California Energy Commission Energy Storage Projects:

Beacon Flywheel Project

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Outline

- Why the interest in energy storage
- Beacon flywheel project
- Other Energy Commission energy storage projects

Why the Interest in Energy Storage

- California is in a time of many energy system challenges
  - Integration of Renewables in large quantities (1000s of Mw)
  - T & D system reliability and stability
  - Emissions and Green House Gas reduction directives
  - System electrical load growth continues
- Energy storage technologies have the potential to provide more options and better flexibility than classical solutions

Why the Interest in Energy Storage

- Energy storage provides the unique ability to match energy supply with energy demand.
- Energy storage can be applied at all phases of transmission, distribution and generation.
- Technologies are available from few seconds to several days; and from few watts to megawatts of power.
- Energy storage can shift peak demand, reduce emission/support GHG reduction goals, firm renewables and make the grid more stable

Examples of Energy Storage Technologies

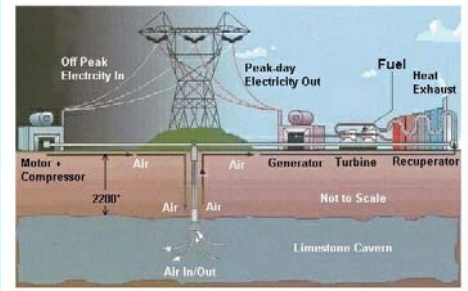
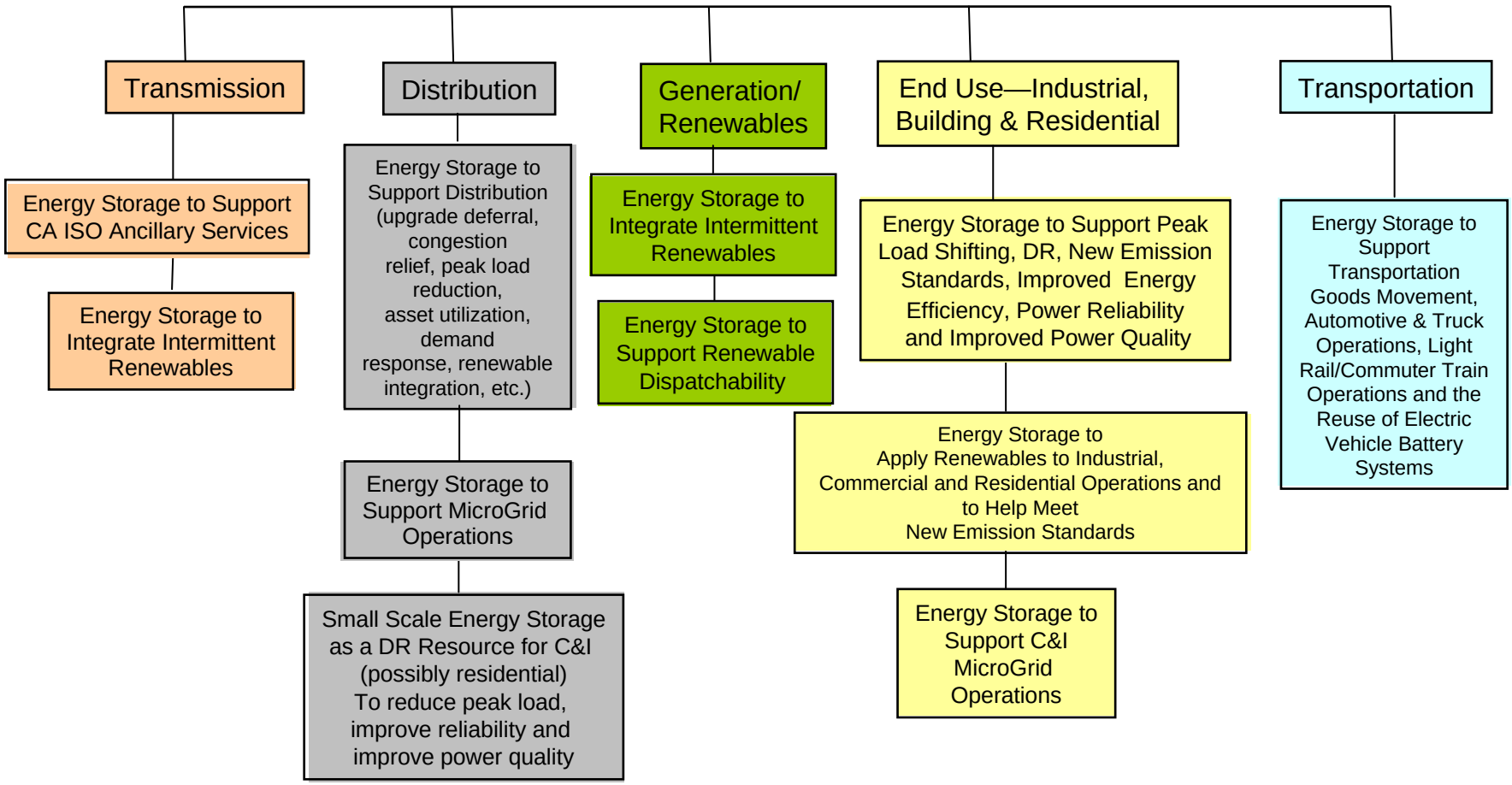


Photo Courtesy of CAES Development Company

Photo Courtesy of Saft America

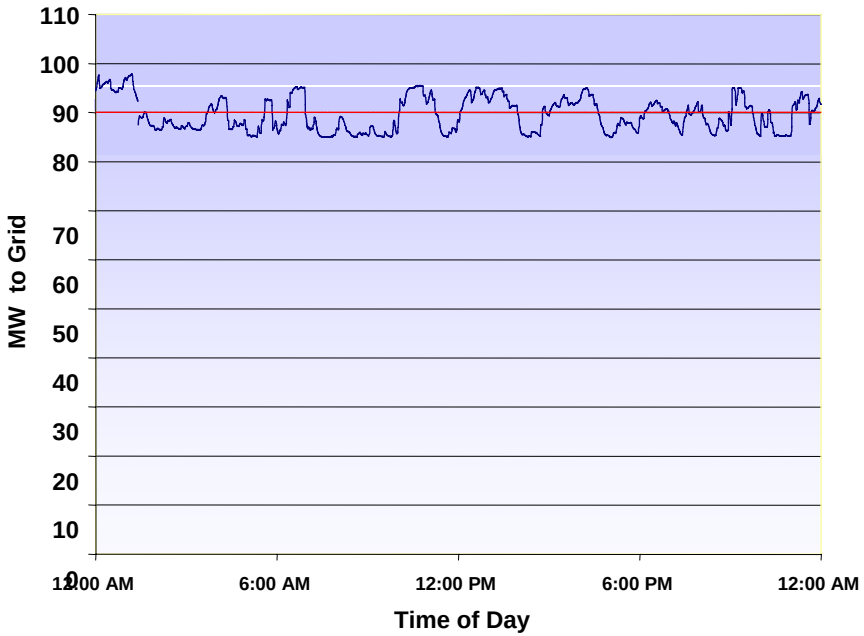
Energy Storage Applications Identified by Subject Areas



