Line Distance Protection Near Unconventional Energy Sources

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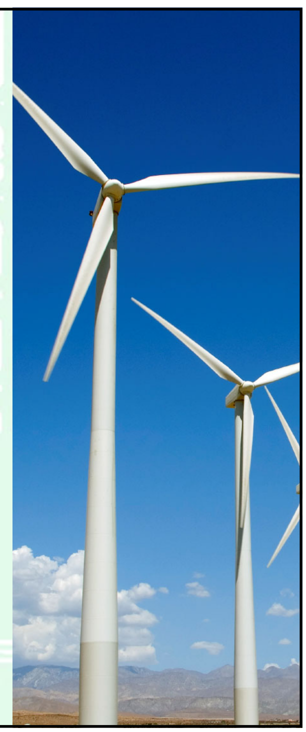
1

1

What is an unconventional source?

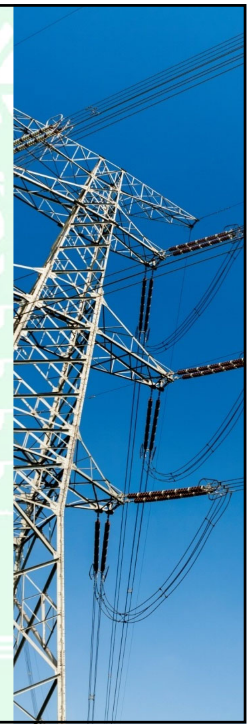
- Any source whose fault response differs significantly from that of a synchronous generator
- A source with most of these characteristics
  - Small or no mechanical inertia
  - Fault current is low and heavily shaped by control algorithms
  - Negative-sequence current does not follow negative-sequence voltage
  - Source impedance is variable and not inductive



2

Distance protection considerations

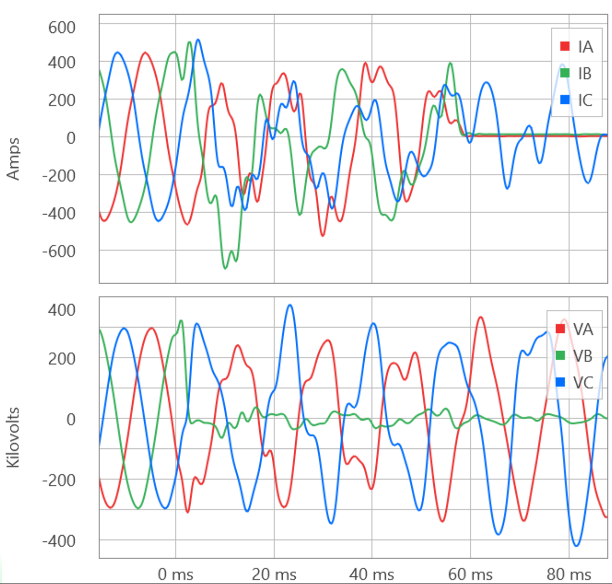
- Distance protection applications
  - Directly tripping Z1 elements (loss-of-channel backup)
  - Instantaneous Z2 elements (detecting line faults for pilot protection)
  - Step distance (time-delayed) zones (remote backup applications)
- Review of issues (analysis, not simulations)
- Distance elements for unconventional sources (no need for modeling or transient testing)

