SunShot
U.S. Department of Energy

ELECTRIC POWER RESEARCH INSTITUTE

SHINES Program Review 2017

Beneficial Integration of Solar PV, Energy Storage, Load Management, and Solar Forecasting

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Electric Power Research Institute (EPRI)

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Presentation Outline

- Project Team
- Objective and Key Research Components
- Budget Period 1 Highlights
  - System and Local Controller Strategies
  - Solar Forecasting
  - Load Management
- Demonstration Sites
- Next Steps
- Conclusion

EPRI SHINES Project Team

Utility Partners

- FirstEnergy*
- NYPA*
- ConED*
- Southern Co*
- Gulf Power*
- LADWP†
- AECC†
- AEP†
- Duke†
- SMUD†
- Gas Natural SDG†

** DOE proposal team member*
† Supplemental Project Participants

University Partners

- Case Western Reserve University (CWRU)
- City University of NY (CUNY), Queens College

Industry Partners

- Eaton
- GE (Alstom Grid)
- Clean Power Research
- PowerHub
- LG Chem
- Smart Inverter vendors

EPRI

- Integration of DER (P174)
- Energy Storage and DG (P94)
- End-Use EE and DR (P170)
- Information and Com Tech (P161)
- System Studies
- Economic Analysis

Objective

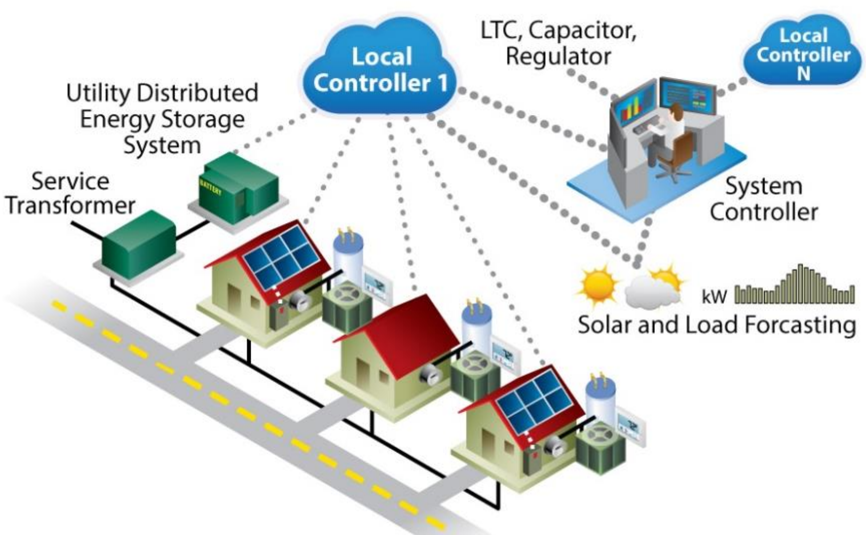
Beneficial Integration of solar photovoltaic generation, energy storage, load management, and advanced forecasting technique,

with

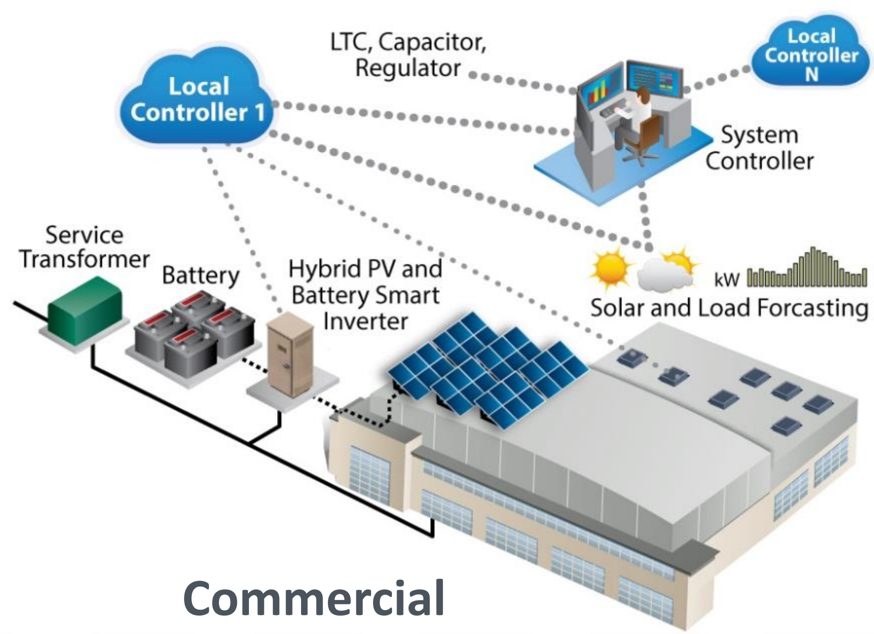
electric power delivery network

through

optimal control strategies at a minimized cost.

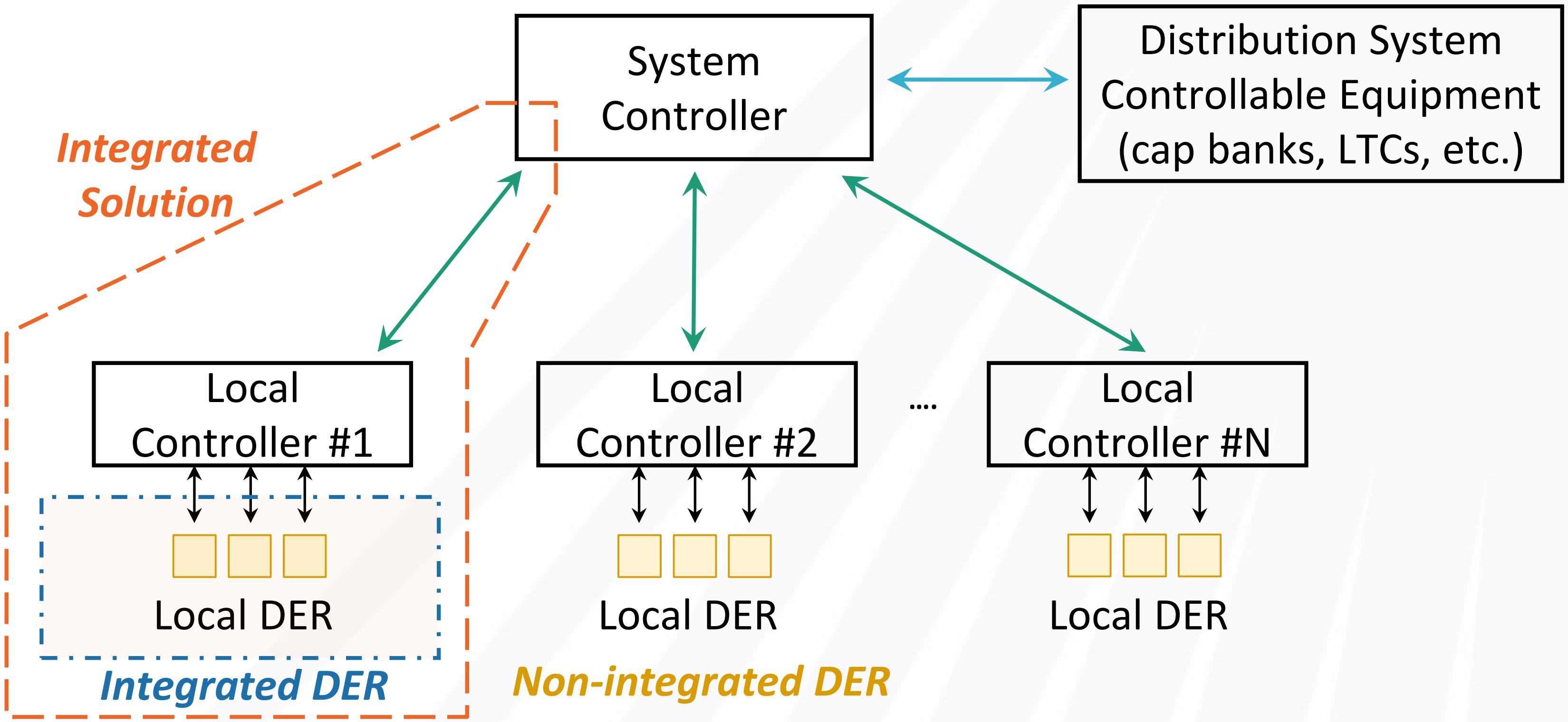


Residential



Commercial

End-to-End Integration



- **Local controller** coordinates DER devices to satisfy local objectives while responding to operational requests received from system controller.
- **System controller** sends setpoints to local controllers and distribution system controllable equipment based on service and reliability needs identified.

Key Research Components

- **End-to-end integrated system** through two-level **optimized control architecture**
- **Controllable Distributed Energy Resources** combining energy storage, and load management with solar PV
- **Improved predictability of solar PV generation** through high resolution solar forecasting
- **Reduced lifetime cost of solar plus storage system** through reliably integrated smart inverters
- **Interoperable and scalable solution** with open standards and communication protocols
- **Identifying power system level benefits** through distribution feeder modeling and impact studies

Budget Period 1 (Feb 1, 2016 ~ Jul 31,2017) Tasks

Task 1.1: Project management and planning

Task 1.2: Create functional requirements and performance metrics for the control architecture and components

