2012 Smart Grid Program Peer Review Meeting

Smart Grid Technology Test Bed

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Smart Grid Technology Test Bed

Objectives

- Create and demonstrate a replicable DER control system—focus on small electrical utilities and co-operatives
    - Integration of renewables
    - Planning of DER portfolios
    - Assess economic DER value
- Development/characterization of DER
    - Commercial HVAC
    - Run-of-river hydro

Life-cycle Funding ($K)

FY10-11	FY12	FY13 Request	FY14 Request
350	300	400	400

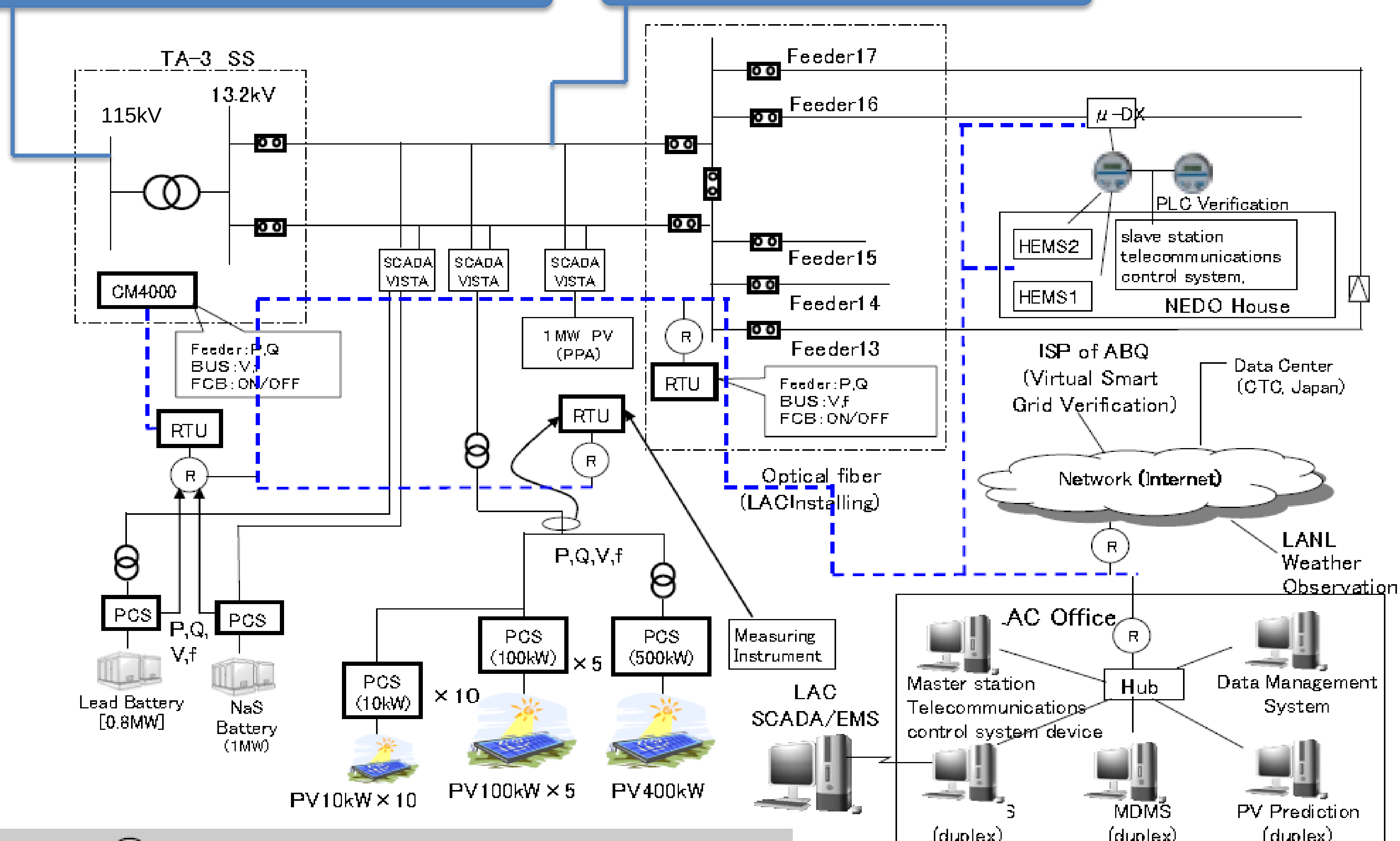
Technical Scope

- Model predictive control (MPC) of diverse portfolios of distributed resources
- Optimal/controllable modification of the statistics of PV variability
- Data-driven models for control of HVAC in large commercial buildings
- Models/control of run-of-river hydro—river impacts

