

CIGRE CROATIA
Next Generation Network (NGN)

Machine Learning in Hydropower Plants



cigre

For power system expertise

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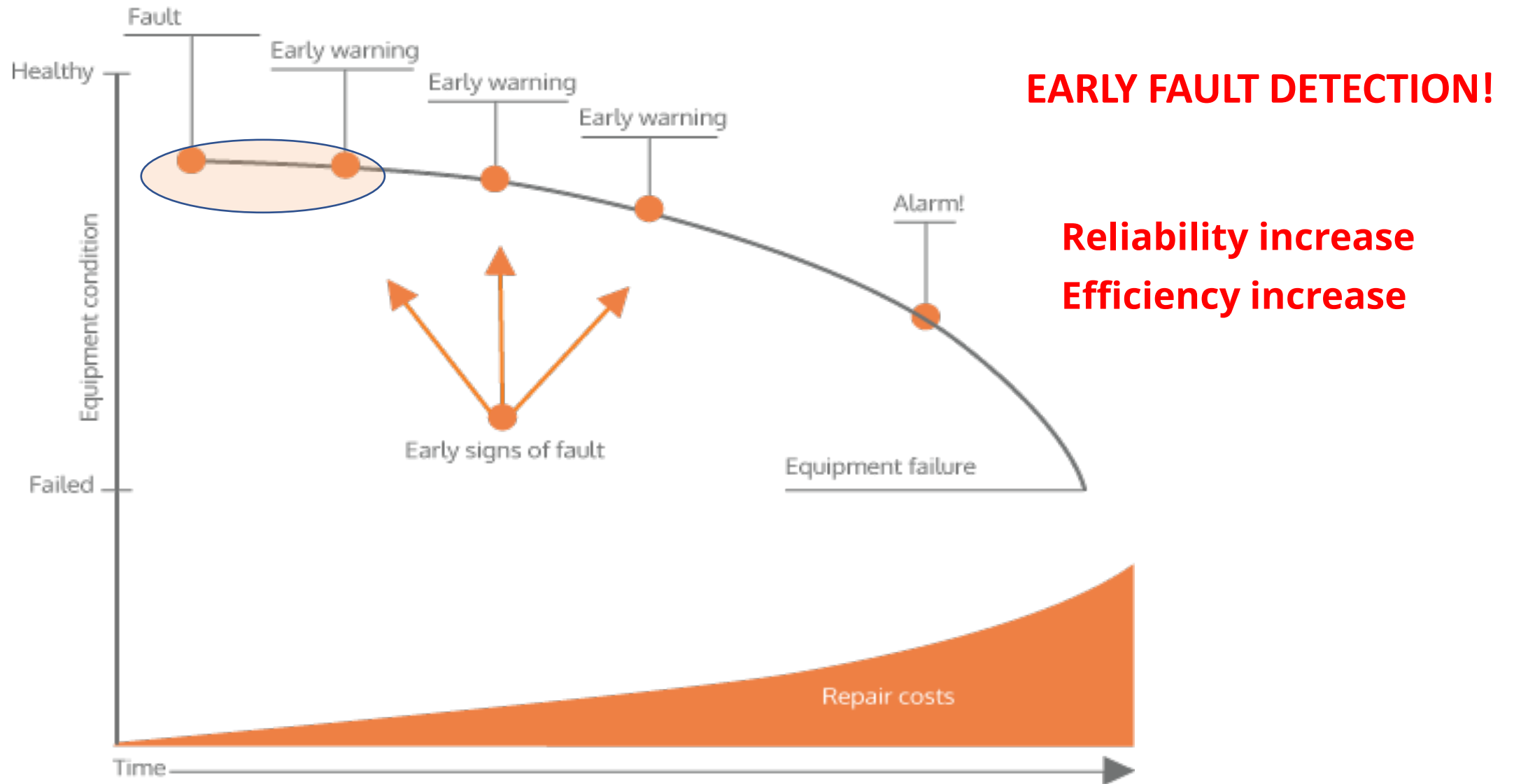
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Machine Learning in Hydropower Plants

