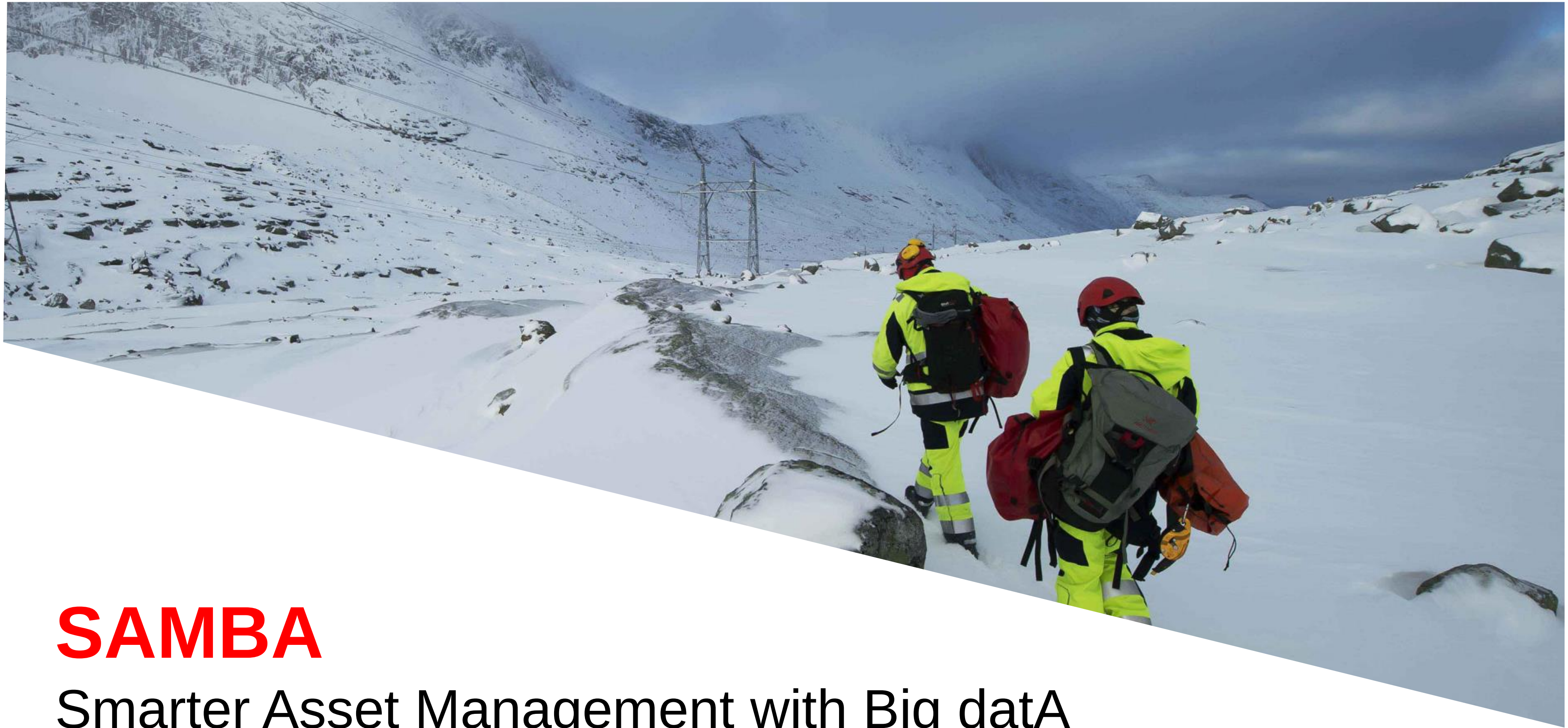


SAMBA

Smarter Asset Management with Big datA

Results from SAMBA WP2 and WP3 - Use case Collection

Statnett

Statnett

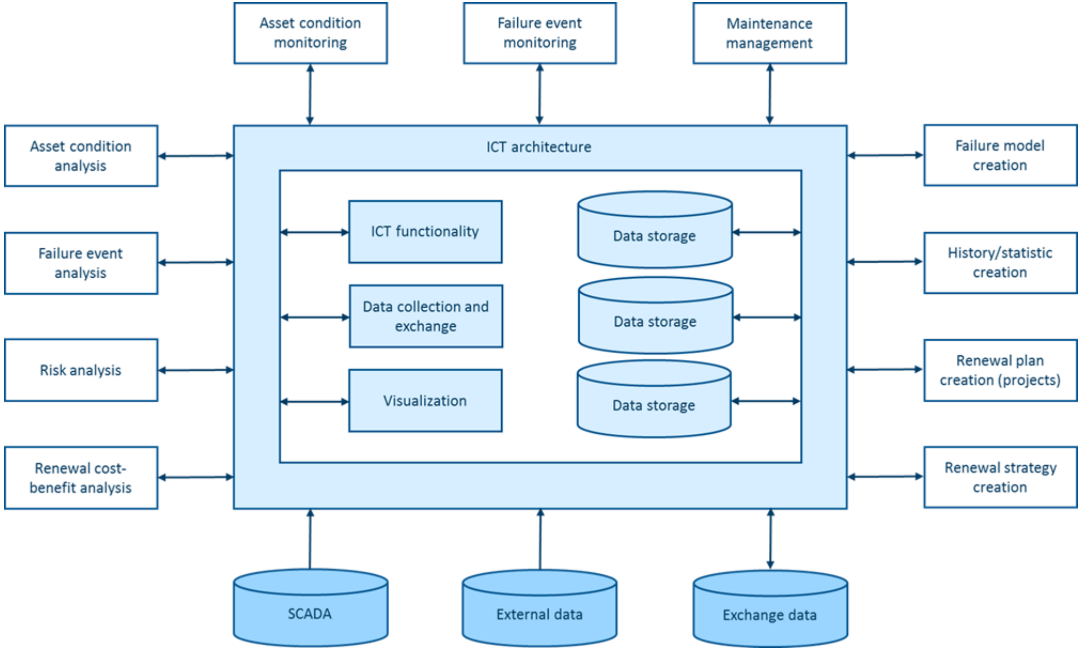
Contents

- Future asset management in Statnett
- The challenges
- Idea behind the SAMBA-project
- Potential benefits of the SAMBA-project
- Method used in the project
- Use cases in SAMBA
- Examples of use cases
- Data needs
- Concluding remarks
- The road to smarter asset management; SAMBA and beyond

Future asset management

- Maintenance and reinvestment decisions based on systematic use of data analysis.
- All analysis are data-driven.
- The necessary data is quality assured and seamlessly available for the different analysis.
- The ICT-architecture supports analytics and also exchange of data both internally and externally.
- Continuous improvement is an important part of all processes of asset management.
- The processes for analysis are well-organized and a part of the overall asset management strategy.

Elements in asset managment



Statnett

Future powersystem

Real time stream analytics

- Event hub
- Alarm management
- Correlate across multiple streams of data
- Knowledge aggregation in large data sets through measurements and simulations

