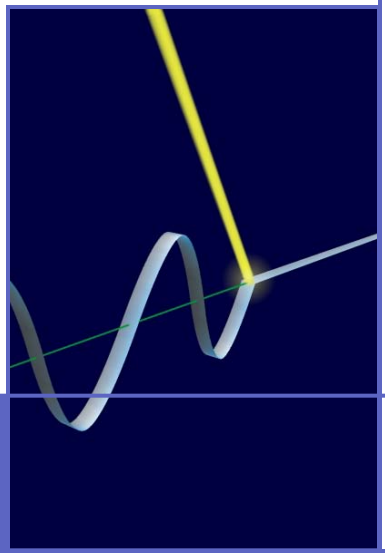
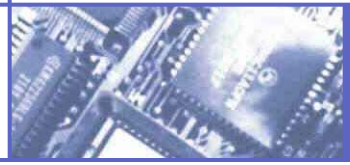
Michael Stanek

CIGRE WG A3.07 Workshop
St. Pete Beach, FL, May 2002



Experiences with Improving Power Quality by Controlled Switching



Contents

- Power quality
- Experiences with (un)controlled switching of
  - Capacitor bank
  - Arc furnace
  - Static VAR compensator
  - Transmission line
- Economical impact
- Conclusions

Definition of Power Quality

A power quality problem can be defined as

any deviation of

- magnitude,
- frequency, or
- purity

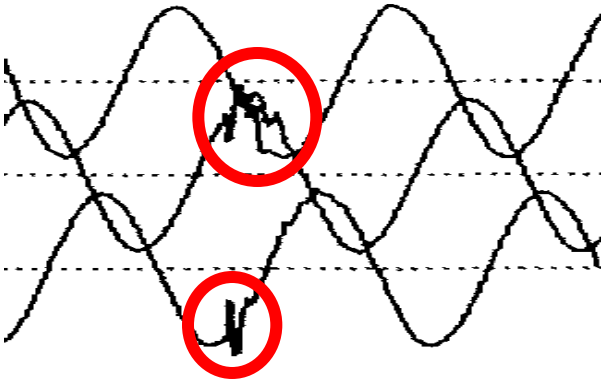
from the ideal sinusoidal voltage waveform.

Power Quality Problems

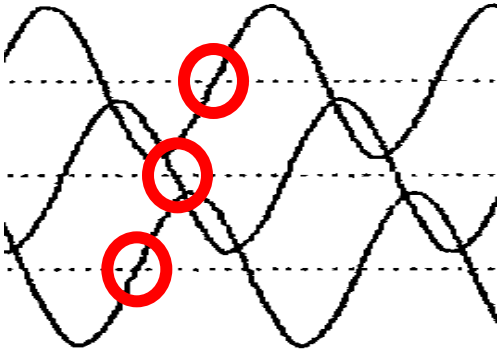
Categories:	Potentially improved by CS
transients (impulsive, oscillatory)	✓
interruption	✓
voltage dip/sag, undervoltage	✓
voltage swell, overvoltage	✓
voltage unbalance	
waveform distortion	
voltage fluctuations (flicker)	
power frequency variations	

Closing on Capacitor Bank

uncontrolled



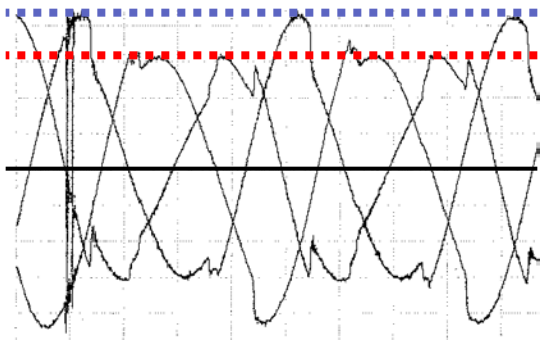
controlled



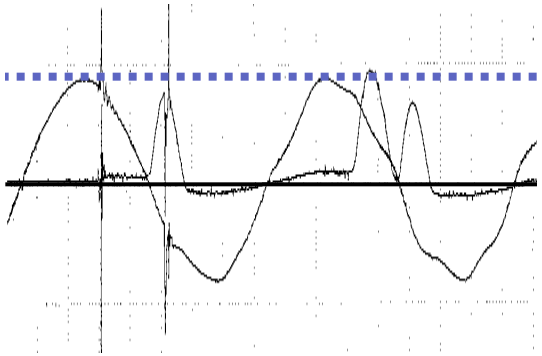
- Major power quality event due to uncontrolled closing:
  - switching transient caused surge arrester operation 11 mi off
  - two bus differential relays operated
  - a large oil refinery lost power in the middle of winter

