Summarizing the Technical Challenges of High Levels of Inverter-based Resources in Power Grids

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The future energy system will have more power electronics-based resources (generation, storage, loads, and mobility).

- PV, wind, fuel cells, microturbines, batteries, EVs all use power electronic interfaces to the grid.
- Looking at over 50% annual energy from PE generation by 2050 for large grids.
- Need to work synergistically with other synchronous generators.
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How do we go from 8% to 54% in continental US?
Case Study - Ireland

Ireland System
Peak Load = 6.5GW
Annual Wind = 29%
SNSP Limit = 65%

Ireland Island Wide System Non-Synchronous Penetration 2018

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25% of the time, the system is dominated by non-synchronous generation

Ireland Island Wide System Non-Synchronous Penetration 2018

SNSP Duration Curve
Number of 15 min intervals at various % levels for the entire year

Source: http://www.eirgridgroup.com/how-the-grid-works/renewables/
So how do we get to very high levels on very big grids?

What does 54% across the US mean?
80% RE Case from NREL Renewable Electricity Futures Study

Exported to other regions

ERCOT system is inverter-dominated 59% of hours

High Renewable Penetrations Require Paradigm Change in Power System Operation

Source: B. Kroposki et al., “Achieving a 100% Renewable Grid – Operating Electric Power Systems with Extremely High Levels of Variable Renewable Energy,”
Need advanced controls and technologies to integrate wind and solar while maintaining grid stability and reliability.

High Renewable Penetrations Require Paradigm Change in Power System Operation

Challenges:

- **Transient and dynamic stability** (loss of system inertia could reduce ability to respond to disturbances—need ride-though capabilities in VRE)
- **Frequency regulation** (need primary, secondary, and tertiary response from VRE)
- **Volt/VAR regulation** (need ability to locally change voltage to stay within nominal limits)
Technology addressed:

• Understanding how variable generation (wind and solar) can provide primary and secondary reserves

Impact:

• Inertial control, primary frequency control, and automatic generation control (AGC) from wind and solar are feasible with negligible impacts on loading.


Demonstrated that PV plants (and wind power plants) can deliver essential grid services.

NREL/FirstSolar/CAISO experiment: 300-MW plant following AGC signal

Control Needs for Deploying High Levels of Distributed Energy Resources

- Demonstrated that large plants can receive and respond to AGC signals on the bulk system, but what about DER?

As we migrate from a centrally controlled, synchronous generator-based grid to a highly distributed, inverter-based system...

We need smart inverters with advanced functionality to maintain grid stability and...

Improved optimization for millions of controllable devices in the grid.

Research Needs
- Control theory
- Advanced control and optimization algorithms
- Imbedded controllers in devices
- Linkage to advanced distribution management systems (ADMS)
- Validation of concepts and deployment.

Source: E. Dall’Anese et al., http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6920041
Other Technical Challenges
Protection Coordination

Other Challenges with High Inverter-Based Systems

Challenges:

• **Black-start**—ability to restore system from outage

• **Intentional Islanding** – ability to operate part of the grid using DER (microgrid)

• **Unintentional islanding** (need methods to protect against unintentional islanding)

• **Cybersecurity**?

Utility Outage Map after Storm

The map shows customers who experienced an outage as part of a storm as red dots. Blue dots are customers that would have been impacted before the distribution automation upgrade, but were not affected during the actual storm.

Source: EPB, Chattanooga
Needs to achieve grids with high levels of inverter-based resources

**Definitely need...**

- Inverter-based resources (IBR) need to provide a range of essential grid reliability services to maintain stable grid operations.
- IBR need to act in concert with synchronous generators at any penetration level including 100% IBR.
- Grid codes and standards are needed that define response characteristics for inverter-based resources to transient and dynamic events.
- Accurate models of IBR controls for transient and dynamic analysis.
- Protection schemes that work under high levels of IBR.
- Ability to Blackstart grids with 100% IBR.

**Would be nice if...**

- Inverters could forecast output and flexibility to provide a specific grid service.
- Accommodate bi-direction control signals and respond quickly.
Providing Solutions to Grid Integration Challenges

Thank You!