Advanced Vanadium Flow Batteries and Applications for Renewable Integration

Vanadis Power GmbH

Intersolar Europe

June 17th, 2013
Munich

Dr. Andreas Luczak

Personal data

44 years old

Education

Dr. rer. nat (PhD) in Physics

Professional experience

1994-1996:	Research Associate Laser Laboratory Goettingen
1996-1999:	Software Engineering Siemens Power Generation
1999-2003:	Innovation Manager Siemens Industrial Services
2003-2008:	Head of R&D group Siemens Automotive Projects
2008-2012:	Business Development & Project Management Siemens PV Inverters
2012-2013:	Head of Siemens Energy Storage Solutions

Since 2013: Managing Director of Vanadis Power GmbH

Vanadis Power GmbH

Vanadis was founded end of 2012 to bring to the European market **Advanced Vanadium Flow Batteries** for integration of renewable energy & other applications.

Through innovation, expertise and global strategic partnerships, **Vanadis**' **mission** is to become a leader in large- and medium-scale energy storage in Europe.

Our activities are sales, project management, system deployment (focus on PCS and grid integration) and services.

Origin of the company name:

„**Vanadis**" is the name of a goddess associated with beauty.

Vanadium was called after this goddess due to the many beautifully colored chemical compounds it produces.

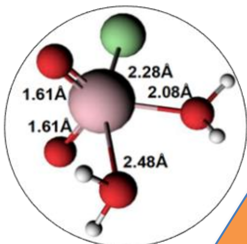
Vanadis' strategic partnerships

UniEnergy Technologies

NEW ELECTROLYTE

- ✓ 2X power and energy density
- ✓ –5°C to +60°C

Pacific Northwest NATIONAL LABORATORY



PRODUCT PACKAGING

6200m² design & manufacturing facility in Seattle, USA

VANADIS POWER

BNM BOLONG NEW MATERIALS

ELECTROLYTE PRODUCTION

Electrolyte production capacity >**1.5GWh**/year

RONGKE POWER

FIELD EXPERIENCE

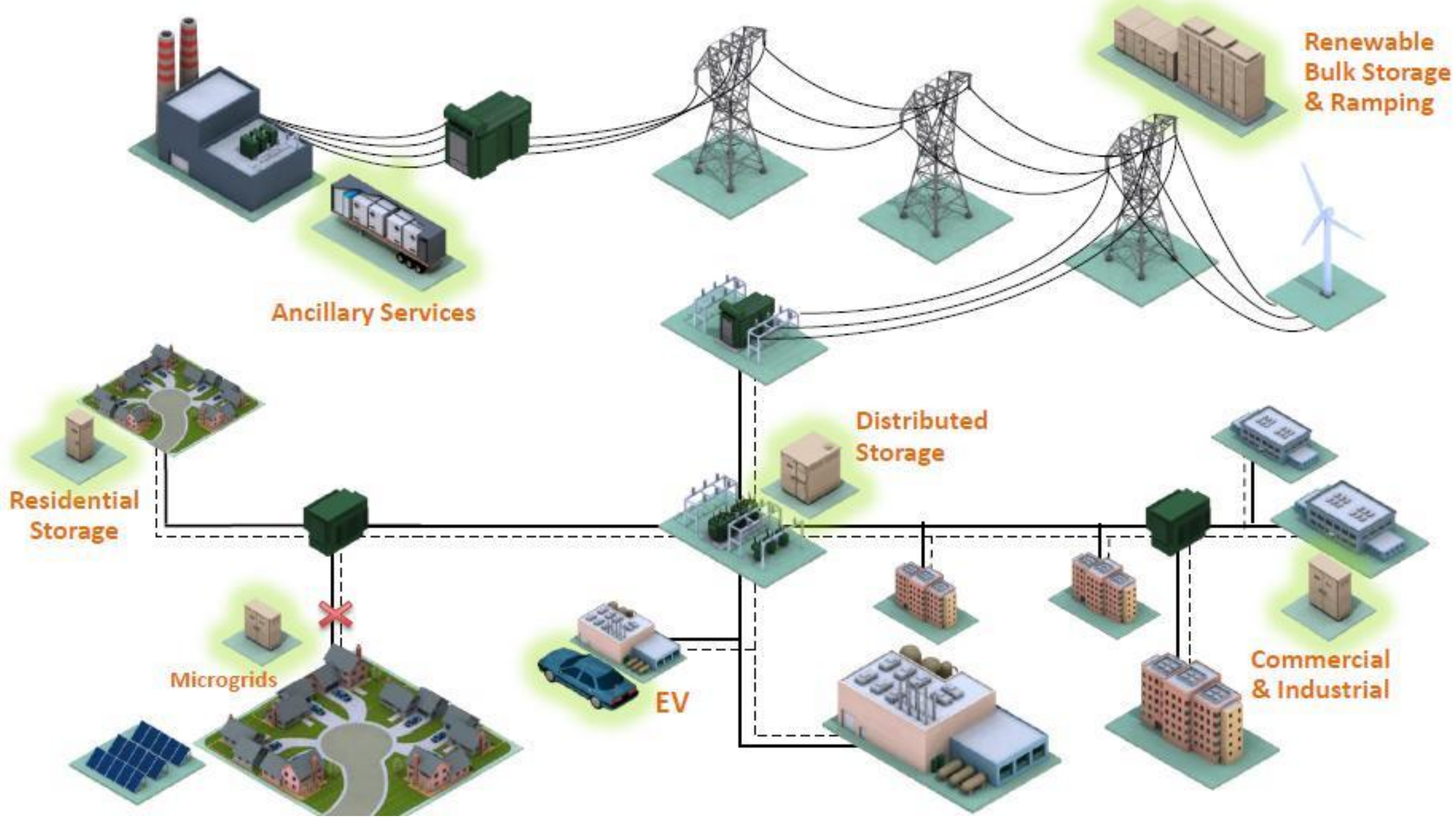
5MW/10MWh wind firming installation and numerous others

