VRB Power Systems

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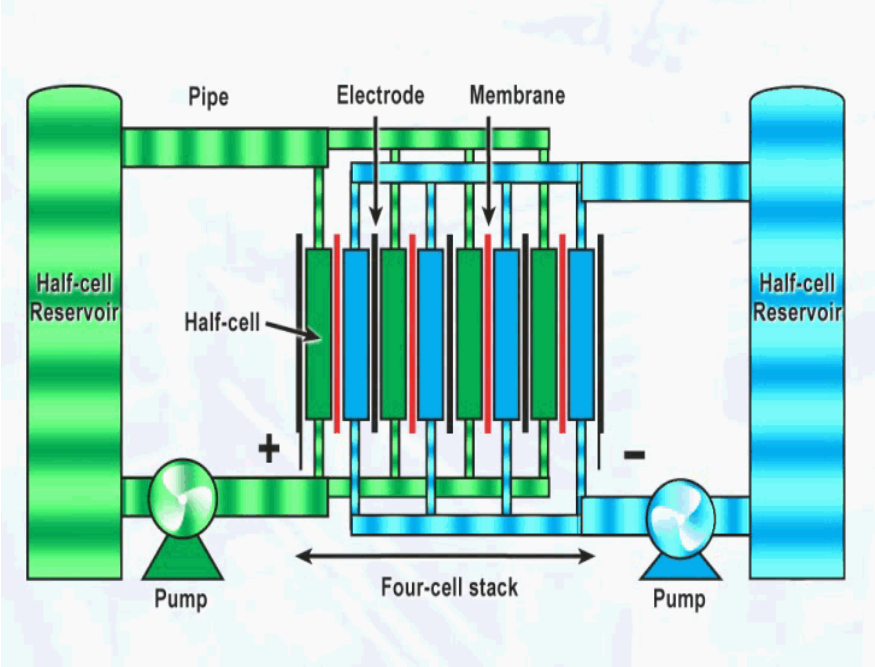
VRB Flow Battery Technology

A liquid electrolyte that is separate from the electrode.

