SunShot
U.S. Department of Energy

SHINES Program Review 2017

The SunDial Framework

Enabling High Penetration of PV through Integrated, Feeder-Scale Control of DERs

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energy.gov/sunshot

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SunDial Project Overview

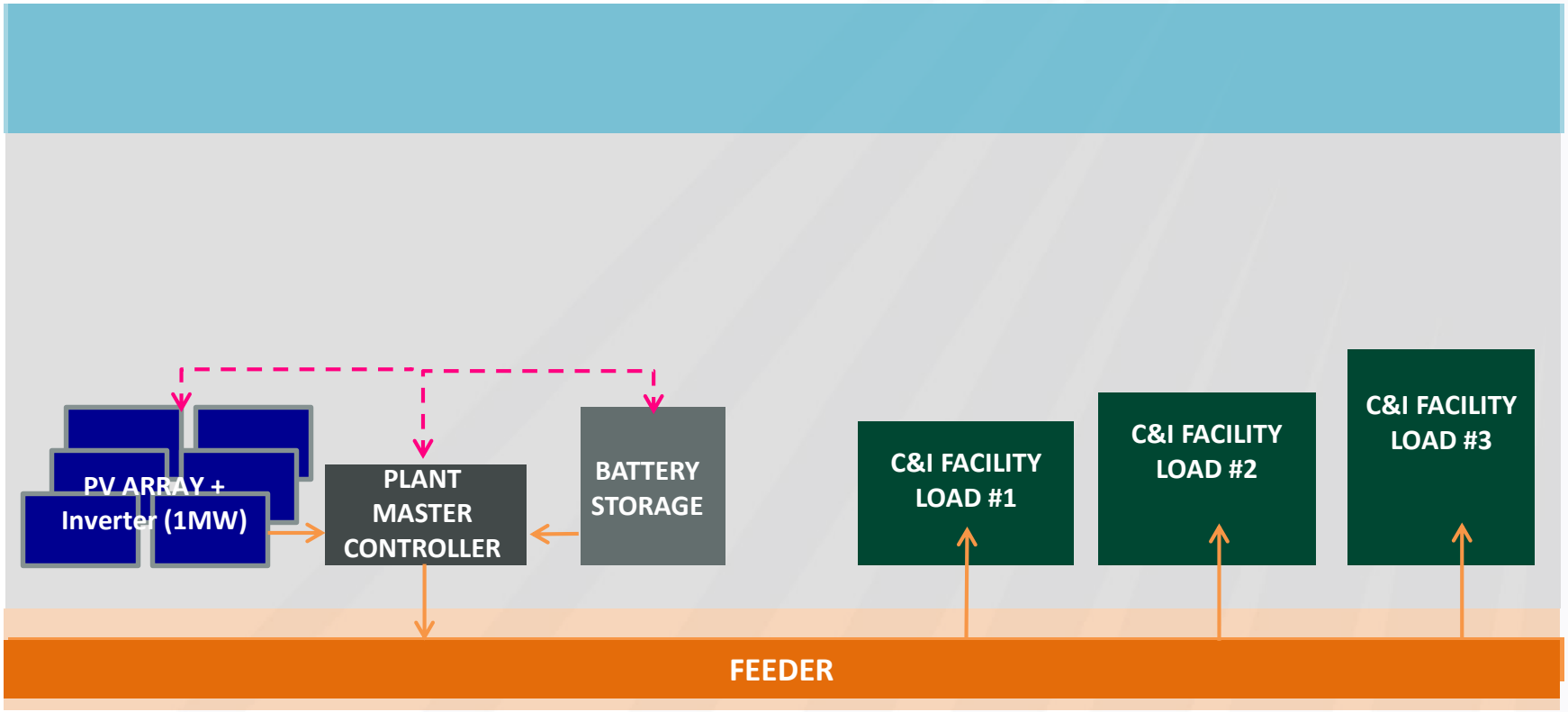
Project Objectives:

- Develop an extensible, flexible framework to readily and cost-effectively integrate loads, storage, and distributed solar PV
- Test and pilot business models and market mechanisms to enable high penetration of PV
- Dynamically manage loads to support high penetration of solar
- Year-long demonstration on National Grid distribution system with a portfolio of C&I customers

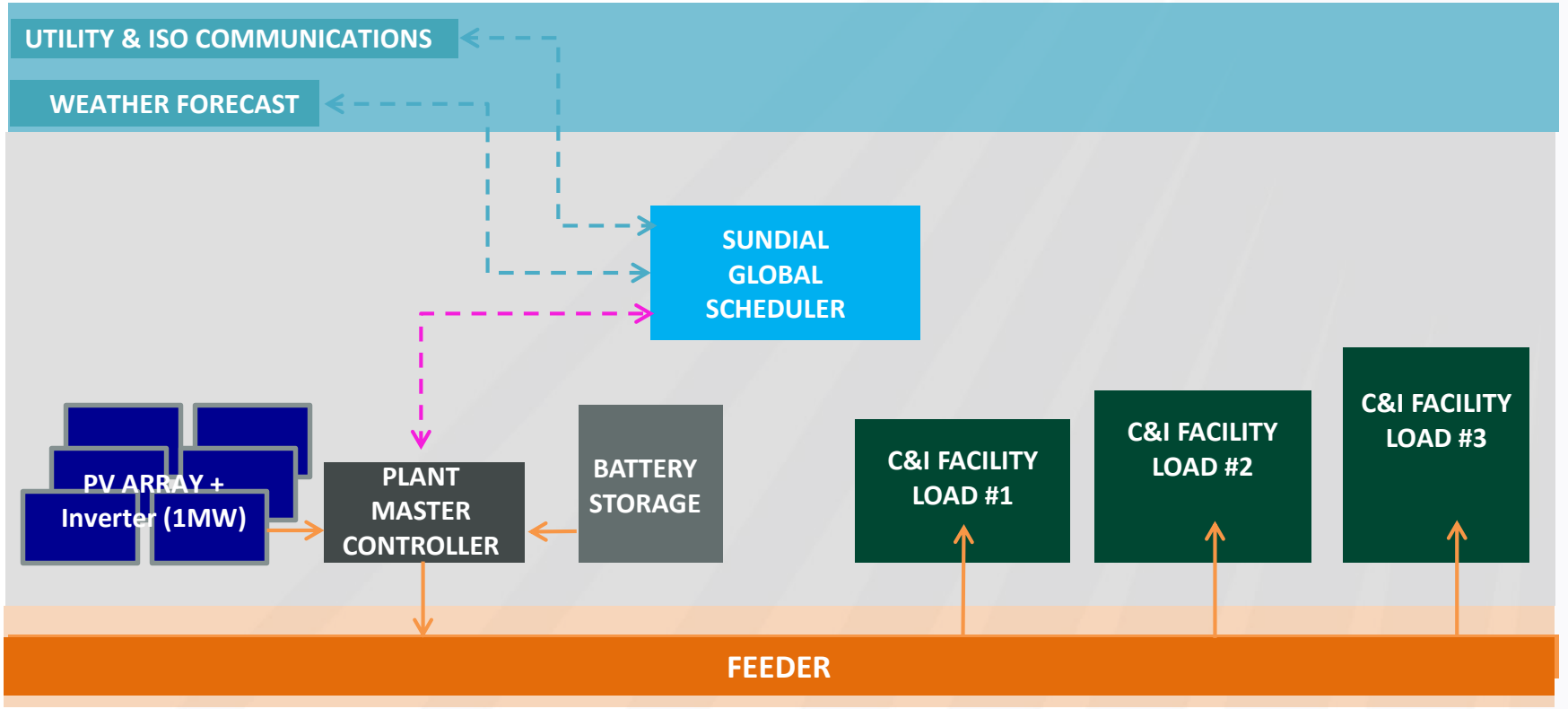
Project Team:

- Fraunhofer CSE
- National Grid
- IP Keys
- DOE SunShot
- MassCEC

Architecture – Major Components



Architecture – Major Components



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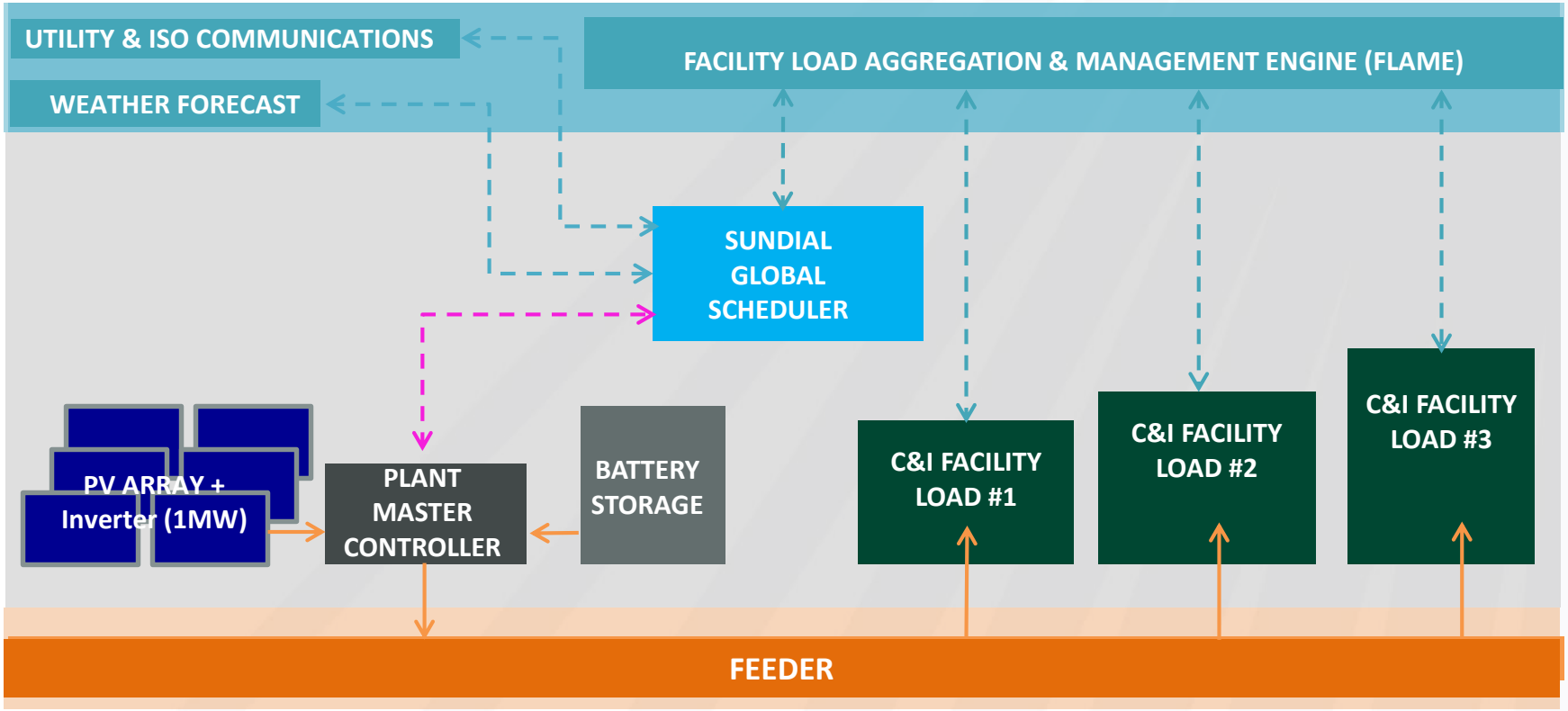

