Comparison between high impedance and low impedance bus differential protection

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Overview

Bus protection requirements

Basics on differential principle

CT saturation

Solution with low impedance differential protection

Solution with high impedance differential protection

Comparison

Conclusion

Bus protection requirements

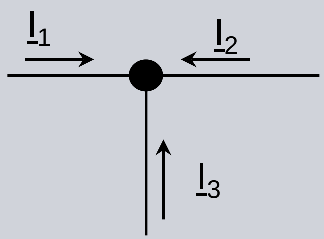
Speed: The bus protection needs to have a fast operating time. Because of the normally high fault current, the damage of a delayed operation can be critical and in may cases cause evolving events with the damage of critical grid elements like breaker or transformers. Sub cycle protection operations are normally required for the application of bus protection.

Reliability/Selectivity: Any bus fault needs to be detected and the operation needs to be 100% selective, so that the breakers that are feeding the faulty bus section will be tripped only...

Security: The bus protection needs to be stable during external faults. This is particularly a challenge for bus protection because the CT measuring the fault current of the faulty feeder becomes often stressed by high fault currents

Differential principle (87)

Based on Kirchhoff's Law: Sum of all currents, measured around a protection zone must be zero!



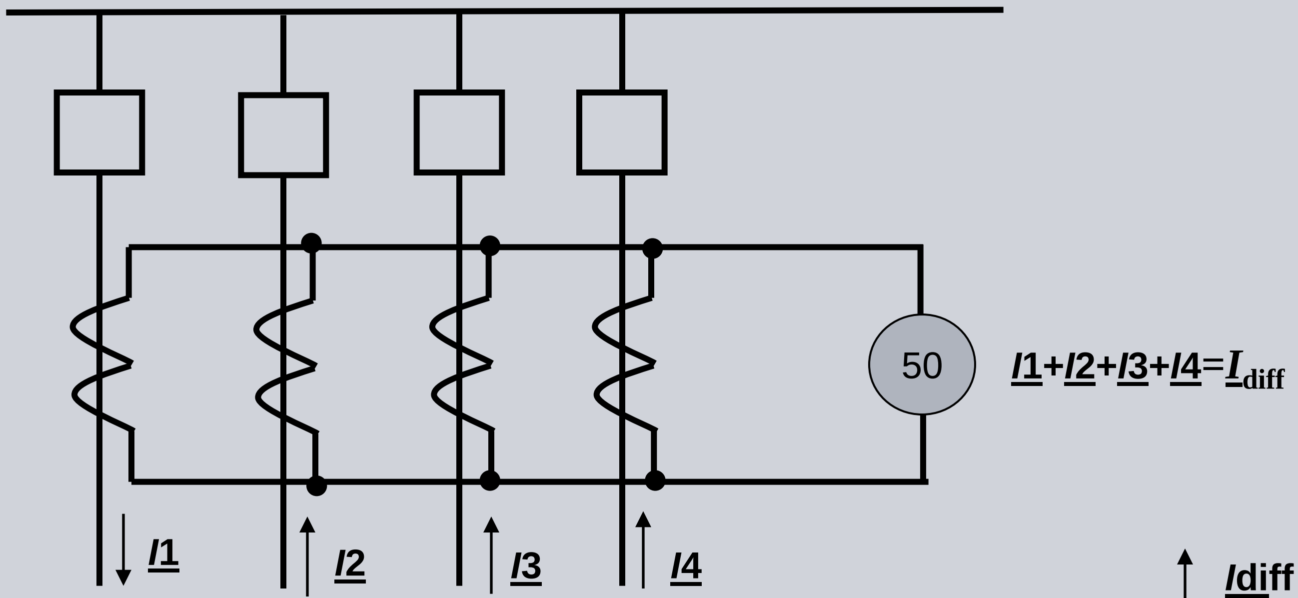
$\underline{I1}+\underline{I2}+\underline{I3}=0$

