The SunDial Framework: Enabling High Penetration Solar through the Integration of Energy Storage, Demand Management, and Forecasting

Matt Kromer, Kurt Roth, Tsz Yip, Michael Zeifman

Fraunhofer Center for Sustainable Energy, Boston, MA 02210, USA

Introduction

Figure 1: *Pilot Deployment PV Site*

An open data exchange standard and vendor agnostic control platform (the "SunDial System") are used to integrate facility loads and demand management, battery energy storage, and solar PV by optimizing power flow on the distribution system in high-penetration solar environments. The integration of forecasting and day-ahead shaping of customer loads enabled by SunDial reduces the need for storage by 10-20% and reduces LCOE by ~10% at solar penetrations ranging from 50 to 150% of peak load. A pilot deployment manages a portfolio of 1.5MW of PV, 0.5MW/1.0MWh battery, and 3.5 MW of customer load on a National Grid distribution feeder through June 2019.

Challenges:

- Distribution level effects: reverse power flow, voltage excursions outside ANSI limits, and additional wear on distribution equipment.
- Network level effects: high penetration solar increase the need for load following generation and introduce negative energy prices.
- Energy storage can help address these problems but deployment of energy storage limited by high installed costs, and difficulty stacking value streams.
- Active demand management (ADM) can be used to increase solar hosting capacity by shifting demand to periods of excess generation – thereby limiting the need for energy storage.
- To date, real-world deployments of solar-integrated ADM have been limited, particularly at the feeder scale.
- Using ADM to support solar integration entails much more frequent up regulation for multiple hours per day compared to traditional demand response.
- Market for multi-hour load-shaping does not exist, there is not a recognized data standard for negotiating long-duration ADM services.

System Architecture

The SunDial System will optimize power flow on the distribution system in high-penetration solar environments.

- A vendor-agnostic control platform minimizes costs based on user-defined policy objectives for a portfolio of distributed energy resources (DERs)
- Assets can be owned and operated by different entities.
- An open data exchange standard facilitates the integration of demand-side management into this framework to provide multi-hour "load shaping" services.

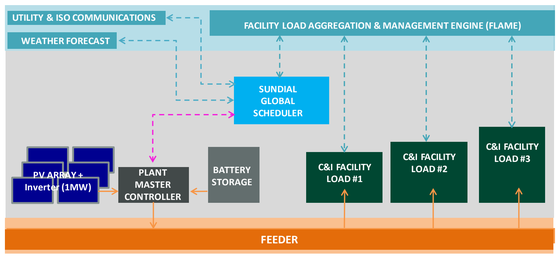

Figure 2: *SunDial System Architecture Block Diagram*

The components of the SunDial System are shown in Figure 2:

- SunDial Global Scheduler – central control platform
- A portfolio of distributed energy resources (DERs) – one or more PV plants, energy storage, and facility load aggregators
- Exogenous signals – weather forecast, pricing information

The Global Scheduler is implemented as a package of application agents on the VOLTTRON platform, an open-source DER operating system developed by Pacific Northwest National Laboratory (PNNL). Individual application agents communicate using a common message bus and internal DER data model. This modular implementation offers flexibility with overall system configuration, external data interfaces, the virtual aggregation and control of classes of devices within the SunDial framework, the specific set of user policy objectives, and optimization methodology (reference implementation is simulated annealing).

The Facility Load Aggregation & Management Engine (FLAME) is a cloud based system that manages the demand side assets. FLAME integrates with local building management systems to provide the Global Scheduler with load shift profiles available for execution. Once the optimizer selects the optimal load profile, FLAME dispatches that profile for execution at the applicable site.

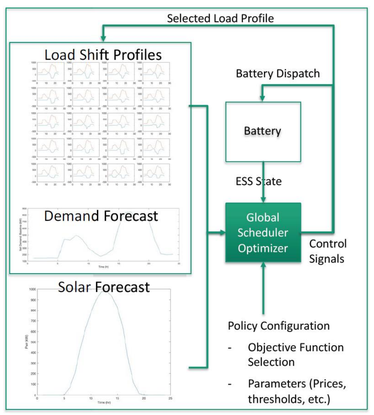

Figure 3: *Global Scheduler Execution Block Diagram*

Results

The performance of the SunDial system was modeled using Fraunhofer's Energy Flow Model (EFM). The EFM generates an optimal dispatch schedule for the SunDial system, enabling a user to analyze power flows, operating cost, and component duty cycles across a range of deployment scenarios. Scenarios were varied in terms of PV penetration (% of peak load), storage system size, system location (Phoenix, AZ), load shape (peaky vs flat), and objective. Illustrative results are shown in Fig. 4 for a summertime peak-shaving objective.

