Planning and Operations Standards for Solar

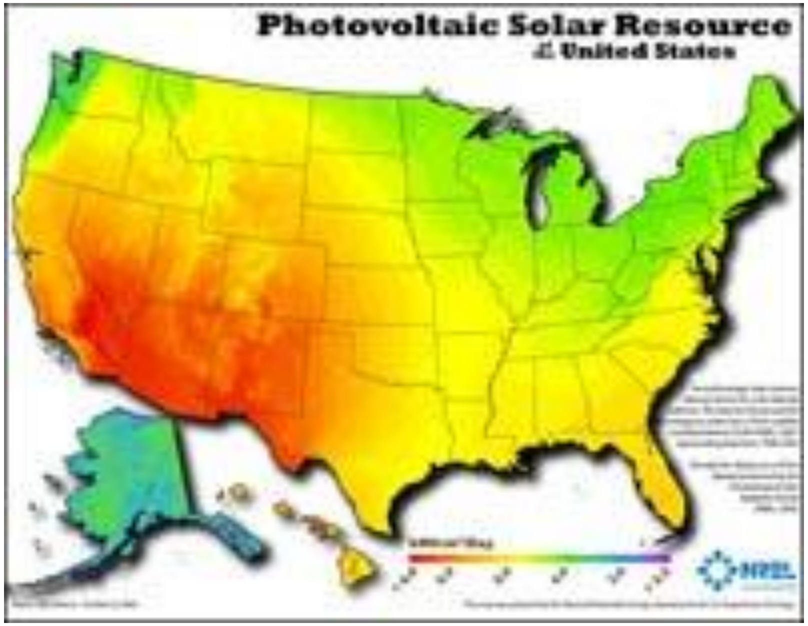
ERCOT

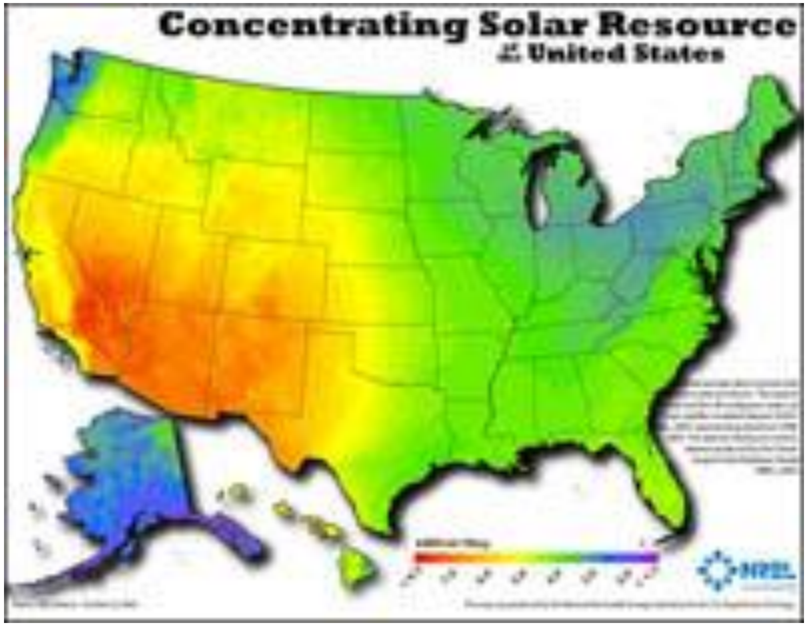
Solar Workshop

April 25, 2011

Outlines

- **Solar Installation Design Issues and Challenges**
- **Protocols and Operating Guides Requirements**
- **Discussion**

