# *MonitorX*

*et norsk-svensk samarbeidsprosjekt om tilstandsovervåking og prediktivt vedlikehold*

**Thomas Welte – SINTEF Energi**

**Digitalisering i vattenkraften**

2019-05-09, Arlanda

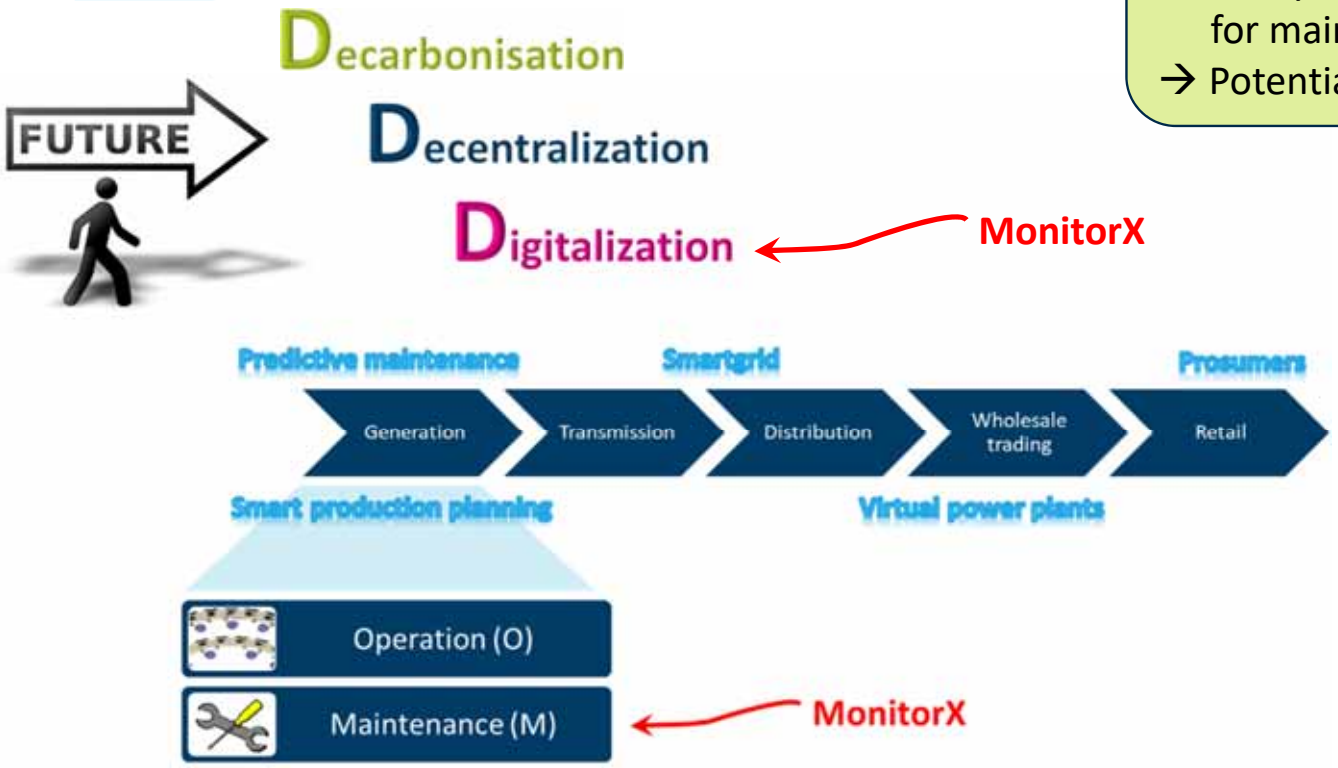
# MonitorX - Background

- Measurements/data available already today

→ Potential data sources for different purposes

- Today [2014], these data are not much used for maintenance decisions

→ Potentially large benefit when using these data




Forskningsrådet

**MonitorX** 2015-2019

Optimal utilization of hydropower asset lifetime by monitoring of technical condition and risk
(Optimal levetidsutnyttelse av vannkraftanlegg basert på overvåking av teknisk tilstand og risiko)

# MonitorX – Project partners

**Project owner:** EnergiNorge

**Financing:** Forskningsrådet

**+ participating companies**

**Norwegian power companies:**

BKK, ECO, Eidsiva, Lyse, Sira-Kvina Kraftselskap, NTE, Skagerak Energi, GLITRE Energi, Statkraft, Hydro, TrønderEnergi, Østfold Energi

**Equipment manufacturers and service providers:**

VOITH, Karsten Moholt, Hymatek controls, Andritz Hydro

**RnD partners:**

SINTEF, NTNU, Universidad Pontificia ICAI ICADE Comillas Madrid

**Swedish power companies represented by Energiforsk:**

Energiforsk, Vattenfall, Umeå Energi, fortum, uniper, Statkraft, Skellefteå Kraft, HOLMEN, Jönköping Energi, Elektra AB Edsbyns Elverk, Karlstadsenergi.se, Varberg Energi, Jämtkraft

**Sollefteåforsen AB**

# MonitorX - Aims

internet of things
machine learning
internet of services
big data
cyber-physical systems
industry 4.0
data mining
predictive maintenance

**Results**

- Model and algorithms for fault detection (and optimal lifetime utilization)
- Demonstrate practical application in selected power plants (cases)

**Benefits**

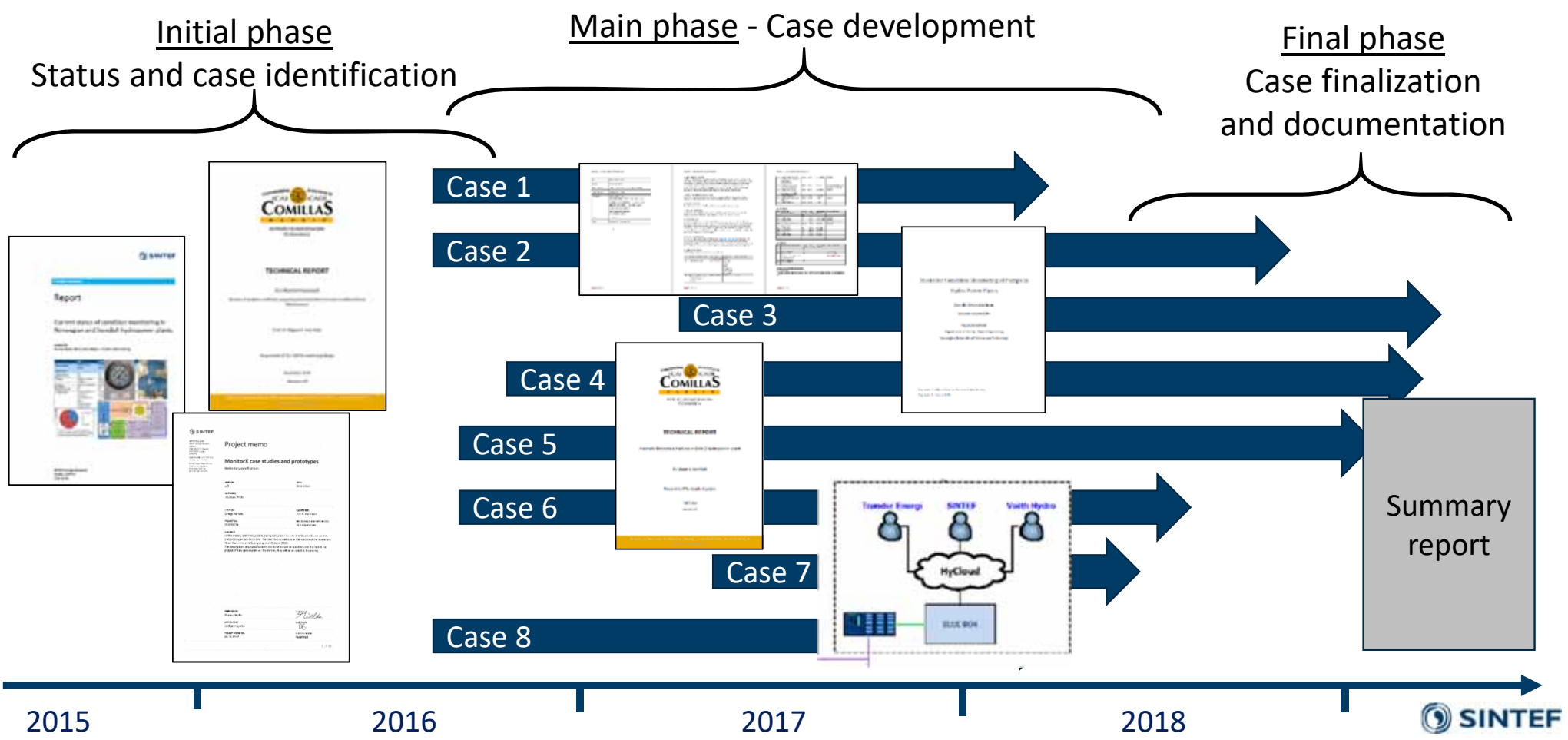
- Reduced maintenance costs by … :
  - … avoiding (catastrophic) faults …
  - … avoiding unnecessary component replacements …
  - … prioritizing the most critical components for maintenance …
  - … optimized maintenance …
- … through early warnings of ageing and potential faults.

**Knowledge gain**

- How can operators utilize the mentioned **concepts and methods** for plant maintenance?
- What are possibilities, challenges & restrictions?
- How can monitoring data be used to carry out maintenance more predictive?