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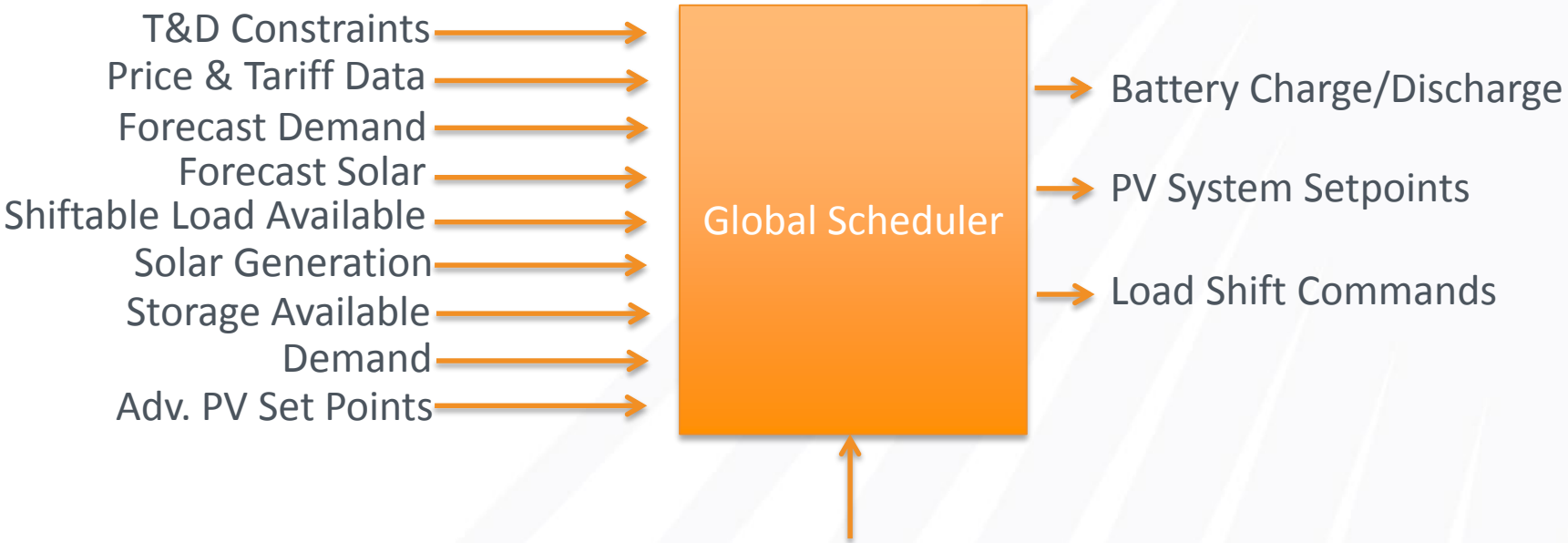
SunDial Global Scheduler



Define Policy, e.g.

- Follow configured load shape
- Minimize customer energy cost
- Maximize IPP revenue
- Etc.

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Phase 1 Objectives & Status

- PV System Construction & Interconnection
- Facility Recruitment
- Scenario Analysis
- Algorithmic Development
- Facility Load Aggregation & Management Engine (FLAME) Development
- Software Development & Systems Integration

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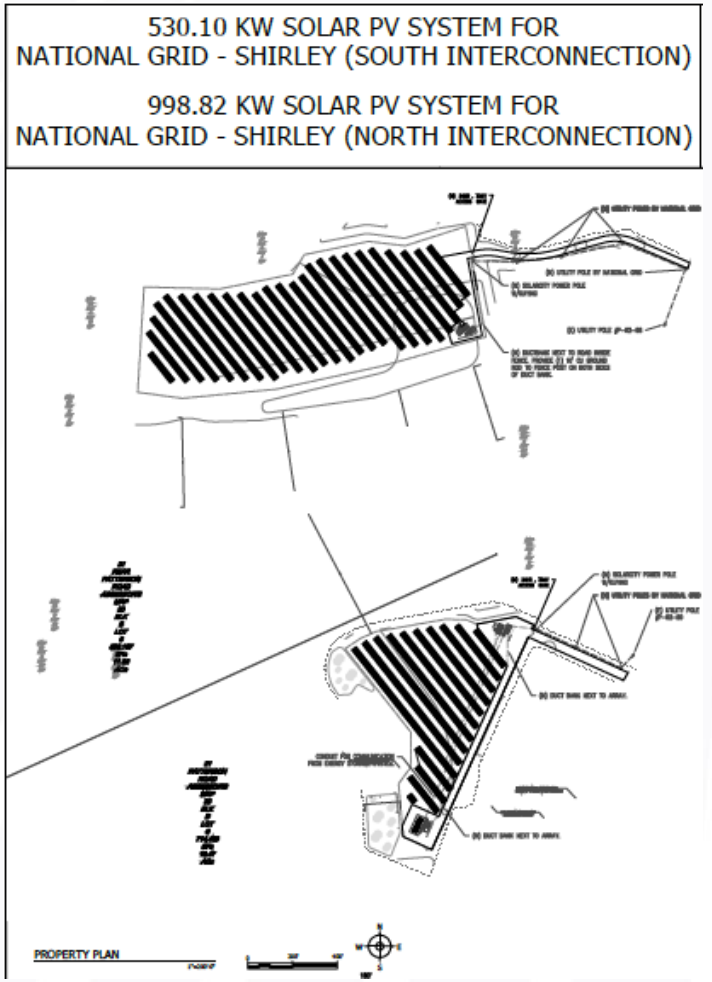
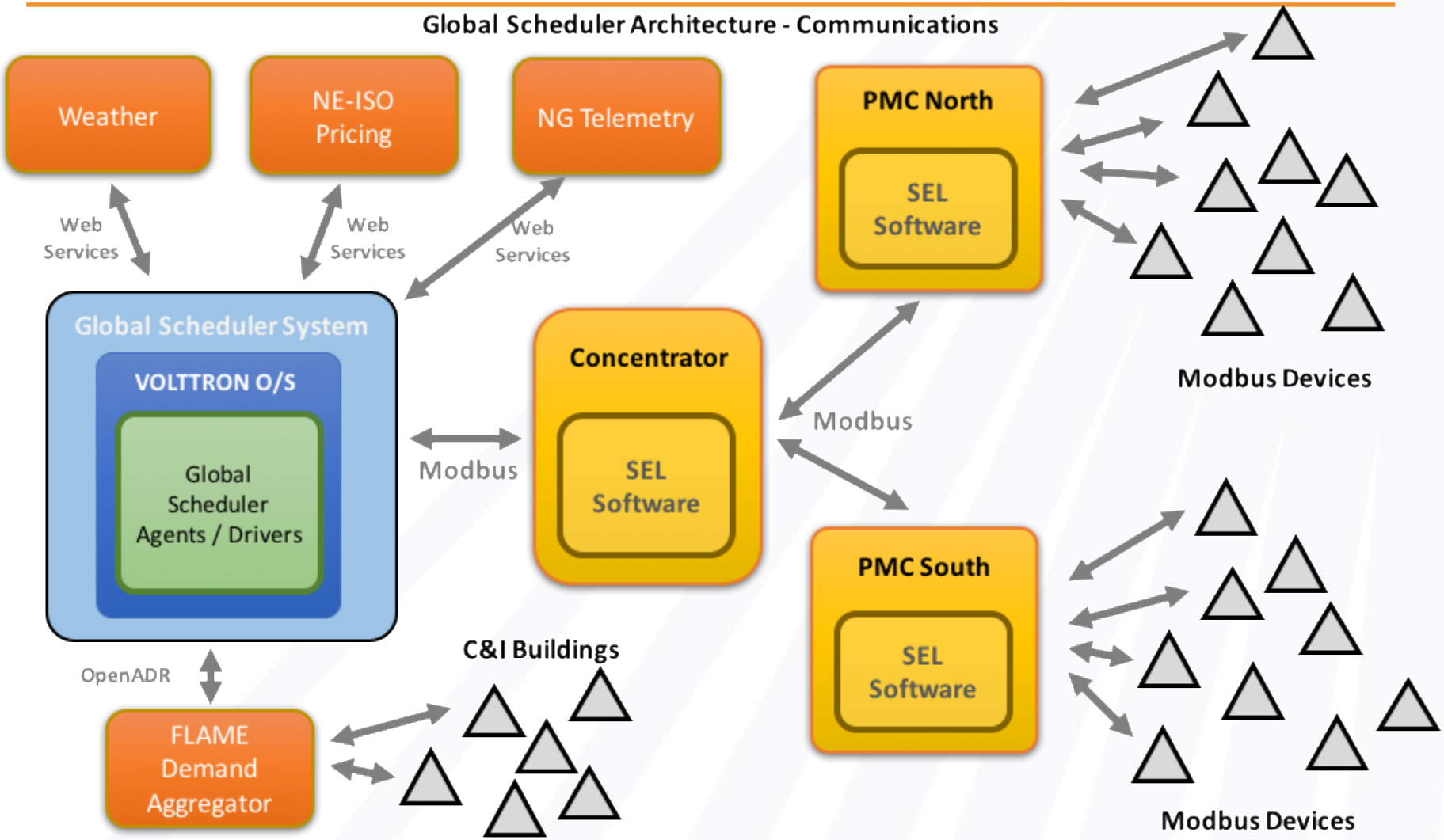
Project Demonstration Plan

