MonitorX

Optimal utilization of hydropower asset lifetime by monitoring of technical condition and risk

A Norwegian-Swedish joint industry project on condition monitoring and predictive maintenance

Background

One of the key enablers for the transition from traditional corrective and time-base maintenance to condition-based and predictive strategies is data collection and data analysis for estimation of components condition and lifetime. SCADA systems in hydropower plants, additional measurement equipment and new sensors are valuable data sources for gaining more knowledge about the components' condition and lifetime. The MonitorX project was launched in 2015 to support the transition to predictive maintenance strategies in hydropower.

Project aim

The aim of the MonitorX project was to develop models, algorithms and corresponding software prototypes (i.e. example codes) for optimal lifetime utilization of hydropower components based on monitoring of technical condition and risk. Here, optimal lifetime utilization means to conduct maintenance and component replacements when required, i.e. not too late, but not too early either. MonitorX focused on development and testing of models for condition monitoring and fault detection based on machine learning and artificial intelligence (AI).

MonitorX cases

MonitorX was case driven, i.e. different cases were identified, data were collected, and different models were developed and tested with the data. The cases covered different types of components, purposes and models, and a case on SCADA data collection was also included; see page 2 for further details.

Project results

The most important MonitorX project results are:

- Models, algorithms and example software code (for selected cases).
- Experience from testing with data from power plants, incl. demonstration of the use of different models for various data analysis purposes.
- Knowledge gain and exchange of experience on various topics related to condition monitoring and digitalization of maintenance and inspection processes.
- Identification of new and remaining challenges, user needs and knowledge gaps.
- Descriptions of project results in form of reports, memos, scientific papers and presentations on international and national conferences, seminars and workshops.

Spin-off activities

MonitorX triggered several spin-off activities both inside the participating companies and outside in terms of new joint projects and activities in the hydropower industry, e.g.:

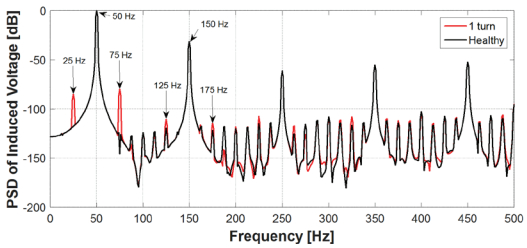
- Many plant operators started to make use of advance condition monitoring and implement new systems and data platforms for data collection and analysis.
- Manufacturers and maintenance service providers developed new services and products to serve the operators' new needs related to data collection and condition monitoring (as demonstrated in MonitorX).
- A new standard for reference designation of components in hydropower plants, i.e. a new reference designation system (RDS) that supersedes the existing EBL code plan. The new standard is called RDS-Hydro Power and is based on the principles of IEC 81346.

MonitorX - Cases

C1 - Rotor fault detection

Aim: On-line detection of rotor short-circuit and other generator faults.

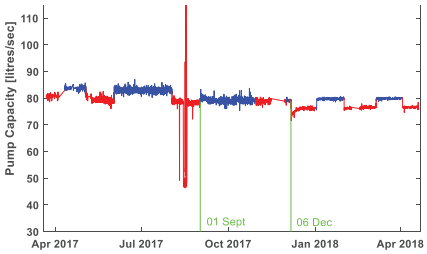
Results: New method for fault detection. Proof of concept by finite element method (FEM). Topic is followed-up by new PhD in the HydroCen research centre (see www.hydrocen.no).



C2 - Pump condition monitoring

Aim: Monitoring the performance and condition of drainage pumps.

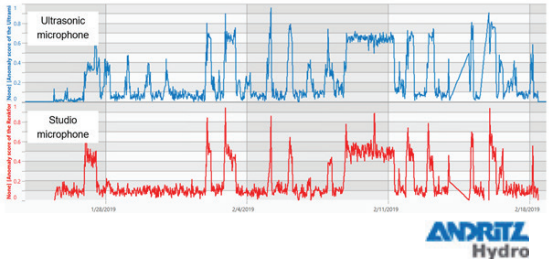
Results: Model for online estimation of pump capacity developed and tested with data from Brattset hydropower plant.



C3 - Audio surveillance

Aim: Detection of faults based on the sound from the equipment under operation.

