Application of Zero-Sequence Filter on Transformer Differential Protection

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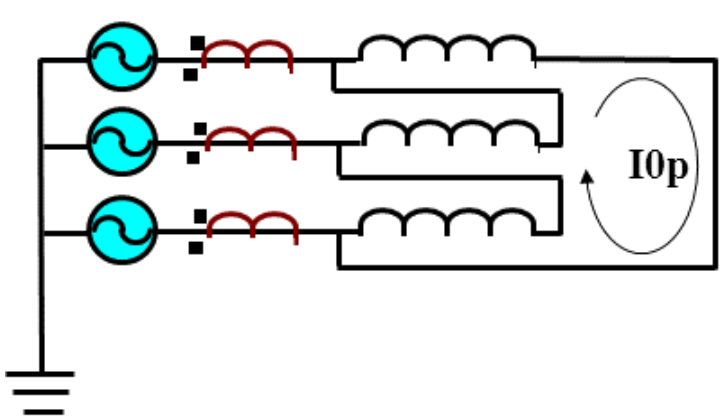
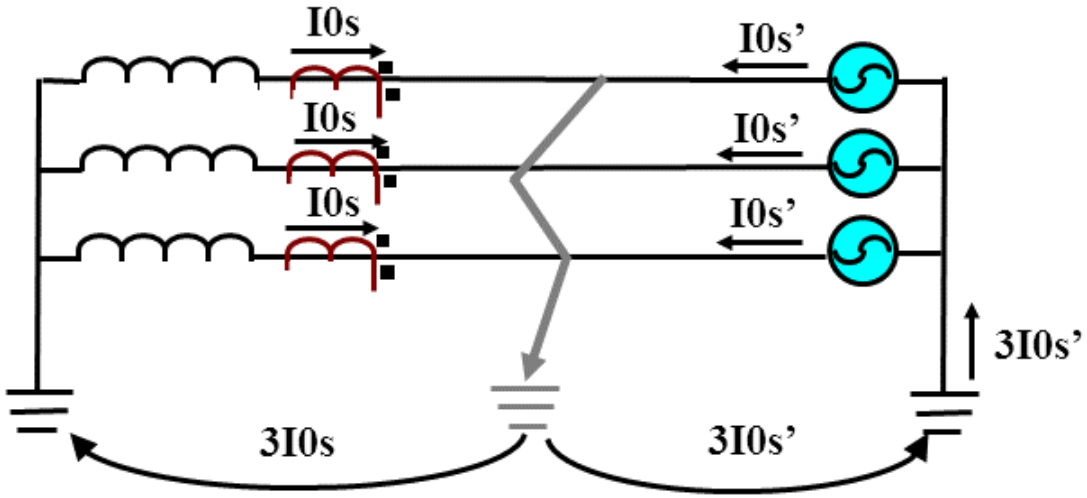
Overview

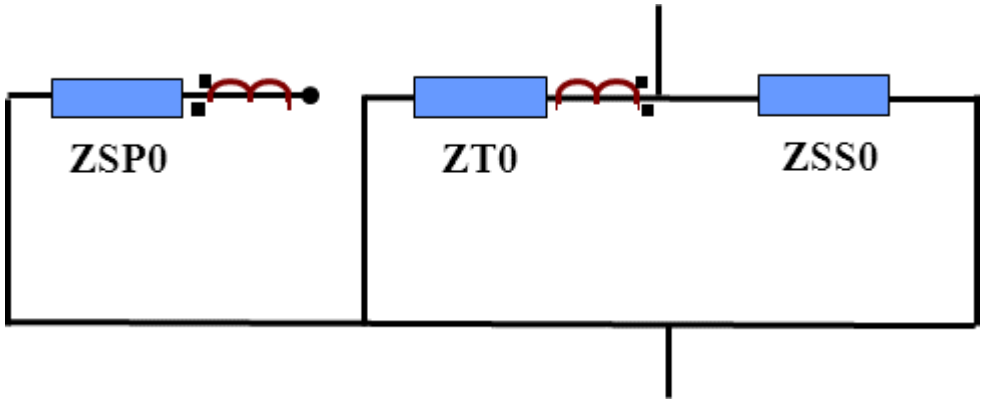
- Transformer configurations that require the use of the zero-sequence filter
- Methods for applying the zero-sequence filter
- Influence of the zero-sequence filter on the differential unit and complementary units

Transformer Dyn

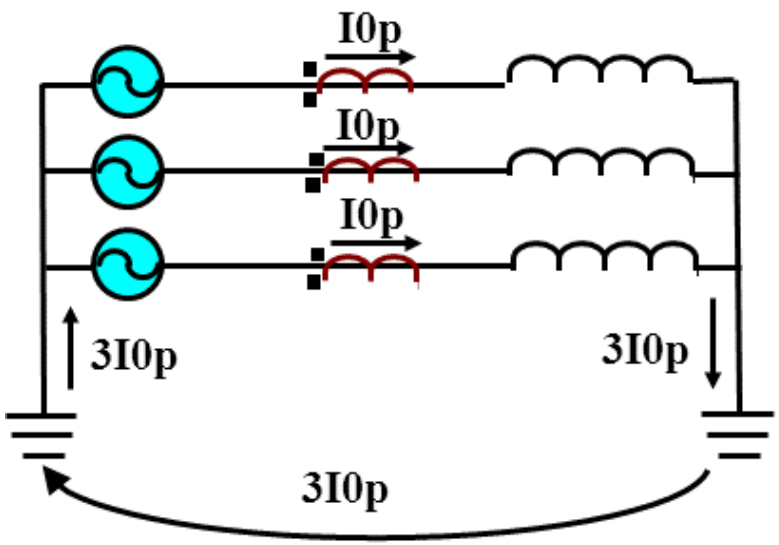


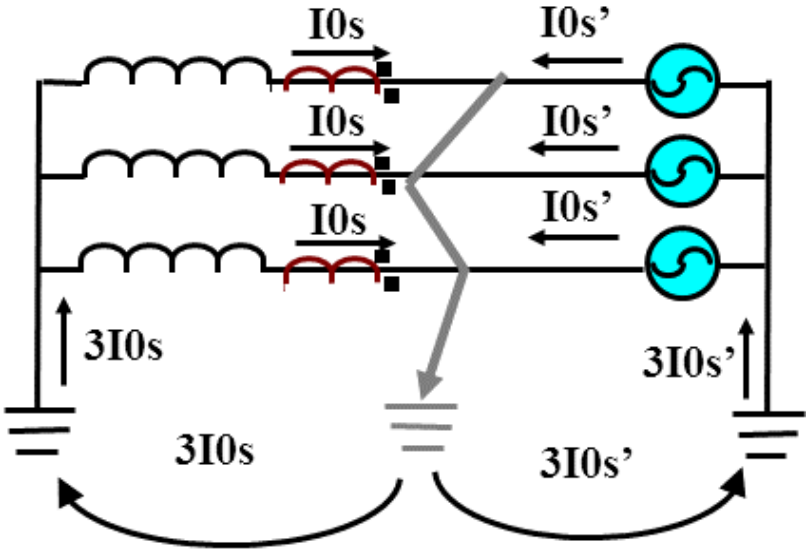


ZERO SEQUENCE FILTER=YES

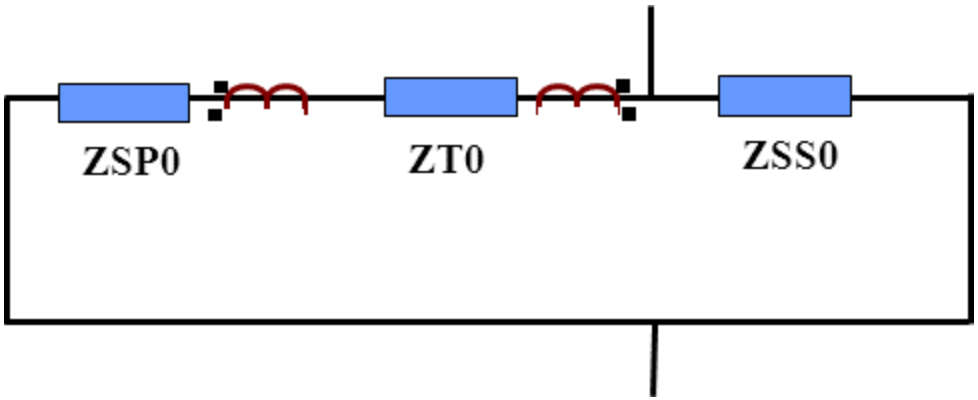


Transformer YNyn

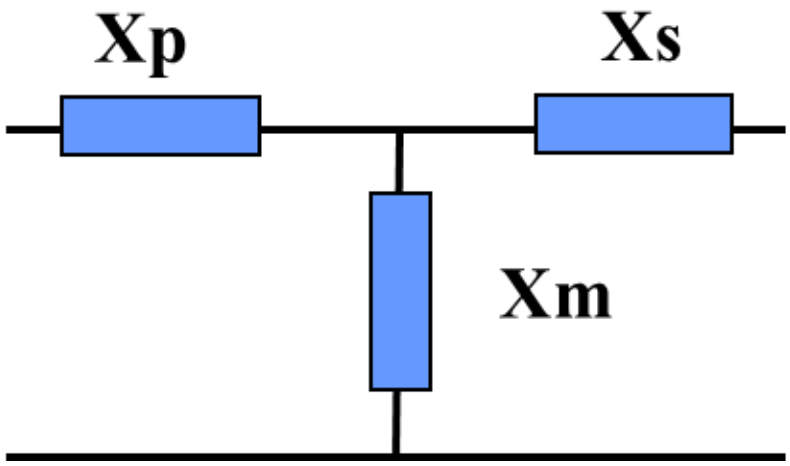




ZERO SEQUENCE FILTER=NO



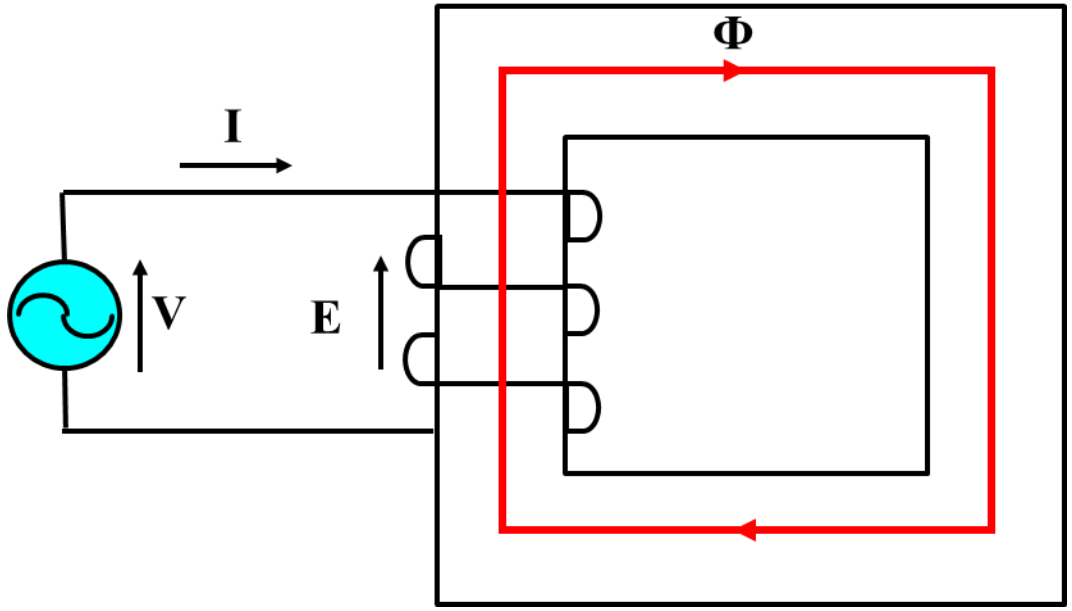
Magnetizing Reactance



Can we neglect Xm?