Task 1.3: Develop optimal control strategies for local and system controllers

Task 1.4: Improvement of PV and ES smart inverters

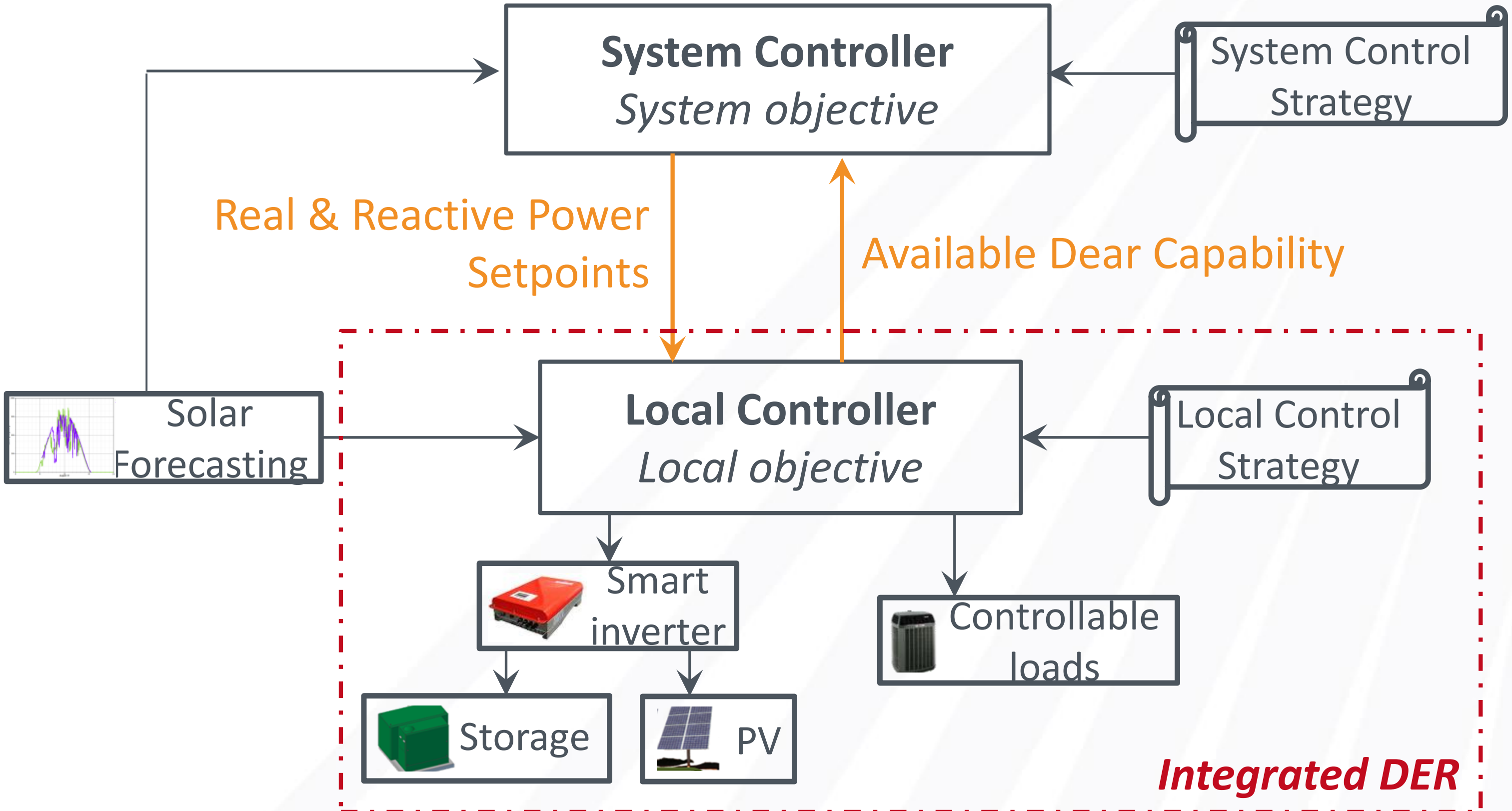
Task 1.5: Enhance solar forecasting resolution and interfaces

Task 1.6: Calculate host site and distribution feeder PV hosting capacity without proposed SHINES solution

Task 1.7: Demonstration site preparation – PV system

Task 1.8: Develop economic assessment methodology to assess the impact of proposed control architecture

Approach – Two-Level Control Strategy



Execution Approach

Solution Design → **Systems Design & Implementation** → **Site Demonstrations** → **Performance Assessment & Impact Analysis**

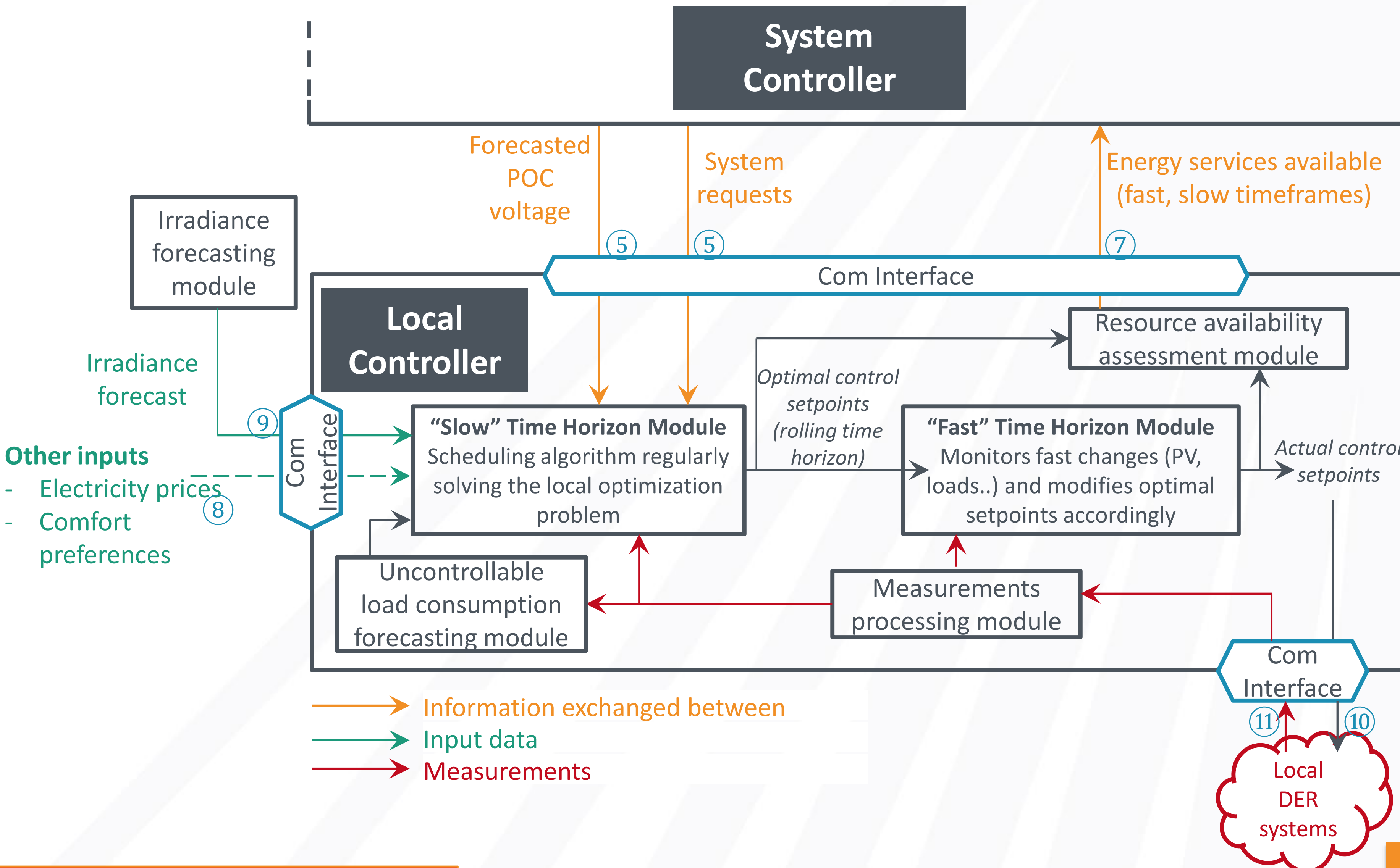
Solution Design
- Control architecture
- Functional requirements
- Performance metrics

Systems Design & Implementation
- Local & system controllers
- Smart inverter design & development
- Improved solar forecasting module

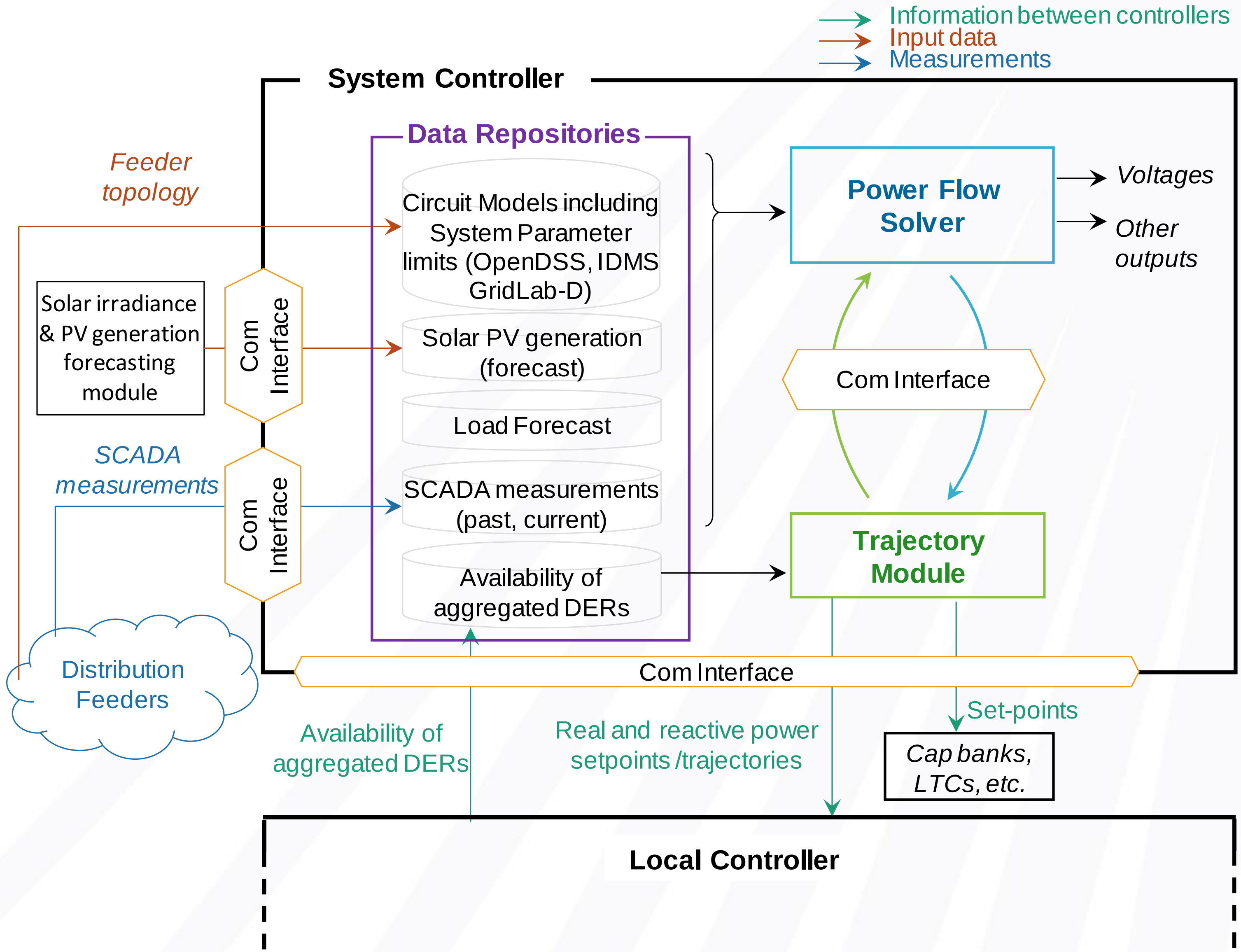
Site Demonstrations
- Site preparations
- PV & ESS Commission
- Data collection

