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Recommendations for RCD Ground Fault Detector Trip Thresholds

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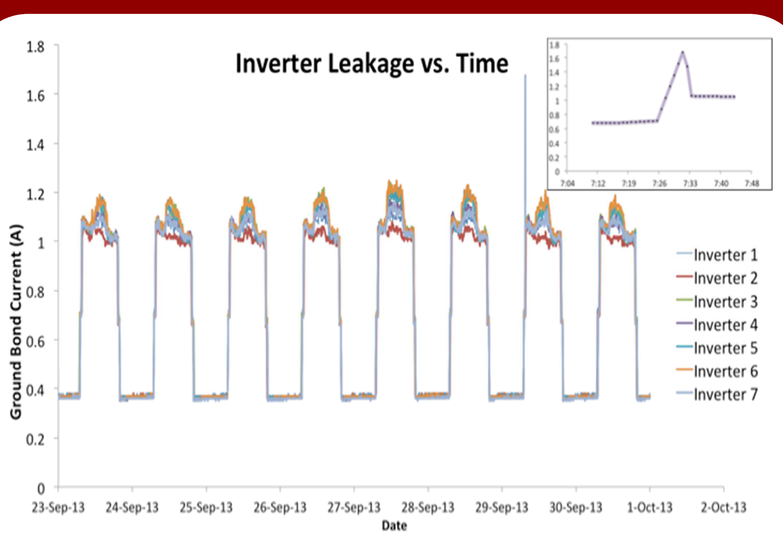
Photovoltaic (PV) ground faults have caused many fires in the U.S. and around the world. Recently, the American PV industry has discovered a blind spot in fuse-based ground fault detection that has spurred a transition to a number of alternatives traditionally used in European markets. This paper investigates the repeatability of one of these methods, residual current detection (RCD), using historical field data from 340 utility-scale inverters in a large 170 MW installation. The distributions of leakage current magnitudes for the inverters is calculated for one year to determine a statistical RCD trip metric that minimizes unwanted tripping but increases the sensitivity of ground fault detection.

RCD leakage values of 340 500 kW inverters

- Co-located in desert environment
- RCD current measured at one-minute intervals
- Data taken for over a year
- RCD set to 5 A_{RMS} based on IEC 62109-2

Figure shows a weeklong subset of the data

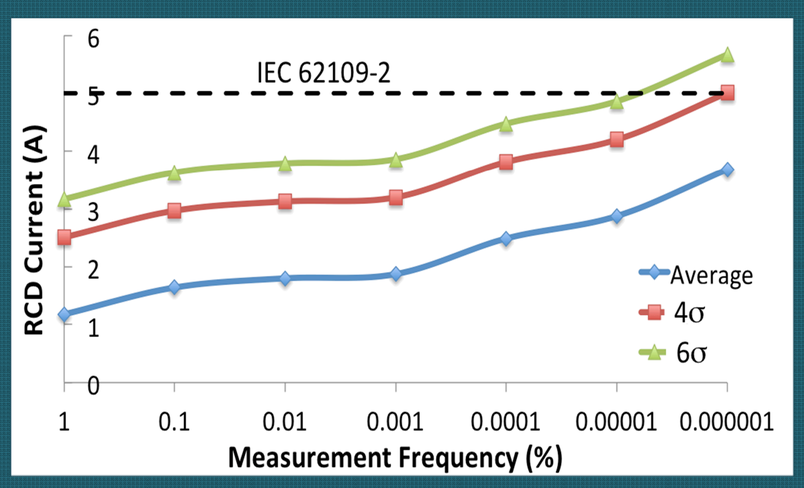
- Seven inverters
- Inverter-to-inverter variation ~200 mA
- One CT measured current spike
  - Spikes always associated with turn-on/off
  - DC contactor at the beginning/end of day
  - Spikes occur as array capacitance is discharged
  - Multi-minute spike from data compression
  - Only single measurement point of current



Suggested Trip Thresholds

4σ and 6σ confidence bands shown as dashed black lines

- 4σ confidence that 99.999% of RCD values <3.1994 A
- 6σ confidence RCD values <3.8616 A
- 5 A (IEC62109) → eight-nines frequency in 4σ band

