SIEMENS

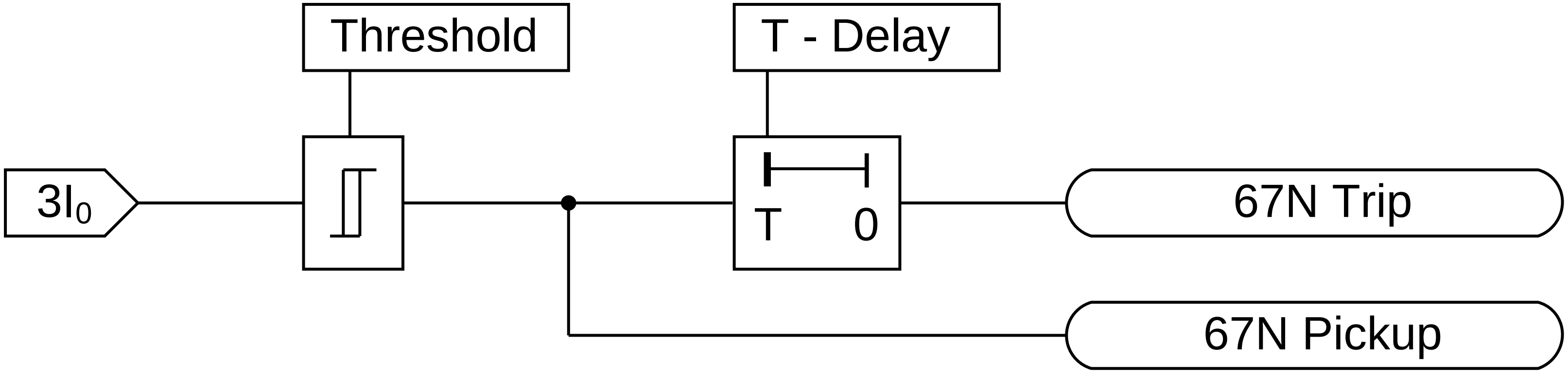
NEW DESIGN OF GROUND FAULT PROTECTION

The 71st Annual Conference for Protective Relay Engineers

Why do we need ground fault protection?

- widely used to protect transmission and distribution lines in case of ground faults
- can detect and isolate even high resistive ground faults which are not seen by distance protection
- often combined with a directional element and used in a teleprotection scheme
- equipped with phase selection also suitable for single pole tripping

Basic principle of ground fault protection



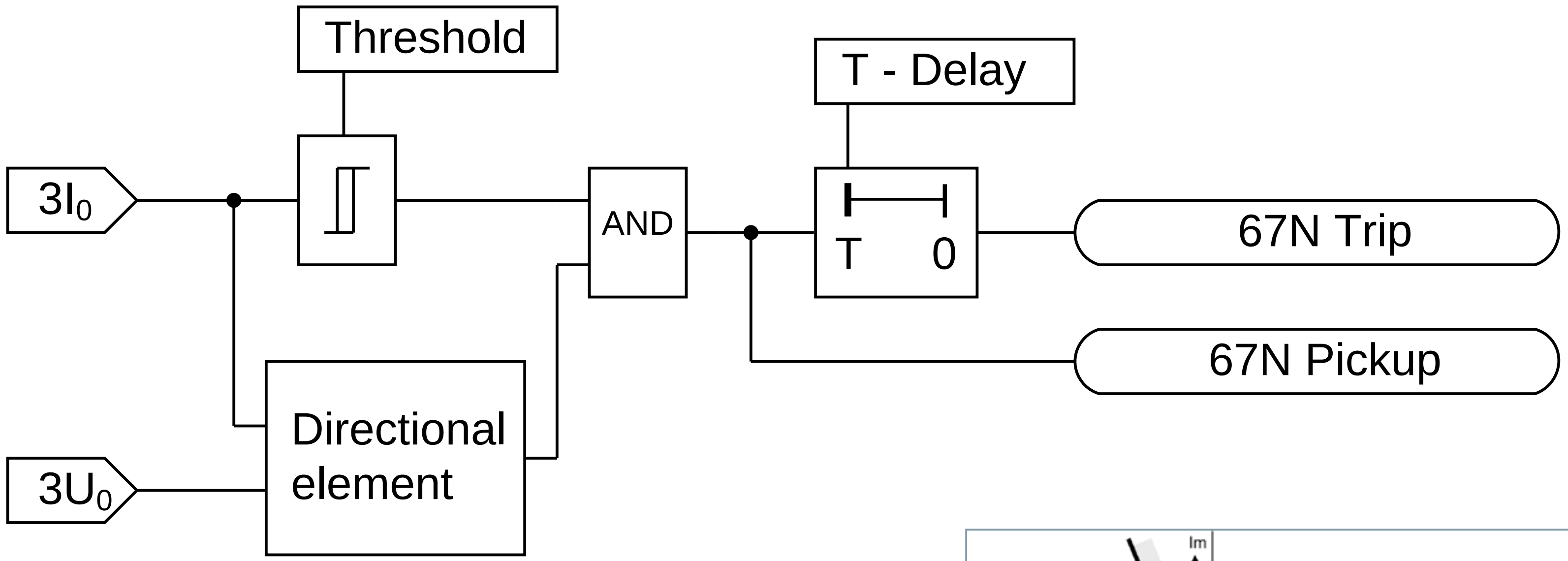
- Ground fault protection is based on zero sequence current

$$3\underline{I}_0 = \underline{I}_A + \underline{I}_B + \underline{I}_C$$

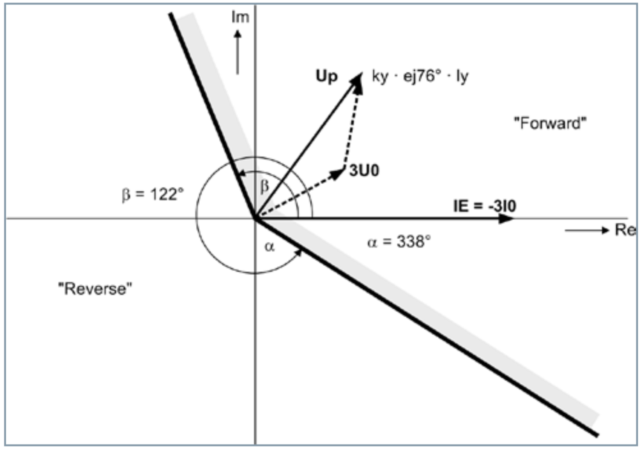
- Ground fault protection picks up if magnitude of zero sequence current exceeds threshold:

$$|3\underline{I}_0| > threshold$$

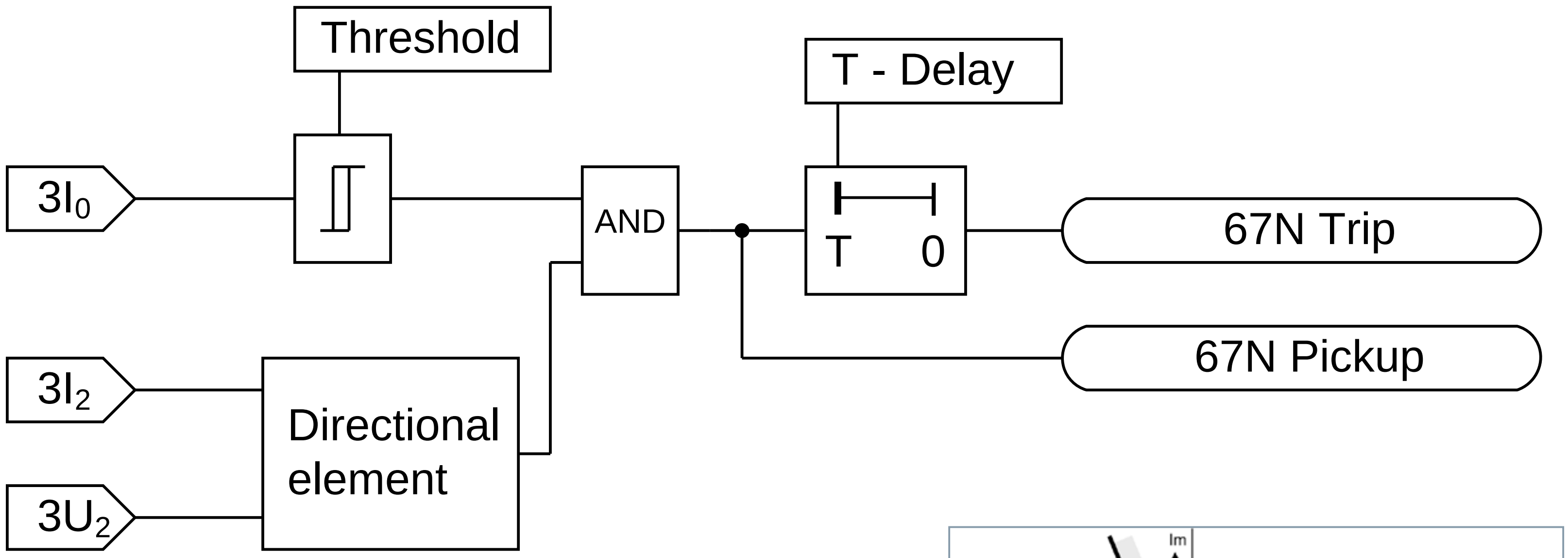
Directional ground fault protection



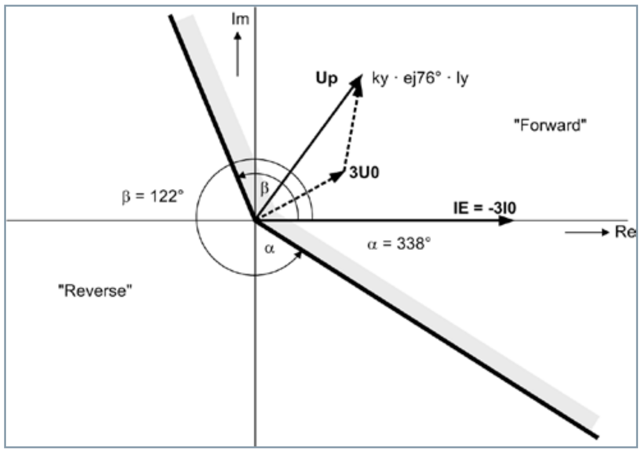
- directional element based on the angle between zero sequence current and zero sequence voltage



