Integrating Solar Energy
Reliability and Integration of Renewables

Mark Ahlstrom
NextEra Energy Resources, WindLogics
51st Annual Minnesota Power Systems Conference
November 11, 2015

Background

- **WindLogics**
  - Computing, meteorology and applied math folks
  - Forecasting & optimization solutions that enable low cost, reliable & sustainable power systems
  - Subsidiary of NextEra Energy Resources since 2006

- **NextEra Energy (NYSE: NEE)**
  - NextEra Energy Resources
    - -- Largest generator of wind and solar energy in North America
  - Florida Power & Light (FPL)
    - -- Large rate-regulated electric utility (4.7 million accounts)
  - Hawaiian Electric (definitive agreement, pending)

Planning and Reliability
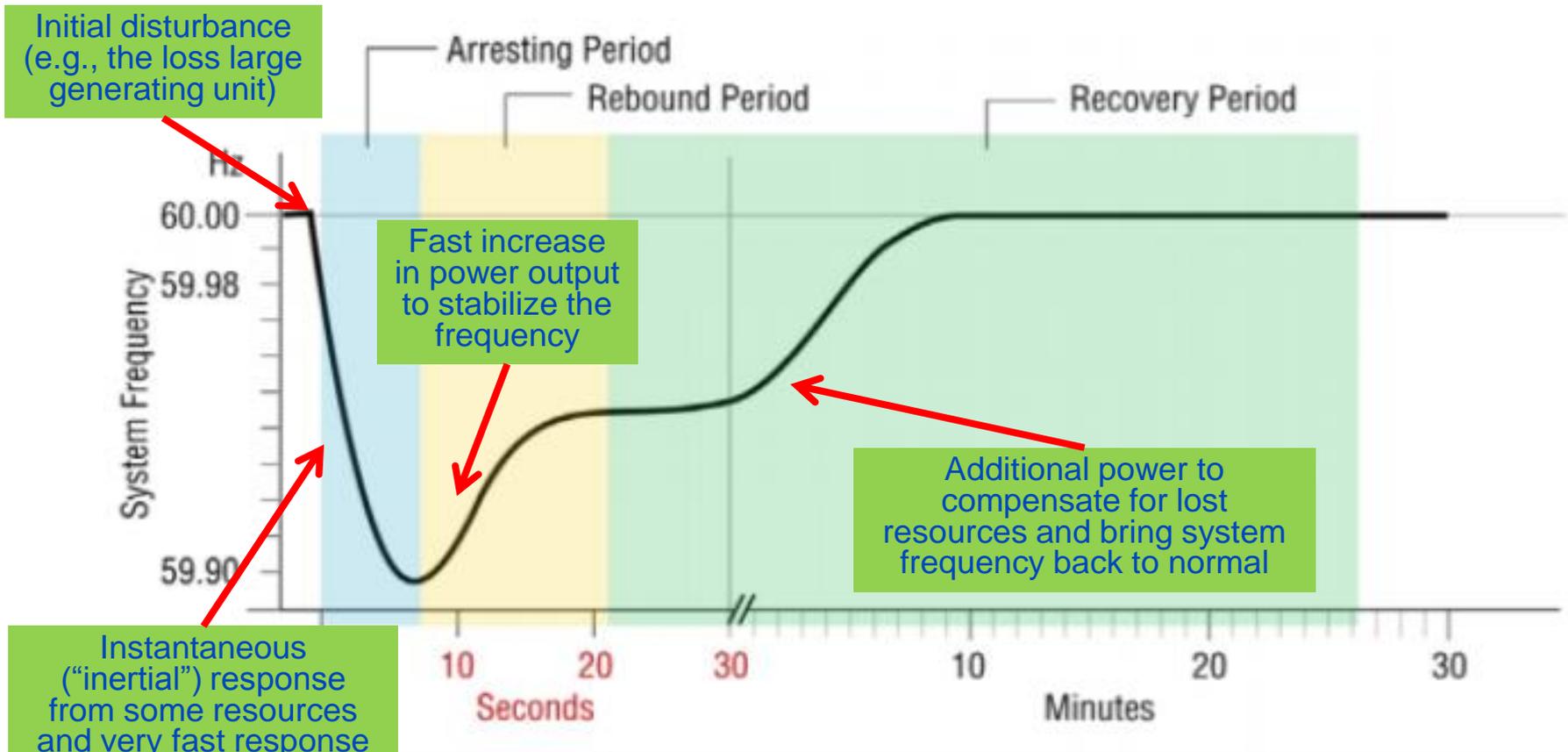
NERC Essential Reliability Services

