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# Advanced Vanadium Flow Batteries

## Vanadis Power GmbH



- **Vanadis** was founded in 2013 to bring **Advanced Vanadium Flow Batteries** for integration of renewable energy & other applications to the European market
- **Our activities** are focused on sales & service, project management, system deployment including grid integration
- Vanadis is the winner of the „**2015 Global Energy Storage Competitive Strategy Innovation and Leadership Award**” awarded by **Frost & Sullivan**.



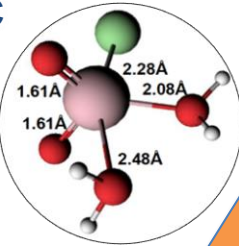
- Vanadis is certified according to DIN EN ISO 9001.

# Vanadis' strategic partnerships



## NEW ELECTROLYTE

- ✓ 2X power and energy density
- ✓  $-40^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$



## SYSTEMS WITH NEW E'LYTE

6200m<sup>2</sup> design & manufacturing facility in Seattle, USA



## VANADIS POWER



## ELECTROLYTE PRODUCTION

Electrolyte production capacity > 1GWh/year



## RONGKE POWER

## SYSTEM DEVELOPMENT

Field installations since 2008  
Numerous MW-scale Projects and more



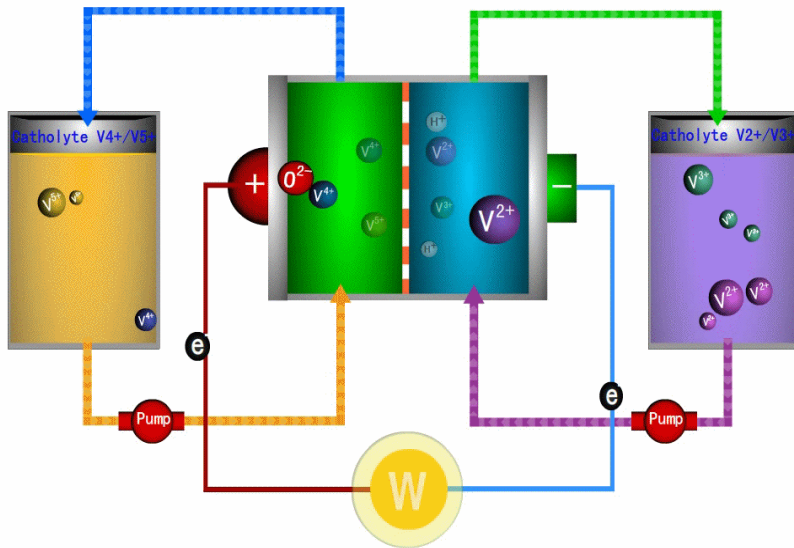
## KEY COMPONENTS AND SYSTEM MANUFACTURING

Over 10 years design & production experience;  
300MW/year capacity

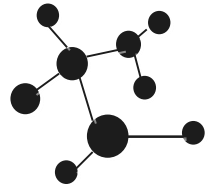
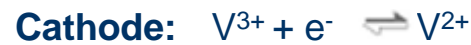