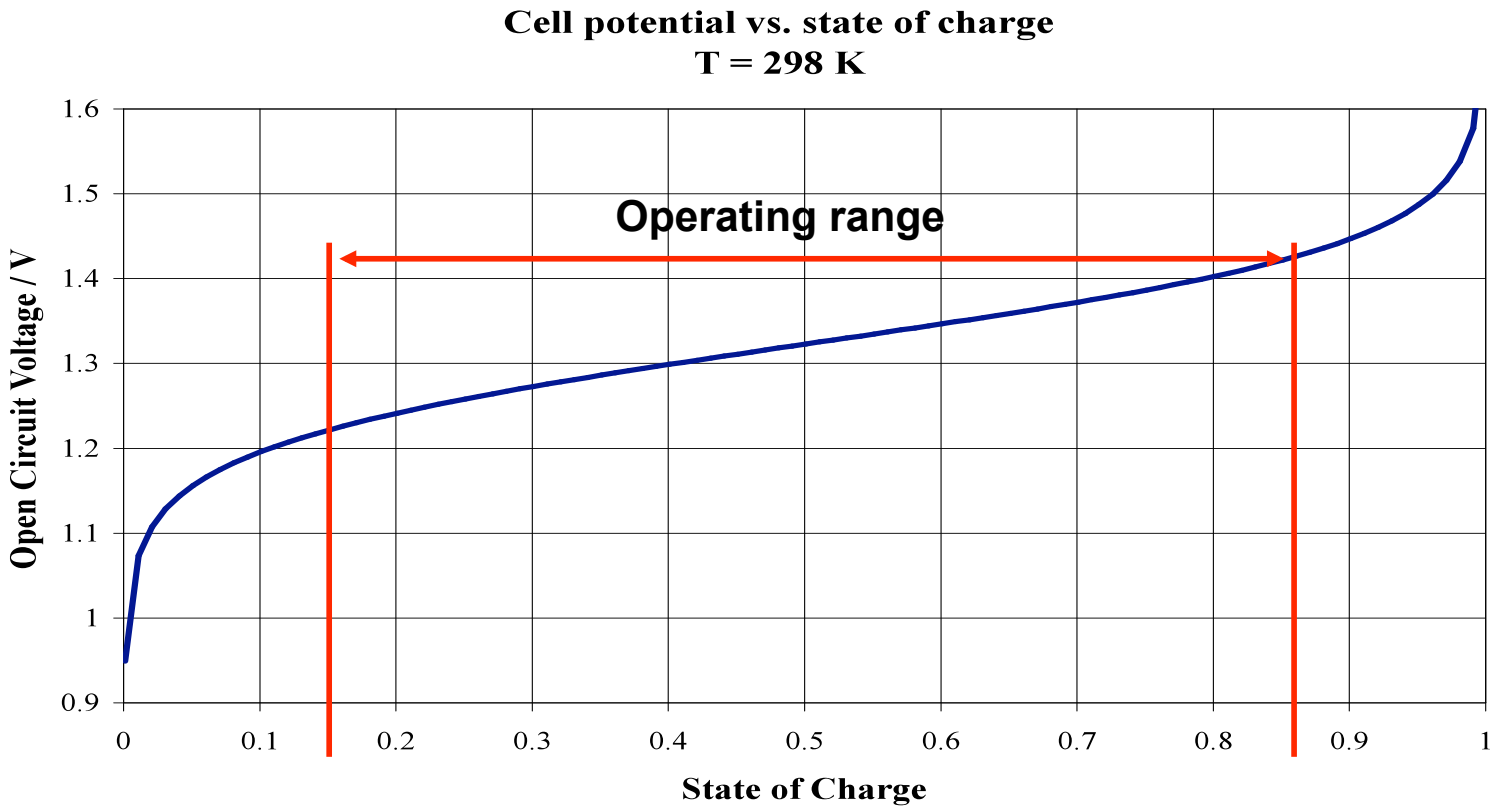


- An electrochemical energy storage system operating at ambient temperatures
- Reversible fuel cell – reduction and oxidation of single unique element: Vanadium
- No cross contamination as with other storage systems. Electrolyte never wears out – high residual value
- Very low maintenance
- Deep cycles (20 to 80%) >10,000
- Low self discharge – indefinite energy storage
- Energy can be recovered instantaneously
- Battery can recharge as fast as it discharges (1:1)
- Power and Energy separately scaleable

Oxidation process		Reduction process
$V^{4+} \Rightarrow V^{5+} + e^-$	Charge ←	$V^{3+} + e^- \Rightarrow V^{2+}$
$V^{5+} + e^- \Rightarrow V^{4+}$	Discharge →	$V^{2+} \Rightarrow V^{3+} + e^-$

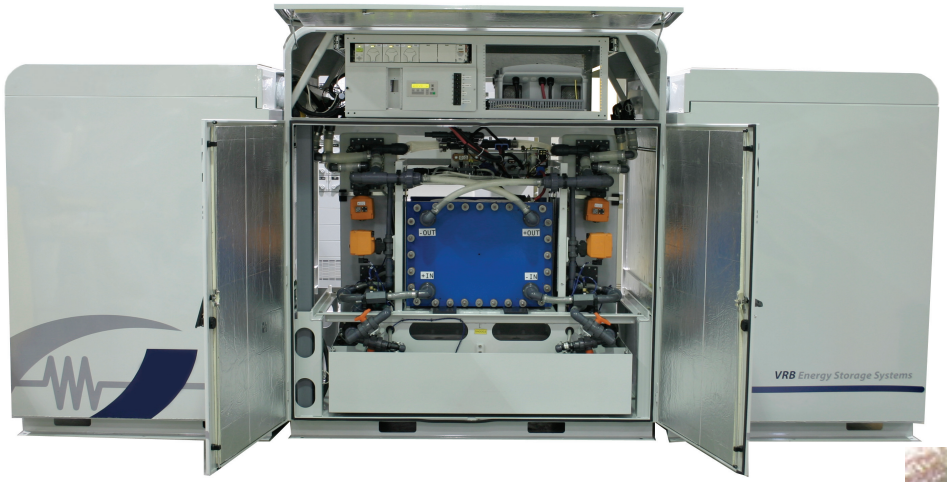
VRB cell open circuit voltage – SOC indicator

What you measure is what you get...