- Duration: One year
- Location: Shirley, MA. 9MVA feeder, approx. 7MW PV installed or under construction
- PV: 1.5 MW, aggregated across two adjacent PV fields
- Energy Storage: 0.5MW / 1.0MWh
- Facility Loads:
  - >1MW aggregate demand
  - >200kW responsive (targeted)
- Optimize performance under different objectives and constraints



National Grid Phase 2 Shirley PV Site

SunDial System Topology



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Shirley PV Site - Status

- Construction completed
- Interconnection Service Agreement completed
- Interconnection upgrades in progress
- Plant Master Controller development in progress
  - Implemented on an RTAC (SEL-3530)
  - Designed to provide a modified SunSpec-compliant interface to GS
  - Alpha revision of code currently under review
- Commissioning / witness testing planned for June 2017

Facility Recruiting: Where we're at and what we've learned

- Target = 1,000kW of peak loads (sum of annual peaks)
- Identified target potential customers with ~4MW of load
  - Industrial facilities, schools, office, country club, hospital, assisted living
- First letter of commitment signed – ~300kW

- C&I outreach through National Grid's leading EE programs a major help
- Facilities care foremost about energy cost savings without disruptions
- Challenge: C&I facilities billed under existing tariff structure
- Value Proposition: Manage facilities' monthly demand and annual ISO peak coincident hour capacity charges during pilot
  - Run in SHINES mode on most days, in energy management mode as needed
  - Estimate 5-10% reduction in annual electric bill typical, assess by facility
- Interval data critical for assessing facility load management potentials

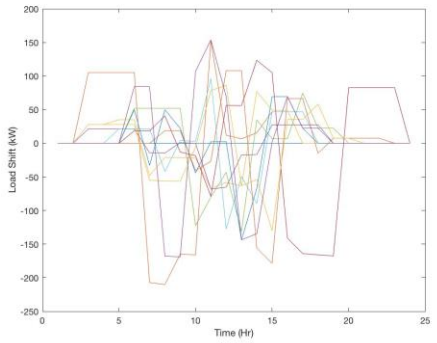
Algorithm Development & Scenario Analysis

- Energy Flow Model Development
- Use Case Definition
- Objective function development
- Multi-Objective Optimization Algorithm development

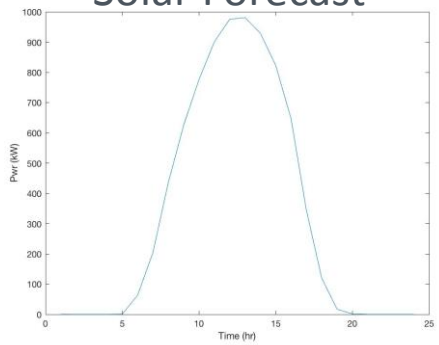
Energy Flow Model Overview

Scenario Configuration
- PV Penetration
- ESS Sizing
- Max Load Shift
- Demand Mix

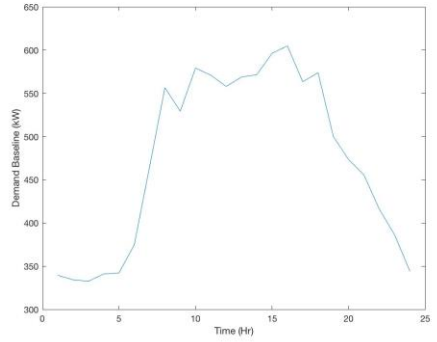
FLAME Simulation



Solar Forecast



Demand Forecast



System State
- ESS SOE
- Solar Production
- Demand
- Load Response

Global Scheduler Optimizer

Control Signals

Policy Configuration
- Objective fcns
- Prices
- …

Results
- Costs
- Bulk Power Flow Analysis
- ESS Duty Cycle
- Load-Shift Duty Cycle