## VANADIS POWER

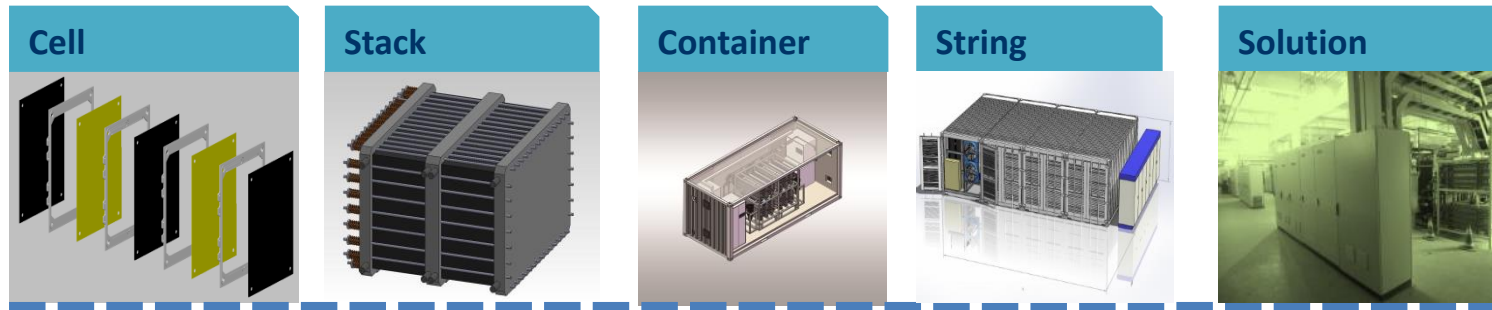
# About Vanadium Redox Flow Batteries



A Vanadium flow battery cell works with a couple of electrochemical reduction and oxidation reactions of vanadium ions in acidic aqueous solution (electrolyte).



A Vanadium flow battery (VFB) system consists power modules as stacks of cells, electrolyte tanks and piping auxiliaries, as well as Power Conversion Systems (PCS).



# Whole value chain: from Vanadium to Battery System

The unique position of Vanadis-UET-Rongke company group to possess the whole value chain from Vanadium to Vanadium Flow Battery systems enables the continuous optimization of chemistry and system design.

- 20 years experience of Bolong Group in processing and recycling of Vanadium-containing raw materials and chemicals – Bolong New Materials is a world leading manufacturer of Vanadium chemicals and electrolyte
- 10 years of research and development in battery cells and key functional materials including membrane and bipolar plate; 10 years field tests of VFB systems lead to mature high performance power stacks and system design
- Leading experts of Vanadium Flow Battery technology in USA and China bring breakthrough research results of laboratory to advanced industrial products



# Proven, High Performance Power Stacks

14 years development, 8 years field experience, 100s deployed



1kW Stack in 2006

2kW Stack in 2008

5kW Stack in 2008

10kW Stack in 2010

22kW Stack in 2011

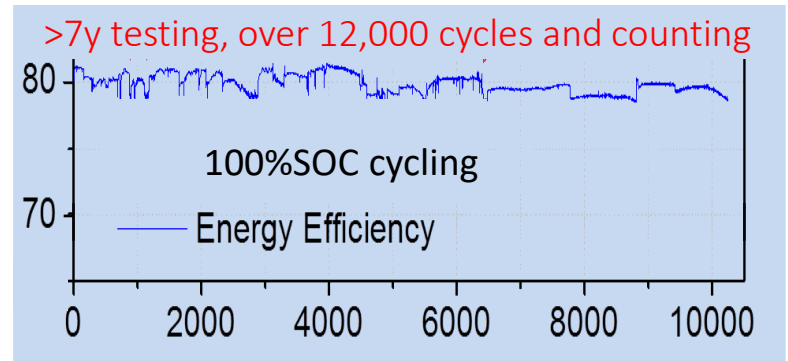
25kW Stack in 2012





**31.5 kW Stack in 2014**

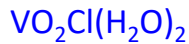
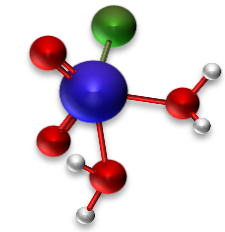
- ✓ Mature, powerful stack
- ✓ ISO9000/14000, GB/T28001 Certified
- ✓ Individual cell voltage data
- ✓ 108,000 ft<sup>2</sup> facility
- ✓ 300MW annual stack and system capacity