Performance Assessment & Impact Analysis
- Solution technical performance
- Impact on PV hosting capacity
- Cost & benefit analysis

Local Controller Functional Blocks



System Controller Functional Blocks



Functional Requirements Local and System Controllers

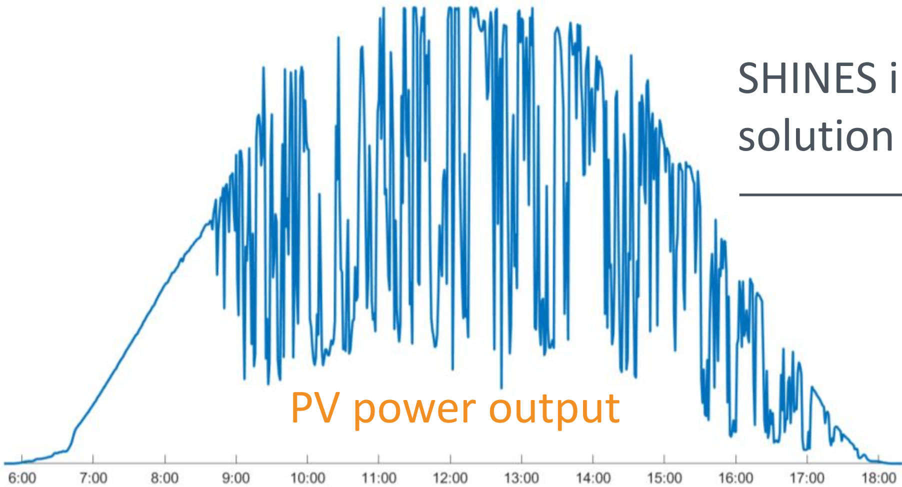
Req ID	Requirement	SC Functional Module
R.SC.1*	SC shall receive SCADA measurements in real time.	Com Interface
R.SC.2	SC may receive PV output forecasts in real time.	Com Interface
R.SC.3	SC shall store information on relevant distribution circuit models (including capacitor banks, LTCs and other controllable devices).	Data repositories
R.SC.4	SC shall store information on past and current circuit conditions (i.e. voltages, power demand, etc.)	Data repositories
R.SC.5	SC shall store information on availability of local DER resources received from local controllers.	Data repositories
R.SC.6	SC may receive and store information on past and current solar irradiance and solar PV power output from the local controllers to apply corrections to the forecasted solar data.	Data repositories
R.SC.7	SC shall compute power flow for any given set of circuit conditions and return key output variables including voltages for the relevant feeder(s).	Power flow solver

**R.SC = Requirement for System Controller*

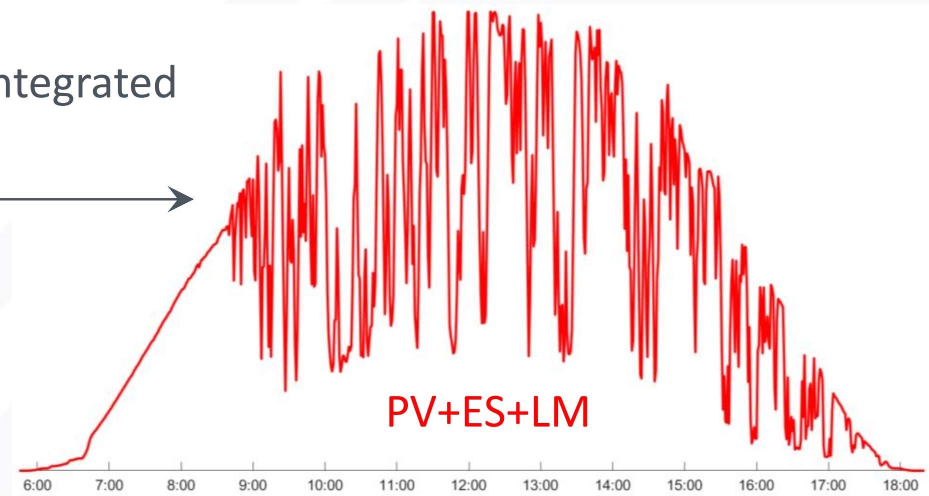
Req ID	Requirement	LC Functional Module(s)
R.LC.1*	LC shall receive real and reactive power setpoints from the SC.	Com Interface
R.LC.2	LC shall adjust the local DER schedules based on real and reactive power setpoints received from the SC.	Dynamic resource allocation; Reactive control loop
R.LC.3	LC shall compute availability of aggregated real and reactive power from local DER.	Resource availability assessment
R.LC.4	LC shall send updates to the system controller on availability of aggregated DERs.	Com Interface
R.LC.5	LC shall operate local DER systems to optimize local objective(s).	Dynamic resource allocation; Reactive control loop

**R.LC = Requirement for Local Controller*

Local Controller Requirement: Enable PV Ramp Control Using Storage and Load Management