Automation

- Platform for analysis and automation
- SW Robots
- Decision support

Machine learning

- Data mining
- AI
- Deep Learning
- Pattern recognition
- Image recognition

Industrial Internet of Things

- Sensor analytics (Fog computing/Distributed systems)
- Redundancy and condition estimation with a large number of sensors.
- IP og connectivity → new options for integration

CONNECT

Forecasting

- Monte Carlo simulations
- Trend analysis
- Alarms/early warnings

Integration and data management

- Platform
- Semantics
- Context-awareness
- Hadoop ETL
- Data factory

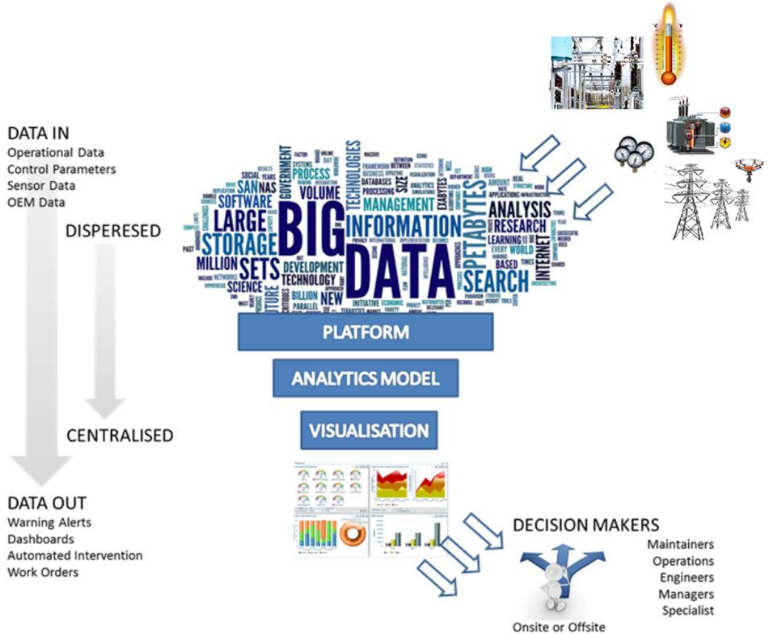
The challenges

- Statnett has an ageing and increasing* asset base.
  - Average age approaching 40 years.
- But many of the assets is *believed* to still have a long remaining life if well-maintained.
- A challenge is to have enough good quality data and models to estimate the current condition and remaining life of the assets.
- Another challenge is to efficiently collect relevant data and make it available for asset management purposes.

*Asset base of Statnett is increasing due to the European Union's Third Energy Package and corresponding changes in the Energy Act - making Statnett the sole owner of the transmission network.