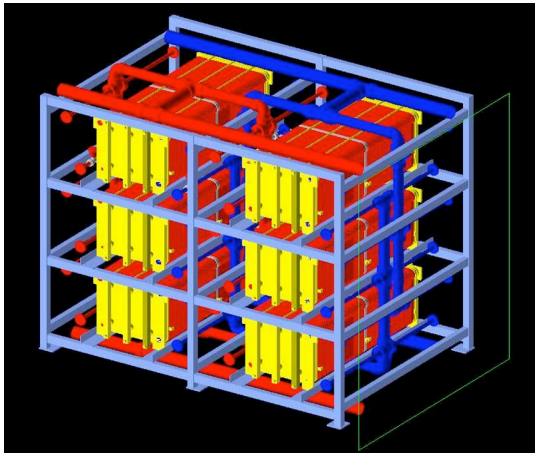


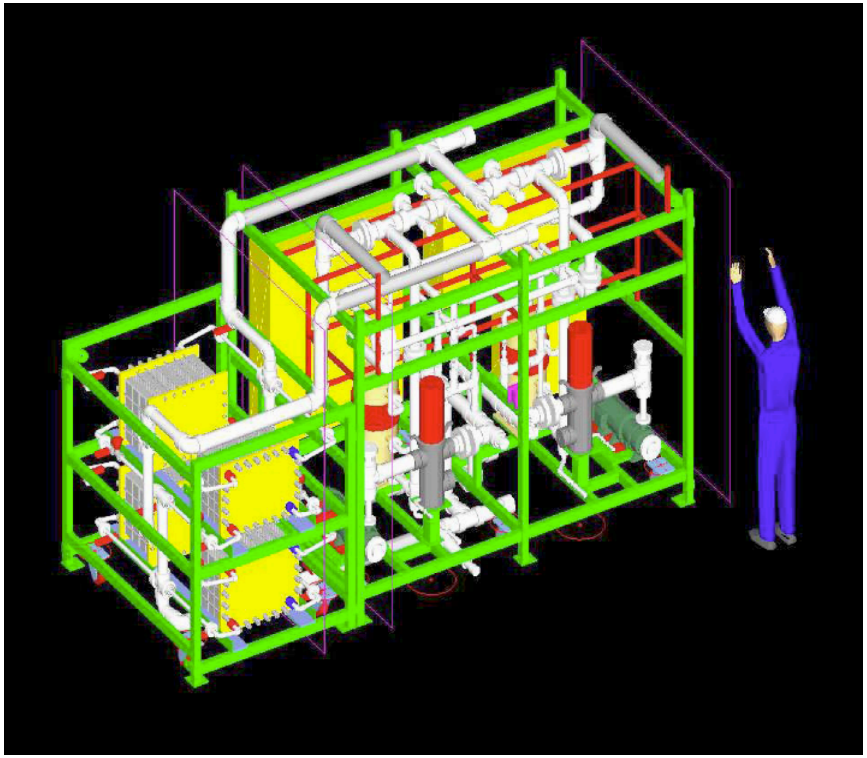
VRB Energy Storage Systems (VRB-ESS)

