

SOLAR ABCs
ANNUAL MEETING
SEPTEMBER 14TH, 2012

**PHOTOVOLTAIC GENERATION:
TEMPORARY OVERVOLTAGE IMPACT AND
RECOMMENDATIONS** Final Draft

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This Report Addresses Two Types TOV:

- Type 1: TOV occurs with a single line to ground (SLG) fault and a voltage rise on the unfaulted phases of a four-wire multi-grounded system.
- Type 2: TOV occurs on the PV generator at its terminals when the inverter is suddenly disconnected from the grid with little or no load connected.



Edith Clarke 1939 Paper on TOV

Circuit Analysis of AC Power Systems, Vol. 1 & 2, Edith Clarke

American Institute of Electrical Engineers, Transactions of the
Date of Publication: Aug. 1939 Author(s): Clarke, Edith
Volume: 58 , Issue: 8 Page(s): 377 - 385



$$\sqrt{3}$$

Solar America Board for Codes and Standards



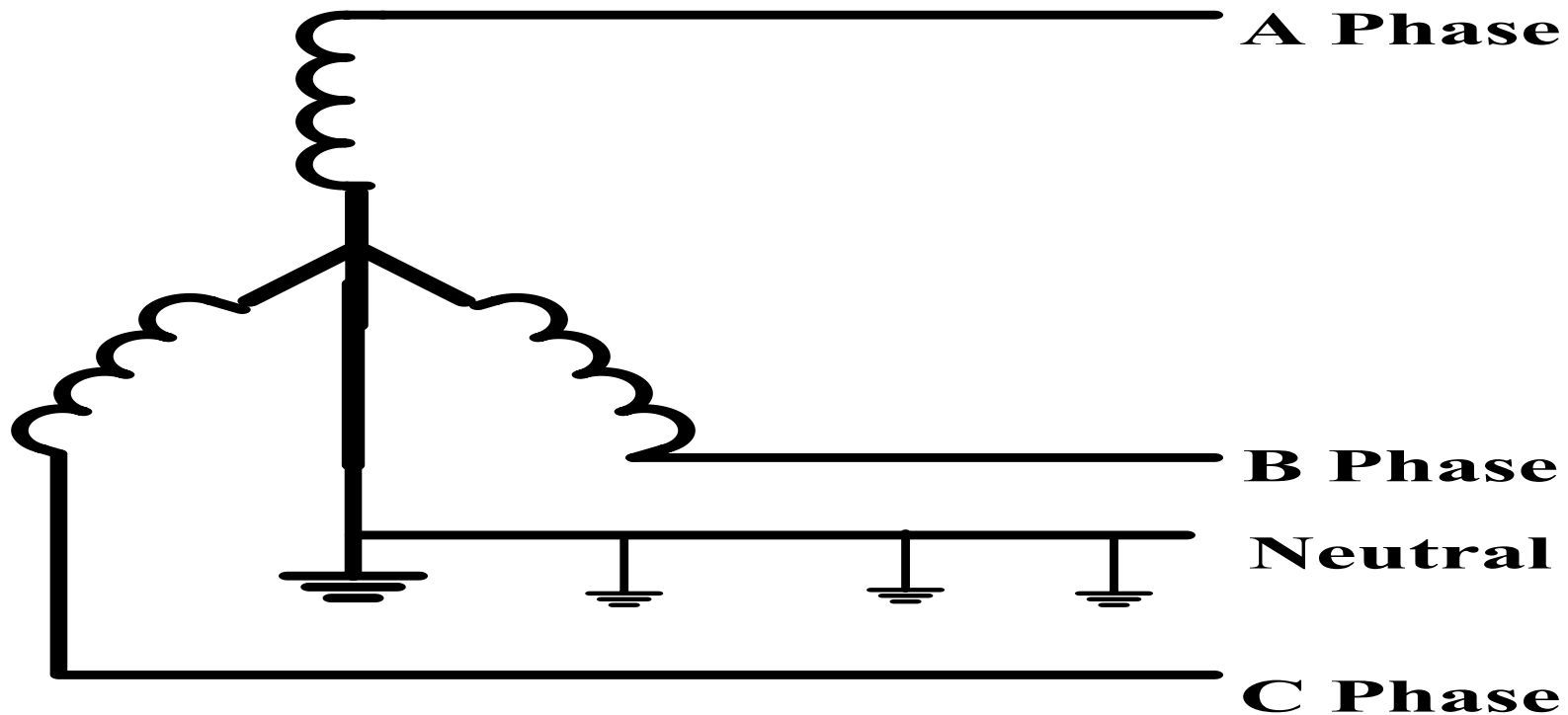
Why This Report on TOV

- *“IEEE 1547 requires that the DR (Distributed Resources) should not adversely affect the grounding arrangement of the power system and should not cause damaging overvoltage to appear under any conditions. This is easy to state, but its implementation leaves utility engineers and inverter manufacturers with a serious dilemma that is not easy to solve. This problem has not received much attention in the various industry forums although it is arguably one of the least understood and most troublesome issues related to the interconnection of DR.”*
- Colin Schauder IEEE paper Stated

