

# Storage for a sustainable future



**Prudent Energy**  
**VRB<sup>®</sup> Systems**

The Leading Clean Energy Storage Company

[www.pdenergy.com](http://www.pdenergy.com)

# Corporate Profile



## Company Overview

Prudent Energy designs, manufactures and installs the patented Vanadium Redox Battery Energy Storage System (VRB-ESS®) - an advanced “flow battery” that delivers reliable, high performance, large scale electrical energy storage. Prudent Energy’s VRB® can precisely align electricity supply and demand, generating or absorbing from several kilowatts up to many megawatts of power within milliseconds. This allows utilities to balance loads, make better use of existing infrastructure and regulate voltage and frequency. Installed at commercial and industrial facilities, the VRB-ESS® reduces operating expenses while improving power quality and providing reliable backup power.

The VRB-ESS® operates at room temperature and provides years of reliable, low-maintenance operation regardless of operating conditions or the number of times the system is charged and discharged. In addition, the system’s modular design means customers can buy or lease a system whose power output and energy storage exactly fit their needs. This flexibility makes the VRB-ESS® an ideal choice for renewable energy integration, remote area power supply and smart grids.

## Corporate Offices



# KW-Class VRB-ESS®



Prudent Energy's patented kW-class VRB Energy Storage System (VRB KW-ESS®) is an advanced flow battery which provides reliable, high-performance energy storage.

Incorporating the VRB-ESS® into a local energy management system yields immediate cost benefits to isolated communities, remote telecommunications site operators, or in any system powered primarily by wind, solar or diesel-fuelled sources.

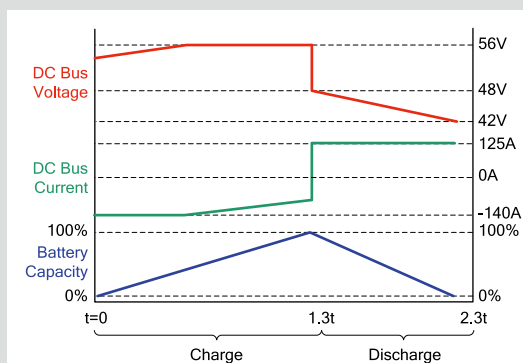
## KW-Class Characteristics

### Performance Characteristics

Nominal voltage	48 VDC
Open circuit voltage range	47 VDC to 54 VDC
Maximum charge voltage	56 VDC
Minimum voltage on discharge	42 VDC
Maximum charge current	140 ADC
Maximum discharge current, continuous	125 ADC
Peak discharge current, <300s	175 ADC
Continuous output power, top of charge state	6.0 kW
Continuous output power, bottom of charge state	5.2 kW
Duty cycle	Continuous
Interface	RS485 / 0-10 VDC

### Physical Characteristics

Power Module only	510 kg / 1,100 lb	1.2m x 1.0m x 1.1m / 48" x 40" x 43"
20kWh kW-Class VRB-ESS®	3,000 kg / 6,600 lb	3.8m x 1.4m x 1.3m / 150" x 55" x 47"
40kWh kW-Class VRB-ESS®	5,300 kg / 11,600 lb	3.8m x 1.4m x 1.9m / 150" x 55" x 75"
Containerized 20kWh kW-Class VRB-ESS®	5,200 kg / 11,400 lb	3.7m x 2.2m x 2.2m / 146" x 87" x 87"



Operating Characteristics



kW-class Power Module



Containerized System



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# MW-Class VRB-ESS®

## VRB-ESS® Technology

Prudent Energy's patented MW-Class VRB Energy Storage System (VRB MW-ESS®) is being deployed on a utility scale to support the integration of renewable energy sources and to improve the stability, power quality and economics of the modern smart grid. Prudent Energy's standard VRB-ESS® module is rated at 200 kW; multi-megawatt arrays of these modules, combined with electrolyte storage tanks, can be combined to exactly suit the power output and energy capacity needed at a given site. Prudent Energy's VRB-ESS® provides unparalleled performance, featuring:

