SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

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

SETO Planning & Operations Workshop

Washington, D.C.

May 16-17, 2019

Dr. Mads R. Almassalkhi

Team: Mads Almassalkhi, Hamid Ossareh, Pavan Racherla (UVM), Dennice Gayme, Enrique Mallada (JHU), Soumya Kundu, Thiagarajan Ramachandran (PNNL)

Support: Nawaf Nazir & Sarnaduti Brahma (UVM), Chengda Ji & Pengcheng You (JHU), Dr.Anand (NIST)

Industry support: ConEd, ORU, Clean Power Research, OpusOne, Smarter Grid Solutions, UL renewables

Orange & Rockland

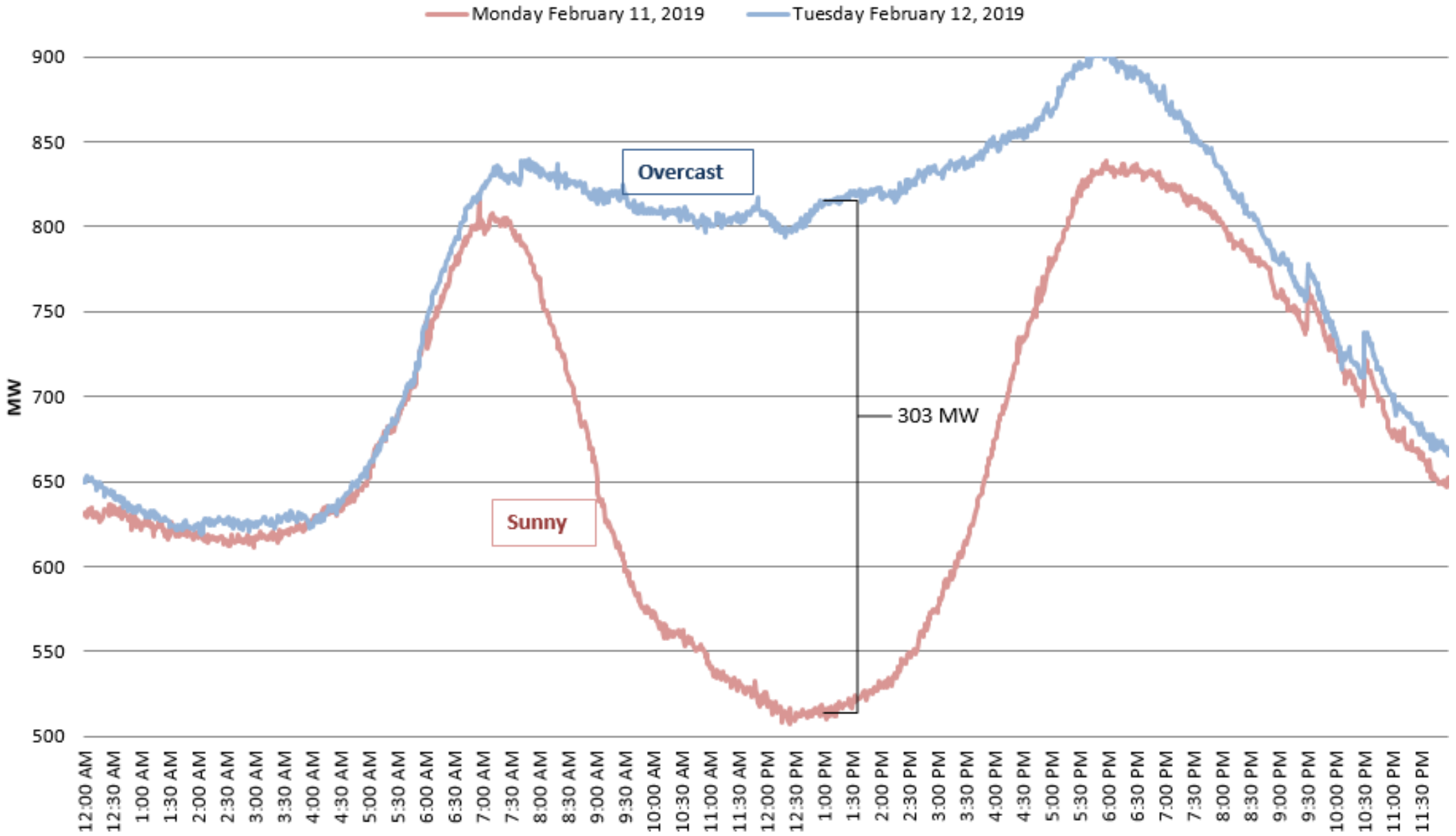
Pacific Northwest NATIONAL LABORATORY

The UNIVERSITY of VERMONT

JOHNS HOPKINS UNIVERSITY

NIST

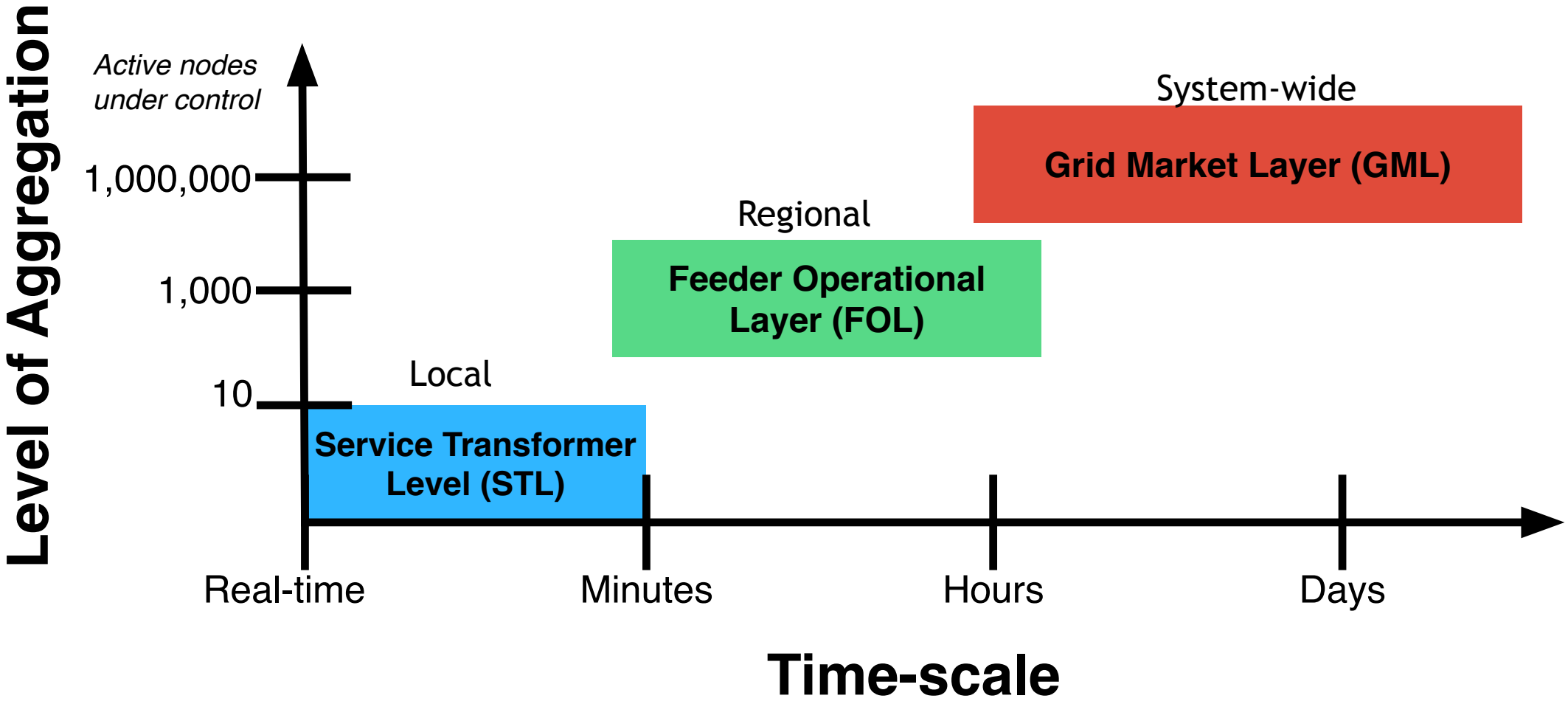
Here comes the sun… two consecutive days