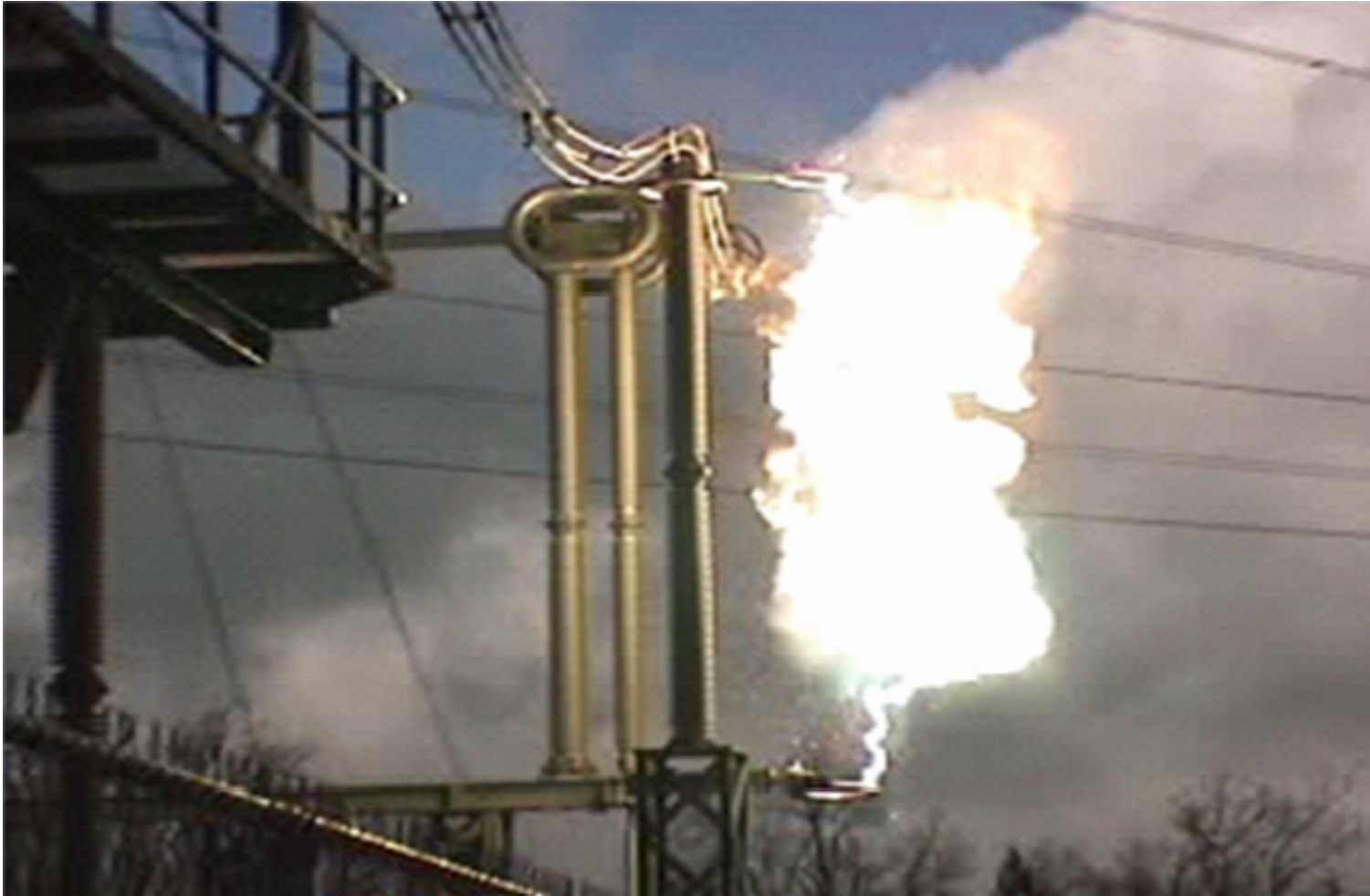


Three Phase Four Wire System
Most Common in North America

**Solidly Grounded
Three Phase Four Wire**



Single Line To Ground Fault



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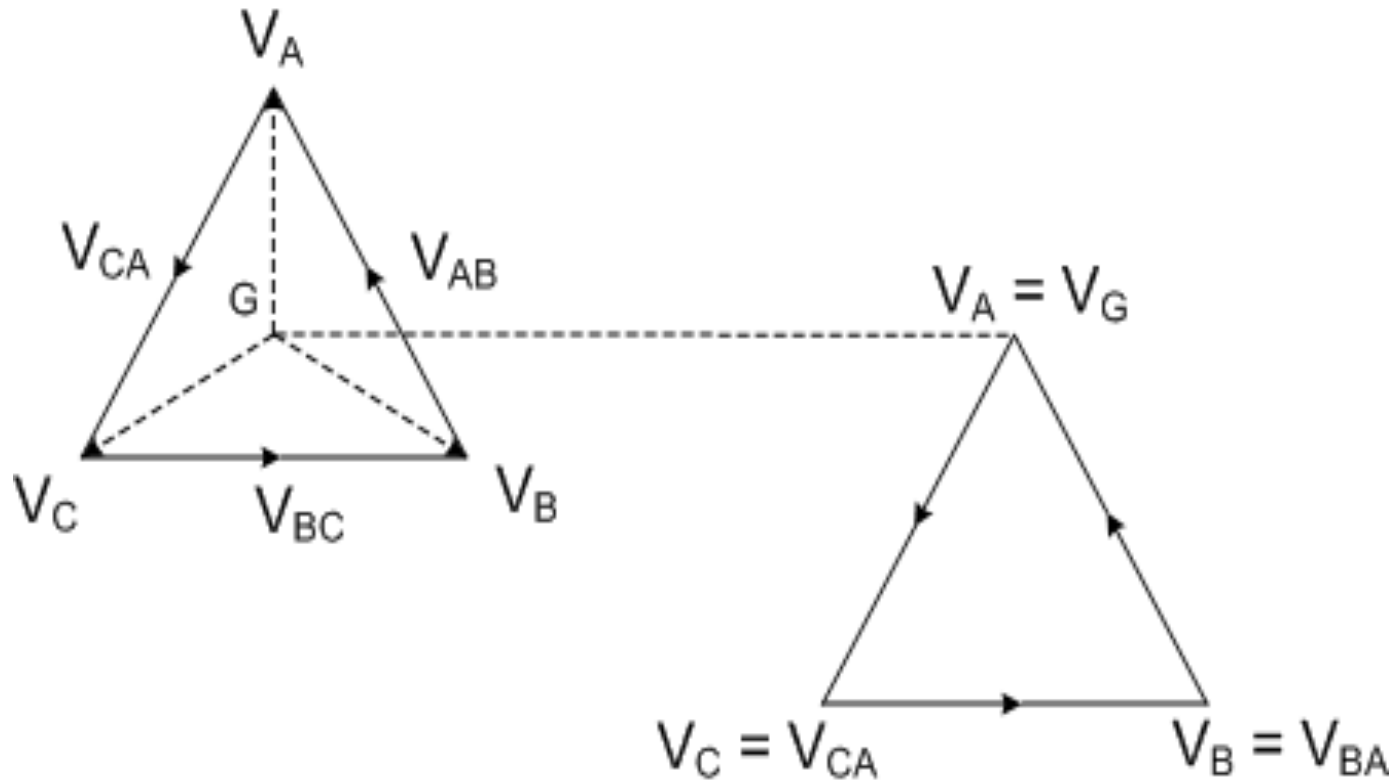


TOV Event Sequence

1. One phase of a three phase system is shorted to ground. Tree limb contacting a power line.
2. The fault is detected by the substation circuit breaker relays.
3. The substation circuit breaker opens and islanding portion of the distribution system.
4. Loss of feeder ground source when the substation breaker opens.
5. The PV remains on the islanding section for some duration (less than 2 seconds).