100% selective, instantaneous tripping

Only current must be measured

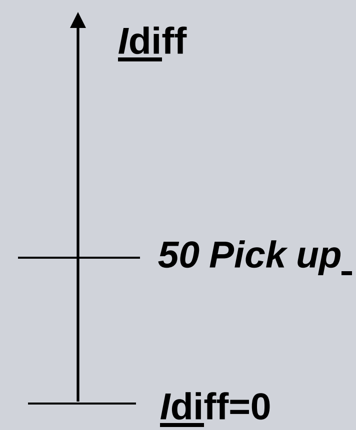
No backup

Differential principle

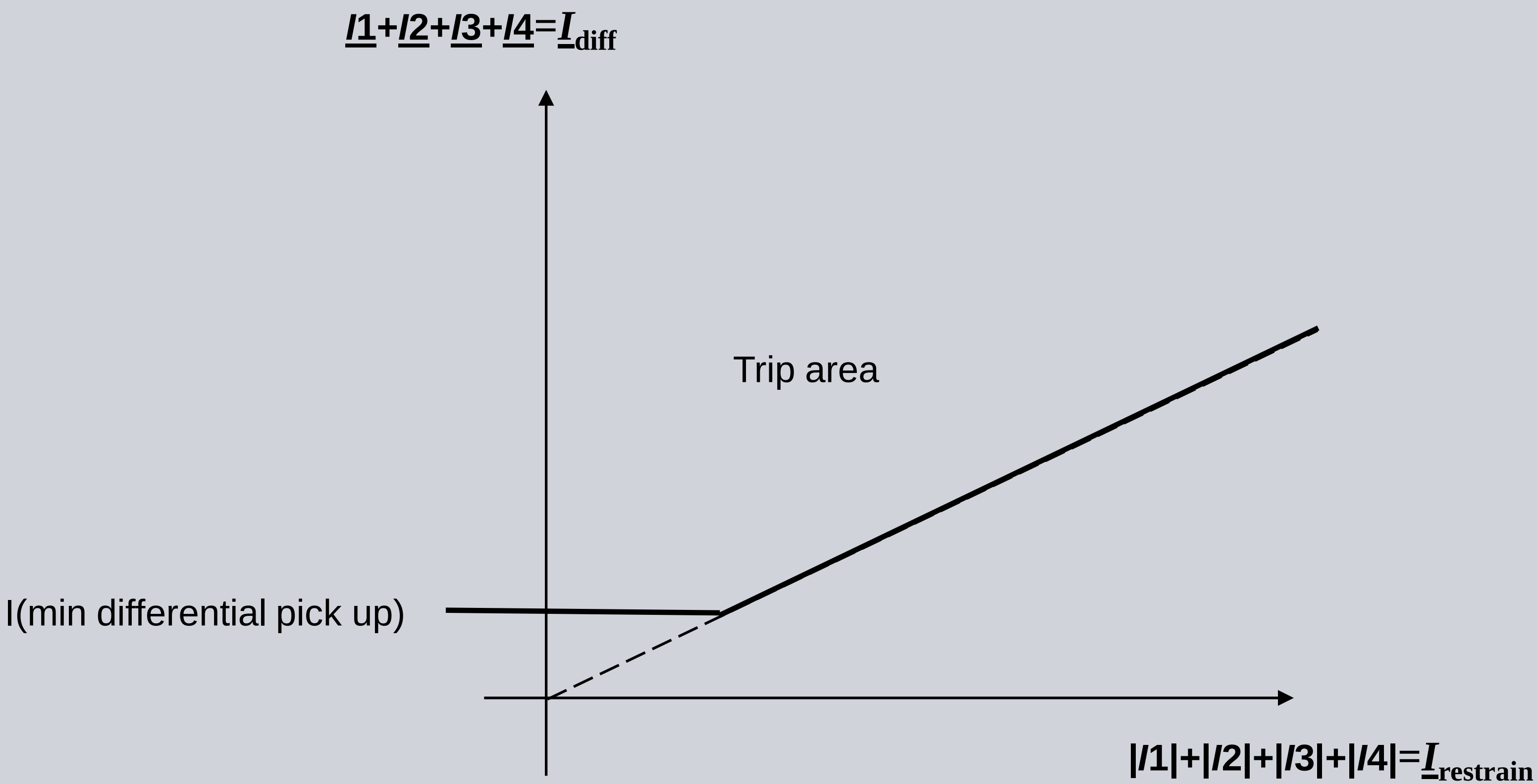


Normal operation: $I_{diff}=0$,

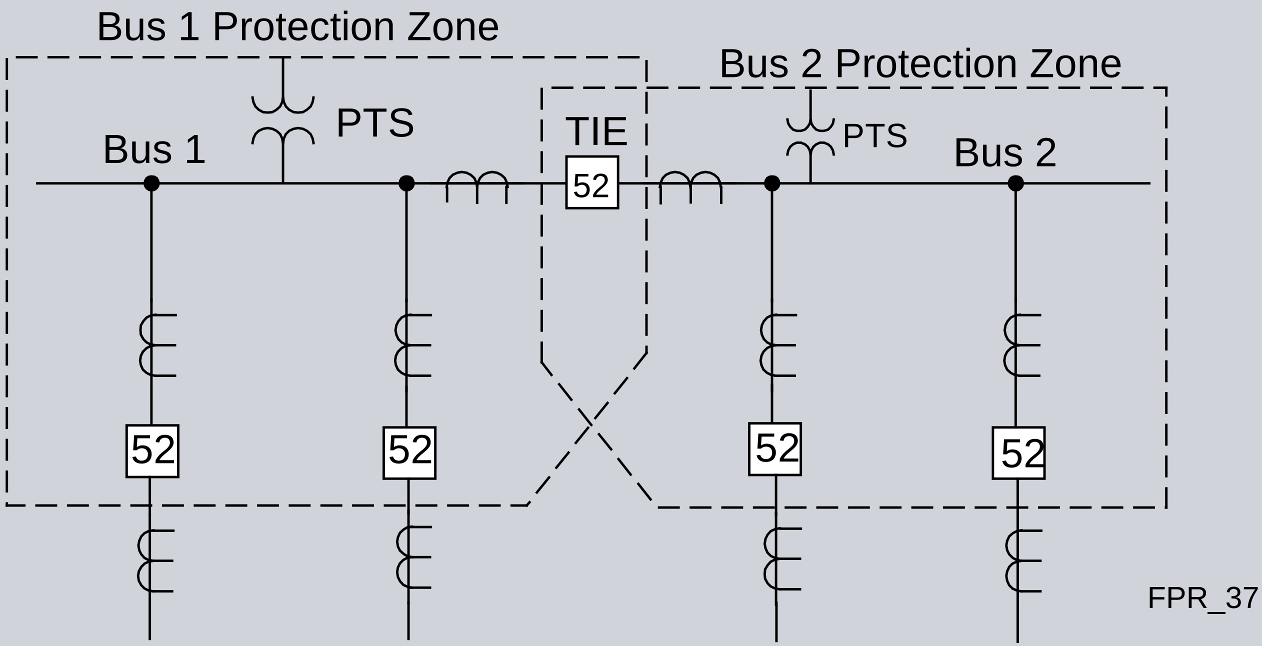
How to set the pick up for the 50 element?



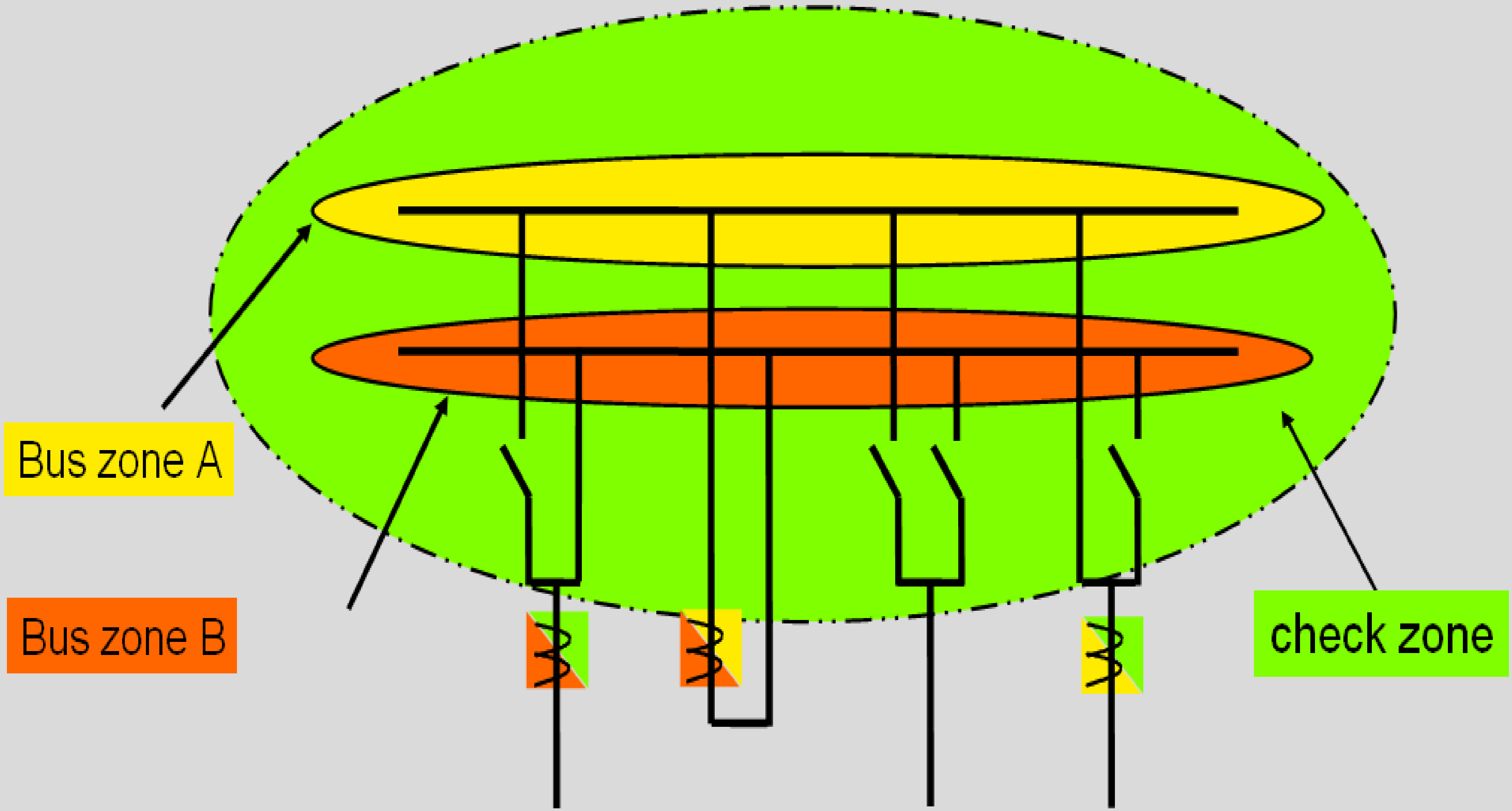
Percentage Restrain Characteristic (1)



