Line Current Differential Protection in Systems With Inverter-Based Resources – Challenges and Solutions

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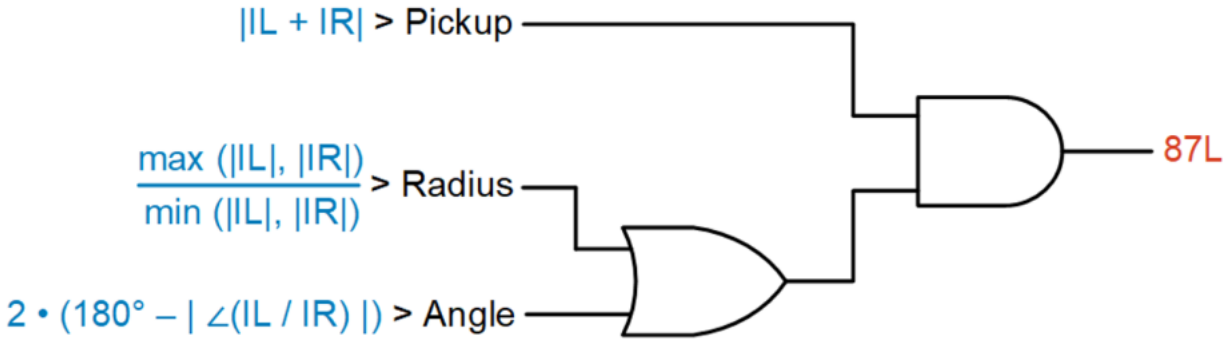
Outline

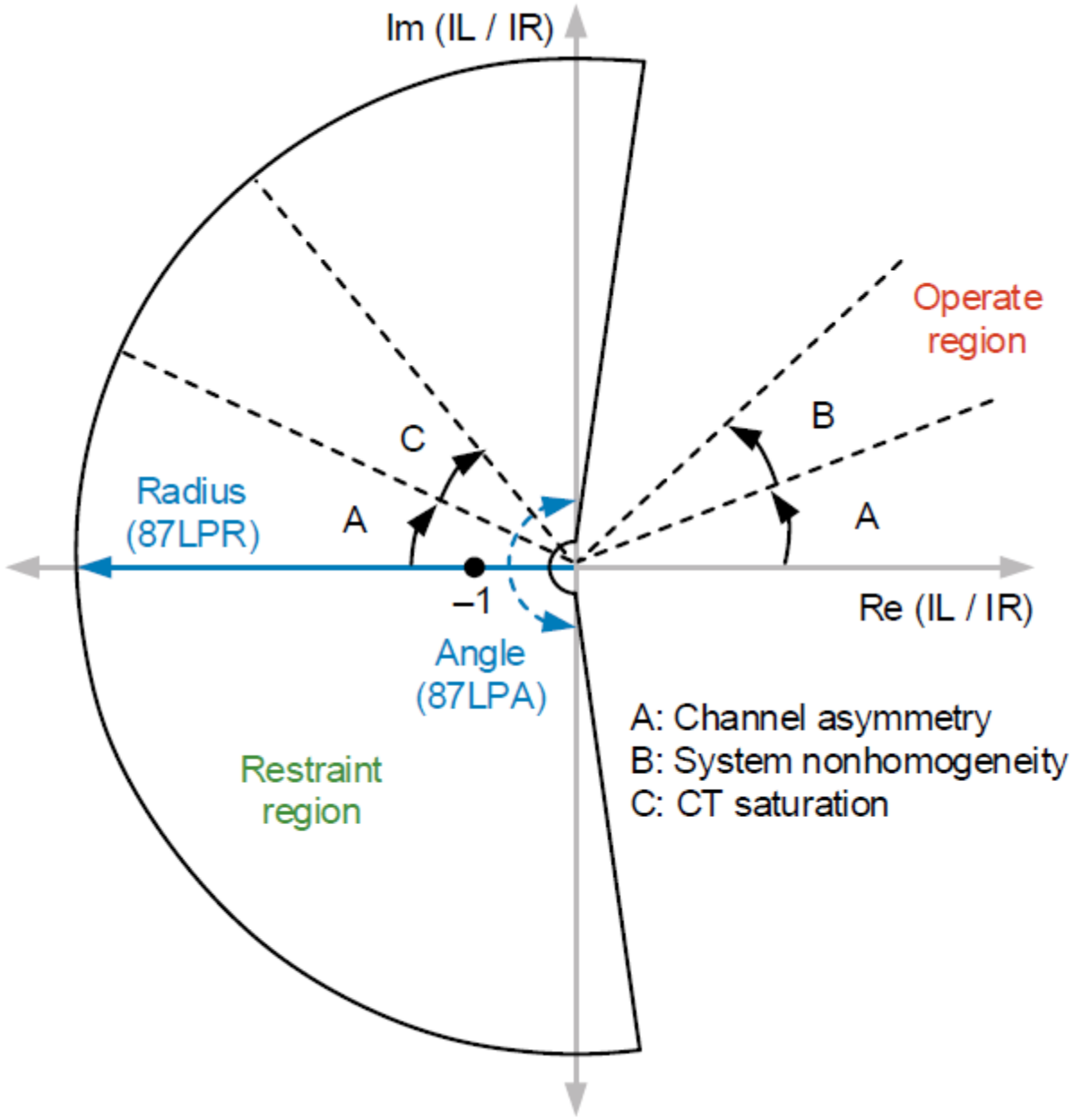
- Element overview
- Challenges
- Solutions
- Application considerations
- Conclusion

87L requirements

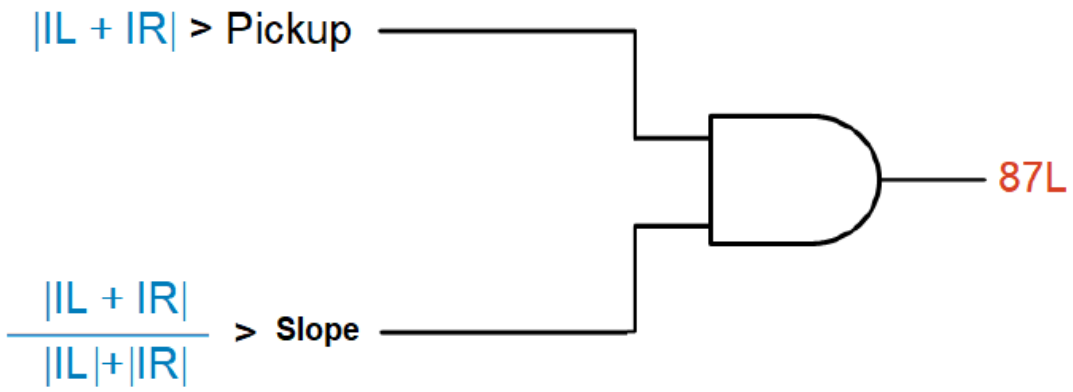
Source of error	Security	Dependability
Channel asymmetry	Major	Moderate
CT saturation (during transients)	Major (can misoperate)	Minor (can delay tripping)
Line-charging current	Minor with compensation, otherwise can be moderate	Minor
Steady-state CT and relay errors	Minor	Minor
System nonhomogeneity	No effect	Moderate