5kW – 25 kWh **Commercial Introduction – June 2007**

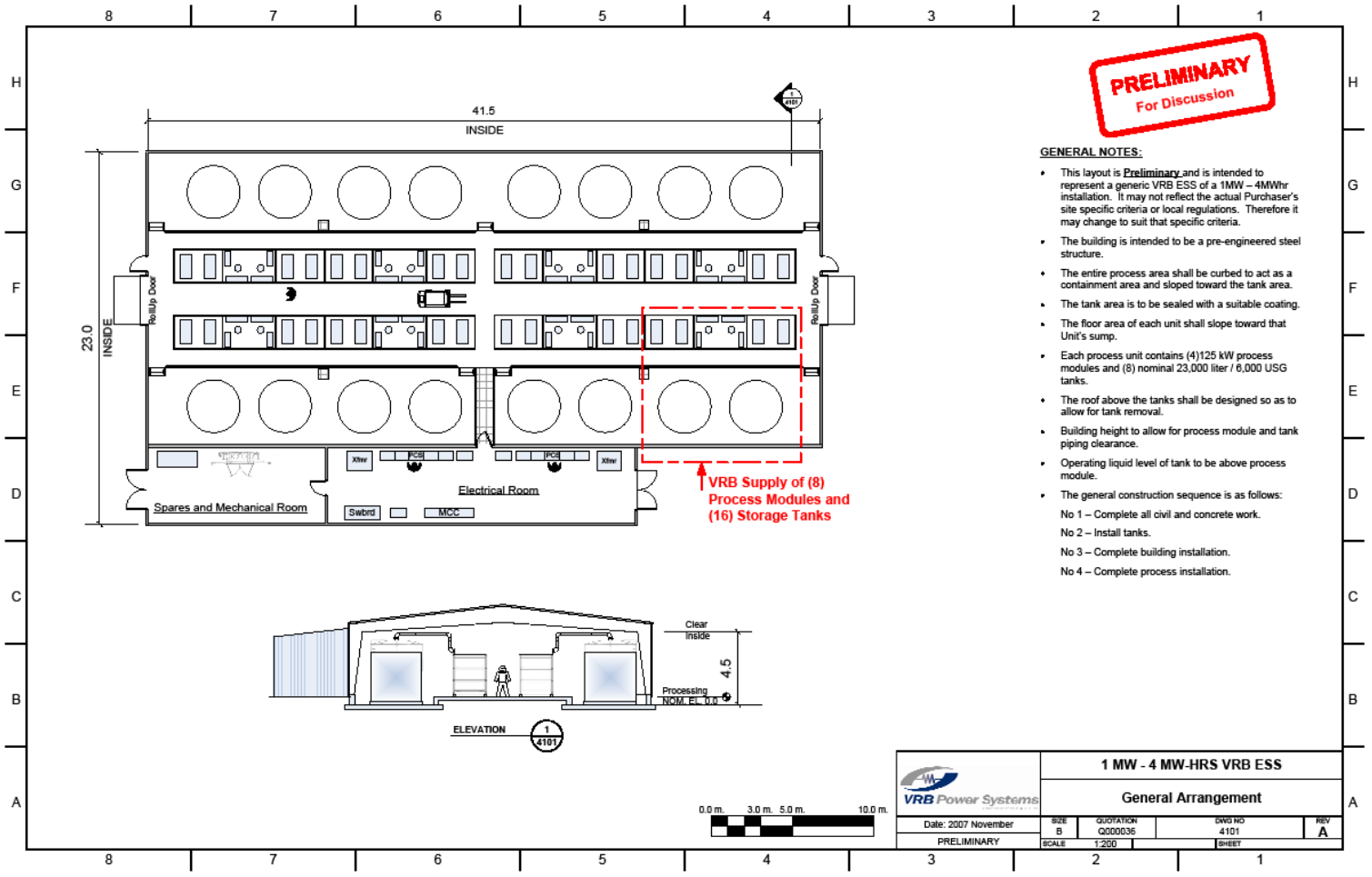


VRB-ESS 125 kW modules





VRB –ESS 1MW; 4MWh



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Energy Storage & Power Quality Solutions

