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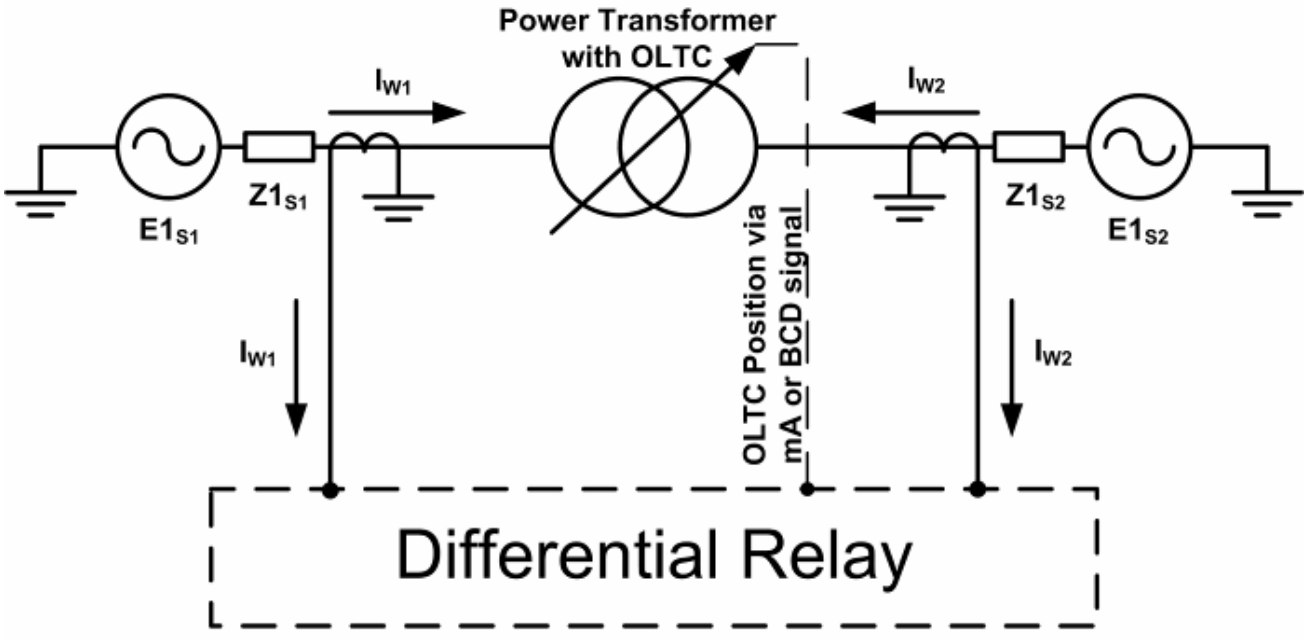
Using Symmetrical Components for Internal / External Fault Discrimination in Differential Protection Schemes

AGENDA

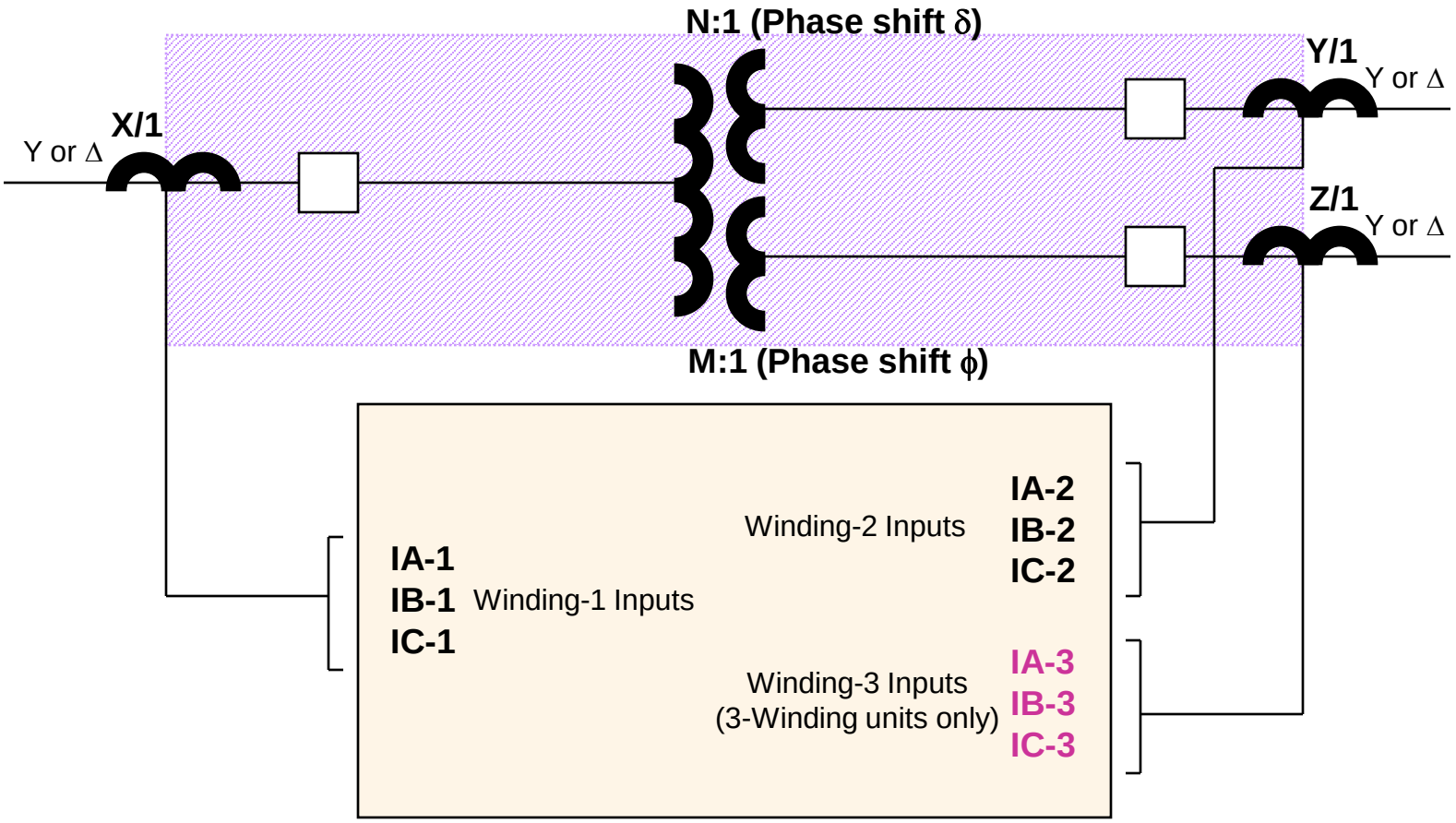
- Differential Protection
- Symmetrical Components
- Properties of Negative Sequence Quantities
- Principle of Internal / External Fault Discriminator
- Impact of Current Transformer Saturation
- Evolving Faults and Inter-turn Faults
- Three-phase Symmetrical Faults
- Improvement in Overall Differential Protection Function
- Implementation at Power Stream MTS4 Station
- Conclusions

Differential Protection



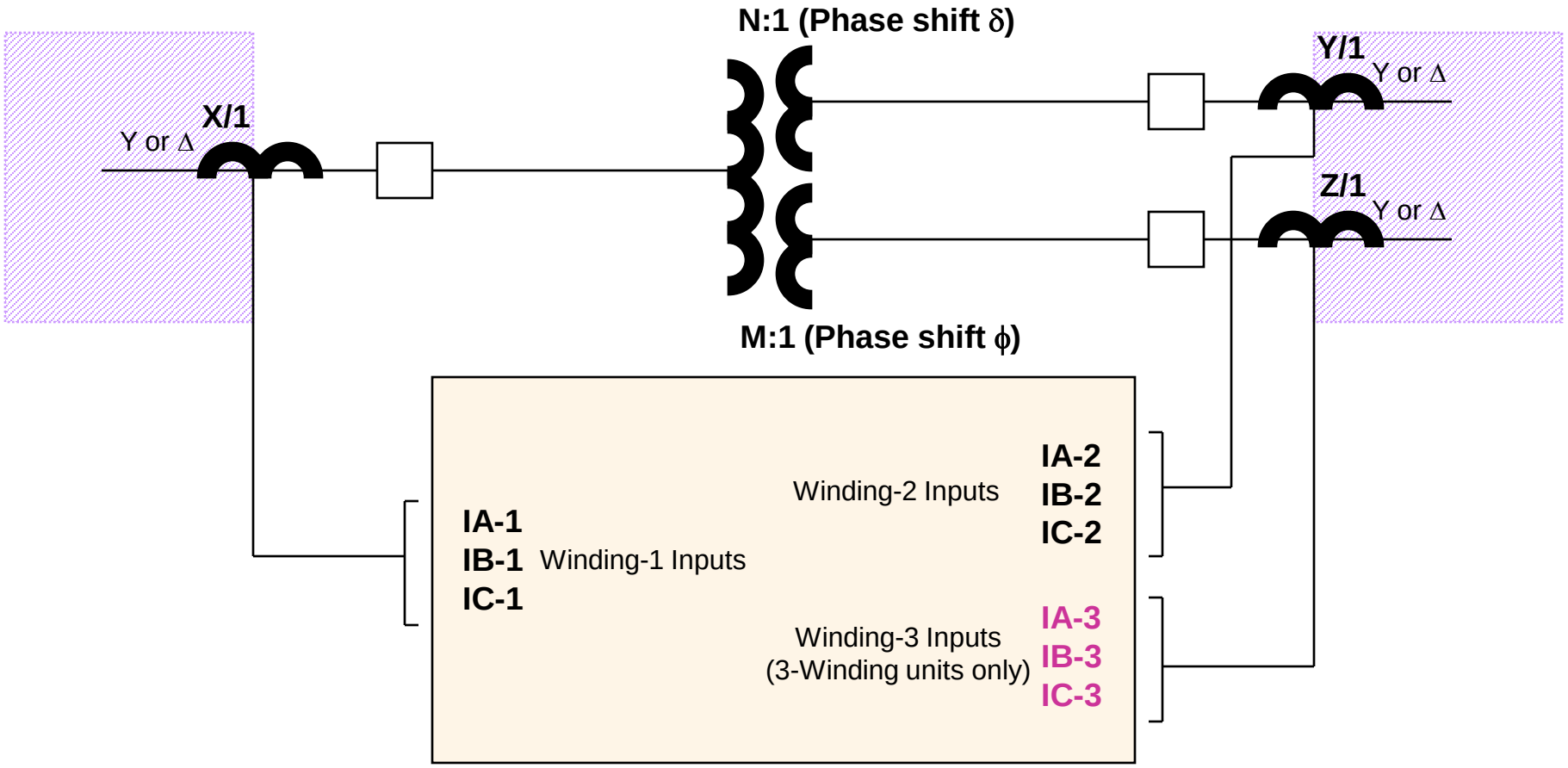
Differential Protection

Zone of protection defined by current transformers (CT's)