STACK PRODUCTION

More than 6 years design & production experience

Up to **30MW/year** stack capacity in 2013

Uses of storage - many grid locations



Storage requirements depend on application

Renewable Integration

Smooth out intermittency of solar and wind-generated power, enable grid interconnection, and make more effective use of renewables

Time Shifting

Storing off-peak electricity to meet peak demand, and reduce curtailment of renewable energy

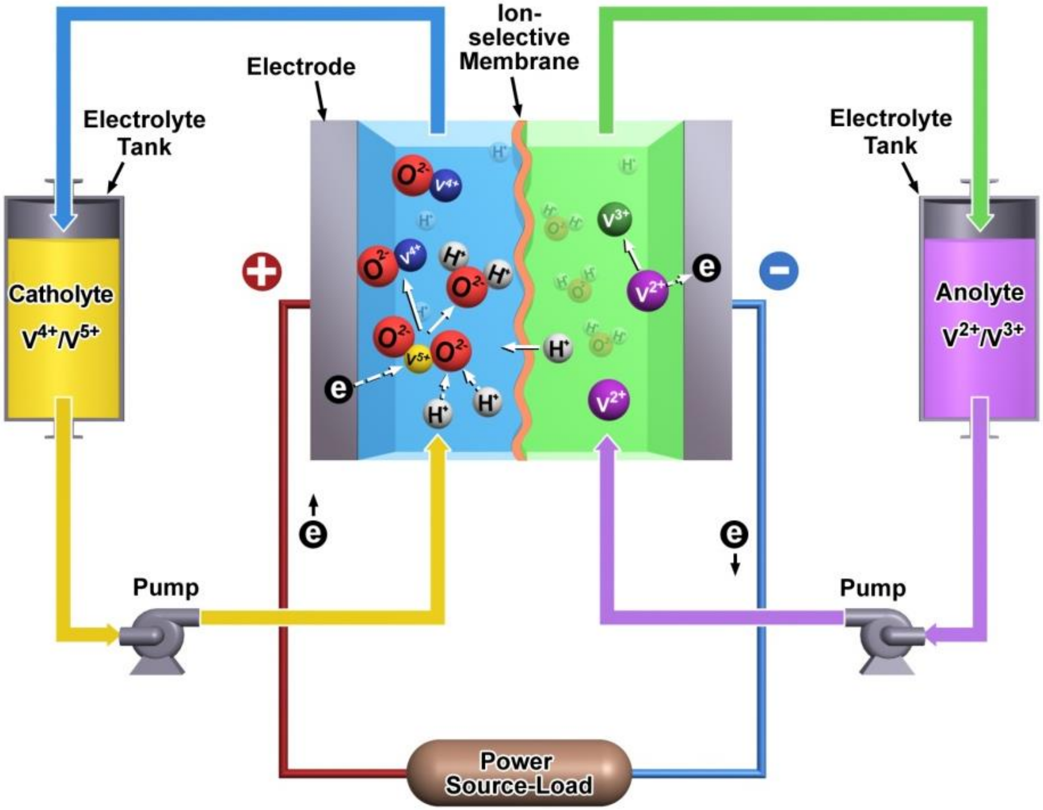
Smart Grid

Enable smart grid functionality to improve grid reliability and compatibility; help balance generation and demands; enhance utility assets

Microgrids & Remote Areas

Provide energy storage solutions and power supply for microgrids & remote areas, including islands, bases, communication stations, mines, and others

