Ground Fault Detection Improvement Study: Mitigation Methods

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Summary of recommended mitigation methods

Enhanced ground fault monitoring	• Residual current monitoring • Residual current monitoring with trip • Electronic sensing in ground circuit • Isolation monitoring
Sensitized overcurrent protection	• Reduce fuse size in ground fault circuit
Other systemic measures	• Targeted annual O&M practices • Arc-fault detection

Shown in authors' order of preference for effectiveness and value
Modifications by qualified personnel only and must involve equipment manufacturers!

Method 1: Residual current measurements
With alarm

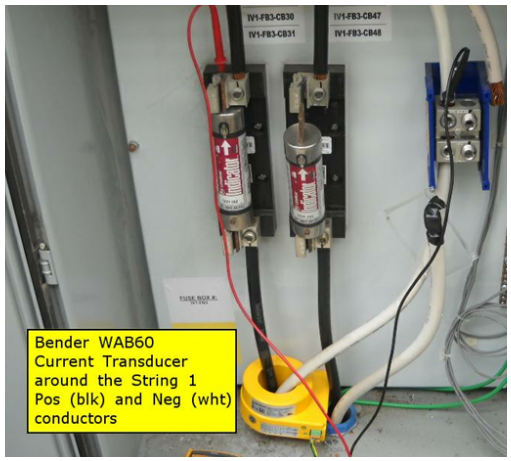
Installed at inverter entrance on positive and negative feeder circuits

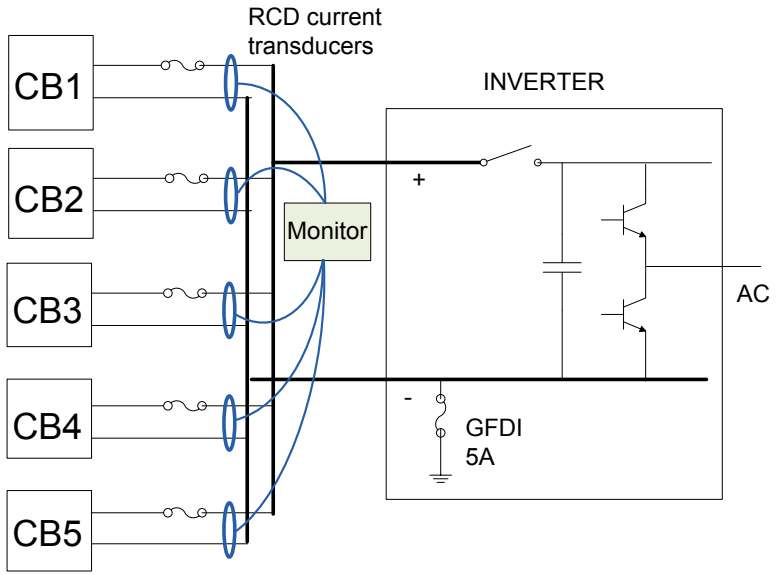
- **Effect:** Major increase in the sensitivity and flexibility of ground fault detection/mitigation

- **Pros:**
  - Proven method for detecting blind spot conditions
  - Alarm gives operator options for response; reduces impact of false trips

- **Cons:**
  - Requires rewire of array conductors through current transducers, and monitor interface
  - Does not interrupt the fault current.
  - May require installation of a new enclosure to access existing conductors

- **Cost:** Moderate to high
  - Possible to run multiple circuits through single CT





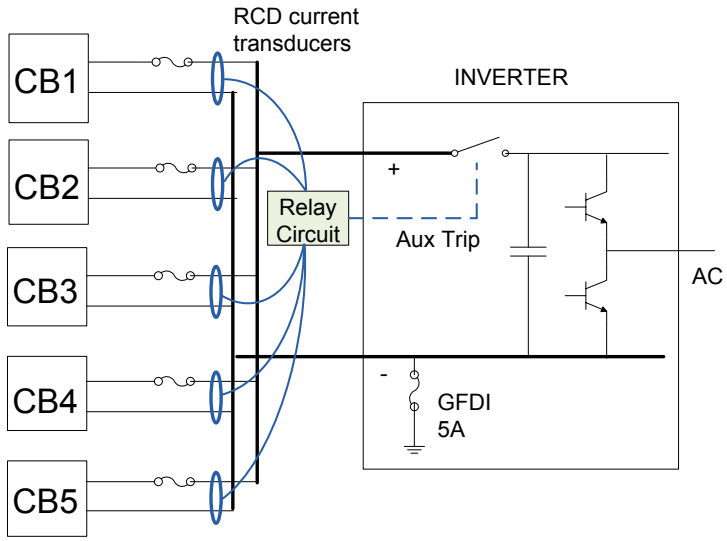
Method 2: Residual current measurements
With auxiliary trip