Projects

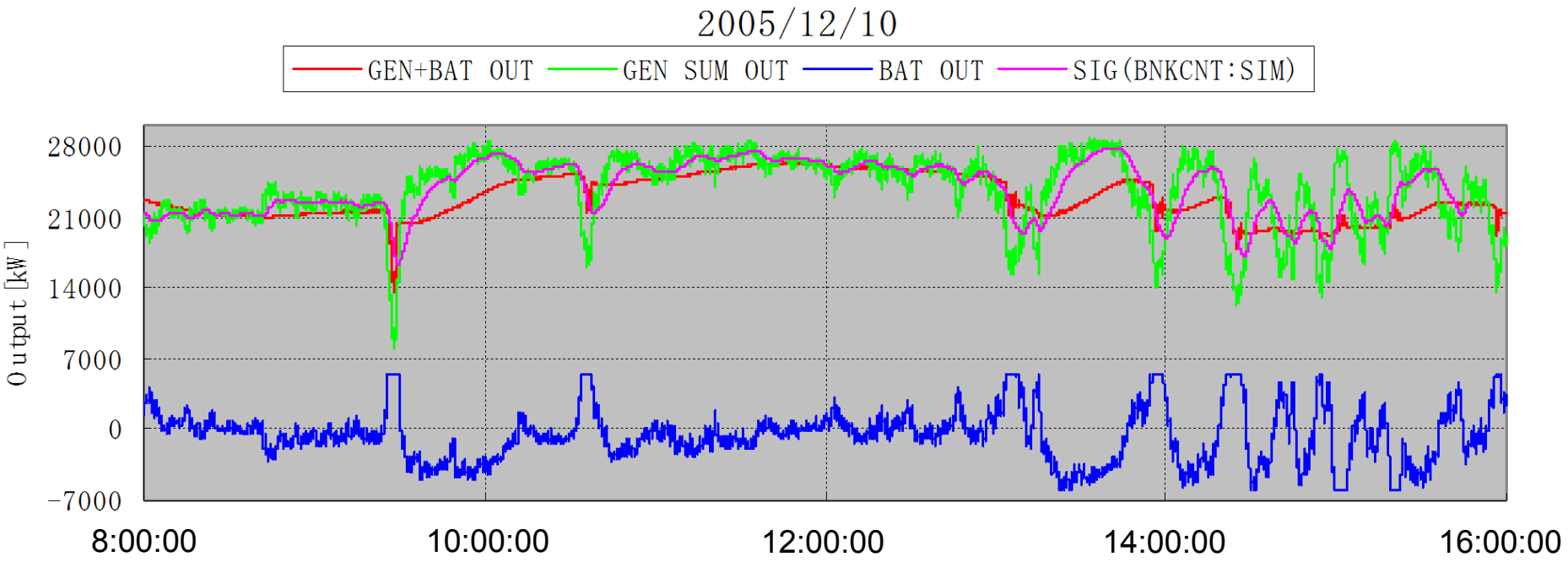
• California – CEC/SMUD/Telecommunications	20kW – 180 kWh	
• Florida – Progress Energy	2 x 5kW – 25kWh	Solar
• Kenya – Winafrique	2 x 5kW – 25kWh	Telecomms
• Denmark – RisØ	15kW – 125kWh	Wind
• Italy – Edison	5kW – 25kWh	Telecomms
• Canada – NRCan	Completion of test program	
• Engineered systems	Design/Proposals	125kW – 20MW

