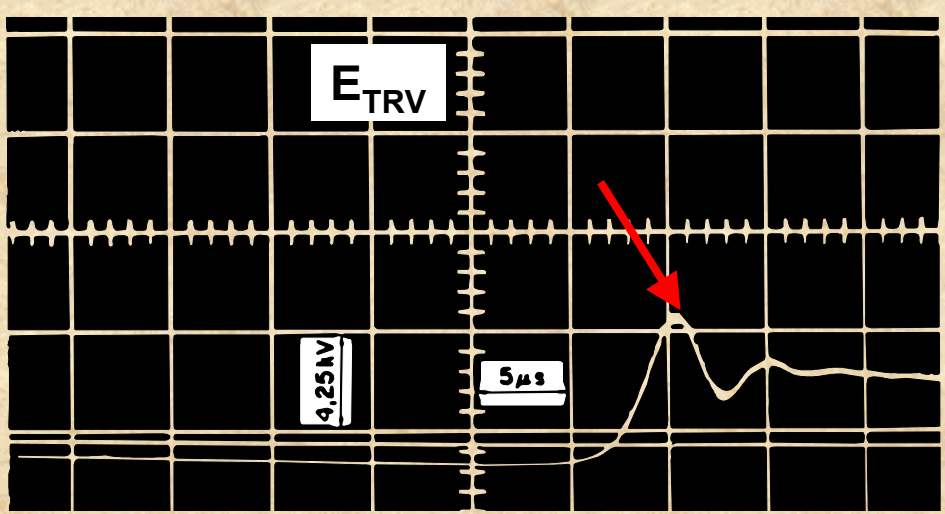
- Rate of Rise of Recovery Voltage (**RRRV**)
- Initial Transient Recovery Voltage (**ITRV**)
- **Reignition** if current re-established <1/4 cycle



successful interruption

failure (reignition)