Evaluating Use Cases

- Use cases are configured by selecting a portfolio of objective functions that collectively define the target policy
- Optimizer then minimizes the applicable cost, analogous to an economic dispatch model

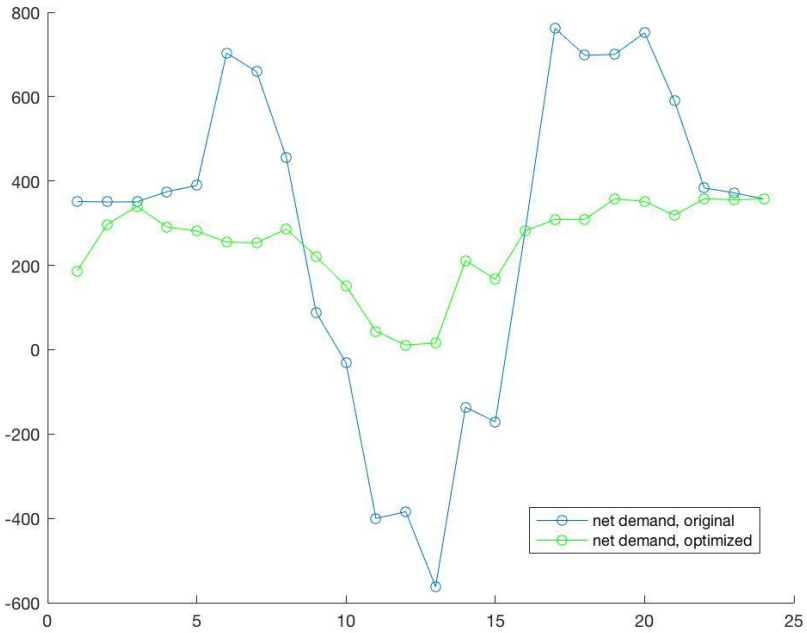
EXAMPLE

Objective Functions	Use Case #1 - Minimize Customer Energy Costs	Use Case #2 - Manage Utility Distribution System Constraints	Use Case #3 - Follow a Target Load Shape
DSO TOU Energy price	✔		
Day Ahead Wholesale Energy Procurement	✔	✔	
Real Time Energy Procurement		✔	
Monthly DSO demand charge	✔		
DSO ICAP charge	✔		
Shift load	✔	✔	✔
Battery - Damage accumulation	✔	✔	✔
Export limit at substation		✔	
Import constraint at substation		✔	
Network - ISO capacity charge		✔	
Schedule signal			✔

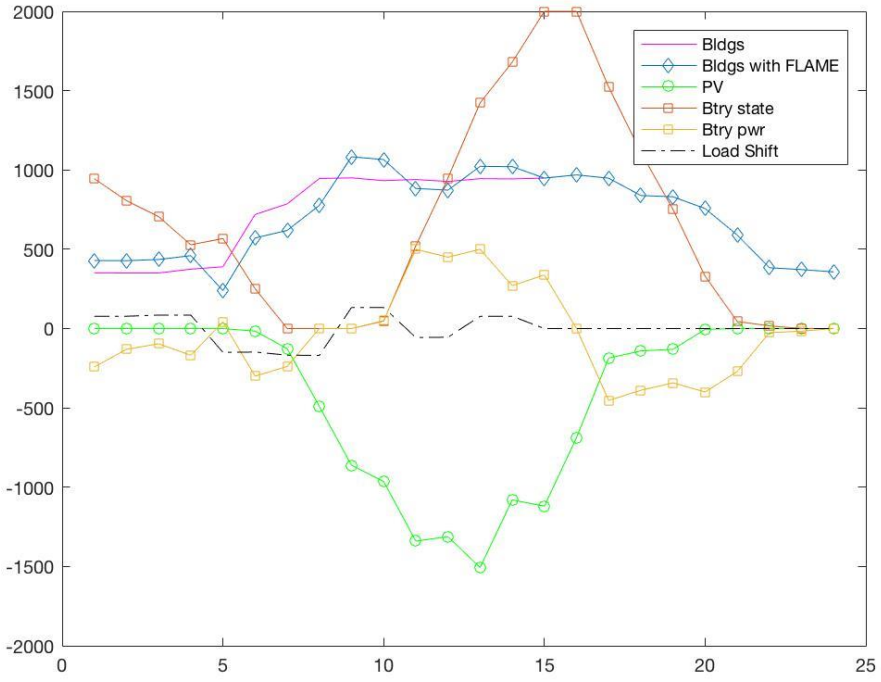
Global Scheduler Optimization Algorithm

- *Optimization Approach*: Simulated Annealing
  - Traditional convex optimization methods, e.g., gradient descent or linear programming are not applicable to the problem
    - Optimization space potentially non-convex
    - System is not memoryless
- Simulated Annealing summary
  - At each time step, it considers a set of multidimensional points sampled from the optimization space.
  - A small disturbance to the original configuration is applied and the system "energy" (related to the combination number and to the optimization function) is calculated
    - New energy and solution accepted, if its energy is lower than the energy at the previous step
    - New solution can be accepted if its energy is higher with a probability that decreases as the number of steps increases
  - This procedure is repeated with gradually decreasing disturbance size and likelihood of accepting a solution with higher "energy"
  - Eventually the simulations "freeze."
  - For properly designed simulations, the system's "freezing" corresponds to an approximate global optimal solution that does not depend on the original configuration

