Harmonic filter design for electrified railways

DIgSILENT USER GROUP

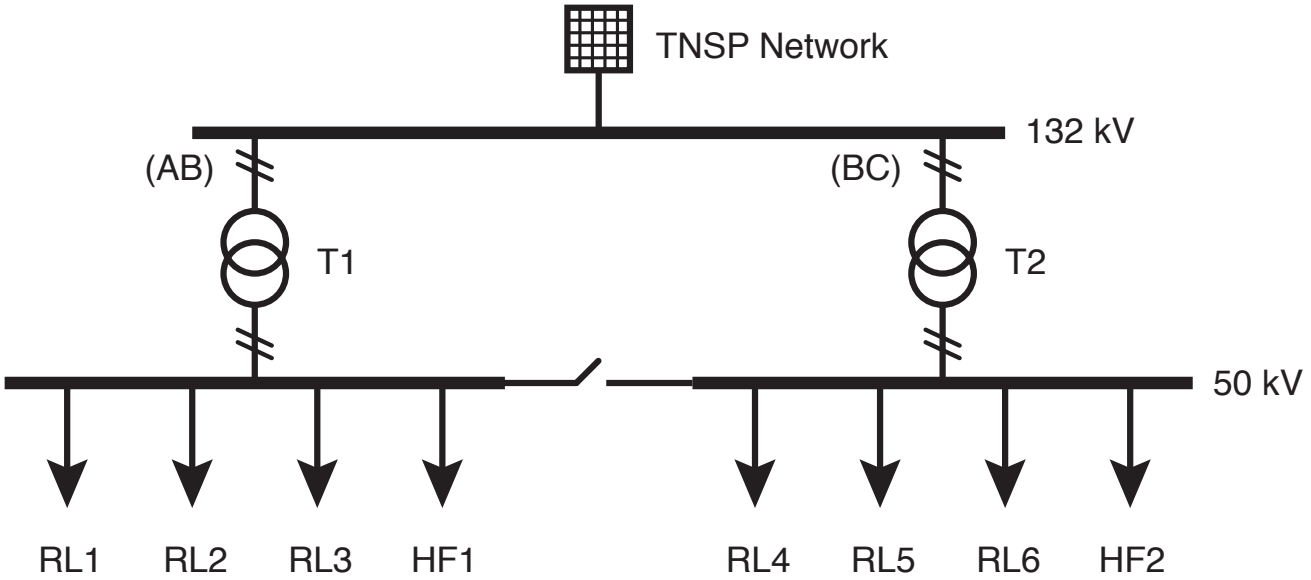
Sydney — 5 September 2013

M Jansen, S Hagaman, T George

Introduction

- Railway electrification project
- Adds significant unbalanced non-linear load to the grid
- PowerFactory used for
  - Harmonic emission/compliance
  - Filter design/rating
  - EMT review
  - Protection design