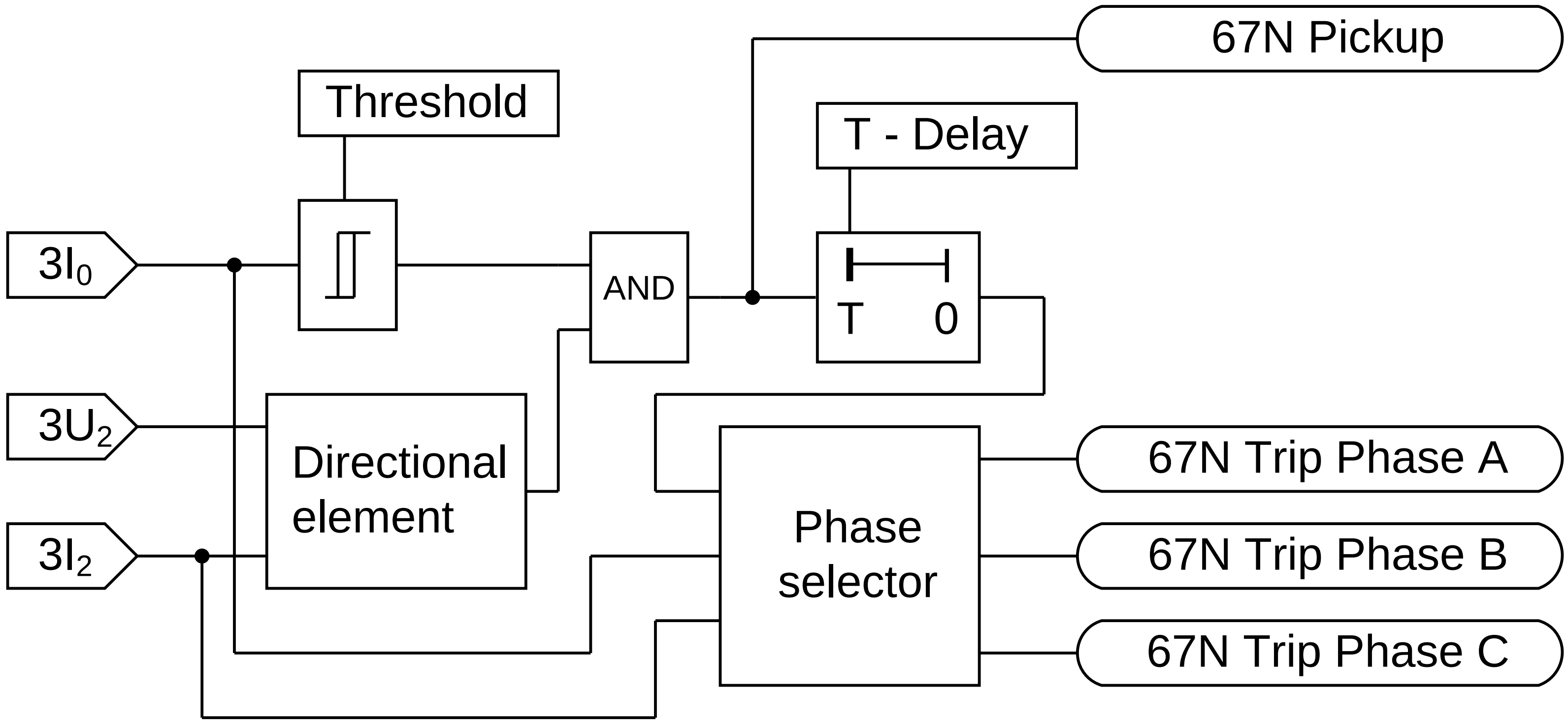
Directional ground fault protection



- directional element based on the angle between negative sequence current and negative sequence voltage

