Status of Battery Storage at FPL

Florida Public Service Commission's

Annual Ten-Year Site Plan Workshop

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Florida Power & Light Company
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Presentation Agenda

- Overview
- Smaller Pilot Projects
- 50 MW Pilot Projects (plus one)
- Battery Valuation

FPL is analyzing battery storage in regard to a number of potential applications which may benefit customers

Overview of Presentation

- **FPL initially deployed smaller battery pilots to start learning how to integrate the technology into FPL's system**
  - A mix of distribution-connected pilot projects were deployed beginning in 2016 totaling ~ 4 MW
- **The 50 MW Pilot Program authorized later under the 2016 Settlement Agreement is underway**
  - This is an expanded effort which utilizes larger, utility-scale batteries
  - 14 MW of storage are now in-service in which batteries have been added to existing solar facilities to create "solar + storage" applications
  - An additional 10 MW of projects are in development which will address different potential applications by early 2019
  - All 50 MW of storage pilots are expected to be in-service by 2020
  - One additional pilot (that will be outside of the 50 MW Pilot Program) is also being developed
- **Work regarding valuation of potential battery applications is on-going and will help guide FPL's resource planning efforts**

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FPL's initial battery pilot projects utilized relatively small batteries and focused on power quality and grid applications

FPL's Smaller Battery Pilots

Pilot	Location	Pilot Objectives	MW	MWh	In-Service
Southwest	Miami-Dade Co.	Test 2nd life car batteries, fuel cost savings	1.5	4	10/16
Florida Bay	Everglades National Park	Test for assisting electrical supply to a remote load	1.5	1.5	12/16
Community Energy Storage (CES)	Tri-County area (3 locations)	Reduce momentary outages thru backup power to residential areas	0.1	0.2	5/16
Mobile UPS	Miami-Dade Co.	Test mobile Uninterrupted Power Supply (UPS) device	0.8	0.1	2/17
		Totals =	**3.9**	**5.8**	

The information and experience gained from these early pilots has been useful and helped guide the next pilots

These smaller pilots helped identify both the pros and cons of utilizing storage in certain applications

- **Southwest:**
  - Benefits from low purchase price of 2nd life car batteries was more than offset by high integration cost
  - However, the experience gained in integrating the batteries into an urban area and the control system was valuable
- **Florida Bay:**
  - The electrical islanding mode was challenging to execute without tripping the system
  - Only limited potential exists for long radial feeders like Florida Bay, but micro-grid applications have promise
- **Community Energy Storage (CES):**
  - Selected systems appear reliable and effective, but very expensive
- **Mobile Uninterruptible Power Supply (UPS):**
  - Successfully used at two sites, but not truly mobile
  - Limited opportunity for C&I customers with high reliability needs (sensitive equipment needing premium power)

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The first 14 MW of these projects are in place and other projects totaling ~10 MW will be in-service by early 2019

50 MW Pilot Projects (plus one) *

50 MW Pilot Program

Pilot	County	Pilot Objectives	MW	MWh	Status & In-Service Date
Babcock Ranch	Charlotte	Solar + storage, AC connected	10	40	In-Service, 3/18
Citrus	DeSoto	Solar + storage, DC connected	4	16	In-Service, 3/18
Wynwood	Miami-Dade	Distribution deferral and integration of storage in urban area	10	40	Proceeding, Mid-2019
Vehicle-to-Grid	Palm Beach	Potential for electric school buses discharging to grid	< 1	< 1	Proceeding, Early 2019
		Totals (approx.) =	**24**	**96**	

One Other Pilot Not Part of 50 MW Pilot Program

Residential	Palm Beach	Distributed residential batteries utility-owned & controlled	< 0.1	< 0.1	Proceeding, Early 2019