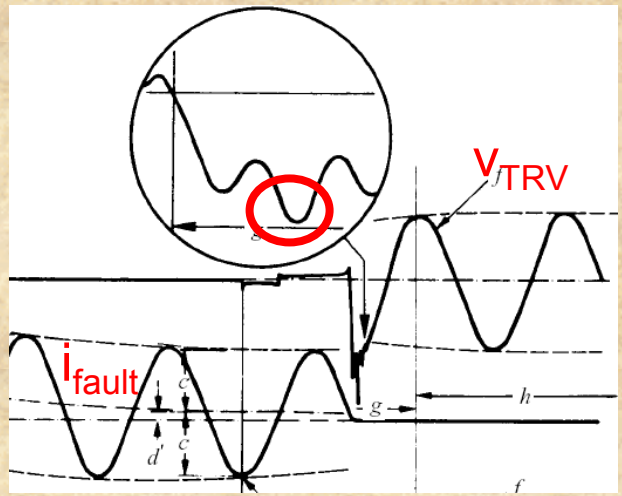


Circuit Breaker Performance Enhancement

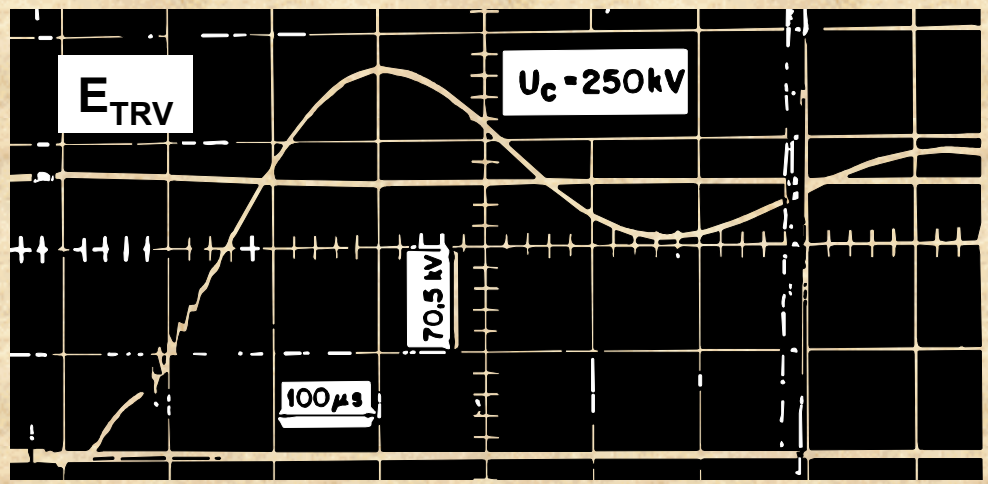
Circuit Breaker Performance Enhancement

Dielectric Region

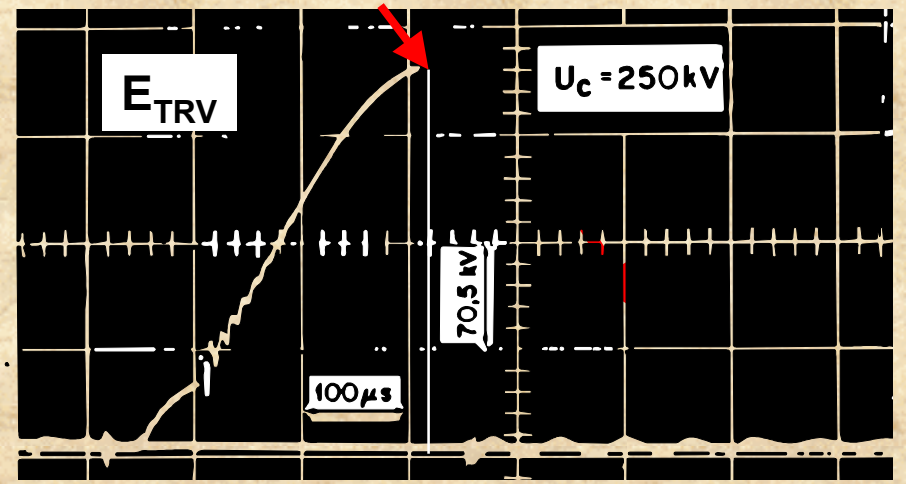
- Peak value of the transient recovery voltage
- **Restrike** if current re-established >1/4 cycle