Technology & Product



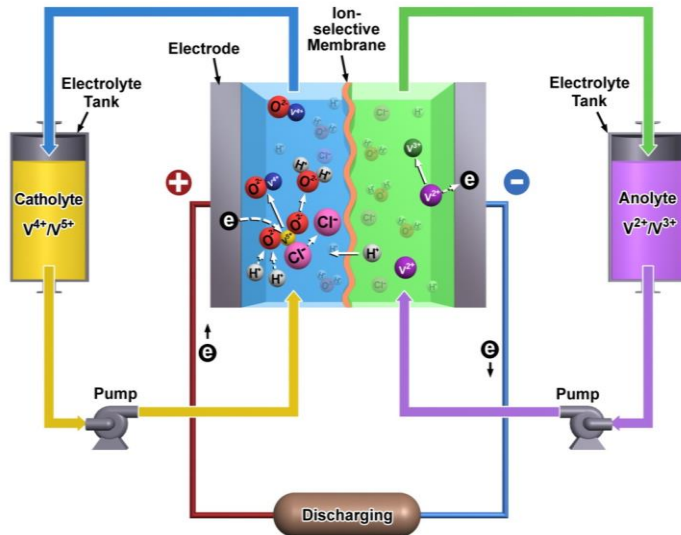
# UET Break-Through VRFB Chemistry



$\text{V}^{5+}$   $\text{V}^{4+}$   $\text{V}^{3+}$   $\text{V}^{2+}$



The new generation of electrolyte - developed at and licensed from PNNL, optimized and commercialized at UET



- double power & energy density improvement → significant product footprint reduction
- Extraordinary electrolyte stability – wide operation temperature window from  $-40^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$
- Remain power/energy flexible, safe, unlimited cycle life, 0-100% SOC
- Won the US Government's highest Award of Excellence in Technology Transfer to UET

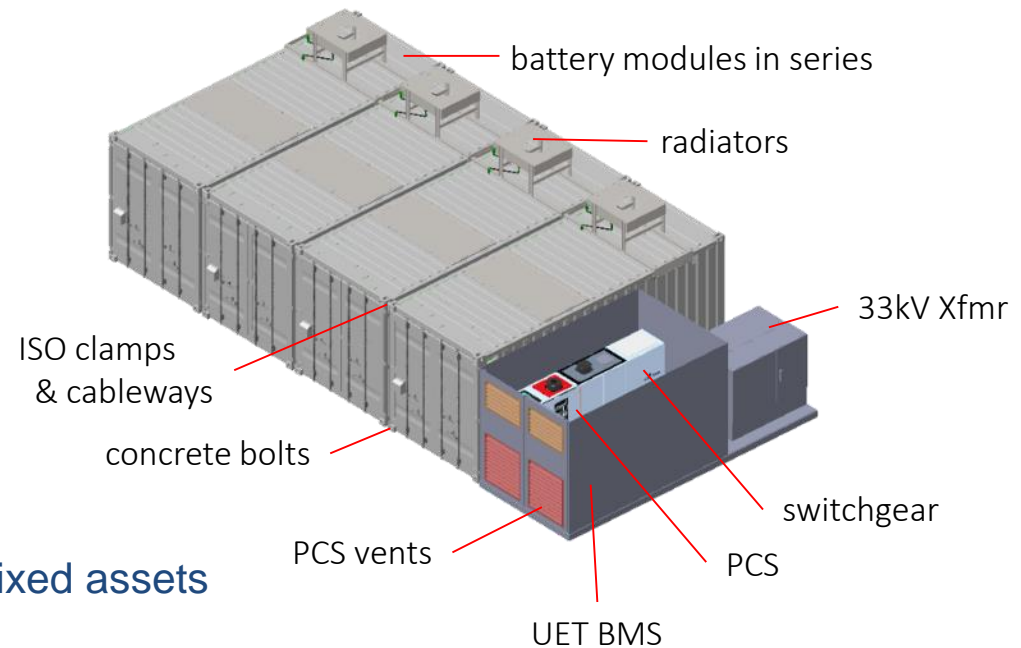


# Highly Integrated Containerized UniSystem™ Design

- Modular, efficient production
- Built-in secondary containment
- Full factory integration
- System-level factory testing
- Ready for transport
- No onsite building required
- More rapid permitting
- “Plug and Play” deployment
- Incremental deployment
- Option for relocation or removal
  - » Enables lease financing as non-fixed assets



## Uni.System™ Configuration



- Smallest footprint for multi-MW large scale storage system - no risk of thermal runaway makes compact block-stacking possible