Idea behind the SAMBA-project

- Asset management in Statnett can improve using:
  - Models and analyses from industry and research partners in the project.
  - Build a new ICT-architecture.
- The project is an open arena for discussion.



Idea behind the SAMBA-project

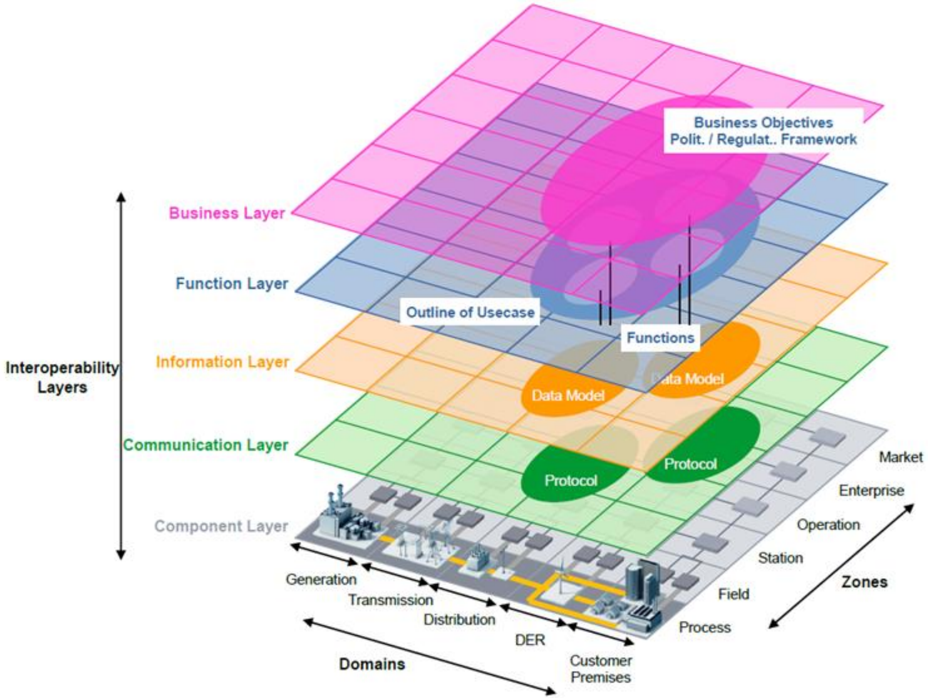
- Input to the future ICT-architecture in Statnett:
    - Which data is needed and how often?
    - Which analysis to perform?
    - How should the visualization be done?
- Outside the SAMBA-project:
    - Type of data collection, analysis and visualization tools to acquire.

Potential benefits from the SAMBA-project

- Optimal timing of reinvestments.
- Optimising of operation versus component condition and capacity.
- Maintenance performed at the right time based on condition.
- Easy overview of the risk picture for the transmission network.
- ICT-architecture supporting asset management functions.

Metode used in the project

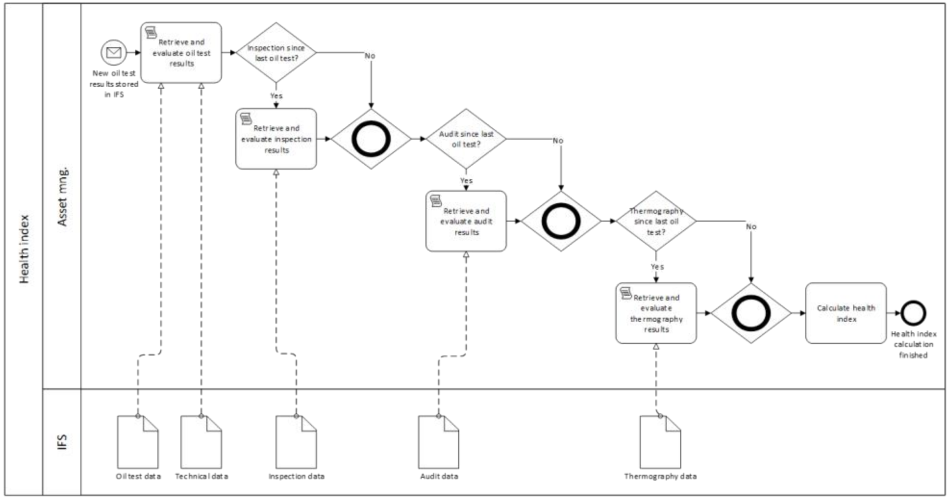
- Use case methodology
  - Description of a function supporting a need in the organization.
  - Can be part of a requirement specification.
  - First used in software development.
  - Well suited for communication between i.e. user and software developer.
- Template from IEC standard 62559-2.