- Unlimited daily cycling 100% DOD
- Lowest total cost of ownership since electrolyte never "wears" out
- Can set operating state of charge for wind power smoothing
- Accurate, real-time capacity measurement
- Individually customized power and energy storage capability
- High availability, low operation and maintenance cost
- Up to 7 years warranty

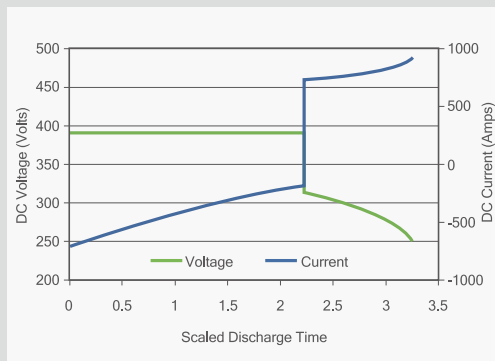
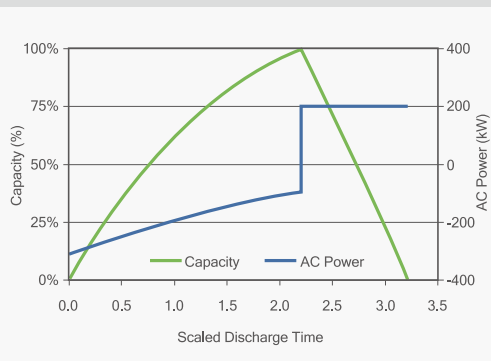
## MW-Class Characteristics

### Performance Characteristics

Rated Power Output, AC	200 kW
Peak Power Output, AC (SOC > 50%)	263 kW (130%) for 10 min every hour non consecutively
Typical Voltage Output	400/480 VAC
Frequency Output	50/60 Hz
Step response (Charge to Discharge)	<50 ms

### Physical Characteristics

Module dimensions	m (ft)	9.3 x 2.0 x 2.8 (30.5 x 6.6 x 9.3)
Module weight, dry	kg (lb)	13900 (30644)
Electrolyte required per hour of rated discharge	m <sup>3</sup>	15.4



