Ulf Radbrandt, 2011-10-31

System aspects on insulation levels for HVDC converter stations

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Introduction, Insulation Coordination

Optimization

- Cost
  - Protection ↗
  - Equipment ↘
- Probability

Type of stresses

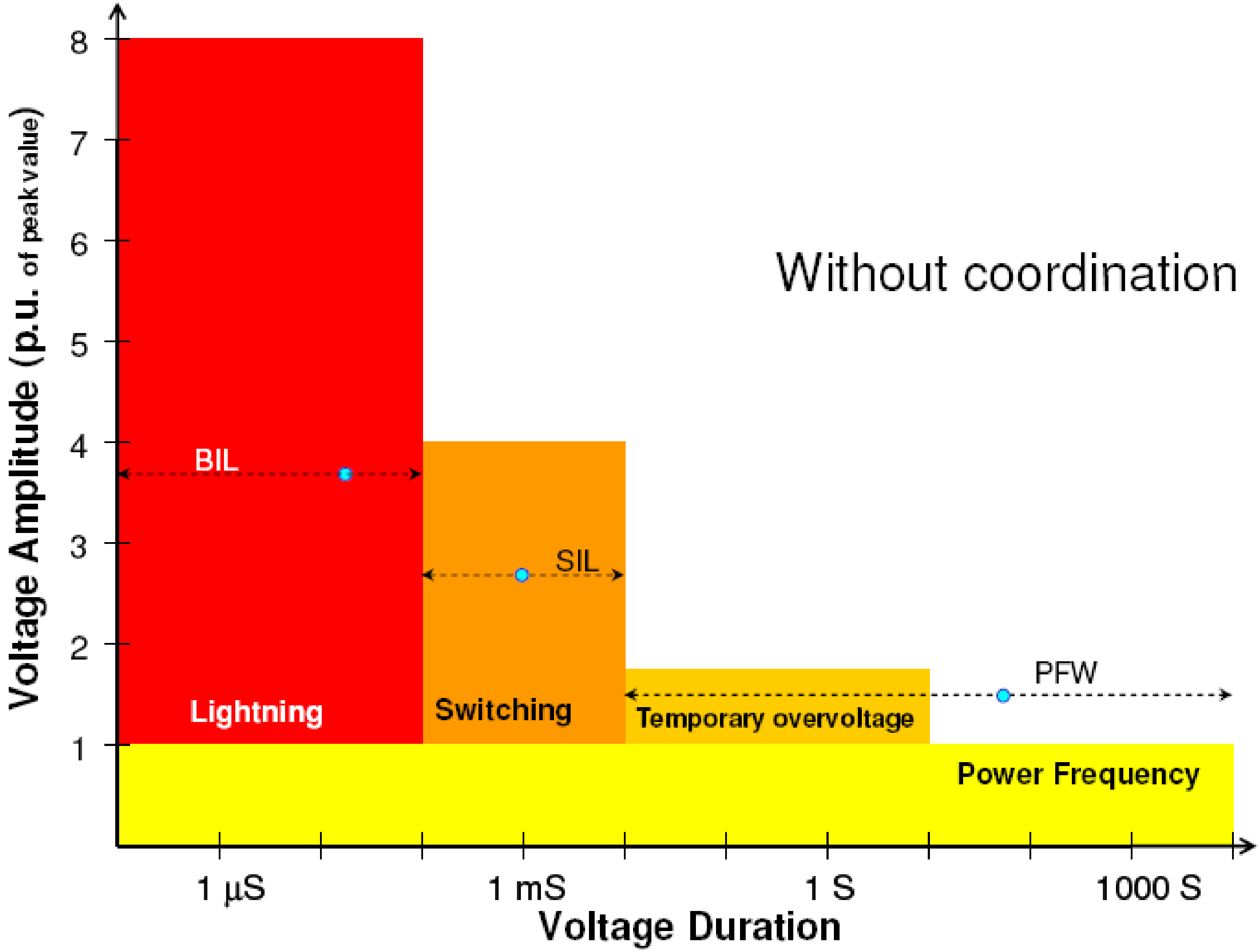
- Continuous AC - Normal operation
  - clean conditions
  - contamination
  - other

