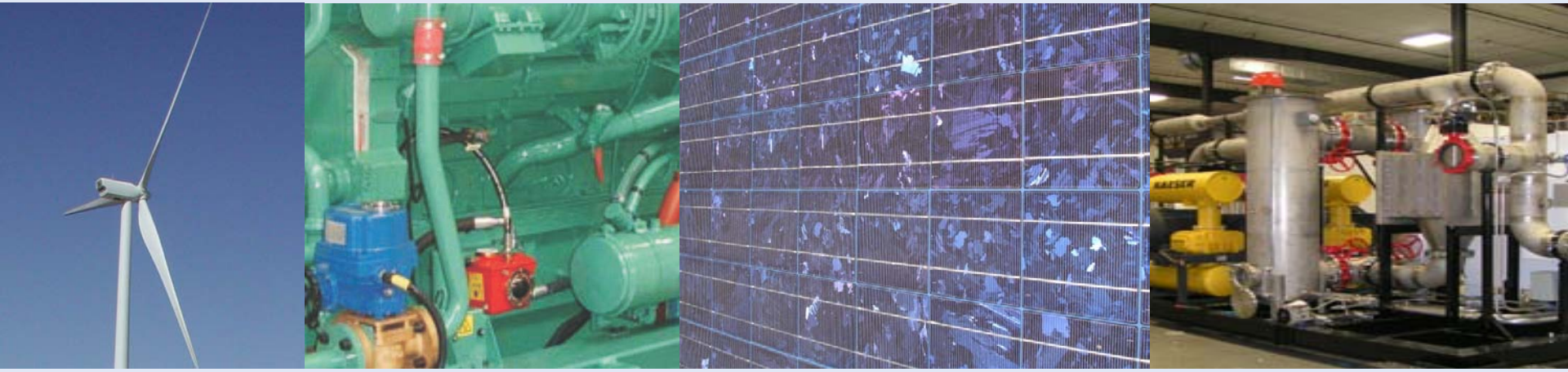

Connecting Renewable Energy is Not a Technical Matter: Rules and Standards to Ensure Safe Interconnection

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Interconnection standards are key

- IEEE 1547 and 1547.1
- California's Electric Rule 21

- Grid Stability and Protection Requirements
- Pre-Interconnection Studies
- Power Quality
- Frequency and Voltage
- Synchronization
- Monitoring Provisions
- Equipment Requirements

Unintentional Islanding

Issue: Islanding occurs when a section of the grid with both load and generation is separated from the larger grid.

Utility Perspective: The biggest concern utilities have about adding to their system is unintentional islanding.

Developer Perspective: The cost of mechanical relays and transfer switches is too expensive and new electronic circuitry can be integrated into inverter components of the facility at a substantially reduced cost.

Regulator Perspective: To ensure the grid's protection, regulators will usually defer to the utilities, as they have the most experience in technical matters of protection.

Best Practices: The risk can be minimized by induction generators, proper protective equipment, and correct sizing and operation of facility.

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Power Quality

Issue: Power quality issues include transients, harmonics, power factor problems, direct current (DC) injection, and voltage fluctuations.

Utility Perspective: Utilities are concerned about voltage and frequency disturbances, voltage flicker, and waveform distortion, so they require that facilities install over/undervoltage and over/underfrequency relays and other protective devices.

Developer Perspective: Protective devices are unnecessary and too costly. New technology, notably in the generators themselves, meets all power quality requirements.

Regulator Perspective: Power quality must be maintained at reasonable levels.

Best Practices:

IEEE Standard 929-2000, Recommended Practice for Utility Interface of Photovoltaic (PV) Systems.

Frequency

Issue: Higher or lower frequencies can lead to improper operation of customer equipment and can damage transformers and capacitors.

Utility Perspective: Must be able to maintain proper frequency levels; use under/overfrequency sensing devices to de-energize circuits that threaten system frequency stability.

Developer Perspective: Facilities less than 30 kW have less impact on system operations and reliability. Facilities over 30 kW improve utility's reliability and should receive credit.

Regulator Perspective: Must avoid frequency changes that affect system operation or customer equipment.

Best Practices:

New York: facility must have minimum automatic disconnect device operated by over/undervoltage and over/underfrequency protection. Three-phase installations must have over/undervoltage protection for each phase and over/underfrequency protection on at least one phase.

Texas: facilities must not deviate more than +0.5 Hz or –0.7 Hz from a 60 Hz base. Generator must automatically disconnect equipment from grid within 15 cycles if limits cannot be maintained.

Voltage/Frequency Disturbance Delay & Trip Times

Range (Frequency in Hz)	Trip Time	
<59.3	0.25	15 (Trip)
59.3 – 60.5	Normal Operating Range	
>60.5	0.25	15 (Trip)

Source: Public Utility Commission of Texas Distributed Generation Interconnection Manual 05/01/02, p. A7-5

Synchronization

Issue: In order to reconnect an islanded portion of the grid to the larger system, various parameters of the power on the separated portion must match those on the larger grid.