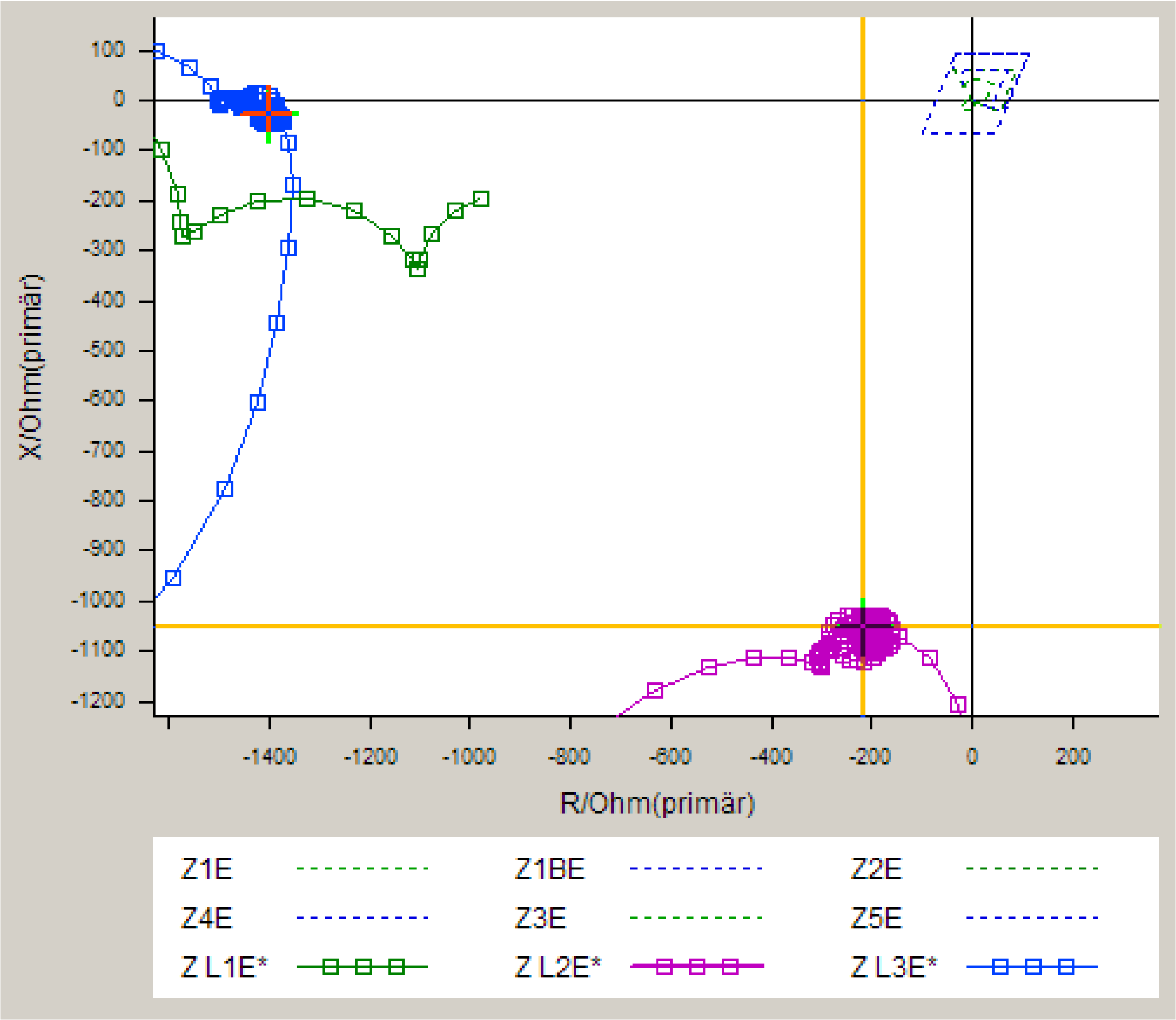


Directional ground fault protection, suited for single pole tripping



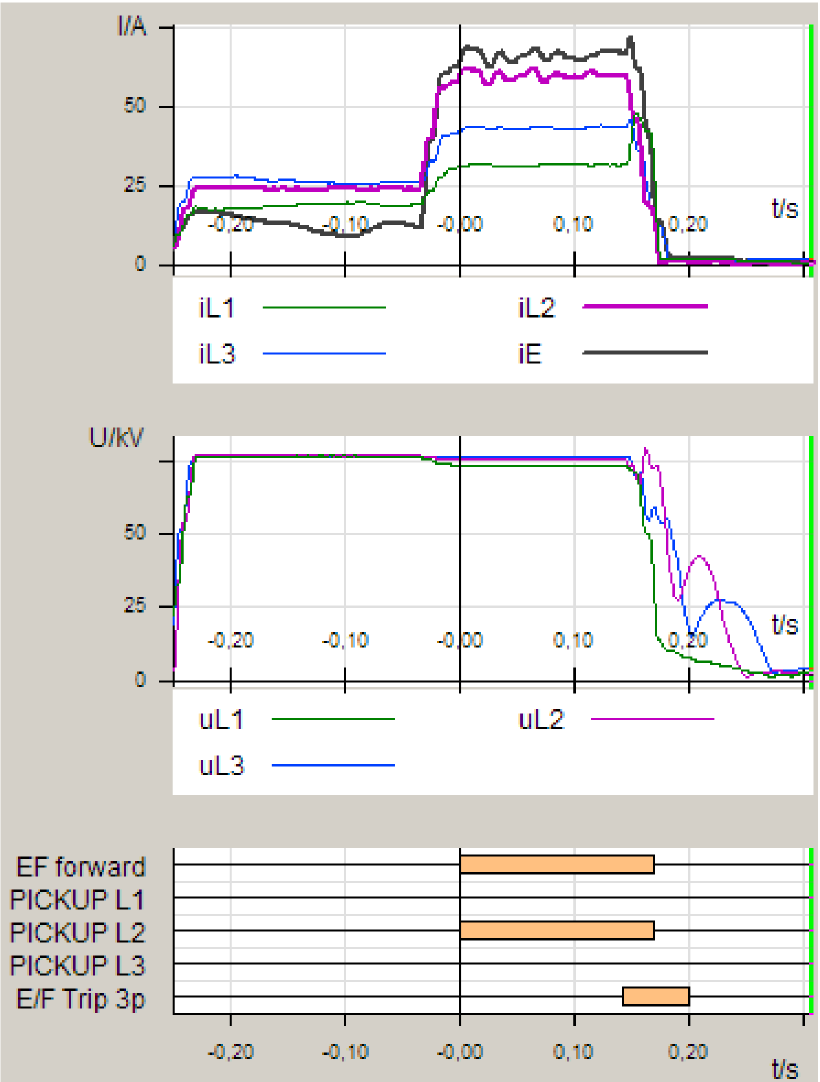
- phase selection using the angle of zero sequence current compared to the angle of negative sequence current

Case 1:
Wrong trip using zero sequence polarization



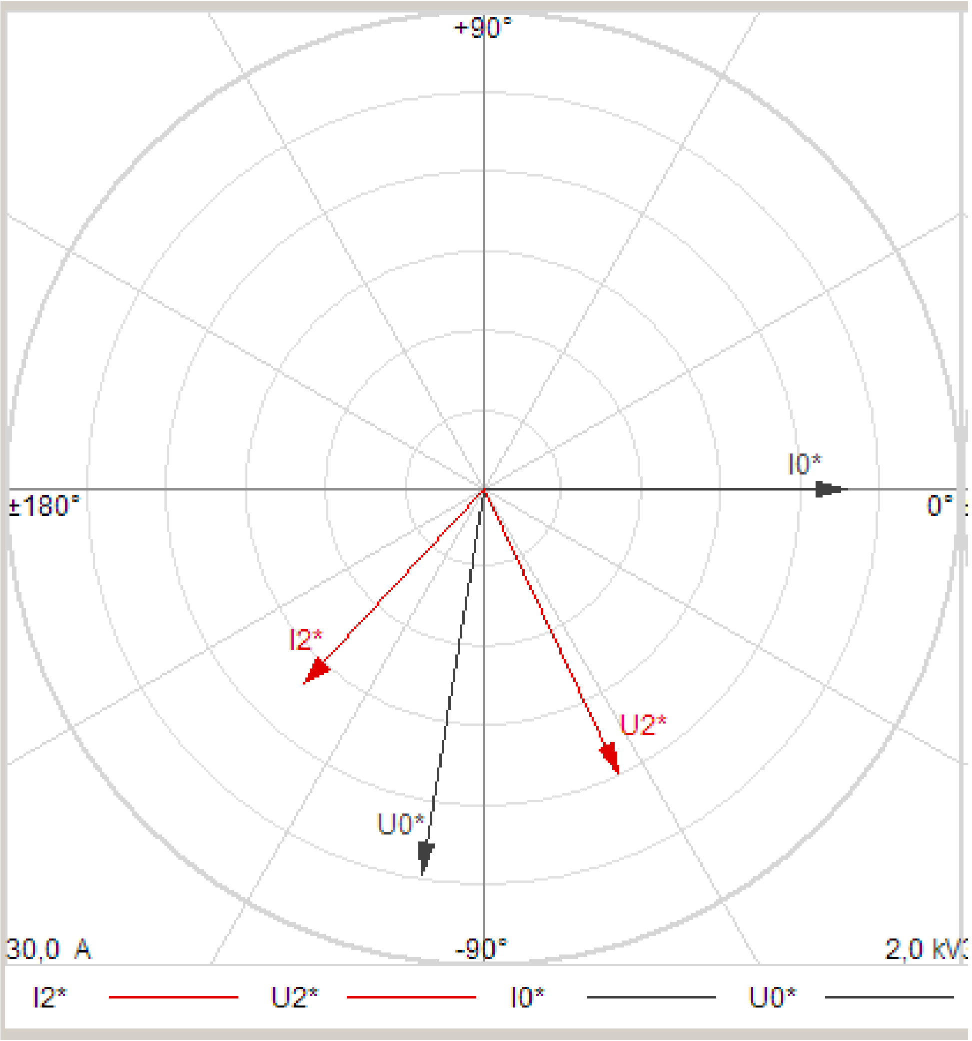
- wrong trip of directional ground fault protection
- Malaysia: 147 km line, 132 kV
- Figure left shows the impedance trajectories in the complex plane
- BG fault, far away from the polygons of distance protection in reverse direction

Case 1:
Wrong trip using zero sequence polarization



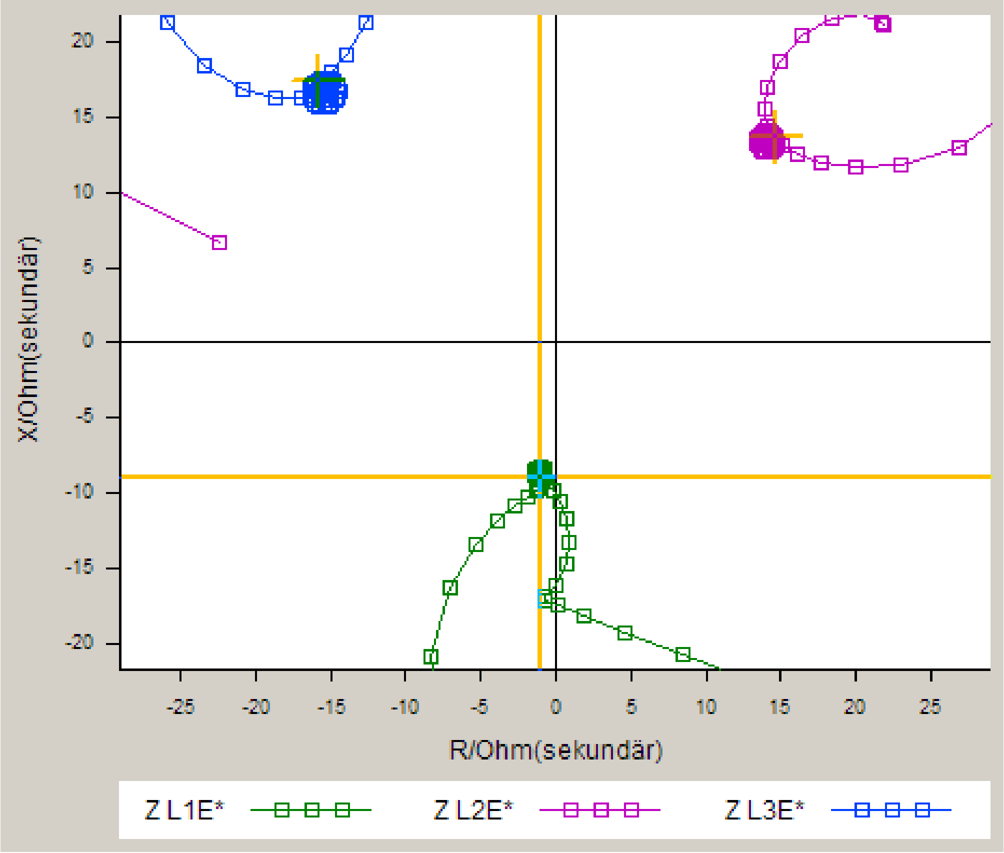
- Ground current iE exceeds the sensitive threshold of 50A primary which leads to a pickup of the ground fault protection
- Current of phase B is raising most which is consistent with the pickup of phase B
- Changes of voltages after fault inception are not very big but leaving enough quantity of zero sequence voltage and negative sequence voltage for the directional element