Source: Smart Grid Reference Architecture (SGAM) proposed by the CEN-CENELEC-ETSI Smart Grid Coordination Group

Diagrams

- BPMN (Business Process Model and Notation) diagrams illustrate the use cases.
- A BPMN diagram is a standardized way to illustrate a function or a process.
  - Interactions and data flow between systems (actors) are illustrated.



Use cases in SAMBA

Statnett

19 use cases described in the report

Enterprise

Enterprise (asset management)

Asset management (A):	*Input use cases:*
A3.1 Estimation of residual lifetime, probability of failure, and risk	O2.1, O2.2, T3.1, T3.6, CB3.2, CB3.3, CB3.5, L3.5, C3.4,
A3.2 Technical-economic analysis of maintenance and reinvestment	A3.6
A3.3 Registration and analysis of historical costs	A3.1, C3.5
A3.4 Visualization of condition/risk for stations and overhead lines	-
A3.5 Condition assessment through sample testing	A3.1
A3.6 Registration and storage of condition information	L3.2
A3.7 Risk monitoring of critical equipment	T1.1-T1.12, CB1.1-CB1.10, L1.1-L1.8, C1.1-C1.8
A3.8 Identification of renewal needs for stations	A3.1, O2.2
A3.9 Benchmarking	A3.1, A3.7

Operation

Electric system operation (risk monitoring center)

Operation (O):	*Input use cases:*
O2.1 Asset condition monitoring	T2.2, L2.1, L2.2, L2.3, C2.1, C2.2, C2.3, C2.4
O2.2 Asset risk monitoring	O2.1
O2.3 Immediate actions	T2.3, C2.5
O2.4 Permissible overload	T2.4, C2.6
O2.5 Event detection	L2.4

Station / Process / Field

Transformer (T):

Data collection:
T1.1 Technical data
T1.2 Periodic oil and gas data (GOT, DGA)
T1.3 Inspections
T1.4 Event history
T1.5 Online gas data
T1.6 Load and temperature
T1.7 Paper sample
T1.8 Decommissioning data
T1.9 Tap changer operations
T1.10 Cooling start/stop
T1.11 Moisture
T1.12 Failure data
T1.13 Electrical condition data
T1.14 Sealing condition data
T1.15 Service Condition Data
T1.16 Surface Condition Data

Operation:
T2.1 Online gas data analysis
T2.2 Health index
T2.3 Immediate actions
T2.4 Permissible overload

Asset management:
T3.1 Thermal winding aging
T3.2 Mechanical paper aging
T3.3 Tap changer operations
T3.4 Oil aging
T3.5 Periodic oil and gas analysis
T3.6 Health index
T3.7 Maintenance

Circuit breaker (CB):

Data collection:
CB1.1 Number of operations
CB1.2 Breaker position
CB1.3 Technical data
CB1.4 Failure data
CB1.5 Short circuit current
CB1.6 Break time
CB1.7 Opening time
CB1.8 Vibration patterns
CB1.9 Gas quality
CB1.10 Gas density
CB1.11 Reactor current
CB1.12 Breaker operations
CB1.13 Condition monitoring data
CB1.14 Weather data
CB1.15 RCM

Asset management:
CB3.1 Maintenance action
CB3.2 Calculation of mechanical wear
CB3.3 Calculation of electrical wear
CB3.4 Vibration analysis
CB3.5 Health index
CB3.6 Re-ignition monitoring of reactor breakers
CB3.7 Temperature measurement on GIS circuit breaker

Overhead line (L):

Data collection:
L1.1 Load
L1.2 Temperature
L1.3 Ice formation
L1.4 Weather data
L1.5 Inspections
L1.6 Thermograpy
L1.7 Technical data
L1.8 Geographical data
L1.9 Short circuit data
L1.10 Failure data

Operation:
L2.1 Sag identification
L2.2 Ice prognose
L2.3 Line condition
L2.4 Failure prediction and preparedness

Asset management:
L3.1 Line condition
L3.2 Connector condition
L3.3 Tower and foundation condition
L3.4 Insulator string condition
L3.5 Health index

Cable (C):