# UniSystem™ product flexibility for 4h/6h/8h Solution

Product Specs		1000V PCS 4 cont/string	1500V PCS 6 cont/string
Uni.System (4hr) 20' container	Power (kW)	500	750
	Energy (kWh)	2,000	3000
Uni.System (6hr) 30' container	Power (kW)	500	750
	Energy (kWh)	3,000	4500
Uni.System (8hr) 40' container	Power (kW)	500	750
	Energy (kWh)	4,000	6000



Uni.System (4hr)  
20' container  
125kW / 500kWh

**Increased storage duration  
requires no additional  
components beyond more e'lyte.  
Therefore on a kWh basis:**

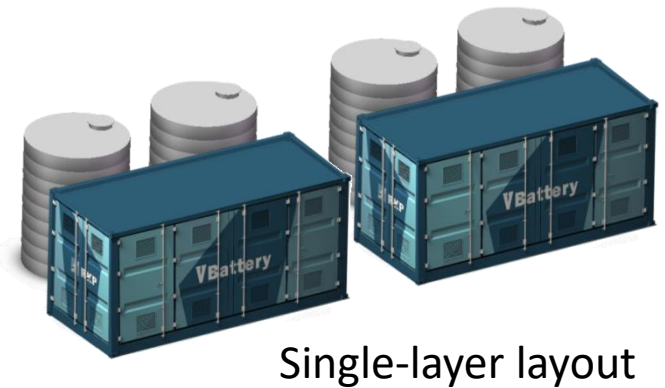
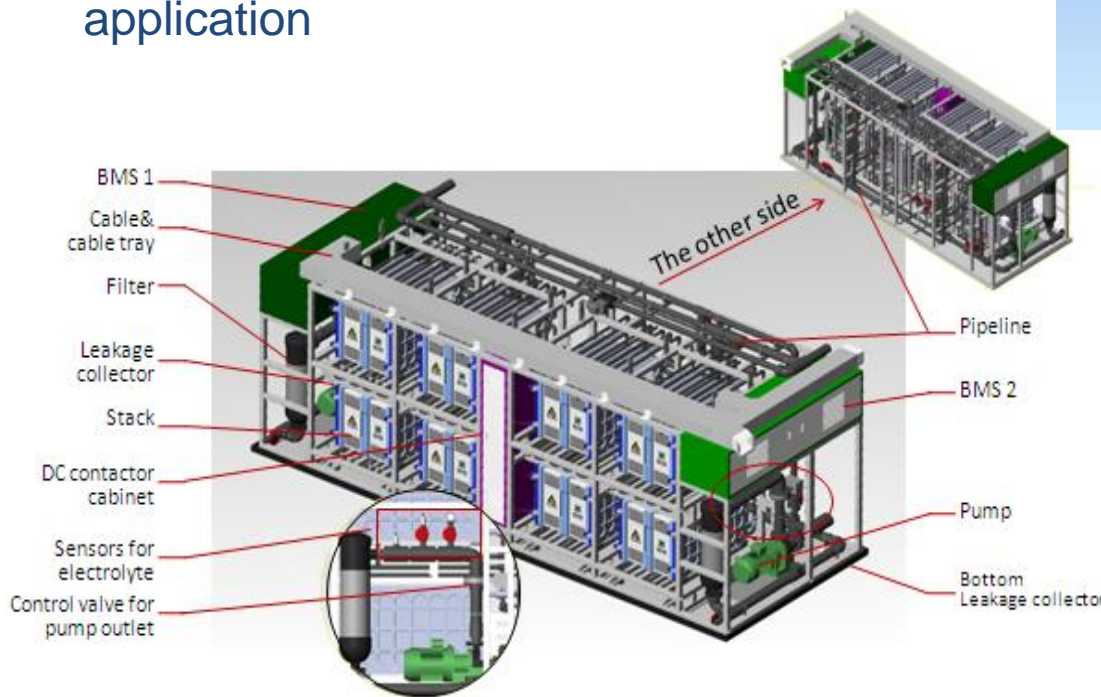
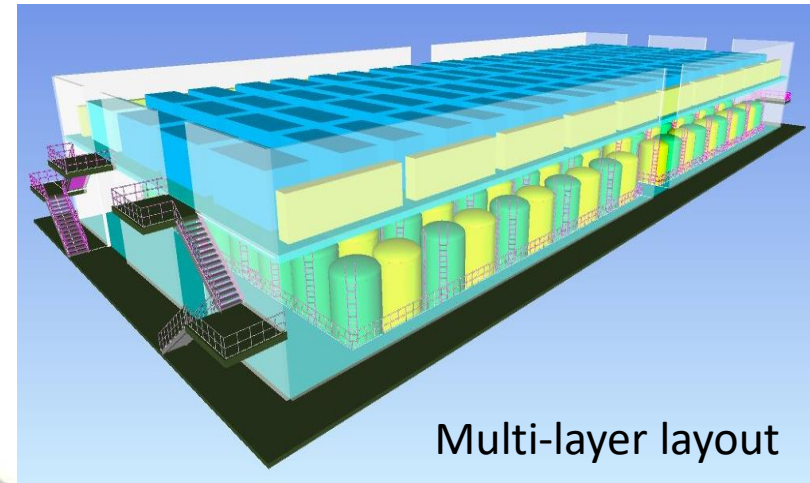
- **System complexity is reduced**
- **Auxiliary power is reduced**
- **Reliability is increased**
- **Maintenance costs are reduced**
- **System footprint is reduced**



