Impacts of the Renewable Energy Resources on the Power System Protection

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Normal Distribution

- Power Flows from Substation to Load
- Fault Currents flow in only one direction
- Protection typically based on series overcurrent device coordinated in time
- Often employ reclosing since many faults are temporary
Distributed Generation

- Change Feeder Voltage Profile
- May affect capacitor & voltage regulator control
- Will effect magnitude and distribution of fault currents
- Will Impact Overcurrent Device Coordination
Utility Concerns

- Safety of the public, the Customer, and the utility workers
- Load and interrupting capabilities of equipment
- Misoperation of utility protection equipment
- Power quality
What Utilities Generally Specify

- **Utility-Grade** interconnection relays
  - Pass all pertinent ANSI standards
  - C37.90-1,2,3

- CT and VT requirements (quantities sensed)

- Winding configuration of interconnection transformers

- Functional protection
  - 81U/O, 27, 59, etc.
  - Settings of some interconnection functions
    - Pick ups
    - Trip times

- Inverters are UL1741 listed
Distributed Generation Transformer Connections

Charles (Chuck) Mozina – Beckwith Electric

The winding arrangements facing the Utility and the Facility have an impact on protection.

Interconnection Transformer convention:
- Utility = Primary
- Facility = Secondary
Distribution System Design Considerations

- Primary Distribution System
  - Grounding

Unfaulted System

Unfaufted System

Effectively Grounded System

$V_A$ $V_C$ $V_B$

$V_{LG} = 1 \text{ pu}$

$V_{LG} \approx 1.2 \text{ pu}$

$\Omega A - \text{Grnd Fault}$

$\text{Gnd} = 0$
Distribution System Design Considerations

- Primary Distribution System
  - Grounding

- Ungrounded System
  - Unfaulted System
  - Ungrounded System
  - ØA – Gnd Fault

\[ V_{LG} = 1 \text{ pu} \]
\[ V_{LG} \approx 1.7 \text{ pu} \]
Distributed Generation

- Provides No Ground Current for Faults at F1 and F2
- Feeder Ground Fault Relaying will not Respond to Fault at F3
- Can supply feeder from an ungrounded source if Feeder Breaker Opens, potentially causing overvoltages for other customers – particularly under ground fault conditions.

Protection
- Install Zero Sequence PT’s (Grounded Wye-Open Delta)
- Detect Ground Faults with 59N (Ground Overvoltage) Relay
Distributed Generation

- Provides No Ground Current for Faults at F1 and F2
- Feeder Ground Fault Relaying will not Respond to Fault at F3
- Can supply feeder from an ungrounded source if Feeder Breaker Opens, potentially causing overvoltages for other customers – particularly under ground fault conditions.
- High ground Fault current into DG

Protection
- Install Zero Sequence PT’s (Grounded Wye-Open Delta)
- Detect Ground Faults with 59N (Ground Overvoltage) Relay
Distributed Generation

- No Overvoltages for L-G ground Fault at F1 due to neutral shift
- Can relay transformer neutral to detect fault current and clear ground fault contributions for Fault at F1
- Ground Current Source for Faults at F1 and F2, weak infeed even when DG is off-line – effects ground relay coordination on all substation breakers
- DG high side relaying will see unbalanced currents on the utility system
- Circulating currents in delta due to unbalanced utility circuit

Protection
- Install CT in transformer neutral with overcurrent relay
- Install 59N relay on the delta side of the interconnection transformer
- Neutral grounding reactor may be needed to limit the fault current contribution
- The interrupting device must be installed on the high side
Distributed Generation

With a grounded source

- No Overvoltages for L-G Fault at F1 due to neutral shift
- Can relay transformer neutral to detect fault current and clear ground fault contributions for Fault at F1
- Ground Current Source for Faults at F1 and F2 if generation is grounded.
- DG relaying will see unbalanced currents from the utility system
- Feeder Protection will see faults at F3

Protection

- Install CT in transformer neutral with overcurrent relay
- Voltage controlled OC relay may be used for inverter generation (maximum fault current is limited to ~120-130% of nominal current)
Many utilities like to see effectively grounded sources at the PCC to limit overvoltages on feeder/system ground faults.

Need to consider criteria for effective grounding:
- $X_0/X_1 \leq 3$ and $R_0/X_1 \leq 1$
Islanded Operation of DG with Utility Load Is Generally **Not** Allowed

SmartGrid and Microgrid may allow islanding in the future

Anti-islanding protection: Direct Transfer Trip (DTT), Power Line Carrier, etc.
DG Facility Islanding to the Utility is normally Allowed
Restoration responsibility on the DG
- Requires synchronizing to Utility

DG can create its own island, and synchronize to the utility
POWER BACK-FEED INTO TRANSMISSION SYSTEM

- Normally the Transmission side of the utility substation transformer is Delta.
- 59N relay may be used to detect the L-G faults on the Transmission system.
- Directional OC relay may be used to detect the ungrounded faults on the Transmission system.
- The impact of DG infeed on the Transmission system Distance Protection must be carefully reviewed.
Network Connections
What we covered

- Utility Distribution Design
- Utility Protection Requirements
- Grounded vs Ungrounded Systems
- Transformer Winding Configurations and their Impact with Generation
Content-Based Review

• What type of transformer allows zero-sequence current from a source pass right through it?

  A grounded wye – grounded wye transformer

• What is the major concern of a ground fault (L-G) on an ungrounded system if not designed for?

  Line to ground voltage can increase up to line to line voltage, raising above insulation levels.

• If an upstream Utility device opens and separates a DG from the Utility, is there a fear of islanding even if the DG requires VARs from the Utility?

  Yes, due to potential VAR support from distribution equipment such as capacitor banks.