Conventional vanadium redox flow battery (VRFB) – Basic electro-chemistry



$$VO_2^+ + 2H^+ + e^- \leftrightarrow VO^{2+} + H_2O$$

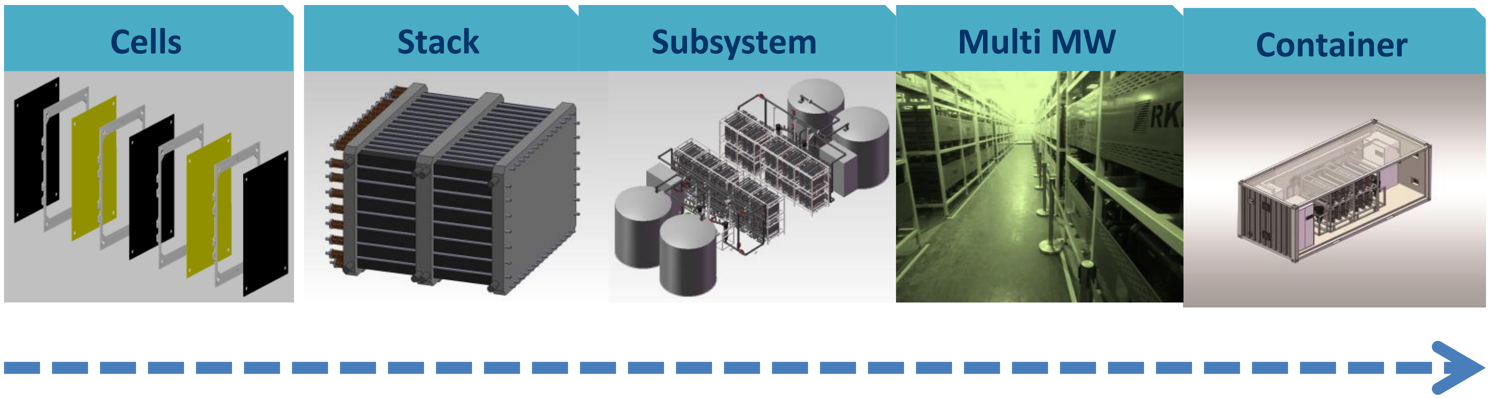
$$V^{2+} \leftrightarrow V^{3+} + e^-$$

Conventional VRFB’s have many advantages

- Separation of power (KW) -stacks - and energy (KWh) – electrolytes -> each can be individually sized according to application needs
- Adding additional energy just requires bigger electrolyte tanks which is simple and quite cheap
- No self discharge in electrolyte tanks
- “Inert” electrodes – no structural changes or stress buildup

  - long cycle life & shelf life, independent of state of charge/depth of discharge
- Inherent active heat management – flowing electrolytes carry away heat generated from electro-chemical reactions -> Uncontrollable fire known with NaS, Lead Acid and Li-Ion applications not possible
- Environmentally friendly since electrolyte only changes the ion valence during operation and can be virtually be reused forever
- Highly dynamic in the millisecond range with high overload capacity
- Capable of storing large quantities of energy (MWh’s) for long periods and discharging upon need

Modular system architecture enables high scalability



- Cells with optimized design & materials, in powerful reliable & efficient stacks
- Standard stack subsystems for ease of installation and operation
- Turn-key Multi MW and Container solutions