- **Essential Reliability Services Task Force (ERSTF) was created in early 2014 by NERC's Planning Committee and Operating Committee**

- **Motivation: possible reliability concerns from changing resource mix - "*transformation of the electric grid*"**
  - Retirement of coal
  - Replacement with gas, renewables and demand response

- **ERSTF reports are under final NERC review now and will be released in December 2015**

NERC Task Force - Areas of Focus

Maintaining reliability characteristics of the grid through prudent engineering analyses & planning to ensure that system operators will have the flexibility to meet real-time system reliability needs

- Frequency support
    - Deviations can result in damage to equipment or loss of load
    - Must restore frequency after a disturbance
- Voltage control
    - Local voltage control - normal operations and after disturbance
    - Reactive power is needed to keep electricity flowing and maintain necessary voltage levels.
- Balancing/Ramping
    - Adequate ramping capability to balance load and generation

NEXTera® ENERGY
RESOURCES

Example: Frequency Response to an "Event"

Initial disturbance (e.g., the loss large generating unit)

Arresting Period

Rebound Period

Recovery Period

Fast increase in power output to stabilize the frequency

Additional power to compensate for lost resources and bring system frequency back to normal

Instantaneous ("inertial") response from some resources and very fast response from other resources to slow the rate of fall

NEXTera ENERGY RESOURCES

Balancing areas or interconnections will eventually have additional reporting obligations (beyond capacity margins)

ERSTF Proposed Measures

"Measures" are trend values that are calculated annually and projected for the coming three years

- Frequency support
    - Instance of minimal synchronous inertial response
    - Frequency deviation 0.5 second after largest contingency
    - Minimum frequency and recovery times after a disturbance
- Voltage control
    - Reserve capability and load power factor at various load levels
    - As a best practice, study short circuit ratios for sub-areas of the system, with additional study of areas with low system strength and high penetrations of non-synchronous generation
- Balancing/Ramping
    - Maximum one- and three-hour up and down net demand ramps (load minus production from variable energy resources)

NEXTera ENERGY
RESOURCES

ERSTF General Recommendations

- **All new resources should have the capability to support voltage and frequency**

- **Coordination of NERC reliability standards with Distributed Energy Resources (DERs) equipment standards such as IEEE 1547**

- **Further examine forecasting, visibility and participation of DERs as an active part of the bulk power system**

NEXTera® ENERGY
RESOURCES

What are the capabilities of wind, solar, and other inverter-based resources?

ERSTF General Recommendations

- **All new resources should have the <u>capability</u> to support voltage and frequency**

- **Coordination of NERC reliability standards with Distributed Energy Resources (DERs) equipment standards such as IEEE 1547**

- **Further examine the forecasting, visibility and participation of DERs as an active part of the BPS**

NEXT**era**®
ENERGY
RESOURCES

Capabilities of Wind and Solar

- **Dynamic reactive power is available from today's utility-scale inverters and turbines**
  - Standard feature of GE wind turbines for over 8 years
  - Already provided by almost all utility-scale wind & solar plants
- **ERCOT requires frequency response from wind**
  - An available option from utility-scale wind & solar vendors
- **Hydro Quebec requires inertial response from wind**
  - "Synthetic inertia" is an option on most new wind turbines (uses wind turbine's kinetic energy for very rapid power injection)
- **These options do have additional costs**
  - Compensation, procurement or market products are important
- **Rules should reflect the economics and characteristics of fuel types and technologies**

FERC approved PJM's "Enhanced Inverter" rule in 2015

PJM "Enhanced Inverter" Rules

- **Applies to all non-synchronous generation facilities**
  - wind, solar, storage, etc.

