U.S. Department of Energy

Office of Electricity Delivery and Energy Reliability

Small Hydro and Smart Grid Integration by the U.S. DOE

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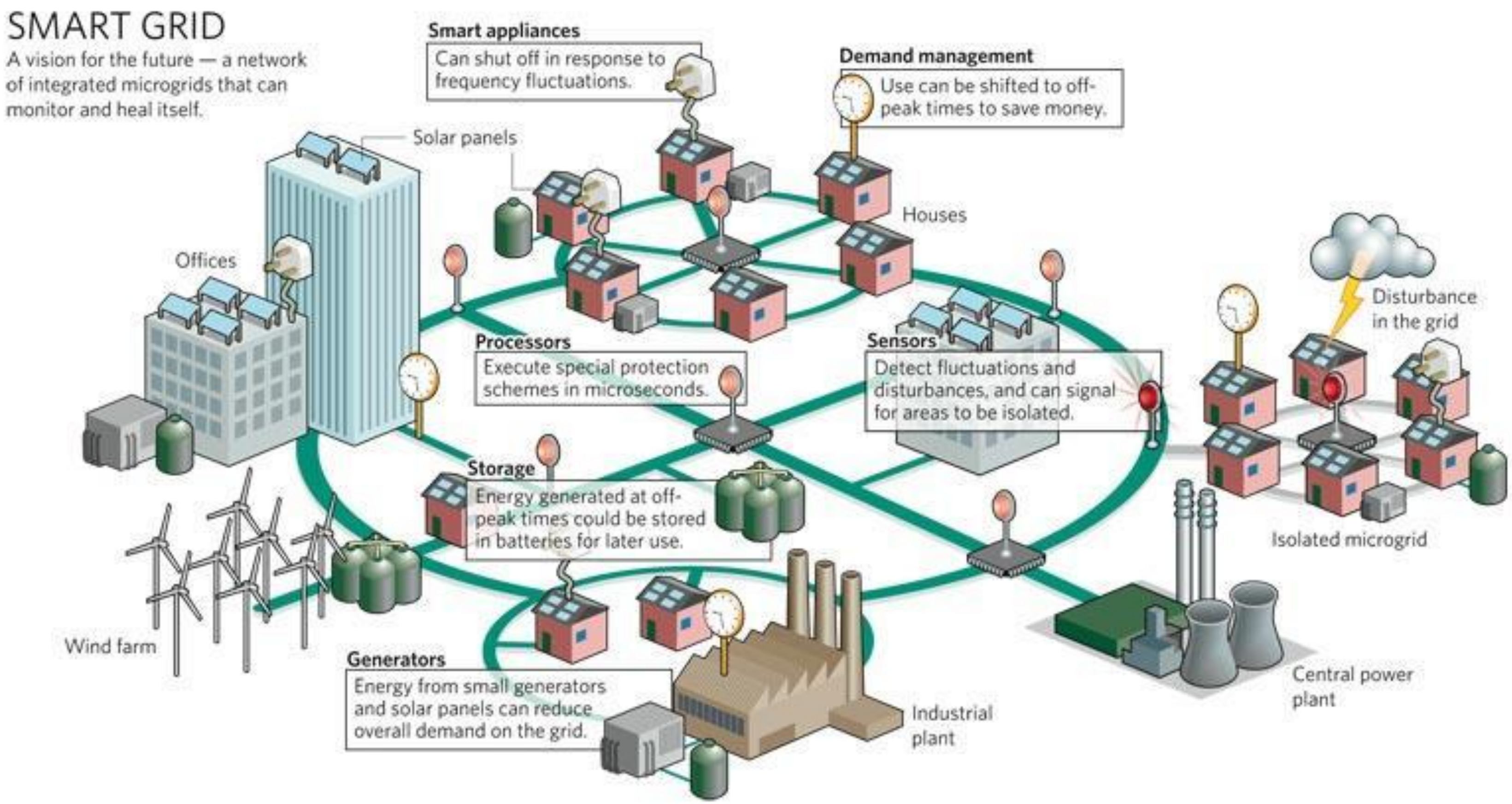
Vision: Smart Grid



Picture courtesy of: Smart Grid 2030

DOE's Smart Grid R&D Program

Focusing on distribution systems and customer solutions, including interfaces and integration with T&G systems

Intelligent Load Management

Develop tools to greatly expand demand response and consumer energy management for improved system efficiency.