Magnetizing Reactance

$$X = \frac{E}{I}$$



$$N \cdot i = \phi \cdot \Re$$

$$e = -N \cdot \frac{d\phi}{dt} = -N \cdot w \cdot \phi \cdot \cos(wt)$$

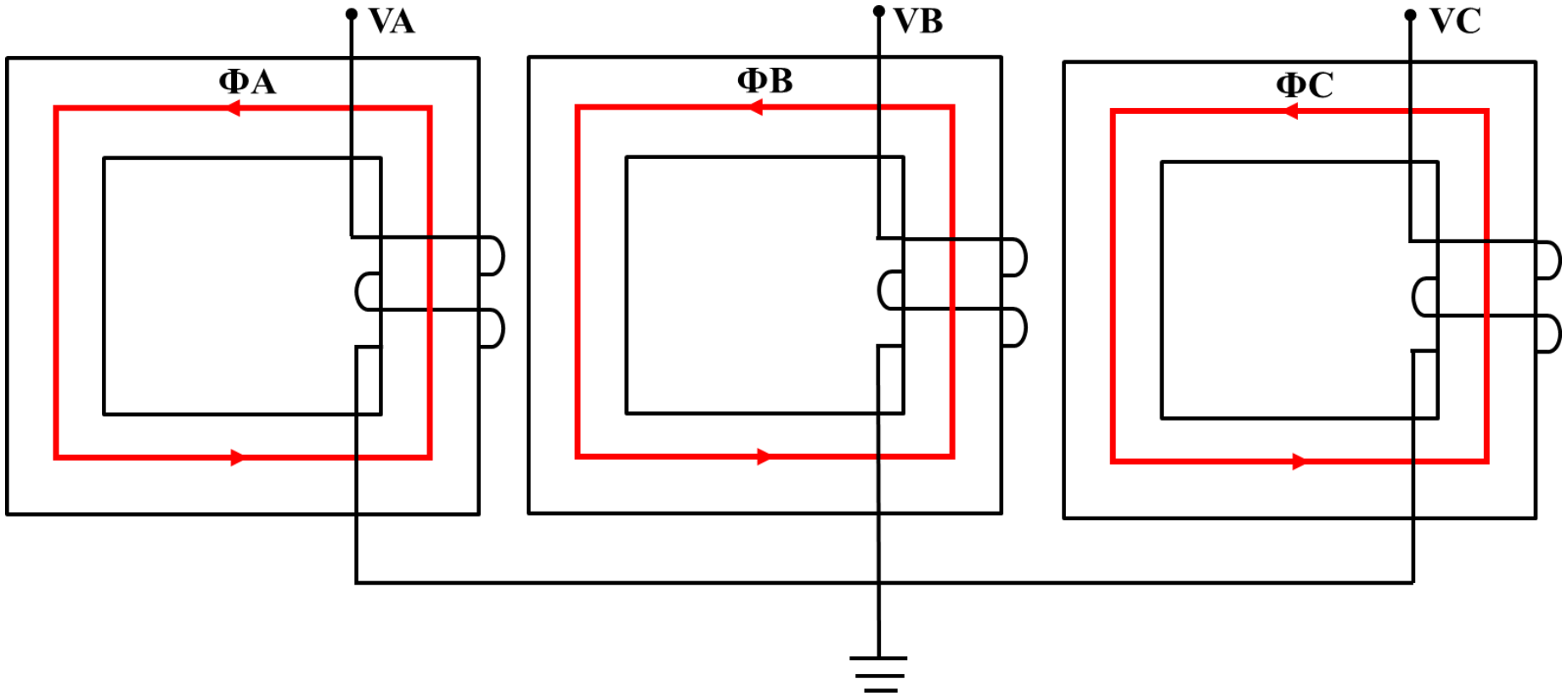
$$I = \frac{\Phi \cdot \Re}{N}$$

$$E = w \cdot N \cdot \Phi$$

$$X = \frac{E}{I} = \frac{N^2 \cdot w}{\Re}$$

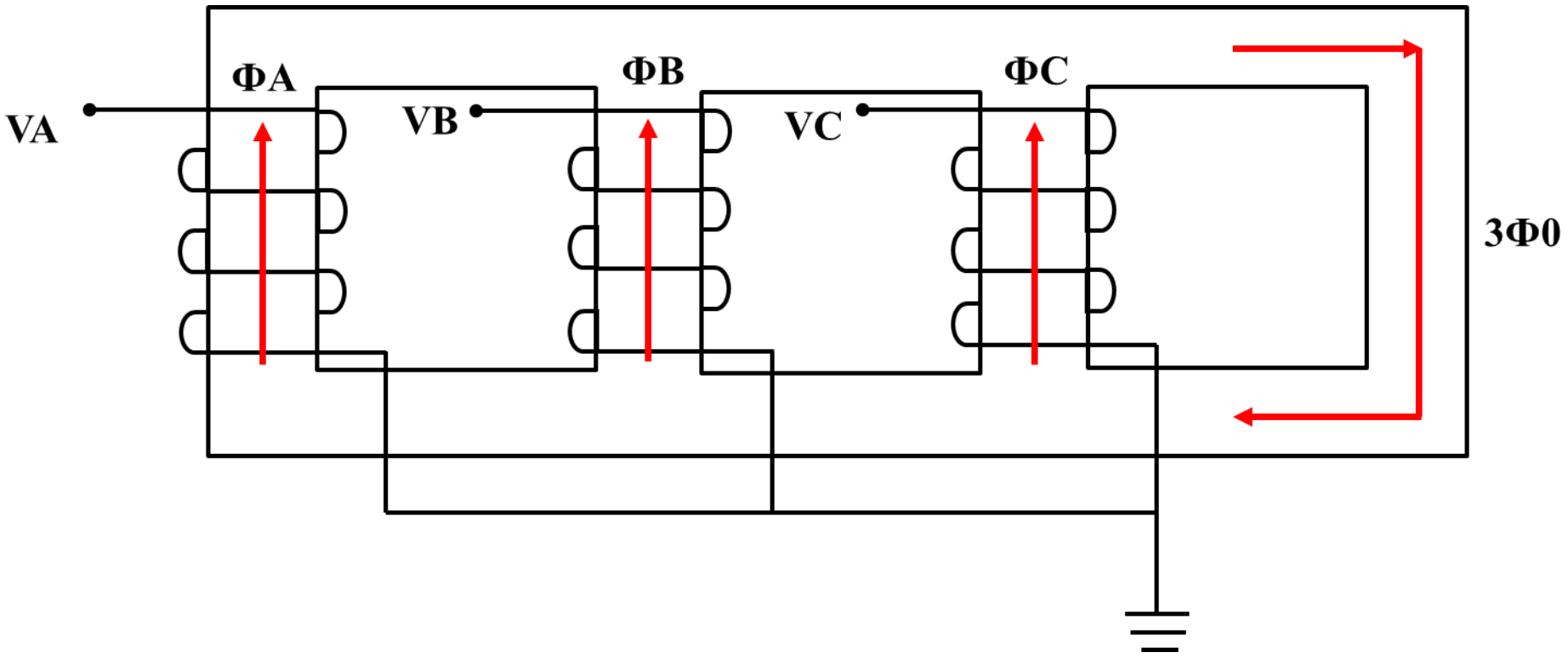
Single-Phase Banks

- Xm1≈Xm0 (high value)
- Im=0.5% - 5% → Xm=20000% - 2000%



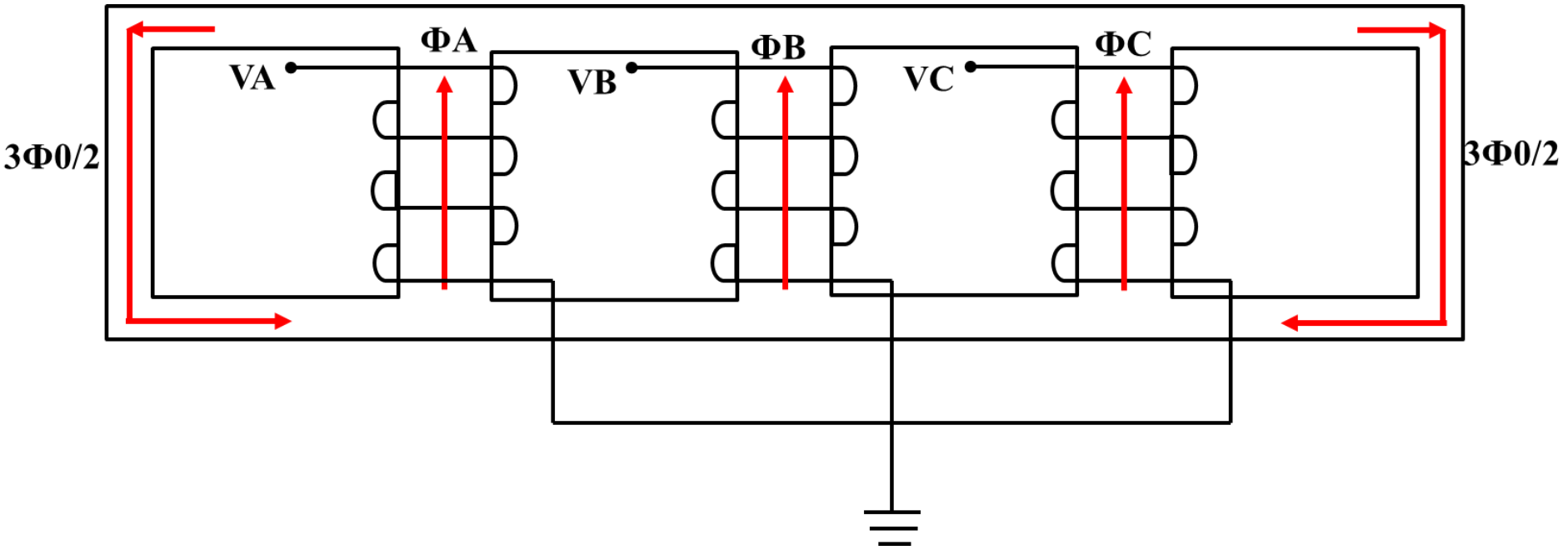
4-Legged Transformer

- Xm1≈Xm0 (high value)



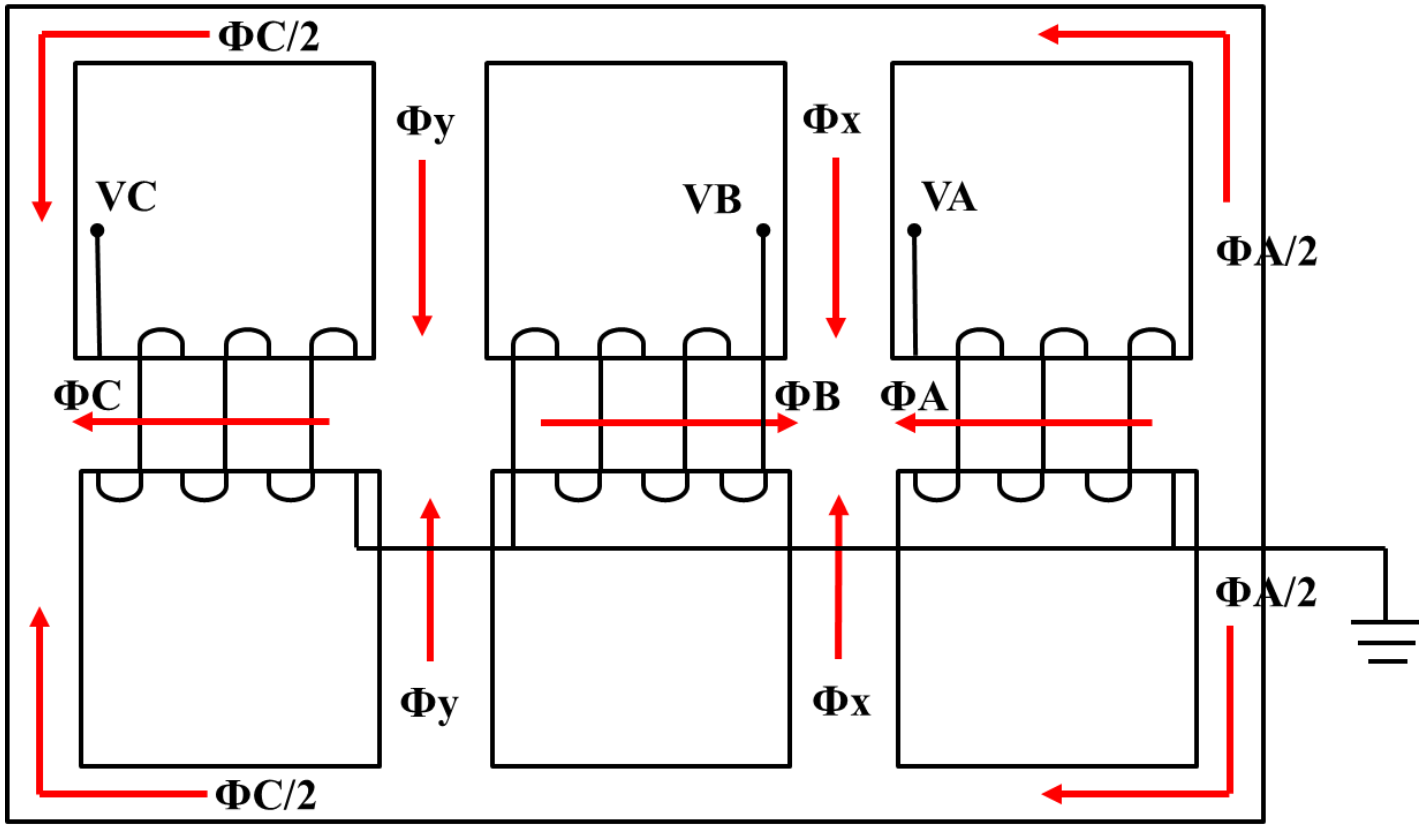
5-Legged Transformer

- Xm1≈Xm0 (high value)



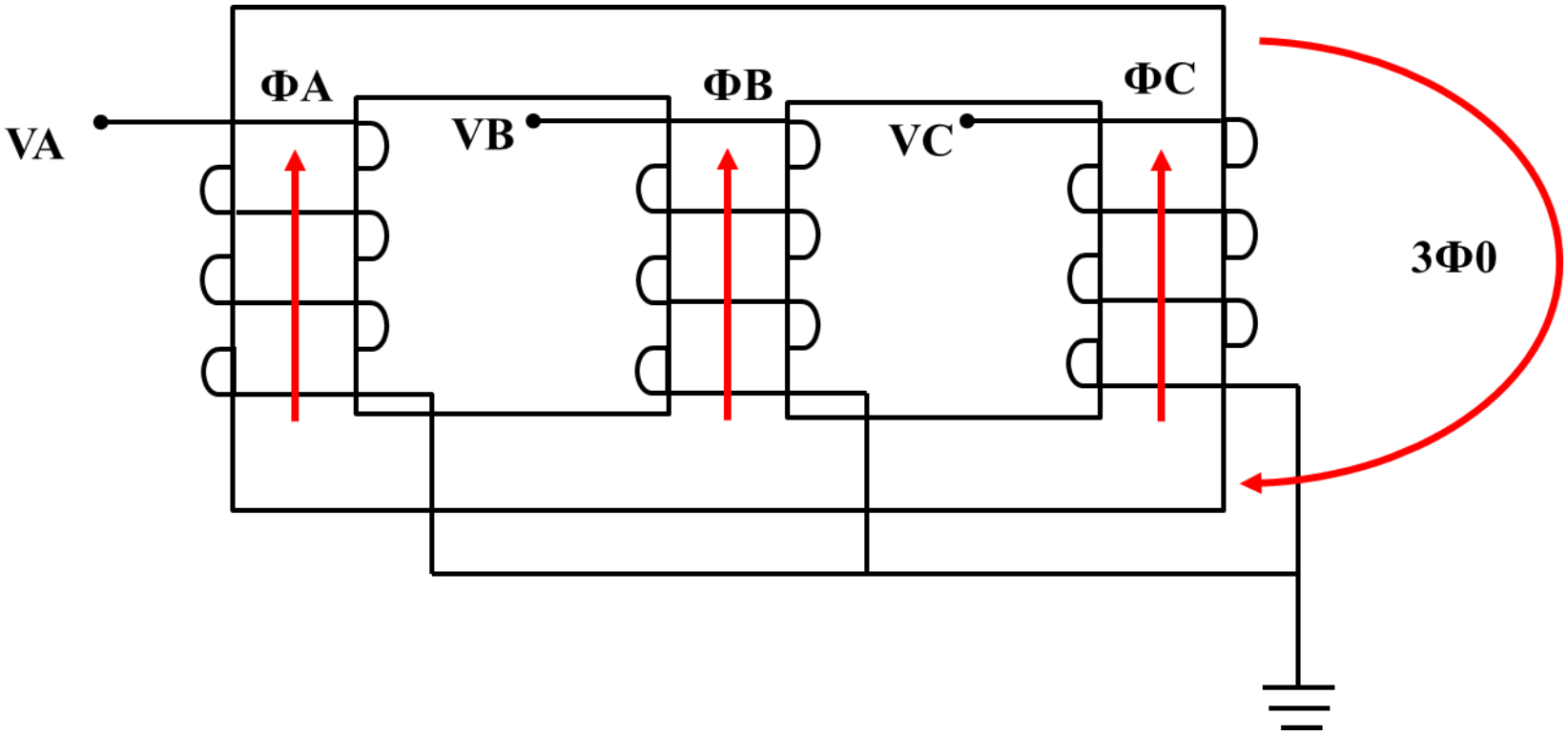
Shell-Type Transformer

- Xm1≈Xm0 (high value)