Testing through cases is important part of the project

# MonitorX – Project phases



# MonitorX – Cases

| | Case | Aim | Main partners |
|---|---|---|---|
| 1 | Rotor fault detection | Develop new methods for online fault detection of generator rotor faults | NTNU, Vattenfall, Eidsiva, Statkraft |
| 2 | Condition monitoring of pumps | Detecting faults and degraded condition of drainage pumps using SCADA data | NTNU, SINTEF, TrønderEnergi, Vattenfall, Voith |
| 3 | Audio surveillance turbine/generator | Anomaly and fault detection in power station by monitoring sound/noise from the hydropower unit | Andritz, Statkraft |
| 4 | Cond. mon. rotating equipment | Anomaly and fault detection in power station by monitoring vibration and other high frequency data | NTNU, Statkraft |
| 5 | Bearing monitoring | Algorithms for early detection of bearing faults using SCADA data | Comillas University, BKK, SINTEF |
| 6 | Kaplan hydraulic system monitoring | Algorithms for monitoring of Kaplan hub mechanism and hydraulic system using SCADA data | Comillas University, Glitre, Vattenfall, Skellefteå |
| 7 | Transformer monitoring | Identification of abnormal temperature behaviour | SINTEF |
| 8 | SCADA data collection system | Establish good and continuous access to SCADA data | Voith, TrønderEnergi |

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Pedersen (NTNU)

Nasselqvist (Vattenfall)

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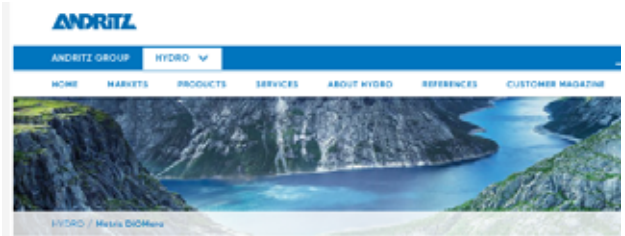
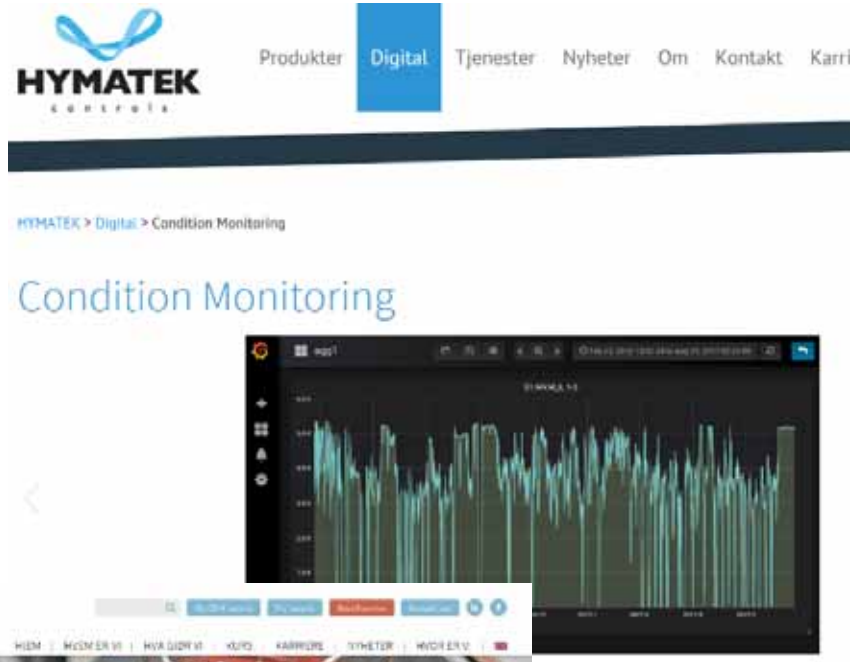
# Manufacturers and service providers – New products and services







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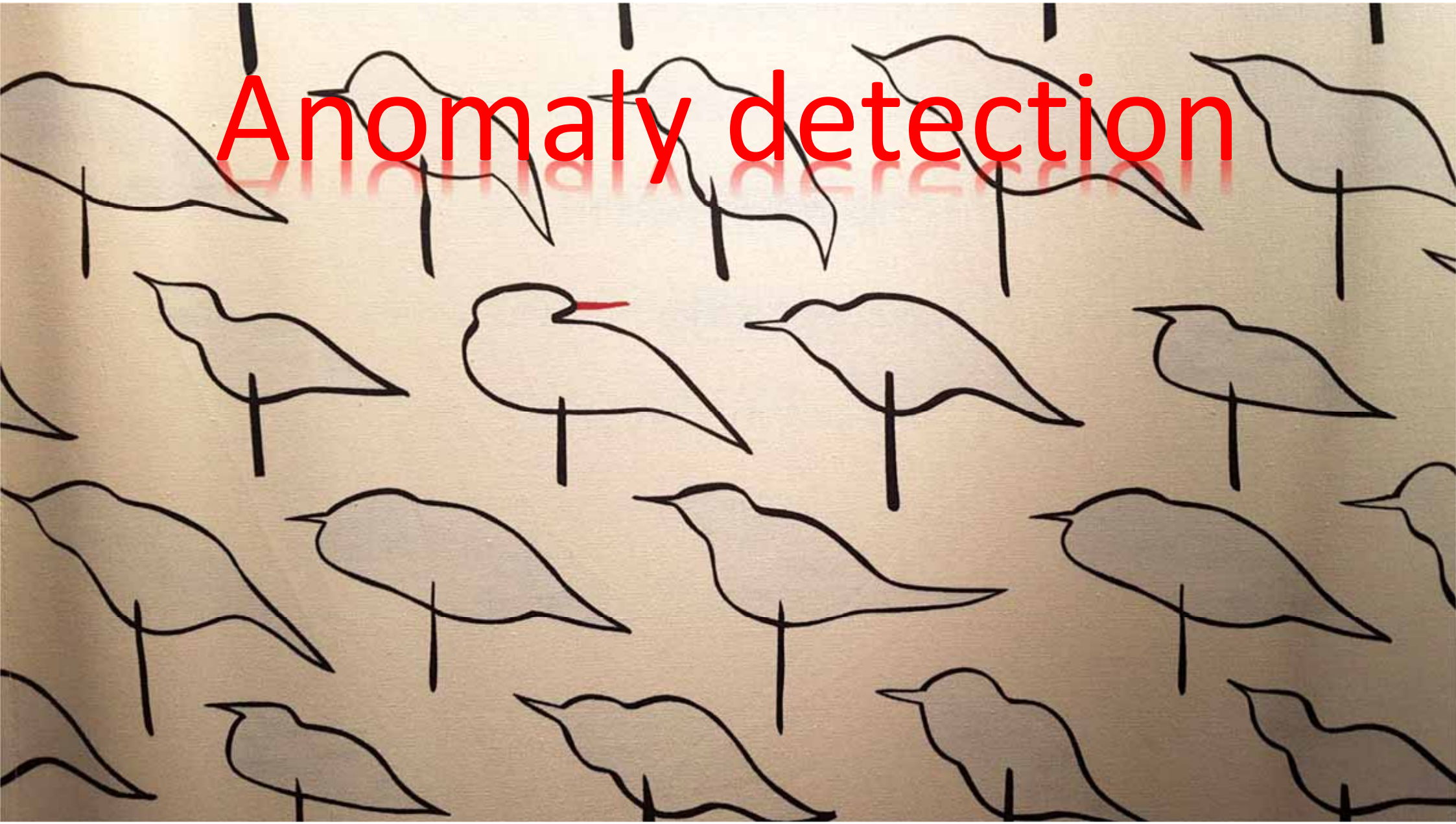
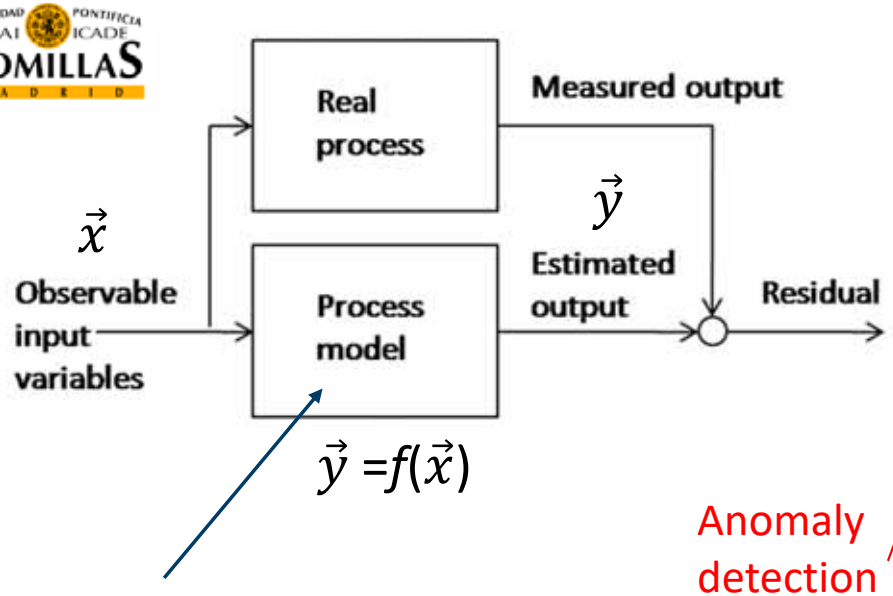
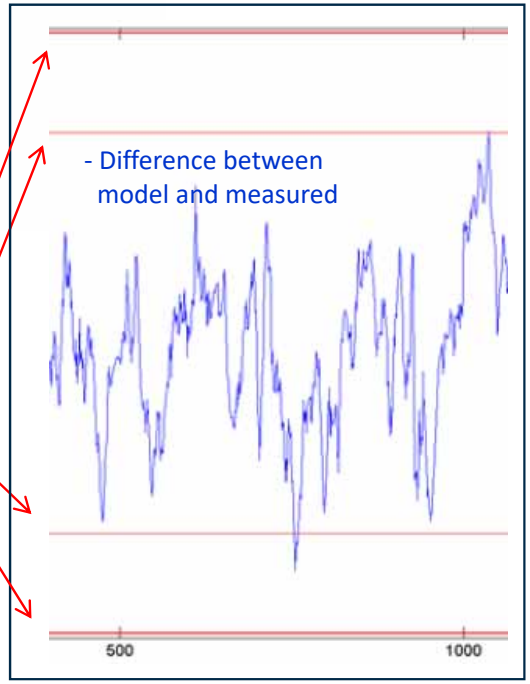

Anomaly detection

# Normal behaviour models and anomaly detection

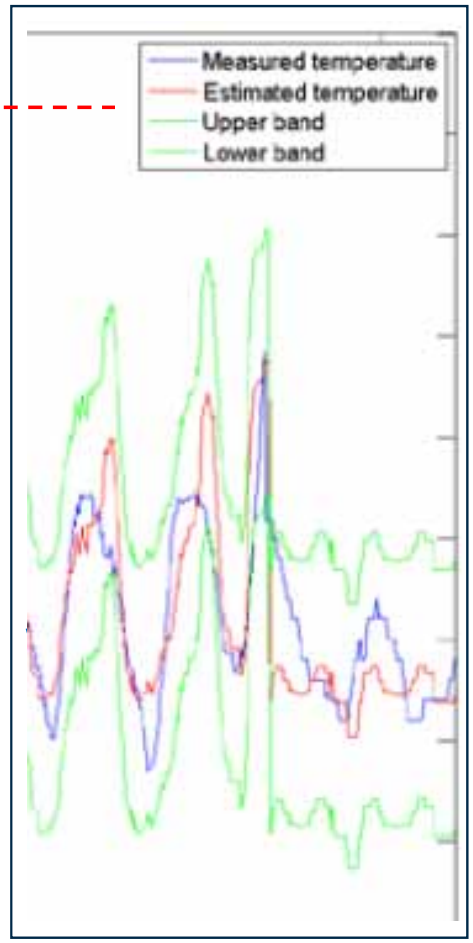



Can use many different types of process models

Anomaly detection model alarm levels

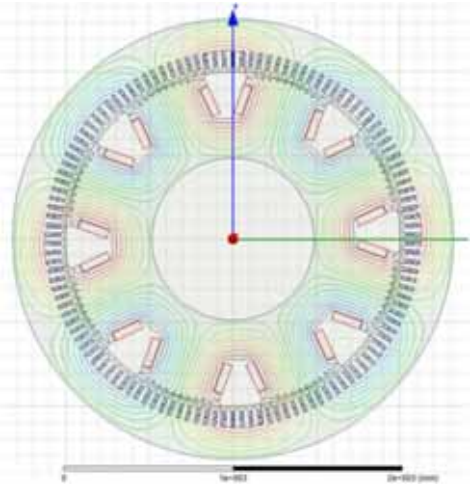


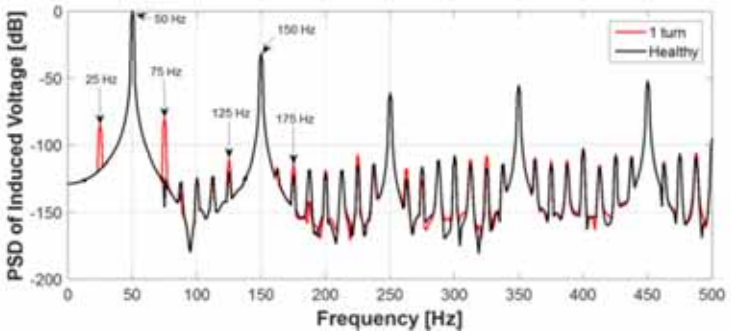

Traditional alarm level (e.g. SCADA)