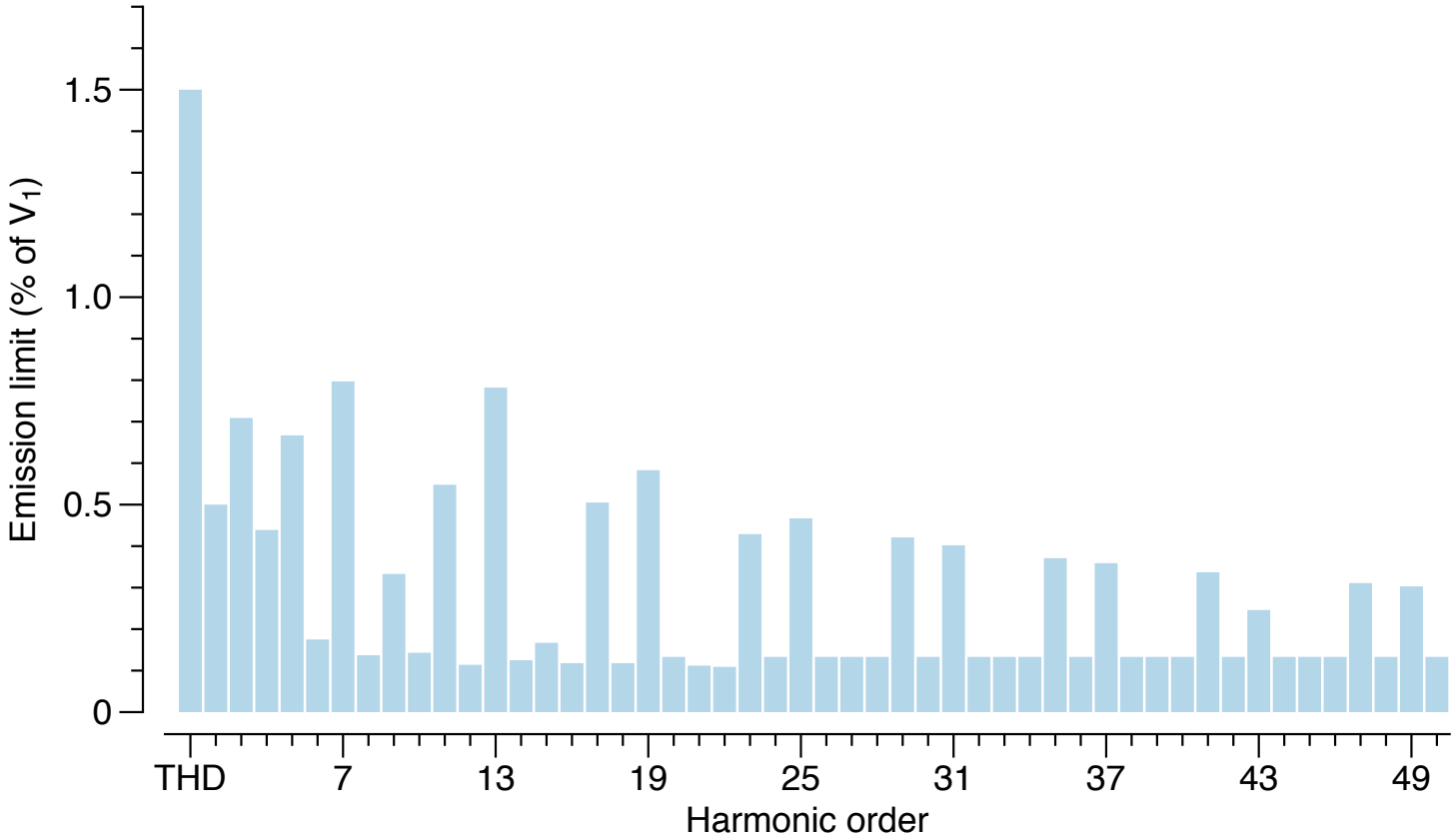
Feeder station topology



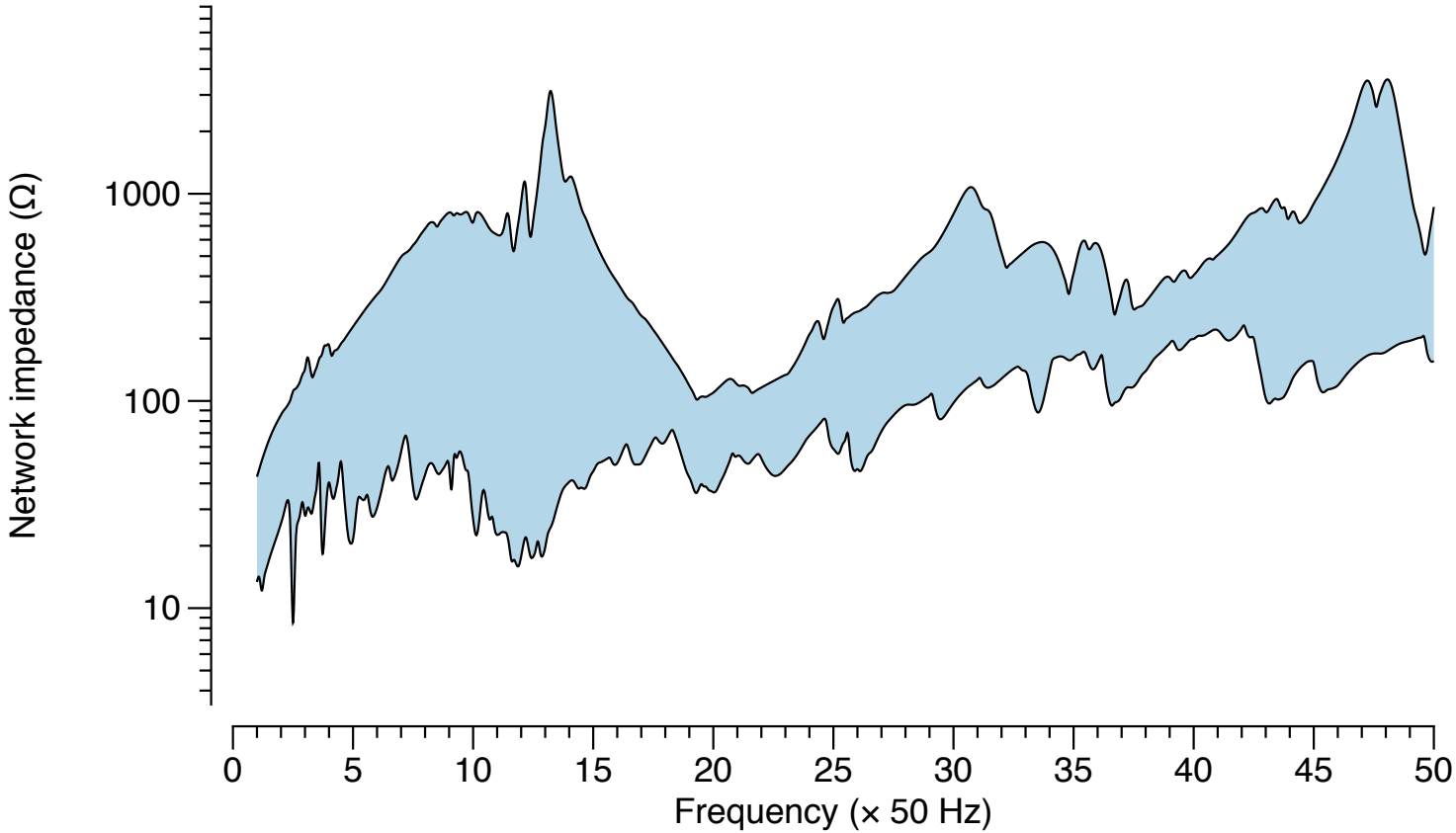
Note: (AB)/(BC) phasing is typical

- Requires single phase compensation
