Introduction to Controlled Switching

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Controlled Switching

What is it?

How ?

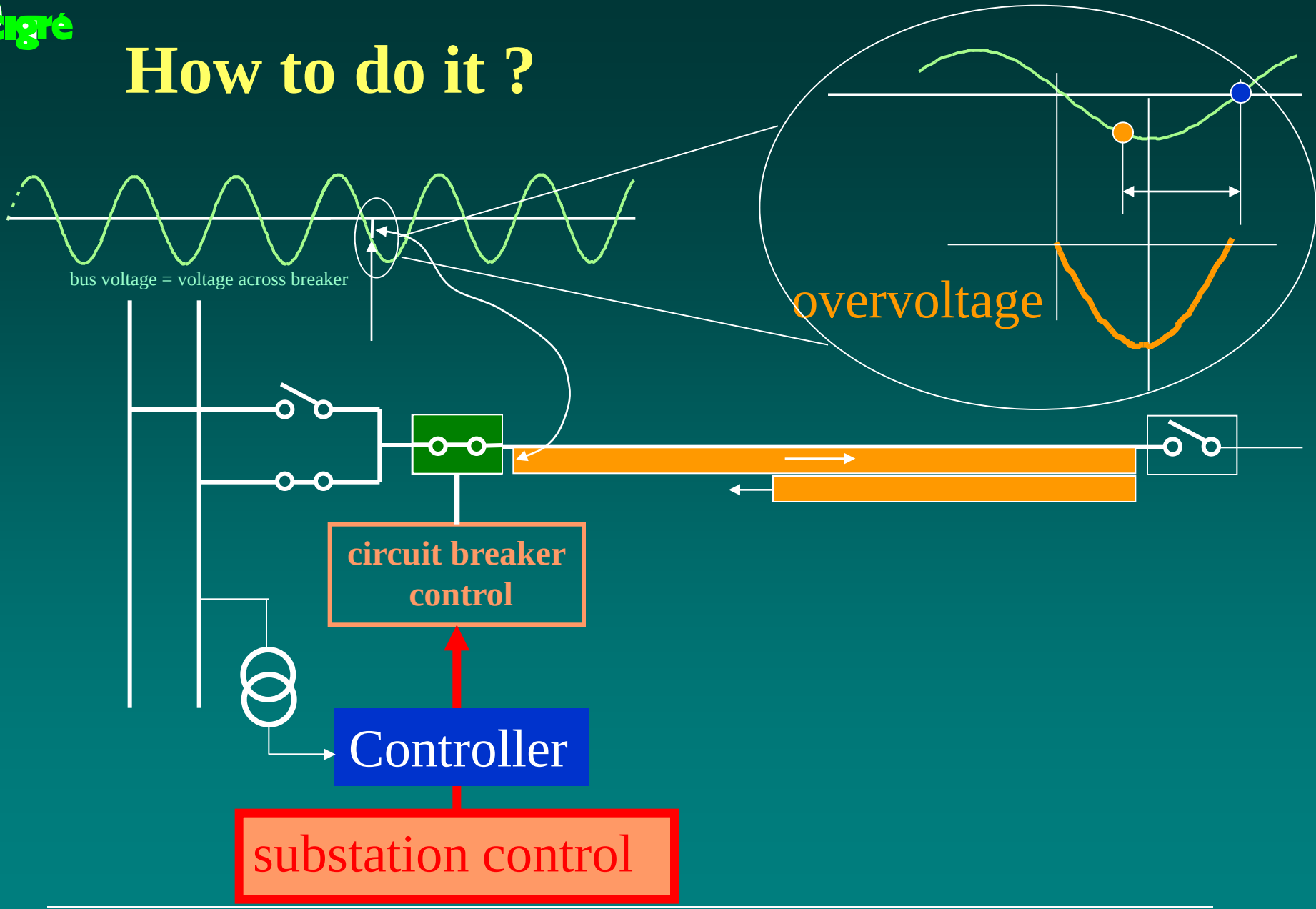
Why ?

Basic Principle of Controlled Switching

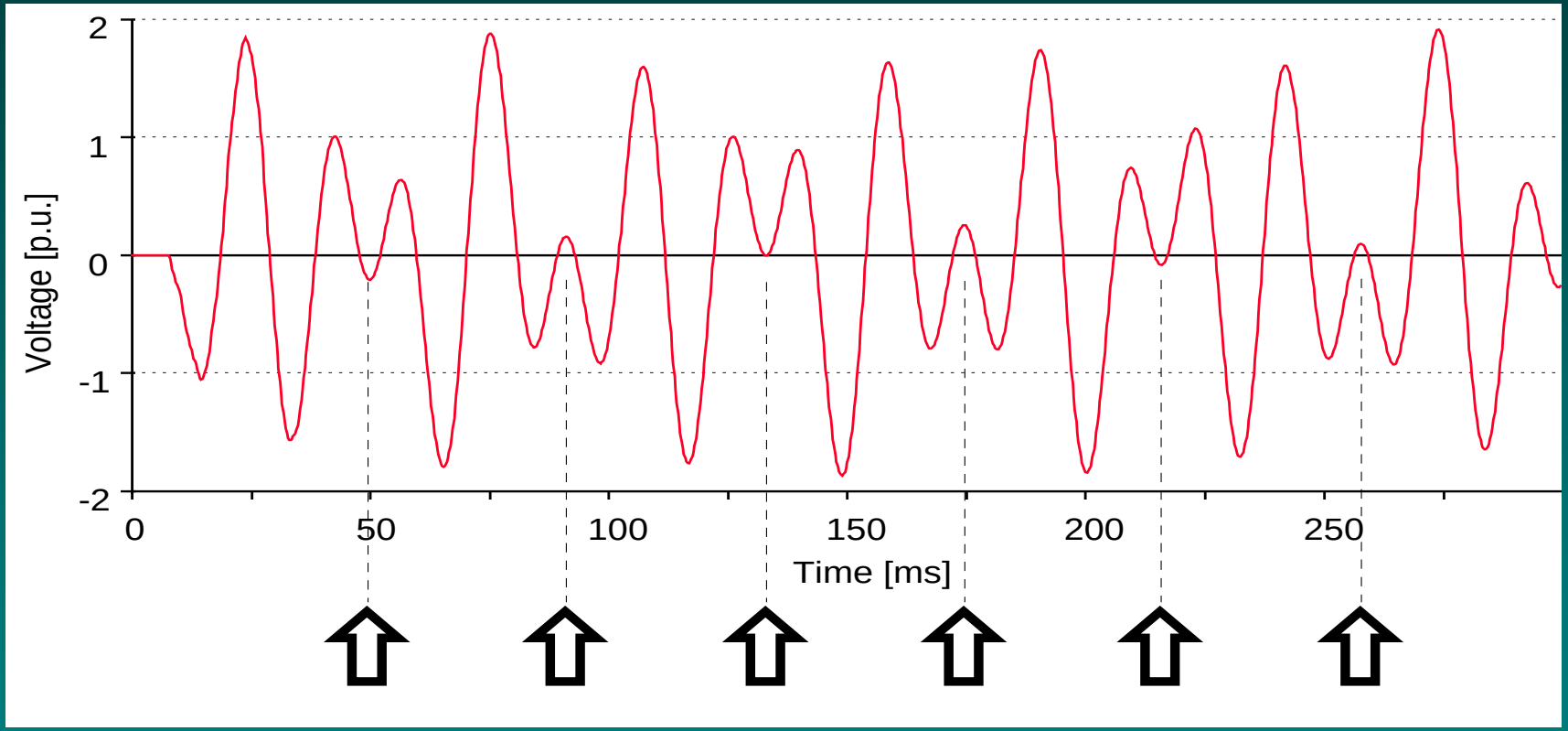
Close and/or open the breaker precisely point on wave in order to

- avoid or reduce transients in the system
- reduce stresses at breaker and other equipment

How to do it ?


bus voltage = voltage across breaker
overvoltage
circuit breaker control
Controller
substation control