- Dry
- Rain
- Snow & Ice

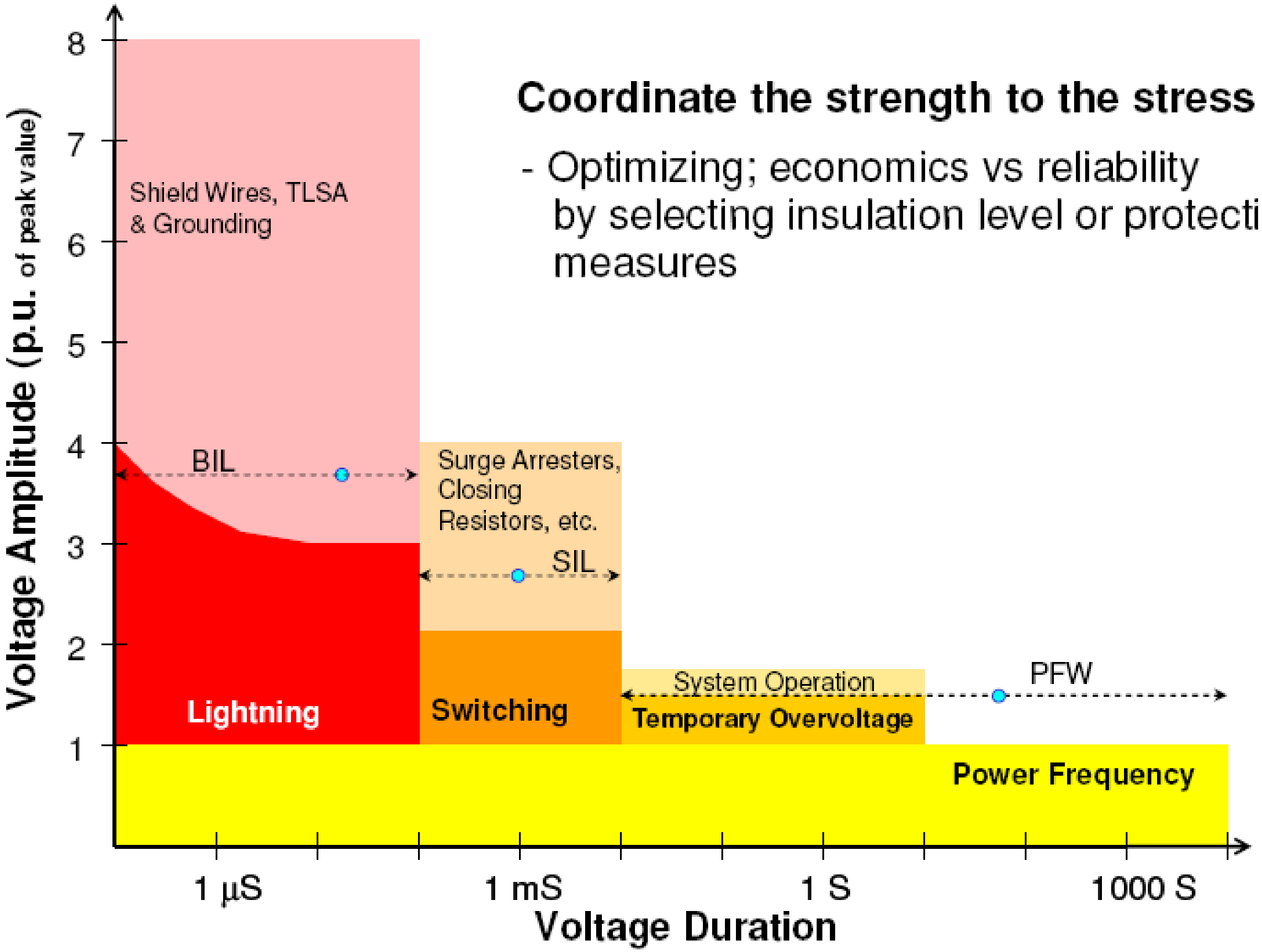
- Birds…
- Fires
- Vegetation

- Temporary overvoltage
  - Abnormal system conditions
- Switching overvoltage
  - System switching operations (lines, loads and equipment)
- Lightning overvoltage
  - Lightning flashes to and around lines

Strength and Stress



Strength and Stress



Coordinate the strength to the stress

- Optimizing; economics vs reliability by selecting insulation level or protective measures

Principles of insulation coordination

Primary objective is:

- Establish maximum steady state, temporary and transient overvoltages on equipment
- Select
  - insulation strength and characteristics of equipment and protective devices

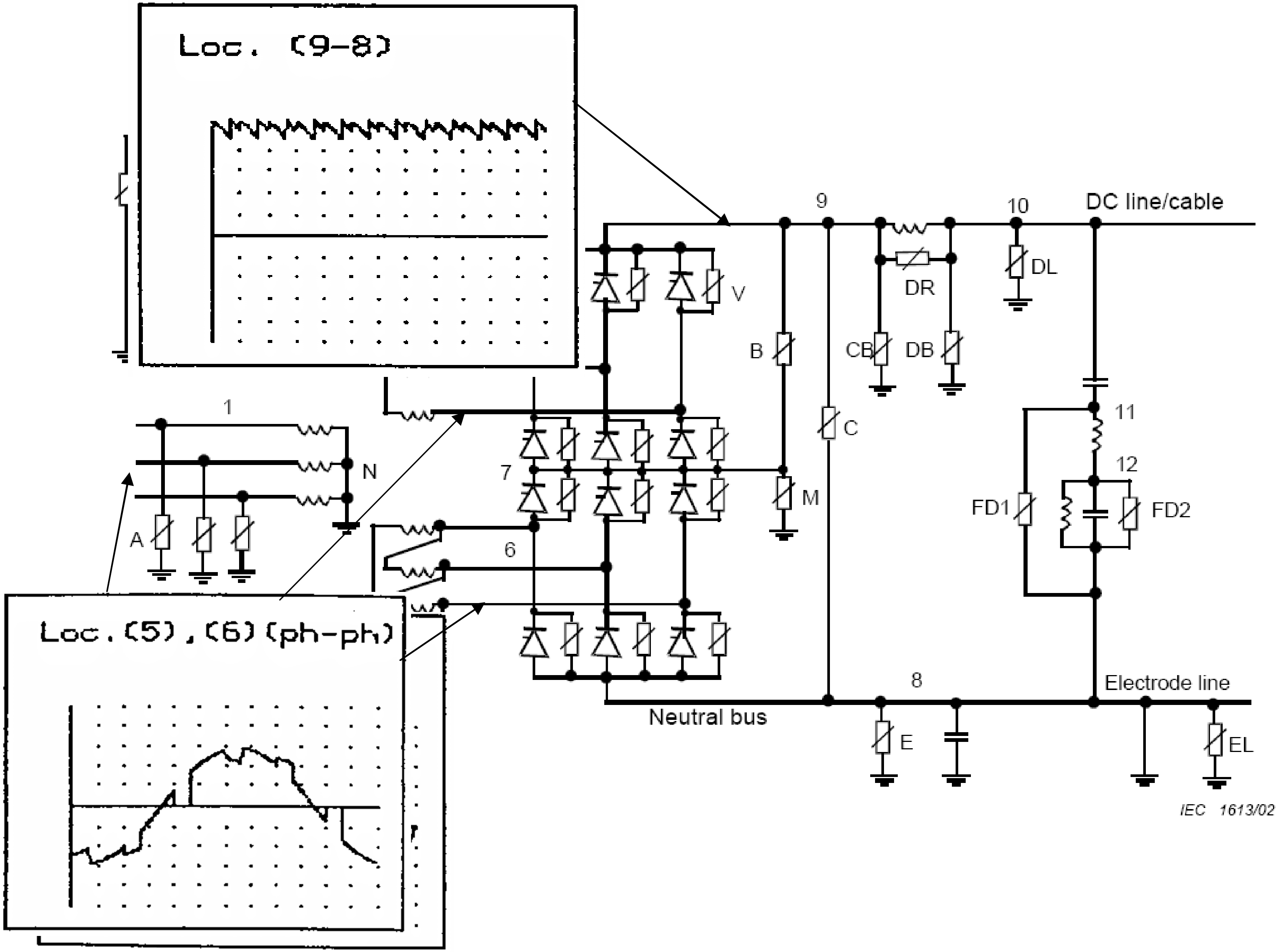
⇓

To ensure a safe, economic and reliable installation.