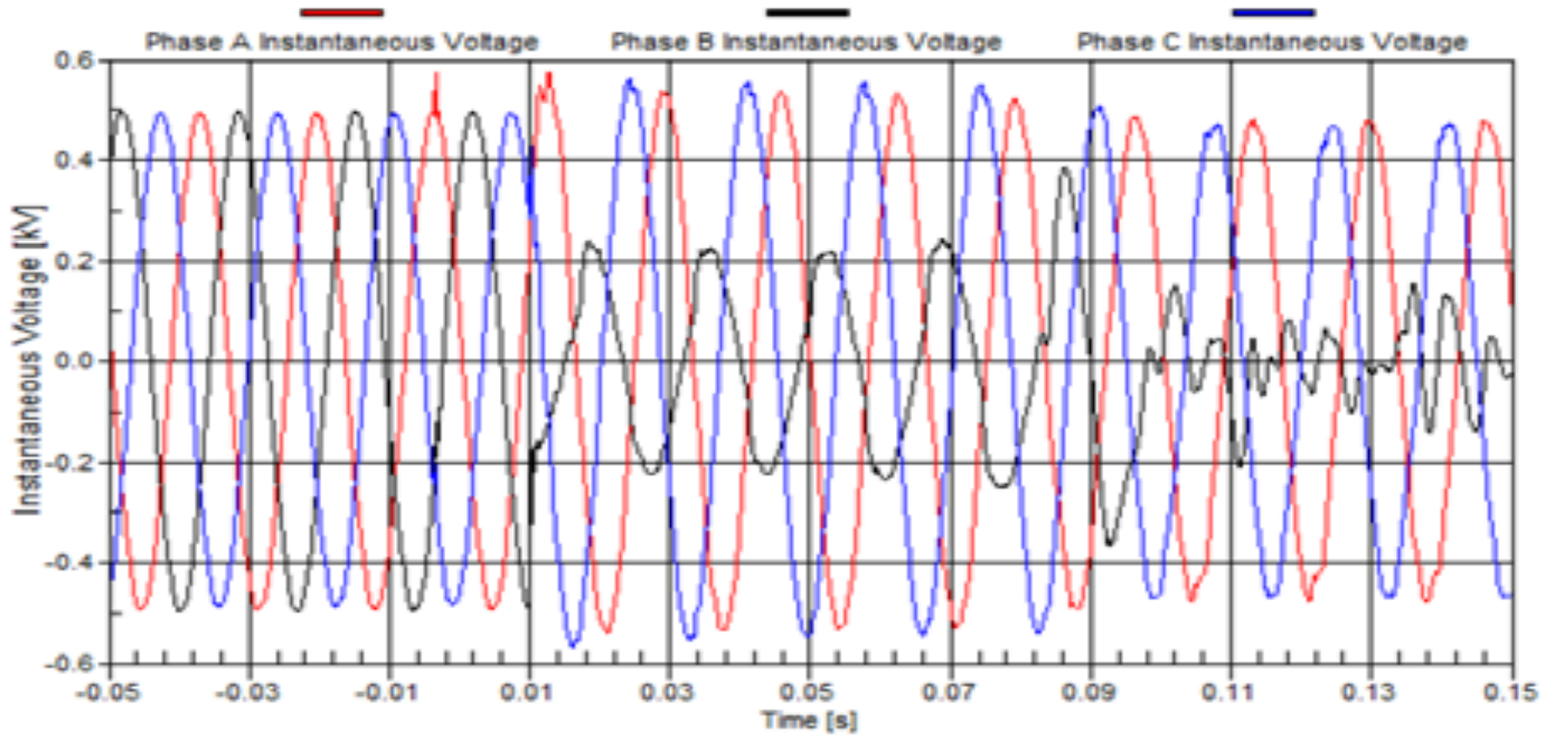


Vector Diagram



TOV Type 1 Event Voltage SLG Swell and Sag

RMS Variation ((NI)_Fepro_Biogas) 06-24-2011 12:38:14

