Study Committee C1

Power System Development and Economics

Paper 11004_2022

Availability of data for asset management and automated condition monitoring

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STATNETT SF

Motivation and objectives

- Statnett has an ageing and increasing asset base
- Statnett need to better know the technical condition and lifetime of their assets
- Better knowledge of asset condition will also lead to safer operation and possibly better utilization of capacity
- Make data available from assets by acquisition of data from the assets and their power systems
- Improve maintenance by increasing use of Condition based maintenance
- Make asset monitoring dashboard for critical assets as power transformers, GIS SF_6 pressure monitoring, and submarine cables
- Ensure quality of data is present for transformer monitoring, continuously checking various transformer measurements for anomalies Data Watch Dog (DWD)
- Make assets available for trend monitoring, abnormal conditions can be detected early
- Statnett wants to be a data-driven organization in the future being able to perform predictive/ prescriptive maintenance, finding the optimal timing for reinvestments and gain better control of risk
- Statnett will in the future make decisions for investment and maintenance based on the technical condition of the assets

Method/Approach

- Statnett SF and Cognite have worked in close cooperation to Digitize selected value chains. Data Science competence has worked with the subject matter experts in powerful knowledge sharing cooperation over time
- Dashboard solutions for monitoring of power transformers, GIS (Gas Insulated Switchgear) SF_6 pressure monitoring and submarine cables has been developed. In addition, a data watchdog dashboard for power transformers has been developed for signal quality monitoring
- The purpose of the FRIDA program has been to improve Statnett's asset management and grid planning through better use of data from the grid assets and the power system
- These dashboards have become important tools for professional expertise in Statnett for mentioned areas to detect errors and possible development of abnormal events
- In investigation, after an incident, the dashboards have been used to find the underlaying cause of the incident. The content in the dashboards can be "tailor made" to your own timeseries, resolution and which parameters to be included. Threshold values can also be added for alarm handling in the dashboards.
- FRIDA program in Statnett had the intention of driving digitalization in the Company through working agile, and in cross functional teams which covers several skills. The purpose of the team working with asset management was to make asset management in Statnett smarter and more efficient.

Discussion and conclusion

- The existing dashboards power transformers, GIS (Gas Insulated Switchgear) SF_6 pressure monitoring and submarine cables has been of great value for the organisation
- Threshold alarms have early warned of a negative trend development of the condition for some assets; resulted in necessary measures being taken to prevent further deterioration
- One overall dashboard show a fleet overview, showing the key performance indicators of the entire fleet (allowing to filter down to a certain region)
- A single-asset one drilling down into the detailed views
- Data Watch Dog (DWD) have the similar solution showing the fleet overview as well as a drilldown overview for the individual power transformer
- The dashboards are great tools for visualizing the assets condition and in daily use especially by the subject matter experts
- To further improve the value of the dashboard solutions more data is necessary, more data acquisition is needed, and from even more assets
- Data Watchdog monitors the timeseries continuously and gives an alert if the timeseries are out of range
- Further development of the dashboards are in continuous improvement, this give the possibility to work out algorithms that can be taken into use in near future

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Transformer dashboard

- For both dashboard (fleet overview and single) source of data are as follows:
  - ✓ Sensor time series of voltage, current, temp. etc
  - ✓ Bushing measurements
  - ✓ Thresholds for analyze of oil samples and dissolved gas concentration
  - ✓ Online dissolved gas analyze for some problematic transformers
- Views:
  - ✓ Time series; build-your-own graph interface where the user can select the time series. All the time series plots are using aggregated data and allow to view data from arbitrary time periods ranging from multiple years to just a certain hour and easily zoom between different resolutions.
  - ✓ Oil and gas analysis: these pages show the analysis results together with the latest oil sample data and the thresholds which were used for this transformer, highlighting the values that led to the conclusion.
  - ✓ Bushing analysis: the single-asset dashboard page lists bushings metadata for the selected transformer (manufacturer, model, etc.) together with factory and latest field measurements of capacitance and tangents delta.
  - ✓ Overload: here the primary side current time series are compared with the rated current value both through a time series chart and a yearly summary table.

