

SCiBreak AB presentation

Lennart Ängquist Tomas Modeer

*PROMOTioN TSO-workshop, Arnhem, NL
2017-02-17*

SCiBreak

- ✓ independent startup company
- ✓ founded 2014 by Lennart Ängquist and Staffan Norrga
- ✓ aim: develop technology for cost-effective dc breaker using an idea to reduce the need for semiconductors
- ✓ in cooperation with: innoenergy, Svenska Kraftnät, Energimyndigheten
- ✓ entered PROMOTioN project February 2017

Team

Lennart Ängquist, born 1946, MSc 1968, PhD 2002: Worked at ASEA/ABB 1968-2008 at Central Research Dept, Power Electronic Dept and Power Systems with power electronics for industrial and traction drives and reactive power compensation, specifically TCSC. Adjunct professor at KTH 2002-2010.



Staffan Norrga, born 1968, MSc 1993, PhD 2005: Worked at ABB/Adtranz 1994-2011 in various capacities related to power electronics. Associate professor at KTH from 2011. Inventor or co-inventor of 12 granted patents and 13 patents pending, and has authored or co-authored more than 65 scientific papers.



Tomas Modéer was born in Stockholm, Sweden, in 1979. He received the MSc and PhD degrees KTH Royal Institute of Technology in 2004 and 2015 respectively. Worked at Optistring Technologies 2011-2015 managing the technology development.

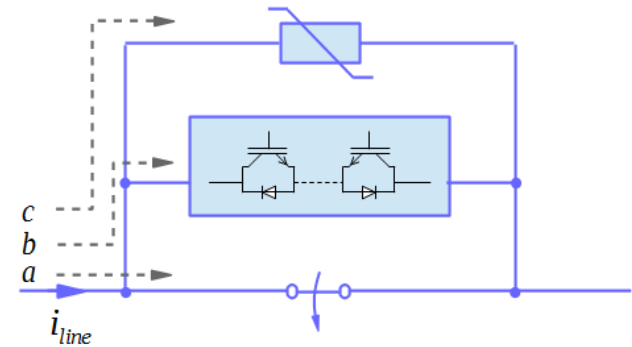


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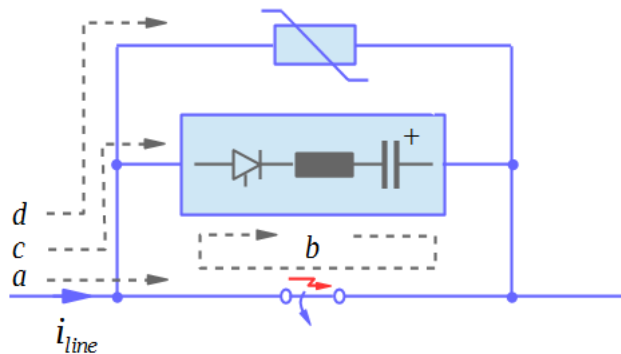
Concepts for **fast** DC breaker

hybrid DC breaker

semiconductors
interrupt the current



DC breaker using artificial current zero-crossings



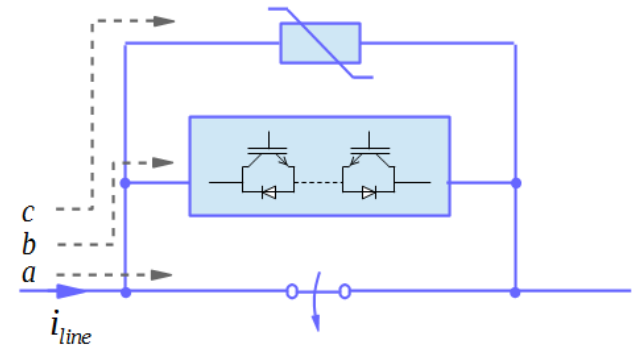
auxiliary circuit forces
current through mechanical
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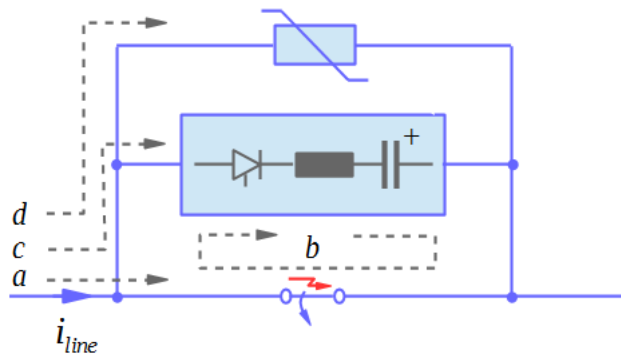
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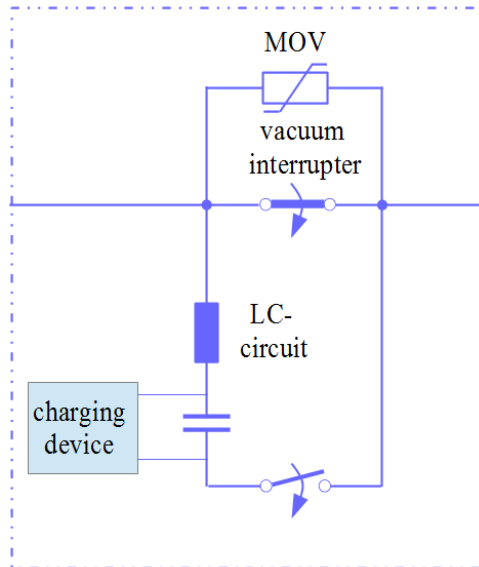
DC breaker using artificial current zero-crossings