successful interruption

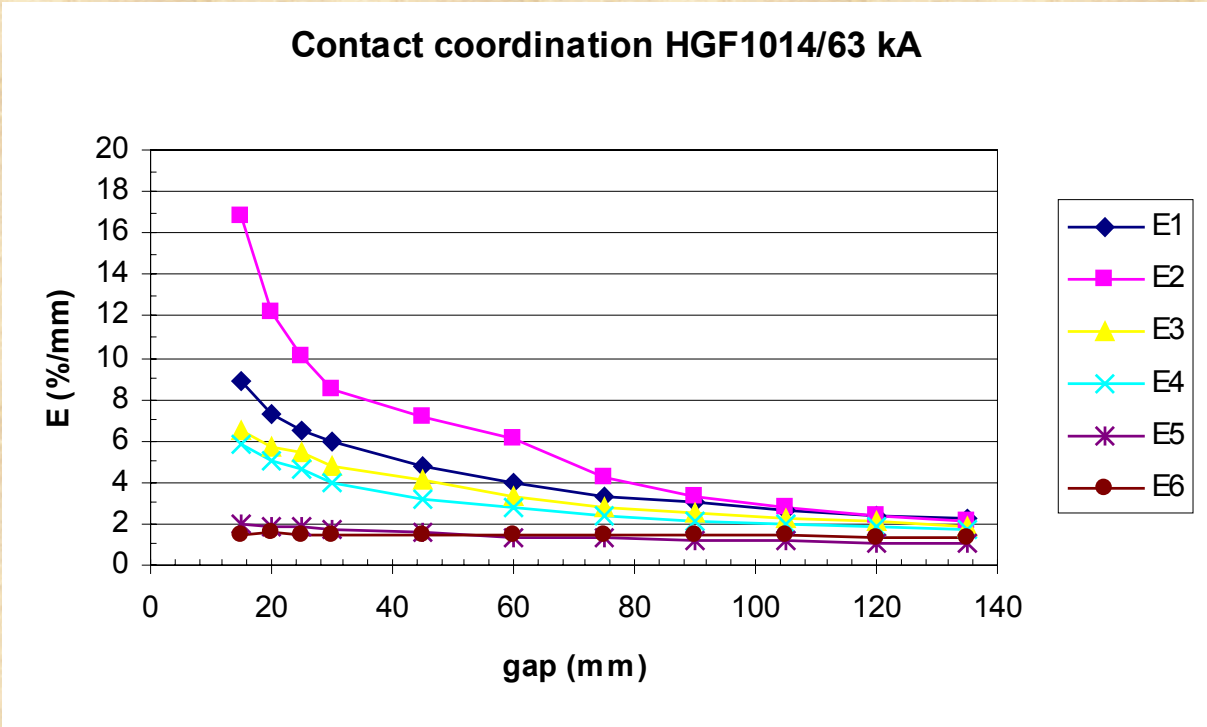


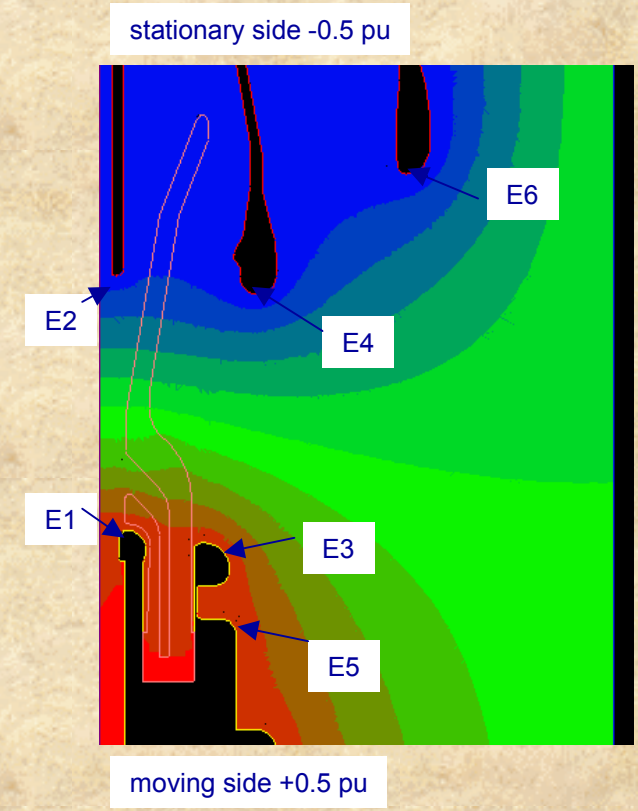
failure (restrike)



Circuit Breaker Performance Enhancement