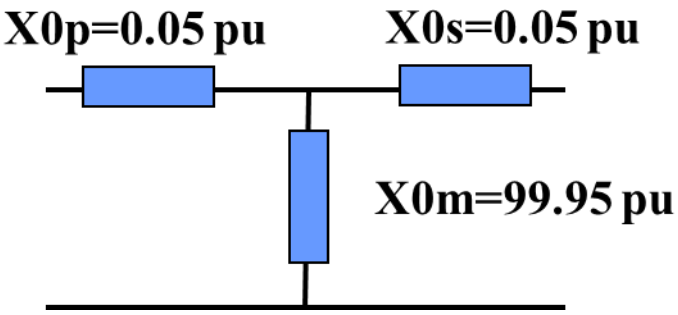
3-Legged Transformer

- Xm0<<Xm1
- Xm0 ≈ 50% - 200%

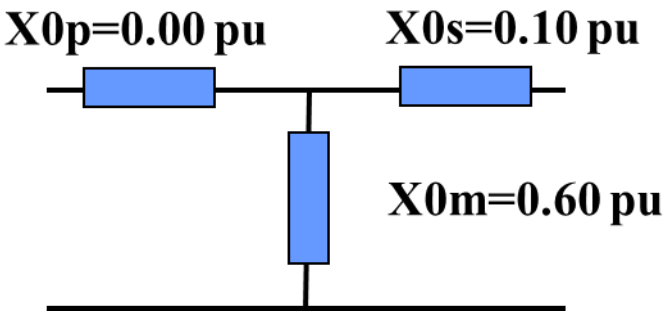


Typical Values for X0

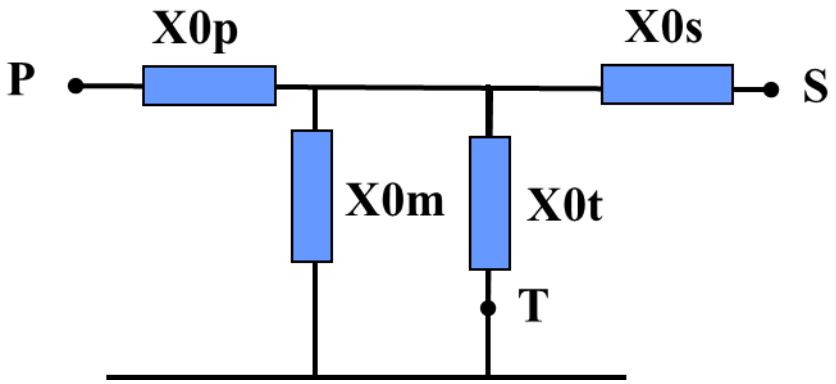
YY SHELL-TYPE OR 5/4 LEGGED



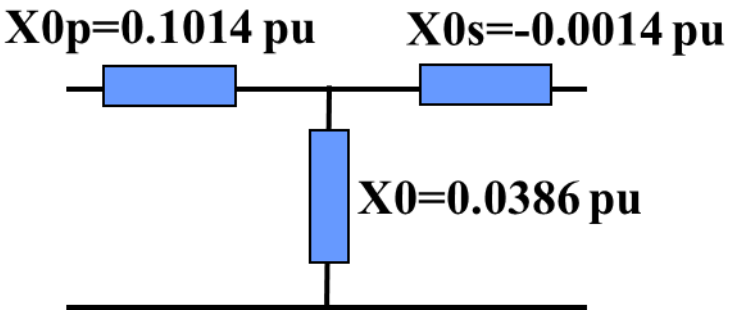
YY 3 LEGGED



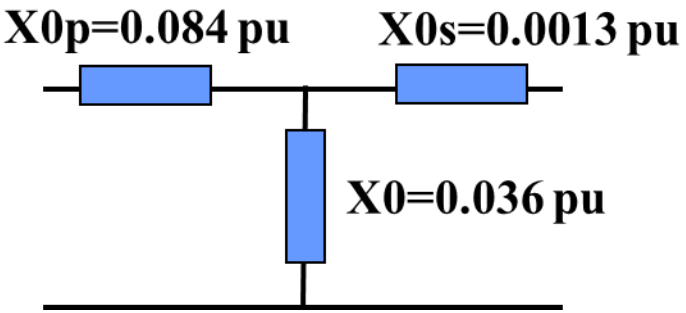
Third Winding



SHELL-TYPE AND 4/5 LEGGED

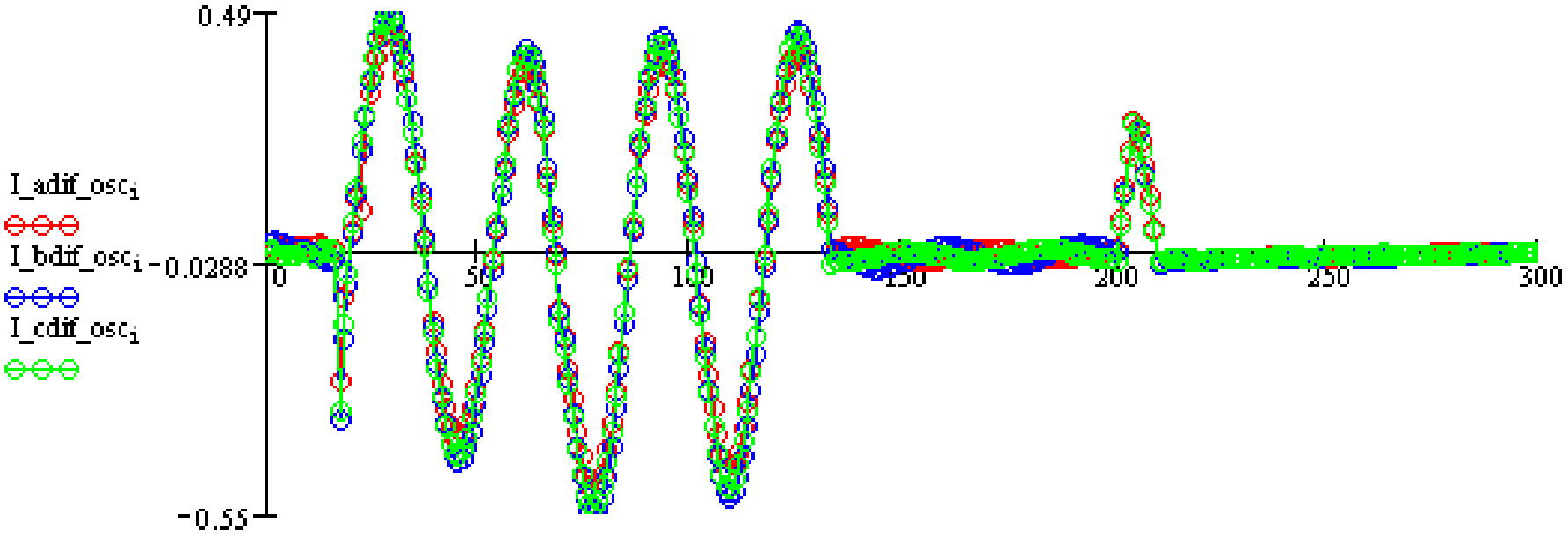


3 LEGGED



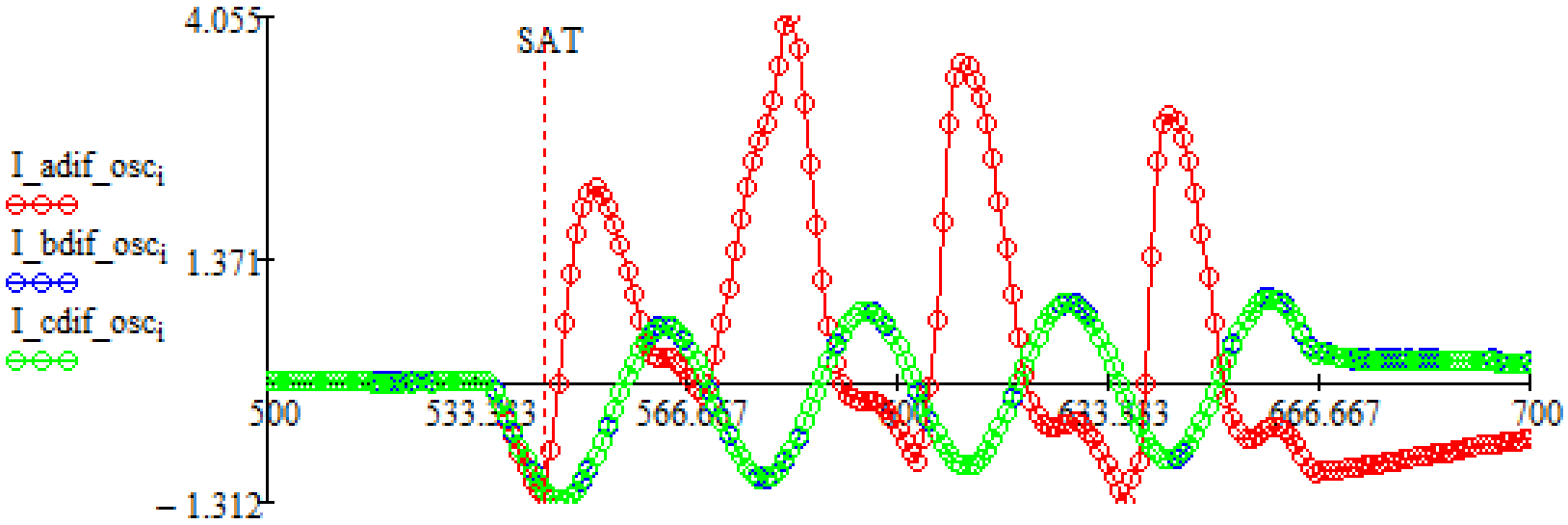
Real External Fault

3 legged YNyn0 30 MVA 115 kV – 13.8 kV



Real External Fault

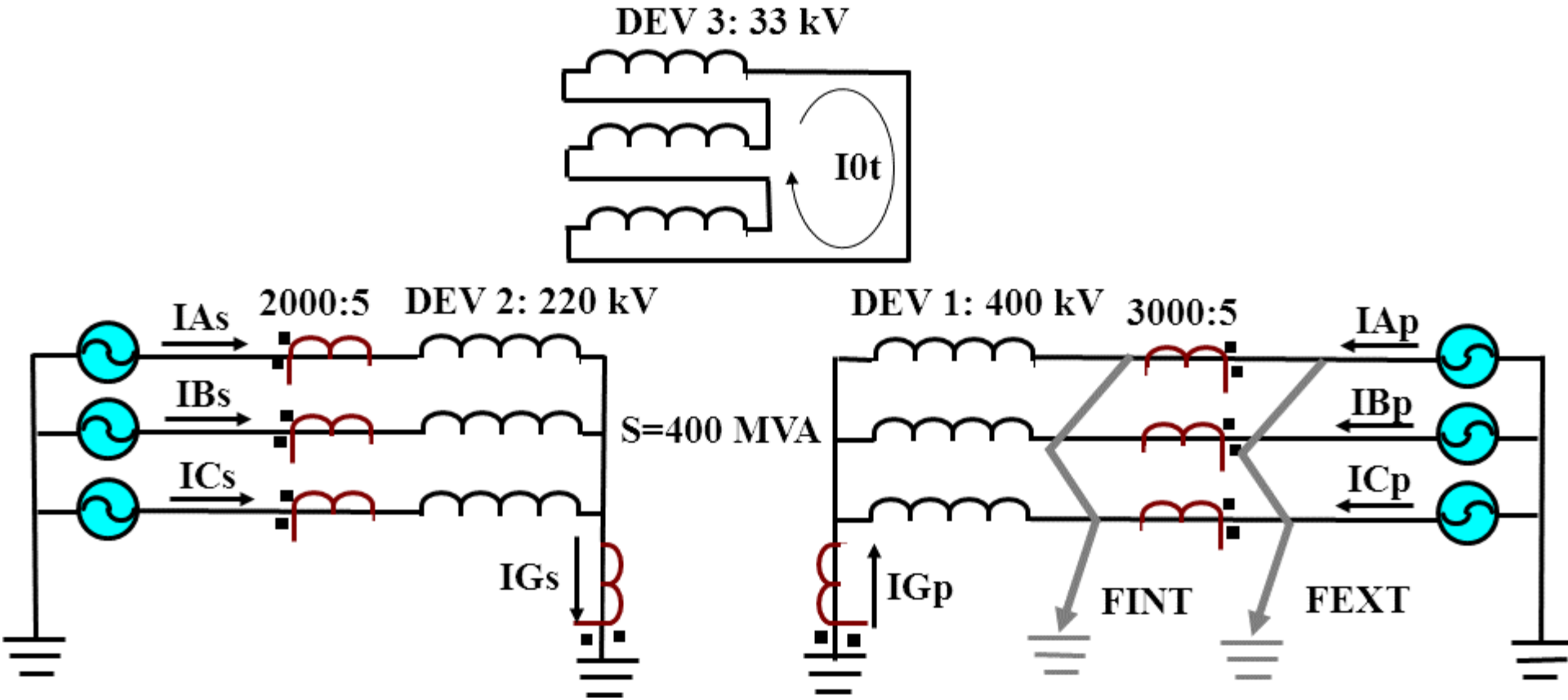
3 legged YNyn0 60 MVA 230 kV – 23 kV



Methods for Zero-Sequence Filter

- Substract I0 calculated from the phase currents (method 1)
- Apply a YD transformation matrix (method 2)
- Substract I0 calculated from the ground current (method 3)