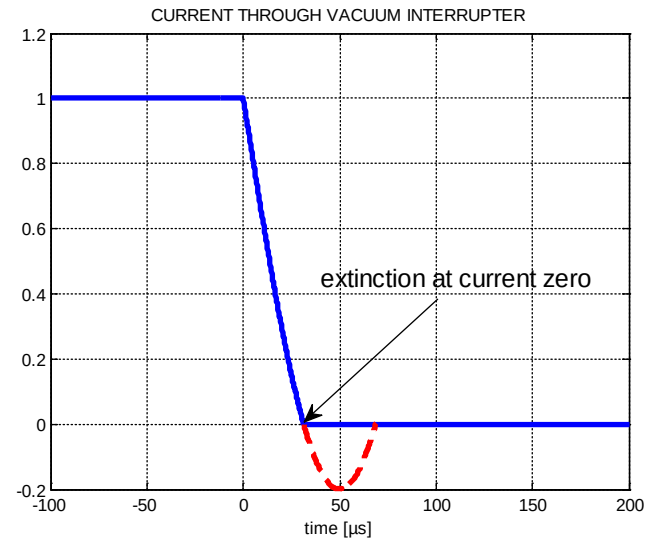
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Vacuum Interrupter (VI) with auxiliary circuit

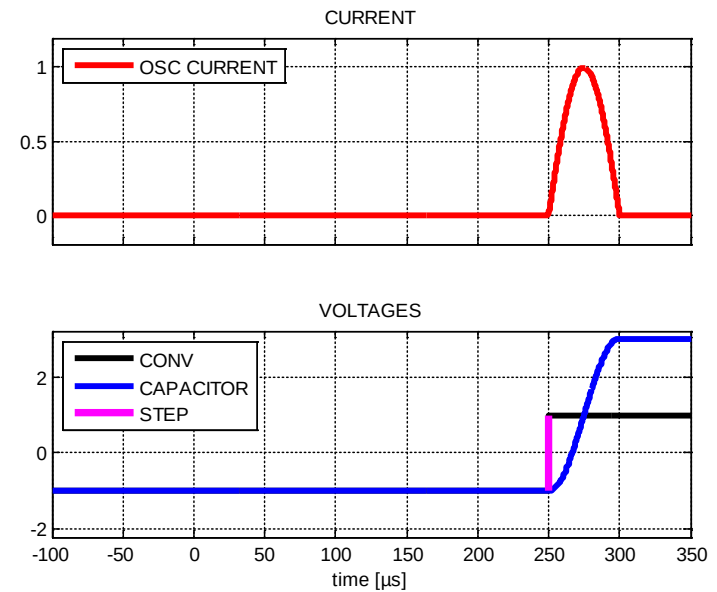
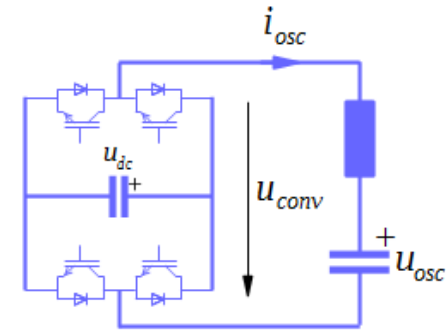
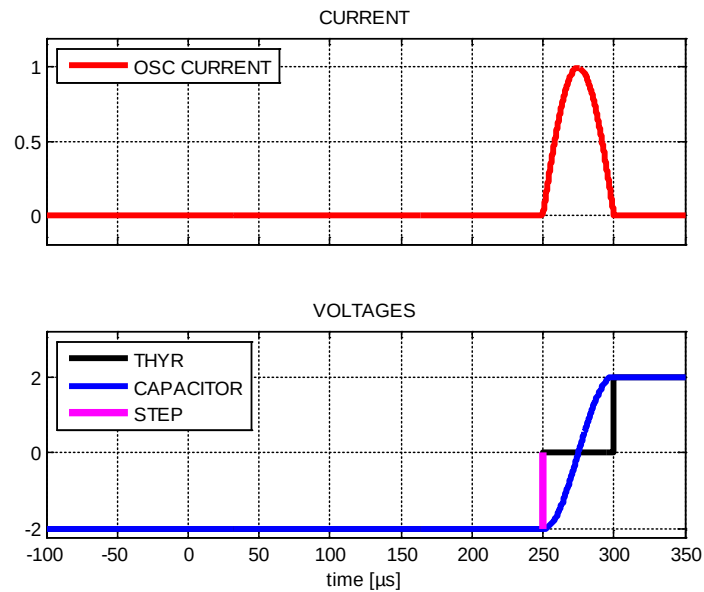
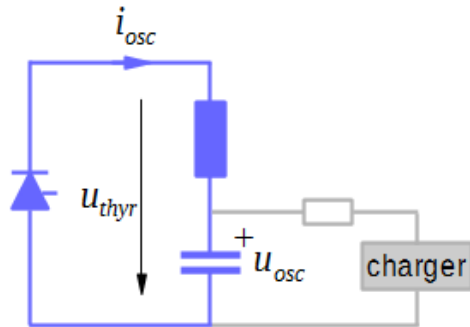