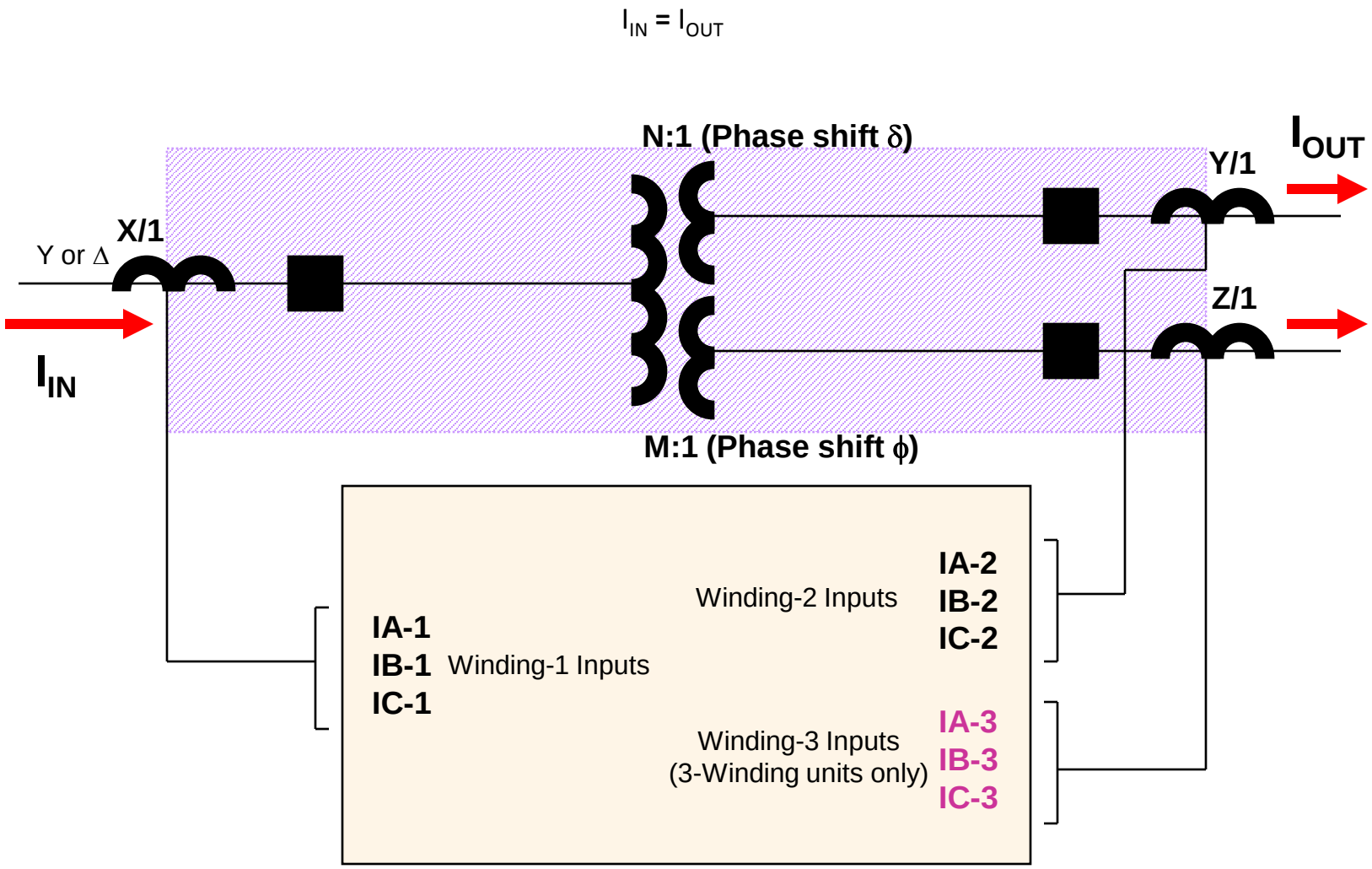


Differential Protection

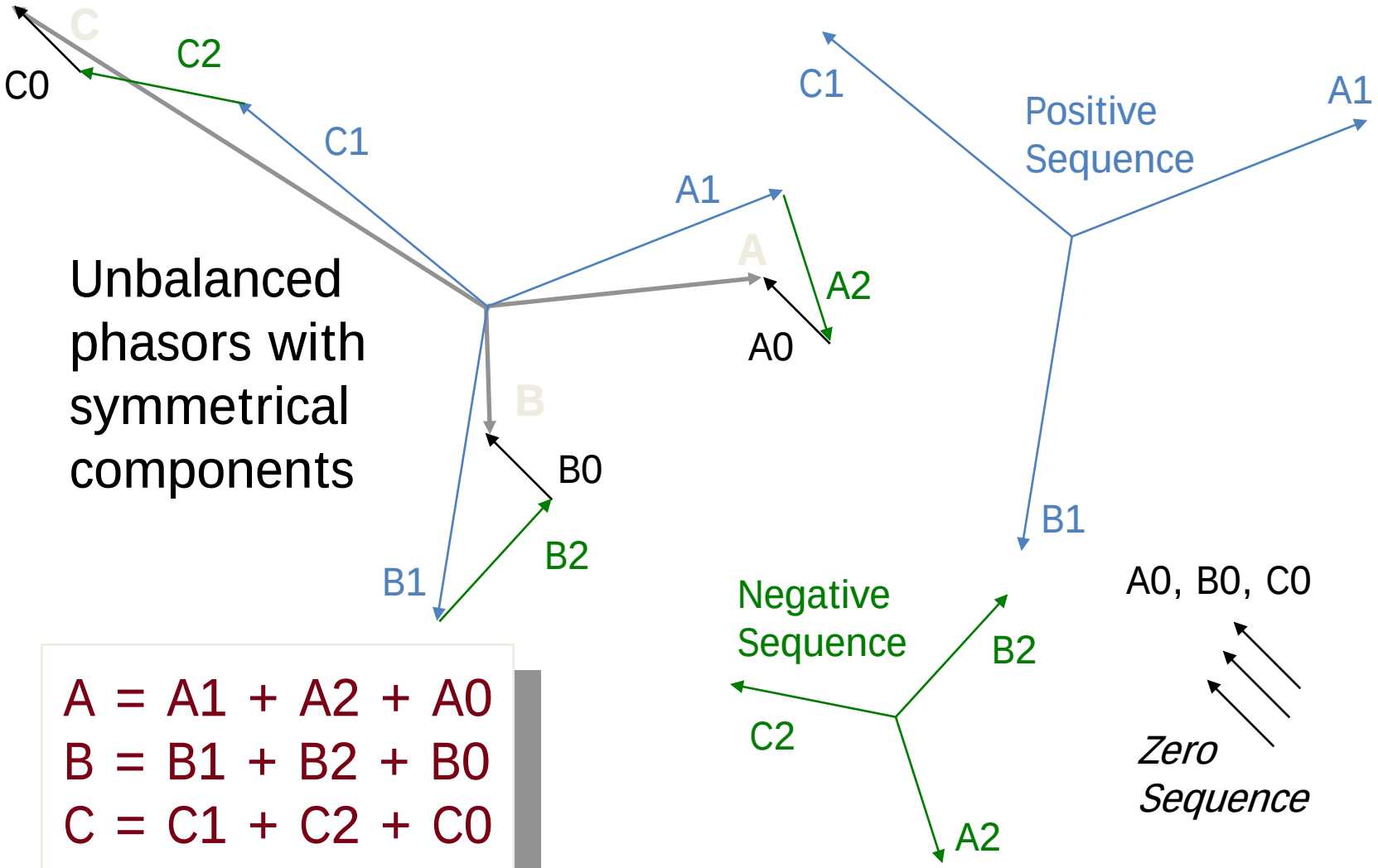
Non-trip zone for phase differential protection



Differential Protection



Symmetrical Components



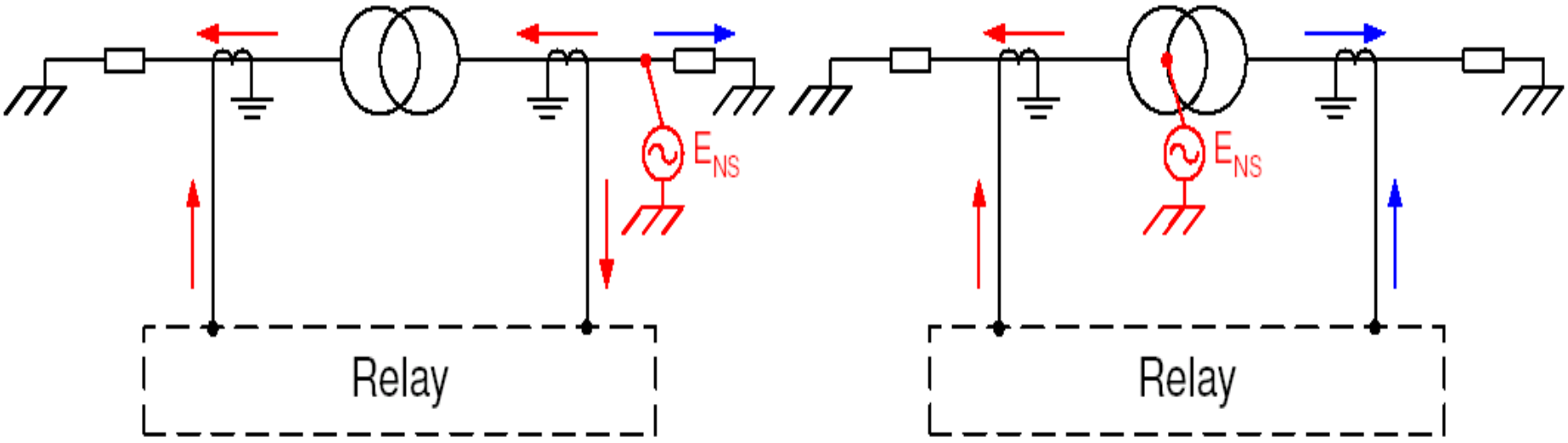
A = A1 + A2 + A0
B = B1 + B2 + B0
C = C1 + C2 + C0

Properties of Negative Sequence Currents

1. Fictitious source of negative sequence current is the point of fault
2. Negative Sequence current distribute through the negative sequence network
3. Negative Sequence current obey Kirchhoff's law