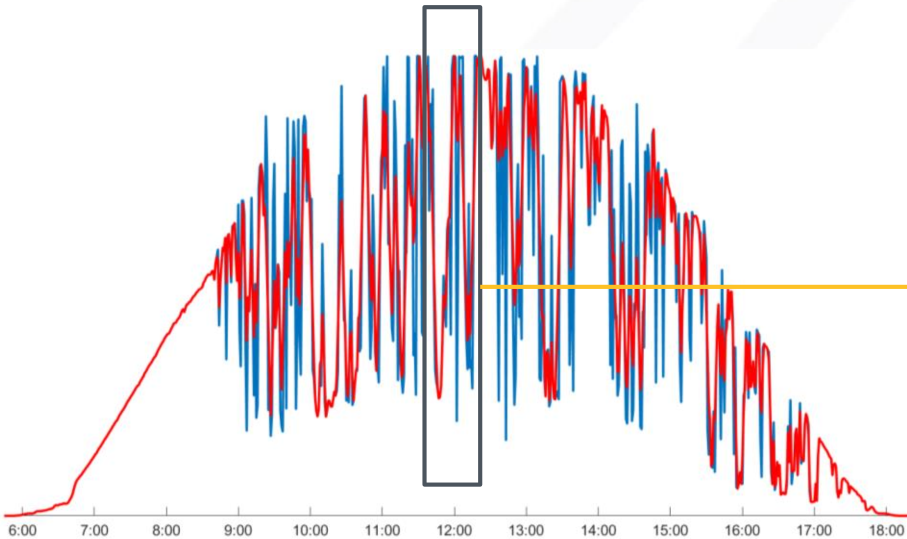


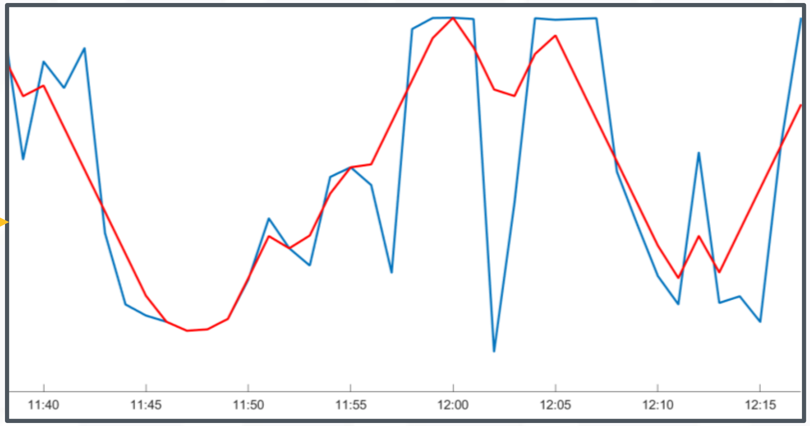
SHINES integrated solution



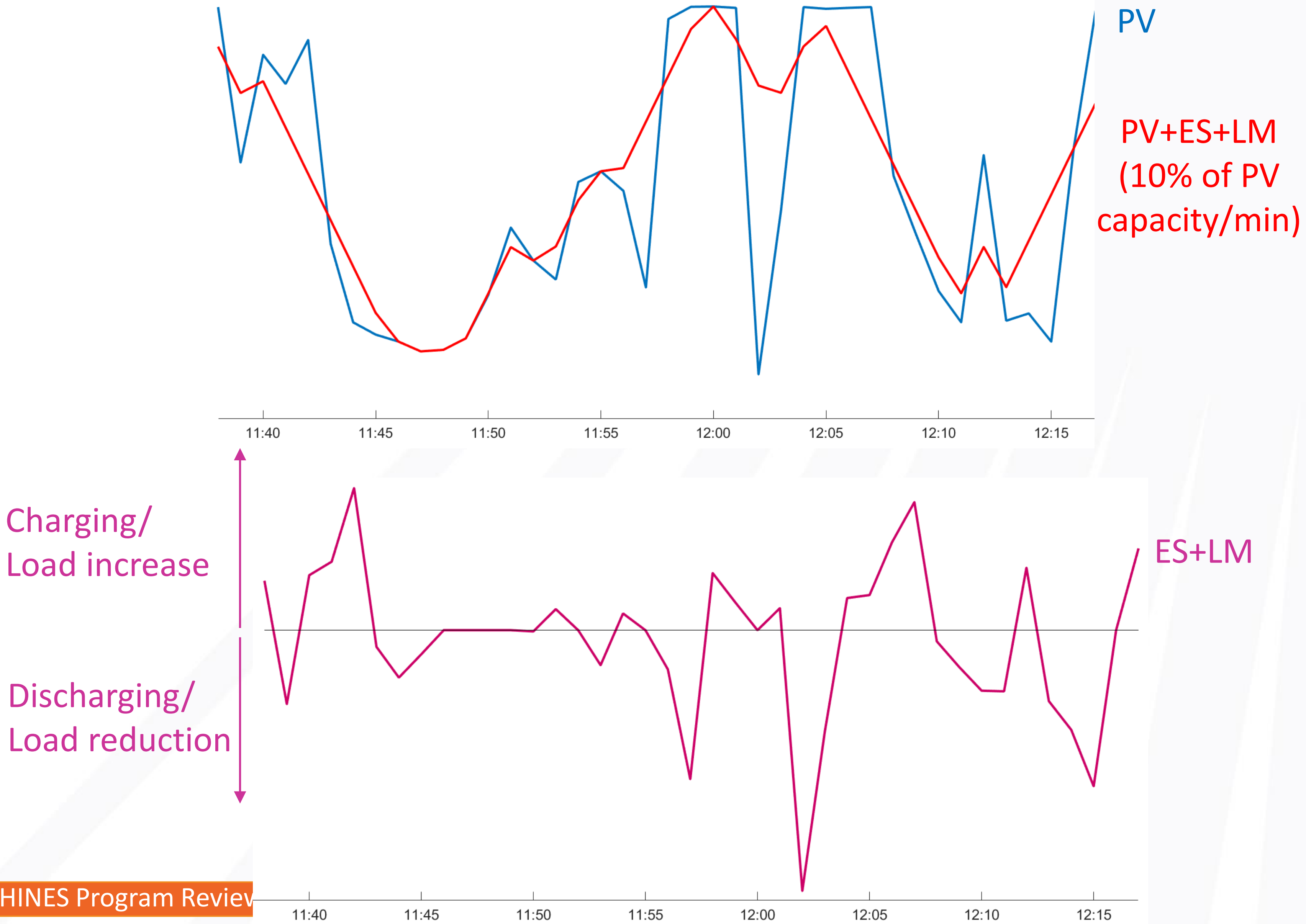
Max ramp rate: +78% of PV capacity/min

Max ramp rate: 10% of PV capacity/min

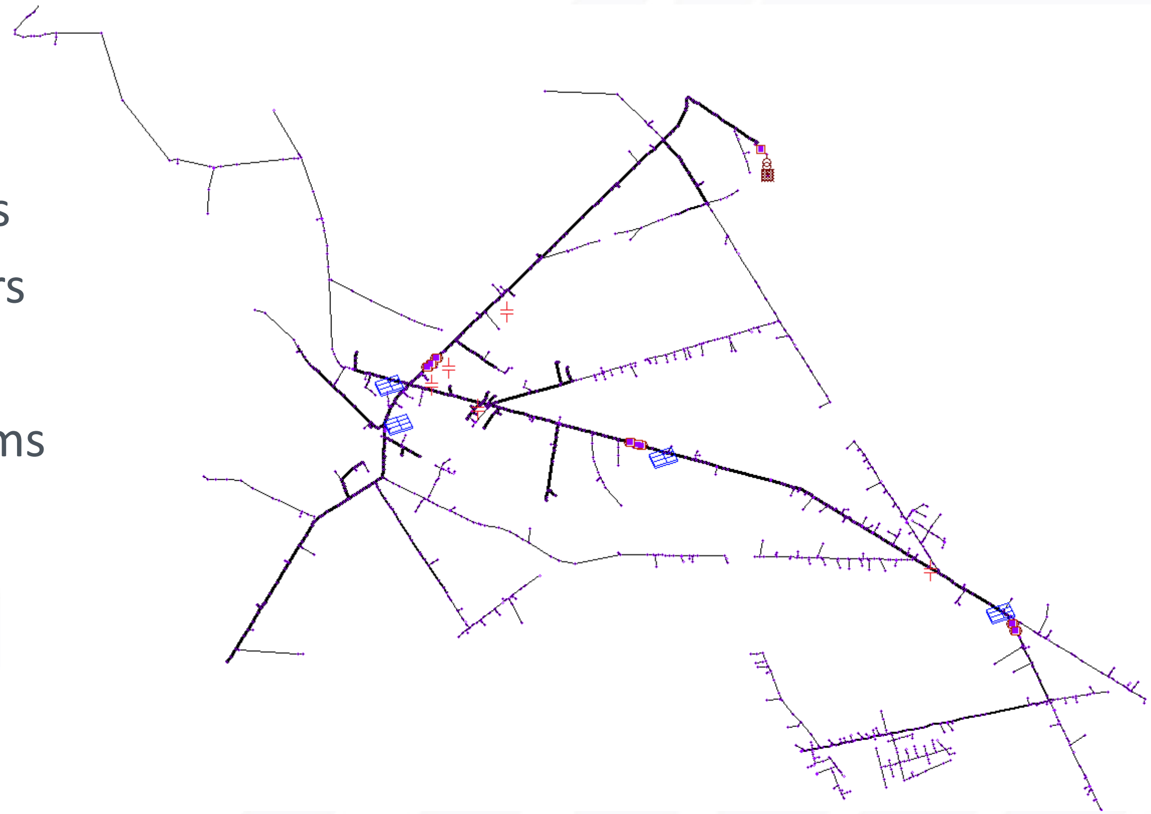




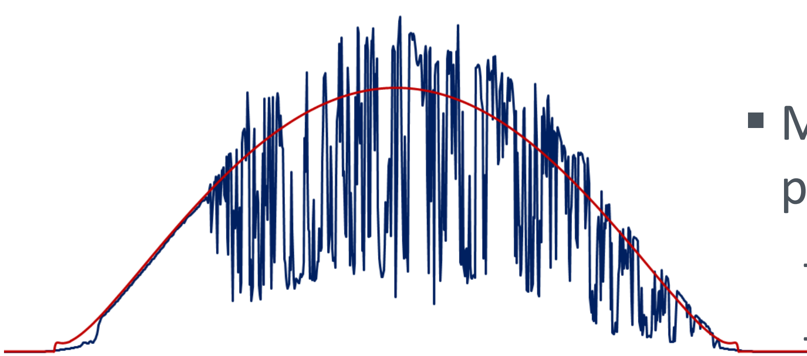
Local Controller Requirement: Enable PV Ramp Control Using Storage and Load Management



System Level Benefit of PV Generation Ramp Rate Control

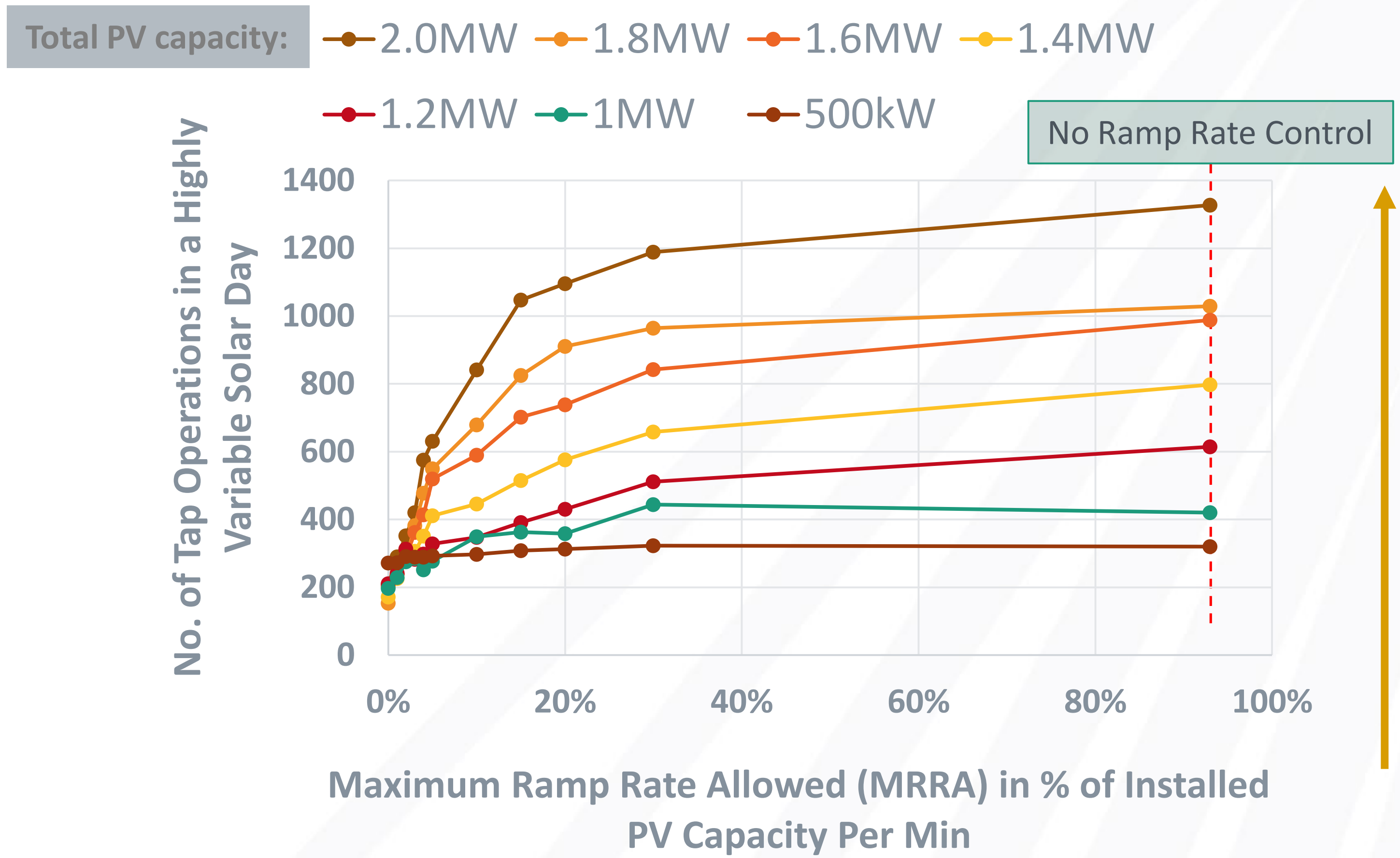


- 3433 buses
- 5 capacitors
- 9 LTC
- 4 PV systems



- Maximum PV ramp rates observed in solar profile assumed (% of installed capacity/min):
  - UP: +87.2%
  - DOWN: -93.7%

