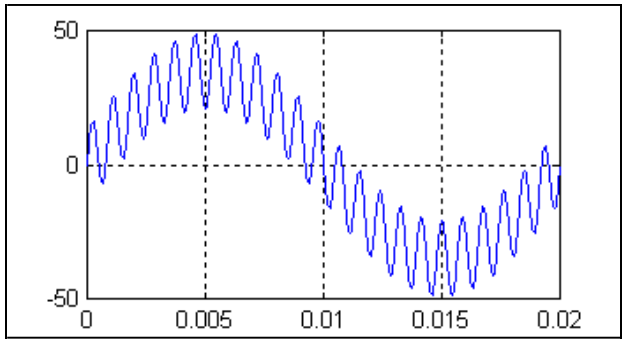
Known problems caused by OHL harmonics

Line voltage ripple

- High peak voltages, surge arrestor overloading
- Multiple zero crossings, loco control systems
- Distorted trainline voltage



Excessive interference currents, psophometric currents, etc.

Overloading of filters in other trains, due to "vacuum-cleaner" effects

Distortion of the Power Grid

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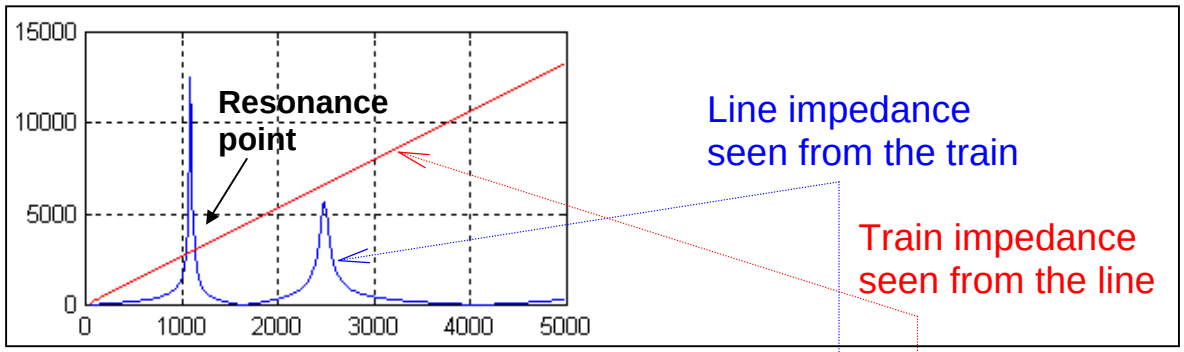
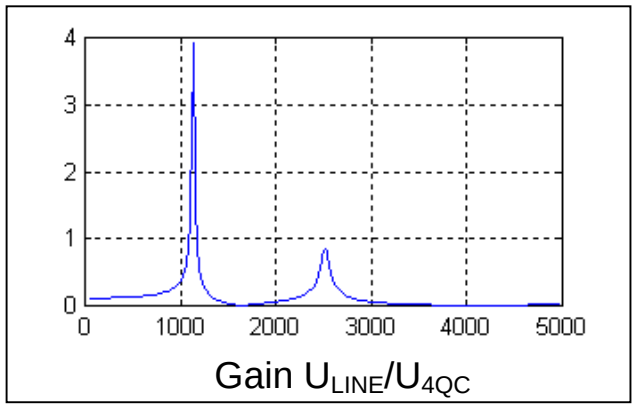
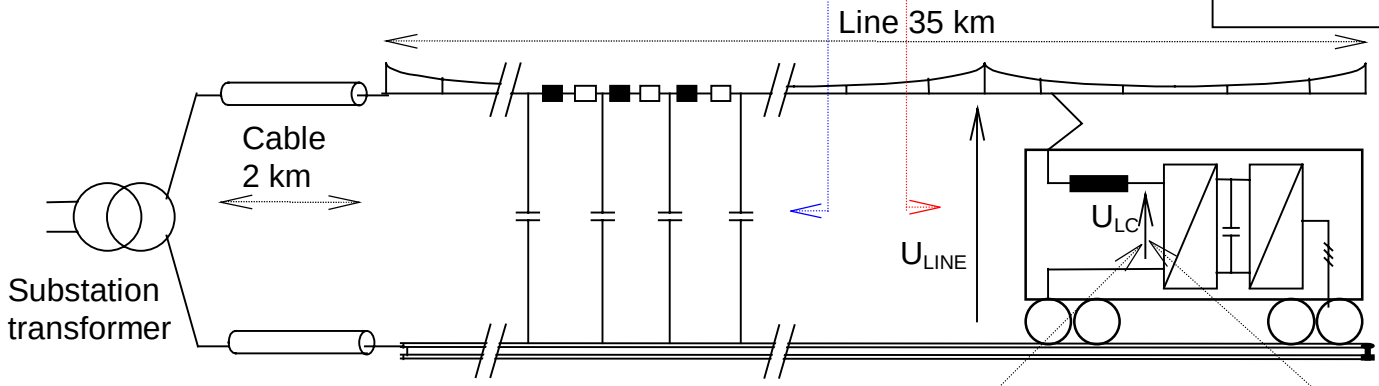
AC Line Harmonics - Problems and Countermeasures



