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Improvement of Line Protection by means of the novel Reactance Method

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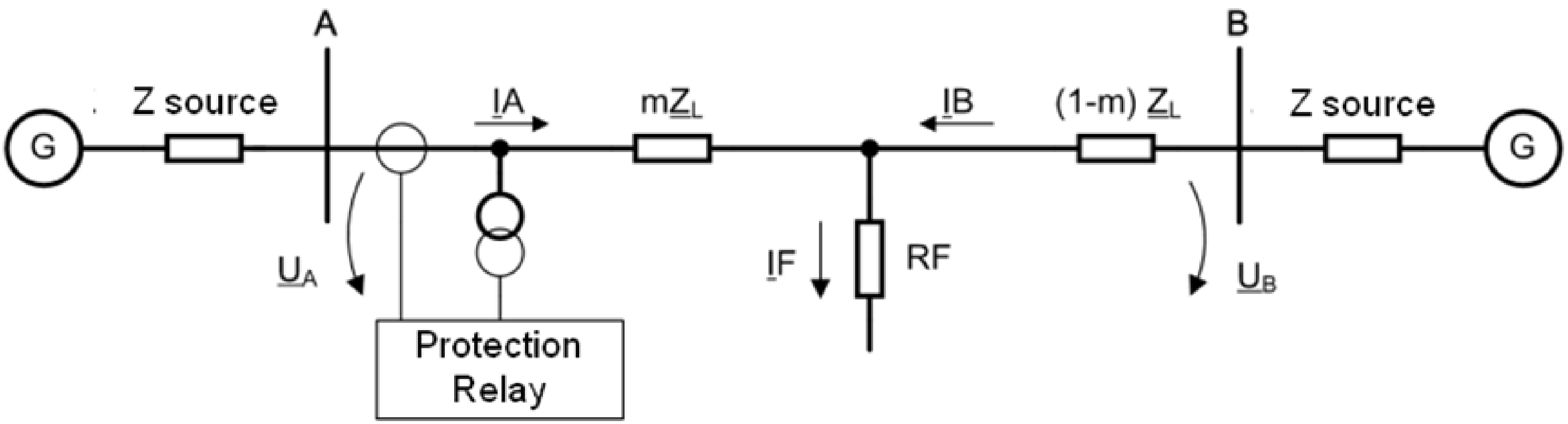
Why a new method was developed?

Fault on a double-end fed line

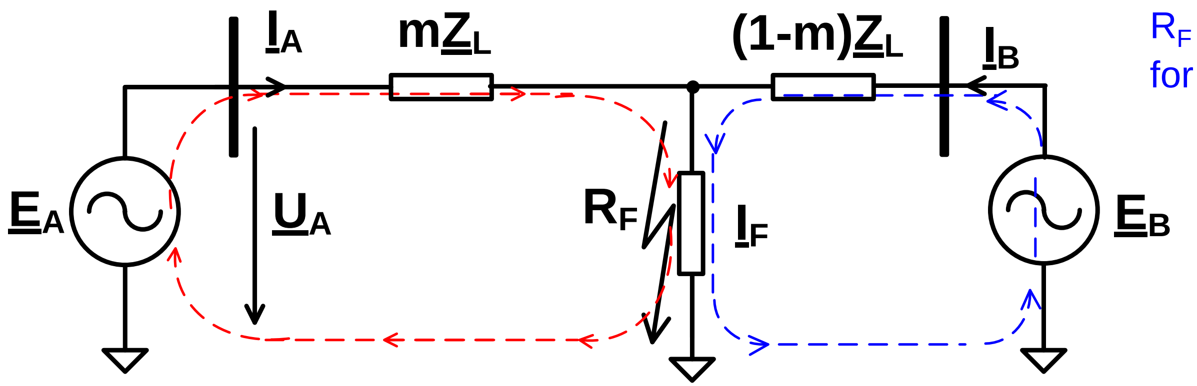
Distance Protection Relays make the fault detection based on measuring voltage and current



Following parameter are influencing of the correct impedance calculation:

- Load flow
- Value of the failure impedance RF
- Short circuit power of sources on both line ends
- Complexity of network topology

Resistenve fault, feeded from both ends of the line



RF and IF are unknown for the relay in A (B)!

- fault current from remote end causes additional voltage drop at fault resistance R_F

$$\underline{U}_A = (m \cdot \underline{Z}_L + R_F) \cdot \underline{I}_A + R_F \cdot \underline{I}_B$$

- Additional impedance depends on the relation between the fault current $\underline{I}_B$ from the remote end and the local fault current $\underline{I}_A$

$$\underline{Z}_A = (m \cdot \underline{Z}_L + R_F) + \frac{\underline{I}_B}{\underline{I}_A} R_F$$

- If the fault currents $\underline{I}_A$ and $\underline{I}_B$ have different angles the additional impedance will have a reactive component

$$\Delta X = \frac{|\underline{I}_B|}{|\underline{I}_A|} \cdot R_F \cdot \sin\left(\angle(\underline{I}_B, \underline{I}_A)\right)$$

Changes of the impedance calculation by the distance protection for double-end fed fault location