Similar to method 1, except relay is used to trip inverter off via E-stop, auxiliary trip, or shunt-breaker

- **Effect:** Major increase in the sensitivity of ground fault detection and interruption

- **Pros:**
  - Proven method for detecting blind spot conditions.
  - Interrupts fault current under blind spot condition
  - Data averaging can mitigate false trips caused by lightning or other transients
- **Cons:**
  - Requires rewire of array conductors through CTs, possible add'l enclosure.
  - Nuisance trips possible
  - Inverter trip wiring could have certification/ warranty implications

- **Cost:** Moderate to high
  - Possible to run multiple circuits through single CT



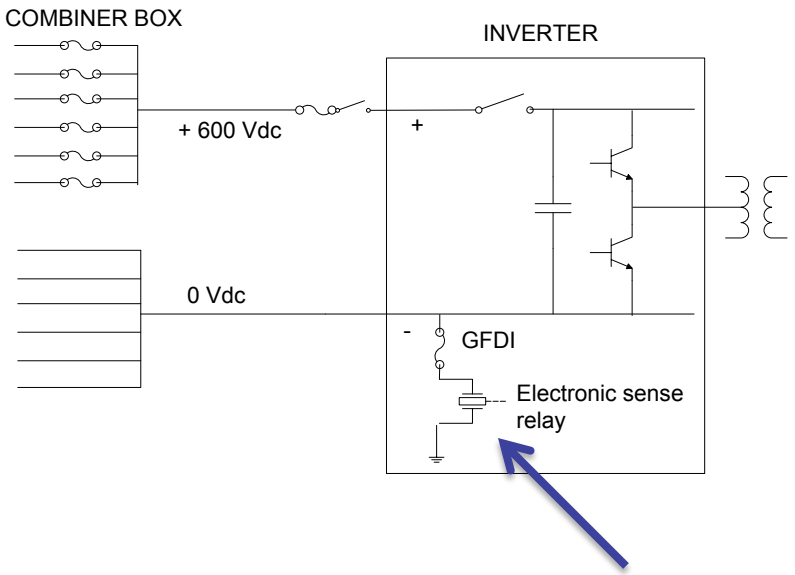
Method 3: Electronic current sense relay in ground circuit

High accuracy sensing is installed in series with ground fault fuse or breaker circuit. Shunt or specialized CT required. Applicable for larger inverters.

- **Effect:** Major increase in the detection sensitivity and mitigation flexibility (~100 mA sensitivity)

- **Pros:**
  - Relays can be programmed to trigger on current and duration levels
  - Can be coordinated with auxiliary trip
- **Cons:**
  - Requires rewire of ground fault fuse circuit
  - False trips possible
  - May impact inverter certification – must have approval from manufacturer.

- **Cost:** Moderate
  - Possible inverter manufacturer retrofit



Method 4: Isolation monitoring with periodic check

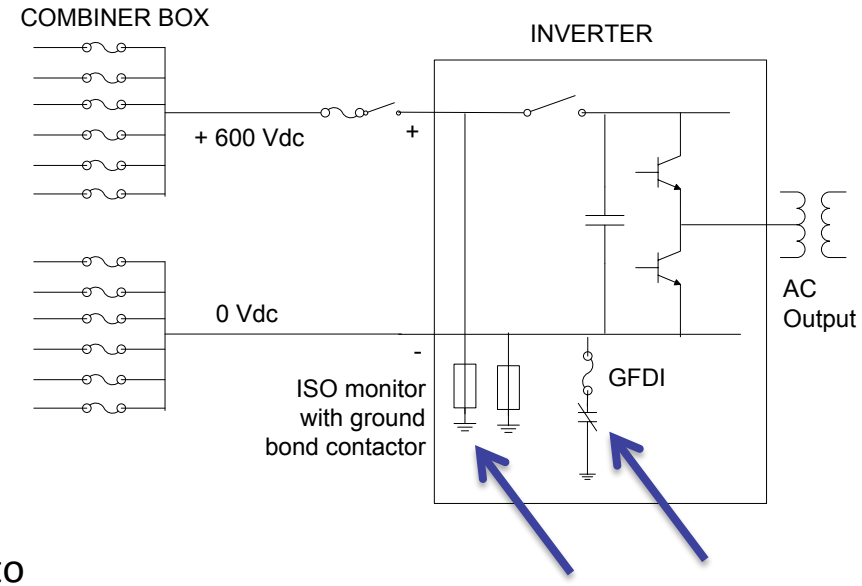
Install isolation monitor, implement periodic checks