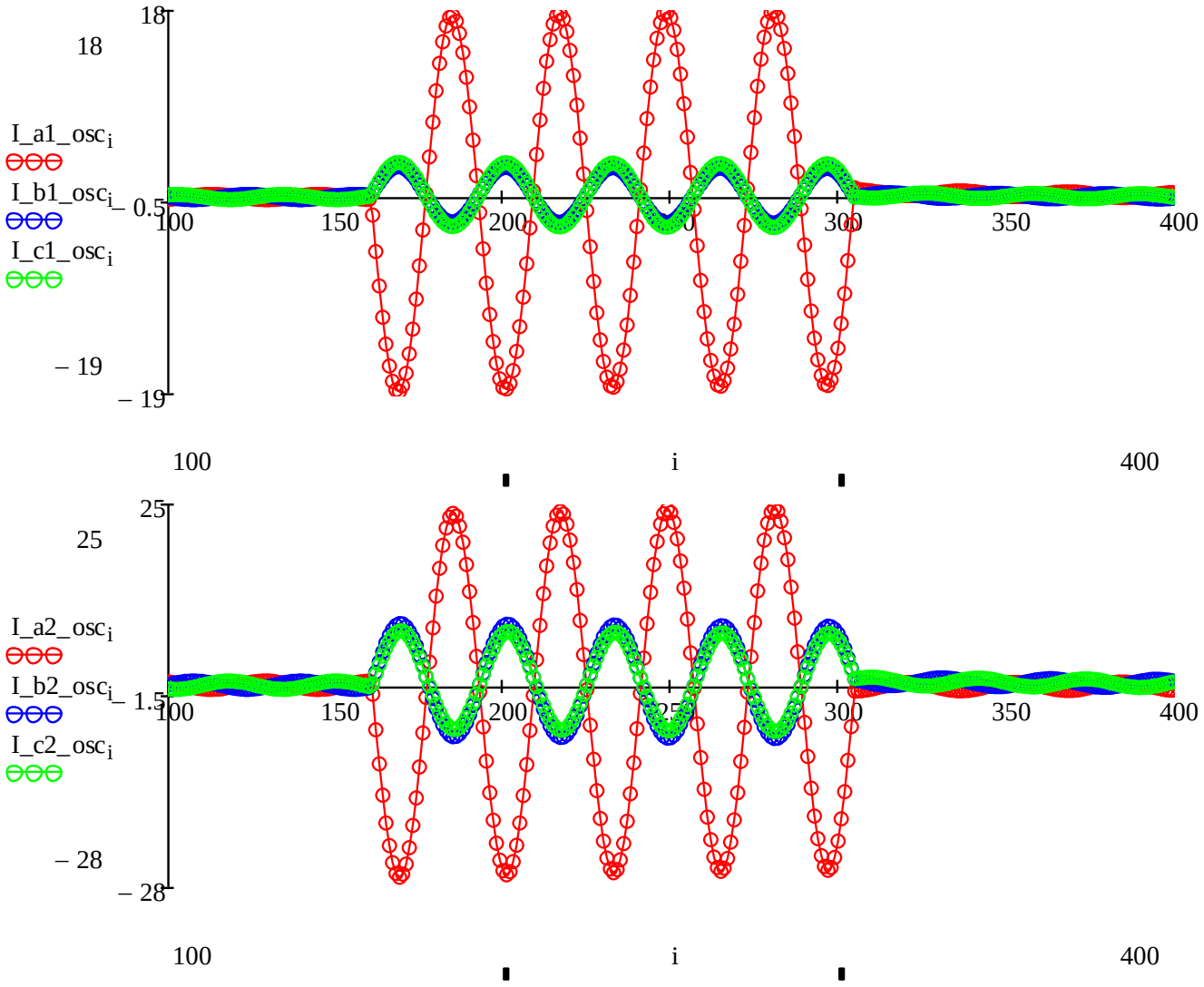
Zero-sequence Filter Effect



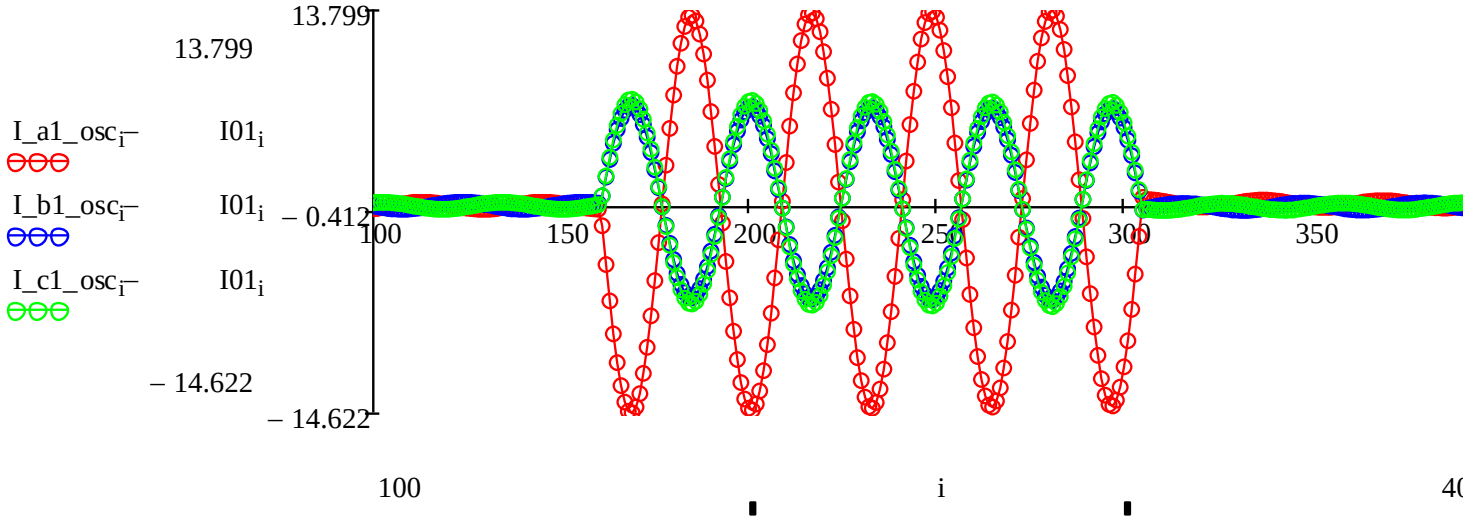
EXTERNAL FAULT: -(IA+IB+IC)=+IG

INTERNAL FAULT: -(IA+IB+IC)≠+IG

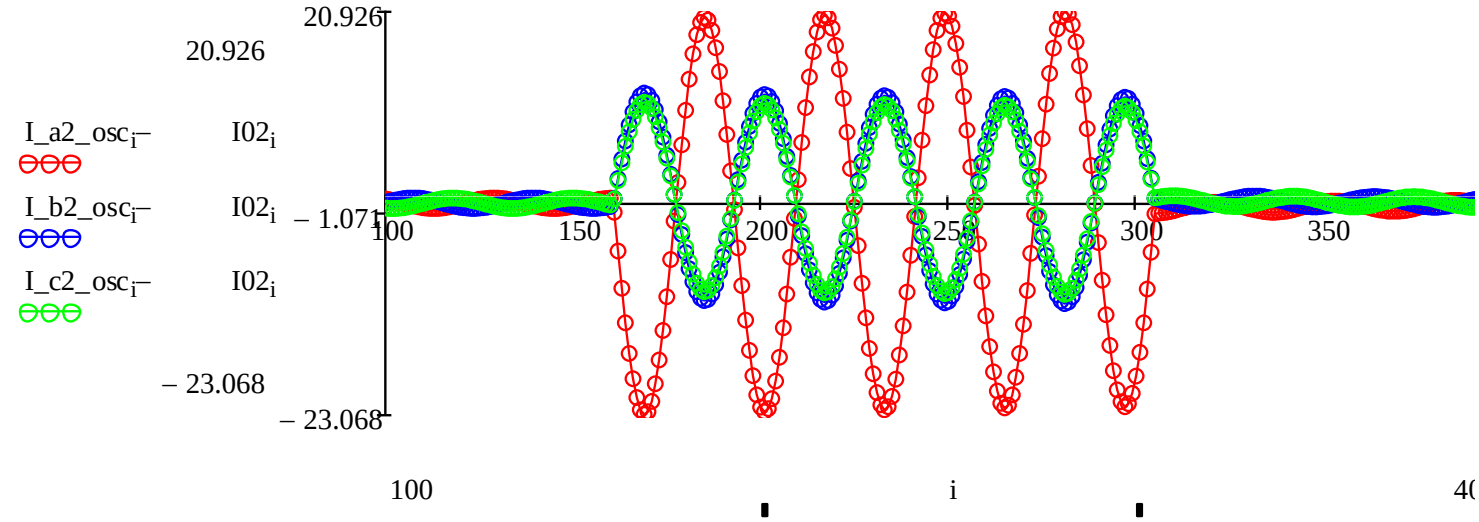
Internal AG fault



Internal AG fault with zero-seq. filter 1

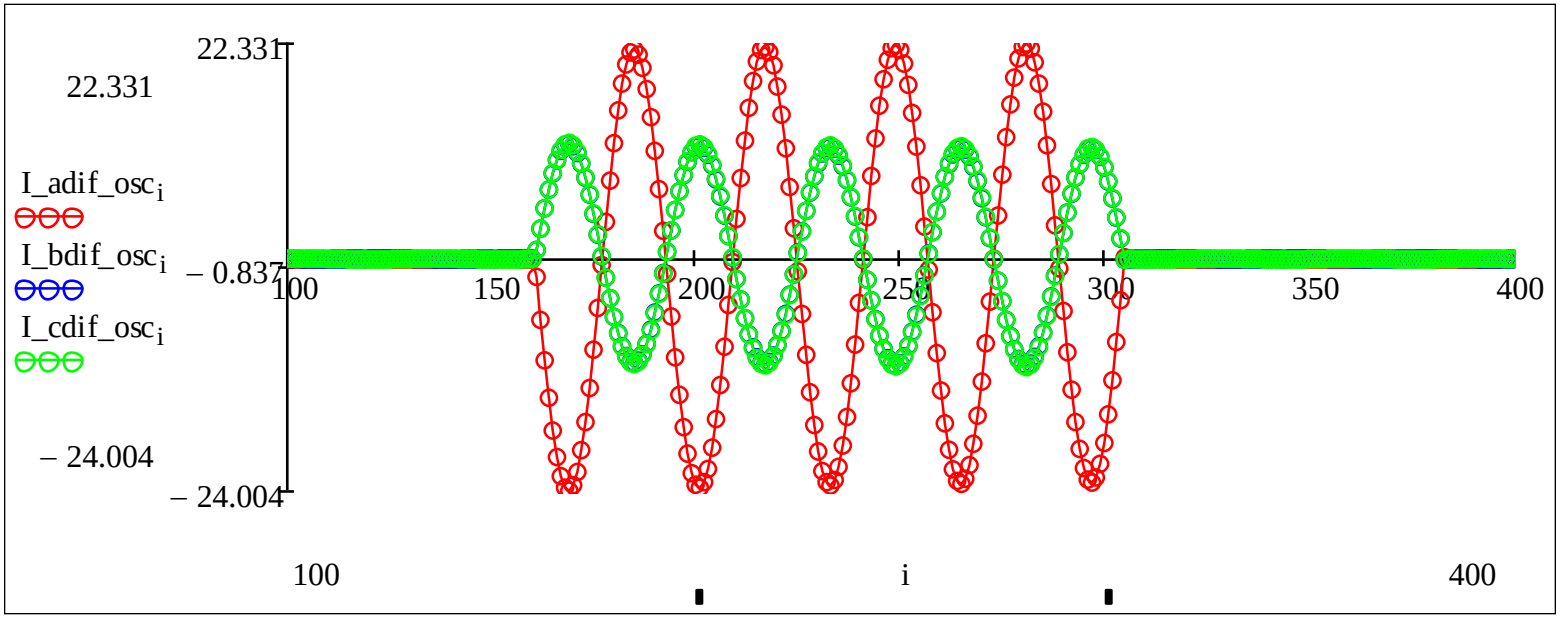


Currents in the healthy phases in phase

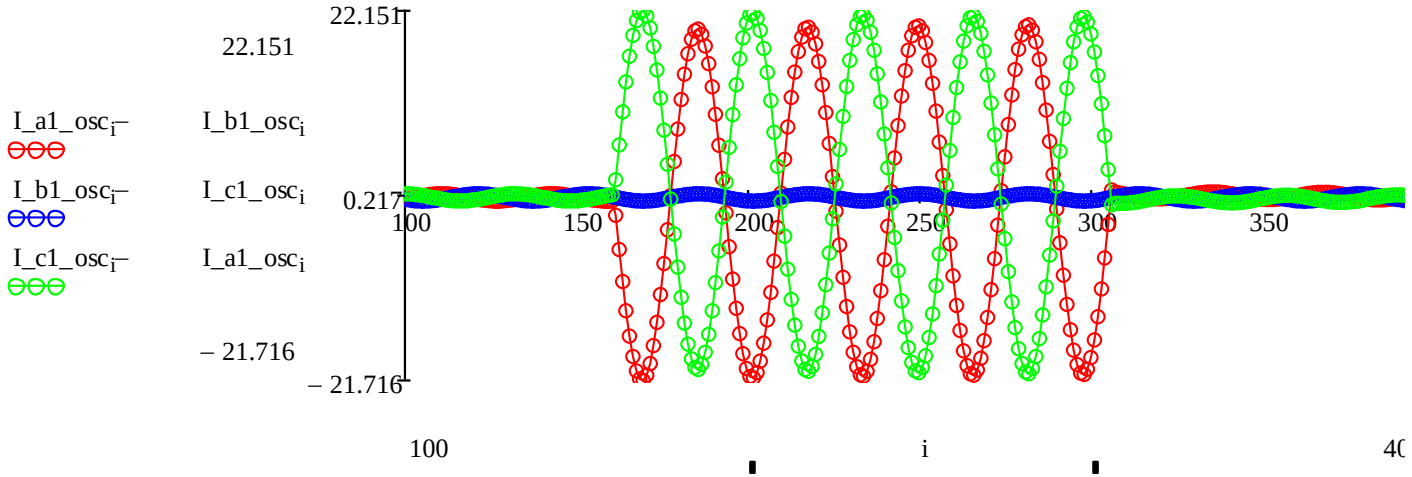


Internal AG fault with zero-seq. filter 1