# C1. On-line detection of rotor faults in hydrogenerators

- Aim: Develop new methods for online fault detection of generator rotor faults
- Results
  - FEM analysis of generator in healthy and faulty state
  - Frequency analysis of (simulated) voltage and current signals
  - Method can also be used to detect other types of faults
- Ongoing (HydroCen)
  - Testing of method at laboratory (PhD, NTNU)
    → Proof of concept in lab
  - Assessment of how different faults influence the frequencies








Reference: Valavi, M., Jørstad, K.G., Nysveen, A., "Electromagnetic analysis and electrical signature-based detection of rotor inter-turn faults in salient-pole synchronous machine", *IEEE Transactions on Magnetics*, accepted for publication, available online, DOI: 10.1109/TMAG.2018.2854670

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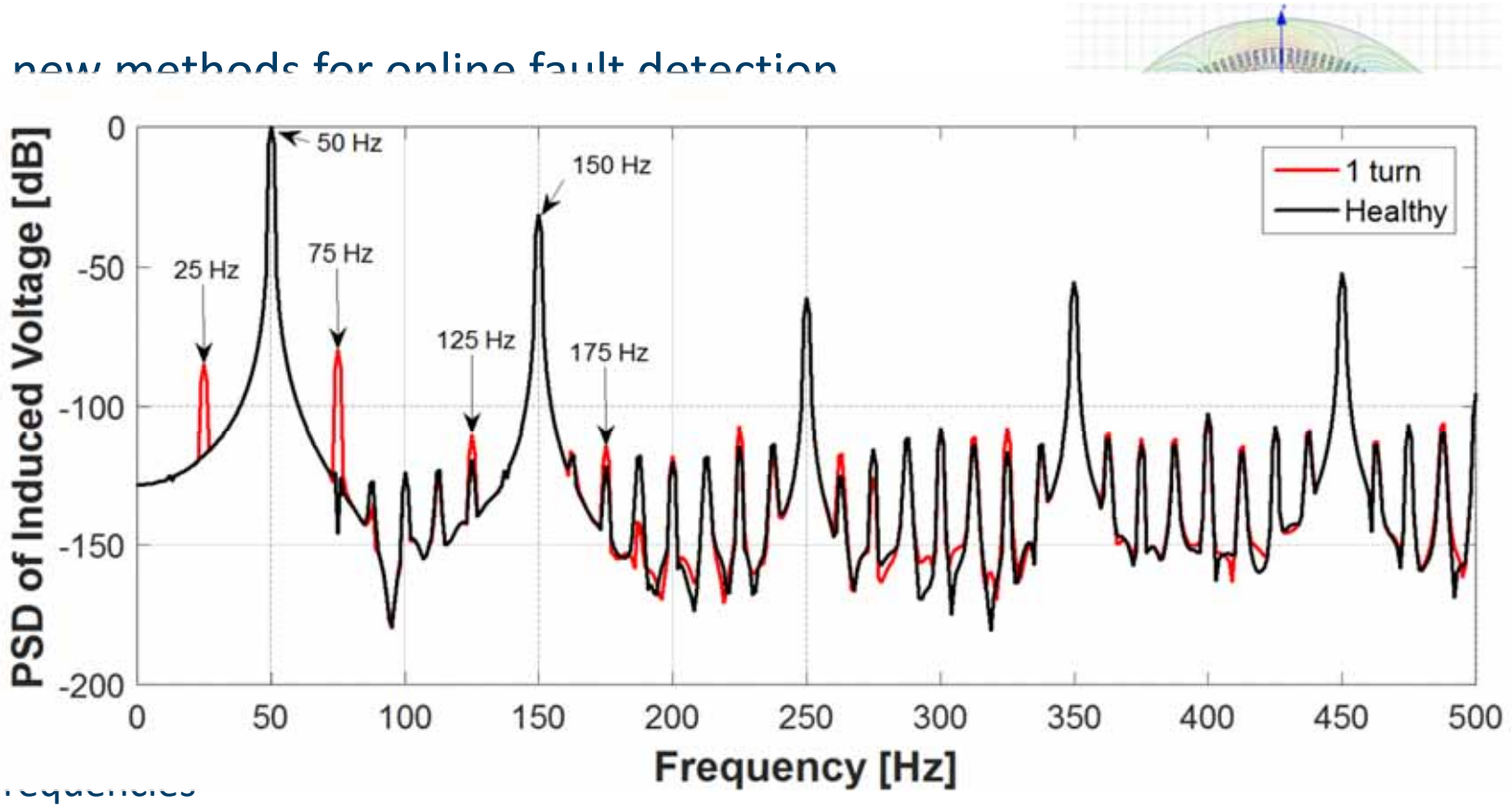




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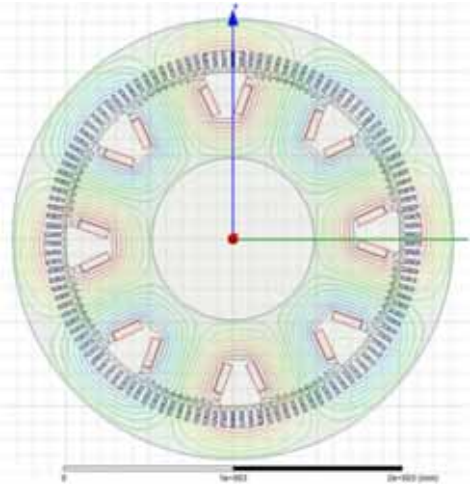
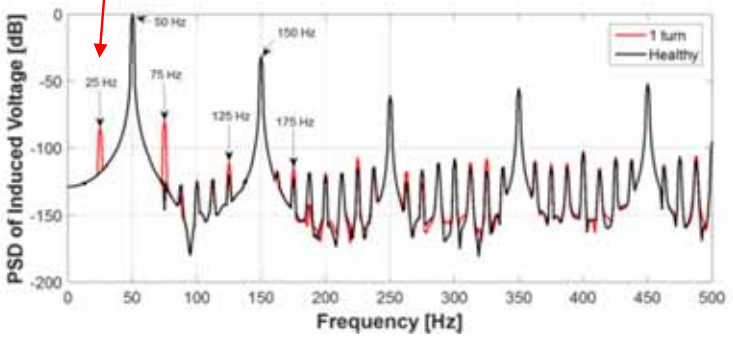


New frequencies vissible (peaks) when condition changes




Eidsiva NTNU VATTENFALL



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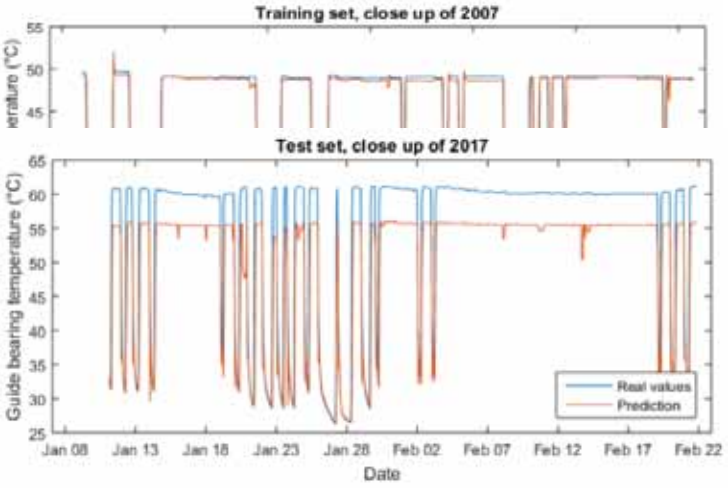
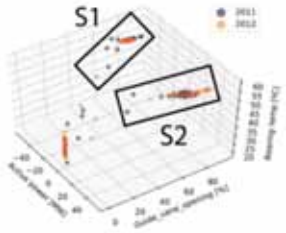
# C5. On-line detection of rotor faults in hydrogenerators

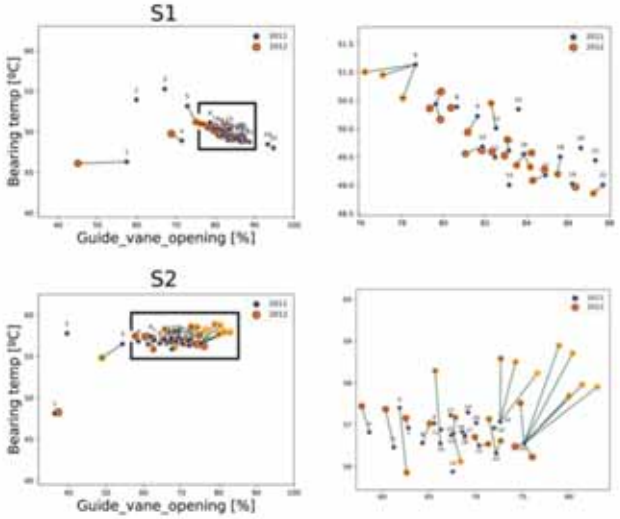
- Aim: Algorithms for early detection of bearing faults and following up degradation using SCADA data
- Results
  - Different models and algorithms developed (ANN, LSTM, clustering) and tested with data from Dale and Nygard power plants