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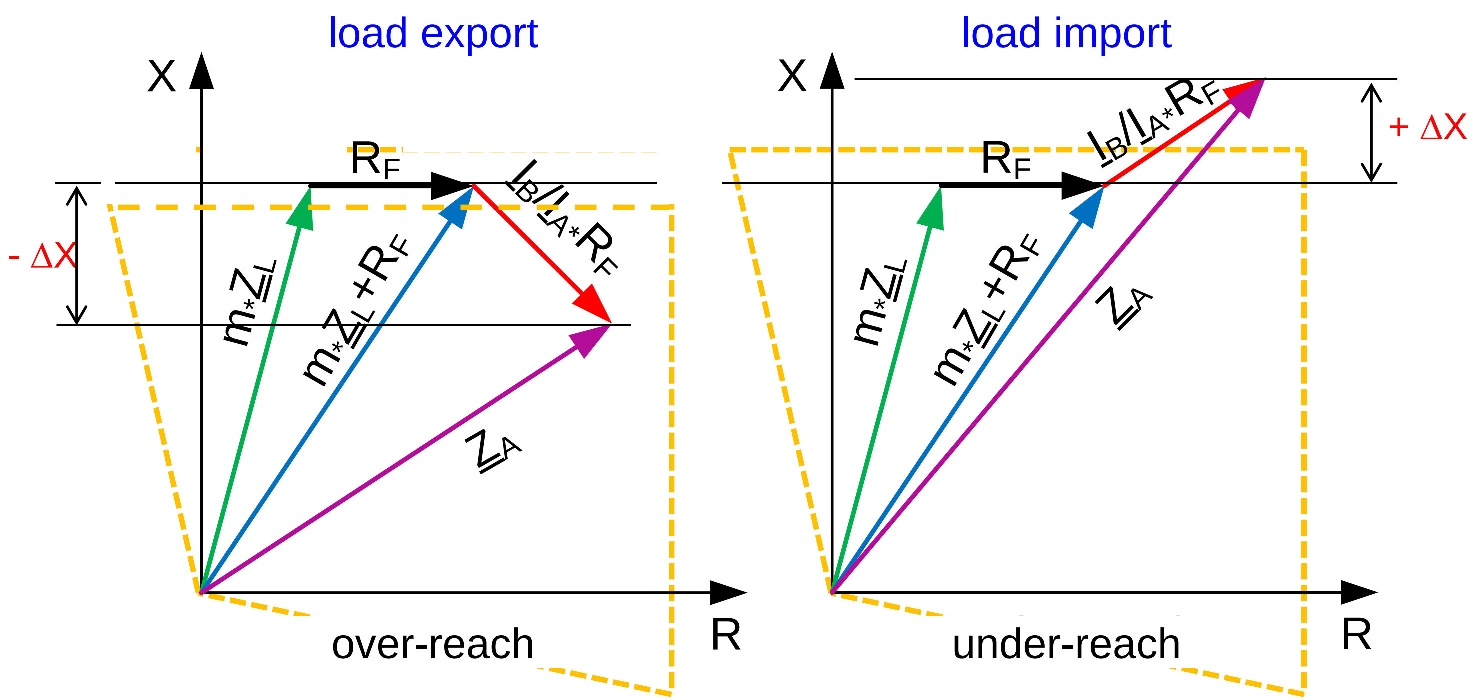
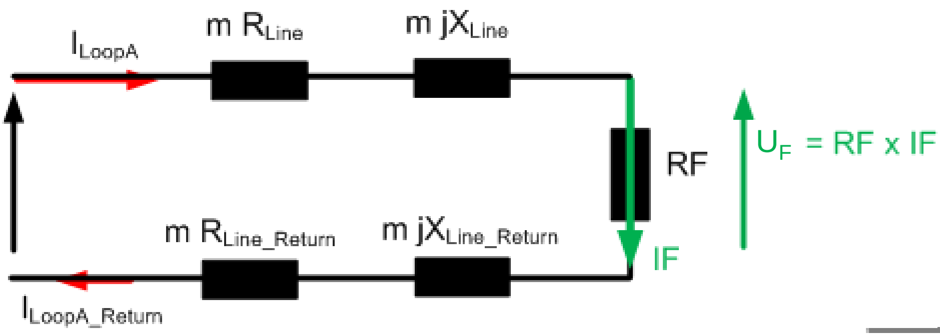
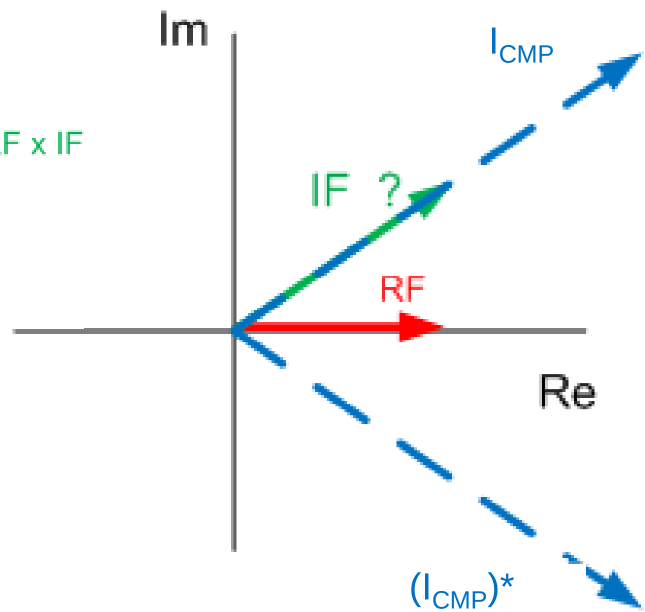


$$\Delta X = \frac{|\underline{I}_B|}{|\underline{I}_A|} \cdot R_F \cdot \sin\left(\angle(\underline{I}_B, \underline{I}_A)\right)$$

- during load flow phase angle of sending end leads phase angle of the receiving end (in case of load export the phase angle of $\underline{I}_A$ leads the phase angle of $\underline{I}_B$)
- idea in principle: → elimination of the reactance measurement error ΔX

Multiplipy with a compensation quantity





$$\underline{U}_F = R_F \cdot \underline{I}_F$$

Multiplication with I_{CMP} :

