Behind the HMI: The Invisible Nervous System powering Next-Gen SCADA

Herbert Wein
Stefan Sommerer

3. Juni 2026

VERBUND Hydro Power

Agenda

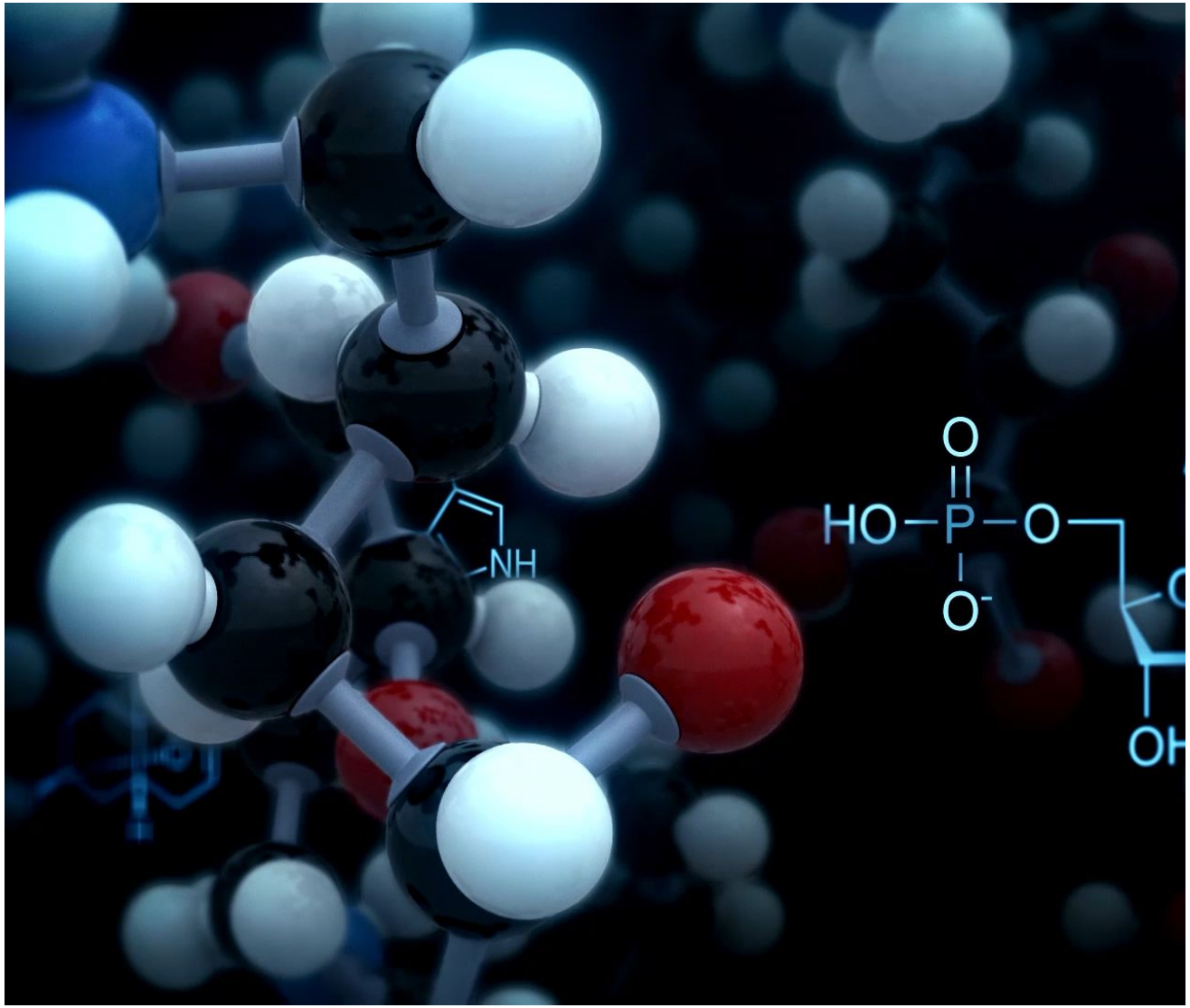
Introduction: The Whispering Giants

Vision: VERBUND Hydropower 4.0

- Unified HP HMI / OpX
- Centralization
- Standardization
- Modernization

Challenge: The Invisible Herculean Task

- Data: From Legacy Data Chaos to the Digital Brain
- LLM Hype and the 50/50 Trap
- The Shift to Determinism
- The Knowledge Graph as the True Digital Brain
- Teaching the Computer Our Language



