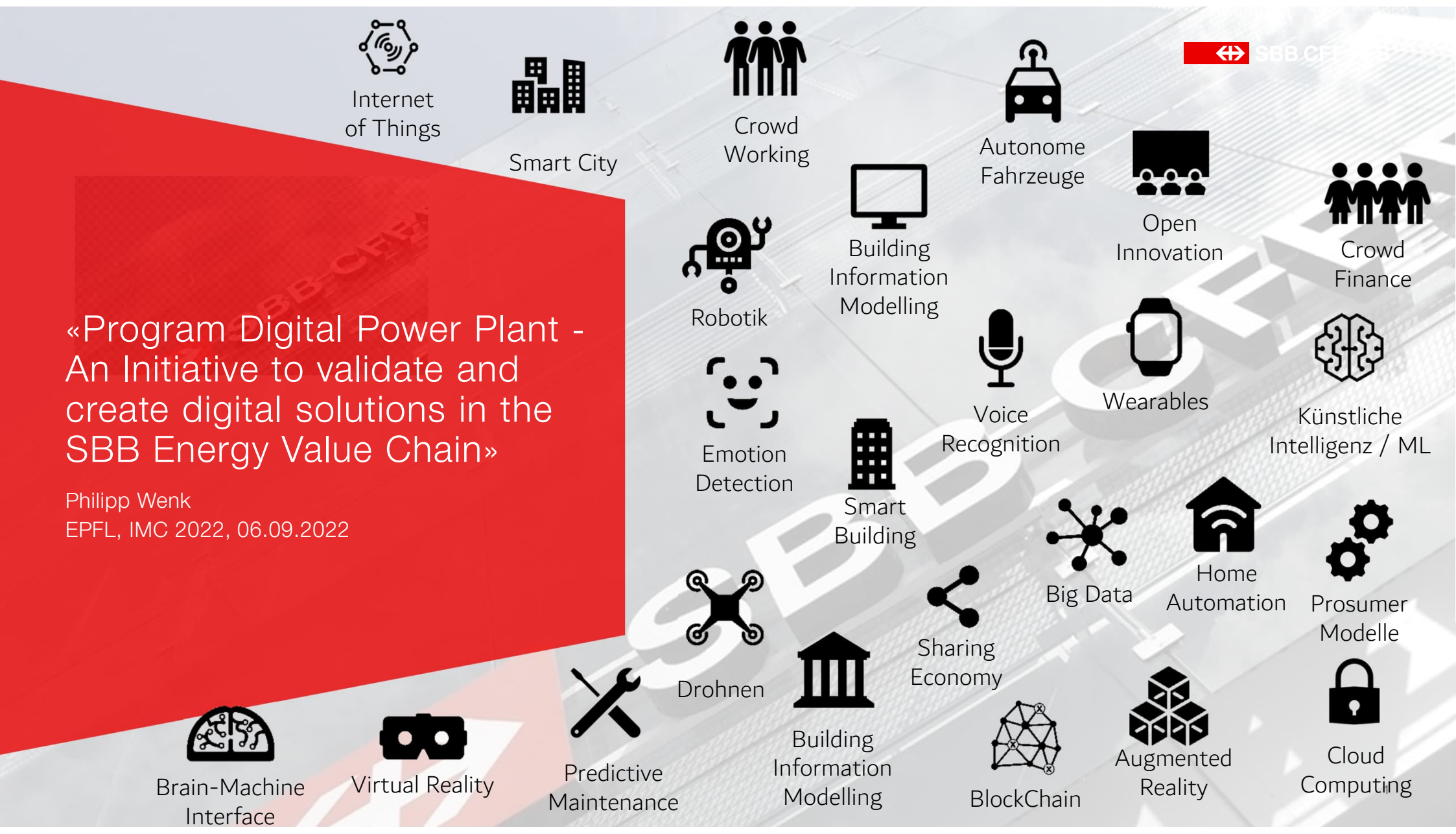


«Program Digital Power Plant - An Initiative to validate and create digital solutions in the SBB Energy Value Chain»

Philipp Wenk
EPFL, IMC 2022, 06.09.2022

«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

90 %
Renewable energy

100%
Per 2025

SBB's Traction Power Infrastructure.

Secure, cost-efficient, ecological.