Contact Coordination
Voltage Gradients on Interrupter Components





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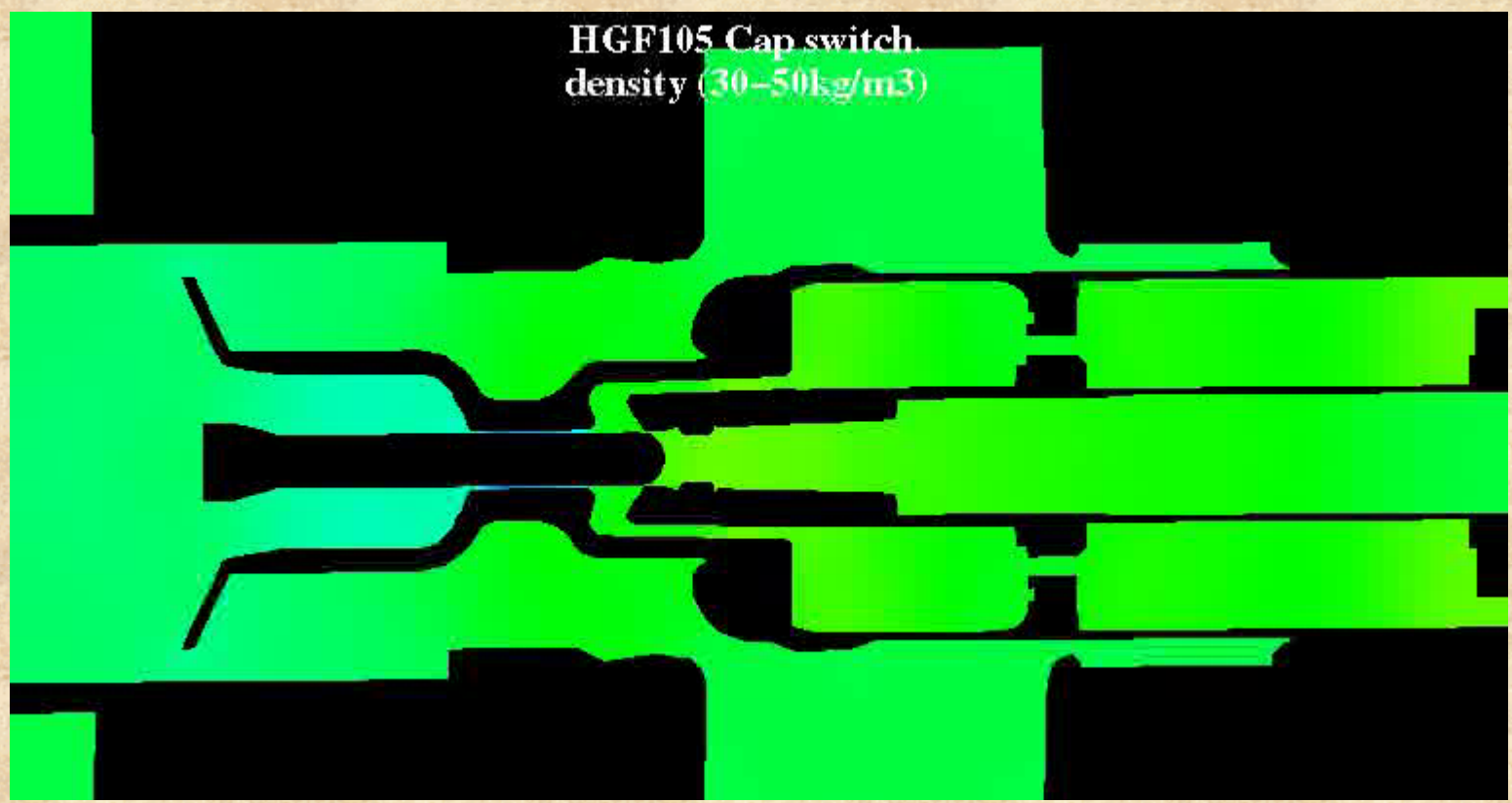