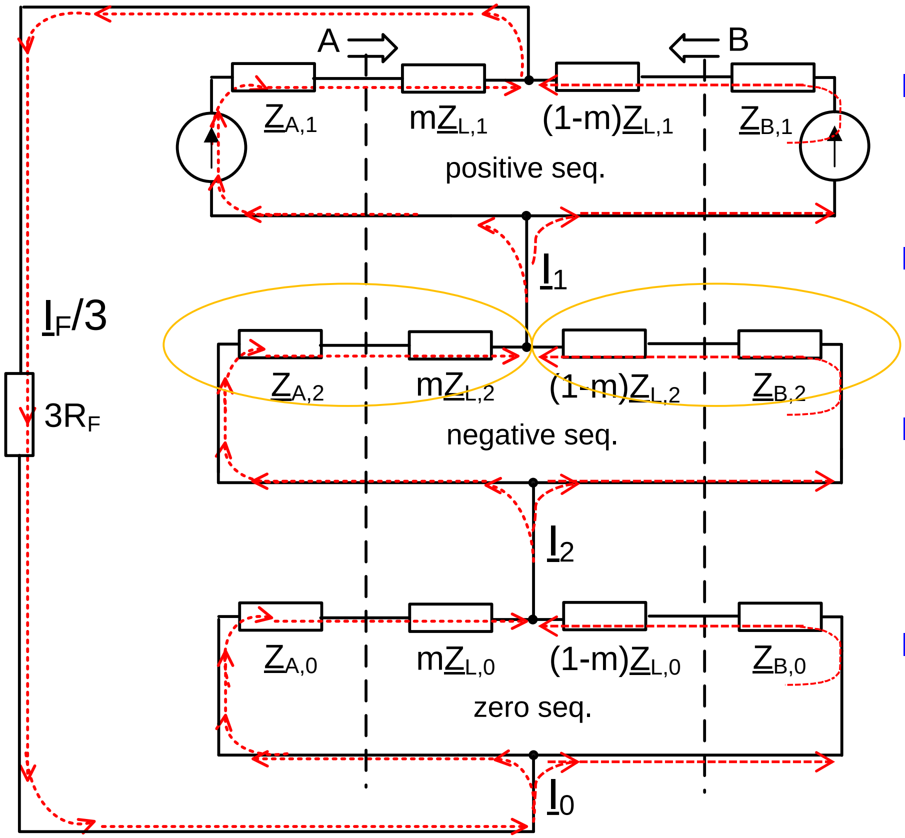
$$\underline{U}_F \cdot \underline{I}_{CMP}^{\,*} = R_F \cdot \underline{I}_F \cdot \underline{I}_{CMP}^{\,*}$$

$$\mathrm{Im}\left(\underline{U}_F \cdot \underline{I}_{CMP}^{\,*}\right) = 0$$

The compensation quantity is the conjugate complex value of the fault current $\underline{I}_F$

If phase angles of currents I_{CMP} and I_F are equal, than result is real.

Compensation quantity for phase to ground faults

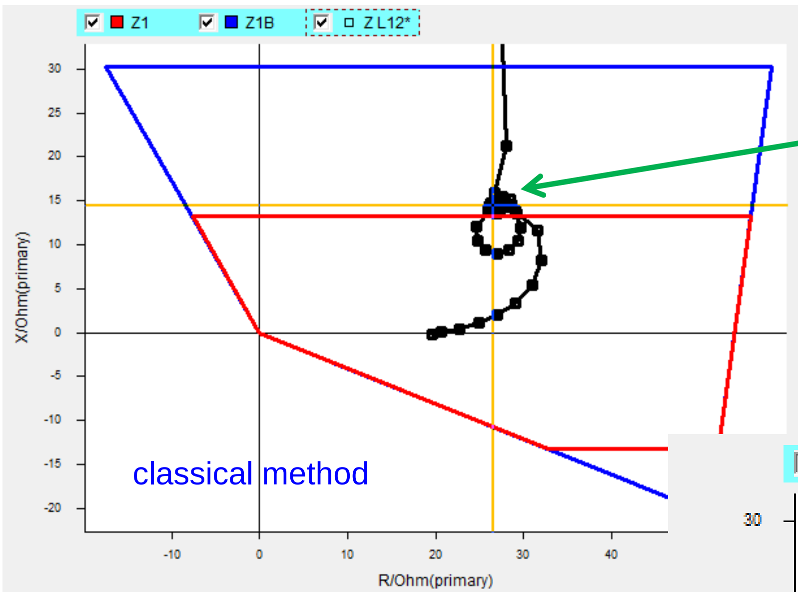


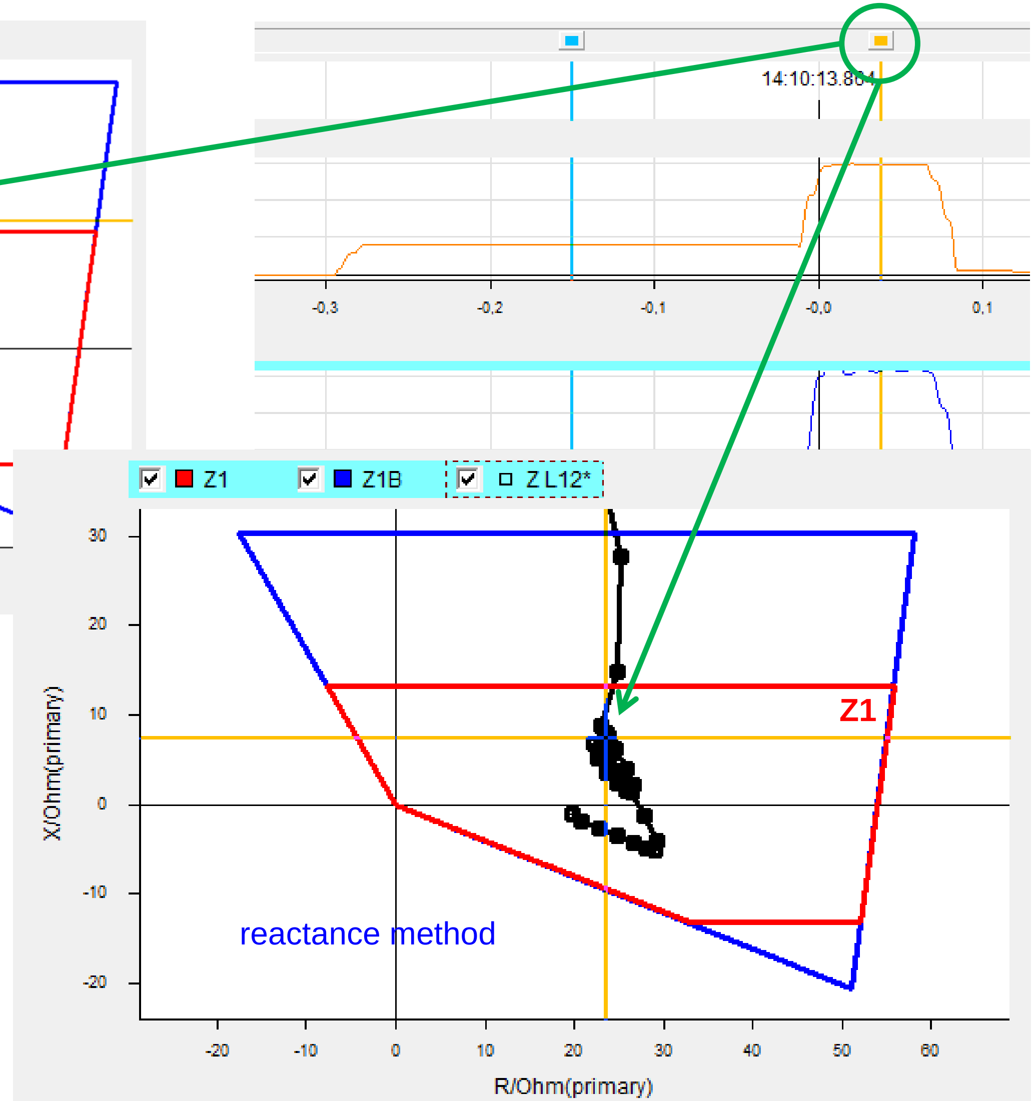
- Positive, negative and zero sequence networks are connected in series
- Positive sequence network includes the sources
- Zero sequence current or negative sequence current can be used as compensation quantity
- Sequence which is more homogenous should be prefered

