GMLC 1.4.2 – Definitions, Standards and Test Procedures for Grid Services from Devices

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MIKE DUOBA, EV LEAD
Argonne National Laboratory

ROB PRATT, PI
Pacific Northwest National Laboratory

Overview

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Timeline	Barriers
• Project Start FY16 • Project End FY18 • Percent Complete: 33% of current year • Percent Complete: 0% of FY18 (funds arrived in March for Project Year 3 start ~ Sep. 1, 2018)	• Integrate device models into framework • Framework to model range of grid services • Characterization and test protocols developed to validate and further refine grid service studies
Budget	**Partners**
• All Labs FY16 – FY18: $6.5M • ANL Funding for FY17: $288k (model) • ANL Funding for FY18: $500k (test / validation)	Pacific Northwest National Laboratory Argonne National Laboratory National Renewable Energy Laboratory Sandia National Laboratory Oak Ridge National Laboratory Lawrence Berkeley National Laboratory Idaho National Laboratory Lawrence Livermore National Laboratory

High Level Summary

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Project Description

Enable a broad range of distributed energy resources (DERs) – to provide operational flexibility required by the power grid in the form of valuable grid services at the bulk system and local distribution levels.

Value Proposition

- ✓ *Grid operators & planners can **accurately assess the contribution of DER devices***
- ✓ ***Encourages manufacturers to add capabilities to devices** by articulating required performance & estimating potential value*
- ✓ ***Level-playing field for modeling DER participation** in planning & operations*
- ✓ ***Battery-equivalent metric for grid flexibility***
- ✓ ***Contribution of different DERs can be "summed"***

Project Objectives

- ✓ **High-resolution models of DER device classes** including engineering, operational, & human constraints
- ✓ **Standard battery-equivalent model interface** applicable to all device classes
- ✓ **Prototypical "drive cycles" for** devices providing a **wide variety of grid services**
- ✓ **Conduct trial analysis** using models & drive cycles **to exemplify device potentials**
- ✓ **Device characterization test protocols & conduct trials** to validate models (water heaters, commercial refrigeration, EVs)
- ✓ **Identify possible extensions to DOE appliance/equipment efficiency standard's test protocols** to characterize important device parameters

Classes of Devices and Services

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Devices (DERs)

Responsive, flexible end-use loads

- Water heaters
- Refrigerators
- Air conditioners
- Commercial rooftop units (RTUs)
- Commercial refrigeration
- Electric vehicles (charging only)
- Electrolyzers

Storage

- Battery / inverter systems
- Electric vehicles (full vehicle-to-grid)

Distributed generation

- Photovoltaic solar (PV) / inverter systems
- Fuel cells

Grid Services

- Peak load management (capacity)
- Energy market real-time price response (wholesale energy costs)
- Capacity market dispatch (market value)
- Frequency regulation (market value)
- Spinning reserve (market value)
- Ramping (new)
- Artificial inertia (new)
- Distribution voltage management (new; e.g., PV impacts management)

What is a *Battery-Equivalent Model*?