Speaker

WEIN
Herbert

Section Manager
&
Operation Manager

for VERBUND Hydro Power
OT Systems

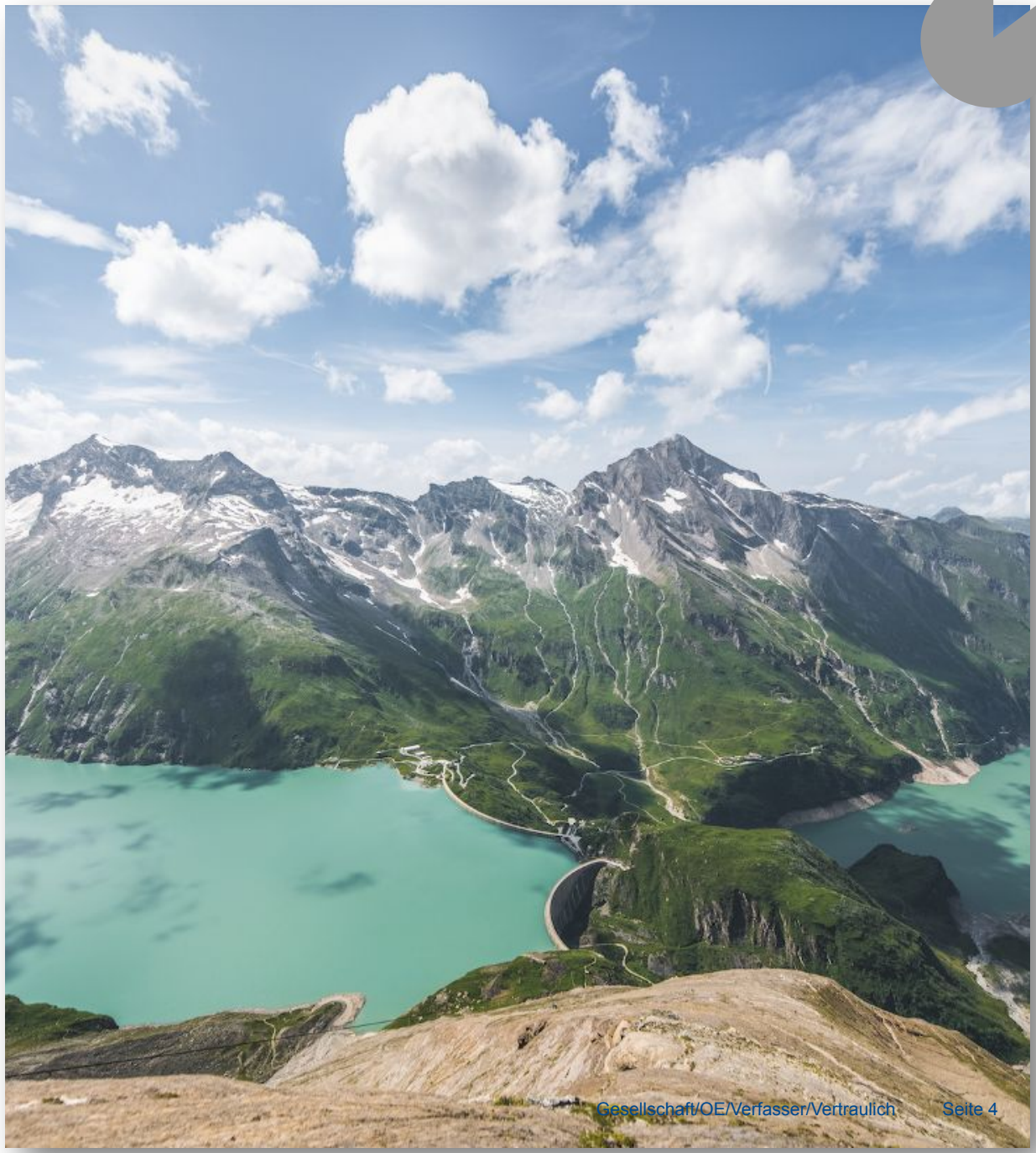
SOMMERER
Stefan

Project Manager
&
System Administrator and Responsible
for the Whispering Giants

for VERBUND Hydro Power Plants
in the Alps

The Whispering Giants…

- Continuous Energy Generation
- Strategic Storage Systems
- Energy at the Push of a Button
- Historically Grown Structures



Who is Verbund Hydro Power GmbH?

- Backbone of the Energy Transition
- Operator of Critical Infrastructure (113 Run-of-River/Storage Power Plants and 28 Large Dams)
- Base Load Coverage via Run-of-River Power Plants
- Peak Load Coverage via Complex Storage Power Plants

Vision: Operation Security Centre (OSC)