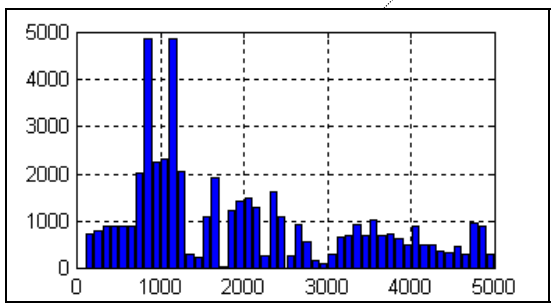


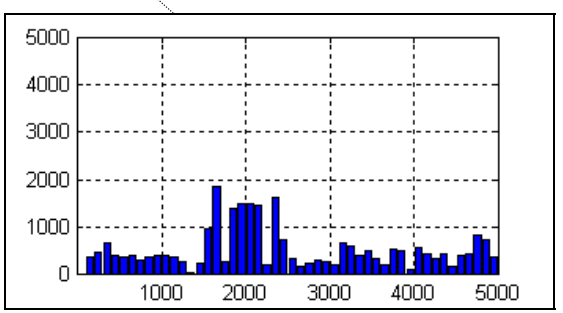


Resonances between the capacitive line and the inductive train (transformer!) cause amplifications of 4QC harmonics!

Examples, 4QC voltage spectra.
50 Hz line frequency,
250 Hz switching frequency.

Left: 2 interlaced bridges
Right: 4 interlaced bridges
(levels refered to the primary side)





