

SF2 Systems for Early Detection of Hydrate Formation in Offshore Wells

Close to 7 days of advance warning in the identification of hydrate formation in crude oil production pipelines



12+

Sensor- and Feature Channels fused simultaneously



722.192

Records analyzed (1 Hz Sampling)



90%

Stable State Matching 13h before expert detection



6T 21H

Drift Indication before failure event

THE CHALLENGE – The Invisible Risk in the Deep Sea

In deep-sea production — as analyzed in the **Petrobras 3W scenario*** — ice-like hydrate clusters form under high pressure and low temperatures. These can lead to critical blockages and costly production shutdowns in offshore systems:

- **Late Detection** → conventional SCADA systems often trigger alarms only after critical threshold values have already been exceeded.
- **Model Complexity** → Physical flow-assurance models require precise thermodynamic parameters and continuous validation for each individual asset.
- **Data Scarcity** → Traditional ML approaches require large amounts of labeled fault examples for every well scenario, along with extensive feature engineering.

*) Vargas, R. E. V., et al. (2019). A realistic and public dataset with rare undesirable real events in oil wells. Journal of Petroleum Science and Engineering, 181, 106223.

The core question is:
Can the progression toward a critical hydrate condition be identified as semantic drift several days before the actual state transition occurs?



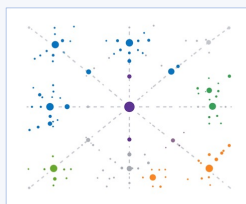
THE SF2 SOLUTION – Making the States of Complex Systems Visible

SF2 transforms raw sensor data into digital state fingerprints, comparable to a “Face ID” for machines. Instead of interpreting individual channels, SF2 learns a characteristic process signature for both normal operation and fault conditions

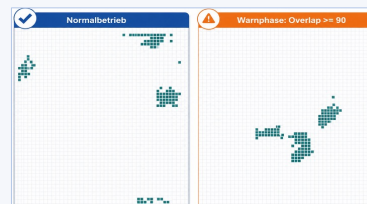
Raw Sensor Channels in WELL-25



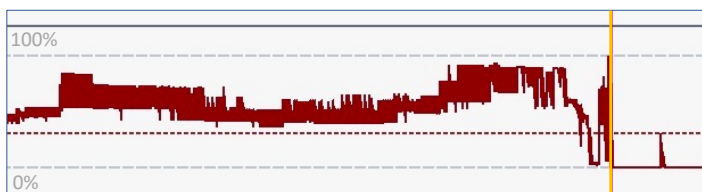
SF2 Sensor Fusion



Fingerprint Operational vs. Warning Phase



THE RESULT – Advanced Early Warning & Continuous Process Drift Detection



Overlap analysis as a time series diagram (excerpt)

Critical range from T-72h to T+12h on a linear axis.

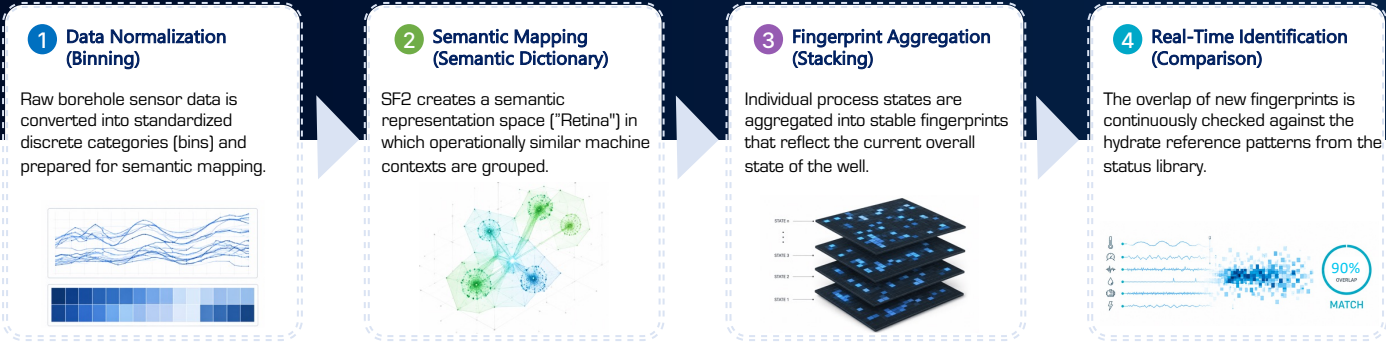
Yellow line marks annotated incident that SF2 identified at an early stage.

Proof of Performance

- ✓ **Substantial Early Warning Lead Time:** Progression toward fault state already visible 6 days and 21 hours before the failure event.
- ✓ **High confidence:** Warning signal (overlap ≥ 90) 13 hours before the expert-flagged event.
- ✓ **Minimal setup effort:** Entire model created in less than 1 hour without manual threshold definition.
- ✓ **No system or data science knowledge required**

SF2 transforms production sensors into an intelligent early warning system for maximum flow assurance

HOW SF2 WORKS



SF2 transforms sensor data into a digital representation of the overall system state and applies semantic mapping to maintain robustness against sensor drift. This enables continuous interpretation of the operational context of borehole sensors at any point in time.

Why Semantic System Understanding Outperforms Statistical AI

SF2 (Deterministic)

✓

Accurate state-based monitoring & prediction

✓

Enables local model per well

✓

No labelled data required

✓

Explainable and reproducible

✓

Real-time, low compute

✓

100% data sovereignty

✓

100% edge-capable / offline – real-time on any device

Model-centric KI (Probabilistic)

✗

Uncertain approximations

✗

Often requires cross-well models

✗

Requires large labeled datasets

✗

Black-box behavior

✗

High compute & high-latency processing

✗

Mostly cloud-dependent (data & security risk)

✗

Not edge-ready

MEASURABLE BUSINESS IMPACT



Per-Well Model

Adaptation to local sensor characteristics



ROI within Hours

Cost-effectiveness even in early operation



Early Drift Detection

Critical conditions visible earlier

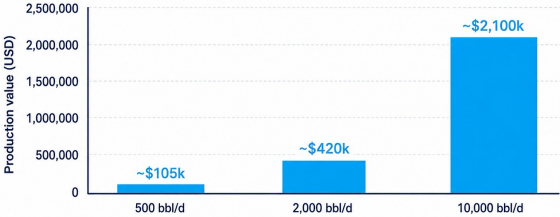


Edge-Ready

Local analysis for offshore infrastructure

Production value only, without workover/remediation costs

Assumption: 70 USD/bbl, 3 days of avoided downtime.



Break-even



\$50k setup at 2,000 bbl/d:
approx. **8.6** hours



\$20k setup at 2,000 bbl/d:
approx. **3.4** hours

CONCLUSION

SF2 converts noisy well sensor data into a consistent real-time representation of system behavior. In this case study, a hydrate formation event with a stable warning time of almost 7 days was detected. This creates the basis for proactive flow assurance and the avoidance of critical pipeline blockages – without complex thermodynamic models.

Learn more at www.SF2systems.com

FUTURE POTENTIAL – Any machine with sensors can become operationally interpretable

Industrial Manufacturing

Chemical & Process Industry

Pharmaceutical Industry

Industrial Equipment

Automotive Systems

Energy Infrastructure

Water & Utilities

Smart Buildings

Digital Infrastructure

Mobility & Transportation

SF2

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