- Unified HMI
- Centralization
- Standardization
- Modernization

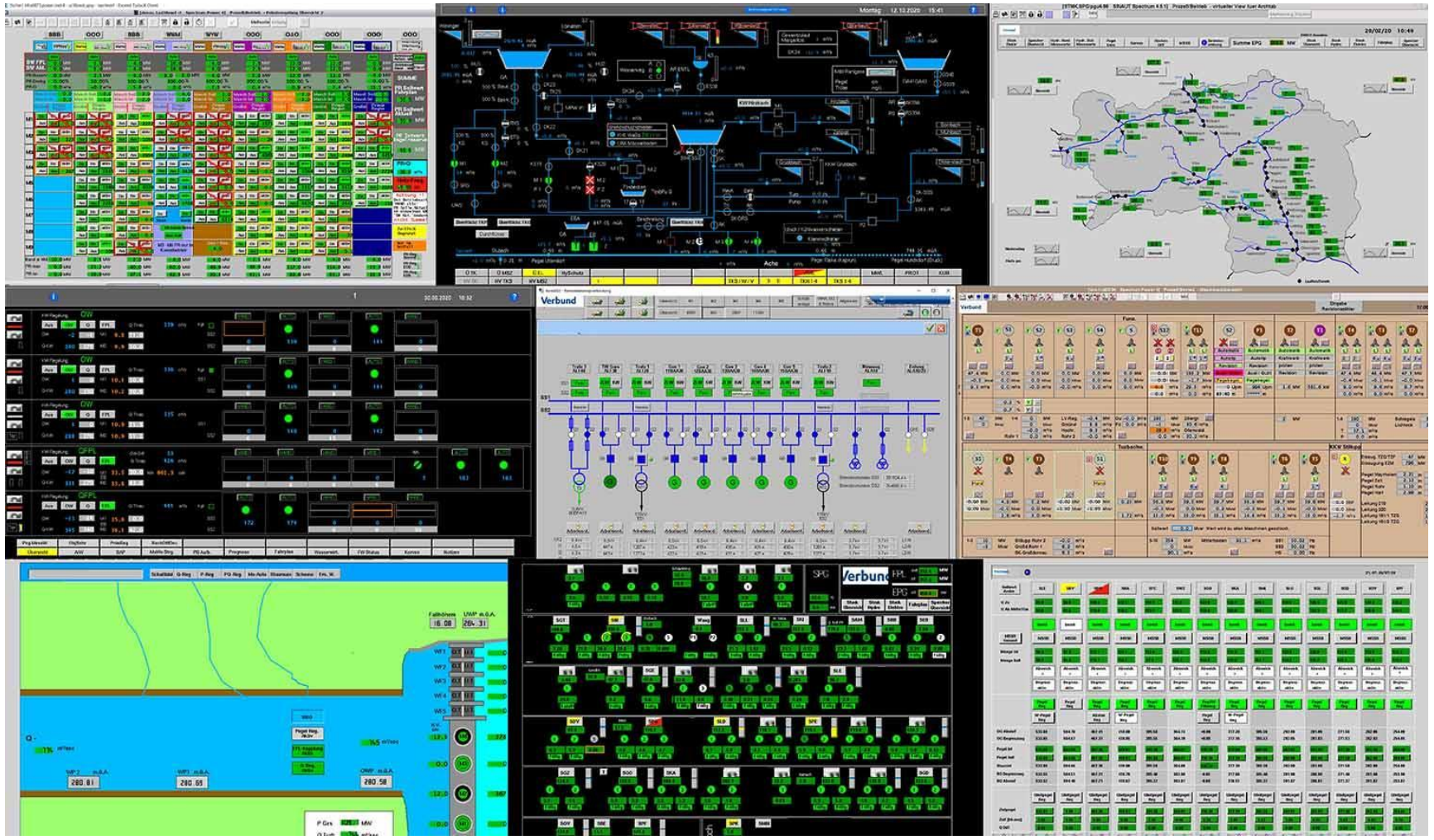
Navigating space, time & data

Let's take a journey through the evolution of HMI in VERBUND's hydropower

Process Automation as a Driver of HMI Complexity

HMI for 1 powerplant in the 1940s

HMI for 8 controlrooms for 113 + powerplants in the 2000s



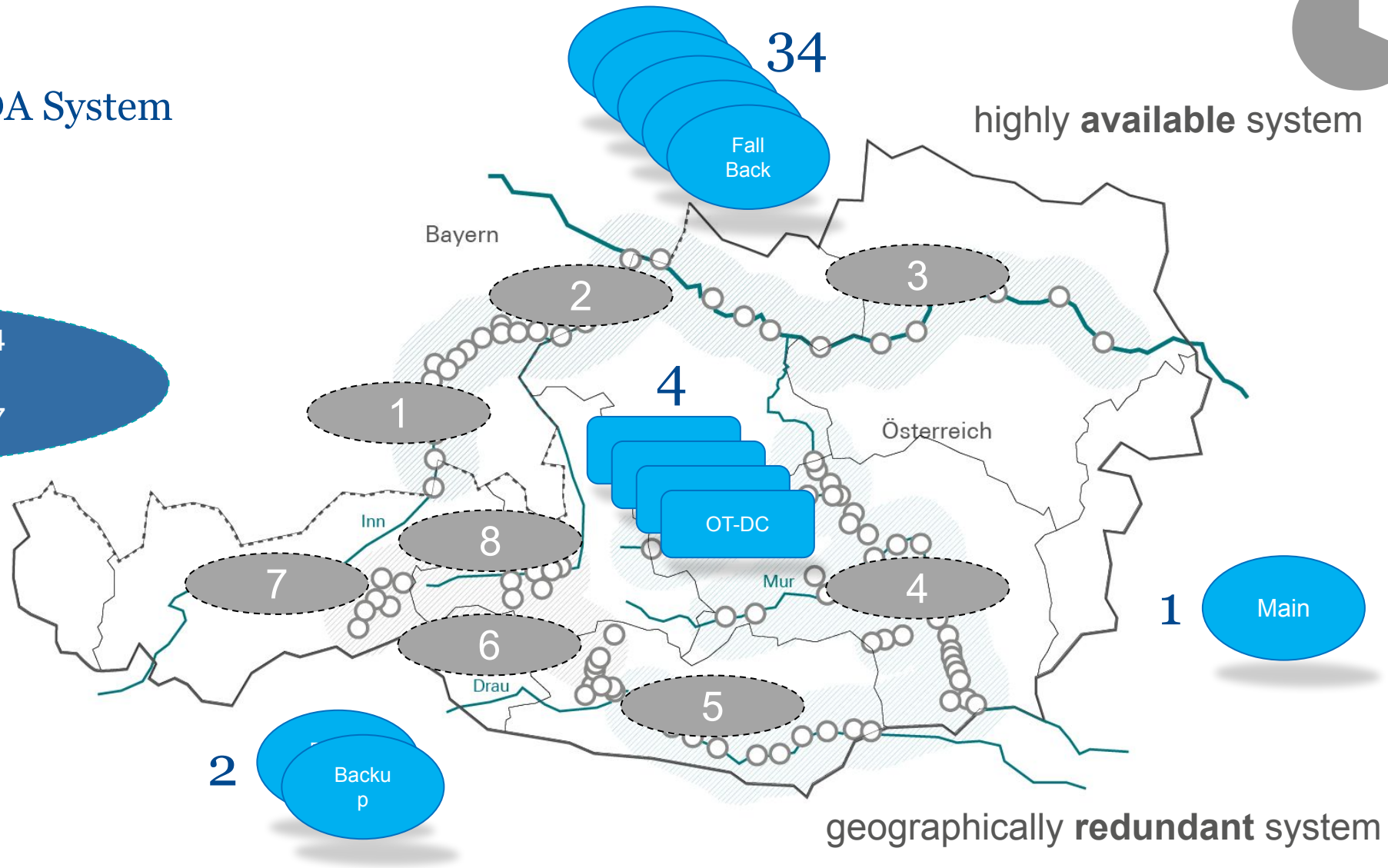
Project OSC

9 Plant Groups und 1 SCADA System

8x Spectrum Power 4
Transfomation to
1x Spectrum Power 7

370.000 Data Points
9.000 Images

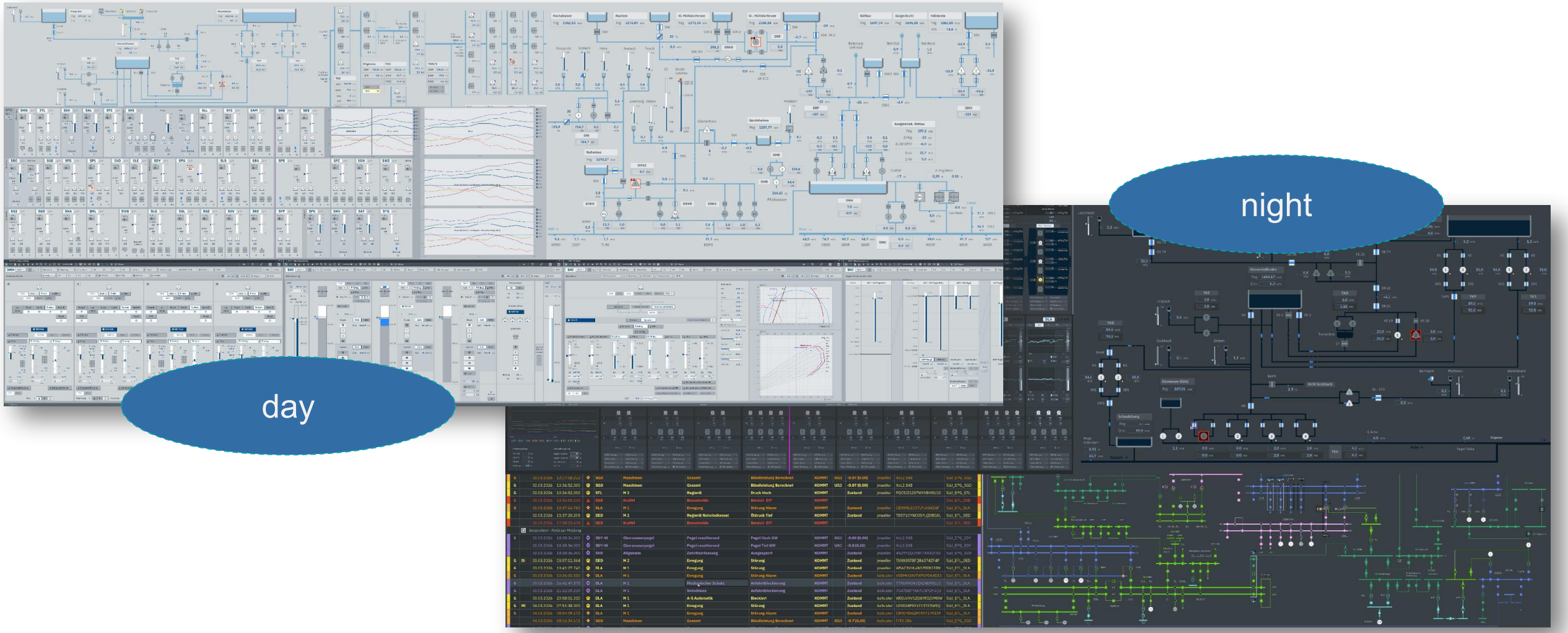
120 Server
150 Clients



113 hydro powerplants (**346** Generation Units und **148** Weir of the hydropowerplant)

New Era – Introducing High Performance HMI

HMI for 1 controlroom to control 130 powerplants for the future



THE HIGH-ALPINE CHALLENGE

Focus on Storage Power Plants

Why the Complexity of Storage Systems defines the Absolute Technological Upper Limit.

Dimensions of the Storage Plants Systems

Extreme Spatial Dispersion

Storage power plants are not compact blocks. They are decentralized networks inside the mountains.

- **Auxiliary Systems**: Dozens of support systems per power plant
- **Penstocks & Waterways**: Kilometers of tunnels equipped with sensitive sensors
- **Asset Density**: Factor of 5–10 higher than in standard run-of-river plants

A run-of-river plant is "simple" by comparison – but the data model must support both

Waterways & Location Topology

The greatest complexity of storage power plants lies within their geography.

- Structured mapping of extensive auxiliary systems.
- Clear and unique paths for maintenance and emergency teams.
- Modeling of complex hydraulic interdependencies.

Only a deterministic model ensures that the team drives to the correct system in an emergency.