Impact of PV Ramp Rate Limiting on Tap Changing

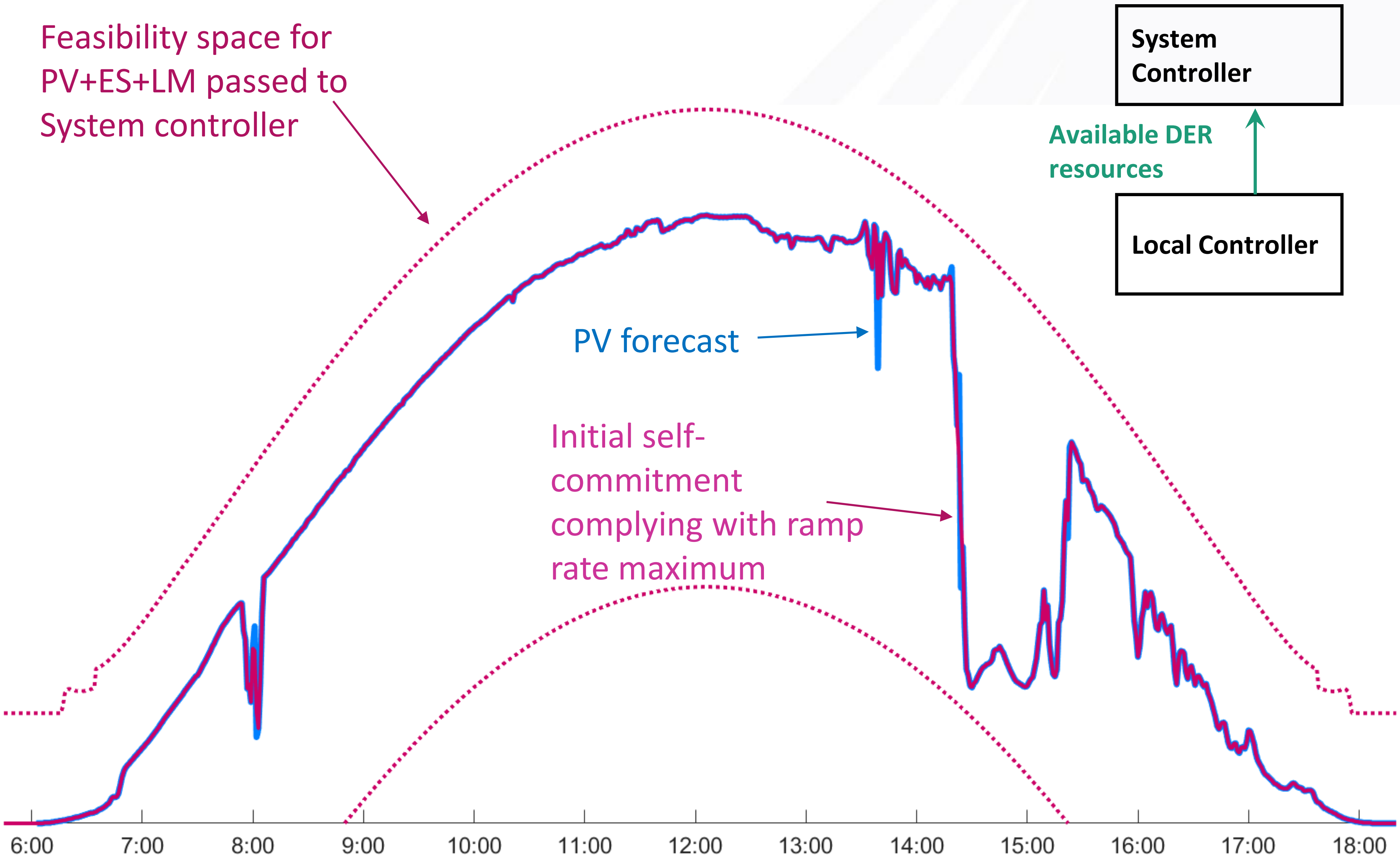


① The number of transformer tap operations increases with the increase of installed PV capacity

② When PV capacity is large enough to impact tap operation, limiting PV ramp rate through integrated DER control reduces the number of tap operations required which extends equipment life

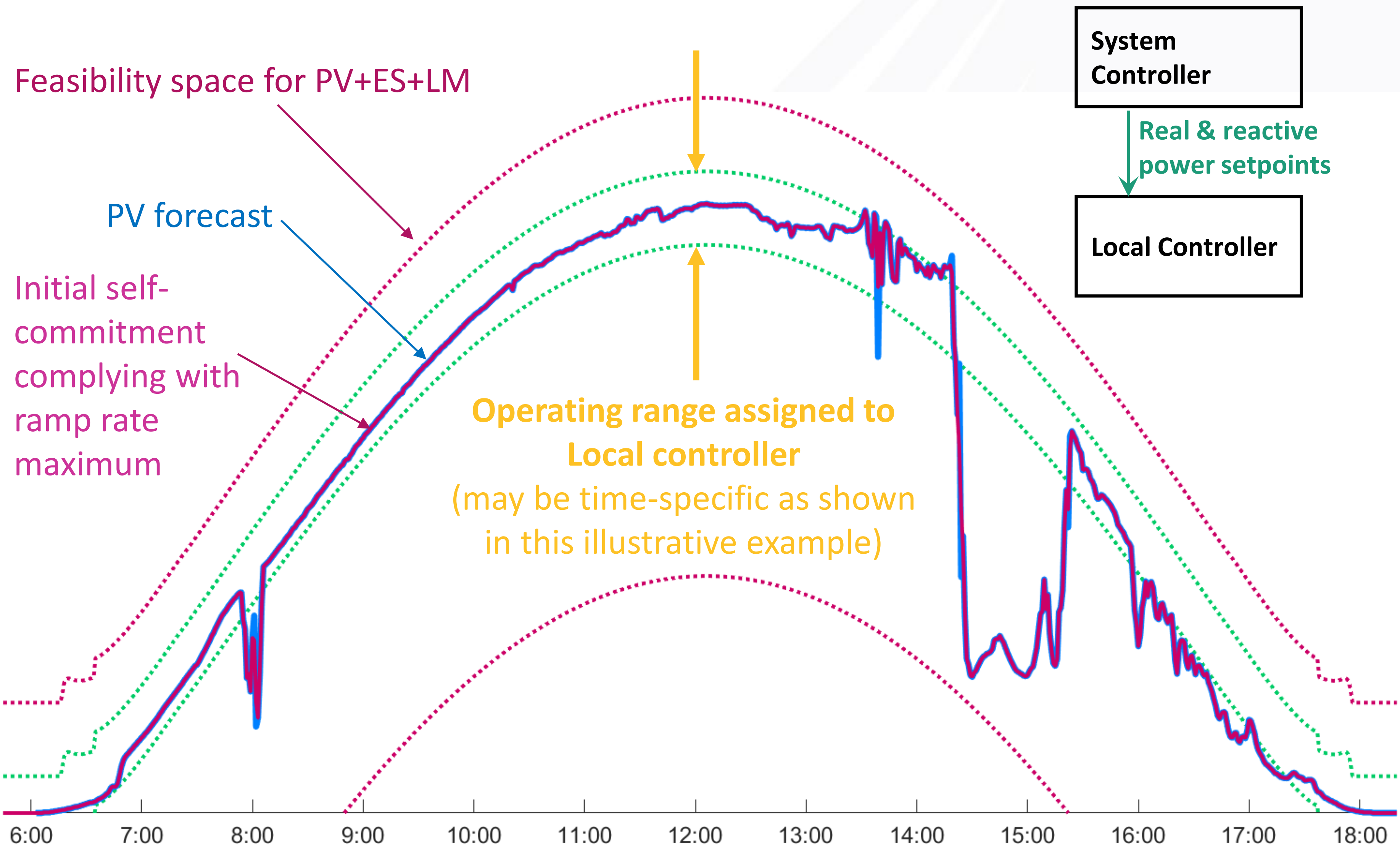
Interaction between System and Local Controllers

Step 1: LC provides set of feasible trajectories to SC for real and reactive power



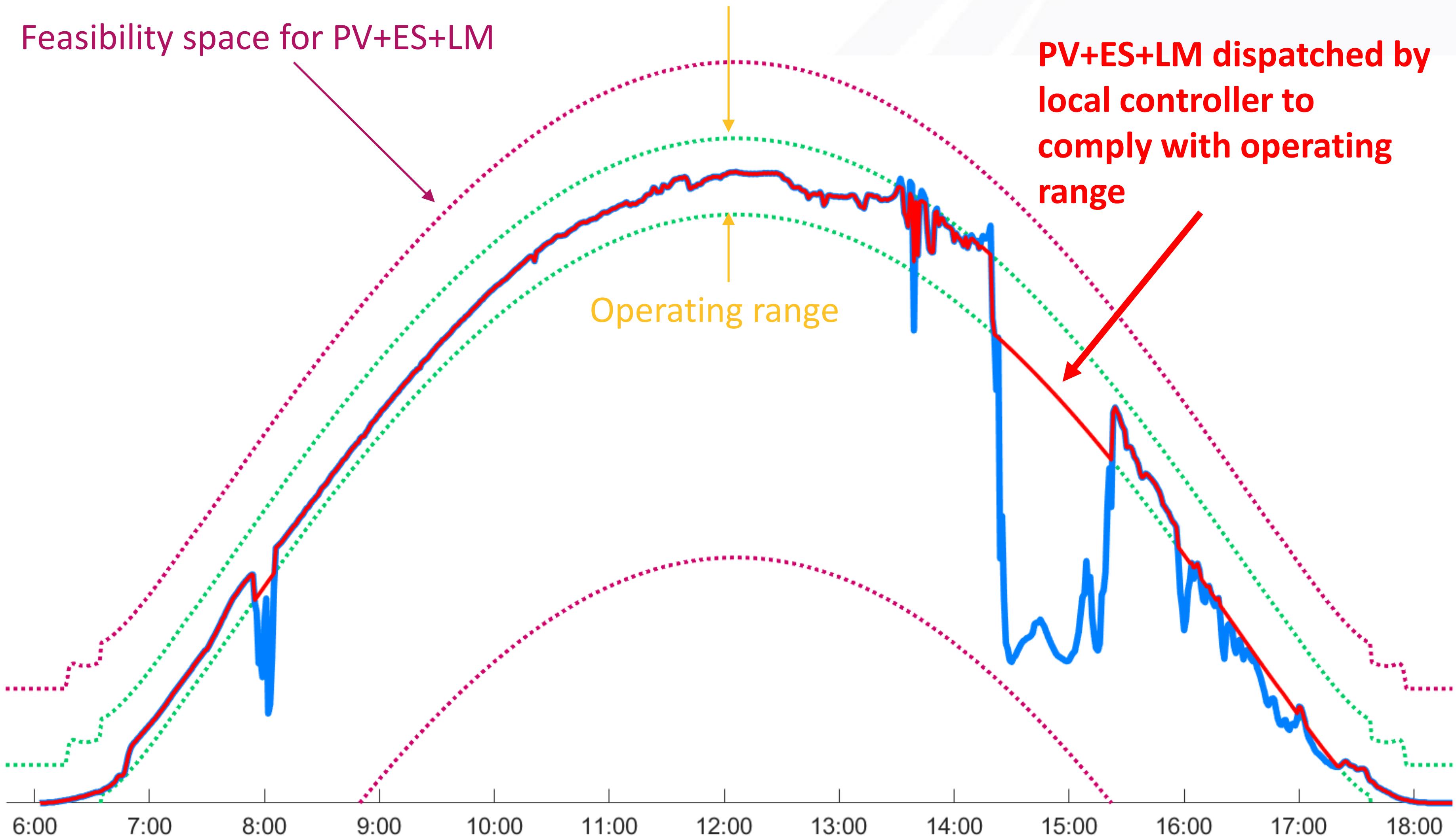
Interaction between System and Local Controllers