HRO CIGRE 2023



The holy grail of predictive maintenance



Key factors for implementing ML



Monitoring

+



Asset analytics



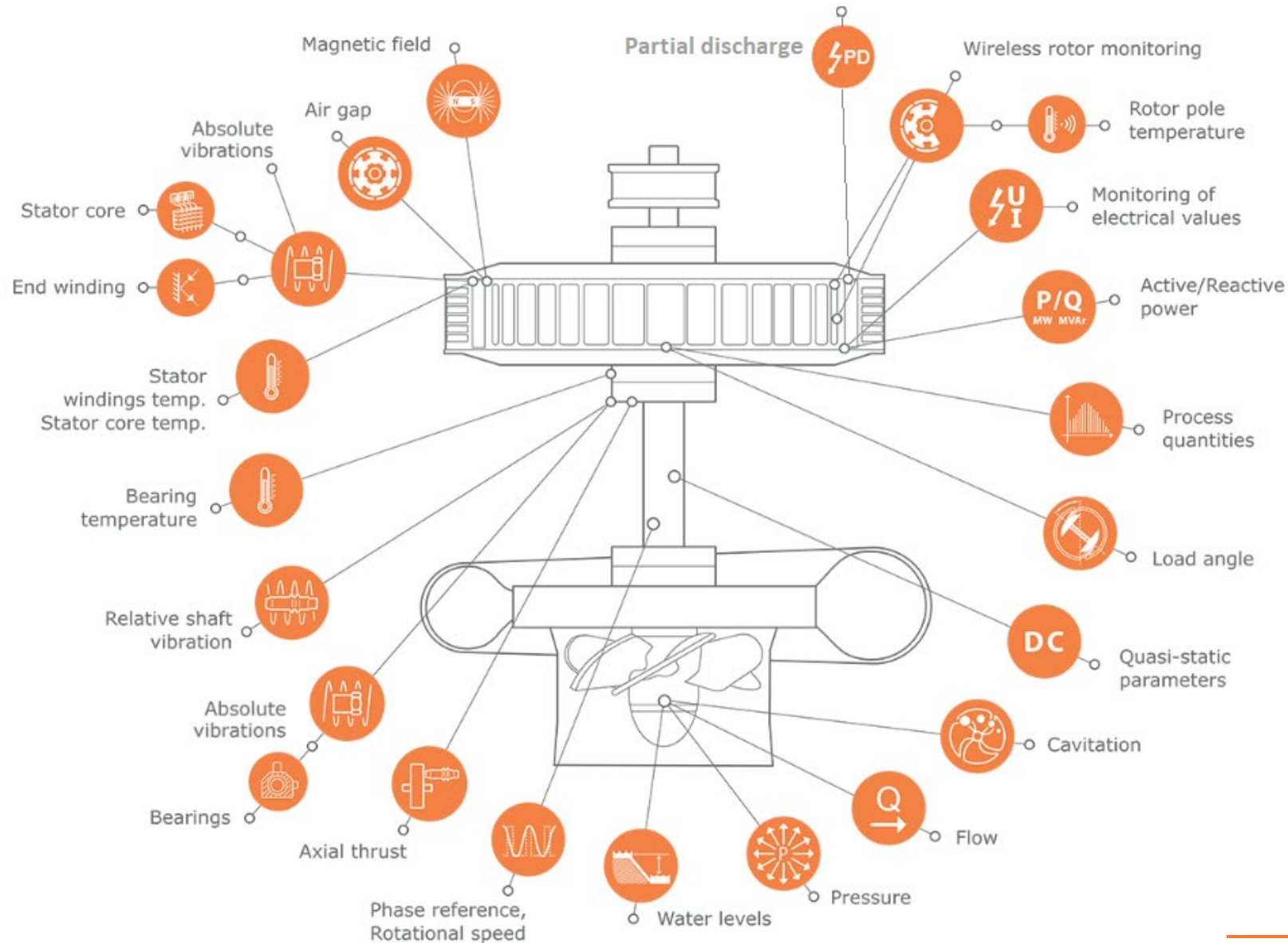
Prediction

(ML, AI...)

KEY FACTORS:

1. (THE RIGHT) DATA SET
2. SW TOOLS
3. DOMAIN EXPERTISE

What to measure?

