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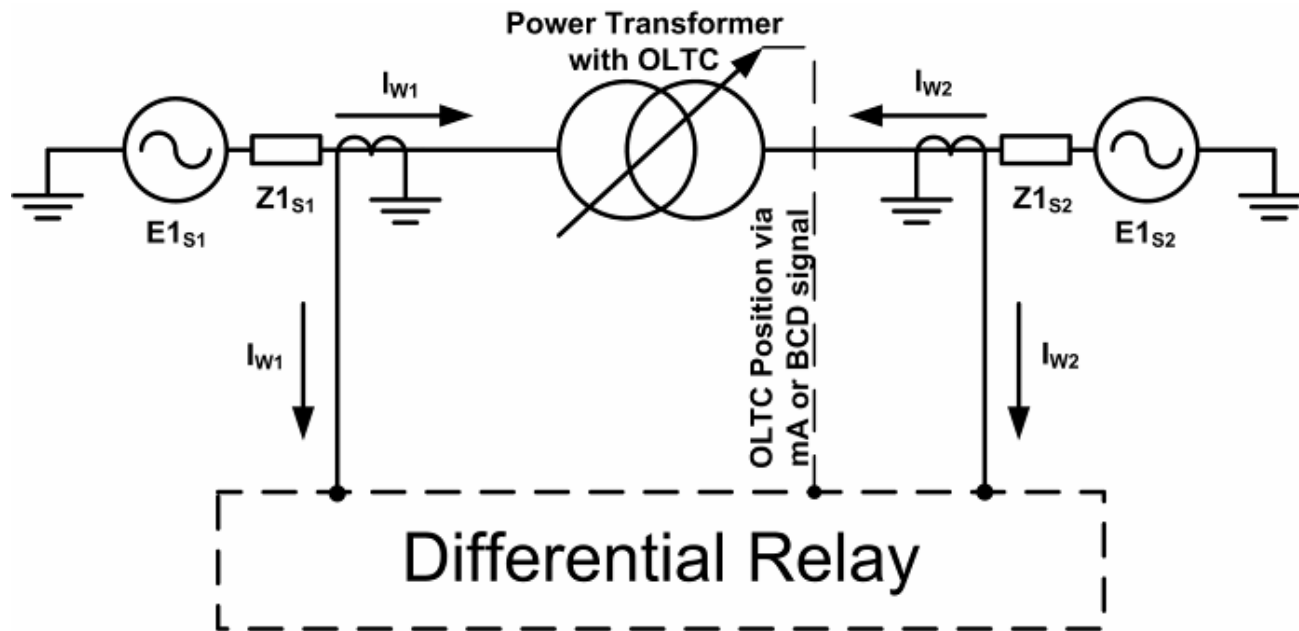
GERRY REESOR, Power Stream

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

AGENDA

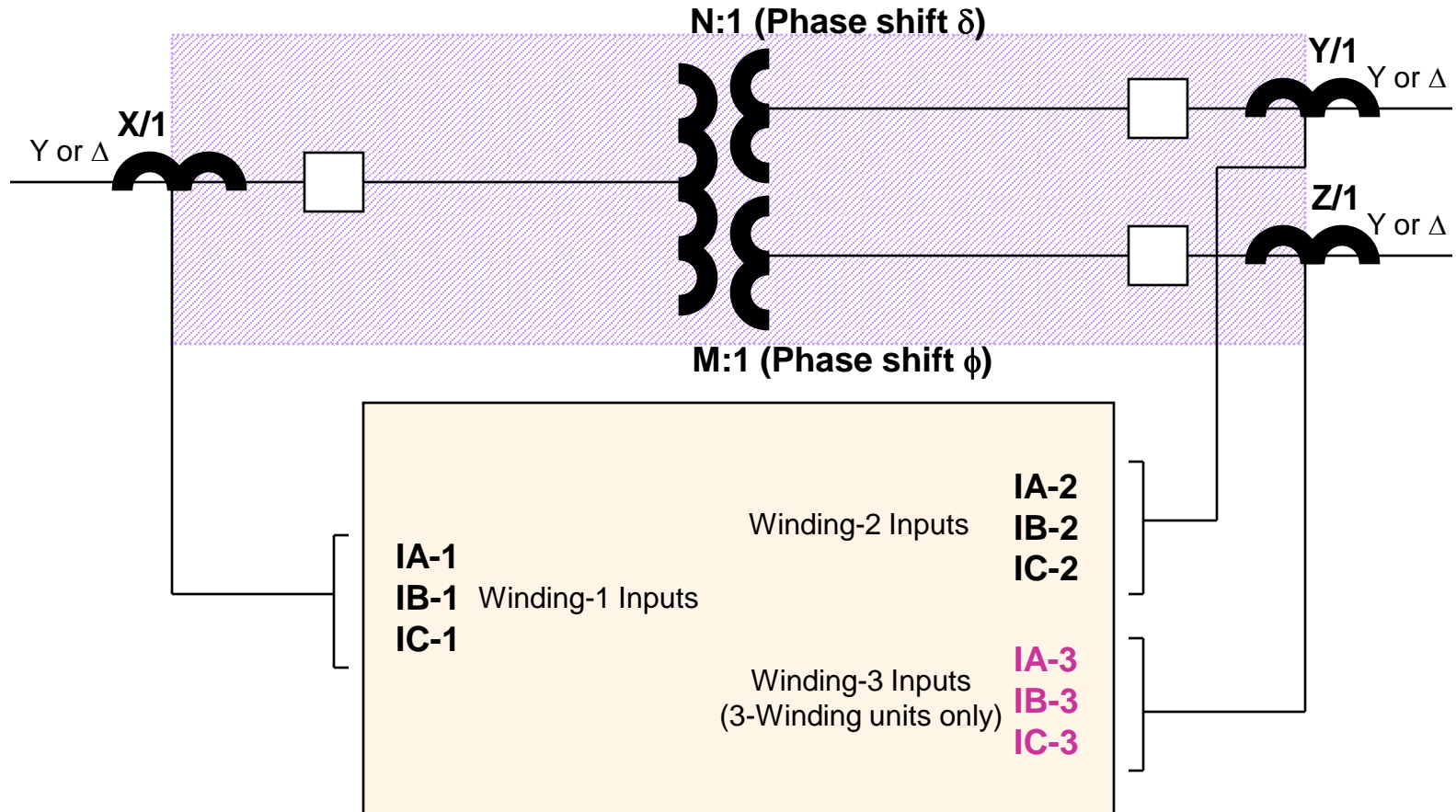
- Differential Protection
- Symmetrical Components
- Properties of Negative Sequence Quantities
- Principle of Internal / External Fault Discriminator
- Impact of Current Transformer Saturation
- Evolving Faults and Inter-turn Faults
- Three-phase Symmetrical Faults
- Improvement in Overall Differential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

