Failure Mechanisms and Technology Evolution in Geothermal Electric Submersible Pumps (ESPs)

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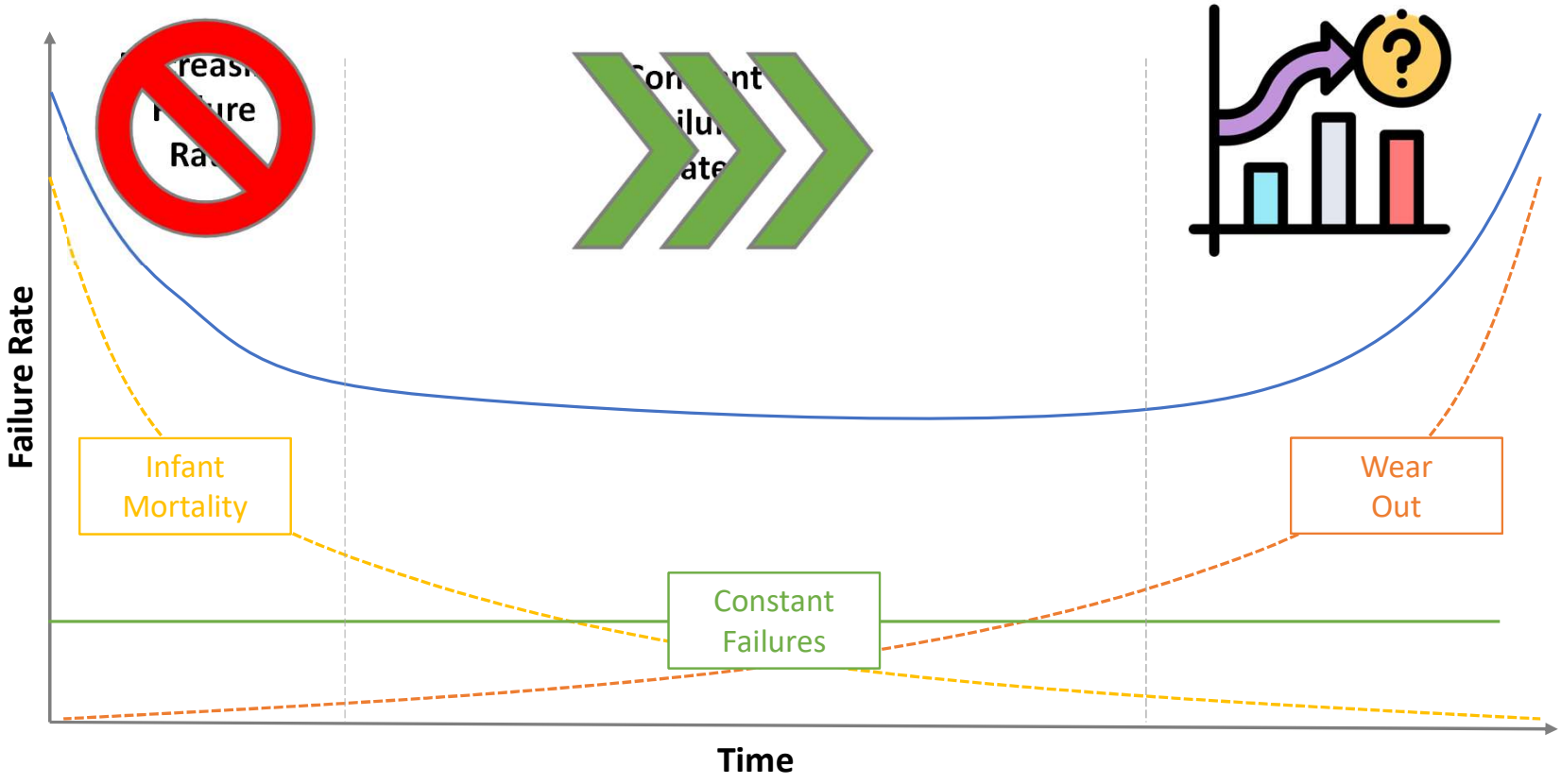
Abstract

Electric Submersible Pumps (ESPs) are the backbone of many geothermal production systems, yet their reliability is constantly challenged by the demanding downhole environment.