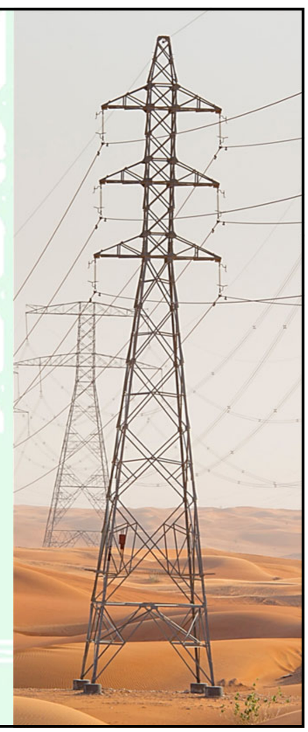


3

Sample line fault

Wind-powered generation

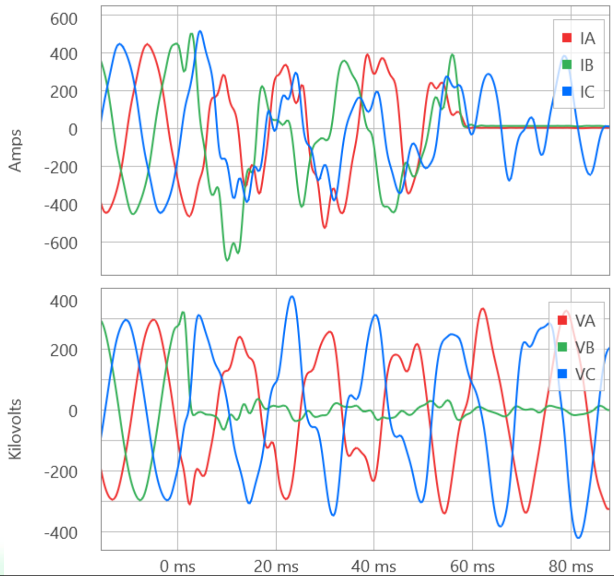


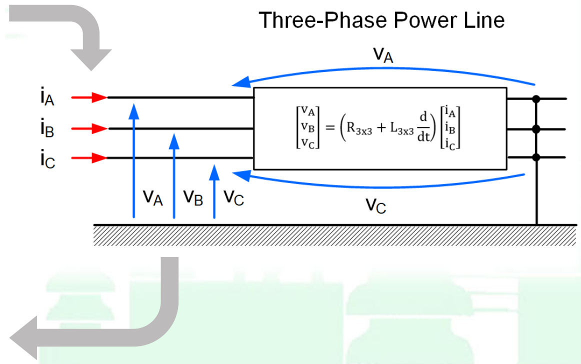


4

Apparent impedance principle

Think ohmmeter



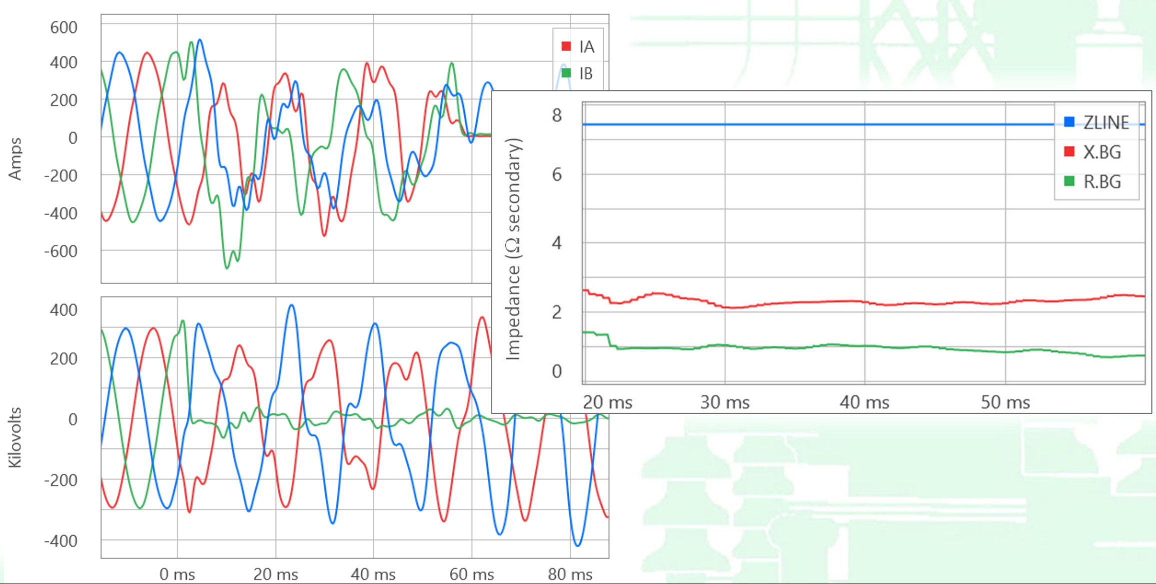


<u>Any current</u> pushed through a power line creates a <u>voltage drop</u> across the line that is consistent with the <u>RL parameters</u> of the line