Differential Protection



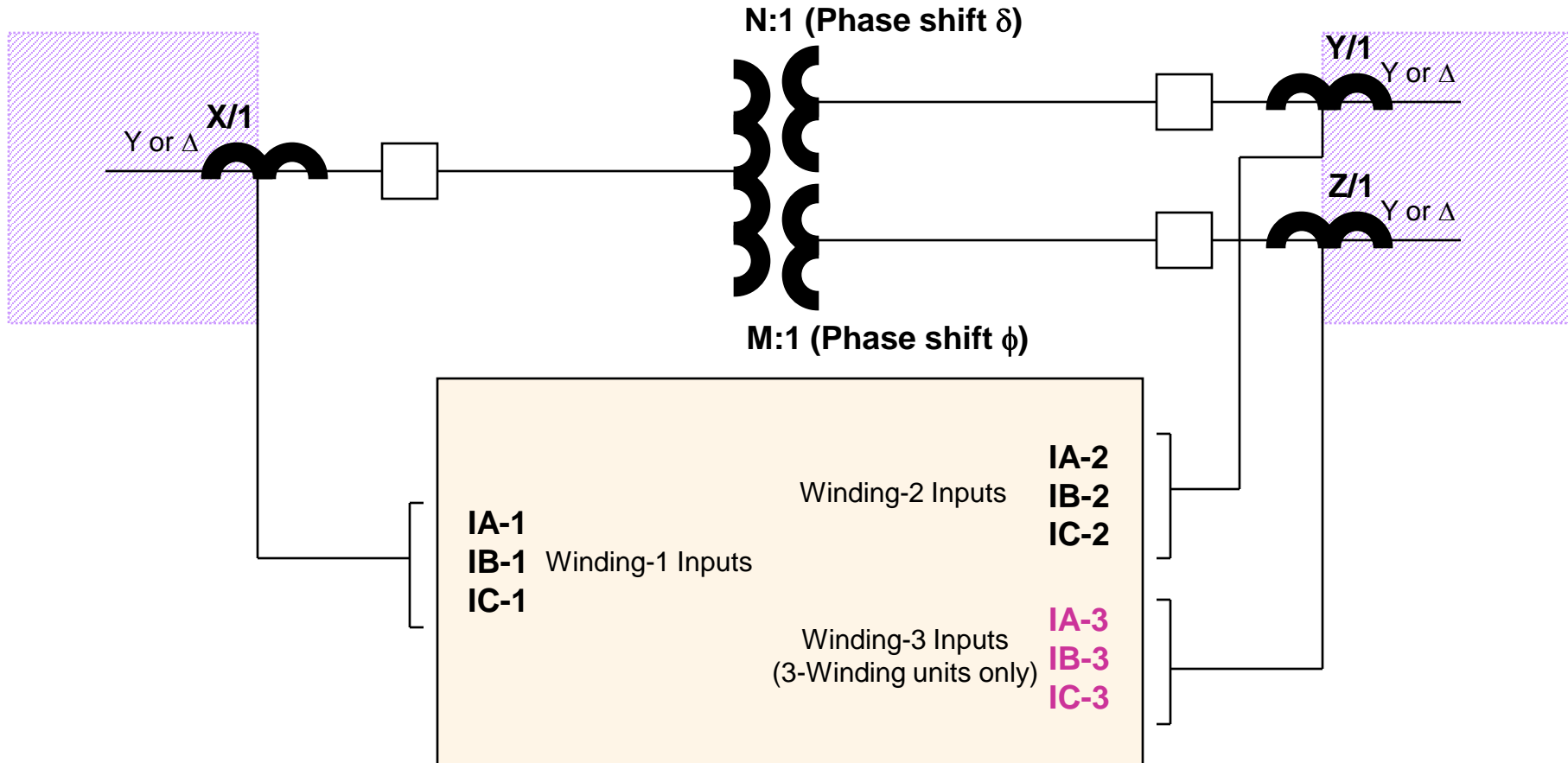
Differential Protection

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



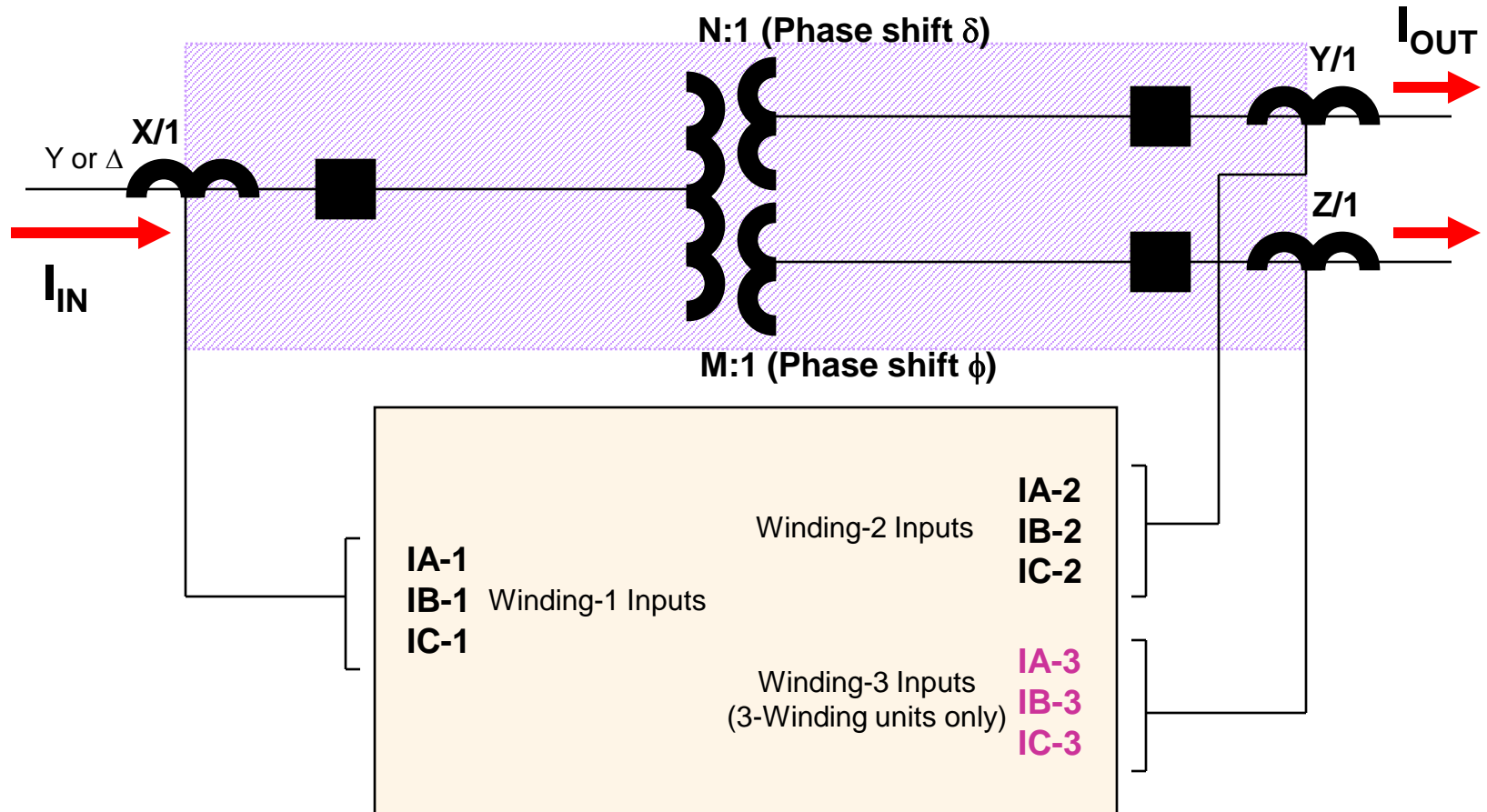
Differential Protection

Non-trip zone for phase differential protection

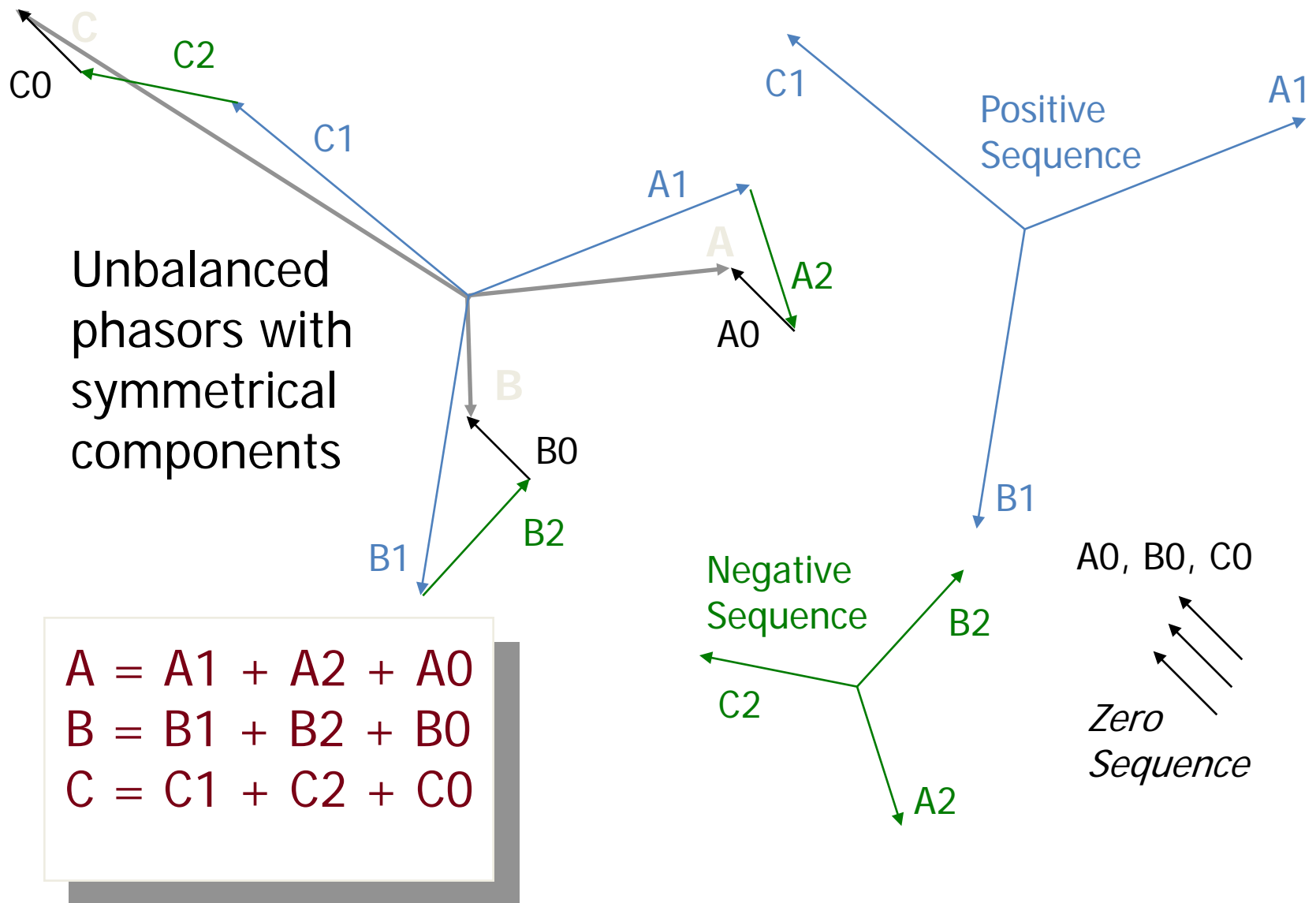


Differential Protection

$$I_{IN} = I_{OUT}$$



Symmetrical Components

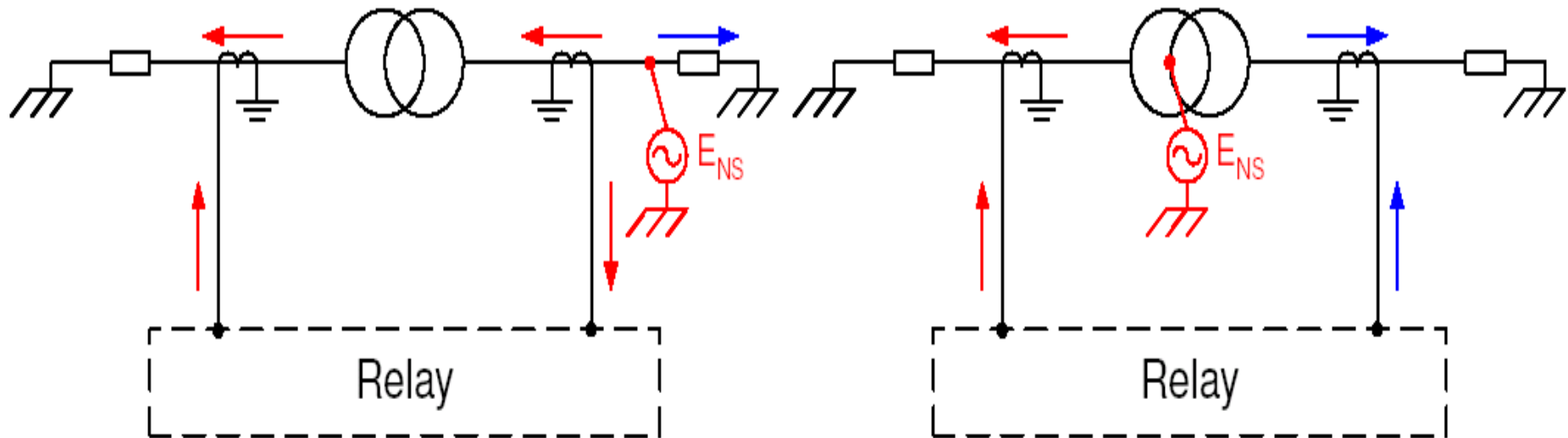


Properties of Negative Sequence Currents

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°

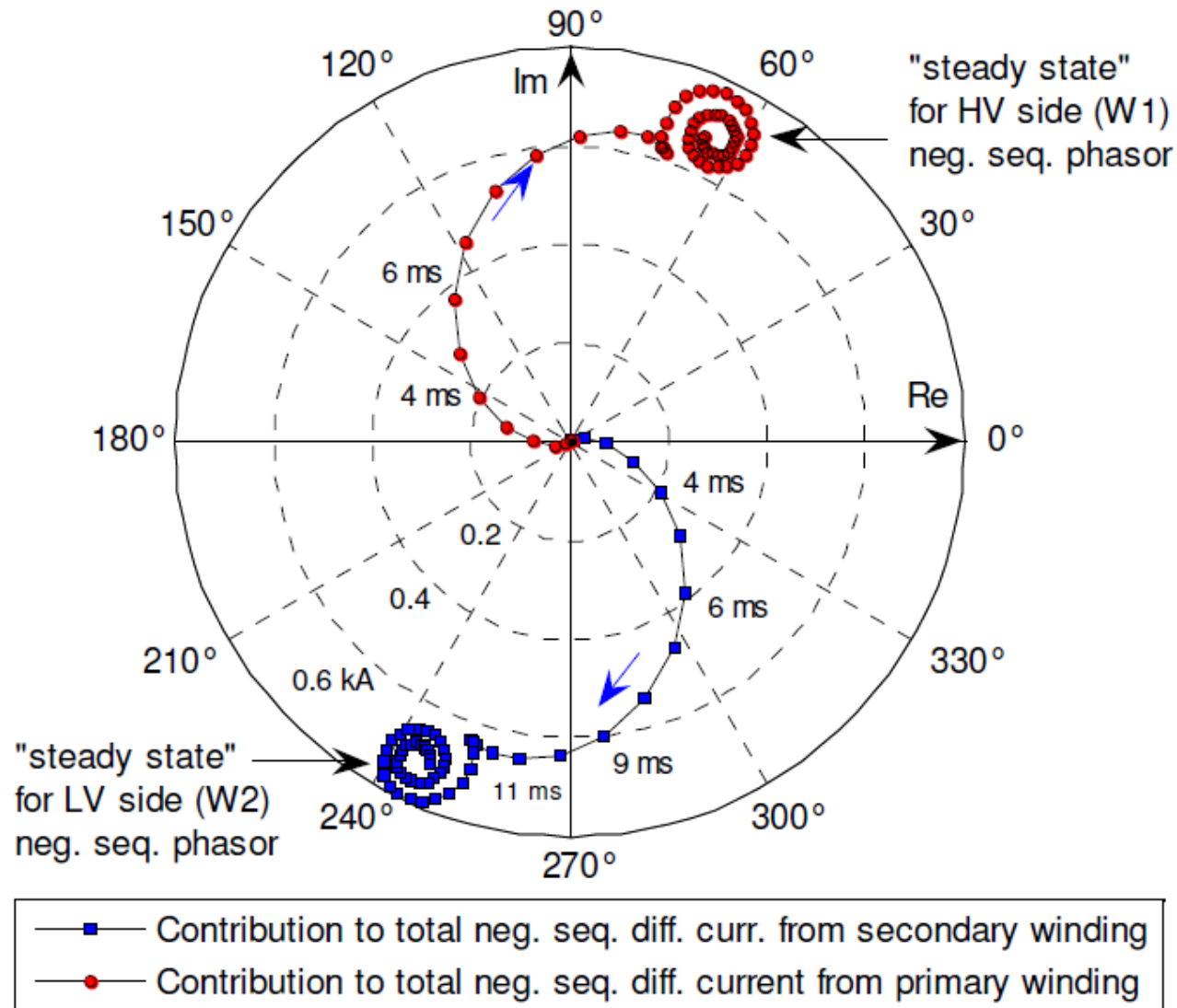


Impact of Transformation Ratio and Phase Shift

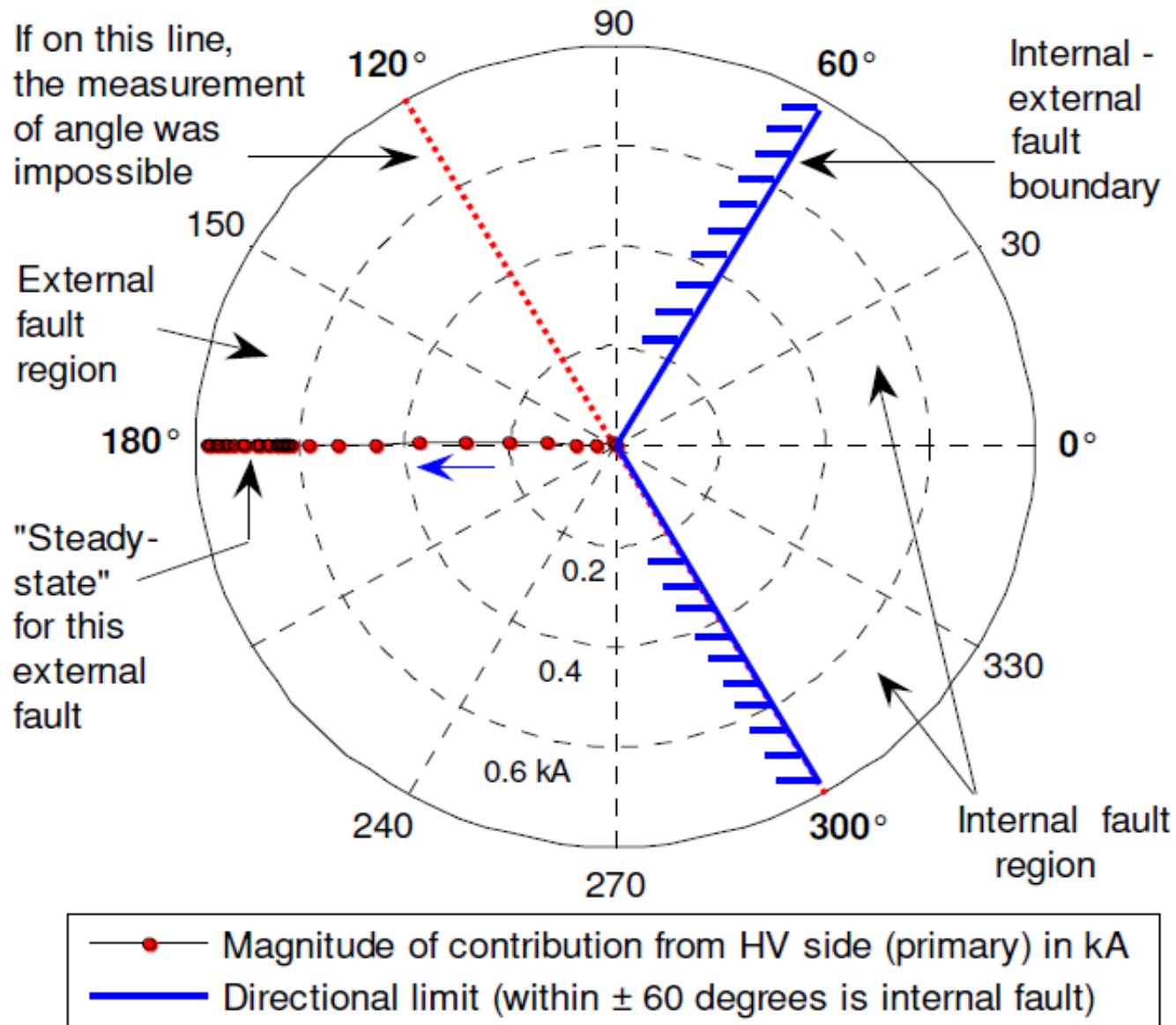
- Negative sequence current components are compensated for power transformer vector group and turns ratio
- The $0^\circ / 180^\circ$ criterion is still valid

$$\begin{bmatrix} Idns_L1 \\ Idns_L2 \\ Idns_L3 \end{bmatrix} = \underbrace{\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} * \begin{bmatrix} Ins_A \\ Ins_B \\ Ins_C \end{bmatrix}}_{\text{Contribution to total negative seq. current from HV side (e.g. Y)}} + \underbrace{\begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} * \begin{bmatrix} Ins_a \\ Ins_b \\ Ins_c \end{bmatrix}}_{\text{Contribution to total negative seq. current from LV side (e.g. d)}}$$