Case 1:
Wrong trip using zero sequence polarization



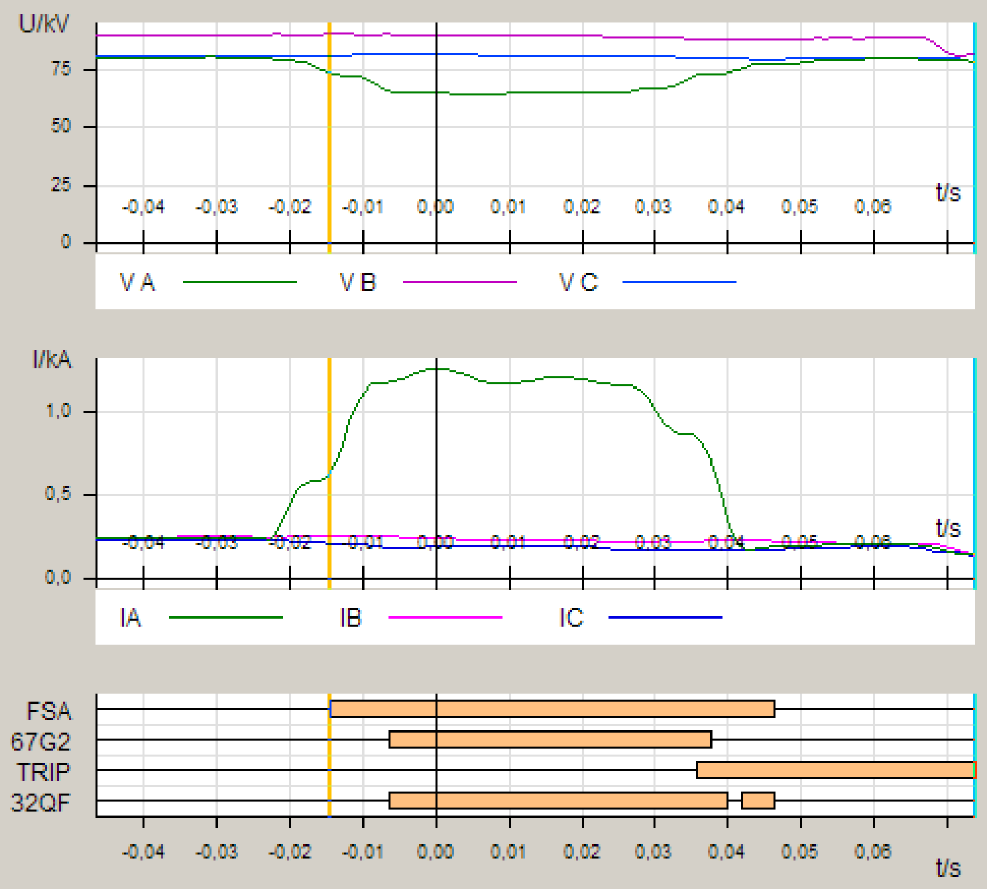
- Figure left is showing zero sequence quantities and negative sequence quantities in the phasor diagram
- zero sequence current is leading zero sequence voltage by approximately 100° → forward fault
- negative sequence current is lagging negative sequence voltage by approximately 60° → reverse fault
- zero sequence quantities are chosen because they are a little larger than negative sequence quantities.

Case 2: Wrong polarization due to an error of voltage transformer



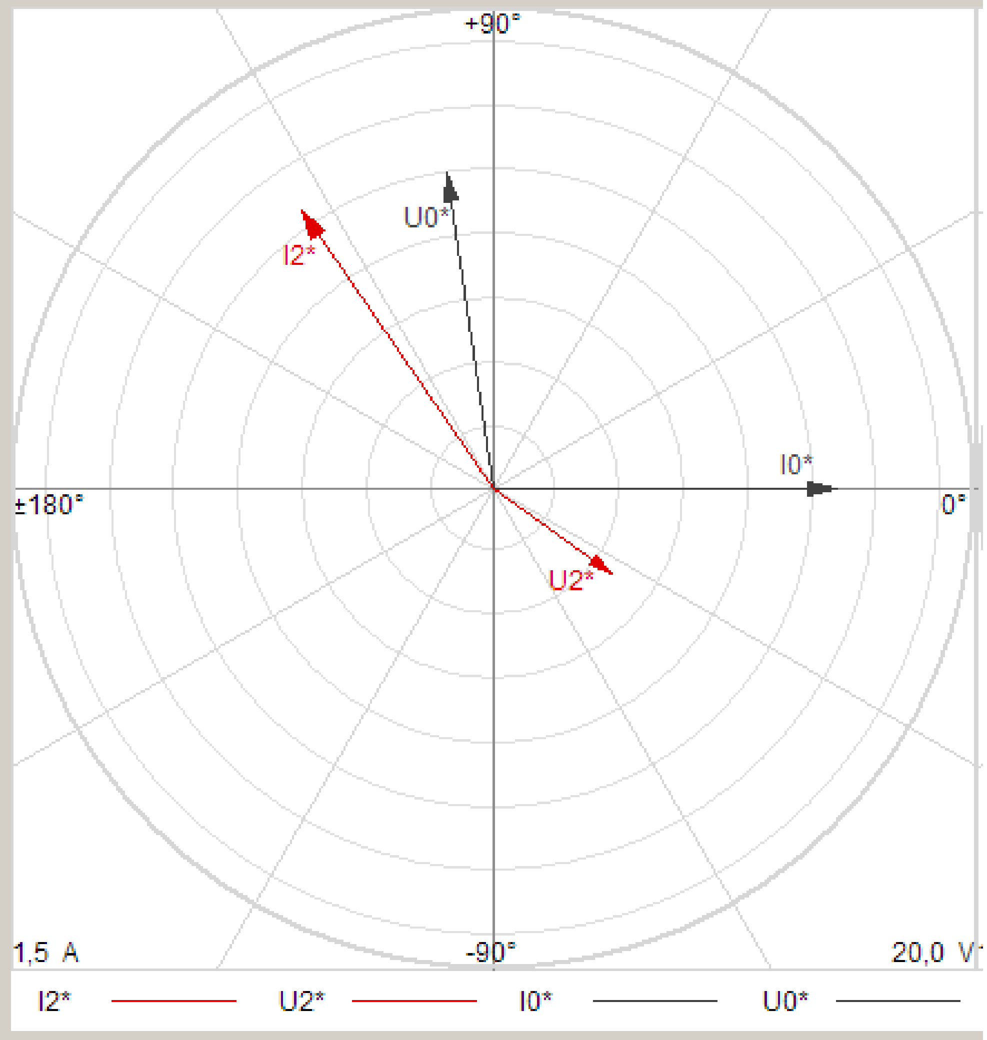
- Figure left shows the impedance trajectories in the complex plane
- It can be seen that the fault AG appears in reverse direction (green marked trajectory)

Case 2: Wrong polarization due to an error of voltage transformer



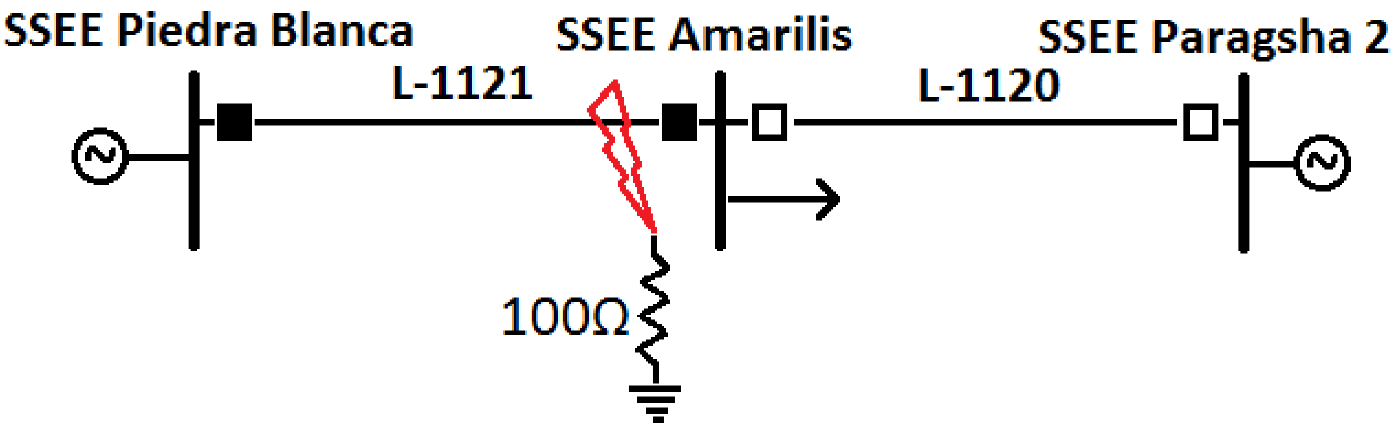
- significant decrease in the voltage VA is a clear indication for a fault AG
- voltage VB shows an asymmetry due to a voltage transformer error
- Wrong reading of VB has a major impact on the wrong direction determination using negative sequence
- Current IA is raising most which leads to a pickup of ground fault protection indicated by the signal “67G2”
- Signal “FSA” indicates that the relay detects the faulted phase A but unfortunately the wrong direction indicated by the signal “32QF”