$$X = \frac{\sin(\varphi)\cdot \mathrm{Im}[\underline{U}_A \cdot \underline{I}_0^* \cdot e^{-j\delta_{Cmp,0}}]}{\mathrm{Im}[e^{j\varphi} \cdot \underline{I}_A \cdot \underline{I}_0^* \cdot e^{-j\delta_{Cmp,0}}]}$$

$$\delta_{Cmp,0} = \arg\left\{\frac{\underline{Z}_{0,A} + \underline{Z}_{0,B} + \underline{Z}_{0,L}}{(1-m)\cdot \underline{Z}_{0,L} + \underline{Z}_{0,B}}\right\}$$

Simulation result for a two-phase fault
Resistance fault at 50% of the line length

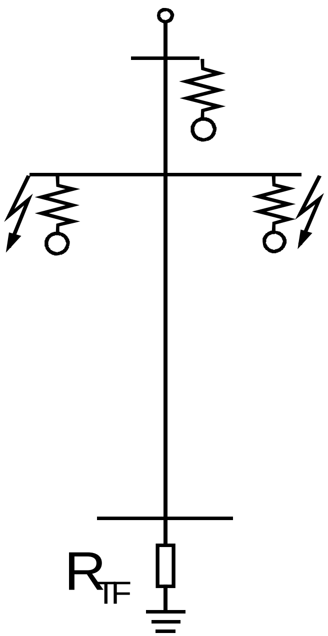




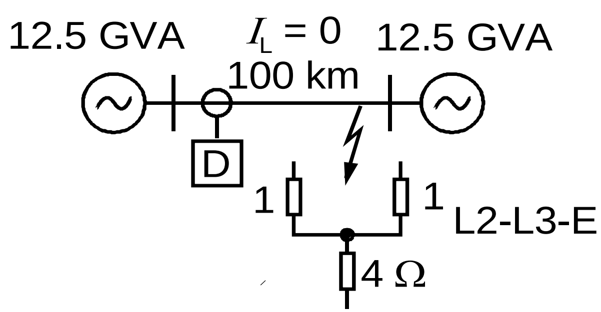
Using the new algorithm the fault is seen in zone Z1!

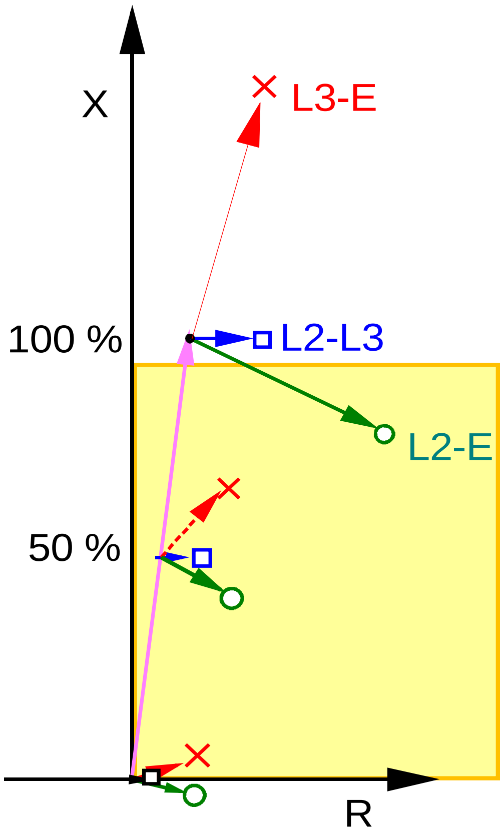
Difficulties in choosing the right fault loops

Virtual impedance and impedance in the case of fault changes



line tower





line-line-earth short circuit with transition resistance R_F - measured loop impedance

Classical scheme of loop selection
(decision tree)