- **Implemented through changes to PJM's pro forma interconnection agreements and the PJM Manual**
  - +/- 0.95 power factor dynamic reactive power at inverter terminals
  - Voltage and frequency ride-through consistent with NERC Reliability Standard PRC-024-1
  - Power management controls must include the capability for active power control, ramp rate control and frequency response

- **Approved by FERC as an "independent entity variation" of FERC Order 661 and 661-A**

- **PJM tariffs include some compensation for the capability, and actual provision of, reactive power**

NEXTera®
ENERGY
RESOURCES

Why Not Use the System Impact Study Process?

- **PJM argued to FERC:**

    – *PJM's system impact studies are not the appropriate mechanism to make long-term planning determinations since they are focused on relatively more near-term transmission conditions.*

    – *Enhanced technologies exist at very low or no incremental cost to allow a prospective interconnection customer to provide dynamic reactive power support.*

    – *A system impact study is only but a small sub-set of expected system condition at the time of the interconnection based on models provided by project developers, and cannot address possible system operating conditions over the life of the project.*

My General Thoughts

- **Reliability services capabilities in new power plants**
  - All power plants should contribute in ways that make economic sense given their fuel and technology characteristics
  - All power plants should ride through disturbances, but we do not expect every plant to provide every reliability service at all times
- **Support performance-based, technology-neutral approaches**
  - Focus on operating performance outcomes
    - -- Discretion on how to achieve performance requirements
  - Identify the needs and procure through the most economic means
- **We will learn and adapt as the generation mix changes**
  - These are good engineering problems

# Operations and Integration

All Generators Impose Operating Constraints

- **Every resource has operating constraints that reflect characteristics of fuel and technology**

- **Conventional limitations**
  - Start-up times & costs
  - Minimum run times
  - Operating ranges
  - Ramp rate limitations
  - Forced outages & contingencies

- **Fuel supply characteristics matter… for gas, nuclear, wind, solar, etc.**

- **The challenge of Variable Energy Resources (VER) is a bit different, but not unique**

NEXTera ENERGY RESOURCES

Unit Commitment and Dispatch

- **Unit commitment and dispatch is a rolling optimization process**

- **"Dispatchable" does <u>not</u> mean being able to provide any desired amount of power at any specified time**
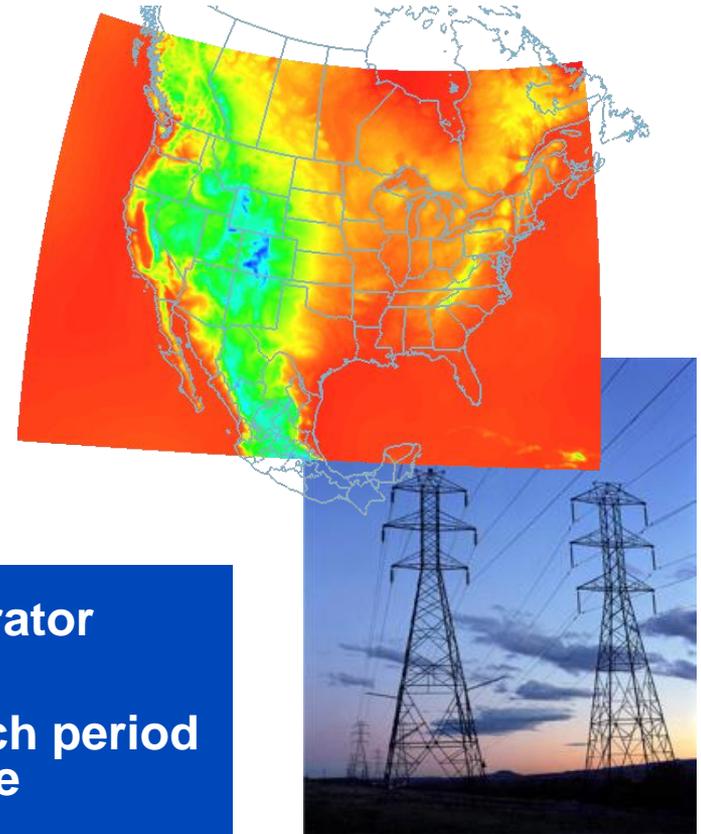
Dispatch is not arbitrarily telling a generator what to produce…

It is knowing what is available for the dispatch period and optimizing the system as a whole

