# IEEE 929–2000

## Recommended Practice for Utility Interface of Photovoltaic (PV) Systems

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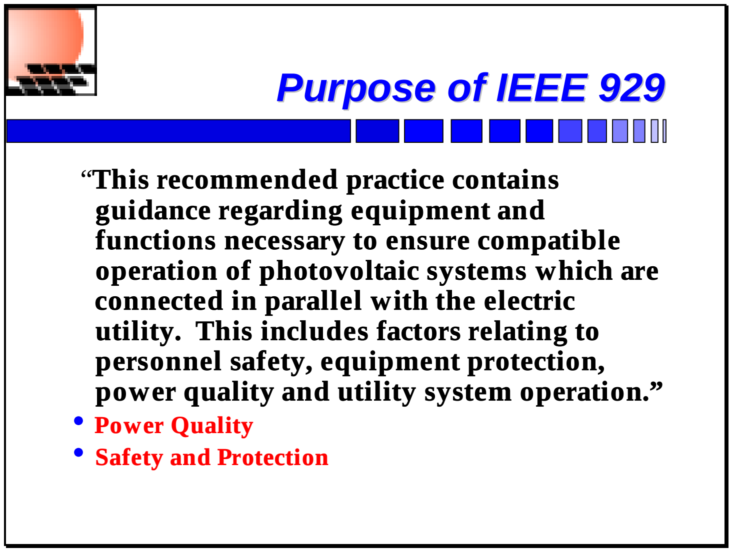
This presentation is a brief overview of the content of IEEE Standard 929-2000. This is the key document for the utility interconnection of PV systems. It contains sufficient requirements for PV systems of 10 kW or less. It also contains reasonable guidelines for larger systems up to 500 kW. Larger systems may need additional review given the constraints specific to the section of the utility system that the PV system is connected.

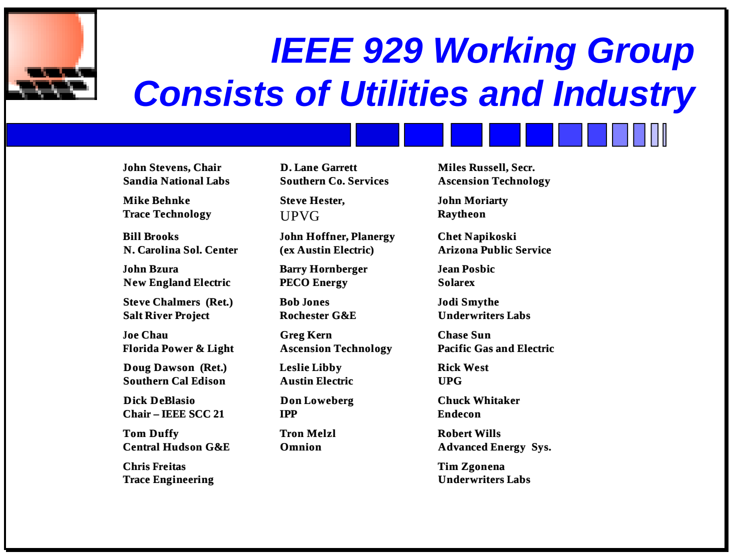
## The Need for PV Interconnection Standards

- **Many utilities were using "Rotating Machinery" requirements for PV systems**
- **Many of the Interconnection Requirements were established in early "PURPA" days**
  - **too many requirements**
  - **telemetery and "Utility Grade" type relays**
  - **special (and costly) engineering were needed for each specific utility requirements**