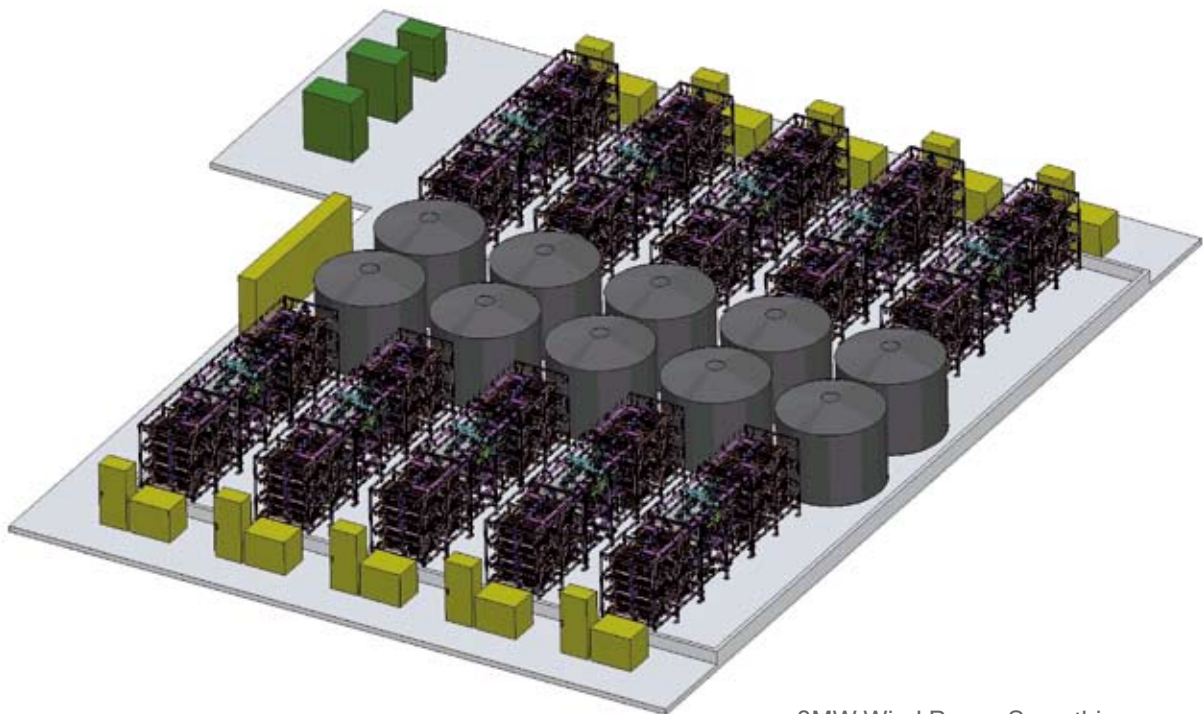
# Flexible and Scalable Systems



Prudent Energy's VRB-ESS<sup>®</sup> is fully scalable and flexible. The system's power capacity is determined by the number of power modules installed, while the system's energy capacity is determined by the volume of electrolyte contained in its storage tanks. Adding modules gives more power handling capacity; adding tanks gives more hours of energy storage. The result is a system engineered to precisely fit customers' requirements, so they never buy more capacity than they need.

This flexibility, combined with the lowest cost of ownership of any grid-scale, advanced flow battery storage system and the ability to continuously charge and discharge the system to its full rated capacity ensures VRB-ESS<sup>®</sup> operators earn exceptional economic benefits over the system's entire service life.

VRB-ESS<sup>®</sup> components, including specialty materials developed by Prudent Energy, are constructed entirely from widely-available commodities. The proprietary electrolyte is based on the element vanadium, which is abundantly available from both primary extraction and industrial waste reprocessing.



3MW Wind Power Smoothing

# System Control



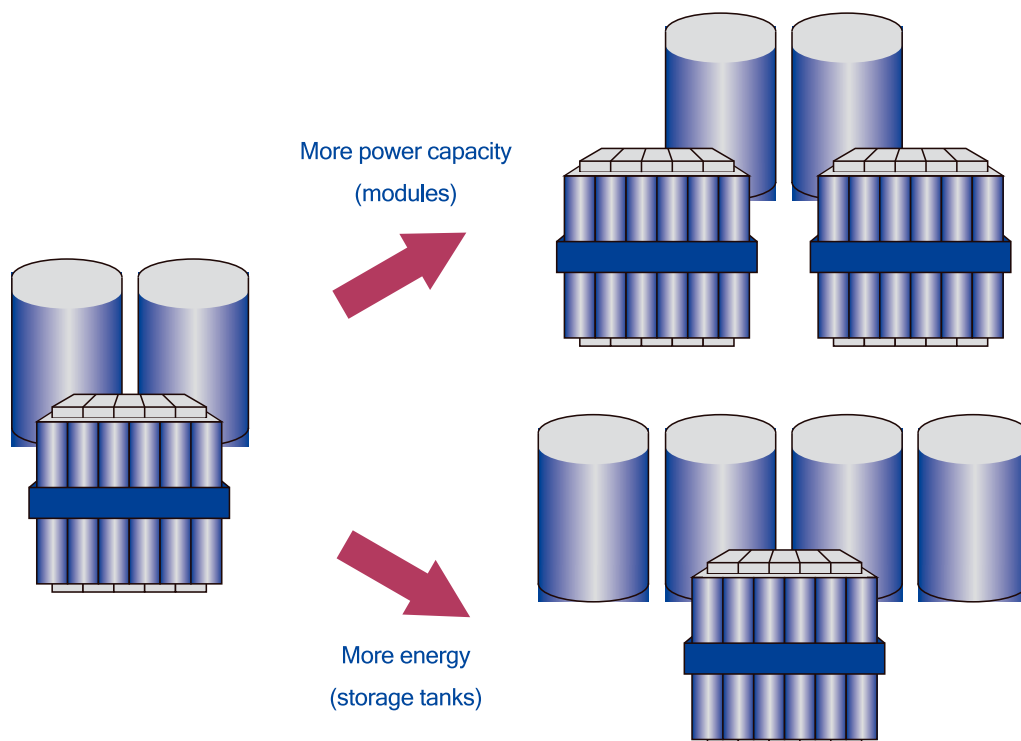
Prudent Energy's control system and PCS ensure that the VRB-ESS<sup>®</sup> is seamlessly integrated into operators' existing infrastructure, adapting to those operator's needs to provide the greatest possible value at a particular site.