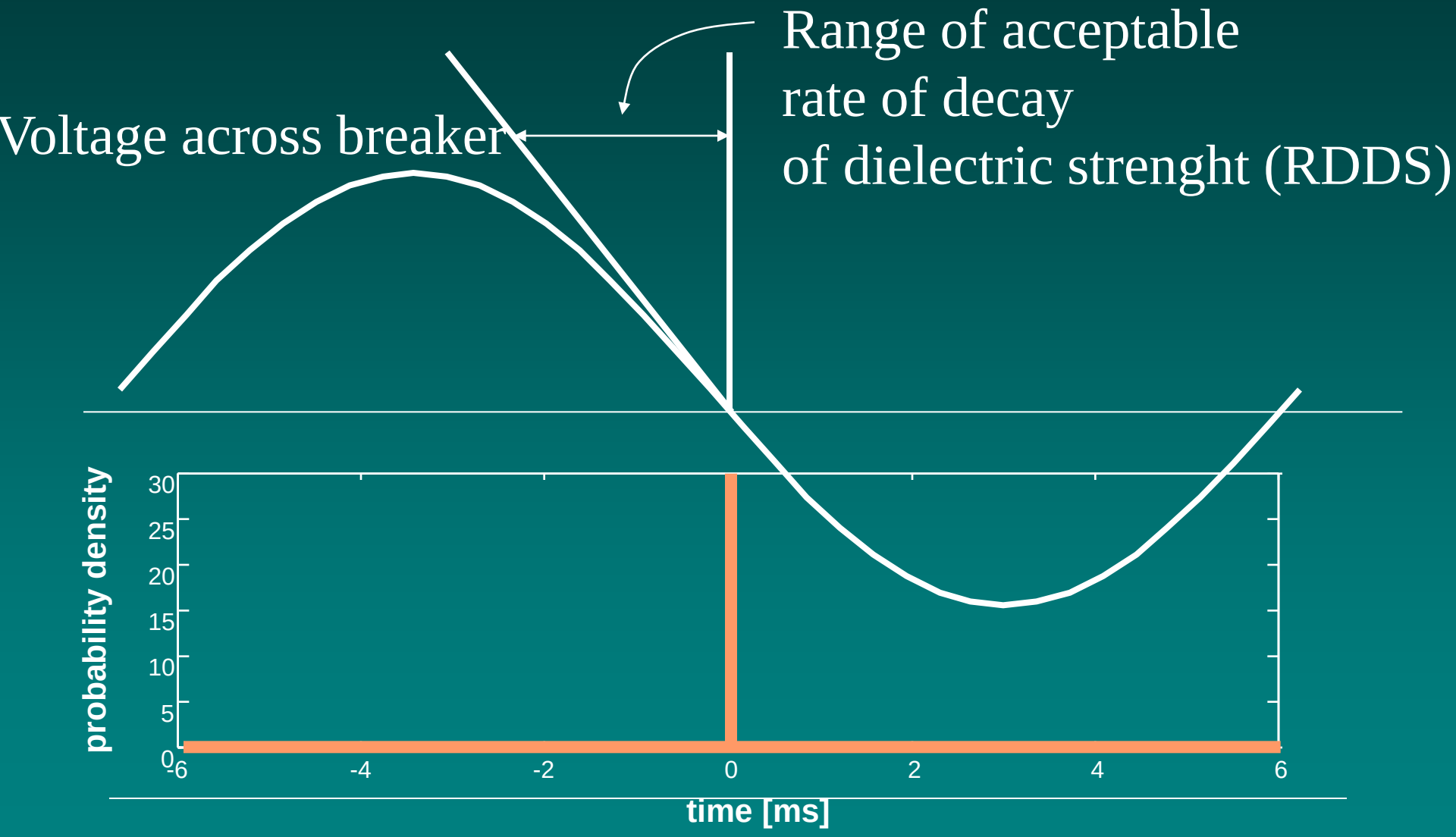
Voltage across breaker at auto reclosing line compensation 30%



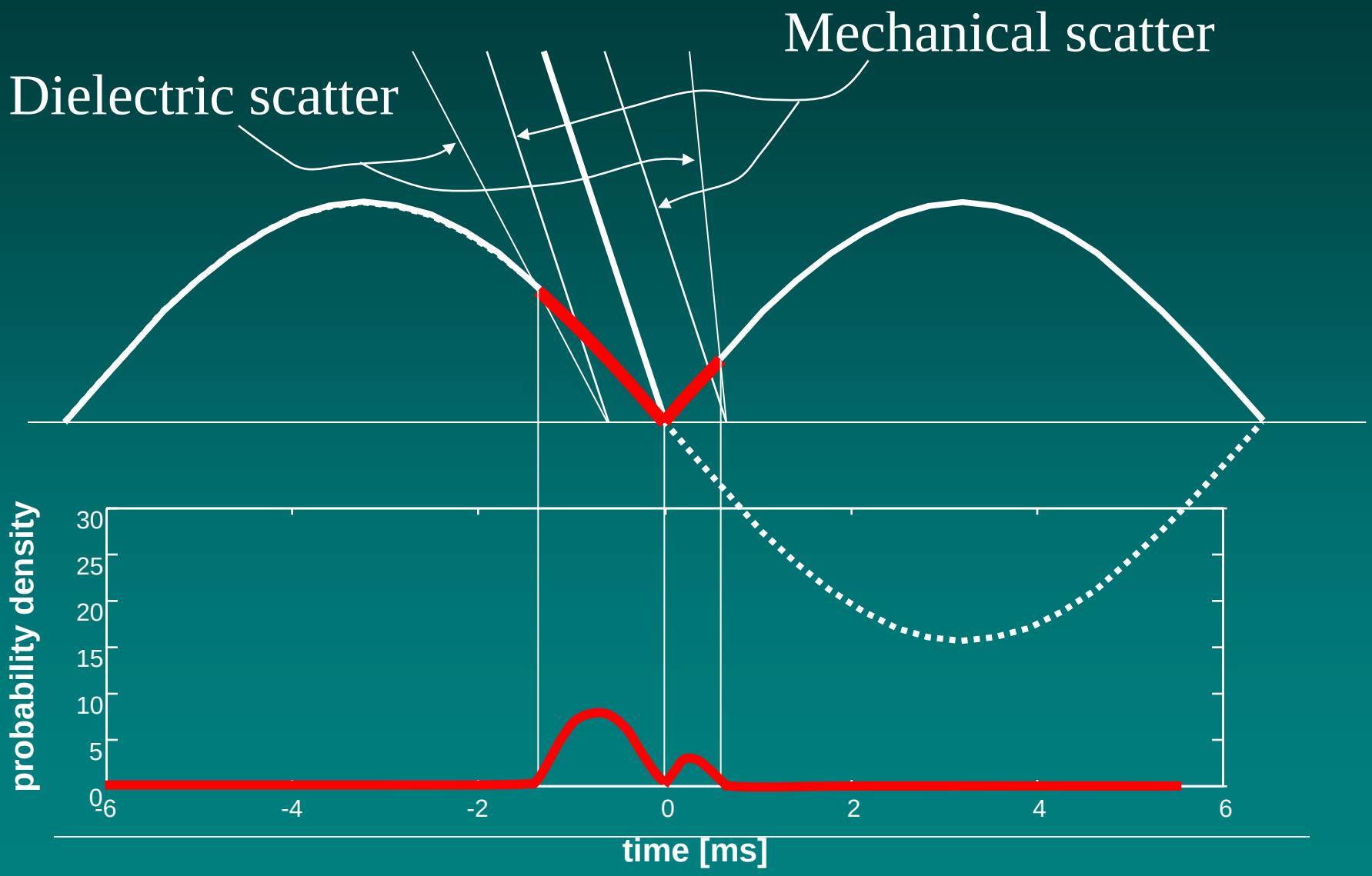
Voltage across the circuit breaker during auto reclosing