One of R&D focus is to increase stack power rating to reduce costs

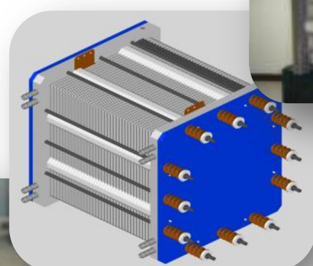
Stack development of

RONGKE POWER

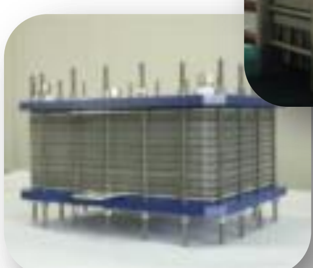

32kW Stack in 2013


22kW Stack in 2011


10kW Stack in 2010


5kW Stack in 2008

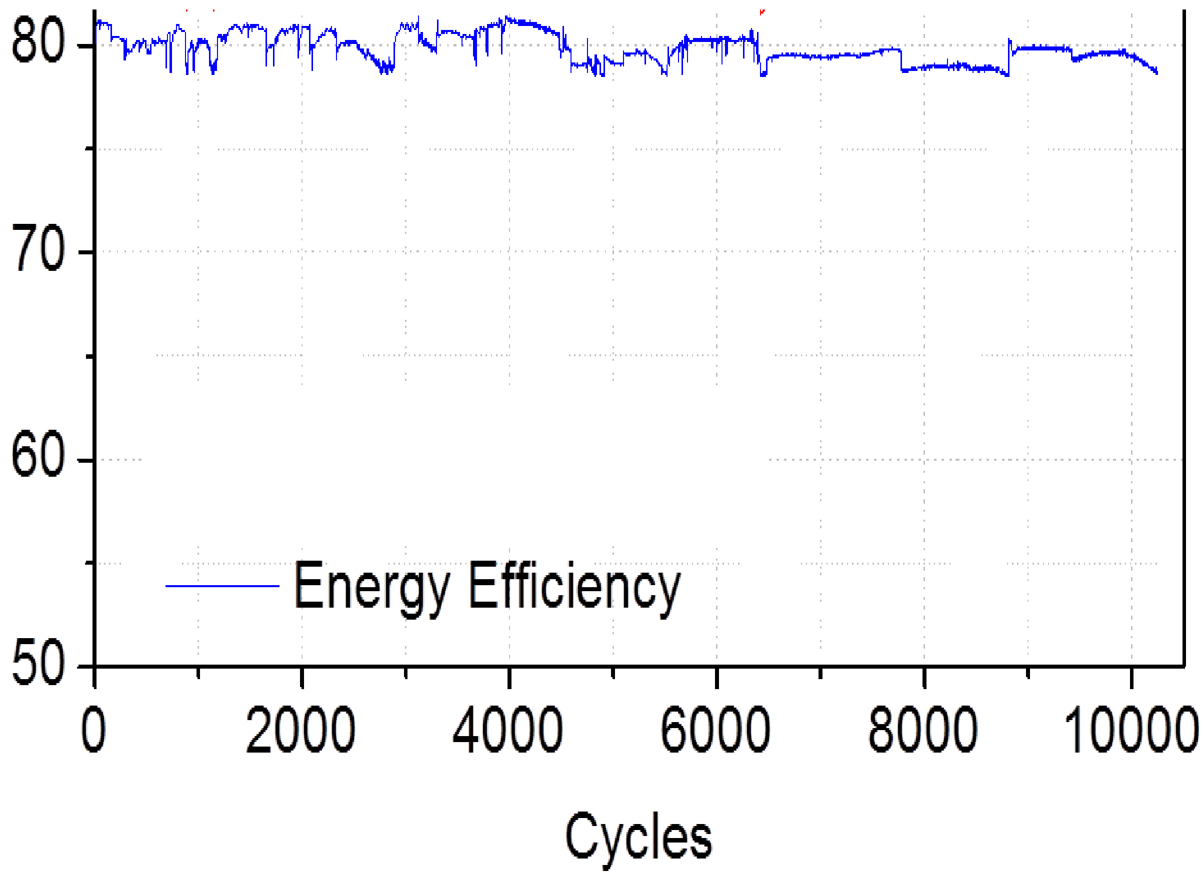

2kW Stack in 2008


1kW Stack in 2006

Stable 22kW stack performance over 10,000 cycles

RONGKE POWER

Stable Production Stack Performance over 10,000 cycles



The mature production hardware provides solid stability over extended cycling, requiring no electrical balancing procedures

Test parameters:

Electric current:	320A
Temperature:	22-25°C
Cooling:	Liquid
E'lyte Temp:	<40°C
Cycles:	10,000

Some of the world largest flow batteries (all Vanadium-based!)

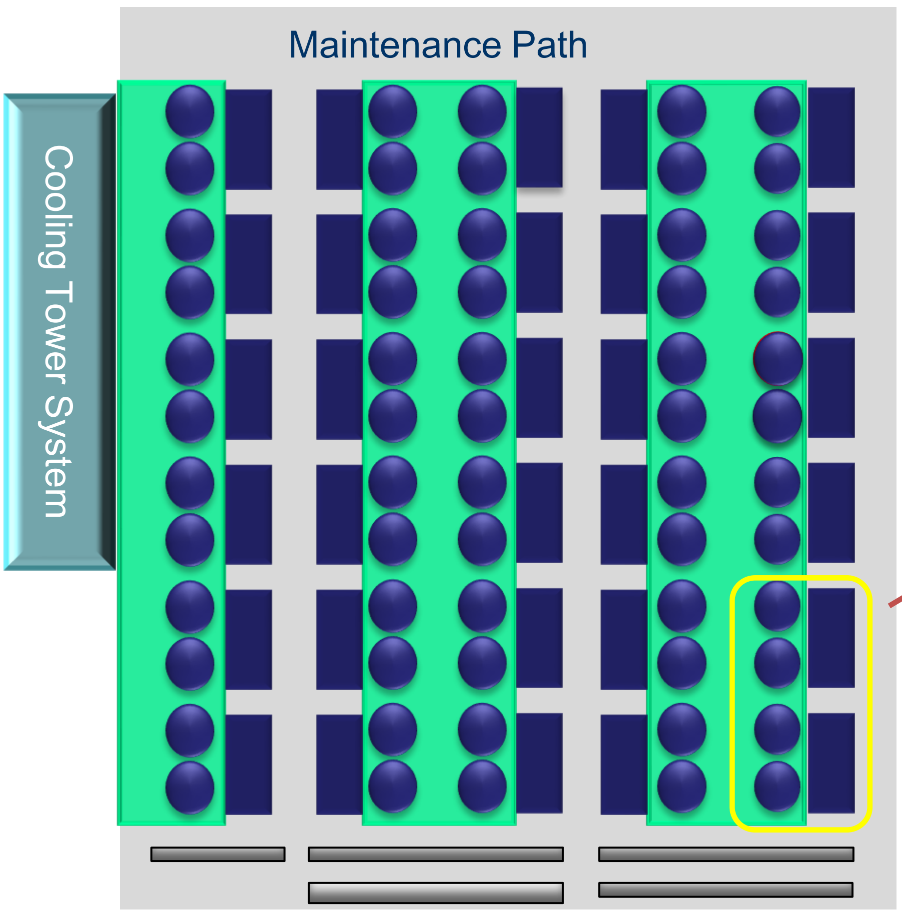
Application	Output Capacity	Year of Installation	Country
Wind farm operation support	5MW/ 10MWh	2012	China
Wind farm operation support	4MW/6MWh	2005	Japan
Wind farm operation support	3MW/6MWh	2013 (in progress)	China
Demonstration project in conjunction with CPV	1MW/5MWh	2012	Japan
Load leveling at university	0,5MW/5MWh	2001	Japan
Wind farm operation support	1MW/4MWh	2013 (in progress)	Germany
Industrial Peak Shaving	0,6MW/3,6MWh	2012	USA
Demonstration with Wind/PV	0,2MW/1,2MWh	2013	Germany

Example: 5MW/10MWh system at Longyuan wind farm

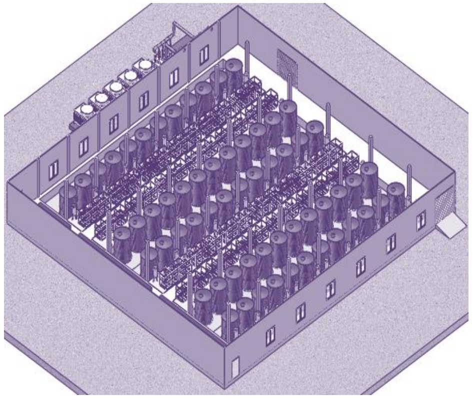
Time	August, 2012
Location	Faku County, Liaoning Province
Owner	Longyuan Group
Function	Scheduled operation following; Wind output smoothing; Voltage support, etc.