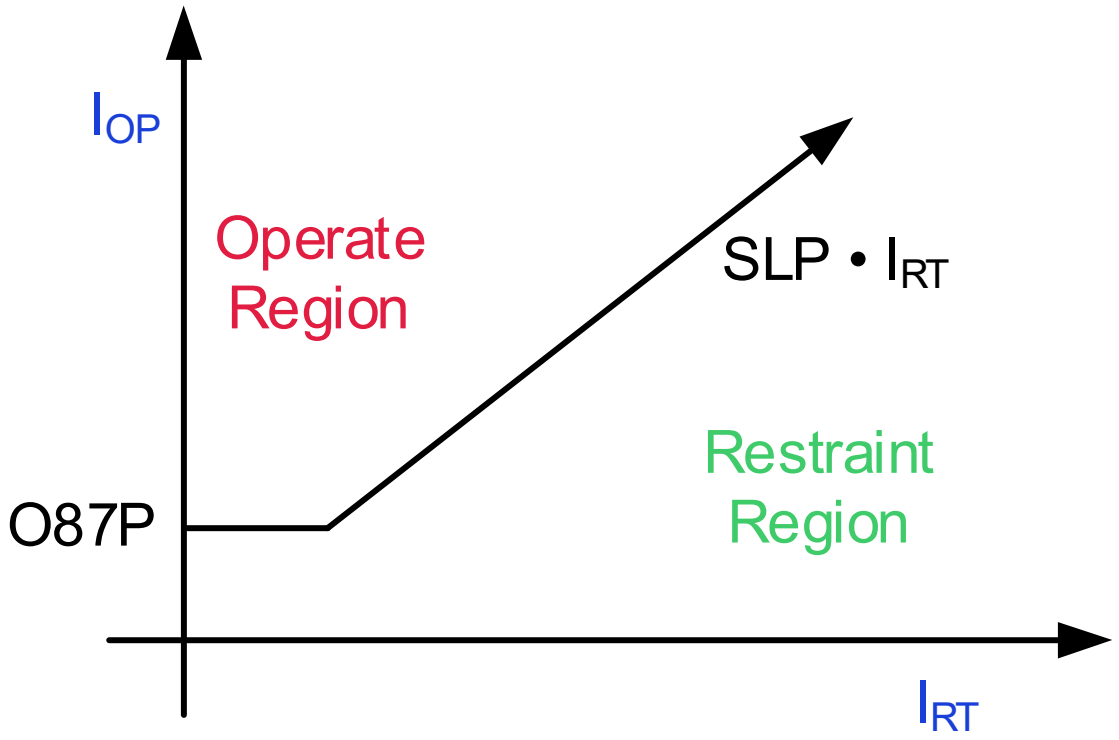
Alpha plane (87AP)



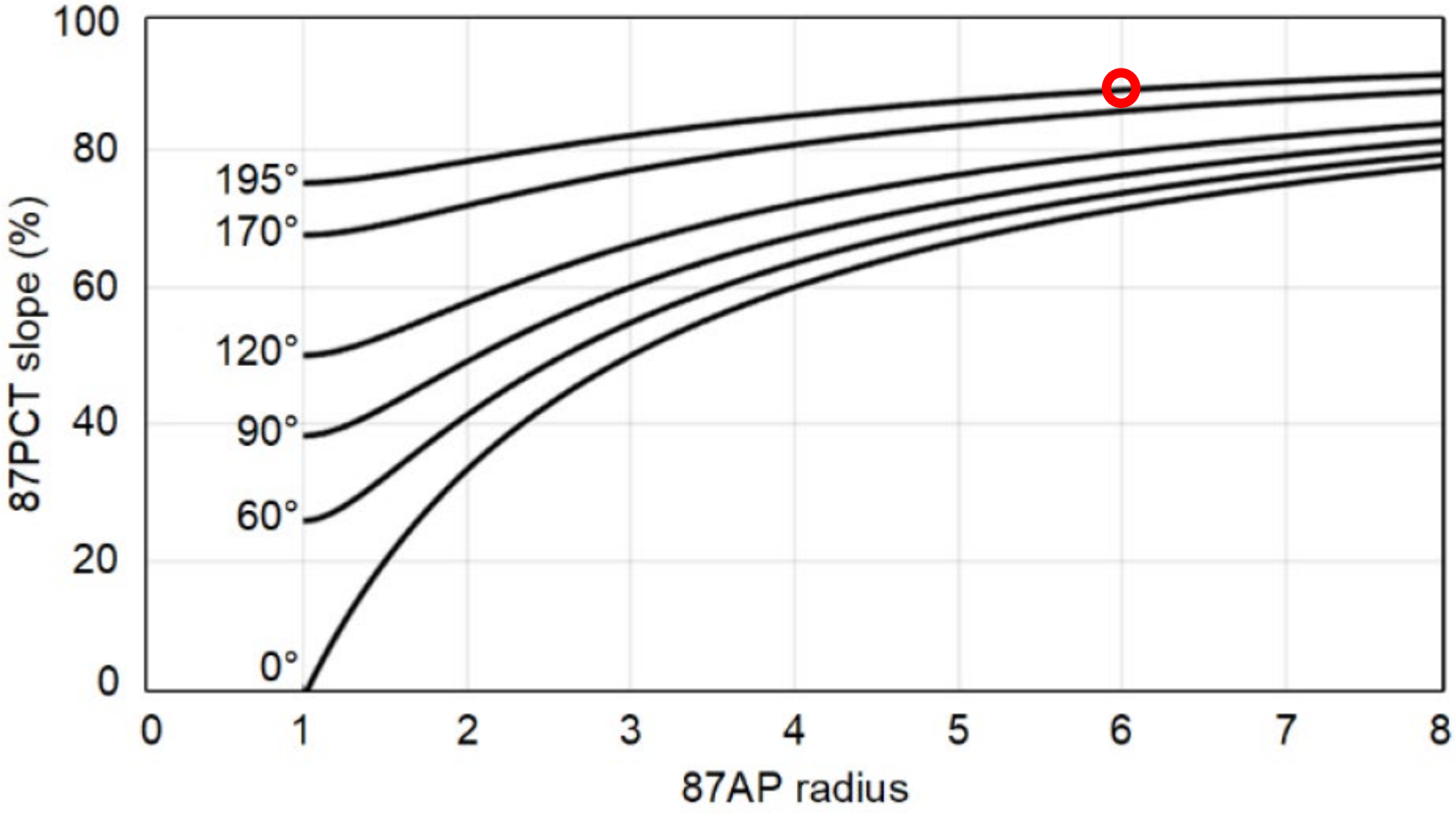


Percentage-restrained (87PCT)