Distribution Automation

Develop advanced sensors, communications, and information technologies, with modeling and decision support tools, to provide intelligent responses to changing loads, supply, and failure conditions for improved system reliability.

Microgrids

Develop commercial scale microgrid systems to meet power quality and reliability needs and economic and noneconomic objectives of individual end users.

Microgrid Testbed —
Los Alamos, New Mexico, USA

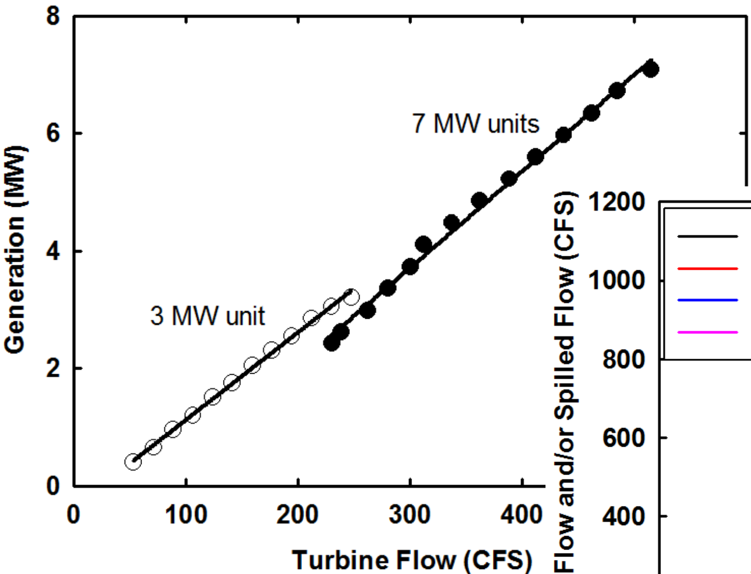
- **~ 1 MW electrical microgrid in collaboration with the local utility, the Japanese NEDO, and LANL**
  - Microgrid includes photovoltaic (PV) generation, battery-based electrical energy storage, and a microgrid controller (µEMS) that integrates the PV into the rest of the utility systems by reducing the inherent fluctuations of the PV generation
  - Fully instrumented to capture system performance—technical and economic
  - Local SCADA link to Abiquiu hydro
  - Microgrid operation already coordinated with local utility electrical dispatch
- **Unique testbed for evaluating small run-of-river (RoR) hydro generation vis-a-vis battery storage in supporting renewable energy integration, while potentially providing other valuable grid services**