Insulation coordination Important parameters

- Minimum Short Circuit Capacity,
  - pre and post fault
  - X/R
  - X1/X0
- AC fault clearing times
- Auto-reclosing? Times?
- Maximum system voltage
- Arresters in the surrounding a.c. network characteristics
- DC and electrode line data
- Insulation margins

Voltage profiles - Arrester scheme



Voltages - Establish operating voltages

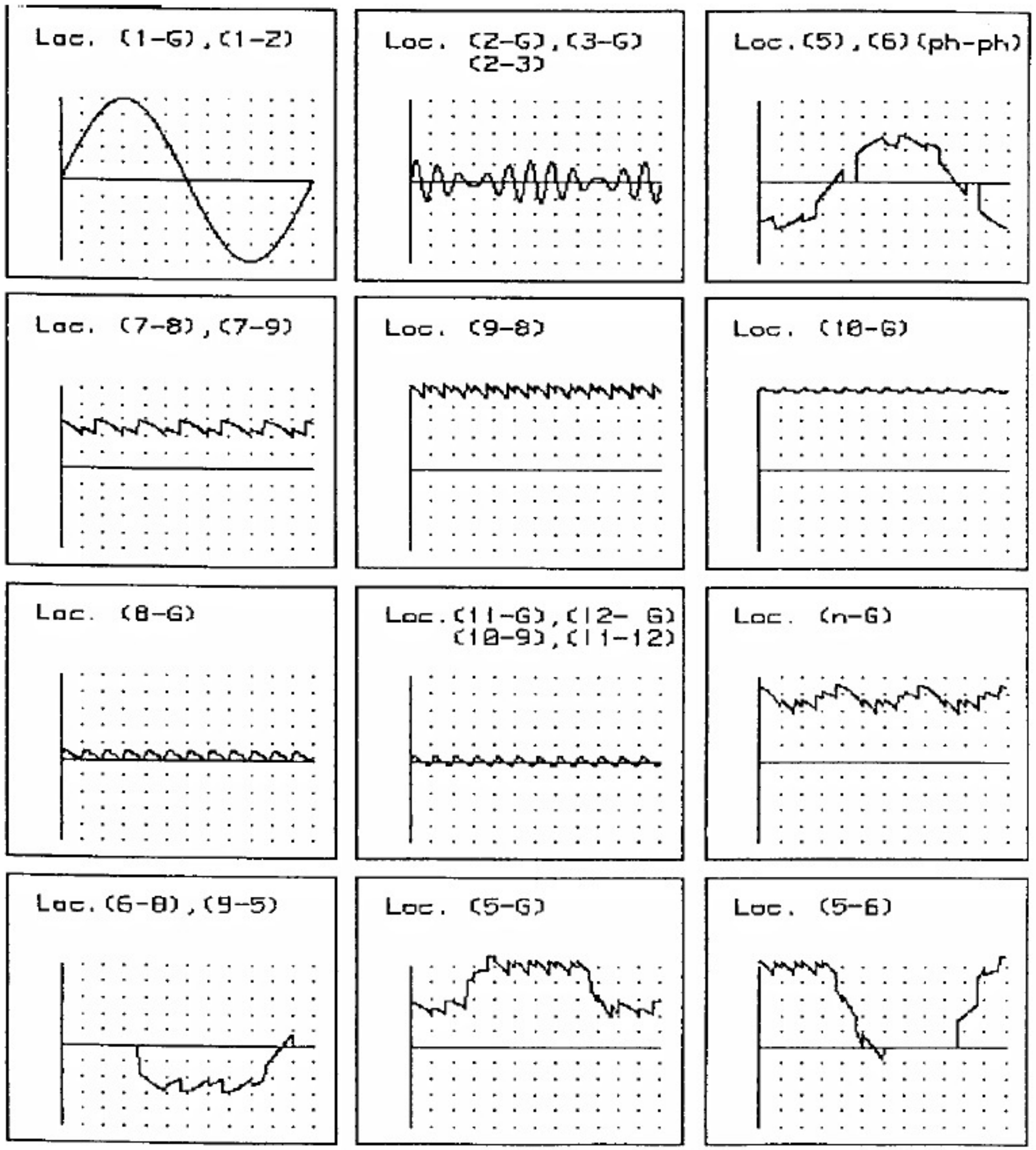
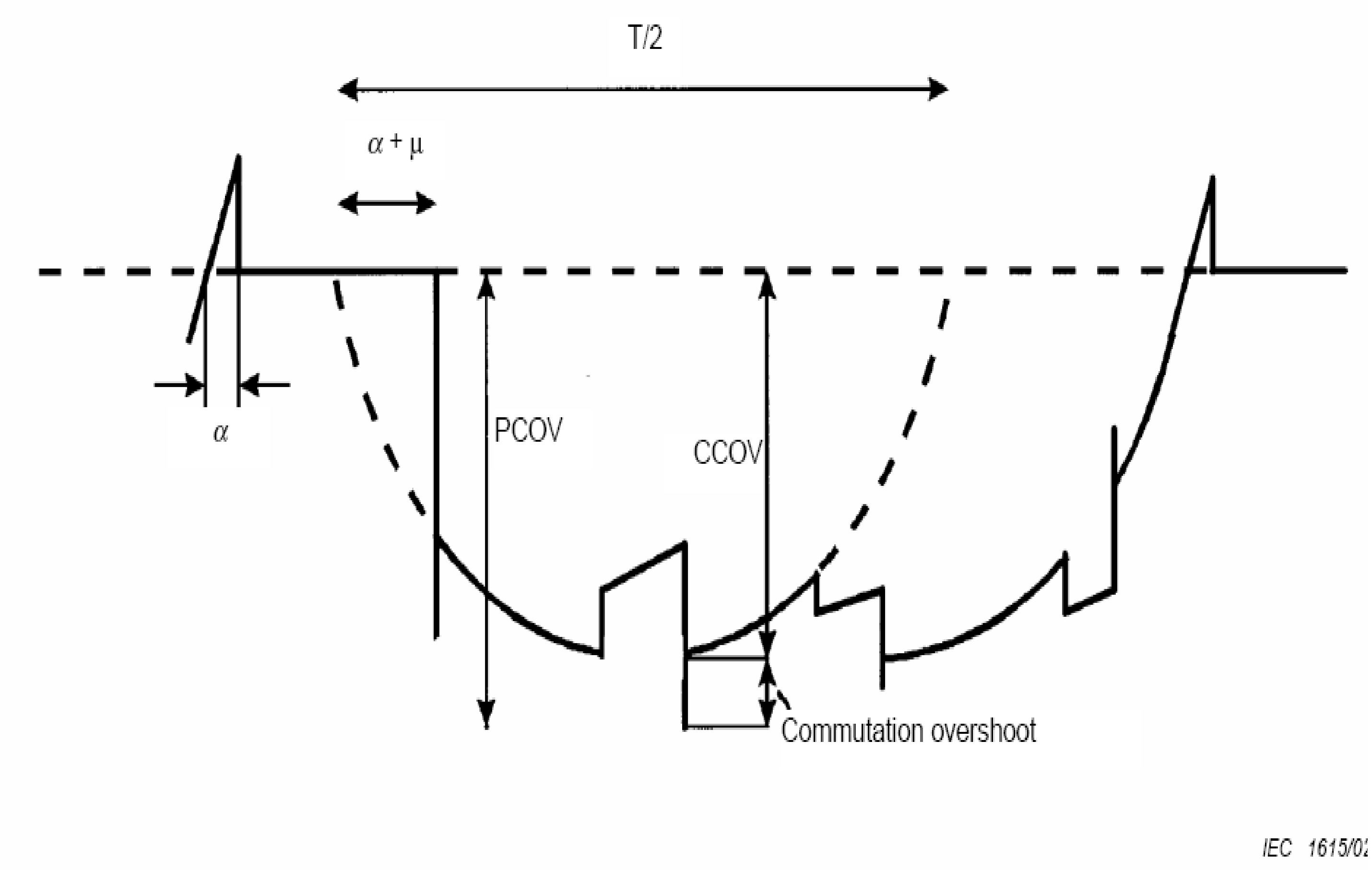