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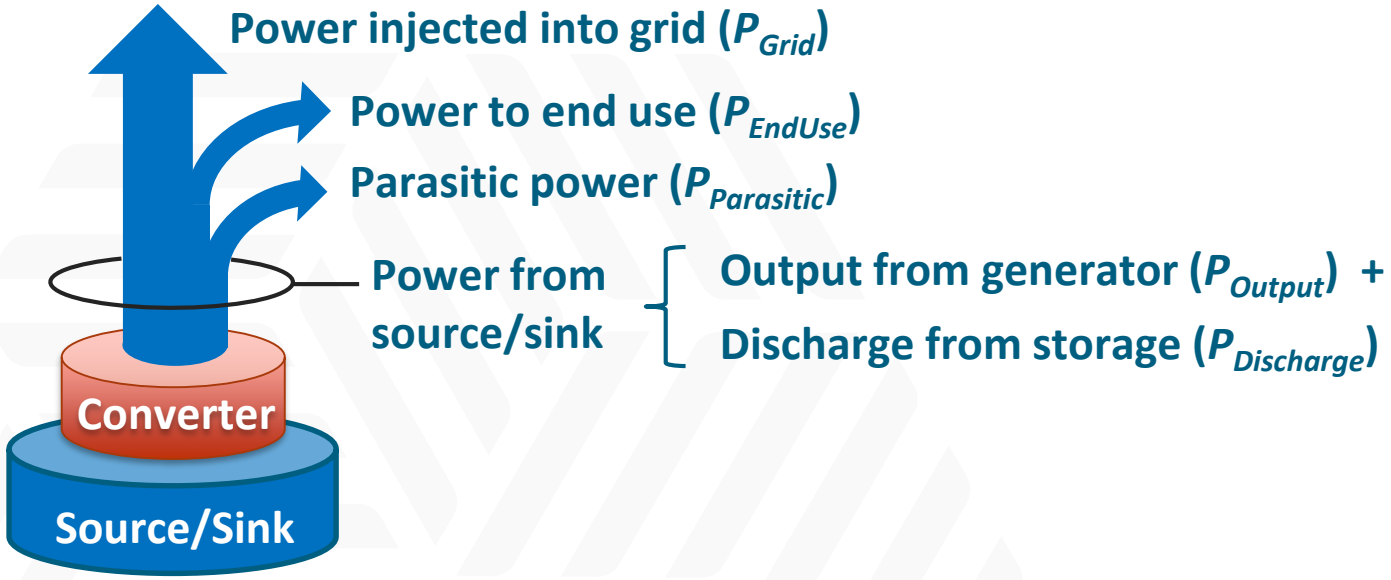
Battery-equivalent model of devices:

- Common, uniform means of representing properties of any DER device fleet as a "virtual battery"
  - In terms used to characterize battery/inverter systems
  - Extended with additional generalized properties & constraints needed to describe other types of DERs
  - Like a "virtual power plant" concept except more general
    - Generates
    - Stores
    - Consumes
- Individual discretely variable ("on/off") devices can't act in continuously variable way a battery does
- Fleets of such devices can do so

Power/Energy Balance and Power for Grid Services from a Generic DER



Power Balance:

$$P_{Grid}(t) = P_{Output}(t) + P_{Discharge}(t) - P_{Enduse}(t) - P_{Parastic}(t)$$

Power for Grid Service:

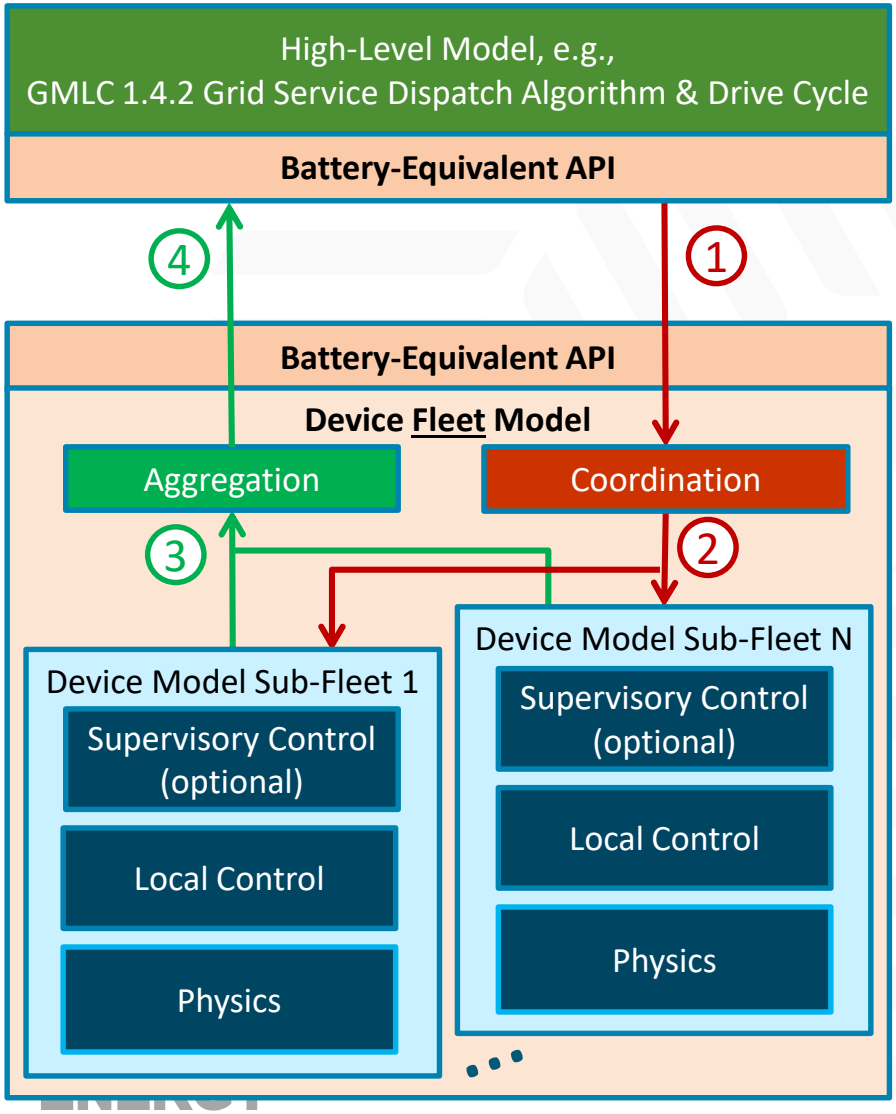
$$P_{Service}(t) = P_{Grid}(t) - P_{GridBase}(t)$$

; where *Base* indicates base case

$$P_{Service}(t) = \Delta P_{Discharge}(t) + \Delta P_{Output}(t) - \Delta P_{Enduse}(t) - \Delta P_{Parasitic}$$

; where Δ is the difference between the service case & base case

Architecture: Device & Fleet Models called by High-Level Model via Battery-Equivalent API



High-Level Model of Grid Planning or Operations

1. Requests power for service from fleet via API

Device Fleet Model
(N sub-fleets representing diverse population, each with uniform parameters, usage patterns, etc.)

2. Coordination: Allocates request to sub-fleets
4. Aggregates & returns fleet's current state:
   - Power delivered for service
   - Power injected into grid
   - Base case power injected into grid

   Aggregates & returns constraints for next time step:
   - Energy stored & total capacity
   - Charge/discharge efficiencies

   Power, price, time constraints

Device Model (1 device · sub-fleet weighting factor)

3. Returns sub-fleet's current state (see 4)
   Returns sub-fleet constraints for next time step (see 4)

Device Model: Plug-in Electrified Vehicles (PEV)

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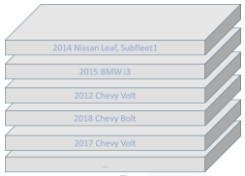
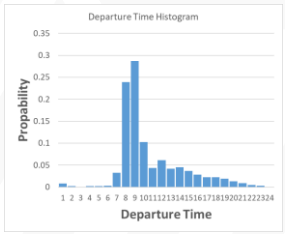
Step 1: Create Sub-Fleet Activity Schedules

Vehicle Models (real or random properties)