## Power Conversion System (PCS)

Prudent Energy's Power Conversion System (PCS) converts between the grid's AC current and the DC current that flows to and from the VRB-ESS<sup>®</sup>, allowing the system to charge and discharge. The PCS's ability to simultaneously manage both real and reactive power means the VRB-ESS<sup>®</sup> can provide both bulk energy storage and ancillary services: using proprietary control algorithms, the PCS can provide enhanced power quality, voltage support and frequency control to the local grid.

## Control System

The control system allows the operator to effectively manage operation of the VRB-ESS<sup>®</sup>, optimizing performance according to individual site characteristics. The control system allows the operator to control the time and rate of charge and discharge, while simultaneously managing parameters for the provision of ancillary services. Some standard communication interfaces are provided for customer option including Modbus TCP/IP, Modbus RTU and Profibus. The system also provides customized reporting and alarm functions.

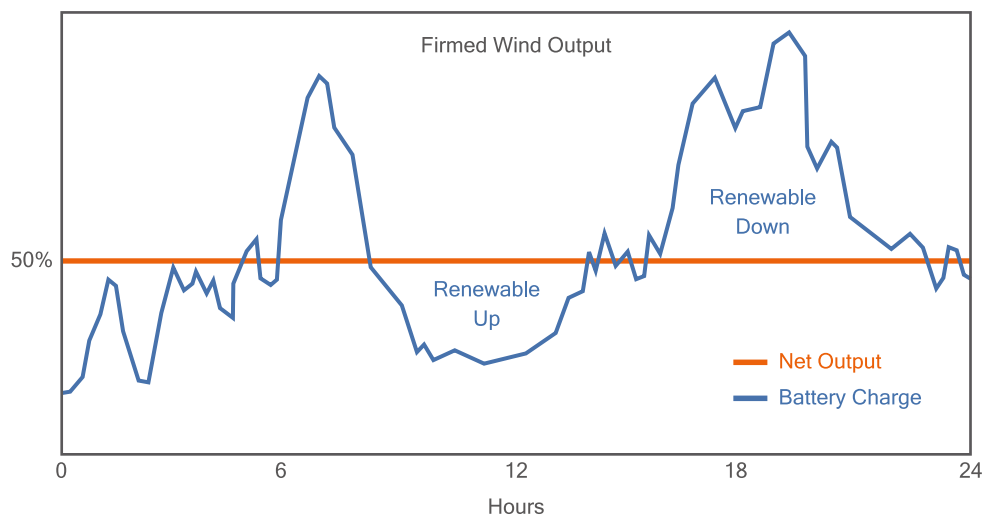


# Applications



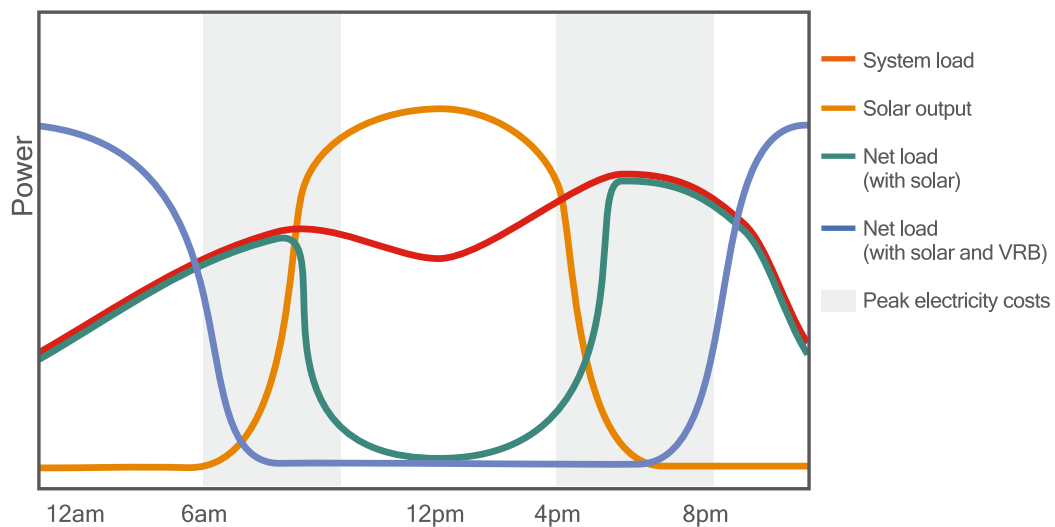
## Renewables smoothing

When installed along with a renewable energy source, the VRB-ESS<sup>®</sup> can make those sources' intermittent energy flow both stable and dispatchable. For users, this means a decreased dependence on electricity purchased from the grid and a higher overall renewable source utilization; for generators and utilities, the VRB-ESS<sup>®</sup> increases renewables' reliability and economics.



## Energy time-shifting

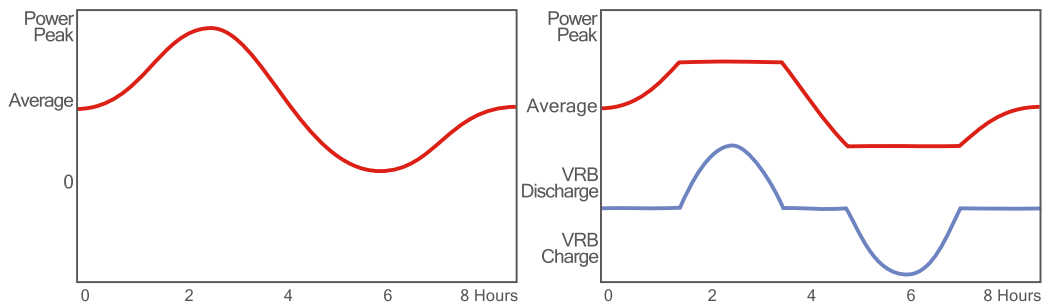
The VRB-ESS<sup>®</sup> has the capability to store and discharge electricity at full rated power over many hours. This allows electricity users, particularly those with large solar generating capacity, to shift their energy consumption away from times with high demand charges, while allowing utilities to improve their overall system performance at peak times.





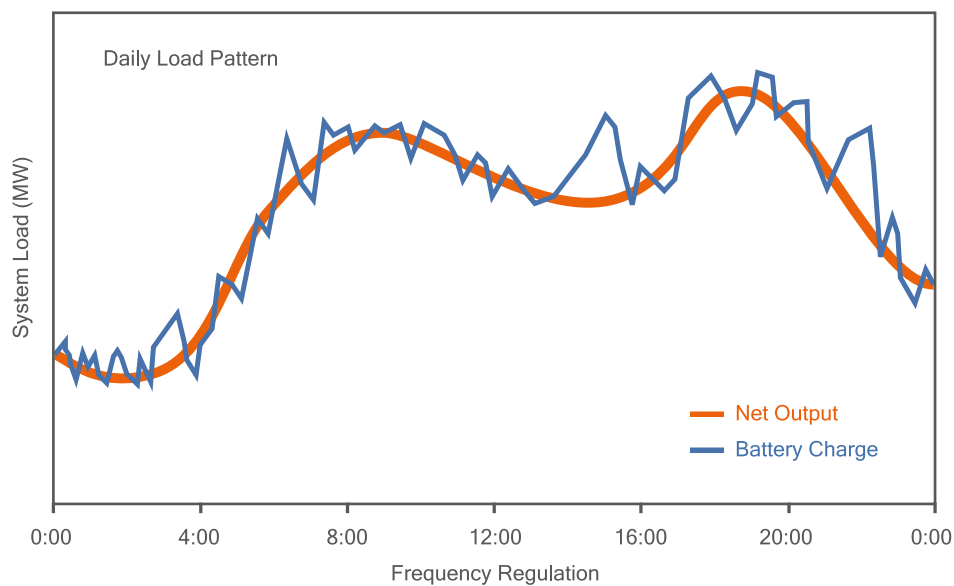
## Peak power capacity and congestion management