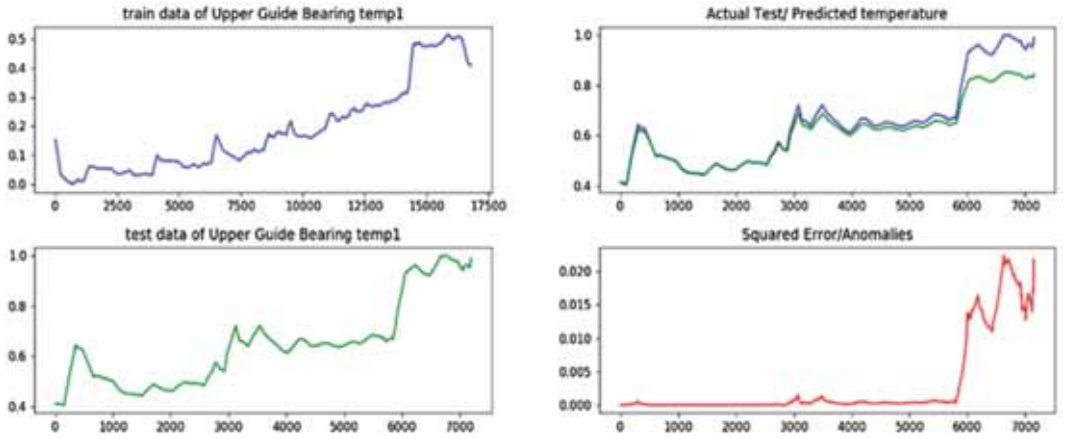
BKK




NTNU

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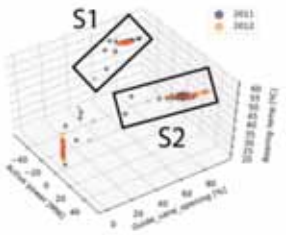
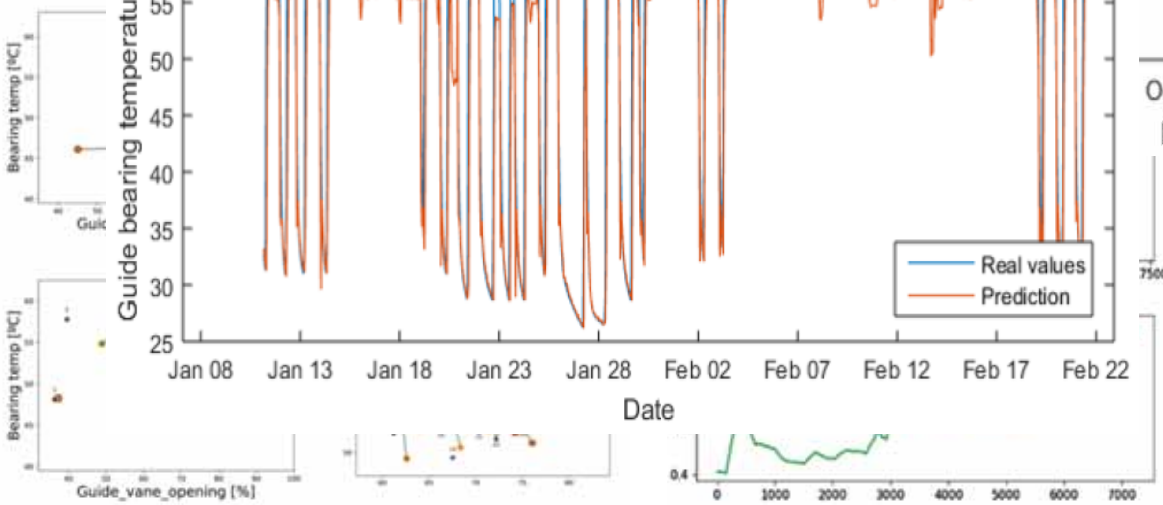
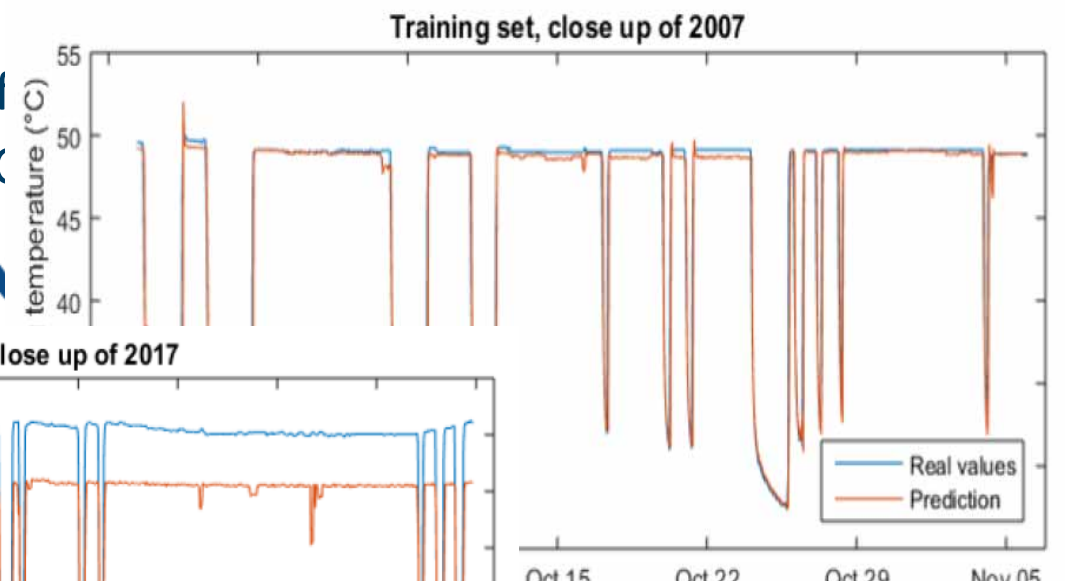
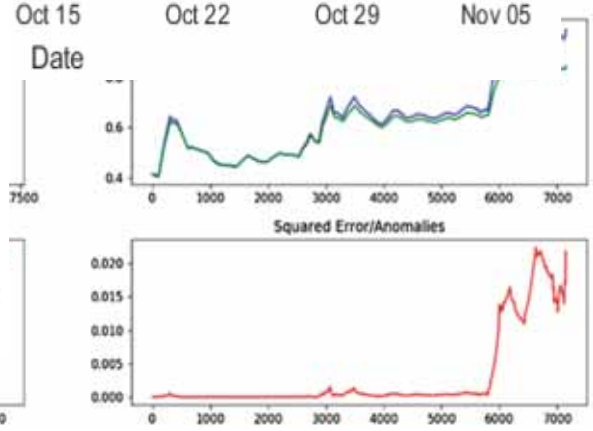
  and following up degradation using SC
- Results
  - Different model
    clustering) and t
    plants



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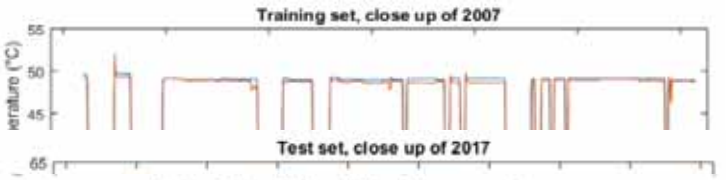