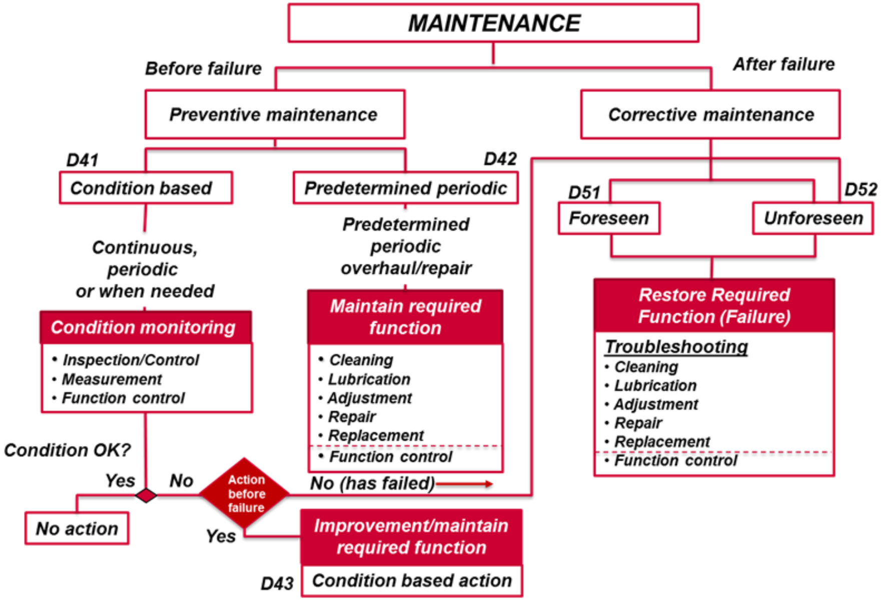
Data collection:
C1.1 Technical data
C1.2 Inspections
C1.3 Event history
C1.4 Online cable data
C1.5 Oil filled termination
C1.6 Load
C1.7 Temperature
C1.8 Decommiss-ioning data

Operation:
C2.1 Online analysis
C2.2 Offline analysis
C2.3 Oil filled termination measurement results
C2.4 Thermal conditions
C2.5 Immediate actions
C2.6 Permissible overload

Asset management:
C3.1 Condition assess-ment of cable
C3.2 Condition assess-ment of accessories
C3.3 Condition assess-ment of oil filled termination
C3.4 Health index
C3.5 Investment and capacity analysis

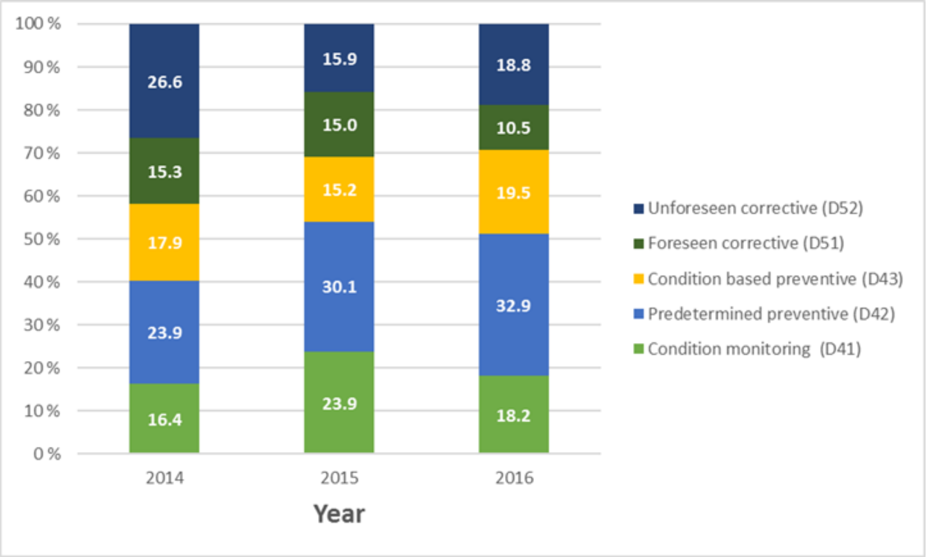
Example: Cost history

- Why cost history?
  - Analyze the benefits and causes for maintenance actions.
  - Present development in costs.
  - Ensure correct cost registration.
  - Improve the reference cost base used for maintenance planning.



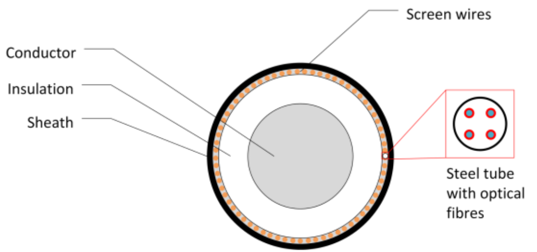
Example: Cost history

- Delivered from SAMBA to Statnett asset management:
  - Overview of cost data available in Statnett today.
- Further work in SAMBA:
  - Examples of costs related to preventive and corrective maintenance for components and transformer stations.
  - Recommendations on how routines for charging of the costs can be changed/improved.
- Will be implemented as a part of a future asset management software.