** In addition to the projects shown, one or more micro-grid projects are under consideration*

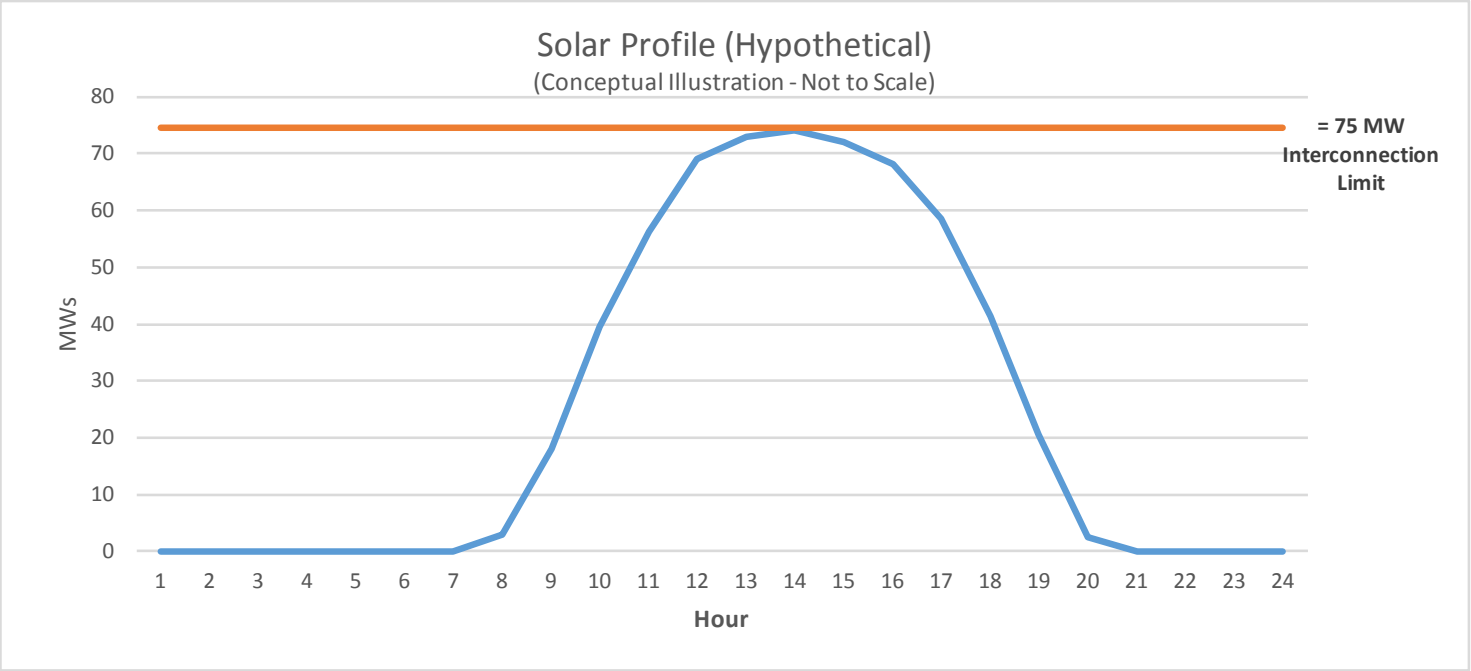
Two projects have battery storage connected to existing solar (PV) facilities using different approaches

FPL's Two "Solar + Storage" Pilots

- **Babcock Ranch**
  - AC-coupled, 10 MW / 40 MWh
  - One of the largest operating solar + storage projects in the United States
- **Citrus**
  - DC-coupled, 4 MW /16 MWh
  - First DC coupled solar + storage at scale in industry

In designing a solar (PV) facility, both the hourly solar profile and the interconnection limit must be considered