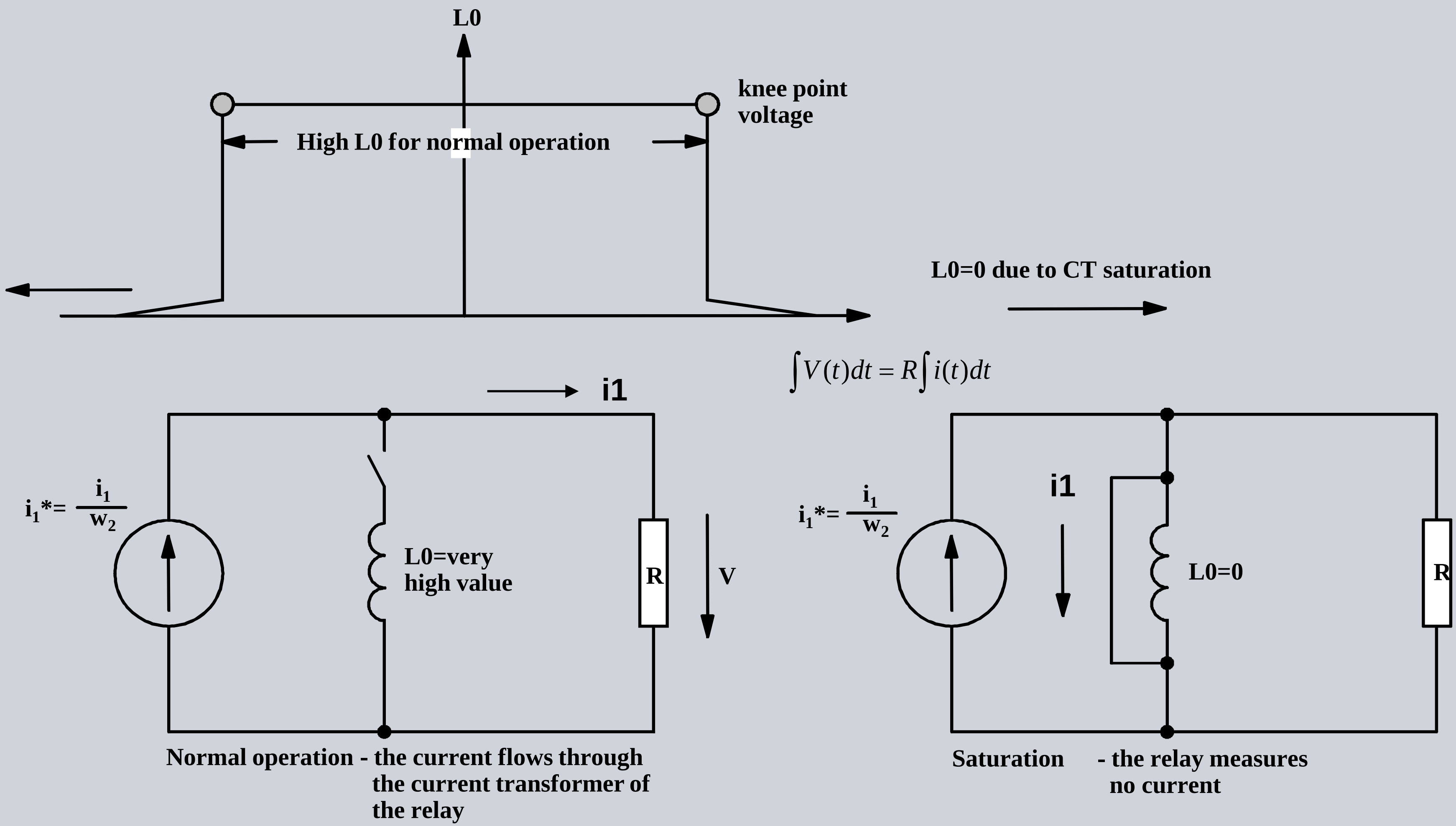
Typical bus configuration



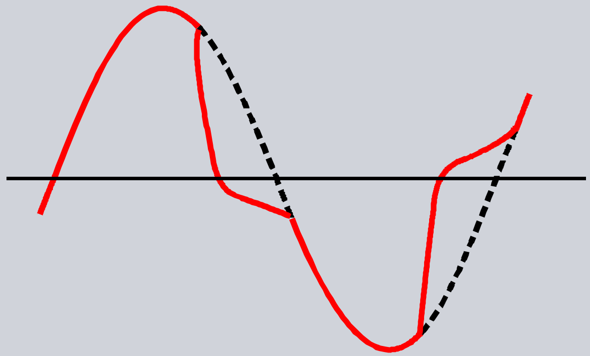
Complex bus configuration with Check Zone



