Disruptive Technology

For Large-Scale, Micro and Off-Grid Energy Storages

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Oct 25, 2018





Outline

- Mission & Vision
- Demand for Cost Effective Energy Storage System
- Tahoe Electric Technologies
- Tahoe Electric Products
- Business Models
- "Alpha-Go" (Launch Phase) Successes and Beyond
- Collaboration with Asia Development Bank



Mission and Vision

Tahoe Electric is:

• Dedicated to develop cost-effective energy storage solutions (ESS) to enable the effective integration of renewable energy and create a cleaner and more resilient energy supply network for a sustainable future

Tahoe Electric is:

•Able to offer the lowest cost energy storage systems by significantly extending the lifetime of AGM leadacid batteries, by leveraging IoT, Big Data, Computingcloud and Artificial Intelligence (AI) technology

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Energy Storage: Crucial Tool for Effective Integration of Renewable Energies





Desperate need for energy re---structuring in China

Renewable energies

- Sustainable Development
- Ideal for developing countries

Energy Storage: key for renewables

- Power Grid balance
- Off-grid Applications
- Intermittent Loss reduction
 - over 20---40% PV/Wind intermittence loss

Existing solutions and requirements

- hydro---pump, CAES, Flywheel, Batteries(Li--ion, Lead--acid, Flow etc.)
- Requirement: low cost, safety, low--emissions, low--pollutions

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Key Issues for Energy Storage Systems

High Safety

- ESS work under hash environments
- High requirement for safety
- Fire control requirement
- Low cost
 - Comparable with Hydro--pump
- **Environment friendly**
 - Lower emission
- □ Scalability and Reproducibility
 - Duplicable worldwide

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Hydro-pump: Still the Most Cost--effective !

-----Environmental limitations for renewables



Zhejiang Tian---Huan---Ping(1.8GW) Annual output: 8000GWh; Efficiency: 74% Cost per kWh: (\$0.012---\$0.03/kWh) Occupied Area: up 280,000m², down180,000m² (30 times more space than battery storage) Construction period: 10 years Cost: \$1.5Billion, ROI period: 10 years Special requirement for environment

Battery Energy Storage:



Efficiency > 85% Cost: ? Safety: ? Area: 18,000m², (1/30 of hydro---pump) Construction period: 0.5-1 yrs



Current Main Stream Battery Technologies

Batteries	Battery Initial Cost (\$/kWh)	Cycle Lifetime (cycle)	Residual Value(%)	Period of ROI (year)
AGM Lead acid(power battery, china dominates)	73—88	~700	45%	5-8
LeadCarbon	132—147	~1500	30%	5-8
Lithiumion (LiFePO)	147-220	~2000	5-10%	~10
Flow Battery	367-441	~5000	5%	

AGM Lead-acid: mature infrastructure, low cost, clean, safe, high residual value
Lead-carbon: mass production, relative low price, clean, safe, but less residual value
Li-ion: high energy density and long lifetime, but cost, safety, recyclability are issues
Flow Battery: long cycle lifetime but high cost, low residual value, not in mass production

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Battery Energy Storage: Li-ion vs. Lead-acid





	Lithiumion battery	AGM Leadacid battery (for ebike)		
Specific Energy	>100Wh/kg	50Wh/kg		
Cycle Lifetime	2500 @70% DoD	700@70% DoD		
Energy storage cost (\$/ kWh)	\$0.15\$0.23	\$0.08\$0.12		
Safety	Big challenge in recent years!	safety guaranteed, and existing large-scale infrastructure from production to recycling		
Recyclability	~10%	~99%		
Charge/discharge rate	high rate	low rate		

- Lead--acid: low cost、 large---scale、 safe、 recyclable; but short life--time, relative slow charge/discharge rate
- Li---ion high cost、safety issues、low recyclability; but longer lifetime、 fast charge/discharge rate
- □ Tahoe Electric Technology: extend lifetime, reduce energy storage cost for Lead acid batteries (cost reduce to <\$0.03/kWh)

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International Fire Codes (safety codes)

-energy density of Li-ion system significantly reduced





Lead--acid battery system: not impacted In 40--feet container: total installed capacity is 600kWh for Li-ion, and more than 2500kWh for Lead-acid

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Tahoe Electric Company Expertise

Silicon valley talents, teamed up with China Local
Manufacturing/Operation expertise



- Battery "Online Doctoring" Technologies
 - IoT, Big Data/Cloud Computing, Artificial Intelligence and energy management; Lifecycle Management for all chemical energy storage systems
 - Domestic E-Bike Batteries (AGM): cycle lifetime more than doubled, cost for storage highly reduced

Profit from

- "Peak-valley" delta of electricity price
- Power grid balance
- Intermittent loss reduction &Off-grid applications
- Power Batteries

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Technology: Topological Controls for Batteries

-- IoT, big data/cloud computing, AI, energy management Double the battery cycle lifetime, Cost reduced to: < \$0.03/kWh





Big data for:

- Stochastic metric distributions:
 - Load & SOH dependent
- Power spectrum for external noise:
 - Load, SOH, SOC dependent
- Artificial intelligence:
 - > algorithm for optimizing SOH, cyclelife

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Topological Controls for Battery Anti--aging

Mechanism for battery Anti-aging:

- External-Noise Induced Topological Phase Transition

w/o external noise w/ external noise



Lyapunov exponent λ: w/o and w/ external noises

Topological Control for AGM Battery --Anti-aging effects under external noise



Battery anti---aging under external---noise control during Charging---discharging cycling

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AGM Battery Cycle Lifetime Improvement



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AGM Battery Lifecycle Improved Significantly Battery

Battery System W/O Control



Battery System W/ Control





Tahoe Electric Technology: The Paradigm Shift

Batteries	Battery Initial Cost (\$/kWh)	Cycle Lifetime (cycle)	Residual Value(%)	Period of ROI (year)
Tahoe Electric AGM Leadacid	73-88	16003000	45%	2—3
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AGM Battery + AI: Revolution in Energy Storage!