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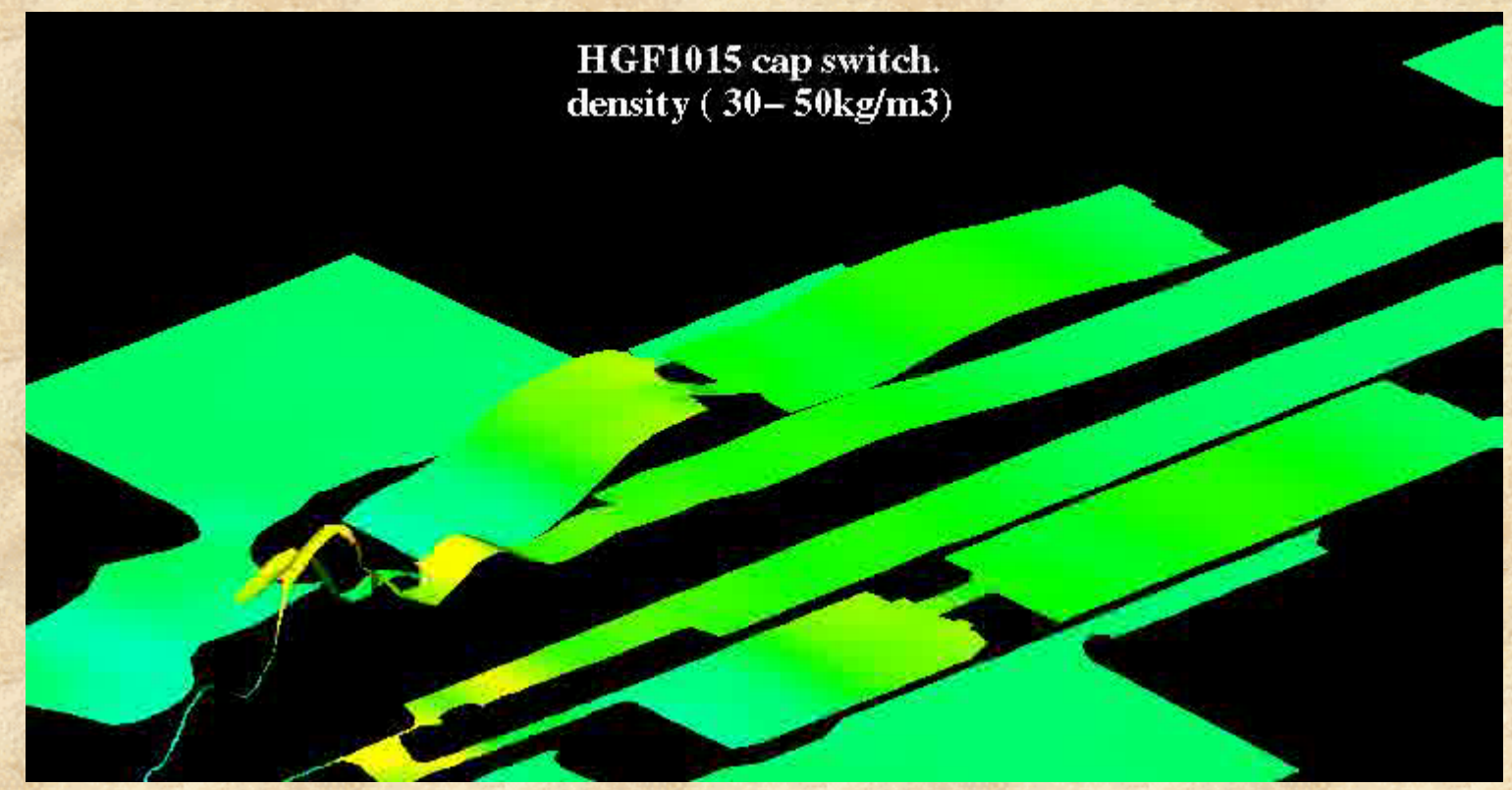