Principle of Internal/ External Fault Discriminator

- Fault position (internal / external) can be determined by comparing the direction of flow of the negative sequence currents on all sides of the transformer
- External fault: the negative sequence currents will have a relative phase displacement of 180°
- Internal fault: the negative sequence currents will have a relative phase displacement of about 0°

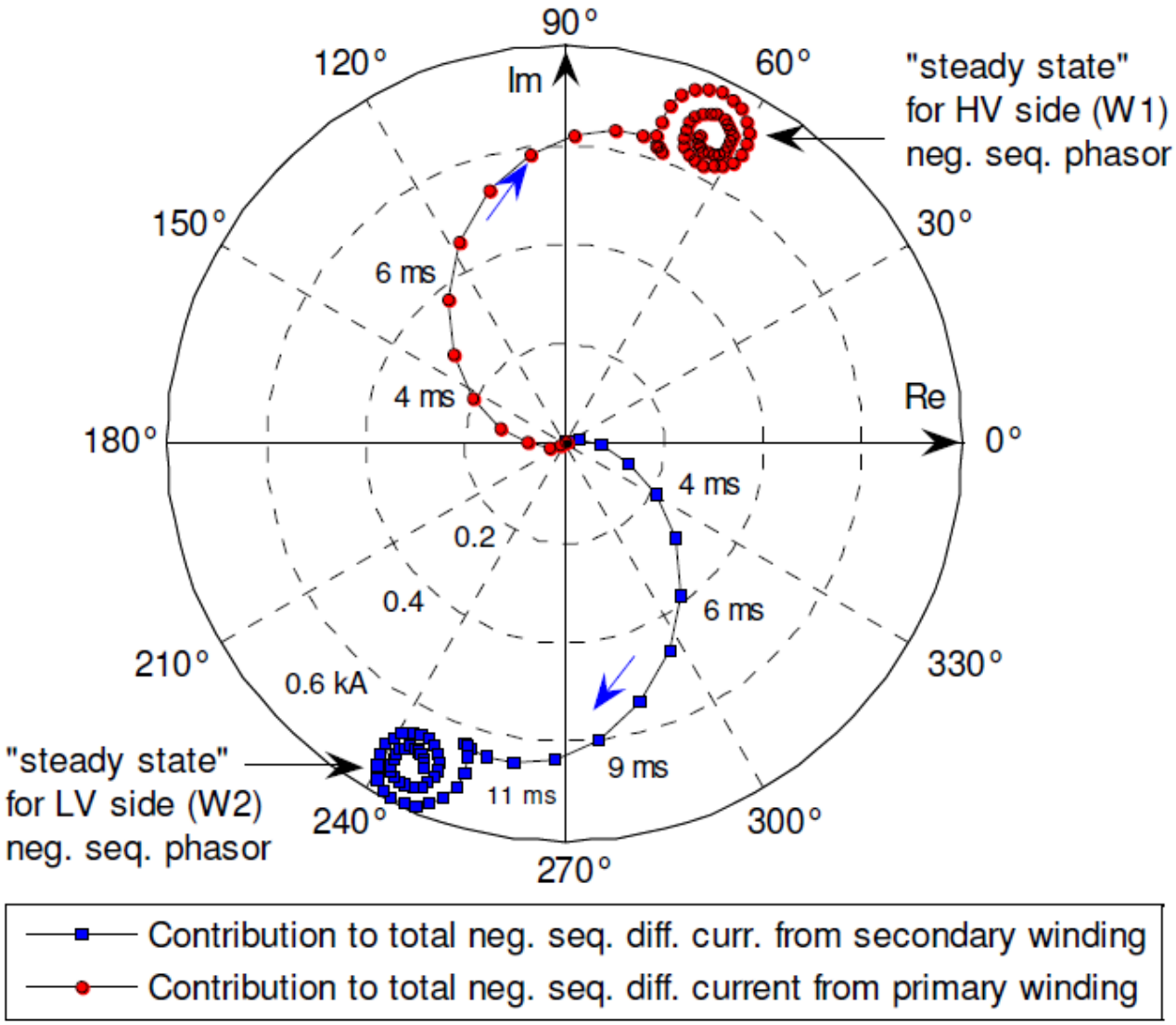


Impact of Transformation Ratio and Phase Shift

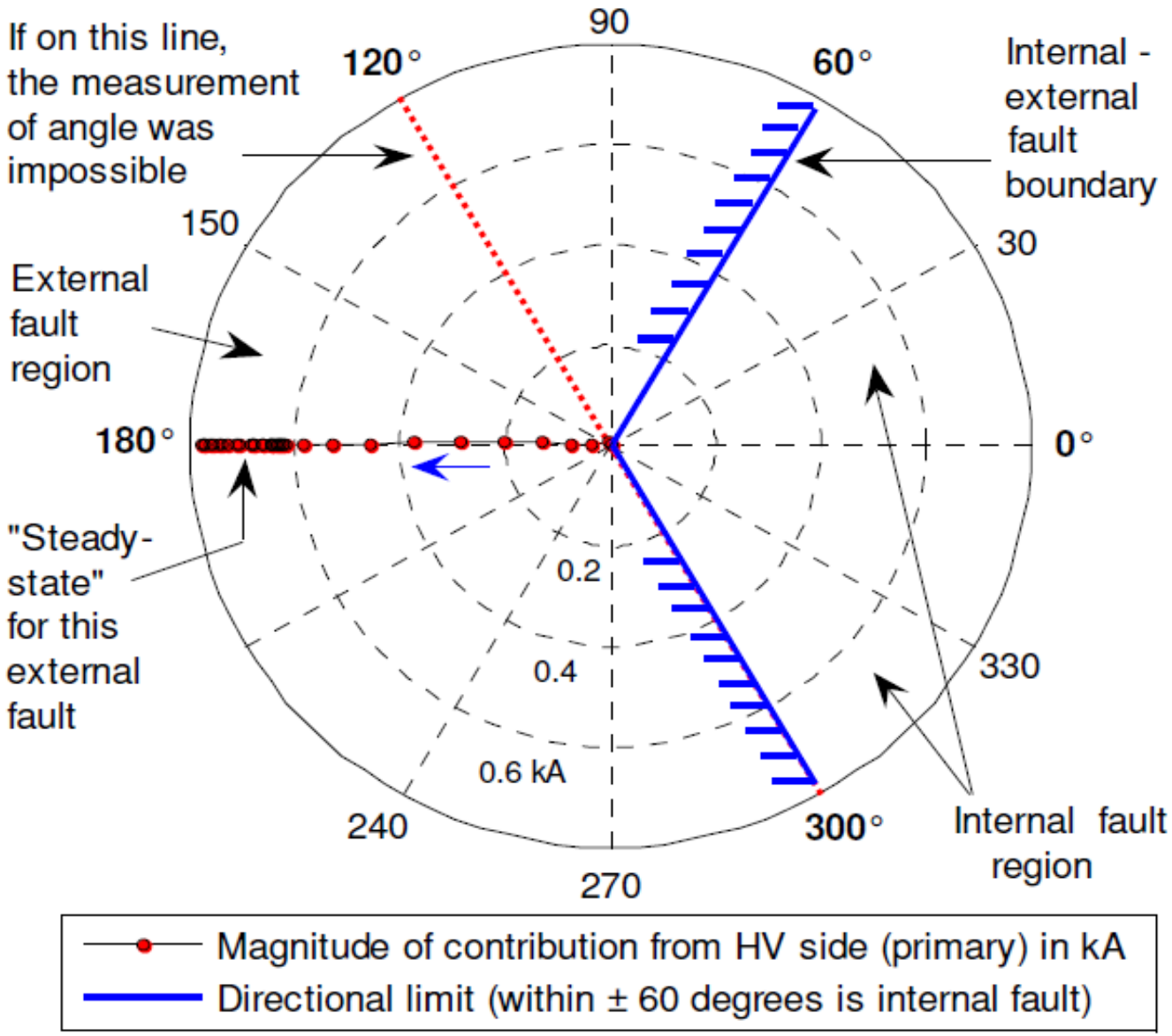
- Negative sequence current components are compensated for power transformer vector group and turns ratio
- The 0° / 180° criterion is still valid

$$\begin{bmatrix} Idns\_L1 \\ Idns\_L2 \\ Idns\_L3 \end{bmatrix} = \underbrace{\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} * \begin{bmatrix} Ins\_A \\ Ins\_B \\ Ins\_C \end{bmatrix}}_{\text{Contribution to total negative seq. current from HV side (e.g. Y)}} + \underbrace{\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} * \begin{bmatrix} Ins\_a \\ Ins\_b \\ Ins\_c \end{bmatrix}}_{\text{Contribution to total negative seq. current from LV side (e.g. d)}}$$

Negative Sequence Contributions for an External Fault



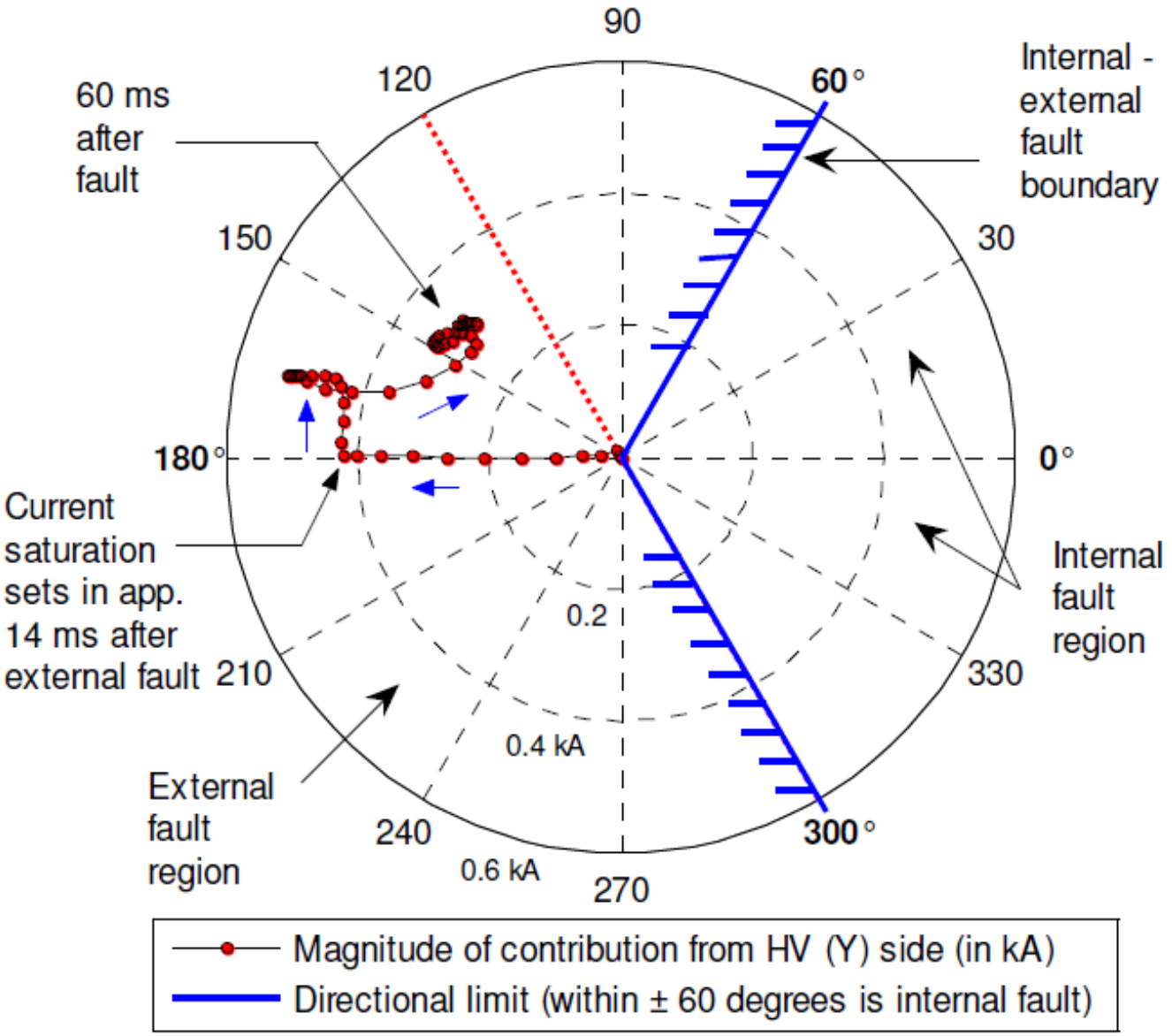
External Fault--- Directional Comparison