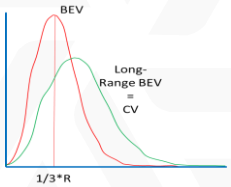


Random vehicle activity schedules based on distribution data

First Departure Time

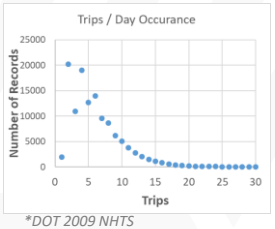


Daily Range



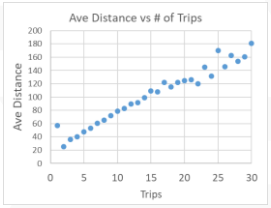
Vehicle Range Determines Probability Curve

Trips / Day



*DOT 2009 NHTS

Dist vs Trips



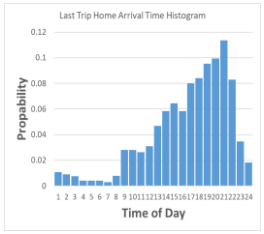
*DOT 2009 NHTS

Where Parked

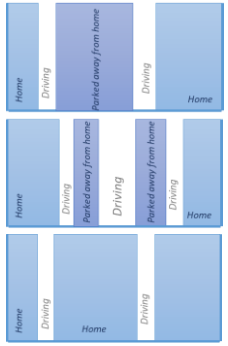
Trip Purpose	Percent
Home	34.3
Work	16.6
School/Daycare/Religious activity	3.1
Medical/Dental services	1.5
Shopping/Errands	19.5
Social/Recreational	8.4
Transport someone	8.5
Meals	6.7
Something else	1.4