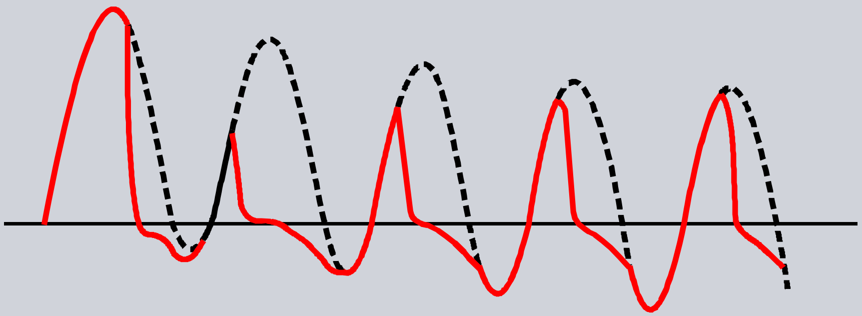
Current Transformer Saturation



Current transformer saturation

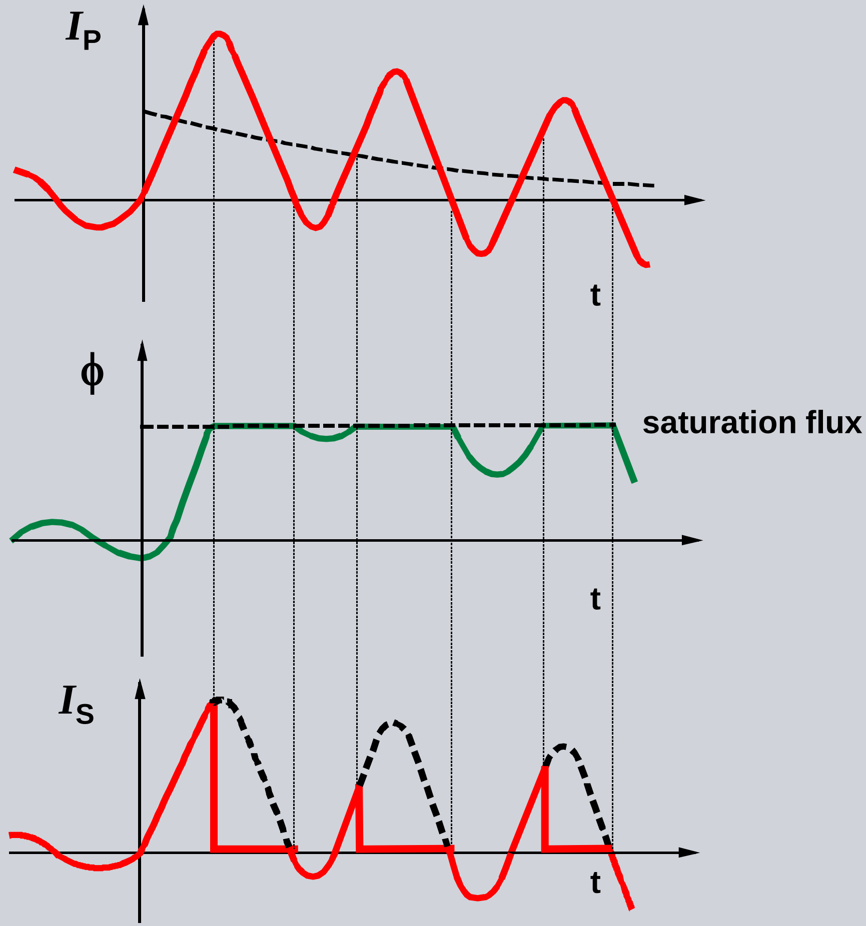


Saturation during steady-state current

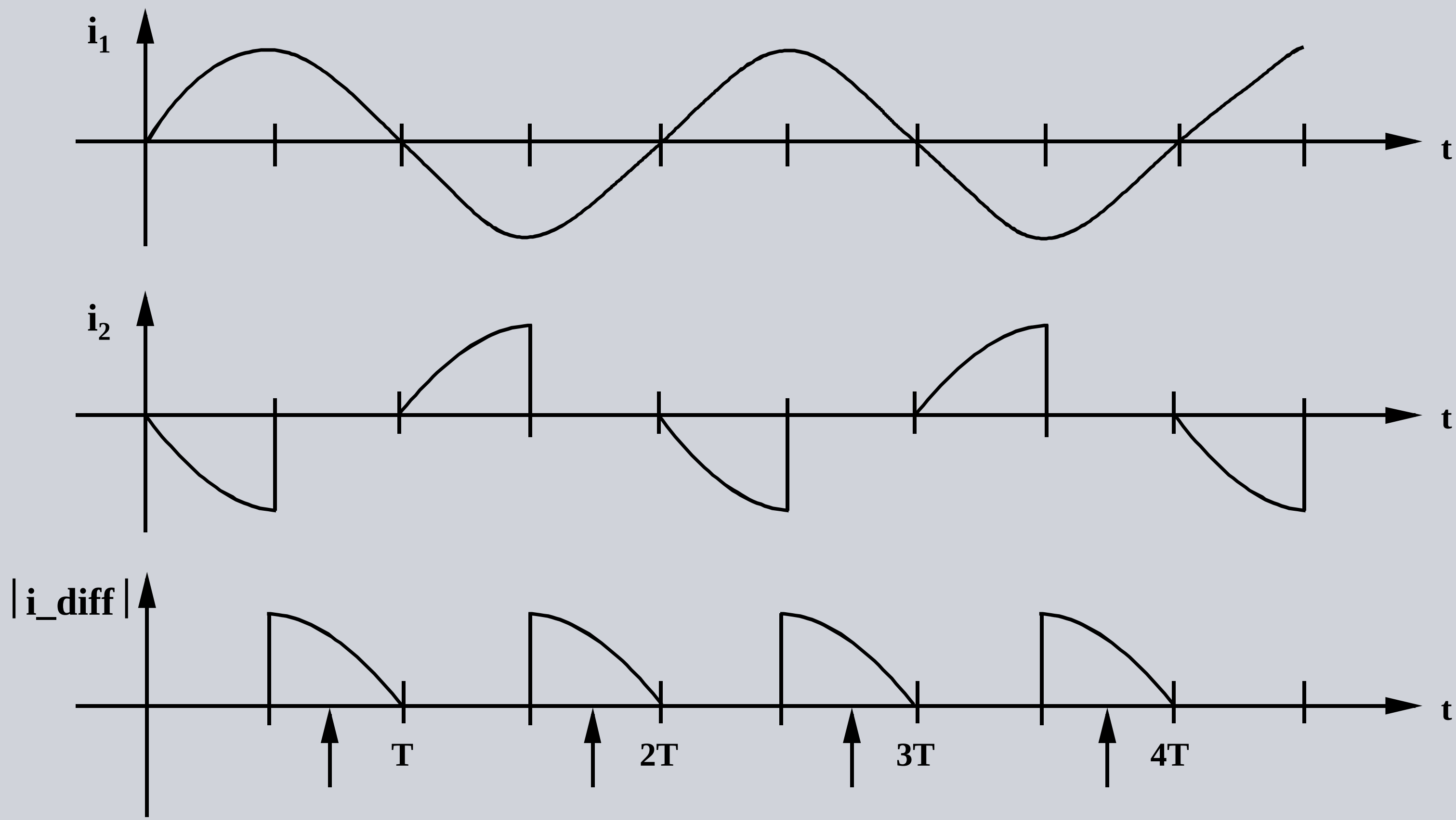


Saturation during offset current

CT saturation
Currents and magnetising

