Line Distance Protection Near Unconventional Energy Sources

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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
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)
Apparent impedance principle

Think ohmmeter

Any current pushed through a power line creates a voltage drop across the line that is consistent with the RL parameters of the line.

Apparent impedance principle works
Z1 security and Z2 dependability concerns
Low inertia, weak source, resistive faults

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

\[ \frac{I_Y}{I_X} = K_{XY} \cdot 1.2 \cdot (\Delta f \cdot 360^\circ \cdot \Delta t) \]

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

Transmission-grade distance elements

- Distance Measurement
- Faulted-Loop Selection
- Polarizing
- Transient Security
- Blinders
- Overcurrent Supervision

Frequency Deviation Between the Local and Remote Sources
Metallic Fault

Radial = \( R_e \cdot K_{XY} \)
Score card for unconventional sources

Take apart, keep what works, fix what does not
**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

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**Reverse offset for dependability**

**Applications**
- Nondirectional (local and remote backup) step distance zone
- Directional zone by using TD32 and 32G elements
**Zone 1 Application**

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

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**Faulted-loop selection**

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

**Solution:** Use undervoltage
Undervoltage faulted-loop selection

Directional supervision with TD32
**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.

**Take apart, fix, put it back together**

- Distance Measurement
- Faulted-Loop Selection
- Transient Security
- Overcurrent Supervision
- Polarizing
- Blinders
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