5

5

Apparent impedance principle works

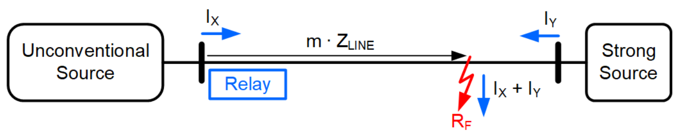


6

6

Z1 security and Z2 dependability concerns

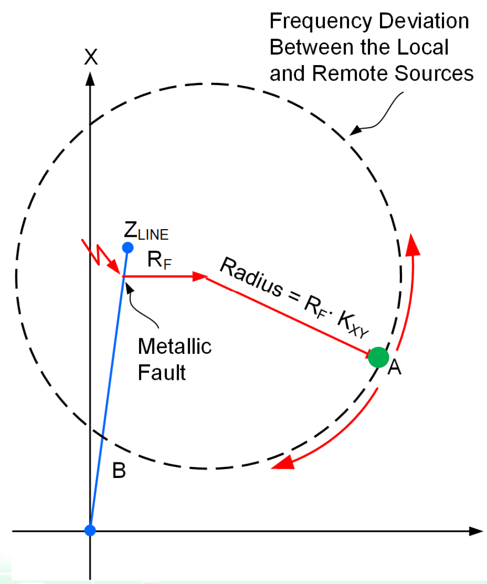
Low inertia, weak source, resistive faults



$$Z_{APP} = m \cdot Z_{LINE} + R_F \left(1 + \frac{I_Y}{I_X}\right)$$

$$\frac{I_Y}{I_X} = K_{XY} \cdot 1\angle\left(\Delta f \cdot 360^\circ \cdot \Delta t\right)$$

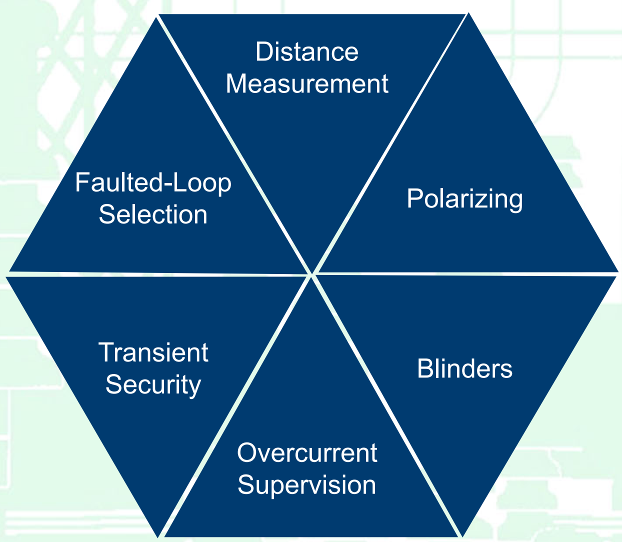
$$K_{XY} = \left|\frac{I_Y}{I_X}\right|$$