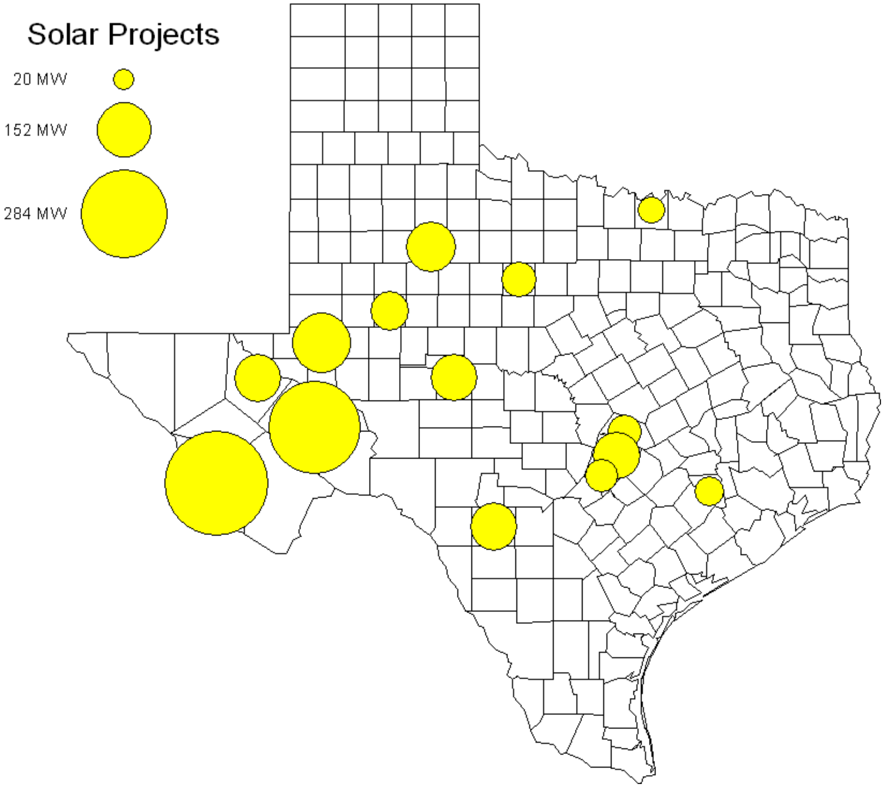




Data source: http://www.nrel.gov/gis/solar.html

Solar Projects in ERCOT

- ~1400 MW under study or in development
- Moving towards larger sized project
- Majority of projects are solar PV



Solar Installation Design Issues and Challenges

Grid Requirement	Design Function	Objective (The need)	Synchronous unit performance	Solar unit options
Static (slow) Voltage Control	Adjust reactive power to maintain voltage profile or in response to central commands	As loading on transmission elements increase, their reactive losses increase. If not compensated, voltage will fall until the grid becomes unstable.	Provided through exciter /automatic voltage regulator control	Solar PV: through DC-AC inverter control and/or additional reactive device such as capacitor/reactor banks.
Dynamic Voltage Control	Rapid, automatic reactive output	During, and after contingency events such as fault conditions, voltage is dragged low by the fault conditions in microseconds. If immediate compensation is not provided, the grid can become unstable and collapse.	Provided through exciter controls.	Solar PV: through DC-AC inverter control and/or additional dynamic reactive device, such as SVC, STATCOM, DVAR…
Inertia Response	Stored energy in the rotating mass	The Inertial Frequency Response provides counter response within seconds to arrest the frequency deviation.	Rotating mass provides inertia support	Synthetic Inertia Response
Primary Frequency Control	Automatic adjust active power in the first seconds in response to a frequency deviation	Primary frequency control is what arrests frequency decline after a loss of generation event. Without it the grid is unstable.	Provided through turbine governor control	Solar PV: through DC-AC inverter control to provide governor-like functions.

Solar Installation Design Issues and Challenges

Grid Requirement	Design Function	Objective (The need)	Synchronous unit performance	Solar unit options
Secondary Frequency Control	Under central control, restores frequency to nominal and restores the generation/load balance at a secure design frequency.	Without Secondary Frequency Control, normally called AGC, frequency drifts from the grid design point, and makes it vulnerable to instability.	Automatic Generation Control	Solar PV: through DC-AC inverter control to provide AGC-like functions.
Ramp Rate Control	The rate of change in MW per minute of a Resource	To prevent a frequency deviation due to larger generation change.	Provided through power regulation	Solar PV: through DC-AC inverter control.
Frequency ride-through	Avoids destabilizing the grid after loss of generation or load events.	If many units trip during a low or high frequency event the grid may become unstable and collapse.	Per operating guides.	Per operating guides.
Voltage ride-through	Avoids destabilizing the grid after fault events	If many units trip during a low or high frequency event the grid may become unstable and collapse.	Per operating guides	Per operating guides.
Small Signal Stability damping	Prevents groups of generators from oscillating against other groups	If groups of units oscillate against other groups of units without dampening, the lines between them may twist out of synchronization and island the group	Provided through tuned power system stabilizers	Solar PV: through DC-AC inverter control to provide PSS-like functions.