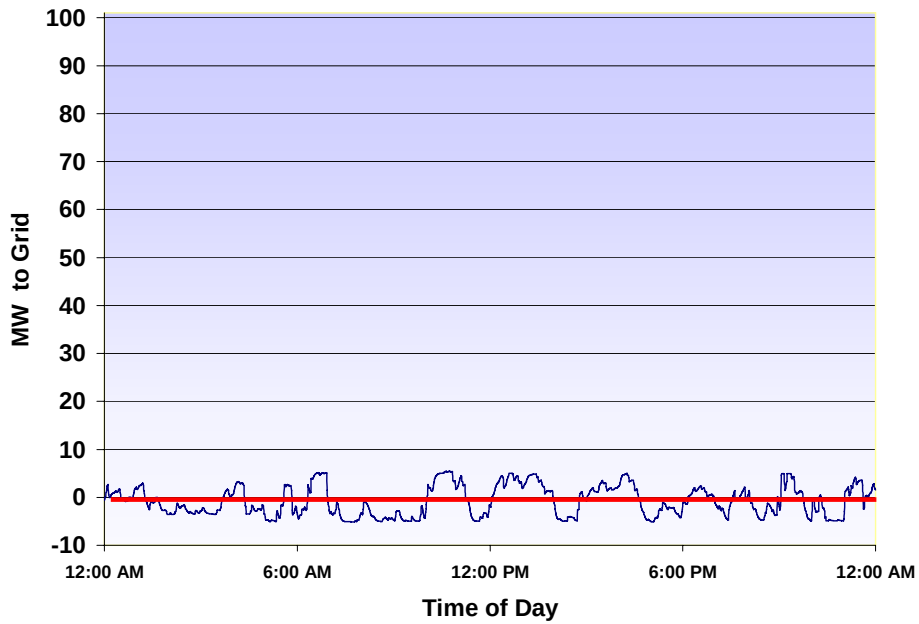
Frequency Regulation Basics

Regulation Using Generator vs. Energy Storage

100 MW Generator
Set at 90 MW with 5 MW Regulation



Energy Storage providing 5 MW of Regulation



- Generator varies output
  - Decreases efficiency
  - Increases emissions
  - Increases maintenance

- Flywheel recycles energy
  - High round trip efficiency
  - Zero emissions
  - Faster Response

Flywheel Energy Storage System (FESS) for Grid Frequency Regulation

- **Pier Funding:** $1,233K **(78%)----------(Total Project Costs: $1,580K)**
- **Technology demonstrated:** Flywheel Energy Storage for Response to ISO Grid Frequency
- Regulation Control (Demonstration Level Scale)
- **Utility:** PG&E **Prime Contractor:** Beacon Power Corporation dba Beacon Matrix Services
- **End Customer:** **CA ISO (Demonstration at the DUIT facility in San Ramon)**
- **How does project work:**

  Project will demonstrate the operation of a matrix of 7 separate flywheels integrated into a 100KW FESS with 15 minutes of electric storage capacity. Control System will monitor and respond to California Grid signals provided by the ISO. The project will provide a proof of concept level demonstration that, if successful, can be sized up to a utility level FESS Grid Frequency Regulation System

- **Project Impact:**

  Demonstrate Grid frequency regulation at a scaled down version

  Demonstrate the ability to receive and respond to ISO sigr

  Demonstrate capabilities of multiple flywheel matrix systen

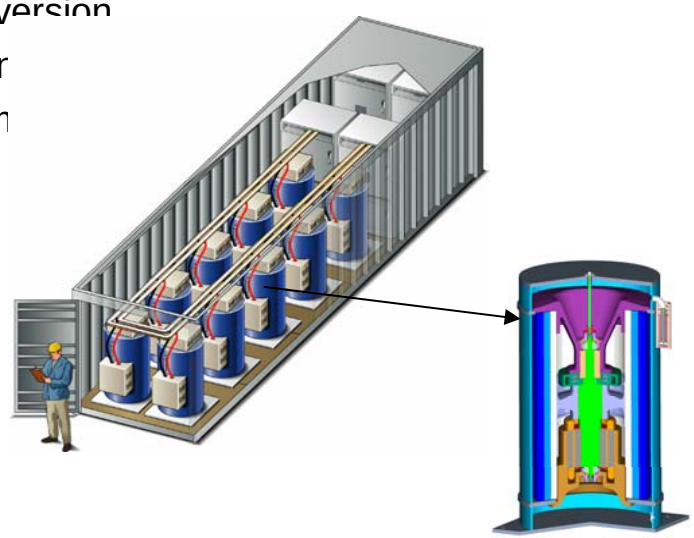
  Potential for use by several other ISOs throughout the US

- **End User Benefits**

  Stabilize grid system frequency
  Provide voltage regulation
  Provide additional reactive power