40
MCHF in revenue (50 Hz)

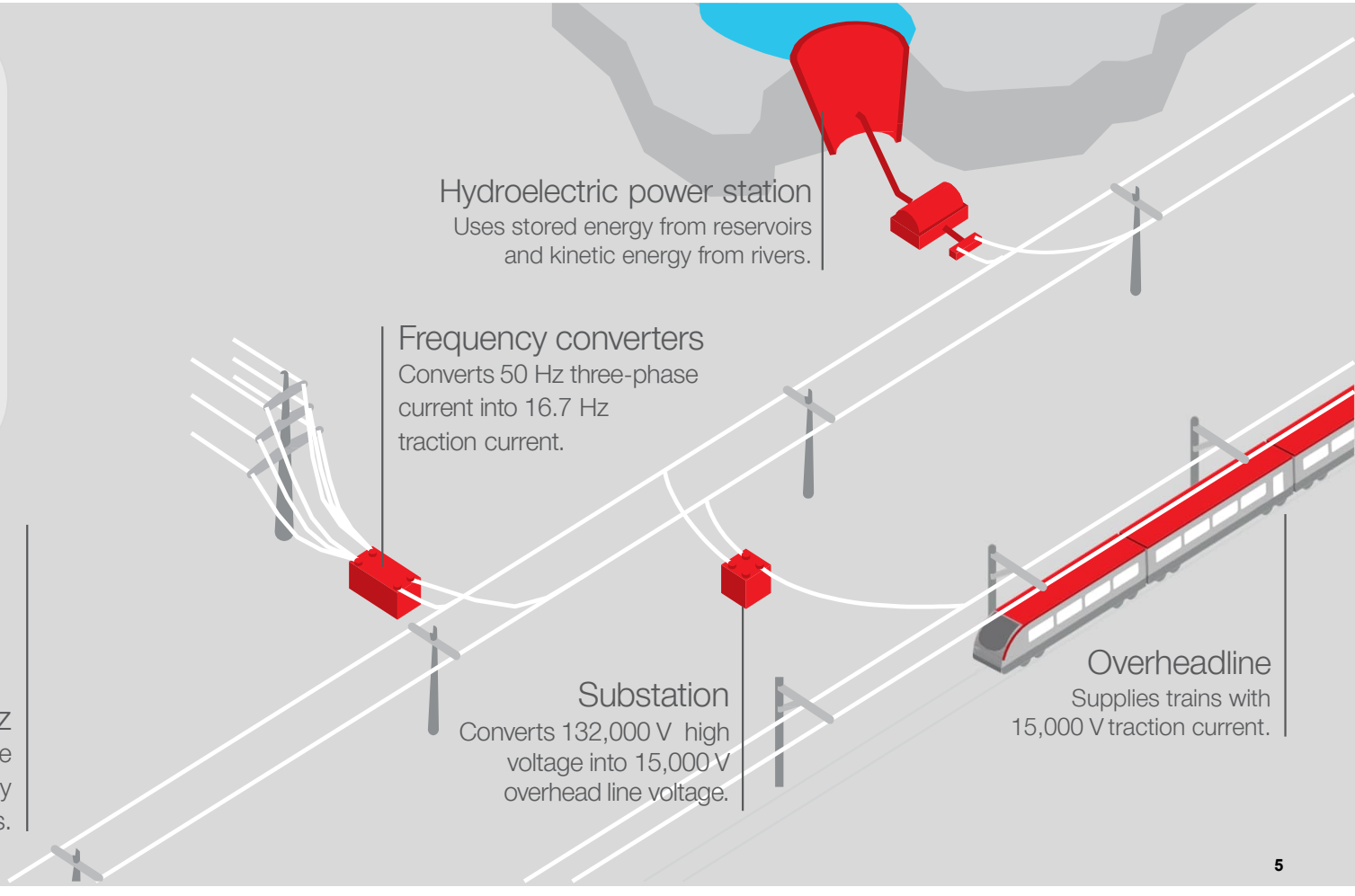
219
MCHF in revenue (traction current)

365
FTEs

1047
MCHF – book value

6790
MCHF – replacement value

2157
GWh – traction current sales in 2020



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

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

Standard network 50 Hz
SBB also "taps into" the electricity used by industry and households.