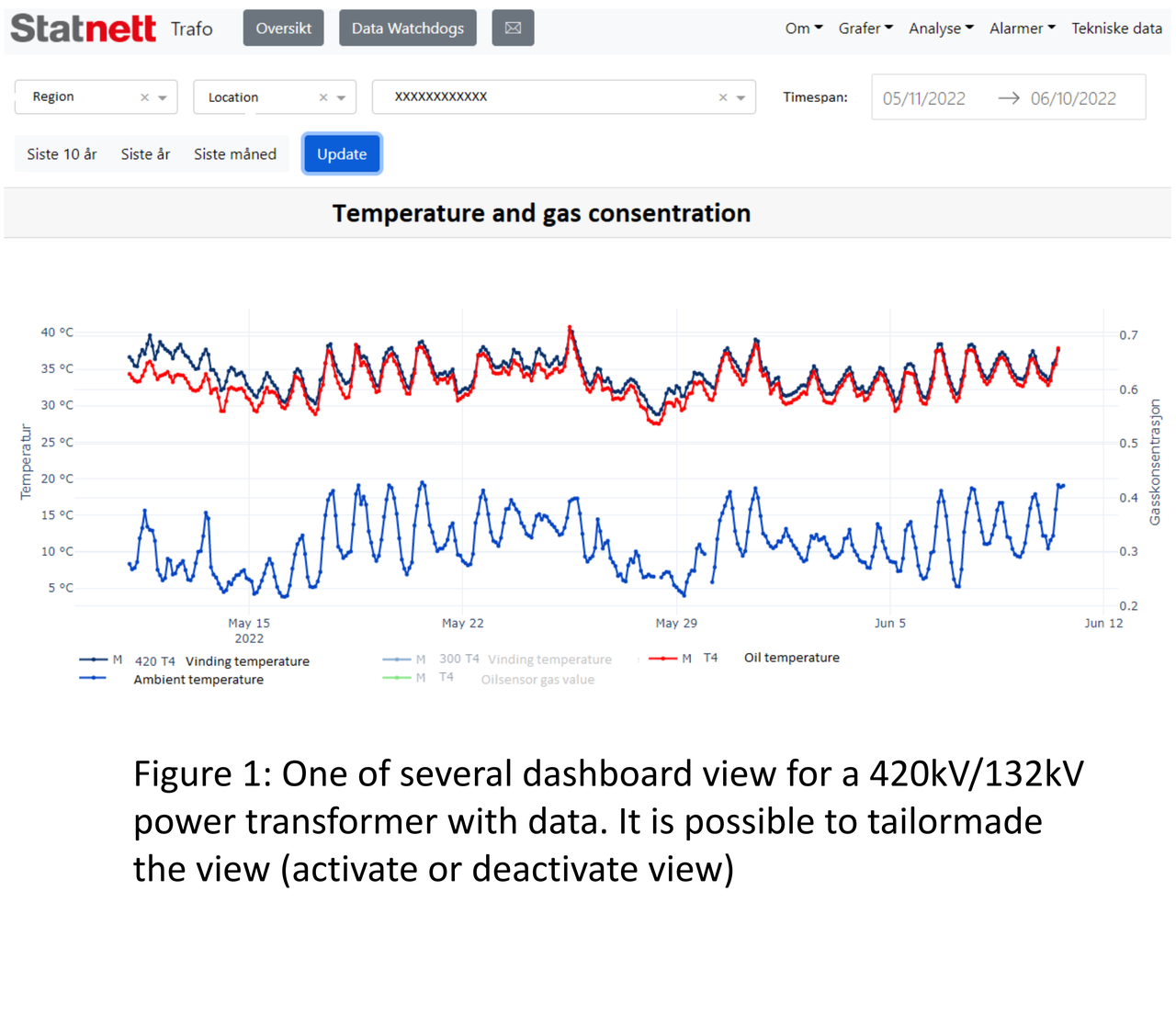

Figure 1: One of several dashboard view for a 420kV/132kV power transformer with data. It is possible to tailormade the view (activate or deactivate view)