VI with auxiliary circuit

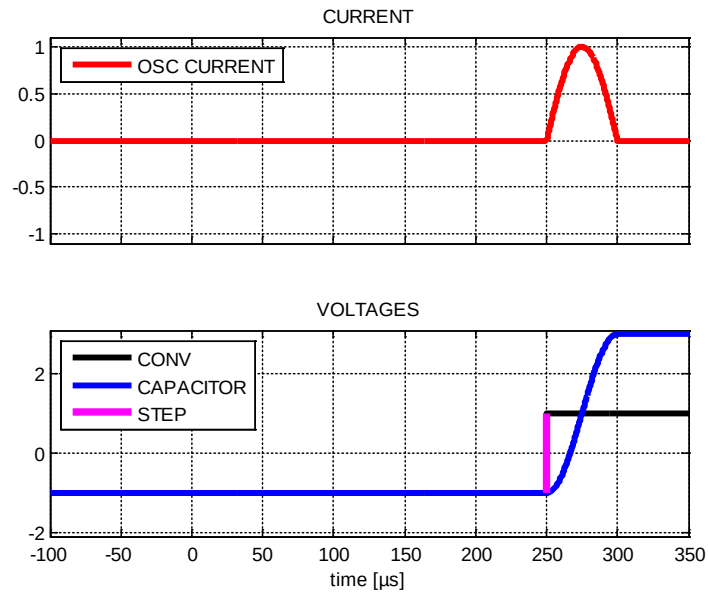


current through VI

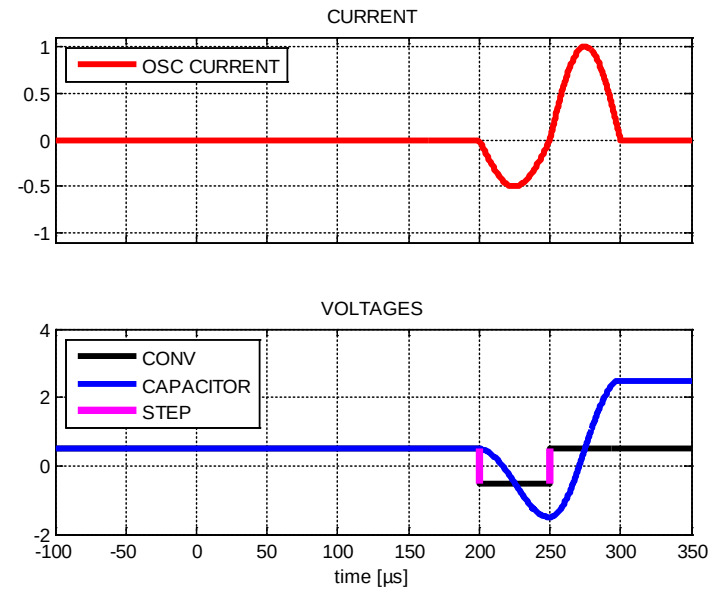
Excitation of current pulse



Excitation of current pulse

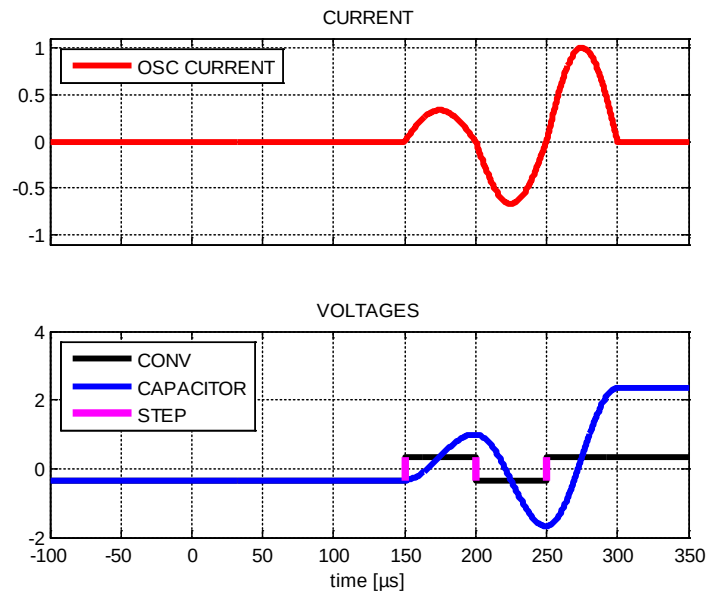


single reversal

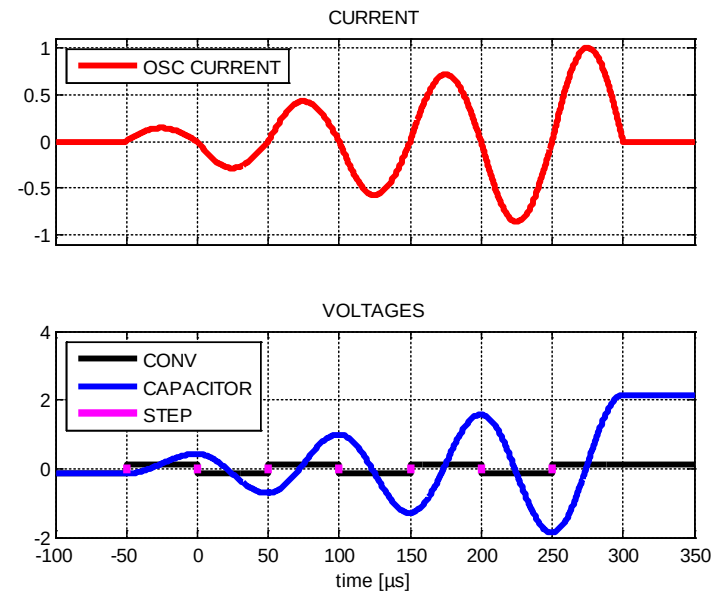


two reversals

Excitation of current pulse



three reversals



seven reversals

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Timing considerations

- ✓ one millisecond is **very short** in the **mechanical** domain:
a falling body moves 5 μm in the first 1 ms (acceleration 1 g)
- ✓ one millisecond is a **long time** in **power electronics**:
ten full cycles at 10 kHz
- ✓ one millisecond is a **very long time** in microprocessors and FPGA
- ✓ conclusion: there is time for **many, well controlled, power electronic interventions** while the mechanical contacts in the interrupter separate

An example

To extinguish:

- ✓ current 10 kA @ prot voltage 100 kV
↓
- ✓ $x_0 = 8 \Omega$ at resonance frequency
↓
- ✓ dc link voltage to extinguish 10 kA in one reversal = $8 \times 10 / 2 = 40$ kV
↓
- ✓ four cycles → seven reversals
↓
- ✓ required dc link $40 / 7 = 5.7$ kV
↓
- ✓ semiconductor blocking voltage
 $4 \times 5.7 = 23$ kV