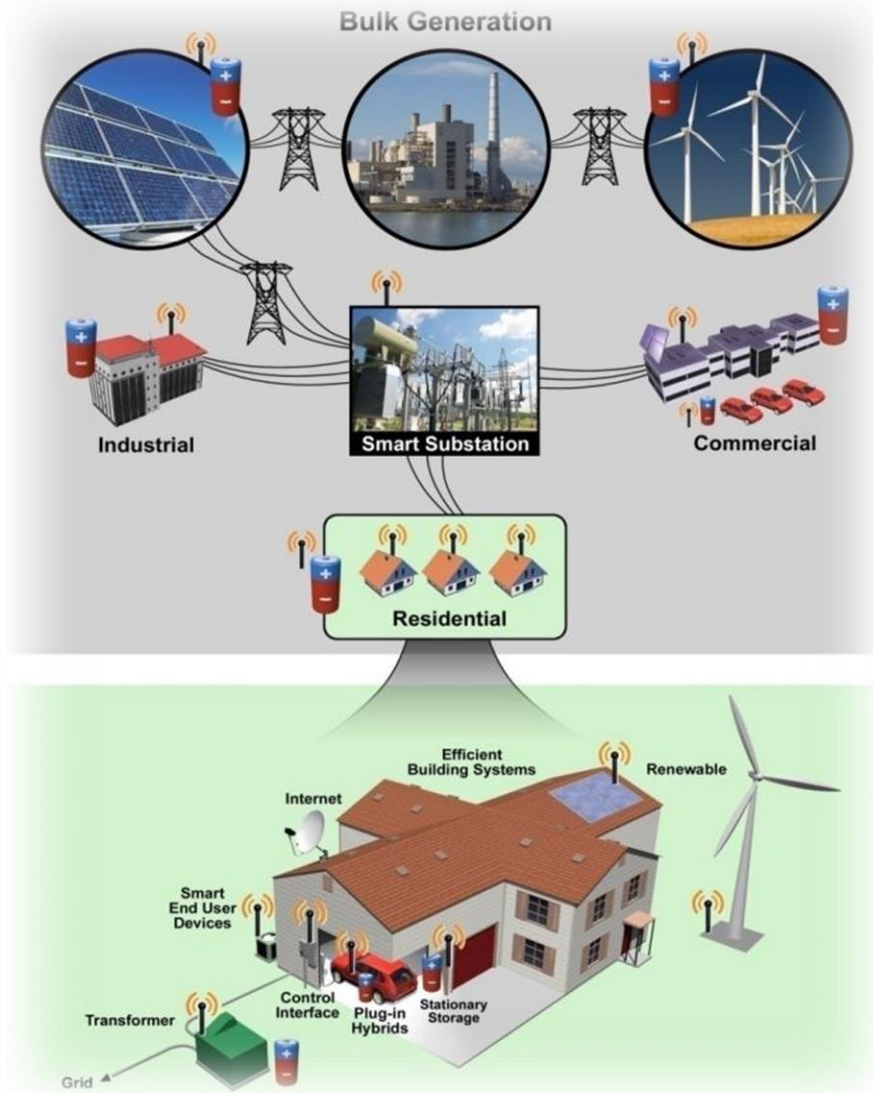
Uni.System (8hr)  
40' container  
125kW / 1,000kWh