Solar Installation Design Issues and Challenges

Grid Requirement	Design Function	Objective (The need)	Synchronous unit performance	Solar unit options
Sub Synchronous Resonance/Interaction (SSR/SSI)	Prevents resonance of units against series capacitors which can cause damage to, or tripping of resources.	Oscillation of turbine shafts, or unit controls at sub-synchronous frequencies can damage resources and equipment.	Provided through tuning of unit design to avoid sub-synchronous frequencies or filtering protection, or protective equipment.	Solar PV may have SSI with series capacitors or neighboring wind/solar plants. Can be improved by adjusting the plant controller.
Energy Schedule and Forecast	Provide the energy output potential for adequate system unit commitments.	For intermittent resources (wind and solar), forecast accuracy can affect the system schedule and result in congestion and/or increasing the need of ancillary service .	Able to provide firm energy schedule in combination with load control allows adjustment of generation output under virtually all conditions with controlled fuel feed.	Wind-powered Generation Resources (WGRs) forecast to provide a reference for wind power energy schedule. Solar Forecast should have the same function.
Dynamic monitoring	Provide high resolution recorded system data (P, Q V, I)	Dynamic performance monitoring allows early detection of system instability and provides a reference for system event investigation after events.	Not provided at this time	To have PMU or DFR for each resource. Not provided at this time.

Solar Installation Design Issues and Challenges

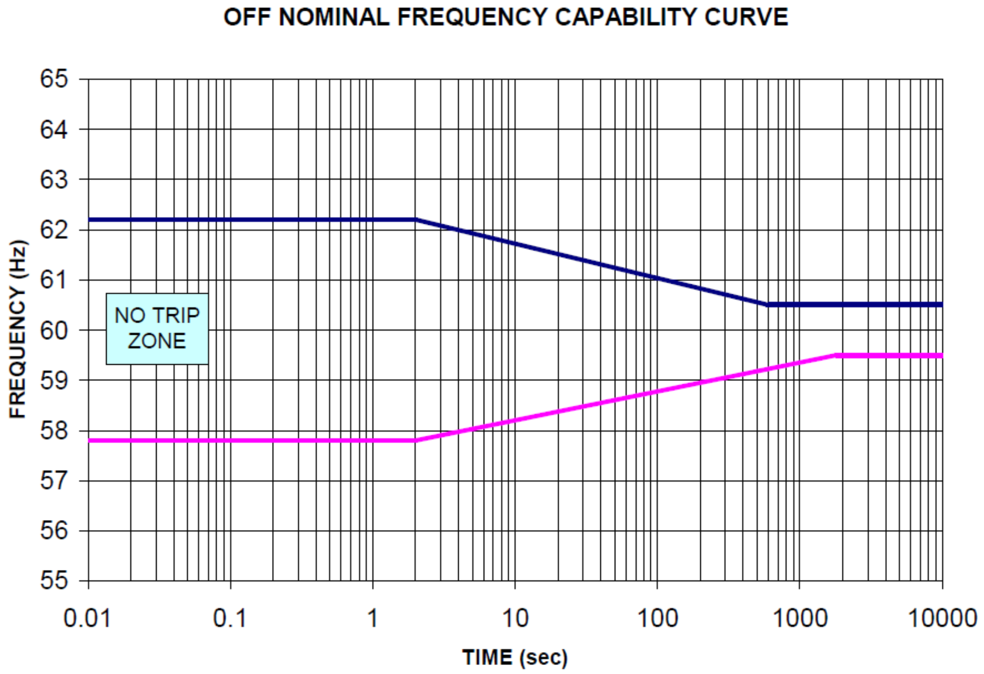
Grid Requirement	Design Function	Objective (The need)	Synchronous unit performance	Solar unit options
Short Circuit Current Contribution	Provide fault current during fault condition.	Relay setting based on fault current can mis-operate or difficult to coordinate with other relays with low or zero short circuit current contribution.	Conventional units generally provides 10-12 times of rated current during fault condition.	It is known that Solar PV provides zero or minimum short circuit current. Improve inverter size and/or control design to provide short circuit current.
Performance when connected to a weak Interconnection Point	Normal response at weak system (for example, low or extre low short circuit ratio)	Minimum short circuit ratio is required for the design units to have normal response.	Help to improve the system strength.	Additional testing and tuning may be needed when connected to weak system.