Negative Sequence Contributions for an External Fault



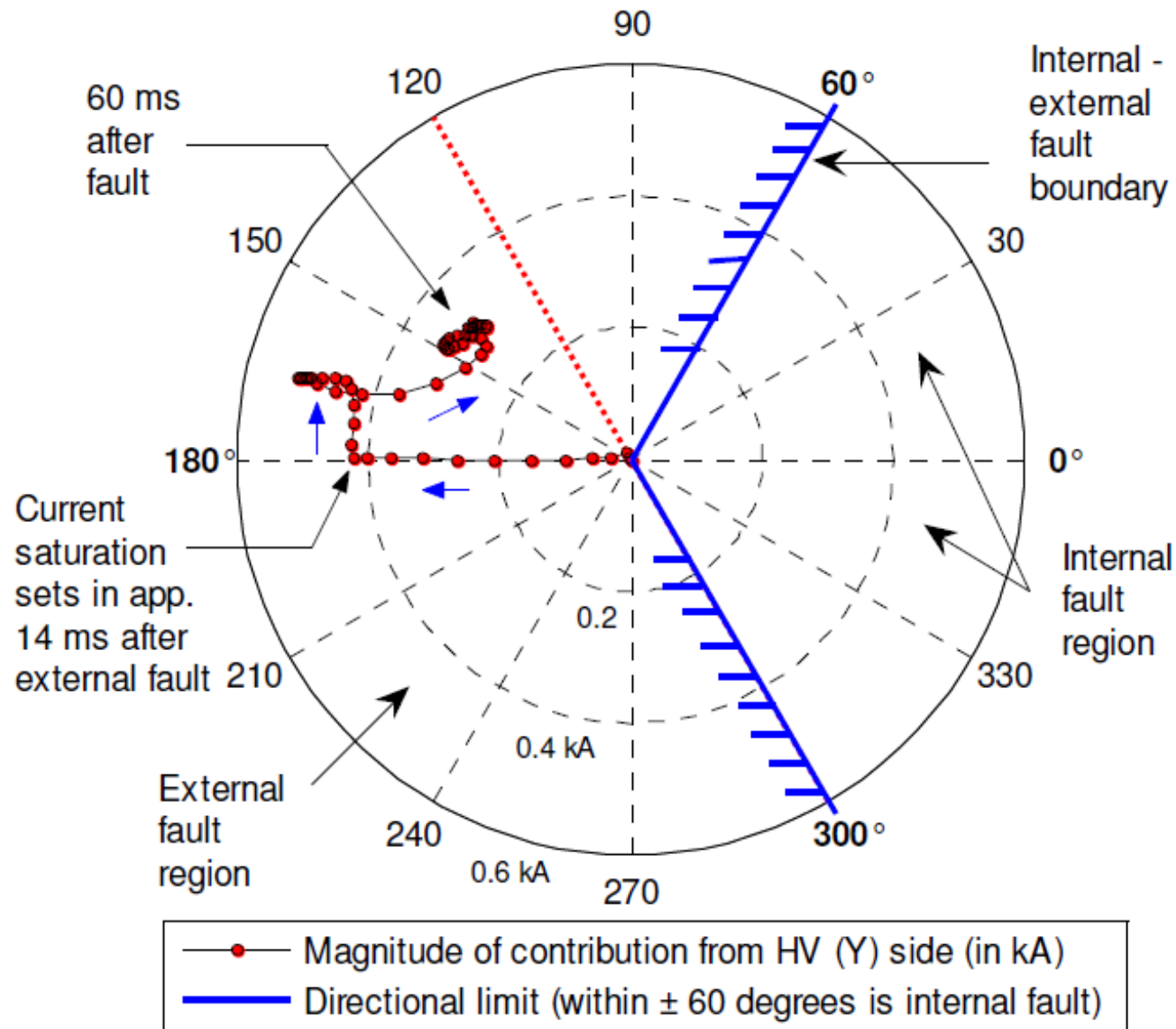
External Fault--- Directional Comparison



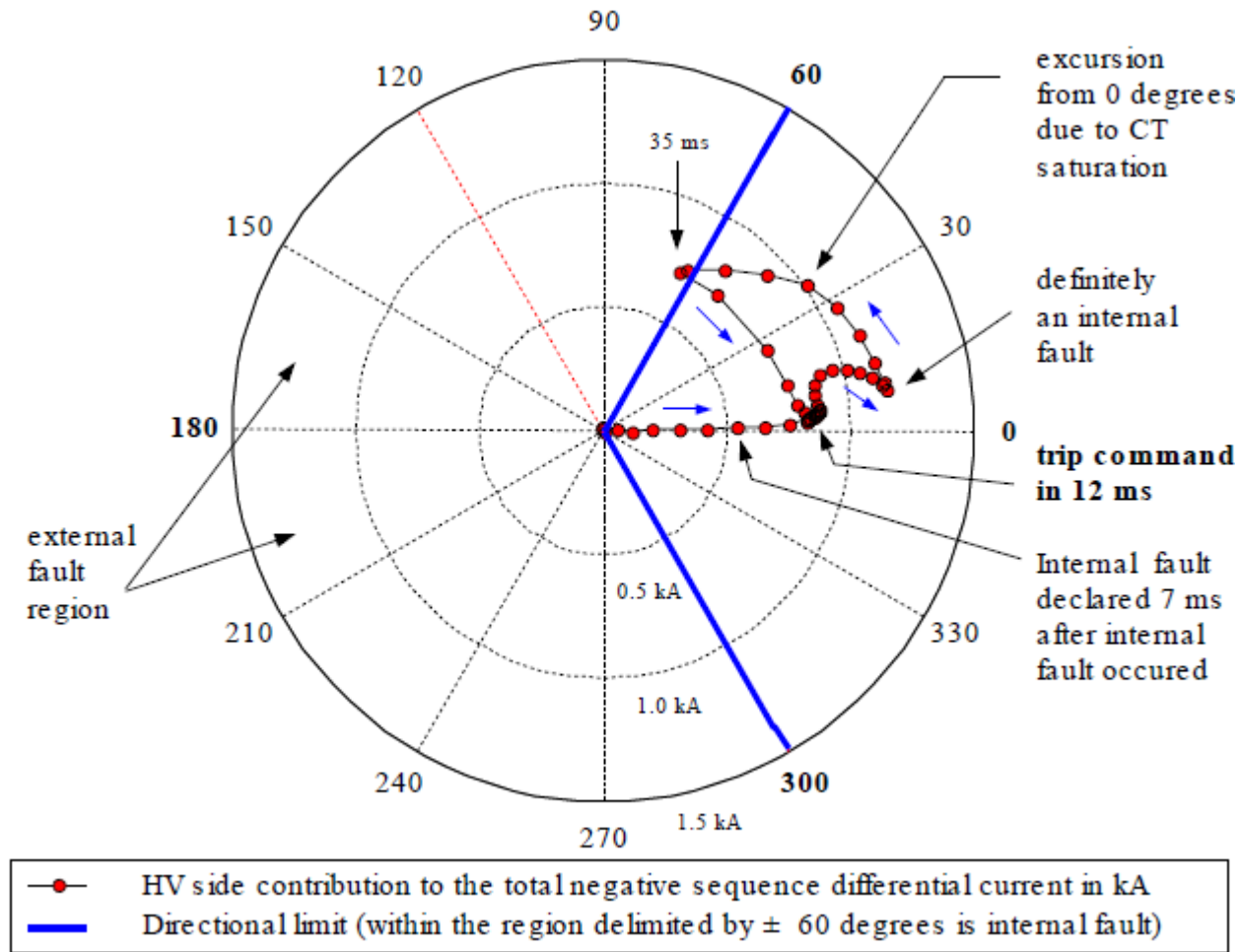
Impact of CT Saturation

- 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

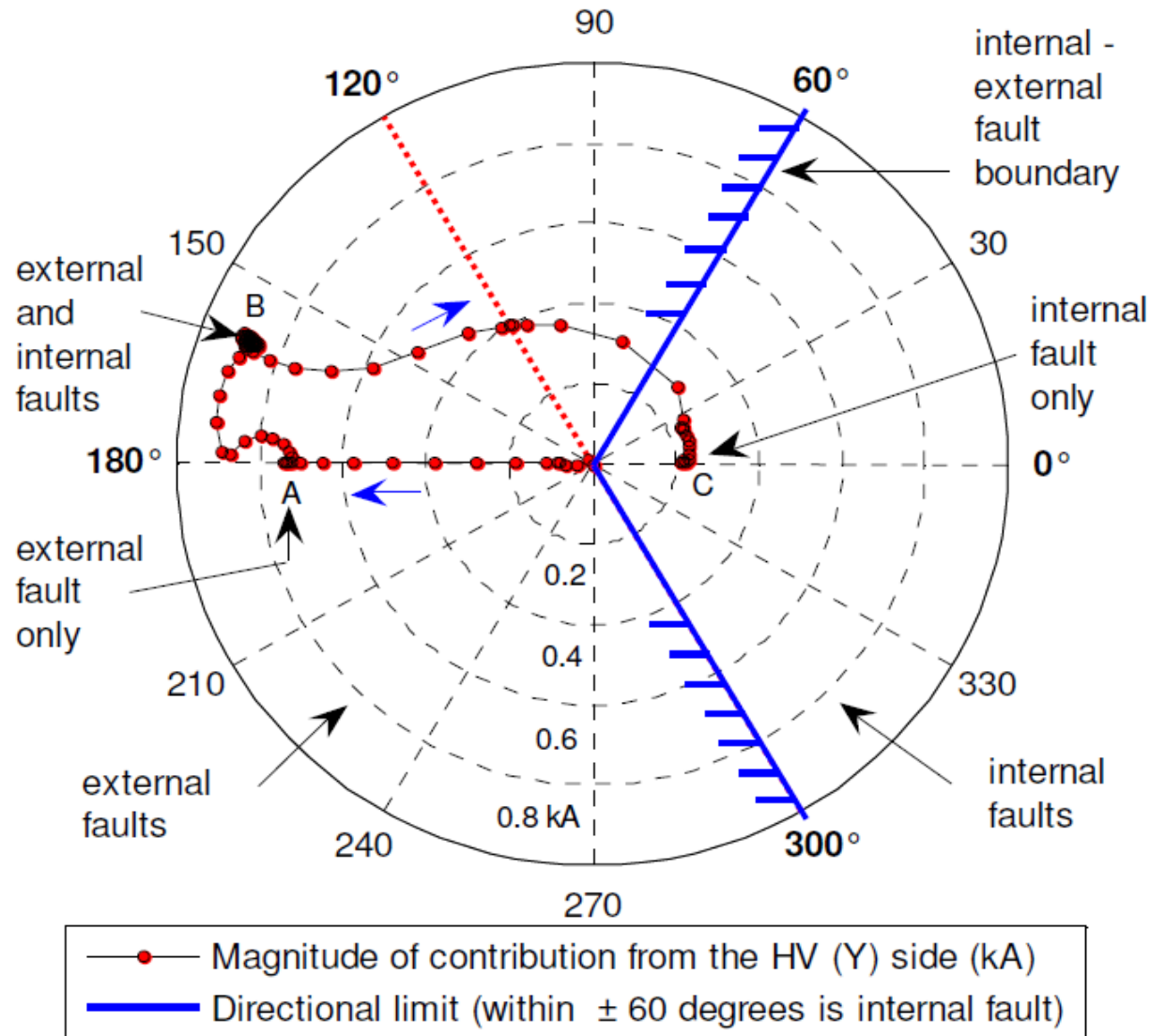
External Fault with Transient CT Saturation