Main parameters of energy storage system	
Power	5 MW
Capacity	10 MWh
Voltage Range	DC 400-620V
Rated Current	DC 640A
Ambient Temperature	5-35℃

5MW/10MWh system layout



Space : 2,300 ㎡

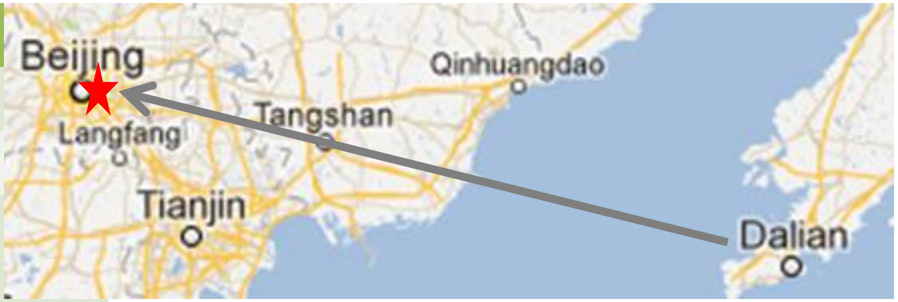


352kW Sub-system

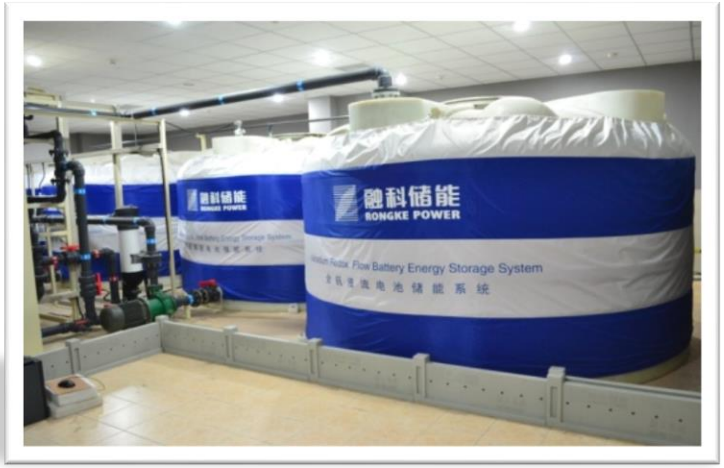
- Electrolyte Tank
- Cell Stacks
- DCS & Invenrteor
- Electrolyte Sink
- Maintenance Path

Example: Goldwind smart grid

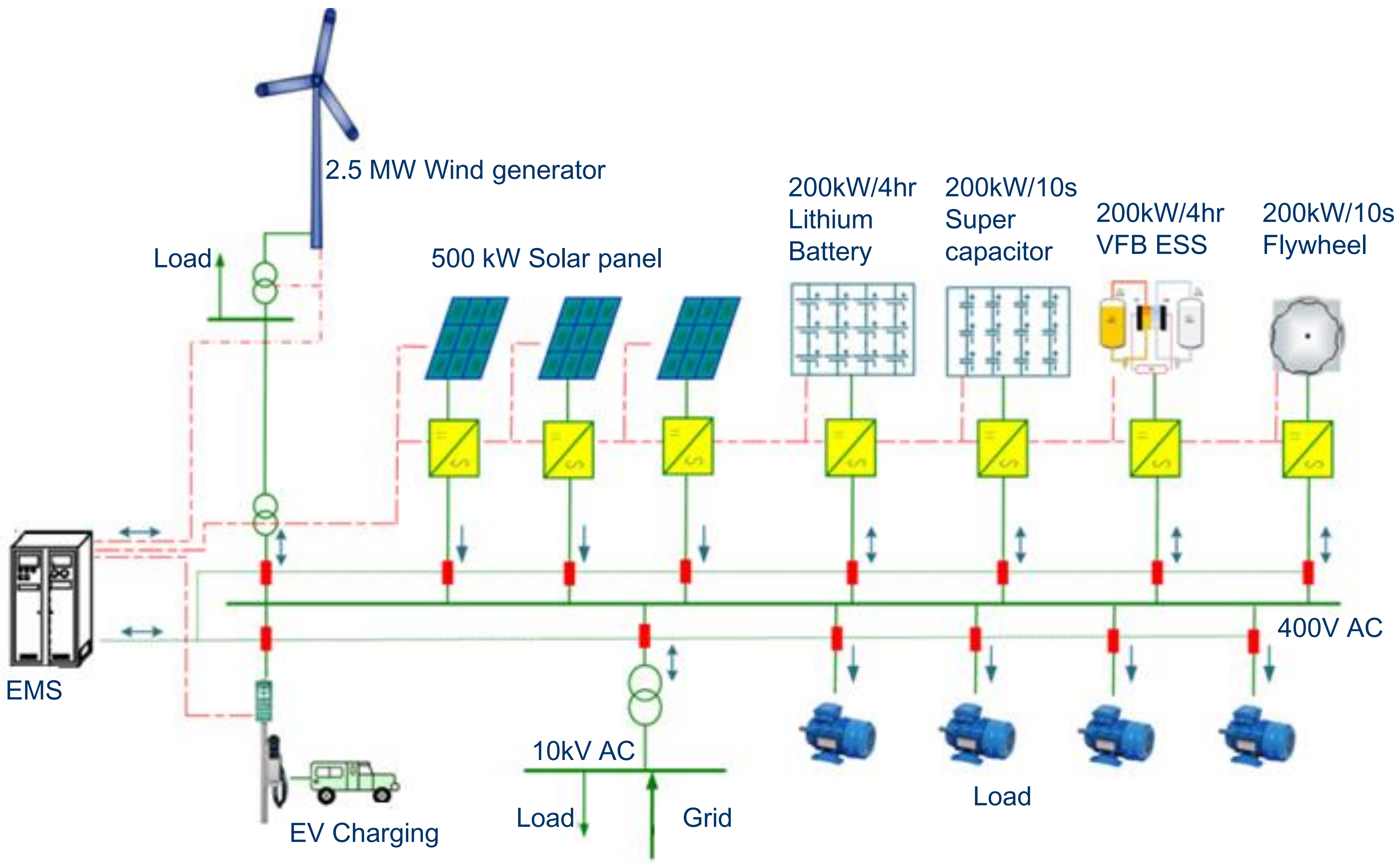
Time	October, 2011
Location	Yizhuang, Beijing
Owner	Goldwind Corporation
Function	Smooth wind output; Improve power quality; Increase grid reliability, etc.