Case 2: Wrong polarization due to an error of voltage transformer



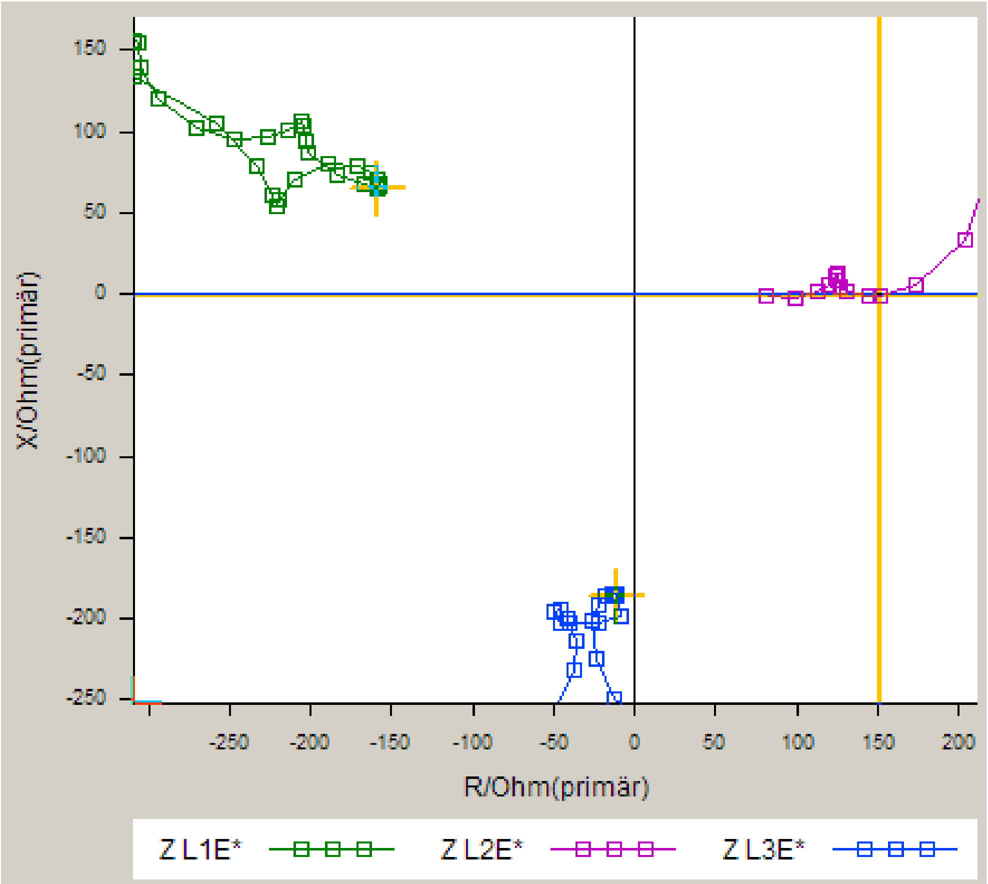
- Figure left shows the zero sequence quantities and negative sequence quantities in the phasor diagram
- negative sequence current is leading negative sequence voltage by approximately 160° → forward fault
- Zero sequence current is lagging zero sequence voltage by approximately 100° →reverse fault
- negative sequence quantities were chosen by setting to detect the direction to fault
- This leads to the wrong trip of the directional ground fault protection

Case 3: Wrong phase selection



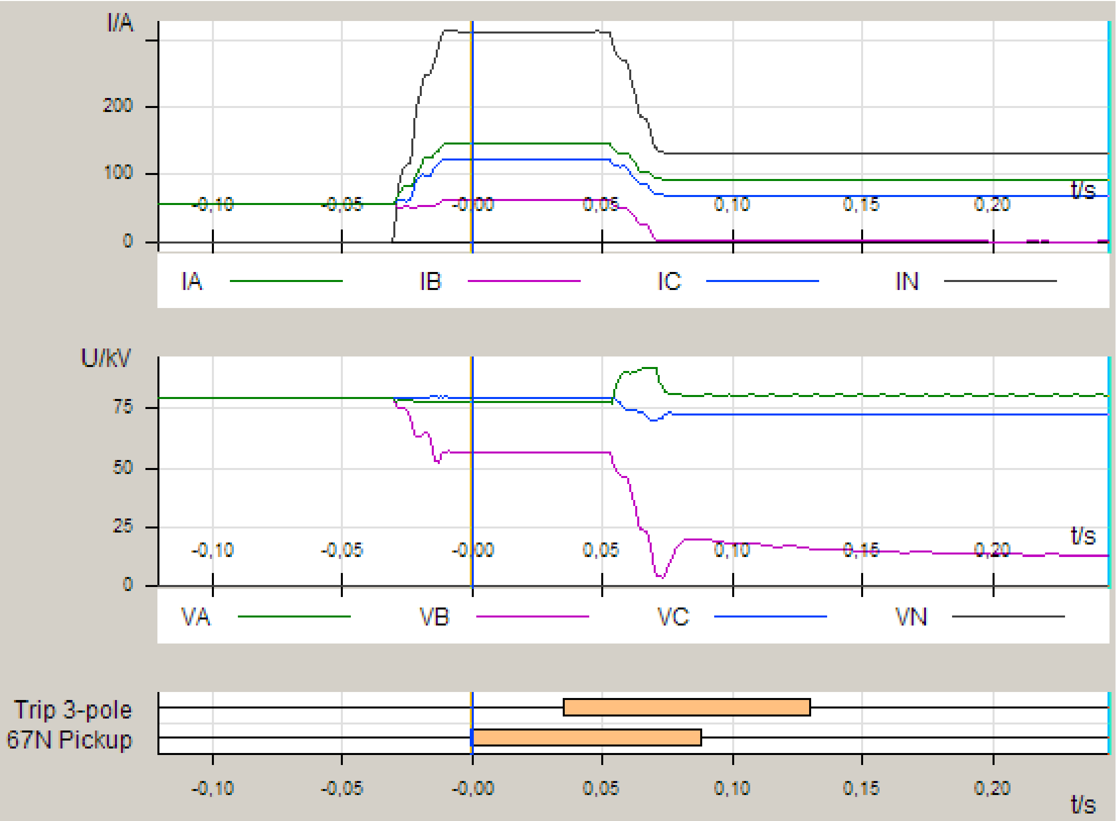
- single phase high resistive fault BG close to Amarilis substation
- At this time the line L-1120 was out of service
- Due to this Amarilis was a weak infeed side with a transformer with a delta winding on its 10 kV side

Case 3: Wrong phase selection



- Figure left shows the impedance trajectories in the complex plane
- fault BG appears on the real axis of the complex plane in forward direction (red marked trajectory)

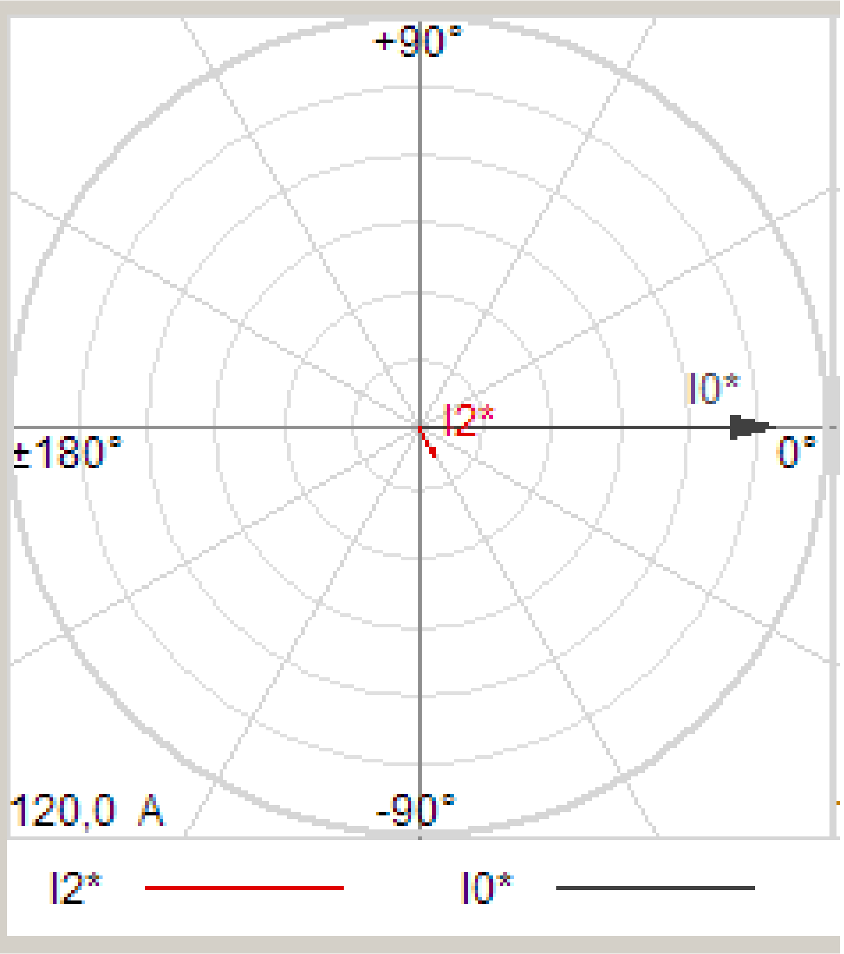
Case 3: Wrong phase selection



- Due to the transformer on the weak side all three phase currents are nearly in phase, producing a ground current which is much bigger than each single phase current
- Ground current causes a pickup indicated by the signal "67N Pickup"
- significant decrease in VB but the faulted phase was not detected

