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NIST Workshop On Power Conditioning System Architectures For Plugin-Vehicle Fleets As Grid Storage

How Might A PEV Fleet Aid In Integration Of Resilient Micro-Grids?
(Storage Functions To Support Resilient Micro-Grids)

Bill Siddall, Director, NextEnergy

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What Size Is The Micro-Grid?

The size of the grid, the amount of generation and load, matters to the effectiveness of individual and aggregated Plug-in Electric Vehicles (PEVs).

Forward Operating Base Simulation

Fort Irwin, CA

60kW to 200kW

Wright-Patterson AFB

Dayton, OH

20MW to 80MW

Benefits, Maximum Market Potential, and Maximum Economic Value

Trade-Offs

#	Benefit Type	Benefit ($/kW)** Low	Benefit ($/kW)** High	Potential (MW, 10 Years) CA	Potential (MW, 10 Years) U.S.	Economy ($Million)† CA	Economy ($Million)† U.S.
1	Electric Energy Time-shift	400	700	1,445	18,417	795	10,129
2	Electric Supply Capacity	359	710	1,445	18,417	772	9,838
3	Load Following	600	1,000	2,889	36,834	2,312	29,467
4	Area Regulation	785	2,010	80	1,012	112	1,415
5	Electric Supply Reserve Capacity	57	225	636	5,986	90	844
6	Voltage Support	400		722	9,209	433	5,525
7	Transmission Support	192		1,084	13,813	208	2,646
8	Transmission Congestion Relief	31	141	2,889	36,834	248	3,168
9.1	T&D Upgrade Deferral 50th percentile††	481	687	386	4,986	226	2,912
9.2	T&D Upgrade Deferral 90th percentile††	759	1,079	77	997	71	916
10	Substation On-site Power	1,800	3,000	20	250	47	600

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Standard Assumption Values for Storage Power

Trade-Offs

#	Type	Storage Power		
		Low	High	Note
1	Electric Energy Time-shift	1 MW	500 MW	Low per ISO transaction min. (Can aggregate smaller capacity.) High = combined cycle gen.
2	Electric Supply Capacity	1 MW	500 MW	Same as above.
3	Load Following	1 MW	500 MW	Same as above.
4	Area Regulation	1 MW	40 MW	Low per ISO transaction min. Max is 50% of estimated CA technical potential of 80 MW.
5	Electric Supply Reserve Capacity	1 MW	500 MW	Low per ISO transaction min. (Can aggregate smaller capacity.) High = combined cycle gen.
6	Voltage Support	1 MW	10 MW	Assume distributed deployment, to serve Voltage support needs locally.
7	Transmission Support	10 MW	100 MW	Low value is for substransmission.
8	Transmission Congestion Relief	1 MW	100 MW	Low per ISO transaction min. (Can aggregate smaller capacity.) High = 20% of high capacity transmission.
9.1	T&D Upgrade Deferral 50th percentile	250 kW	5 MW	Low = smallest likely, High = high end for distribution & subtransmission.
9.2	T&D Upgrade Deferral 90th percentile	250 kW	2 MW	Same as above.
10	Substation On-site Power	1.5 kW	5 kW	Per EPRI/DOE Substation Battery Survey.
11	Time-of-use Energy Cost Management	1 kW	1 MW	Residential to medium sized commercial/industrial users

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Standard Assumption Values for Discharge Duration

Trade-Offs

*Hours unless indicated otherwise. Min. = minutes. Sec. = Seconds.

#	Type	Discharge Duration*		
		Low	High	Note
1	Electric Energy Time-shift	2	8	Depends on energy price differential, storage efficiency, and storage variable operating cost.
2	Electric Supply Capacity	4	6	Peak demand hours
3	Load Following	2	4	Assume: 1 hour of discharge duration provides approximately 2 hours of load following.
4	Area Regulation	15 min.	30 min.	Based on demonstration of Beacon Flywheel.
5	Electric Supply Reserve Capacity	1	2	Allow time for generation-based reserves to come on-line.
6	Voltage Support	15 min.	1	Time needed for a) system stabilization or b) orderly load shedding.
7	Transmission Support	2 sec.	5 sec.	Per EPRI-DOE Handbook of Energy Storage for Transmission and Distribution Applications.[17]
8	Transmission Congestion Relief	3	6	Peak demand hours. Low value is for "peaky" loads, high value is for "flatter" load profiles.

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PEV Fleet Characteristics

Organizational Control Of Fleet Designs and Operations

- Vehicle Specification: PEV Balance of Parts' Design as presented by Original Equipment Manufacturer (OEM)

- Vehicle Location: Operational requirements when PEV is not a micro-grid storage device

- Vehicle Service Time: Operational duty cycle compatibility with micro-grid duty cycle.

Micro-Grid Storage Application Recommendations

Application	Definition	Power	Duration	Response	Locaton of Storage	Use Description	Application Element
Regulation of Voltage & Frequency	second-by-second power balancing to regulate frequency	1-2% of system max	up to 5 min.	<10 sec.	Sub-Station	"Short Term" Power Quality maintenance Ideal PEV Fleet Application	Voltage Support
							Transmission Support
							Electric Service Reliability
			15 - 30 min	< 10 sec			Electric Service Power Quality
							Wind Gen. Grid Integration (short duration)
Spinning Reserve Reduction/ Load Following	Displace reserve generation asset with storage	8-12% of load	5 to 30 min.	<10 sec.	Sub-Station / Peaker Plant location		Load Following
							Area Regulation
			15 - 30 min				Electric Supply Reserve Capacity
T&D Deferral/Load Profile Management (Transmission & Distribution)	Delay investing in transmission & distribution infrastructure by storing energy for peak periods	XX% of max load	up to 12 hrs	10 to 30 min.	Sub-Station / Peaker Plant location	Distributed Load Management Some PEV Fleet Application	T&D Upgrade Deferral 50th Percentile
							T&D Upgrade Deferral 90th Percentile
			hours				Transmission Congestion Relief
Peaking Generation/ Deferral							Electric Supply Capacity
Arbitrage	Buy-low-sell-high on energy cost	depends on business case up to 12 hrs.		10 to 30 min.	Peaker Plant /Generator location		Electric Energy Time Shift
							Time of Use Energy Cost Management
			1 hr				Demand Charge Management
Diurnal or Longer Load Profile Management	Matching generation profiles of AE source to daily or longer load	realtive to % of AE sources	12 hours or longer (6-12 hrs)	30 min.	AE site location	Bulk Energy Storage No PEV Fleet Application	Renewables Capacity Firming
							Renewables Energy Time Shift
							Weind Generation Grid Integration: long duration

PEV Fleet Considerations In Support of Micro-Grids

In Summary:

- Micro-Grid Size
- PEV Design from OEMs
- Benefits Trade-Offs
- Application Suitability