Cable dashboard

- One dashboard focusing on a single cable system at a time while the fleet overview dashboard provides a view of the entire fleet. Data sources are:
  - ✓ Sensor time series of currents and insulator pressures
  - ✓ Distributed temperature sensing (DTS) profiles
  - ✓ Point temperature sensing (PTS) time series
  - ✓ Depth of cover, depth of lowering, seabed depth
  - ✓ Annotations which are manually added by the cable system experts
  - ✓ Thresholds for both pressures and temperatures
  - ✓ Conversion tables between the different length units
- Views:
  - ✓ DTS temperatures, multiple views, ranging from a single-profile view to an animation of data spanning a few days as well as heatmaps and aggregated profile views
  - ✓ DTS signal quality: In case the cable suffers damage from, for example, a ship's anchor, there will be a new drop on the signal quality graph which can be used for fault localization.
  - ✓ Insulator pressures: we provide a zoomable time series plot of pressure values and the computed pressure deviations together with thresholds
  - ✓ GIS maps: an integration with GIS provides a map showing regions where cable systems with DTS or PTS are installed together with the last observed temperature readings
  - ✓ Fleet overview shows the summary of all connected cable systems

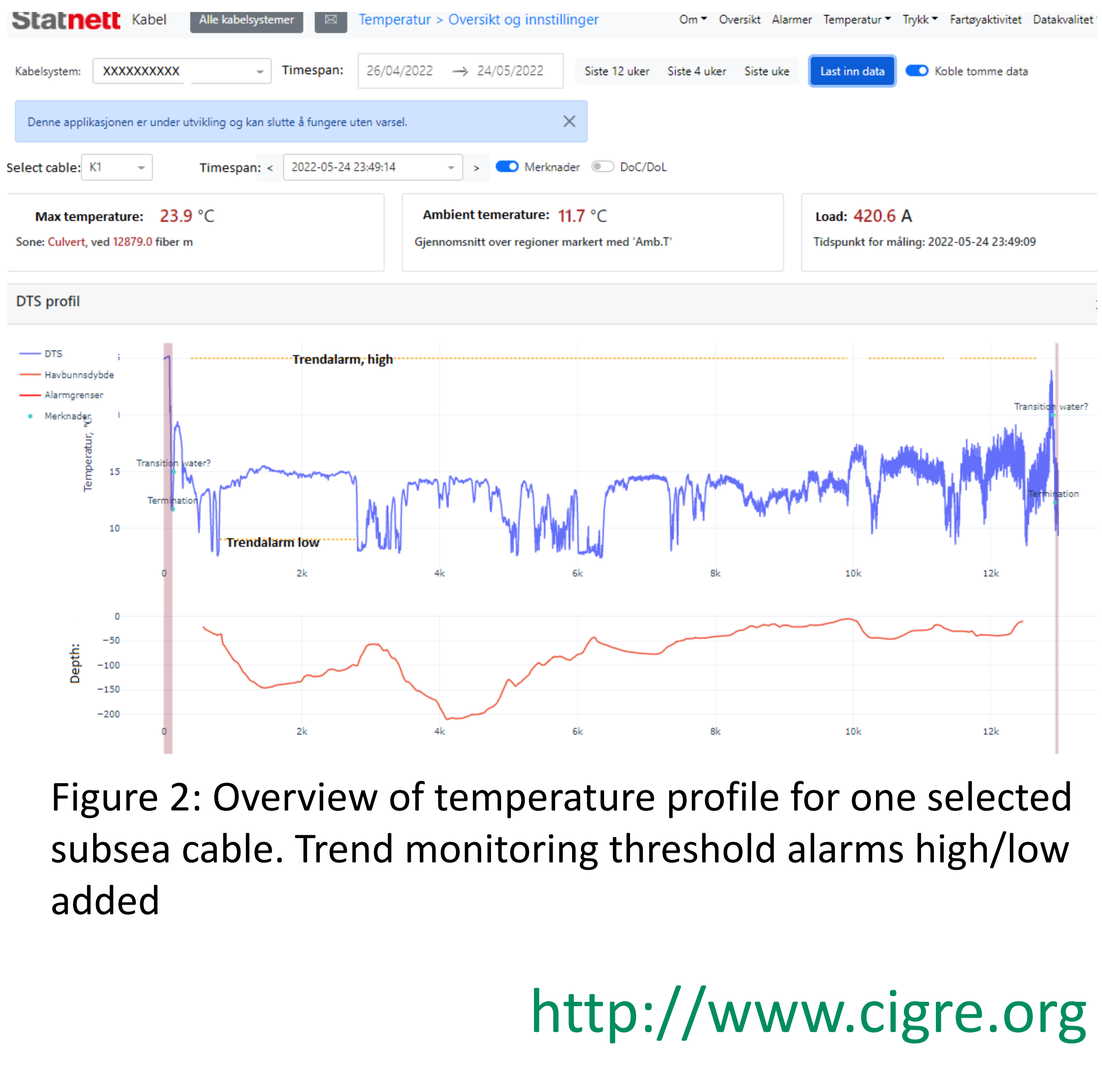

Figure 2: Overview of temperature profile for one selected subsea cable. Trend monitoring threshold alarms high/low added

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Gas Insulated Switchgear Dashboard

- For both dashboard (fleet overview and single) source of data are as follows:
  - ✓ Sensor time series of voltage, current, total volume of SF_6 gas, leak rate for SF_6 gas, expected gas loss
  - ✓ Thresholds for trend monitoring values
- Views:
  - ✓ Time series; build-your-own graph interface where the user can select the time series. All the time series plots are using aggregated data and allow to view data from arbitrary time periods ranging from multiple years to just a certain hour and easily zoom between different resolutions.
  - ✓ Leakage rates of SF_6 gas are generated in data the collection units or in the superior asset data unit for timely warnings to expected gas leakages. This possibility of external programming opens better reaction times for mobilization and prevents unexpected leakages and associated with it network disruptions.
  - ✓ Current load and the system voltage (phase to earth potential) per phase and bay. With these features, Statnett can evaluate and document technical events, high transition resistances on main bus bars and breaking function on circuit breakers.