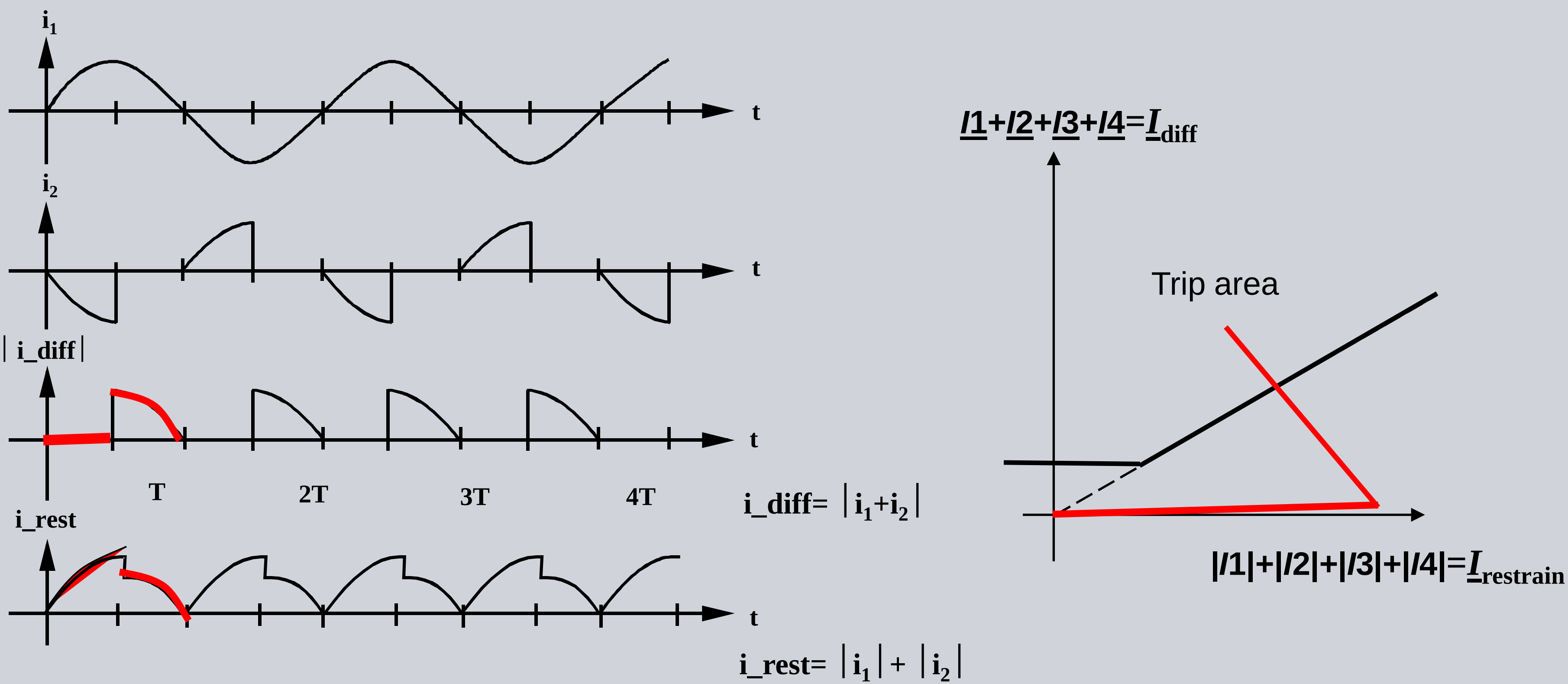


Differential Current due to CT-Saturation

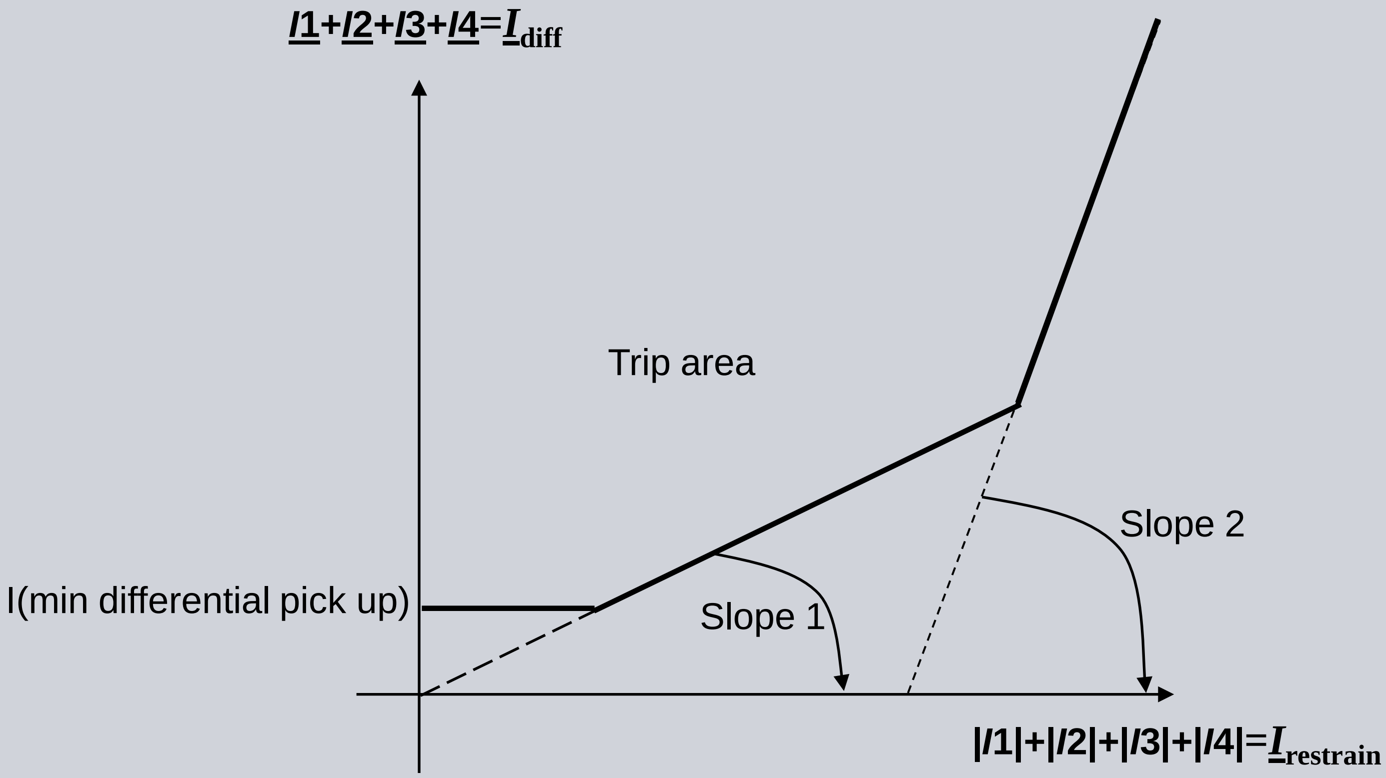


Differential Current may cause maloperation in case of CT-saturation

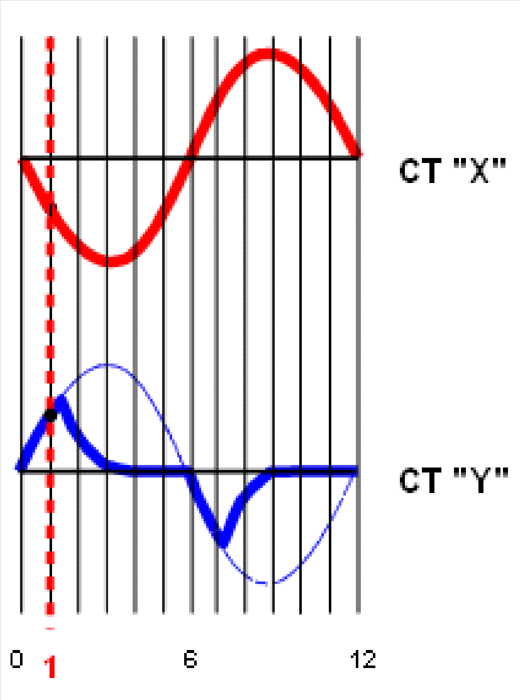
Percentage Restrain Characteristic during CT-Saturation