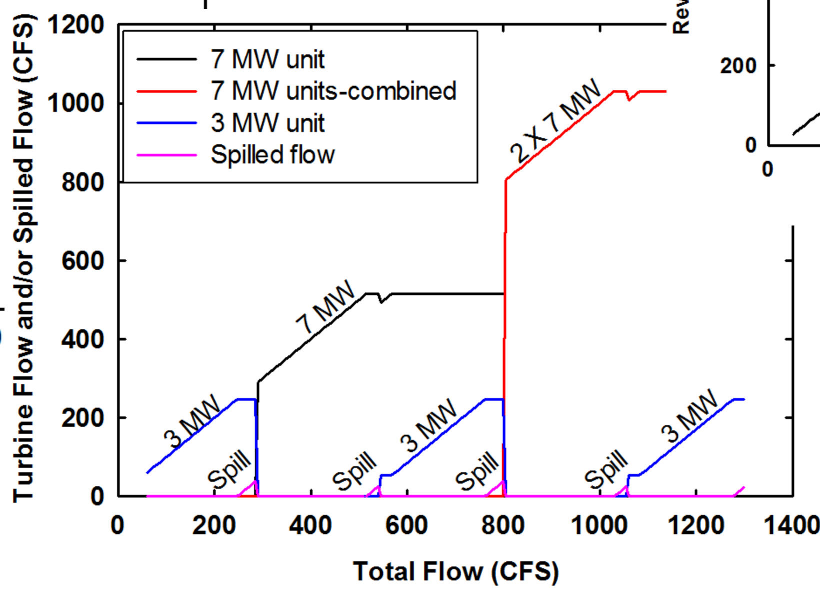
Run-of-River Hydro — What We Have Done

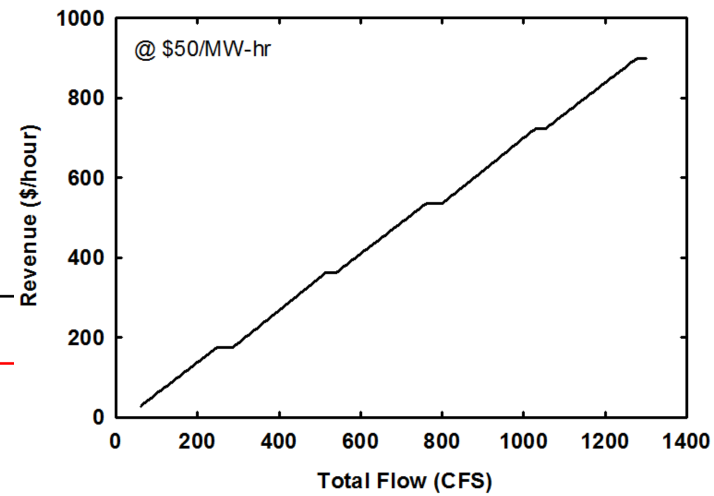
- **Identified available resource**
  - How much flexibility (in MW) Abiquiu can provide without impacting energy revenues
- **Identified desired windows of “steady-state” water flows and compared them to existing operations**
- **Estimated transient impacts on river flows from providing spinning reserve**
- **Performed simulation studies of real-time operations**
  - Estimated PV-smoothing capability of the hydro under a range of operating assumptions
    - Allowable deviation from water flow schedule
    - PV forecast quality
  - Estimated impact on instantaneous water flow and daily discharge accounting

Identify the Available Resource—Base Revenue

- **Abiquiu is a 17 MW hydro station including 3 turbines:**
  two 7-MW units; one 3-MW unit
- **The two types of units have different flow regimes and efficiencies**
- **The efficiencies drive an economic dispatch among the turbines to maximize energy production/revenue**

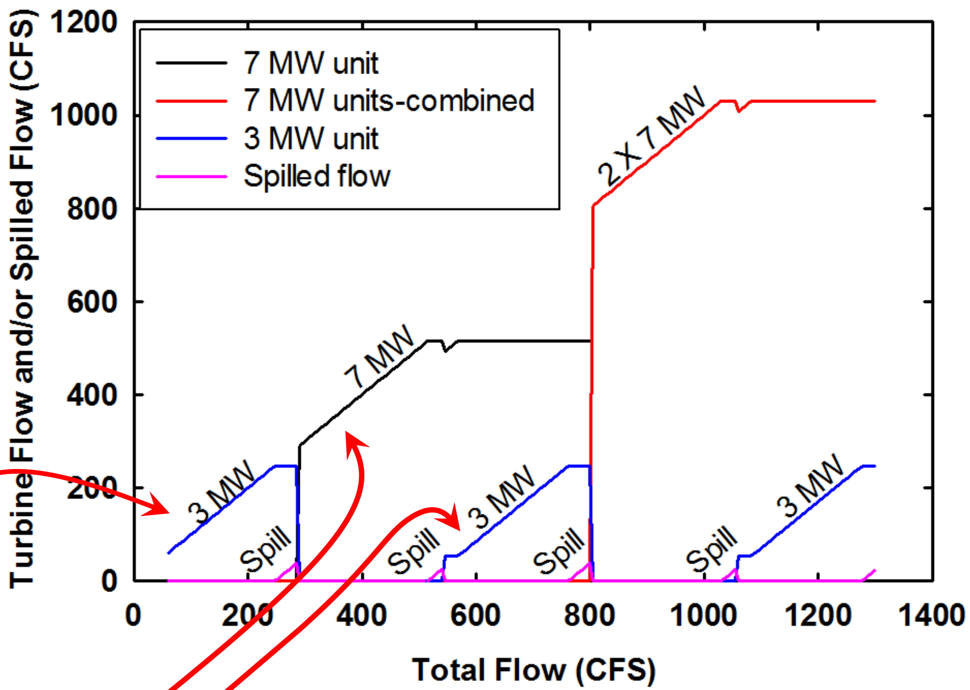






Identify the Available Resource—Flexibility w/o Loss of $

- Fast response demands that units be spinning and synchronized
- We must choose a unit commitment and stay with it
- Our "windows of flexibility" are now determined by the boundaries of the unit commitment