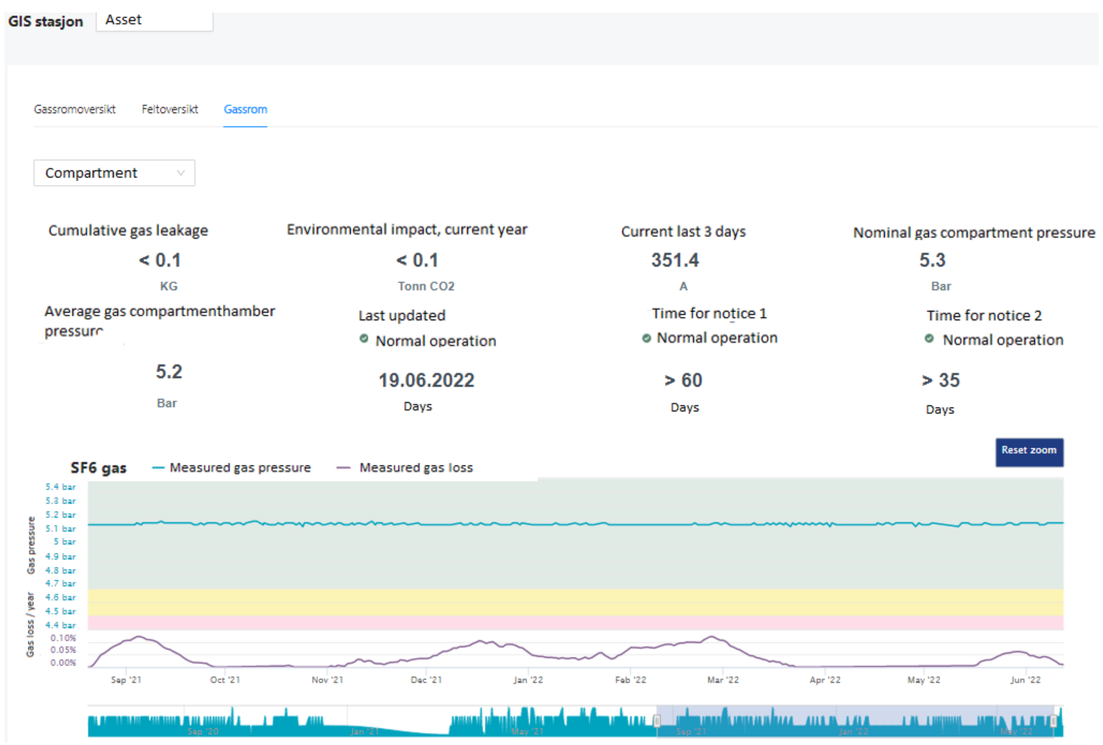

Figure 4: SF_6 pressure monitoring for one specific compartment with monitoring

Data Watchdog (DWD) Dashboard

- Data Watchdogs is a system for continuously checking various transformer measurements for anomalies. Anomaly events are presented in a dashboard for interpretation by transformer experts. Statistics show the prevalence of data quality issues and can point to equipment failures.
- The dashboard presents both ongoing and historic events as a summary table. Each event can be further investigated.

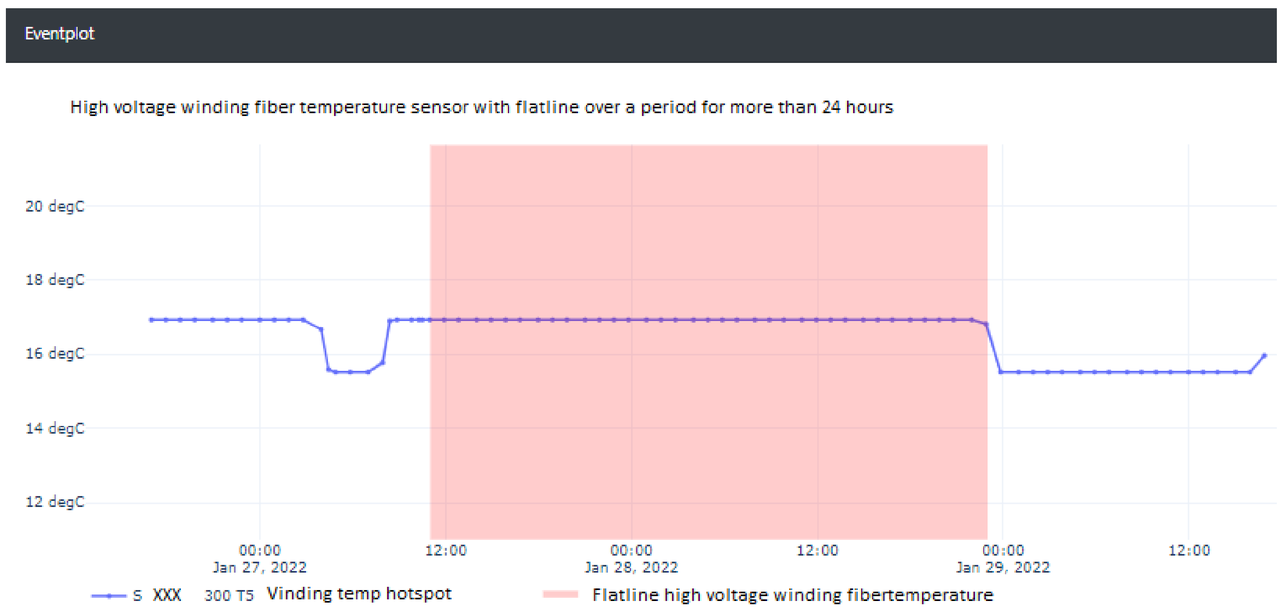

Figure 5: High voltage winding fiber temperature sensor with flatline measurement over a longer period than 24 hours

Conclusion and further work

- Statnett aims to automatically make data-driven decisions, if this shall be possible, the data quality, uptime and availability from sensors and transmitters must be as high as possible for that the decision must be reliable. Statnett aims to focus on the following areas in the future to strengthen monitoring and control of our critical asset:
- Asset Health Index for critical assets like power transformers
- Adapt and develop algorithms
- Develop better and useful trend development tools
- Define need for useful sensors and transmitters
- More Condition based maintenance
- Interdisciplinary collaboration between subject matter experts, asset management and IS/IT
- Interdisciplinary competence development
- Develop digital twins
- Optimization of costs and benefits through economic calculations, for example, the calculation of future risks and the automated budget making