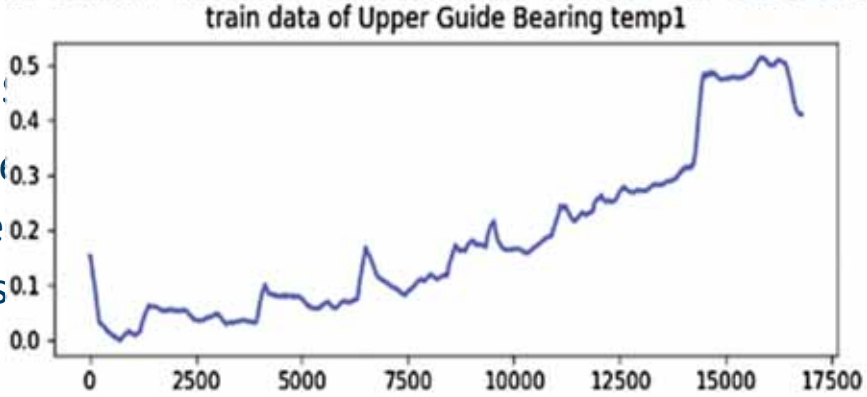


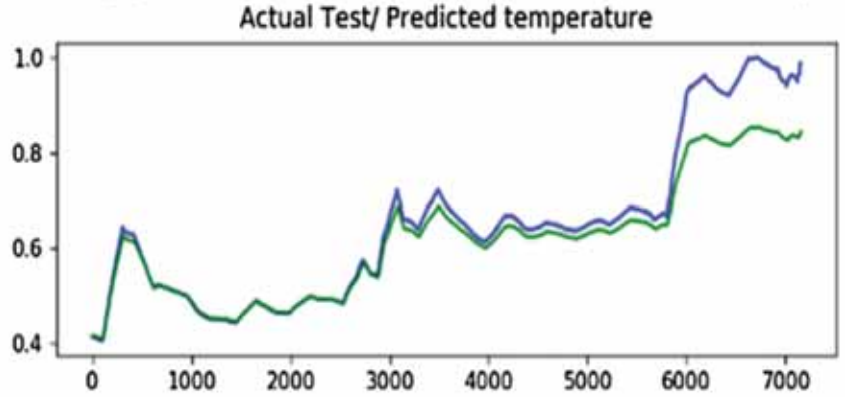


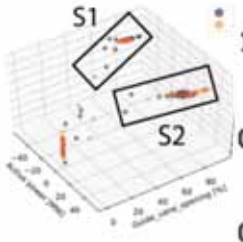


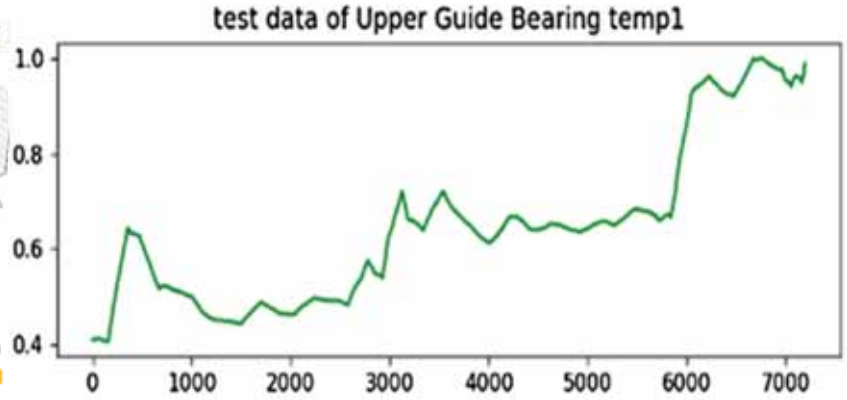


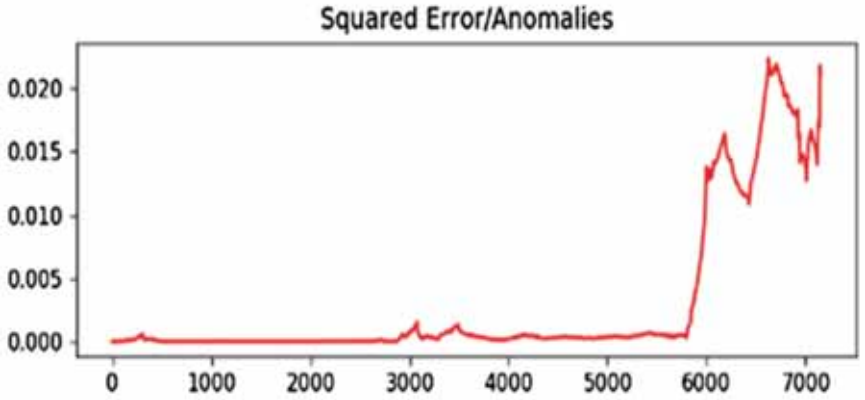

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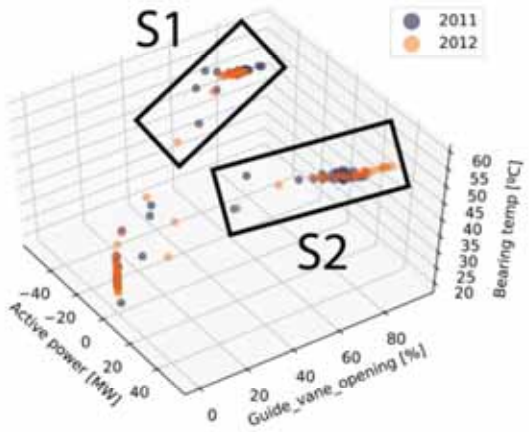


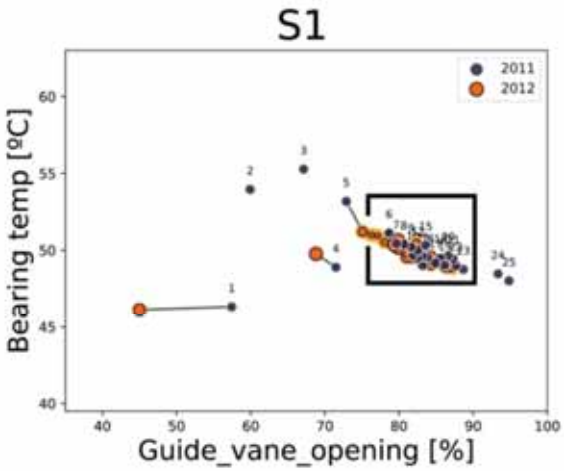


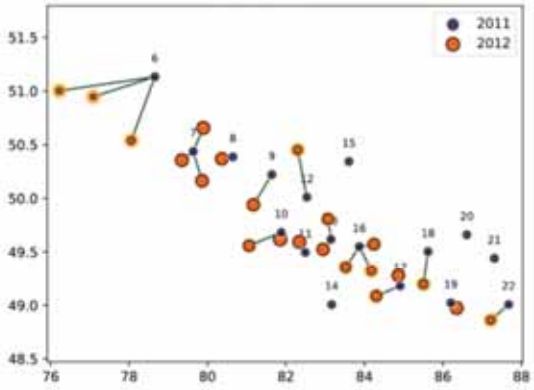


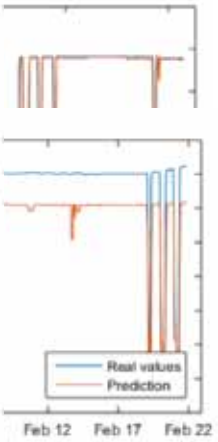


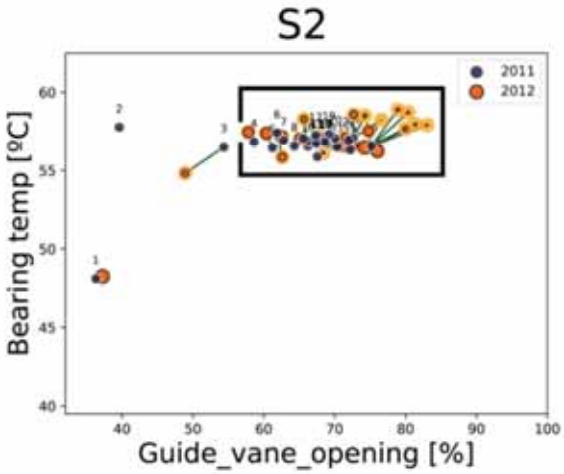


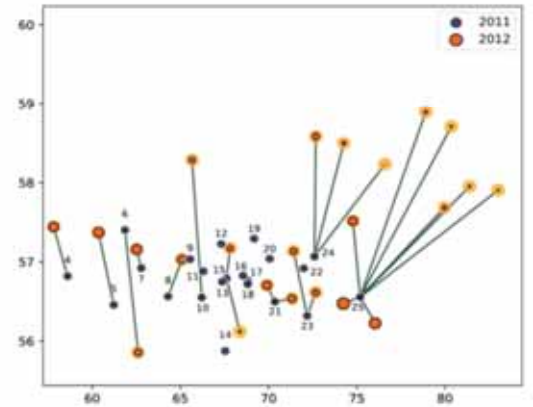


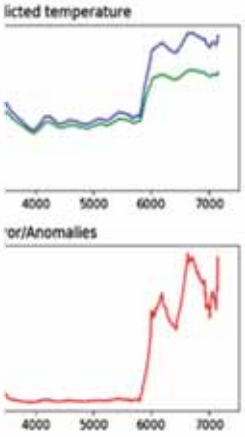

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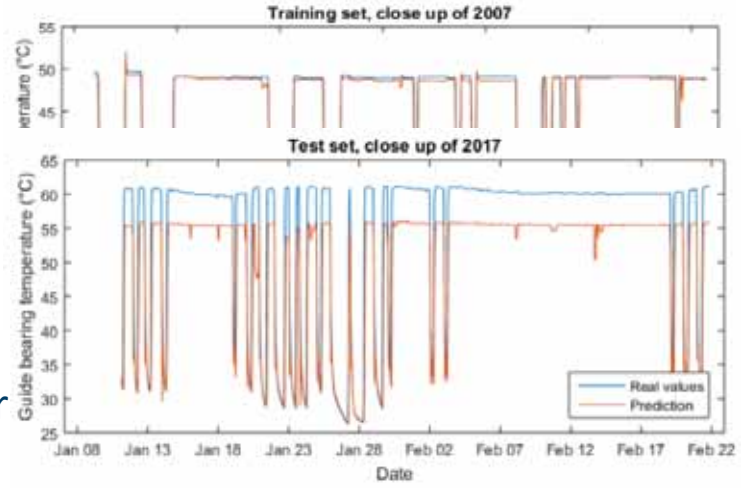
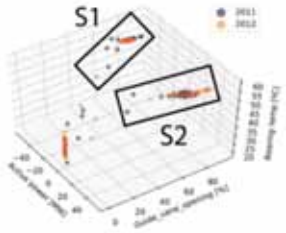
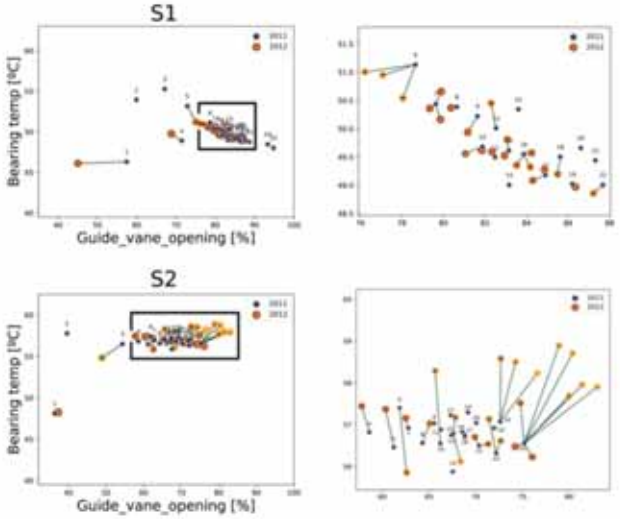
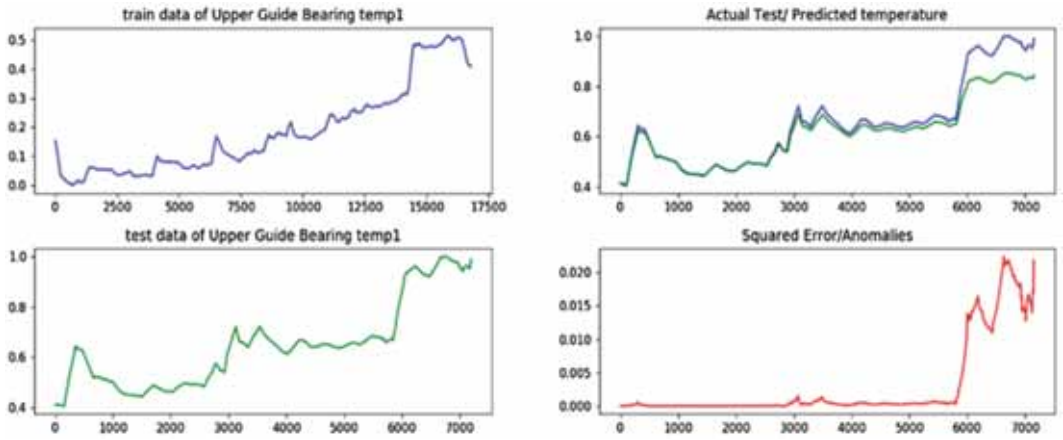