Example for different levels of spinning reserve (up regulation only)

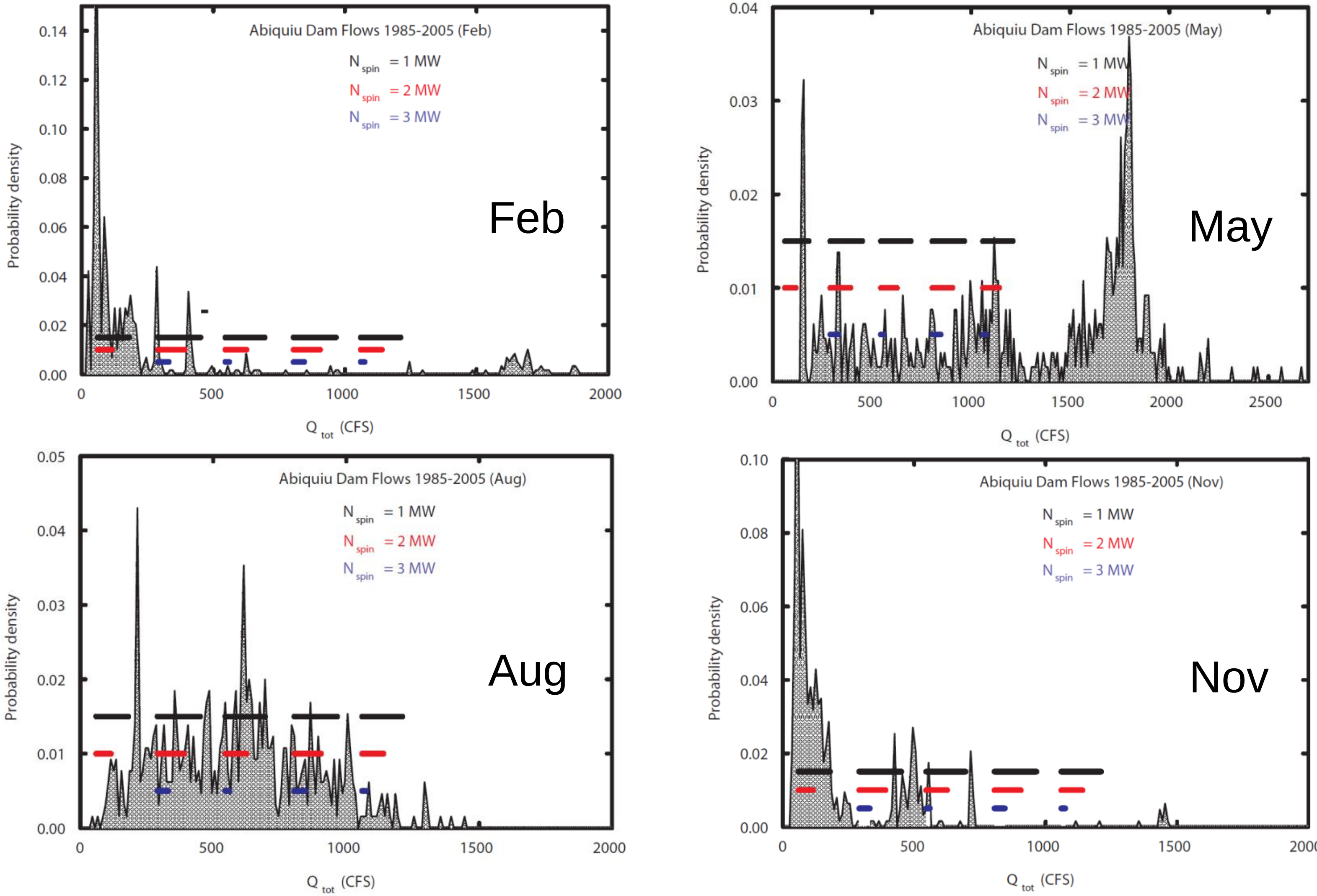
Selection of windows similar for up/down following for PV smoothing

N_{spin}=1 MW	N_{spin}=2 MW	N_{spin}=3 MW
60–180	60–115	XX
290–450	290–390	290–330
545–695	545–625	545–560
805–965	805–905	805–845
1060–1210	1060–1140	1060–1075

Windows of flexibility in CFS

Impact of Flexibility— “Steady-State” Operations (Monthly)

How do the “windows of flexibility” overlap with historical flows?