Most Wind in North America is Dispatched Today

Most ISO/RTO systems now include wind in Day Ahead Unit Commitment and Security Constrained Economic Dispatch (SCED)

- **Wind dispatch done with a 10-minute-ahead forecast or faster**

  - Using the current telemetered value ("persistence" forecast)

    -- NYISO, ERCOT, SPP

  - Using a rolling five-minute forecast ("persistence + model" forecast)

    -- MISO, PJM, IESO

- **Not a markets issue (markets may help, but this works anywhere)**

  - Forecast wind into day ahead unit commitment

  - Dispatch the entire system (including wind) every five minutes using a very short term wind forecast or the current telemetered output value

NEXTera® ENERGY RESOURCES
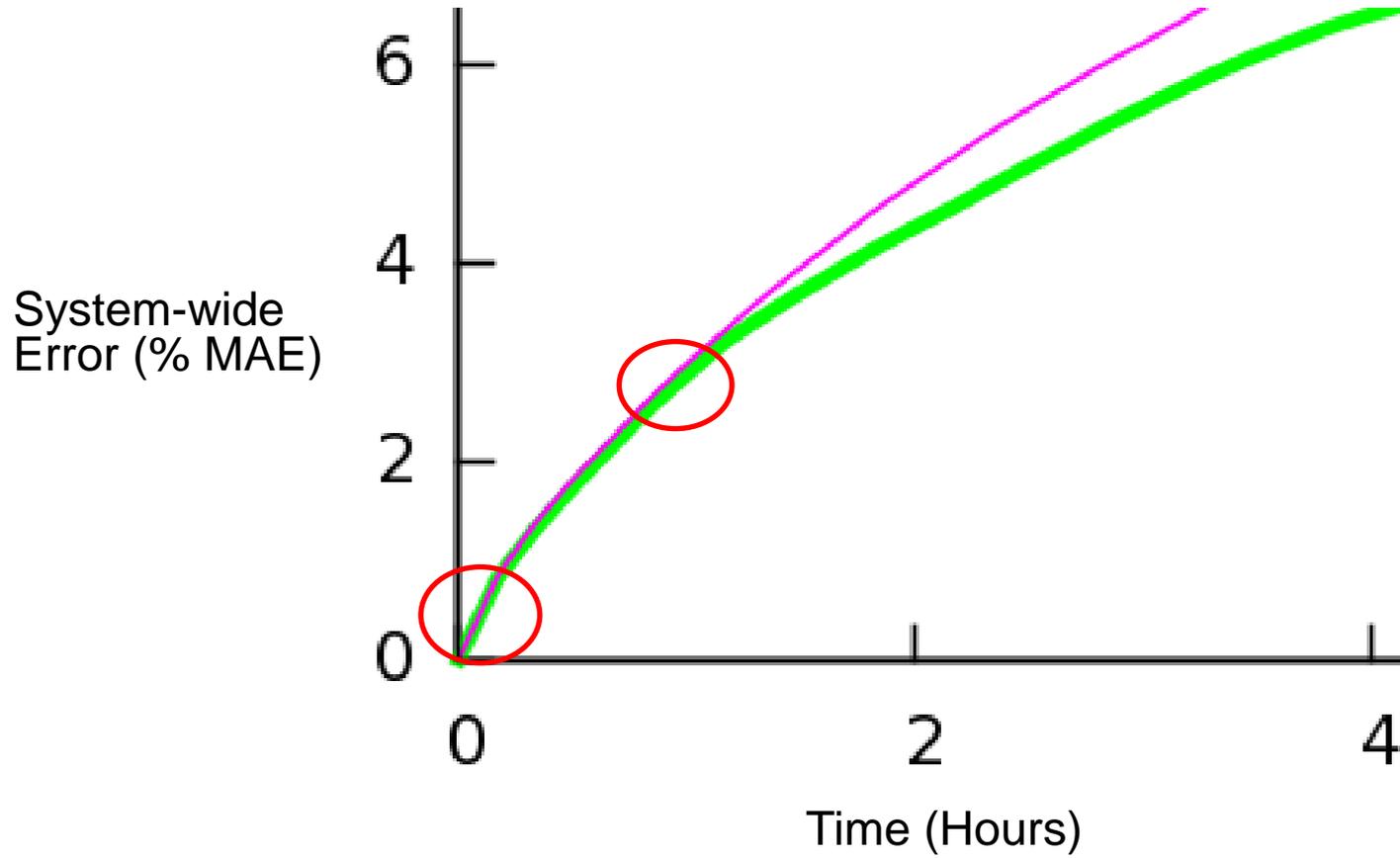
Why is "10 minutes or less" Important?
The Wind Forecast Error Curve