23 % of protective voltage

Hybrid breaker needs 200 % of protective voltage!

$$x_0 = \sqrt{\frac{L_{osc}}{C_{osc}}} \quad \omega = \frac{1}{\sqrt{L_{osc} C_{osc}}} \quad i_{osc} = \frac{u_{osc}}{x_0}$$

Means:

- ✓ $x_0 = 8 \Omega$, $f = 10$ kHz
↓
- ✓ $L_{osc} = 127 \mu\text{H}$
- ✓ $C_{osc} = 2 \mu\text{F}$

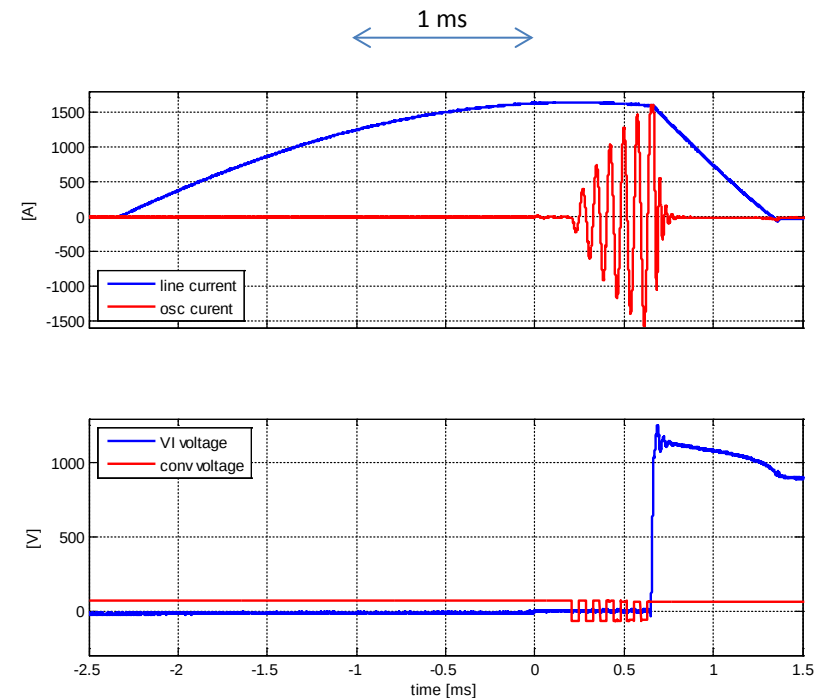
four cycles = 0.4 ms

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Basic principle of the proposed breaker

sufficient amplitude of oscillating current can be achieved **much faster than the time to separate** the VI contacts

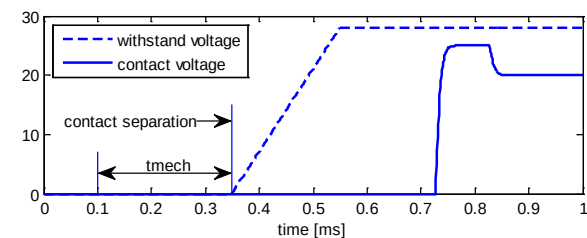
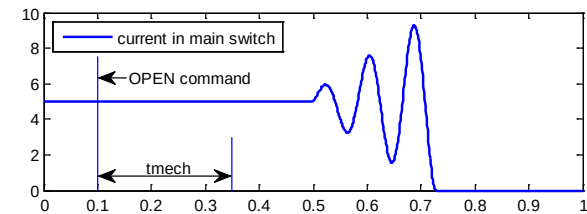
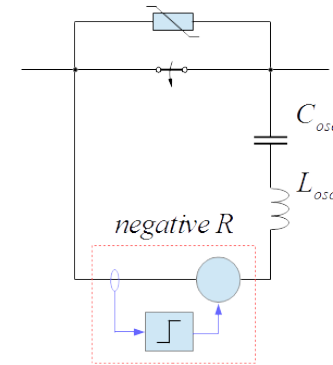
required converter voltage is very low compared to “breaker voltage” i.e. **reduced semiconductor ratings**



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Coordination of control

- fast mechanical actuator commanded to OPEN
- voltage withstand capability starts to buildup when contact separation occurs
- excitation of oscillating current is started in order to achieve the first zero-crossing when full voltage withstand capability has been obtained
- excitation disabled when main current has commutated into the energy-absorbing branch (MOV)