Field test in 500kV system of BC-Hydro, Canada

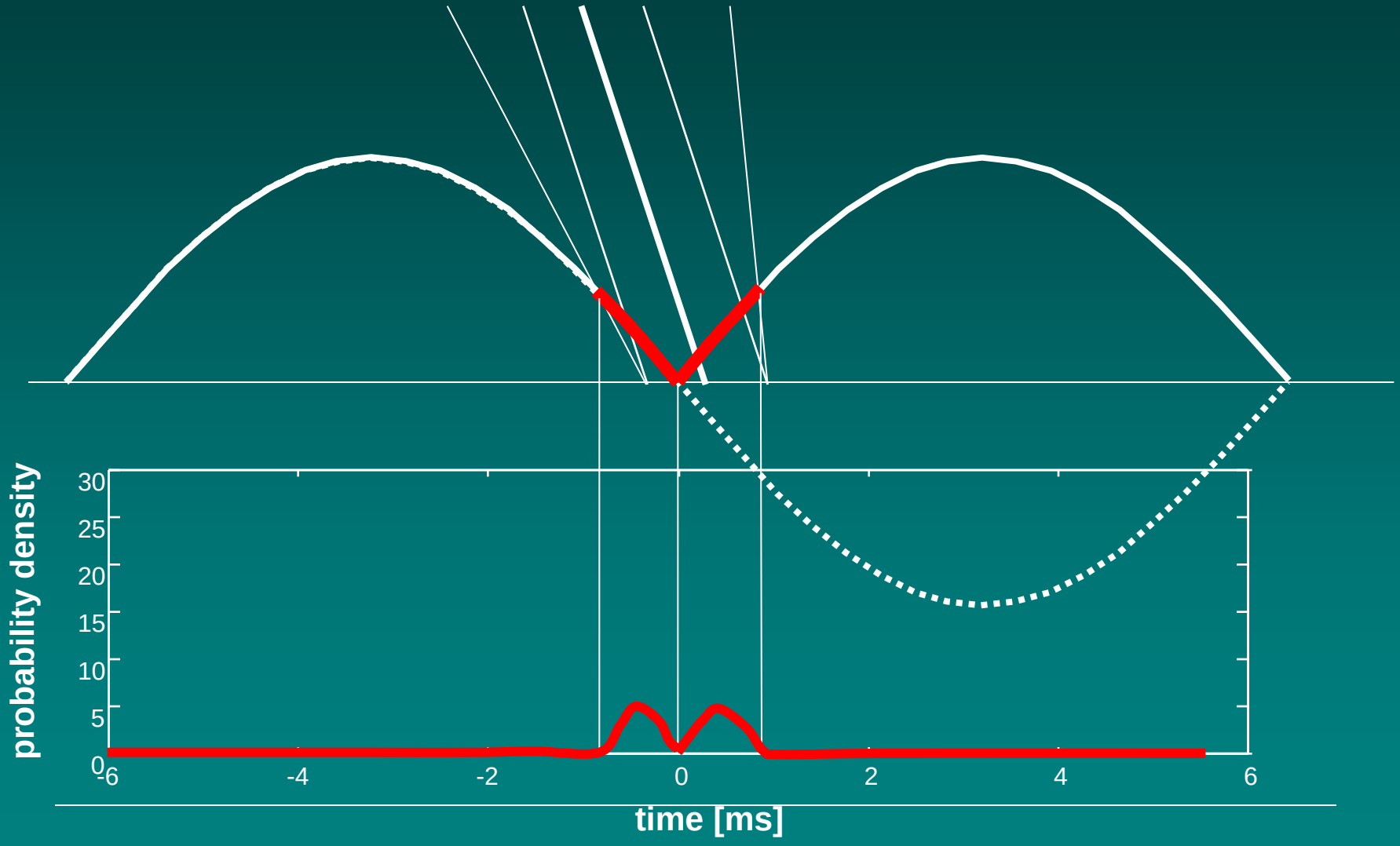
Influence of the circuit breaker



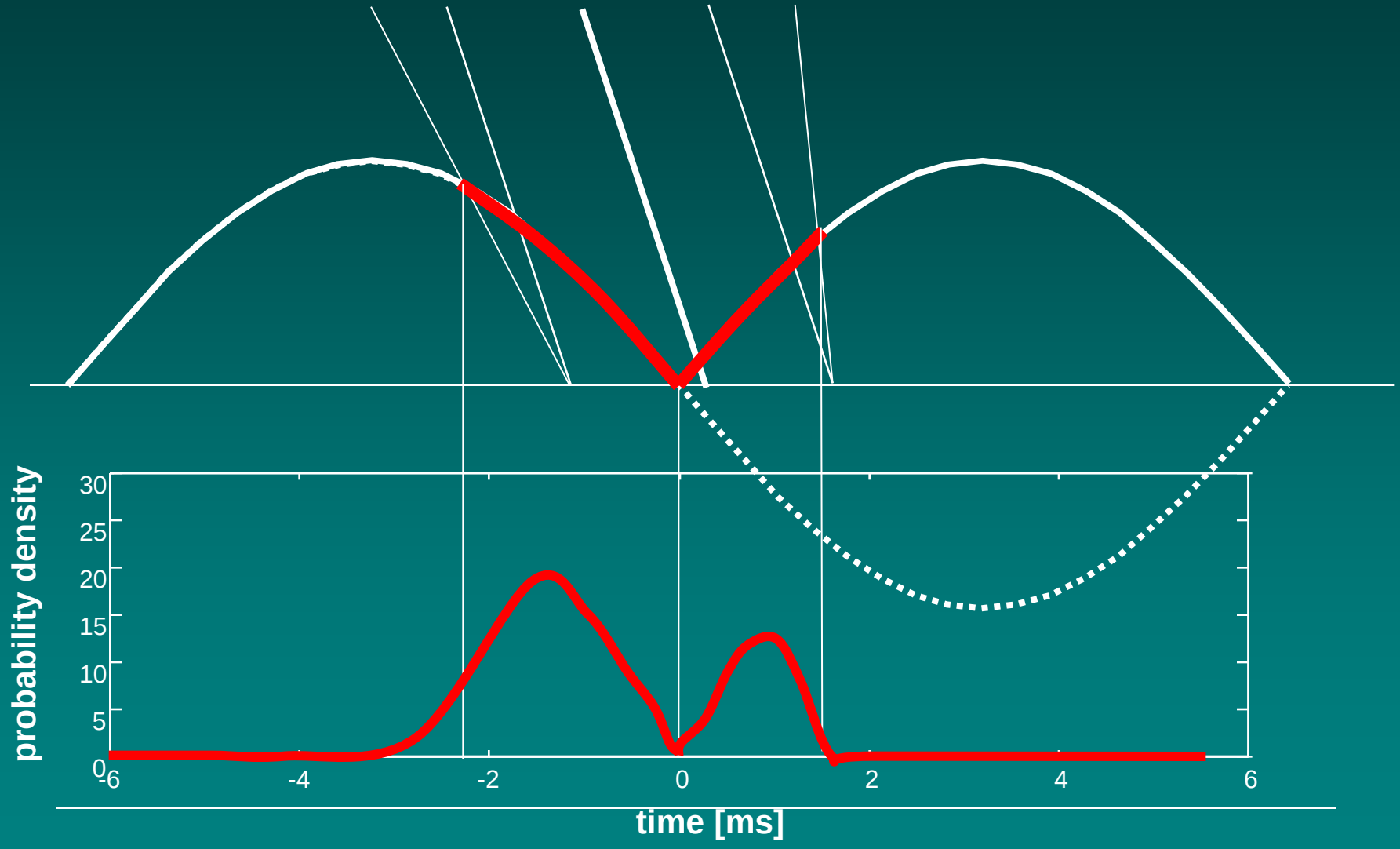
Influence of the circuit breaker



Influence of the circuit breaker



Influence of the circuit breaker

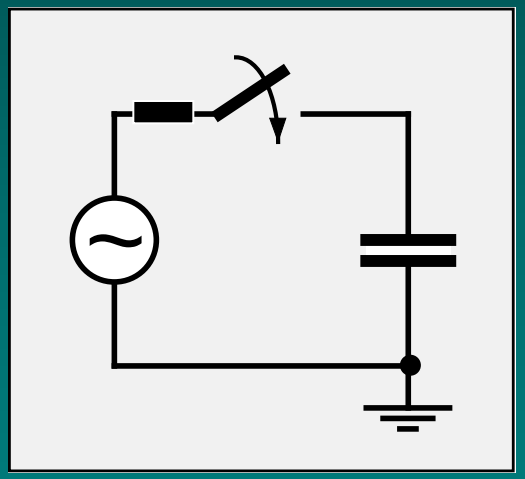


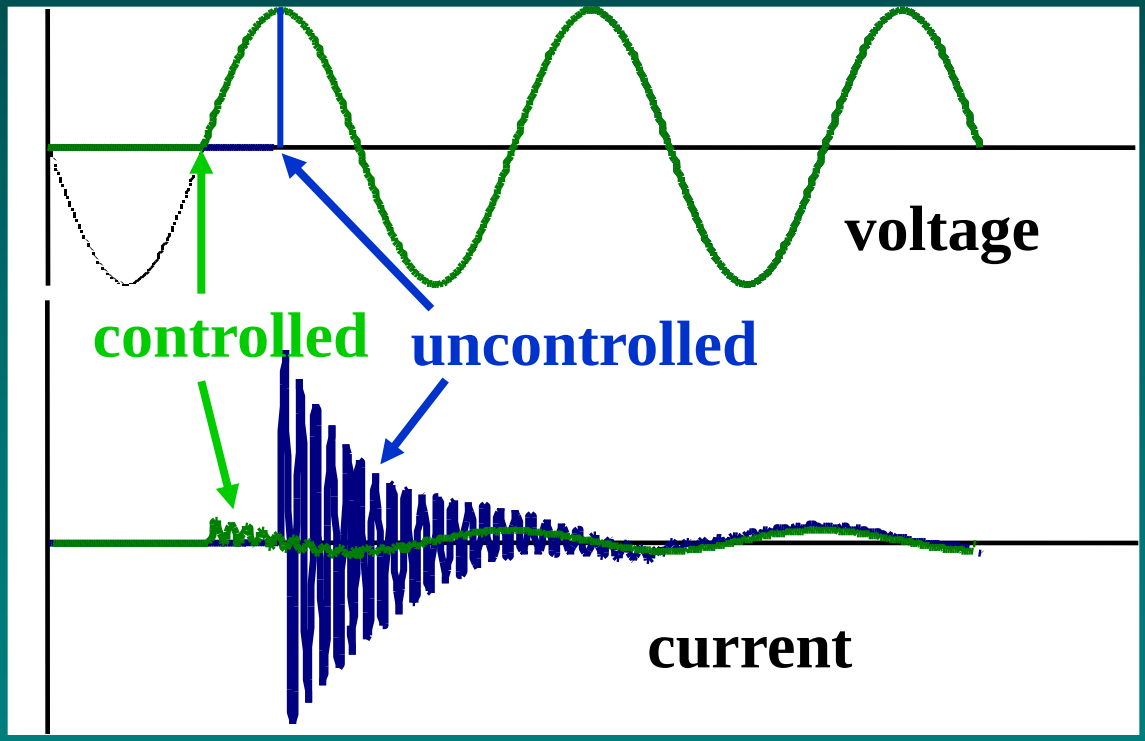
Today‘s most common applications