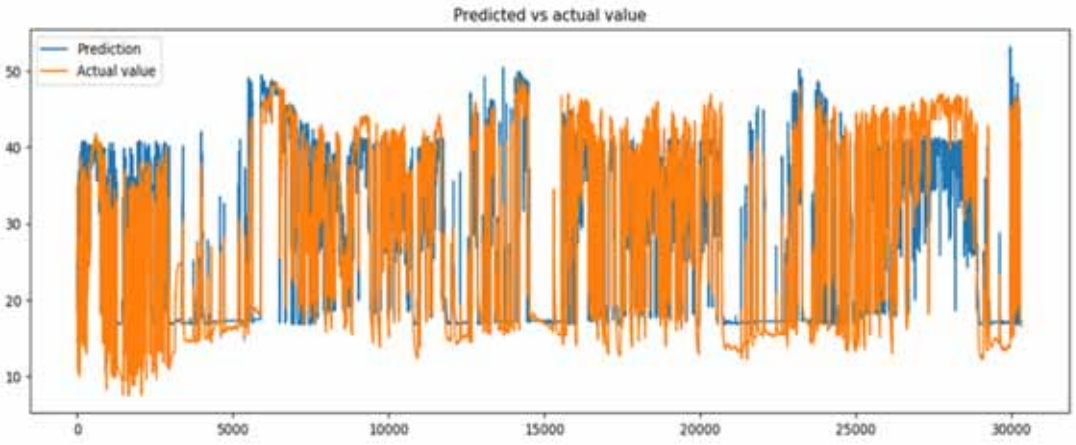



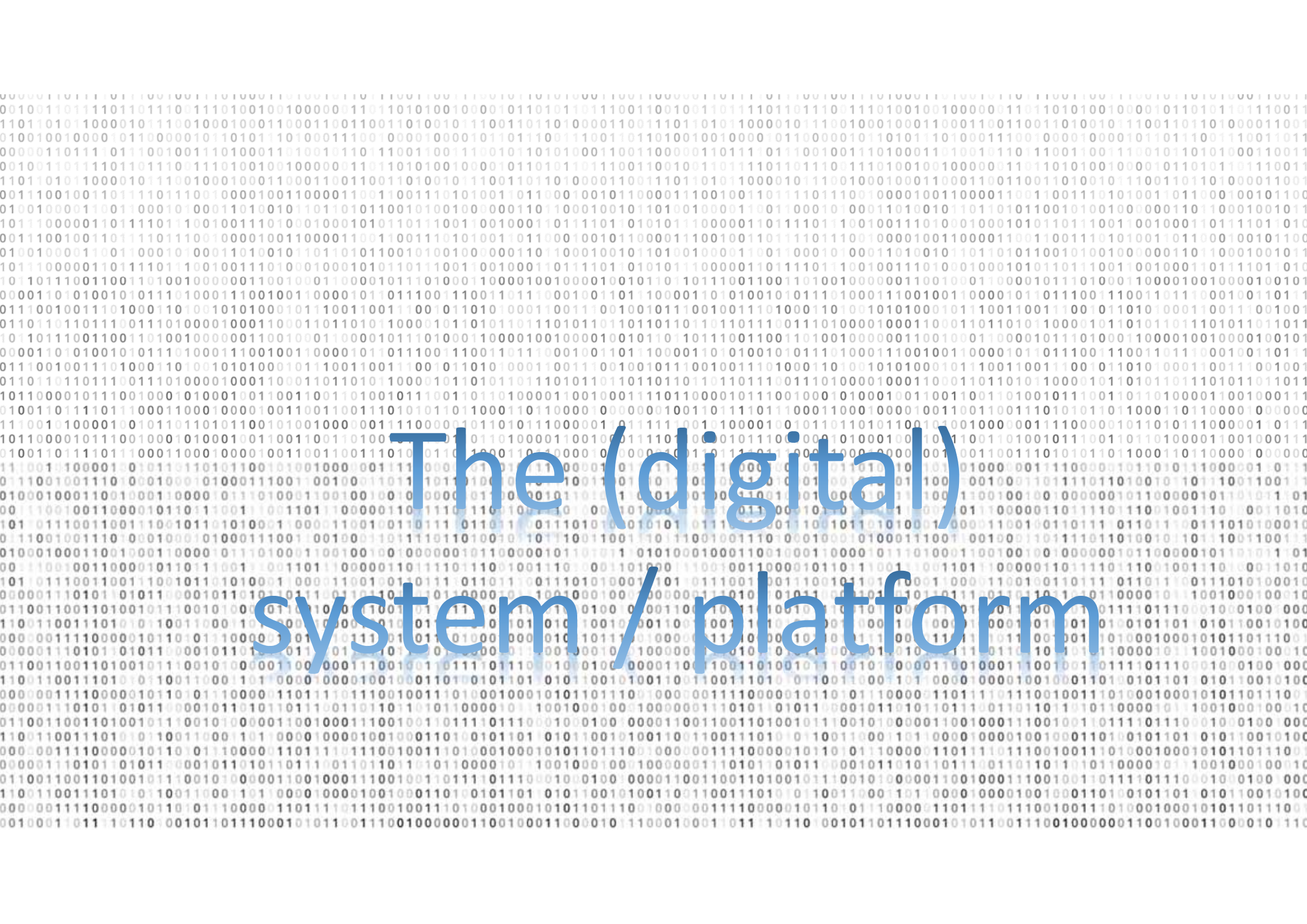



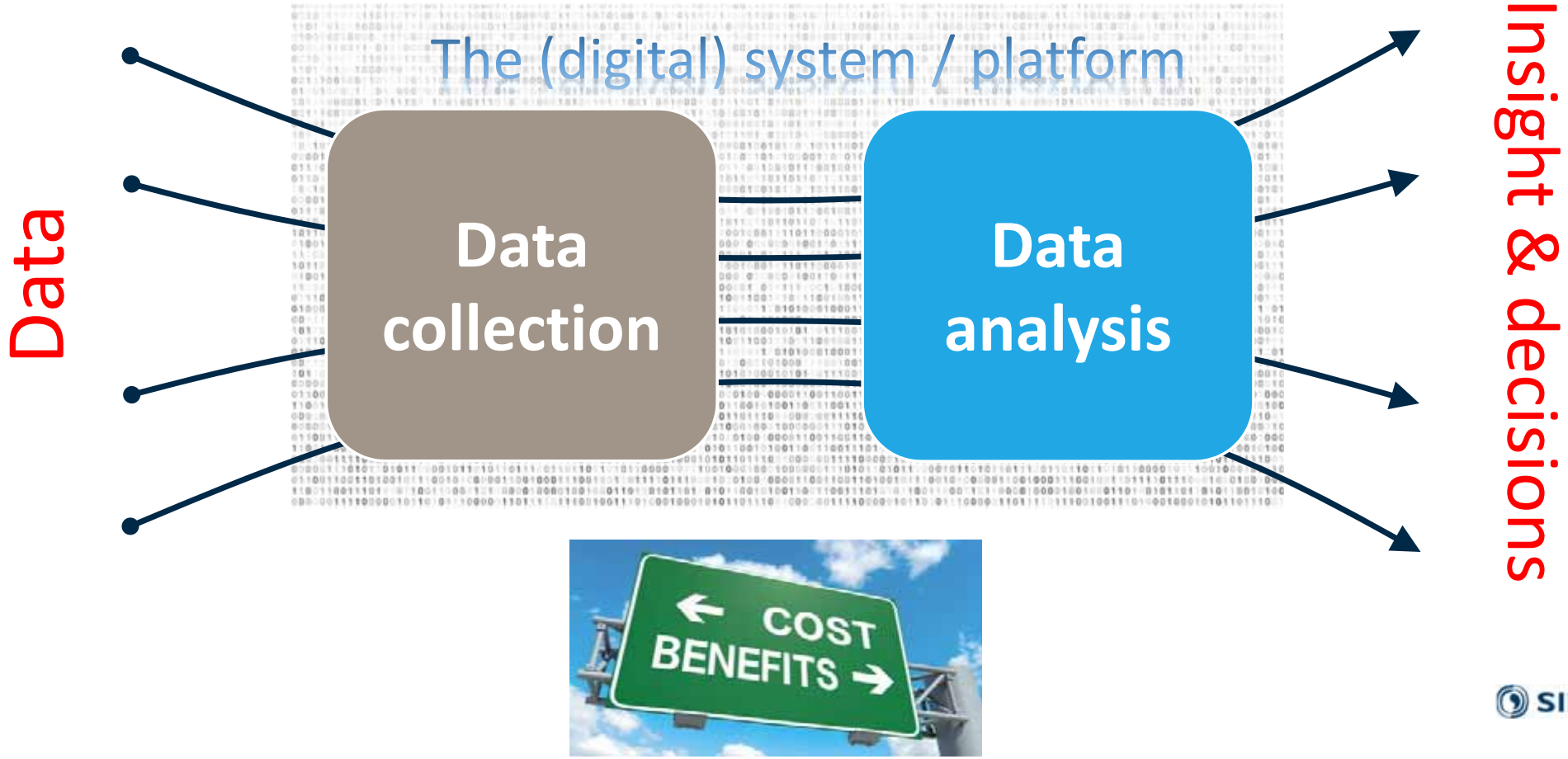
# C7. Fault detection for power transformers

- Aim:
  - Detect transformer faults through monitoring of temperature behaviour
  - Use similar models as developed and tested for C6 for other application
- Results
  - ANN anomaly detection model tested with data from Uvdal transformer
  - Quite large uncertainty due to that few input parameters (signals) ae available




The (digital)
system / platform

# System/platform for data collection and handling



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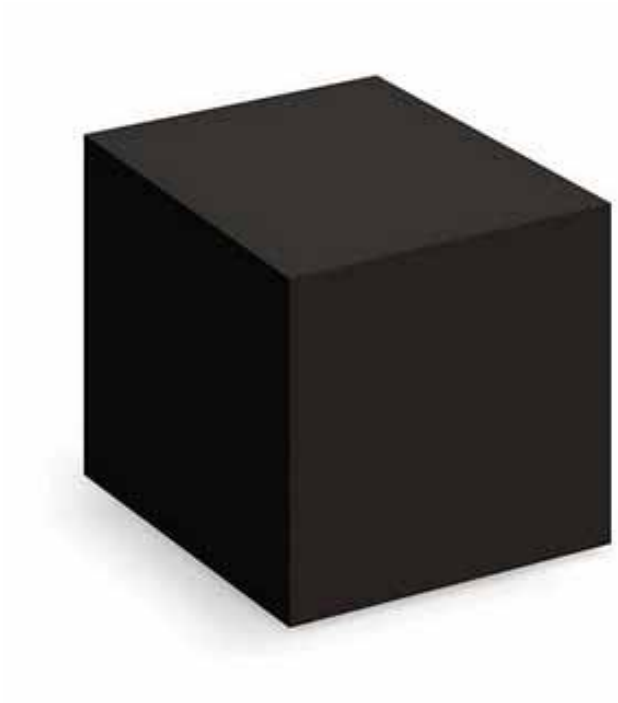
# Types of models

Y
= $f$(X1,X2)
= X1 + X2





Y
= $f$(X1,X2)
= ?