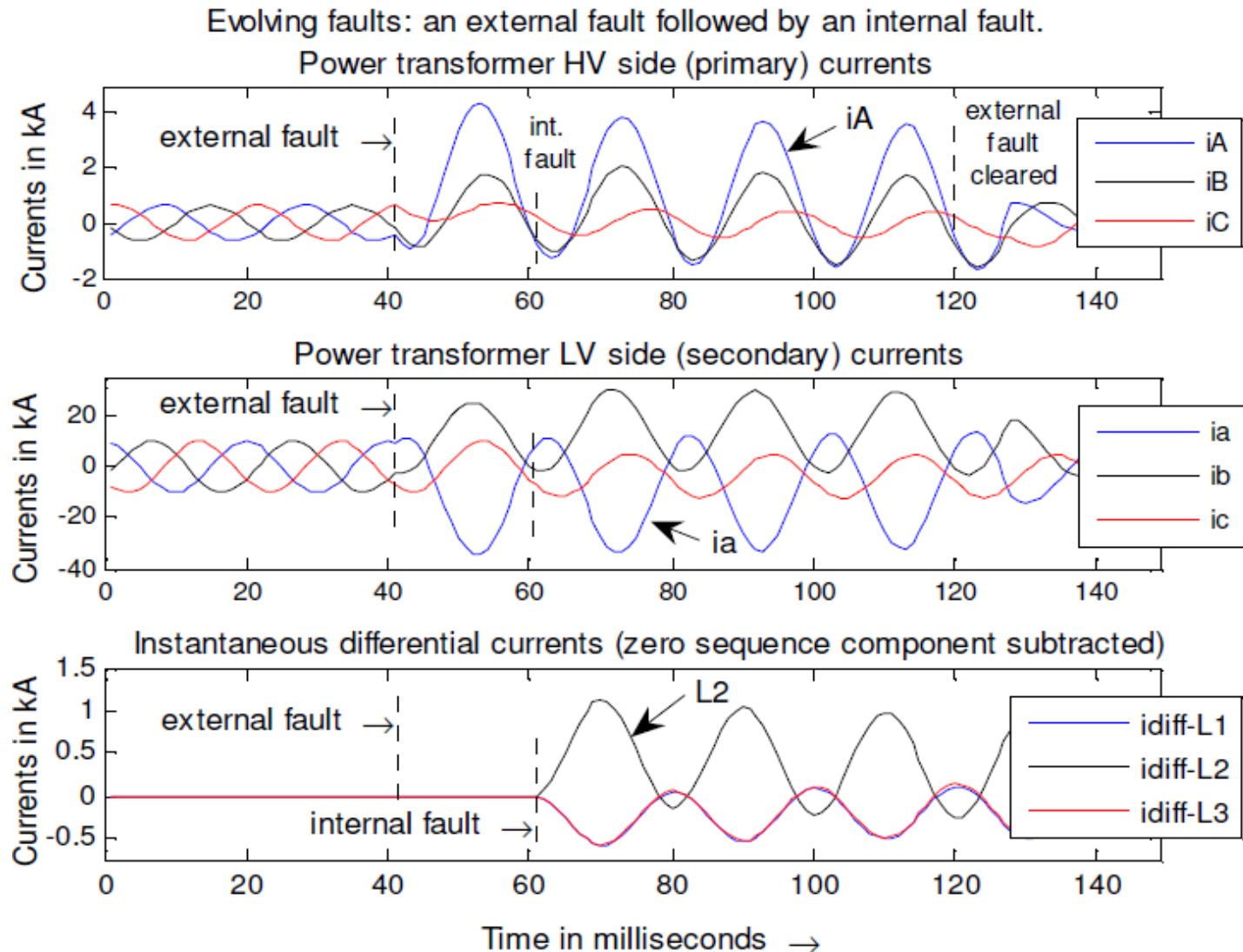
Internal Fault with Transient CT Saturation



Evolving Faults: External Fault Followed by Inter-turn Fault



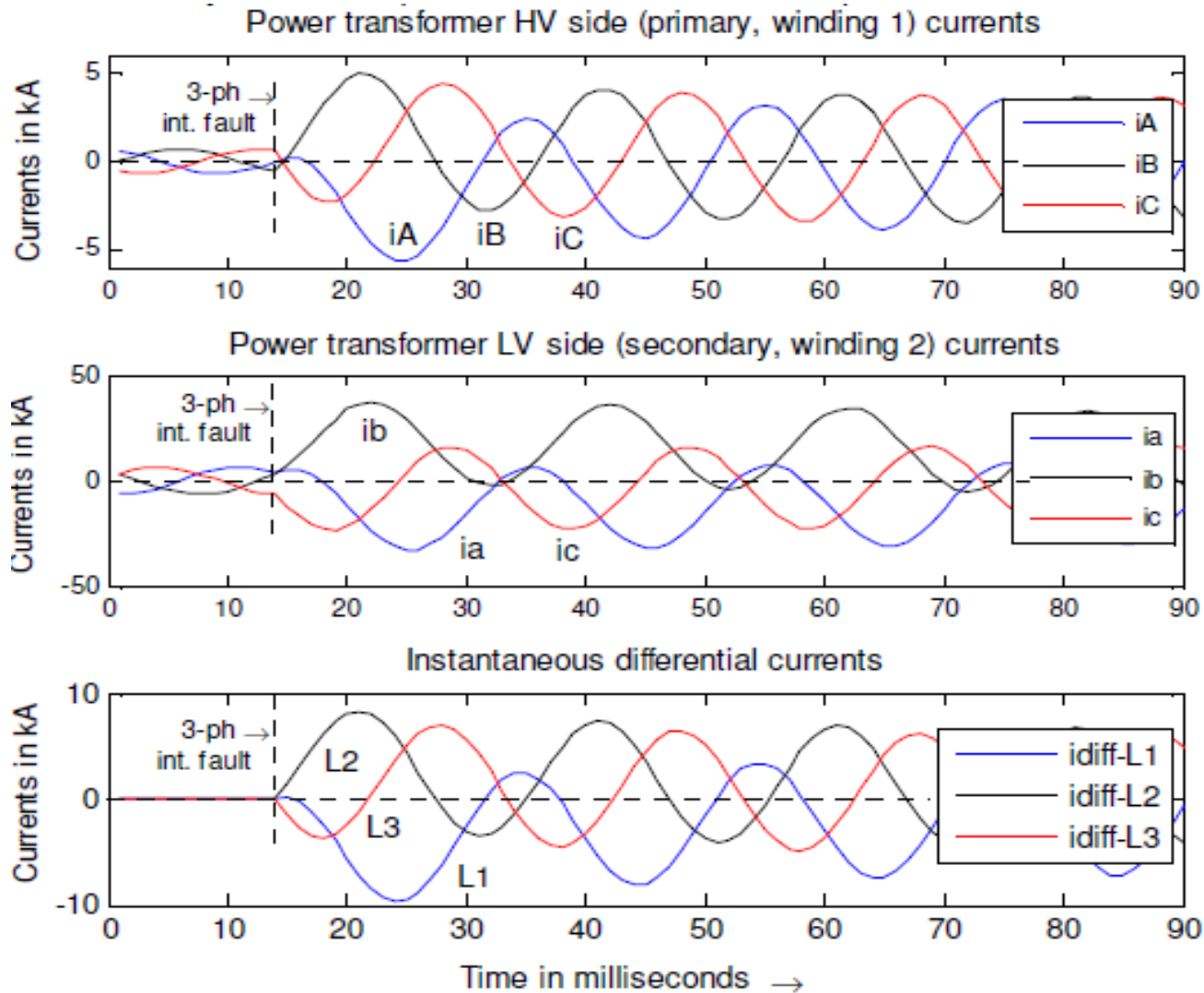
Evolving Faults: External Fault Followed by Inter-turn Fault