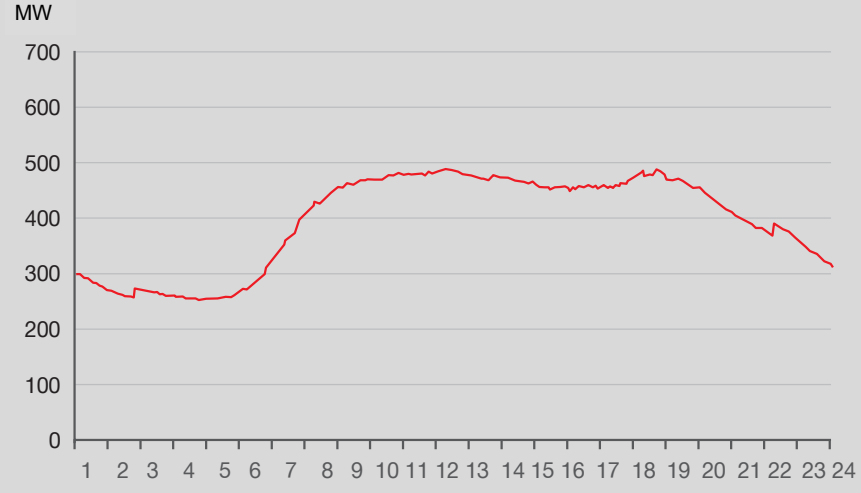
Substation
Converts 132,000 V high voltage into 15,000 V overhead line voltage.

Overheadline
Supplies trains with 15,000 V traction current.

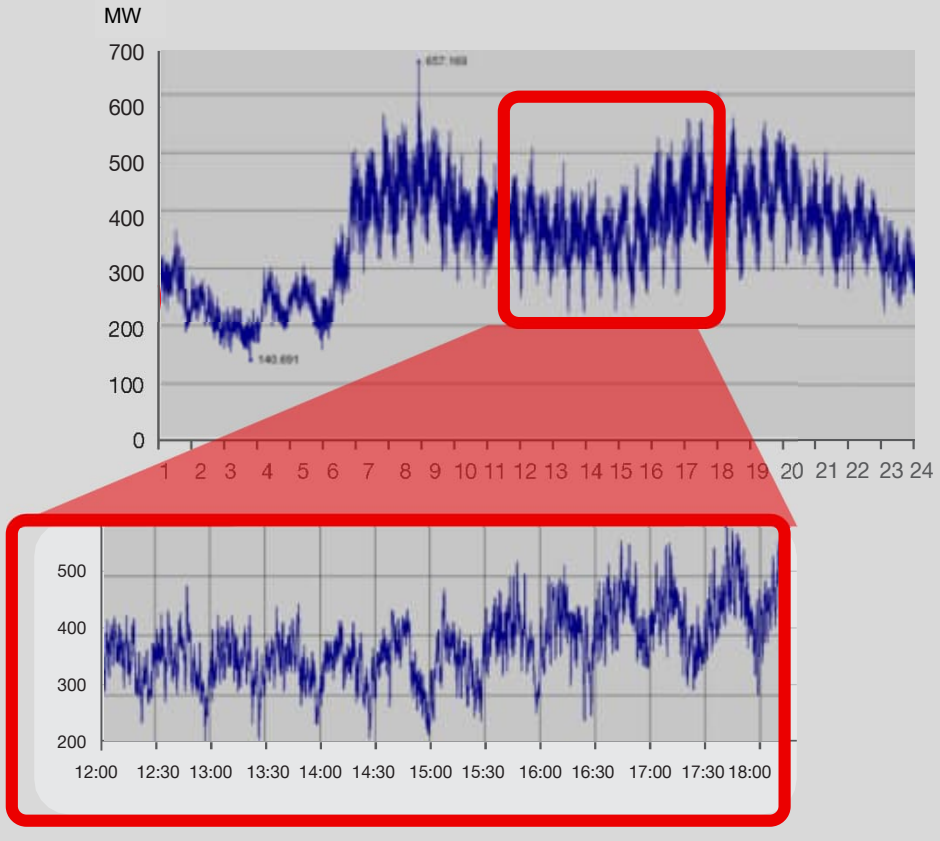
Traction current network (16.7 Hz).

Dynamic power profile is challenging and expensive.