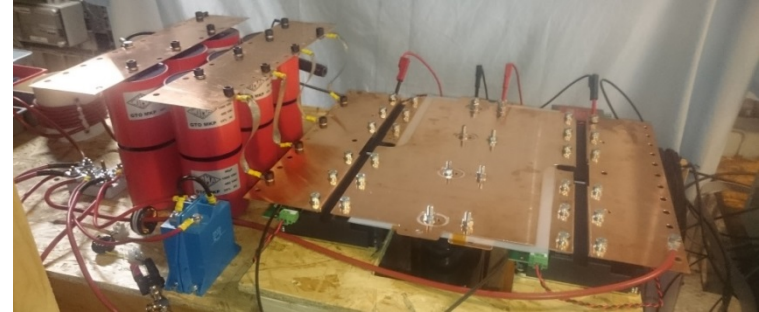
Advantages of the SCiBreak breaker

- substantial **reduction of number of semiconductor** devices as converter is rated for a fraction of the system voltage
- uses **minimum amount of MOV**
- **low stress of passive components**, lasting capacitor voltage is only a fraction of the maximum operating voltage
- converter **commutates at zero current**, low requirement for semiconductor breaking capability
- voltage across separating mechanical contacts increases **linearly** during switching, no voltage spikes
- capacitor voltage **adapts to breaking current level**, no steep voltage across breaker at breaking of low current
- breaker is **inherently bidirectional**
- operation is **independent of line voltage before fault** (zero initial capacitor voltage)
- **failsafe operation** due to increasing magnitude of oscillating current
- fast **reclosing** is possible

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Experimental setup

power electronic converter



control card using FPGA control

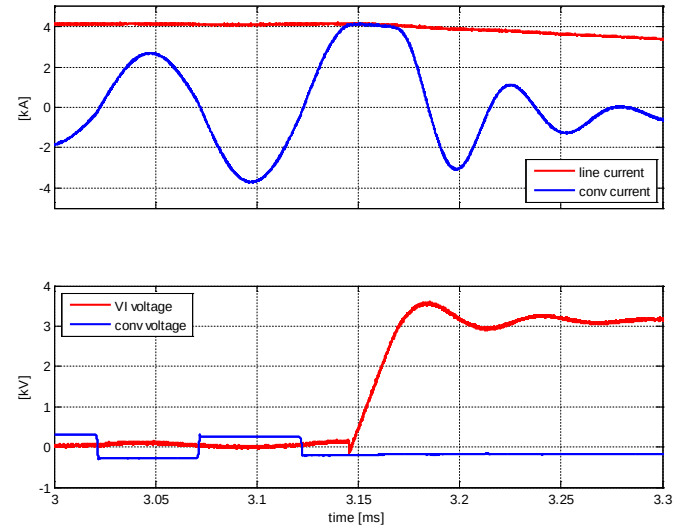
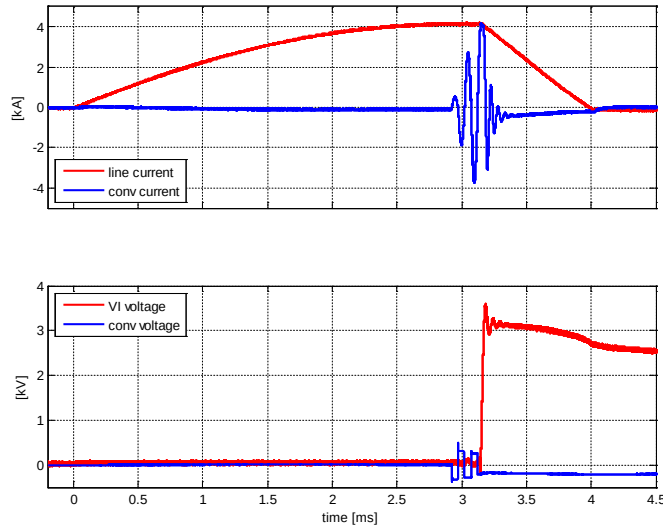


vacuum breaker rated 24 kV, 630 A
conventional mechanical actuator
1.1-1.7 m/s



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Experimental results



max experimental results (Dec. 2016): **5 kA peak @ 10 kV peak**

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Ongoing work

✓ 2017

- interrupting current, electrical functions
goal 40 kV 10 kA
- mechanical actuator
goal faster than 5 ms

✓ 2018

- combine to breaker to be tested
- validating tests