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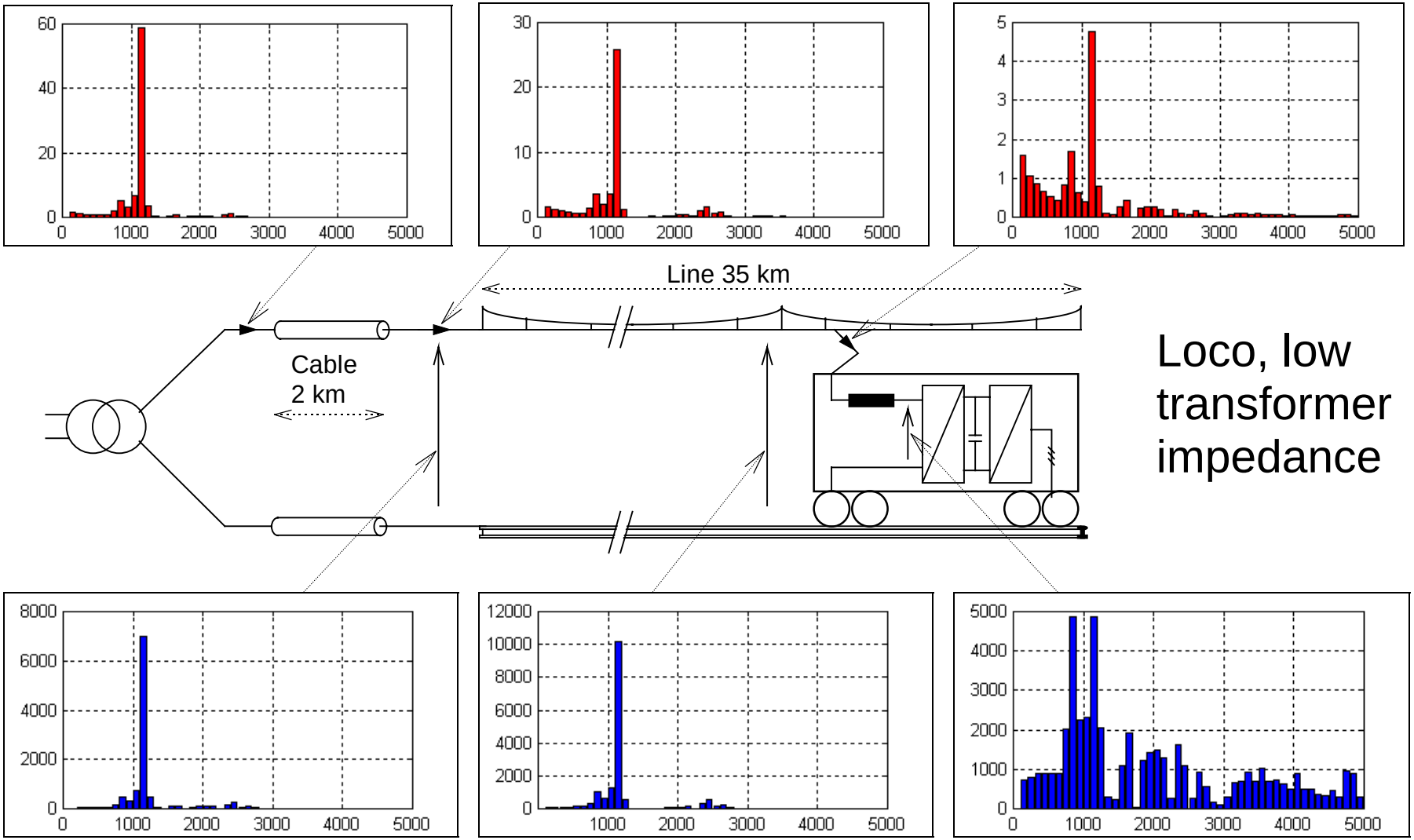
AC Line Harmonics - Problems and Countermeasures