This presentation explores the evolution of ESP performance and failure behavior over the lifecycle of the equipment—from early “infant mortality” failures to steady-state operation and eventual wear-out. By examining real-world examples, the discussion will highlight how dominant failure mechanisms shift as systems mature, and how proactive design, operation, and maintenance strategies can effectively mitigate each phase’s risks.

The second part of the presentation focuses on current and emerging developments in ESP technology. It will provide an outlook on how the geothermal industry is addressing critical challenges such as corrosion, erosion, high-temperature operation, increasing power demands, and efficiency optimization. The goal is to provide an integrated perspective on both understanding failure patterns and advancing technology to achieve longer run lives, improved reliability, and greater overall system performance in geothermal applications.

Failure Statistics - The Bathtub Curve



Infant Mortalities

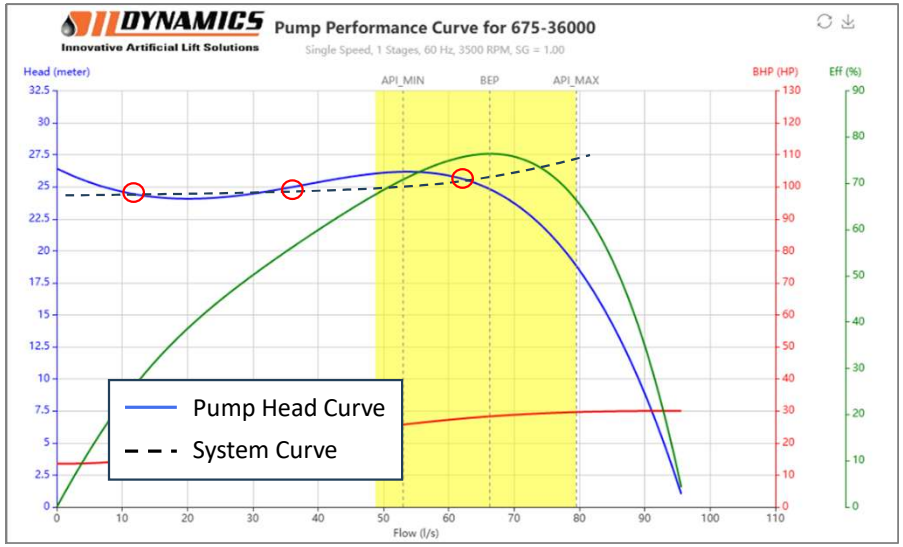
Failure causes

- Design
- Manufacturing
- Handling
- Installation
- Foreign objects, kill fluid
- Alarm and trip settings
- Monitoring

Steady-State Operation

Failure Causes

- Alarm and trip settings
- Monitoring
- **Design**
- Operating practice
- System vibrations
- Scaling
- Sand fall-back



Unstable pump head curve

Steady-State Operation

Failure Causes

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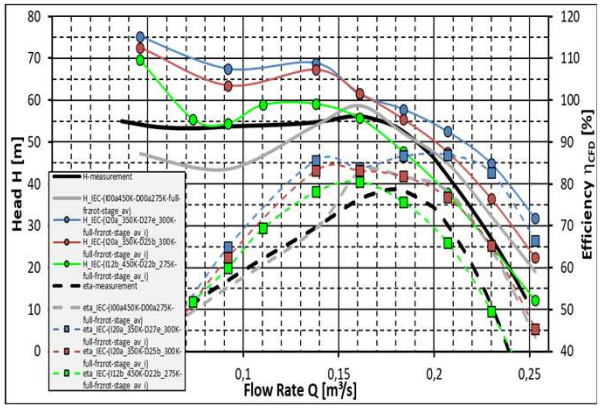