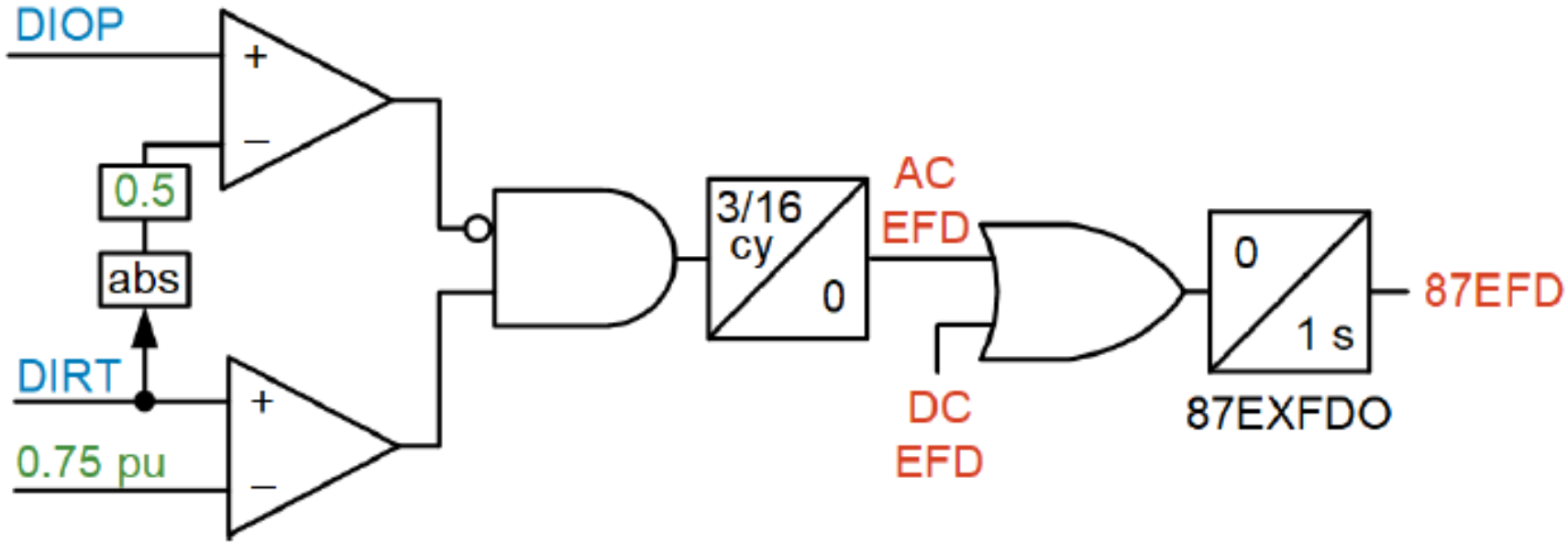




87AP → 87PCT settings conversion



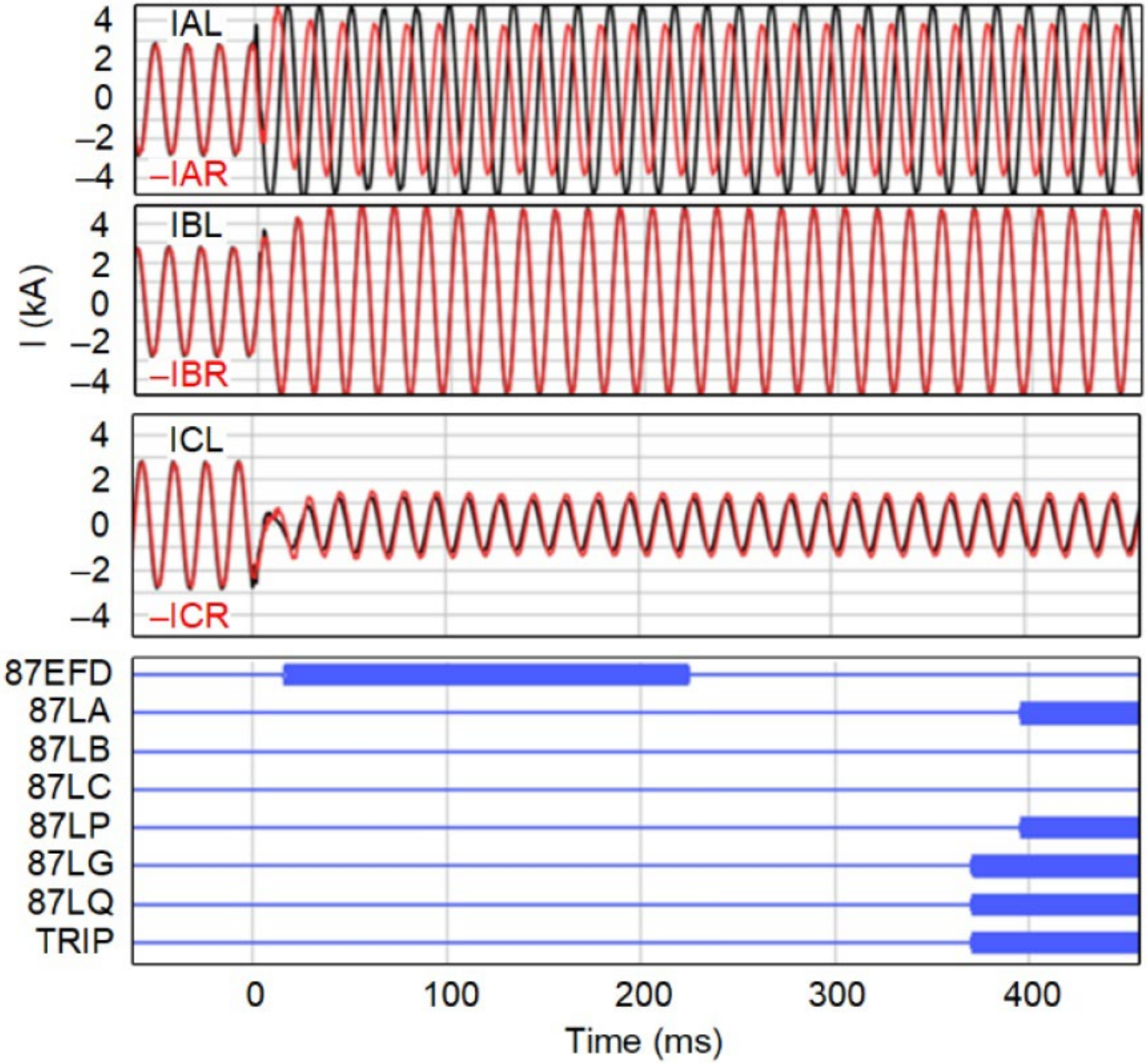
External fault detector



Challenges

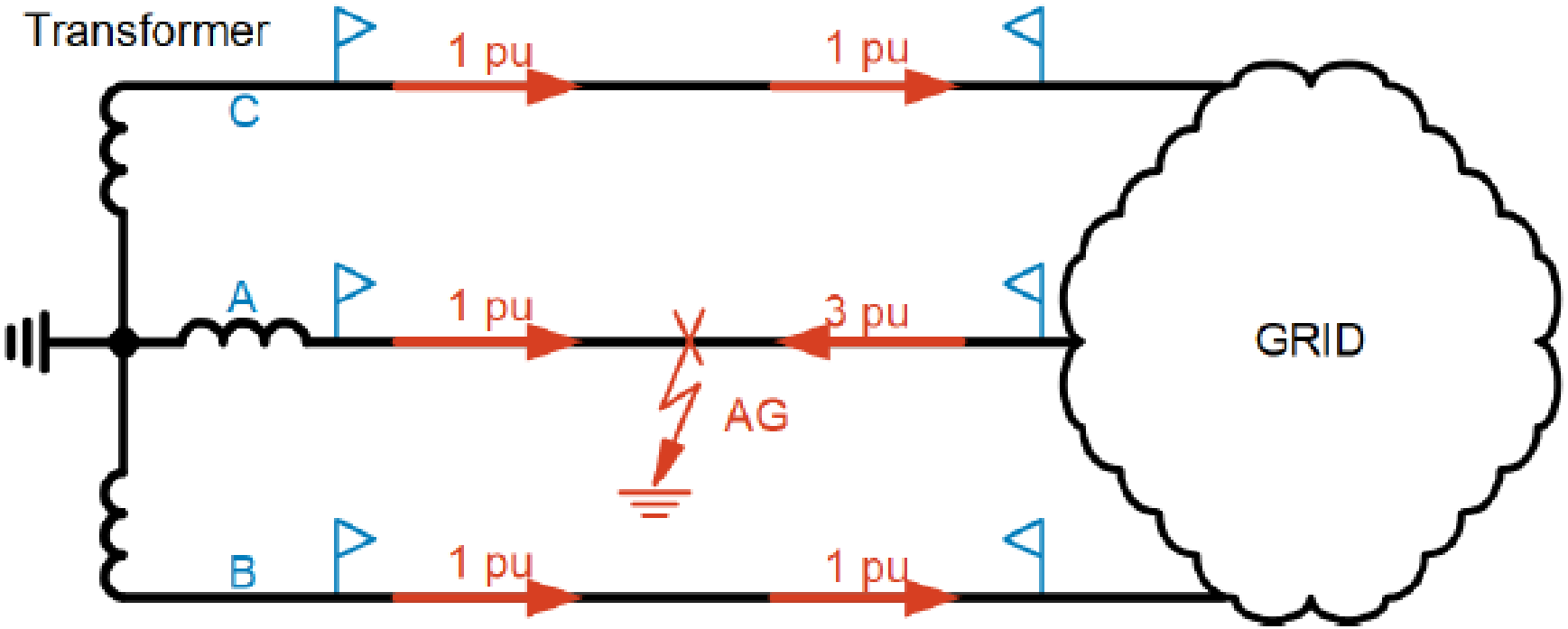
Internal AG fault

15-ohm

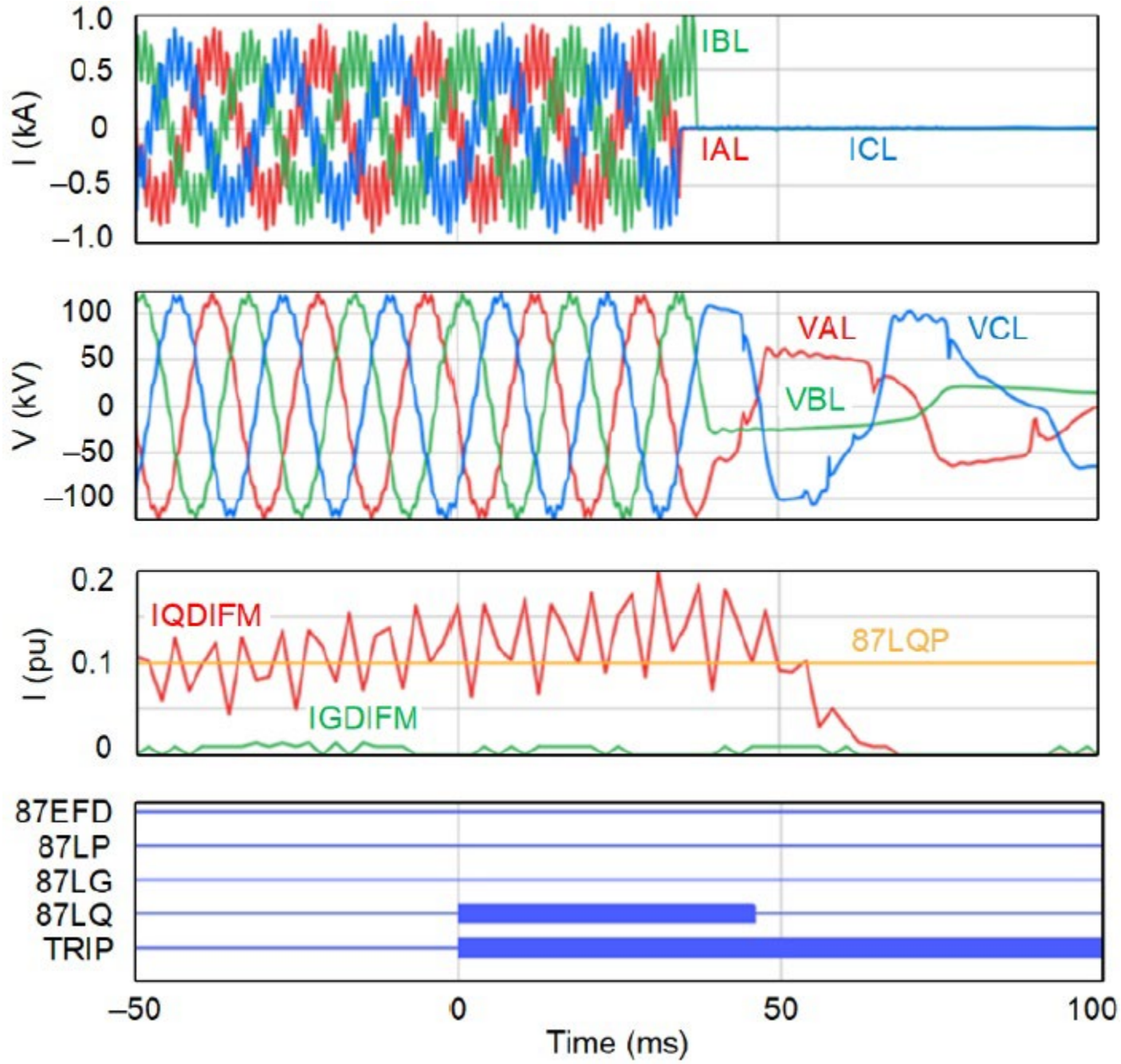


IBR fault response

Strong zero-sequence, but weak otherwise



No fault
Harmonics



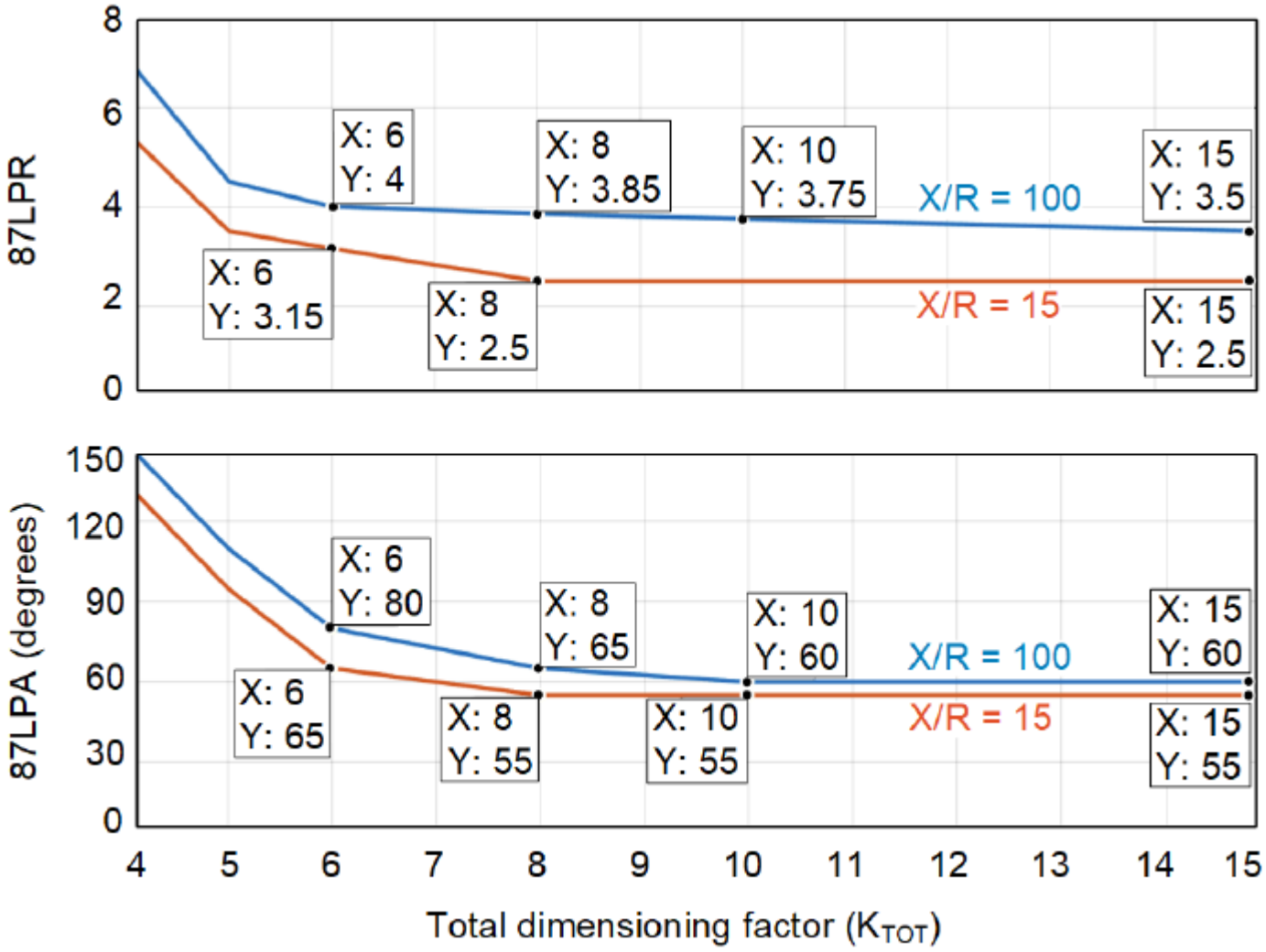