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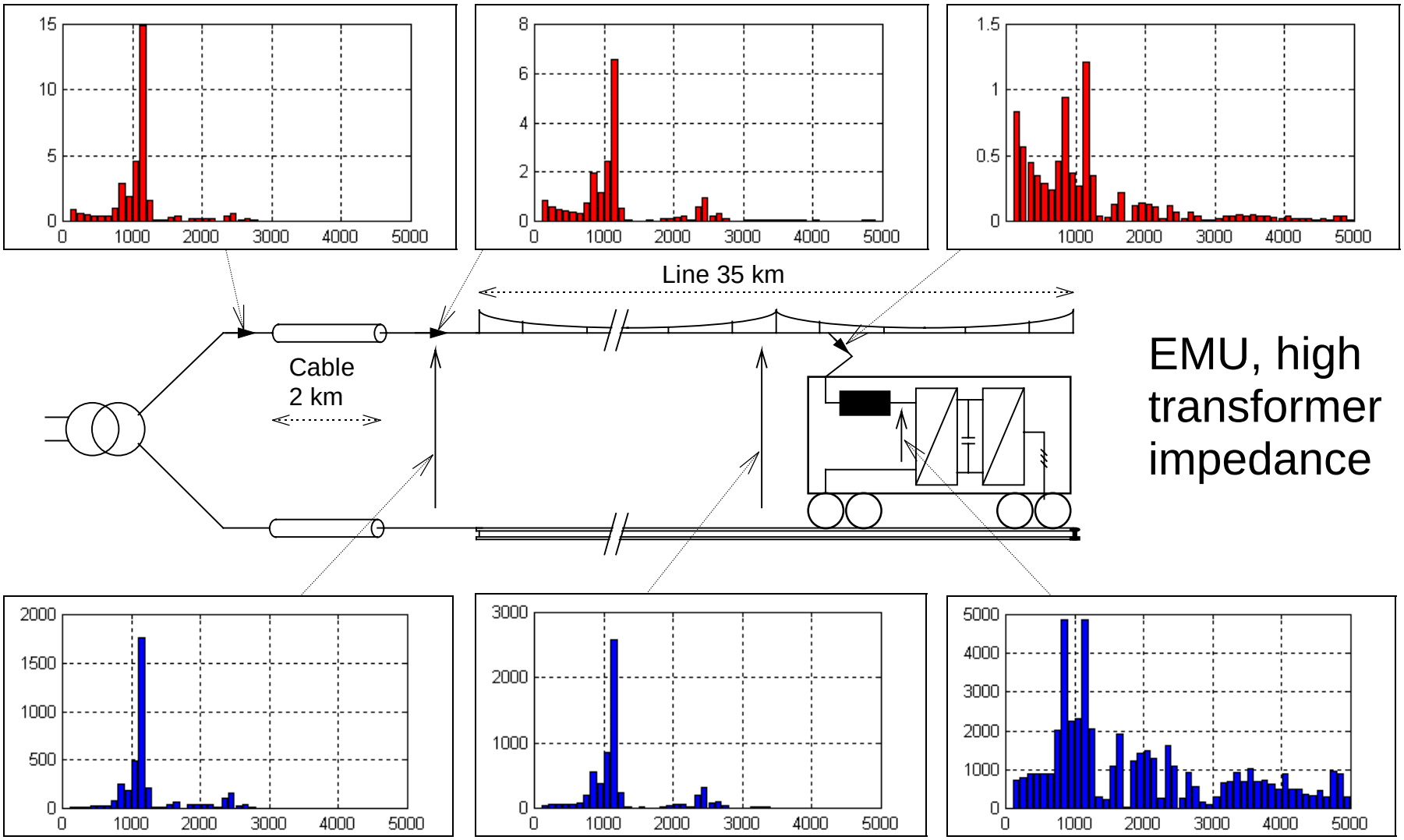
AC Line Harmonics - Problems and Countermeasures



