Battery Monitoring – Importance and Solutions for Public Transport Companies

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WRI India

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Volytica diagnostics GmbH

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WRI India

**Supported by:**
Rohan Shailesh Modi
German Chancellor Fellow,
Die Alexander-von-Humboldt-Stiftung

**Supported by:**

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Tüv Süd

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WRI India

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SHAKTI

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ROSS CENTER
volytica diagnostics GmbH
Who we are? - Key facts

Claudius Jehle, CEO
Syrs Group Manager
Battery Diagnosis

Sebastian Stoll, CTO
11yrs Cloud Engineering Experience (Industry)

Now

2 Experienced Founders
with relevant Market & Technology Background

4 High Profile Employees
experts from Battery, AI and Software Engineering

Strong Technology & Network
Close Research (Fraunhofer and TU Dresden) and Industry Network, Pilot Projects from Q2/2020

Ambitious Strategy
Ambitious, yet long-term, sustainable growth with strong focus on independences and trustworthiness

2025

2 Core Target Markets
Diagnosis Software for Non-Car OEM/Tiers

Service Provider for Car Battery Assessments

Dresden
volytica diagnostics GmbH

What do we do? - Our solution

Source-agnostic
Use existing telematics solution or choose from our third-party portfolio

Cloud-Based
Automated, scalable software deployed in trustable and safe clouds

Full Transparency
Get rate, state, predictions and realistic ageing information over the lifecycle

No Sensors
We use the signals every battery provides: only U, I, T are needed

Plug and Play
Minimum apriori parameterization due to self-learning algorithms

Save Costs...
Less testing, optimize system size, reduce service costs, warranty risks...

Minimal Data Volume
We’ve got SDKs for 10:1 onboard compression

Top-Notch Quality
Built on >10 years of Li Ion diagnostics, characterization and machine learning experience

... and Earn Money
Boost after-sales, sell warranty top-ups, lease & pay-per-use, full service and many more...
Battery Monitoring – Importance and Solutions for P. T. C.

Agenda

1. Setting the Frame: Why is Degradation important?
2. Battery Basics and Degradation in a Nutshell
3. Battery Monitoring - Why and How?
4. Outlook: Tendering
Battery Monitoring – Importance and Solutions for P. T. C.

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Setting the Frame: Why is Degradation important?

Problem to solve - The Battery is ...

30% of vehicle value

... single most expensive component

... subject to usage-dependent wear

... extremely complex to diagnose & predict
Setting the Frame: Why is Degradation important?
Battery - The Heart of an EV

- *The essential component*
- Degradation inevitably
- Health assessment needs a ‘deep view’

“A vehicle battery is like a human heart”

- Determines overall performance
- Degradation is usage dependent
- Take good care!

Source: https://commons.wikimedia.org/wiki/File:Heart_normal.svg
## Battery Monitoring – Importance and Solutions for P. T. C.

### Agenda

1. Setting the Frame: Why is Degradation important?
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# Battery Basics and Degradation in a Nutshell

## Chemistry

<table>
<thead>
<tr>
<th>Li-Ion</th>
<th>Li Iron Phosphate</th>
<th>Li-Ion</th>
<th>Nickel Manganese Cobalt</th>
<th>Li-Ion</th>
<th>Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>🔄 short: LiFePO₄, LFP, ...</td>
<td>🔄 &quot;Chinese Automotive Standard&quot;</td>
<td>🔄 short: NMC, NCA, ...</td>
<td>🔄 &quot;European, Korean Automotive Standard&quot;</td>
<td>🔄 several other “exotic” chemistries in the pipeline</td>
<td>🔄 Li-Air, Li-Sulfur, ...</td>
</tr>
<tr>
<td>🔄 modest energy (lower risk?)</td>
<td>🔄 modest prices</td>
<td>🔄 higher energy (higher risk?)</td>
<td>🔄 higher prices</td>
<td>🔄 tendency for prone to balancing problems</td>
<td></td>
</tr>
<tr>
<td>🔄 difficult SOC determination</td>
<td>🔄 Li-Poly is just a reference to the internal liquid!</td>
<td>🔄 better SOC determination</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Battery Basics and Degradation in a Nutshell