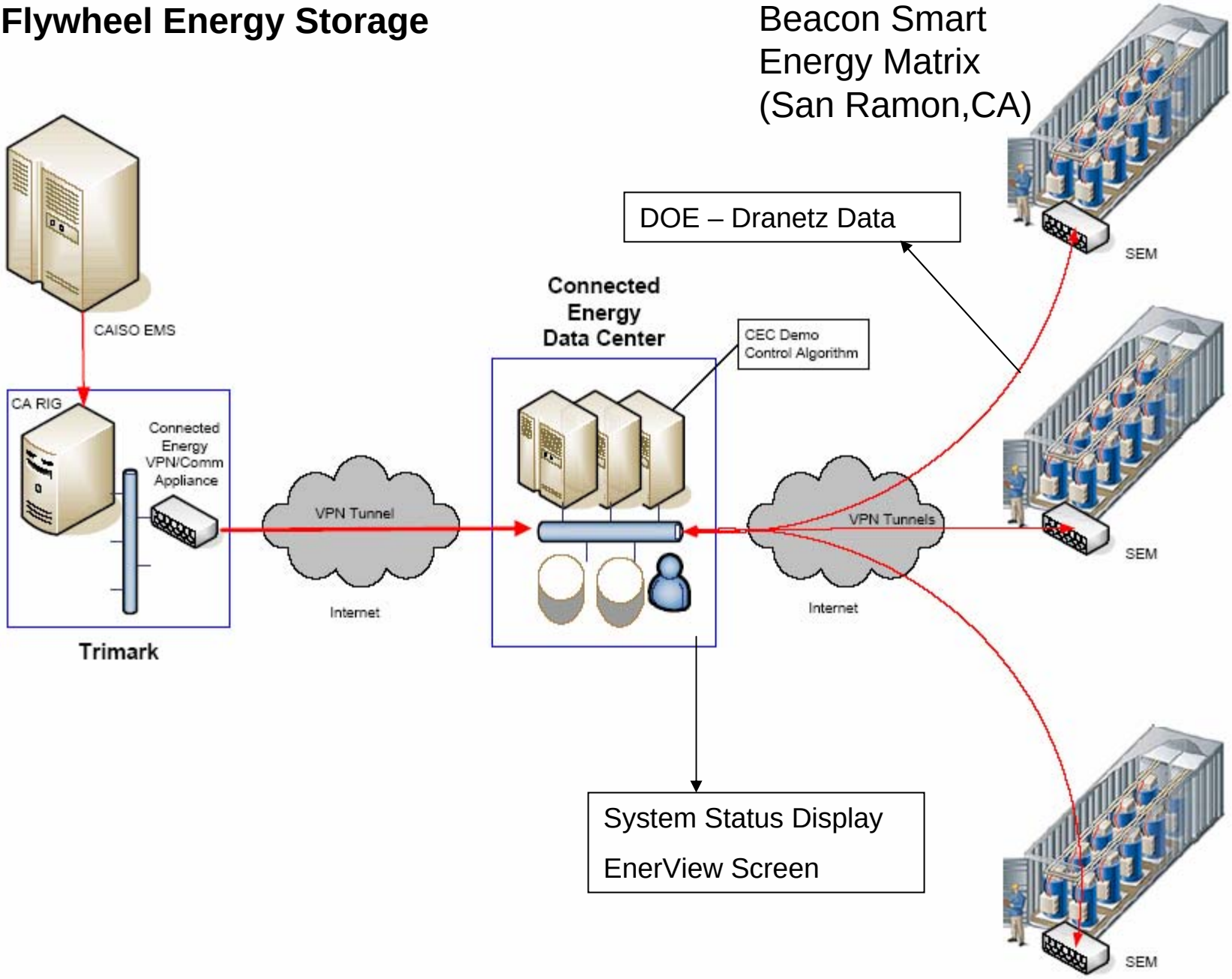
- **Project Timeline:**

  Start: January 2005
  Commission: March 2006
  Field Trial: 8/2006 – 1/2007

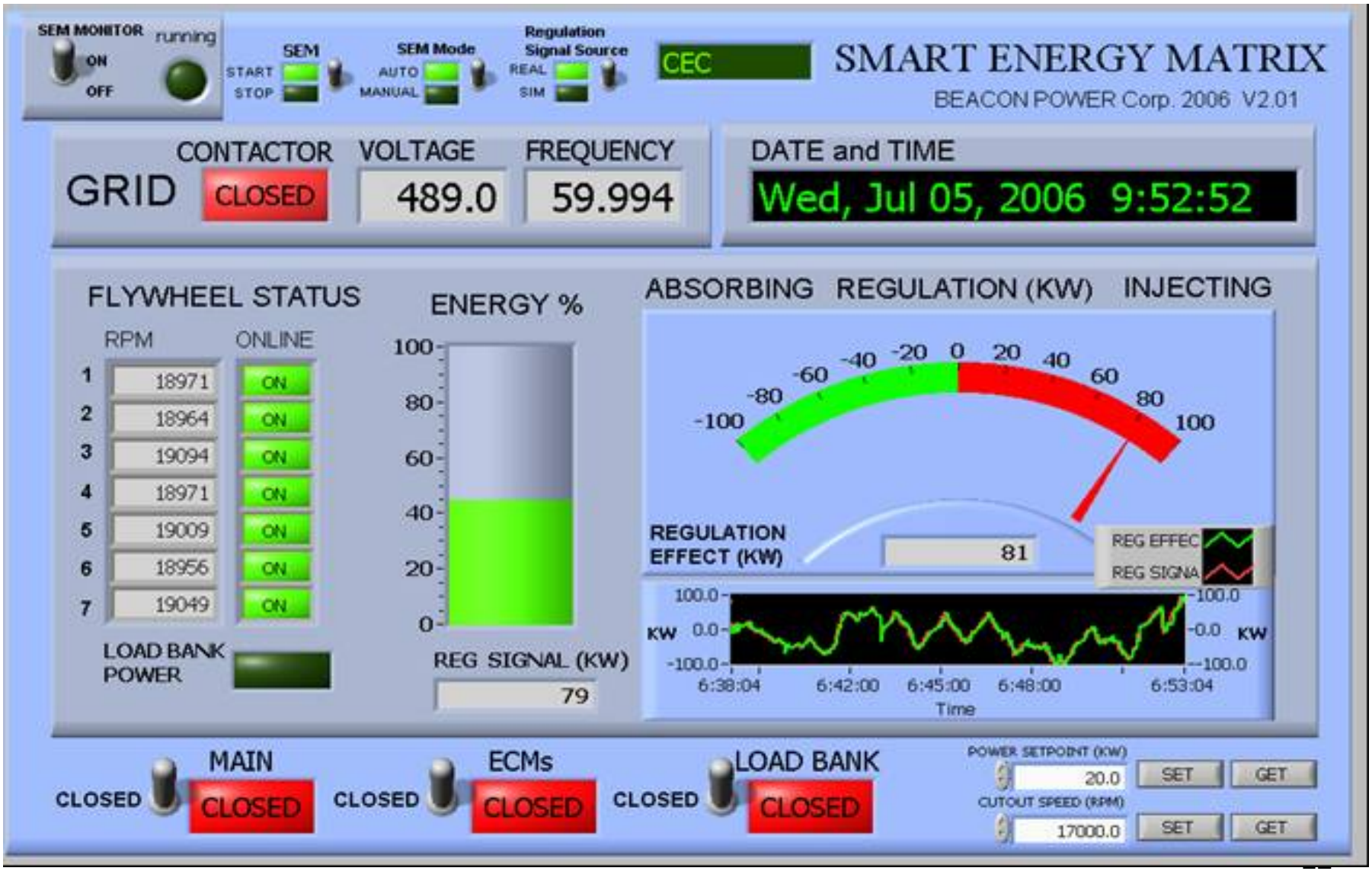


Beacon Flywheel System Installed at PG&E Testing Facility in San Ramon

Proposed Communication System for Flywheel Energy Storage



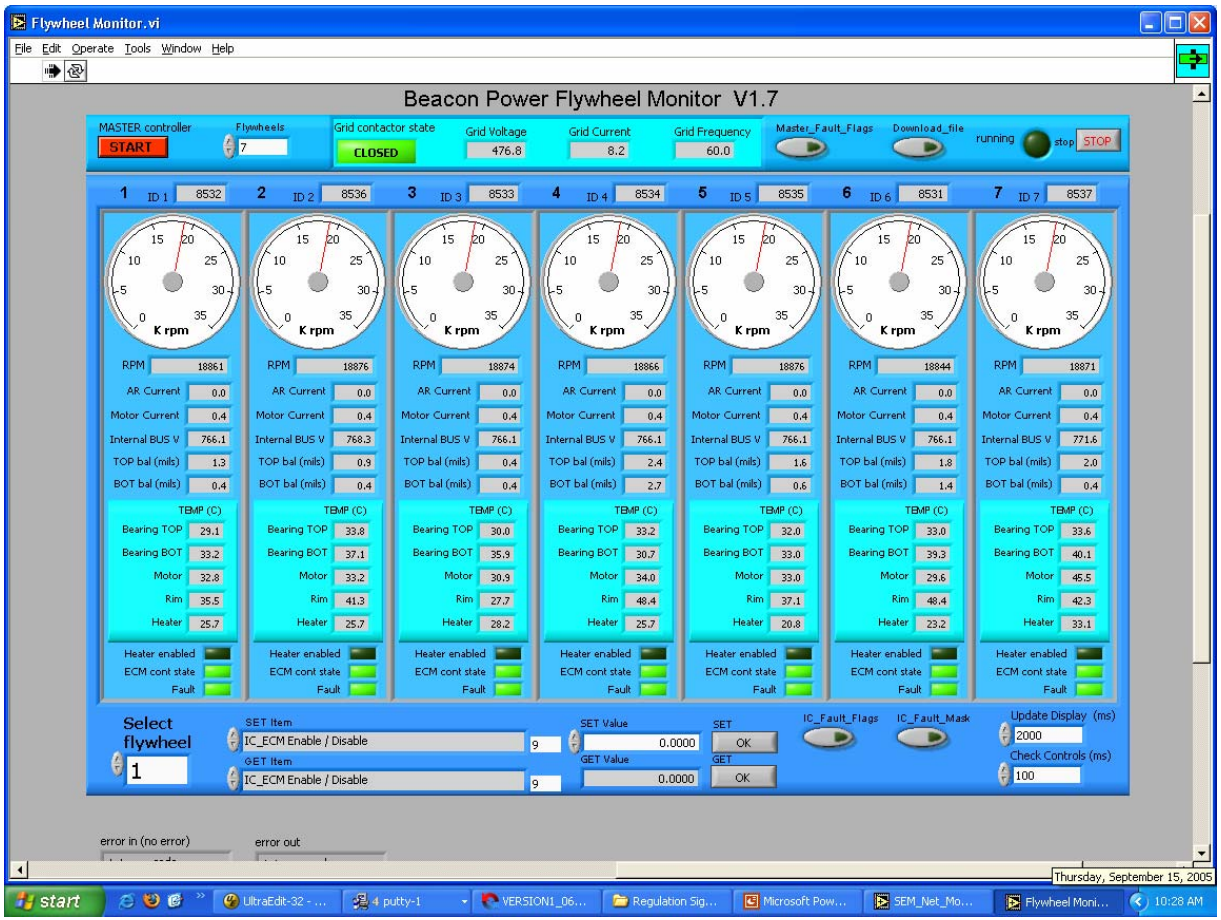
System Graphic User Interface



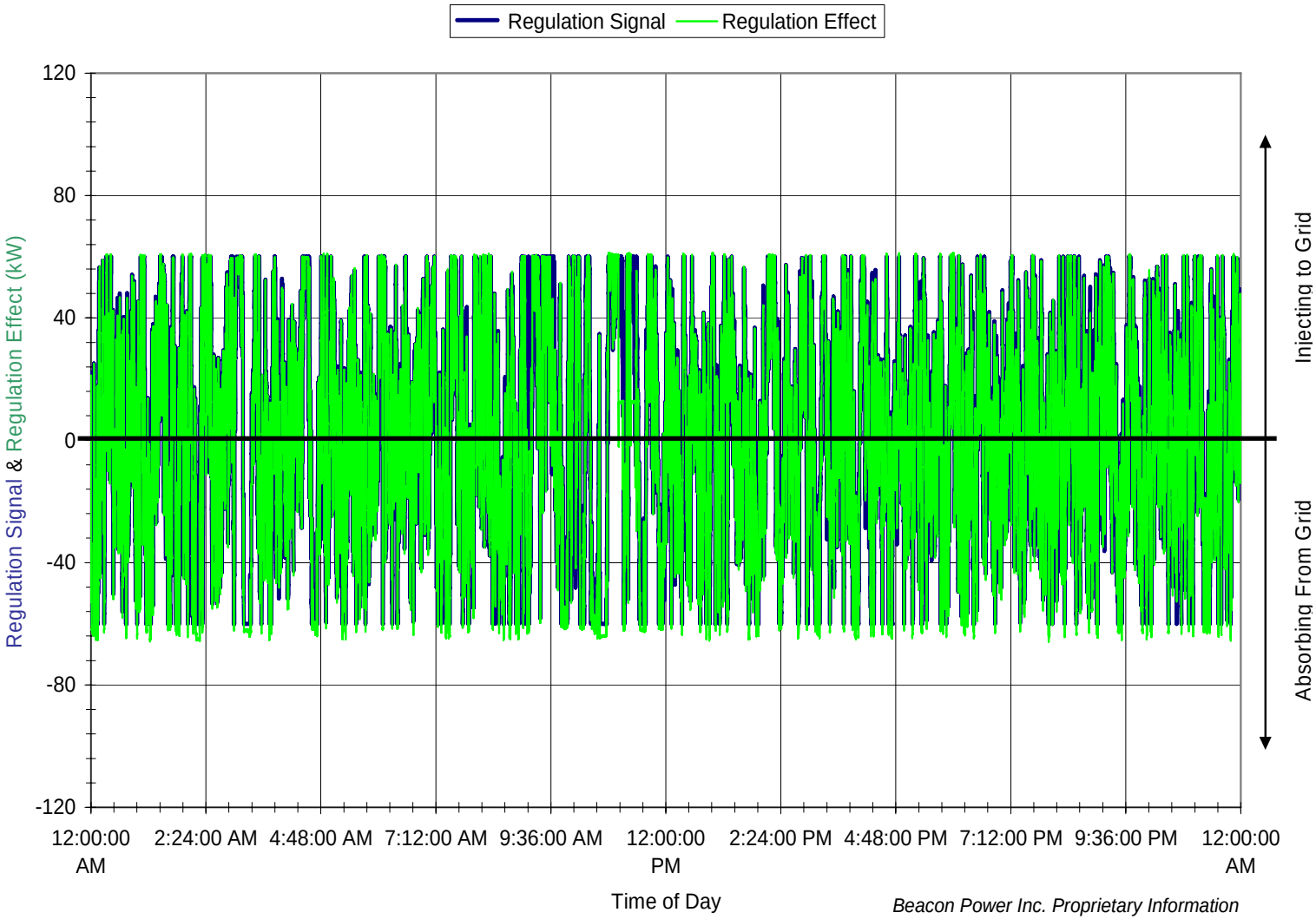
Date	Freq Reg	Energy Depleted	Total Online Hrs	Offline Unsched	Offline Sched	Availability	Deviation	Deviation w/ depletion	Max KW	Setpoint KW	Cutout Speed RPM	Max FW's	Comment
1-Aug	12.49	0.00	12.49	0.02	11.49	99.85%	2.27%	2.27%	60	17.5	17,000	7	Initiated 60 kw, 17500RPM cutout , 17.5 KW SP Start Official Test.
2-Aug	23.69	0.29	23.98	0.02	0.00	98.71%	2.30%	2.99%	60	17.5	17,000	7	None
3-Aug	23.69	0.29	23.98	0.02	0.00	98.72%	2.30%	2.99%	60	17.5	17,000	7	None
4-Aug	23.69	0.28	23.98	0.02	0.00	98.73%	2.30%	2.98%	60	17.5	17,000	7	**Getter pump cycled for 3 hrs.**
5-Aug	23.66	0.33	23.98	0.02	0.00	98.56%	2.24%	2.92%	60	17.5	17,000	7	None
6-Aug	23.68	0.30	23.98	0.02	0.00	98.67%	2.22%	2.91%	60	17.5	17,000	7	None
7-Aug	23.69	0.29	23.98	0.03	0.00	98.69%	2.02%	2.73%	60	17.5	17,000	7	None
8-Aug	23.69	0.29	23.98	0.02	0.00	98.71%	2.27%	2.95%	60	17.5	17,000	7	FW 6 and 7 were offline due to faults for an hour or so.
9-Aug	23.66	0.32	23.98	0.02	0.00	98.59%	2.64%	3.40%	60	17.5	17,000	7	None
10-Aug	22.15	0.30	22.45	0.14	1.41	98.05%	2.49%	3.25%	60	17.5	17,000	7	Set system to change to 80 kW at midnight. ~1:41 Hrs Scheduled Offline to change test conditions. One Beckwith trip
11-Aug	21.66	0.57	22.23	0.04	1.73	97.27%	1.37%	2.63%	80	17.5	17,000	7	Restart Playback. Bug with Software. For about 1 hr, the reg signal was scaled to 100 kW
12-Aug	23.43	0.53	23.95	0.05	0.00	97.62%	1.52%	2.87%	80	17.5	17,000	7	None
13-Aug	23.40	0.55	23.95	0.05	0.00	97.50%	1.46%	2.87%	80	17.5	17,000	7	None
14-Aug	23.43	0.53	23.96	0.04	0.00	97.61%	1.86%	3.25%	80	17.5	17,000	7	FWs 1,2,3 and 5 were offline from 15:18 to 16:45 due to AR under freq faults.
15-Aug	20.71	0.67	21.38	0.99	1.63	92.59%	2.34%	4.22%	80	17.5	17,000	5.5	Began extensive diagnosis of ECM 7. Reset Signal to 60 KW at 18:30