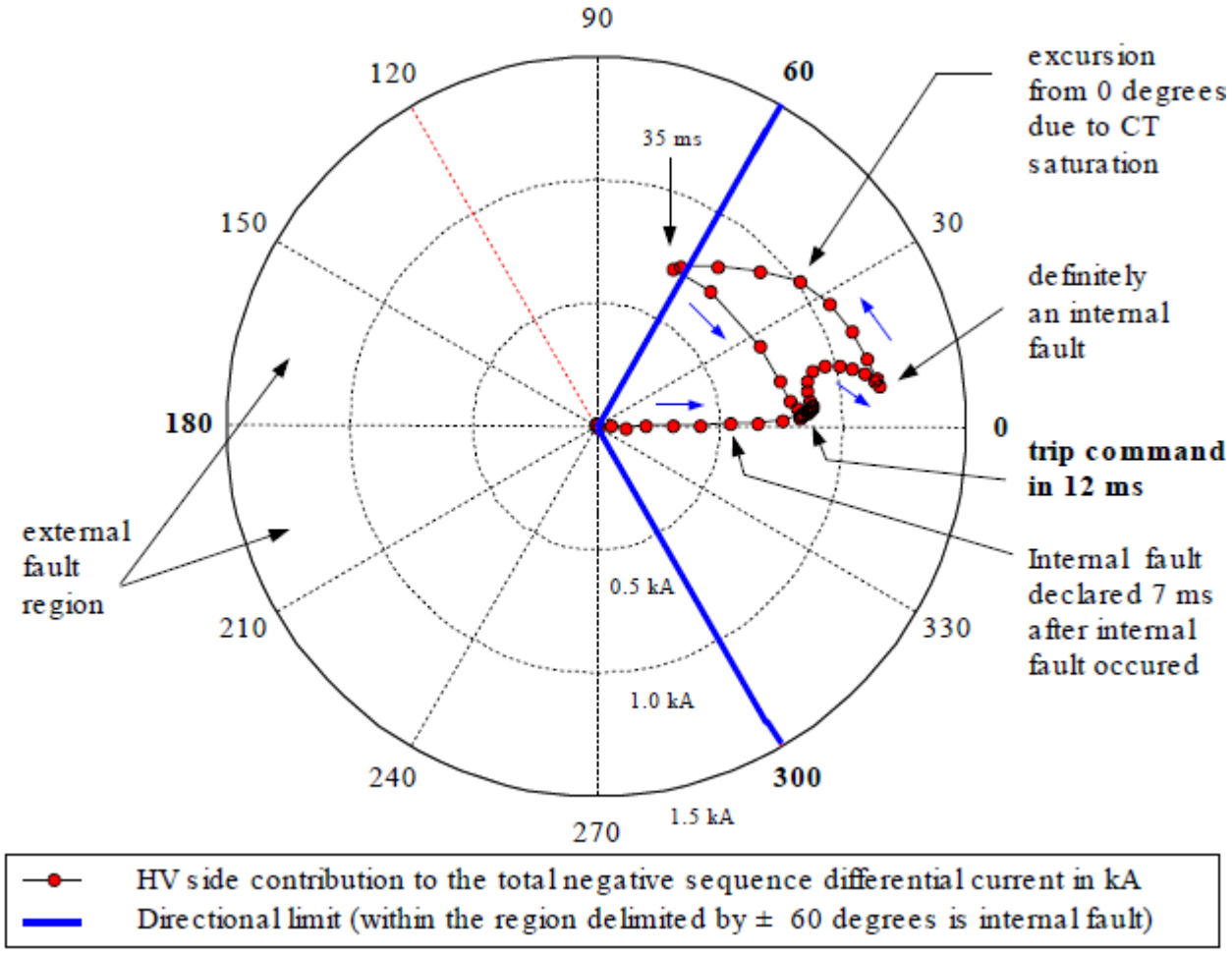
Impact of CT Saturation

- During heavy faults, CT saturation might cause the measured phase angle to differ from 180° for external faults, and from about 0° for internal faults
- At heavy faults, approximately 5ms time-to-saturation of the main CT is sufficient in order to produce a correct discrimination between internal and external faults

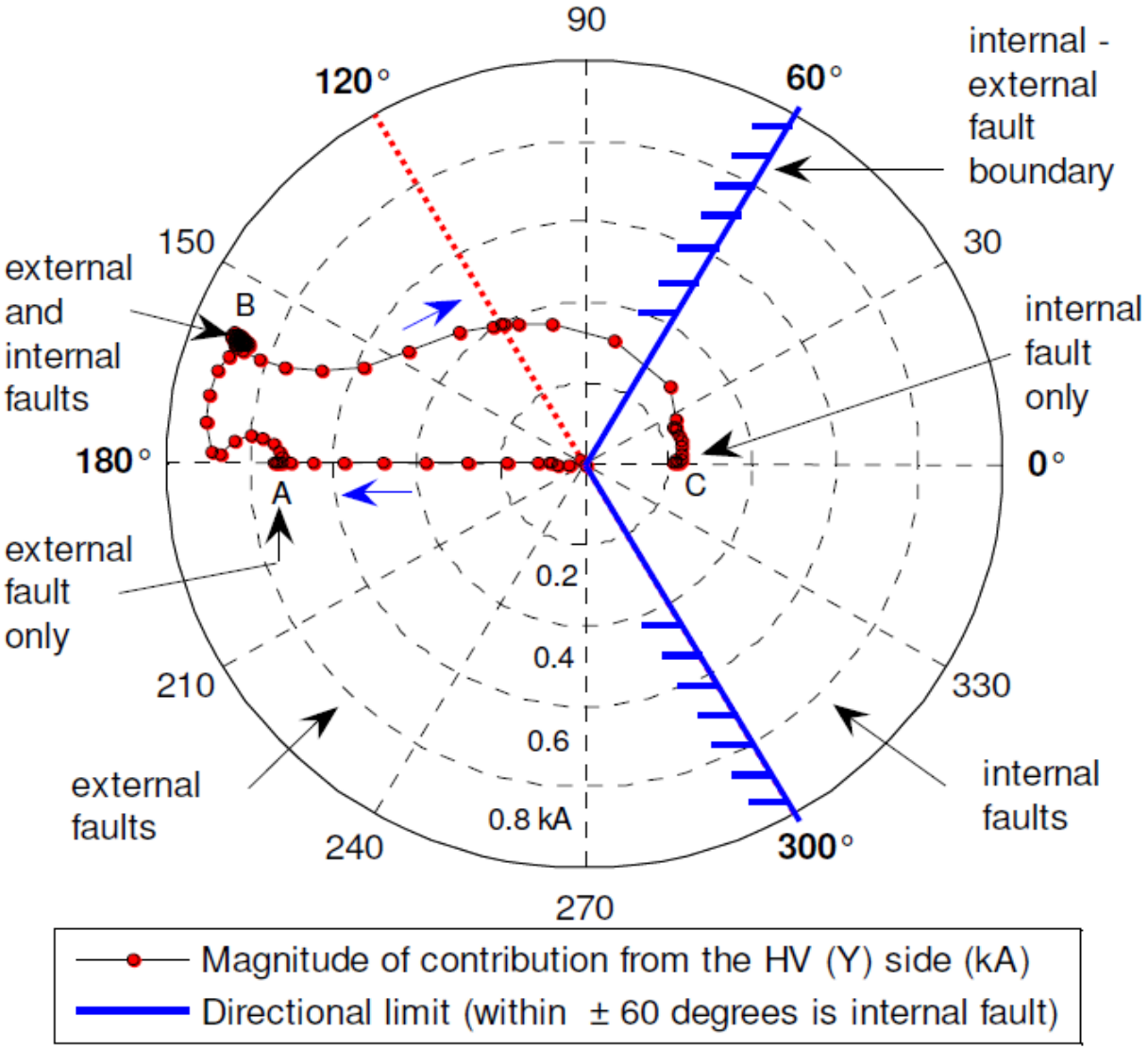
External Fault with Transient CT Saturation