- Limited output power

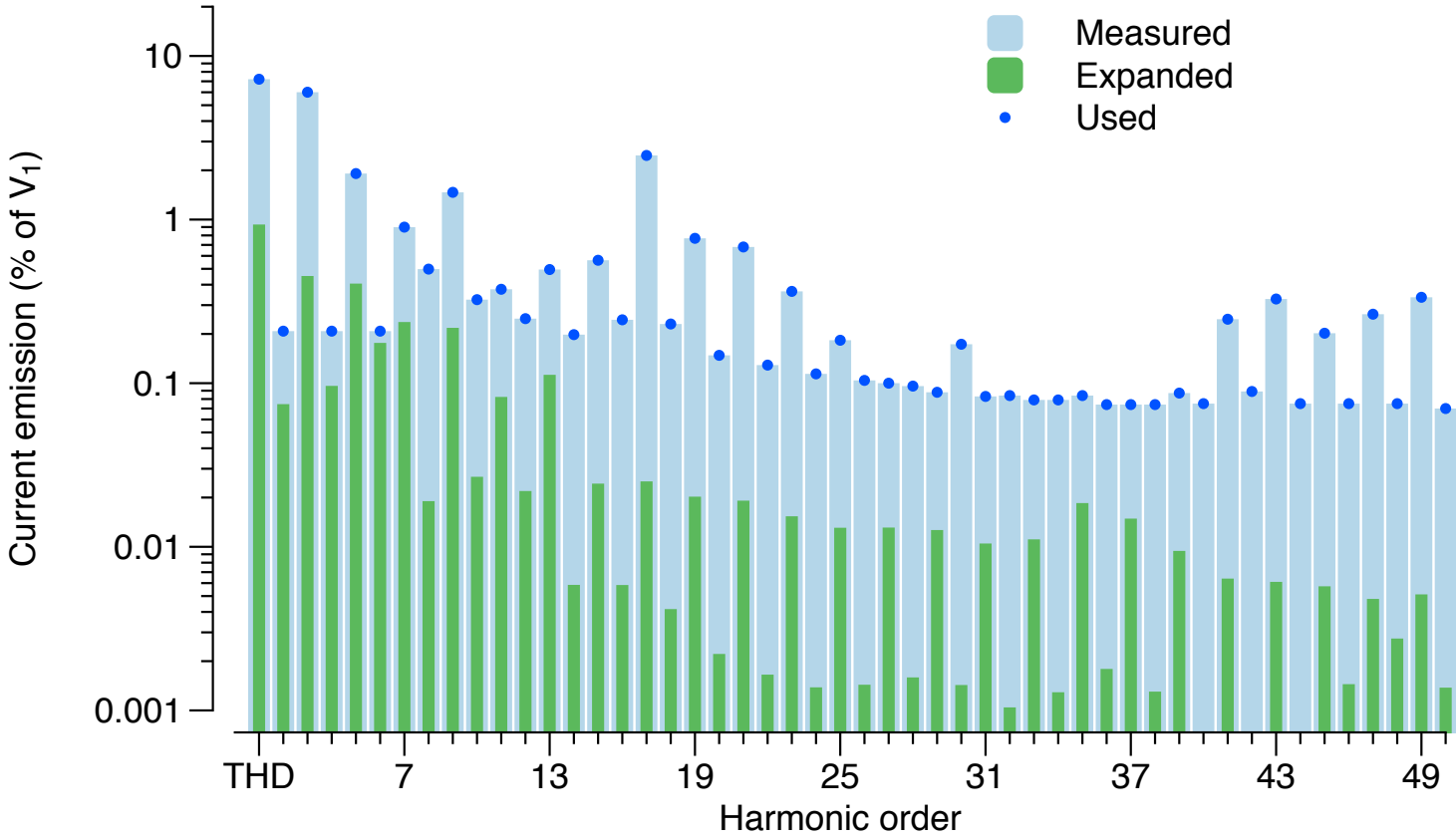
Emission limits



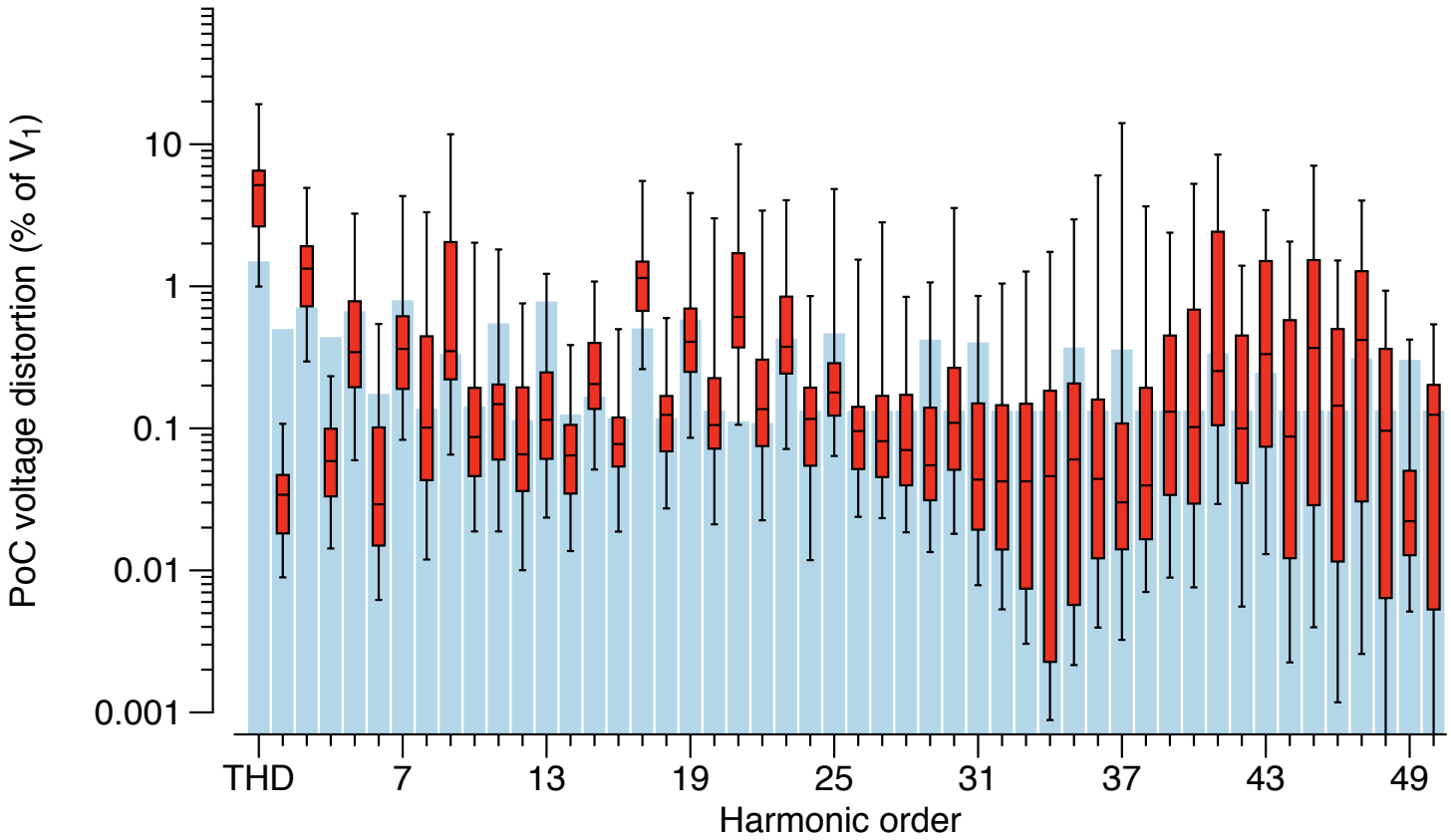
Range of network conditions



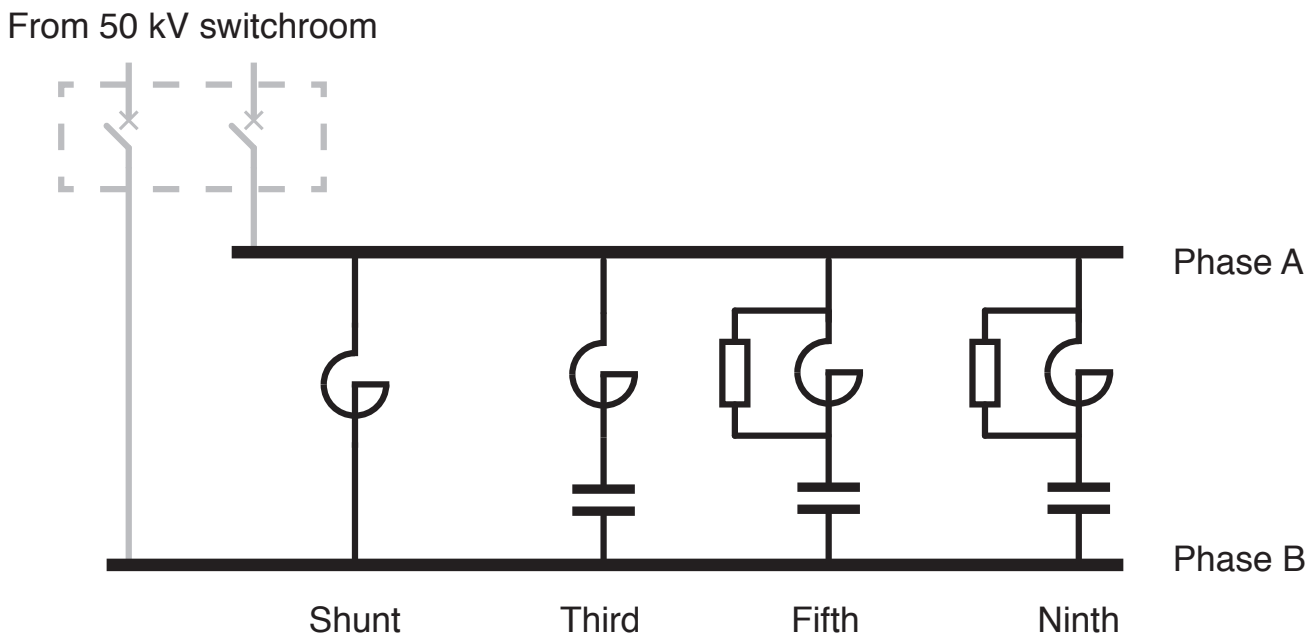