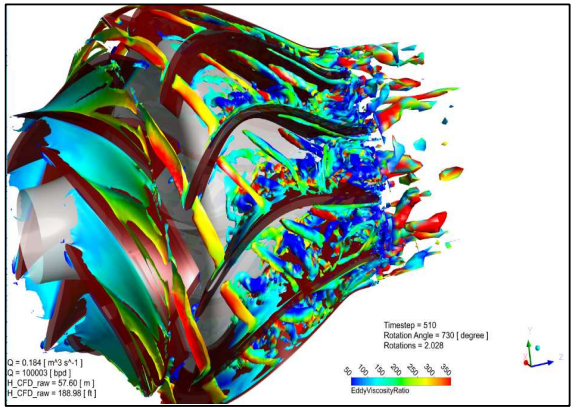

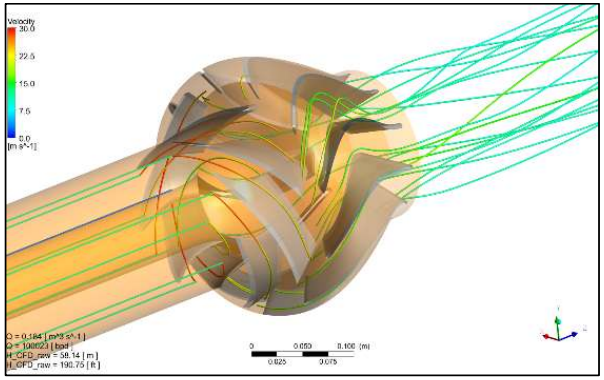

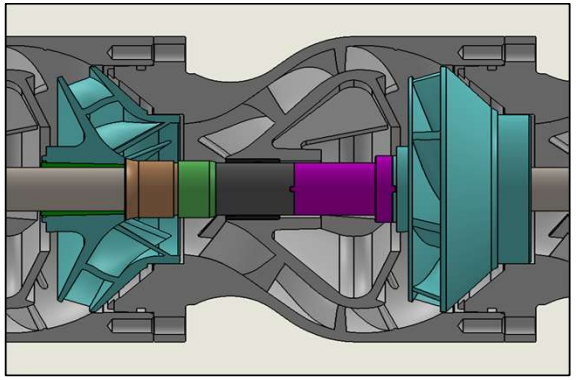

Steady-State Operation

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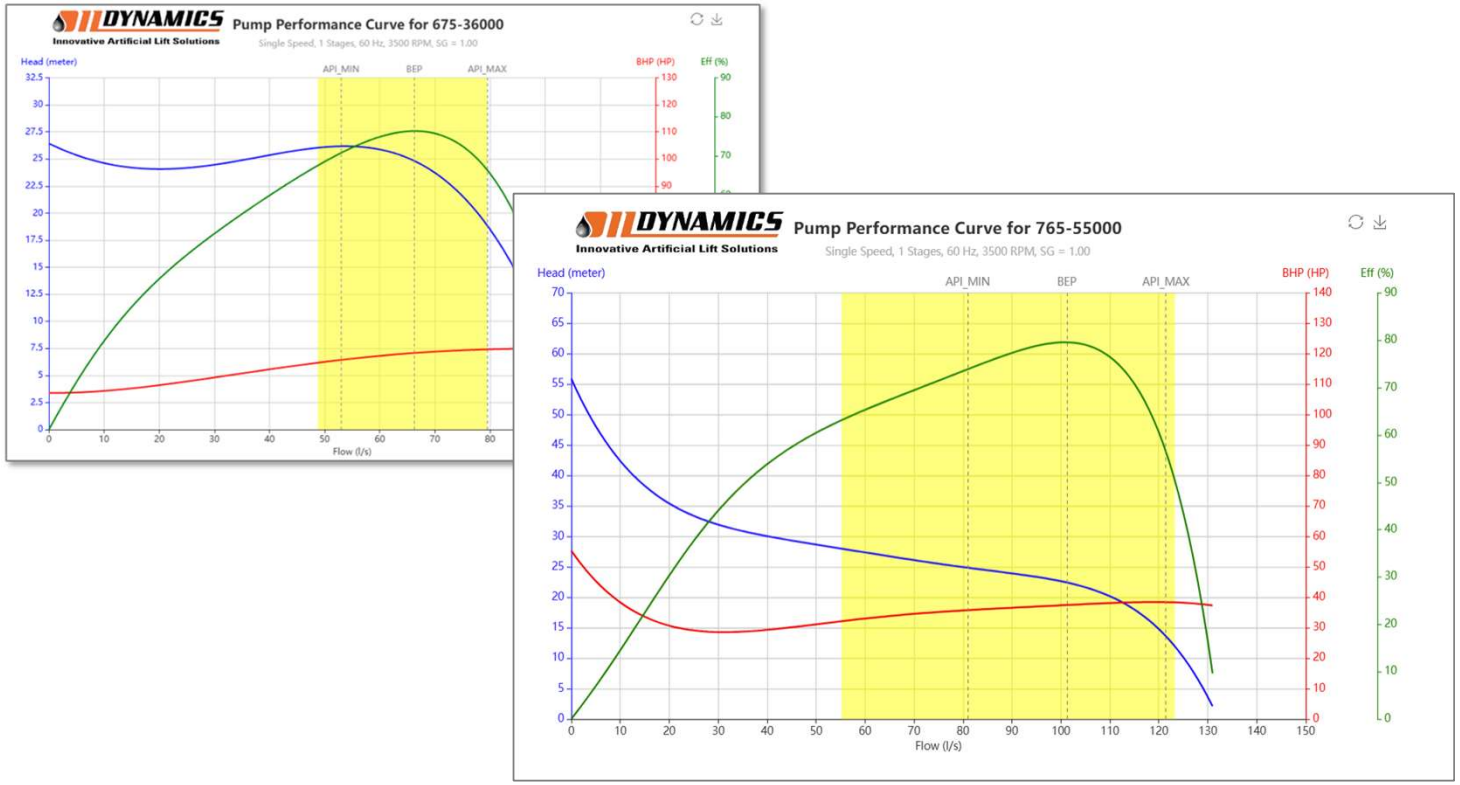
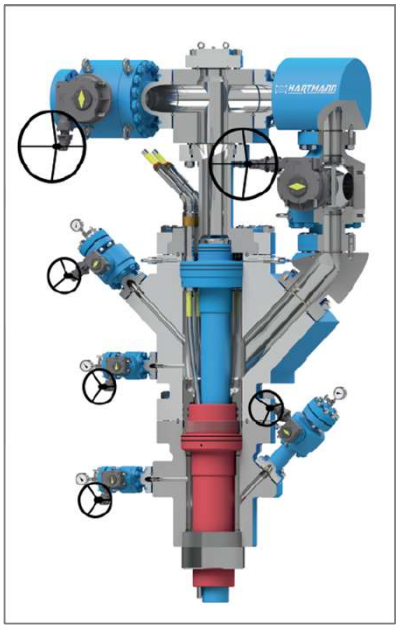