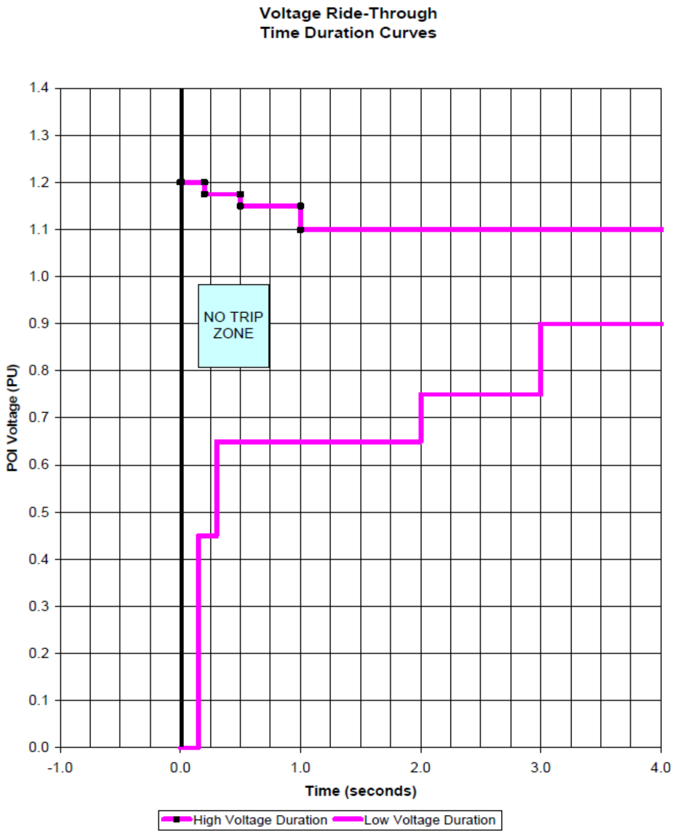
Solar Installation Design Issues and Challenges

Grid Requirement	Design Function	Objective (The need)	Synchronous unit performance	Solar unit options
NERC compliance	Secure system and standard compliance			
Energy Scheduling	The ability to schedule energy with reasonable accuracy			Could we substitute Energy Forecasting?
Load Following or Tertiary Frequency Control	The ability to increase and decrease electrical power and energy output on command	Allows aggregate resource power output to match demand to maintain adequate system frequency (60Hz).	Controlled fuel feed in combination with load control allows adjustment of generation output under virtually all conditions.	Due to the intermittent nature, may not able to increase output without having a active power reserve.

NERC Standard: Example

- **PRC-024 (under development):**
  - Generator Frequency and Voltage Protective Relay Settings





Model Requirements

- **Models are needed for**
  - Interconnection study
  - Grid planning study
  - Operations security assessment
  - Future system assessment
- **Steady-State Study(Power Flow)**
  - Active/Reactive Power capability
  - Voltage control settings
  - Collector system
- **Dynamic Study**
  - Compatible PSS/E standard model or user defined model
- **Short Circuit Study**
  - Pad-mount transformer configuration
- **Other Studies**
  - Detailed (PSCAD) model for Sub-synchronous Interaction (SSI)