Figure 5 – Continuous operating voltages at various locations (location identification according to figure 4)

Valve voltages



$CCOV = \pi/3 * U_{di0absmax}$

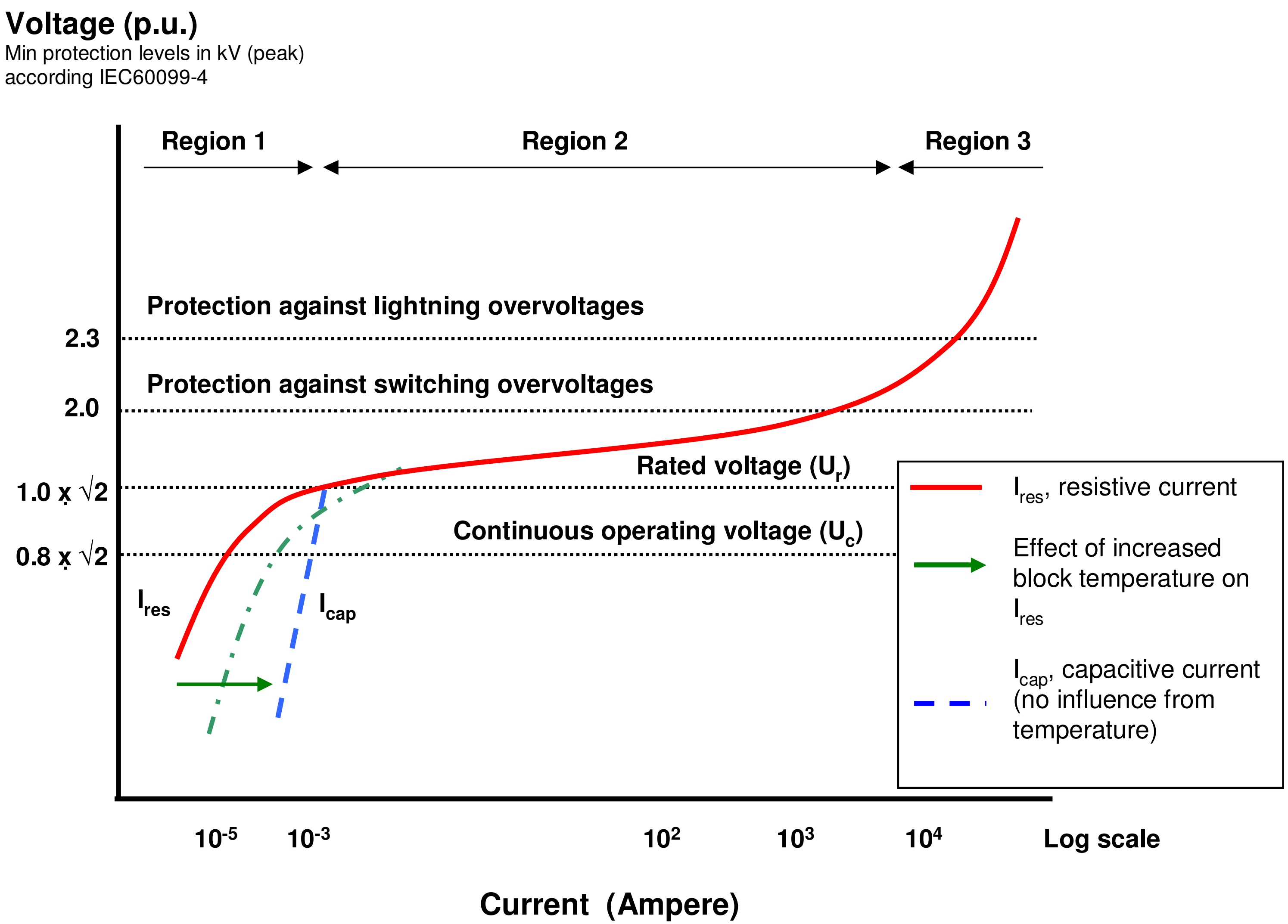
Figure 6 – Operating voltage of a valve arrester (V), rectifier operation