Solutions

Settings considering CT dimensions

Improved sensitivity and dependability

$$K_{TOT} = \frac{V_{SAT}}{I_F \bullet (R_{CT} + R_B)}$$

V_{SAT} = saturation voltage of CT
K_{TOT} = total dimensioning factor
I_F = fault current (amperes, sec)
R_{CT} = CT winding resistance
R_B = burden resistance



87LQ element security

$$87LQP_{SENS} = 1.25 \bullet \frac{S_{IBR}}{\sqrt{3} \bullet V_{HV} \bullet (CTR \bullet I_{NOM})} \text{ pu}$$

$$87LQP_{SECURE} = 1.30 \bullet 87LQP_{SENS} \text{ pu}$$

Improved settings guidelines

Sensitive 87L Settings Guidelines

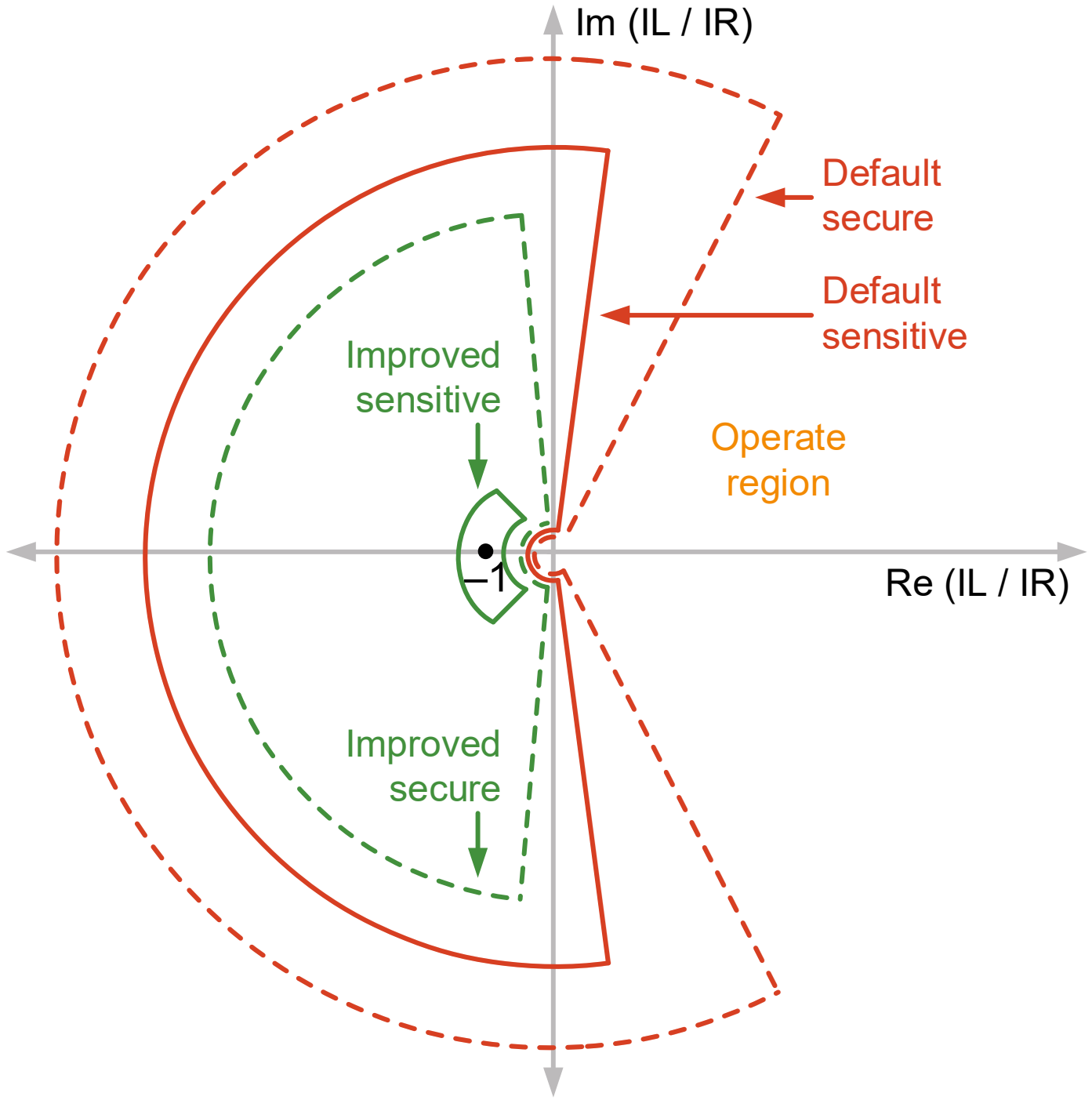
Setting	87LP	87LG	87LQ
Pickup	0.30 pu	0.20 pu	1.25 pu[C]
Radius	1.35	1.35	1.35
Angle	90 degrees[A]	90 degrees[A]	90 degrees[A]