Utility Perspective: Synchronization matches voltage magnitude, frequency, phase rotation, and phase angle of the facility with the utility prior to closing the paralleling device. Facility must be able to parallel the utility's system without causing a voltage fluctuation of more than +/-5% at the PCC and meet flicker requirements.

Developer Perspective: Synchronization mostly a major concern for synchronous generators..

Regulator Perspective: Power from the facility must be in synch with the utility for safe and reliable operations.

Best Practices:

Use automatic synchronization devices instead of manual devices

Electric power systems over 10 kW that could potentially be islanded and rely on manual synchronization should have, at a minimum: two voltmeters, two frequency meters, and a synchroscope.

If the SCCR > 0.05 (large relative to the size of the local distribution system), the generating facility must use automatic. Facility must be equipped with loss of synchronism protective functions.

California does not allow manual synchronizing when the generating facility is large due to risk of severe voltage problems during synchronization

Monitoring Provisions

Issue: Utilities want to monitor status of generator exporting to grid.

Utility Perspective: Facilities must be monitored for their connection status, real power output, reactive power output, and voltage at the point of connection to ensure personnel safety and avoid operating problems.

Developer Perspective: Utilities often insist on performing the monitoring themselves and charge a fee that increases the cost to develop the project. Furthermore, utilities are not always familiar with the equipment and insist that familiar and more expensive monitoring equipment be used

Regulator Perspective: Monitoring of equipment is important to maintain system integrity and is included in the contract or tariff between the developer and the utility.

Best Practices:

No monitoring is required for units under 200 kW. Units between 200 kW to 1 MW do not require monitoring if protective relaying prevents the facility from injecting energy into the utility's network. All units over 1 MW require monitoring.

The monitoring arrangement should include:

- remote terminal units that provide supervisory control and data acquisition (SCADA)
- communications equipment
- telephone circuit protection equipment
- Transducers
- potential and current transformers
- electrical energy and demand information
- reactive power information
- voltage information
- alarms

The monitoring should display two seconds of data from before and after any fault and should keep data for past 10 fault conditions.

The utility should receive signals for remote monitoring of the isolation device status and normal voltage and frequency levels and notice that the distributed generator is unable to connect to the utility network.

Equipment Requirements

Issue: The equipment necessary varies but all aspects of facility's installation can be greatly simplified when standard equipment is used.

Utility Perspective: Utilities require that the developer's equipment meet certain standards (IEEE, National Electrical Code, etc.) or create specific lists of types of equipment facility must have, usually based on generator output.

Developer Perspective: All developers will have to have the same types of devices so no advantages/disadvantages.

Regulator Perspective: Standard equipment list simplifies application/ approval process and provides an incentive to developers to use "pre-approved" equipment.

Interconnection Equipment Requirements

Public Utility Commission of Texas; http://www.puc.state.tx.us/electric/business/dg/dgmanual.pdf, p. 3-3.

	Closed Transition	Single-Phase	Three-Phase			
	Capacity					
Feature	≤10 MW	≤50 kW	≤10 kW	10 kW–500 kW	500 kW–2 MW	2 MW–10 MW
PUCT Rule Reference	§25.212 (g)	§25.212(d)	§25.212 (e) (3)(A)	§25.212 (e)(3) (B)	§25.212 (e) (3)(C)	§25.212 (e)(3)(D)
Interrupting devices (capable of interrupting maximum available fault current)	X	X	X	X	X	[4]
Interconnection disconnect device (manual, lockable, visible, accessible)	X	X	X	X	X	X
Generator disconnect device	X	X	X	X	X	X
Overvoltage trip	X	X	X	X	X	X
Undervoltage trip	X	X	X	X	X	X
Over-/under-frequency trip	X	X	X	X	X	X

	Closed Transition	Single-Phase	Three-Phase			
	Capacity					
Synchronizing check (A: Automatic, M: Manual)	A	A/M [1]	A/M [1]	A/M [1]	A [1]	A [1]
Ground overvoltage or overcurrent trip	[2]			[2]	[2]	[2]
Reverse power sensing				[3]	[3]	[3]
If exporting, power direction function may be used to block or delay underfrequency trip					X	X
Automatic voltage regulator						[1]
Telemetry/transfer trip						X

[1] Required for facilities with stand-alone capability.
[2] May be required by TDU; selection based on grounding system.
[3] Required, unless generator is less than applicant minimum load, to verify nonexport.
[4] Systems exporting shall have either redundant or listed devices.
Notes: kW = kilowatt; MW = megawatt; PUCT = Public Utility Commission of Texas; X = Required feature; blank = not required.

Additional Information

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NRECA Guide to IEEE 1547
http://www.nreca.org/Documents/PublicPolicy/DGApplicationGuide-Final.pdf

California's Electric Rule 21
http://www.energy.ca.gov/distgen/interconnection/SUP_REV_GUIDELINE_20050831.PDF

Handbook on Best Practices
http://www.usea.org/Programs/APP/Best_Practices_Handbook_India_HYPERLINKS.pdf