PV Hourly Output for a Possible Solar Design

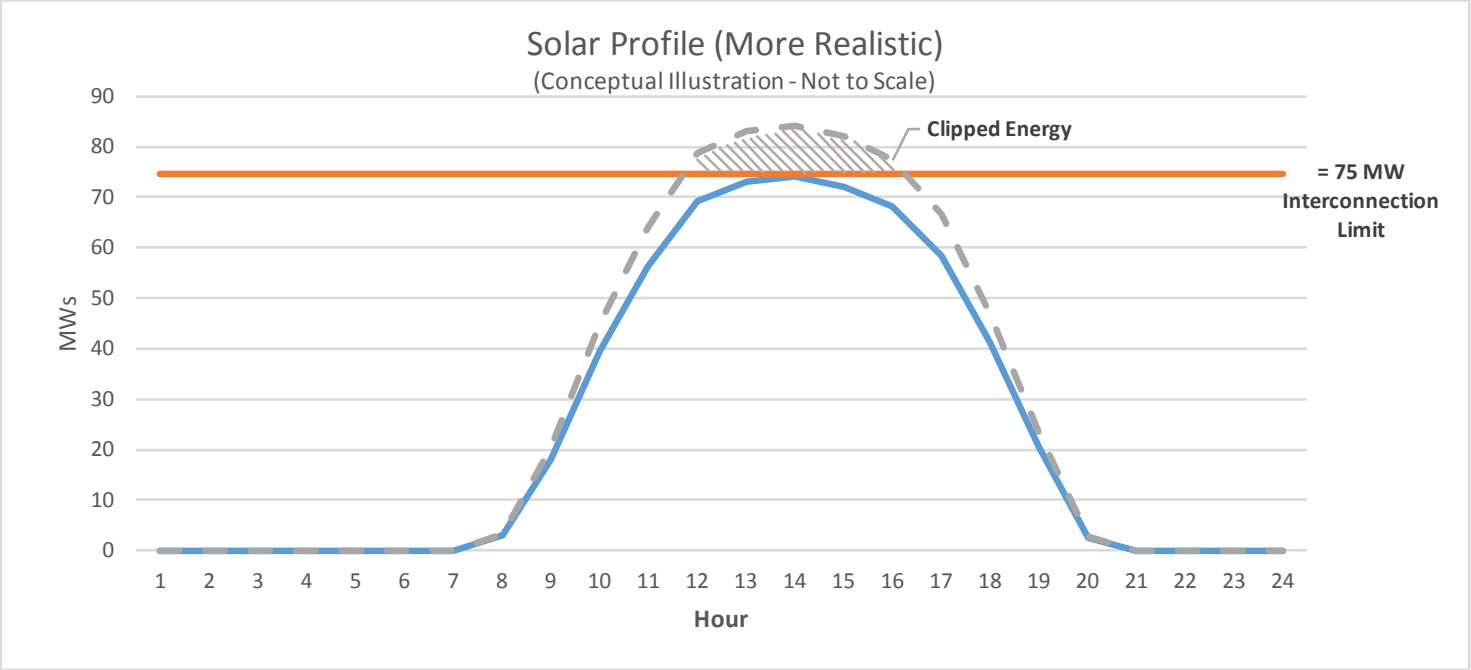


- In a theoretical design such as this, the solar output essentially matches the rating of the DC-to-AC inverter (~ a 1:1 DC to AC ratio)

However, such a design neither maximizes solar MWh output nor minimizes solar $/MWh cost for customers

FPL's solar designs have a greater than 1:1 DC-to-AC ratio, thus increasing the solar output curve (see dotted line)