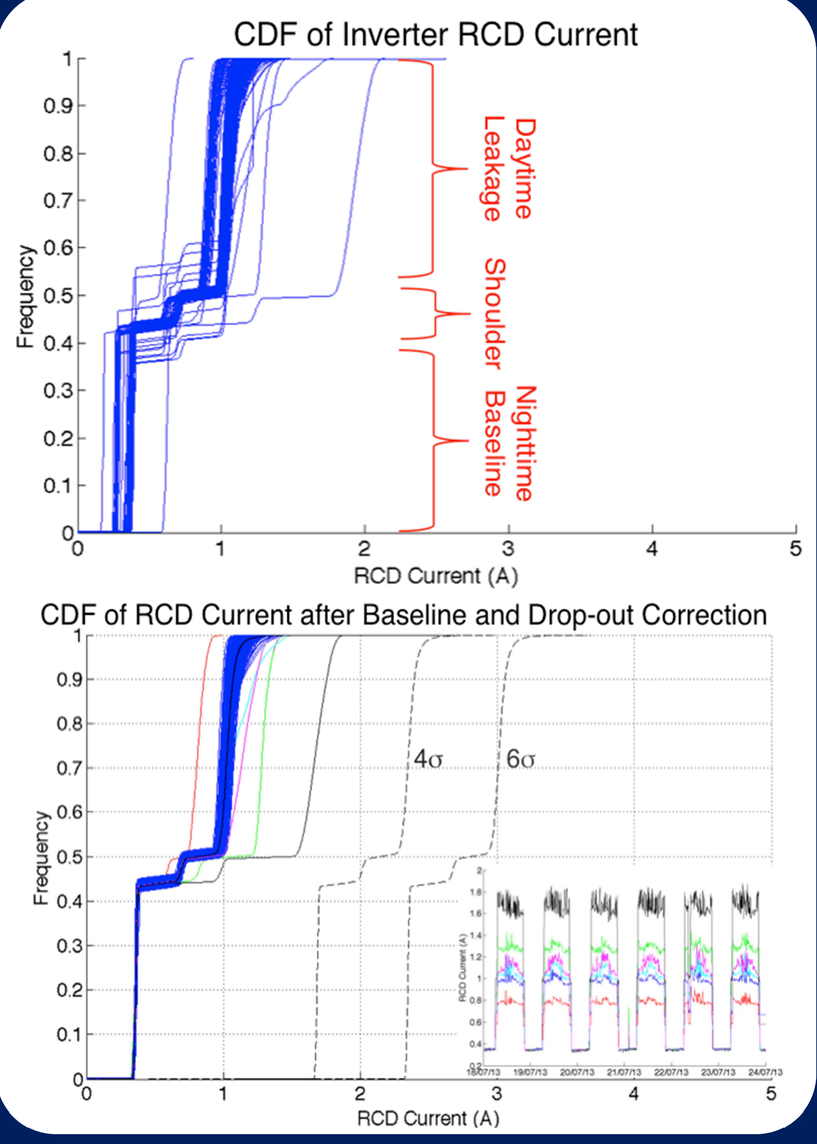


CDFs of all 340 RCDs

- Similar multi-tiered shape.
- 50% of the leakage frequency occurs at 0.8-1.2 A
- Corresponding to daytime leakage values

Data dropouts and incorrect baseline values

- Spreads CDFs of inverters
- If corrected, all but 5 of the 340 inverters
- 1.14–1.51 A at 99.99% frequency
- Colored outlier inverters gain problem in the RCD
  - Not actual increase of leakage in inverter