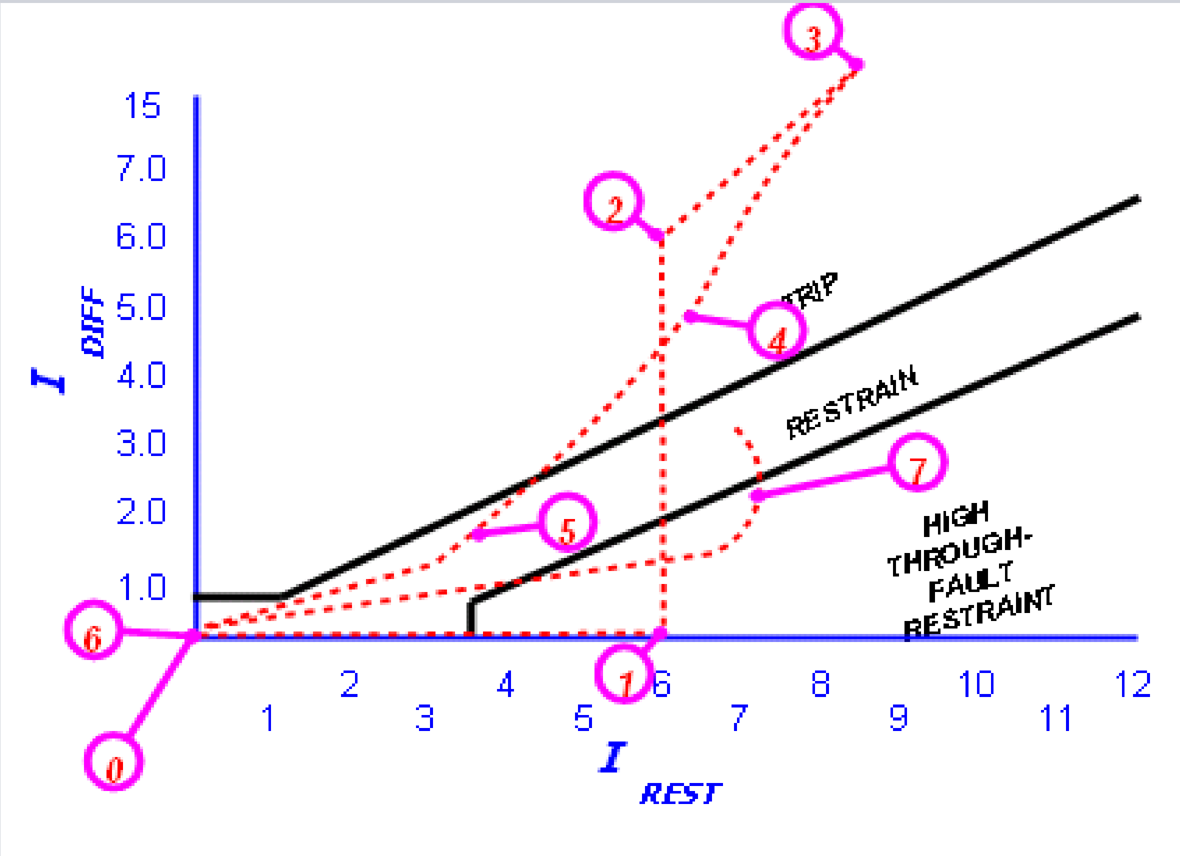


Solution 1
Percentage Restrain Characteristic

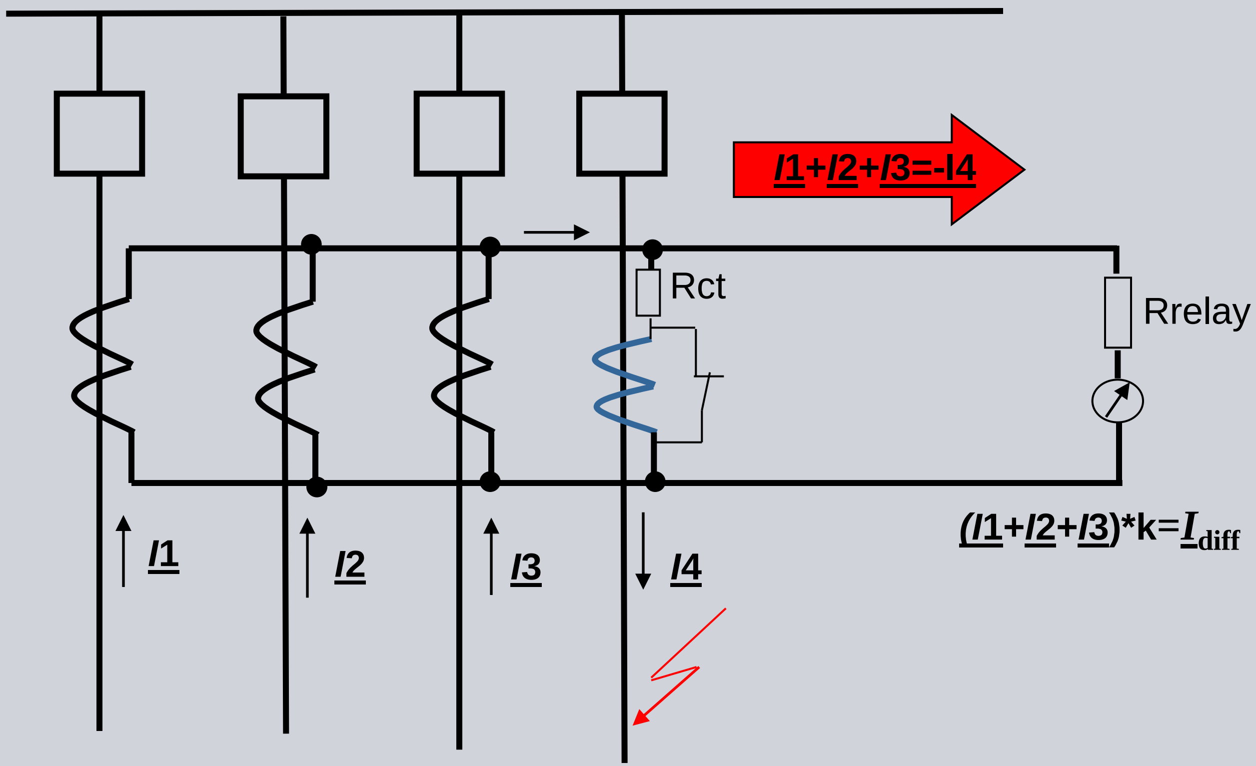


Solution 2
Percentage Restrain Characteristic with additional restrain area





Low Impedance Measuring Principle

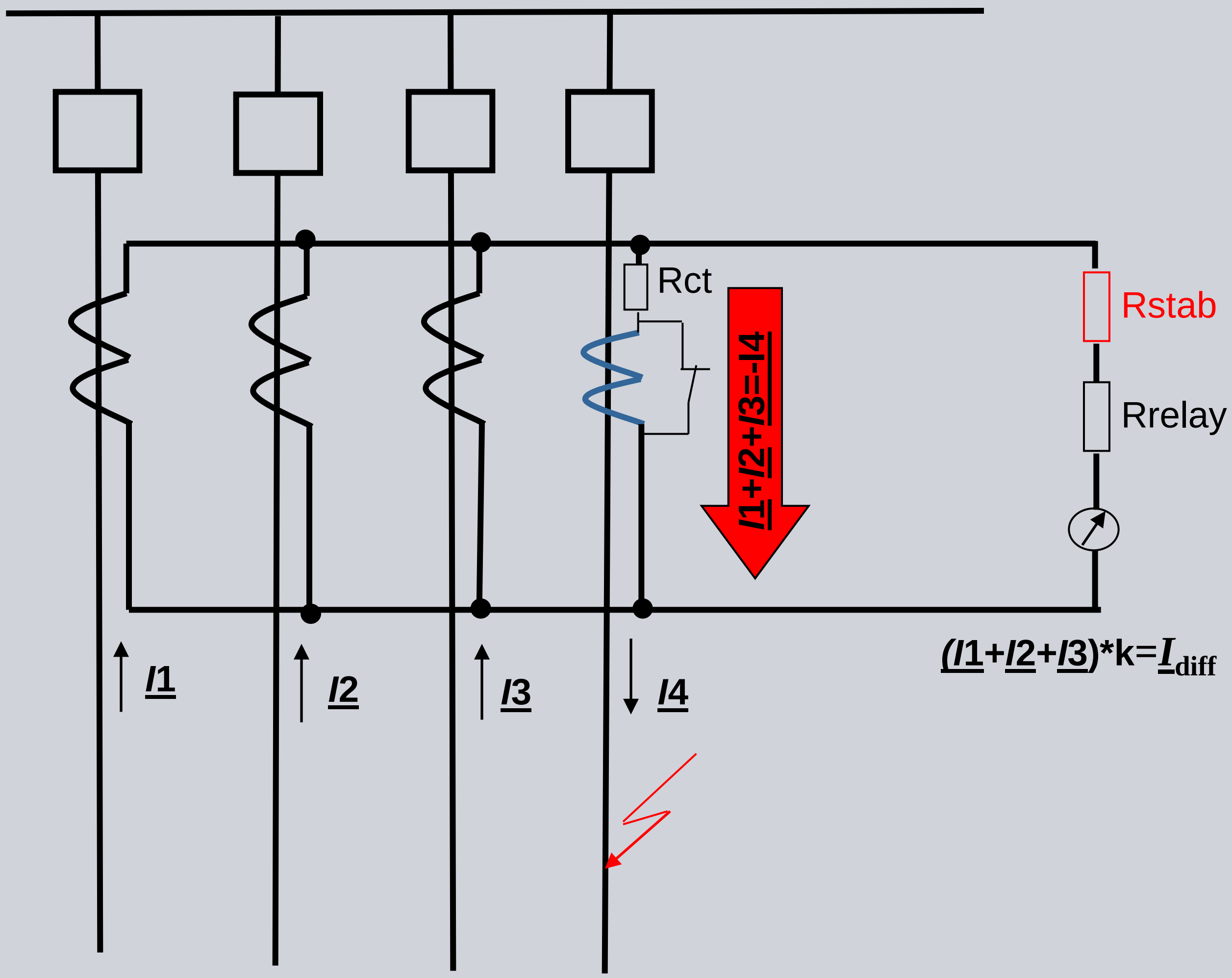


$$k = \frac{R_{CT} \| R_{relay}}{R_{relay}}$$

$$if \;\; R_{relay} << R_{CT}$$