Step 2: SC assigns operating range for real and reactive power trajectories to LC

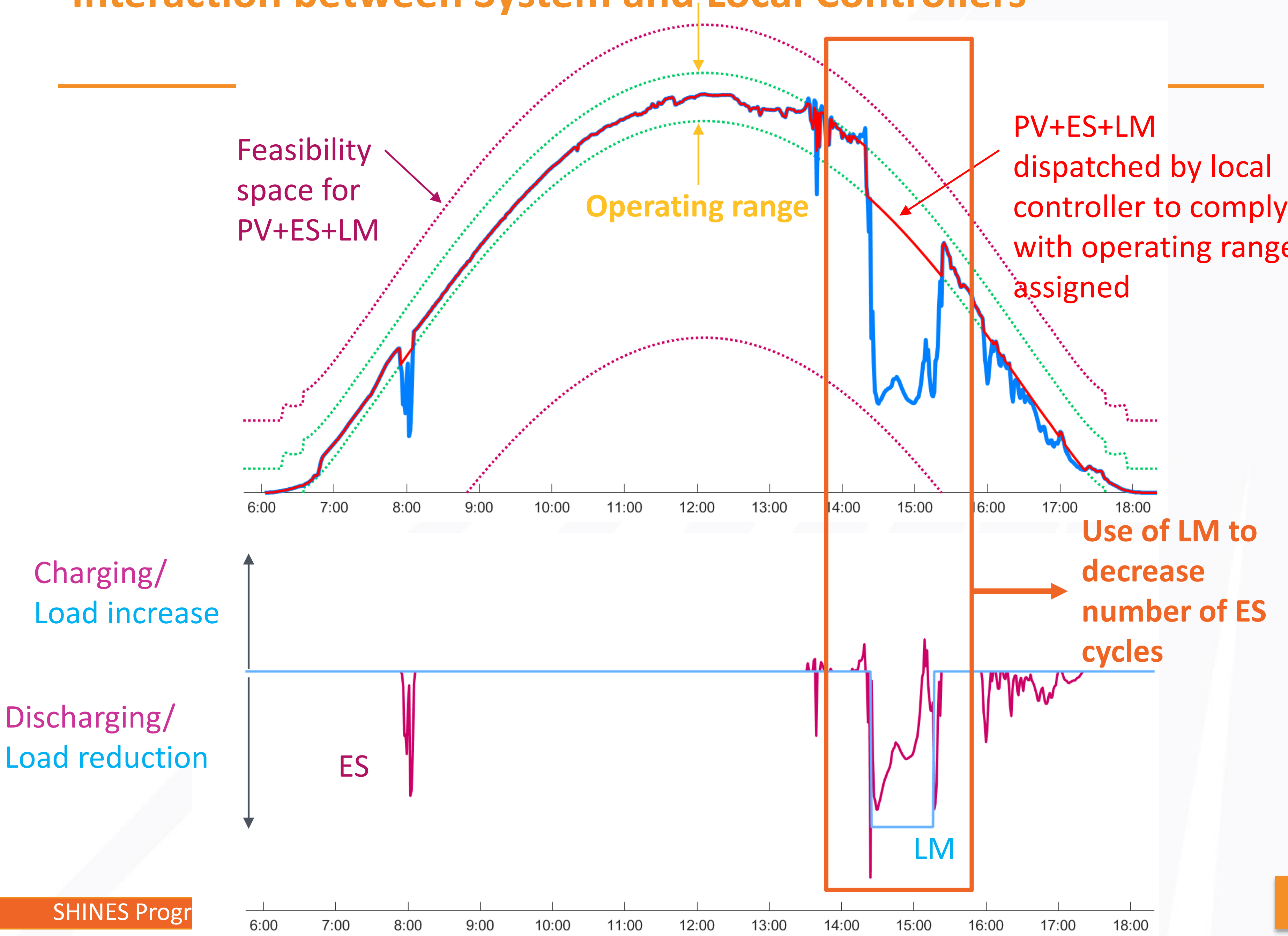


Interaction between System and Local Controllers

Step 3: LC is free to dispatch DER resources within operating range assigned by SC