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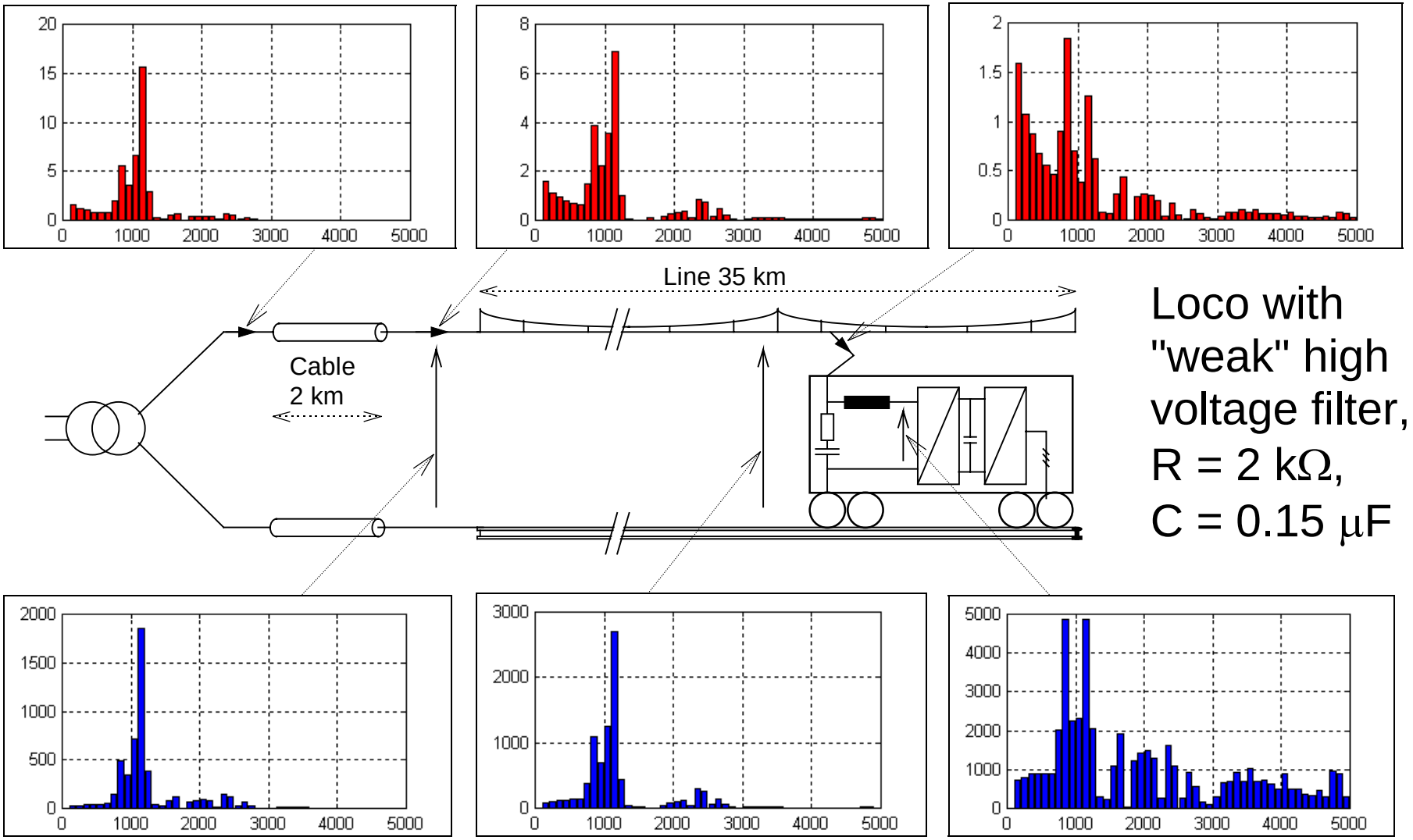