- Energisation and de-energisation of capacitor banks
- Energisation and deenergisation of shunt reactors
- Energisation of unloaded power transformers
- Energisation and de-energisation of unloaded transmission lines
- Future: Fault interruption

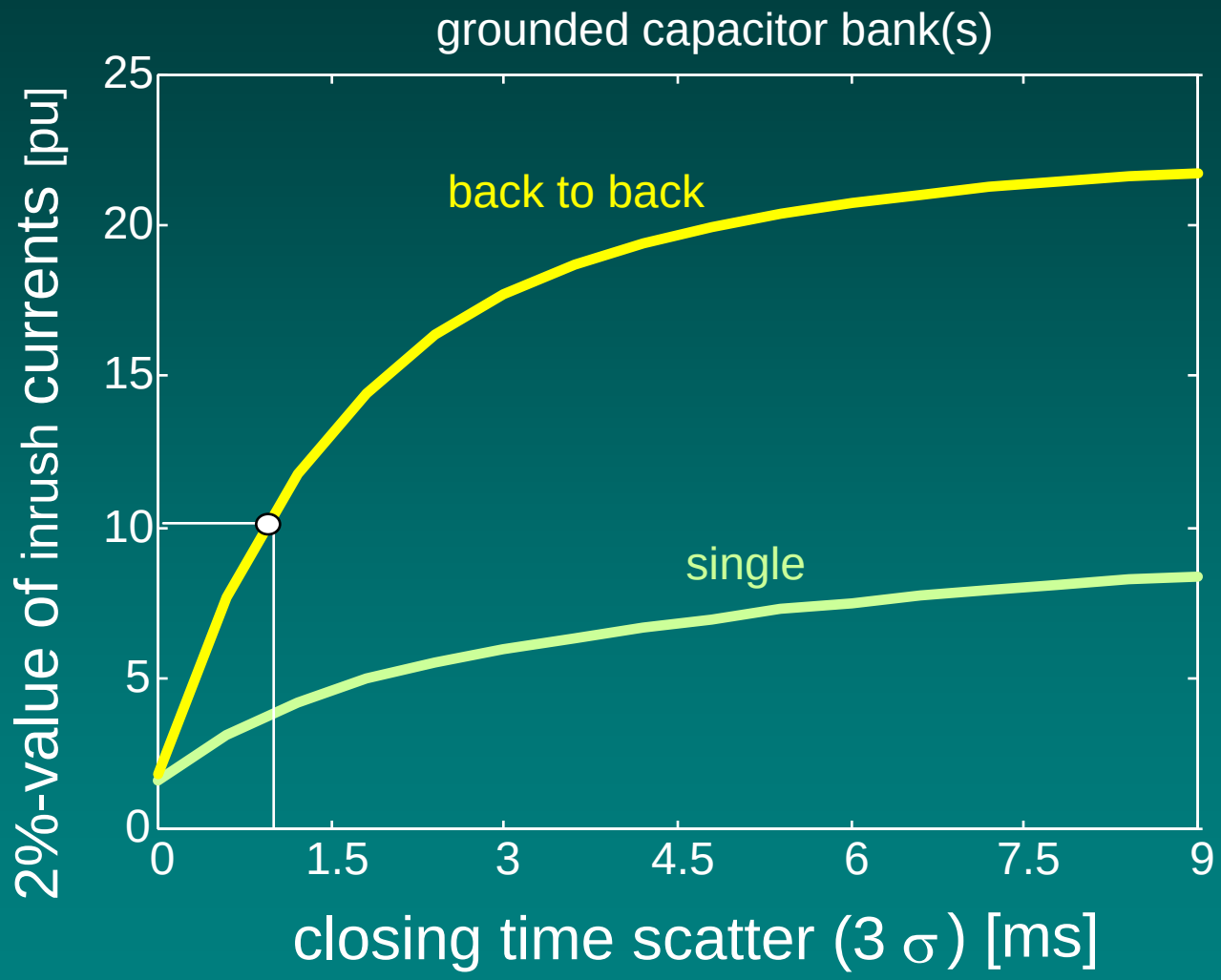
Energization of Capacitor banks

- Problem: Excessive, high frequent inrush current
- Solution: Close at zero of voltage across breaker



