Engineering the Future Grid

Maximizing Renewable Electricity and Reliability

Mark Ahlstrom

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My Personal Prime Directive

Maximize the reliable and economic deployment of wind and solar in the power system

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Which power system is easier to operate reliably?

75% wind and solar

or

100% wind and solar

What does 75% mean?

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Energy versus Power

% Energy = average over the year

- Today, several regions get 15% of annual energy from wind/solar

% Power = instantaneous percentage of online generation

- For some hours of the year, these same regions get 45% - 60% of their instantaneous power from wind/solar

For reliability considerations, we need to carefully consider the peak power hours, too

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Frequency Response to an "Event"

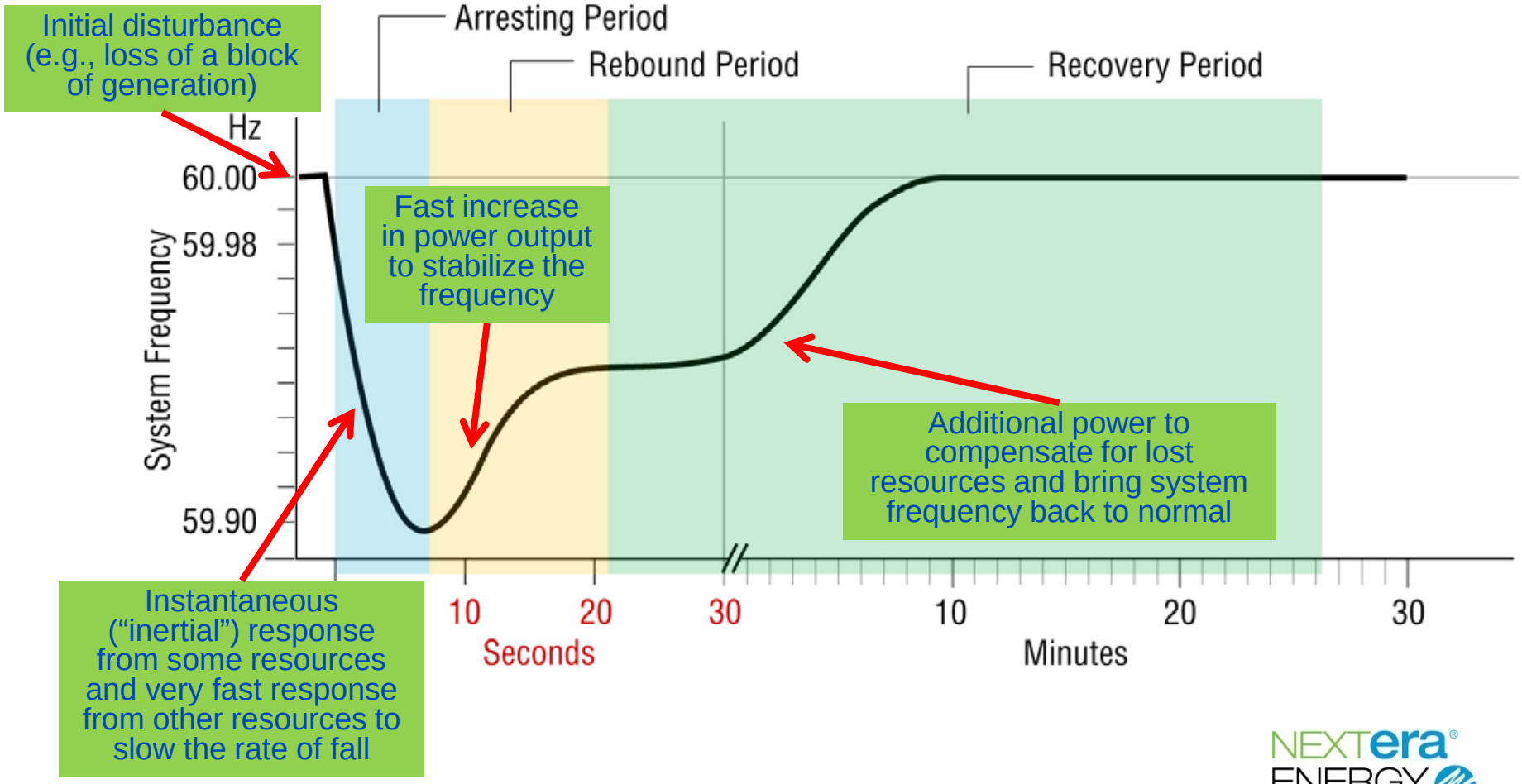

Figure from J. Eto, LBNL,
https://www.ferc.gov/industries/electric/indus-act/reliability/frequencyresponsemetrics-report.pdf

Synchronous versus Non-synchronous Generators

Conventional power plants are electro-mechanically coupled to the grid

- Heavy generators spinning at grid frequency (60 hertz)

Wind and solar power plants are electronically coupled to the grid

- Inverters with very fast power electronics (DC to AC converters)
- This is a digital revolution in power generation, with the ability to program the behaviors that we want to see

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What Behaviors Do We Want?

- **A wonderful engineering problem!**
  - Equipment designers and power system planners find this to be a fascinating challenge
  - Control room operators… perhaps not as excited about it yet
- **Is very accurate frequency still important?**
  - Historically, accurate frequency was important (even for clocks)
  - Still important for synchronous generators and motors
  - But becoming less so (electronics, chargers, high efficiency motors, etc.)
  - Electronically-coupled devices, like wind and solar, can respond so quickly that we need to slow them down to work on today's grid
- **The "inertia-less" power system concept**

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So which power system is easier to operate reliably?

75% wind and solar

or

100% wind and solar

**100% is probably easier than 75%,
but we must maintain reliability through this major transition of the resource mix**

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How do we make the transition?

Wind and Solar Plants are Modern Power Plants

- **Very fast frequency response**
  - So fast, they could respond in the “inertial” timeframe
- **Voltage support**
  - Stabilize local and regional voltage levels on the grid
- **Ride through extreme disturbances**
  - Wind ride-through requirements currently exceed those of conventional generators
- **Ramping and following dispatch signals**
  - Very fast and accurate response over entire capability range

Wind and solar power plants are part of the solution

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Closing Thoughts

- **Value both energy and reliability**
  - All resources should contribute in ways that make economic sense given their fuel and technology characteristics
- **We will learn and adapt as the generation mix changes**
  - These are fascinating engineering problems
  - There is a lot of good work to do
- **Renewables are catalysts for innovation in power systems**
  - A great place for new and creative minds!

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Contact Information

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