Steady-State Operation

Failure Causes

- Inadequate alarm and trip settings
- Inadequate monitoring
- Design
- **Operating practice**
- System vibrations
- Scaling
- Sand fall-back



Controlled shut downs and temporary re-circulation

Steady-State Operation

Failure Causes

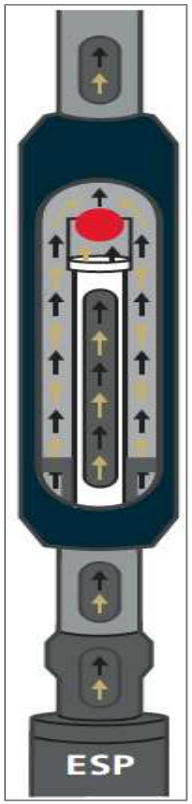
- Inadequate alarm and trip settings
- Inadequate monitoring
- Design
- Operating practice
- System vibrations
- **Scaling**
- Sand fall back

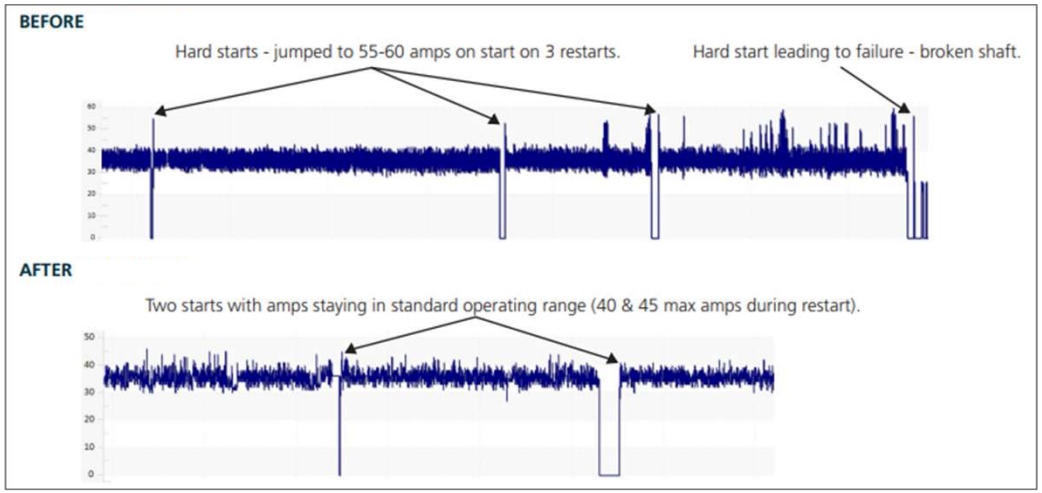
Autonomous Chemical Injection for ESP Protection