Main parameters of energy storage system	
Power	200 kW
Capacity	800 kWh
Voltage Range	DC 250-388V
Rated Current	DC 640A
Ambient Temperature	5-35℃



Site Design Overview

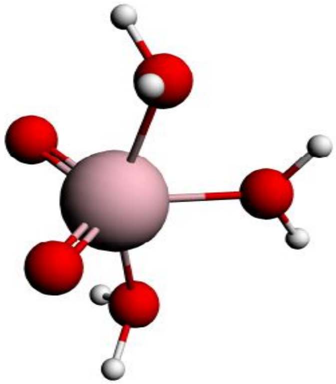


Challenges of conventional VRFB's

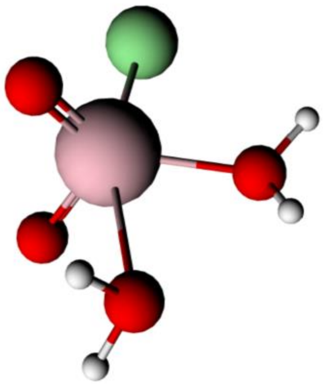
- Fundamental chemistry challenge:
  - Limited stability of conventional VRFB electrolyte chemistry
  - >~35°C or <~10°C, V^{n+} compounds precipitate out
  - Limited Vanadium concentration: <1.5 M vanadium

- Consequences:
  - Low energy density ~15Wh/L, limiting battery design and siting
  - Operation limited to ~10°C - ~35°C, requiring strict heat management and associated cost and efficiency loss
  - Low current densities (≤80 mA/cm^2), limiting stack power and reduction in $/kW

New electrolyte chemistry – vanadium mixed acid



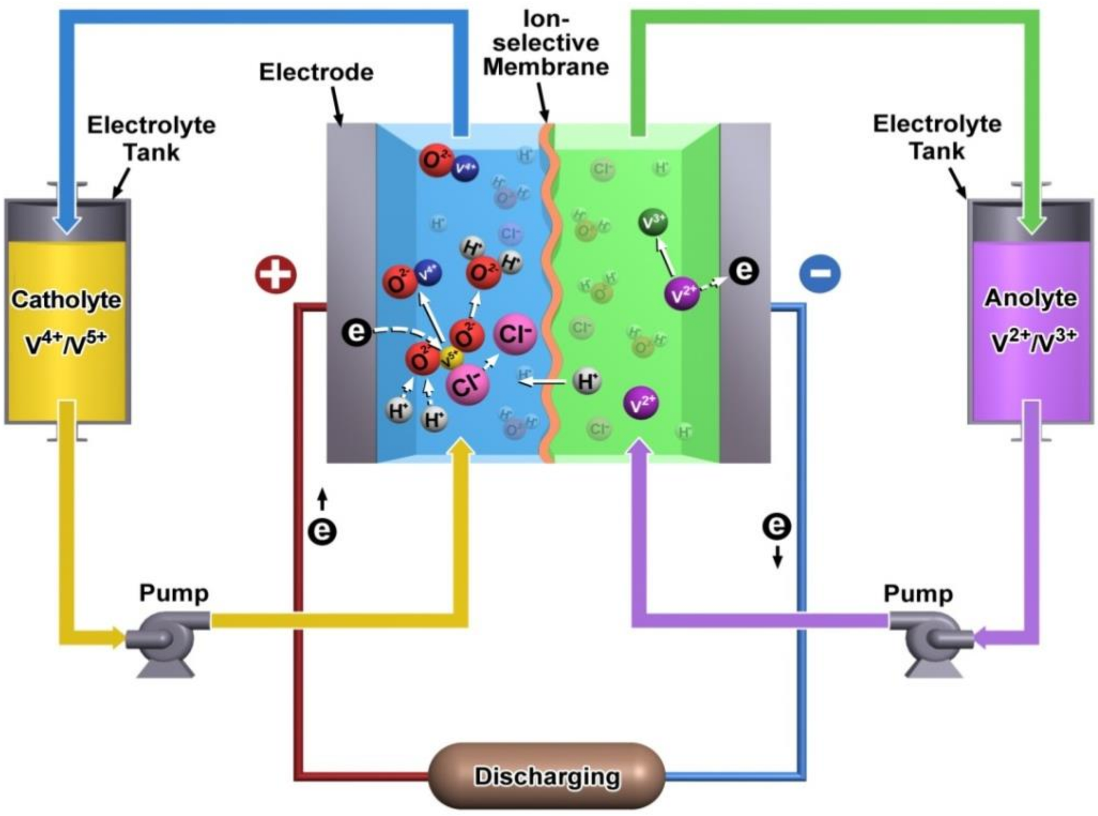
V^{5+} in sulfuric acid --
$[VO_2(H_2O)_3]^+$