16-Aug	14.28	0.45	14.73	0.16	9.11	95.92%	1.98%	3.66%	60	17.5	17,000	6	ECM 6 and 7 offline for 14.75 hrs; lost the regulation signal for 1.5 hrs after that. System in Manual Mode while troubleshooting (about 9 hrs)
17-Aug	7.07	0.01	7.08	0.04	16.88	99.34%	3.02%	3.08%	60	17.5	17,000	6	The system was in MANUAL until about 5 PM, then we let the system resume the test plan. FW 4 was down for another 1.5 hrs even after that (vibes).
18-Aug	19.17	0.41	19.58	0.88	3.55	93.75%	2.24%	3.34%	60	17.5	17,000	6	System was in MANUAL from noon until 4:45 PM, while diagnosing ECM #7.
19-Aug	23.56	0.43	23.99	0.02	0.00	98.15%	2.97%	3.92%	60	17.5	17,000	5	FW 1 was down for 9 hrs (MC over current), and FW 3 for 6 hrs (hardware shutdown)
20-Aug	23.49	0.50	23.99	0.02	0.00	97.86%	2.26%	3.45%	60	17.5	17,000	6	FW 1 was down for 3 hrs (MC over current)
21-Aug	21.48	0.85	22.33	0.06	1.60	95.87%	2.57%	4.36%	60	17.5	17,000	6	FW 1 was down for 5 1/4 hrs (MC over current). **Getter pump cycled for 6.5 hrs.** During diagnostics, the system was brought down for 1.5 hrs.
22-Aug	21.28	0.40	21.68	1.11	1.20	93.32%	2.17%	3.20%	60	17.5	17,000	6	System down for diagnostics from 14:30 to 17:00 while trying to bring FW 7 back online.
23-Aug	18.58	0.40	18.98	0.98	4.04	93.09%	2.38%	3.56%	60	17.5	17,000	6	System taken offline at 6:30 PM to begin repairing FW 7
24-Aug	7.09	0.00	7.09	0.00	16.91	99.97%	2.18%	2.18%	60	17.5	17,000	6	System offline while repairing Unit 7
25-Aug	2.38	0.00	2.38	0.02	21.61	99.35%	2.29%	2.29%	60	17.5	17,000	6	System offline while repairing Unit 7. Brought back on line at 9:30 PM
26-Aug	23.63	0.30	23.93	0.07	0.00	98.45%	2.59%	3.36%	60	17.5	17,000	7	None
27-Aug	23.63	0.32	23.94	0.06	0.00	98.44%	2.28%	3.03%	60	17.5	17,000	7	None
28-Aug	23.59	0.36	23.95	0.06	0.00	98.28%	2.25%	3.08%	60	17.5	17,000	7	FW #1 was down for 8 hours due to MC overcurrent fault.
29-Aug	23.63	0.31	23.94	0.06	0.00	98.46%	2.05%	2.79%	60	17.5	17,000	7	None
30-Aug	23.63	0.31	23.95	0.06	0.00	98.47%	2.22%	2.97%	60	17.5	17,000	7	None
31-Aug	23.70	0.16	23.86	0.14	0.00	98.76%	2.54%	2.83%	60	17.5	17,000	7	FW #1 was down for 5.5 hours due to MC overcurrent fault.
Avg for August	20.54	0.35	20.89	0.17	2.94	97.56%	2.24%	3.11%					