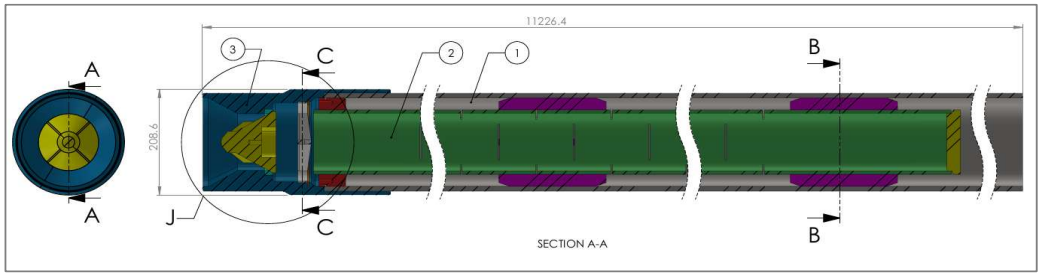
Steady-State Operation

Failure Causes

- Inadequate alarm and trip settings
- Inadequate monitoring
- Design
- Operating practice
- System vibrations
- Scaling
- **Sand fall-back**





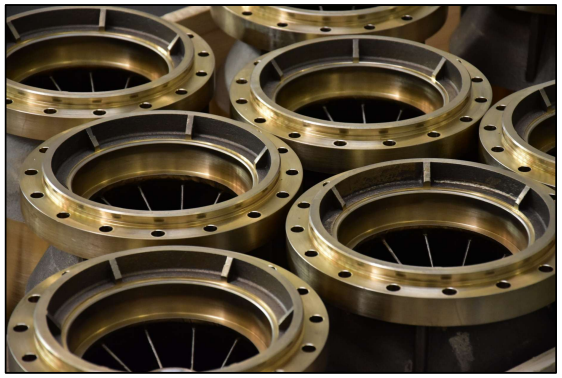


Sand-fallback ESP Protection

Wear Out

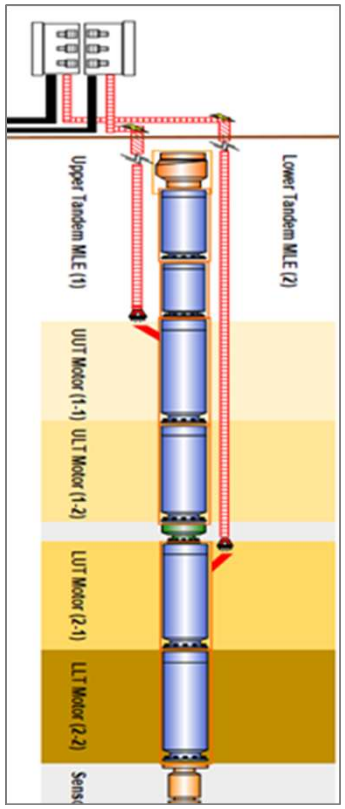
Failure Causes

- Corrosion & erosion
- Mechanical wear
- Protector seals
- Insulation degradation