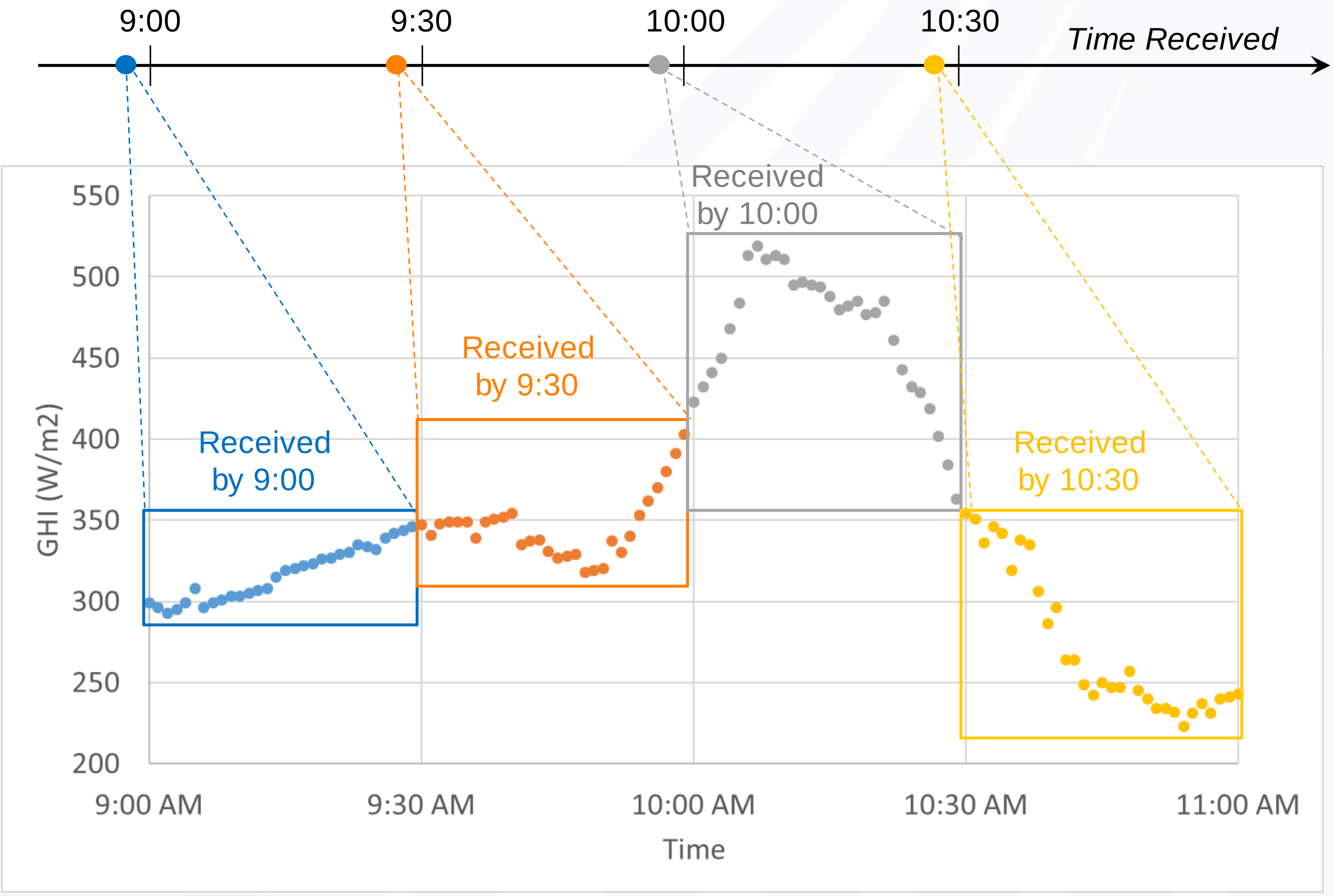


Interaction between System and Local Controllers

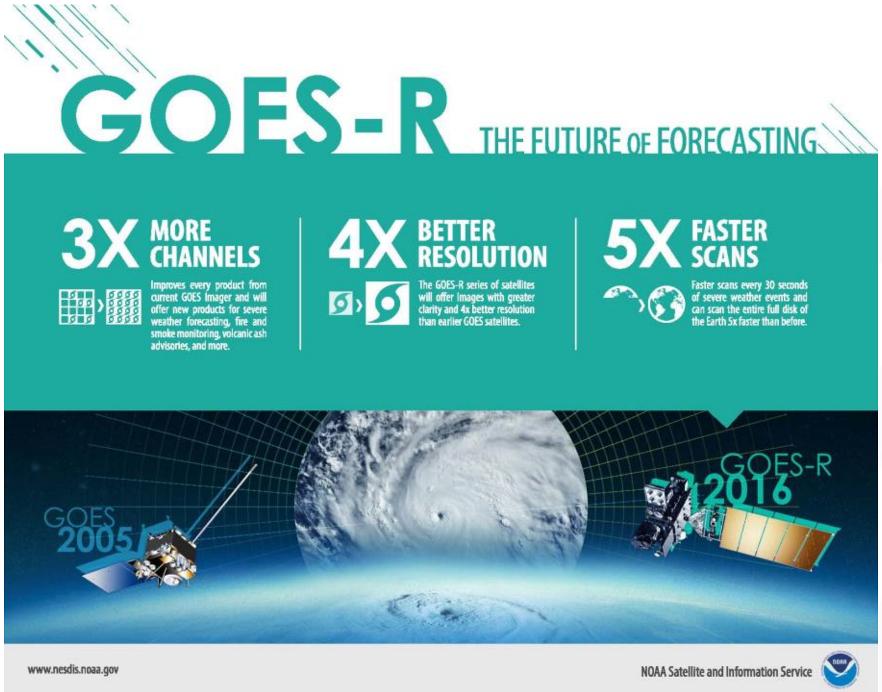


Advanced Solar Forecasting

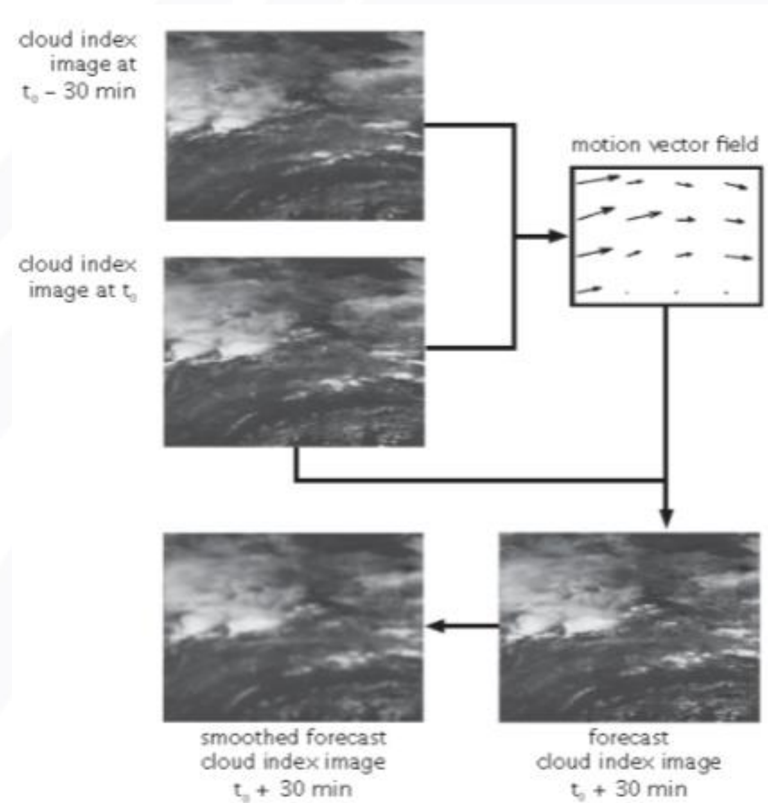
- One-min temporal, 1-km spatial resolution, 30-min ahead, and
- Thirty-min temporal, 1-km spatial resolution, 7-day ahead solar forecasting



Improving the Accuracy of Near-Term Solar Forecasting



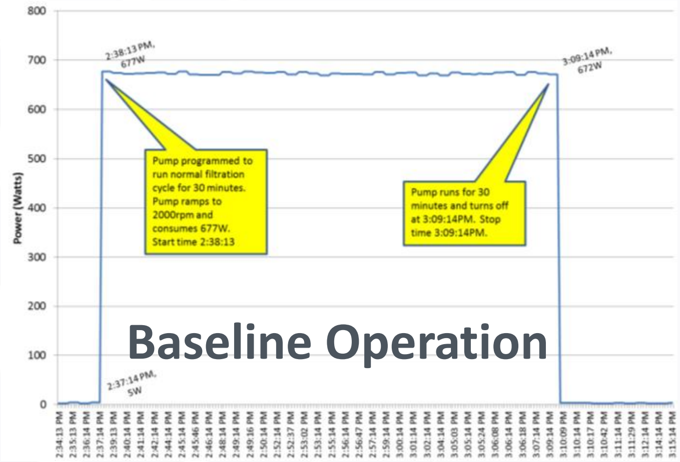
Launched on 19 November, 2016

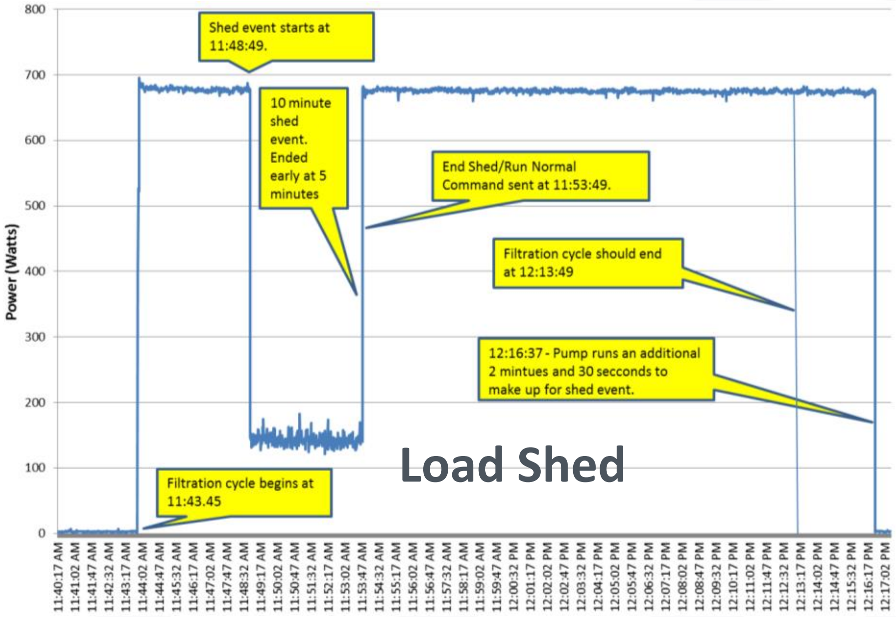


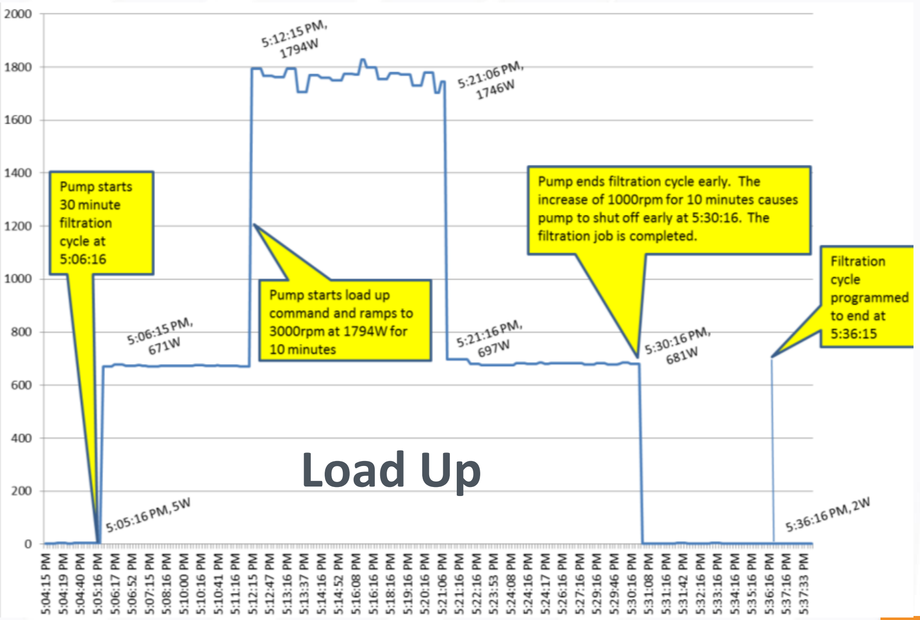
- Getting ready to use the higher resolution Images from ***GOES-R***
- Accuracy of forecasted data will be evaluated against field measured data