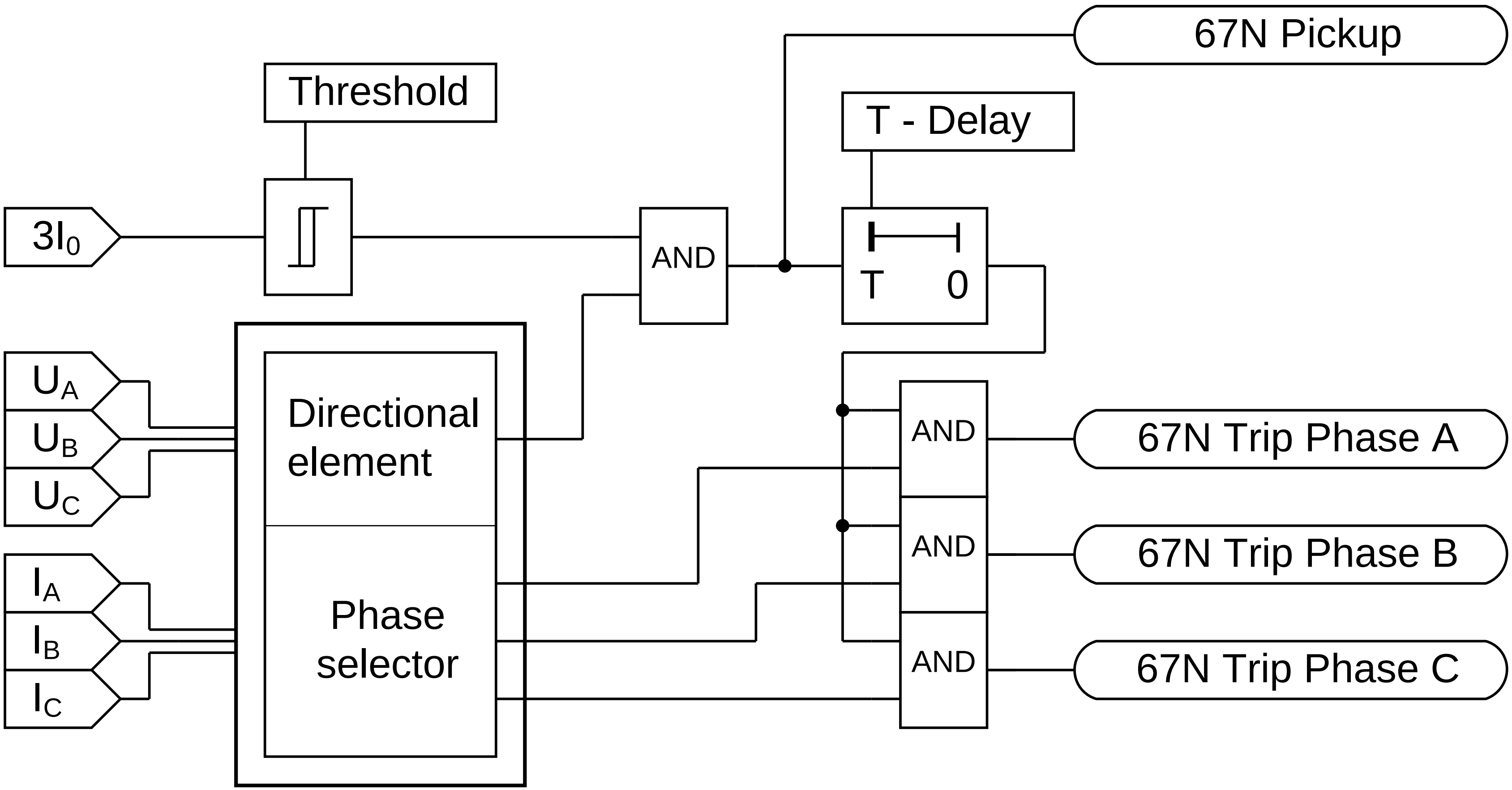
→ Instead of a single pole trip command for phase B a three pole trip was issued indicated by the signal "Trip 3-pole"

Case 3: Wrong phase selection



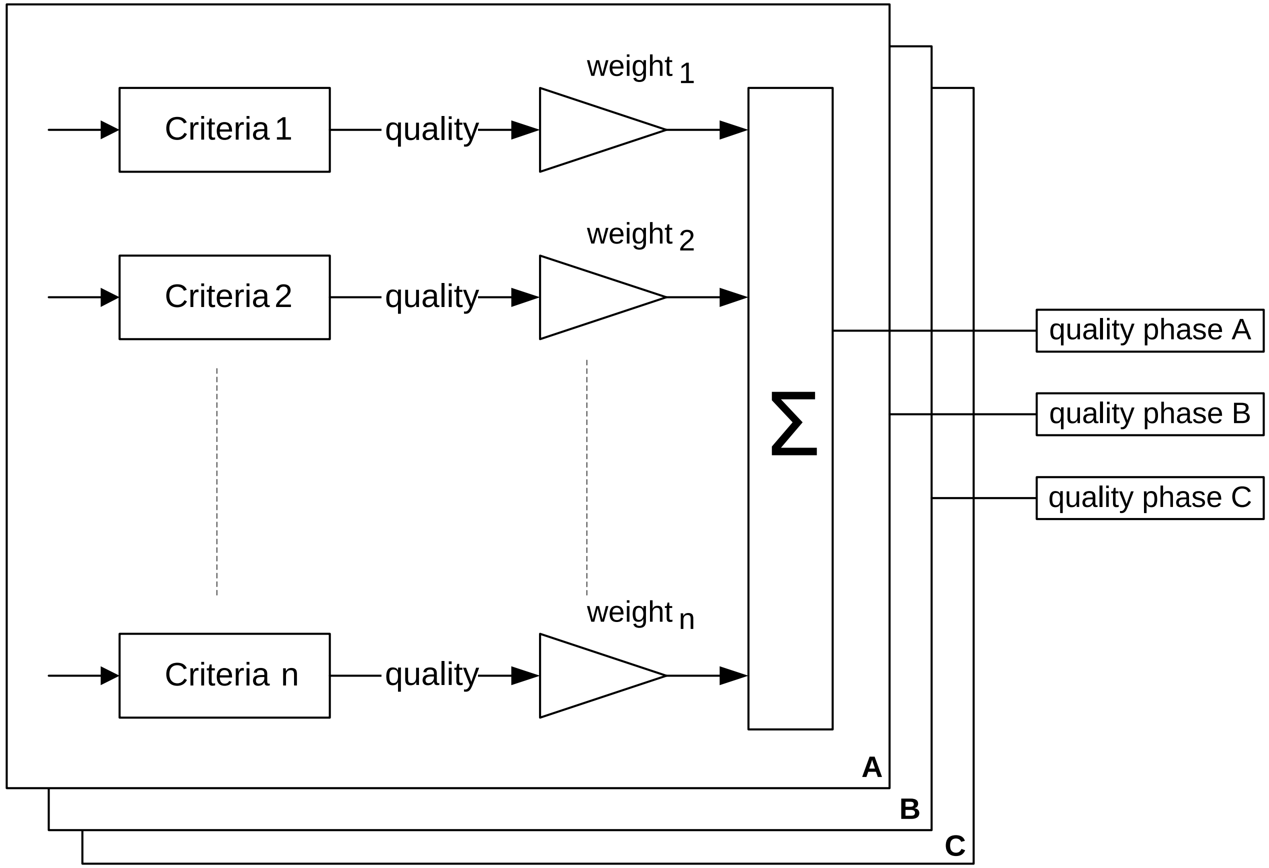
- reason for unselective trip was method applied to detect the faulted phase
- Method is based on the relation between angle of negative sequence current and angle of zero sequence current
- Zero sequence current should lead negative sequence current by approximately 120° for a fault BG
- But zero sequence current is leading negative sequence current by approximately 60° only
  → no clear indication for any type of fault
- Magnitude of the negative sequence current is very small compared to the magnitude of the zero sequence current

