Coordinating Dissimilar Line Relays in a Communications-Assisted Scheme

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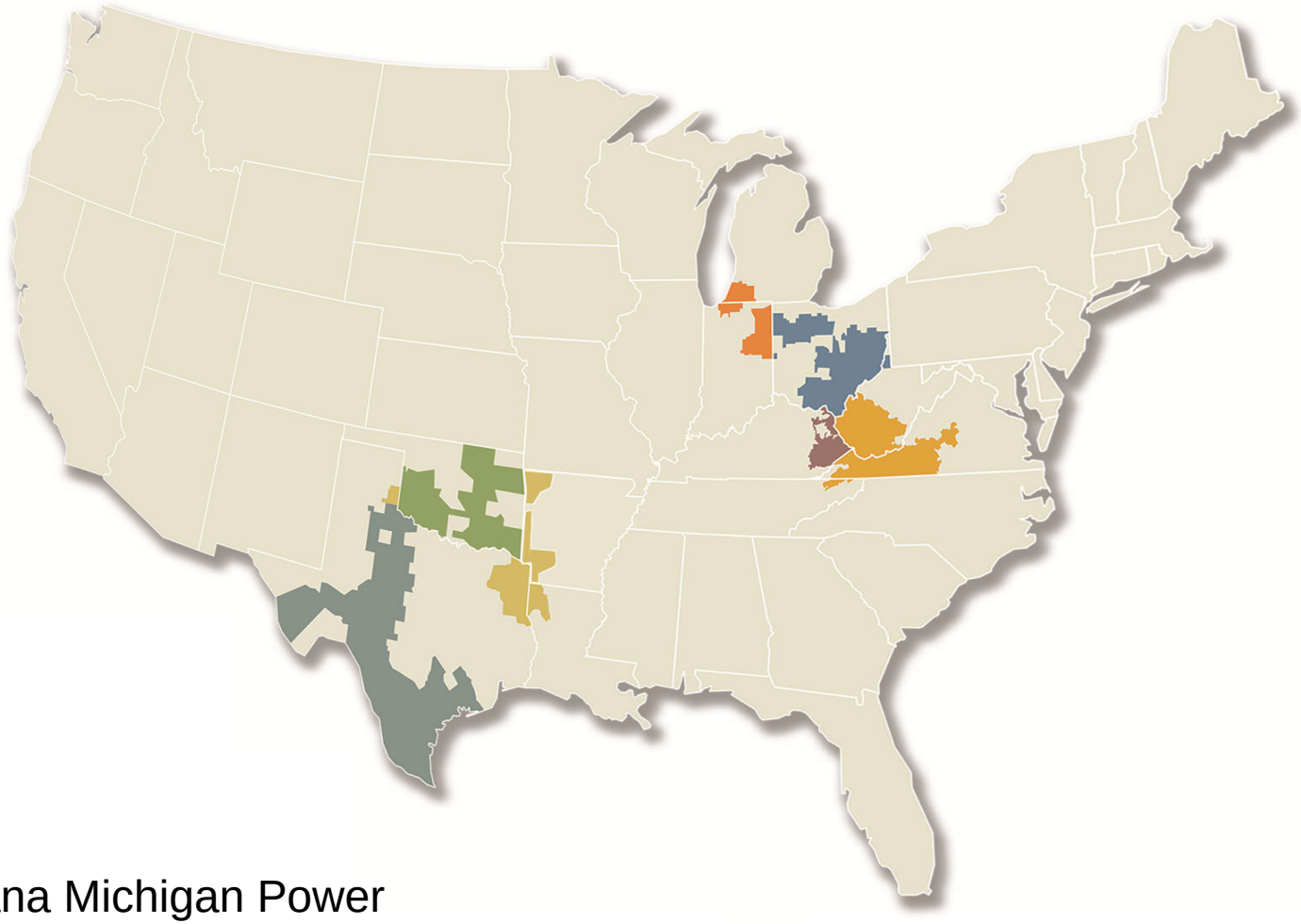
Outline