1 day in Zurich city (50 Hz)



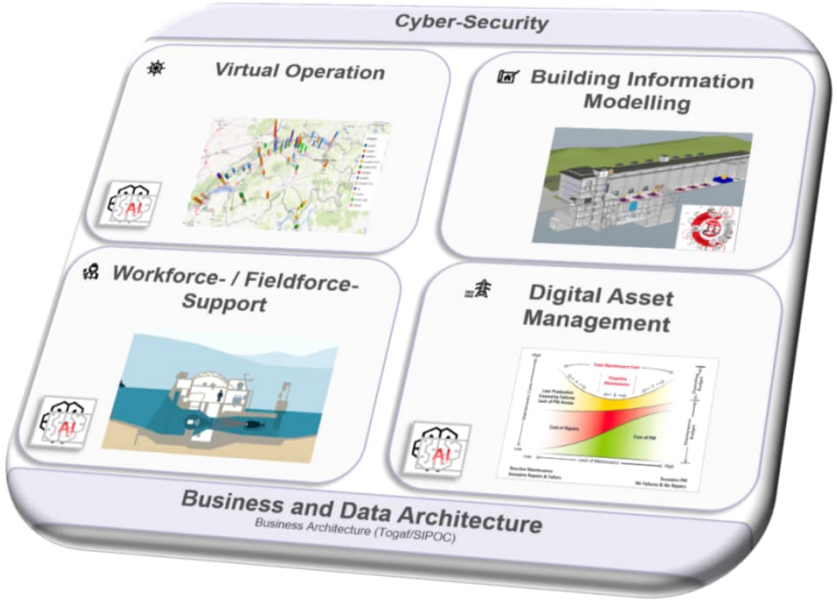
1 day at SBB (16.7 Hz)



Load changes	Zurich city	SBB
daily	up to 250 MW	up to 500 MW
within 15 min.	up to 35 MW	up to 300 MW
	7% of maximum load	**50% of maximum load**

Overview «Program digital power plant»

Overview «Program Digital Power Plant»



Key Facts

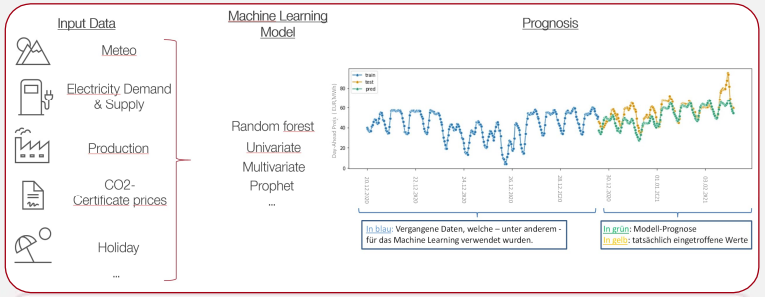
- Digitales Kraftwerk started autumn 2019
- Four fields of actions
- About 39 PoCs (16 of them terminated)
- Interdisciplinary teams with more than 50 employees participating
- 25 PoCs in Inno-funnel for 2022

- 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.

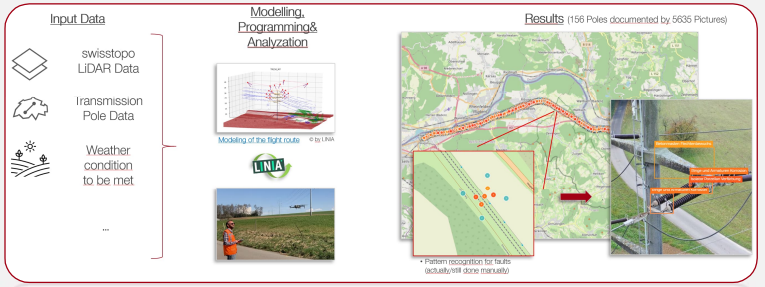


Building Information Modelling

Open Innovation with Startup Gilytics for faster and comprehensive exploration of line paths – brings better arguments towards stakeholders

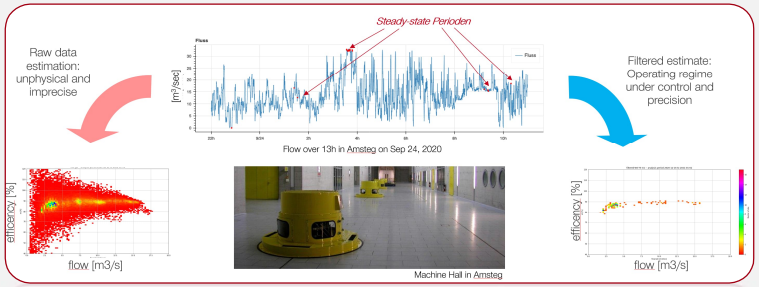
Work- and Fieldforce Support

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.