Smart Grid Technology Test Bed-Overview

LA County Run-of River Hydro

LANL Commercial HVAC



Needs and Project Targets

Integration of DER/DR/ES

• Design and analysis of control algorithms that shape the statistics of PV variability, i.e. the net interface flow to the transmission system

- Uncertain local renewable energy forecasts

• Simultaneous control of a diverse set of DER/DR/ES

- Energy storage systems—NaS and lead-acid batteries
- Commercial building HVAC load
- Locally-controlled generation—run-of-river hydro
- Discrete loads

• Control of complex loads—Large commercial HVAC

- Models too large/complex for use in MPC or other controls

Smart Grid business cases—will be engaging Tri-State G&T for guidance

• Assess the economic value of DER/DR/ES—Different time scales for control

• DER portfolio design

- Optimal design of portfolio to meet control objectives
- Minimal/optimal sizing of storage

Technical Approach - 1

Model Predictive Control (MPC)

- A diverse portfolio of DER will have
  - Different dynamics—spanning time scales
  - Different end use requirements—different constraints
  - Constraints over time—ES state-of-charge constraints

- <u>MPC—a control technique that unifies a DER portfolio</u>
  - Spans time scales—many dynamics
  - Easily adjusts to many different end-use constraints—future constraints

- <u>MPC—incorporates uncertain forecasts of renewable generation</u>
  - Allows for recourse as forecasts are updated

- <u>MPC—Adapts to different control objectives</u>
  - Allows for shaping of net transmission interface flows
  - Shaping of residual renewable fluctuation statistics

- <u>Operations-Based Planning of DER portfolios (Tri-State G&T)</u>

Technical Approach - 2

Data-driven models for large commercial HVAC DR

- Large-building HVAC are complex control systems
  - Coupled thermodynamic systems—chillers, fans, conditioned spaces, local controllers
  - Hundreds of thermostats/VAV control points
  - Combination of centralized and distributed control
- First-principles dynamical models—too complex for control

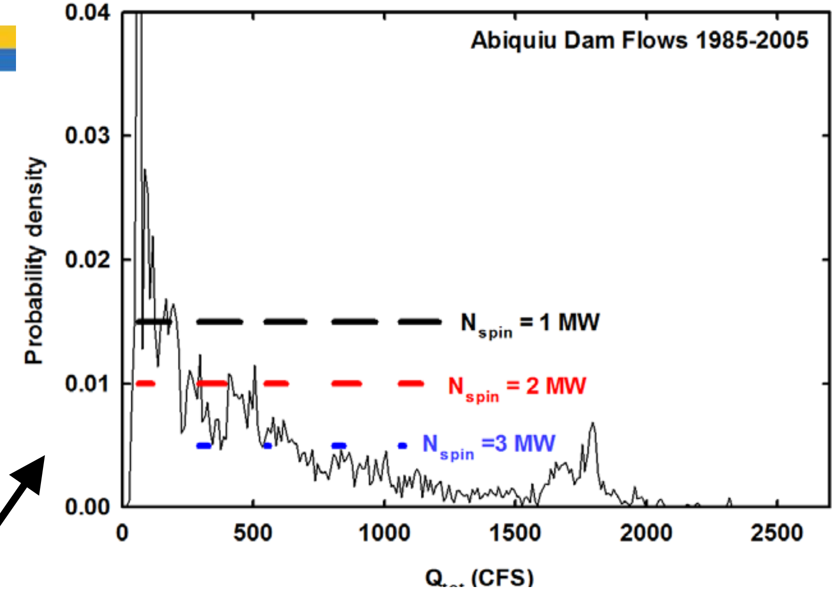
- <u>Bypass complexity—develop data-driven dynamical models via system identification</u>
- Experimentally create "look-up tables" for building dynamics
- Build the look-up tables into MPC formulations