# Types of models



C1 C2 C3

physical under-standing

C6 C7 C4 C5

data-driven

simple

C2

C6 C7 C1

C4

C5

advanced

- Visualization of data – $x(t)$
- Simple models
  (e.g. duration start & stop sequences, valve opening, etc.)
- Simple statistics, correlations, trending, etc.
- Advanced statistical analysis,
  frequency analysis, machine learning


Hydropower:
High reliability & few faults
→ Normal behavior models
→ Anomaly detection



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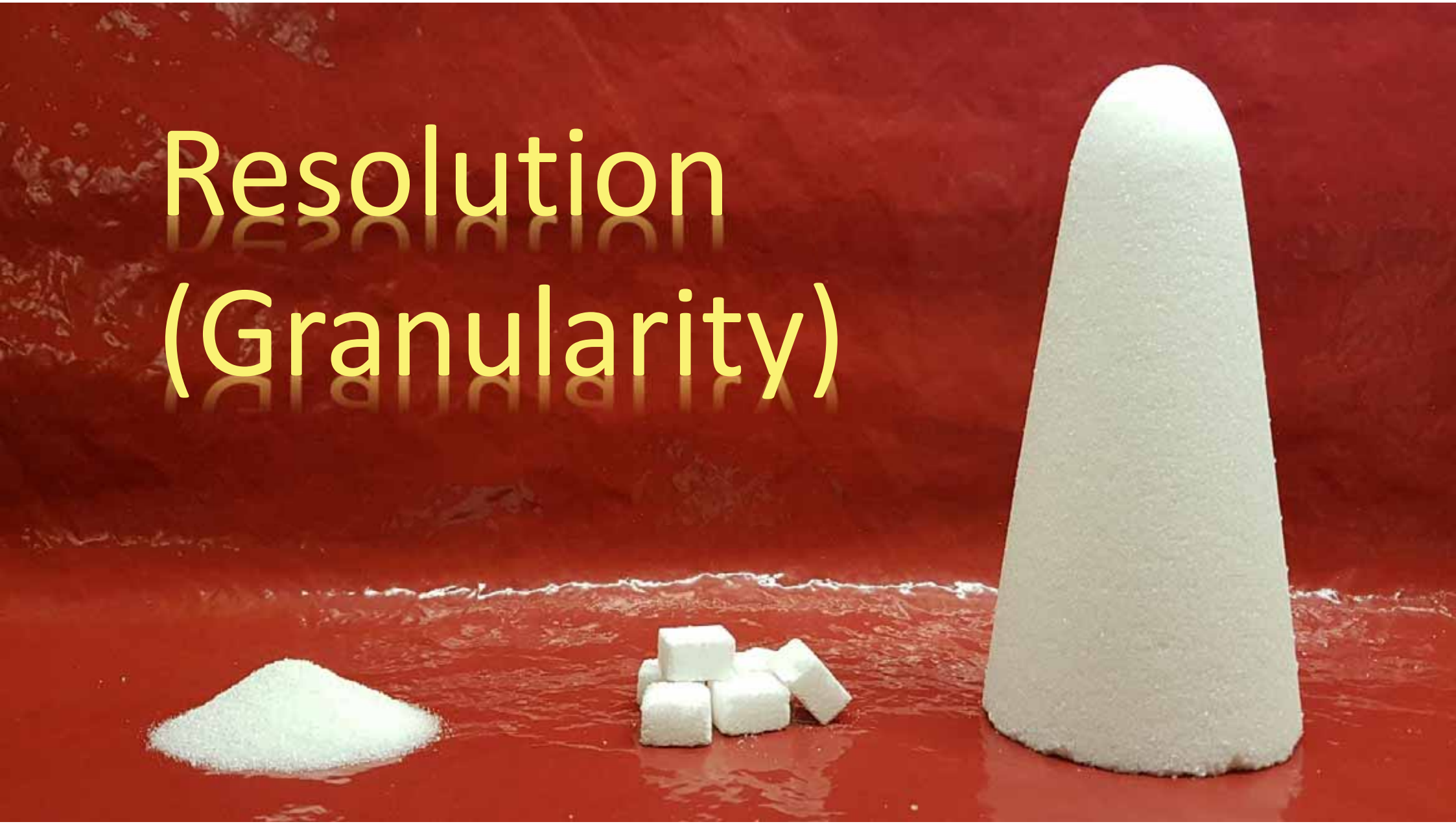
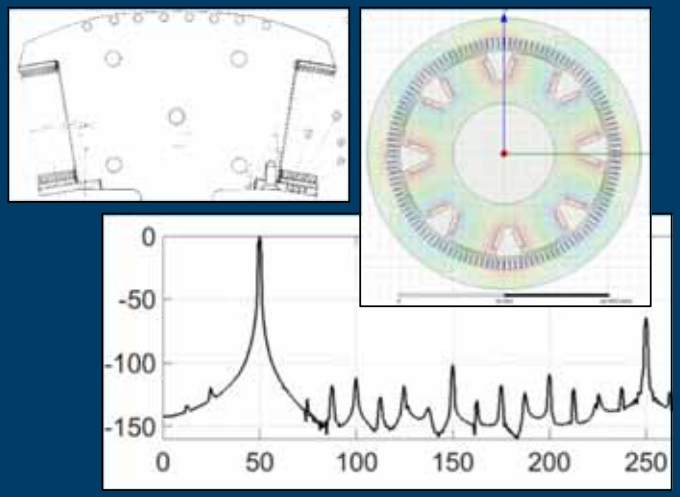

Resolution
(Granularity)