Capacity and SOC

1,0 Full Cycle
Δ SOC 100%

0,5 Full Cycle Equivalents
Δ SOC 50%

1,0 Full Cycle Equivalents
Δ SOC 50%

Source: https://en.wikipedia.org/wiki/File:Glass-of-water.jpg under public domain
Battery Basics and Degradation in a Nutshell
Usable Capacity and Displayed SOC

Source: https://en.wikipedia.org/wiki/File:Glass-of-water.jpg under public domain
Battery Basics and Degradation in a Nutshell

Some further Terms and Wordings

**Nominal Capacity** $C_N$:
Is the minimum amount of charge that can be discharged at **nominal current** $I_N$ and at **nominal temperature** $T_N$ from a new fully charged battery

$$C_N = I_N \times t$$

**Actual Capacity:**
The capacity actually available to the system depends, among other things, on:
- Discharge current rate
- Temperature
- Time pattern of the discharge
- Ageing of the battery

**C-Rate:**
To compare cells and batteries of different capacities, charge and discharge current is specified in relation to the capacity.

As an example for battery with $C_N = 3.5$ Ah:
- $1C \equiv 3.5$ A
- $0.2C$ or $C/5 \equiv 0.7$ A
- $10C \equiv 35$ A
Battery Basics and Degradation in a Nutshell
Charging Method

**CC-CV-Method:**
- Common method for LI-Ion-batteries in laboratory to reach a fully charged battery
- In the “real world” often slightly adapted

1. **Phase CC:**
   - **CC = Constant Current**
   - Charging with a constant current until the charging cut-off voltage is reached
   - Typical current with 0.3 to 1 C

2. **Phase CV:**
   - **CV = Constant Voltage**
   - Charging with a constant voltage until the current felt below a limit
   - Typical current limit C20
Battery Basics and Degradation in a Nutshell
Sense and nonsense of high charging power

Boundary Conditions:
- Simulation results of an existing traction battery of an electric bus
- Cell chemistry LFP
- Start-SOC 50%
- Surrounding temperature 30°C

- Increase in charging power + Shorten the charging time
- BUT: Increased power = reduced service life

Battery Basics and Degradation in a Nutshell

Degradation Effects

Reduced Capacity

inevitable (Ageing)

evitable* to be excluded by design

R
 C

Inhomogeneity
catastr.

failure

range & power decrease
early failure

* in a "nominal case", i.e. disregarding extreme situations

Source: https://en.wikipedia.org/wiki/File:Glass-of-water.jpg under public domain
How long will a battery live?

There exist definitions, which determine the end of life of a battery:

- Usable capacity decreased to 80% of its initial value in mobile applications (for stationary batteries it’s 70%)
- Internal resistance increased to 200% of its initial value

### Key factors:
- temperature
- SOC-Swing
- current rate
- mean SOC
Battery Basics and Degradation in a Nutshell

Broadness of Degradation Evolution

Different degradation gradients for a single cell type because of different operation conditions (laboratory measurement at 25°C)

Speed of Degradation strongly depends on the operating condition and can not be estimated without detailed knowledge of them
### Battery Basics and Degradation in a Nutshell

#### Ageing - Conclusion and Take Away

<table>
<thead>
<tr>
<th>Influencing Factor</th>
<th>Temperature</th>
<th>Δ-SOC</th>
<th>mean SOC</th>
<th>C-Rate resp. Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal Values*</td>
<td>15°C - 30°C</td>
<td>the lower the better</td>
<td>~50% better than ~80%</td>
<td>the lower the better</td>
</tr>
<tr>
<td>Mitigation Strategy</td>
<td>(Difficult to influence during operation)</td>
<td>(Most difficult to influence)</td>
<td>(Difficult to influence)</td>
<td>Far-sighted driving</td>
</tr>
<tr>
<td></td>
<td>Avoid parking in the sun</td>
<td>Strongly depends on the needed usage time</td>
<td>Avoid parking @ 100%</td>
<td>Full usage of recuperative braking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Modest charging more often</td>
<td>If available, use “smart charging”</td>
<td>Raising driver awareness</td>
</tr>
</tbody>
</table>

* the concrete value is highly dependent on the used cell
Battery Monitoring – Importance and Solutions for P. T. C.