Run-of-river hydro

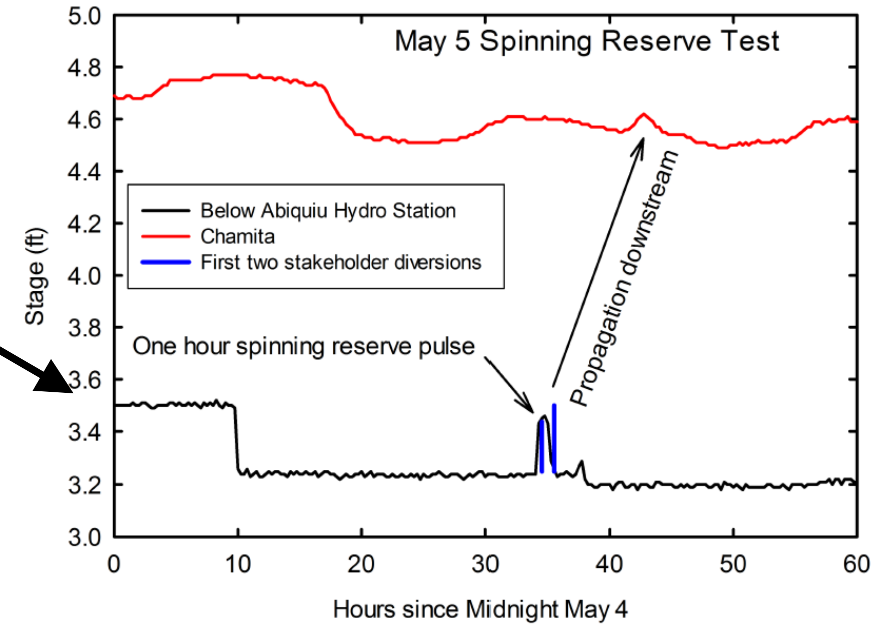
- Utilizing MPC to simulate effects of PV mitigation on the river flows
- Working with Army Corps of Engineers to develop a standardized process

Technical Accomplishments – (FY10)-FY11

- **Data-driven HVAC models**
  - BAS of 300,000 ft^2 office building reprogrammed to enable global set point control of all 500 thermostats
  - HVAC submetering installed
  - System identification experiments under wide range of HVAC loadings



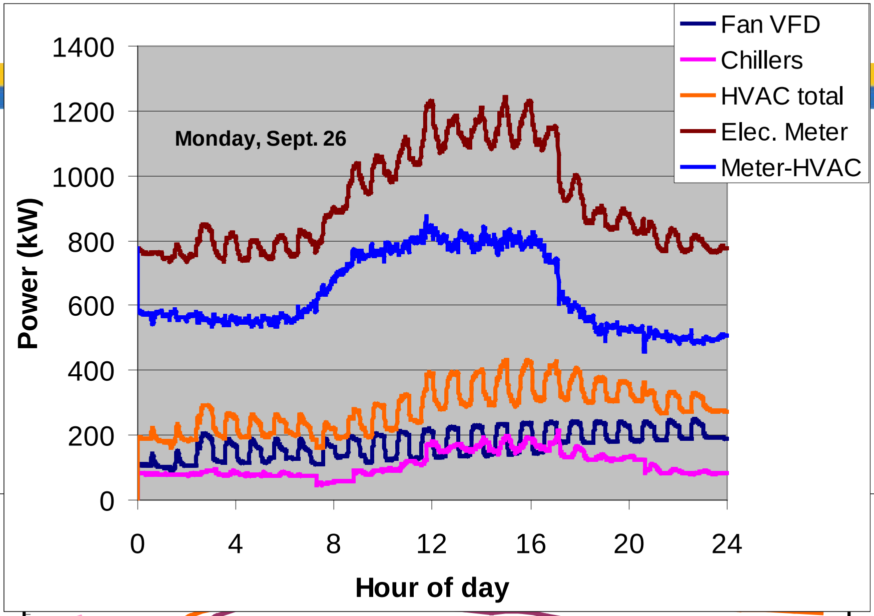
- **Run-of-river hydro**
  - Model of dam operations built into MPC
  - Determined impact of MPC-based PV mitigation on daily river flows
  - Carried out tests of hydro control to determine downstream effects