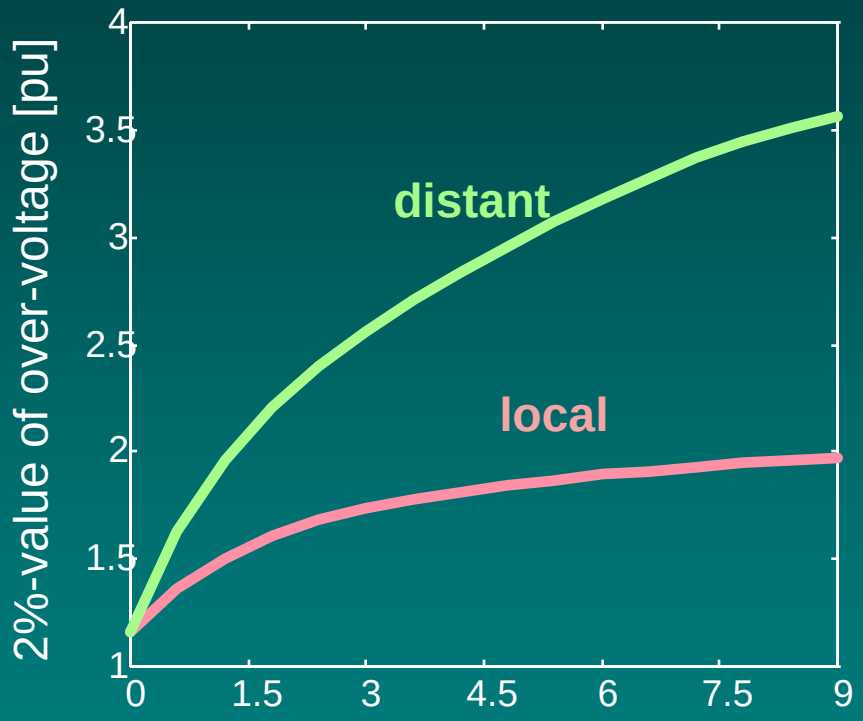


Inrush current of a capacitor bank



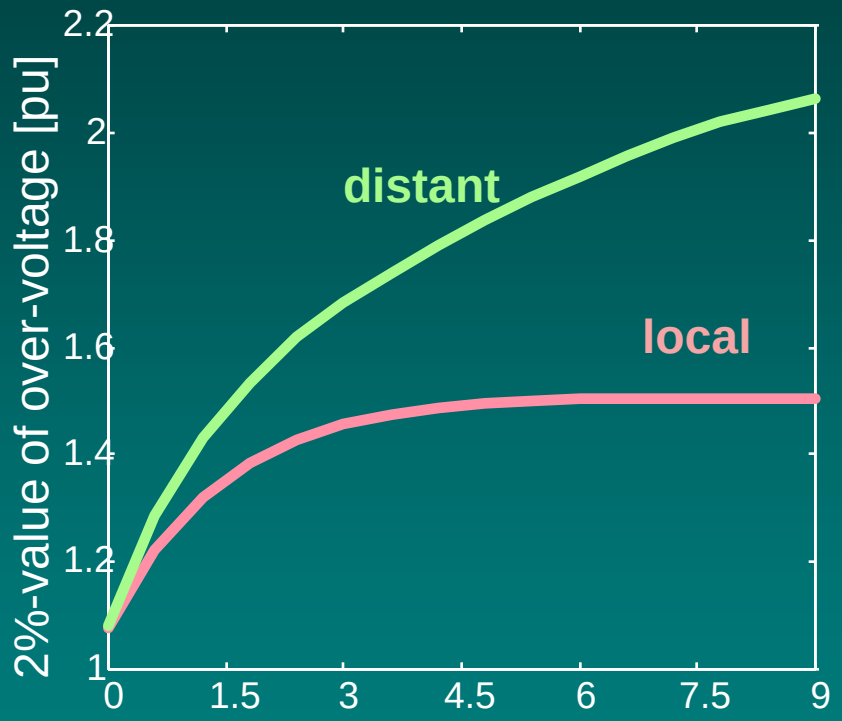
Overvoltage during energization of a capacitor bank

single grounded capacitor bank



closing time scatter (3 σ) [ms]

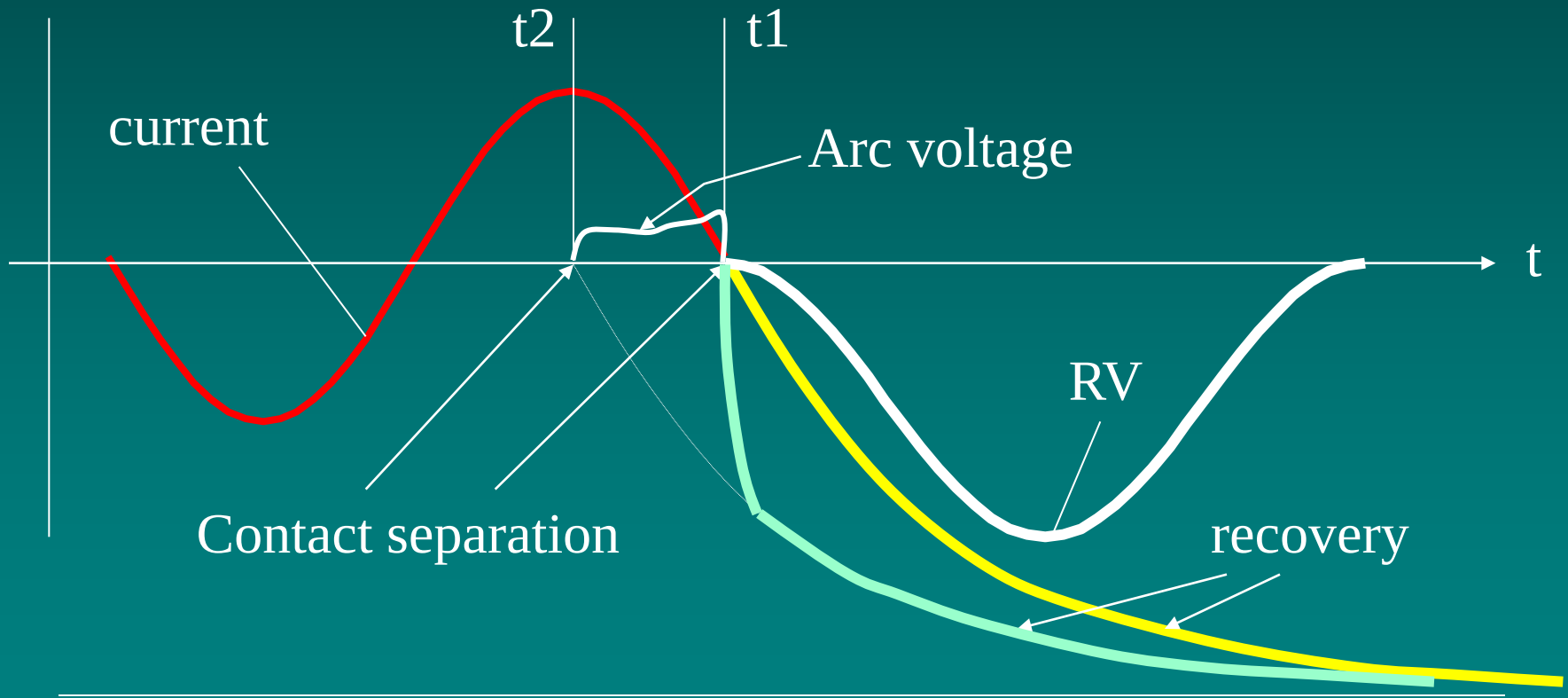
grounded back to back capacitor banks



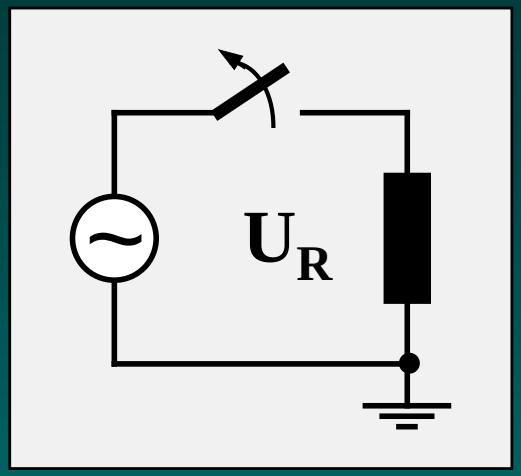
closing time scatter (3 σ) [ms]