7

7

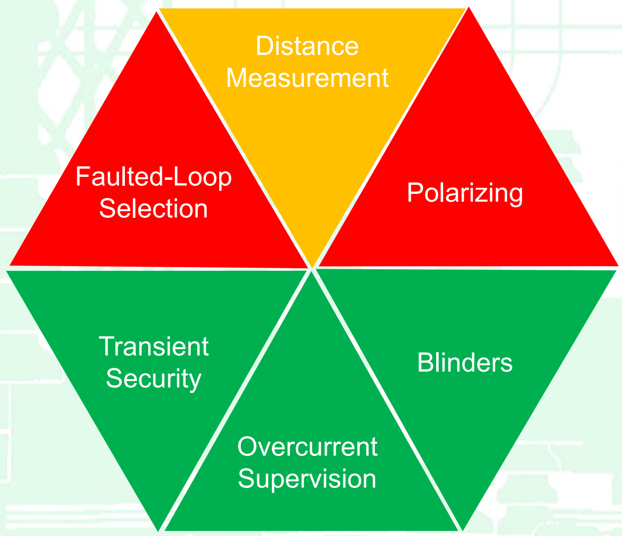
Transmission-grade distance elements



8

8

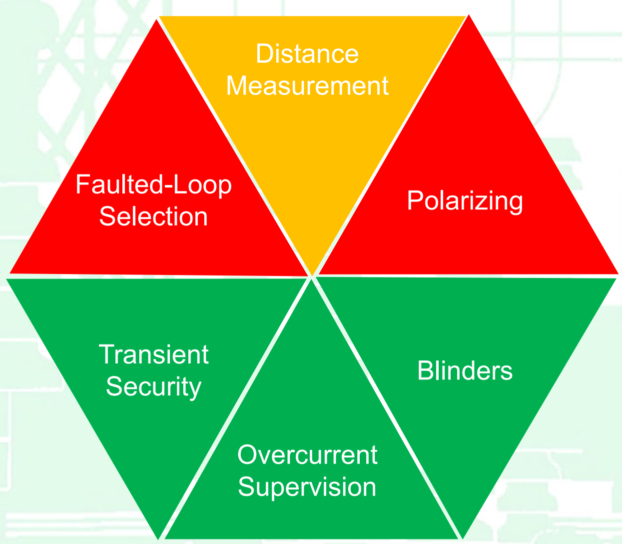
Score card for unconventional sources



9

9

Take apart, keep what works, fix what does not



10

10

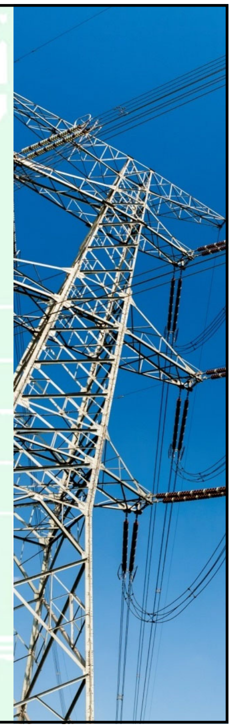
Directional polarizing

Problem

- Cannot trust V_{MEM} (small or no source inertia) in mho elements
- Cannot trust I_2 (angle rotates) in phase quadrilateral elements

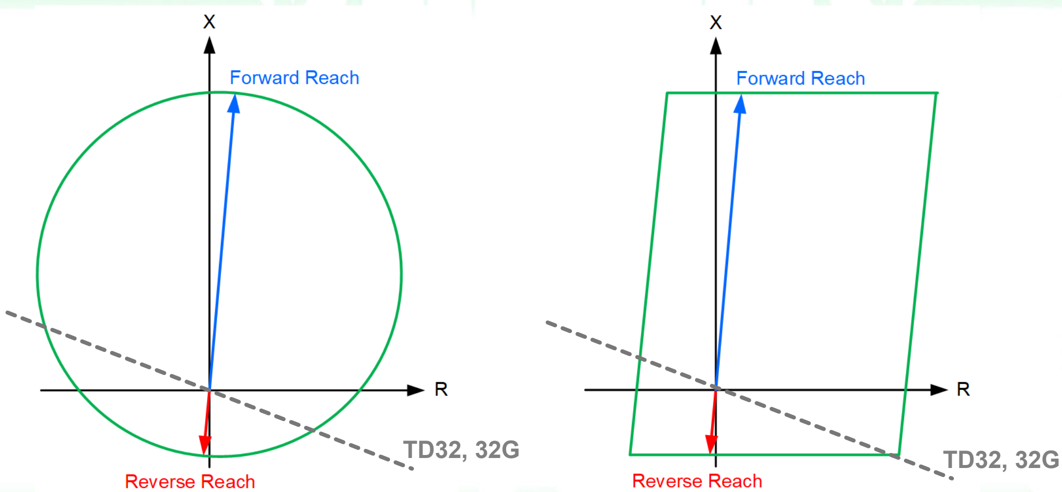
Solution

- Use apparent-impedance offset operating characteristics
- Supervise, if needed, with appropriate directional elements