Optimally coordinating energy resources at scale

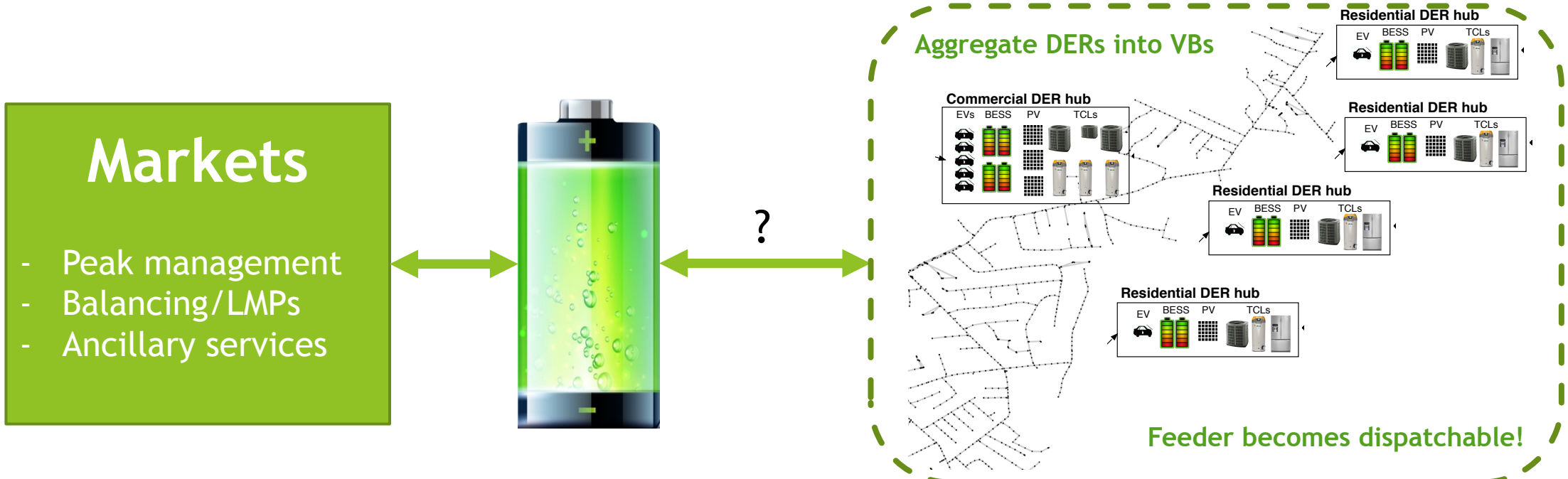
Key idea: adapt wide-area control concepts to distribution grid operations

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



Project Objectives

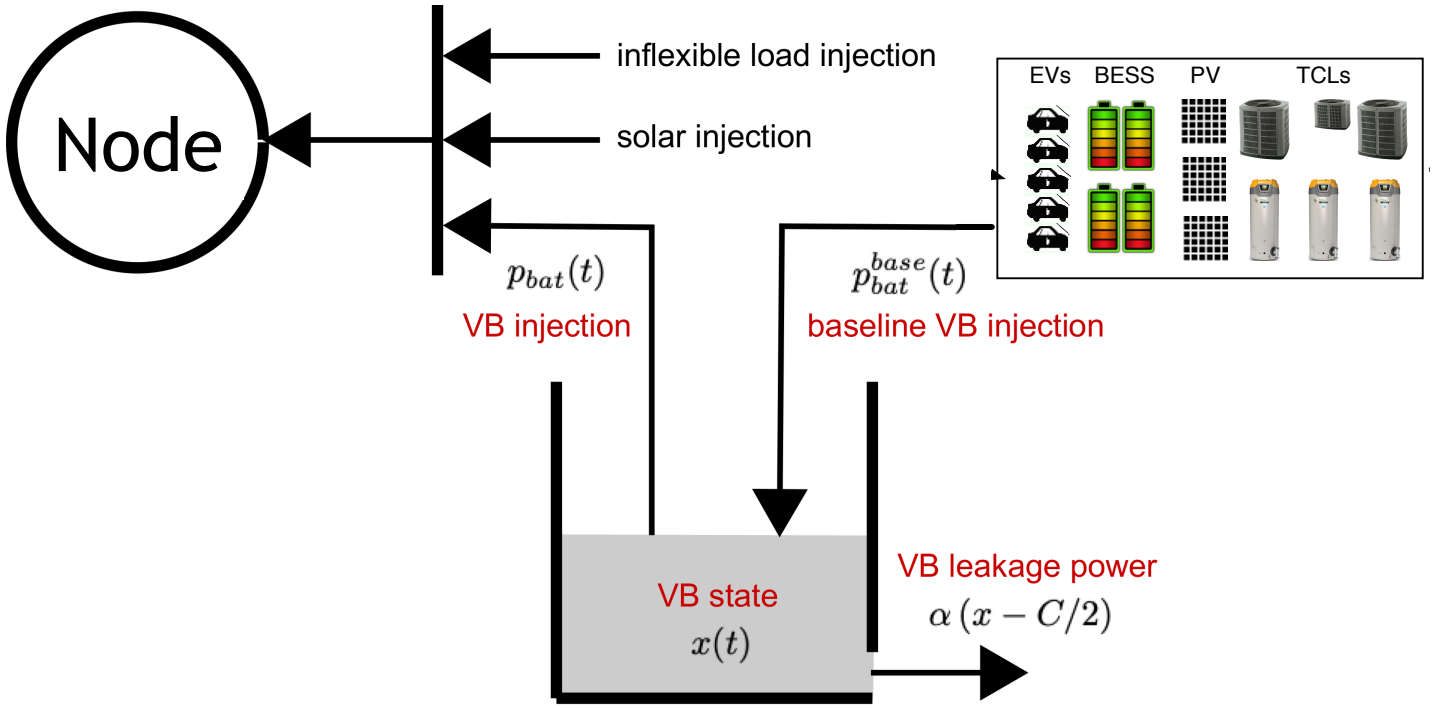
Vision: a technology that unleashes the flexibility of controllable grid assets and turns the the utility from a volt/VAR-focused loss-minimizer into **a full-service energy coordinator** (e.g., NYREV's "DSP")