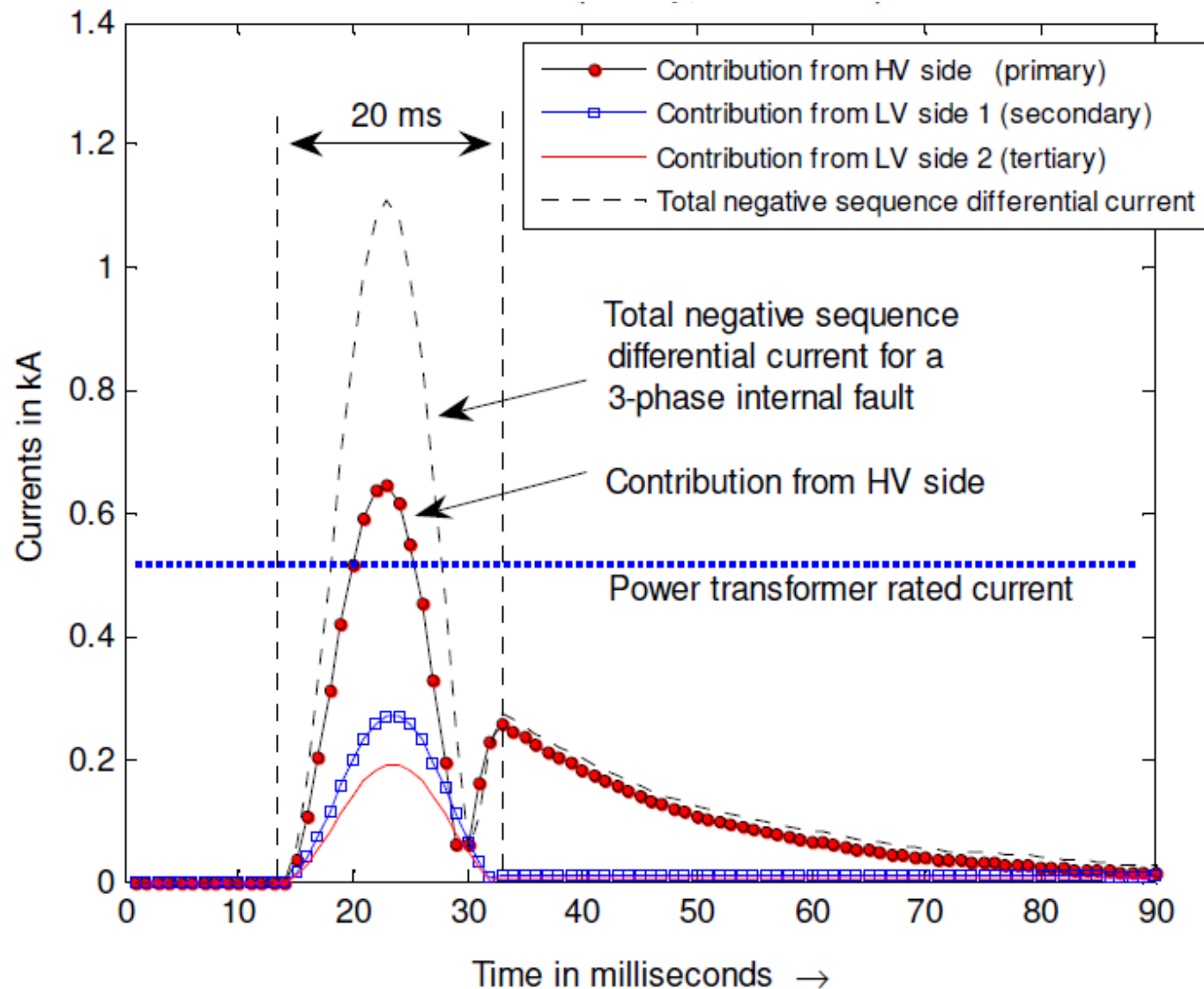
Fault Discrimination for 3-Phase Symmetric Faults

- 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

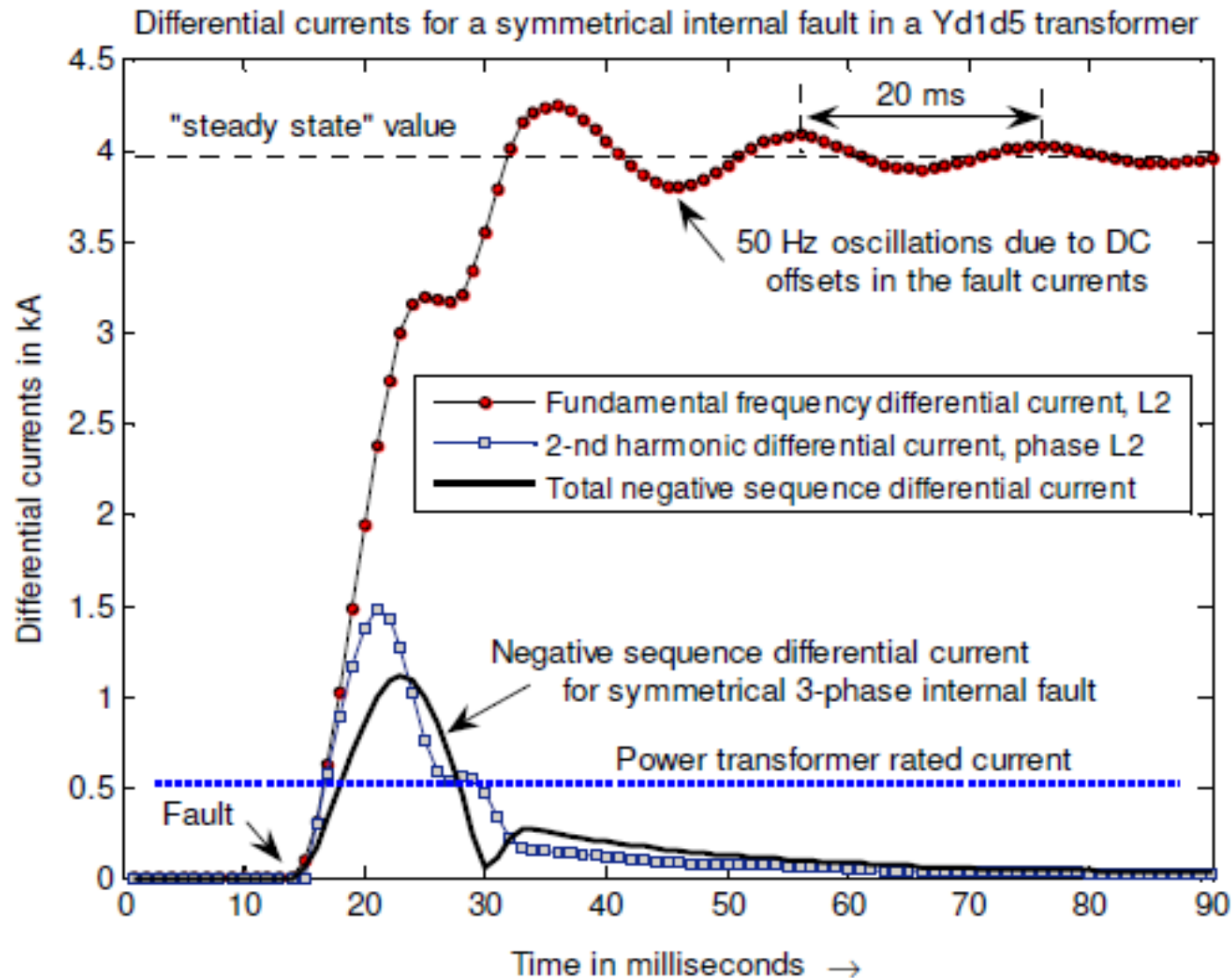
Symmetrical 3-Phase Internal Fault



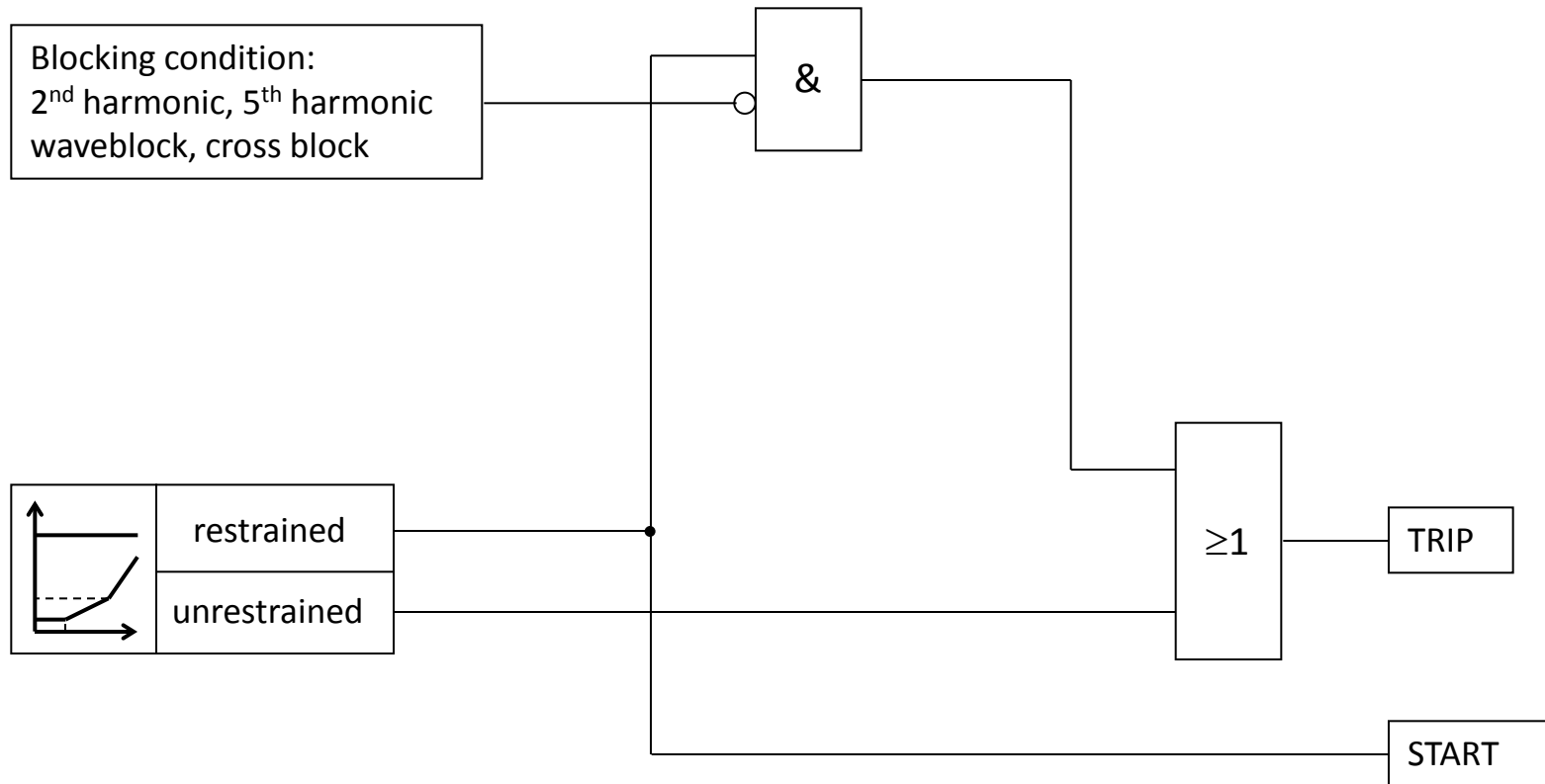
Negative Sequence Contributions in 3-phase Symmetric Fault