Objective Function Example #1 – Minimize Peak Demand & Peak Export



Net Demand



Component Power Flows

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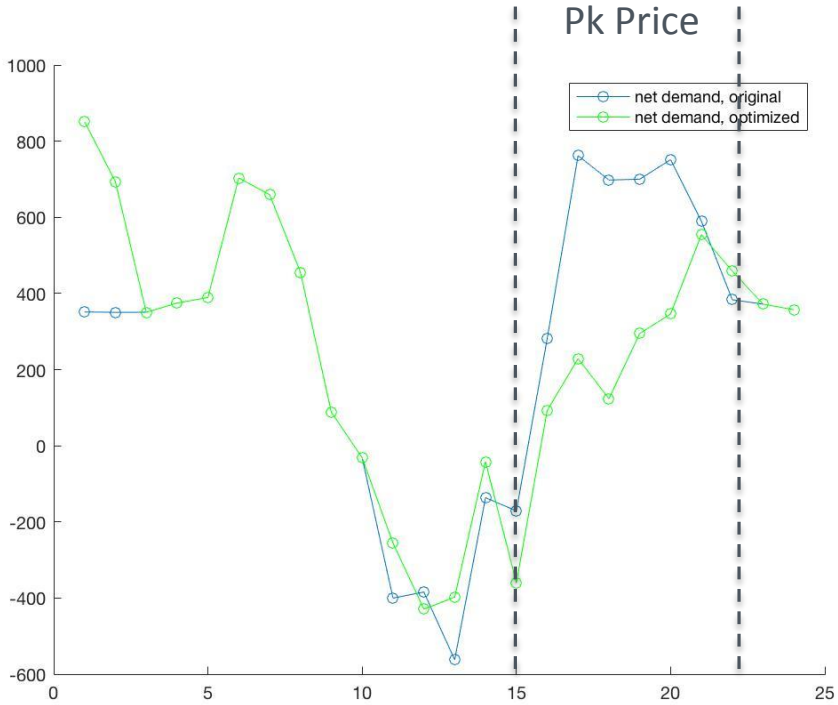
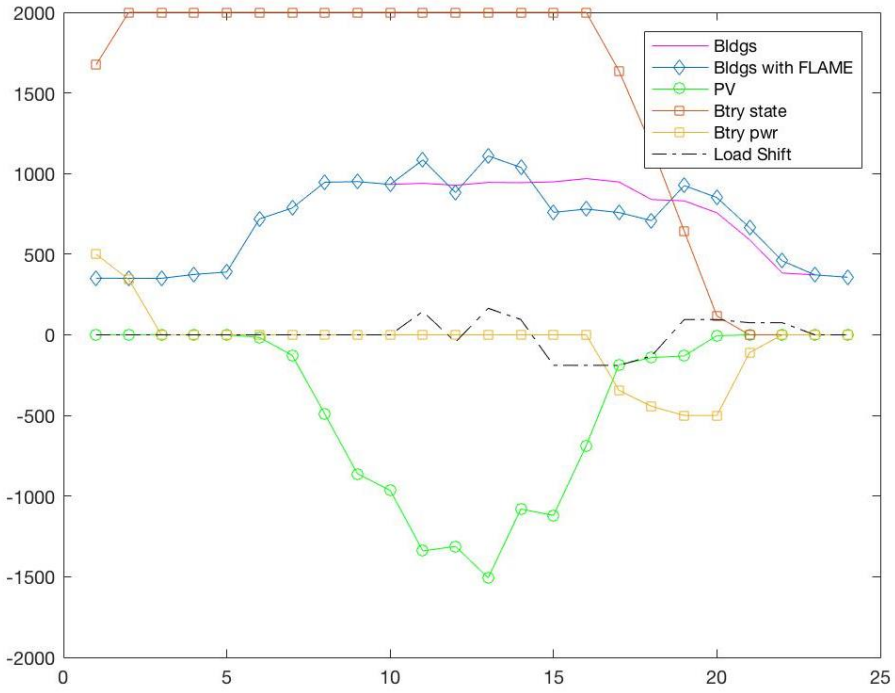
Objective Function Example #2 – Time-of-Use Tariff



Net Demand



Component Power Flows

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FLAME Development: Load management differs a lot from traditional DR

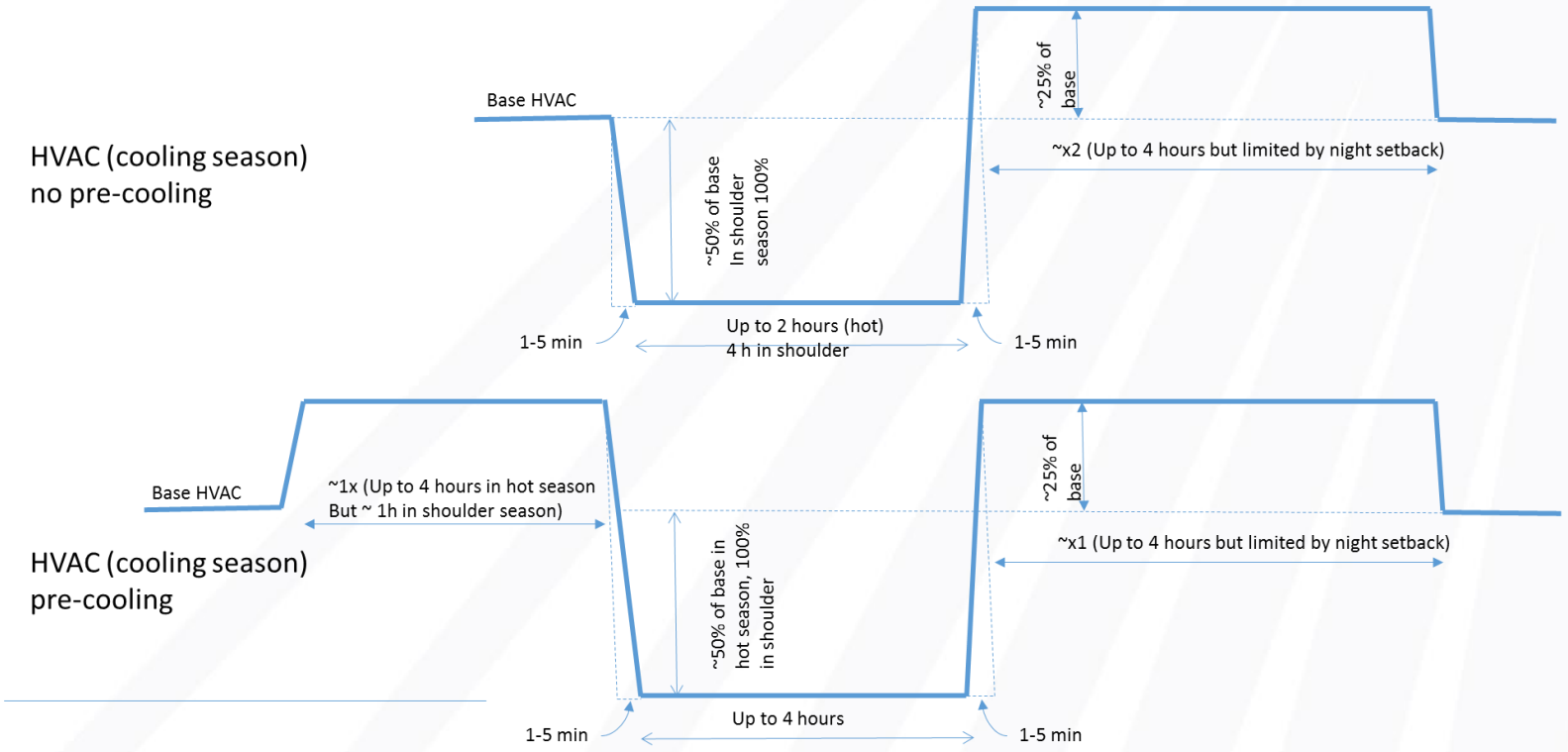
Attribute	Traditional DR	Load Shifting w/SunDial
Frequency of Calls	Order of 5-20 times/year	Majority of days/year
Key Goal	Load shedding	Load sinking to increase PV and load coincidence
Duration of LM	1 to 4 hours	Up to 16 hours/day
Most Needed	Usually summer or winter peak	Mid-/late-spring – largest surplus