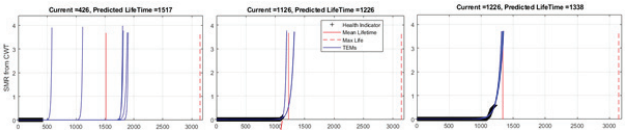
Results: Development of methods for identifying different sound patterns and detecting deviations from normal operation. Experience from testing in Svorka power plant.



C4 - Condition monitoring of rotating equipment using vibration data

Aim: Fault detection and prediction of remaining useful life (RUL) of rotating equipment based on high frequency sensor data (kHz resolution and higher) from vibration sensors (accelerometers), acoustic emission sensors and microphones.

Results: Different models developed, for feature extraction, RUL estimation, and anomaly detection and state classification. Models tested with lab test data (bearings).



X2 - Model and algorithm integration

Aim: Integration of MonitorX models and algorithms in systems and platforms for data collection and analysis.

Results: Different integration solutions tested with OSIsoft PI platform.

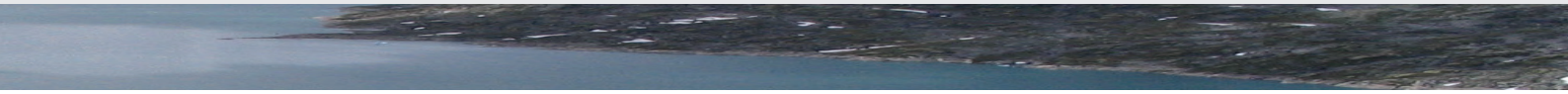
Benefits

Utilizing the MonitorX project results by implementing advance condition monitoring and intelligent data analysis will give the following potential benefits:

- Better knowledge about the real technical condition of the components, and the relation between operation conditions, loads, degradation and lifetime.
- Fewer manual inspections and shorter downtime by using more condition-based and less time-based maintenance.
- Reduced cost for corrective maintenance due to reduced probability of failure.

In a study conducted for the Research Council of Norway[1], the potential benefit of condition monitoring and predictive maintenance for Norwegian hydropower plant operators was estimated to be 650 MNOK (ca. 68 M€) as an effect of postponed investment and 4 000 MNOK (ca. 420 M€) as a consequence of reduced production losses due to less downtime for corrective and preventive maintenance.

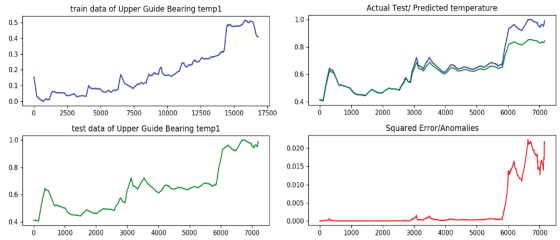
[1] Effekter av energiforskning – Hovedrapport, http://bit.ly/hovedrapport



C5 - Condition monitoring of generator bearings

Aim: Early detection of bearing degradation or faults using available SCADA data.

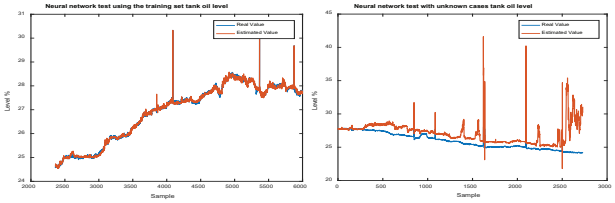
Results: Different models (ANN, LSTM, clustering) developed and tested with available data from Dale and Nygard power plants.



C6 - Condition monitoring of Kaplan turbine hydraulic system

Aim: Monitoring the condition of the hydraulic regulation system for a Kaplan turbine using SCADA data.

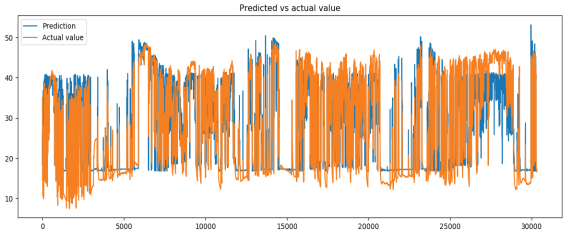
Results: Artificial neural network (ANN) based models for detecting anomalies and faults., tested with data from Embretsfoss and Laxede.



C7 - Fault detection for power transformers

Aim: Monitoring the performance of the transformer cooling system.