11

Reverse offset for dependability



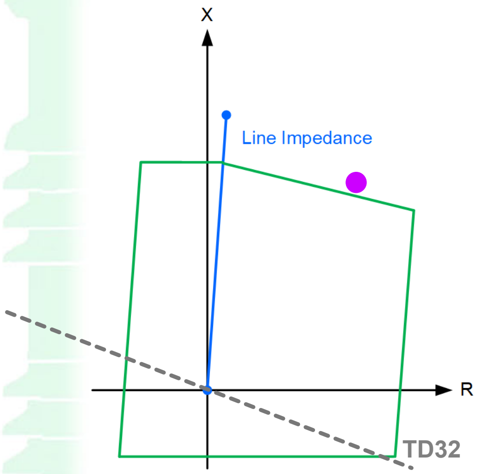
Applications

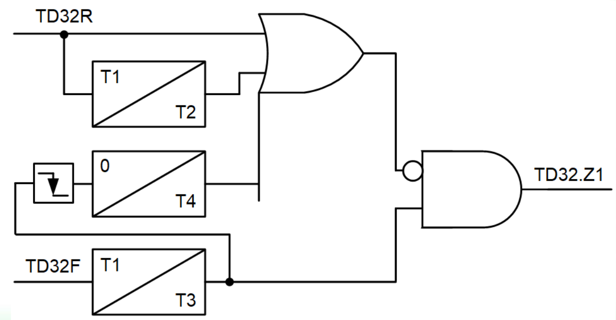
- Nondirectional (local and remote backup) step distance zone
- Directional zone by using TD32 and 32G elements

12

12

Zone 1 Application





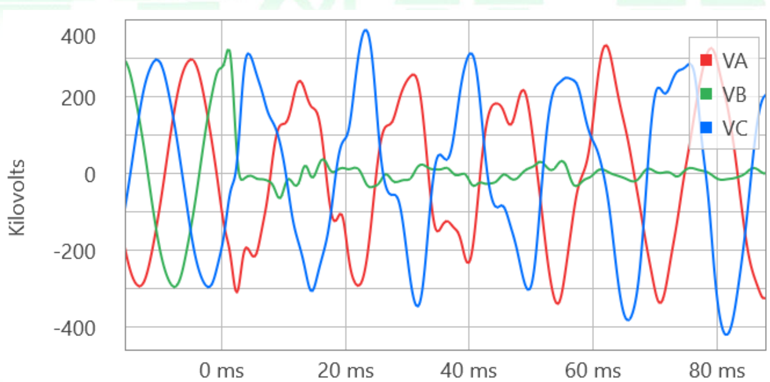
Zone 1 logic. Supervise with TD32, shut down Z1 before frequency error causes overreach

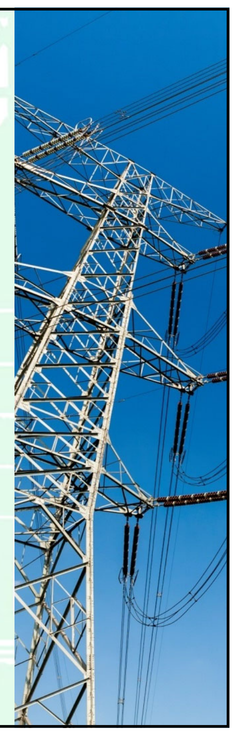
13

Faulted-loop selection

Problem: Cannot trust I_2
(angle rotates with respect to I_0 and V_1)