Flywheel Graphical User Interface

Remote Monitoring and Control of Flywheel and System Parameters



Results – Typical Response

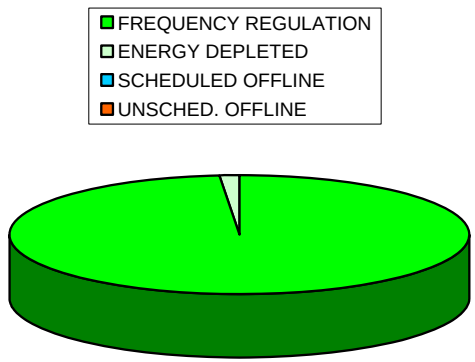


Results – August 2, 2006 Summary

CEC Run Data Summary Sheet **Date: 2006-08-02T04:00:09Z**

Beacon Power Proprietary Information

		Percent	Hours
DAILY SUMMARY	**FREQUENCY REGULATION**	**98.7%**	**23.69**
	ENERGY DEPLETED	**1.2%**	**0.29**
	SCHEDULED OFFLINE	**0.0%**	**0.00**
	UNSCHED. OFFLINE	**0.1%**	**0.02**
	Total	**100.0%**	**24.00**
ON-LINE PERFORMANCE	**Deviation Excluding Depleted Time***	**2.3%**	
	Deviation Including Depleted Time*	**3.0%**	
Frequency Regulation Provided	Injection Signal [kWh]	350	
	Injection Actual [kWh]	336	
	%	96%	
	Absorbed Signal [kWh]	337	
	Absorbed Actual [kWh]	351	
	%	104%	
Net Energy Exchanged	Injection Signal [kWh]	177	
	Injection Actual [kWh]	164	
	%	92%	
	Absorbed Signal [kWh]	584	
	Absorbed Actual [kWh]	599	
	%	103%	
Distribution of Energy	Setpoint Energy [kWh]	420	
	Absorbed Load Bank [kWh]	180	
	Absorbed FW System	419	
Initial Conditions	**Max Power [kW]**	**60.0**	
	Minimum Set point [kW]	-17.5	
	Maximum Set point [kW]	-17.5	
	Cutout Speed [kRPM]	17	