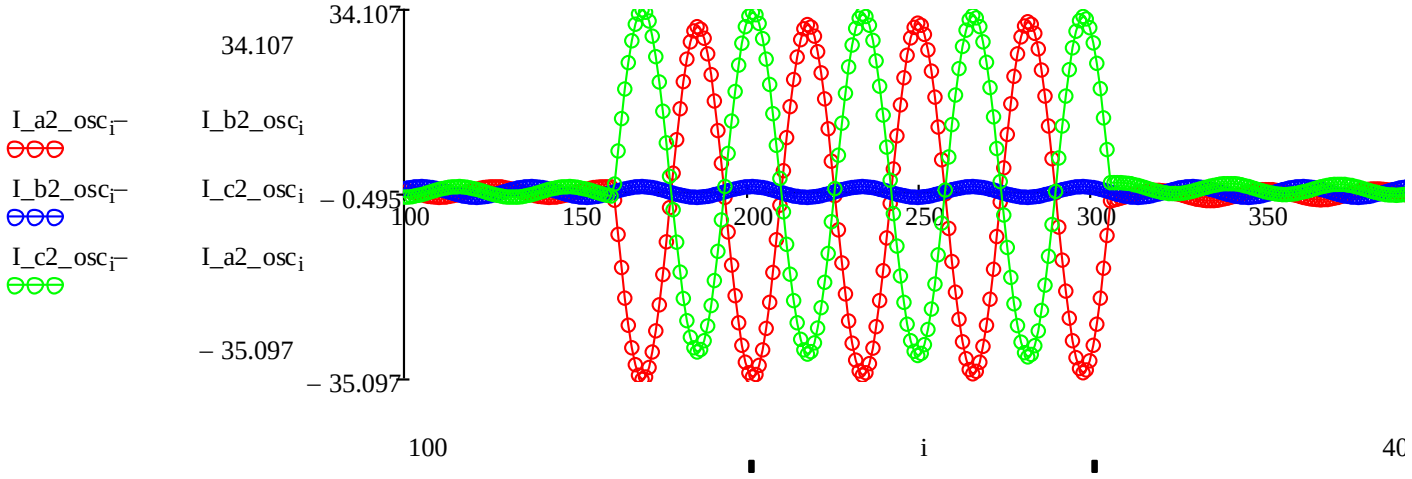
- Appearance of differential current in the healthy phases → erroneous faulted phase selection



Internal AG fault with zero-seq. filter 2

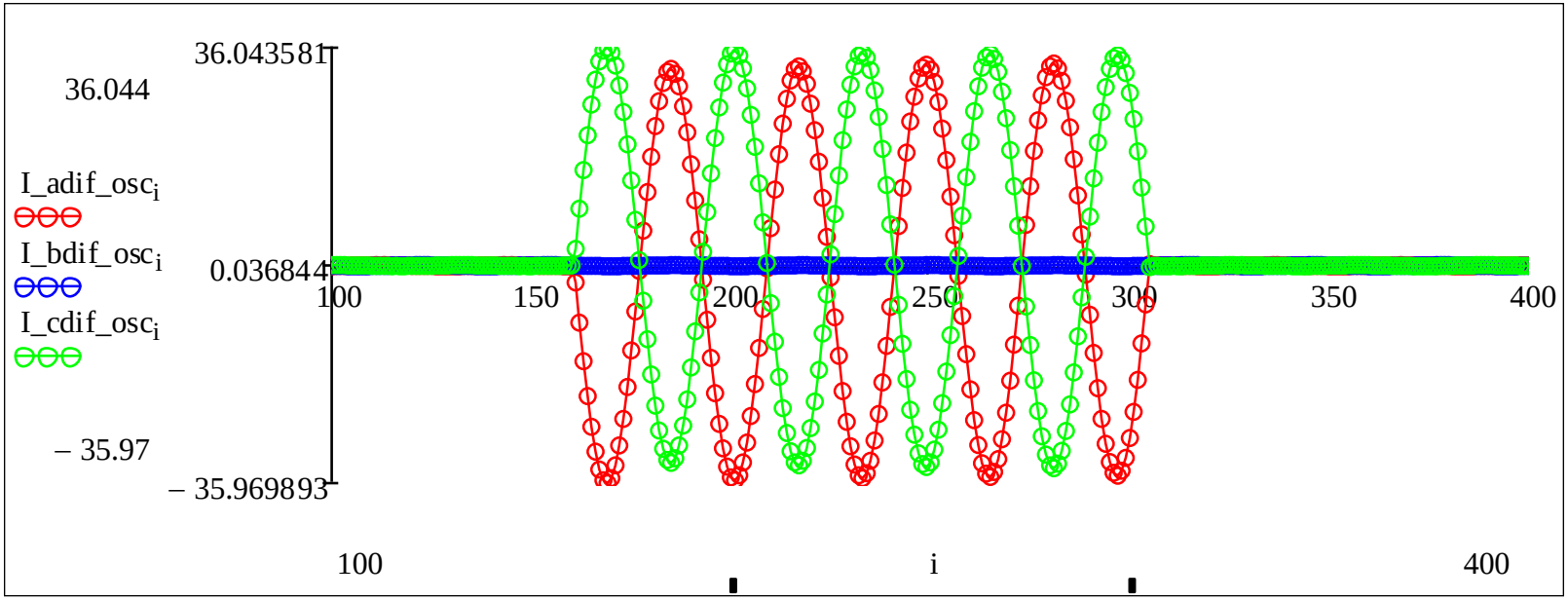


Currents in the healthy phase C in phase

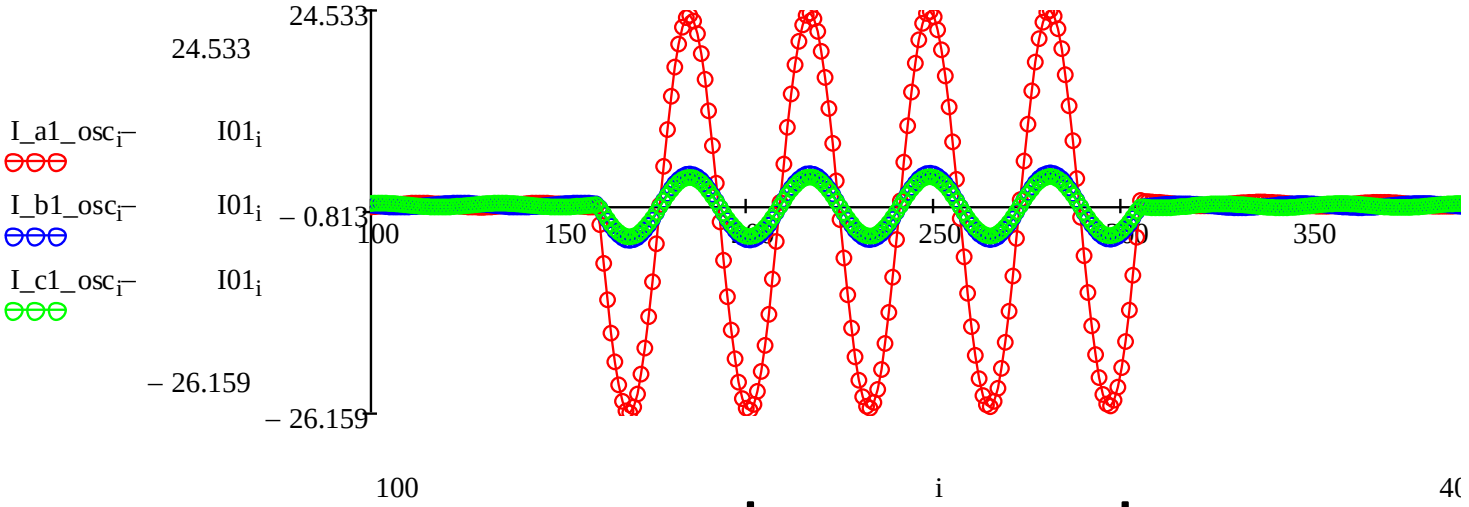


Internal AG fault with zero-seq. filter 2

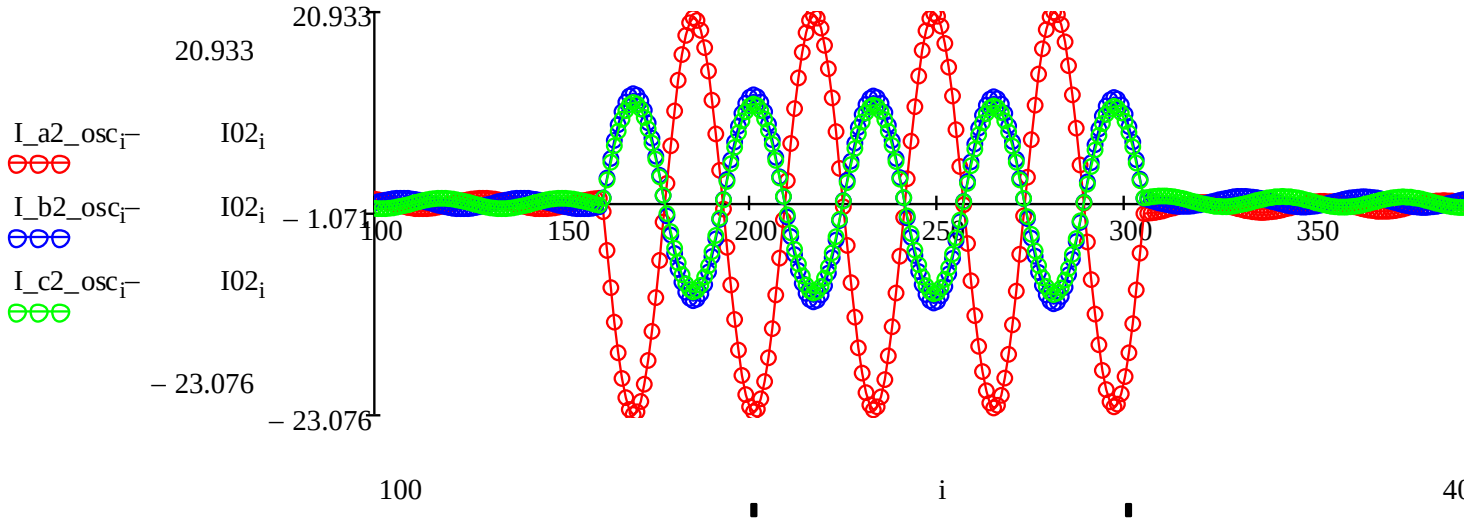
- Appearance of differential current in a healthy phase C → erroneous faulted phase selection