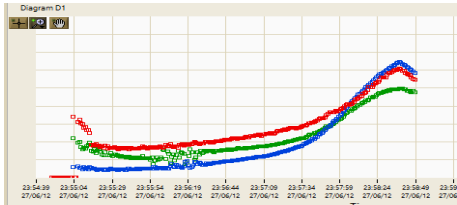
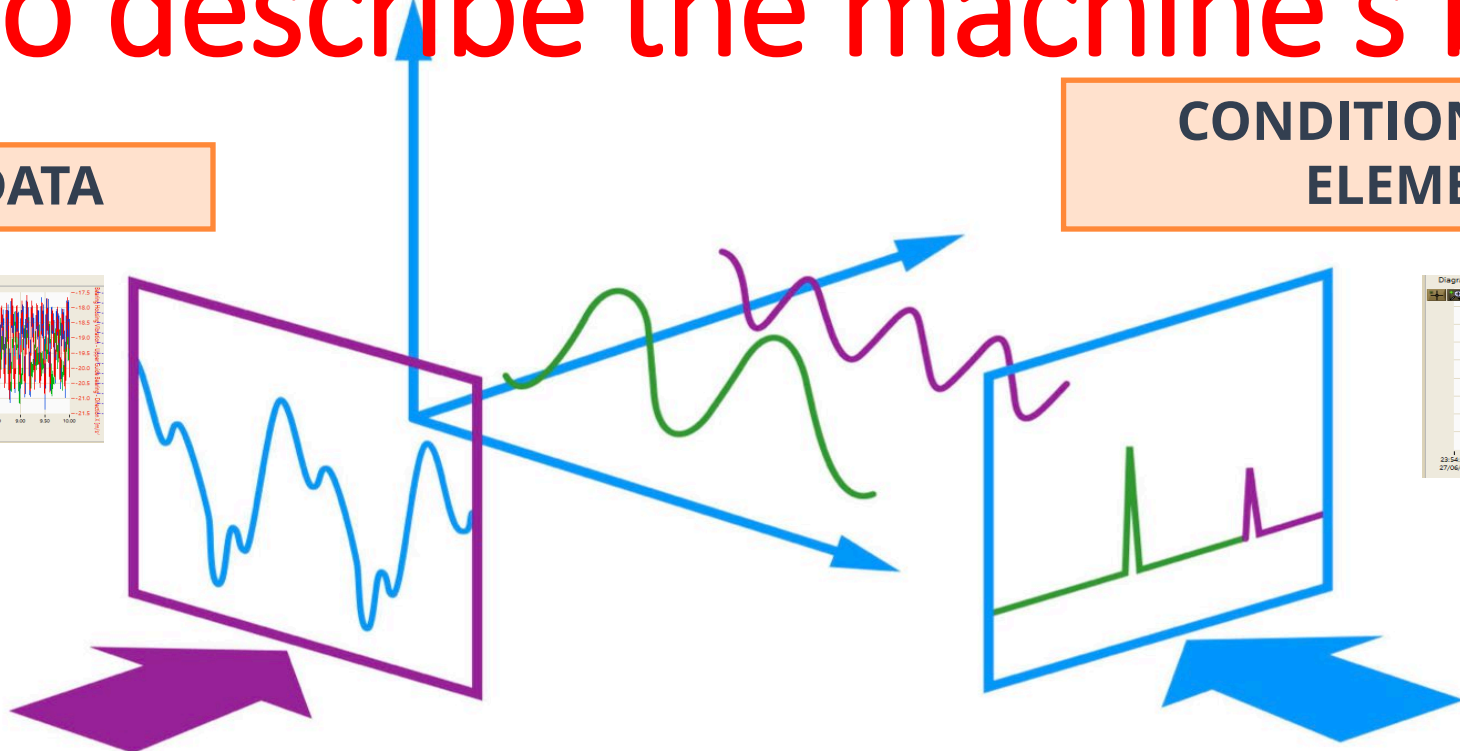
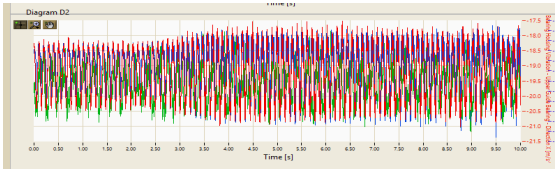


VECTORS and SCALARS

essential to describe the machine's behavior

RAW DATA

CONDITION VECTOR
ELEMENTS



View from Time Domain
(Raw Waveform Signals)

View from the Frequency Domain
(Spectra, FFT)