Differential Current Profile for 3-Phase Symmetric Fault

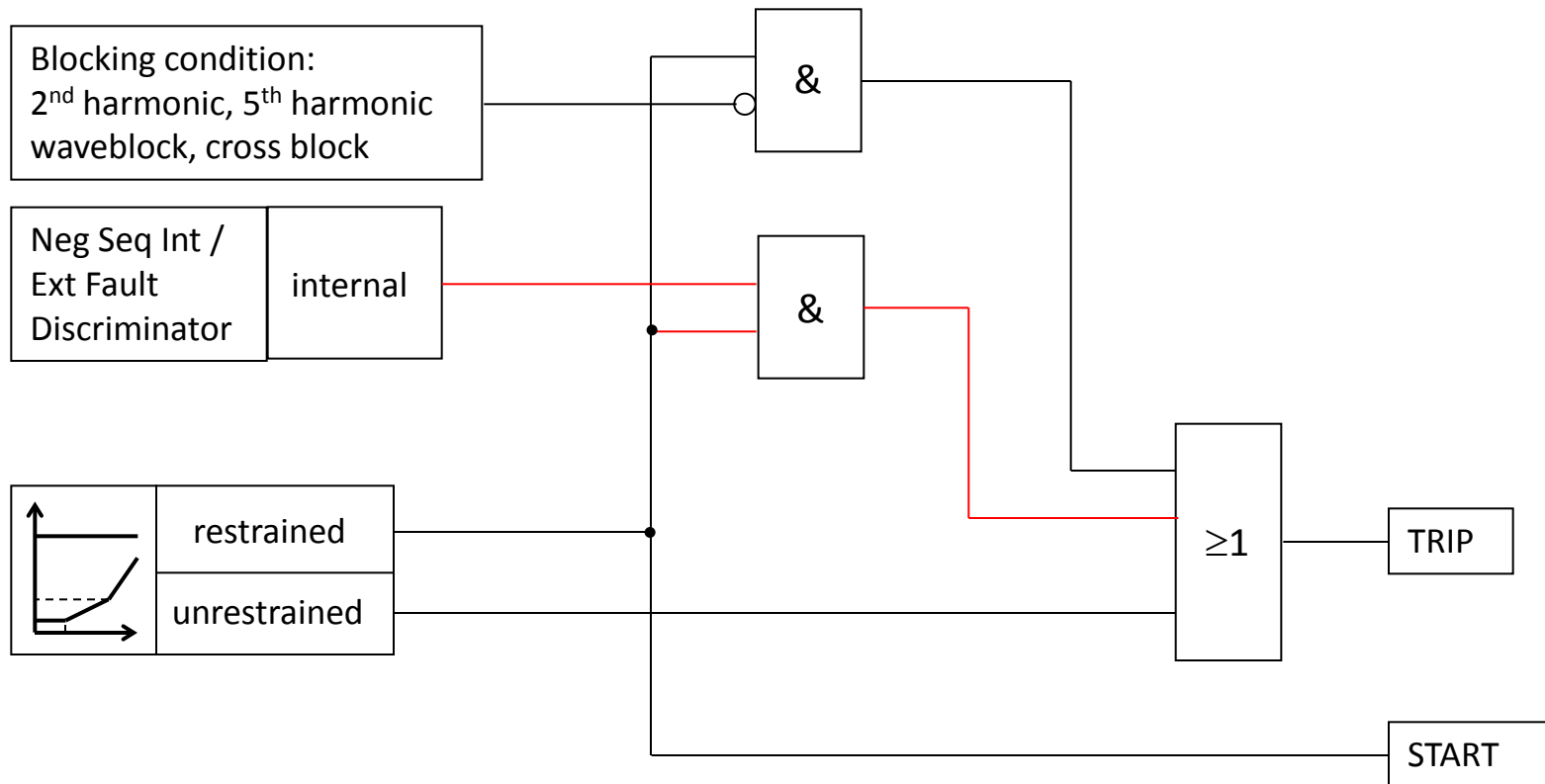


Traditional Transformer Differential Protection



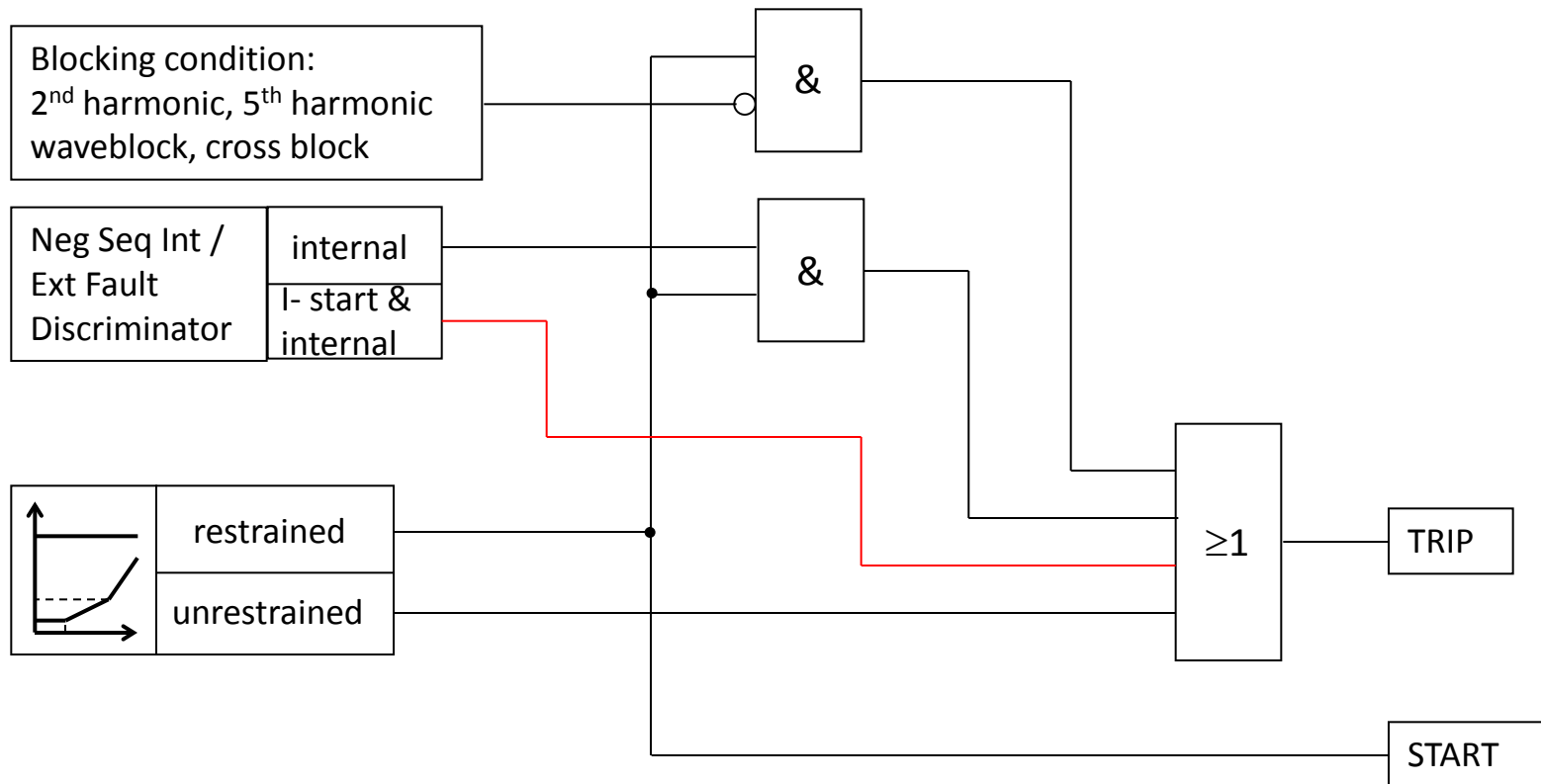
Improvement in Traditional Differential Protection

- 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)