Internal AG fault with zero-seq. filter 3

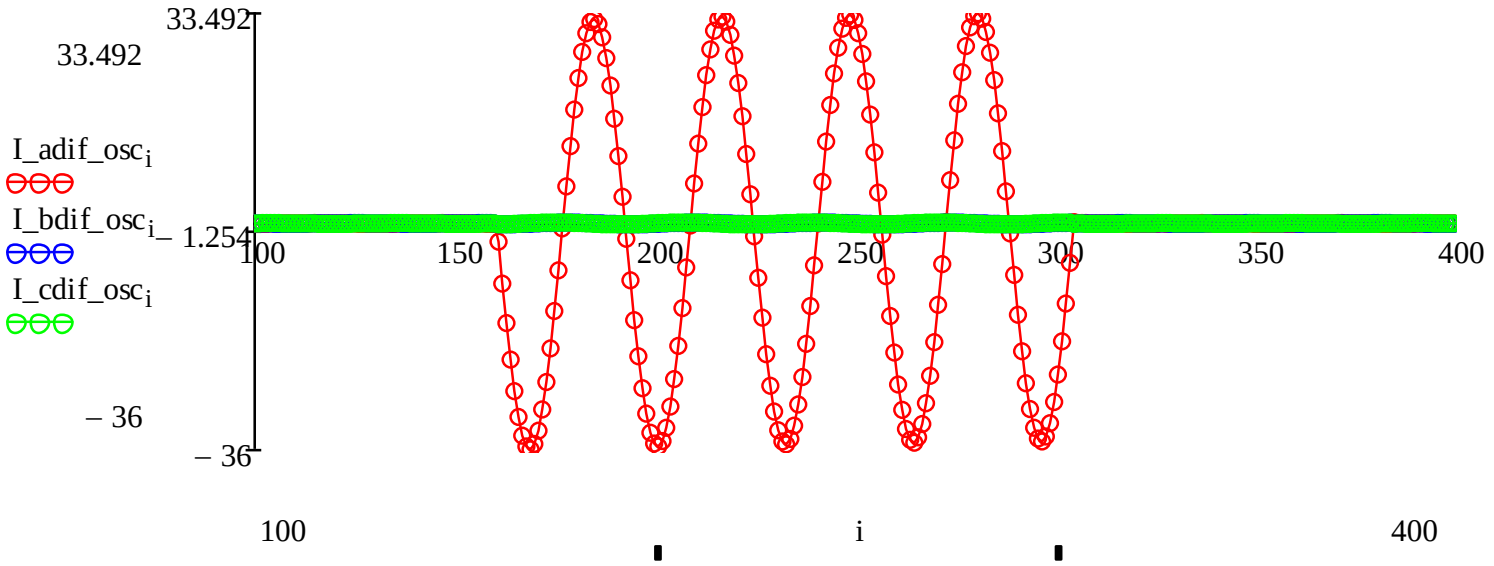


Currents in the healthy phases out of phase



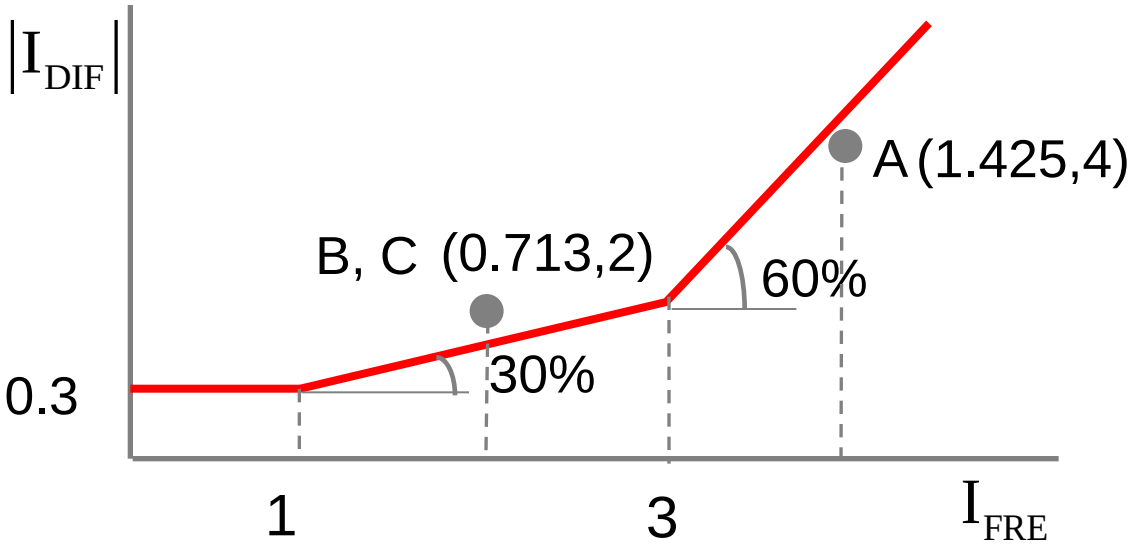
Internal AG fault with zero-seq. filter 3

- No differential current in the healthy phases → correct phase selection
- Higher differential current in the faulted phase → Better sensibility



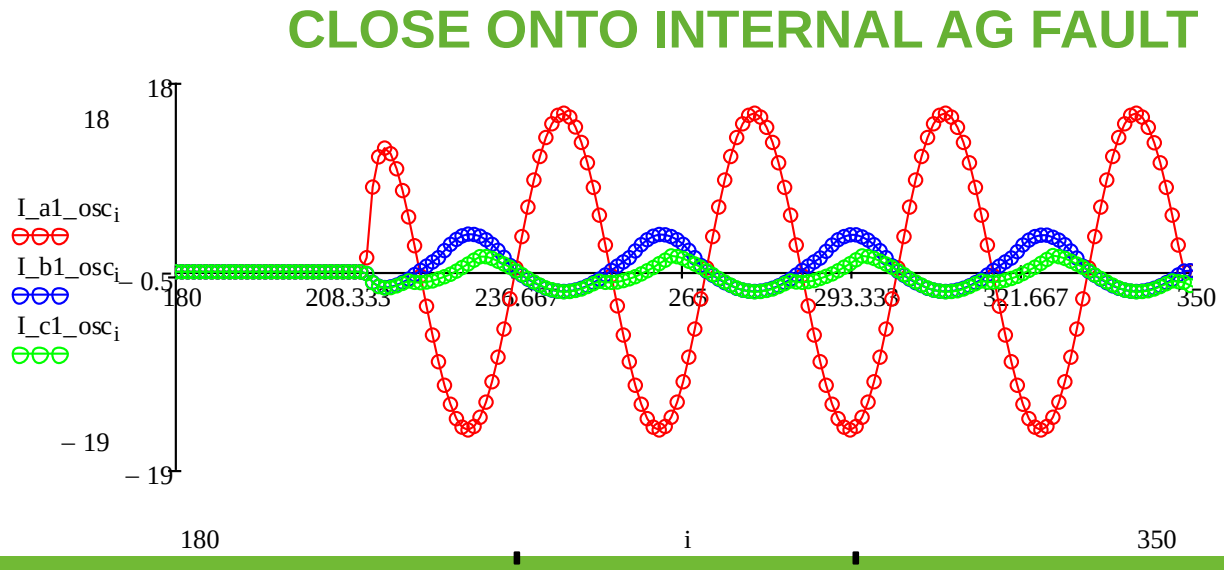
Testing 87 With Zero-Sequence Filter

WITHOUT FILTER	WITH FILTER (Is NOT FILTERED)	WITH FILTER (Is FILTERED)
IADEV1=3.288 $_{0^o}$	IADEV1=4.939 $_{0^o}$	IADEV1=3.288 $_{0^o}$
BDEV1=0	BDEV1=0	BDEV1=1.644 $_{0^o}$
ICDEV1=0	ICDEV1=0	ICDEV1=1.644 $_{0^o}$
IADEV2=4.713 $_{180^o}$	IADEV2=7.069 $_{180^o}$	IADEV2=4.713 $_{180^o}$
BDEV2=0	BDEV2=0	BDEV2=2.356 $_{180^o}$
ICDEV2=0	ICDEV2=0	ICDEV2=2.356 $_{180^o}$



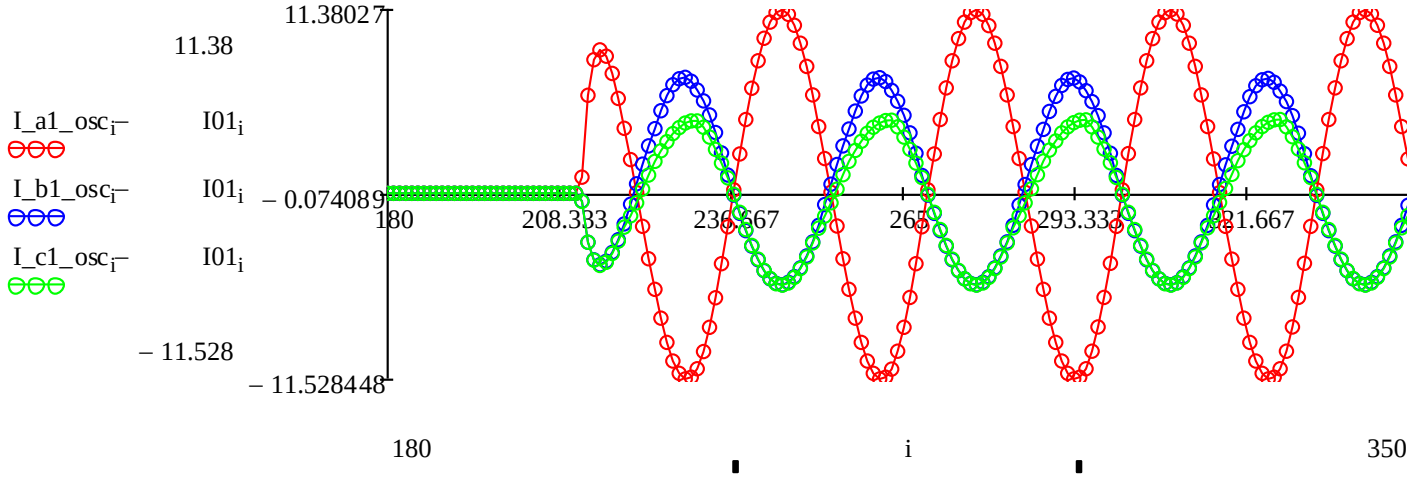
Zero-Sequence Filter with Inrush

- Cross-blocking logic increases the security during inrush
- What about the dependability?
- "2 out of 3" logic is very dependable with zero-sequence filter method 1 and 2

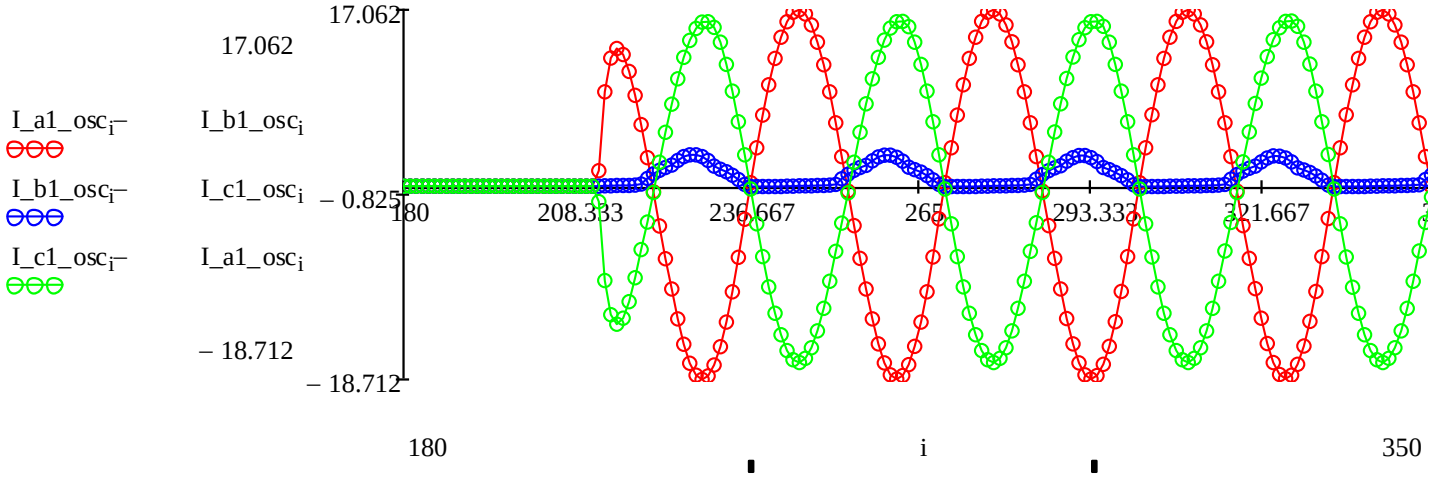


Zero-Sequence Filter with Inrush

ZERO-SEQUENCE FILTER WITH PHASE CURRENTS (METHOD 1)

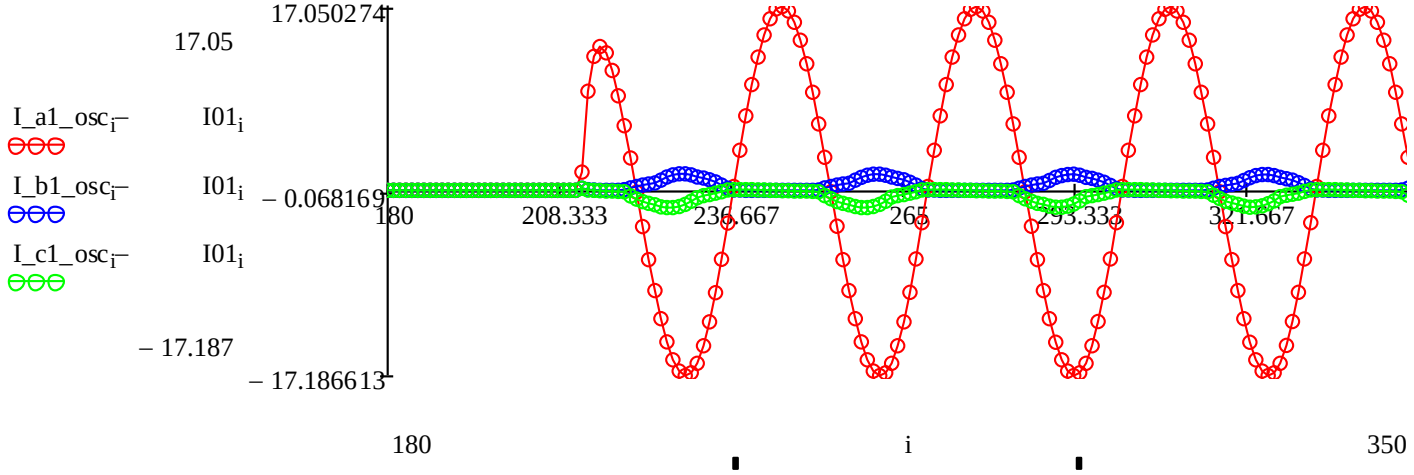


ZERO-SEQUENCE FILTER WITH PHASE CURRENTS (METHOD 2)



Zero-Sequence Filter with Inrush

ZERO-SEQUENCE FILTER WITH GROUND CURRENT (METHOD 3)