Fault matrix

MEASUREMENT															
FAULTS	FAULT DETECTION & CORRESPONDING MEASUREMENTS	Bearing vibrations	Relative shaft vibrations	Bearing temperatures	Turbine cover vibrations	Air gap	Magnetic field	Stator core vibrations	Stator frame vibrations	Generator temperatures	Process quantities	Cavitation	Electrical quantities	Partial discharge	Hydraulic quantities
	Mechanical unbalance	1x •	1x •												
	Electrical unbalance	1x •	1x •				•								
	Loose rim	1x •	1x •			2x •	•								
	Hydraulic unbalance	1x, nx •	•		•										•
	Misalignment	1x, 2x •	1x, 2x •												
	Eccentricity of stator and rotor		DC •			•	•								
	Bearing wear	•		•											
	Stator windings vibrations							100Hz • 200 Hz •	100Hz • 200 Hz •						
	Insulation wear													•	
	Rotor shape													•	
	Overheated stator coils														
	Phase symmetry														
	Bearing stiffness														
Excitation problems															
Load angle detection															
Pressure pulsation															•
Faults analysis process:															
- Cross correlation of signal vector components in different operating modes (e.g. Run up, steady state, partial load etc.)															
- Comparison to reference data in different operating modes															
- Change detection															
- Fault analysis															

- measuring point / sensor
- 1x** – Vibration signal component on first harmonic frequency of rotation
- 2x** – Vibration signal component on Second harmonic frequency of rotation
- DC** – static signal component

Machine learning in Power plants



Trending

Trend of gearbox oil temperature against the produced power



Clustering

Clustering techniques like k-means, self-organizing maps, and DBSCAN



NBM

Normal Behavior Modeling for a specific fault case



Damage Modeling

Implementation of physics of failure(PoF) models to calculate the damage of the equipment



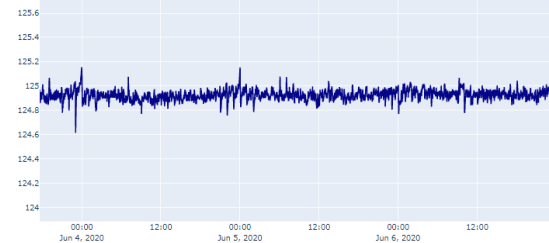
Abnormal Sample Detection

Normal

Normal start



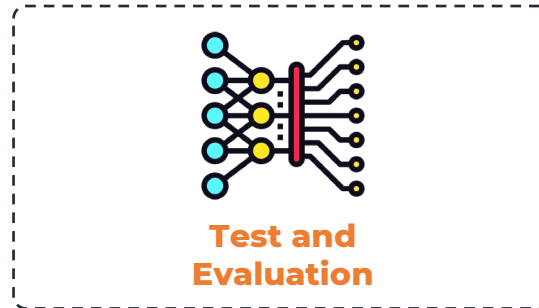
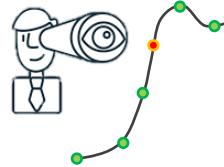
Nominal speed



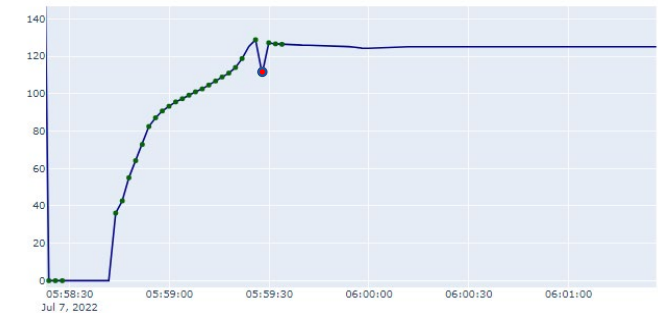
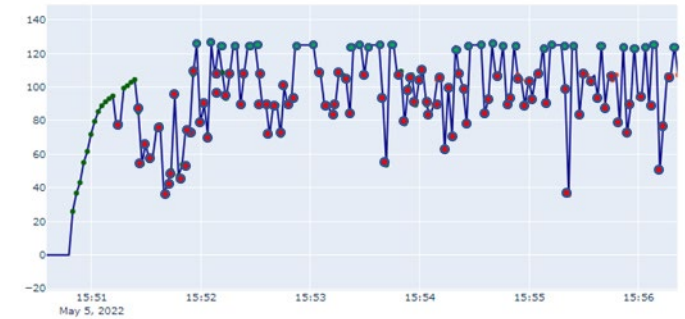
Normal stop