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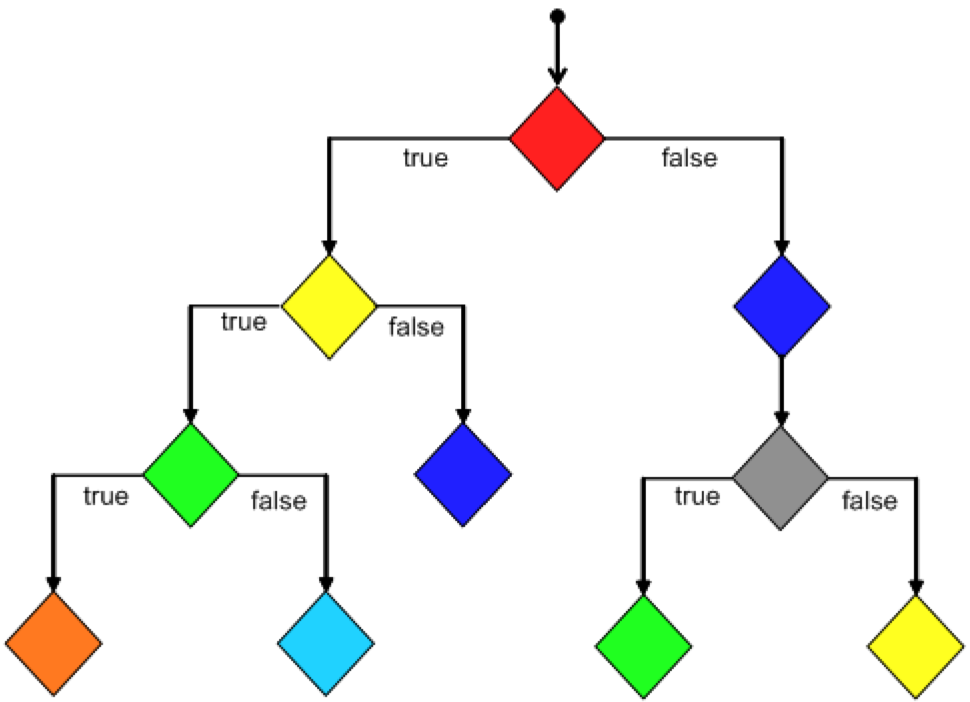
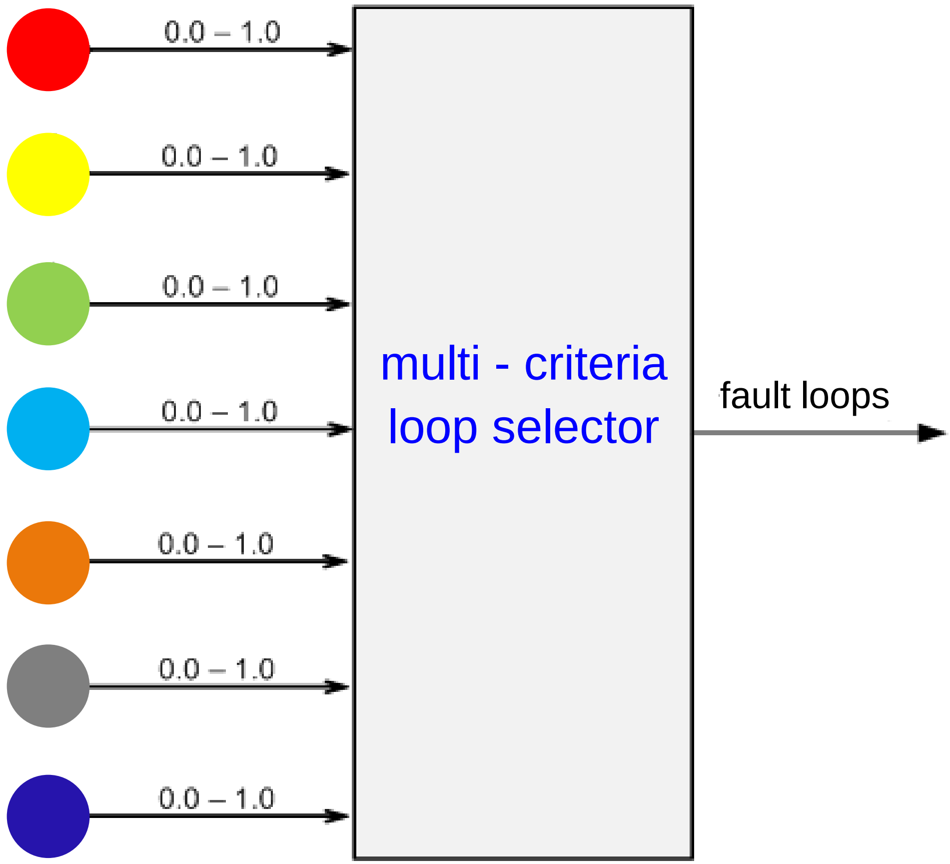


- Each criteria can respond with true or false only
- Execution of a choice of criteria
- Some criteria exists multiple times in the decision tree