□ Artificial Intelligence:

- Algorithm training: through 30-50kWh system (with 100 12V20Ah cells), each station with 100 30-50kWh sub-systems
- Iterations: Cycle-life and cost improvement
- **Cascading utilization for batteries: further improve cost**

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Cloud-Computing Center

Battery IoT and real-time maintenance
Power and energy real-time management







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App I: Forklift and Residential Energy Storage

-Also known as "Alpha-Go"







App II: Energy Storage Station



Over 12,000 battery cells, 300kW/3000kWh, 30m², 76 tons Cost per kWh

= depreciation cost / kWh

+ electricity price/round-trip efficiency

=\$0.03+electricity price / 0.85 (\$/kWh)

Mass production: depreciation cost reduce to \$0.01-\$0.02/kWh

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Power Battery Applications





Electric---ForkliftElectric Towing Vehicle电动叉车系牵引车系列



重型牵引车

座驾式



|车



机场专用牵引车



iESS(Smart Energy Storage) Products

- Residential energy storage: 5kWh---30kWh
- □ Off---Grid energy storage: 100kWh---300kWh
- □ Micro---grid/Grid energy storage: 600kWh---3MWh

Off--grid, Commercial Micro---grid, Grid---scale

Residential











ESS Application Examples













Applications- Off-Grid, Micro-grid & Grid



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Huge Market

Applications

- Power Battery
- Grid Stabilization for Micro-grid
- Intermittent Loss for Renewable Energies
- Super Charge Stations
- Virtual Power Plant
- Internet of Energy
- □ Market potential
 - Over \$1.5Trillion China only
 - Over \$5 Trillion world-wide

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Business Model – **B-a-a-S**



Energy Storage Station

- **EMC (EPC, ECS)**
- ➢ E---a---S
- Rental



Innovative Financing



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Practice in China: Forklift Battery in Service

-Success of "Alpha Go"



Different Locations:

- Over 28 provinces
- Over 3,000 units

Recall Rate in 20 Months

- Traditional e-bike battery: > 30%
- Tahoe Electric: ~1%

Offline Services

< 20 times</p>

Different Customers

Big brands

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iESS (Smart Energy Storage System) in Service in Zhejiang Province



Tieying Power Co., 1MW/10MWh; area: 150m²



Narnia, Huzhou, Zhejiang 750KW/9MWh; area: 160m² on 2nd floor

Zhejiang Energy Co LTD 750KW/6MWh; area:

浙江浙能能源服务室

2.5MW/25MWh in service

- 1.75MW/16MWh in user side with EPC
- 750KW/9MWh for Zhejiang Energy Co LTD

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iESS in Service for Jiangsu State Grid Company

-Balance the grid



14MW/52MWh in service,

- Contract with Jiangsu state grid company, for user side EPC
- Participate in the peak---shiming service for grid side

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iESS in Utility Service for State Grid Company





12MW/48MWh, Utility side, in 2018

Participate in peak---shiming service for utility side

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Marketing and Business Development Different Applications

- Dever Battery Rental Business: e-Forklift, e-Truck, e-Boats, EV etc.
- □ Energy Storage: Frequency/Peak Regulations, energy storage
 - Utility, User and Generation side
 - Intermittence Loss Reduction for Wind, PV, Water and Nuclear
 - Micro Grid & Off-line Grid
- □ Supercharge Stations; UPS Upgrade(Cell Tower, IDC etc.)

Different Areas

- □ Marketing and Business Development in USA (California &DC)
 - Power batteries (forklift, e-boat/golf car); ESS(I&C ESS, Utility ESS)
- **D** Emerging Markets
 - To achieve SDG7 Energy Access
 - Collaborate with international org to penetrate the markets

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Selected Tahoe Accomplishments Timeline (All with the same battery cell)



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Standard or Tailor-Made Solutions for Asian Development Bank Projects

- Diverse and scalable applications, e.g.,
 - Household applications(1KW-2KW/ 10-20kWh?), Community level applications:
 - Mini-grid/off-grid applications: 1- 5 MWh?
 - Grid/utility level applications and generation level applications
- □ Collaboration through ADB's new projects and/or existing projects
- □ Flexible business/service models, e.g.,
 - Service provision
 - > EPC contract
 - Leasing arrangement

Will train project owners/users and provide on-time monitoring and technical support to ensure reliability

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Tahoe Is Ready to Participate with...

- Reliable, low cost technology, adaptable and scalable for all geographic locations
- □ Reliable supply chain (e.g., battery supply and replacements)
- □ After sales service and maintenance
- □ Finance arrangement available
- Full compliance with Environmental and Social Standards, procurement and other operational policies of the Asian Development Bank
- □ Proper risk management in collaboration with the ADB
- □ And, a dedicated, competent Tahoe team...

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