Secure 87L Settings Guidelines

Setting	87LP	87LG	87LG
Pickup	0.75 pu	0.30 pu	1.63 pu[C]
Radius	5.00[B]	5.00[B]	5.00[B]
Angle	170 degrees[A,B]	170 degrees[A,B]	170 degrees[A,B]

[A] Adjust based on worst-case channel asymmetry
[B] Adjust based on CT sizing guidelines
[C] Adjust based on IBR rating and system parameters

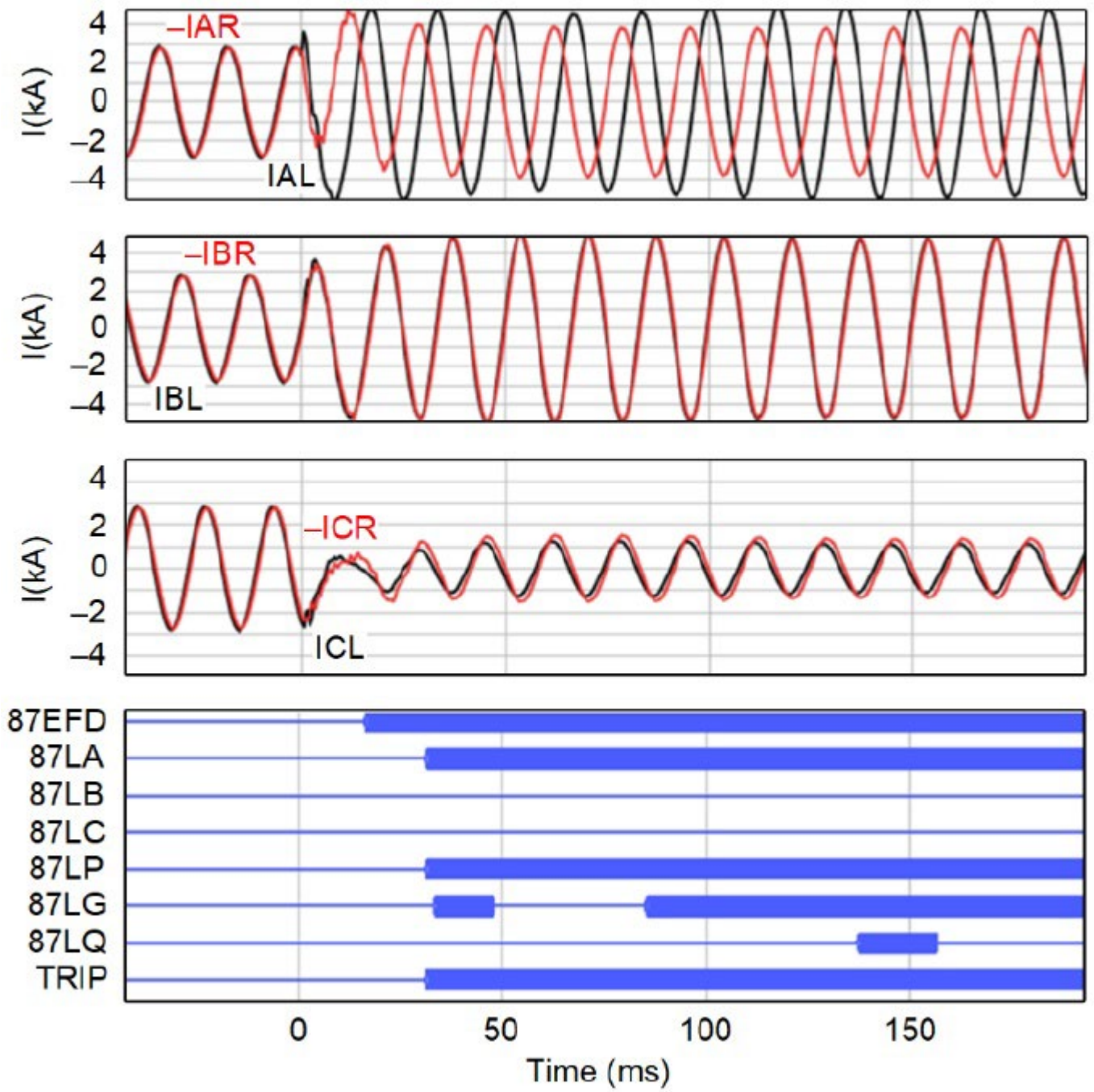
Improved settings guidelines



Solutions evaluation

Internal AG fault

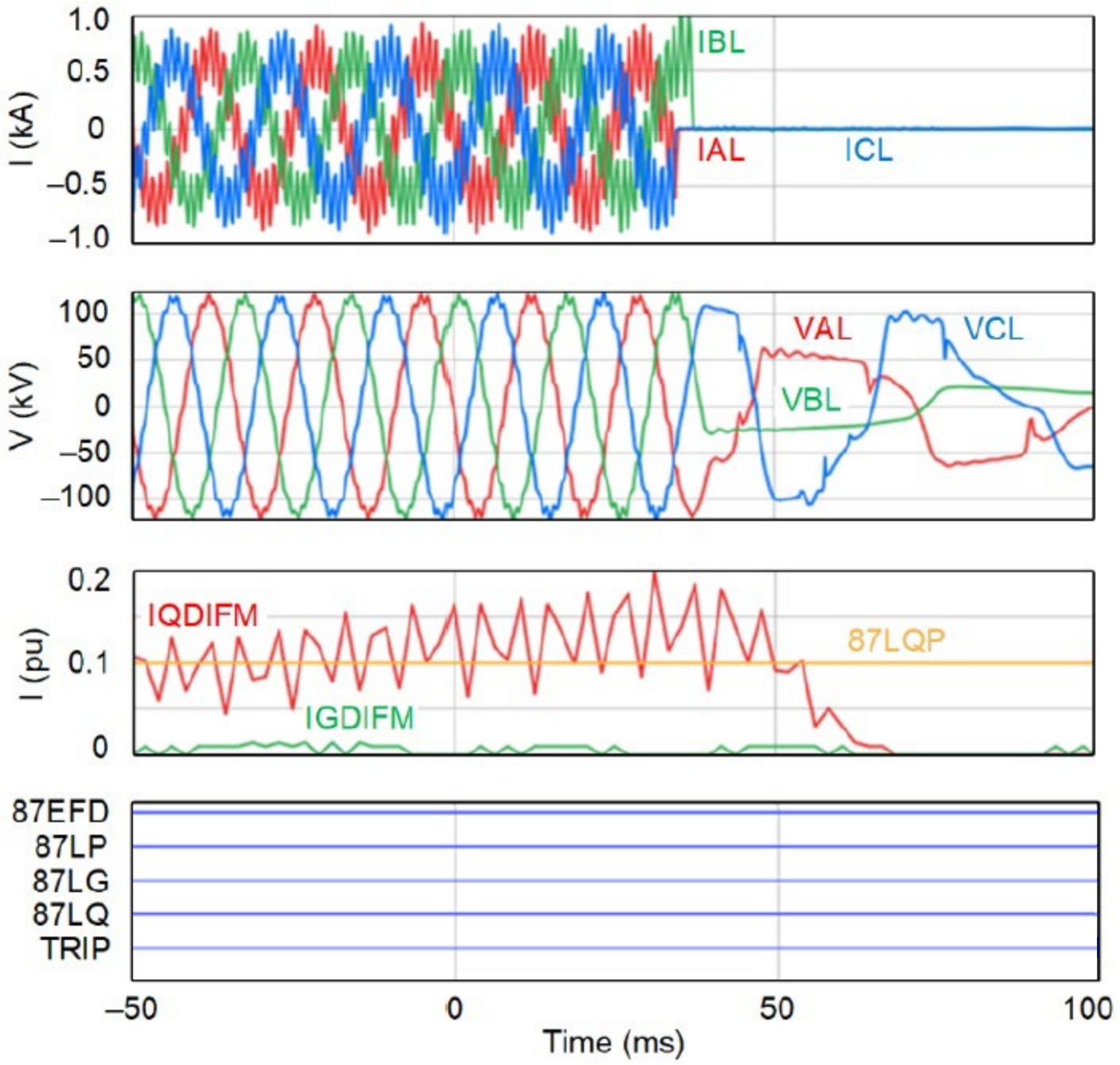
Improved settings



No fault