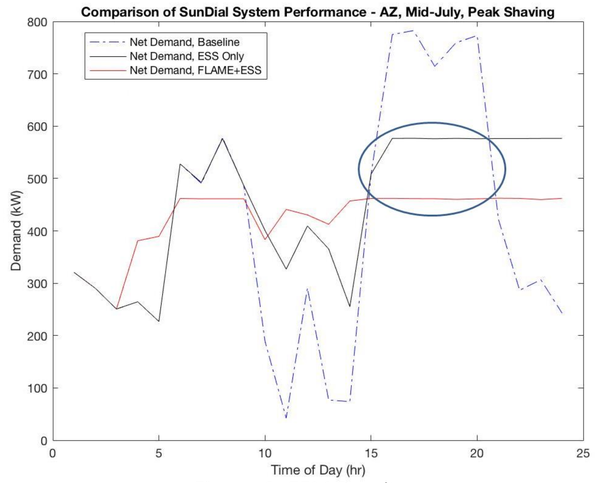

Figure 4: *EFM Results*

In addition, the SunDial system is currently under hardware in the loop testing using the to be deployed system controller to generate performance results of the system. Fig 5. and Fig. 6 show recorded data of the Global Scheduler operating on simulated system inputs and executing various performance objectives. The hardware in the loop test setup is reflective of the demonstration site in Shirley, MA USA.

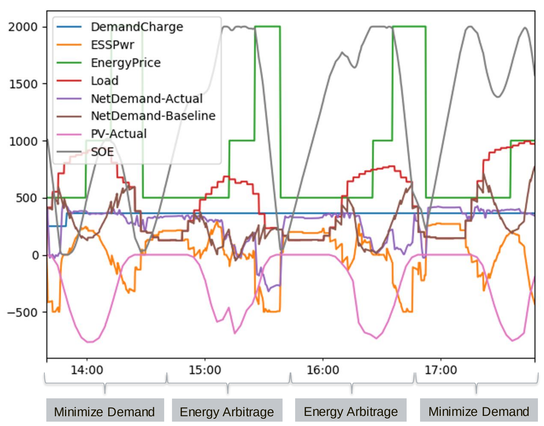

Figure 6: *Energy & Demand Cost Minimization*

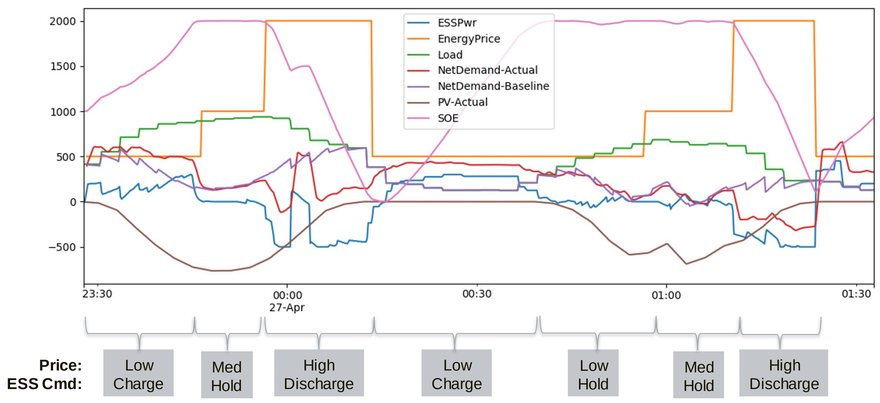

Figure 5: *Time of Use Energy Price Cost Minimization*

Conclusion/Future

The SunDial framework offers a new methodology to use demand-side management in combination with traditional energy storage to provide "load shaping" services, thereby reducing friction and risk associated with deploying solar in high penetration environments. A pilot implementation of SunDial was deployed on a National Grid distribution feeder in Shirley, MA in Spring 2018 using a dispatch platform developed by Fraunhofer that optimizes control of DERs for different use cases. It manages a portfolio of 1.5MW of PV, 0.5MW/1.0MWh battery storage, and 3.5 MW of customer load, 10-20% of which is flexible (Fig. 5). Customer load is distributed across three different facilities – a school and two industrial plants – that are aggregated within IPkKeys' cloud-based FLAME platform. Through June 2019, the project team of Fraunhofer CSE, National Grid, and IPKeys will test operation over a range of stacked use-cases to characterize the potential for (and limits of) integrated storage + load management.

Fraunhofer USA | SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy | MASSACHUSETTS CLEAN ENERGY CENTER | nationalgrid | IPKeys