◇ criterion

Advantages of new scheme

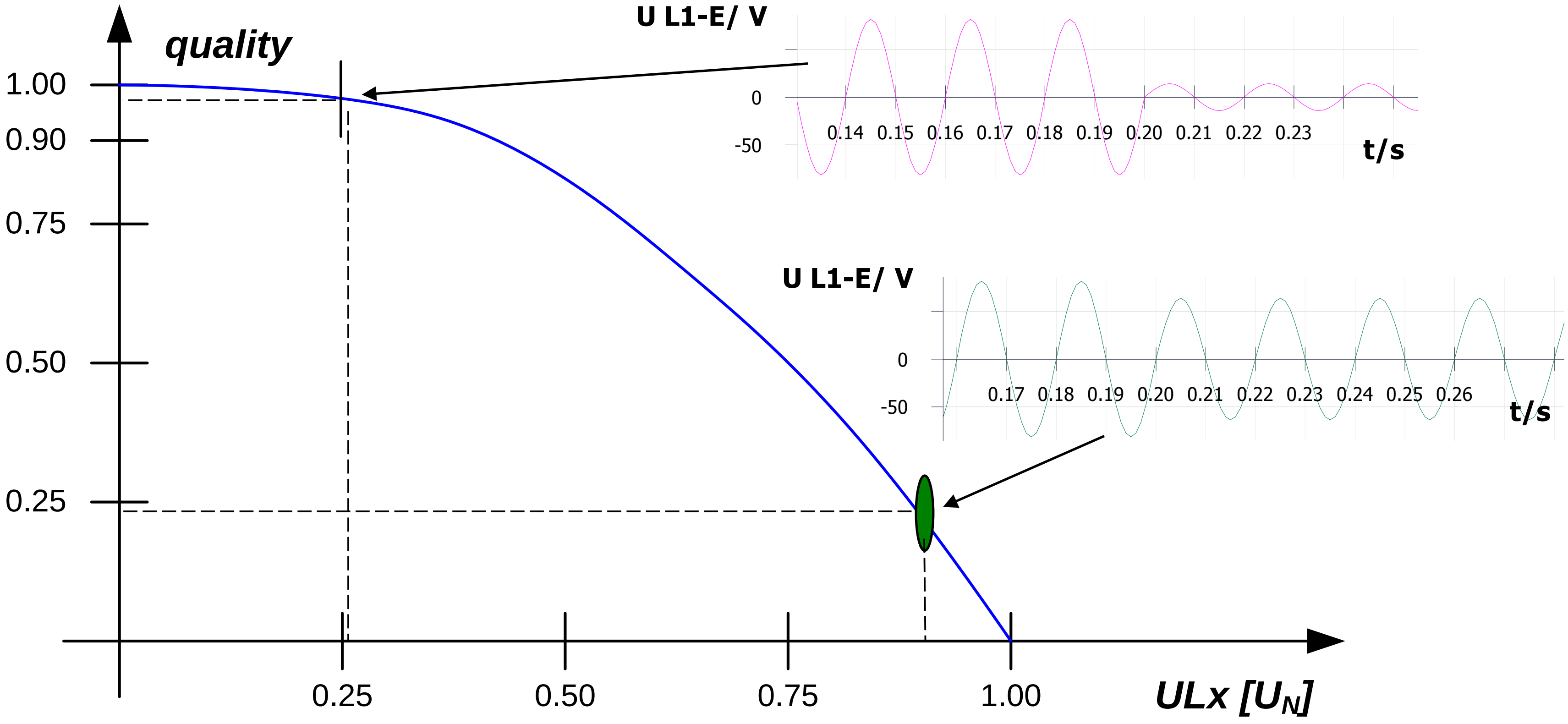


- Excecition of all criteria
- Each criteria can respond with 0.0 – 1.0 or “unvalid”
- Each criteria exists only once

- Wrong response of some criteria does not lead to a wrong behavior ot the algorithm
- Importance of criteria can be adjusted by weighting
- Uncertainty of criteria can be expressed with quality

Voltage magnitude criteria

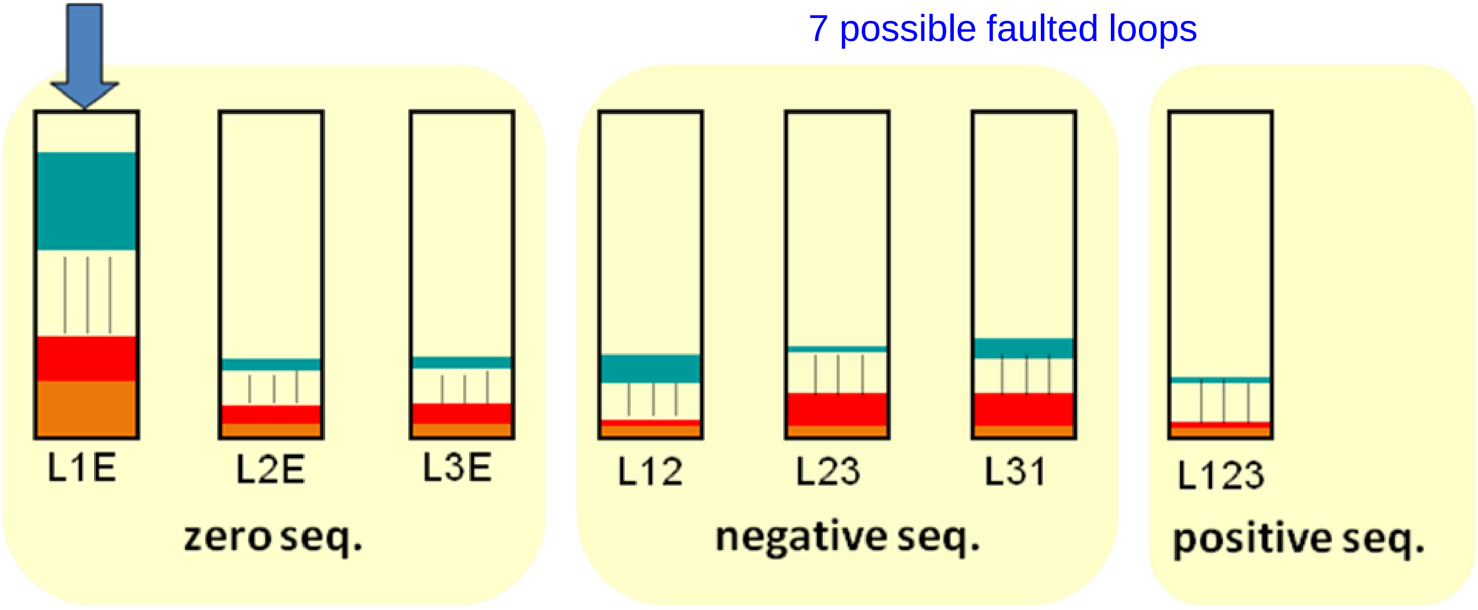
The lower the voltage, the higher the quality of then result.