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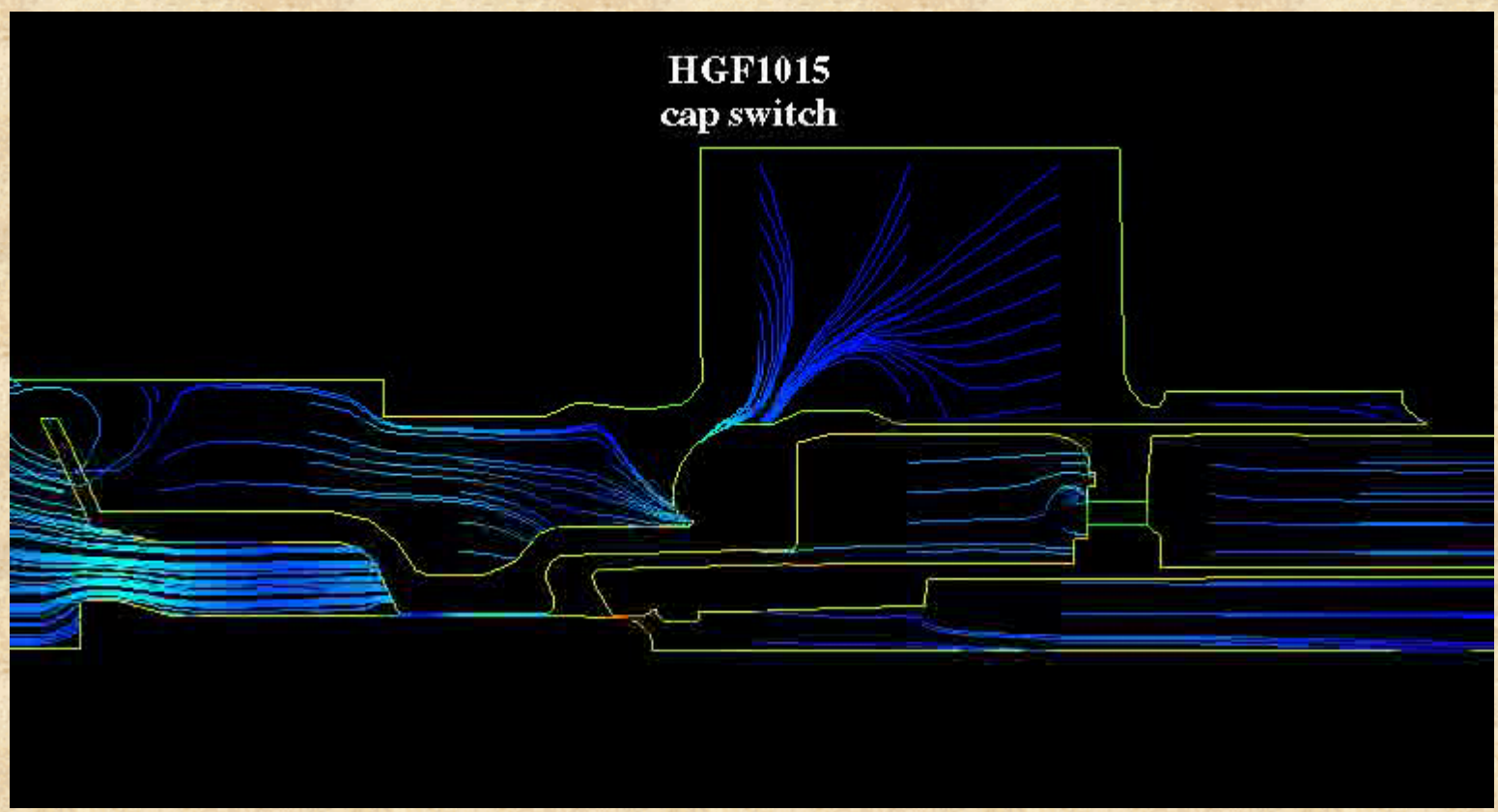
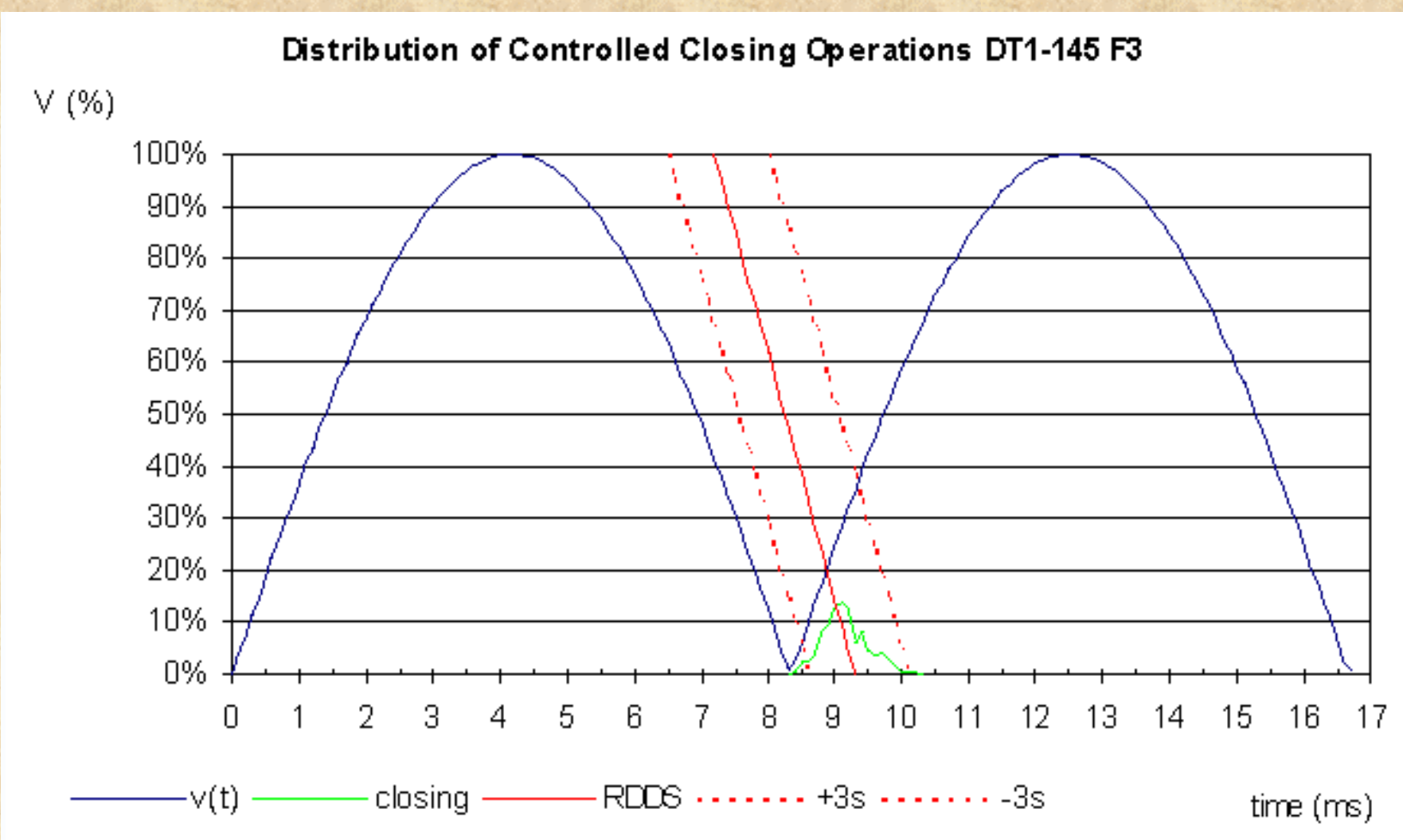