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



VB Model and Parameters

$$\dot{x} = -\alpha\,(x - C/2) + p_{bat}^{base}(t) - p_{bat}(t)$$

$$x \in [0, C]$$

$$p_{bat} \in [-R, 0]$$

x : battery state-of-charge [kWh]

p_{bat} : battery power injection (≤ 0) [kW]

p_{bat}^{base} : battery baseline power injection (≤ 0) [kW]

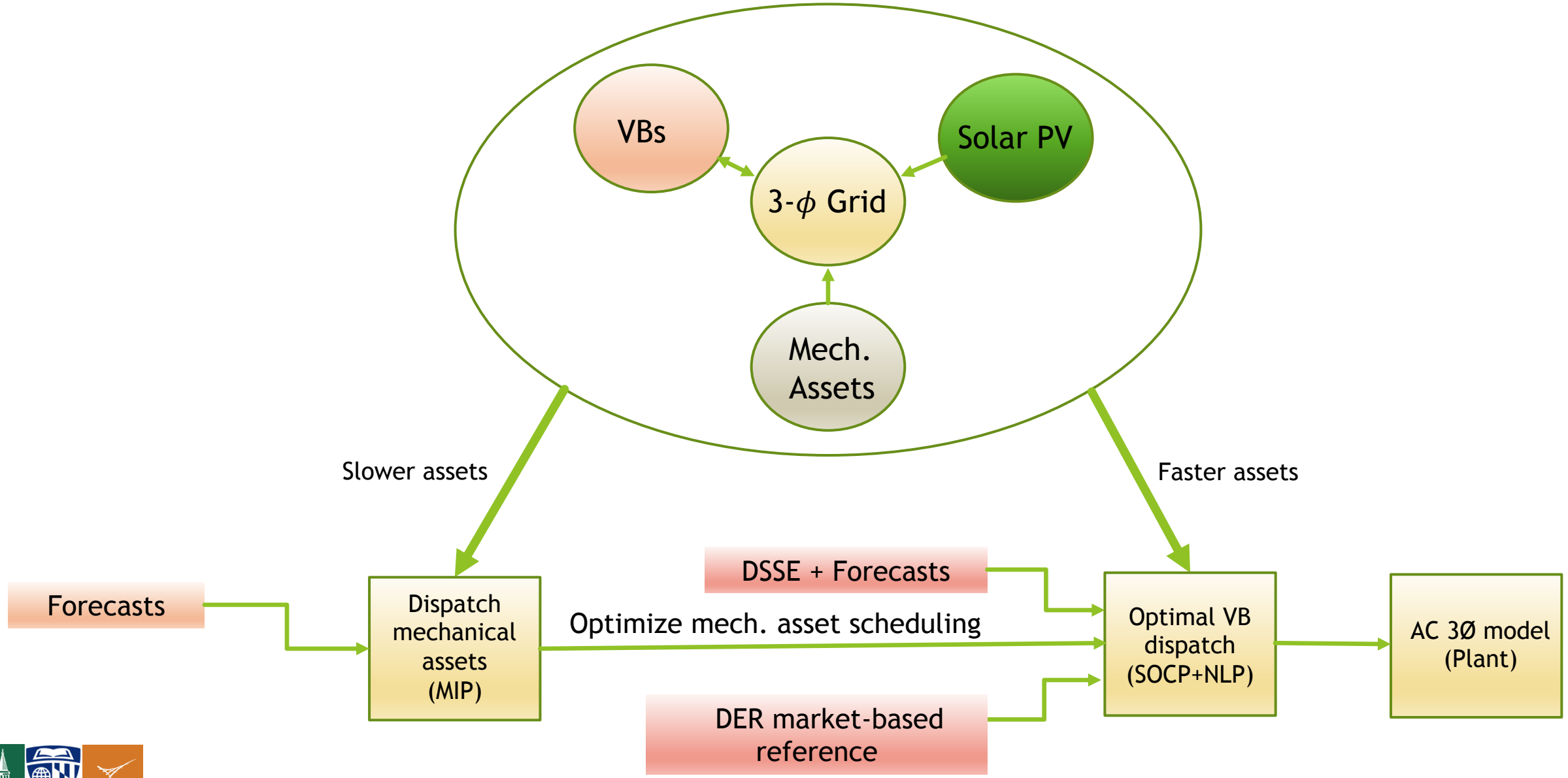
α : self-dissipation rate [min^{-1}]