Method

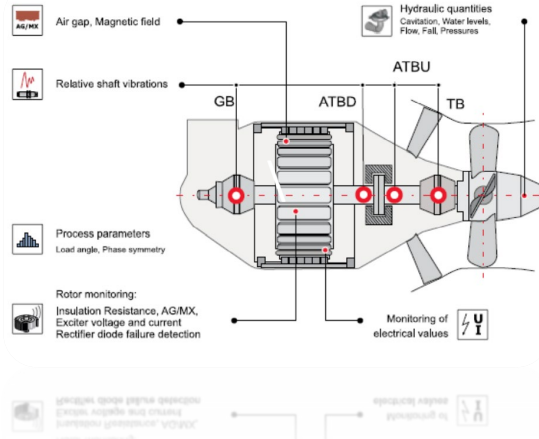


Abnormal samples detection

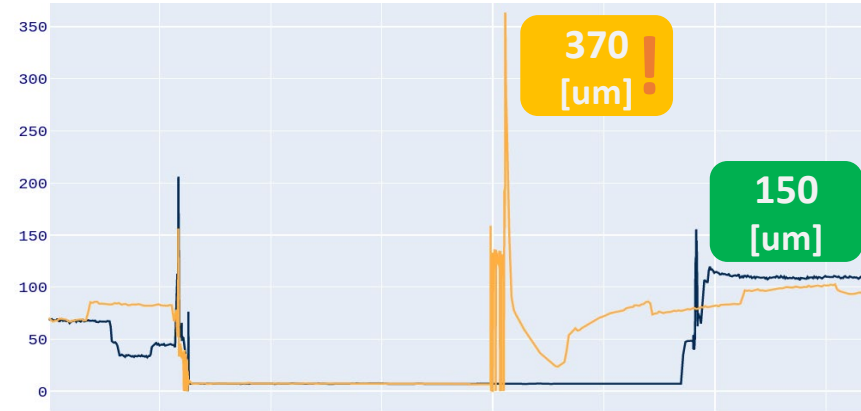


High Vibration Starts Prediction

Bulb Hydro Turbine



Vibration



Data preparation

Data Cleaning



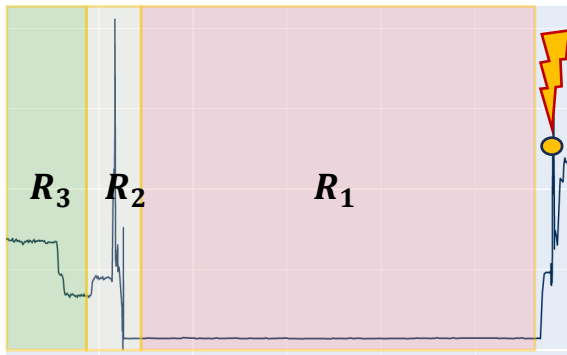