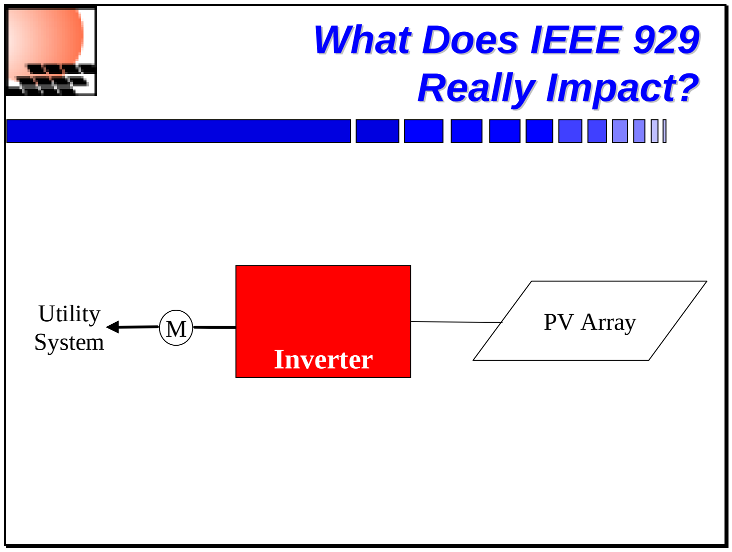
The earlier version of IEEE 929-1988 was not specific enough to pass as a sufficient requirement. It was virtually unused after it passed the IEEE Standards Board. Many utilities have used requirements developed for much larger systems (over 1 MW) for very small systems (under 10 kW) making the cost of interconnection too expensive to be practical.



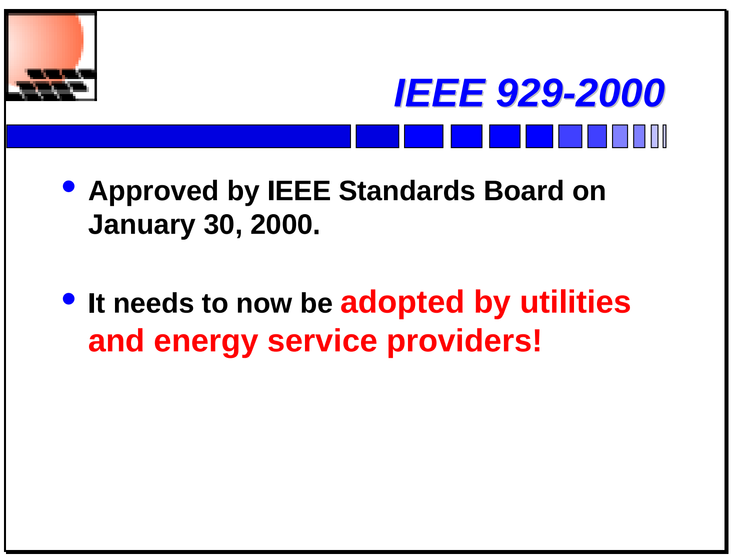

This is a direct quote from the IEEE 929-2000 document.



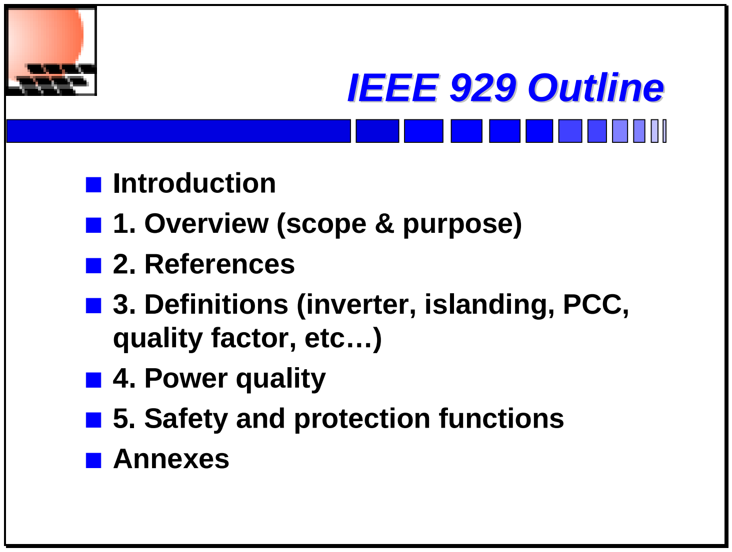

The development of IEEE 929-2000 was a consensus process that had broad representation from a wide variety of stakeholders. Several of the utility members of this committee are among the foremost engineers in the protection engineering field. This is significant particularly for utility companies that may be unfamiliar with PV but may be familiar with, and trust the judgment of, the engineers who worked on this committee.