PoCs in DigiKW 2022: Innovation funnel

Status Aug2022

IDEAS

BACKLOG

Standort-bezogene Drohnen für UW-Über-wachung

Automatische Erkennung Schadensbilder UL

Monitoring Abarasion (NG-Hydro)

Hydro Condition-Monitoring

Preisprognose Intraday

Bieterstrategie SDL

Lastprognosen Intraday

Echtzeit Anlage-zustand Massaboden

Zustands-monitoring Trafos

Initiative SENSE (externe Anfrage)

Mitarbeit EN

Optimierung Leistungstarif GBT

Flexibilitäts-bewirtschaft-ung USV

validate

Optische Schallmessung Etzelwerk (Körperschall)

Produkt DCS Daten

Inno-Ecosystem: AI Camera

Inno-Ecosystem Health Index

develop

Daten-speicherung/-archivierung Pointclouds& 3D

Strategische Kabelplanung SDE

Inno-Ecosystem: Incidents & Failure-Mgmt.

Optimierung Übertragungs-verluste Umformer

Maschinen-ersatz KW Wassen

Leitungs-ersatz UL361

Daten-management Schaltposten Romanel

Failure-Mode-Modell Beschaffung

SCADA-to-the-Cloud für KW VE

Leistungs-schalter - Projekt INCITE

pilot

UL-Inspektion (LINIA)

Inno-Ecosystem BVLOS Macro

Analysen ZLS-Daten - Projekt INITIATE

Efficency forecast hydro - Projekt INITIATE

UW Boudry-Boucle Nord (Corneaux – Yverdon)

BVLOS Drohnenflug (LINIA)

UL Digitalisierung mit IED für Netzgebiet Tessin

Predictive Maintenance Leistungs-schalter II

IoT-Über-wachung Wandler-Kästen

implement

Feldtest Netz-wiederaufbau in 5'

Semi-AI-Powered Dokumenten-klassifikation

Reference Cases S/4 - Functionality sensors

BIENE – Batterie Zugkunft

Zufluss-prognose m. Meteomatics

Digitalisierung UL Netze (Clean-up)

Zufluss-prognose m. Meteomatics

BUC Erprobung Etzelwerk

Preis-prognose day-ahead

Adaptathon PoC Energy Storage

BIENE – Batterie-schwarm im Netz

Predictive Maintenance Leistungs-schalter I

AR Fernunter-stützung

Virtuelle Begehung

Netz-wiederaufbau in 5'

Skallerung Virtuelle Begehung

AI-Powered Dokumenten-klassifikation (Visium)

Hotspot Detektion

Staudamm-Inspektion mit AI

50Hz Flexibilitäts-bewirtschaft

Skal. AR Fernunter-stützung

Mastap – Überwachung Stabilität v. Masten

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. Bewirtschaft. BIM Work- & Fieldforce Digital Asset Management

Example «managing a future battery swarm»

Project BIENE (= Batterieschwarm im Bahnstromnetz)

Ambition 2040: 100% renewable

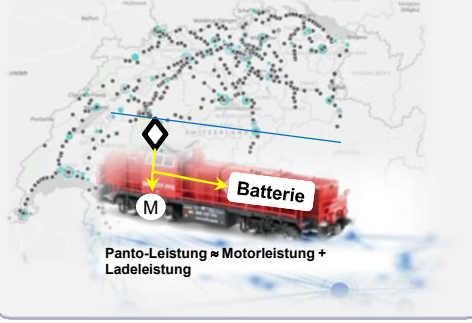
since 2020: "With immediate effect, all new and replacement purchases will be made with renewable energy instead of fossil fuels."

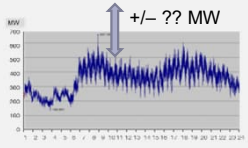
Today around 700 diesel-powered vehicles

..likely to bring a huge battery swarm Into the railway grid.