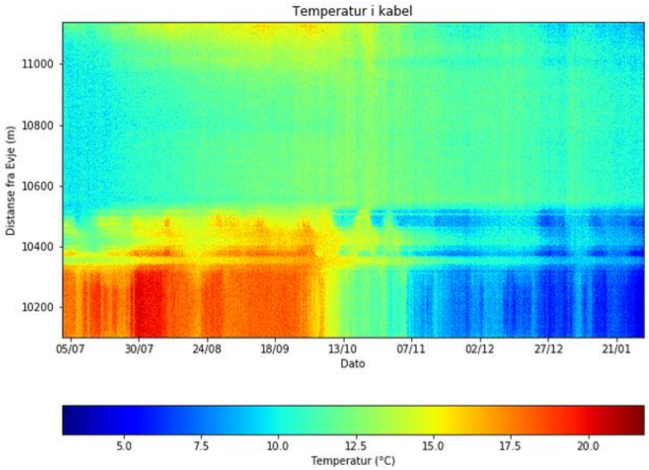
Example: Distributed temperature sensing along cables (DTS)

- Why DTS:
  - Estimate ampacity based on DTS and detection of altered thermal properties along cable route.
  - Accommodate dynamic line rating (DLR).
  - Detect anomalous temperatures.



Example: Distributed temperature sensing along cables (DTS)

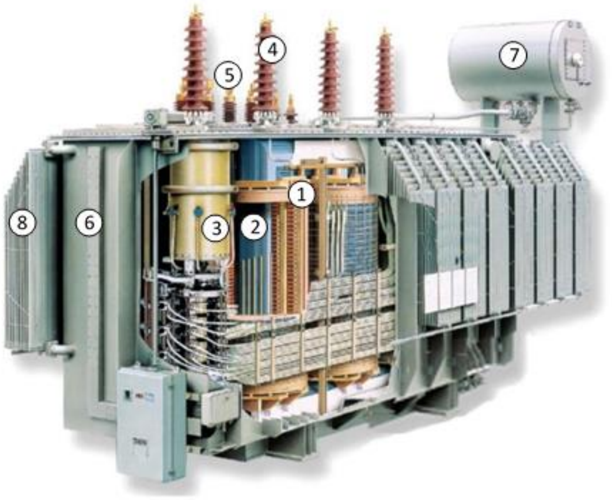
- Delivered from SAMBA to Statnett cable specialist environment in Statnett:
  - Script loading and visualizing the temperature in cable as a function of position and date.
  - Test performed on temperature measurements from Ytre Oslofjord.
- Further work in SAMBA :
  - Automatic detection/prediction of abnormal temperatures and anomalous measurements.
    - Correlate to load and meteorological data.



Example: Transformator condition/health index

Statnett

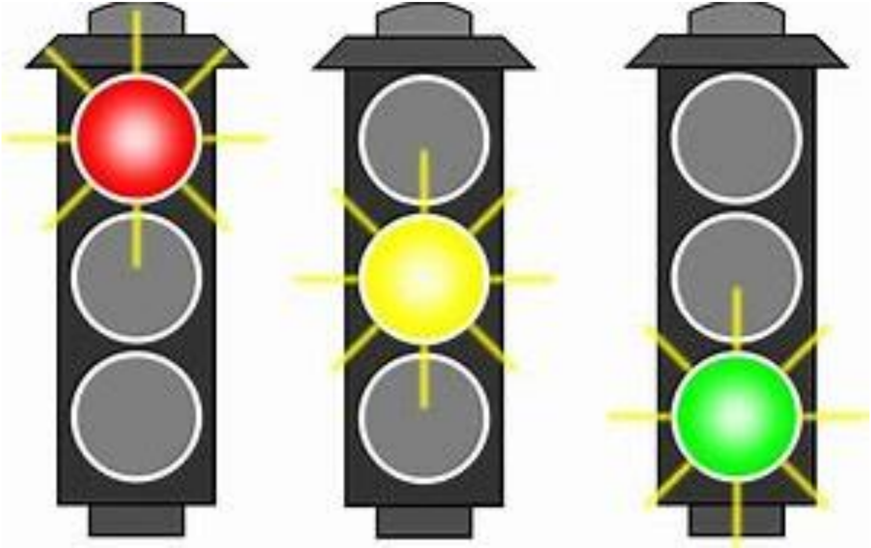
- Many subcomponents and different condition measurements.
  - Oil analysis and temperature data are important.
- But, what is the overall condition?
  - Health index is an aggregation/weighting of several condition measurements in to one index.



1) Winding with paper insulation. 2) Core. 3) Tap changer. 4) HV bushing 5) LV bushing. 6) Tank. 7) Oil expansion tank. 8) Cooling arrangement.

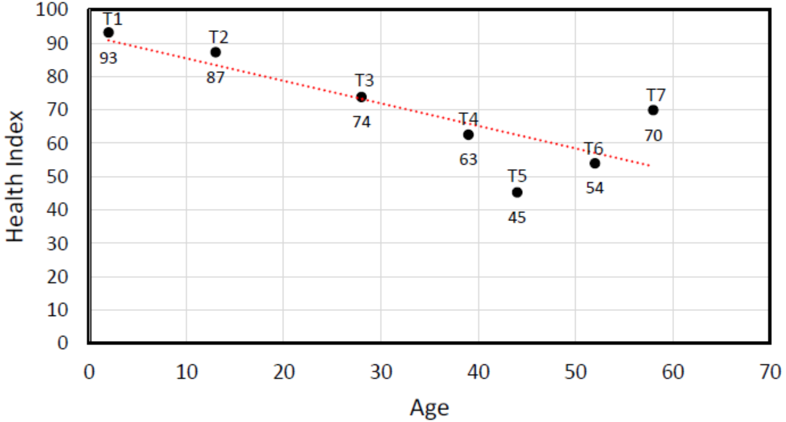
Example: Transformator condition/health index

- Why health index?
  - Overview and ranking of transformers based on condition.
  - Input to further analysis, i.e. risk analysis.
  - Improved decision basis for maintenance and reinvestments.