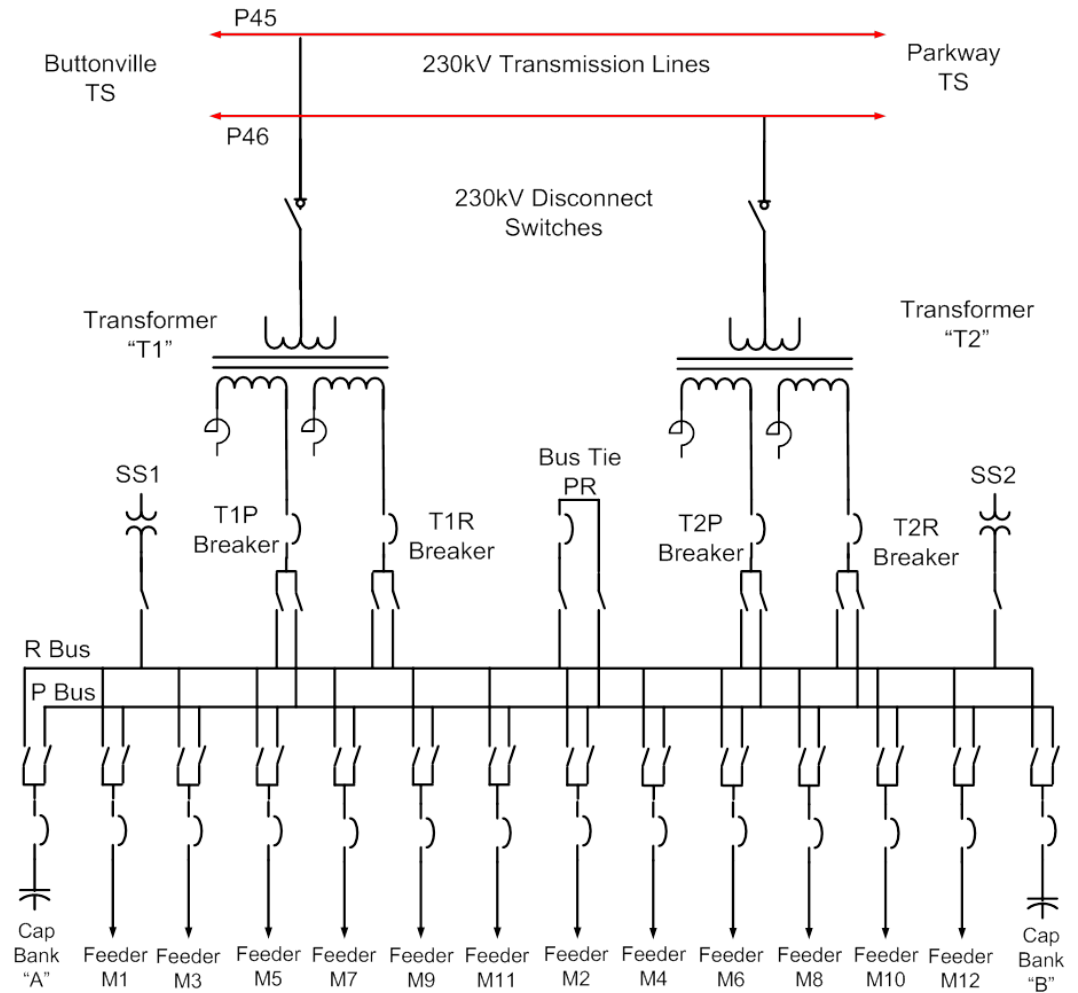


Implementation at Markham TS #4 Station

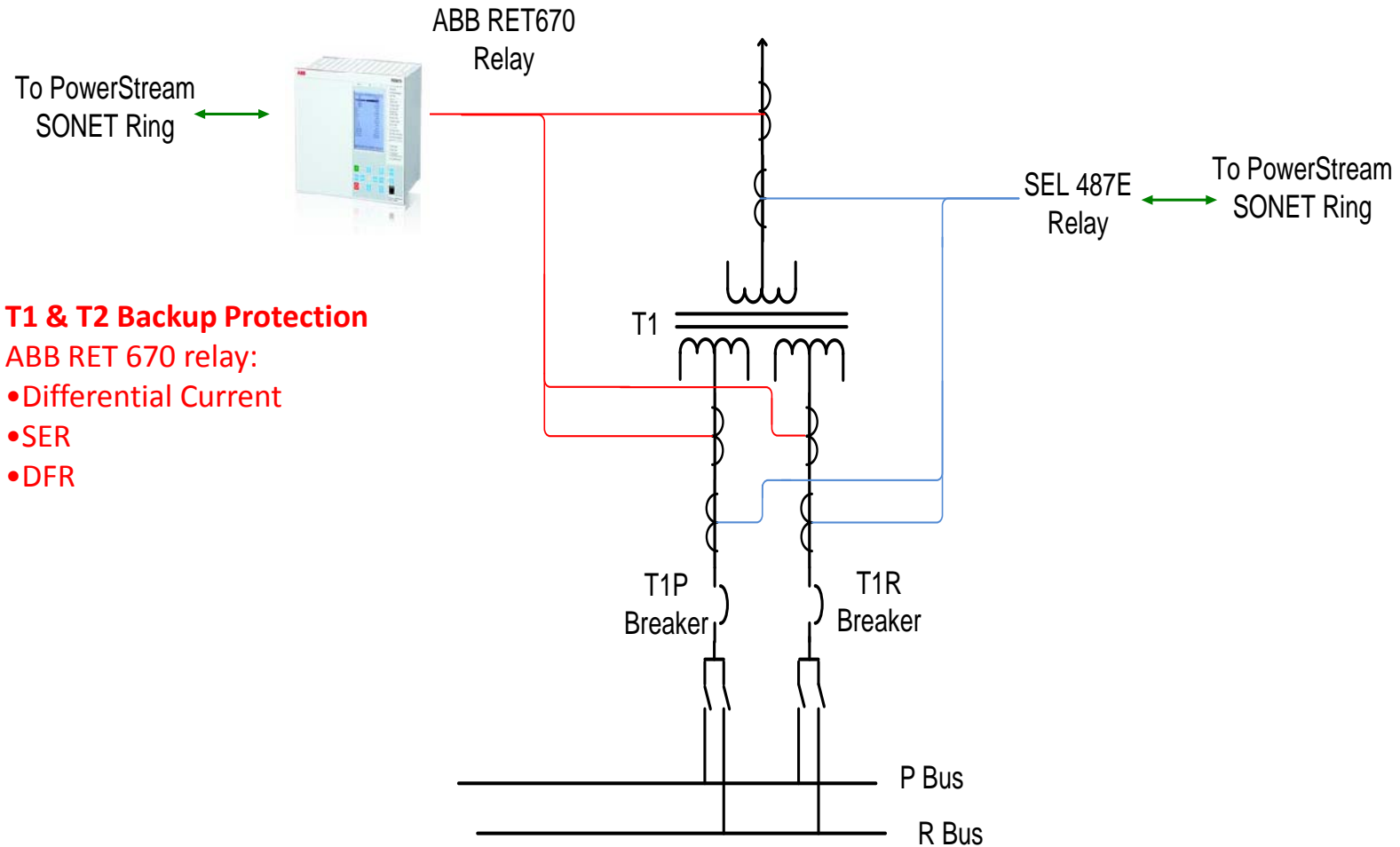


•Transformer Specifications:

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



Main & Backup Transformer Protection



Function Block for Improved Differential Protection

The screenshot displays the PowerStram MTS4 (3) - PCM600 software interface. The left pane shows the 'Plant Structure' tree, with 'T1RET 670' selected. The main workspace displays the 'T3WPDIF' protection logic diagram, which is a green box with various input and output connections. The right pane shows 'Object Properties' for 'T3WPDIF(87T): 1'. The bottom status bar indicates '528.477' and 'T3WPDIF(87T): 1 Application Configuration'.

Settings for Improved Differential Protection

Local Server\Powerstram MTS4 (3) - PCM600

File Edit View Tools IED Window Help

Project Explorer

Plant Structure

- Powerstram MTS4 (3)
 - Substation
 - Voltage Level
 - Transformer
 - T1RET 670
 - IED Configuration
 - Application Configuration
 - OVERVIEW
 - HV_AI
 - LV1_AI
 - LV2_AI
 - DIFF_87N
 - DIFF_PROTN
 - Differential protection
 - TransformerDiff3Wind(PDIF,87T)
 - T3WPDIF(87T): 1
 - Logic
 - HV_PROT
 - LV1_PROT
 - LV2_PROT
 - TRIP
 - BINARY_IO
 - LOGIC
 - MEAS
 - DREP
 - COMMON
 - LON_COM

- Busbar
- REDphaseREB 670
 - IED Configuration
 - Application Configuration
- WHITEphaseREB670
 - IED Configuration
 - Application Configuration
- BLUEphaseREB670
 - IED Configuration
 - Application Configuration

T1RET 670 - Application Configuration

T1RET 670 - Parameter Setting

Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
Setting Group1					
Operation		Enabled			
SOTFMode		Enabled			
IDiffAlarm		0.30	IB	0.05	1.00
tAlarmDelay		10.000	s	0.000	60.000
IdMin		0.43	IB	0.05	0.60
EndSection1		1.25	IB	0.20	1.50
EndSection2		3.00	IB	1.00	10.00
SlopeSection2		30.0	%	10.0	50.0
SlopeSection3		50.0	%	30.0	100.0
IdUnre		7.00	IB	1.00	50.00
I2/I1Ratio		15.0	%	5.0	100.0
I5/I1Ratio		50.0	%	5.0	100.0
NegSeqDiffEn		Enabled			
CrossBlockEn		Enabled			
IMinNegSeq		0.04	IB	0.02	0.20
NegSeqROA		60.0	Deg	30.0	120.0
OpenCTEnable		Enabled			
tOCTAlarmDelay		3.000	s	0.100	10.000
tOCTUnrstDelay		10.00	s	0.10	6000.00
tOCTResetDelay		0.250	s	0.100	10.000
Setting Group2					
Operation		Disabled			
SOTFMode		Enabled			
IDiffAlarm		0.20	IB	0.05	1.00
tAlarmDelay		10.000	s	0.000	60.000
IdMin		0.30	IB	0.05	0.60
EndSection1		1.25	IB	0.20	1.50

Object Properties

[000] Appearance

Caption	Description	Function
T3WPDIF(87T): 1		

Misc

Function ID	Function Rev
d607f6c5-be05-4ff4	1.2_8.0

Instance ID

Output

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 ?