*DOT 2009 NHTS

Time return home

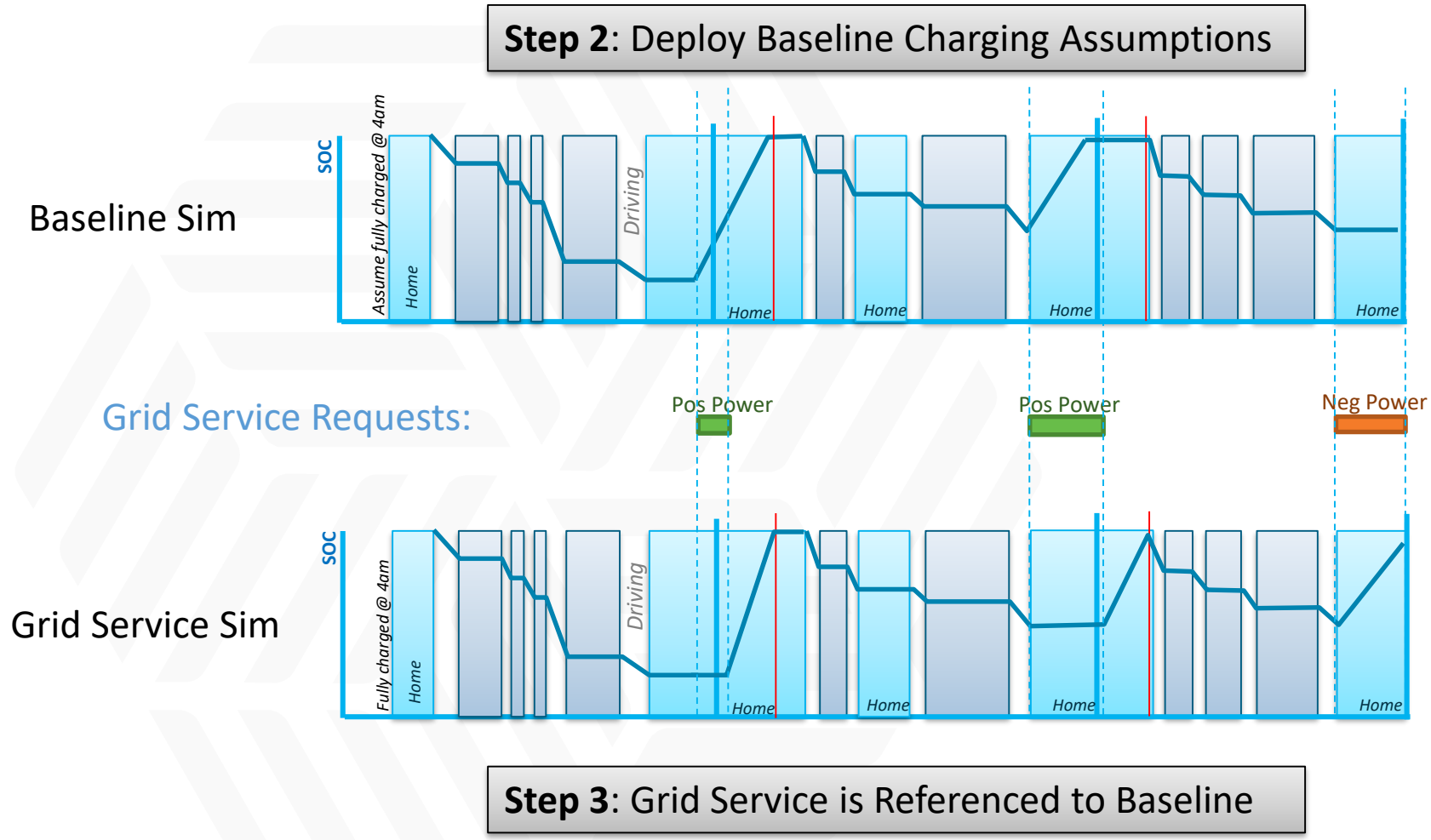


Each sub-fleet has unique activity schedule



Literature data of distributions employed

Device Model: Plug-in Electrified Vehicles (PEV)



Sub-Fleet Models Operate in Generic "Battery-Equivalent API"

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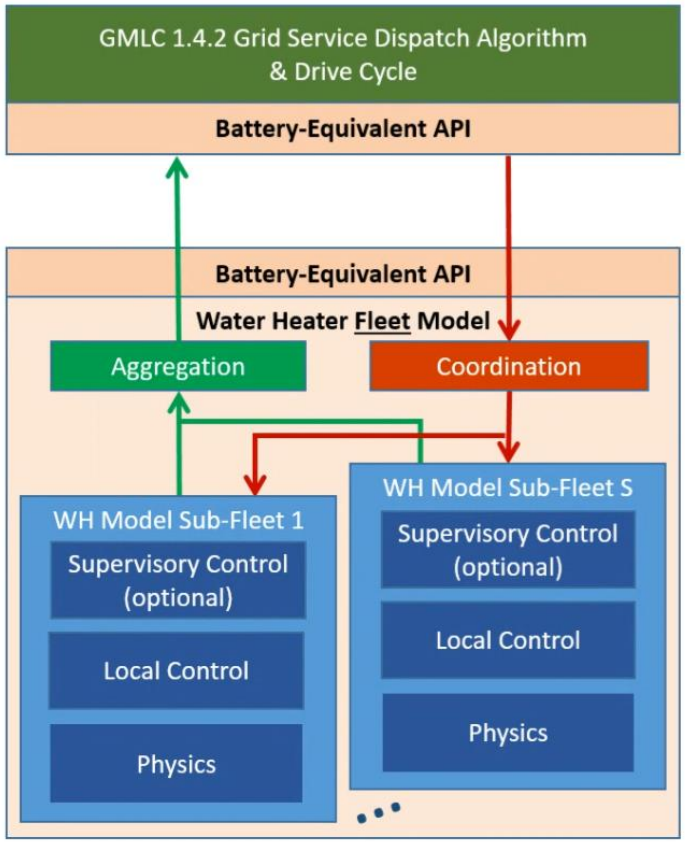
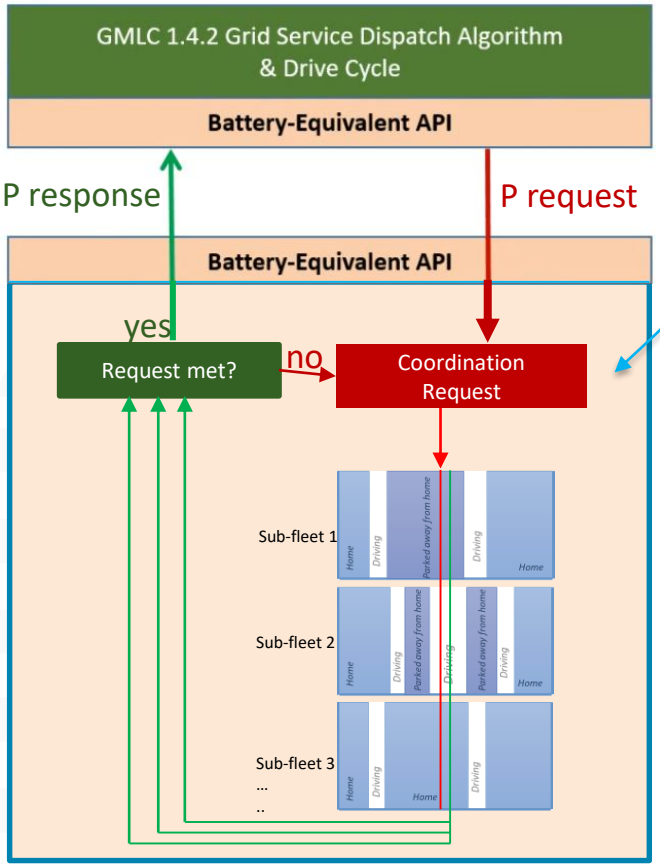
Generic Battery-Equivalent API