$$k \approx 1$$

High Impedance Measuring Principle
Stability

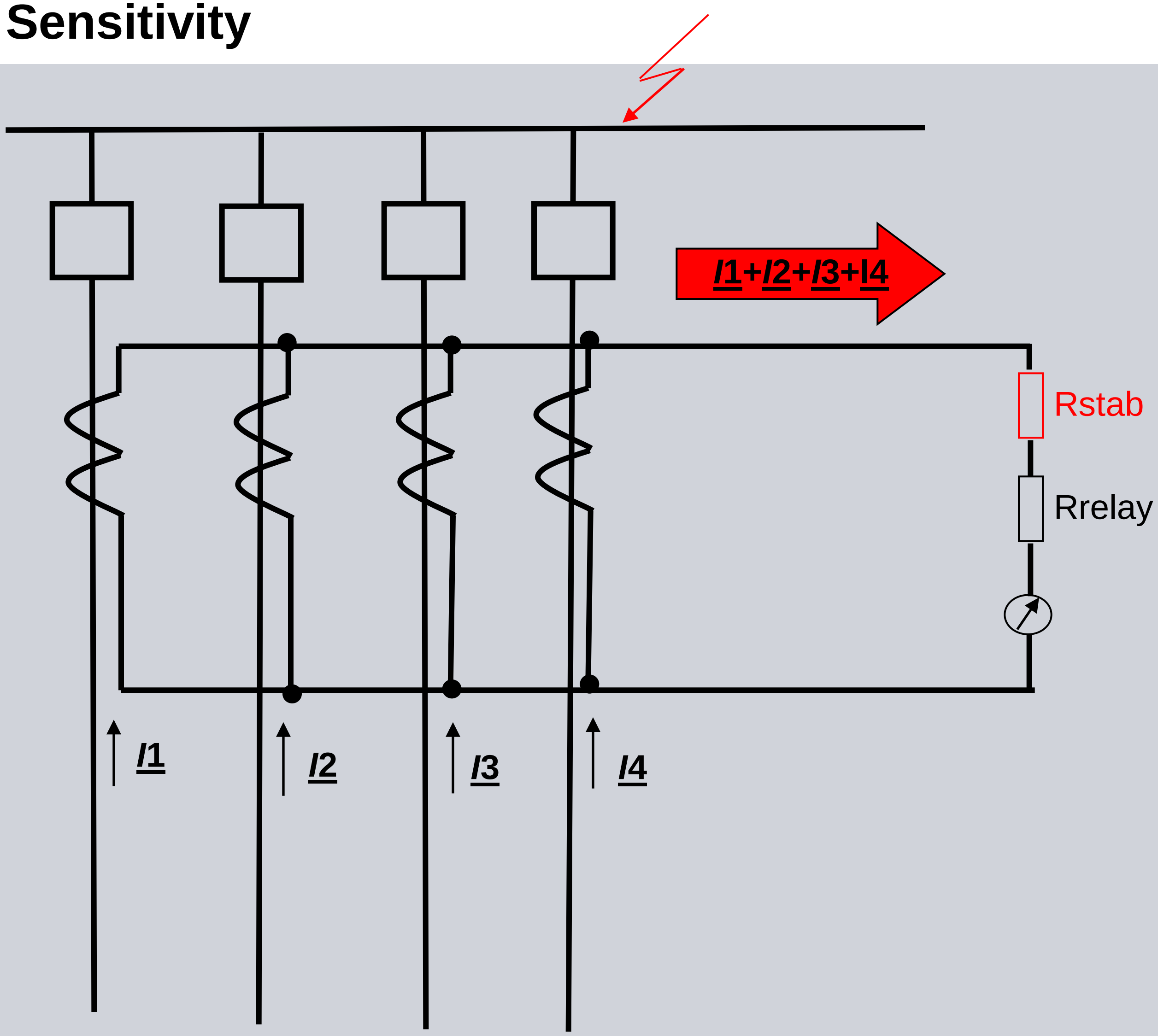


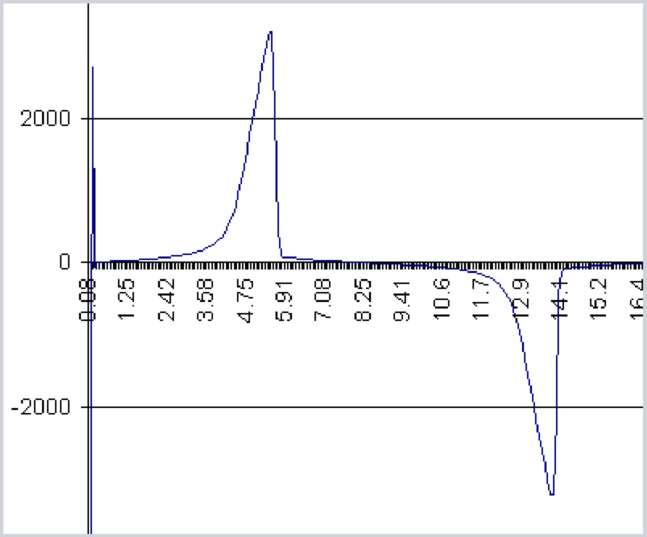
$$k = \frac{R_{CT} \| (R_{relay} + R_{stab})}{(R_{relay} + R_{stab})}$$

$$if \;\; (R_{relay} + R_{relay}) >> R_{CT}$$

$$k \approx 0$$

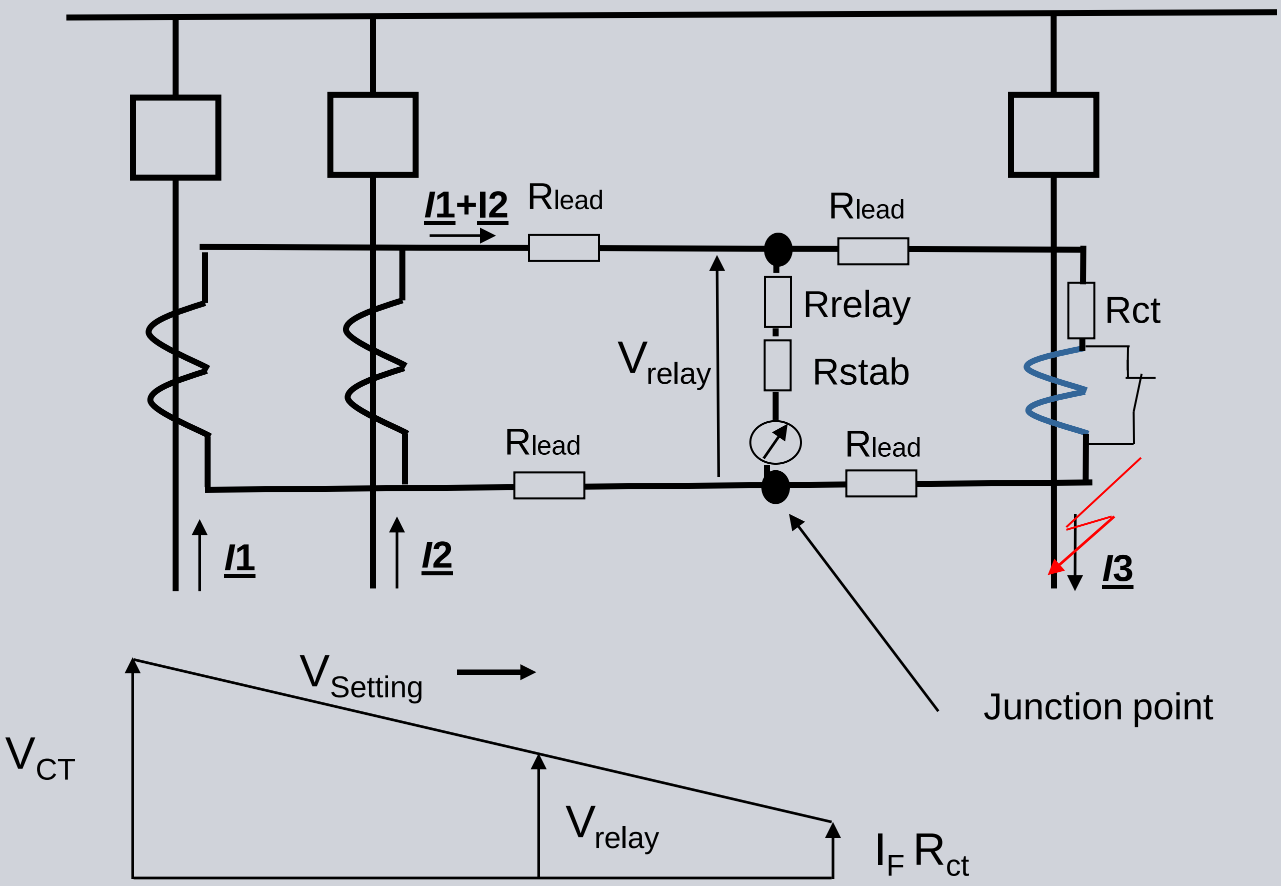
High Impedance Measuring Principle
Sensitivity