- Introduction to AEP
- Comparison of pilot schemes
- Ground element sensitivity
- Response of elements
- Case studies
- Recommendations

Introduction to AEP System



- Indiana Michigan Power
- Kentucky Power
- Public Service Company of Oklahoma
- Southwestern Electric Power Company
- AEP Ohio
- AEP Texas
- Appalachian Power Company

AEP Line Relay Standards

- Two microprocessor-based relays from different manufacturers
- At least one pilot scheme at 115 kV or above, two at extra-high voltage (EHV)

Most Common Communications-Assisted (Pilot) Schemes at AEP

- Directional comparison blocking (DCB)
- Permissive overreaching transfer trip (POTT)
- Line current differential

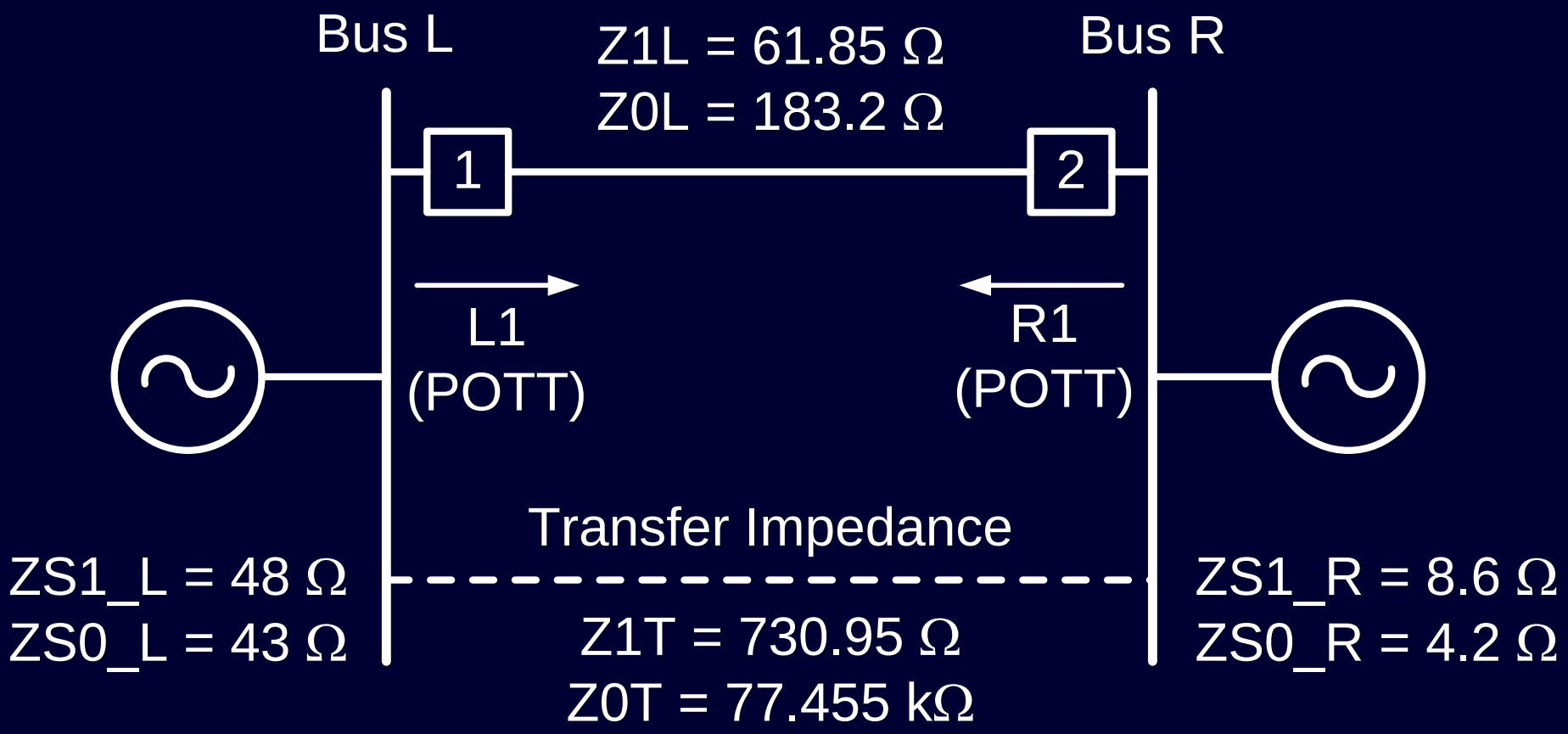
Review of Pilot Schemes

- Preference for identical line relays
- Common elements in pilot schemes
  - Mho phase distance
  - Mho ground distance
  - Directional ground overcurrent
- Dissimilar relays in pilot scheme

Comparison of Pilot Schemes

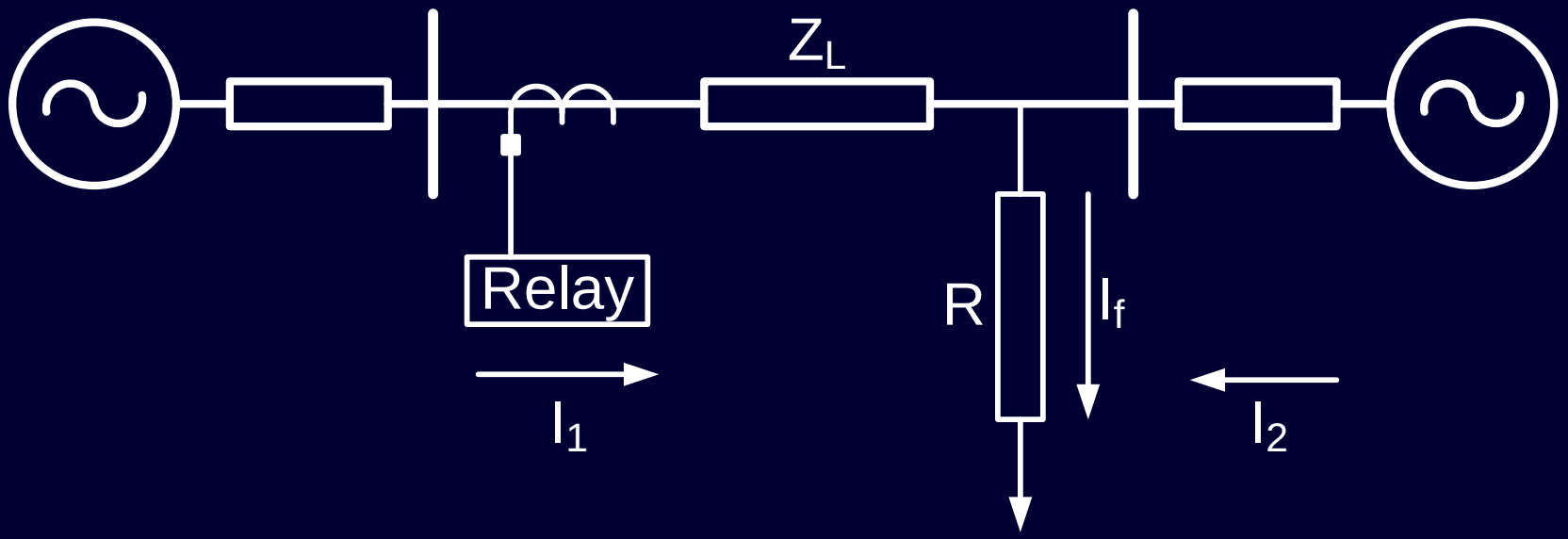
Elements / Logic	DCB	Traditional POTT	Hybrid POTT
Forward-looking pilot (tripping) elements	Yes	Yes	Yes
Reverse-looking pilot (blocking) elements	Yes	No	**Yes**
Echo logic	No	No	Yes
Current reversal logic	Yes	No	Yes
Weak infeed trip logic	No	No	Yes
Coordination necessary?	Yes	No	**Yes**