C : battery capacity [kWh]

R : battery rated power [kW]

- 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**

Holistic grid optimization: managing resources from hours to minutes



Market optimization: maximize revenue with VBs

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

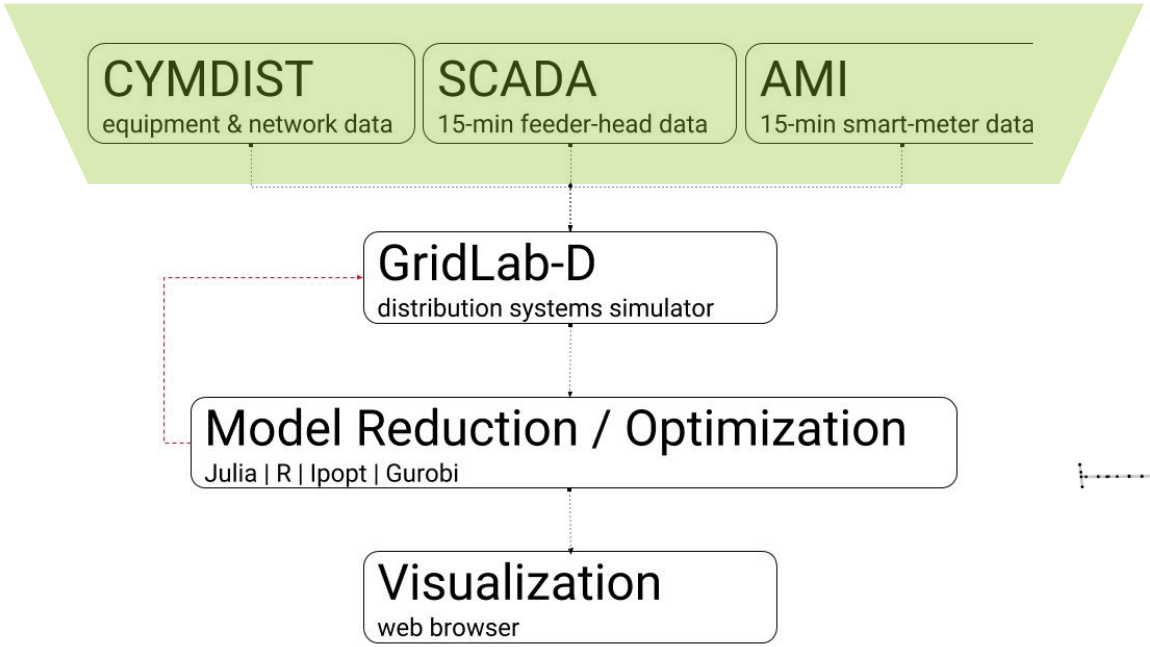
day-ahead price; day-ahead schedule; real-time price; real-time schedule; 10/30 min reserve price; 10/30 min reserve; power gen. feeder f

- **Min** $$\sum_{t=1}^{T} \delta_t \left(\lambda^{\mathrm{da}}(t) P^{\mathrm{da}}(t) + \lambda^{\mathrm{rt}}(t) \left(P_0(t) - P^{\mathrm{da}}(t) \right) - \alpha(t) P_{\mathrm{rsrv}}(t) + \sum_f f_{f,t}(P_f^g(t)) \right)$$

day-ahead cost; co-optimization of real-time dispatch and reserves; FOL cost

- **Subject to:**
  - network constraints
  - Virtual battery constraints

Quantifying techno-economic benefits with software



Orange & Rockland

Thank you! Questions? Comments?

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

Contact info

Mads Almassalkhi

malmassa@uvm.edu

@theEnergyMads

- 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!