Concept of Multi-Criteria Loop Selector (MLS)

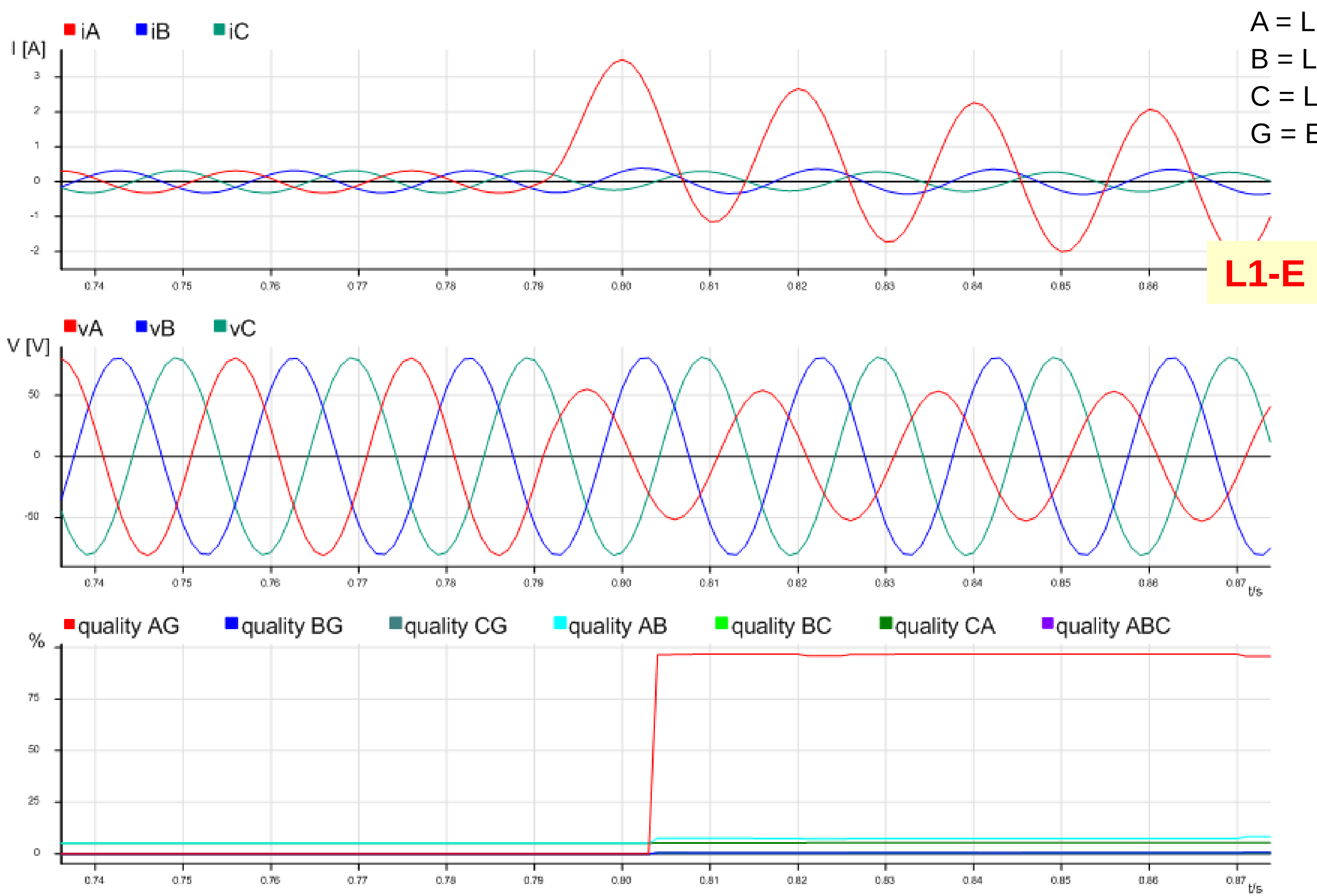
„n“ – criteria:
criteria 1
criteria 2
…
criteria n

7 possible faulted loops



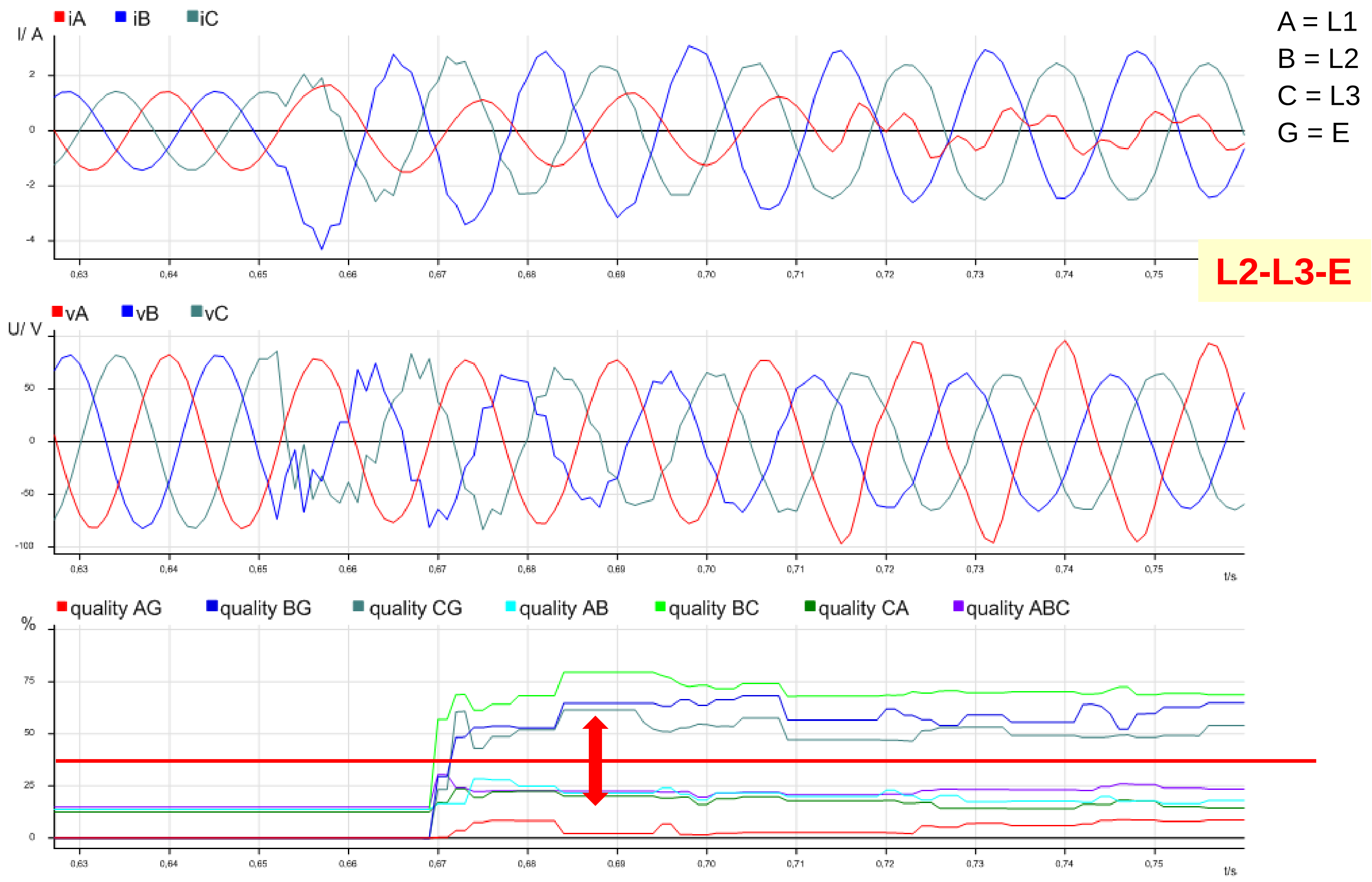
- The MLS calculates each cycle a quality for each loop
- The loop with the highest quality which exceeds a dynamic threshold will be chosen