Benefits for Power System and Equipment



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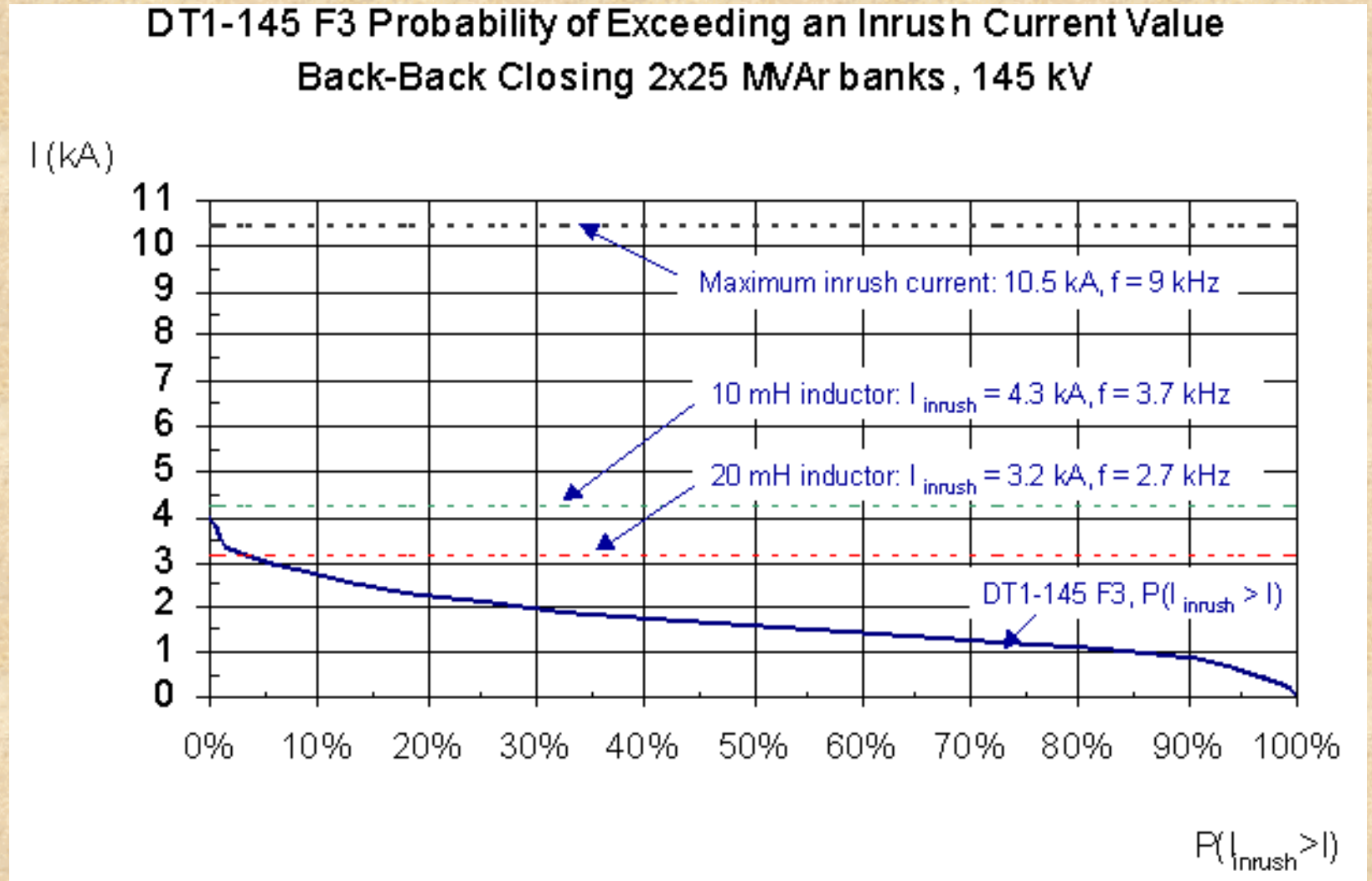