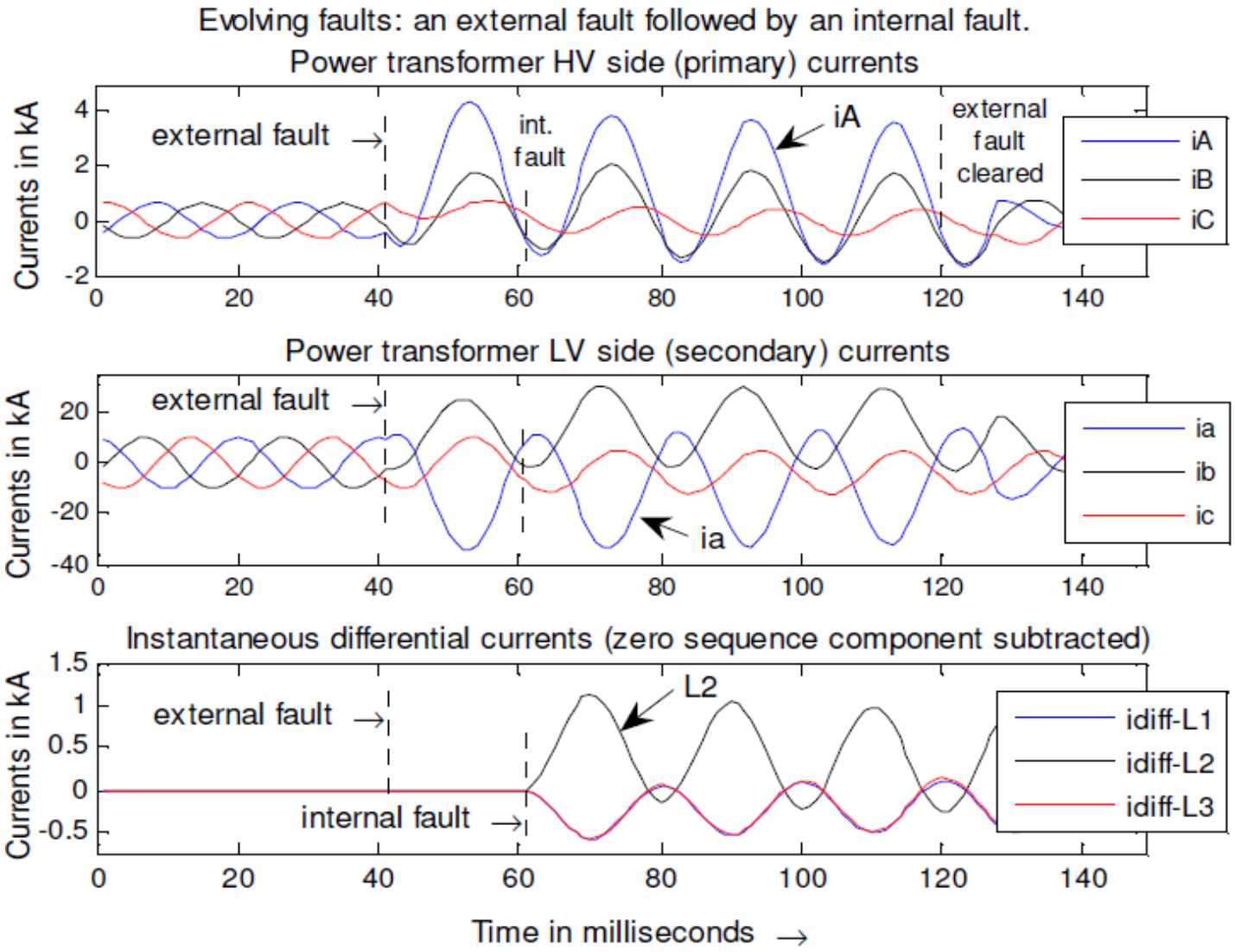
Internal Fault with Transient CT Saturation



Evolving Faults: External Fault Followed by Inter-turn Fault



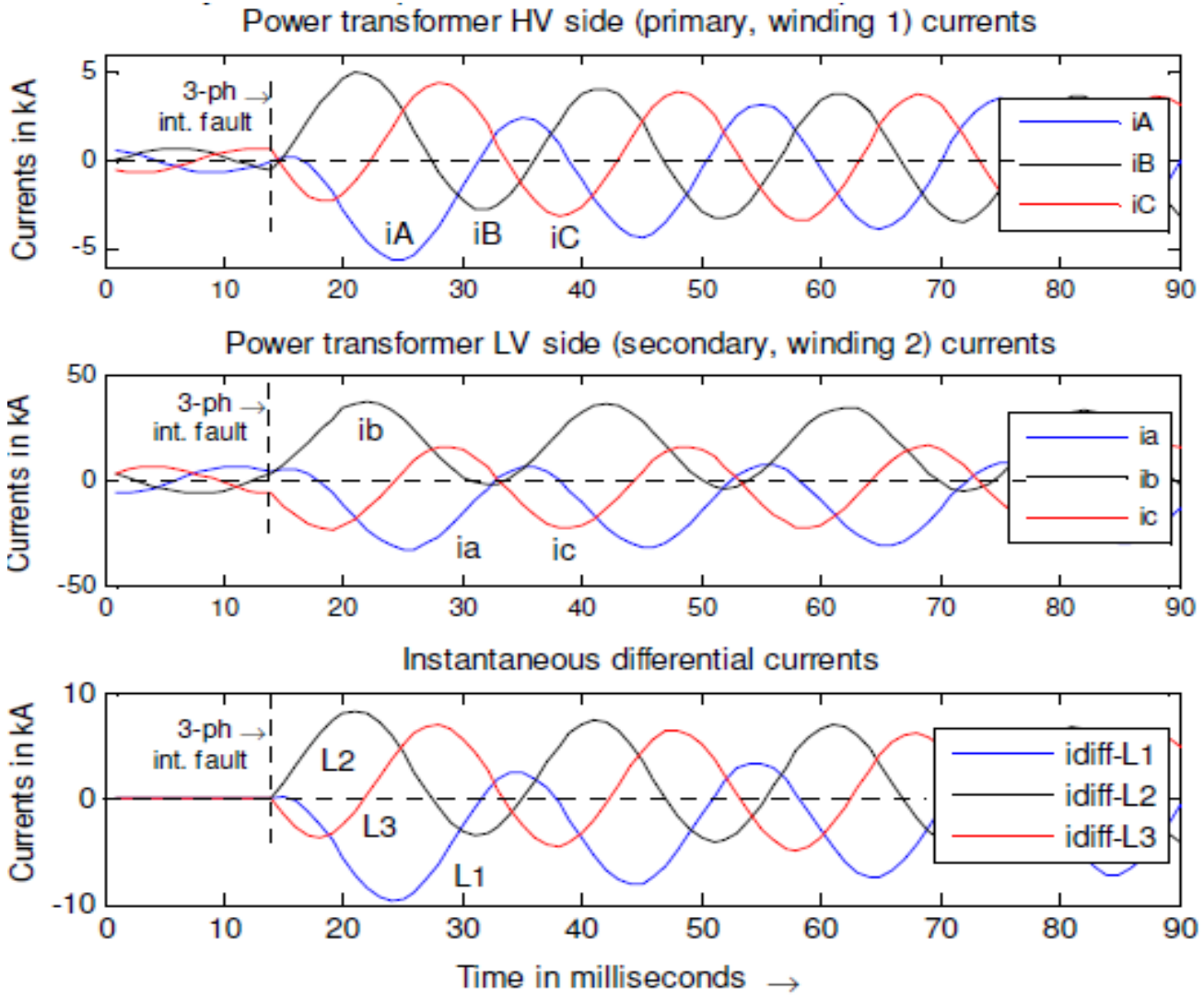
Evolving Faults: External Fault Followed by Inter-turn Fault



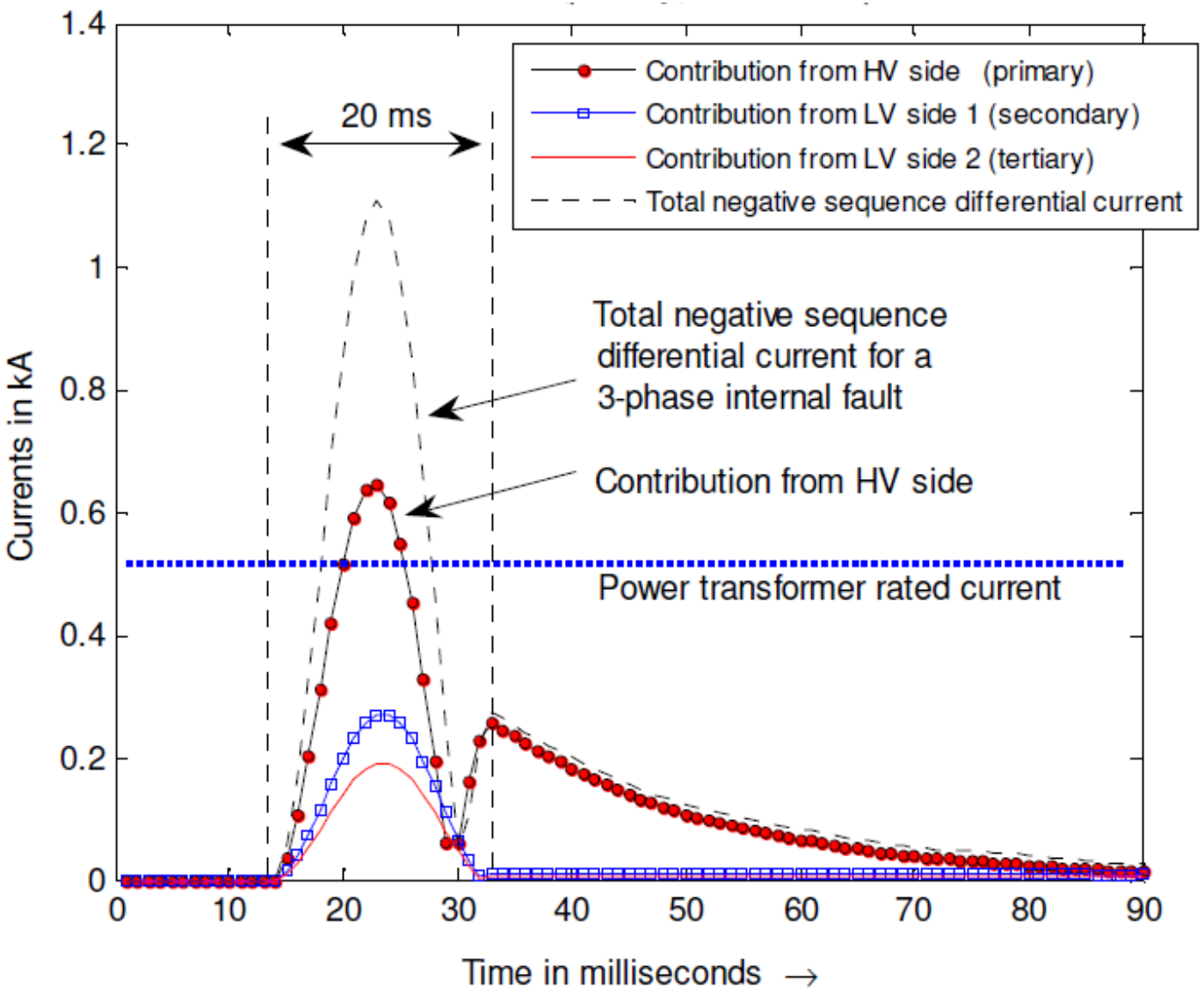
Fault Discrimination for 3-Phase Symmetric Faults