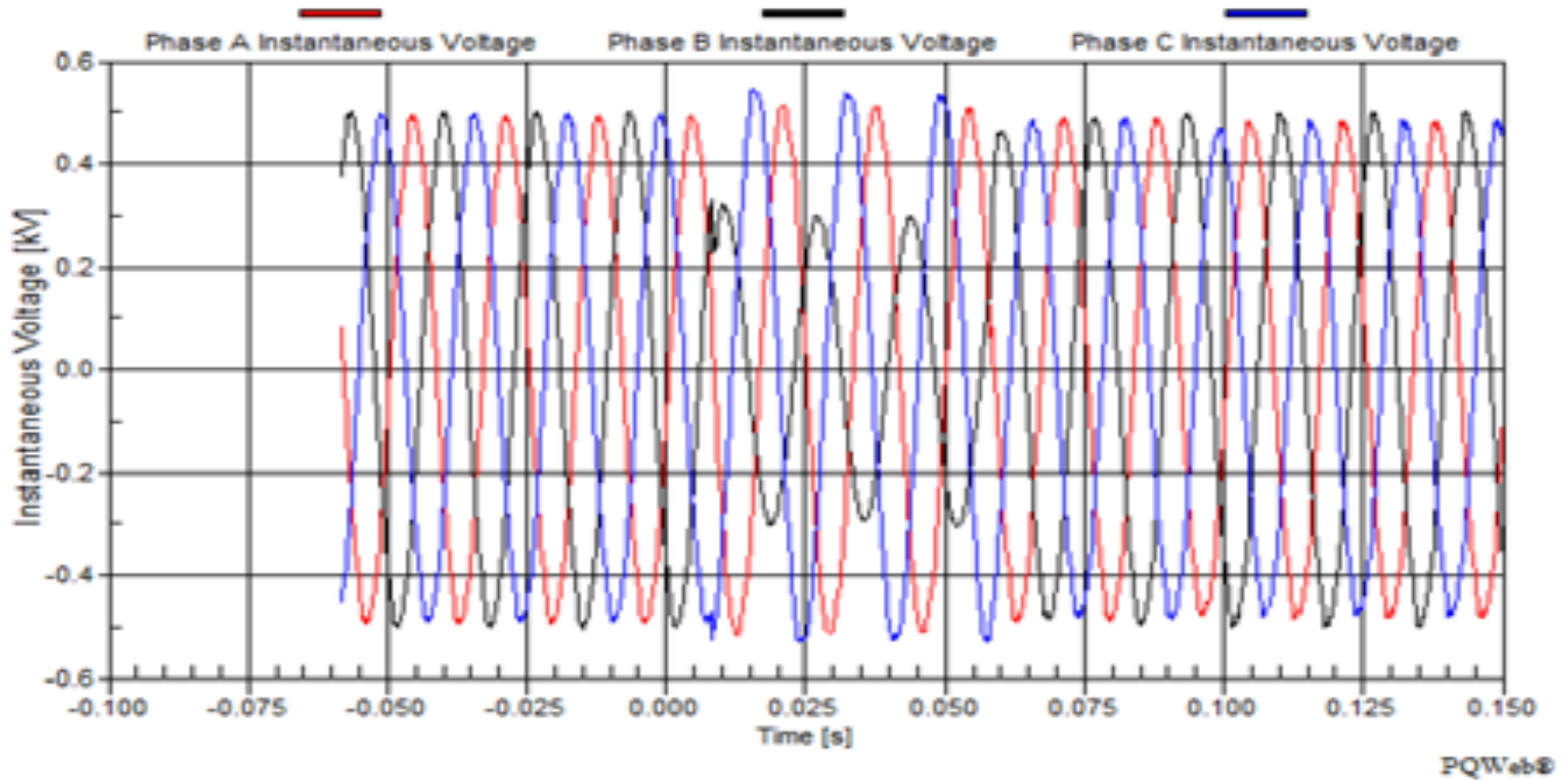


Graph Hydro One



TOV Event

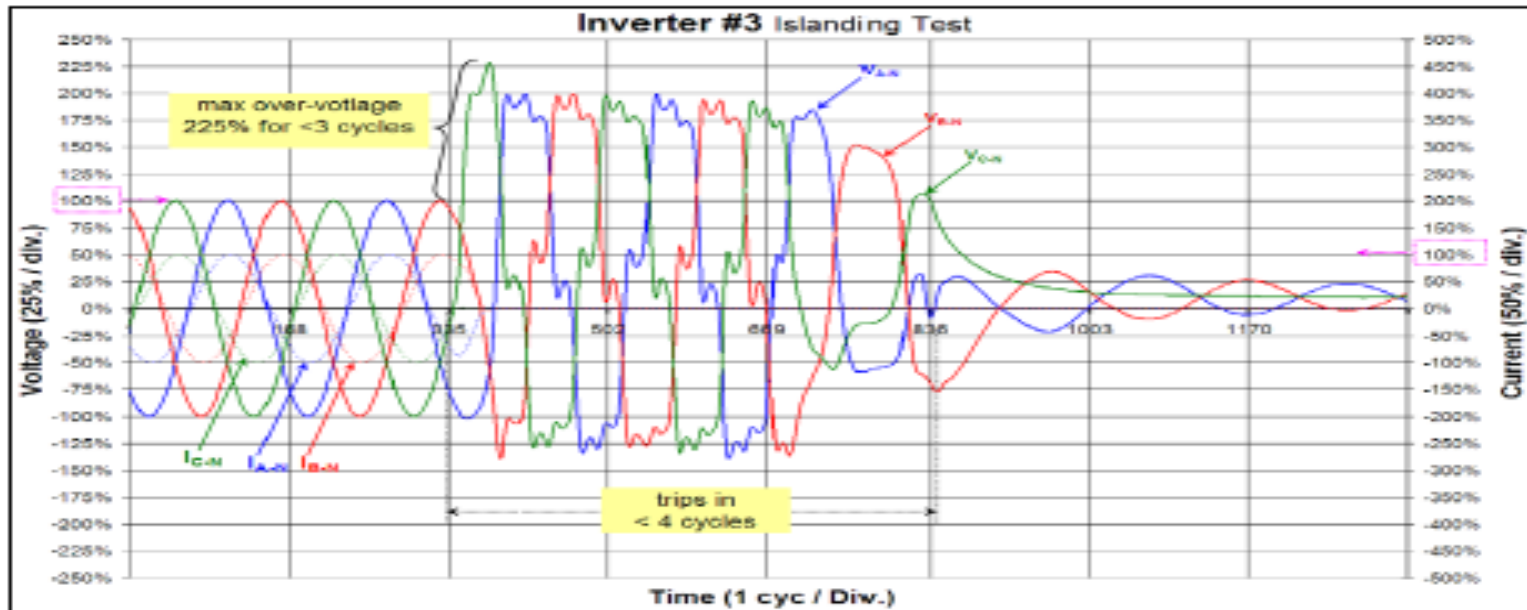
RMS Variation ((NI)_Fepro_Biogas) 08-01-2011 09:32:06