New design of directional ground fault protection



- use all available information to detect faulted phase and direction to fault

Multi criteria phase selection

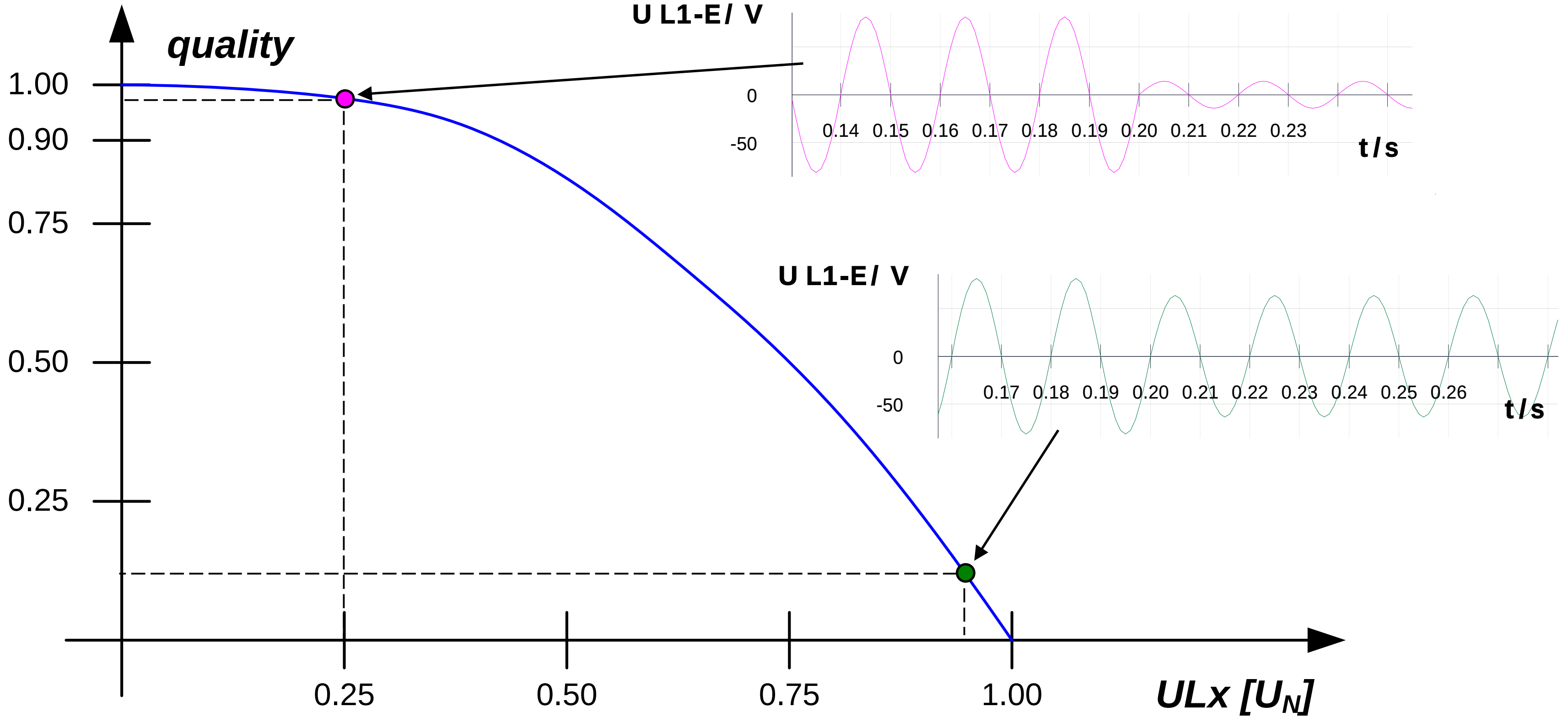


Criteria for phase selection

- Symmetrical components
- Impedance
- Phase current
- Delta current
- Current sample
- Current phasor
- Phase voltage
- Delta voltage
- Voltage sample
- Voltage phasor

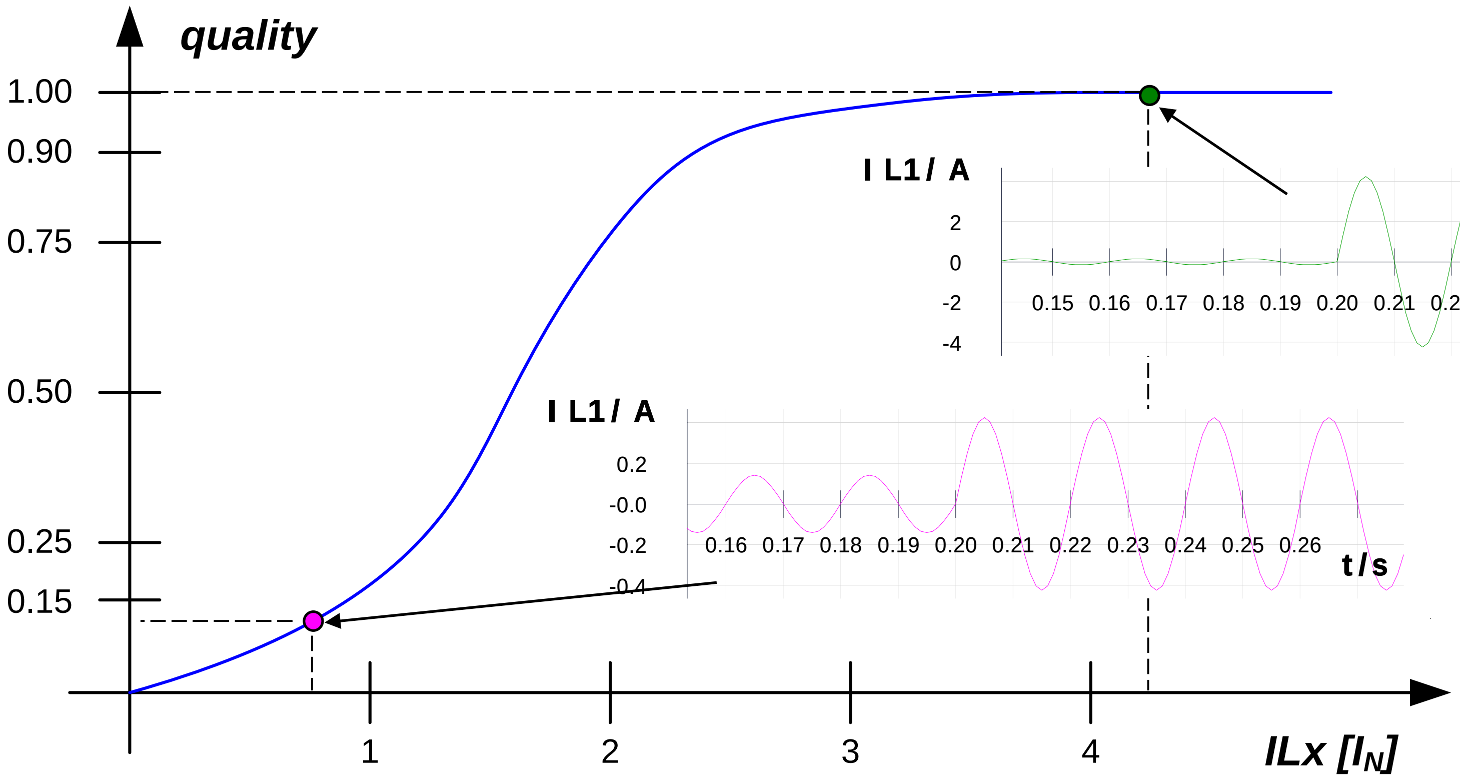
Voltage magnitude criteria

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



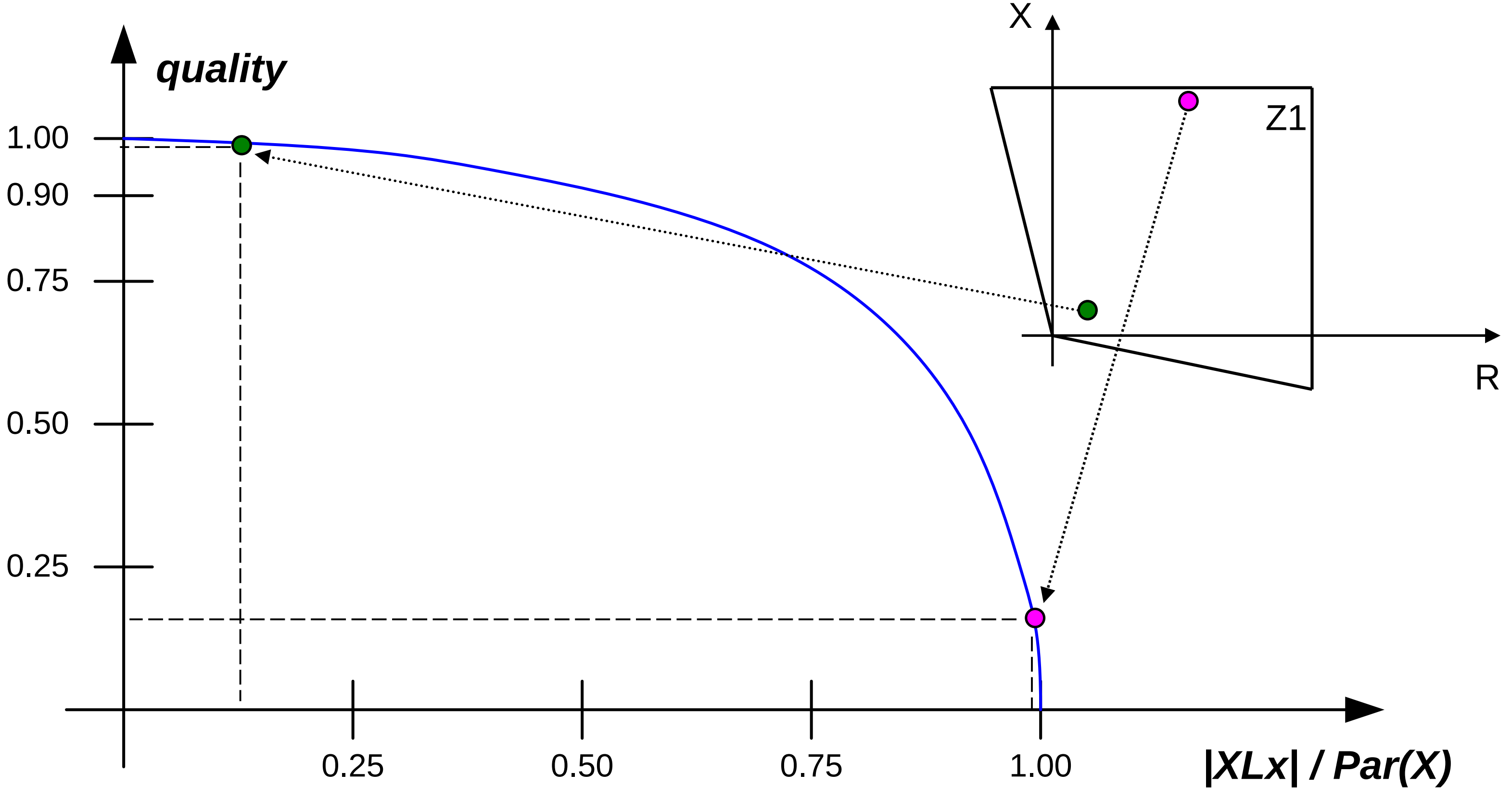
Current magnitude criteria

The higher the current, the higher the quality of the result.