# Containerized Power Modules + Electrolyte Tanks

- Containerized power modules with integrated stacks and auxiliaries
- Separate electrolyte tanks flexible regarding design and volume.
- Flexible layout for building large scale systems and flexible long duration application



# All-In-One VFB Capable for Stacking Applications



- ← Renewable Integration (solar, wind power)
- ← Ancillary Services & Other Market Revenue Services
- ← T&D System Capacity & Reliability Support
- ← Commercial & Industrial Customer Savings
- ← Microgrids & Isolated Loads

***Vanadis VFB systems support multiple applications, capturing multiple benefits***

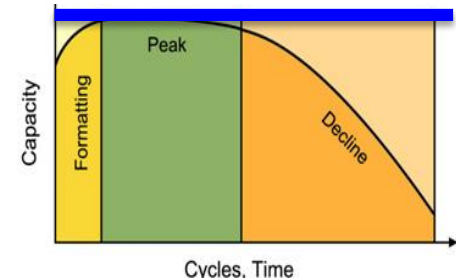
# Competitive edge - Safe, flexible, sustainable and economic

- **Intrinsically safe:** Non-flammable Aqueous electrolyte; No thermal runaway; Electrochemical reaction at normal pressure and temperature;
- **Flexible:** Independently rated energy and power capacity, better scalability;
- **Sustainable:** No degradation under deep discharge; unlimited cycle life; Recyclable electrolyte;
- **Economic:** Lowest levelized cost of system and energy (LCOS and LCOE); Recyclable electrolyte

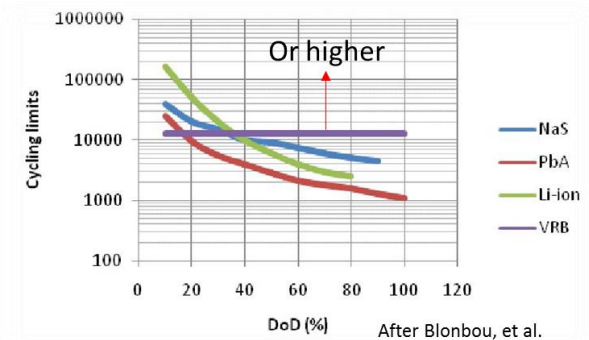
“The singular advantages of flow batteries...make them particularly well-suited for relatively large utility applications.” — *EPRI, USA (2006)*



Fire accidents reported on Li-ion, Na-S, advanced Pb-acid, etc.



Capacity degrades over cycling for traditional batteries, but remains stable for VFB (blue)





# VFB has been established as mainstream of flow batteries

***The world largest operational flow batteries are all Vanadium-based!***  
***- No cross contamination of reactive materials***

Application	Power/Capacity	Commissioning	Country
Wind farm operation support	4MW/6MWh	2005	Japan
Demonstration project in conjunction with CPV	1MW/5MWh	2012	Japan
Utility Service	15MW/60MWh	2015	Japan
Wind farm operation support	5MW/ 10MWh	2012	China
Wind farm operation support	3MW/6MWh	2013	China
Wind farm operation support	2MW/4MWh	2014	China
Smart Grid	0.75MW/3MWh	2016	China
Peak load power plant (*under construction)	200MW/800MWh	2017-2018	China
Industrial Peak Shaving	0,6MW/4MWh	2012	USA
Grid support at industrial plant	1MW/4MWh	2014	USA
Grid support at substation	2MW/8MWh	2016	USA
Demonstration with Wind/PV	0,2MW/1MWh	2013	Germany
Wind farm operation support	0,3MW/1MWh	2014	Germany
Grid support at substation	0,5MW/2MWh	2016	Italy