Graph Hydro One



Type 2 TOV Event Up to 225% Transient Over Voltage



Graph SCE

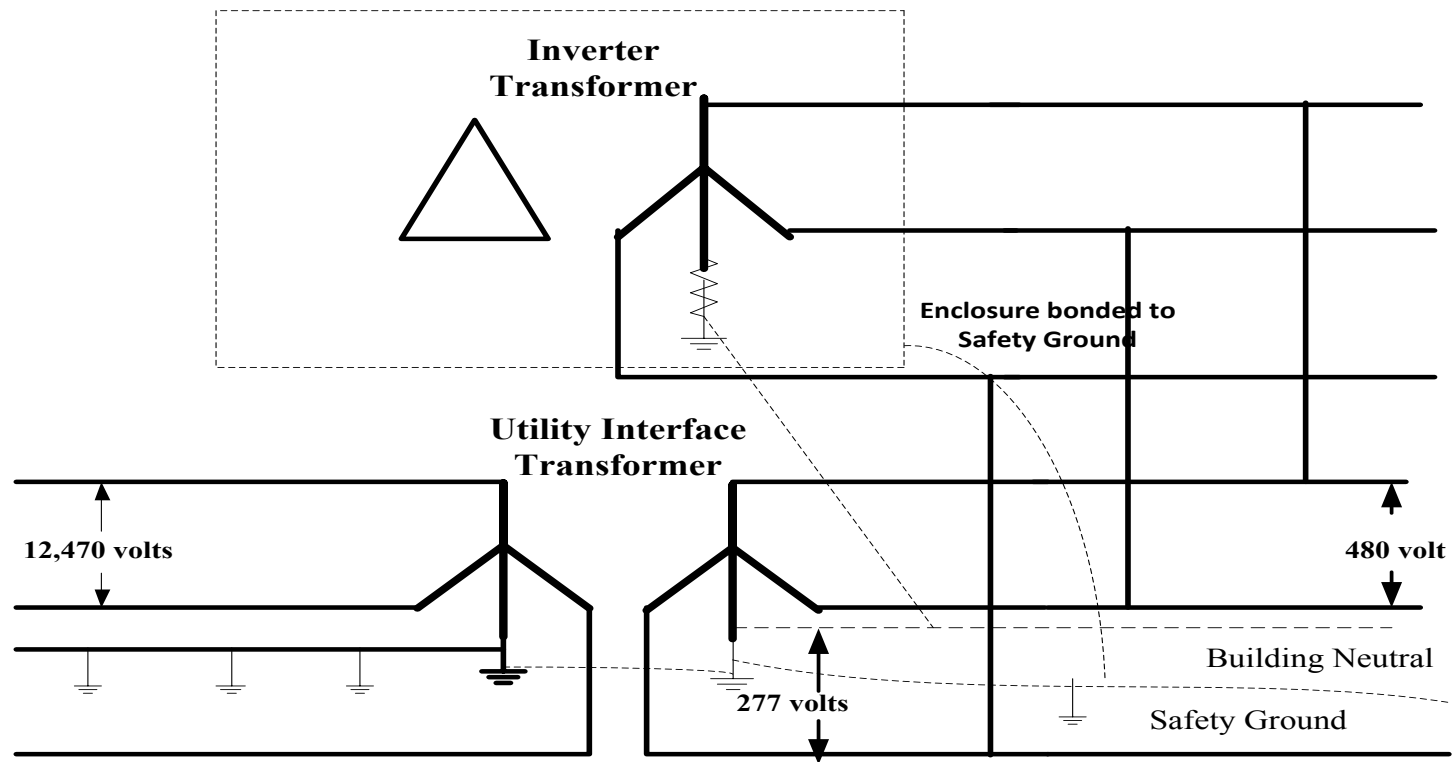


California Rule 21 Screen

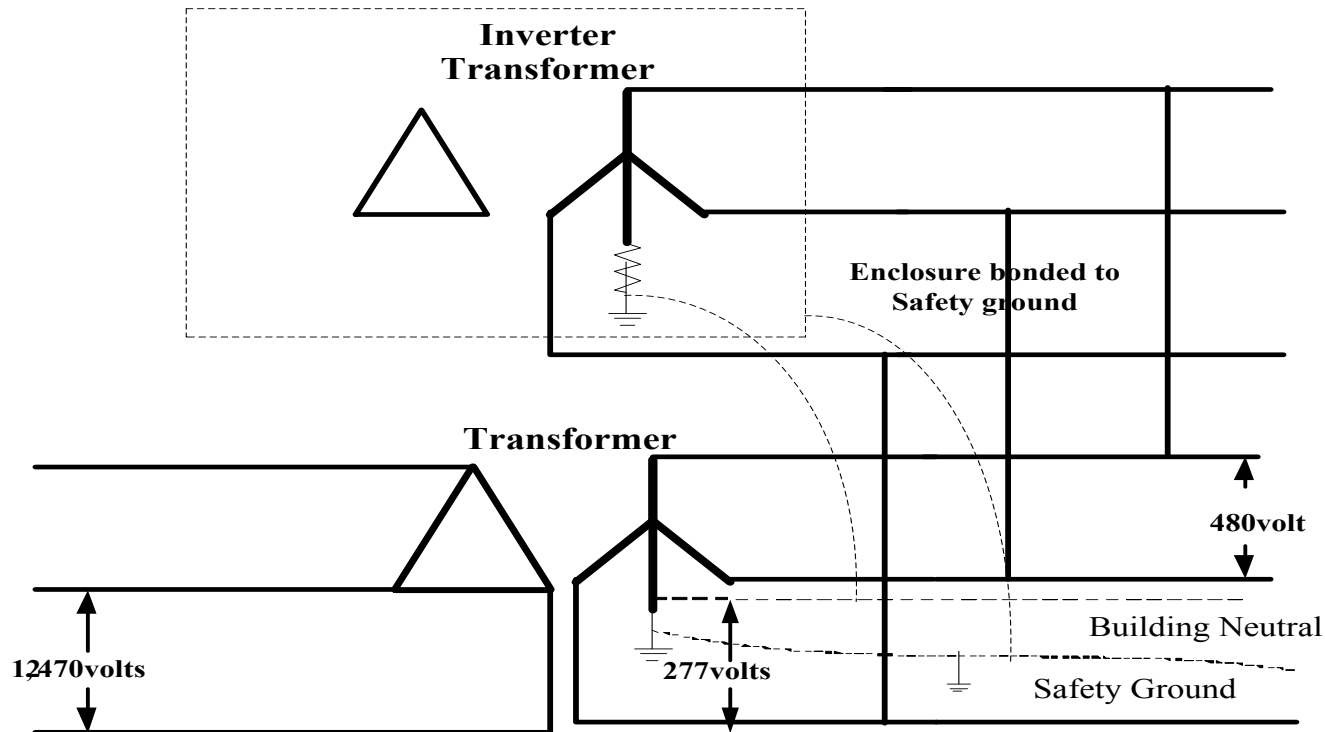
Primary-Distribution Line Type	Type of Interconnection to Primary-Distribution Line	Result/Criteria
Three-phase, three-wire	Any	Pass screen
Three-phase, four-wire	Single-phase, line-to-neutral	Pass screen
Three-phase, four-wire (for any line that has such a section or mixed three-wire and four-wire)	All others	To pass, aggregate DG capacity must be less than or equal to 10% of the line section's peak load