# Type of data and data resolution

**MonitorX case C1**

***Detection of rotor inter-turn faults***

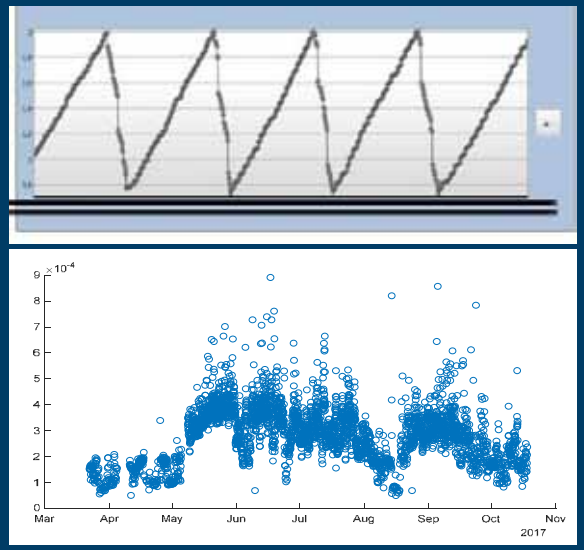
- (min. 2 …) 4 kHz




**MonitorX case C2**

***Monitoring of drainage pump behaviour***

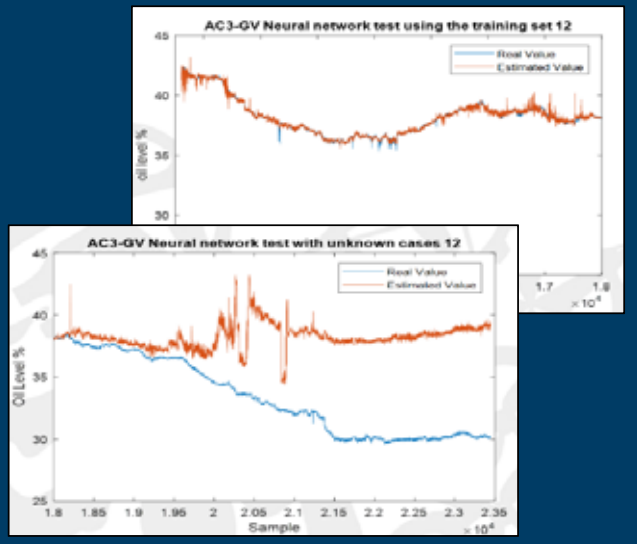
- approx. 30 sec. values

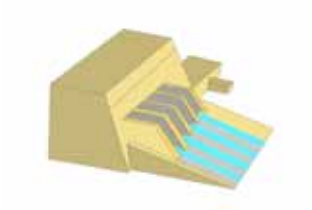


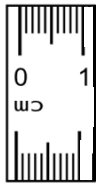

**MonitorX cases C6**

***Bearing and Kaplan condition monitoring***

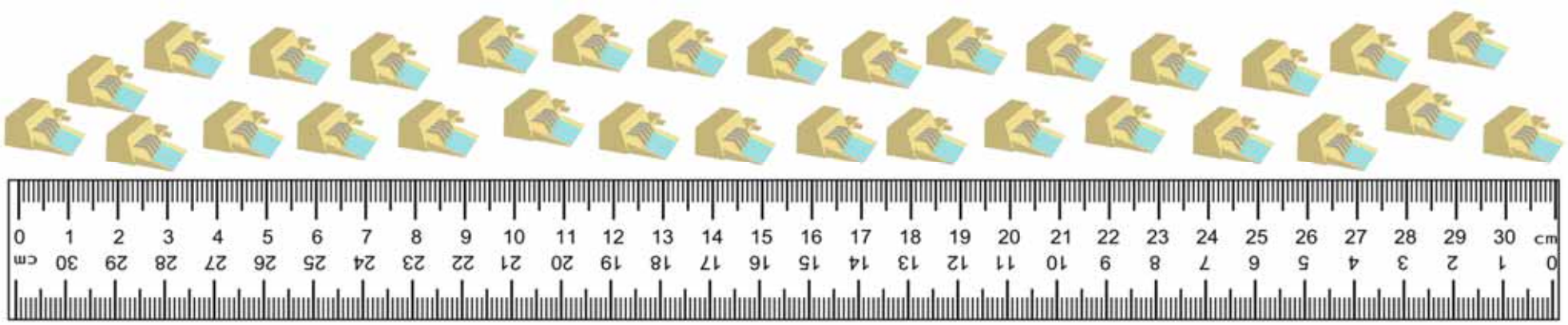
- 1 hr average values



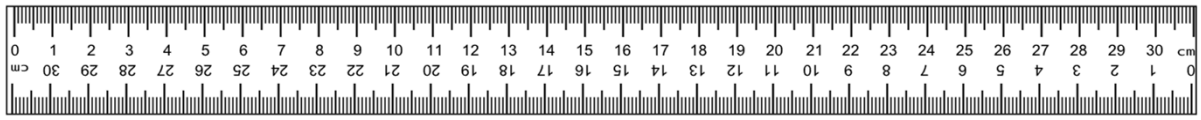





# Scalability

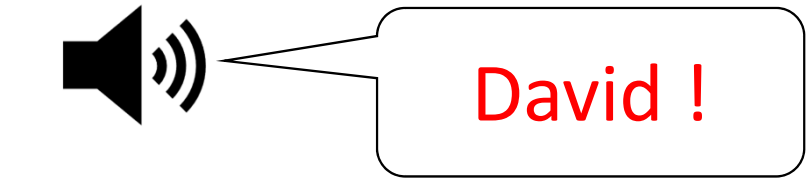


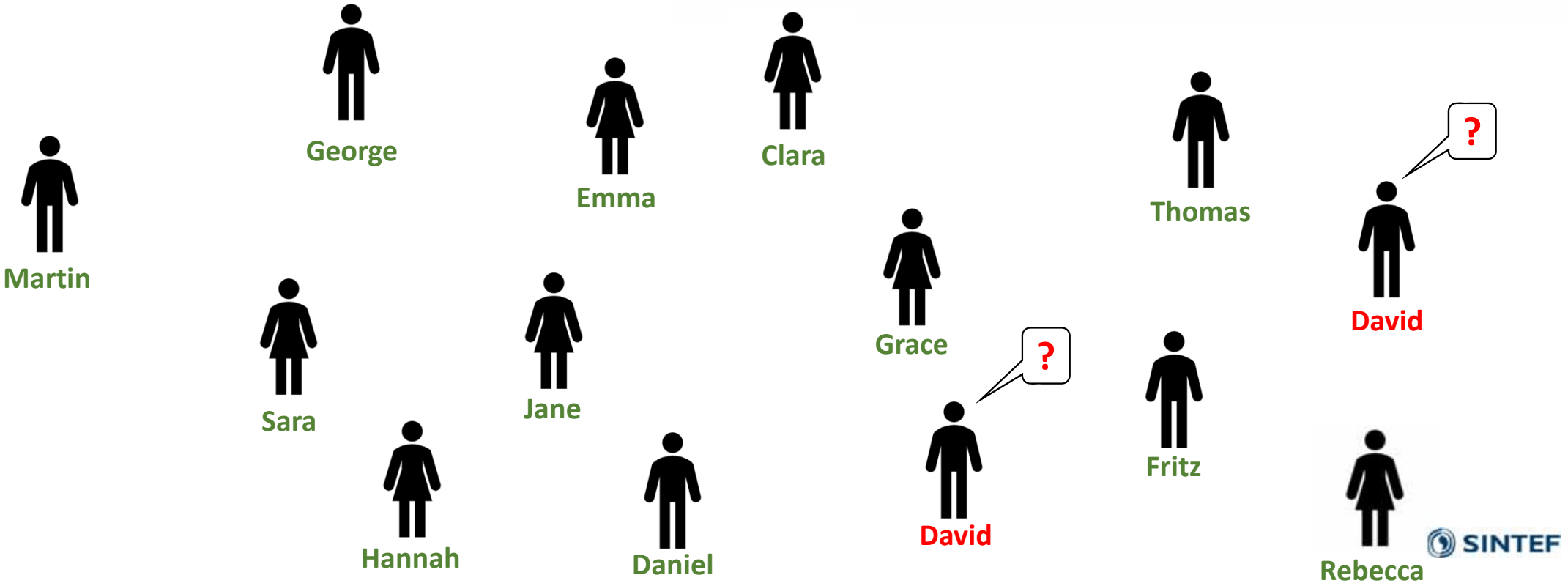
# Scalability



- Scalability / transferability:
  - **Large scale implementation**
  - Application of a model developed and tested with data from one component to same type of component in other power plant (unit) or to similar components/problems
- Some (general/simple) models can directly be used for all plants/components of same type
- Input data sets can be different and models must be rebuilt
- Models that are based on learning need usually training with data set from plant/component model is used for

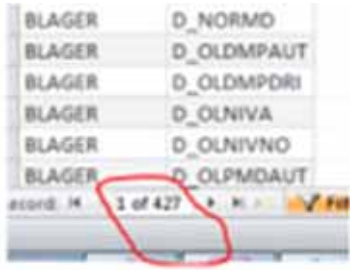
# Designation



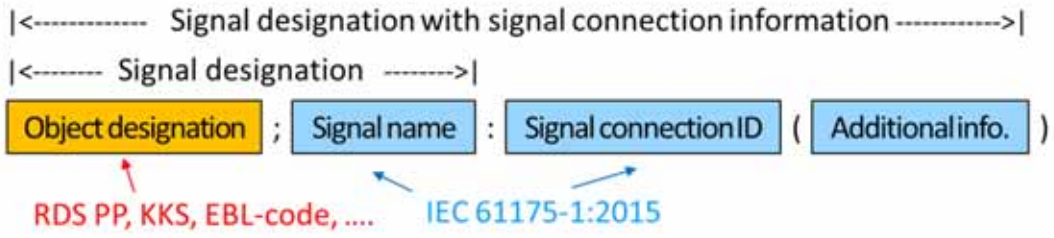



# Reference designation system

Example from power plant operator:
They have **around 10 signals** for thrust bearings.




- Consistent designation of different signals from different systems/components



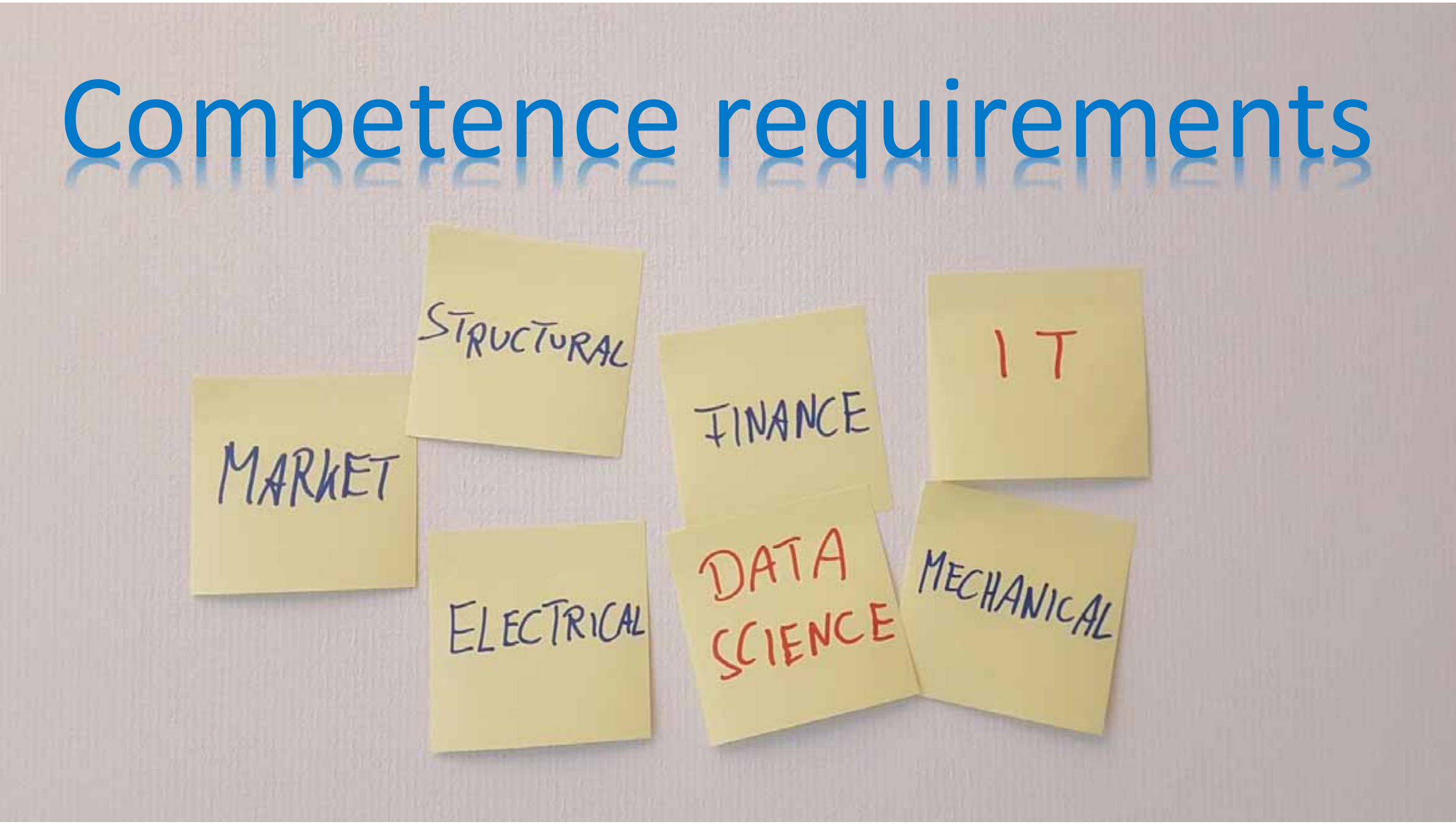

Example from power plant operator:
They **use 427 different names** for these signals


- Object designation
  - Should be consequently built on principles of IEC 81346
  - Non-proprietary, should be developed by IEC (/ISO)
  - Need for a consensus (and new RDS that fulfils principles above)

→ New RDS-Hydro Power

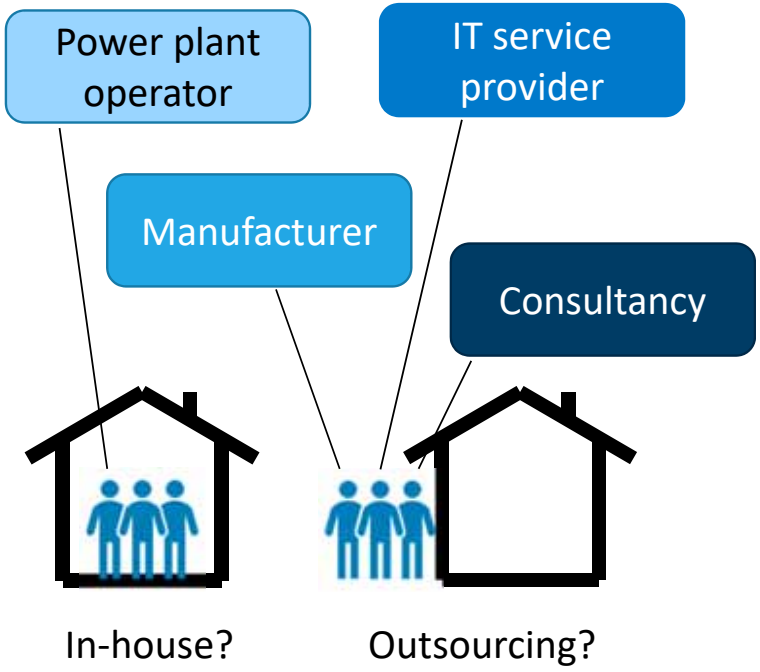
EnergiNorge

# Competence requirements



# Responsibility, competence and work processes

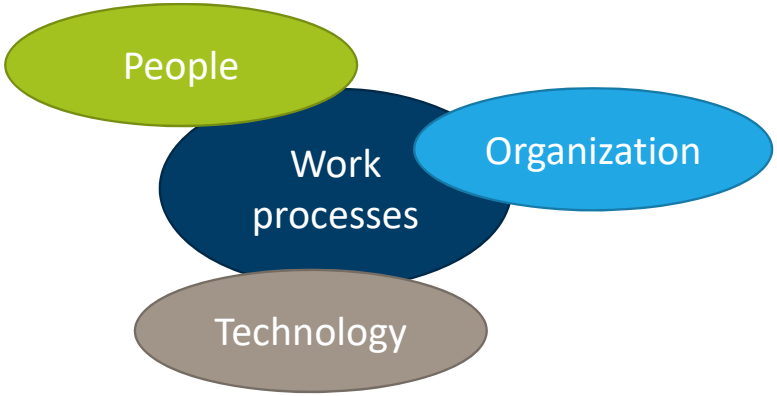
## Responsibility




## Competence


## Work processes

- New technology → New ways of working



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