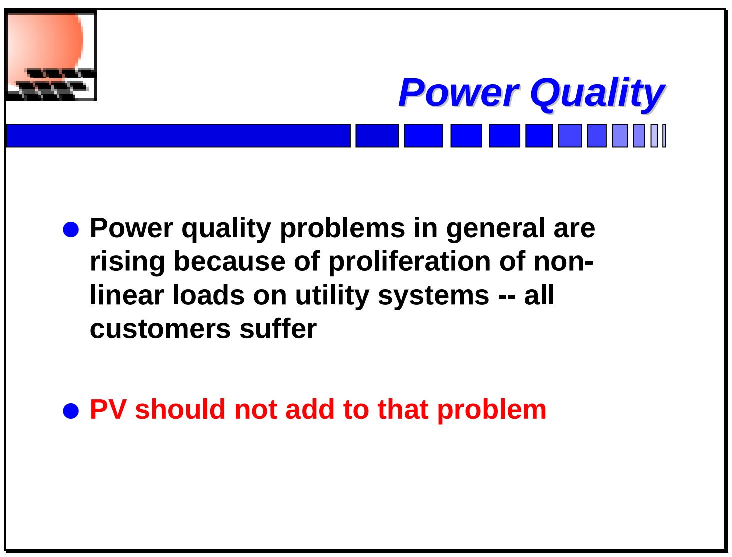

The inverter is the focus of the IEEE 929 standard since it contains the necessary utility interconnection controls.




IEEE 929 is a voluntary standard that must be adopted by individual utilities. As an IEEE standard it carries significant weight and the working group make-up provides additional support for why a utility should adopt the standard.




IEEE 929-2000 Document outline




Power quality guidelines are very important so that utilities have the assurance that the proliferation of PV systems on their utility system will not negatively impact other customers.

## Power Quality

- Power Quality
  - 1. Service Voltage
  - 2. Voltage Flicker
  - 3. Frequency
  - 4. Waveform Distortion
    - IEEE 519
  - 5. Power Factor

These are the sections of the document that contain the power quality requirements.

## Safety and Protection Functions

- 1. Response to Abnormal Utility Conditions
  - a. *Voltage Disturbances*
  - b. *Frequency Disturbances*
  - c. *Islanding Protection*
  - d. *Reconnect After a Utility Disturbance*
- 2. Direct Current Isolation
- 3. Grounding
- 4. Manual Disconnect

These are the sections of IEEE 929 dealing with the safety and protective function requirements of PV inverters.

## Response to Abnormal Utility Conditions

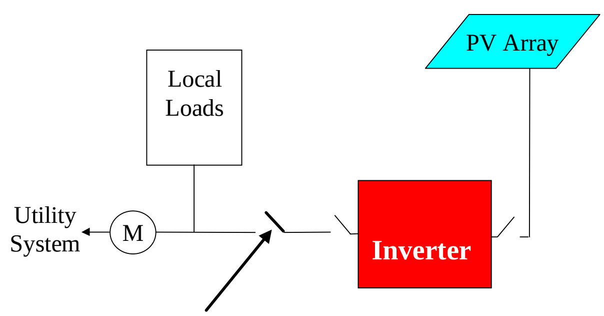
| Voltage (at PCC) | | Maximum Trip Time* |
|---|---|---|
| V< 60 | (V<50%) | 6 cycles |
| 60≤V<106 | (50%≤V<88%) | 120 cycles |
| 106≤V≤132 | (88%≤V≤110%) | Normal Operation |
| 132<V<165 | (110%<V<137%) | 120 cycles |
| 165≤V | (137%≤V) | 2 cycles |

| Frequency (at PCC) | Maximum Trip Time* |
|---|---|
| <59.3 Hz | 6 cycles |
| 59.3 - 60.5 Hz (normal) | -- |
| >60.5 Hz | 6 cycles |

*"Trip time" refers to the time between the abnormal condition being applied and the inverter ceasing to energize the utility line. The inverter will actually remain connected to the utility to allow sensing of utility electrical conditions for use by the "reconnect" feature.

These tables contain the voltage and frequency requirements within which the PV inverter is allowed to operate. Conditions outside these limits must initiate a "trip", which is described as the time between the abnormal condition being applied and the inverter ceasing to energize the utility line. The inverter will actually remain connected to the utility to allow sensing of utility electrical conditions for use by the "reconnect" feature, but no power will flow from the inverter to the grid in this state.