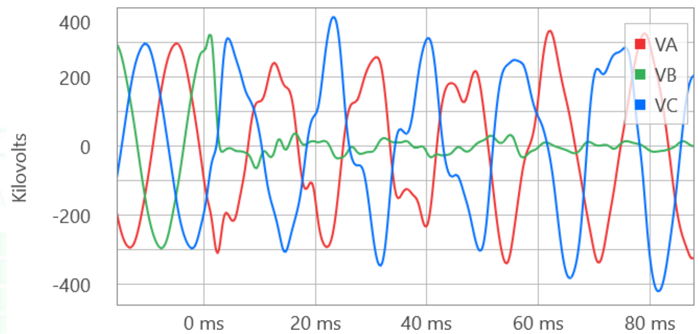
Solution: Use undervoltage

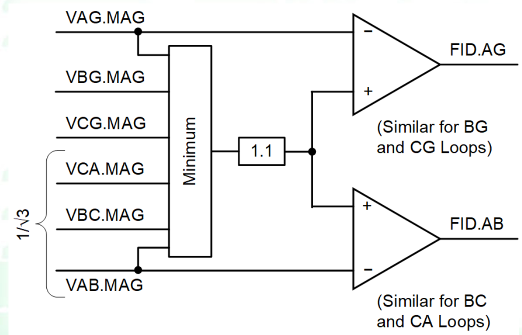


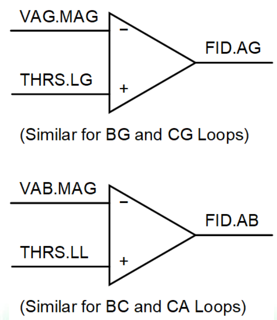


14

Undervoltage faulted-loop selection

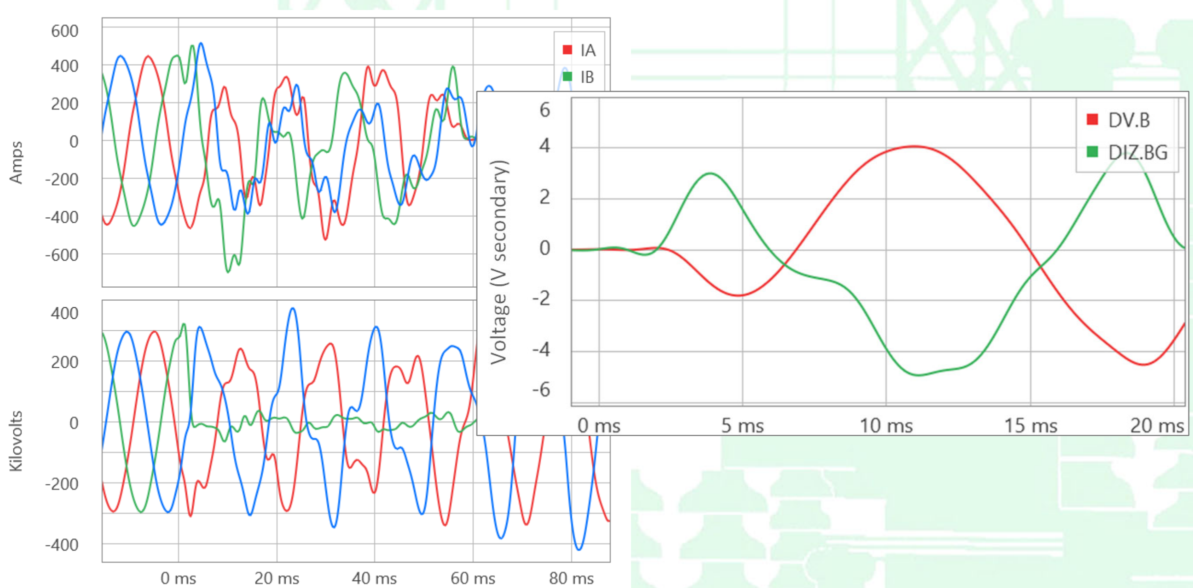






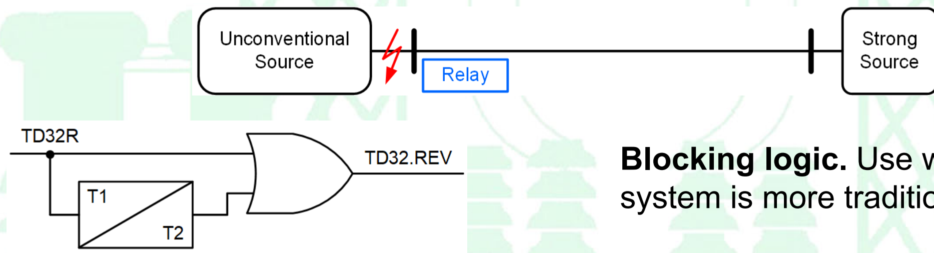
15

Directional supervision with TD32

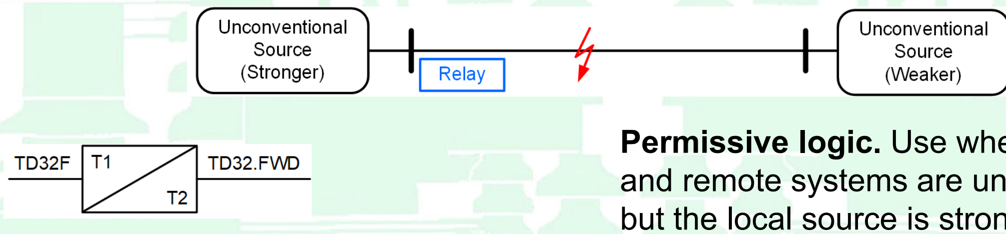


16

TD32 principle works… but is transient



Blocking logic. Use when the remote system is more traditional and stronger

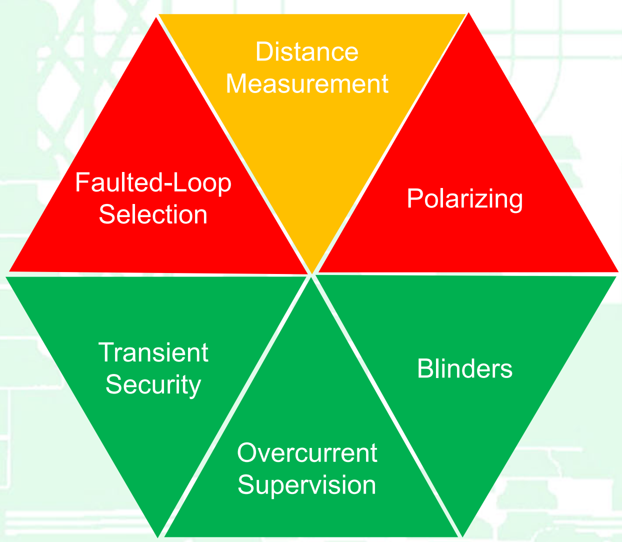


Permissive logic. Use when both local and remote systems are unconventional, but the local source is stronger

17