Output from FPL's Solar Design

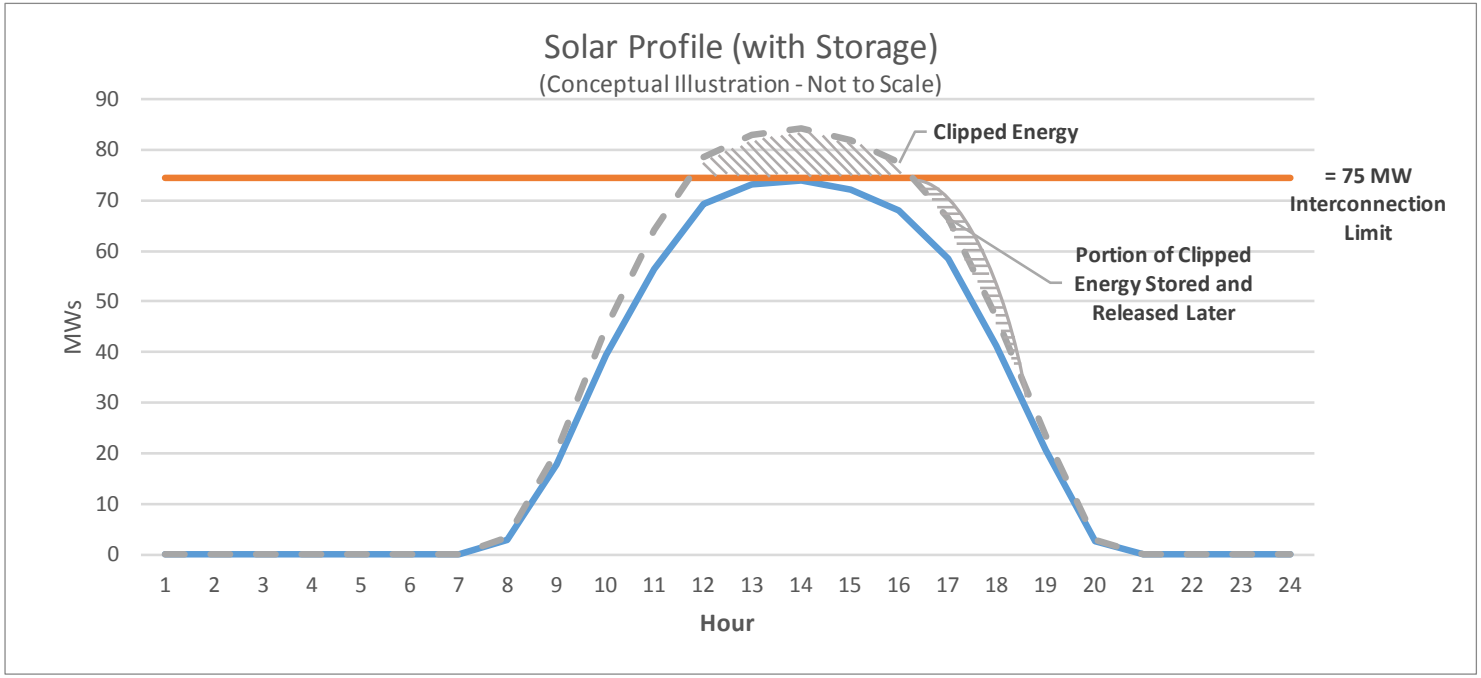


- The area that is both: (i) between the dotted line and the solid blue line, and (ii) below the orange interconnection limit line, represents additional solar MWh delivered to customers

The shaded area above the orange line represents "clipped" solar MWh that are not delivered to customers

Pairing batteries with a PV facility can capture some of the clipped solar MWh for later delivery to customers

Output from a Solar + Storage Design



- Storage paired with a PV facility can capture a portion of the solar MWh that are clipped during peak solar output hours for delivery to customers later in the day

FPL believes that "solar + storage" applications, whether AC- or DC-connected, have significant potential to benefit customers

Information gained will help determine the relative advantages of AC- versus DC-connections to PV facilities

FPL's Current View of Relative Advantages for AC- versus DC- Connection

Consideration	Advantage to AC-Connected ?	Advantage to DC-Connected ?
Technology currently better known	Yes	---
Ability to capture a greater amount of clipped solar energy	---	Yes
Cost ($ per installed kW)	Economics are case-specific	Economics are case-specific
Round trip efficiency (charging to discharging)	---	Yes
Ability to charge from the grid / less affected by shading of solar facility	Yes	Yes

These current views are subject to change as experience is gained from these two "solar + storage" pilot projects

Another of the pilot projects is designed to defer distribution costs and examine the potential for "stacking" of applications

Wynwood Distribution Pilot

- **Projected In-Service: Mid-2019**
- **10 MW / 4 hour battery on FPL-owned 0.3-acre parcel in Wynwood, City of Miami**
  - Meet peak loads
  - Defer distribution upgrade by 4 years
- **Pilot Objectives:**
  - Learn how to best design and permit in dense urban area
  - Examine if both distribution and generation benefits can be achieved (a form of "stacking" of applications)