PEV Battery-Equivalent API Coordination Strategies

- Pricing (requires sub-fleet strike price info)
- Highest efficiency result
- Random selection of on/off
- Proportional charge level control
- Other advanced predictive models



Project Team, Roles, Budgets by Lab

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Project Participants and Roles			Project Funding			
Lab	**Device Class**	**Grid Services**	**FY16**	**FY17**	**FY18**	**Total**
PNNL		A. Peak load management B. Artificial inertia/fast frequency response	$351K	$406K	$196K	$953K
NREL	1. Water heaters 2. PV/inverters	C. Distribution voltage management / PV impact mitigation	$226K	$351K	$508K	$1,085K
SNL	3. Batteries/ inverters		$106K	$153K	$0K	$259K
ANL	4. Electric vehicles (DR, V2G)		$141K	$276K	$508K	$925K
ORNL	5. Com. HVAC 6. Com. refrigeration		$146K	$308K	$508K	$962K
LBNL		D. ISO capacity market (e.g., PJM's) E. Regulation F. Spinning reserve G. Ramping	$211K	$225K	$0K	$436K
INL	7. Fuel cells 8. Electrolyzers		$146K	$158K	$0K	$304K
LLNL		H. Wholesale energy market price response	$94K	$154K	$38K	$286K
Totals			**$1,421K**	**$2,031K**	**$1,758K**	**$5,210K**

Key Project Milestones

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Milestones* (FY16-FY18)	Status	Due Date
1. Standard definitions & drive cycles for grid services (draft for industry review)	1. Complete ✓	October 1, 2016
2. General device model (draft for industry review)	2. Complete ✓	
3. Extrapolation procedure for performance of grid services	3. Complete ✓	April 1, 2017
4. Project re-scoped (new negotiation template developed)	4. Complete ✓	October 1, 2017
5. Device model & battery equivalent interface software **6. Specify device characterization tests** (for Year 3) **7. Recommendations re. additional tests or results from efficiency standards testing**		**July 1, 2017**
8. Report on grid services definitions & prototypical drive cycles, device models & battery-equivalent interface		**October 1, 2018**
9. Grid services testing and model validation 10. Final industry meeting of stakeholder groups		April, 2018

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Backup Slides

Data Flow between Device Model and Grid Service: the Battery Equivalent Model (API)