Method 3 will activate the "2 out of 3" cross-blocking logic

Directional Comparison

INTERNAL FAULT

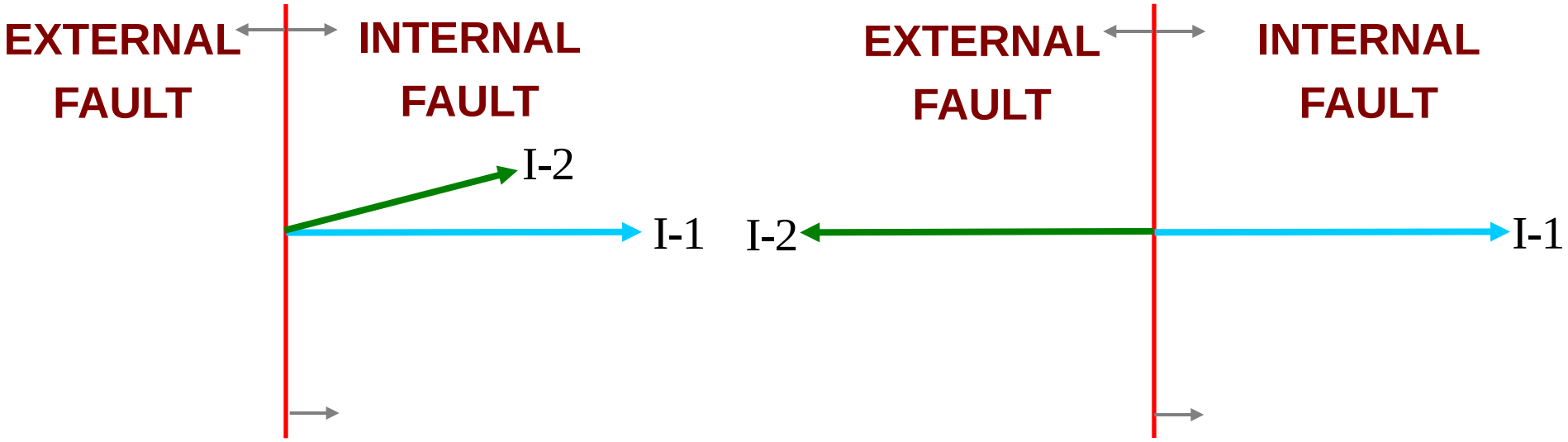
Currents "in phase"

$|\arg(I2)-\arg(I1)| < 90^{o}$

EXTERNAL FAULT

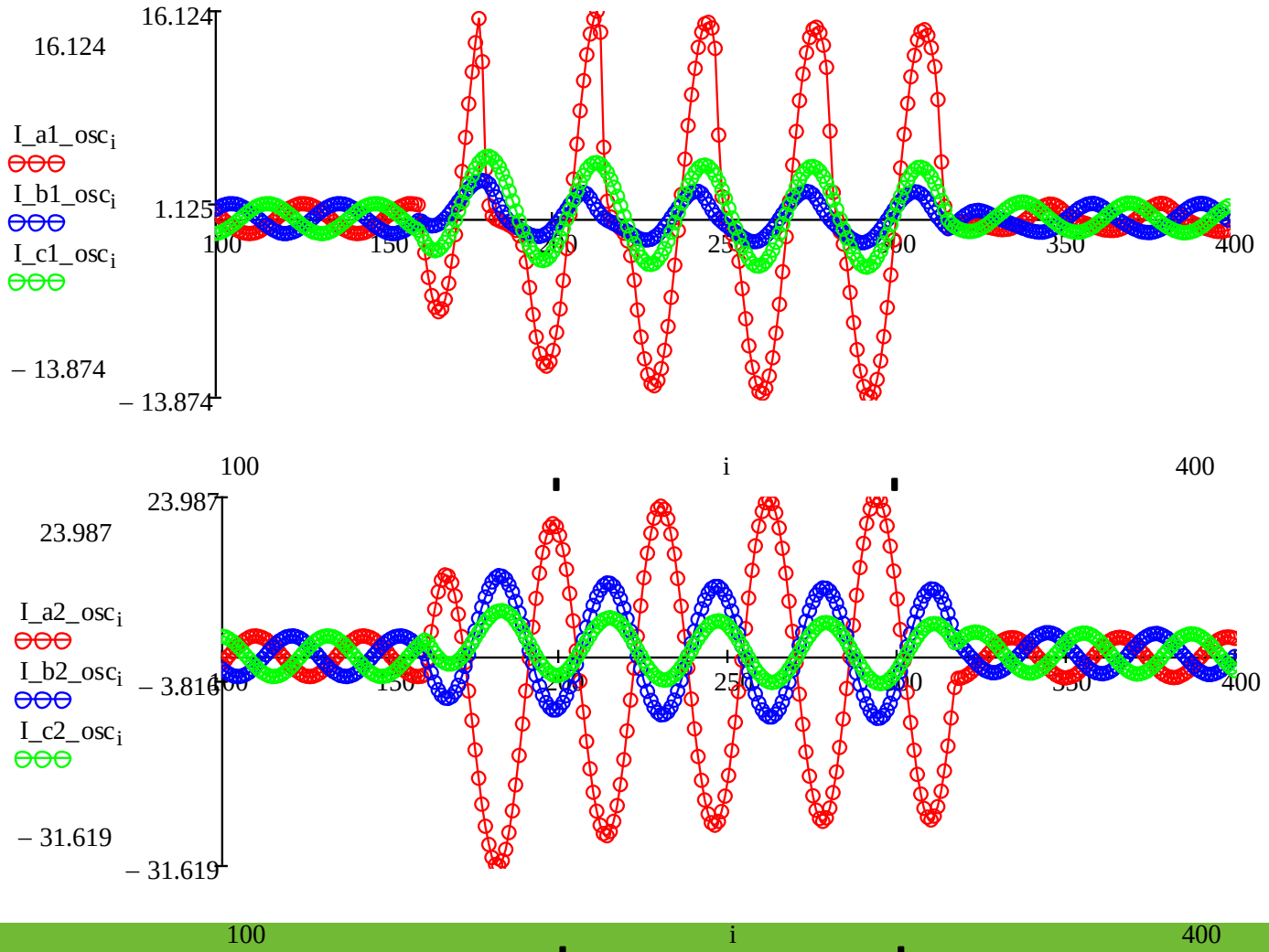
Currents "out of phase"