FLAME development shaped by these differences:

- Automated load management essential
- Develop of new algorithms for load sinking over extended periods of time
- Millions of potential managed load profiles due to temporal path dependence of load management – need techniques to simplify assessment of options
- OpenADR does not readily accommodate communication of potential load profiles
- Accuracy assessment of baseline loads and load management potentials focuses on hours in and around significant PV generation

FLAME – Load Shift Example

- Example load management (i.e., sink and shed) potentials for different end uses, in different facility type



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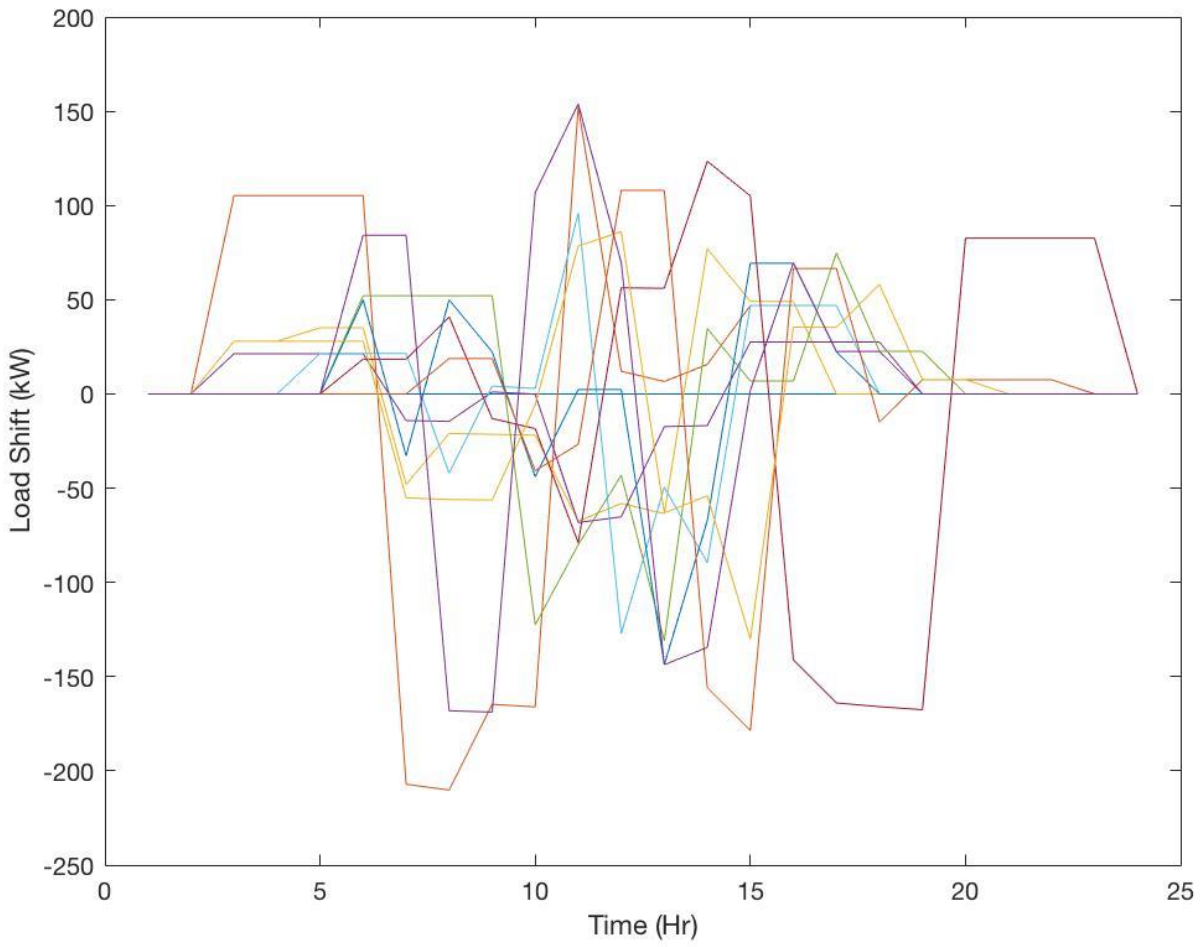
Generating & Selecting Load Shift Scenarios



- GS communicates an “ideal” load shape to FLAME
- FLAME communicates a portfolio of load shift options to GS that approximate the ideal
- GS selects the “ideal” profile
- Implementing as extension to OpenADR, with potential avenue for adoption