Company

- Personnel: No. employees: April 2007 - 35 April 2008 - 56

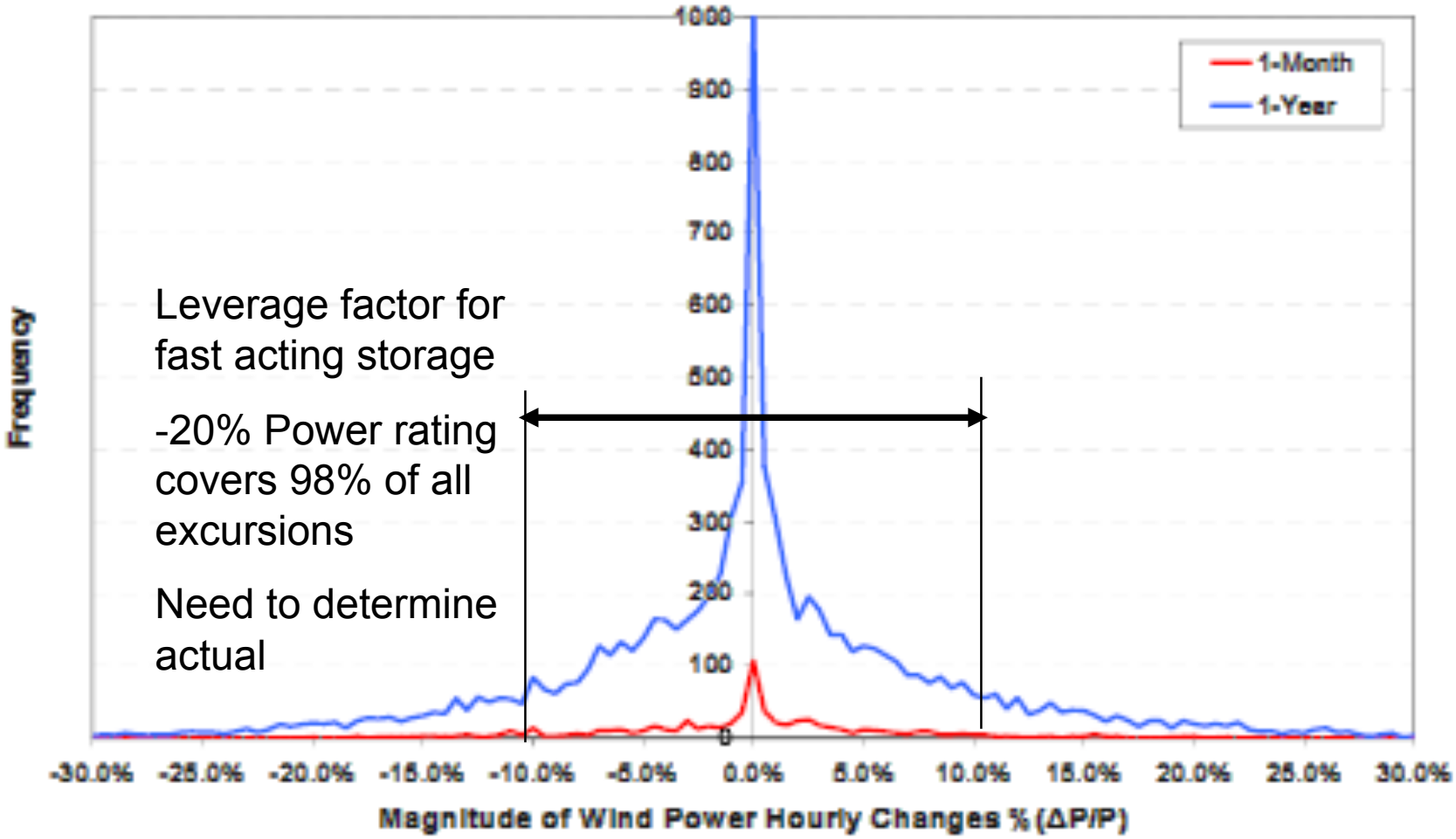
- Facilities

Daily Wind Output Smoothing at J-Power



- The VRB-ESS (blue line) runs continuously to smooth wind farm production (green line)
- At only 20% of the wind-farm's nameplate capacity, the VRB ESS has a significant smoothing effect to total wind-farm + battery output (red line)
- The VRB-ESS intelligently recharges throughout the day so that it maintains 50% SOC

