«Program Digital Power Plant - An Initiative to validate and create digital solutions in the SBB Energy Value Chain»

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«Agenda».

- Overview SBB Energy 5’
- Overview «Program digital power plant» 5’
  - what we adress
- Overview Portfolio – sight on «work under construction» 10’
  2 Examples in the «fields of action»
  - virtual operation
  - work and field force support
Overview SBB Energy
SBB’s Traction Power Infrastructure. Overview.

- 8 hydroelectric power stations
- 9 frequency converters
- 1 shared power stations
- 5 Rights of use to power stations
- 2 interconnections with DB
- 1 interconnection with ÖBB
- 84 substations
- 1,859 km of transmission lines
SBB’s Traction Power Infrastructure.
Secure, cost-efficient, ecological.

- **Standard network 50 Hz**: SBB also “taps into” the electricity used by industry and households.

- **Frequency converters**: Converts 50 Hz three-phase current into 16.7 Hz traction current.

- **Substation**: Converts 132,000 V high voltage into 15,000 V overhead line voltage.

- **Overhead line**: Supplies trains with 15,000 V traction current.

- **Hydroelectric power station**: Uses stored energy from reservoirs and kinetic energy from rivers.

- **40 MCHF in revenue (50 Hz)**

- **219 MCHF in revenue (traction current)**

- **1047 MCHF – book value**

- **6790 MCHF – replacement value**

- **365 FTEs**

- **2157 GWh – traction current sales in 2020**

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Traction current network (16.7 Hz).

Dynamic power profile is challenging and expensive.

1 day in Zurich city (50 Hz)
1 day at SBB (16.7 Hz)

Load changes

<table>
<thead>
<tr>
<th>Daily</th>
<th>Within 15 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zurich city</td>
<td>up to 250 MW</td>
</tr>
<tr>
<td>SBB</td>
<td>up to 500 MW</td>
</tr>
</tbody>
</table>
Overview «Program digital power plant»
Overview «Program Digital Power Plant»

Key Facts

- Digitales Kraftwerk started autumn 2019
- Four fields of actions
- About 39 PoCs (16 of them terminated)
- Interdisciplinary teams with more than 50 employees participating
- 25 PoCs in Inno-funnel for 2022

The program “Digital Power Plant” has started in autumn 2019 with the aim of developing and testing innovation based on digital trends.

PoCs or ideas formulated and addressed in subject areas come from workshops of Inno circles/communities or individuals.

Possibility of collaboration or participation for some PoCs is advertised on a “marketplace”.

Up until today PoCs were processed with the participation of over 50 employees.
Overview program – 4 Examples

**Virtual Operations**
forecasting tomorrow’s hourly electricity price in Switzerland so that traders can make successful decisions in the markets.

**Building Information Modelling**
Open Innovation with Startup Gilytics for faster and comprehensive exploration of line paths – brings better arguments towards stakeholders.

**Work- and Fieldforce Support**
Using drones, more can be inspected in same time, and faults can be documented faster (automatically) and more comprehensibly.

**Digital Asset Management**
Efficiency monitoring enables predictive maintenance and operational optimization. A change in efficiency quickly causes big impact.

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**Data-Input**
- Point Cloud and Scanning
- Specialist data catalog
- Geographical Data
  - different layer
  - Lidar Data
- Specific Parametric Handling
  - electrical parameter
  - distance
  - vegetation

**Data-Output**
- Project model
- Inventory model

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**Apprenticeship Program**

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**Overview**

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**Virtual Operations**

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**Work- and Fieldforce Support**

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**Digital Asset Management**

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PoCs in DigiKW 2022: Innovation funnel

Status Aug 2022

25 Proof-of-Concepts (time-boxed):
- To Generate: 8
- In progress: 14
- To be Killed: 3 (Prognosis)
- To extend: 0
- Back-to-log: 1
- Backlog: 9

Themenfelder:
- Virt. Bewirtschaftung
- BIM
- Work- & Fieldforce
- Digital Asset Management
Example «managing a future battery swarm»
Project BIENE (= Batterieschwarm im Bahnstromnetz)

Ambition 2040: 100% renewable since 2020: "With immediate effect, all new and replacement purchases will be made with renewable energy instead of fossil fuels."

Today around 700 diesel-powered vehicles

-..likely to bring a huge battery swarm into the railway grid.
-..of shunting locomotives, construction site, maintenance & crane to fire engines and special vehicles..