## Manual Disconnect Switch




The bolded switch shown on this diagram is the manual disconnect switch referred to in IEEE 929. The primary purpose of this switch is to provide a visible load break from the PV system when the utility determines that the PV site needed to be isolated from the utility during maintenance on utility lines. This switch would only be operated when the utility were operating in the immediate vicinity of the maintenance work.

## IEEE 929 - Annexes

- **Annex A (Normative) – Minimum Test Procedure for a Non-Islanding PV Inverter**
- **Annex B (Informative) - Bibliography**
- **Annex C - PV Inverters and the Utility Interface (Terminology)**
- **Annex D - Disconnect Switches & Utility Procedures**
- **Annex E - Islanding as it Applies to PV Systems**
- **Annex F - The PV Inverter Under Utility Fault Conditions**
- **Annex G - Dedicated Distribution Transformer**

This a list of the Annexes to IEEE 929. The first Annex is a test requirement for the document. The remaining six Annexes are informative by nature and provide excellent background information for engineers who are unfamiliar with PV systems.

## Terminology

- Power Conditioning Unit or Inverter
  - Line-Commutated Inverters
  - Self-Commutated Inverters
  - Inverter Shut Down
  - The PV Inverter as a UPS
  - Power Factor
  - Controls Integrated into the Inverter
- Islanding

Annex C of the document explains some common terminology in the utility-connected PV industry.

## The PV Inverter as a UPS

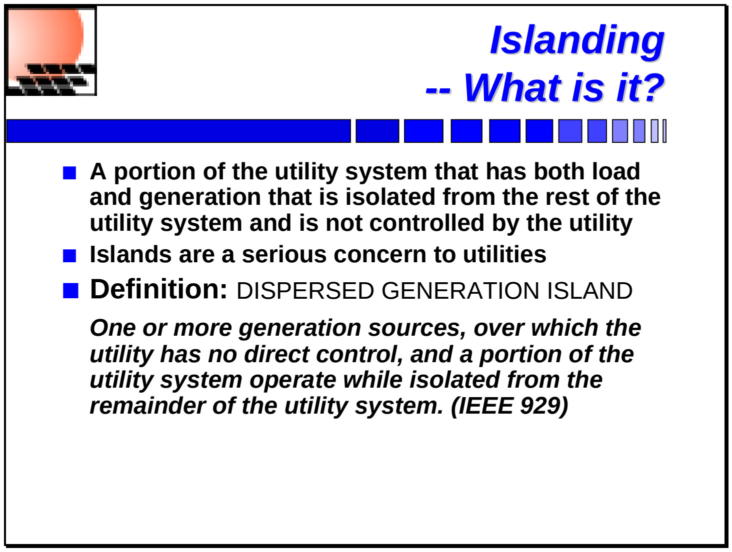
- Some inverters are designed to provide uninterruptible power to critical loads
- The power to critical loads is maintained when the connection to the utility is severed
- When the inverter ceases to energize the utility line (due to abnormal conditions, the inverter will continue to maintain the loads connected to a special distribution panel isolated from the utility, also no power flows to the utility

Many smaller PV systems, and some larger systems, contain uninterruptible power capabilities. These unit disconnect from the grid and only power the local load during abnormal utility conditions, no power flows to the grid..

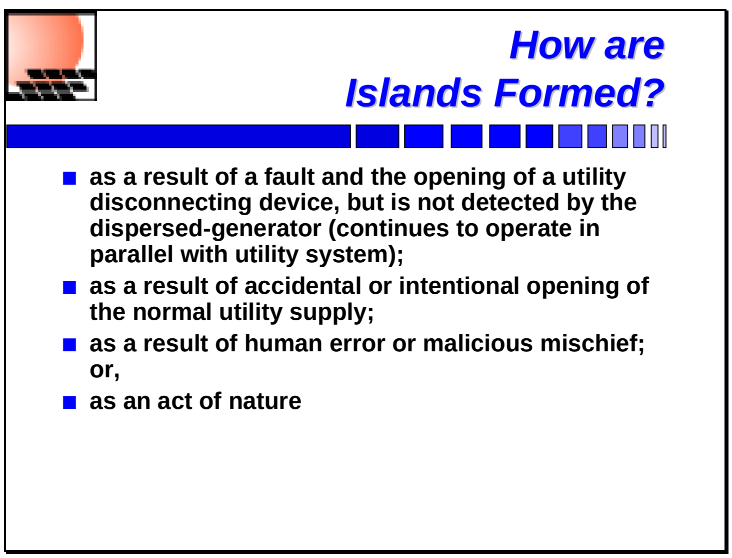
## How Does a Utility, or a PV-System Purchaser, Know If An Inverter Meets The Requirements of IEEE 929?