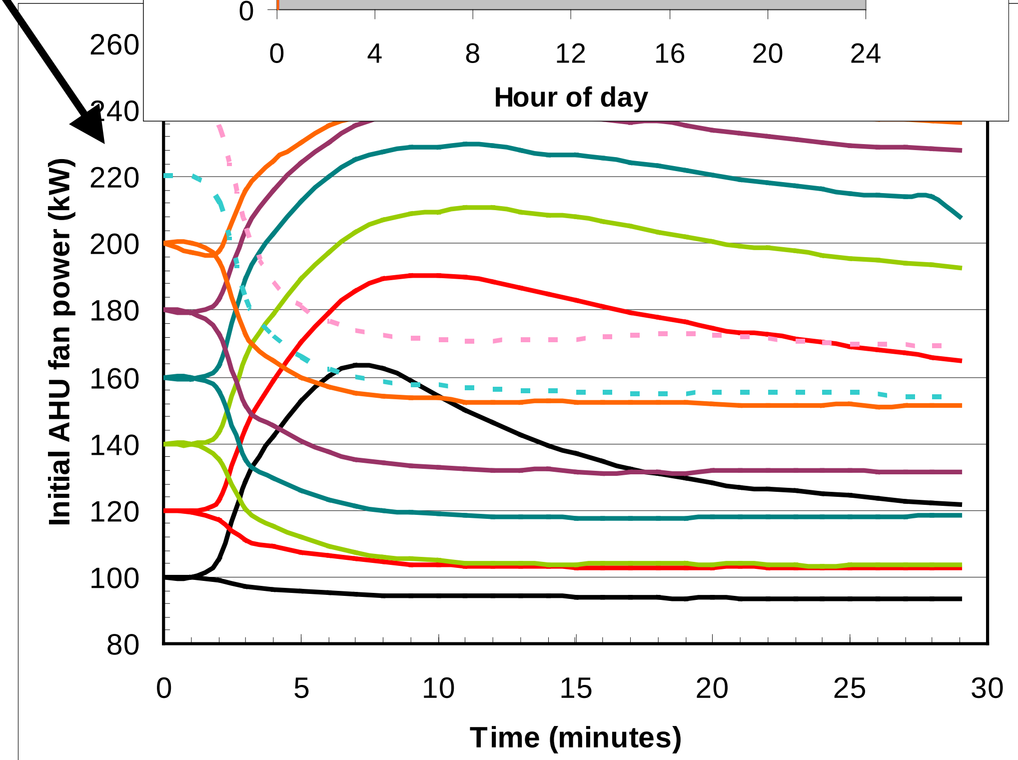


- **MPC**
  - Controller for coded for continuous resources (batteries, hydro)

Technical Accomplishments – FY12

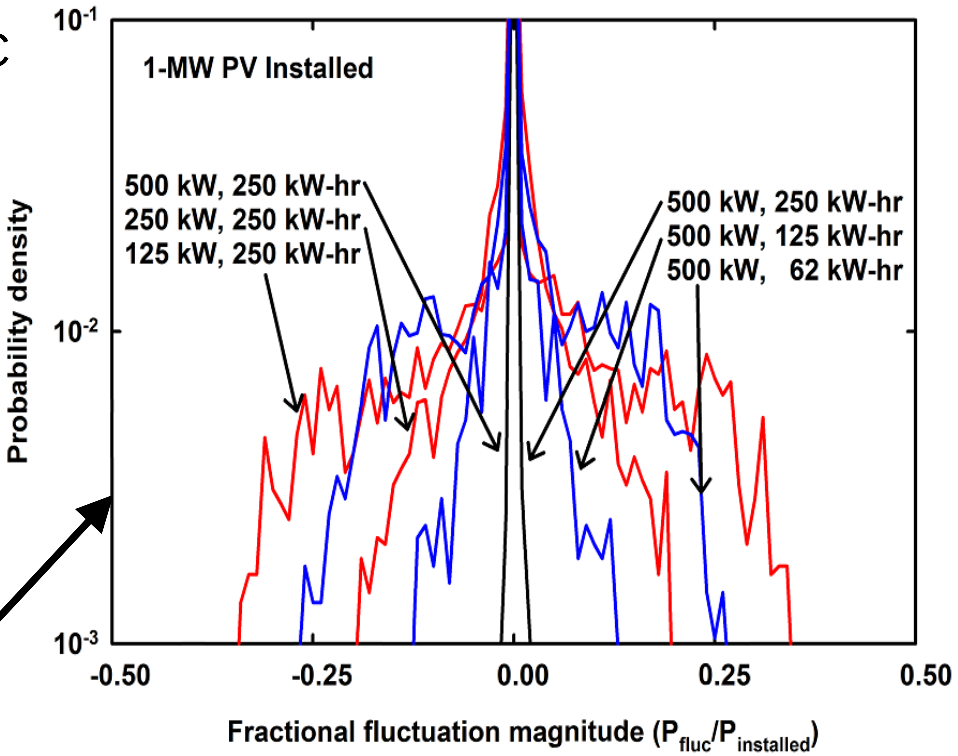
- **Data-driven HVAC models**
  - HVAC submetering validated
  - Dynamical models identified
  - TRANSYS dynamical model constructed
  - Implement control in BAS
- **Run-of-river hydro**
  - River flow control simulations completed for Army Corps
- **MPC**
  - Operations-based battery sizing with synthetic PV data
  - Implementation of MPC with historical PV and system load data
  - Incorporation of discrete loads