Loco with "weak" high voltage filter,
R = 2 kΩ,
C = 0.15 μF

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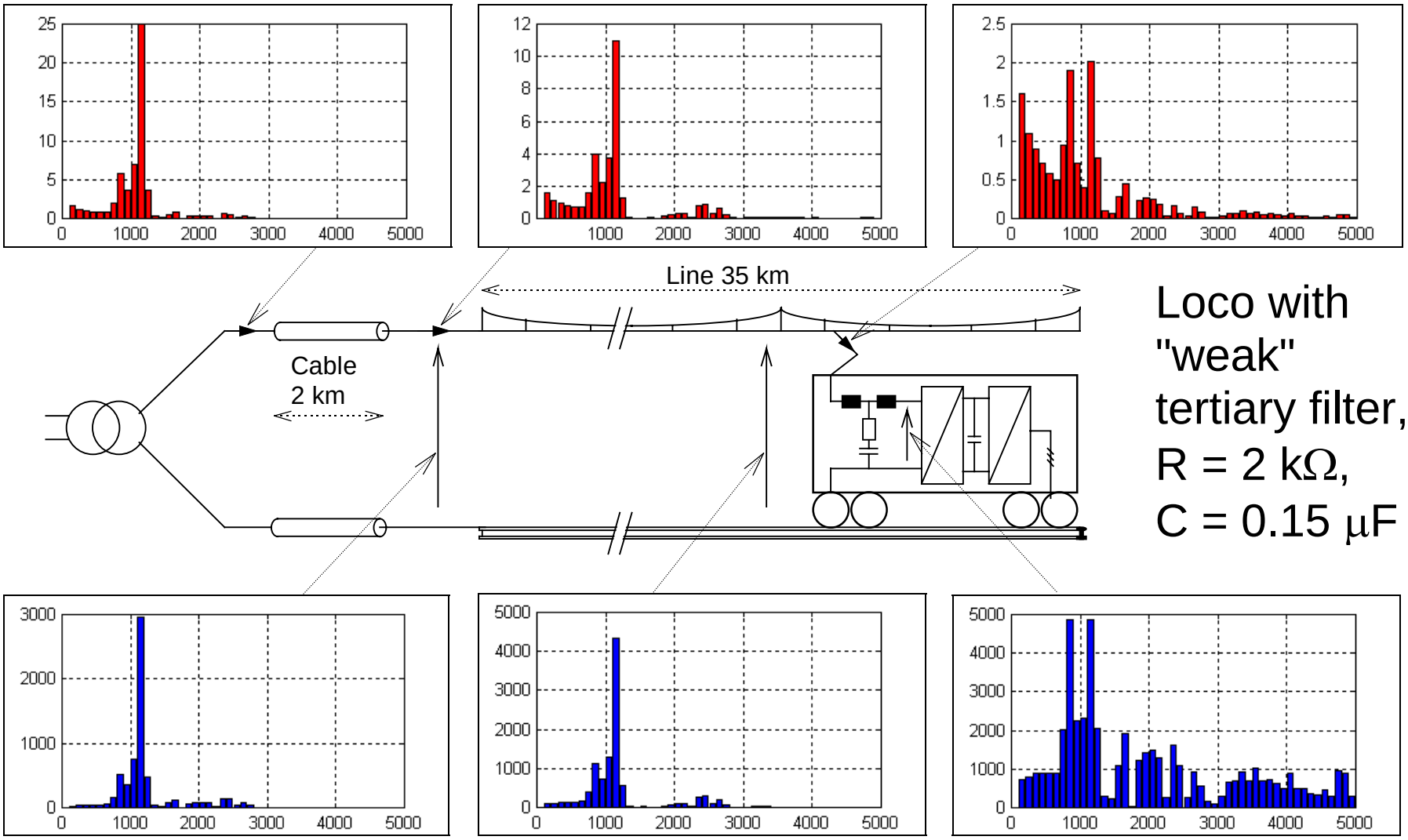