Dimensions of the Storage Plants Systems

Construction Area of an Underground Cavern Power Station

Babylonian Data Heterogeneity

9 Power Plant Groups

Each plant group uses a different, historically grown legacy system.

Cryptic Abbreviations

Asset tags that are unreadable without proprietary VHP "decoder" knowledge.

Inconsistency

Identical asset types are named completely differently across systems.

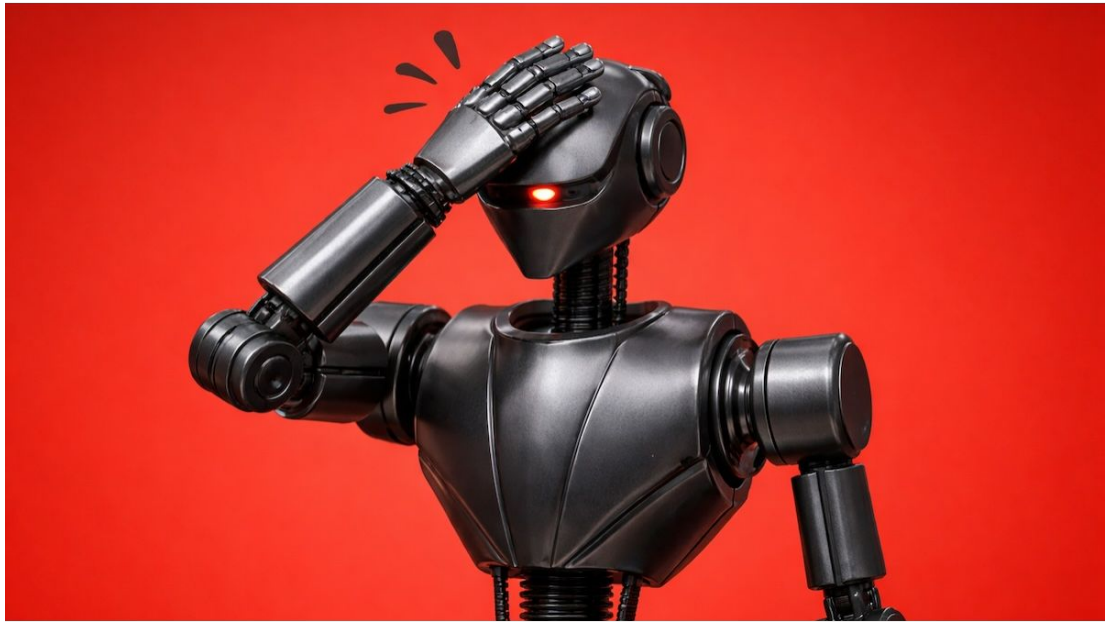
AI Has No Real Intelligence

AI Has No Real Intelligence

Statistics over Causality: LLMs are based on probabilities. Brilliant for creative writing – a massive hazard for technical translation.

```
Input: "220V Schalthaus" -> P(Output) = ?
Problem: Same prompt = Different results.
```

Without a closed context, the model "invents" new technical terms (hallucinations).



The 50/50 Trap (Accuracy)

50

Accuracy

%

The Measurability Problem

Since the output of the LLM cannot be verified automatically, it is worthless to us.

- LLM-internal metrics hold no real-world validity.
- Distance measurements (RAG Vector) only measure similarity.
- Similarity <> Technical Accuracy.

The RAG Paradox

Context Explosion

A RAG system with 5,000 sample translations bloated the context window so heavily that the model became unable to decide.

Inconsistency Transfer

Manual examples contained errors themselves. The LLM "rolls the dice" when faced with inconsistent input – multiplying the unreliability.

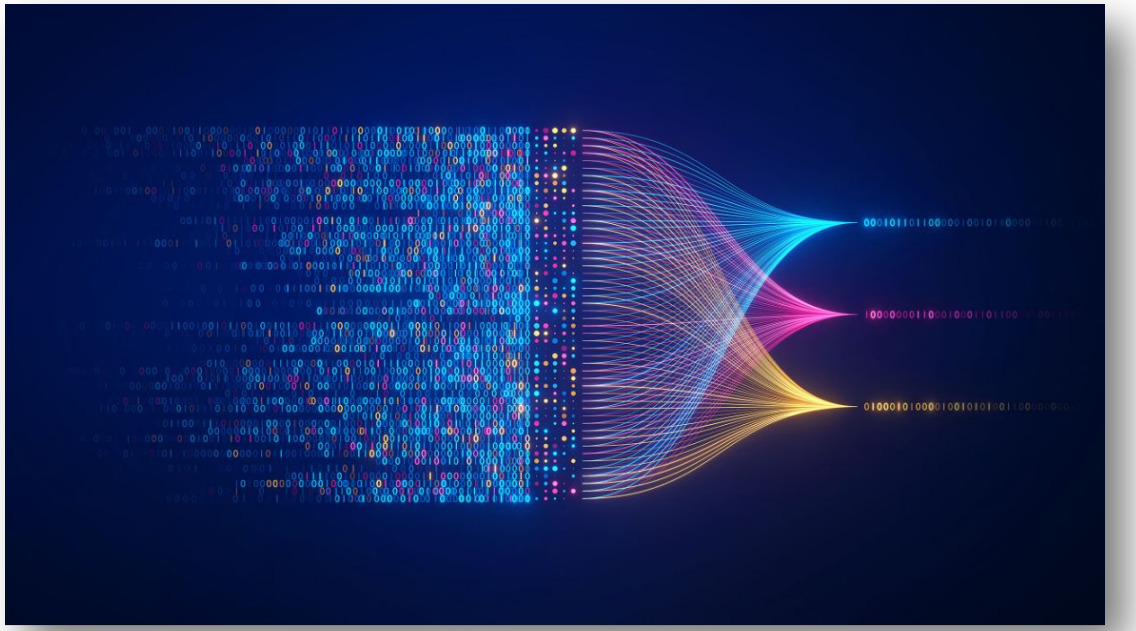
Result: Manual verification effort remained at 100%.