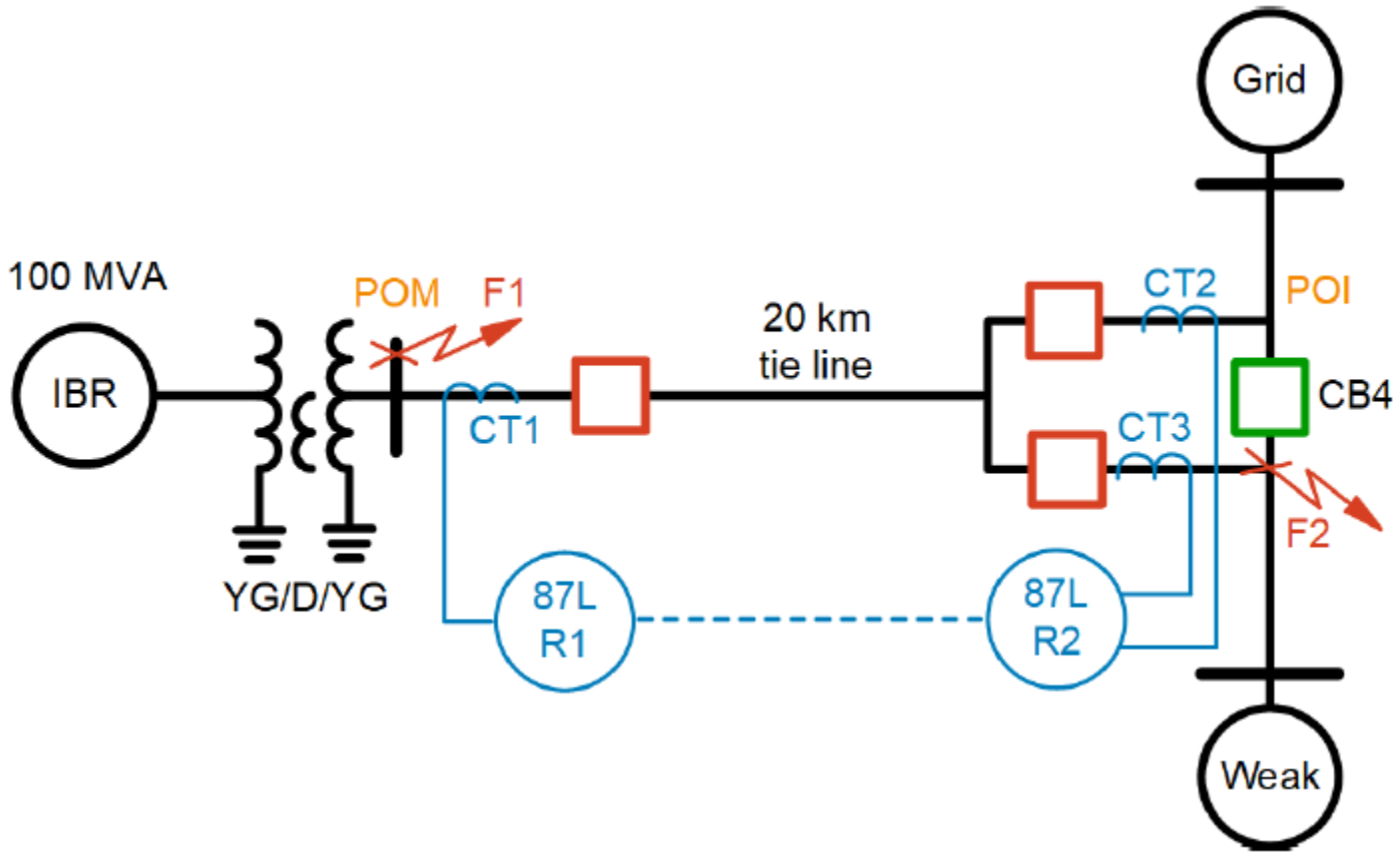
Improved settings

- $87LQP_{SENS}$ = 0.48 pu
- $87LQP_{SECURE}$ = 0.63 pu



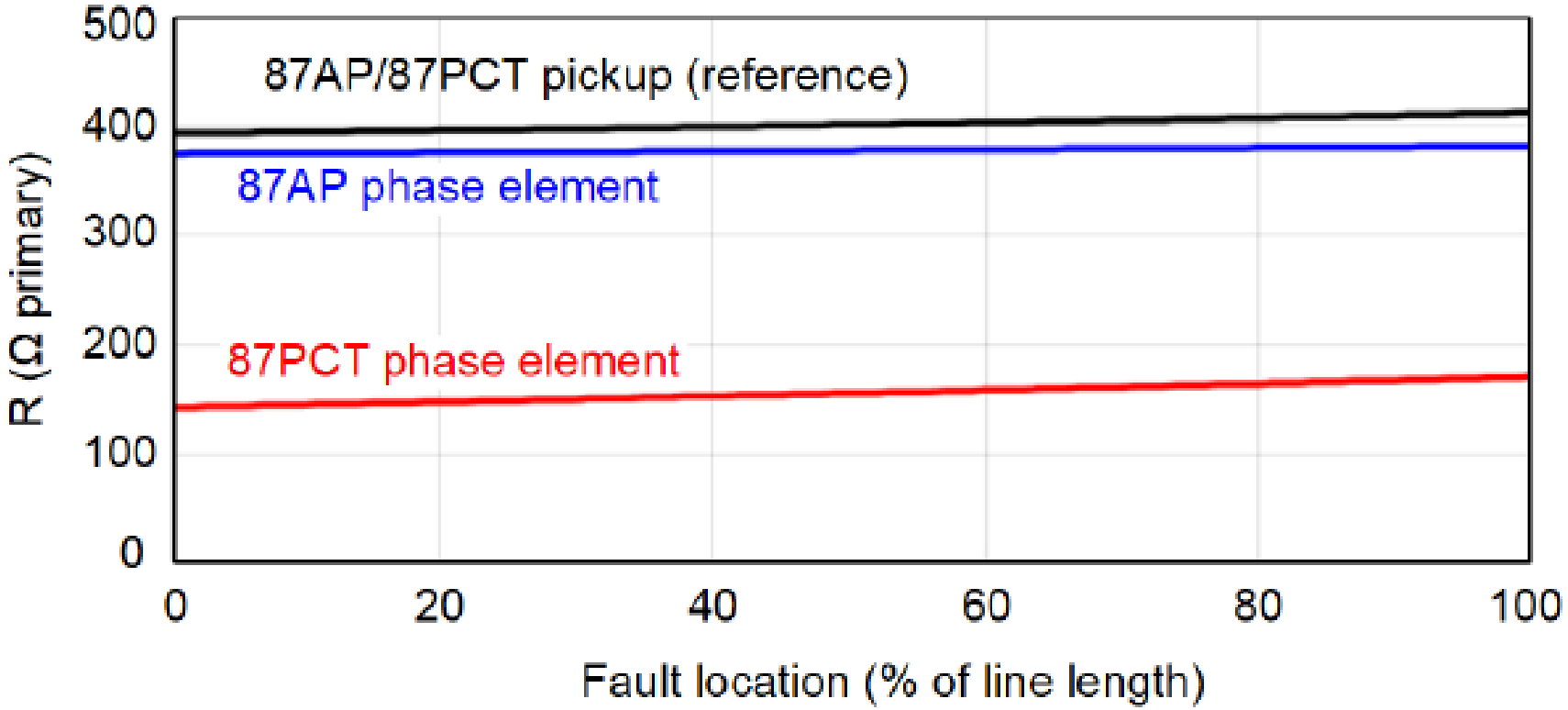
Example IBR system

Tie-line connecting to three-ring breaker bus



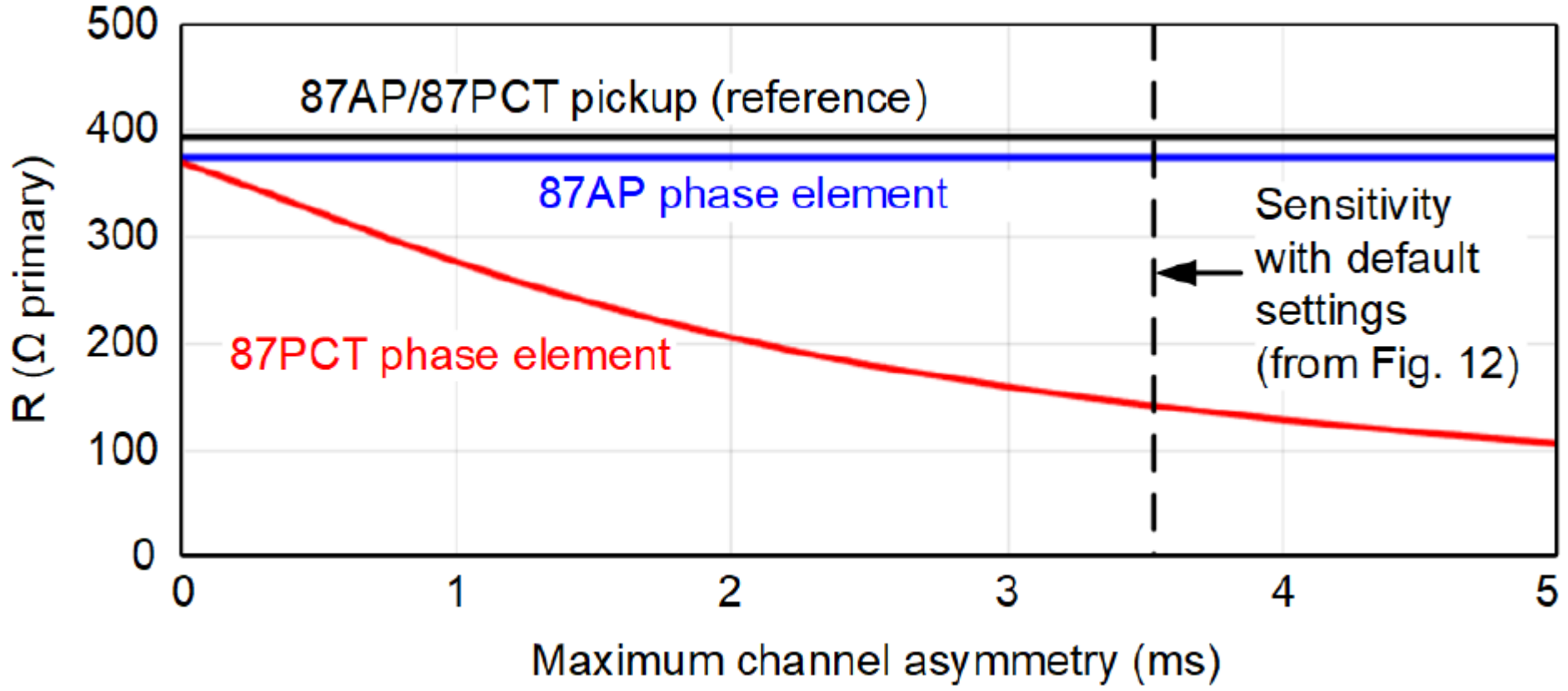
87AP vs. 87PCT sensitivity

Considering maximum 3.5 ms asymmetry



87AP vs. 87PCT sensitivity

Depends on maximum channel asymmetry



New and general settings guidelines

- IBR applications, including with high penetration
- Series-compensated lines, including with current inversion
- Single-phase tripping applications
- Evolving external-to-internal faults
- Increases sensitivity, without a loss of security, for all applications!

Conclusion

- 87L is excellent for IBR applications
- Dependability challenge for internal ground faults
- Security challenge to 87LQ because of harmonics
- New settings improve dependability and security
- Strong new default settings guidelines
- Solutions can be extended to all applications

Questions?