Technical Accomplishments – Out years

- **Data-driven HVAC models**
  - Integrate data-driven model into MPC
  - On-line control demonstration with smart grid testbed
- **Run-of-river hydro**
  - Complete impact study with Army Corps of Engineers
  - On-line control demonstration with smart grid test bed
- **MPC**
  - Operations-based planning/design of DER portfolios with historical and smart grid testbed data
  - Collaborate with Tri-State Generation and Transmission to determine economic value of DER portfolios



Significance and Impact

- **Data-driven commercial HVAC models—Enables control**
  - Reduces complexity of models for control purposes
  - Adaptable to control schemes other than MPC

- **MPC**
  - Enables combined control of continuous and discrete DER/DR/ES
  - Easily adaptable to other types DER (e.g. irrigation pumping). Only needs:
    - Dynamical model DER
    - End use constraints
  - Probabilistic/Statistical targets for interface flows easily incorporated

- **Run-of-river hydro**
  - Building a translatable methodology for engaging the Army Corps of Engineers on renewable integration
  - MPC models for generation control translate to other utility-owned generation

Interactions & Collaborations

- New Energy and Industry Technology Development Organization-Japan
  - PV and battery developer
  - Control system

- Los Alamos County Public Utilities
  - Grid owner
  - Hydro station owner

- LANL Utilities and Infrastructure
  - Owner of commercial HVAC system and BAS

- Army Corps of Engineers
  - Control of “run-of-river” water flows

- Trane (contractor)
  - Assistance the HVAC/BAS reprogramming

- *Tri-State Generation and Transmission*
  - *Assessment of economic value of controlled DER*

Contact Information

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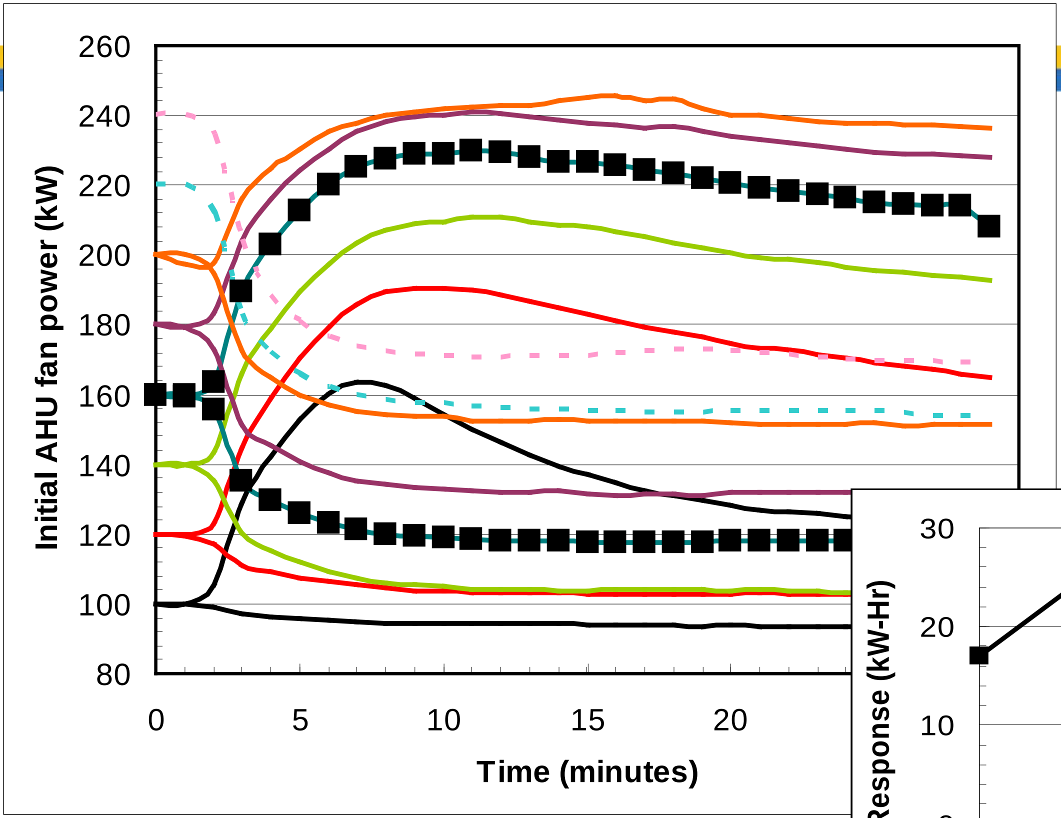
Back-up Slides



At 160 kW initial fan power

- +60 kW up regulation
- -40 kW down regulation

Energy storage

- ~ 40-50 kW-hrs