Normalization



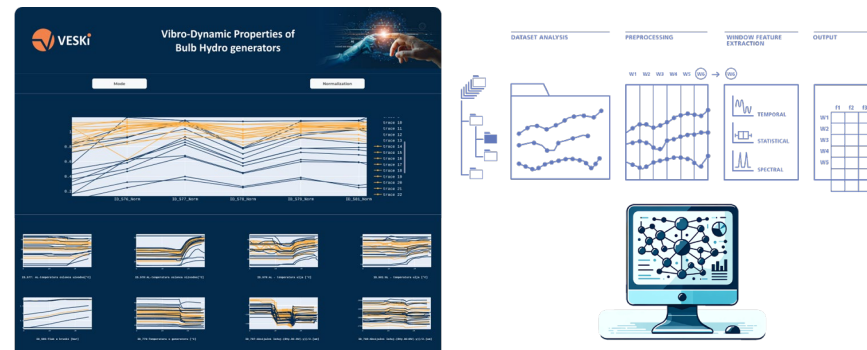
Labeling



Targeted Regions Selection



Feature Extraction

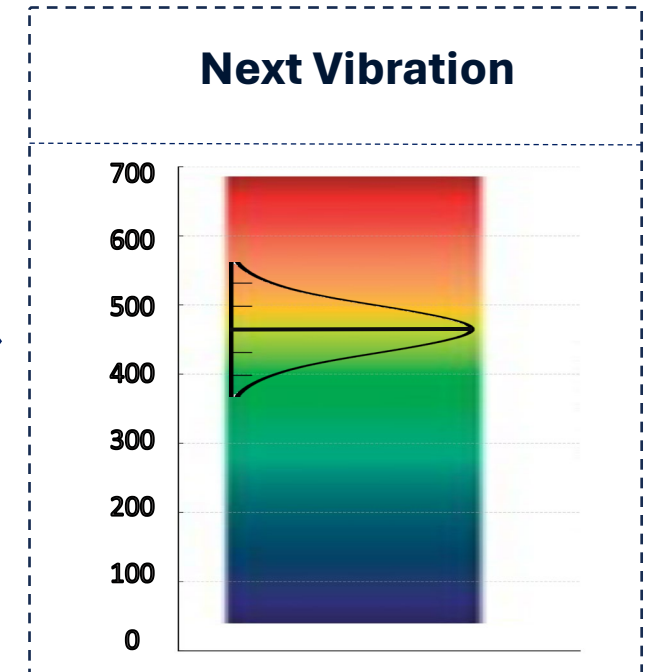
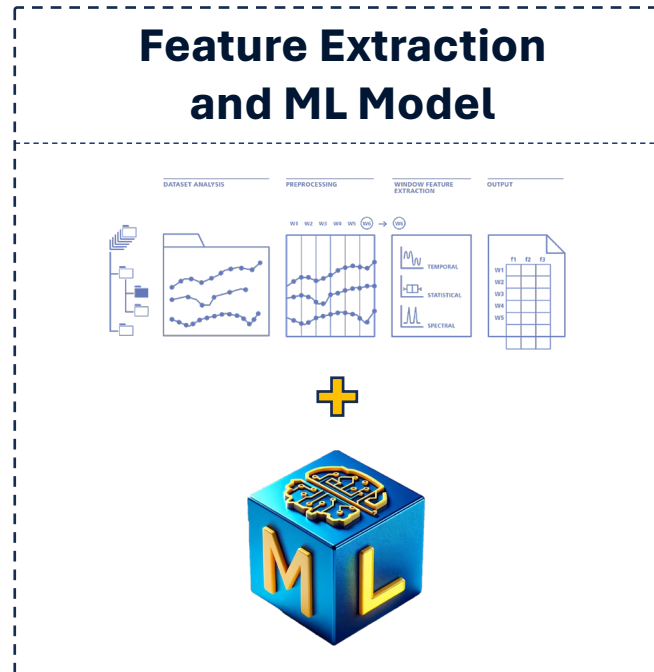
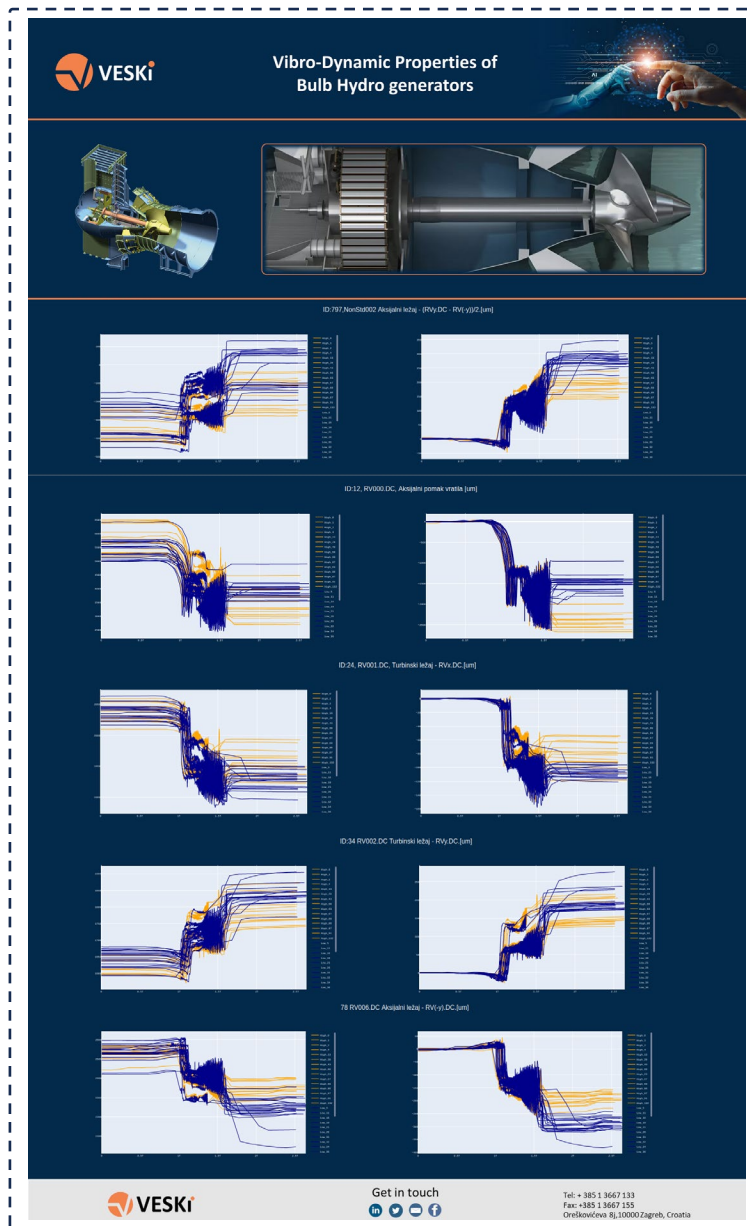