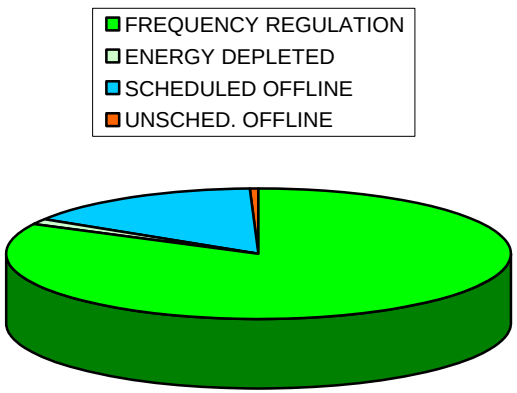
DAILY SUMMARY

Monthly Performance Summary

CEC Run Data Monthly Summary Sheet **Date: August, 2006**

Beacon Power Proprietary Information

		Percent	*Hours*
DAILY SUMMARY	**FREQUENCY REGULATION**	**86%**	**20.5**
	ENERGY DEPLETED	**1%**	**0.3**
	SCHEDULED OFFLINE	**12%**	**2.9**
	UNSCHED. OFFLINE	**1%**	**0.2**
	Total	**100%**	**24.0**
ON-LINE PERFORMANCE	**Availability = Freq Reg / 24 Hrs minus Scheduled Offline Hrs**	**97.6%**	
	Deviation Excluding Depleted Time	**2.2%**	
	Deviation Including Deplete Time	**3.1%**	

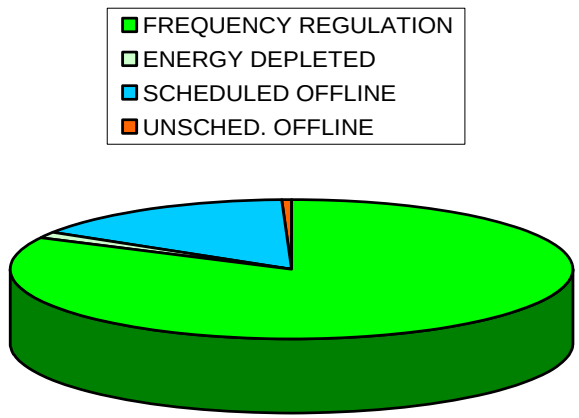


Monthly Performance Summary

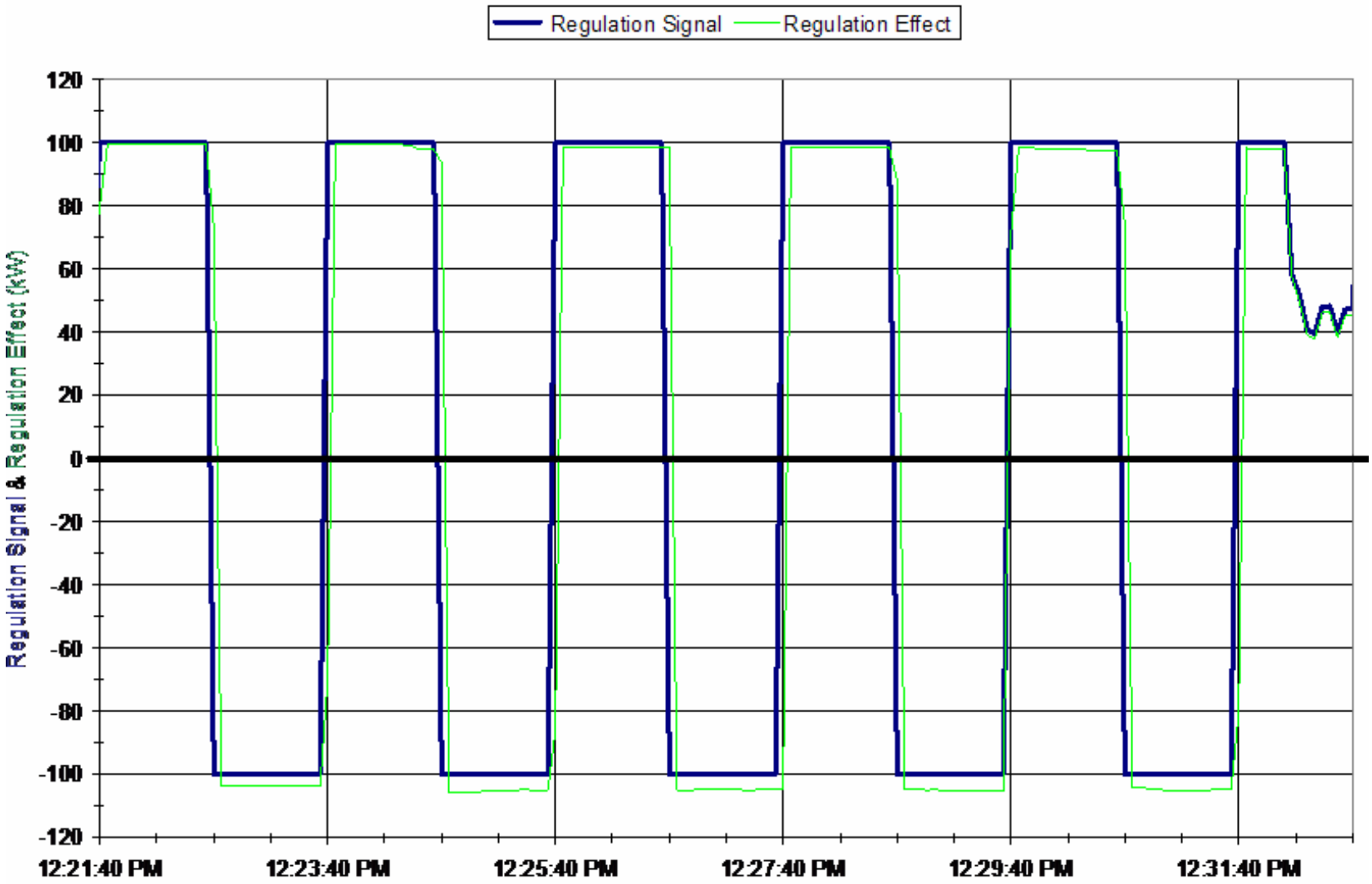
CEC Run Data Monthly Summary Sheet **Date: September, 2006**

