VRB Energy Storage
Lessons learned

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Vanadium Redox Battery

The Technology
Electric Energy Storage

Storage is essential component for Smart Grids and RES integration

Not treated accordingly in national and international development programs

Patents, Industrial property rights

Difficult/expensive to develop

Huge progress in last 20 years and many new basic technologies

Storage is needed to replace conventional energy sources
Electric Energy Storage technologies
**VRB storage technology**

Charging / Discharging 1:1
- Efficiency 80%
- Dynamic response – few ms
- Sizing 
  - P=5-10,000 kW
  - W=10-100,000 kWh

→ Vanadium Redox Battery
→ Independent dimensioning P / W
→ Long lifetime – 12,000 cycles
VRB storage - construction

1. Power Module
2. PV Charge controller with 3,2kWp and 70V – 140V input
3. Single phase 230V AC Inverter with 3,5kW each
4. FB Controller
5. Internal circuit breaker/fuses
6. External switch cabinet / load hook up
Vanadium Redox Battery
Experiences Gathered
Promisses given – are they fulfilled?

- Efficiency up to 80%  
  Yes
- Long life time (12,000 cycles)  
  Yes
- Fast dynamic response  
  Yes  
  few milliseconds
- Competitive purchase installation costs <500USD  
  NO  
  current prices are between 1000-2000 EUR
- Low maintenance costs  
  Yes  
  lower than batteries, but higher than promised
- Energy density up to 40 Wh/litre  
  NO  
  about 10-20 Wh/litre
- Charge / discharge power 1:1  
  Yes
Our testing results

– High voltage changes during operation 48 V nominal – from 40 to 58 V

– Very good overloading ability – 150% for up to few minutes

– No discharge detected in the electrolyte tanks – does this help?

– There is discharge in the stacks – stand by problems

– Electrolyte is temperature sensitive – electrolyte temperatures out of interval 0-40°C can not only compromise performance but also damage the electrolyte
Additional findings about VRB

- Electrolyte disposal can be costly – better to reuse it
- Transportation of acid – local preparation of electrolyte
- Vanadium availability – limited number of producers
- Construction problems – leaks of electrolyte
- Although two components of electrolyte this is chemically same substance (practical)
- Independent dimensioning of energy capacity and power (can be developed according needs on particular project)
Tested unit
Transportation to the site
Electrolyte Leaks
Vanadium Redox Battery

Applications
Application: Load leveling for industrial customer
Application: Secondary P/f control

→ Control band: \( P_{sc} = \pm (1...1,5)\sqrt{P_k} \Rightarrow \pm 80 \text{ MW for Slovenia.} \)

→ Wide range of power fluctuations frequency.

→ Provided by conventional power plants (Hydro & Thermal) – They need to operate with lower power \( \Rightarrow \) lower generation of existing power plants

→ About \( \pm 35 \text{ MW} \) of power band in fluctuation frequencies high enough to be compensated with energy storage

→ Suggested configuration: 5-6 Storage units in 110/20 kV substations

→ Increased generation from existing power plants
Application: RES integration

Solar or Wind

AC / DC converter

Partnerstvo za uspeh
Application: Wind for industrial consumer
Application: 0 CO₂ emission mobility

<table>
<thead>
<tr>
<th>Model</th>
<th>Battery capacity (kWh)</th>
<th>Range (km)</th>
<th>Recharge time (h)</th>
<th>Charge Power (kW)</th>
<th>Battery type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vectrix Scooter</td>
<td>3,7</td>
<td>55 - 90</td>
<td>3</td>
<td>1,5</td>
<td>Ni/MH</td>
</tr>
<tr>
<td>IO 1500GT Scooter</td>
<td>2,0</td>
<td>50 - 70</td>
<td>3 - 6</td>
<td>0,6</td>
<td>Pb/acid</td>
</tr>
<tr>
<td>IO Citybike Vienna</td>
<td>0,2</td>
<td>20+</td>
<td>1 - 3</td>
<td>0,2</td>
<td>Ni/MH</td>
</tr>
<tr>
<td>Flyer T8 bike</td>
<td>0,3</td>
<td>12 - 37</td>
<td>4 - 6</td>
<td>0,06</td>
<td>Li-ion</td>
</tr>
<tr>
<td>Lectra VR24 Motorbike</td>
<td>2,6</td>
<td>22 - 40</td>
<td>4</td>
<td>0,44</td>
<td>Pb/acid</td>
</tr>
<tr>
<td>EZ Go Golf Cart</td>
<td>7,9</td>
<td>10</td>
<td>10</td>
<td>1,0</td>
<td>Pb/acid</td>
</tr>
<tr>
<td>Smart fortwin E2</td>
<td>15,0</td>
<td>115</td>
<td>3,5 - 8</td>
<td>2,8 - 3</td>
<td>Na/NiCl</td>
</tr>
</tbody>
</table>

4-Wheel Electric Vehicles

<table>
<thead>
<tr>
<th>Model</th>
<th>Battery type</th>
<th>Energy (kWh)</th>
<th>Range (km)</th>
<th>Charge Power (kW)</th>
<th>Recharge time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart For 2 EV</td>
<td>Na/NiCl</td>
<td>15</td>
<td>115</td>
<td>2,8 - 3</td>
<td>4 - 8</td>
</tr>
<tr>
<td>Austin Mini Mini E</td>
<td>Li-ion</td>
<td>35</td>
<td>160 - 250</td>
<td>11,5/6,9/2,76</td>
<td>2,4/3,8/10,1</td>
</tr>
<tr>
<td>Renault Ondelio Ze</td>
<td>Li-ion</td>
<td>16, 2 - 20</td>
<td>125</td>
<td>&lt;6,8</td>
<td>n/a</td>
</tr>
<tr>
<td>Chery S18</td>
<td>Li-ion</td>
<td>14 - 15</td>
<td>150</td>
<td>3,75 - 2,7</td>
<td>4 - 6</td>
</tr>
<tr>
<td>GEM 4x4</td>
<td>Li-ion</td>
<td>6,5</td>
<td>50</td>
<td>1,73</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Tesla Motors Roadster</td>
<td>Li-ion</td>
<td>57</td>
<td>350</td>
<td>14,8/6,9</td>
<td>3,5/8</td>
</tr>
<tr>
<td>Ford e-Ka</td>
<td>Li-ion</td>
<td>28</td>
<td>150 - 200</td>
<td>&lt; 6,8</td>
<td>6 - 8</td>
</tr>
<tr>
<td>Mitsubishi i-MiEV</td>
<td>Li-ion</td>
<td>16</td>
<td>160</td>
<td>3-ph 50/3</td>
<td>30min/7</td>
</tr>
</tbody>
</table>
Application: Other benefits for the system

- Peak shaving
- Better use of existing generation and transmission capacities
- Regulations
- PQ
- Reliability
- Stability
- Supply of sites without power network
- Contingency supply
Applications

- Many different possible applications in electric power system
- Deregulated energy industry – many players – many different interests
- Solution for each particular function/application is often not economicaly feasible with VRB technology
- Can we combine these functions in one installation? Yes, we can to a certain extent
- Can we combine all these players and interests in one alpplication? I have doubts so far.
Conclusion

→ VRB has several advantages
  - Long lifetime
  - Charge/discharge power ration 1:1
  - High efficiency 80%
  - Fast dynamic response (in few ms)
  - Electrolyte and most of the plant can be reused after designed lifetime

→ So far costs are still preventing more intensive use

→ Technology so far proved most of the promises given and most of the ‘childhood diseases’ are over

→ New technology requires new project/business model approaches
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