Surge Arresters – Polymeric type

PEXLIM P arrester

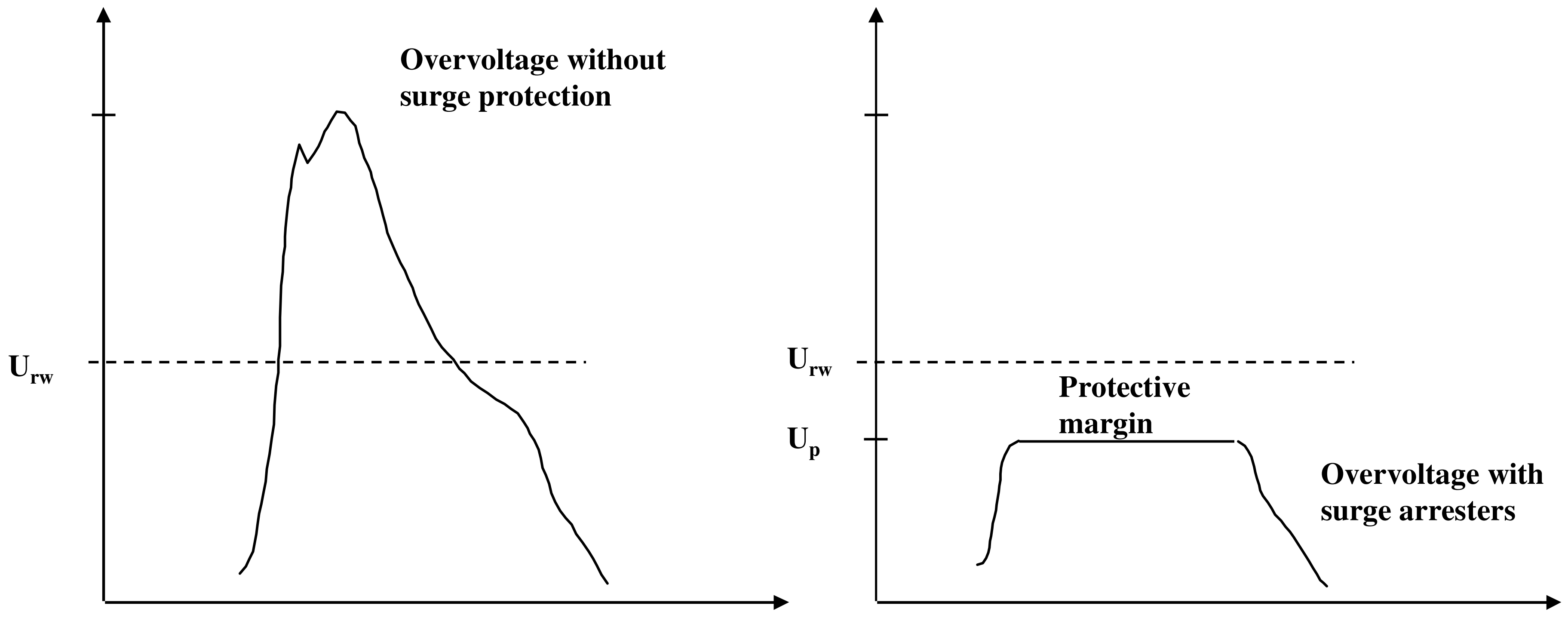
Surge Arresters - Valve hall arrester

Surge Arresters



Surge Arresters – Protective parameters

U_{rw} = Insulation level of equipment
U_p = Protective level of the S.A.



Insulation Coordination

- Exemple of minimum Insulation margins (based on IEC 60071-5):

Valves

- 20 % for steep front impulses
- 15 % for lightning impulses
- 15 % for switching impulses

DC equipment

- 20 % for lightning impulses
- 15 % for switching impulses

Converter transformer, valve side

- 20 % for lightning impulses
- 15 % for switching impulses

AC equipment, line side

- 25% for lightning impulses
- 20 % for switching impulses

Factors affecting on surge arrester dimensioning

- Continuous operating voltage
- Climate (ambient temp., rain, sunshine)
- Mechanical stresses
- Temporary overvoltages, TOV
- Transient overvoltages
    - Protection function
    - Energy- and current strength
    - Outer insulation
- High outer pollution
- Short circuit proof

Energy dimensioning

- Current amplitude
- Duration
- Time between current pulses
- The number of pulses before cooling
- Total energy