Beacon Power Proprietary Information

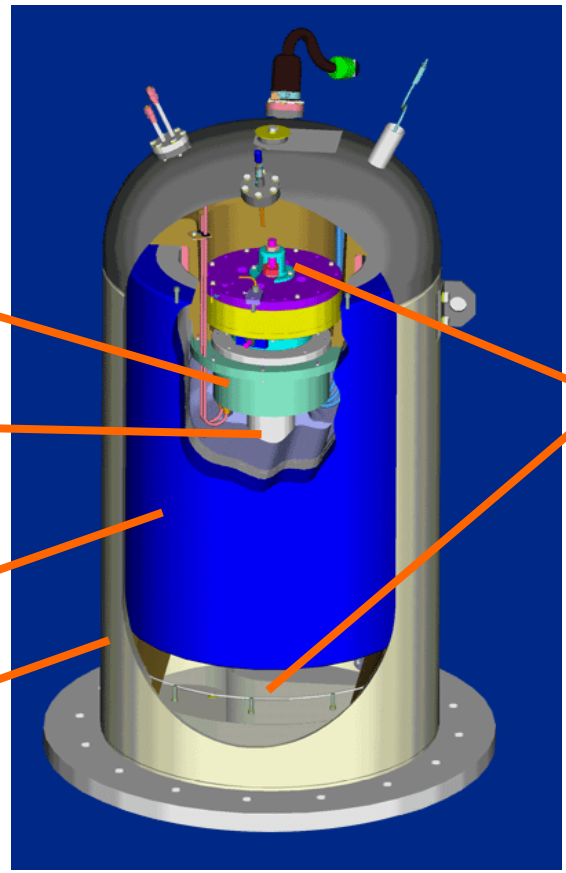
		Percent	*Hours*
DAILY SUMMARY	**FREQUENCY REGULATION**	**82%**	**19.8**
	ENERGY DEPLETED	**2%**	**0.4**
	SCHEDULED OFFLINE	**16%**	**3.7**
	UNSCHED. OFFLINE	**0%**	**0.1**
	Total	**100%**	**24.0**
ON-LINE PERFORMANCE	**Availability = Freq Reg / 24 Hrs minus Scheduled Offline Hrs**	**97.7%**	
	Deviation Excluding Depleted Time	**2.6%**	
	Deviation Including Deplete Time	**3.7%**	



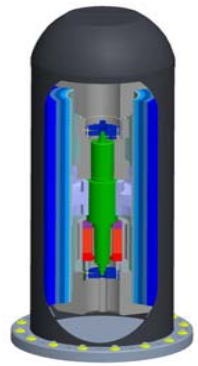
Results – Slam Test



Advanced Flywheel Technology



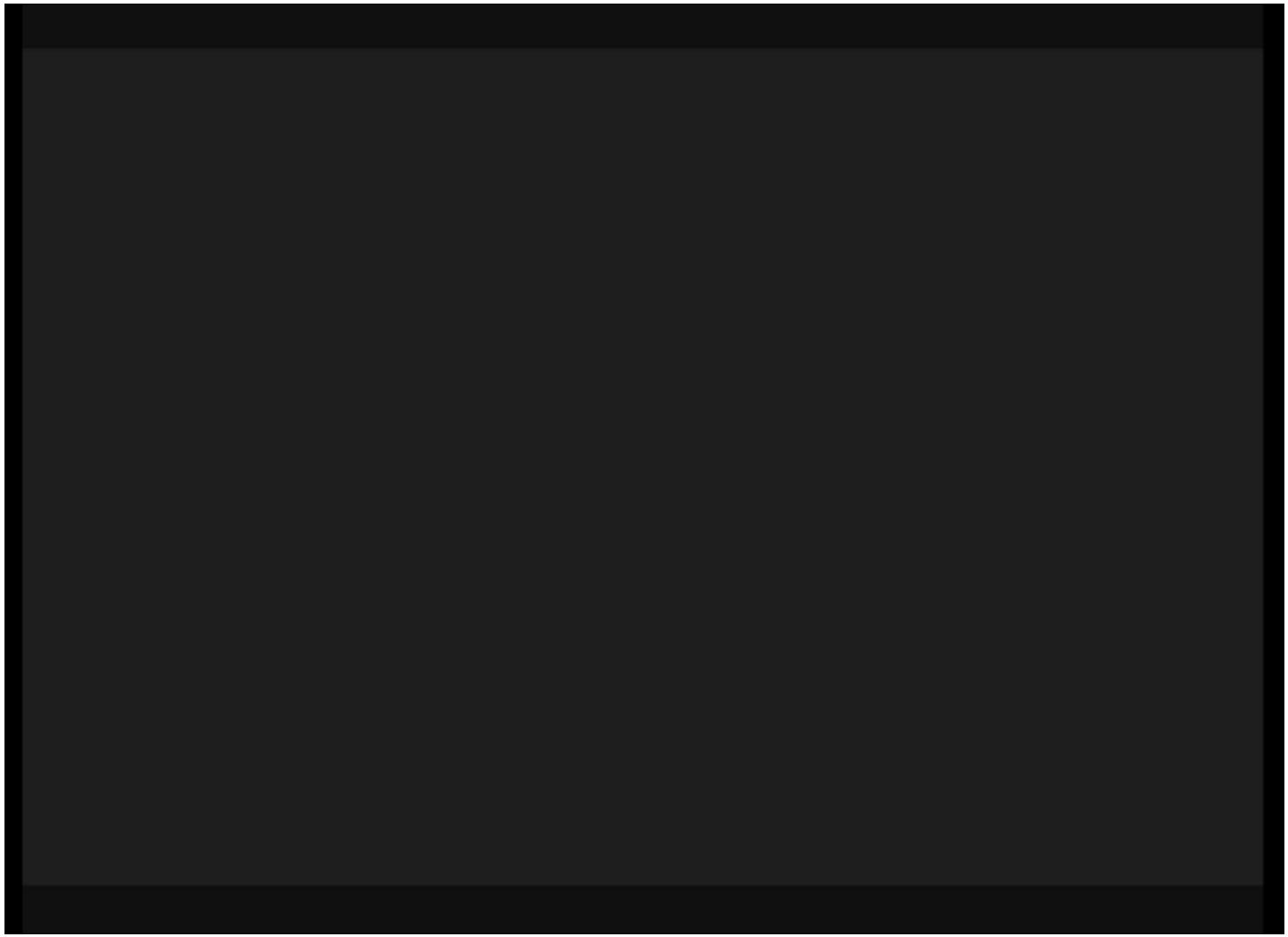
Flywheel Product Comparison

	PILLER	ACTIVE POWER	URENCO	PENTADYNE	BEACON POWER		
							
MODEL	PB 1100	CLEANSOURCE 2	SMART POWER 200	VSS+dc	Gen 2	Gen 3	Gen 4
Flywheel Speed	3,600 RPM	7,700 RPM	37,800 RPM	54,000 RPM	22,500 RPM	22,500 RPM	16,000 RPM
Ride-Through Time	25 sec @ 600 kW	12 sec @ 250 kW	30 sec @ 200 kW	12.5 sec @190 kW	3 Hours @ 2 kW	15min @15 kW	15 min @ 100 kW
Stored Energy	15.0 MJ / 4.2 kWh	3.0 MJ / 0.83 kWh	6.0 MJ / 1.67 kWh	2.4 MY / 0.66 kWh	21.6 MJ / 6 kWh	13.5 MJ / 3.75kWh	90.0 MJ / 25 kWh
Height	88 in.	96 in.	63 in.	71 in.	49 in.	49 in.	82 in.
Weight	13,224 lb.	3,800 lb.	3,300 lb.	1300 lb.	1780 lb.	1830 lb.	6000
Wh per lb.	0.3	0.2	0.5	0.5	3.4	2.0	4.2