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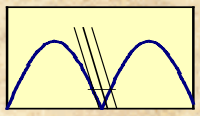
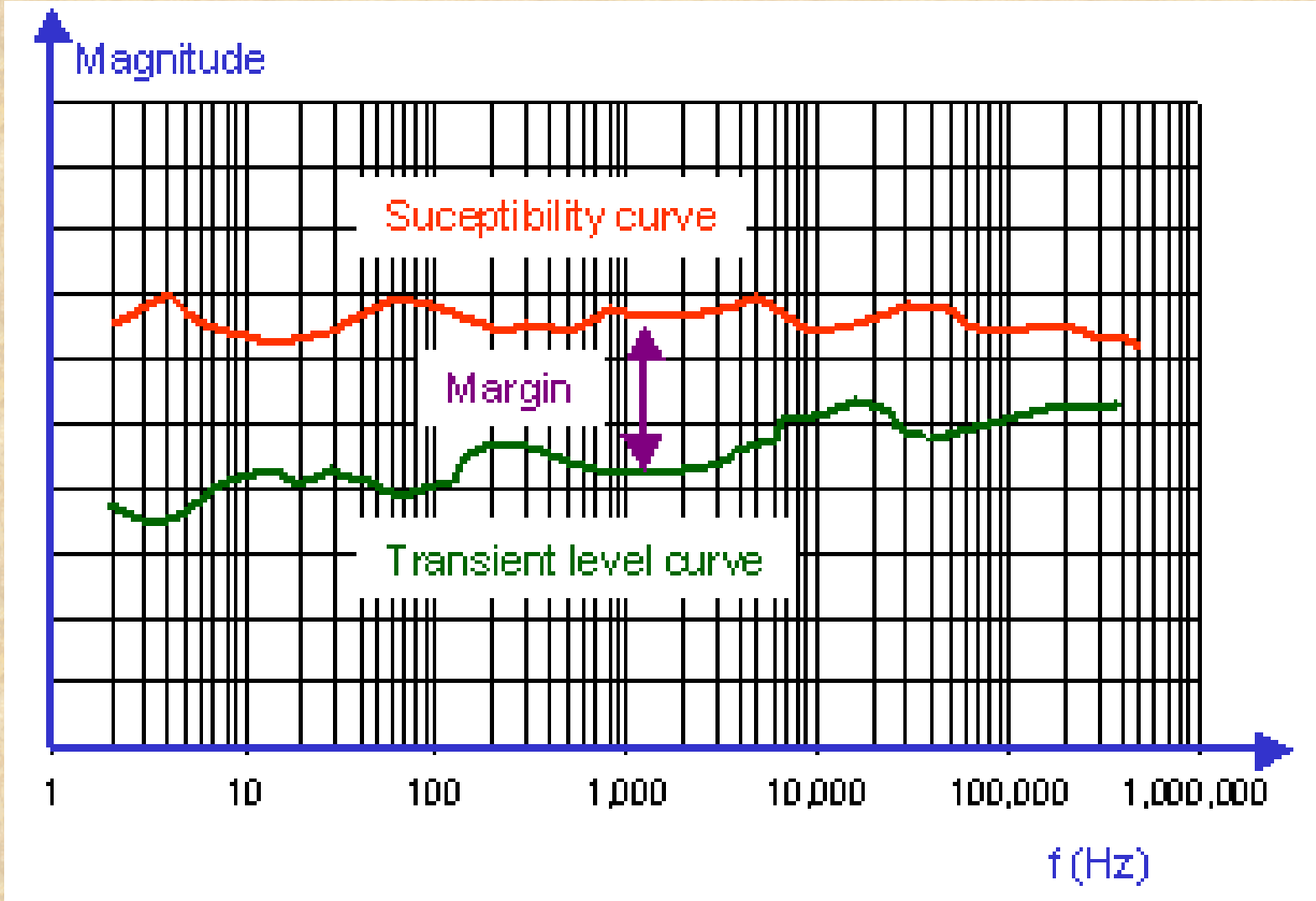
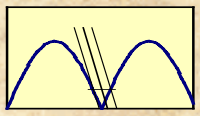


Benefits for Power System and Equipment

- Technical and economic benefits
  - reduction of stresses on switched equipment leading to life extension,
  - control of local transients in the substation,
  - local surge supression, reducing possible coupling to the control and protection scheme,
  - decrease in the severity of remote transients and their effects on sensitive loads.

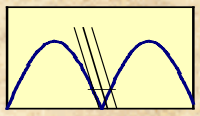
Benefits for Power System and Equipment





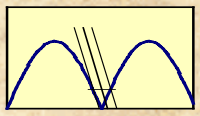
Benefits for Power System and Equipment

- Suceptibility
  - Compromise of system of equipment function
  - Frequency dependent
- Mechanism
  - Coupling
    - conductive, inductive, radiative
  - Modes
    - common mode, differential mode



Benefits of Controlled Switching

- Conclusions
  - Effective means of reducing switching transients and their effects on a power system and equipment
    - life extension
    - reduction of maintenance costs
    - system reliability
    - power quality
  - Enhancement of circuit breaker performance
  - Alternative to tradition means of transient control



Benefits of Controlled Switching

- Conclusions
  - Assessment depends on conditions:
    - new or existing installation
    - planned or unplanned effects
  - Driver may be:
    - desire to acquire experience
    - problem solving
    - preventive or corrective
  - Can be used in combination with other means of transient control