- **Effect:** Capable of detecting low insulation conditions and ground faults on either pole

- **Pros:**
  - Proven method for detecting blind spot fault conditions. (Similar to international non-isolated system protection)
  - Prevents inverter start up until faults are corrected
  - Consistent with evolving UL and IEC standards

- **Cons:**
  - More significant changes needed in inverter to implement monitoring, logic control and ground bond contactor

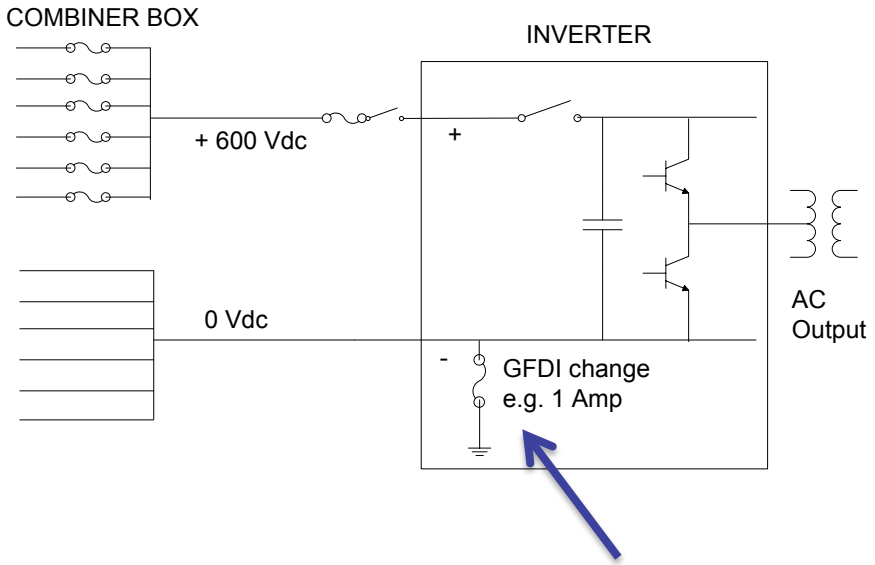
- **Cost:** High (in most cases)
  - Involves inverter manufacturer retrofit



Method 5: Reduce fuse size in ground fault circuit

Replace fuse.

- **Effect:** Minor increase in the sensitivity of ground fault detection. ~10x less sensitive than Methods 1-4.
- **Pros:**
  - Easy, inexpensive retrofit
- **Cons:**
  - Not as sensitive as electronic ground current monitoring
  - May conflict with other inverter functionality
  - May impact inverter certification
  - May result in nuisance trips
- **Cost:** Low



Method 6: Targeted operations and maintenance practices

Routine visit by qualified personnel to perform tests

- **Effect:** Capable of identifying blind spot faults

- **Pros:**
  - O&M can find undetected faults and degraded insulation
  - Annual operation and maintenance inspections are useful for many reasons beyond the blind spot.
  - **Cons:**
  - Requires routine visit by technicians to perform tests.
  - Faults that occur between inspections may still go undetected.
  - Not a blind spot cure

- **Cost:** Moderate, but recurring

Method 7: Use of arc-fault detection

Series arc fault current interrupters (AFCIs) installed in contactor combiner boxes or at inverter feeder input circuits

- **Effect:** Can isolate circuits when arc is detected
- **Pros:**
  - Isolating strings when arc is detected may lessen any fault severity
  - May isolate 2nd dangerous fault that follows a blind spot fault (becomes series arc).
  - Detects other fire-causing faults
- **Cons:**
  - AFCI may not be able to detect blind spot faults
  - Series AFCIs are not evaluated for response to arcing faults to ground.
  - Limited commercial availability of proven equipment
- **Cost:** High (expected)