Deterministic Transformation

The 4 Phases of Translation

Step	Action	Goal
1. Tokenization	Decomposition of legacy terms	Identification of technical core components
2. Categorization	Distinct assignment	Generating structural metadata
3. Allocation	Rule-based mapping	Populating target fields in the new model
4. Normalization	Standardized suffix rules	Always yields the same, fully auditable result

The Knowledge Graph: The Brain



Dictionary & Grammar of VHP

The graph is far more than a database. It links data silos and stores the implicit know-how of our engineers.

- No Knowledge Loss: Experience is directly hardcoded into nodes and edges.
- Interface: The primary platform for human-to-machine communication.
- Documentation: The data model documents itself natively within the graph.

From String to “Real Object"

The "Bank" Ambiguity Problem

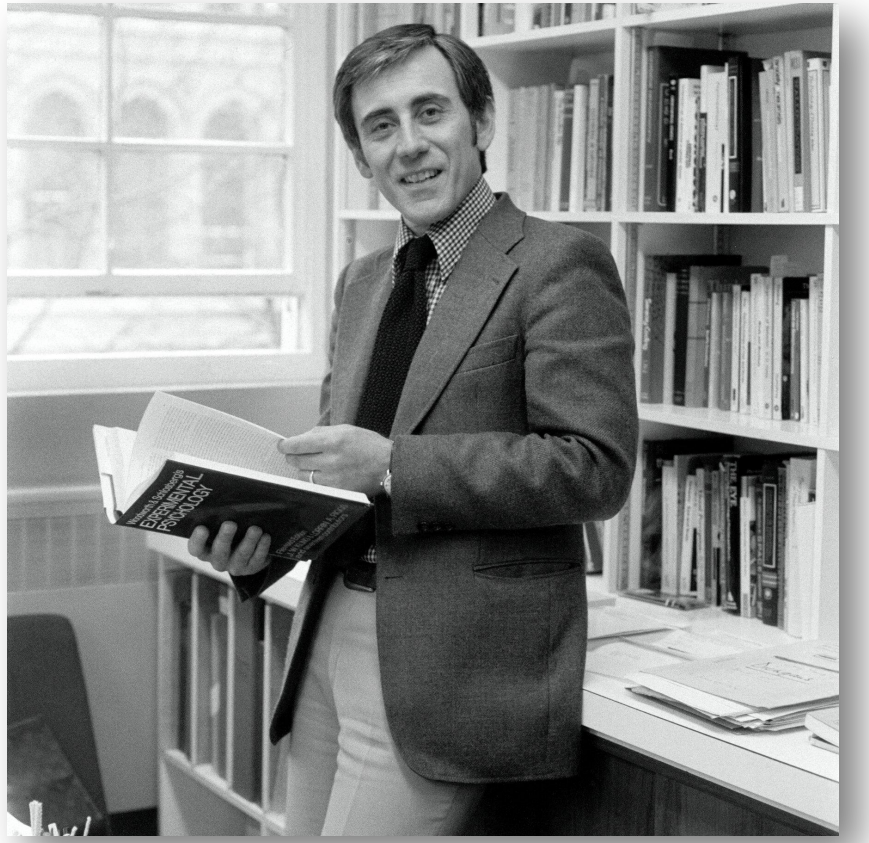
The LLM guesses statistically (Park bench? Financial institution?). The Knowledge Graph knows via topology: Riverbank at the Danube power plant.

Real Assets

We do not define text strings ("220V DC"), but a unique asset that physically exists in the mountains.