Loco with "weak" tertiary filter, R = 2 kΩ, C = 0.15 μF

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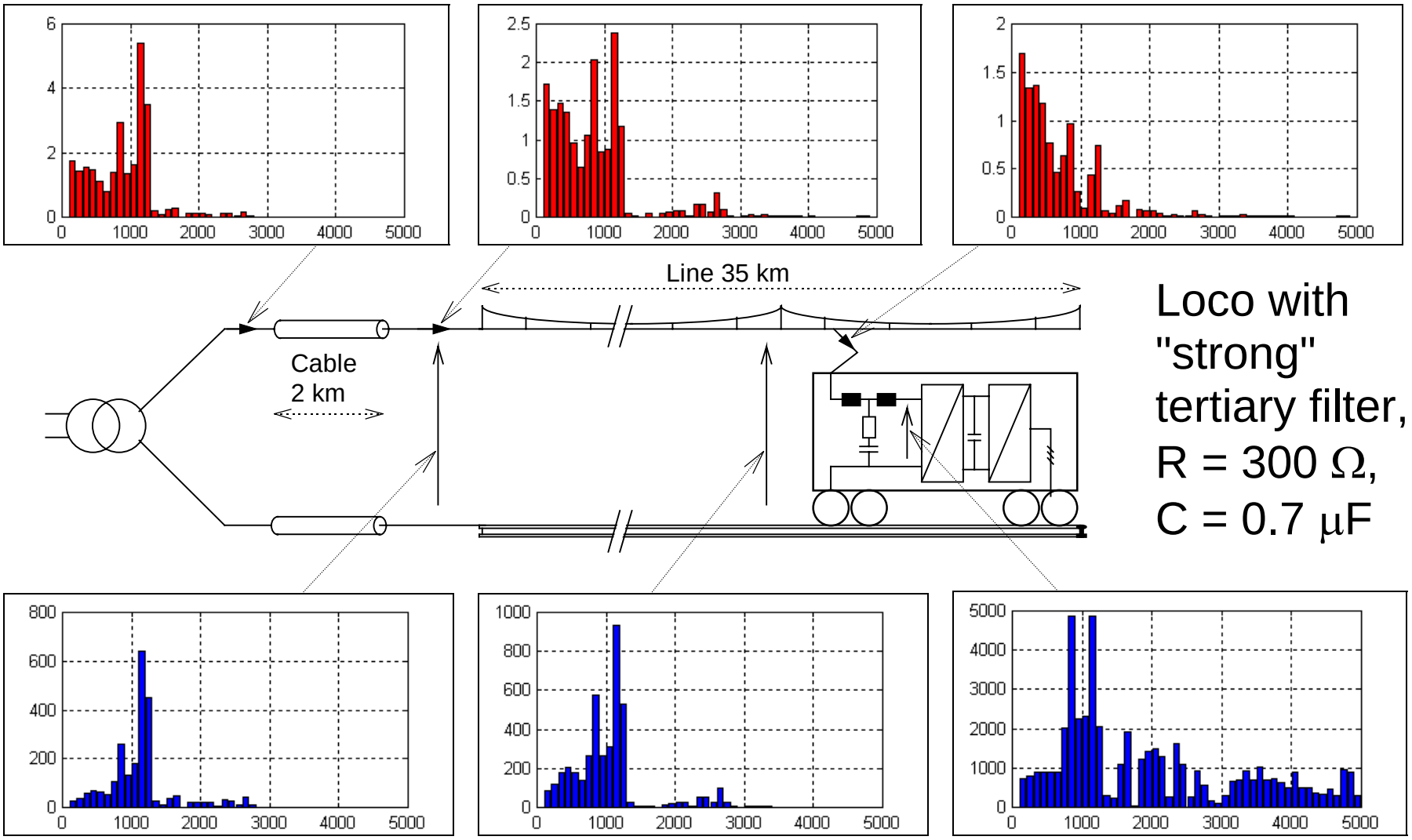
AC Line Harmonics - Problems and Countermeasures