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Battery Monitoring - Why and How?
Knowing the Health of a Battery

Scenario A:
- Conservative design
- Easier usage profile than assumed

Scenario B:
- Harder usage profile than assumed
- Warranty condition breach

Take away:
- Relevant for both the OEM and the PTC
- To predict the future, detailed knowledge on the battery and the usage profile is crucial

⇨ Only possible to recognize via detailed battery monitoring
Battery Monitoring - Why and How?
Things to be considered

What to evaluate?
- Statistics?
- Mission profile?
- Merging of data sources?
- Degradation reports?
- Lifetime prediction?
- Algorithms?
- Who is developing the needed algorithms? Do they work online (dashboard) or offline (paper report)?
- Knowledge?
- Battery parameters?
- Stress-Maps?
- Battery knowledge?

What is the data source?
- Additional sensors?
- CAN-interface?
- Where to get the CAN-Matrix?
- Available Data (U, I, T)?

Telemetry hardware?
- Space to mount?
- Power supply?
- Who provides it?

How to transmit the data?
- Mobile network provider?
- Needed data rate and amount?
- Network Stability?
- Security?

Where to store the data?
- Cloud Service Provider?
- Own server in the basement?
- Security?
- Fail-safe operation?

Scalability?
- How many vehicles?
- When will they go online?
- How long to store the data?
- Data reduction/compression?

What speed is needed?
- Latency of the data?
- Evaluation period (daily, weekly,...)?
- Real time view needed?

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Knowledge?
- Battery parameters?
- Stress-Maps?
- Battery knowledge?
Battery Monitoring - Why and How?
Web Dashboard - “Asset Cockpit”
Battery Monitoring - Why and How?
Volytica Report

Operation Profile Overview
(Operation Conditions)

- Evaluation Period: 7/2016 - 9/2019
- 24 months
  - 38% (~9.5 months) no data
  - 720 monitored FCE
  - avg. 38/month

Operation Profile Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average</th>
<th>Dominant Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOC</td>
<td>72-85%</td>
<td>65-88%</td>
</tr>
<tr>
<td>DOD</td>
<td>10%, max. 30%</td>
<td>comfortable</td>
</tr>
<tr>
<td>Temperature</td>
<td>avg. 30°C</td>
<td>elevated stress optimal avg. 28°C</td>
</tr>
<tr>
<td>Power</td>
<td>&lt;1C</td>
<td>comfortable</td>
</tr>
</tbody>
</table>

Residual Capacity
SOC-Consistency
Battery Monitoring – Importance and Solutions for P. T. C.

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Outlook: Tending
Full Electric Buses - A Complex Ecosystem

Technological
- Battery capacity
- Charging technology
- Charging power
- Depot charging vs. on track charging
- Air conditioning
- Size of the bus
- Heating
- ...

Economical
- Price for car
- Vehicle service life
- Price for battery
- Battery service life
- Energy costs
- Costs for charging infrastructure
- ...

Operational
- Charging strategy
- Demand for space in the depot and on the track
- Circulation times
- Workshop equipment
- Reliability
- Turn around times
- ...

Nearly every point is linked at least to one other point in another domain and all have to be considered together

Strong need for experts and consultants
Outlook: Tending

Takeaways

● Be aware of the complex ecosystem “full electric bus”. It’s not only buying an electric bus and replace a diesel bus, at least if you want to do it right.

● Every single decision has an impact on other points you have to decide. ⇒ Take the helping hand of experts and consultants.

● Look out for an intelligent charge control system to:
  ○ Enhance battery life
  ○ Reduce energy costs
  ○ Reduce infrastructure costs

● The evaluation of battery ageing is a challenging thing to do, from knowing the actual State of Health up to predicting the End of Life.

● It can only be done by detailed monitoring during the whole life of a battery.

● A minimum data set should be provided by the OEM:
  ○ Battery voltage
  ○ Lowest and highest cell voltage
  ○ Current with a high sampling rate or with a lower sampling rate an additionally the Charge throughput
  ○ Mean temperature of the battery
  ○ Lowest and highest cell temperature
  ○ Average State of Charge

● The detailed monitoring could also be a gain for the OEM ⇒ Win-Win-Situation for both