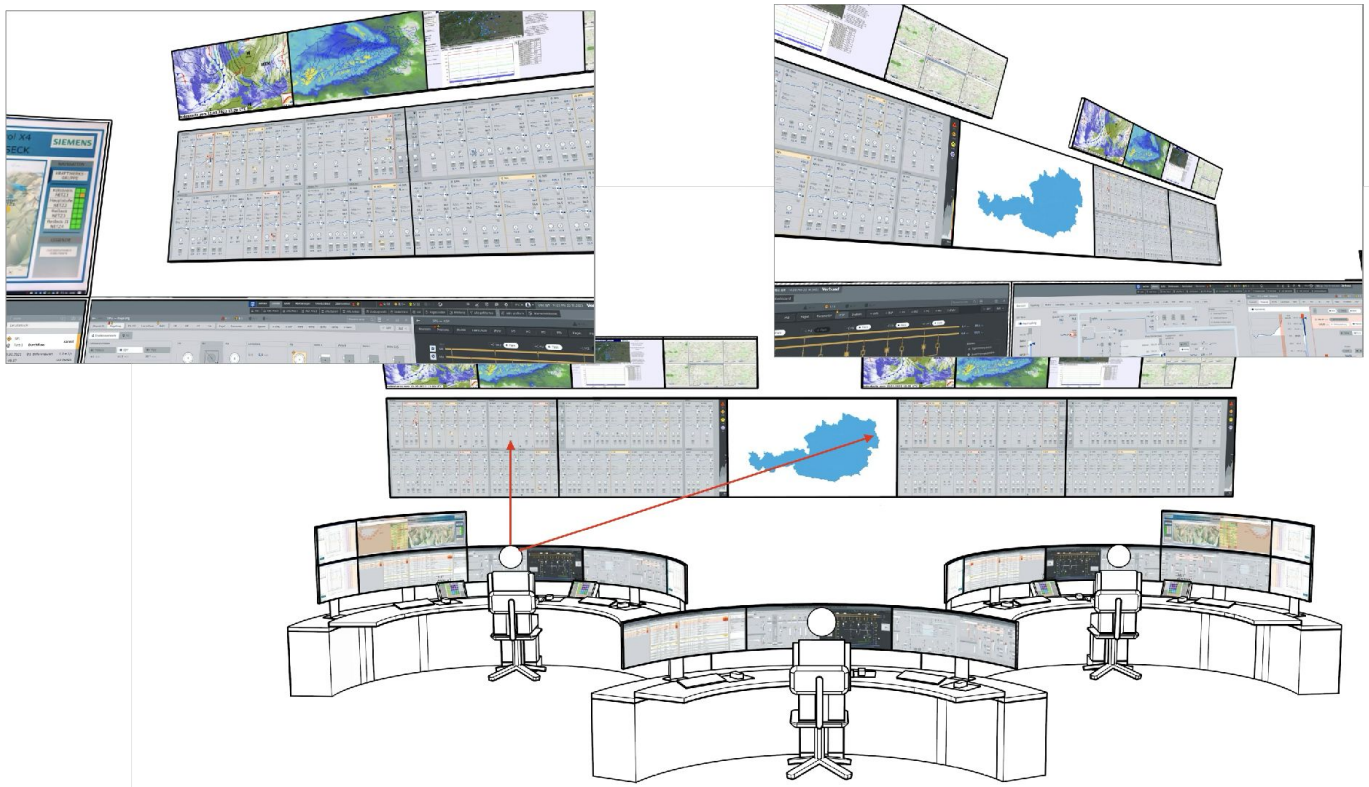
The Art of Work

“You cannot change the human condition, but you can change the conditions in which humans work.”



James Reason

The New Operation Control Center



Status Quo of the Transformation

Reference Model

Completed. All plant group legacy datasets are fully integrated.

Workflows

All conversion and validation pipeline stages are finalized.

SCADA Interface

The interface connecting to the central SCADA system is fully operational.

The Path to the Digital Brain

202

Global Go-Live

6

By establishing a clean structure inside the Knowledge Graph, we created the foundation for true Industrial AI.

We taught the computer our language instead of letting it guess.

Summary

There is light at the End of the Tunnel…

- ✔ Storage power plants successfully harmonized as primary complexity drivers.
- ✔ LLM shortfalls resolved through deterministic Knowledge Graphs.
- ✔ Safeguarding institutional knowledge by encoding engineer know-how directly into data.
- ✔ Foundation successfully laid for future automation and AI optimization.

Questions?

From Data Chaos to Alpine Mastery.

VERBUND Hydro Power
Centralization & Data Engineering

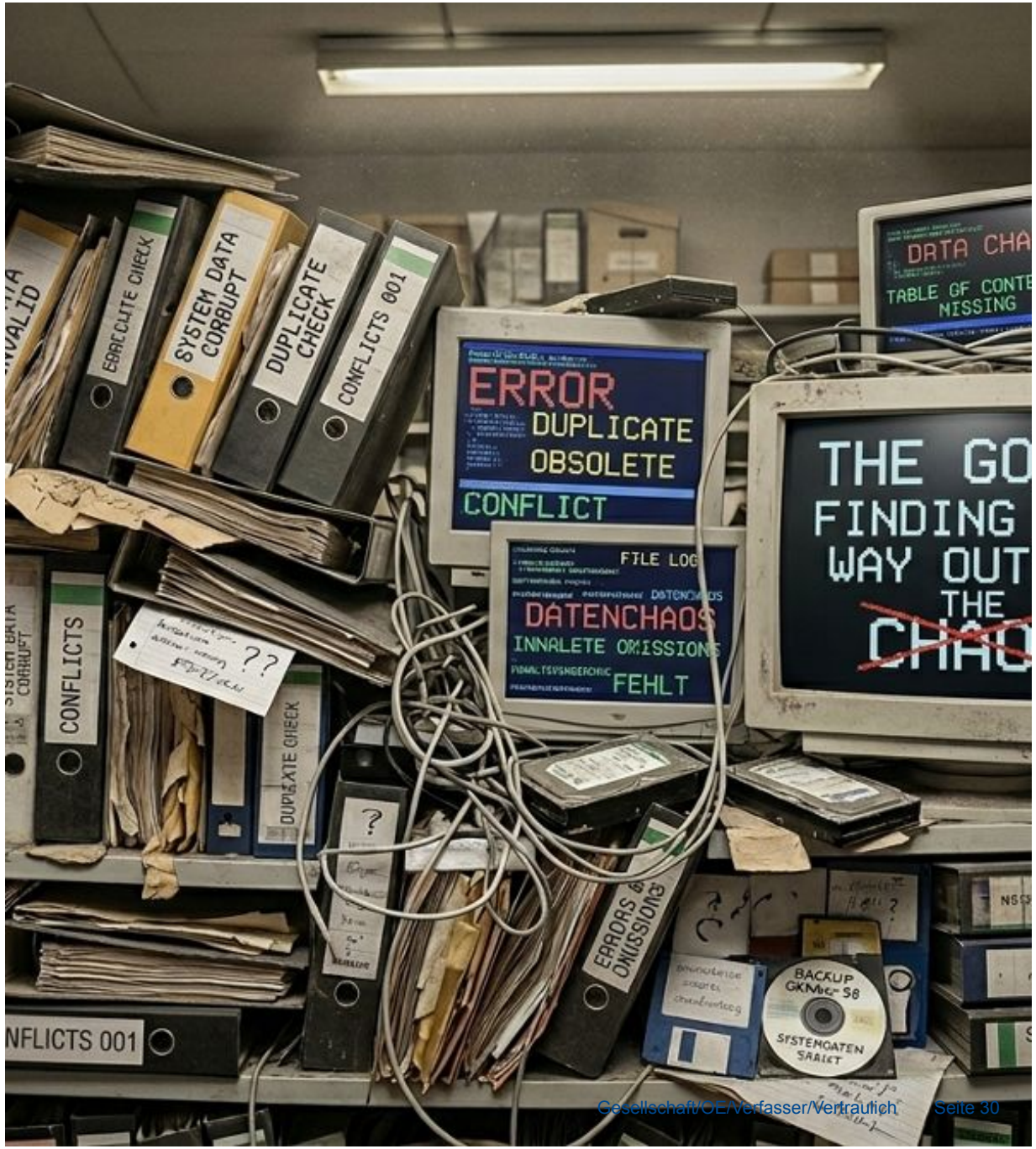
Data Week 2026
Building the Knowledge Graph