Require an inverter that meets the testing requirements of Underwriters Laboratories test standard UL 1741 and has the words "Utility-Interactive" printed directly on the listing label

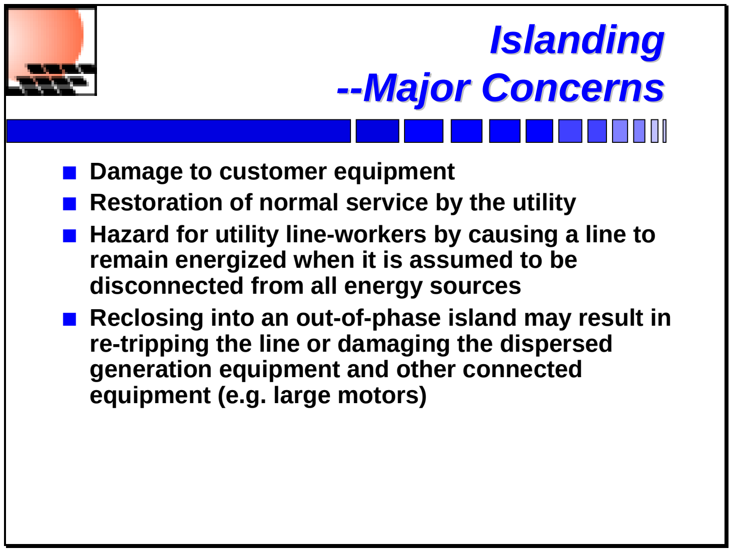
The UL 1741 test standard contains the testing required by IEEE 929. A utility engineer, customer, or inspector, simply needs to know that it was tested to the most recent UL 1741 test standard. It should also have the words "Utility-Interactive" printed on the listing label.



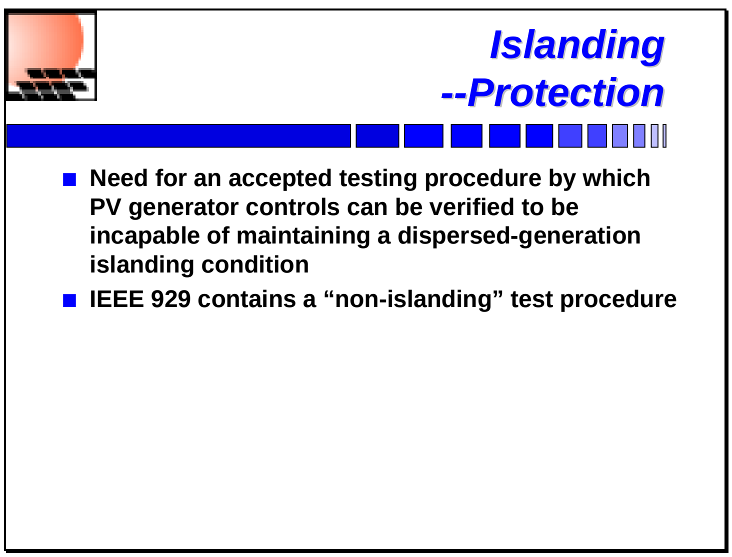

This slide describes the concept of unintentional utility system islands. This is a serious concern to utilities for safety and reliability reasons.




This are the typical causes for unintentional islands.




These are the primary concerns of utilities with unintentional islands.




The issue of detecting unintentional islands and disconnecting a PV system from these islands has been a subject of discussion in the utility industry for 20 years. Many methodologies have been developed to address this concern, but each method has come under criticism by various utility engineers. The method developed for IEEE 929-2000 contains a detection method that meets the concerns of utilities and can be implemented fairly easily by inverter manufacturers. The next section will go into detail on this testing procedure.