ESP metallurgy, stage geometry, bearing materials

Motor oil vs. Barrier fluid



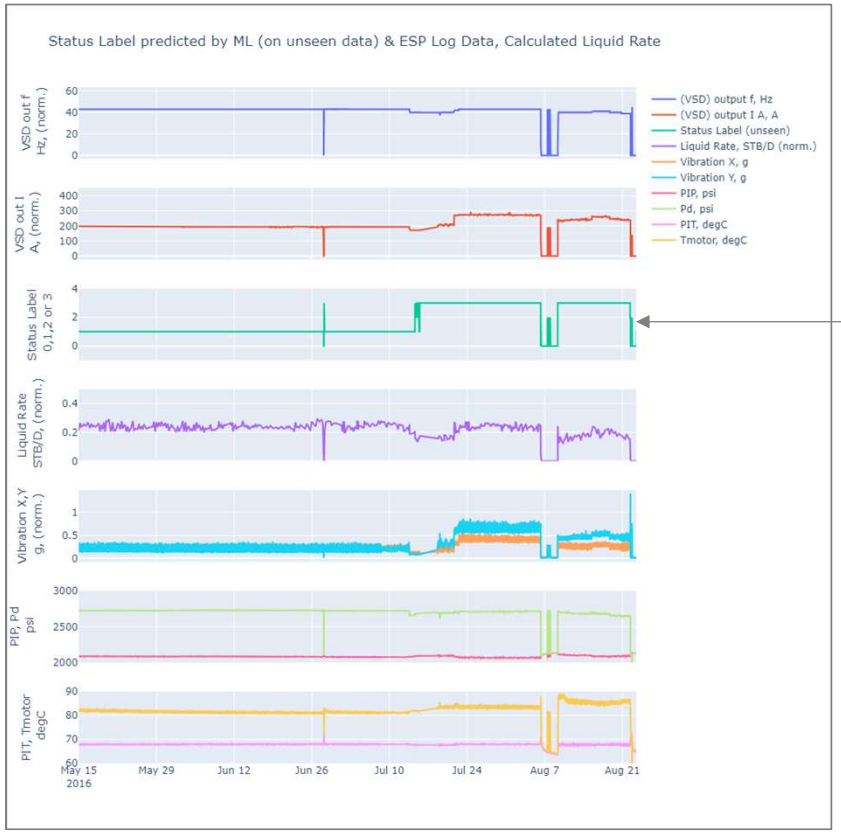
Modular Motor System

Survival Analysis with Machine Learning

Example: Mechanical wear

- Event leading to increased vibrations & downhole current.
- The motor draws more current, presumably to overcome additional mechanical friction
- …ultimate failure cause in form of a broken shaft was confirmed after pull out

Operational status prediction by machine learning
(shaft breakage due to mechanical instability)



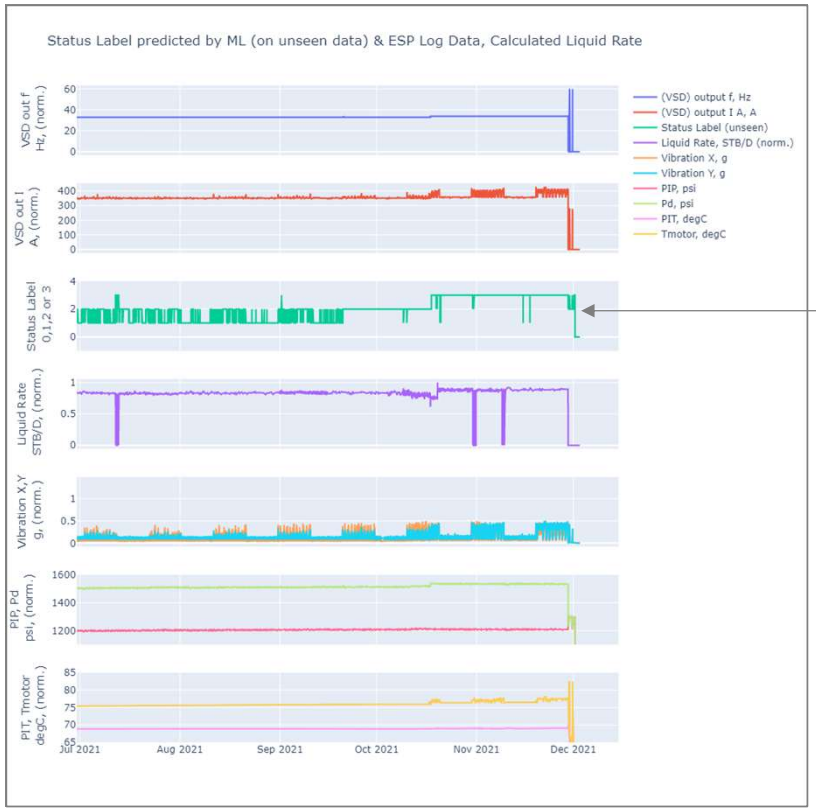
Operational Status	Label
pump off	0
normal operation	1
electrical wear	2
mechanical wear	3

Survival Analysis with Machine Learning

Example: Electrical wear

- Periodic usage (of about 10 days) of a specific diesel power generator device creates current spikes
- …which induce mechanical load spikes on of the ESP components that
- …are reflected increased vibrations, among others.

Operational status prediction by machine learning
(shaft breakage due to poor power supply quality)



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Questions & Answers

Looking forward to your questions!

Contact:

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