Example System



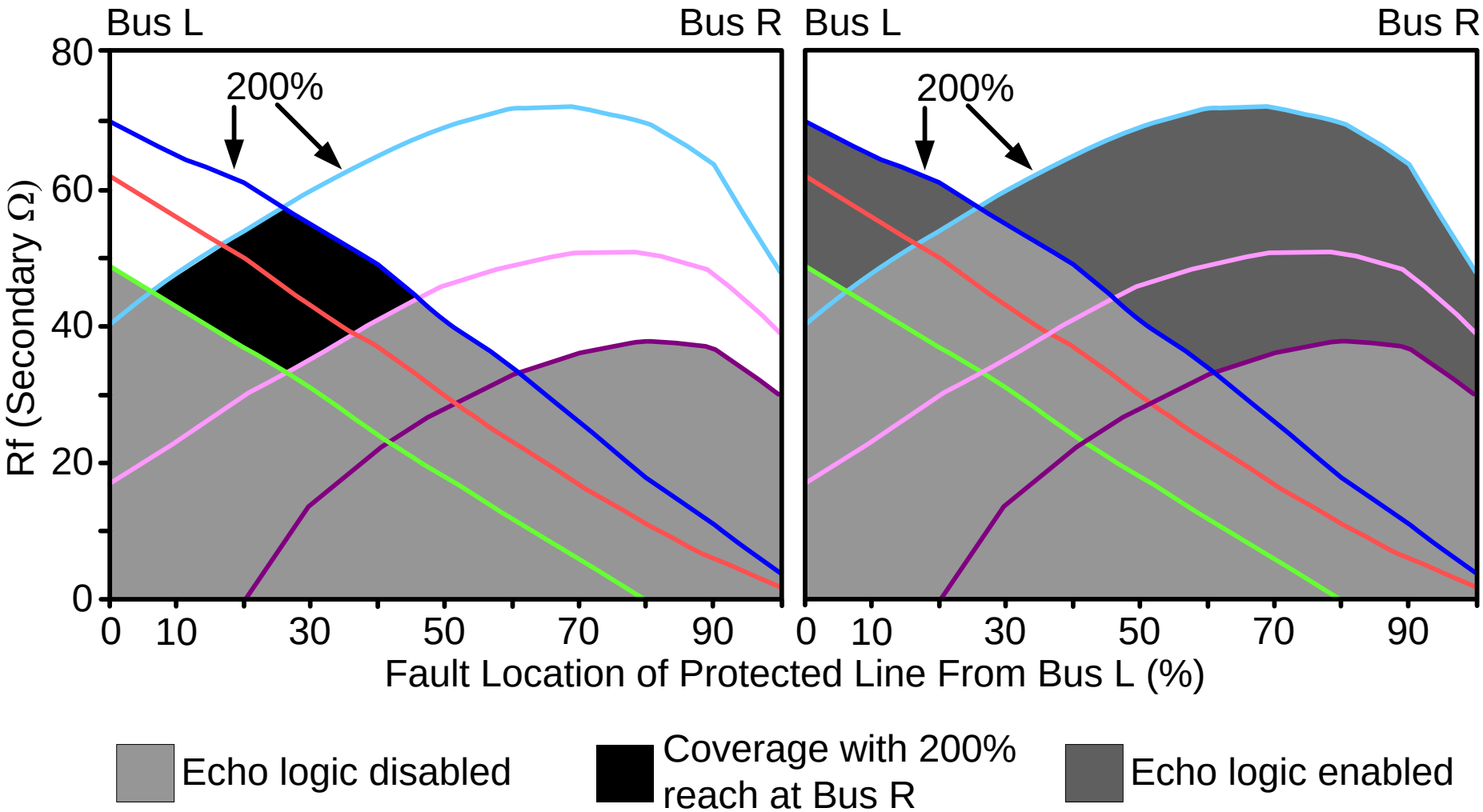
All Values Are in Primary Ohms

Effect of Remote Infeed



$$Zapp = Z_L + \frac{(I_1 + I_2) \bullet R}{I_1}$$

Fault Coverage of Ground Distance Elements



Response of Elements

- CTD – speed of response, not different sensitivities
- External versus internal faults
- Coordination
  - At maximum torque angle
  - In primary quantities
  - Fault detectors for directional elements
- Faults at the ragged edge