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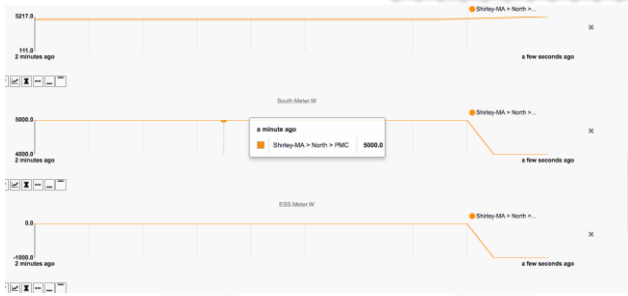
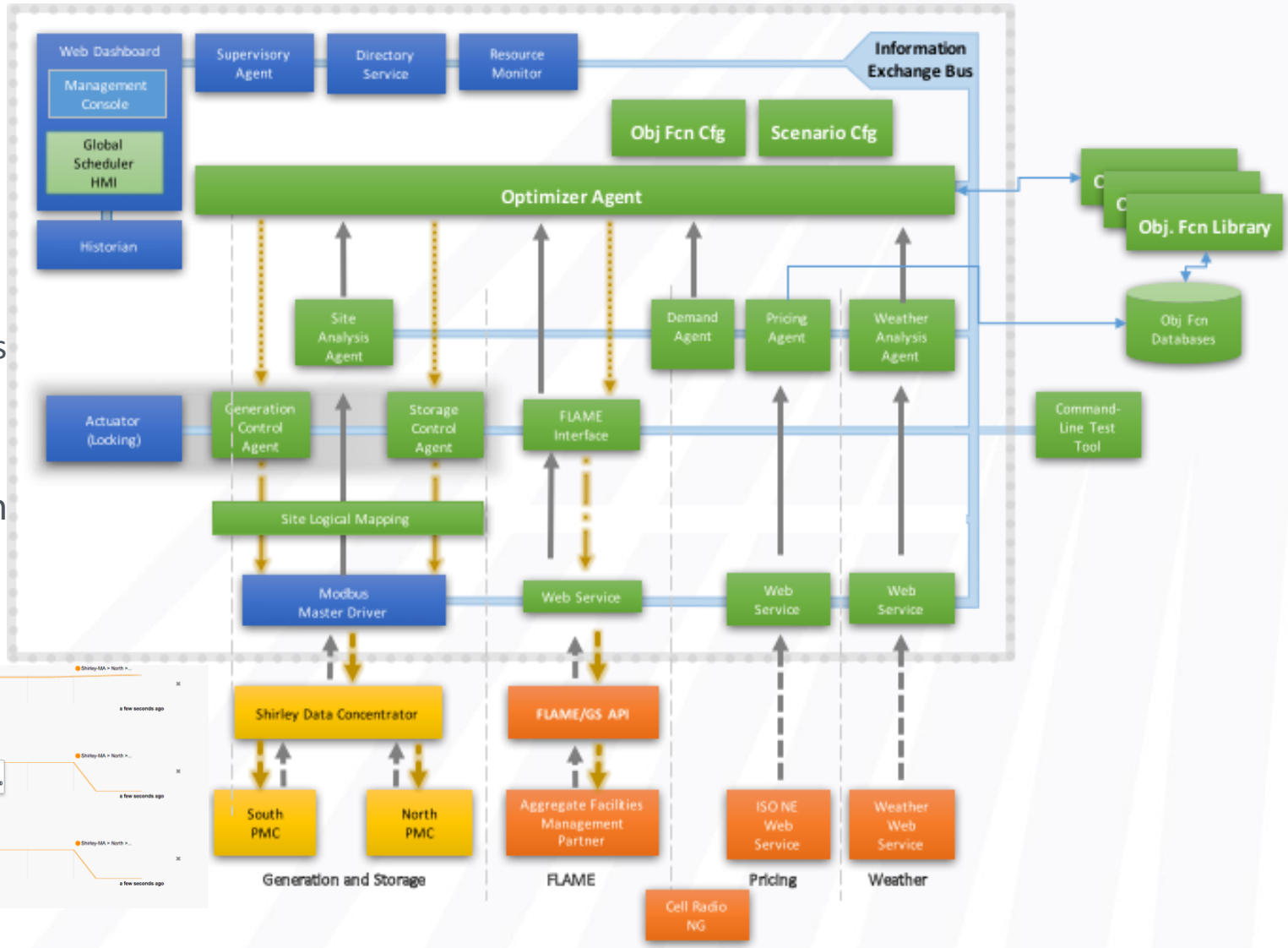
Global Scheduler Software Architecture & Implementation

- VOLTTRON platform
- Flexibility to modify
  - Resource Portfolio
  - Data Sources
  - Optimizer
  - Policy
- Communication Specification





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Next Steps

- **Phase 1**
  - Phase Review planned for May 2017
  - Complete system upgrades, witness testing
  - Facility Recruitment – Secure additional LOIs from potential partners
  - Implementation of FLAME forecast & bulk power shift profiles
  - Apply Energy Flow Model, SAM to proposed use cases, complete scenario analysis
  - Complete core Global Scheduler platform & simulation test environment
- **Phase 2:**
  - Complete software development & integration
  - Field Deployment of FLAME & Global scheduler
  - Demonstration / deployment ~Q4 2017/Q1 2018
- **Phase 3:**
  - Field test
  - Evaluation
    Synthesize lessons learned

Accomplishments (To Date)

- Developed a highly flexible platform for driving a portfolio of DERs towards user-defined objectives
- Novel application of an optimization algorithm to address the specific characteristics of load shifting & energy storage
- Foundational work that supports the use of demand-side management to support local matching of supply & demand on a timescale of hours
- Potential reduction in energy storage size to support high-pen PV
- Preliminary deployment of assets for field demonstration

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Anticipated Project Outcomes

- Framework for cost-effectively integrating demand-side management to support high penetration of PV, supported by
  - Initial commercial implementation of demand management platform
  - Data standard for negotiating long-term load shift
  - Reference control platform
  - Results of field testing
- Flexibility to handle current and future conditions – e.g.,
  - import/export constraints,
  - negative pricing, etc.
  - Summer peak
  - Shoulder month surpluses,
  - …and more

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Learn more about SHINES and SunDial

- https://www.energy.gov/eere/sunshot/sustainable-and-holistic-integration-energy-storage-and-solar-pv-shines
- http://www.cse.fraunhofer.org/shines

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