Surge Arresters – Difference between AC and DC

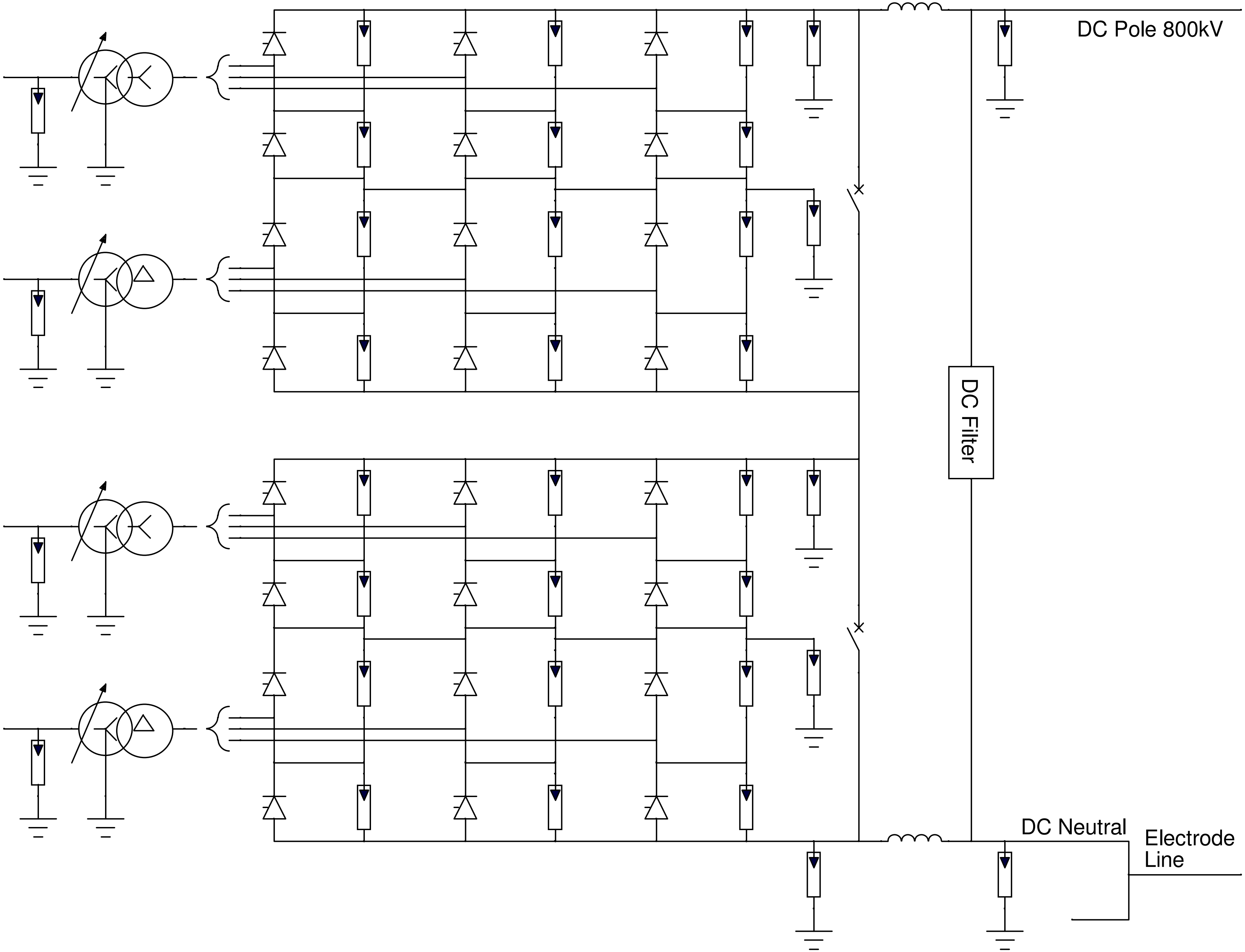
AC

- **Much higher current through arresters (coordinating current) for lightning than for switching overvoltages. That leads to higher BIL than SIL**
- **The same maximum operating voltage in both ends of a transmission line**

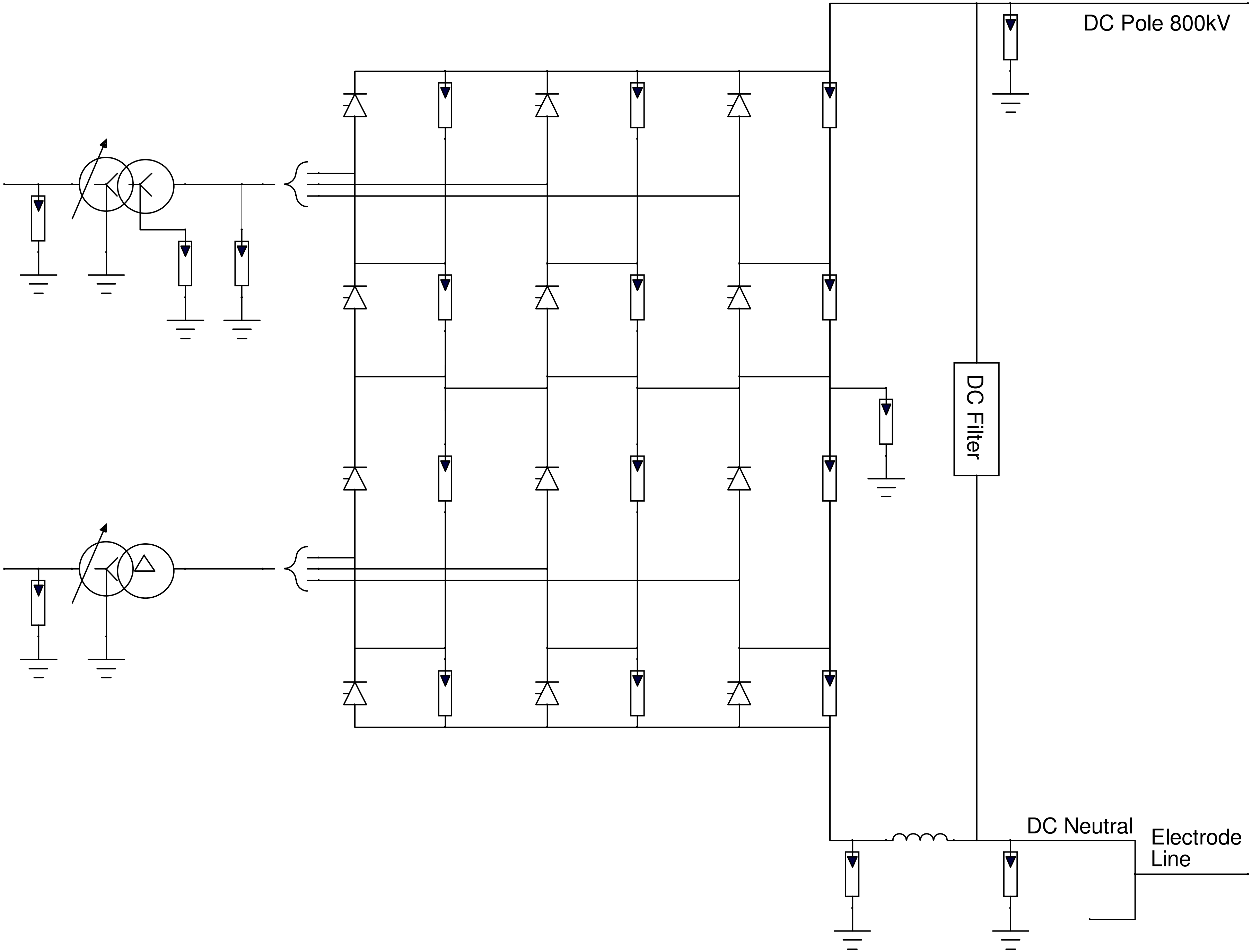
DC

- **About the same current through arresters (coordinating current) for lightning as for switching overvoltages. That leads to about the same BIL as SIL**
- **Lower maximum operating voltage in the receiving end of a transmission line**