Increases demand for power

-Will SBB become the largest battery owner in Switzerland?

Project-Scope (in terms of PoC)

- Risks&Chances
  - Congestions
  - Value Cases

- Solution (Concept)
  - Load-Management
  - Communication/control
  - Framework

- PoC
  - Central Load-Management based on a simulation

- Requirements for Pilot
  - Design a follow-up
  - Next steps

flexibility through battery management for ..

- Grid services
- System services
- Market services

Practical Use/Value

- Optimization
  - Invest cost / Life-cycle cost

Security of supply / reduction Design

Efficiency
- System Operation
User expectations of central charging/battery management system.

I want battery-friendly charging achieving a long lifecycle.

I need data for asset management, e.g. for condition-based maintenance.

Is the battery capacity sufficient for the planned rotation?

Is an unplanned intervention with a quick charging possible? If Yes, then I want to be able to trigger it.

Do I have to park the locomotive under overhead line during the break or is the state of charge sufficient for afterwards?

Loadmanagement platform

I want to forecast the power demand, use the flexibility of the batteries for a safe and optimally operated traction current grid and reach a cost-effective traction current price for my customers.

Employee SBB Energy

Vehicle owner

Vehicle dispatcher

Locomotive driver

Insights:
- user need and interest higher than anticipated
- additional user value added
- cooperation topics broader than expected
Comprehensive Simulations of scenarios. The proof of concept shows that system risks of coincident charging are manageable, a centralised charging management due to available high flexibility is very valuable and the solution enjoys a high level of acceptance by the users.

### Input Data
- Vehicle deployment data
- Energy Demand data
- Geographical railway grid data
- Battery properties (aging, charging, costs, ..)

### Model
- Simulation for unplanned Load risks
- Simulation for flexibility estimation
- Simulation for benefits of value cases

### Results
- Weekly profile for load power, unmanaged fleet of 252 Vehicles
- Weekly profile for available Flexibility@OL fleet of 252 Vehicles

### Practical Use/Value
- Additional load due to battery charging uncritical (max. 1 % of max. load)
- Over 60 MWh of battery capacity available in the traction current grid (at all times)
Benefit from a central charging/battery management system.

1. User-optimised charging management

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.a. Secured state of charge for vehicle use</td>
<td>*** Indispensable for vehicle operation, alternatives more expensive</td>
</tr>
<tr>
<td>1.b. Battery-friendly charging</td>
<td>*** Savings &gt; 1 million CHF/a, Reduction of grey energy due to longer battery lifecycle</td>
</tr>
<tr>
<td>1.c. Asset management and data access/availability</td>
<td>*** More reliable operation and cost savings. Alternatives more expensive</td>
</tr>
</tbody>
</table>

2. Minimise costs and risks from additional load

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.a. Avoiding grid reinforcement due to overload</td>
<td>Reduction in need for additional infrastructure at charging hotspots</td>
</tr>
<tr>
<td>2.b. Avoiding expanding production capacities</td>
<td>NPV: approx. -1-3 MCHF through load management</td>
</tr>
</tbody>
</table>

3. Added value of energy management

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.a. Strengthening weak grids</td>
<td>60-80 MWh of energy available grid-wide for stabilisation in crisis situations</td>
</tr>
<tr>
<td>3.b. Cover extreme load spikes</td>
<td>NPV &gt; CHF 20 MCHF due to reduced need of frequency converter capacity</td>
</tr>
<tr>
<td>3.c. Reduction of auxiliary power</td>
<td>&gt;1 million CHF/a, through release of hydro power reserve, used on the market</td>
</tr>
<tr>
<td>3.d. Load shifting</td>
<td>Lower demand of regulation, reduced wear and tear hydro-machines</td>
</tr>
<tr>
<td>3.e. Market price-dependent charging and discharging</td>
<td>? Depending on future market, and technical requirements</td>
</tr>
</tbody>
</table>
Main take-aways.

• A reserve power plant (almost) for free!
  ✓ Additional load not critical (max. 1 % of today's maximum traction power load).
  ✓ > 60 MW over 1 h or > 120 MW over ½ h reserve capacity in grid-wide (critical) situations in the traction power grid.
  ✓ > 1 million CHF per year through reduced reserve provision.
  ✓ > 20 million NPV through reduced expansion of frequency converter capacity.