Prudent Energy's VRB-ESS<sup>®</sup> can reduce congestion constraints both within the electric power grid and on users' sites. For utilities, this means that capacity investments can be deferred by making more efficient use of existing infrastructure. Users who are assessed both demand and capacity charges can benefit by shaving the peaks from their daily consumption, offering significant capacity charge savings.



## Power quality management

Prudent Energy's systems can provide voltage compensation, reactive power management, frequency regulation and local area backup power services. For utilities this means extracting more value from existing assets; grid services providers can take advantage of ancillary services markets; and facility operators can ensure their facilities get only high quality, uninterruptible power.





State Grid Project, China



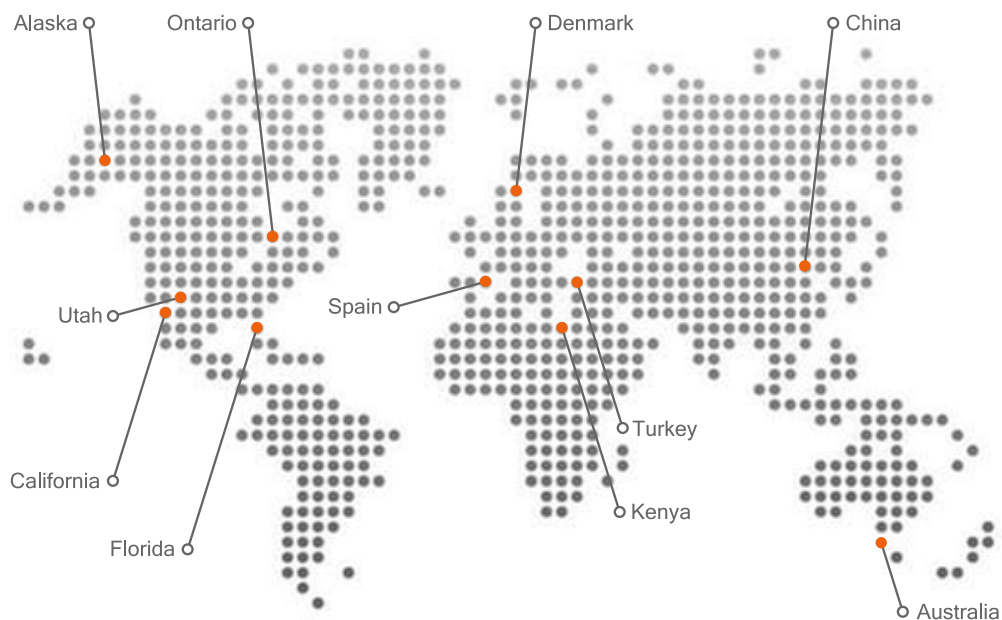
State Grid Project, China

# Project Reference



VRB-ESS systems have been in commercial service for over fifteen years. Between 1996 and 2004 over seven megawatts of VRB-ESS capacity was installed in Japan. Since 2004, Prudent Energy has installed over 50 VRB-ESSs at sites around the world.

Prudent Energy's quality and environmental management systems are ISO 9000 (2008) and ISO 14000 (2004) certified.



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