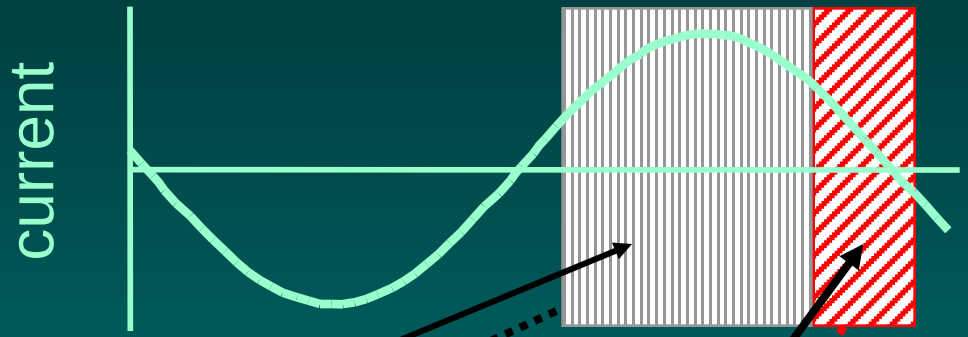
De-energization of capacitor banks

- Problem: Potential jeopardy of restrikes
- Solution: Avoid small arcing time



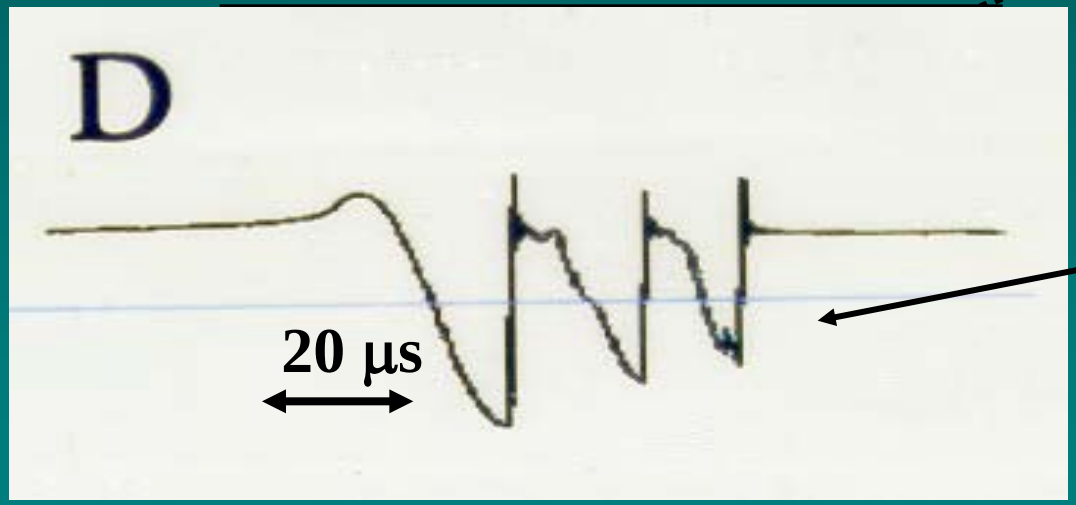
De-energisation of a shunt reactor

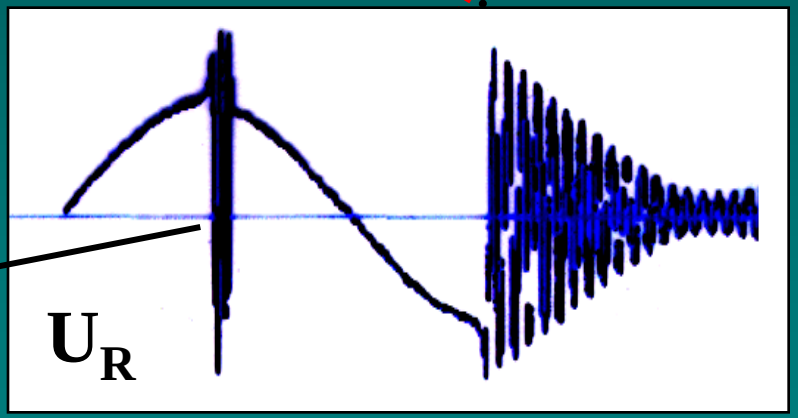




Accepted zone

Critical window





Energization of shunt reactors

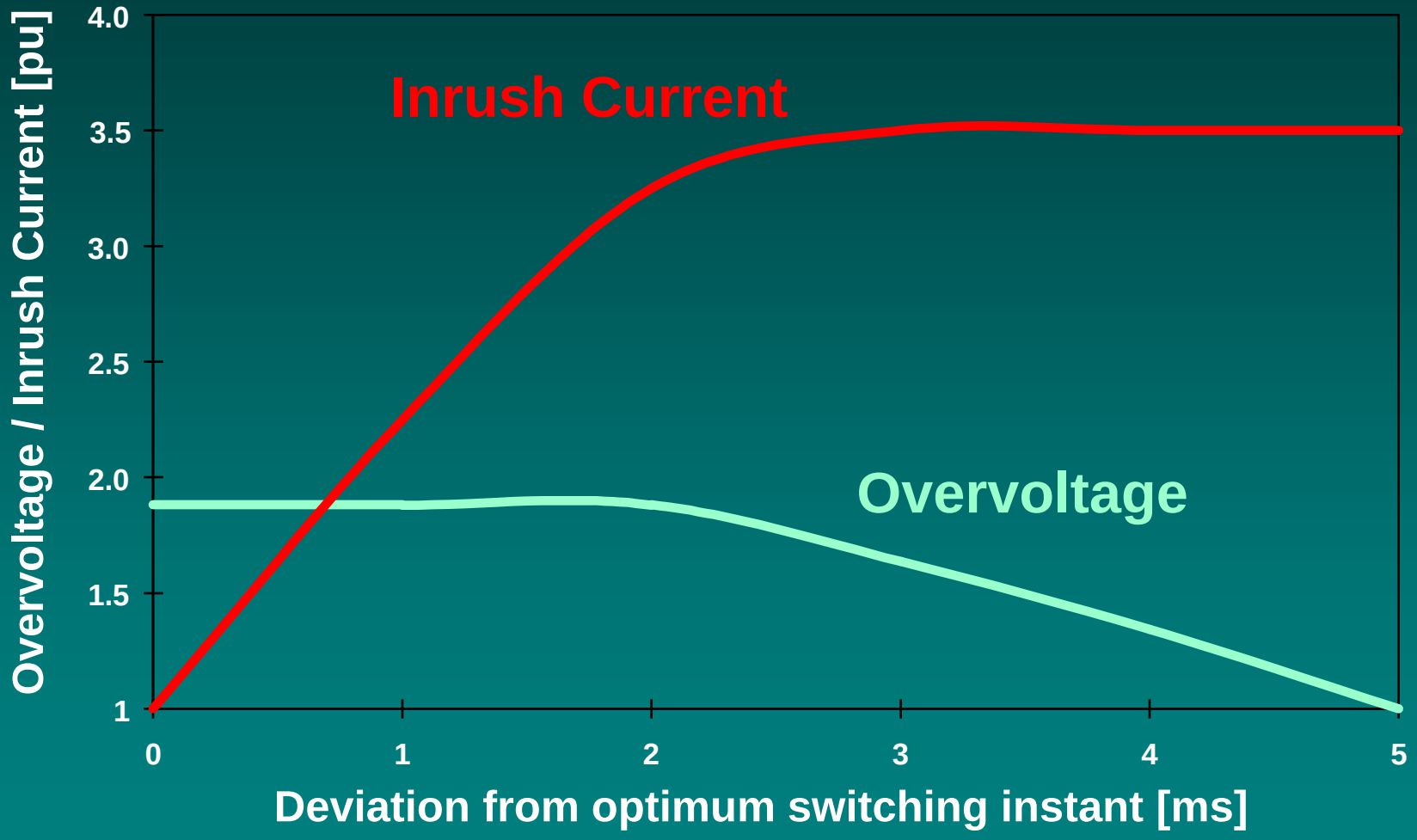
Problem: Inrush current up to 2.5 pu

Solution: Close at voltage peak

Disadvantage:

Transient overvoltage of steep wave front

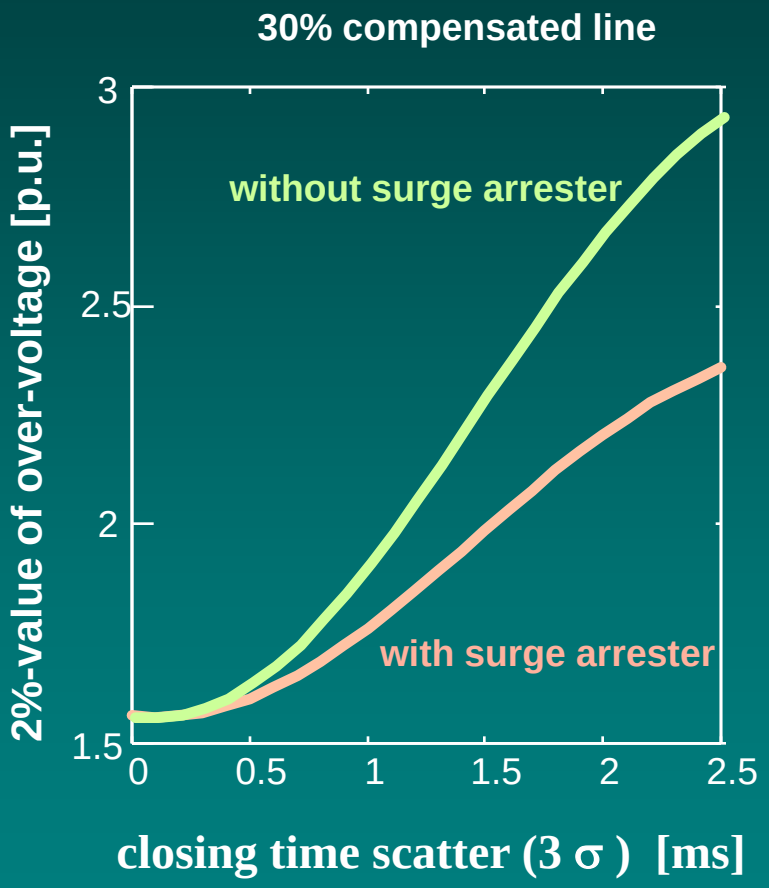
Inrush current and overvoltage versus closing angle

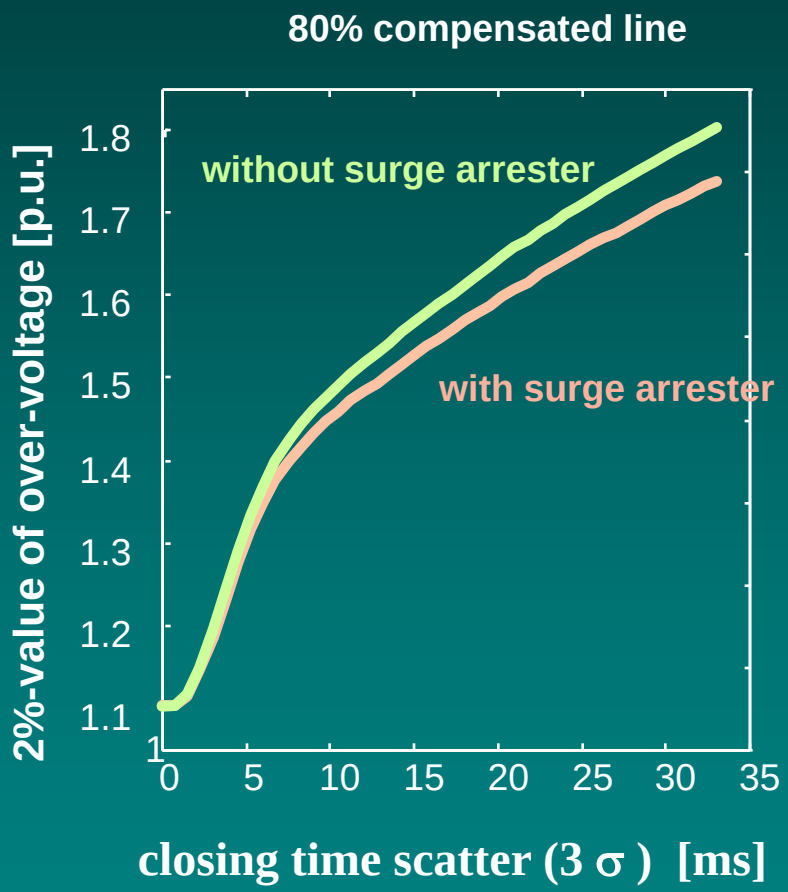


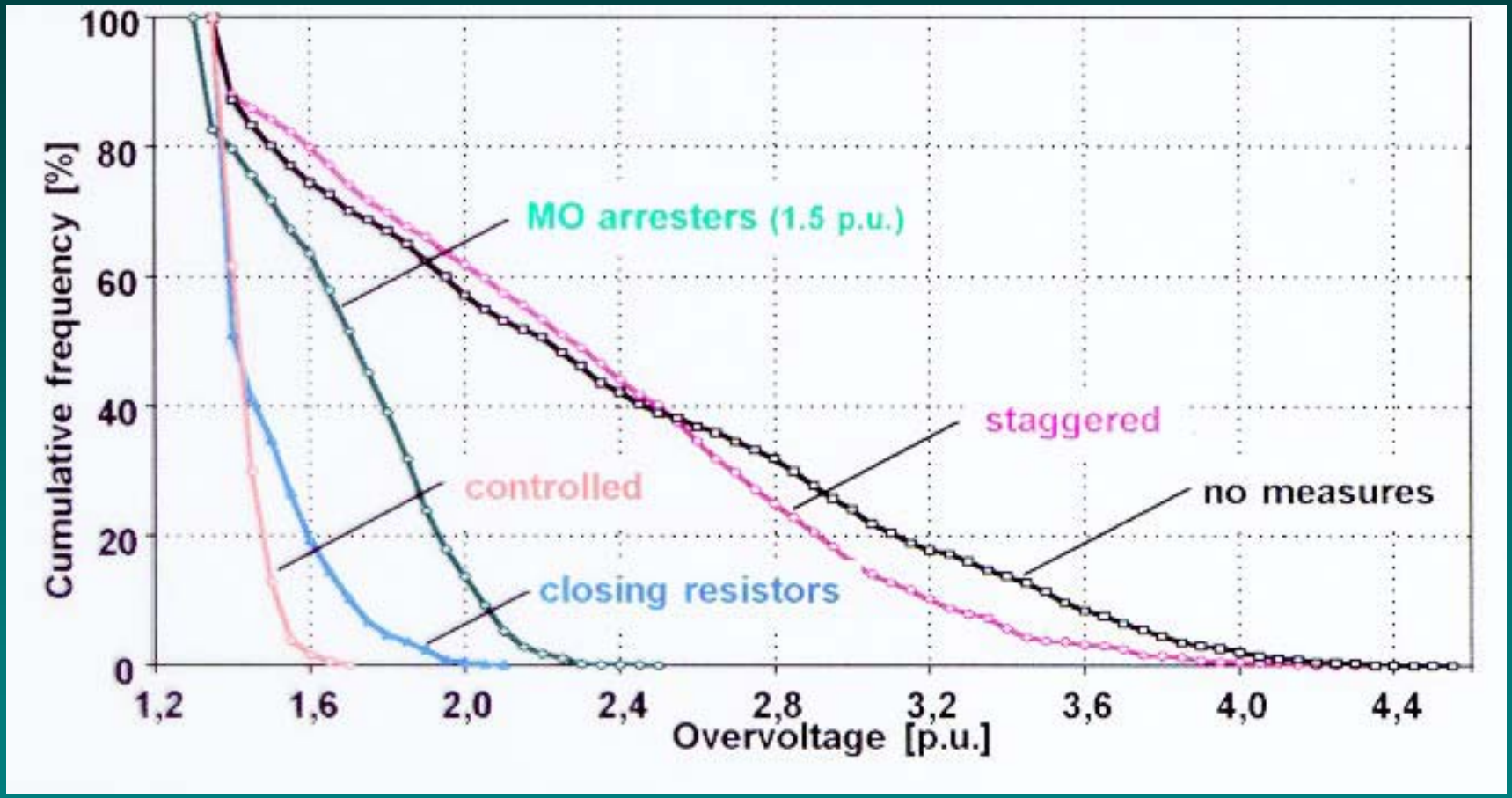
Energisation of unloaded transmission lines

- Problem: Excessive overvoltages
- Solution: Close at zero of voltage across breaker