AESO Shortterm Forecast Mean Absolute Error August 2012
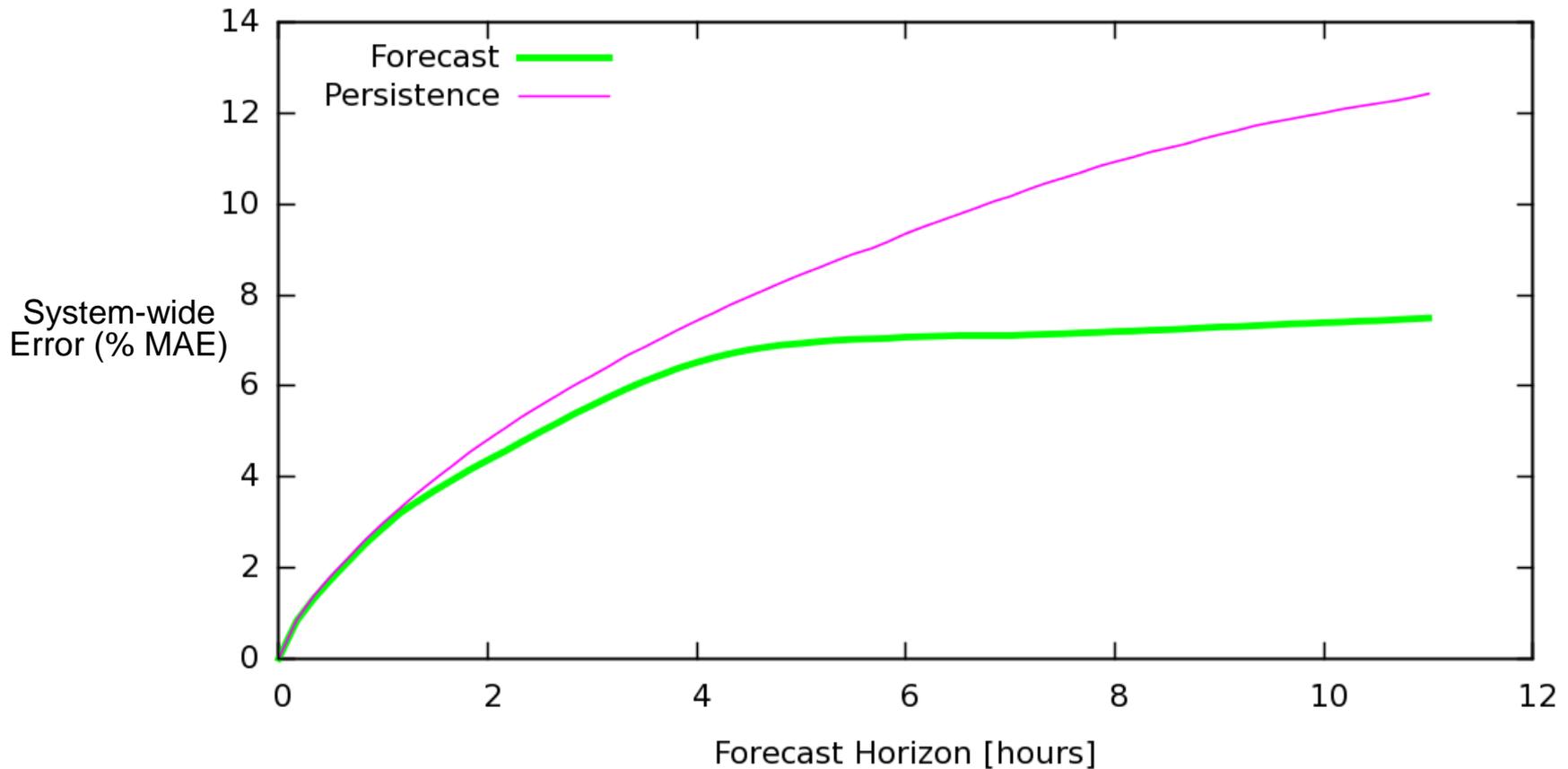
From: Jacques Duchesne, AESO

