A Review of Distance and Overcurrent Protection Considering Increased Inverter-Based Resources

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Background

- Protection detects and isolates faults in the power system
- Relays measure current and voltage to determine conditions of system
- Relays send trip signals to breakers if conditions are unsafe
- Breakers open on either side of faulted equipment

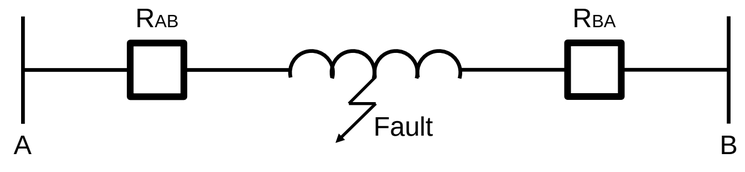

Fig. 1. One Line Diagram With Relays and Fault

Distance Protection

- Calculate impedance to ground using $Z_{relay} = V/I$
- Electrical distance is correlated to physical distance
- If $Z_{relay} < Z_{line}$, there is a fault on the line
- Multiple Z zones are used to create coordination

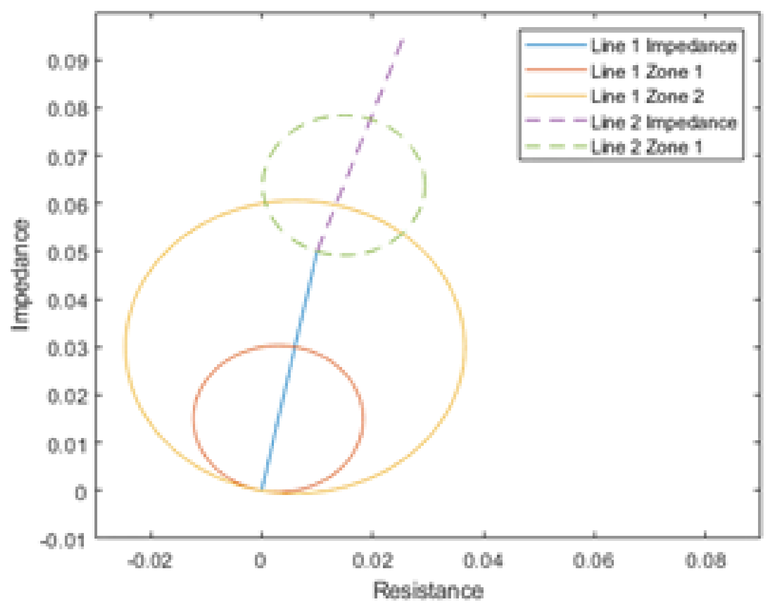

Fig. 2. Example of Distance Protection Zones

Overcurrent Protection

- Set I_{pickup} reasonably above $I_{nominal}$
- Once $I_{relay} > I_{pickup}$, trip after t seconds
- Inverse curve decreases t as I_{relay} increases
- Curve is adjusted to coordinate multiple relays

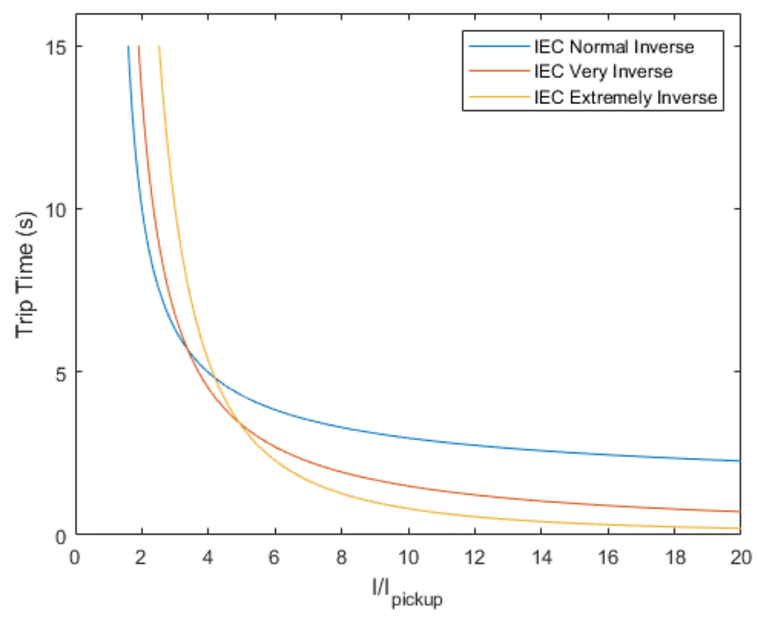

Fig. 3. Example of Inverse Time Curves

Inverter-Based Resource (IBR) Impact

- Inverters generate much less fault current, which can be too low to detect
- Inverters have less negative sequence current than conventional generation, which is sometimes used by distance protection
- Renewable energy can create reverse current flow
- Different distributed generation statuses create wide variety in nominal current, protection overreach, and mis-coordination
- Protection is currently set-and-forget, which is not adaptable to these issues

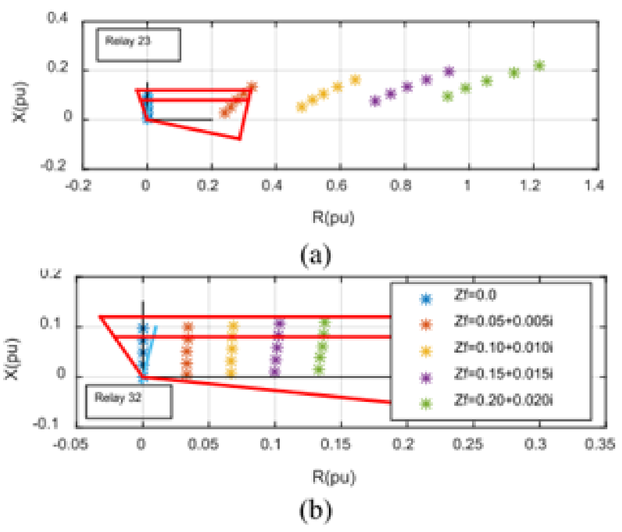

Fig. 4. Example of calculated fault impedances (a) being too high to trip seen from the IBR while (b) being detected as fault conditions from the grid

Review of Proposed Solutions

- Additional distance elements to improve directionality in cases where reverse power flow may occur
- Adaptive voltage factors that adjust trip current based on line loading
- Protection devices that estimate IBR modes based on machine learning
- Centralized processing with status of all generation considered
- Multi-agent adaptive protection systems

Scheme	Underreach	Overreach	Mis-coordination	Reverse Power Flow	Existing Hardware
Traditional	At Risk	At Risk	At Risk	At Risk	Yes
New Distance Element	At Risk	At Risk	At Risk	Protected	Yes
Mode Estimation	Improved	Improved	Improved	At Risk	Yes
Infeed Adaptive	Improved	Improved	Improved	Improved	No
Centralized	Protected	Protected	Protected	Protected	No
Multi-Agent	Protected	Protected	Protected	Protected	No

Table 1. Summary of Reviewed Protection Schemes