V^{5+} in mixed acids --
$VO_2Cl(H_2O)_2$

- Substantially improved chemical stability
- V^{n+} up to 2.5M, practically double energy capacity (30Wh/L, due to a higher utilization as well)
- Stable ~-5°C↔~60°C without irreversible solid phase precipitation, minimizing thermal management
- Improved performance, durability, and reliability with reduced capital and levelized costs

Advanced VRFB's

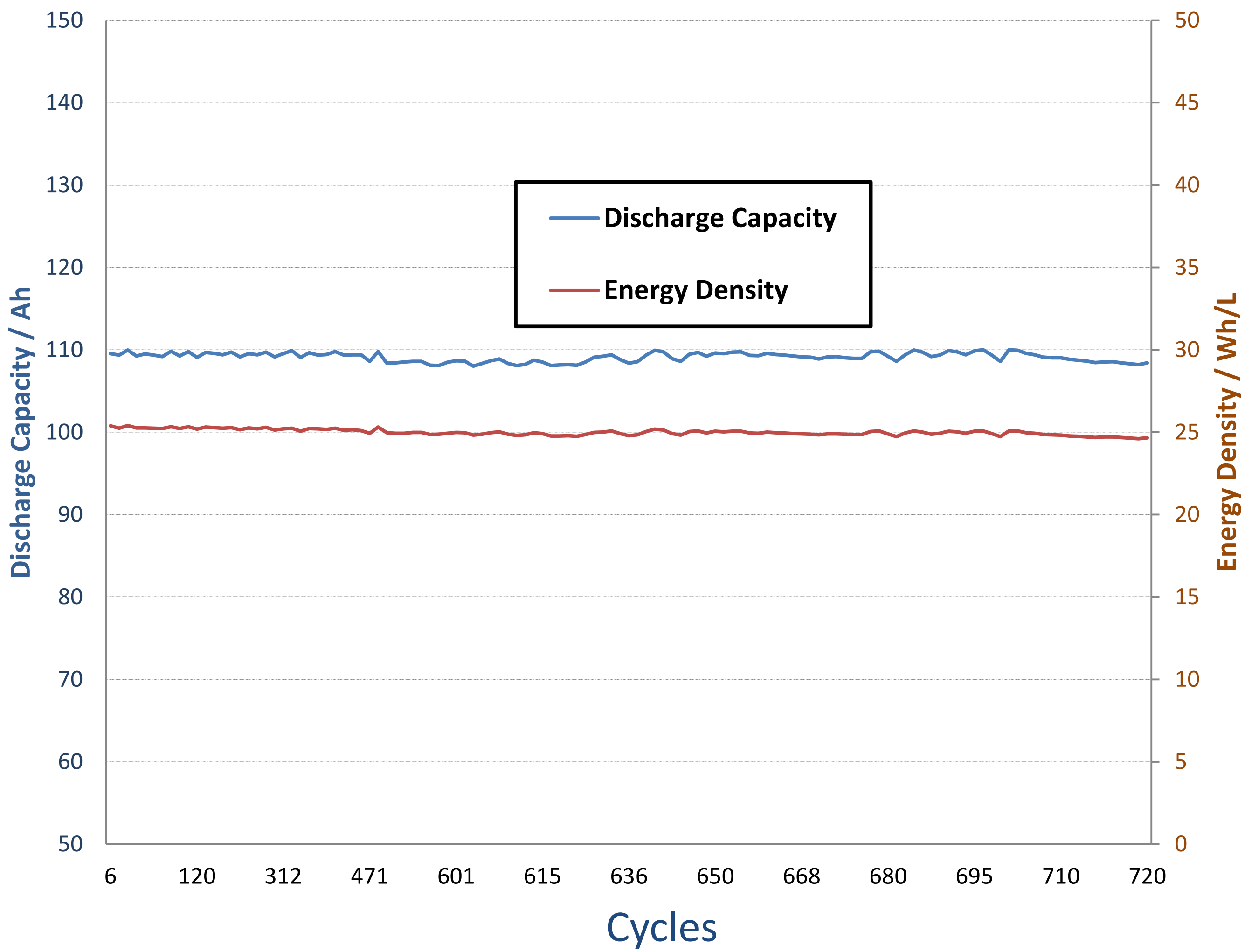


- V^{n+} concentration ~2.5M; 2x increase in energy and power density
- Stability window extended to ~-5°C - ~60°C, minimizing heat management
- Stable operation without frequent balancing
- Reduction in capital and levelized cost by factor of 2 or even 3