Closing on MV Arc Furnace

uncontrolled



controlled



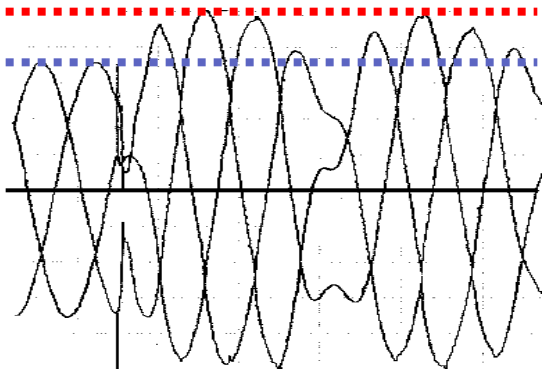
nominal

sag

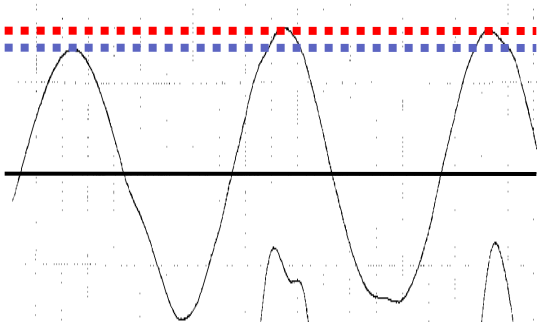
- Uncontrolled energization caused high inrush currents up to 10 kA and associated voltage sags to 0.7 p.u., sometimes even protection operation.
- Workaround procedure: reduce production to 50%, energize furnace, resume production.