Current spectra



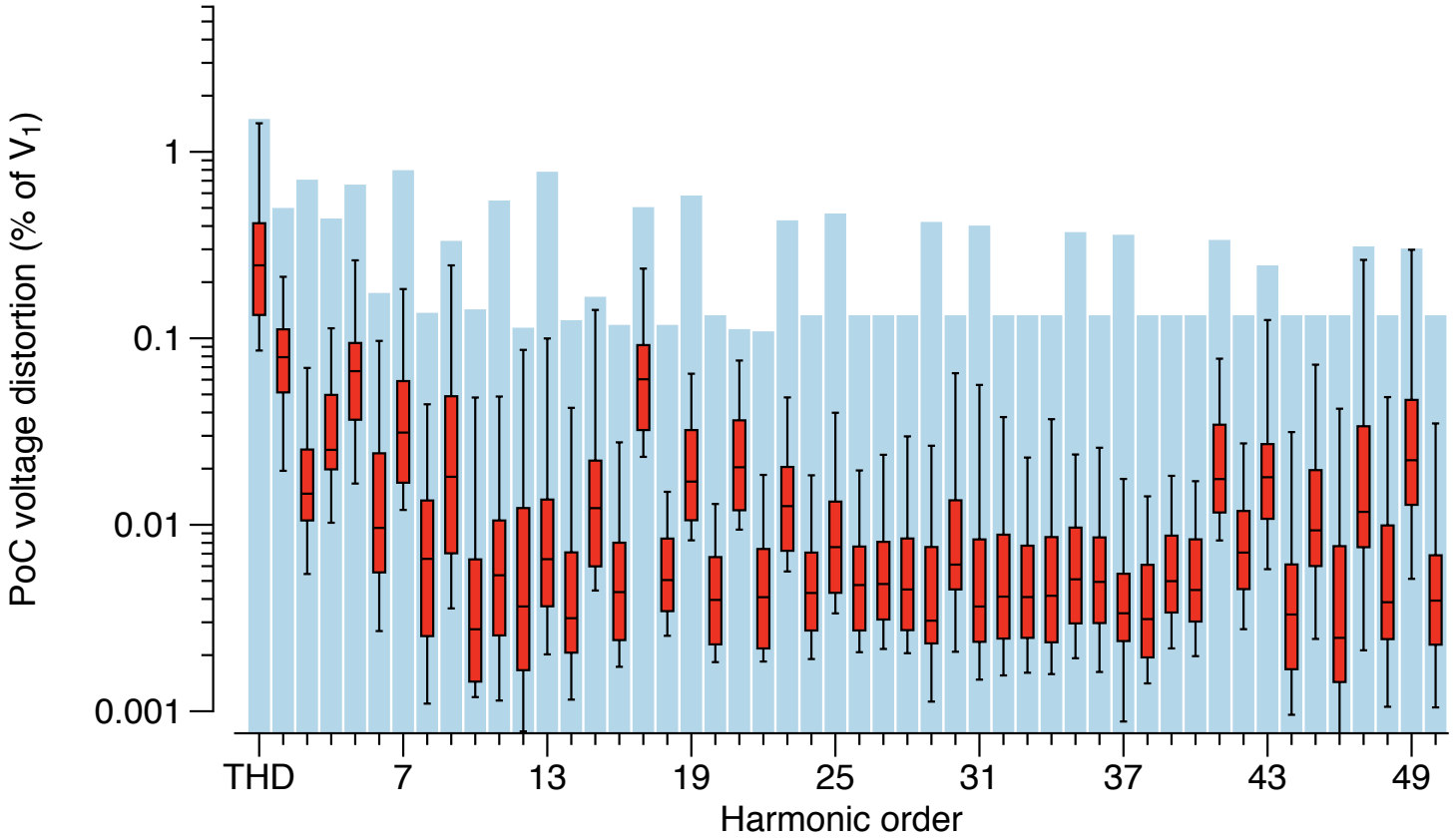
Voltage distortion without filters



Filter configuration



Voltage distortion with filters



Filter parameters

Branch	*Type*	*Rating* (Mvar)	*C* (μF)	*L* (mH)	R_p (Ω)	*Tuned to* (Hz)
Shunt	—	20	—	398	—	—
Third	Single tuned	7	7.92	142	—	150
Fifth	Damped	5	6.11	66.3	800	250
Ninth	Damped	18	22.6	5.53	50	450