$$V_{kneeCT} > 2 \cdot V_{relay}$$

High Impedance Measuring Principle
Stability

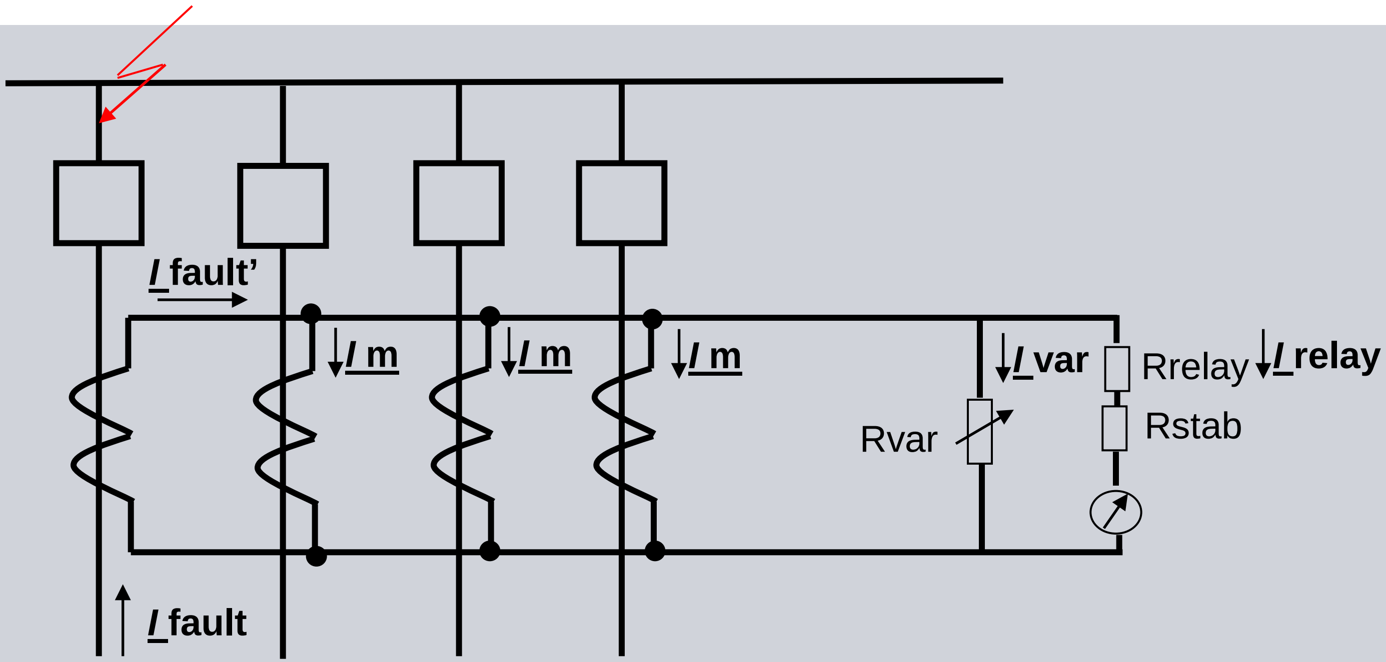


Setting for Stability

$$\left(R_{CT} + 2 \cdot R_{lead}\right) \cdot I_{fault} < V_{relay}$$

Saturated CT is replaced by R_{ct}

High Impedance Measuring Principle
Sensitivity



Setting for Sensitivity $I_{fault} - (n \cdot I_m + I_{var}) > I_{relay}$

$with$

$n = number\ of\ \ feeder$

I_m = CT magnetizing current at relay pickup voltage

I_{var} = Varistor current at relay pickup voltage

High impedance requirements

General requirements on high impedance differential applications

All current transformers need to have the same ratio.

The CT’s should have a low magnetization current, because this will reduce the sensitivity for internal fault .

The resistor of the wiring from the CT’s to the junction point should be as small as possible and not be too different for the different CT’s.

High voltages are generated on internal faults. The voltages will normally become limited by a varistor. The insulation of the wiring needs to be rated for the voltage limited by the varistor.

The current transformer used for the high impedance application can not be shared with other applications.

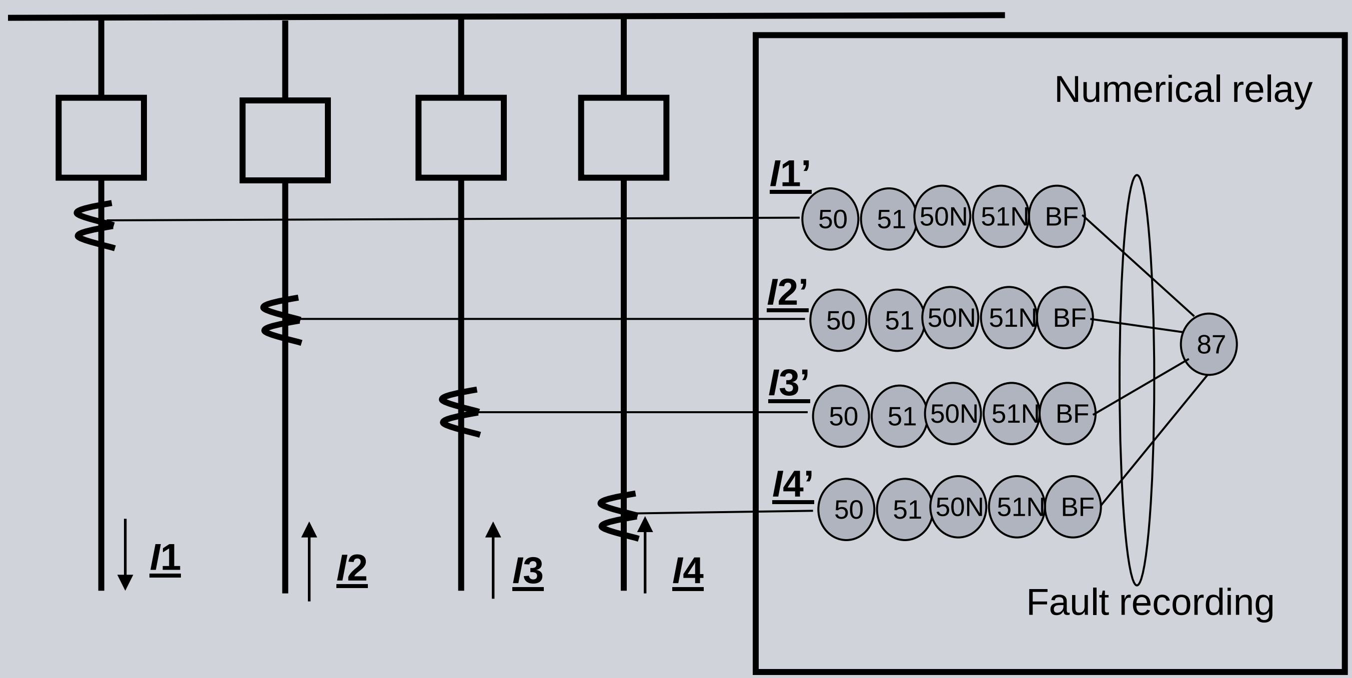
Each bus zone needs a dedicated relay with dedicated CT’s assigned to it.

High Impedance: advantages

Stable stable CT saturation during external fault

Economical solution for simple bus systems

Low Impedance Measuring Principle with numerical relays



Low Impedance: Advantages

no special CT requirements
-> iron closed and linear CT‘s can be combined

different ratios of CTs allowed

CT core can be shared with feeder protection

no separate core necessary for check zone

complex configuration can be handled with medium effort

Commissioning and installation is easier because the requirements are simpler.

Low Impedance: Disadvantages

Special measures required to handle CT saturation

can be expensive for simple systems

Conclusion

Both, low and high impedance bus differential principles have advantages and disadvantages!

The experience of the protection engineer and the requirement of the specific utility application need to be factored in, for the selection of the appropriate bus protection principles.

On simple, single bus systems the advantages and disadvantages of both systems should be evaluated and based on the actual application, one or the other will be best for the application.

On complex bus systems the low impedance principle, realized with modern numerical relays offers more advantages in security and reliability.