Train, Test, Evaluation

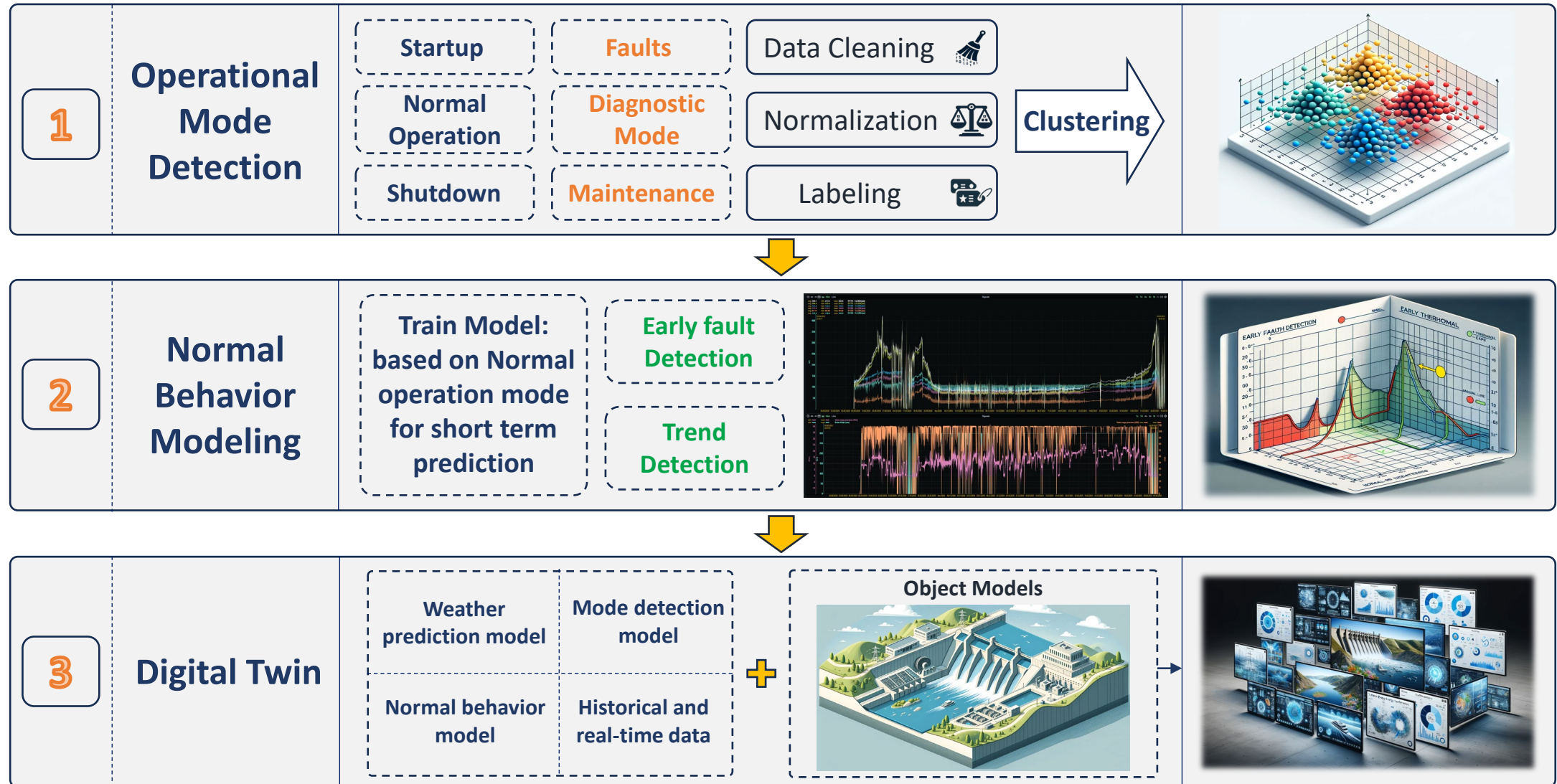


Vibration Prediction Model

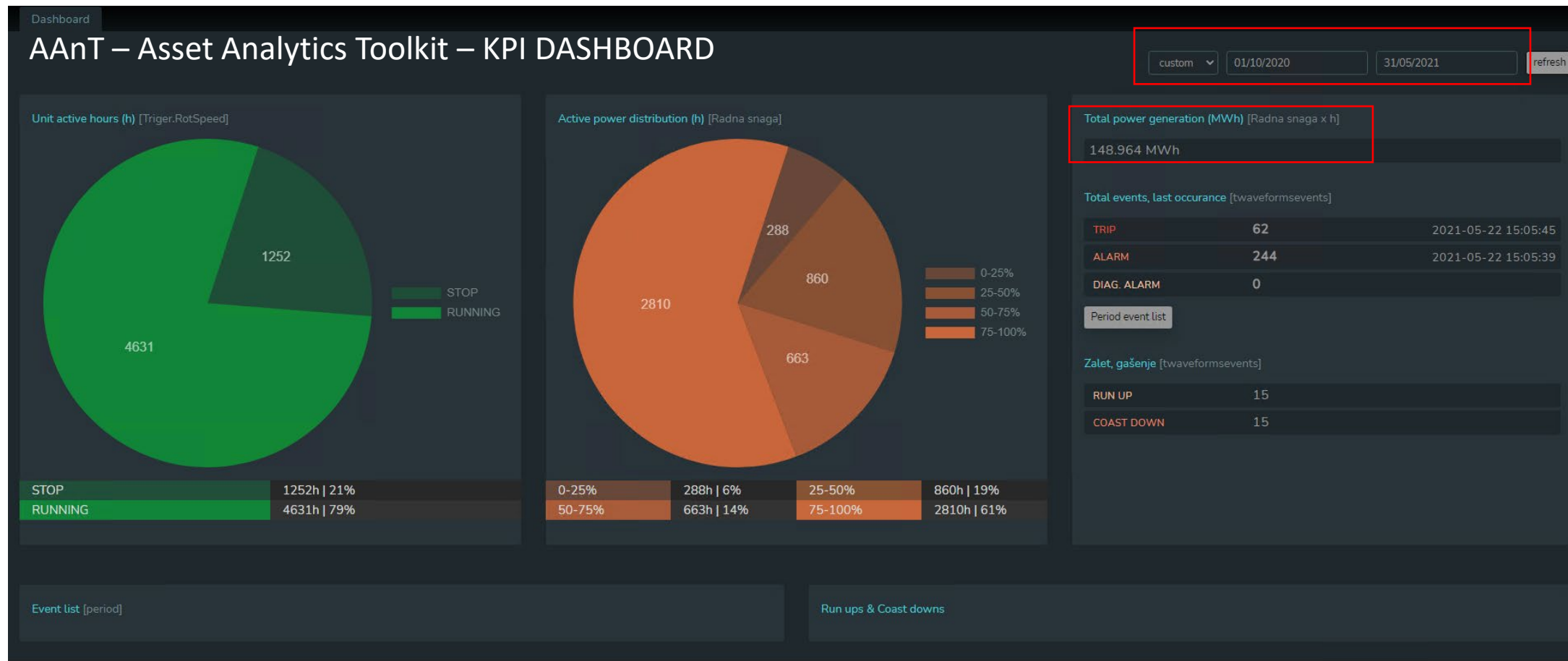
Vibration Prediction Model



ML Targets



Is it worth it?



In 8 m of operation = stopped cca 1252 h
Overhaul duration / 40days = 960h
205 working days, with 22h daily @ 33MW
1d ~700MWh= cca 80.000Eur



Thank you