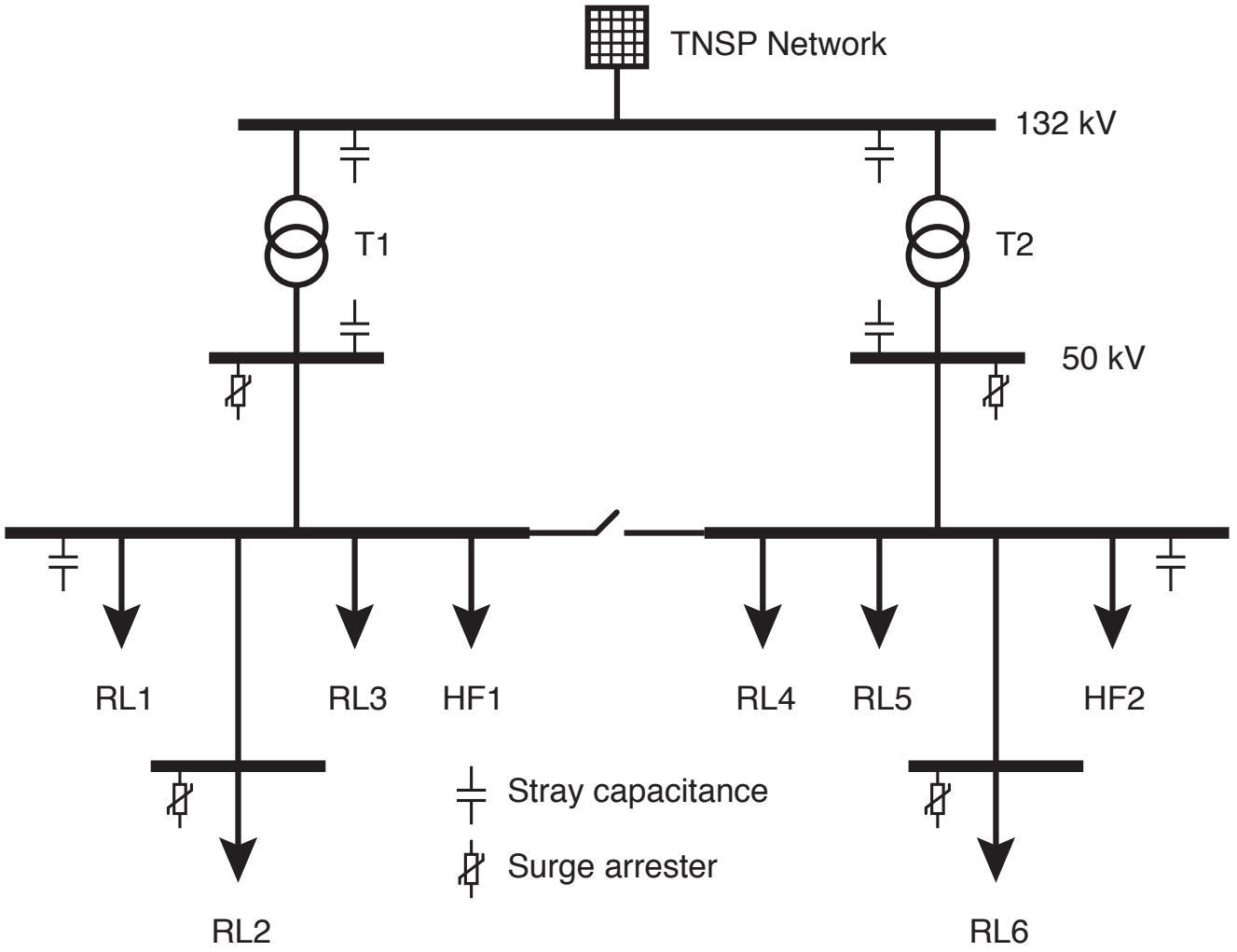
Component ratings

	Capacitor V_N *(kV)*	*Reactor* I_{RMS} *(A)*	*Resistor* P_R *(kW)*
Third	78.2	178.78	–
Fifth	64.8	117.21	16
Ninth	61.0	414.45	80

Electromagnetic study

- Design for electromagnetic transient (EMT) phenomena
  - Peak voltage across capacitor banks
  - Peak currents
  - Protection setting stability
- Studies for switching transients and lightning surges
- Specification of mitigation measures