Sizing - Distribution of Hourly Step Change Values



Leverage factor for fast acting storage

-20% Power rating covers 98% of all excursions

Need to determine actual

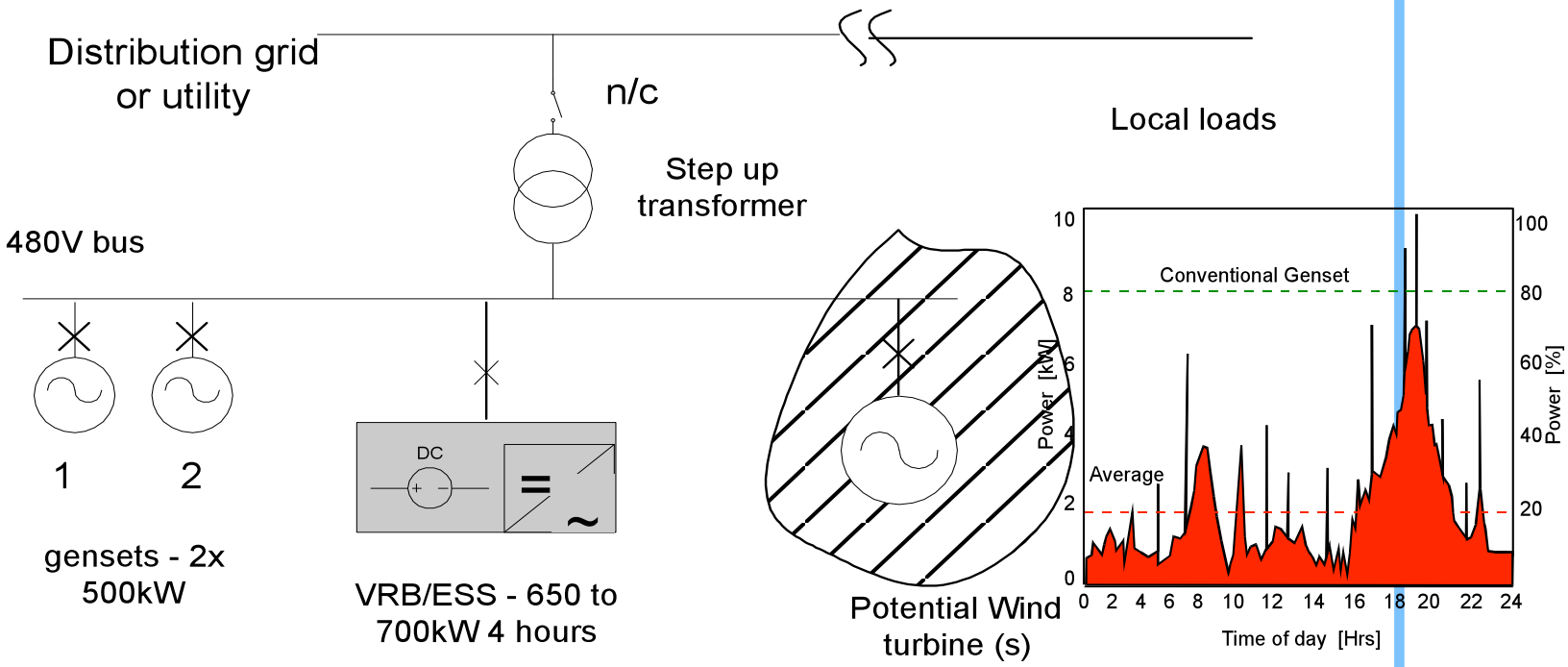
NREL 2004

Ancillary Services

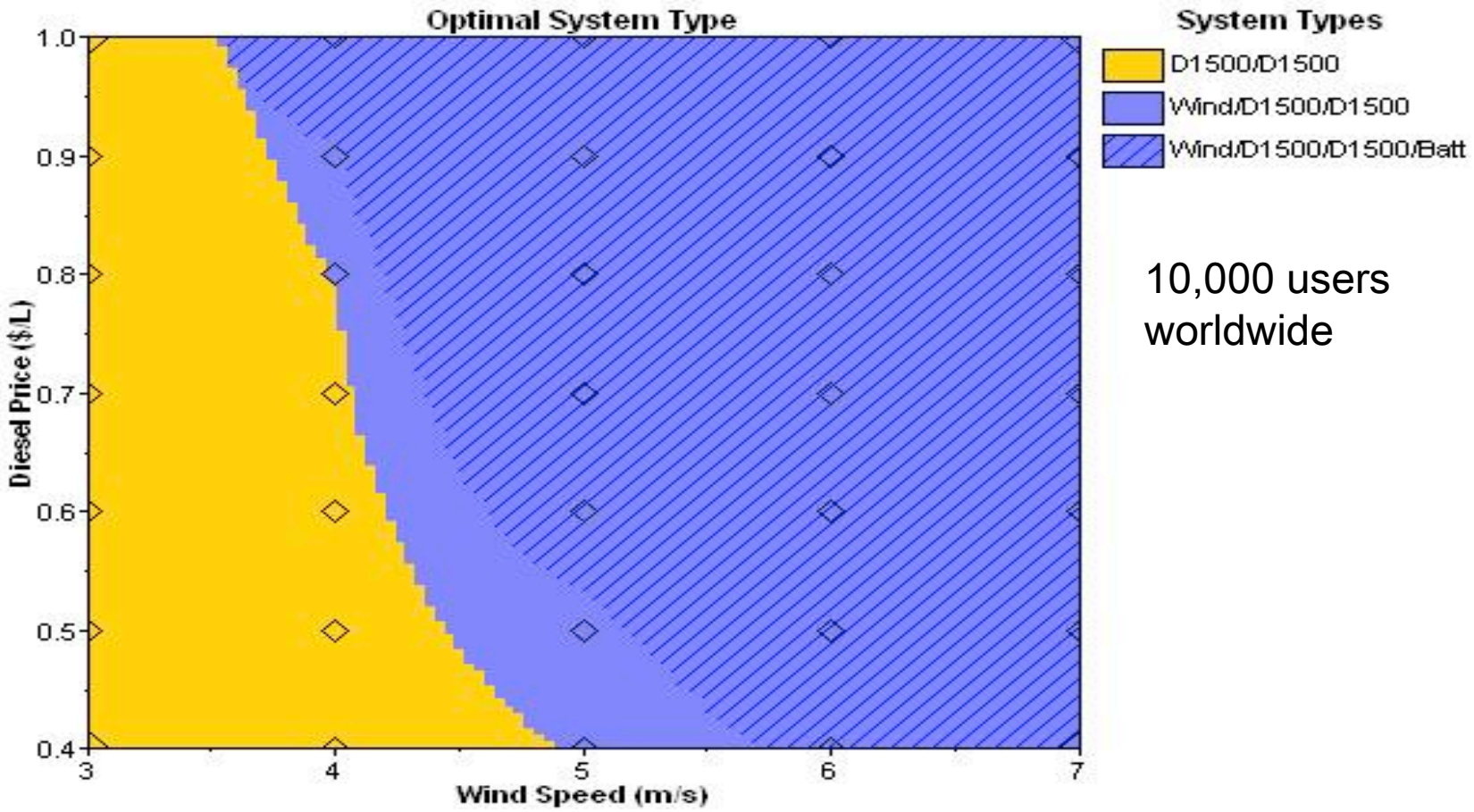
- Regulation ‘up’.
- Regulation ‘down’.
- Voltage support.
- Black start.

- Merchant storage.

Single line for VRB-ESS™ RAPS application



NREL and HOMER - Wind Diesel Storage



10,000 users worldwide

HOMER chooses the flow battery for almost all the scenarios in which it chooses wind turbines.

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