Histogram of all 340 RCDs

Leakage values cluster into three groups

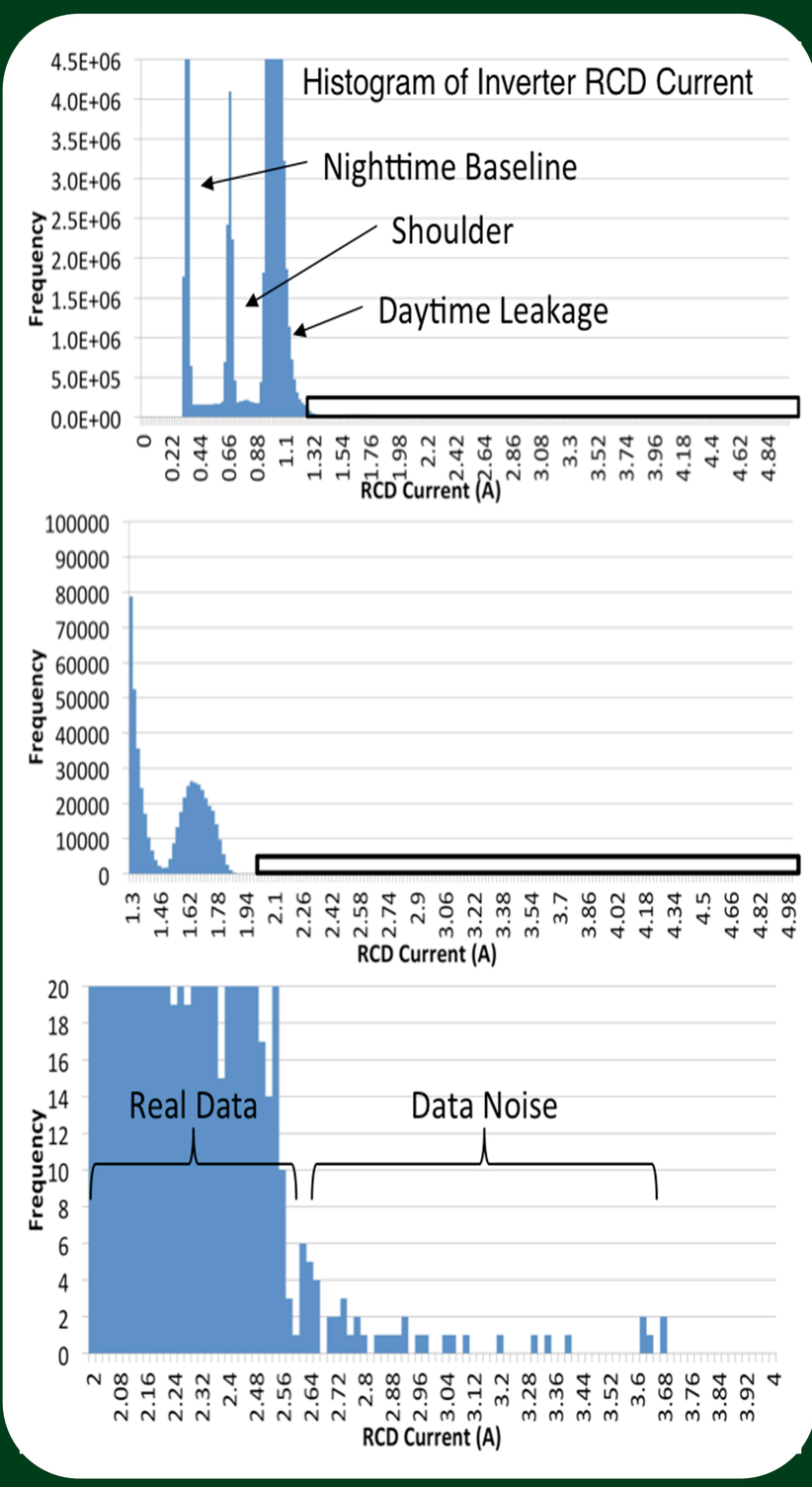
- Nighttime baseline (0.32-0.38 A)
- Turn-on/turn-off shoulder (0.64-0.72 A)
- Daytime leakage (0.92-1.39 A)

At higher RCD currents (1.50-1.82 A)

- From the capacitive discharge spikes that occur when the inverter connects to array

At even larger currents (2.5-4.0 A)

- Small number of high current, low frequency points
- Noise in measurement, recording or transient events



Conclusions

- Large-scale, long-term data presented
- Trip points in UL 1741 and IEC 62109-2 could be lowered from 5 to 2.5-3 A
- The trip threshold reduction would not increase the number of nuisance tripping events
- Proper averaging or noise reduction techniques would minimize unwanted tripping
- Statistical analysis of plant performance an improved RCD trip levels after installation

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