Conceptual Architect Rendering – PRELIMINARY DRAFT

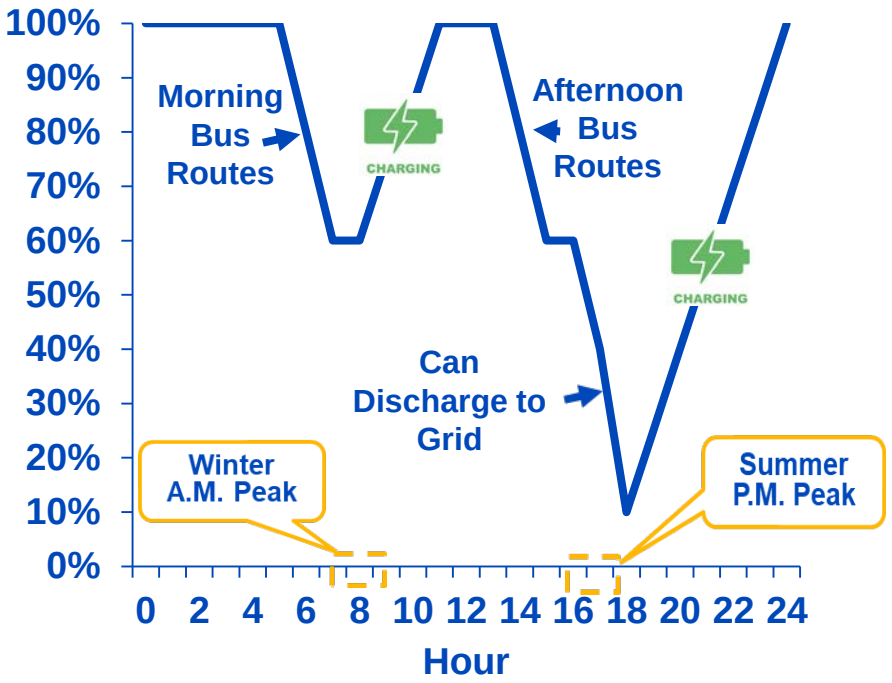
- **Status: Project is now undergoing design and permitting**

Electric school buses, with a predictable schedule, provide a good test platform for Vehicle to Grid (V2G) technology

Vehicle-to-Grid Electric Bus Pilot

- **Projected In-Service: Early 2019**
- **Ten V2G buses (~70 kW each) available for utility use when charging**
  - FPL to own bus batteries
  - Host to own and operate buses
- **Pilot Objectives:**
  - Influence electrification of fleets
  - Develop controls architecture to enable efficient V2G dispatch
  - Test viability of scheduling conflicts and reliability of V2G model
- **Status: Design is underway**

Bus Battery Usage Example



- Bus routes allow ample remaining capacity for discharge during peak demand periods

In addition to the 50 MW Pilot Program, FPL is also considering a residential "virtual power plant" (VPP) pilot

Small Scale Residential VPP Pilot *

- **Projected In-Service: Early 2019**
- **5-to-8 kW batteries each at ~ 20 homes**
- **Pilot Objectives:**
  - Gain first-hand experience in the residential battery market
  - Understand potential value of aggregated batteries on FPL's system and to participants
  - Develop capability of deploying and controlling multiple distributed storage units
  - Assess feasibility of larger program for customers
- **Status: Design is underway**

Residential Battery System

** Not part of the 50 MW Pilot Program; will be funded separately as R&D*

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FPL is analyzing other *(non-solar + storage or T&D)* potential battery applications to see which might be most beneficial to customers

Other Potential Battery Applications

Potential Applications	Planning or Operational?	Description
Capacity	Planning	Considered in resource planning as firm capacity (as a CT, CC, etc. would) for reserve margin/LOLP purposes
Energy arbitrage (a.k.a. "peak shaving")	Operational	Battery is charged during low energy cost hours and discharged during higher energy cost hours to lower system energy costs
Contingency reserve	Operational	Battery is kept at a full state of charge and is discharged only to meet immediate capacity needs
Frequency regulation reserve	Operational	Battery is kept charged and is dispatched as needed to maintain system frequency near 60 Hz
Voltage support	Operational	Battery is kept at a full state of charge, then provides or absorbs reactive power as needed to maintain grid voltage
"Stacked"	Operational	A combination of some/all of the "operational" applications

FPL has formed a preliminary view of the relative value of these other relative applications on FPL's system

FPL's Current View (to-date) of the Relative Value of Other Potential Applications

Potential Applications	Planning or Operational?	Preliminary View of Relative Value
Capacity	Planning	Largest potential benefit category
Energy arbitrage (a.k.a. "peak shaving")	Operational	Significantly less than the capacity benefit *(due to FPL's low cost energy from nuclear, gas, & solar)*
Contingency reserve	Operational	Significantly less than energy arbitrage
Frequency regulation reserve	Operational	Significantly less than energy arbitrage
Voltage support	Operational	Negligible
"Stacked"	Operational	Negligible increase over energy arbitrage alone

This view is preliminary only - the evaluation of the potential values of these applications is ongoing