- The Internal / External fault discriminator works equally well for symmetrical 3-phase faults
  - When a symmetrical 3-phase fault occurs, negative sequence currents (the negative sequence current source) will be present until the dc component in the fault currents die out
  - This interval of time is long enough for the internal / external fault discriminator to declare either an internal or an external fault

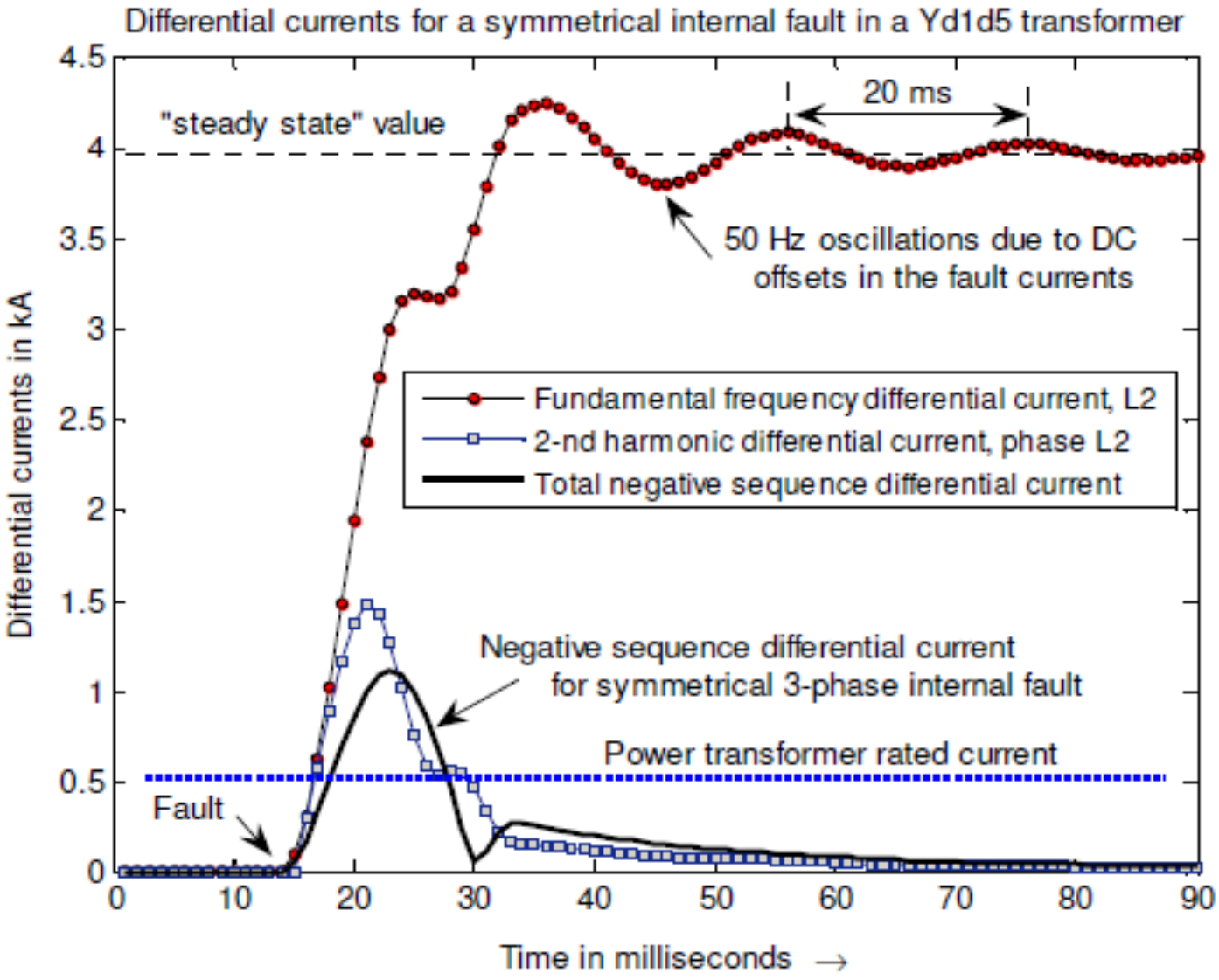
Symmetrical 3-Phase Internal Fault



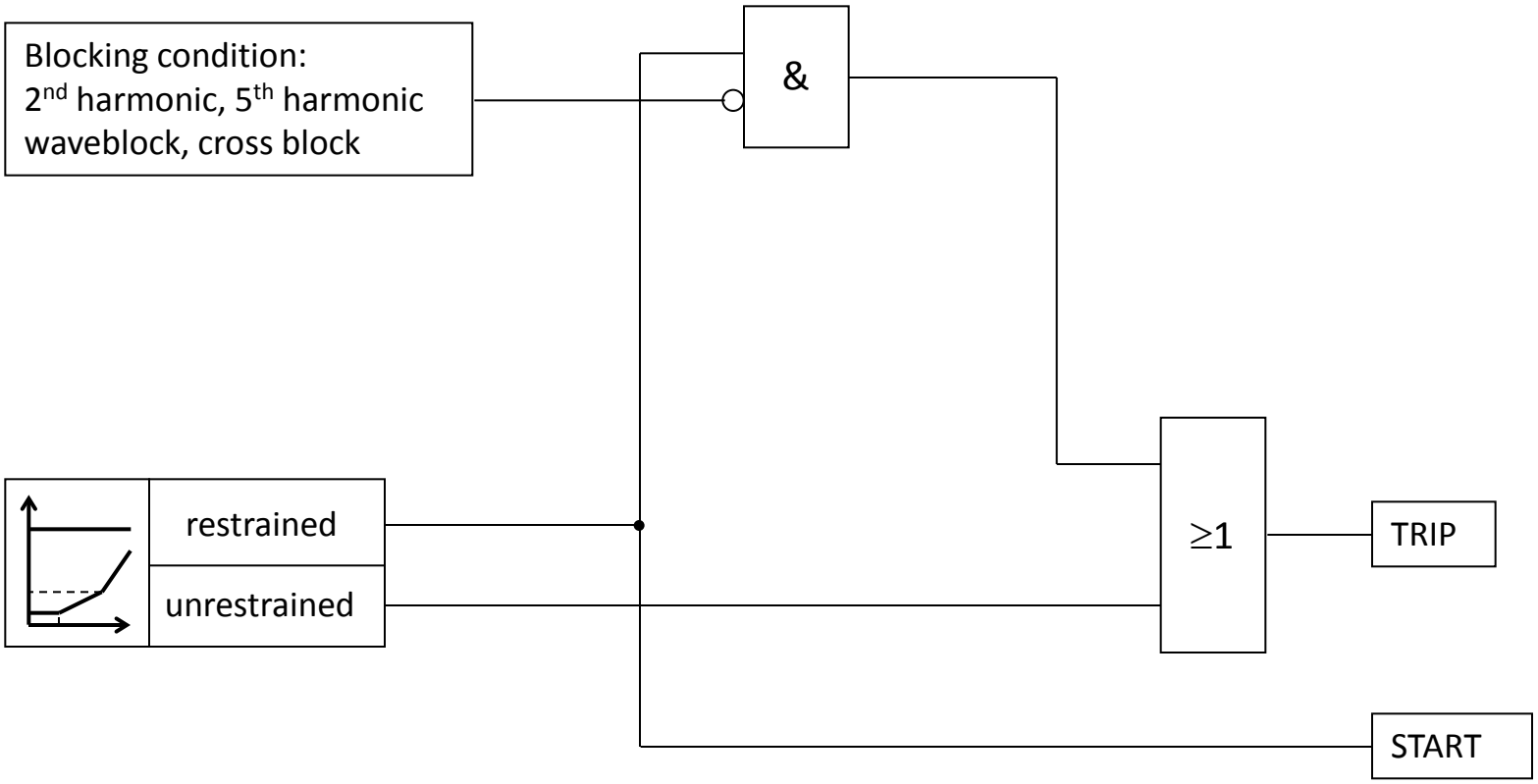
Negative Sequence Contributions in 3-phase Symmetric Fault