Element Sensitivity Concerns
Distance Elements

- Elements (mho, quad, compensator)
- Memory time constants
- Phase element supervision – phase or sequence quantities
- Ground element supervision – more options
- Limited reach – (120 to 300%) • Z_L
- Risk – acceptable if principles are similar

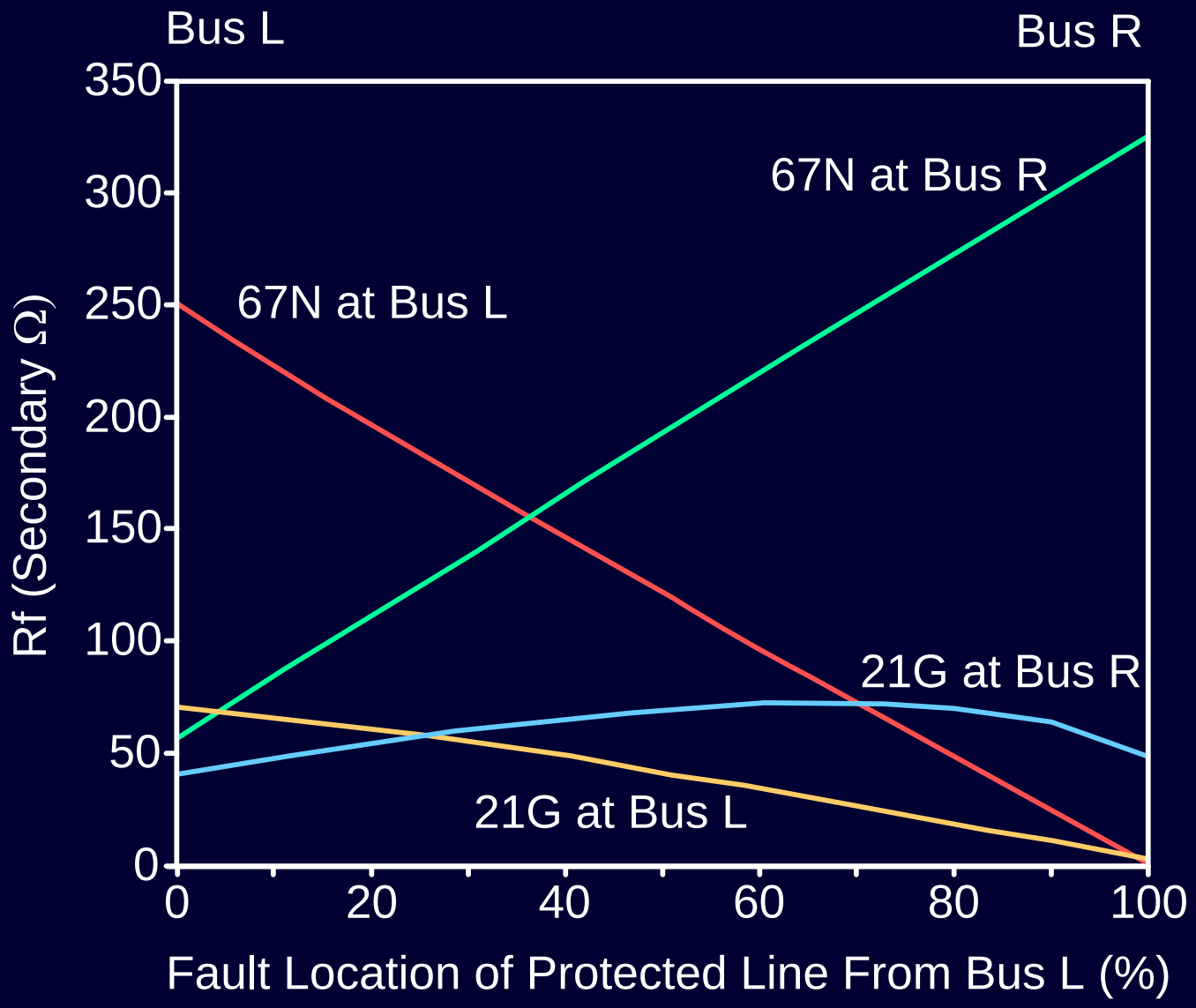
Element Sensitivity Concerns
Directional Ground OC Elements