Fault at 50% of line (simulation with test equipment)



Fault at 90% of line

(RTDS network model, series compensated line)



A = L1
B = L2
C = L3
G = E

Conclusion

- Reactance method gives the possibility to compensate the significant infuence by resistive faults on heavy loaded lines in electrical grids with direct earthed starpoints
- The MLS is optimized for all network topologies
- New algorithm are better prepared for the decentralized energy generation
- Latest technology of numerical protection relays are powerful enough for the more complexe algorithm

Back up slides

Stromhöhe-Kriterium

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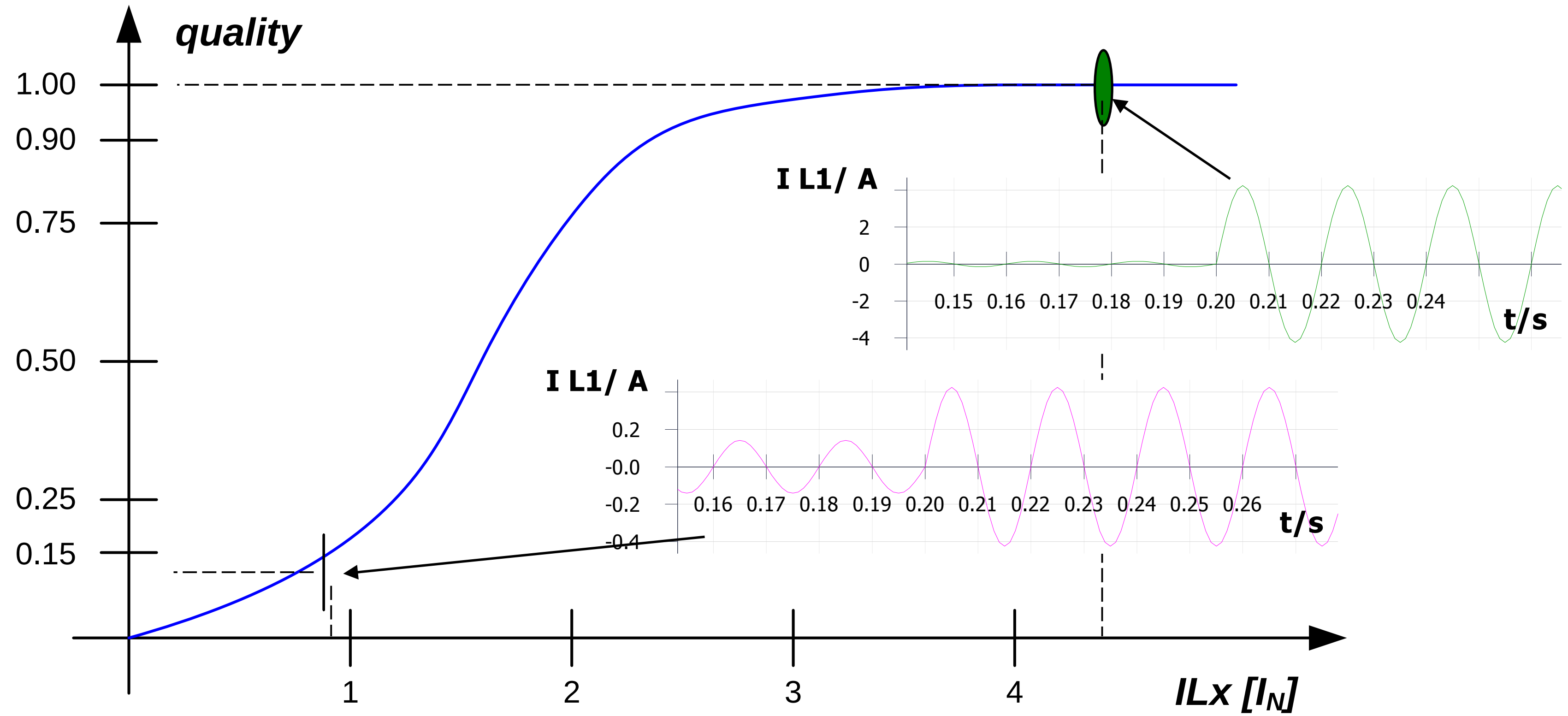
Je höher der Strom, desto höher das Qualitätsmerkmal



Impedanz-Kriterium

Je kleiner das Verhältnis zw. gemessenem X und parametriertem X, desto höher ist die Qualität der zugehörigen Schleife