Differential Current Profile for 3-Phase Symmetric Fault

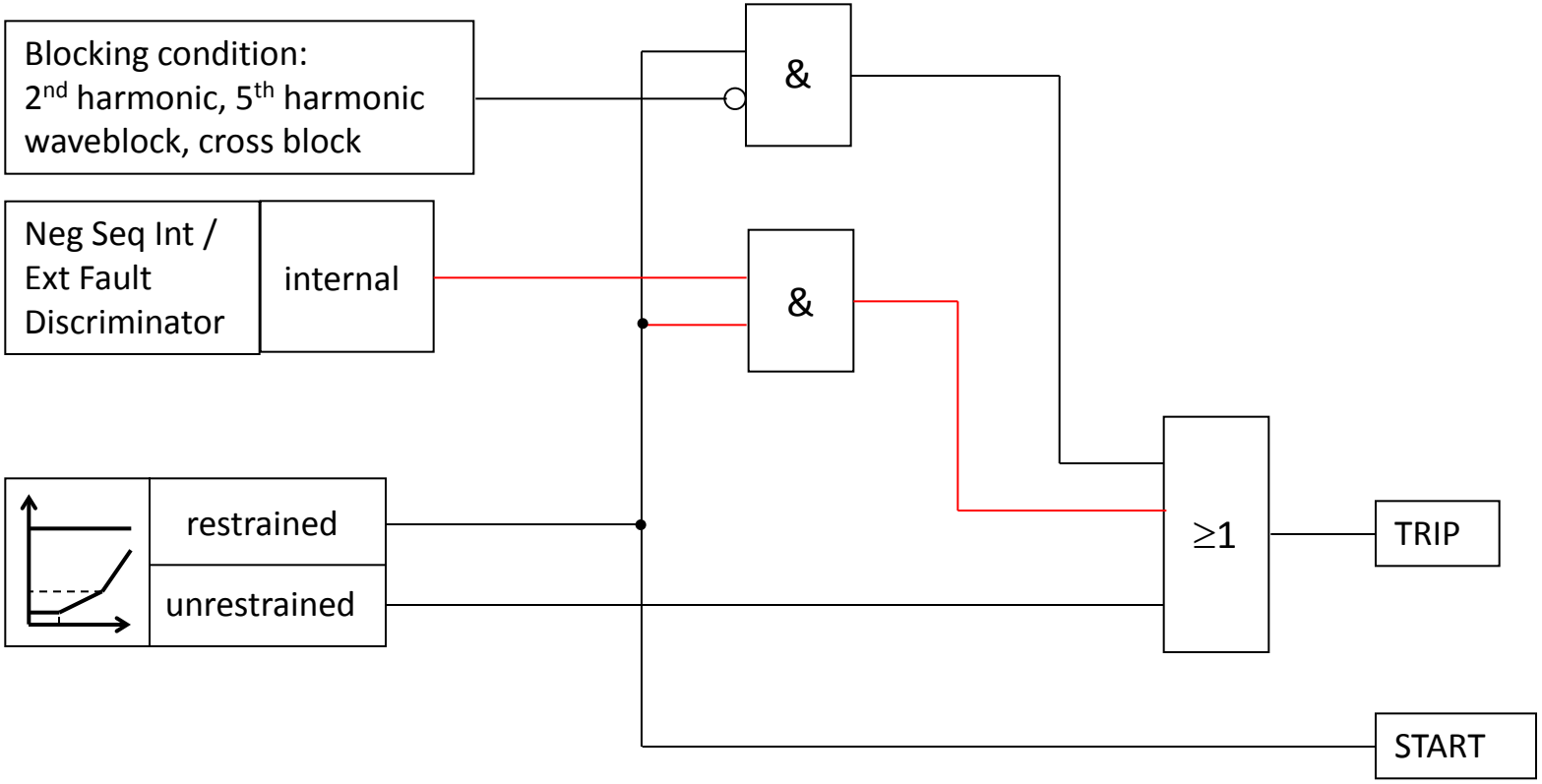


Traditional Transformer Differential Protection



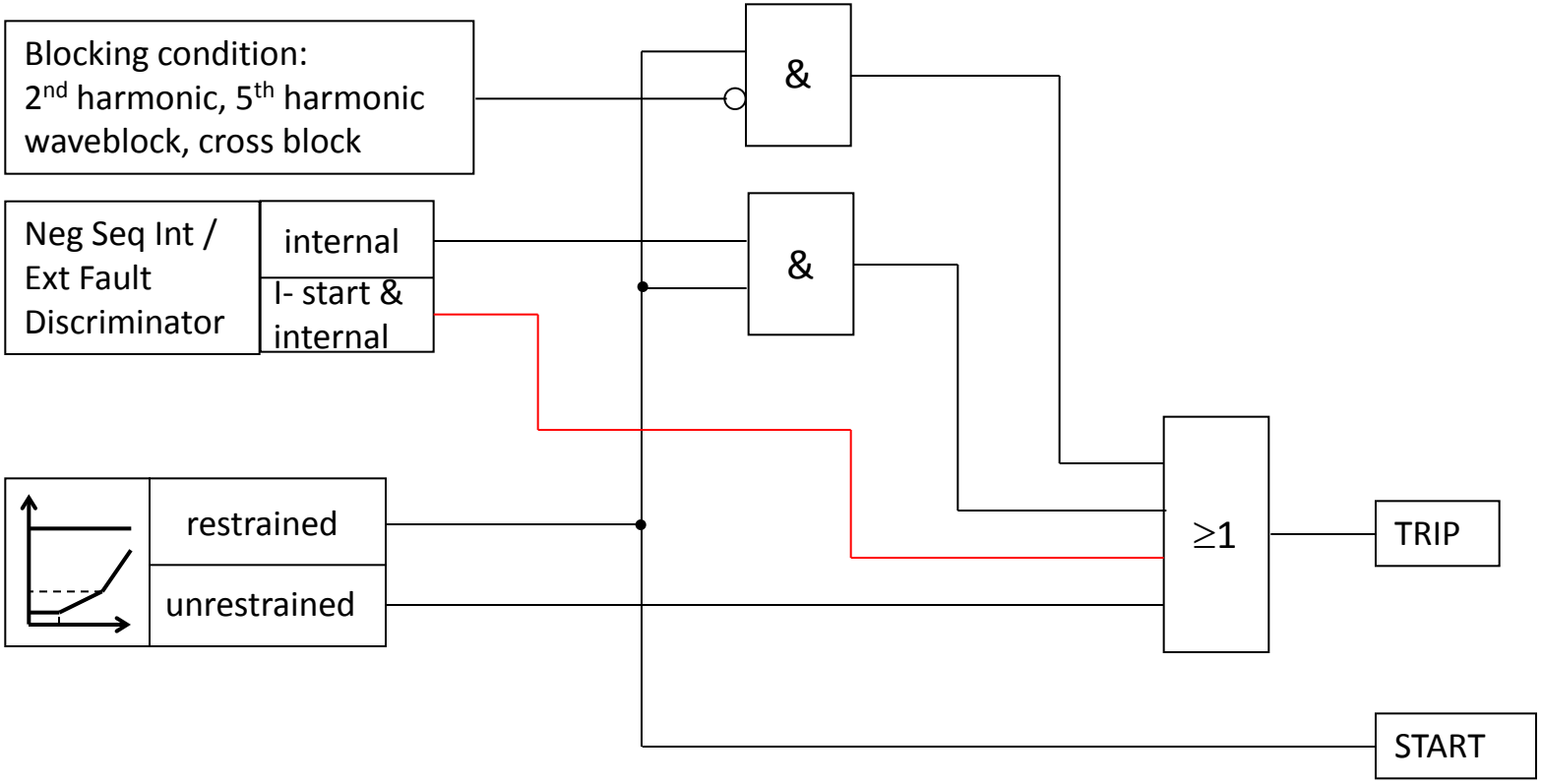
Improvement in Traditional Differential Protection

– Unrestrained negative sequence differential protection in conjunction with traditional transformer differential protection (Fast and Reliable)



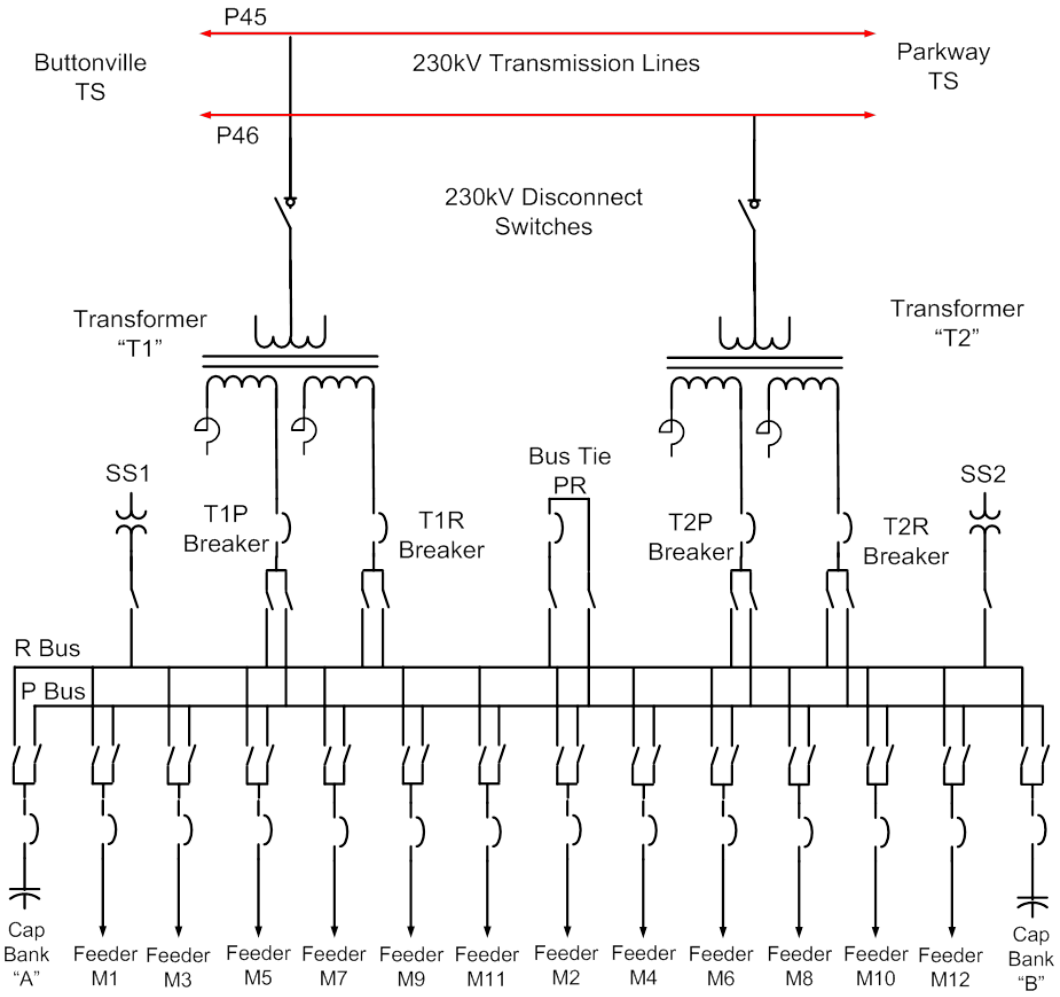
Improvement in Traditional Differential Protection

– Sensitive negative sequence protection (Inter-turn Faults)