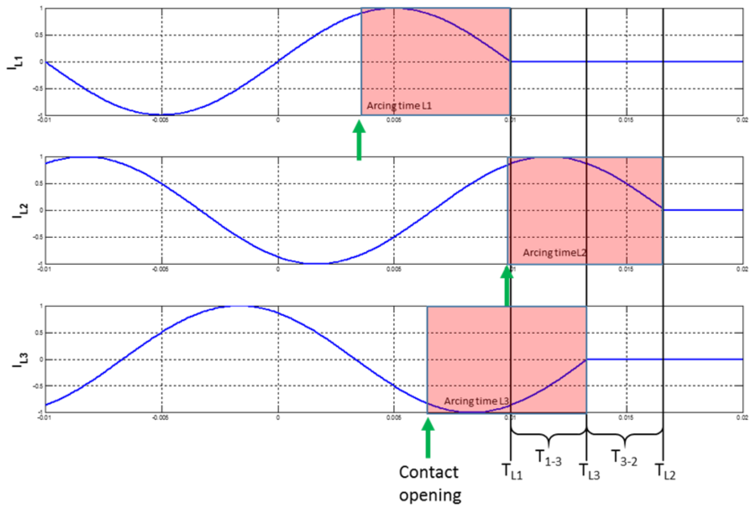
Example: Transformator condition/health index

- Delivered from SAMBA to Statnett asset management:
  - Methods for calculation of health indices from GE, ABB and SINTEF Energy Research.
  - Test on data for selected transformers is ongoing.
- Further work in SAMBA:
  - Recommendations for further data collection for transformers in Statnett.
- Implementation will be part of a future asset management software.



Example: Identifying re-ignitions in reactor circuit breakers

- Breaking a current is done by opening the contacts of a breaker.
- A successful breaking without re-ignition is made if:
  - The sequence for breaking of the phases is: L1 - L3 - L2
  - $T_{1\text{-}3} = T_{3\text{-}2}$ = 3,33 ms.
- Re-ignition during breaking causes wear which can eventually lead to failure of the entire breaker.