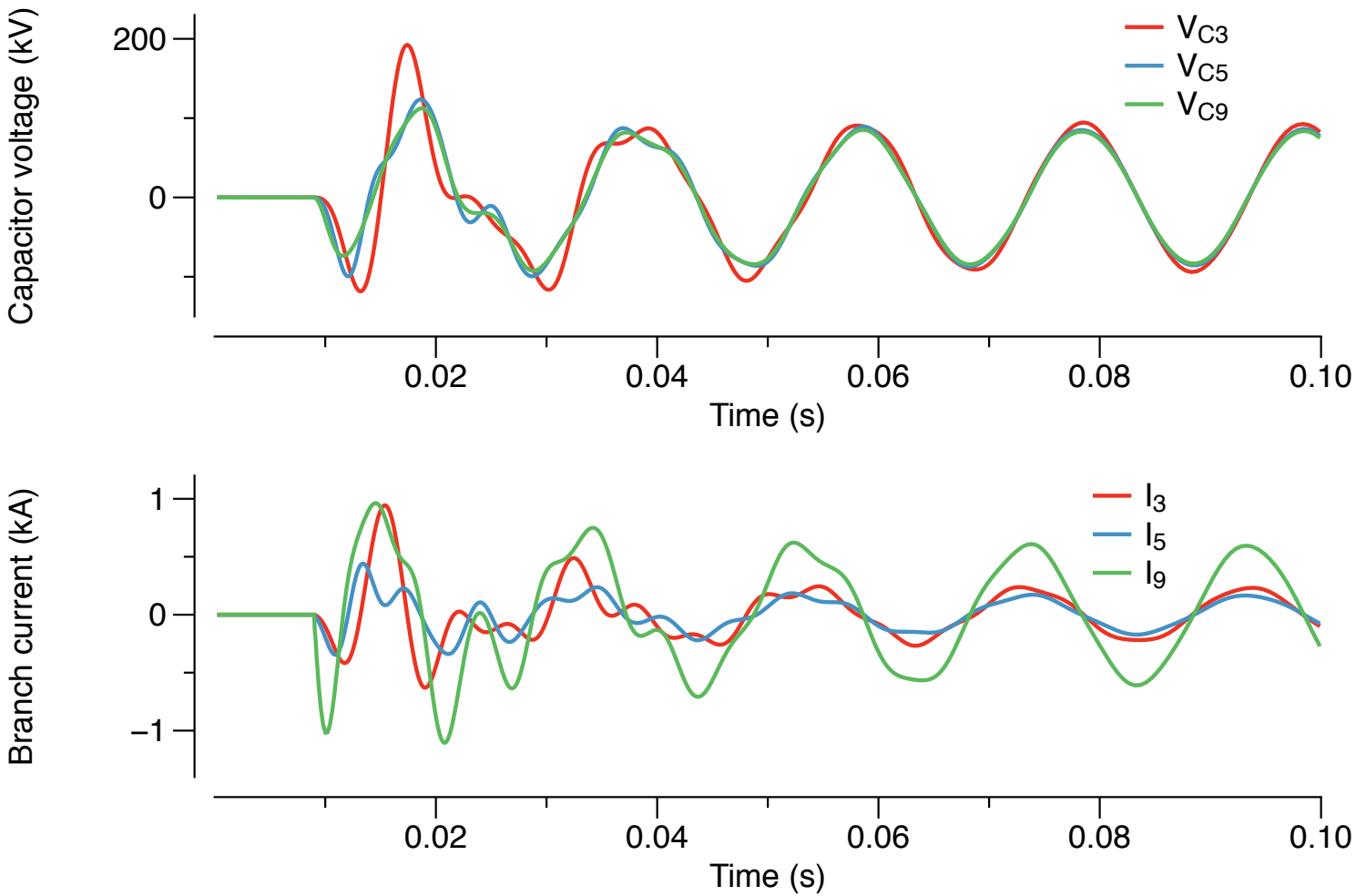
Model augmentation for EMT study



PowerFactory simulation

- Operational scenarios to define different switching arrangements
  - 1 or 2 transformers online
  - 1 or 2 filters online
  - Several different track feeder arrangements
  - Lightning strike points
- Study cases for each switching/lightning case
- Analysis of different point on wave switching
- DPL scripts to automate study cases, print plots and analyse waveforms

