The GRID + Renewable Energy > The Basics...
The World is Changing: Are We Changing With it?

- Metaphor is a shorthand for how the world works.
  - As the world changes, our models need to change with it.

- “There are few things as toxic as a bad metaphor. You can’t think without metaphors.”
  -- Mary Catherine Bateson

- Some less helpful metaphors:
  - “Renewable energy costs too much.”
  - “Renewable energy is unreliable.”
  - “Power system operators ensure that generation and load match at every instant.”
  - “We are running out of flexibility to integrate wind.”
  - “We need to back up the wind.”
Power Grid Basics

- The power grid (for our purposes) consists of all electrically interconnected equipment:
  - Generators
  - Transformers
  - Distribution Lines
  - Transmission Lines
  - Customer Loads
  - Ancillary equipment (switches, capacitors, etc.)

- The purpose of the power grid is to generate and deliver electric power to customers in a reliable and economically efficient manner.
  - Growing “distributed generation” (e.g., rooftop solar) and storage could change this.
Water Analogy

• The power grid is almost completely analogous to a water system.
  • Generators = Pumps
  • Transformers = Pressure Reducers/Boosters
  • Distribution Lines = Local Low Pressure Pipes
  • Transmission Lines = Long Distance High Pressure Pipes
  • Customer Loads = Customer Loads
  • Ancillary equipment (switches, capacitors, etc.)
    • Switches = Valves
    • Capacitors = Small Reservoirs
  • Voltage = Water Pressure
  • Current = Flow Rate (e.g., gallons per minute)

Metaphors sometimes come in very handy!
What it Looks Like

The power plant generates electric power in large quantities but at relatively low voltage (pressure) for long distance travel.

Transformers in the substation boost the voltage (pressure) for long distance travel.

Transformers in local substations reduce the voltage for distribution to customers.

Transmission lines convey the electrical power at high voltage (pressure) to efficiently cover large distances (3-7% losses).

Distribution lines carry the low voltage power to our homes.

The power plant generates electric power in large quantities but at relatively low voltage (pressure).
When Everything Works
Power when and where it’s needed

Adequate pressure (voltage) and flow (current) to do the job (power).
Low Voltage (Low Pressure)

Low voltage—plenty of water, but not enough pressure to do the job.
Plenty of voltage—but not enough water to do the job.
Flexibility

Ability to adjust quickly to changing circumstances.
POWER = V \times I
Wind: Benefits and Challenges

• Benefits:
  ➢ Competitive Costs compared with other resources.
  ➢ Relatively benign environmental footprint.
  ➢ Low carbon resource.
    ➢ Estimated carbon savings range from 810 (CEC) – 1,628 pounds per MWh (PJM) depending on mix of fossil resources.

• Challenges:
  ➢ Not completely controllable.
  ➢ More variable and less predictable than other resources.
  ➢ Not available at all times—may not be available at times of high demand.
  ➢ May be abundant at times when demand is low.

• Wind characteristics are different enough to cause system operators to rethink current practices.
Typical Week on BPA System

BPA = Bonneville Power Administration

Based on 5-min readings from the BPA SCADA system for points 45583, 79587, 79682, and 79685
Balancing Authority Load in Red, Wind Gen. in Green, Hydro Gen. in Blue, and Thermal Gen. in Brown
Click chart for installed capacity info
BPA Technical Operations (TOT-Opinfo@bpa.gov)
Day Ahead Wind Forecast

MISO Day Ahead Wind Generation Forecast is provided by a third party vendor. The forecast is produced based on Numerical Weather Prediction models with weather forecast services that are procured by the wind vendor. The snapshot of the forecast is captured at 3:45 p.m. MISO system time the day prior to the displayed day. The displayed date represents the 24 hour of the current calendar day. All points on the chart represent the hourly integrated value and are displayed with the timestamp at the hour ending.

- Download Forecast XML data
- Download Generation XML data

Jun. 16, 2016 - Interval 04:59 EST
What About Storage?

• The need for storage can be reduced through all of the measures on the previous slide.
  • Special emphasis on allowing end use loads to contribute their form of storage capability.
• There already exists a lot of storage in gas fields and pipelines, coal piles, and hydro reservoirs.
• The problem of storage is mainly one of cost—viable technologies exist today (e.g. pump storage).
  • Storage technologies tend not to be cost effective today because our need for storage has not caught up with our concern over it.
Water Heater Storage Pilot

- Water heaters can act as battery storage for the power grid”
  Gary Huhta, Power Manager Cowlitz County (WA) Public Utility District
Can we depend on wind?

- Incremental improvements in current practices can get us to 20%.
- Denmark produces 20% of its electric power from wind today.
  - Denmark’s objective is 50% by 2025.
- Ireland targeting 40% of electric power from wind.
  - Expects to rely on a combination of flexible fossil plants and wind curtailments, without needing storage.
- Island of Bornholm is working toward 100% renewable energy.

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