By Vanadis/Rongke/UET





# USA - AVISTA Utility Project 1MW / 4 MWh



## Applications:

- Energy shifting
- Provide grid flexibility
- Improve distribution systems efficiency
- Enhanced voltage control
- Grid-connected and islanded micro-grid operations
- Islanding, black start, 4 cycle ride-through
- Optimal utilization of energy storage



Deployed December 2014

# Germany - Customized indoor system

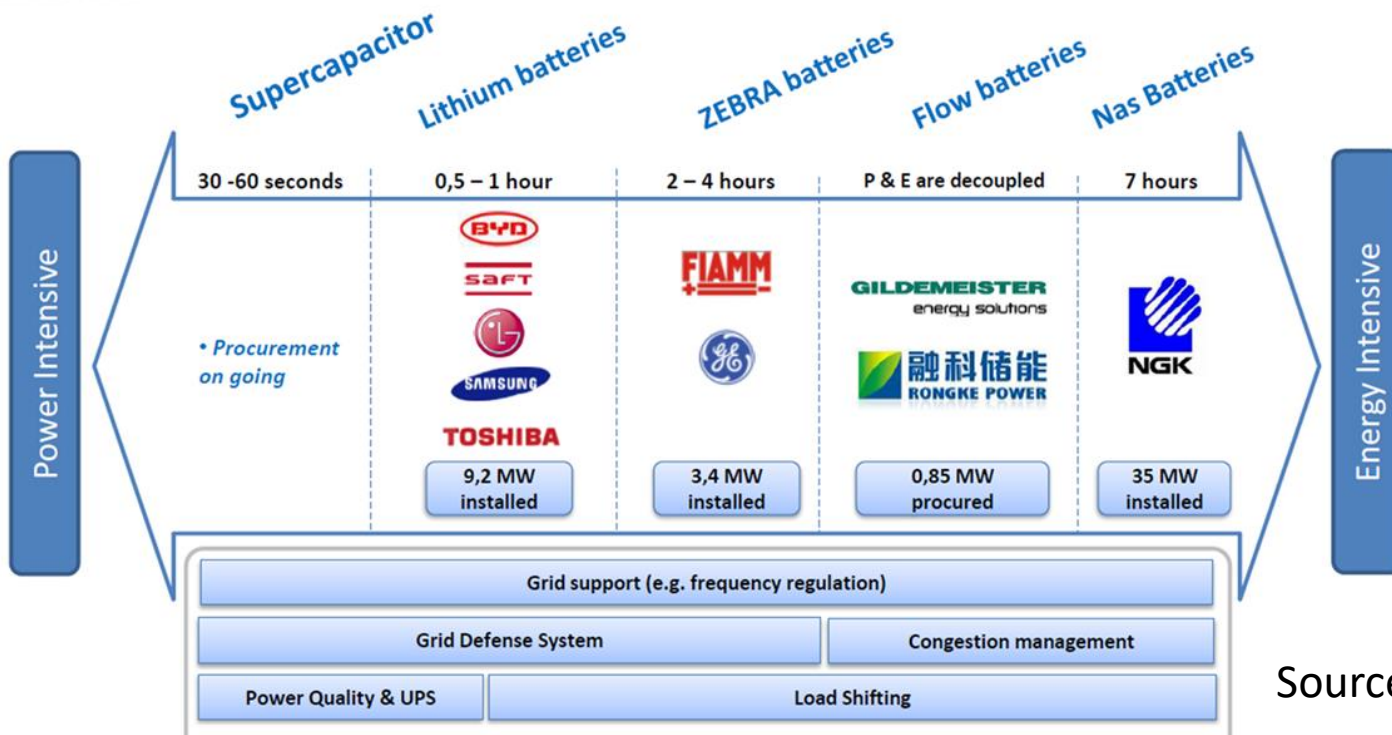


- 325kW/1MWh in Germany's largest installed Redox Flow Battery
- Customer: Energiespeicher Nord (Bosch & BWP)
- Commissioned in September 2014
- Applications:
  - Optimization of self consumption of wind farm
  - Reduction of curtailments