Validation of advanced chemistry by UET

Two 2kW systems operating in series at UET's facilities in Seattle

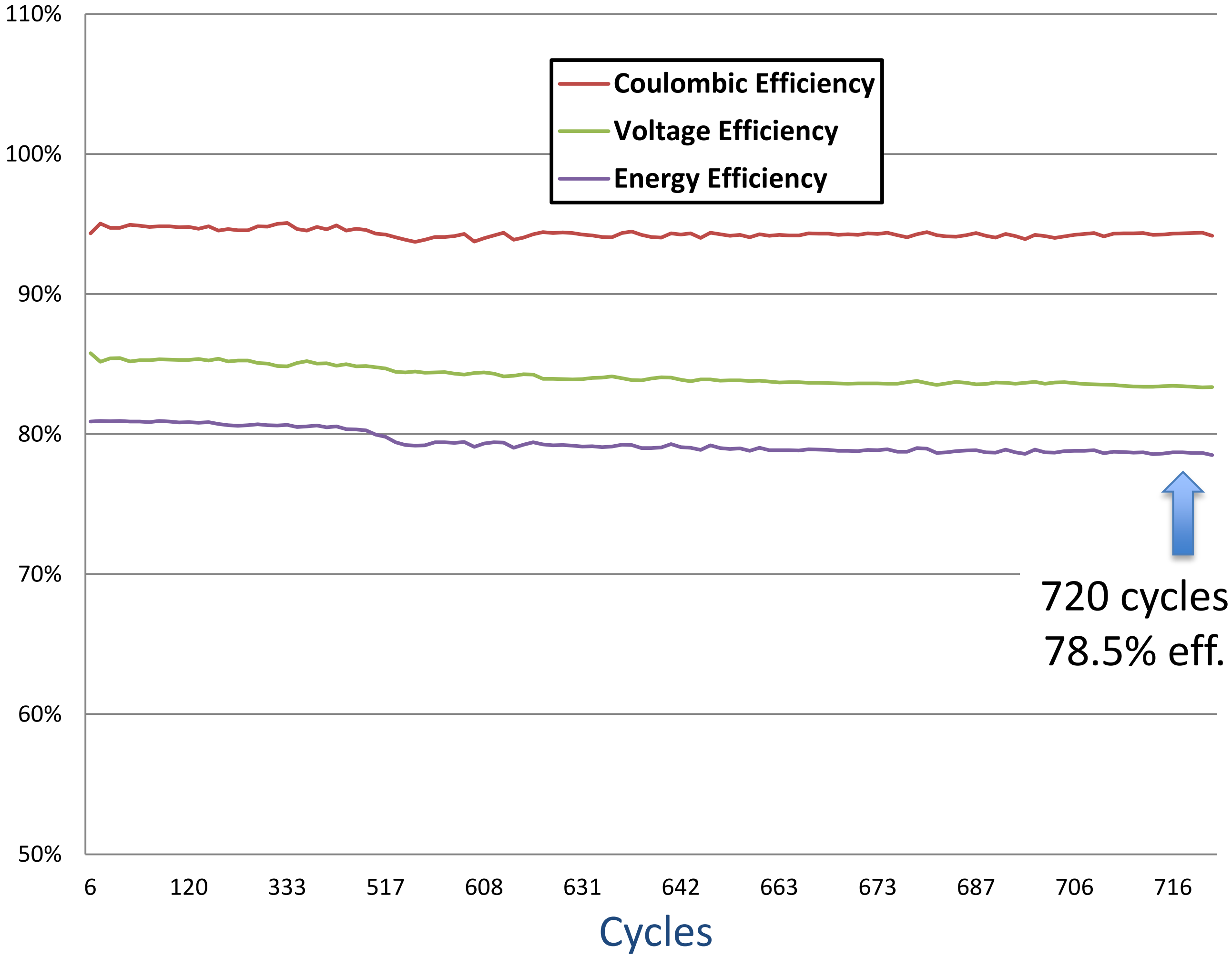
2kW systems in series testing – capacity analysis



Test Conditions

- Systems in Series
- Constant Power cycling
- Started Jan 4th, 2013
- 3.5h cycles
- Ongoing cycling

2kW systems in series testing – efficiency analysis



Test Conditions

- Systems in Series
- Constant Power cycling
- Started Jan 4th, 2013
- 3.5h cycles
- Ongoing cycling test

Full-scale advanced VRFB testing at UET

33 kW system operating at UET's facilities in Seattle

Advanced electrolyte allows better packaging with less cooling

Example of 1MW/4MWh with electrolyte integrated in container

195m² footprint (***5kW/m²***)
Can be further increased by stacking

Standard 20' containers

8 x 125kW/500kWh battery modules
(no step-in, side or rear access needed)

500kW power & control module

Footprint of containerized solution with advanced electrolyte is significantly smaller than previous installations

1MW/5h "classic" System

1MW/4h UET System



Vanadis Power

UniEnergy Technologies

融科储能 RONGKE POWER

BNM BOLONG NEW MATERIALS

Dr. Andreas Luczak
Vanadis Power GmbH
🖃: Zeltnerstr. 3
90443 Nuremberg, Germany
☎: +49 911 8819 7218
@: andreas.luczak@vanadispower.com

Thank you!