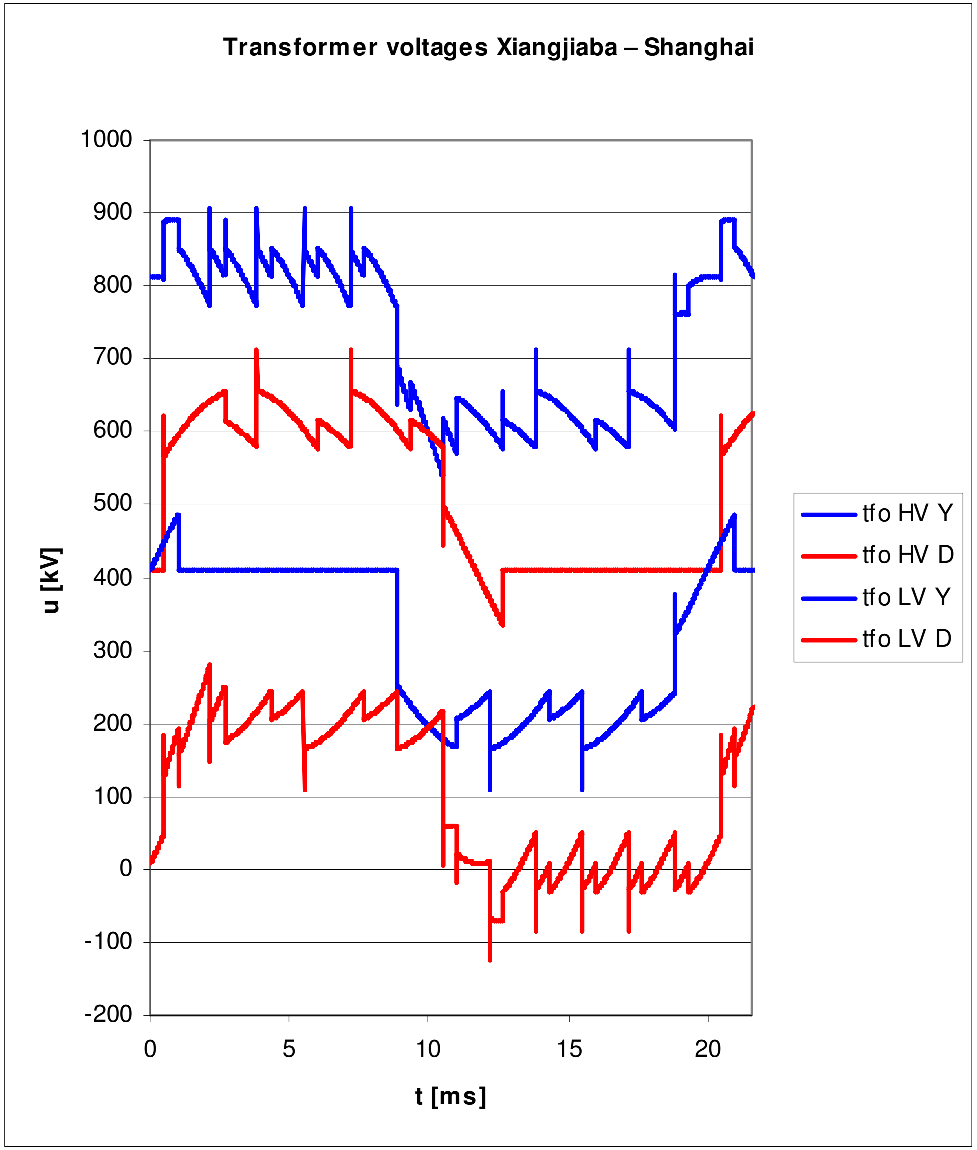
Converter Configuration for Xiangjiaba – Shanghai