- Very sensitive
- Greater variation in principle of operation and supervisory elements
  - 3V0, 3I0, 3V2
  - Order selection versus fixed
  - V • I versus V/I
- Risk – unacceptable

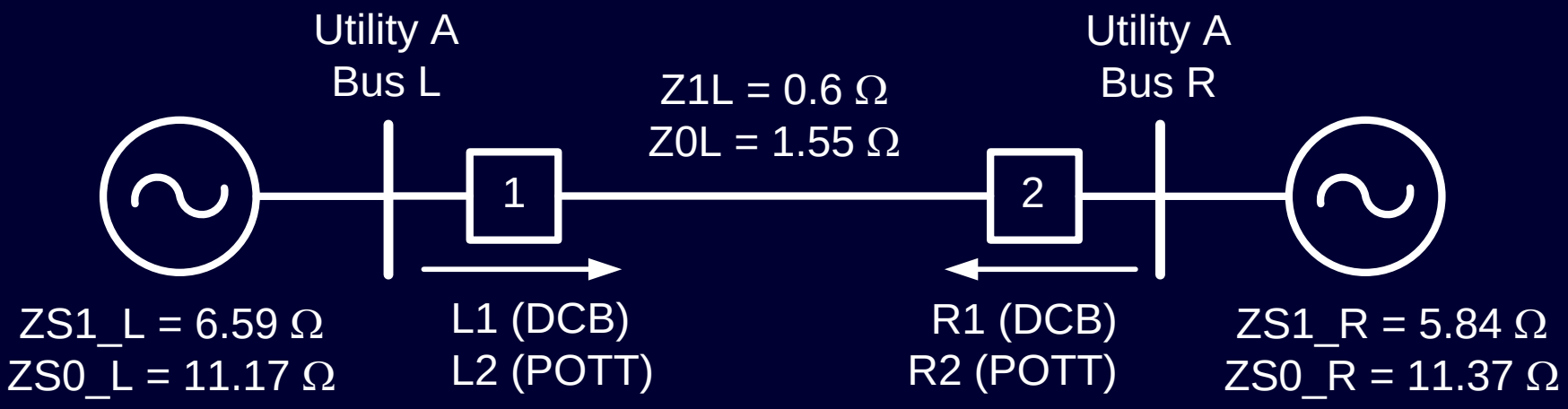
Ground Element Sensitivity

- System stability versus personnel safety
- 67 versus 21
- Factors affecting ground distance sensitivity
  - Infeed across fault resistance
  - Polarization technique
  - Expansion and source impedance
  - Reach setting

67 Versus 21 Sensitivity



Case Study 1



All Values Are in Primary Ohms

- DCB, Different manufacturers
- POTT, Same manufacturer but different vintage

Primary DCB Scheme

- L1 and R1 – V1MEM polarized phase and ground distance elements
- L1 – fixed torque directional element
- R1 – impedance (order-based) directional element

Alternate POTT Scheme

Elements / Logic	L2	R2
Mho phase distance elements	Compensator distance phase	V1MEM polarized
Directional element	Torque-based	Negative-sequence impedance-based
Mho ground distance elements	Not included	Included
Echo logic	Not included	Included

