Robust and resilient coordination of feeders with uncertain distributed energy resources: from real-time control to long-term planning

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Industry support: ConEd, ORU, Clean Power Research, OpusOne, Smarter Grid Solutions, UL renewables
Here comes the sun... two consecutive days

Monday February 11, 2019
Tuesday February 12, 2019

Overcast

Sunny

303 MW
Optimally coordinating energy resources at scale

Key idea: adapt wide-area control concepts to distribution grid operations

Key challenges: uncertainty/variability, scalability, finite energy, and holistic optimization
Project Objectives

Vision: a technology that unleashes the flexibility of controllable grid assets and turns the utility from a volt/VAR-focused loss-minimizer into a full-service energy coordinator (e.g., NYREV’s “DSP”)

Markets
- Peak management
- Balancing/LMPs
- Ancillary services

Research question: with extreme solar PV and 1000s of controllable DERs, how do we adapt wide-area control concepts to distribution system operations to
1. coordinate devices in real-time (primary control ➔ Service Transformer Layer, STL)
2. manage the networked resources optimally, (2ndary control ➔ Feeder Operational Layer, FOL)
3. ensure economic operation of the entire system (tertiary control ➔ Grid Market Layer, GML)
4. develop proof-of-concept open-source platform, iDGA, for analyzing effects of DERs
Machine learning to estimate time-varying VB parameters

- Different AC/EWH ensembles have been tested with this proposed deep-learning framework
- This framework is **generalized** and can be extended for other ensembles (mix of different type of DERs)
- Proposed framework introduces a **novel approach** of defining VB state
- Addition of transfer learning make the **proposed framework adaptable over time**
- All the deep network trainings had been done on a **normal laptop**

**VB Model and Parameters**

\[ \dot{x} = -\alpha (x - C/2) + p_{bat}^{\text{base}}(t) - p_{bat}(t) \]

- \( x \in [0, C] \)
- \( p_{bat} \in [-R, 0] \)
- \( x \): battery state-of-charge [kWh]
- \( p_{bat} \): battery power injection (\( \leq 0 \)) [kW]
- \( p_{bat}^{\text{base}} \): battery baseline power injection (\( \leq 0 \)) [kW]
- \( \alpha \): self-dissipation rate [min\(^{-1}\)]
- \( C \): battery capacity [kWh]
- \( R \): battery rated power [kW]
Holistic grid optimization: managing resources from hours to minutes

- VBs
- Solar PV
- 3-φ Grid
- Mech. Assets

Slower assets:
- Forecasts
- Dispatch mechanical assets (MIP)
- Optimize mech. asset scheduling
- DSSE + Forecasts

Faster assets:
- Optimal VB dispatch (SOCP+NLP)
- DER market-based reference
- AC 3Ø model (Plant)
Market optimization: maximize revenue with VBs

- **GML Objective Function spans two timescales (DAM + RTM)**

\[
\begin{align*}
\text{Min} & \quad \sum_{t=1}^{T} \delta_t \left( \lambda^{\text{da}}(t) P^{\text{da}}(t) + \lambda^{\text{rt}}(t) (P_0(t) - P^{\text{da}}(t)) - \alpha(t) P_{\text{rsrv}}(t) + \sum_{f} f_{f,t}(P^g_f(t)) \right) \\
\end{align*}
\]

- **Subject to:**
  - network constraints
  - Virtual battery constraints
Quantifying techno-economic benefits with software
Thank you! Questions? Comments?

Contact info

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Enabling Advanced Grid Operations with DER coordination (PSOPE, 8/6 @ 1-3pm)

Optimization Methods for Unbalanced Power Distribution Systems (AMPS, 8/7 @ 10am-noon)

Advanced Grid Architectures to support scalable DER integration (SBLC, 8/7, 12-2pm)

Join us in Atlanta, GA!