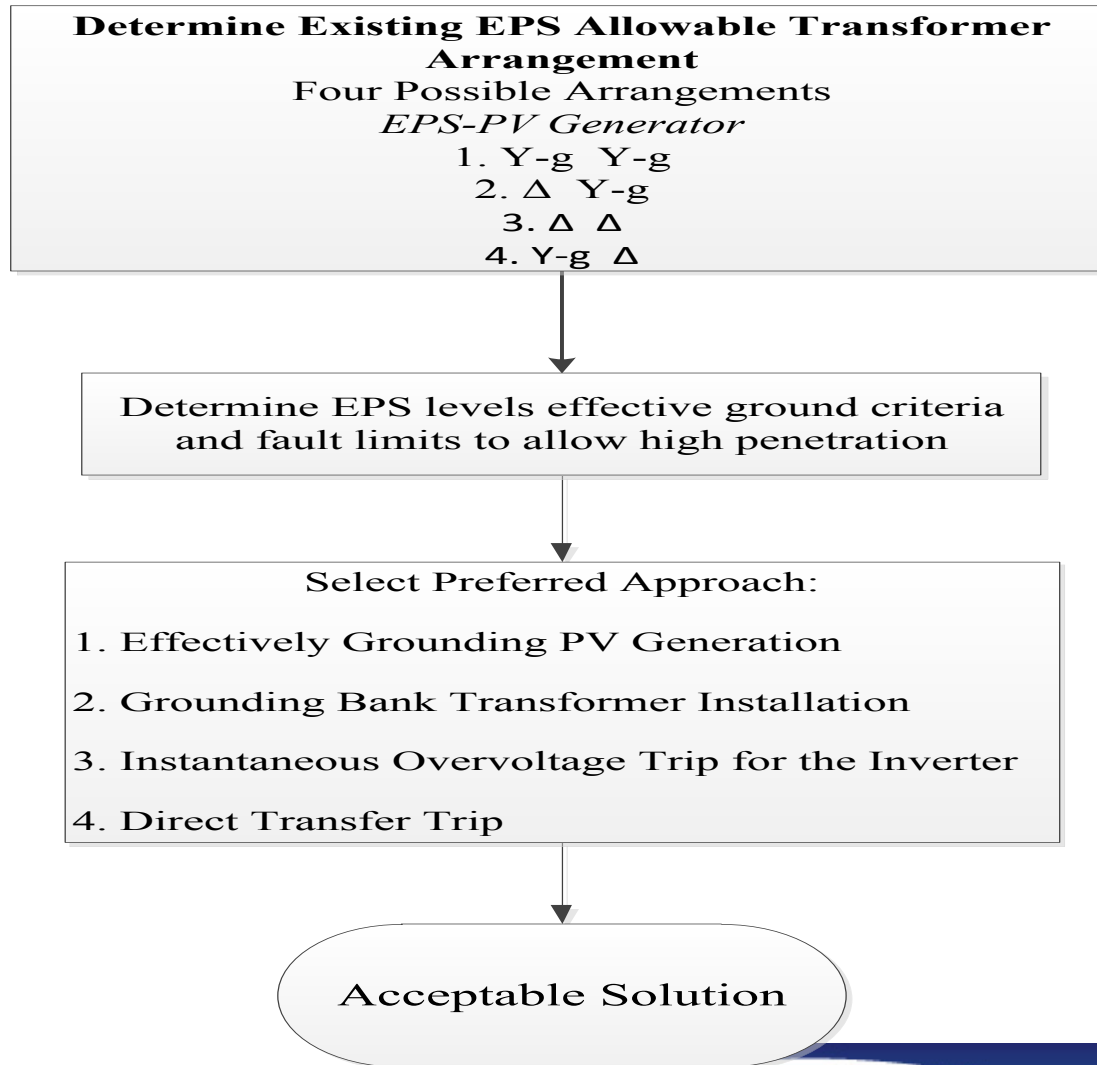
Grounded-Wye Grounded-Wye: Most Common



Delta Grounded-Wye: Second Most Common U.S. and Most Common Europe



Recommended Process to Mitigate Risk of TOV From PV Interconnection



Next Steps

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Solar America Board for Codes and Standards



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