Load Management – Pool Pump

Pentair Pump with CTA2045 DR Controller

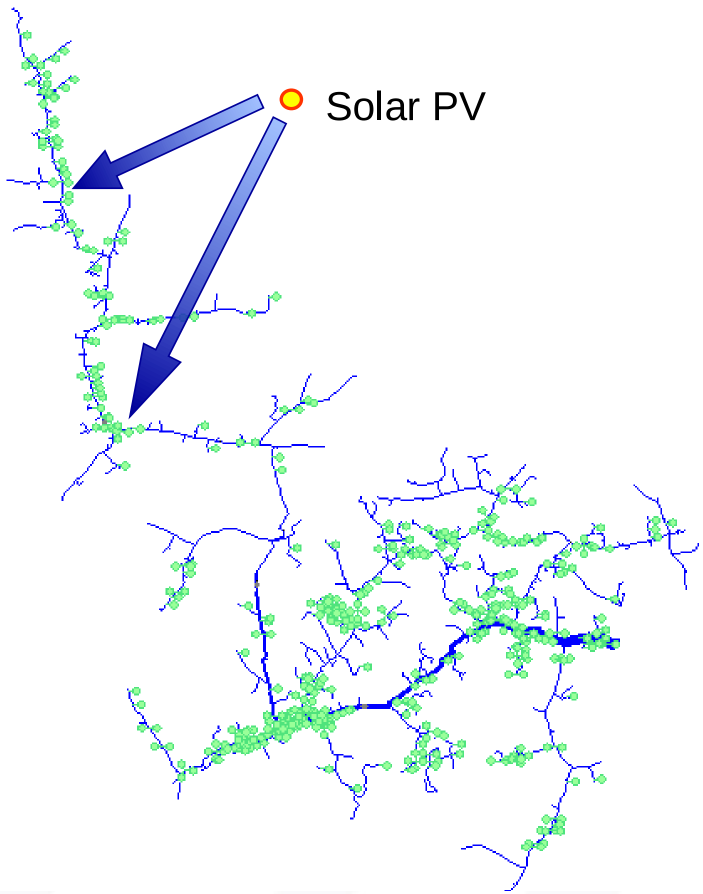


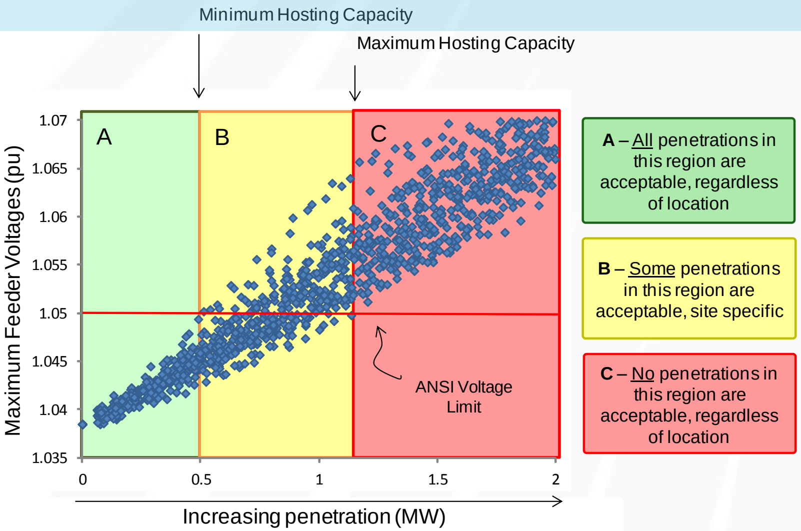


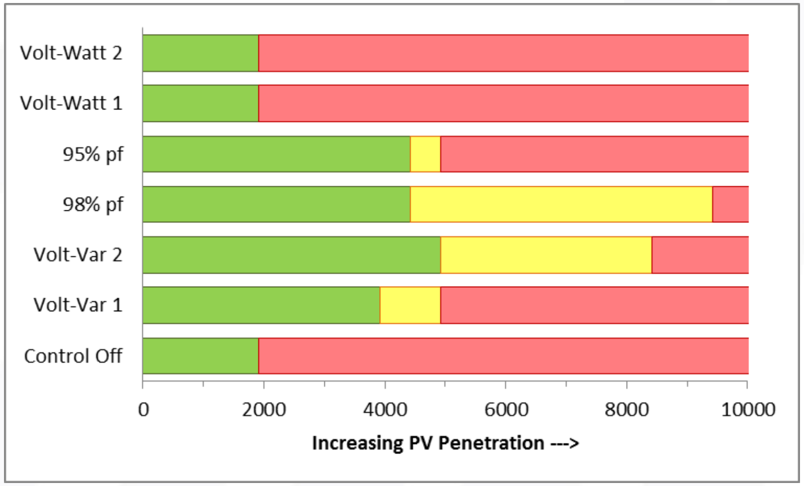


Identifying System Level Benefits – Feeder PV Hosting Capacity

- Can this integrated DER solution increase feeder PV hosting capacity without requiring expensive infrastructure upgrade?

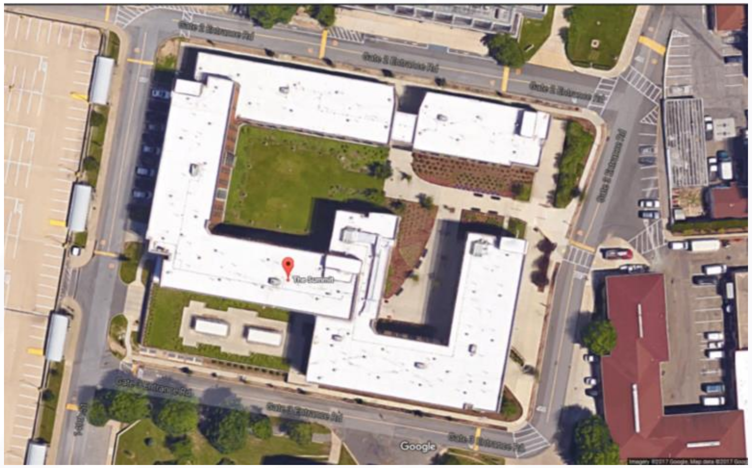






Demonstration Sites

Case Western Reserve University (CWRU) / Mandel School of Applied Social Science (MSASS)
Cleveland, OH



City University of New York (CUNY), Queens College/The Summit, 64-80 Kissena Blvd, **Flushing, NY**

SCS/GP Residential Demo Site
Pensacola, FL

Demonstration Sites

	Commercial Site#1	Commercial Site#2	Residential site#1
Owner	CWRU	Queens College/CUNY	Individual home owners
Utility	FirstEnergy/MCCo	NYPA/ConED	Southern Co/Gulf Power
PV	50kW	50 - 60kW	Two; each 5kW
Energy Storage	50kW/200kWh	100kW/200kWh	14kW/40kWh
Solar Forecasting	CPR	CPR	CPR
Smart Inverter	Eaton AC-coupled hybrid Inverter	Dynapower DC coupled hybrid inverter	PV Smart Inverter - SMA, PowerHub SiC-based 4-quadrant DESS
Battery	LG Chem, SuperCap	LG Chem	Saft
Local Controller	Eaton	TBD – BEMS will be considered	TBD – HEMS will be considered
System Controller	GE (Alstom)	TBD	TBD
Data Monitoring and Analysis	CWRU, EPRI	Queens College, EPRI	Home Owners, EPRI

Budget Period 2 & 3 Key Tasks

Budget Period 2 (Aug 1, 2017 ~ Jul 31, 2018)

- Verification of controllers' optimization algorithms and implementation in commercial platform
- On-site commissioning of PV, ES, and controllable loads
- GOES-R satellite image based improved near-term solar forecasting
- Economic analysis

Budget Period 3 (Aug 1, 2018 ~ Jul 31, 2019)

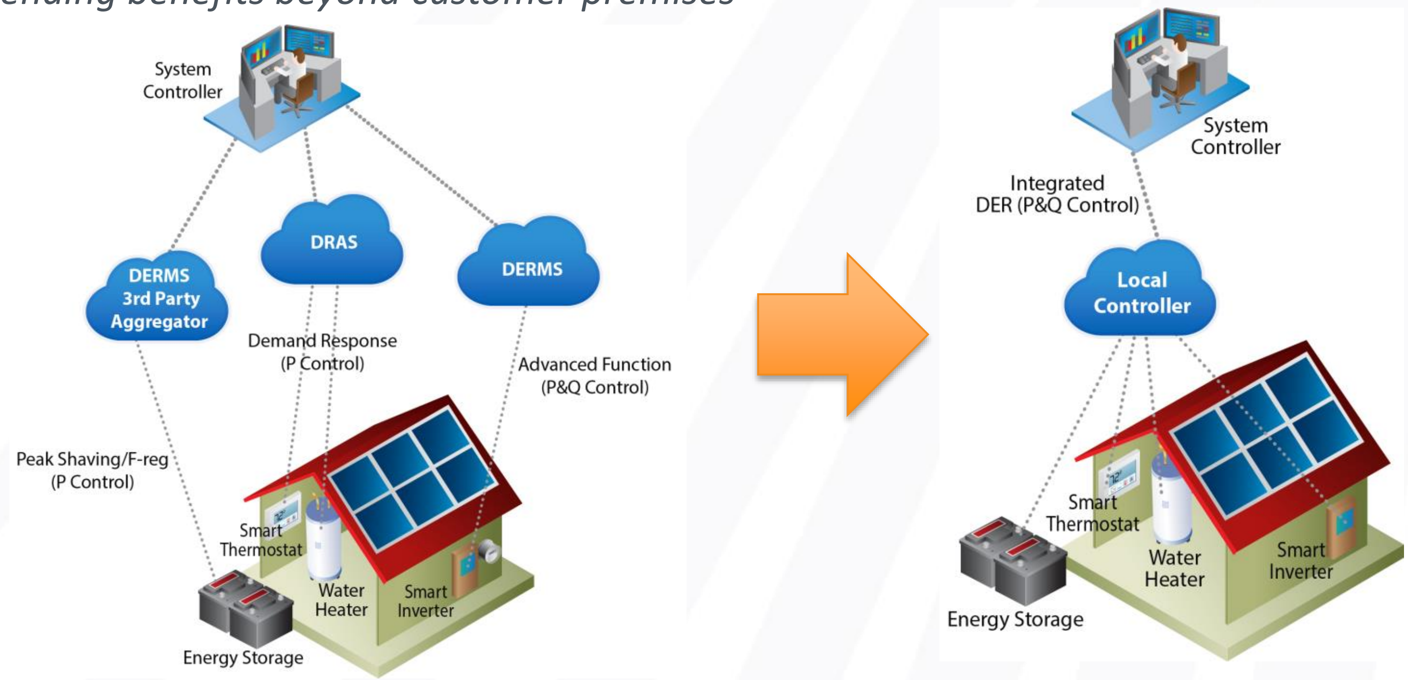
- Feeder level PV hosting capacity improvement through integrated DER with local and system level controllers
- Demonstration of the integrated DER solution, data collection, and performance analysis
- Final economic analysis

Lessons Learned

- Contract negotiation, especially IP issues can be complicated and time consuming
  - Diverse type of stakeholders: non-for profit tax exempt, non-for profit universities, for-profit large business, for-profit small business
- Change in business model
  - GE purchased Alstom Grid
  - PowerHub's business priority changed to EV charging
- Potential snow loading concerns, identified through structural analysis, required demo site change at CWRU
- Energy storage system (ESS) cost can vary widely and interconnection permitting for Li-Ion based battery system can be a challenge at certain jurisdictions

Relevance to Solar Challenge

- **Making the grid ready for seamless integration of solar plus storage to support customer choice**
  - *while optimizing the electric system: technically and economically*
- **Making solar plus storage more operationally integrated**
  - *in a cost competitive manner*
- **Improving the value proposition of solar plus storage and other distributed energy resources**
  - *extending benefits beyond customer premises*



Together…Shaping the Future of Electricity

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