Smart Energy Matrix 20 MW Plant

Preliminary design

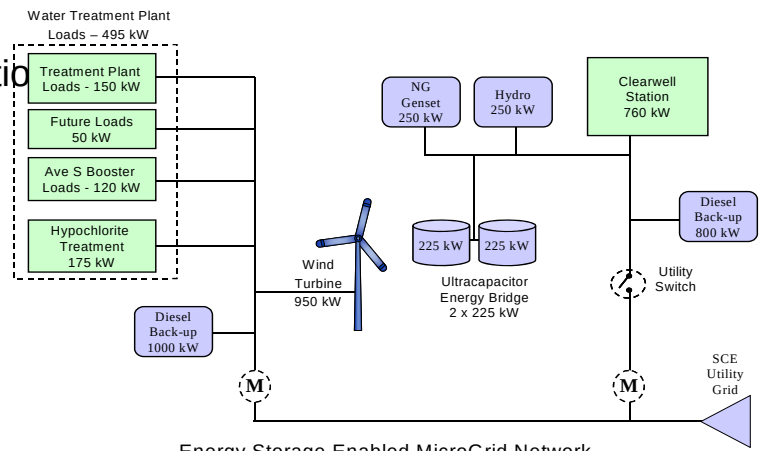
Smart Energy Matrix 20 MW Plant



Energy Storage Enabled Renewable MicroGrid Power Network

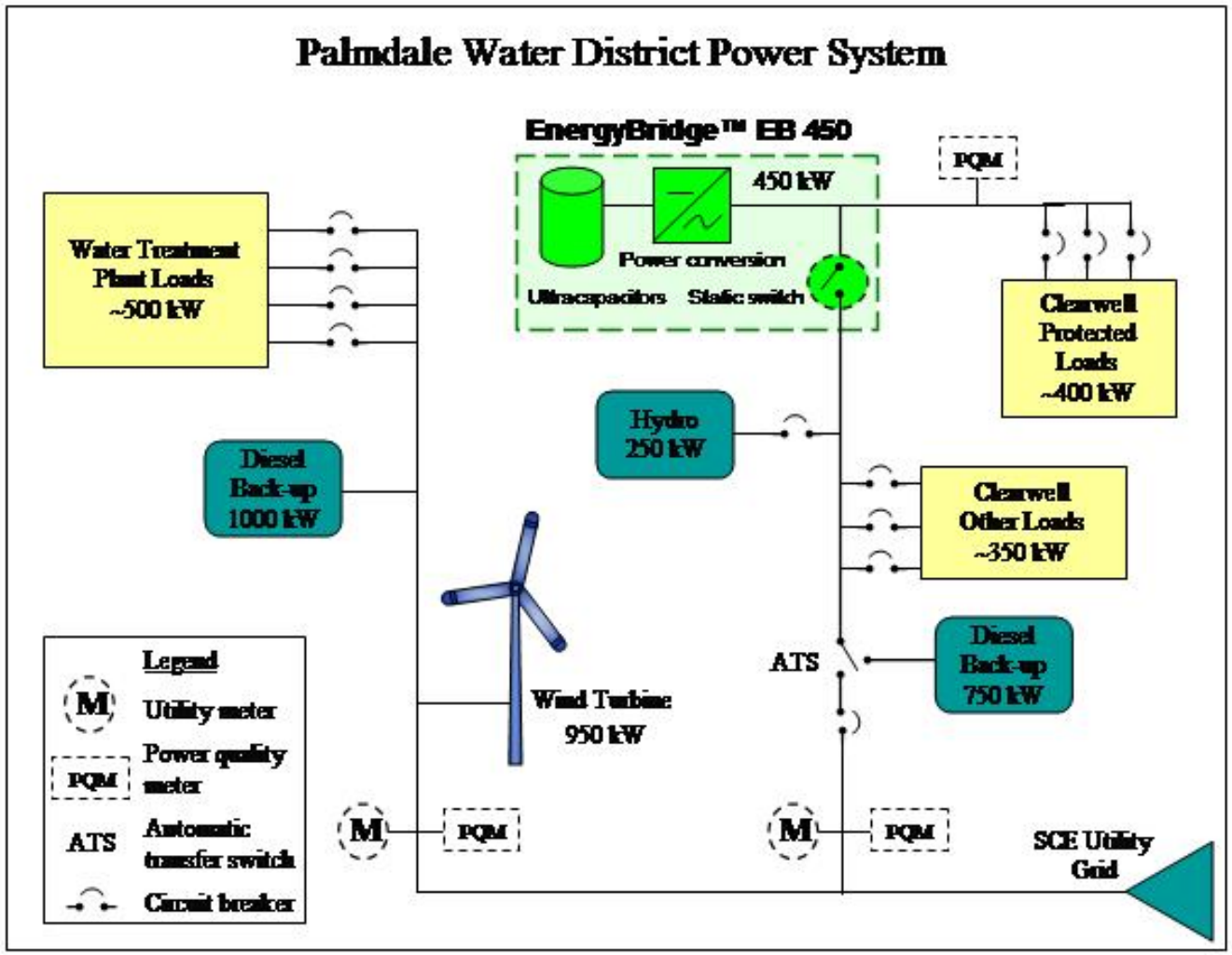
- **Pier Funding:** $979K **(35%)----------(Total Project Costs:** $2,819K**)**
- **Technology demonstrated:** Integration of wind, hydro & DG in MicroGrid using ultracapacitors
- **Utility:** SCE **Prime Contractor:** Palmdale Water District
- **End Customer:** Palmdale Water District
- **How does project work:**
  - Project integrates a 950kW wind turbine, 250 kW hydro and 250kW natural gas generator into a MicroGrid using 450kW ultra-capacitor energy bridge Ultracapacitor energy storage technology is used as an energy bridge to enable the smooth transfer of renewables and DG technologies**.**
- **Project Impact:**
  - Enable the growth of DG, renewables and MicroGrids
  - Apply energy storage as enabling technology
  - Provide critical missing link for renewable & DG integratio
- **End User Benefits**
  - Reduced energy costs
  - Improved system reliability
  - Back-up power protection
  - Improved power quality
- **Project Timeline:**
  - Start: February 2005
  - Commission: Spring 2007
  - Field Trial: 2007 – 2008

Clearwell Proposal



Energy Storage Enabled MicroGrid Network

Energy Storage Enabled Renewable MicroGrid Power Network at Palmdale



Demonstration of ZBB Energy Storage System

- Pier Funding: **$1,873K** (75%)----------Total Project Costs: **$2,476K**
- Technology demonstrated**:** **Zinc-Bromine battery storage for substation upgrade deferral**
- Utility: **PG&E** Prime Contractor: **ZBB Energy Corporation**
- End Customer: PG&E
- How does project work:

  Project will demonstrate the value of using energy storage to improve T&D Congestion conditions and defer T&D upgrades. A transportable 2MW/2MWH ZBB battery energy storage system will be installed at substation to demonstrate and assess value of T&D upgrade deferral.

- Project Impact:
  - •T&D system reliability improvement
  - •Demonstrate economic impact of applying energy storage to T&D congestion problem
- End User Benefits
  - •Continue to use T&D resources without making system upgrade
  - •Improved system reliability
  - •Improved system flexibility
- Project Timeline:
  - •Start: April 2004
  - •Commission: 2007
  - •Field Trial: 2007 – 2008

ZBB System for PG&E Substation Deferral

Questions ???

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