Impedance ratio criteria

The lower the ratio between the measured X and the parameterized X, the higher the quality of the related loop.



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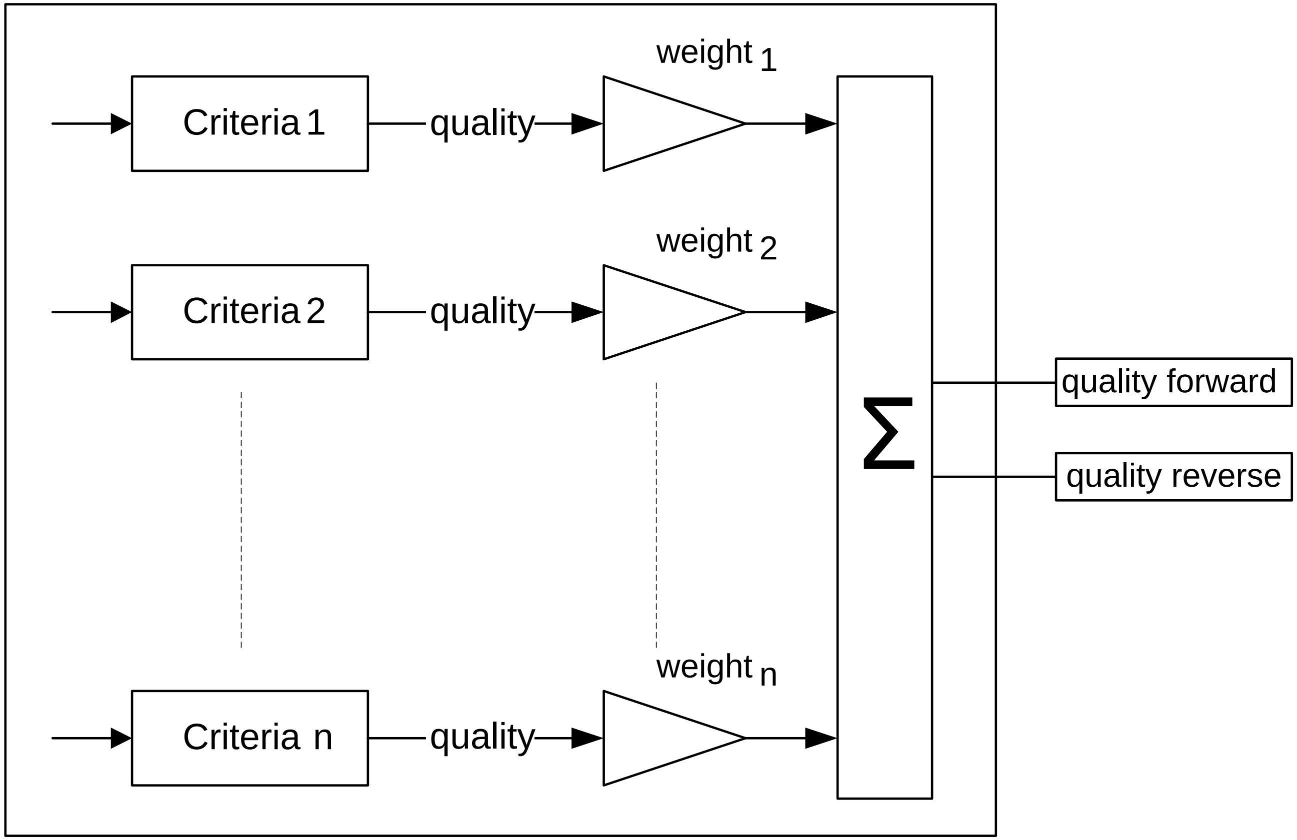
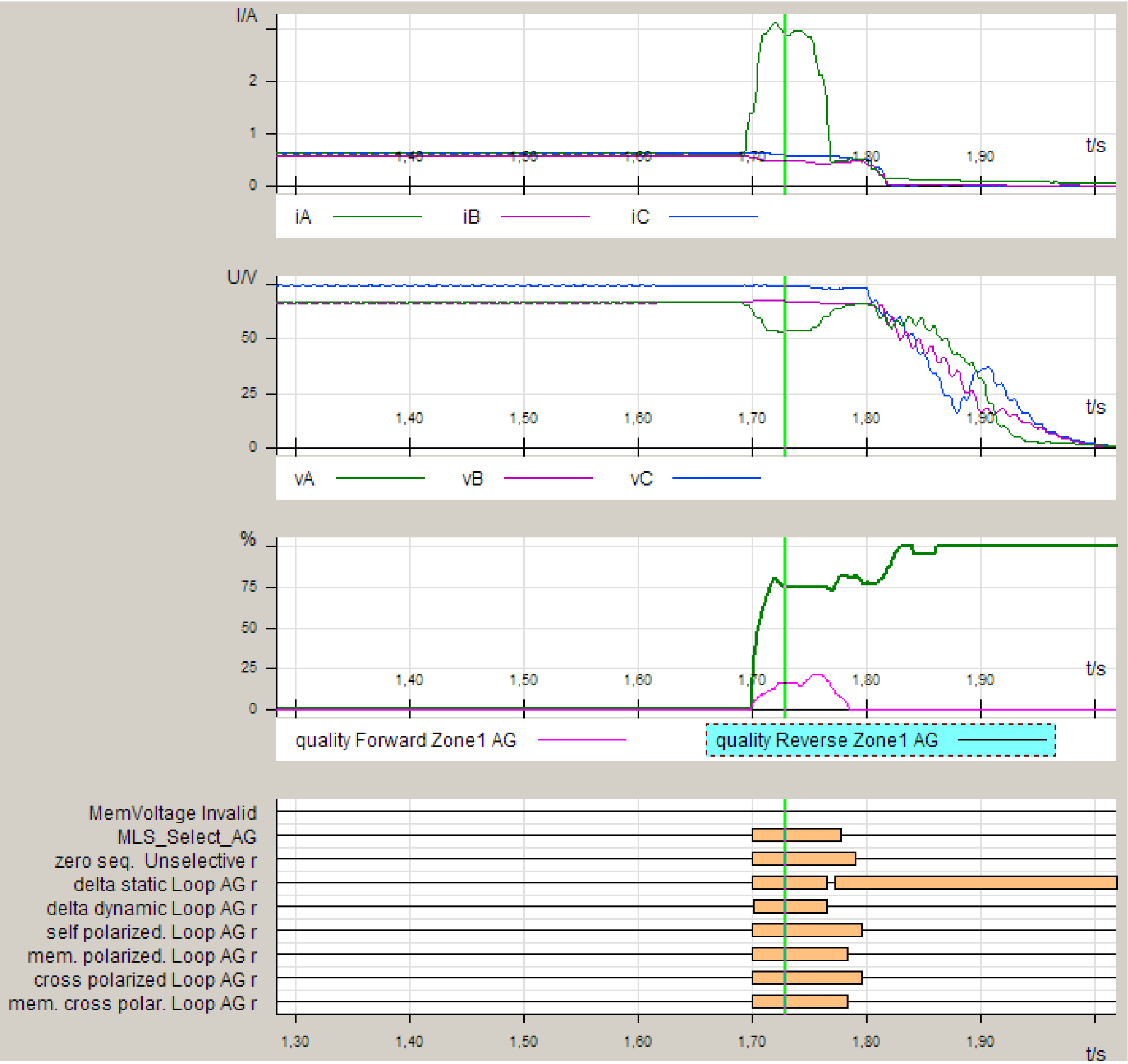
Multi criteria directional element



Criteria for directional element

- Zero sequence
- Negative sequence
- Self polarization
- Memory polarization
- Cross polarization
- Memory cross polarization
- Polarization using delta quantities of faulted phase
- Polarization using delta quantities of symmetrical components

Multi-criteria directional element applied to case 2



- The binaries show that 7 criteria determine the fault in reverse direction
- Quality of reverse direction: >75%
- Quality of forward direction: <25%

→ **Multi-criteria directional element can detect the right direction even if some criteria fail**

Conclusion

- It was shown that the reach of the classical impedance calculation method is significantly influenced by resistive faults on heavy loaded lines.
- Using the reactance method this reach error can be eliminated.
- Additionally a new method of loop selection was presented which is optimized for all network topologies.
- The same philosophy is applied for directional element where different algorithm are weighted dependent on network topology.

Thank you for your attention!

Jörg Blumschein
Principal Key Expert Protection
EM DG PRO LM&D PPM

Wernerwerkdamm 5
13629 Berlin

Phone: +49 (30) 386 20135
Fax: +49 (30) 386 25158

E-mail:
joerg.blumschein@siemens.com

siemens.com/answers