ERCOT Protocols and Operating Guides

- **Definition:**
  - *Intermittent Renewable Resource (IRR)*

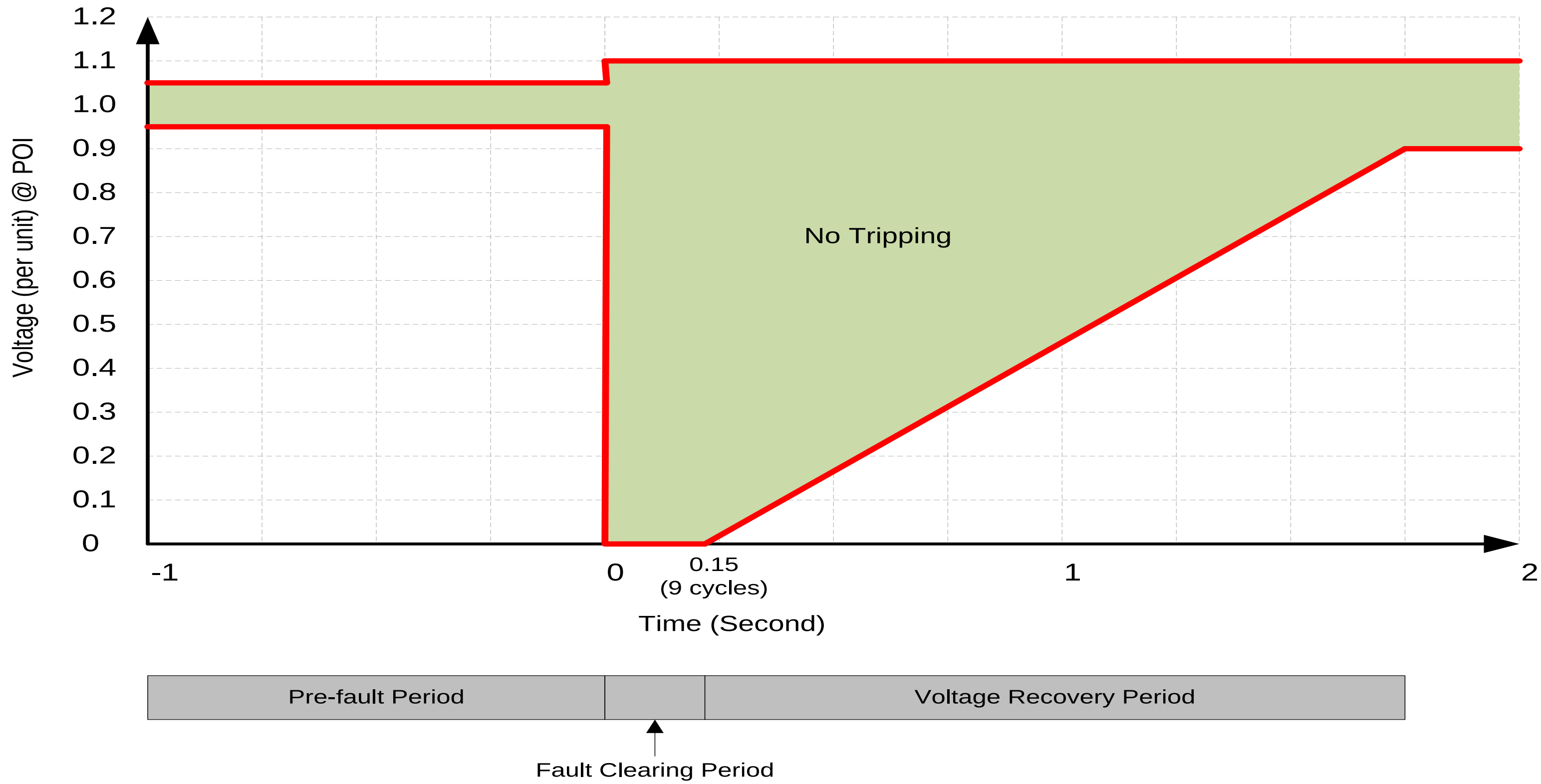
    A Generation Resource that can only produce energy from variable, uncontrollable Resources, such as wind, **solar**, or run-of-the-river hydroelectricity.