Impact of Flexibility—
“Steady-State” Operations (Yearly)

How do the “windows of flexibility” overlap with historical flows?

Level of Flexibility—
Spinning reserve
“up regulation”

Annual revenue from flexibility based on typical spinning reserve costs = $10/MW/hour. Assuming 24 X 365 flexibility

N_{spin} (MW)	% time in band	Flexible Operation
1	54%	$87,600
2	33%	$175,200
3	7%	$262,800

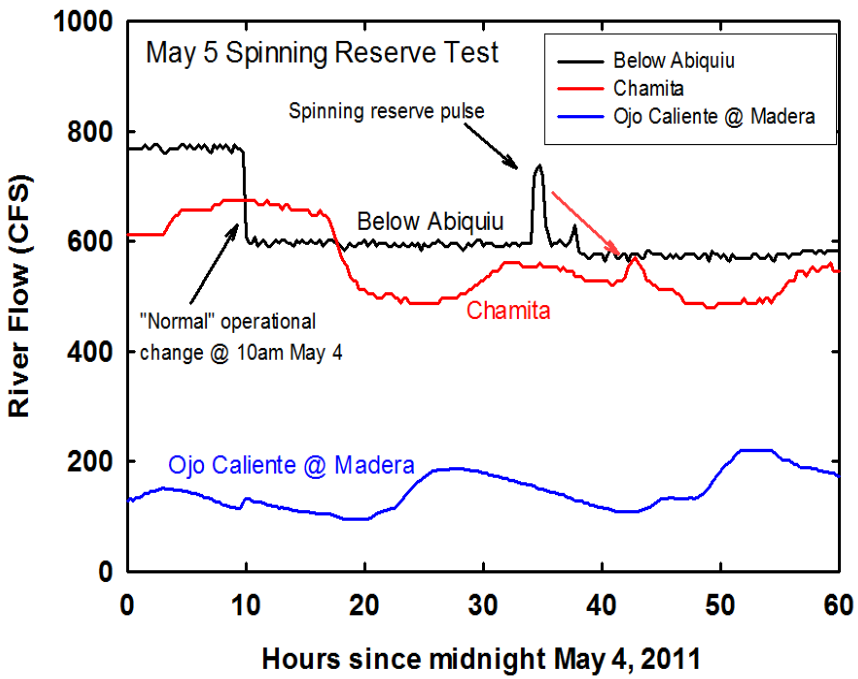
Chance of historical flows falling in the windows of flexibility

Annual Revenue for Flexible Operation

- Basing revenue on spinning reserve prices, i.e., up regulation—only related ancillary service with a well-defined price ~ $10/MW/hour
- Up/Down following for PV smoothing does not currently have a market or a well-defined price—Should be equal to or larger than spinning reserve price
- CO_2 benefits—No longer reserving capacity on coal plants, allowing them to run more efficiently or finally resulting in no longer running a coal plant

Impact of Flexibility—Transients of River Flow

- **Leveraged Low-Flow Turbine acceptance testing to simulate spinning reserve event**
  - 135 CFS increase X 1 hour
  - 2 MW up regulation X 1 hour
- **Impact is minimal for 2 MW changes**
  - Expected to decrease proportionally for smaller MW changes
  - Expected to smooth out for more frequent changes