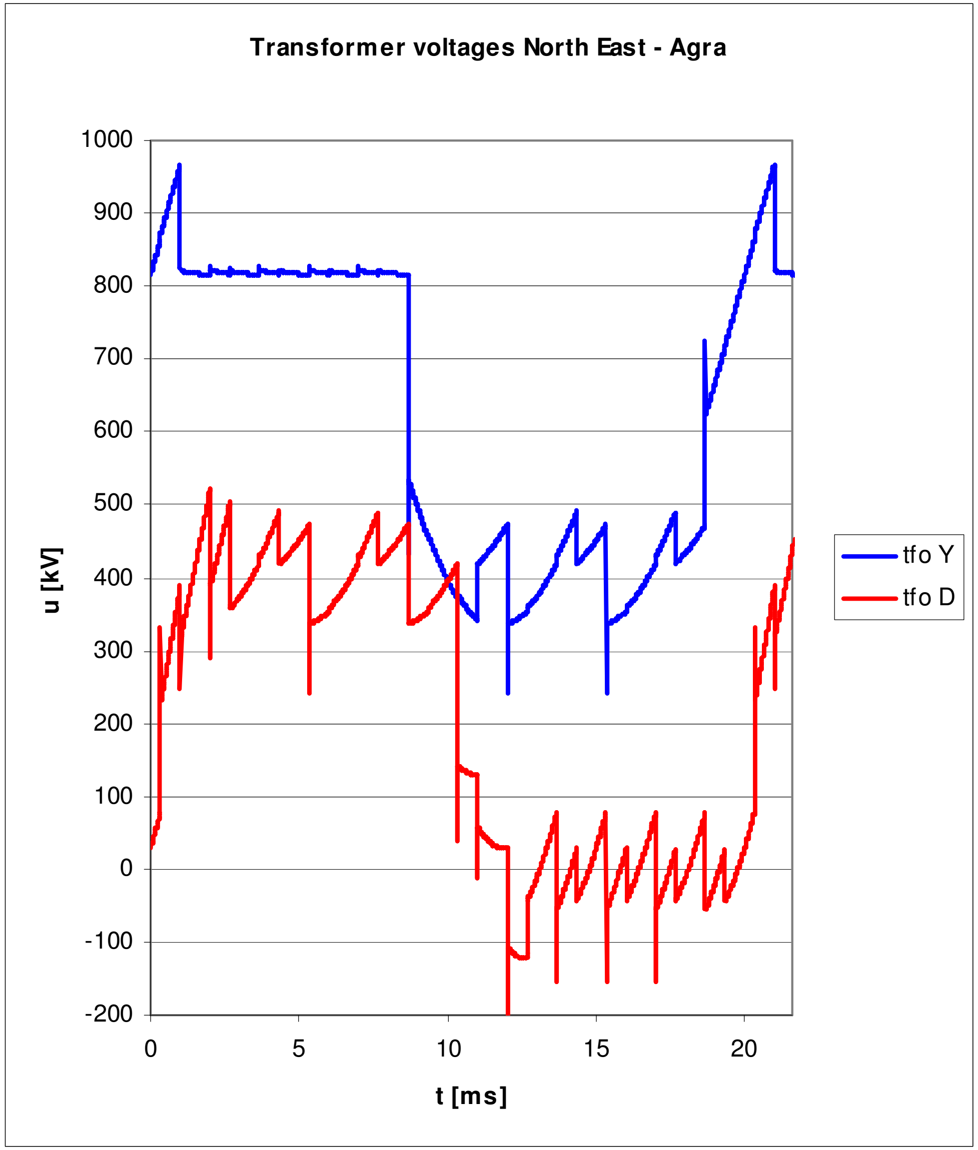


Converter Configuration for North East - Agra

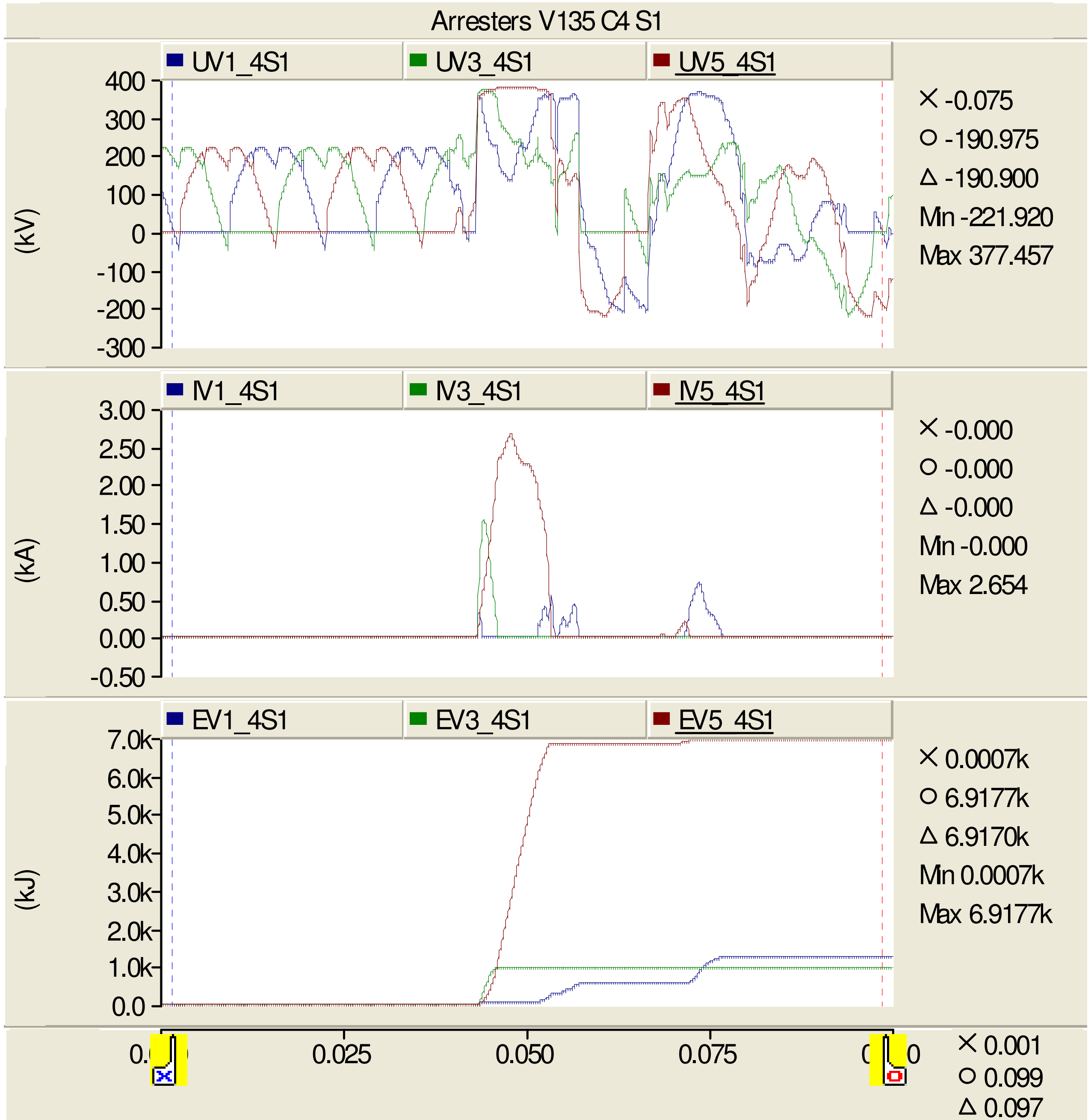


Transformer voltage characteristics – Steady State





Transformer voltage characteristics – Transient



Pros and cons with standard insulation levels for HVDC

Pros:

- Manufacturers can standardize their product portfolios
- Utilities can have the same equipment for several converter stations (same voltage level)
- Increased insulation margins for e.g. transformers and bushings because thyristor valves will be optimized anyway (minimized insulation levels)
- Less need for thorough calculations/simulations?

Cons:

- Standard levels will mean higher levels (due to e.g. different insulation margins by different utilities and different minimum short circuit capacity) which will give higher cost for equipment
- Higher insulation levels will limit the number of possible test institutes
- Higher insulation levels for transformers will lead to increased difficulties for transport
- Higher insulation levels for transformers will lead to increased amount for oil
- Higher insulation levels for transformer bushings will lead to increased size of valve halls
- Correction factors for external insulation might require selection of the next standard level
- Higher insulation levels for transformers might lead to higher commutation reactance which will lead to increased number of thyristors and increased need for reactive power compensation

Ongoing work within IEC

<u>Extract from IEC TS 60071-5, Insulation co-ordination – Part 5 HVDC:</u>
“Selection of standard withstand voltages for a.c. side equipment only. The present step is skipped for equipment on d.c. side because there are no standardized withstand voltage levels for such equipment

For equipment on the d.c. side, specified insulation levels are rounded up to convenient practical values”

<u>Ongoing work for the revision of IEC 60071-5</u>
The work is going in the direction to even more emphasize the principle with tailor made insulation coordination and insulation margins instead of standard insulation levels within the converter
The following line is added in the new draft under Clause 6.1 Essential differences between a.c. and d.c. systems:
“• there exist no standard insulation levels in the case of d.c. systems“

The following is added in the new draft under Clause 12 Clearances in air:

- “The clearances in d.c. applications are based on insulation levels of equipment which are determined to provide the appropriate margin over the protective level of the arresters rather than on standard equipment levels.“