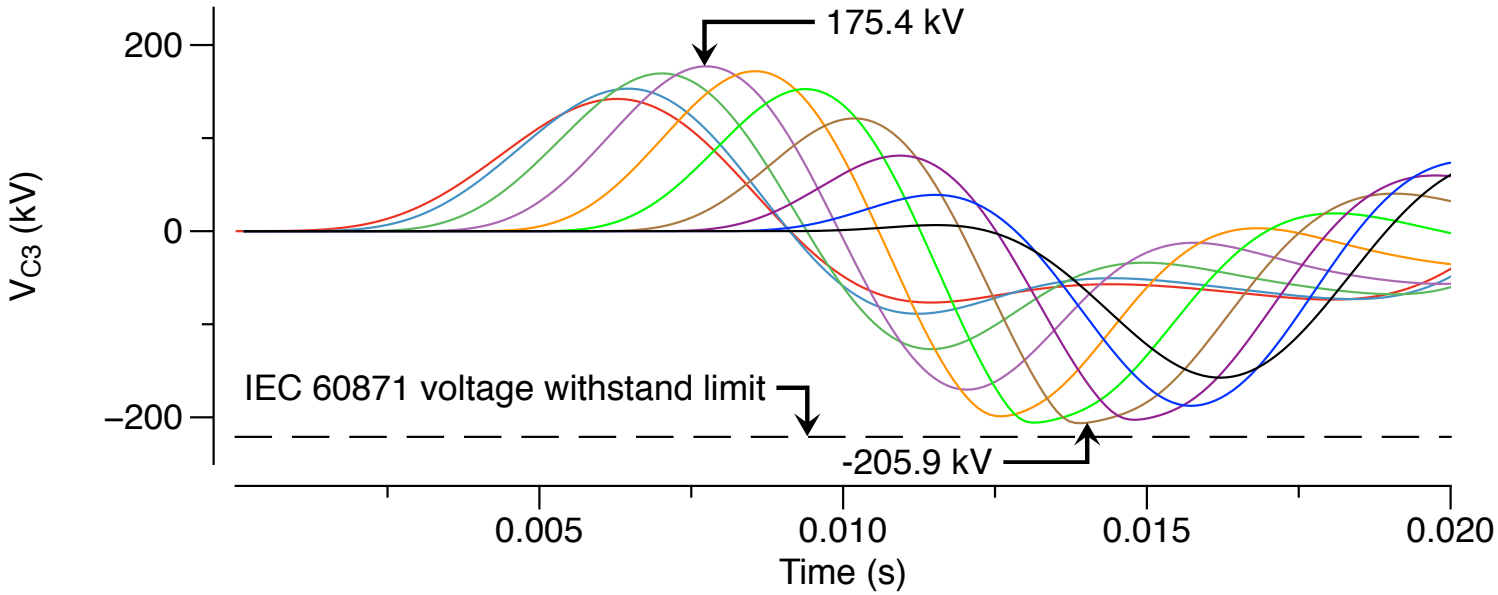
Switching study



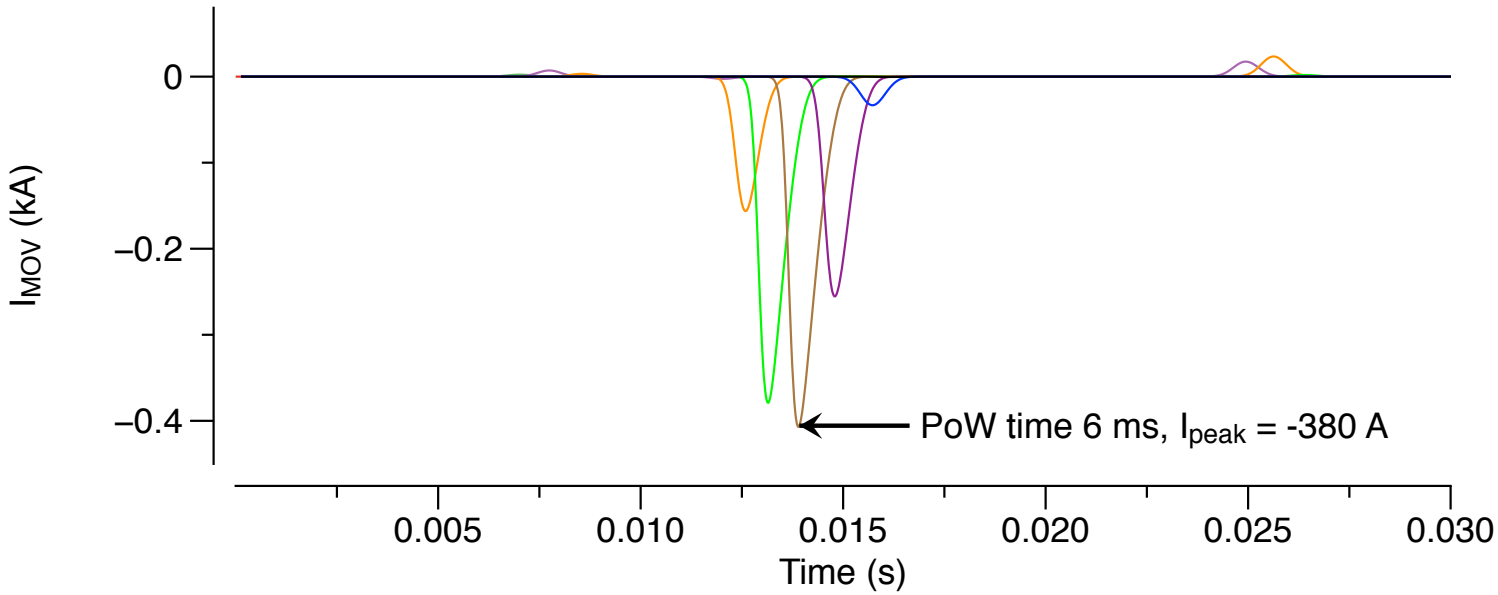
Mitigation measures

- Switching transient
  - Surge arresters specified across the 3^{rd} tuned branch capacitor bank (approaching IEC 60871-1 peak limit)
  - Overcurrent protection graded to avoid spurious trips on filter energisation
- Lightning surge
  - Surge arresters specified for the filter busbars

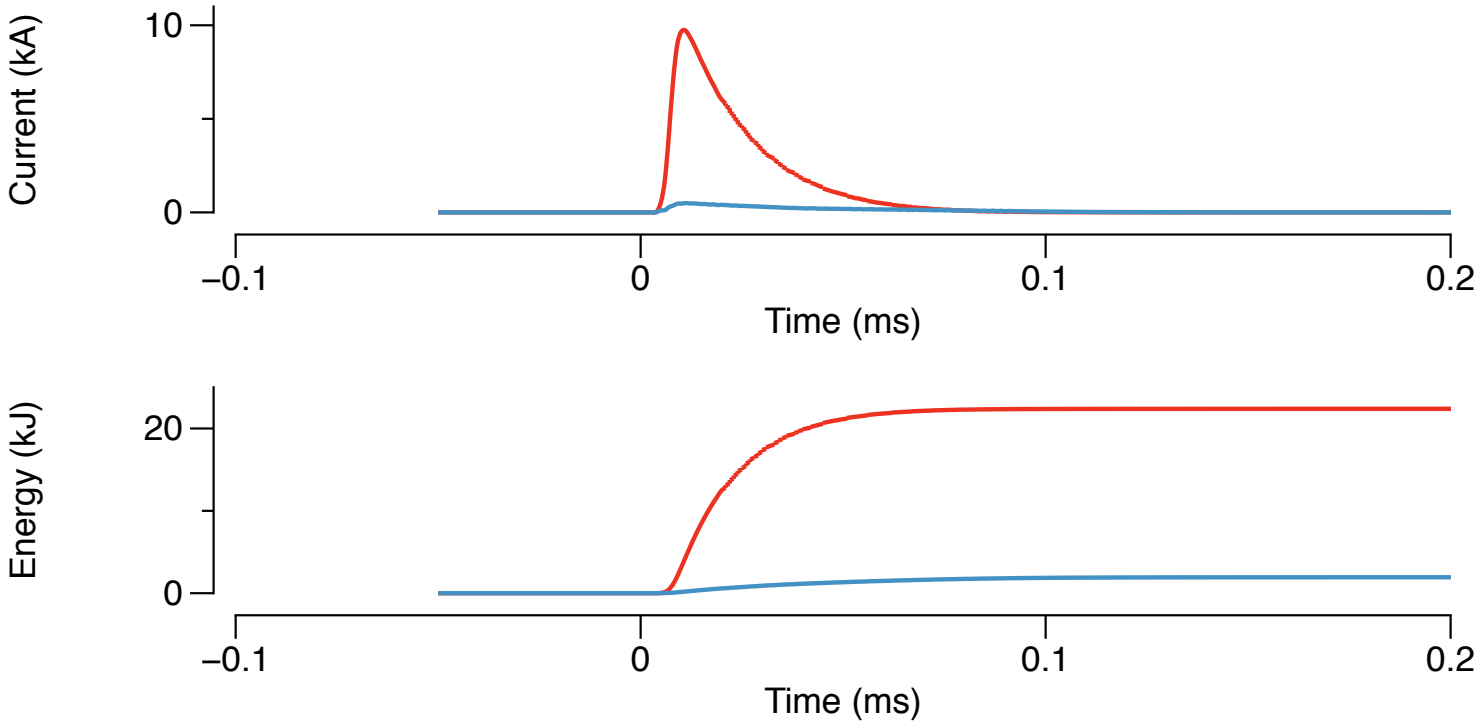
Capacitor bank voltages with surge arresters



Surge arrester current — PoW switching



Surge arrester current — Lightning



Conclusion

Thank you for your time

Questions?