• In a next/first step embedding upcoming battery Loks in the SBB Energy IT system landscape - in the existing Loadmangement platform

• Diesel engines can only power vehicles, batteries can do much more!
  A lot of (customer) benefit is generated by a "charging management as a service":
  ✓ sufficient battery capacity for next use/shift
  ✓ battery-friendly charging
  ✓ supports asset management (by additional/comprehensive data)
  ✓ increased security of supply and cost-effectiveness of traction current
  ✓ Communication via vehicle, no intelligent charging infrastructure necessary

• Additionally: Electricity is much cheaper than diesel (and more climate-friendly, emission-free, sustainable...)

• From diesel to battery: change of technology carrier with influence on operation and charging infrastructure/energy supply.
  A follow-up project “BatterieZugkunft 1.0” is taken up with broader/interdivisional topics
  System tasks & coordination / Central battery management / Vehicle & battery requirements / Charging infrastructure
Example «power grid restoration within 5 minutes»
"Power grid restoration within 5 minutes" after blackout

Impact of a blackout

Blackouts 16.7 Hz have become much less likely, the damage would still be immense: 6h no power, high costs. Ambition is to reduce rebuild time and thus the damage drastically.

Implementation

The implementation is based on three pillars.

The simulation models & Field Tests ensure robustness.

Grid Restoration Process

Grid restoration today and in the future

<table>
<thead>
<tr>
<th>Topic</th>
<th>Feature</th>
<th>conventional</th>
<th>actual optimized</th>
<th>partially-automated</th>
<th>automated</th>
</tr>
</thead>
<tbody>
<tr>
<td>process simplification</td>
<td>number of switching operation</td>
<td>≈ 1600</td>
<td>≈ 500</td>
<td>≈ 450</td>
<td>≈ 450</td>
</tr>
<tr>
<td>automation in control system</td>
<td>switching commands</td>
<td>manually</td>
<td>manually</td>
<td>manually</td>
<td>automated</td>
</tr>
<tr>
<td>power generator control</td>
<td>behavior in fault-events</td>
<td>shut down</td>
<td>shut down</td>
<td>Restart automatically</td>
<td>Restart automatically</td>
</tr>
<tr>
<td>Overall-Results</td>
<td>time for Re-Supply</td>
<td>6 h</td>
<td>3 h</td>
<td>2 h</td>
<td>5 m</td>
</tr>
</tbody>
</table>

2021 2022 2023 2025

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Blackout SBB 2005

Practical Use/Value

Massive reduction in blackout duration

Probability of blackouts is reduced

Better prediction of fault duration

Faster information about the grid status
Fieldtest 2021 – automatic Restoration of 132kV Grid Section

Test area:
- Long section of the 132 kV SBB grid comprised between Geneva and Zurich Seebach
- Two production units:
  - Frequency converter unit in Foretaille
  - Hydro power generator unit in Vernayaz

Test objectives:
1. prove simulations & theoretically developed concepts in practice
2. test implemented adaptation on production units
3. test response of protection equipment

Test procedure:
- Generate artificial blackouts on the test grid
  - ca. 20 blackouts initiated
- Power up the grid using different configurations
  - Ramp up times between 2 – 40 s tested
- Measure response of production units, transmission lines and protection with high resolution measurements
Field Test 2021 – what has been tested, validated and outlook

What has been tested and validated

1. Concepts and simulations
   - Process flow of production units behavior after a grid event
   - Methods for fast connection of transformers (control of inrush currents)
   - Grid studies (grid stability, i.e., frequency and voltage)

2. Production units adaptation
   - Frequency converter → new 132 kV grid “soft black start” function
   - Hydro turbine → new start-up logic

3. Protection system behavior
   - Adequate response during voltage ramp-up (no spurious protection action)
   - Adequate protection in case of real faults

Test outcome: test grid could be restored in 2s

- Soft black start function on frequency converter works as desired → soft ramp up of voltage on large test area
- New start-up logic works as desired → further production units can be synchronized to the grid instantaneously
- Overhead lines transformers stay connected → effects of inrush currents negligible and no switching required → faster!
- Test insights allow further increase of grid restoration process speed and robustness

Outlook

- Field test 2022 includes consumer load in Blackout Test Scenario → assess robustness of restoration process on the 15kV level and locomotives (inrush currents & protection system behavior)
- Rollout of power control features to converter and power stations by 2023 → grid restoration within 2h
- Implementation & testing of automated restoration sequence in the network control system by 2025 → grid restoration within 5 min
Thank you very much for your attention.

Any Questions