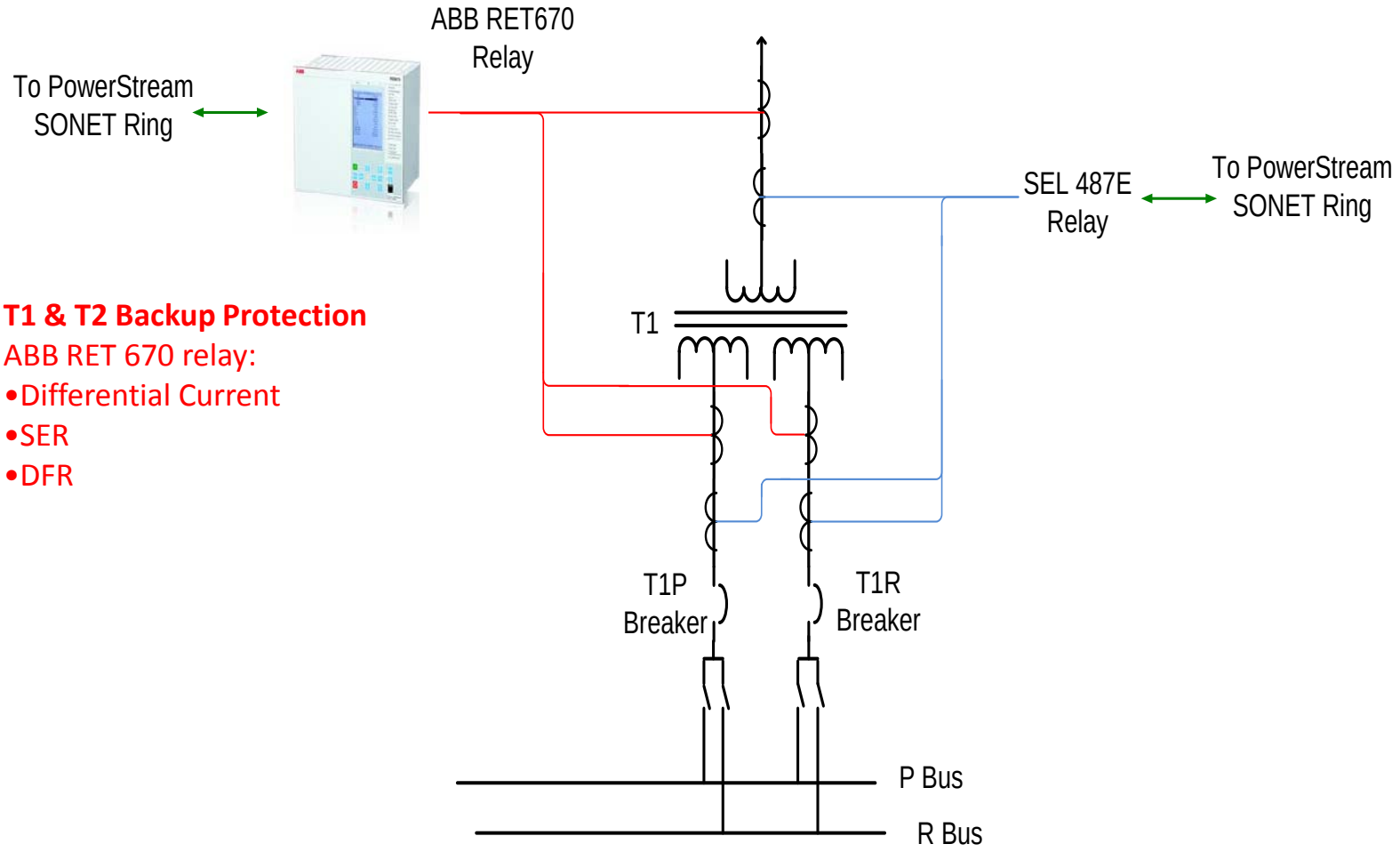


Implementation at Markham TS #4 Station

•Transformer Specifications:
- 230 kV to 27.6kV
- Wye Primary
- Dual Zig-Zag Secondary
- Cooling - ONAN/ONAF/ONAF
- Rating 75/100/125 MVA



Main & Backup Transformer Protection

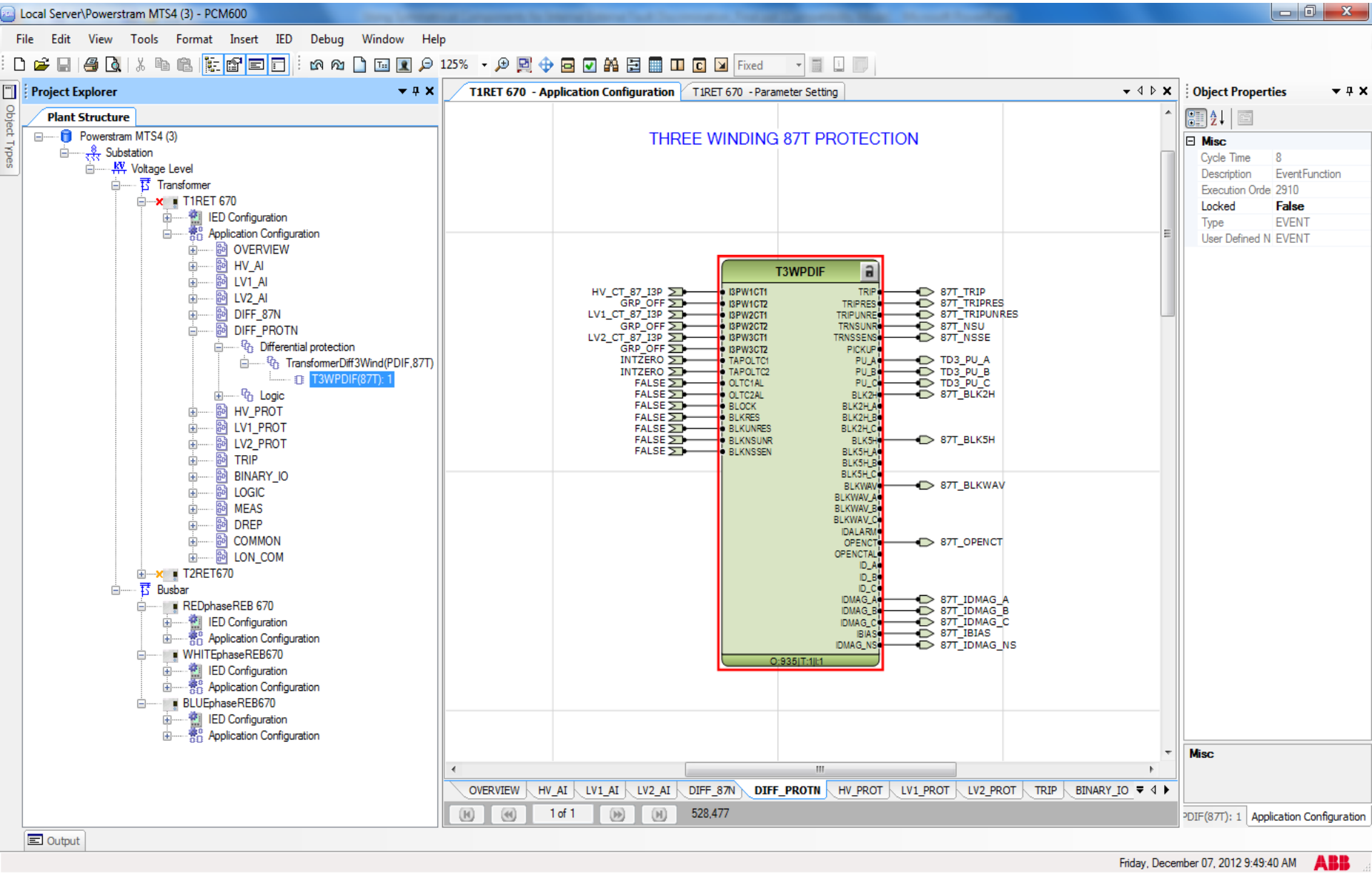


T1 & T2 Backup Protection

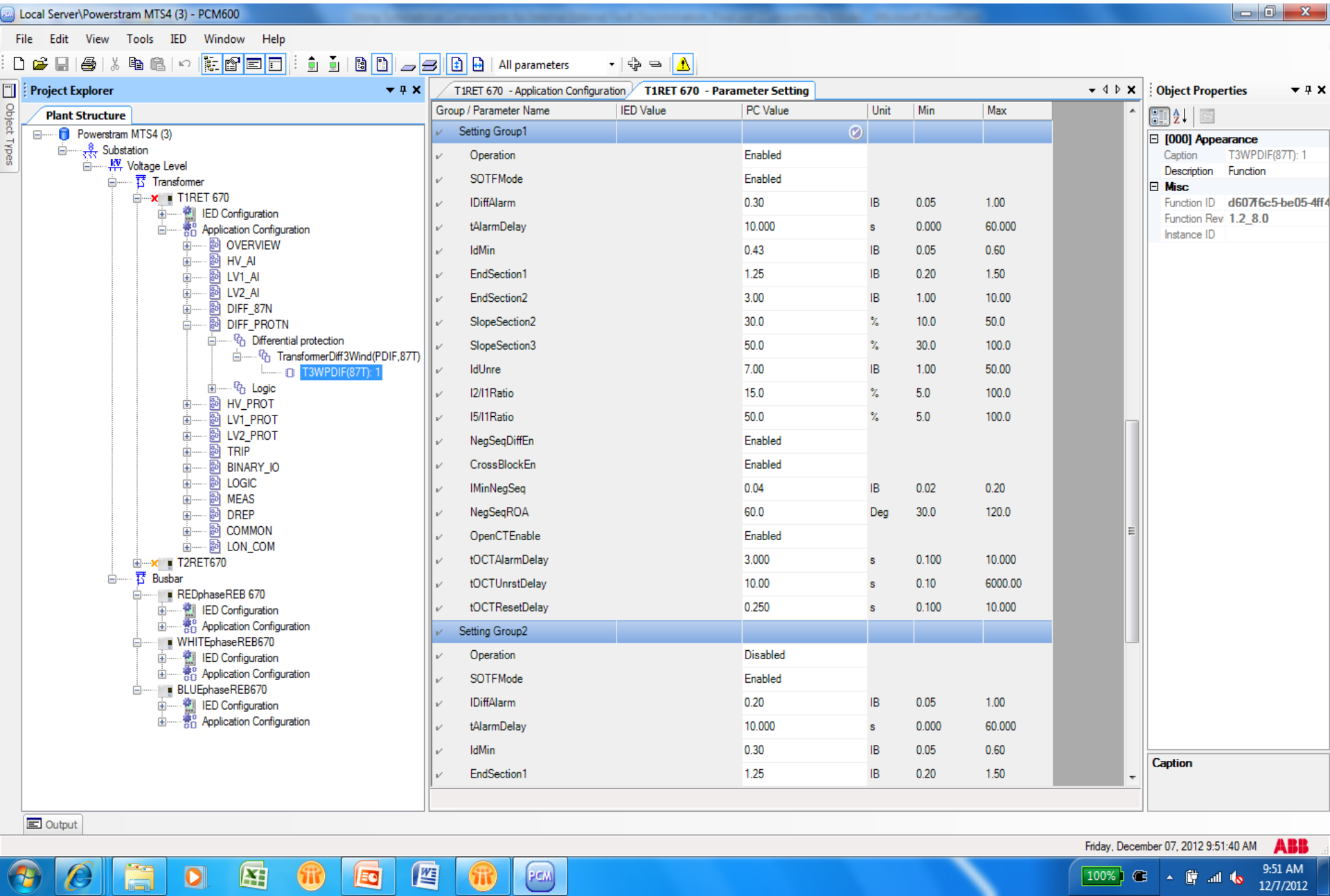
ABB RET 670 relay:

- Differential Current
- SER
- DFR

Function Block for Improved Differential Protection



Settings for Improved Differential Protection



Conclusions

- Existence of high Negative Sequence Currents are indication of system disturbance
- Even for 3-phase symmetric faults, negative sequence currents are present for some time, during the DC offset
- Internal/ External Fault Discrimination based on negative sequence currents is fast (6-8ms) and reliable
- Improves the traditional differential protection by bypassing the blocking and restraining criteria.
- Effective for Evolving faults and CT saturation conditions
- Better sensitivity for low level inter-turn faults
- Improves stability of traditional differential protection schemes

Questions ?