..of shunting locomotives, con-struction 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

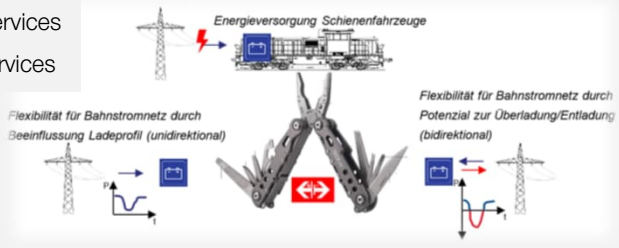
Solution (Concept)
- Load-Management
- Communication/control
- Framework

PoC
- Central Load-Management based on a simulation

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

flexibility through battery management for ..

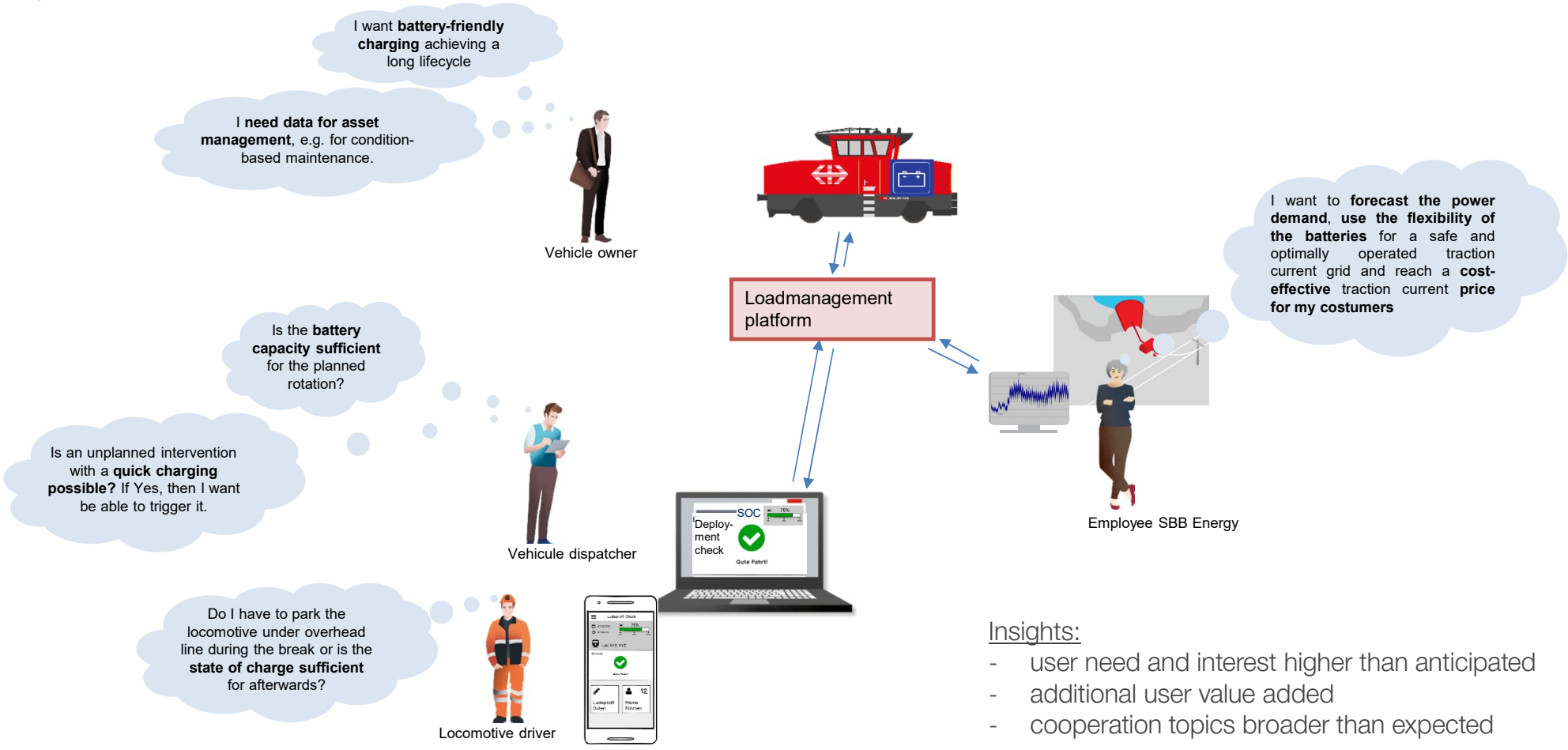
- Grid services
- System services
- Market services



Practical Use/ Value

- Optimization — Invest cost / Life-cycle cost
- Security of supply / reduction Design
- Efficency — System Operation

User expectations of central charging/battery management system.