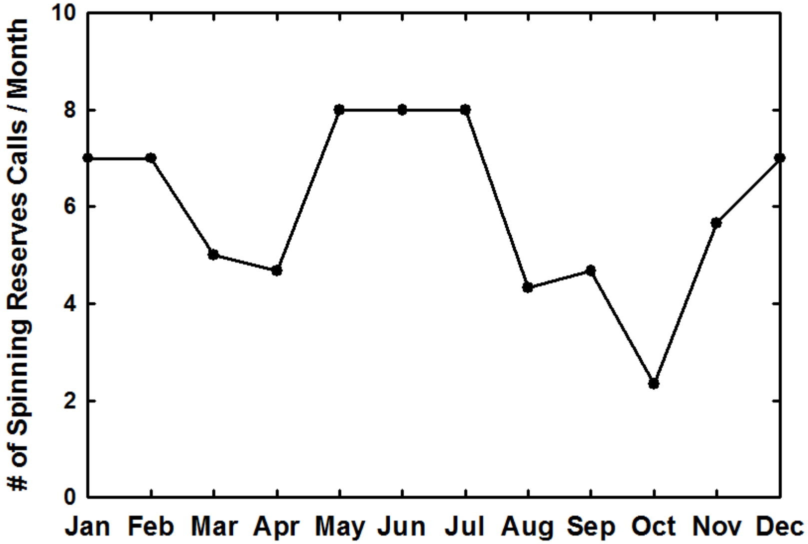


Impact of Flexibility—Frequency of Transients

Two Types of Grid Ancillary Services from RoR Hydro

Spinning Reserve

- 1-2 events per week
- One hour duration
- Year-round operation
- Benefit/Impact is clear from measurements



Up/Down Following for PV Smoothing Demonstration Project

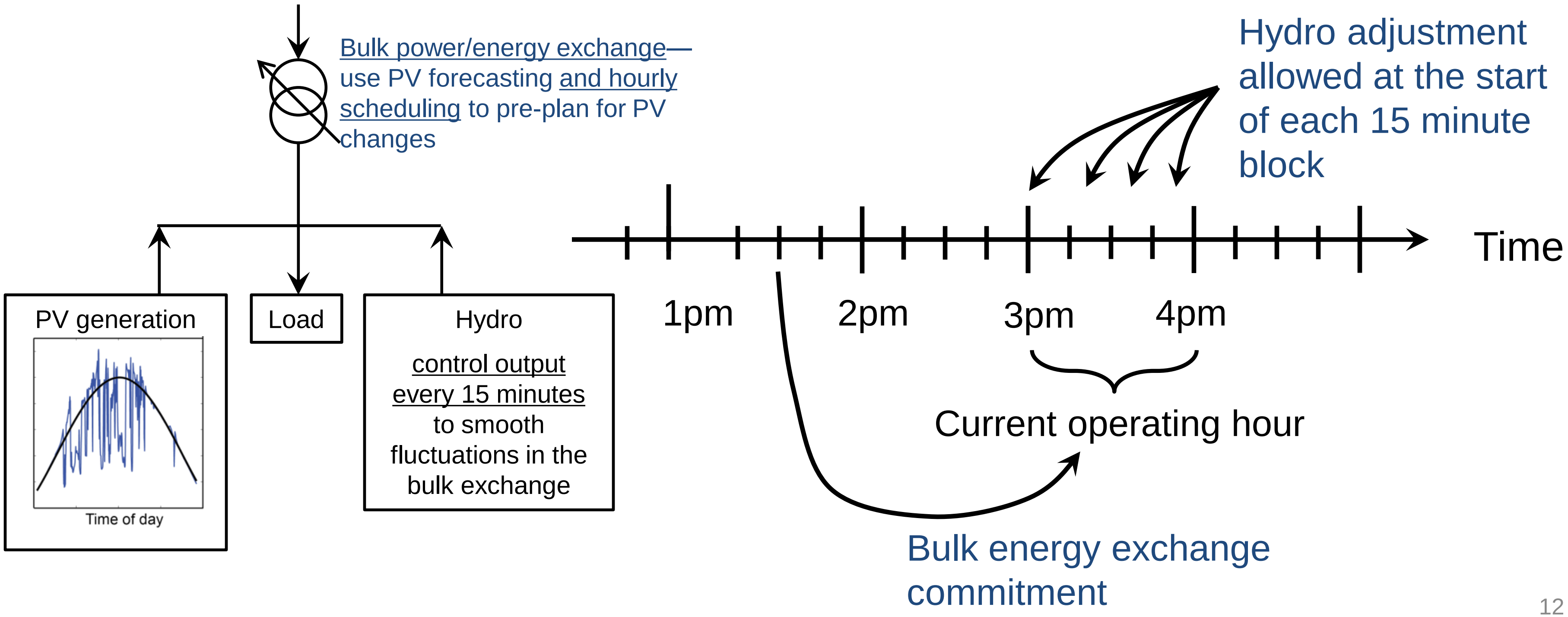
- Generation change every 15 minutes
- Requesting ~ 2 week demonstration
- Transient impacts not obvious—requires simulations to assess effects on river flows and stage