WEIN Herbert
HP HMI / UX > OpX

Operation Centered Design

Daten: vom Altdatenchaos zum digitalen Gehirn

- **Die Kernaufgabe:** Ein einziges, einheitliches Datenmodell
- **Die Harmonisierung:** einheitliche, standardisierte Sprache
- **Die Balance:** Flexibilität vs. Stabilität
- **Das Ziel:** Standardisierung der Datenpunktsbezeichnungen für ein konsistentes HMI- sowie Alarmierungskonzept



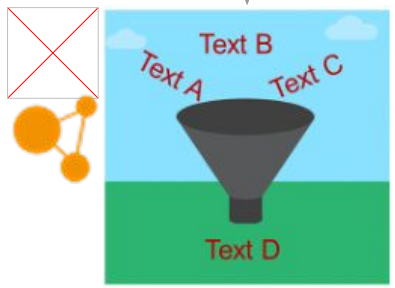
With semi-automated conversion, we achieve a high degree of harmonized structures & designations.

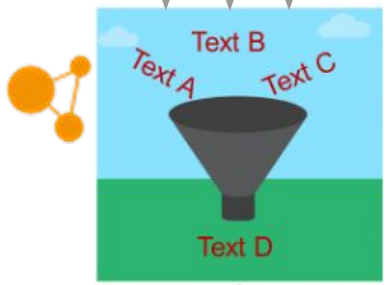
Bestand

	werksgruppe	bildrelevant	b1	b2	b3	elementtext	elementtyp	elementtyp_status_kommend
1	EZM	false	TZB	Großdor-SK	F 24-GLR	Verteilung Allgemein	EWMNAL00	Autfall
2	EMH	false	DRP	TWK Burgstall	24V DC-Anlage GLR	SiAut	3201	Warnung
3	EKH	false	TKO	Käfer EN	AllgemeineAnl	GLR-Sicherungsausf.	Warnung	Warnung Ein

→ von 347.000

Konvertierung





LLM-Ziel

werksgrup	vv_dnfKraftwerk_llm	vv_dnfAnlage_llm	vv_dnfFunktionsbereich_llm	vv_dnfAggregat_llm	vv_dnfBetriebsmittel_llm
EZM	TZB	Großdor Schieberkammer	Verteilung Allgemein	24V DC Gleichrichter	EM_Störung
EMH	DRP	Burgstall Triebwasserknoten	Sicherungen Ausfall	Automat	EM_Ausgelöst
EKH	TKO Bachfassung	Allgemeine Käfer	Geichrichter Sicherungsausf.	48V DC Gleichrichter	EM_Störung

Ziel

werksgruppe	_DnF_Kraftwerk_KORR	_DnF_Anlage_KORR	_DnF_Funktionsbereich_KOR	_DnF_Aggregat_KORR	_DnF_Betriebsmittel_KORR
EZM	TZB	24V DC-Anlage Schieberkammer Großdor	Gleichrichter	Automat	EM_Ausgelöst
EMH	DRP	24V DC-Anlage Triebwasserknoten Burgstall	Gleichrichter	Automat	EM_Ausgelöst
EKH	TKO-BF	24V DC-Anlage Käferbach Entsander Nord	Gleichrichter	Automat	EM_Ausgelöst

Comparison: Human vs. AI vs. Semi-Automated Conversion

Topic	Manual Konversion	KI Konversion	Semi-Automated Konversion
Context Window	Limited, losses track	1.000-2.000 records	Covers all systems simultaneously
Consistency	Risk of typos	50/50 error-prone	100% rule-based & deterministic
Documentation	External/Separate	Limited audatability	Embedded in the data structure itself
Scalability	Time-consuming & expensive	12-24h / €150-400	Automated workflows enabled

ENDE

Wein Herbert

Backup