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

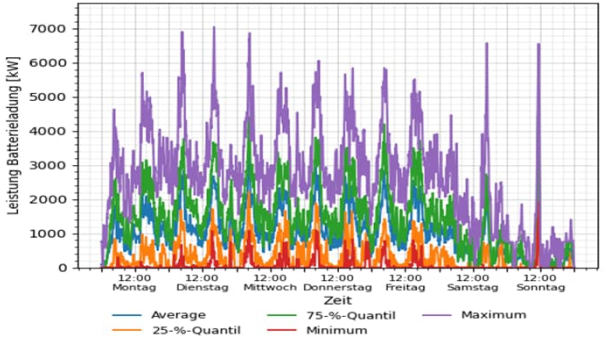
- Vehicle deployment data
- Energy Demand data
- Geographical railway grid data
- Battery properties (aging, charging, costs, ..)
- ...

Model

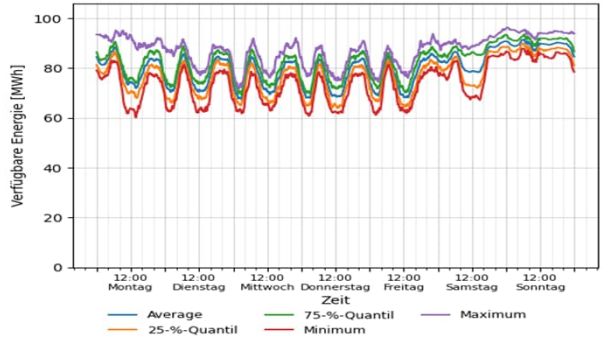
- Simulation for unplanned Load risks
- Simulation for flexibility estimation
- Simulation for benefits of value cases
- ...

Results

Weekly profile for load power, unmanaged fleet of 252 Vehicules



Weekly profile for available Flexibility@OL fleet of 252 Vehicules



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)

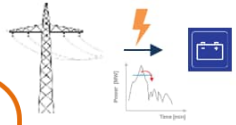
Benefit from a central charging/battery management system.

1. User-optimised charging management

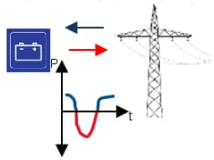
	Benefit
1.a. Secured state of charge for vehicle use	●●● Indispensable for vehicle operation, alternatives more expensive
1.b. Battery-friendly charging	●●● Savings > 1 million CHF/a, Reduction of grey energy due to longer battery lifecycle
1.c. Asset management and data access/availability	●●● More reliable operation and cost savings. Alternatives more expensive

Energy supply for rail vehicles

Reduction of additional load for traction power grid by influencing the charging profile



Flexibility brings economic benefit for the traction power grid



2. Minimise costs and risks from additional load

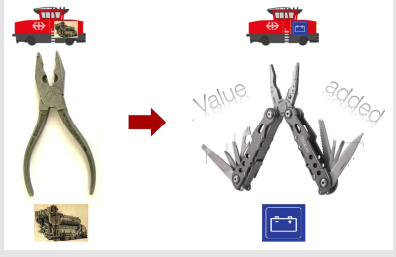
	Benefit
2.a. Avoiding grid reinforcement due to overload	● Reduction in need for additional infrastructure at charging hotspots
2.b. Avoiding expanding production capacities	●● NPV: approx. -1-3 MCHF through load management

3. Added value of energy management

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

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...)

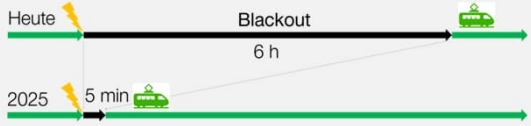
- From diesel to battery: change of technology carrier with influence on operation and charging infrastructure/energy supply.
- A follow-up project “BatterieZugkunft 1.0” is taken up with broader/interdivisional topics
  System tasks & coordination / Central battery management / Vehicle & battery requirements / 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.