# Italy - 0.5MW/2MWh Uni.System for grid operator Terna



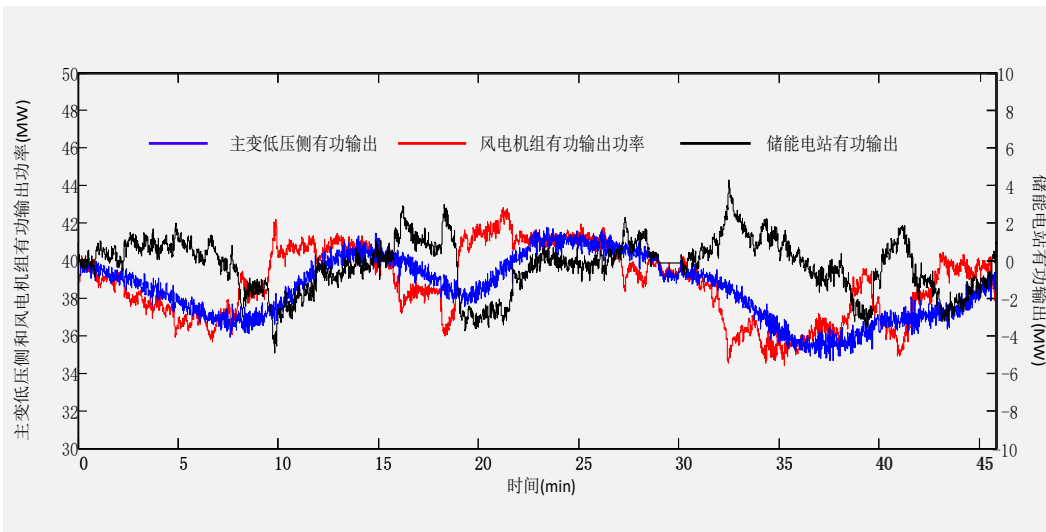
Flow Batteries as part of Terna's storage projects



Source: Terna



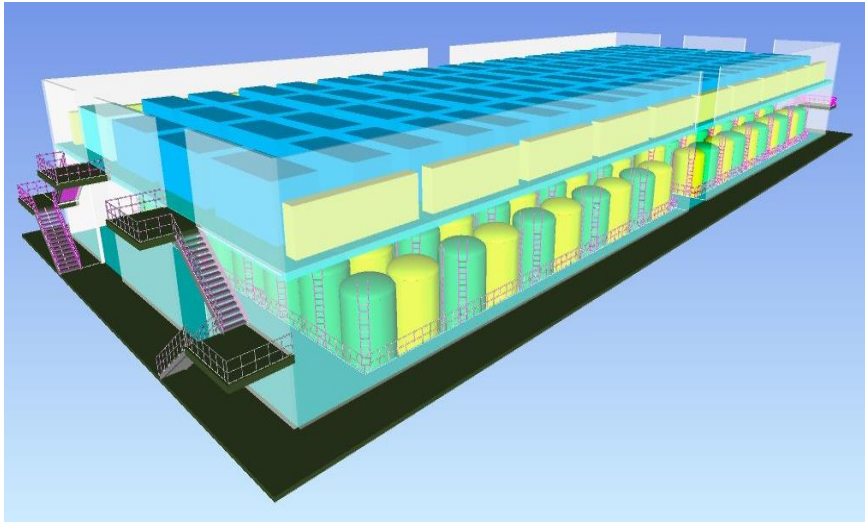
# China – Windfarm Project with 5MW/10MWh storage



- 5MW/10MWh Indoor System
- Location: Liaoning, China
- Customer: Longyuan Substation
- Commissioning: August 2012
- Applications
  - » Wind-Firming
  - » Wind-Smoothing
  - » Grid support, etc.



# China – 200MW/800MWh storage as peak power plant



- A pilot project of the National Energy Department with 200MW/800MWh VRFB as peak load reserve for electricity supply of Dalian city
- 2 Phases realization till end of 2018
- Container power modules and stacked electrolyte tanks







# VANADIS POWER



**UET** UniEnergy  
Technologies



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