Highest overvoltage on a transmission line

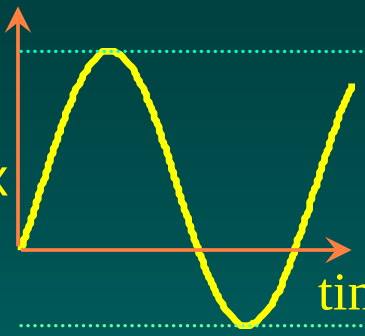


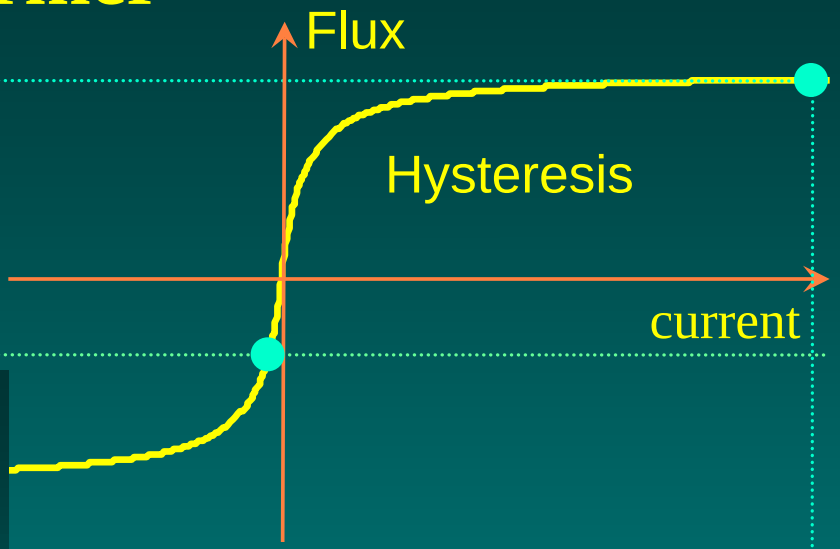


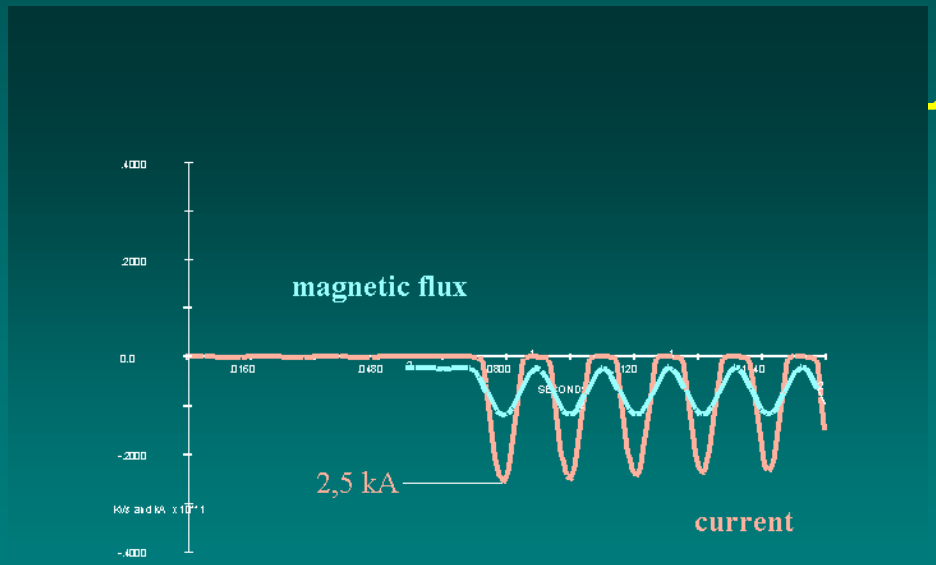

100
80
60
40
20
0
Cumulative frequency [%]
MO arresters (1.5 p.u.)
staggered
controlled
no measures
closing resistors
1,2
1,6
2,0
2,4
2,8
3,2
3,6
4,0
4,4
Overvoltage [p.u.]

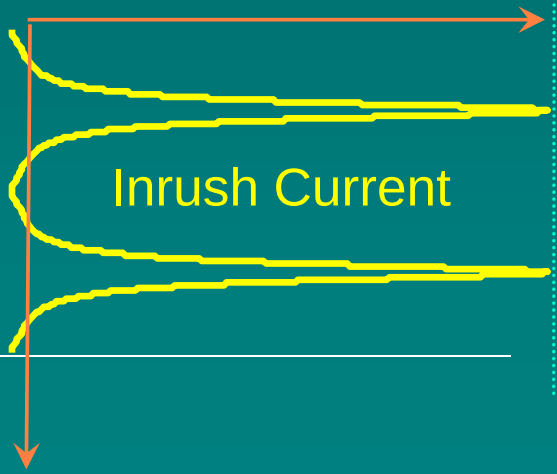
Inrush current at energizing an unloaded power transformer

Asymmetrical magnetical flux









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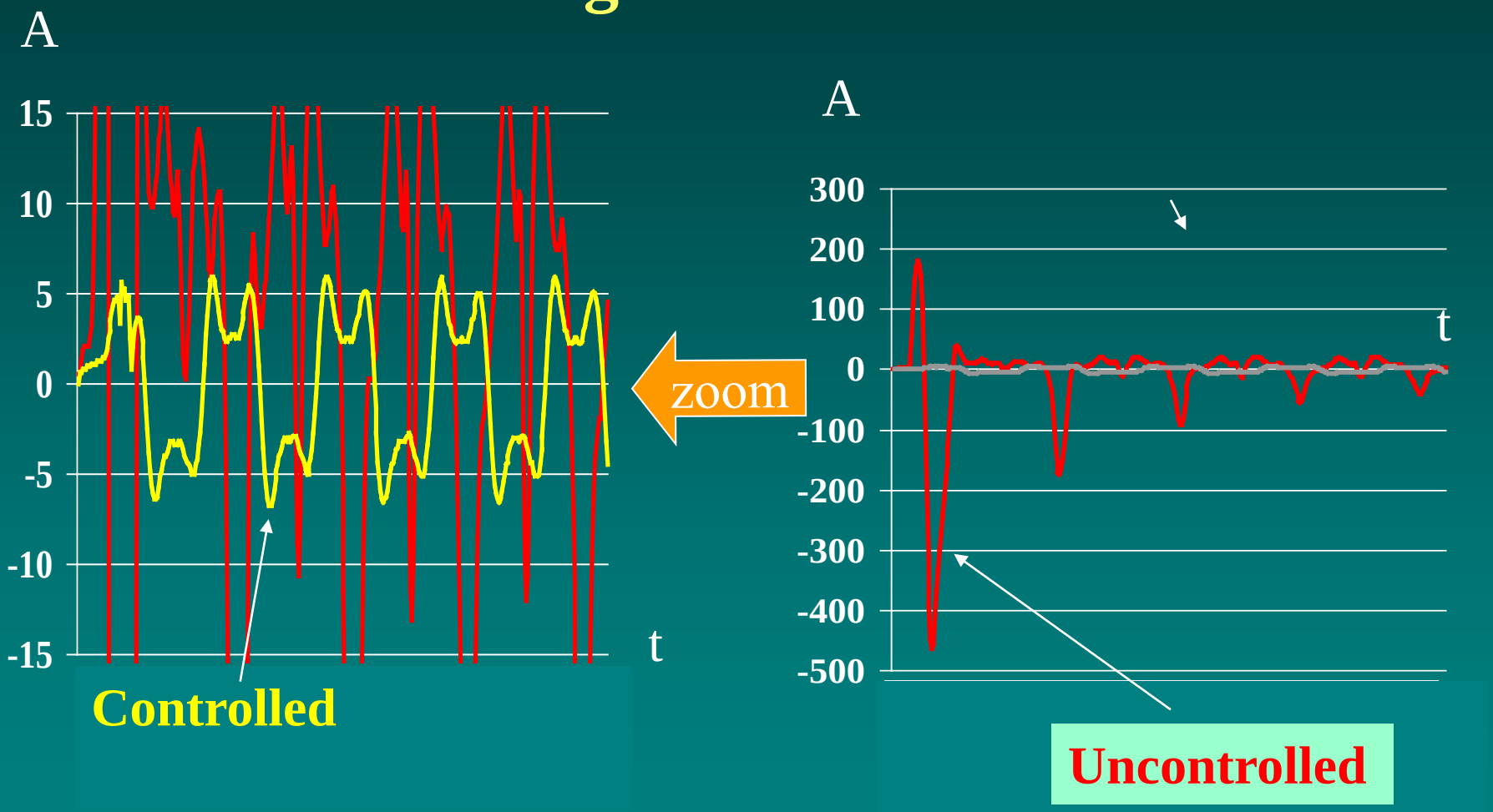
Energization current of a power transformer with controlled switching considering the remanence flux



Future potential of controlled switching

- Load interruption
- Fault interruption
- Control for existing breakers