Focus of rest of discussion

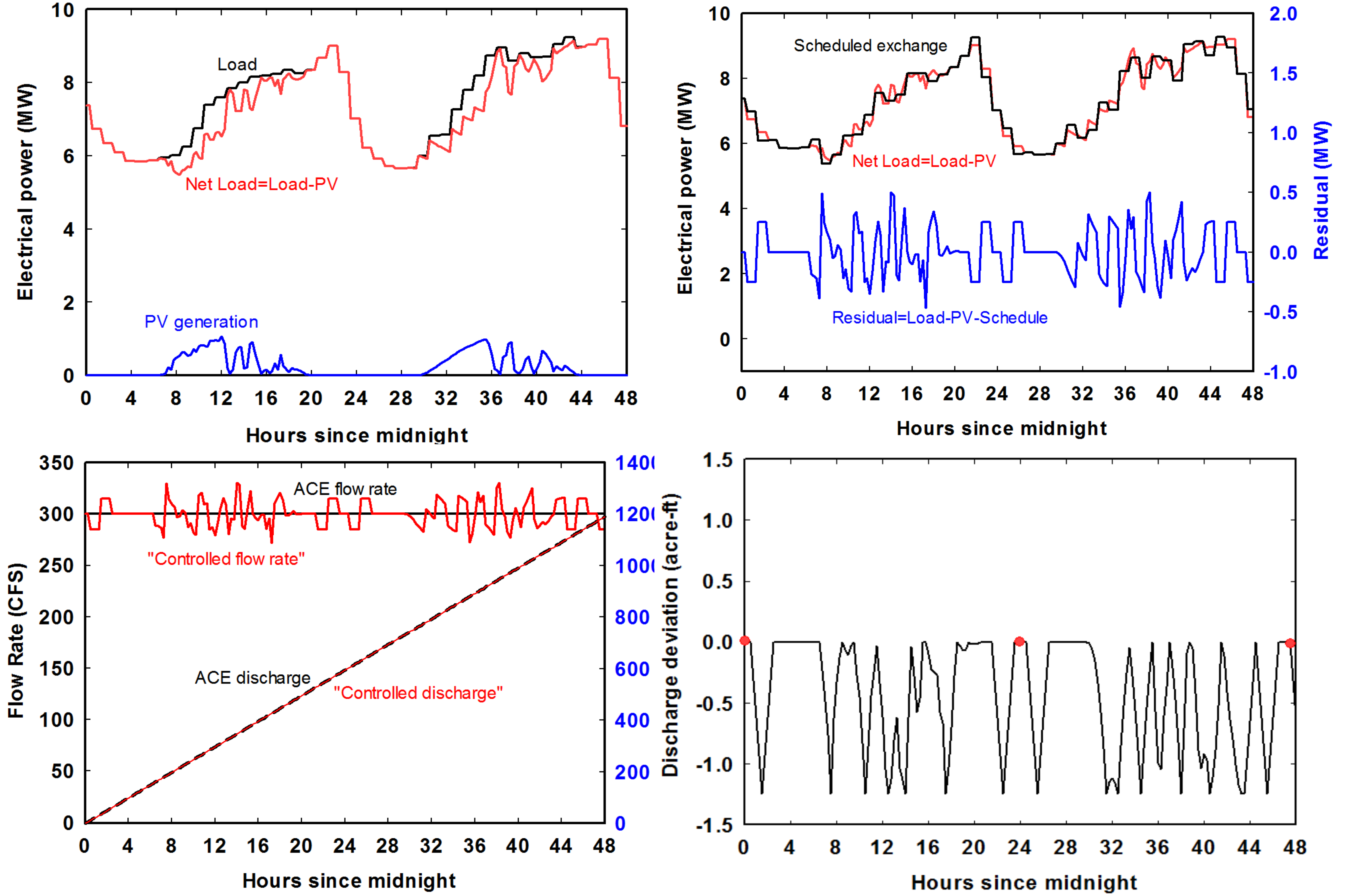
PV Smoothing—Simulations of Operations

Abiquiu hydro resides within existing utility operations—operational simulations should mimic these operations

- Bulk energy exchange is scheduled 90 minutes before the top of the current operator hour
- Once committed, the scheduled bulk energy exchange cannot be altered
- Within the current hour, the hydro can be adjusted every 15 minutes to help maintain schedule