17

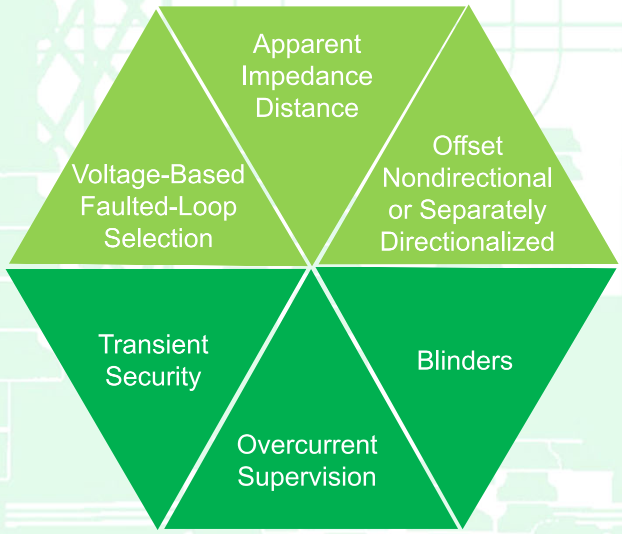
Take apart, fix, put it back together



18

18

Take apart, fix, put it back together

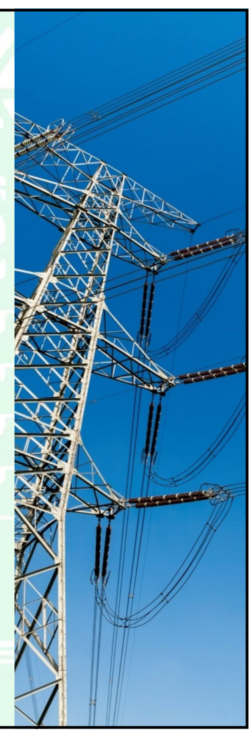


19

19

Conclusions

- Distance elements near unconventional sources work reasonably well when properly simplified
  - Avoid directional polarizing (offset instead)
  - Avoid negative-sequence (undervoltage instead)
  - Use Z1 for a limited time
- Directionalize distance elements by using
  - Incremental-quantity directional (TD32)
  - Zero-sequence directional (32G)
  - Weak-infeed directional (32WID)
- Some step distance zones do not have to be directional



20