Closing on MV Static VAR Compensator

uncontrolled



controlled

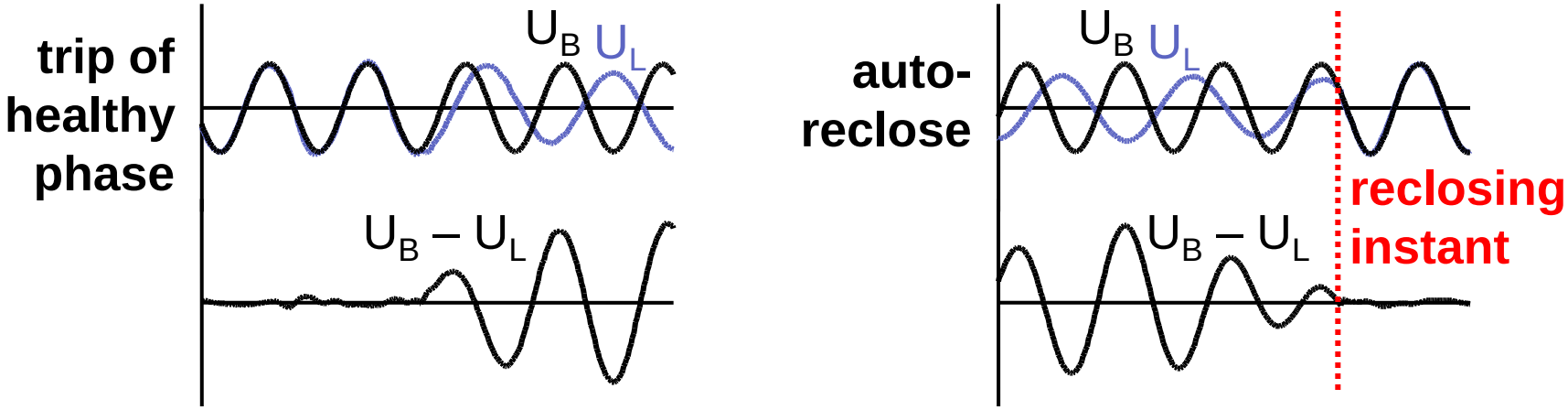


nominal

swell

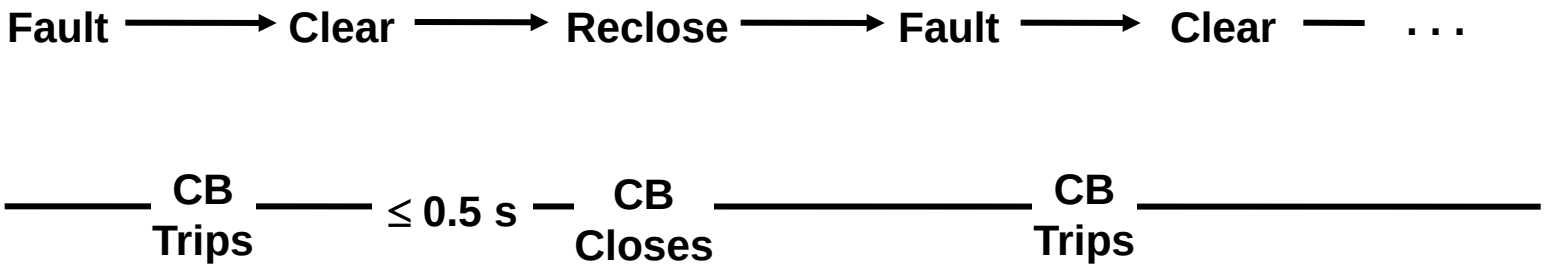
- Uncontrolled energization caused high inrush currents in excess of 6 kA and voltage swells up to 1.5 p.u., sometimes even protection operation.
- Workaround procedure: reduce production to 50%, energize compensator, resume production.

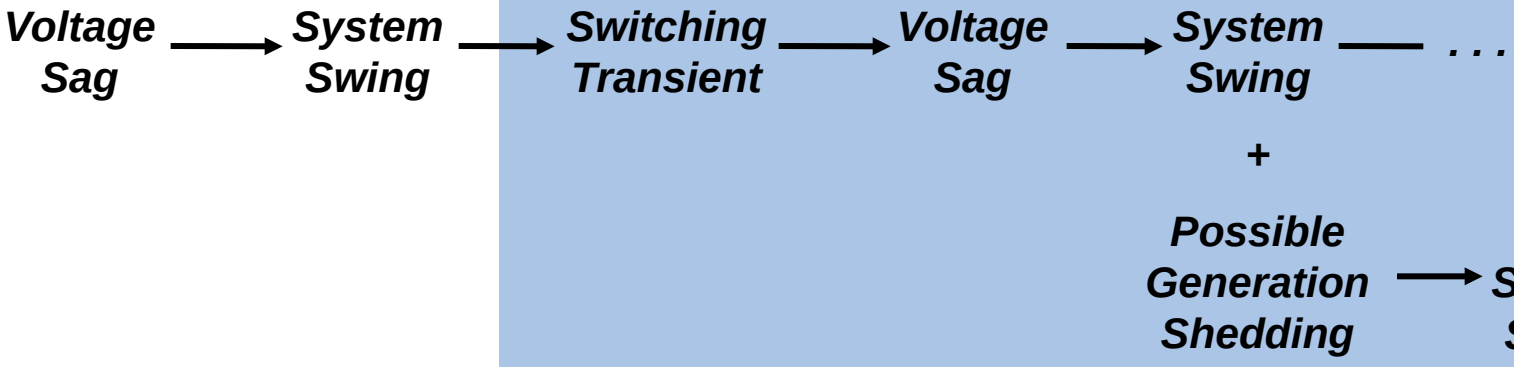
(Closing and) Auto-Reclosing on Line



- Reclosing on an unloaded long line can cause transient overvoltages up to 4 p.u. at the receiving end.
- Scenario of fault clearing and unsuccessful reclose due to the switching transient, may cause system swing and possibly generation shedding.

Line Reclosing Escalation Scenario





Prevented by controlled switching

Economical Benefits of Controlled Switching

- Capacitor Bank:
  Cost of incident due to uncontrolled energization amounted to several million USD

- Arc furnace and static VAR compensator:
  Savings from elimination of workaround procedure are estimated 100,000 USD p.a.

- Transmission line (500kV):
  Reduced tower dimensions due to lower switching overvoltages saved in construction costs 1 million USD

Conclusions

- Controlled switching can eliminate many power quality problems associated with switching operations in transmission networks.
- Depending on the network and the switched load, the economical benefits from controlled switching can be substantial (if only by reducing the probability of worst-case scenarios).