ERCOT Protocols and Operating Guides (continued)

- **Voltage control (Protocol 3.15)**
  - Reactive Power Requirements: an over-excited (lagging) power factor capability of 0.95 or less and an under-excited (leading) power factor capability of 0.95 or less, both determined at the generating unit's maximum net power to be supplied to the ERCOT Transmission Grid and at the transmission system Voltage Profile established by ERCOT, and both measured at the POI.
  - The Reactive Power requirements shall be available at all MW output levels and may be met through a combination of the Generation Resource's Unit Reactive Limit (URL), which is the generating unit's dynamic leading and lagging operating capability, and/or dynamic VAr capable devices.
  - Generation Entities may submit to ERCOT specific proposals to meet the Reactive Power requirements established in paragraph (3) above by employing a combination of the URL and added VAr capability, provided that the added VAr capability shall be automatically switchable static and/or dynamic VAr devices. ERCOT may, at its sole discretion, either approve or deny a specific proposal, provided that in either case, ERCOT shall provide the submitter an explanation of its decision.

ERCOT Protocols and Operating Guides (continued)

- **Voltage-Ride-Through (Operating Guide 2.9.1)**



The default clearing period is nine cycles or 0.15 seconds. Recovery time to +/-10% of per unit voltage should be within 105 cycles, or 1.75 seconds. IRRs should not trip for system voltages within the boundary

ERCOT Protocols and Operating Guides (continued)

- **Frequency Control (Protocol 8.5 Primary Frequency Response Requirements and Monitoring)**

  At all times an All-Inclusive Generation Resource is On-Line, its Governor must remain in service and be allowed to respond to all changes in system frequency except during startup, shutdown, or testing. …All Generation Resources that have capacity available to either increase output or decrease output in Real-Time must provide Primary Frequency Response, which may make use of that available capacity. Only Generation Resources providing Regulation Up (Reg-Up), Regulation Down (Reg-Down), Responsive Reserve (RRS), or Non-Spinning Reserve (Non-Spin) from On-Line Resources, as specified in Section 8.1.1, QSE Ancillary Service Performance Standards, shall be required to reserve capacity that may also be used to provide Primary Frequency Response.

ERCOT Protocols and Operating Guides (continued)

- **Frequency Control**
  - *Protocol 6.5.7.10 WGR Ramp Rate Limitations*
    - Each WGR that is part of an Interconnection Agreement signed on or after January 1, 2009 shall limit its ramp rate to **ten percent per minute of its nameplate rating (MWs)** as registered with ERCOT when responding to or released from an ERCOT deployment.
    - Plan to include an IRR ramp rate requirement.

ERCOT Protocols and Operating Guides (continued)

- **Base-Point Following**
  - *Protocol 6.5.7.9 Compliance with Dispatch Instructions*
    - An IRR must comply with Dispatch Instructions when receiving a flag signifying that the IRR has received a Base Point below the HDL used by SCED.
    - This language is currently grey-boxed but will be implemented by ERCOT on 5/18/11
  - *Protocol 6.6.5.2 IRR Generation Resource Base Point Deviation Charge*
    - ERCOT shall charge a QSE for an IRR a Base Point Deviation Charge if the IRR metered generation is more than 10% above its Adjusted Aggregated Base Point and the flag signifying that the IRR has received a Base Point below the HDL used by SCED has been received.
    - This language is currently grey-boxed but will be implemented by ERCOT on 6/1/11

ERCOT Protocols and Operating Guides (continued)

- **Base-Point Following**
  - *Protocol 8.1.1.4.1 Regulation Service and Generation Resource/Controllable Load Resource Energy Deployment Performance*
    - GREDP (%) = ABS[((ATG – AEPFR)/(ABP + ARI)) – 1.0]*100
    - GREDP(MW) = ABS(ATG – AEPFR – ABP - ARI)
    - An IRR must have a GREDP less than 10% or the ATG must be less than the expected MW output for 95% of the five-minute clock intervals in the month when the Resource received a Base Point Dispatch Instruction in which the Base Point was two MW or more below the IRR’s HSL used by SCED. The expected MW output includes the Resource’s Base Point, Regulation Service instructions, and any expected Primary Frequency Response.
    - All Resources, including IRRs, are also scored separately during EEA events

Discussion

- **Registration**
  - Solar will be added to the Resource Asset Registration Form
- **Short Circuit Current Contributions**
- **Solar Forecast**
- **Plant behavior when connected to a weak system**
- **Sub-synchronous Interaction (SSI)**