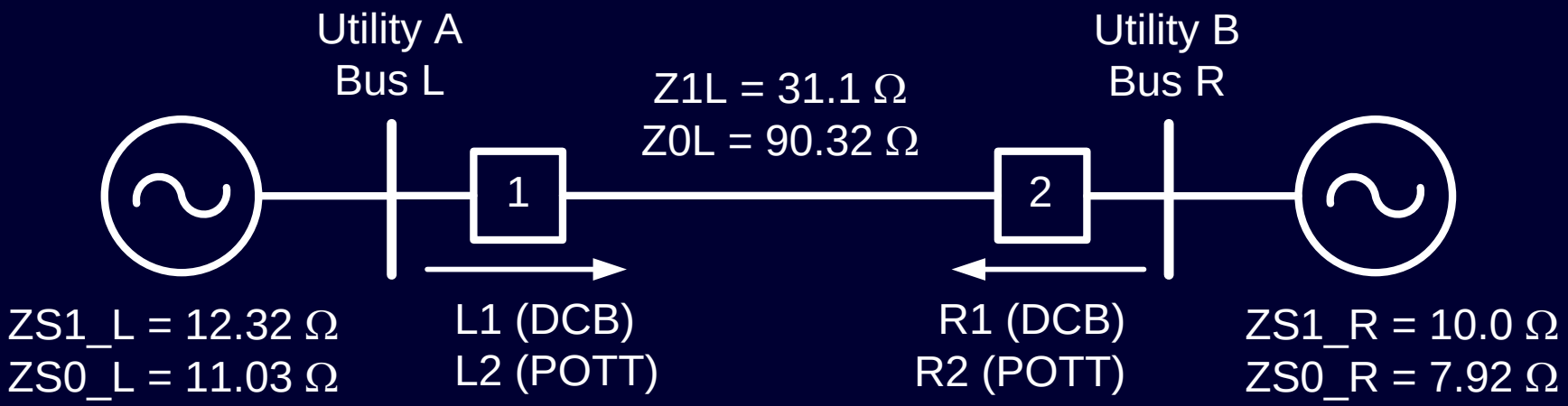
Case Study 1 Recommendations

- Primary DCB scheme – disable dissimilar ground directional elements
- Alternate POTT scheme
  - Disable echo logic in R2
  - Operate as traditional POTT scheme due to
    - Dissimilar operating principles of distance elements
    - Absence of echo logic in L2

Overall Scheme Advantages and Disadvantages

- Advantages
  - More security
  - High sensitivity for resistive ground faults achieved by alternate POTT scheme
  - Open breaker fault clearance in primary DCB scheme
- Disadvantages – none

Case Study 2



All Values Are in Primary Ohms

- DCB, Same manufacturer, different philosophies
- POTT, Different manufacturer

Different Utility Philosophy

- Utility A – forward pilot reach is 200% of ZL, no preference for quadrilateral elements
- Utility B – forward pilot reach is 120% of ZL, preference for quadrilateral elements and directional OC elements
- Primary DCB scheme – same relays at either end

Alternate POTT Scheme

Elements	L2	R2
Mho or quadrilateral element	Either can be enabled	Both can be enabled
Directional element	Fixed torque	Impedance (order-based)
Phase and ground distance elements	Positive-sequence memory polarized	Positive-sequence memory polarized

Case Study 2 Recommendations
Primary DCB Scheme

- Enable mho distance and directional OC elements in both relays
- Disable quadrilateral elements in both relays (one utility already has them disabled by default)

Case Study 2 Recommendations
Alternate POTT Scheme

- Disable echo logic and enable directional OC

OR

- Disable directional OC and enable echo logic

Solution 1: Disable Echo Logic and Enable Directional OC Elements

- Advantages
  - Increased fault resistance coverage
  - No coordination required
- Disadvantages
  - Both ends must declare forward fault
  - Slower clearance of internal faults when either terminal is weak / open

Solution 2: Disable Directional OC Elements and Enable Echo Logic

- Advantages
  - Rapid clearance of internal faults when
    - Either breaker is open
    - Either terminal sees high-resistance fault
  - Maximum use of ground distance elements
- Disadvantage – lesser fault resistance coverage

Summary

- Distance elements
- Directional OC elements
- High resistance faults
- Echo logic – fault resistance coverage is maximized
- Hybrid POTT schemes – coordination necessary

Recommendations

- DCB scheme with dissimilar relays
  - Disable directional OC elements
  - Enable distance elements in pilot scheme if similar principles are used
- POTT scheme with dissimilar relays
  - Disable echo logic and enable directional OC elements
  - Disable directional OC elements and enable echo logic

Questions?