Loco with "strong" tertiary filter, R = 300 Ω, C = 0.7 μF

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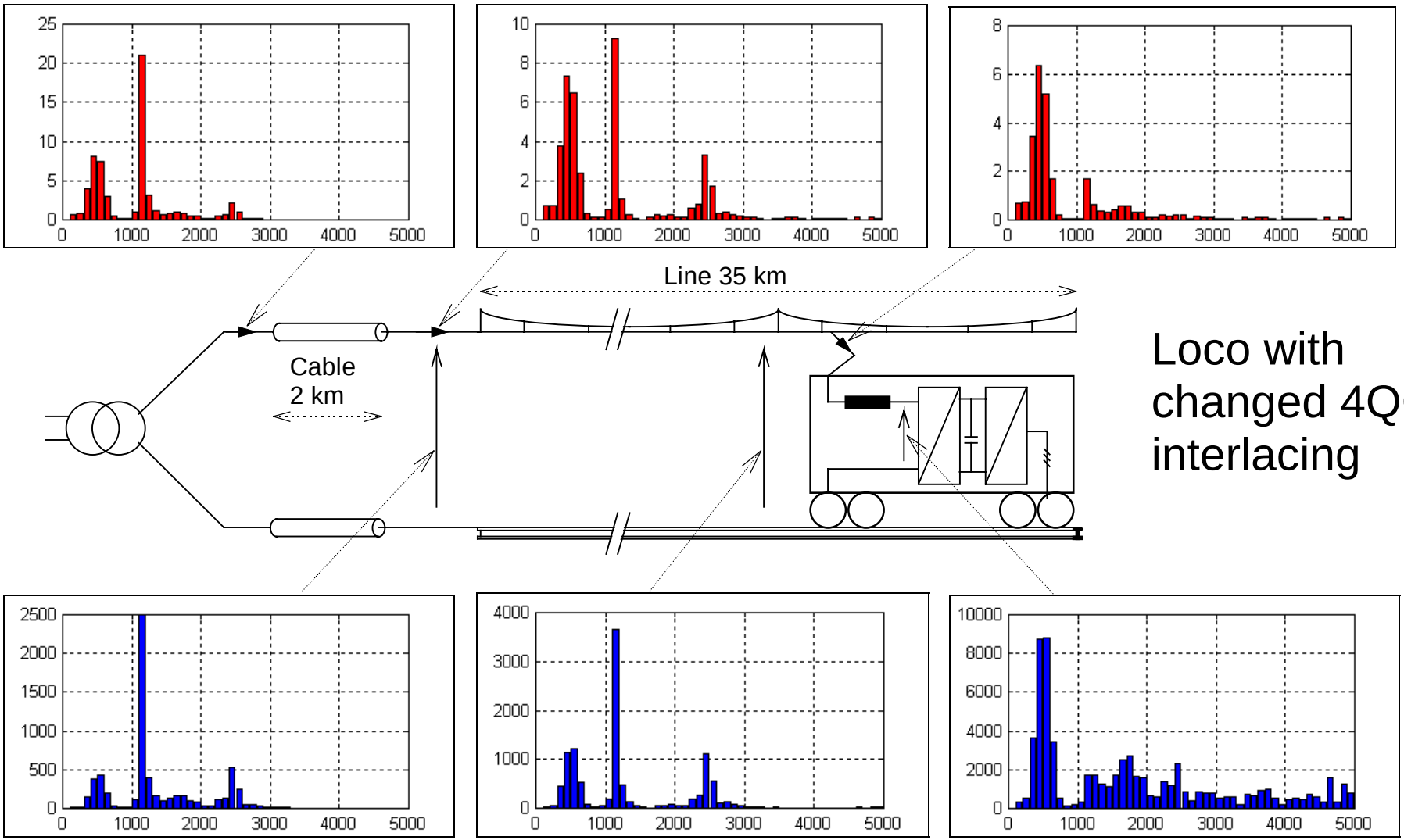
AC Line Harmonics - Problems and Countermeasures



Loco with changed 4QC interlacing

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Conclusions

Countermeasures against AC line harmonics generated by a AC-AC vehicle:

- Increased transformer inductance
- AC line filter
  There is no real difference performancewise between a high voltage filter and a filter on a tertiary transformer winding, but the latter is cheaper and easier to design due to the lower voltage level
- More interlaced 4-quadrant converters
- Higher switching frequency
  This works because of the increased resistances at higher frequency. But be careful: If the switching frequency is doubled and the main harmonics are shifted from say 2 kHz to 4 kHz, then the interference levels at 4 kHz will be higher than before!

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Filters on tertiary windings of existing transformers

Winding for auxiliary converter (rectifier), train line, or another system

Need to consider:

- Current loading of the winding (fundamental and harmonic)
- Distortion of the winding voltage - additional filtering might be required
- The coupling to other windings at all operation modes
- Current ripple in the 4QC brigdes - the filter reduces the impedance
- Filter currents and power losses due to other vehicles

Required data:

- Fairly detailed main circuit diagram
- Detailed transformer data sheet
- Measured short circuit impedances (vs frequency) between all transformer windings
- Details of the 4QC (switching frequency, interlacing, etc.)
- Information on other vehicles
- Information on the railway lines and supply (electrical and geographical data)

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