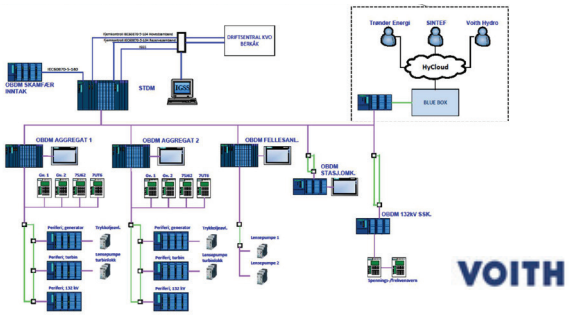
Results: ANN anomaly detection models (similar to the ones in C7) developed and tested with data from Uvdal powerplant.



C8 – SCADA data collection system

Aim: Data access and collection from power plant's control system.

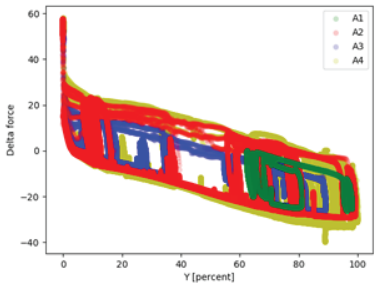
Results: System for secure collection of data from the power plant's control system (Brattset power plant)



C9 – Continuous Servomotor monitoring

Aim: Detecting changes in servomotor forces.

Results: One Class Support Vector Machine (OC SVM) model that accurately defines the boundary for the servo forces.



HYMATEK

MonitorX industry partners

Norwegian power plant operators:
E-CO Energi AS
Gitre Energi Produksjon AS
Eidsiva Vannkraft AS
Hydro Energi AS
Lyse Produksjon AS
NTE Energi AS
Sira-Kvina Kraftselskap AS
Skagerak Energi AS
Statkraft Energi AS
TrønderEnergi Kraft AS
Østfold Energi AS

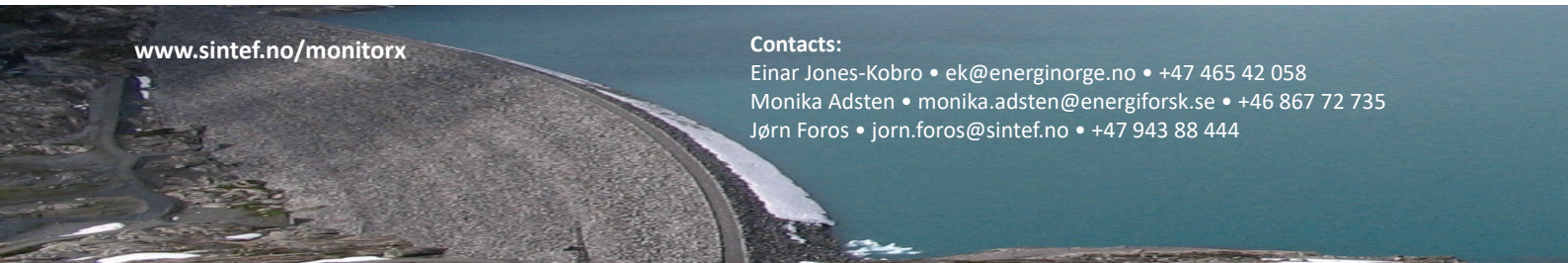
Swedish operators (represented by Energiforsk):
Vattenfall Vattenkraft AB
Umeå Energi AB
Vattenfall Indalsälven AB
Fortum Generation AB
Uniper - Sydkraft Hydropower AB
Sollefteåforsens AB
Statkraft Sverige AB
Skellefteå Kraft AB
Holmen Energi AB
Jönköping Energi AB
AB Edsbyns Elverk
Varberg Energi AB
Karlstads Energi AB
Jämtkraft AB

Manufacturers and service providers:
Andritz Hydro AS
Hymatek Controls AS
Karsten Moholt AS
Voith Hydro AS

MonitorX – Overview and facts

Type of project:	Innovation project for the industrial sector (IPN)
Project period:	July 2015 – June 2019
Budget:	13.6 MNOK + 3.6 MNOK industry in-kind
Financing:	Industry partners, Research Council of Norway
Project owner:	Energi Norge (Energy Norway)
Industry partners:	Energiforsk, power plant operators and manufacturers/service providers
R&D partners:	SINTEF Energy Research, NTNU, Comillas University (Madrid)

EnergiNorge Energiforsk SINTEF



www.sintef.no/monitorx

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