$|\arg(I2)-\arg(I1)| > 90^{o}$



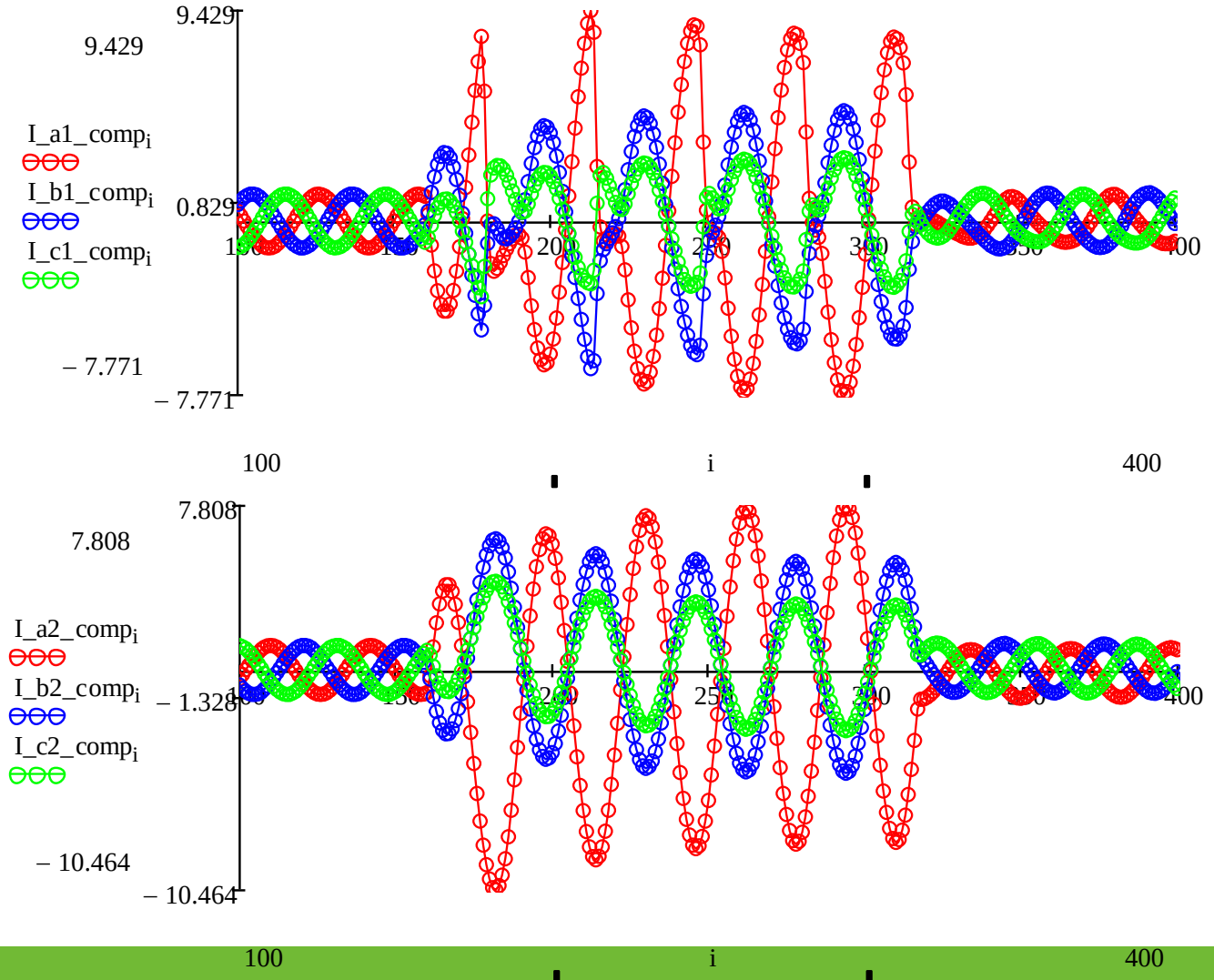
Directional Comparison

EXTERNAL FAULT WITH AG SATURATION

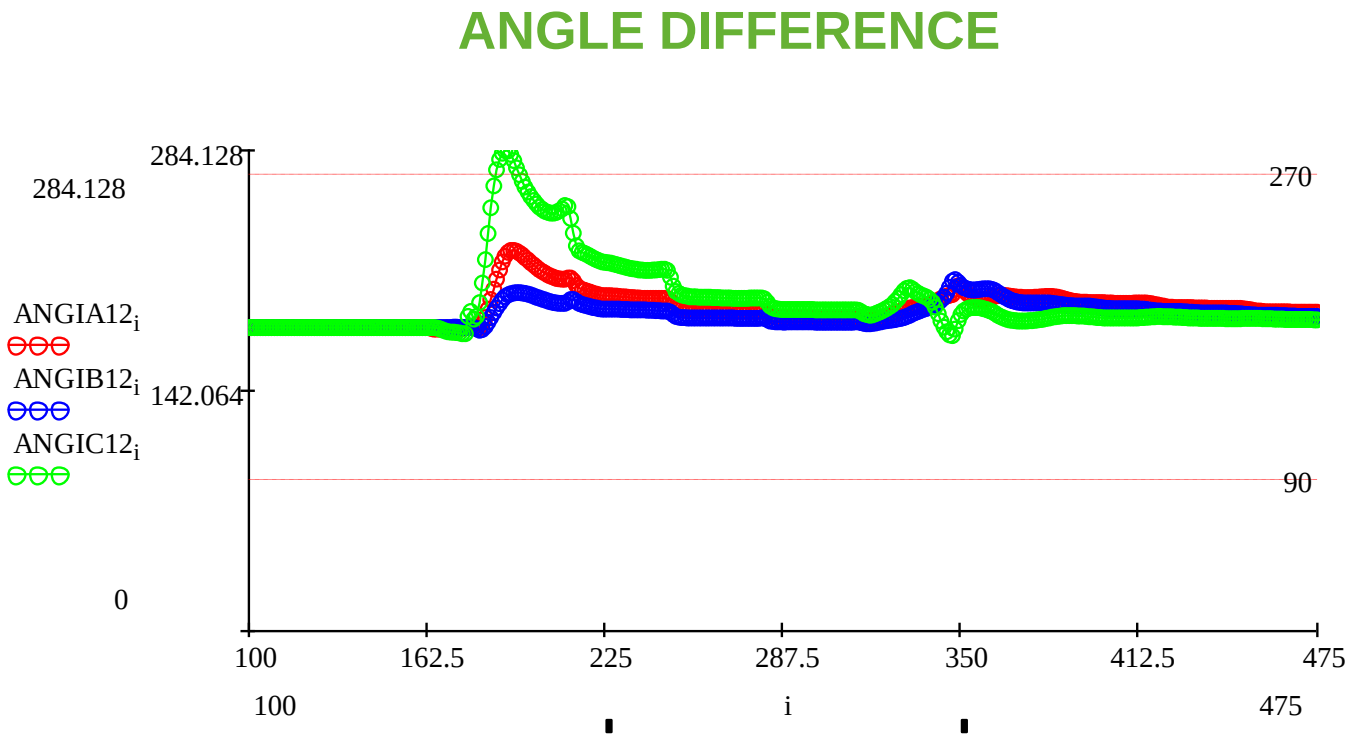


Directional Comparison

CURRENTS WITH ZERO-SEQUENCE FILTER

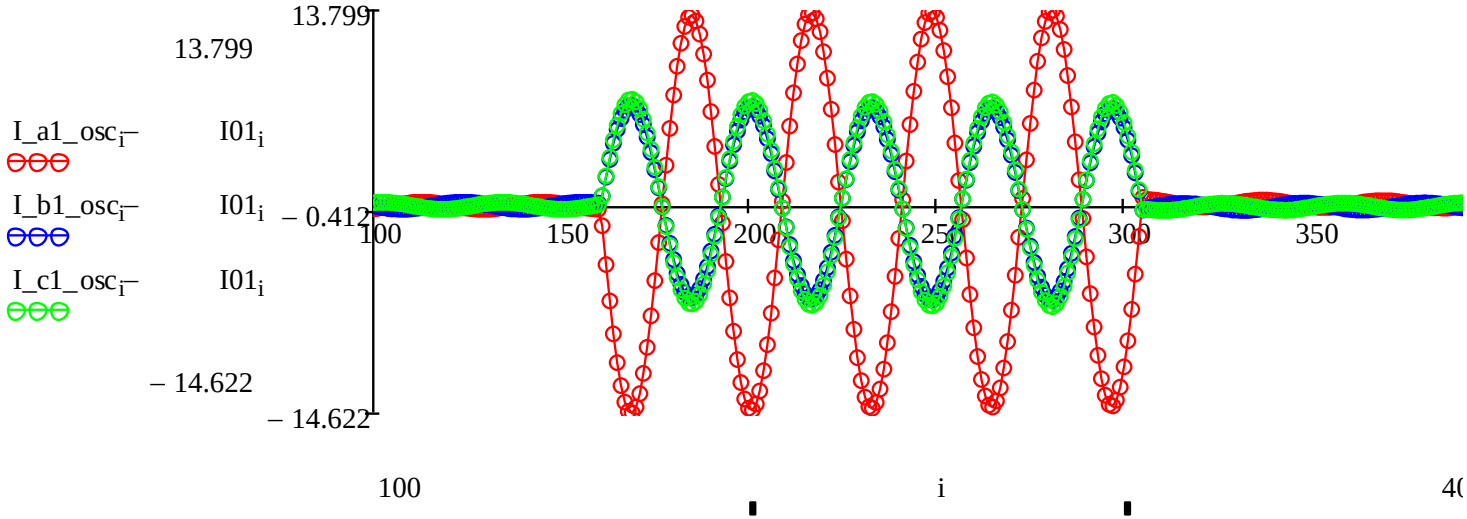


Directional Comparison

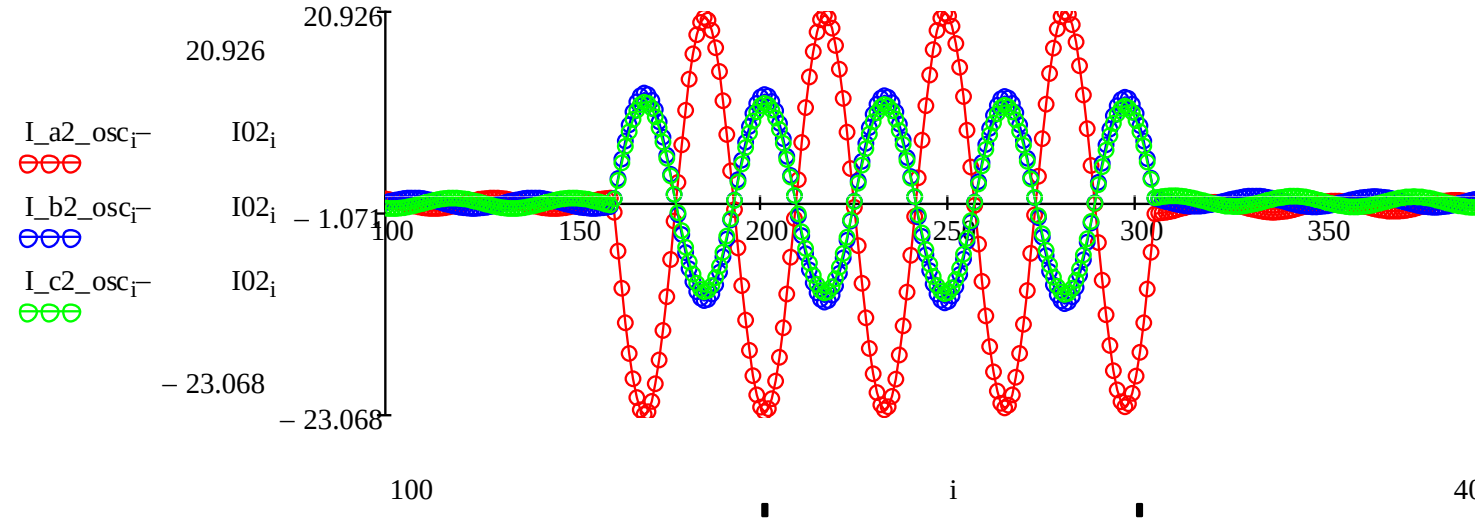


- Use of "2 out of 3" logic for method 1 and 2 improves the security

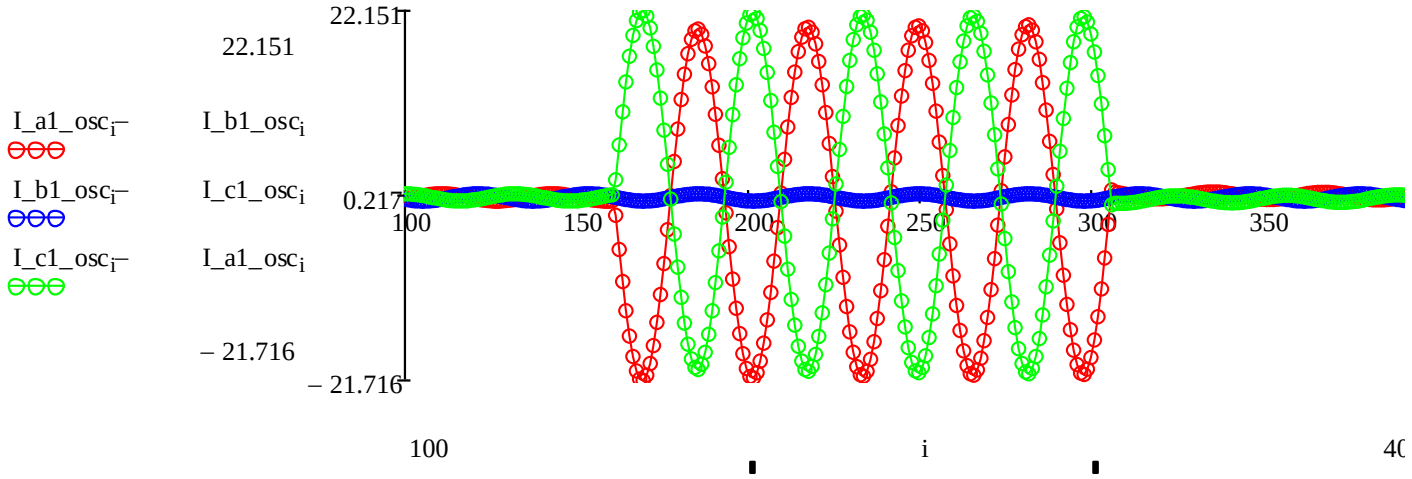
Internal AG fault with zero-seq. filter 1



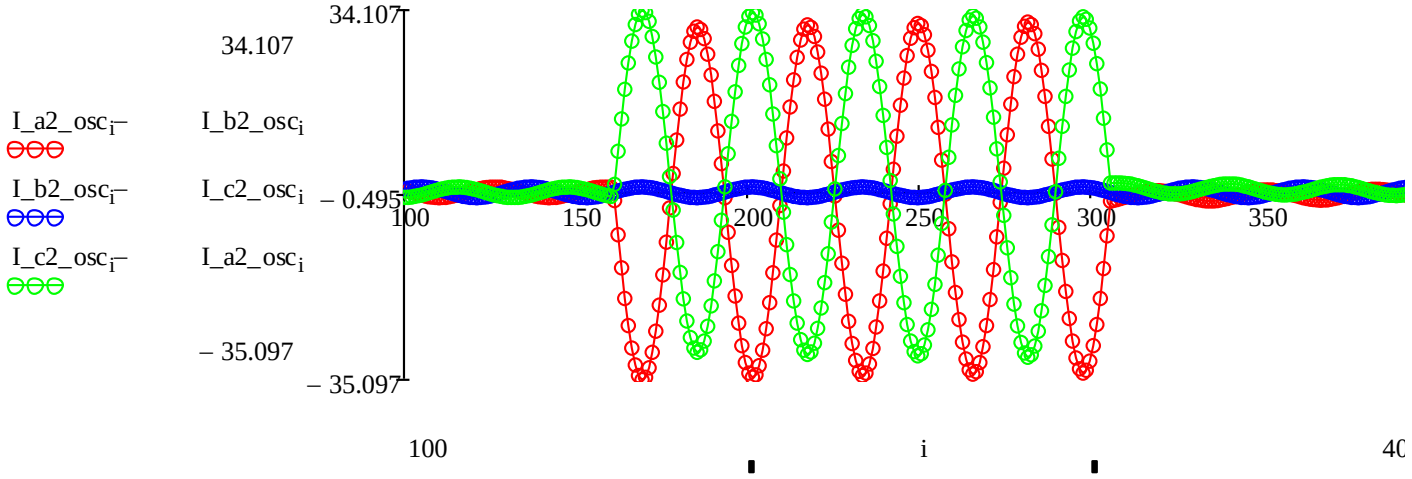
"2 out of 3" logic in directional comparison not fulfilled



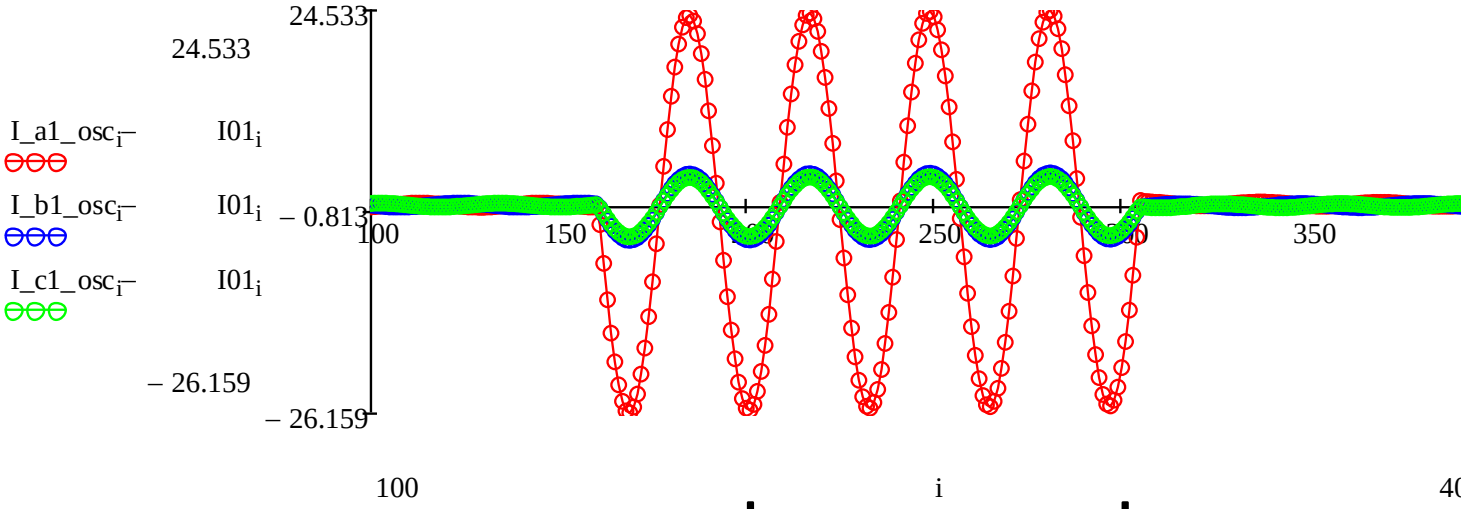
Internal AG fault with zero-seq. filter 2



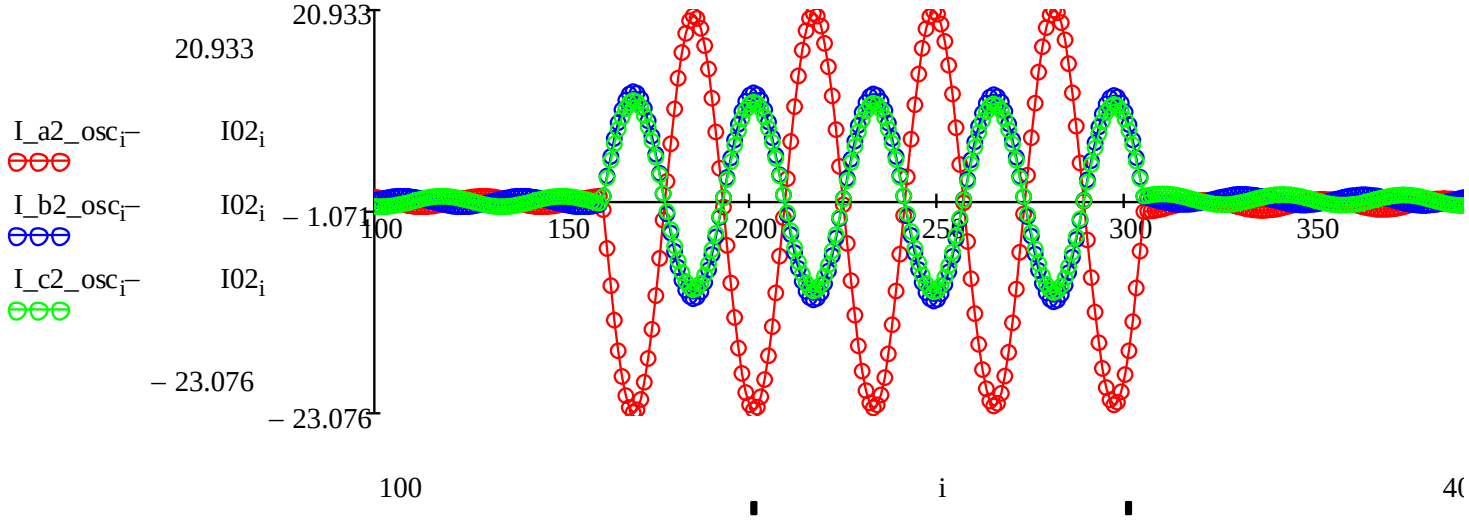
"2 out of 3" logic in directional comparison not fulfilled



Internal AG fault with zero-seq. filter 3



"2 out of 3" logic in directional comparison fulfilled



Conclusions

- Not only YND transformers require the use of the zero-sequence filter but also YNY 3-legged transformers
- Zero-sequence filter applied from the **phase currents (methods 1 and 2)**:
  - Produces a loss of sensibility and an erroneous phase selection: an independent phase selector should be used
  - Allows the application of "2 out of 3" logics increasing the security both for directional comparison and harmonic blocking

Conclusions

- Zero-sequence filter applied from the **ground current (method 3)**:
  - Provides good sensibility and phase selection
  - Does not allow the use of "2 out of 3" logics decreasing the security both for directional comparison and harmonic blocking

Thank you

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