The Short Term Wind Forecast Error Curve

System-wide Error (% MAE)

Time (Hours)

Adapted from Jacques Duchesne, AESO

Dispatch Changes the Perception of the Problem

"Variability" is the change or error within the dispatch period

  Uses a small amount of regulation

"Uncertainty" is mostly the error from the day-ahead forecast

  Largely handled through the real time dispatch stack

  Could use some non-spin reserve for extreme situations

Is there a ramping or flexibility problem?

  With a deep and robust real time dispatch… not really

  » Wind/solar ramping up - you have dispatch control if needed

  » Wind/solar ramping down - other units are backed down & have room to move up

> **The concept of "net load" becomes irrelevant when wind and solar are dispatched**

NEXTera ENERGY RESOURCES

Is Solar Different that Wind? - System Level

Wind is mostly an uncertainty challenge

Solar is more of a variability challenge

Aggregation greatly reduces both issues

Same "integration best practices" apply

Even at 30-50% penetrations (wind+solar), studies show reliable operation with minimal curtailment of VER resources[1] and no fundamental stability issues introduced by VER[2]

As with any system reengineering scenario, we will need appropriate transmission upgrades, all power plants (including VER) should contribute to reliability, and local issues must be addressed through generator interconnection requirements

1. Useful studies to read: DOE ERGIS and WWSIS, MRITS (Minnesota/MISO)
2. See WWSIS Phase III and MRITS reports for stability/disturbance results

NEXTera ENERGY RESOURCES

Is Solar Different that Wind? - Plant Level

Over short time periods, the wind and wind turbines have significant mass and inertia, so the next 5-10 minutes are quite predictable

But many clouds have abrupt edges and PV solar cells responds instantly (although they are smoothed by large arrays or aggregation)

- Is solar more of a forecasting challenge even within the dispatch time horizon?

- Would nodal wind dispatch, such as done for wind in MISO, lead to excessive penalties by failing to reflect the implicit characteristics of solar PV?

- If so, what level of aggregation will allow reasonable "virtual dispatch" of solar?

- How would this be done in the markets, which assume that generation is nodal?

- What are the political and regulatory realities of solar visibility, control and curtailment? Should they differ for utility-scale solar versus distributed solar?

NEXTera® ENERGY RESOURCES

Best Operating Practices
for Integrating Variable Generation

Recommendations of numerous studies[1]

1. Larger balancing areas

2. Shorter scheduling intervals

3. Better use of flexibility from the entire power system[2]

4. Integrate wind and solar forecasts into tools and markets

5. Review causes and incentives that lead to system inflexibility… many are not physical in nature

1. See http://uvig.org/resources/

2. Integration studies have not shown that storage is needed to integrate wind, nor have the benefits of storage been sufficient to justify building new storage... at least not yet!

NEXTera® ENERGY RESOURCES

Wind and Solar Plants are Power Plants

- **Dispatchable**
  - Easy if done right, high errors if "fuel characteristics" are ignored
- **Ride through disturbances**
  - Wind ride-through requirements exceed those of conventional generators (FERC Order 661A vs. NERC Standard PRC-024)
- **Provide frequency response and voltage control**
  - Implemented for wind in ERCOT and other regions
- **Impressive ramping and active power control**
  - Very fast and accurate response over entire capability range

Wind and solar power plants are part of the solution

NEXTera® ENERGY
RESOURCES

Why UVIG?

Global expertise for wind and solar operations and integration

The leading experts collaborating on today's critical issues

Utilities, RTOs, OEMs, operators, planners, project developers, researchers, forecasting experts, market designers and more

Technically-grounded information and education without lobbying, selling or advocating

Spring Annual Meeting - April 26-28 in Sacramento, CA

O&M User Group Meeting - April 6-8 in Des Moines, IA

www.uvig.org

Utility Variable-Generation Integration Group
Charting the Future of Wind and Solar Power Integration and Operations

UVIG

Discussion

Mark Ahlstrom
651-556-4262
mark@windlogics.com