PV Smoothing—Simulations of Operations

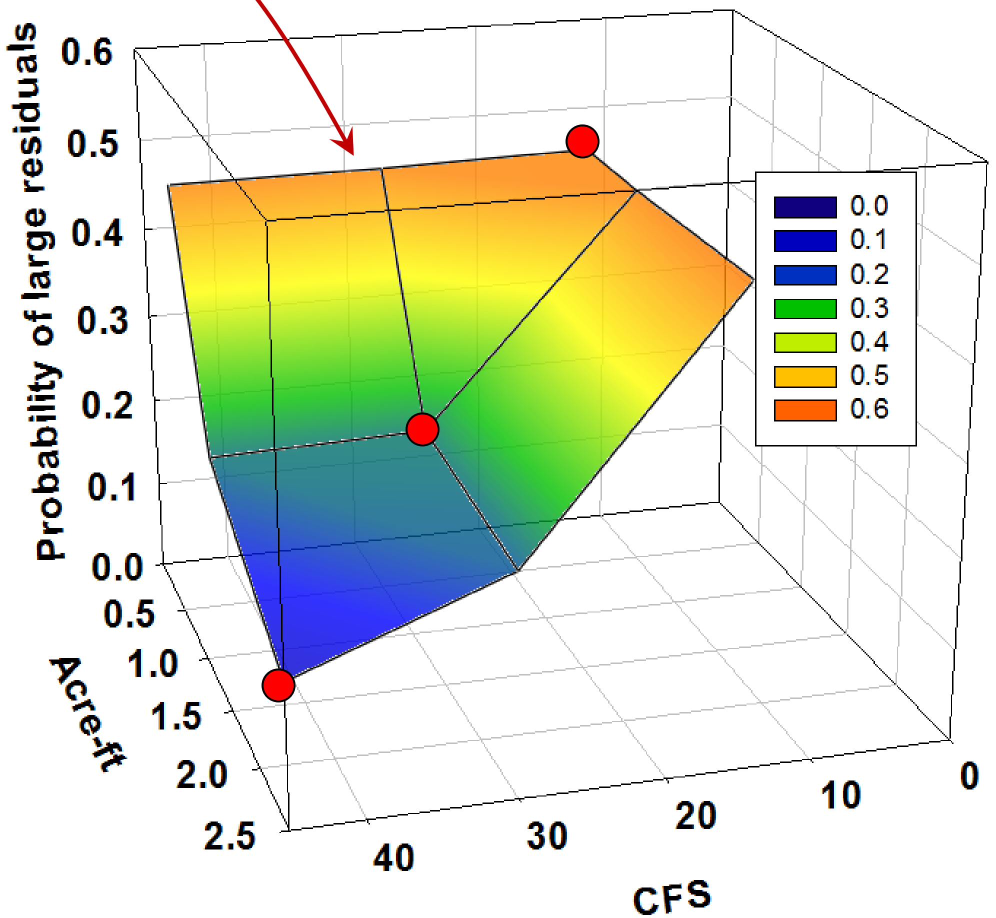


PV Smoothing—Simulations of Operations

Compute the total probability of a residual fluctuation larger than 0.1 MW

● = minimum required hydro flexibility at "fixed" residual fluctuations

Case #	ΔQ_{max} (CFS)	ΔW_{max} (acre-ft)	ΔP_{max} (MW)	ΔE_{max} (MW-hrs)
● 1	45	2.50	0.75	0.50
● **5**	**30**	**1.25**	**0.50**	**0.25**
● 9	15	0.63	0.25	0.13



Summary—
The Opportunity for Run-of-River Hydro

- **Increasing grid stress demands more operational flexibility from generation (and load) assets. Valuable services include:**
  - Spinning reserves
  - Balancing of intermittent generation (or related fluctuations)
  - …..others are possible
- **Run-of-river hydro is an underused electrical grid asset that can provide these services while meeting other water stakeholder needs**
- **Increases effectiveness of local planning for energy choices, such as locally-generated renewables**
- **Enables development of lower-cost, firm renewable energy for rural communities with access to a RoR asset**
- **Simulations and experiments/observations have identified**
  - The impacts on daily flow scheduling to accommodate different levels of flexibility
  - The quality of the services that could be delivered by different levels of flexibility
  - The transient impacts that could be expected on intra-day river flows and stage
  - The optimal balance of flow (CFS) and discharge (acre-ft) flexibility
- **Next step is to plan for a RoR hydro/PV demonstration during two weeks of the summer of 2013 (TBD)**

Contact Information

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Smart Grid: smartgrid.gov