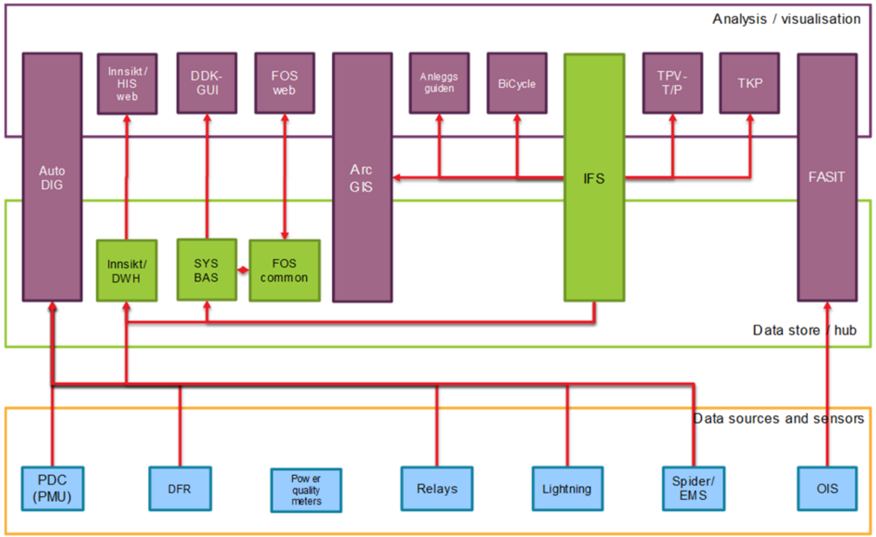


Example: Identifying re-ignitions in reactor circuit breakers

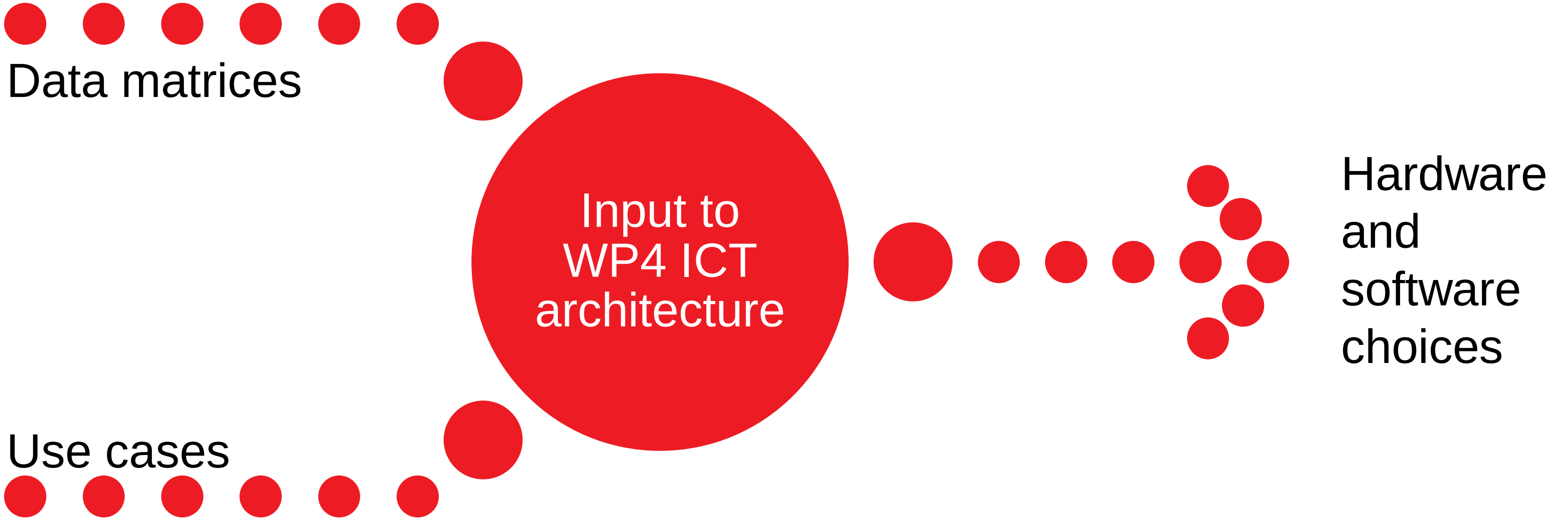
- Why detect re-ignition?
  - Warning when re-ignition has occurred.
  - Implement measures to avoid failures.
- Delivered from SAMBA to circuit breaker specialist environment in Statnett :
  - Algorithm to detect re-ignition.
  - Test on historical data from fault recorders in Holen.
- Further work in SAMBA:
  - Test in Big Data Lake.

Data needs

- The use cases rely on many different input data.
- The required input data for all the use cases has been summarized in data matrices in the report.
- WP3 in SAMBA has focused on locating data in systems that Statnett use today.



Statnett


Data matrices
Use cases
Input to WP4 ICT architecture
Hardware and software choices

Concluding remarks

- Use cases have been described and necessary input data identified in the different systems that Statnett currently have.
- Some data is not registered today and other data was limited by time resolutions, time periods or selected components.
- The use cases presuppose high quality data, but when testing the use cases in WP5, mainly based on historical data, the consequences of any lacking or bad data will be apparent.
- As a part of WP5 recommendations will be made for what Statnett must do to increase the value of the use cases.

Concluding remarks

- Use cases are not static descriptions, and must be updated and further developed after the SAMBA-project.
- The data input sources will probably change as Statnett makes decisions on ICT systems and architectures.
- The overview of where the data is today is a valuable input for use case testing in WP5

Concluding remarks

- There are important decisions to be made when taking the use cases from SAMBA and further to implementation:
  - Which use cases to prioritize?
  - How much resources should be utilized to find and quality assure historical data?
  - Which of the suggested new measurements should be performed and for how many components?
  - Who in Statnett should be responsible for each use cases?
  - How will the results will be implemented?

The road to Smarter Asset Management

Statnett

Today`s situation

- Calendar and condition based maintenance
- Subjective assessment and age on component background for reinvestment
- Inadequate and access for condition data
- Lack of documentation for decisions

SAMBA

- The project is a R&D project that will look at how Statnett can optimize asset management
- Test different models and methods for condition assessments to retrieve information and predict condition development, components residual life, risk and optimal time of maintenance and/or reinvestments.
- Statnett has a lot of data about its facilities, but needs to be able to utilize and gather data even more efficiently with the focus on being able to perform predictive maintenance

Req. spec. Procurement Implement

- Requirements specification for a future "top-system"
- Mapped of desired work and decision-making processes in Statnett
- Data capture methodology
- Selected functionality, system and supplier. (POC).
- System ready for use in pilot
- Process adjustment completed

Goal

- Established predictive maintenance
- Risk-based decisions in asset management dep.
- Comprehensive analysis environment
- Prescriptive Analysis and Autonomous Solutions (Machine Learning)

Developing work processes and organization