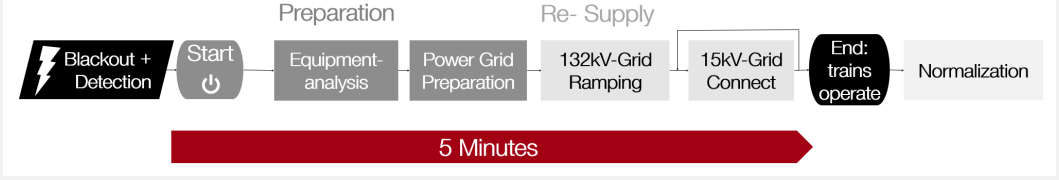


Implementation

The implementation is based on three pillars.

The simulation models & Field Tests ensure robustness.

Grid Restoration Process



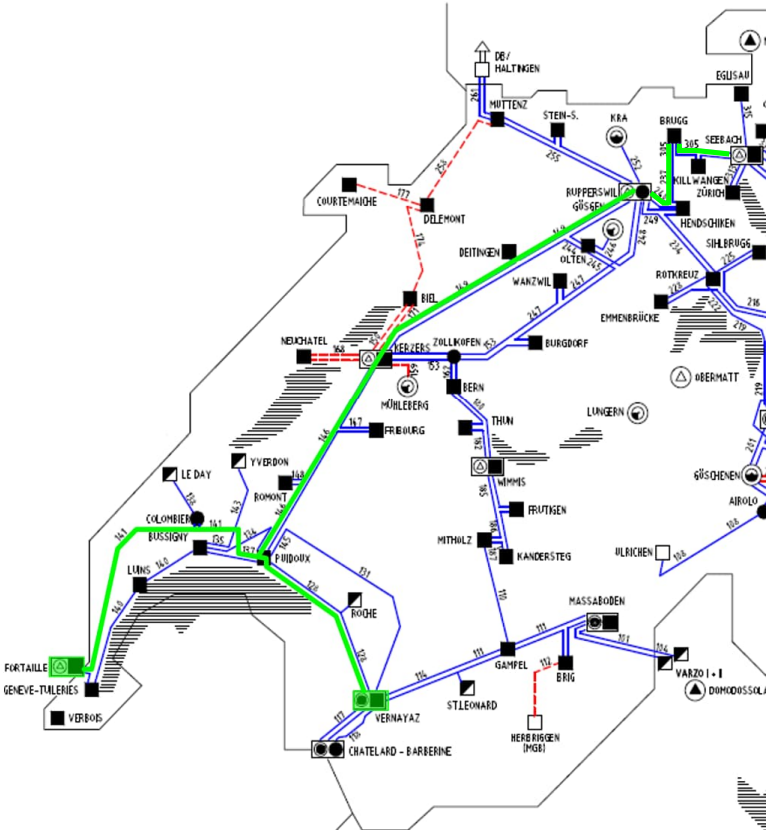
Grid restoration today and in the future

Topic	Feature	conventional	actual optimized	partially-automated	automated
process simplification	number of switching operation	≈ 1600	≈ 500	≈ 450	≈ 450
automation in control system	switching commands	manually	manually	manually	automated
power generator control	behavior in fault-events	shut down	shut down	Restart automatically	Restart automatically
Overall-Results	time for Re-Supply	6 h	3 h	2 h	5 m
		2021	2022	2023	... 2025

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

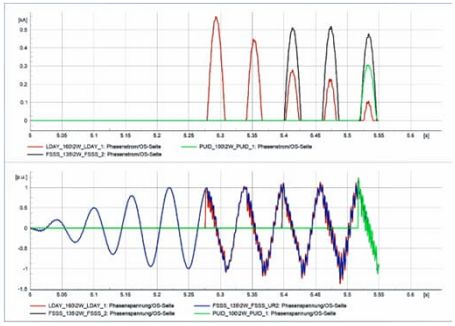
Test procedure:

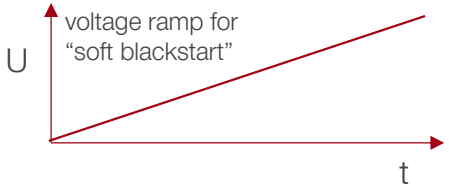
- Generate artificial blackouts on the test grid
  - ca. 20 blackouts initiated
- Power up the grid using different configurations
  - Ramp up times between 2 – 40 s tested
- Measure response of production units, transmission lines and protection with high resolution measurements

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