Smarter Asset Management in Statnett

Digitalisering i vattenkraften 9.maj 2019, Quality Airport hotel Arlanda

Arne Smisethjell, Project Manager SAMBA, Statnett
arne.smisethjell@statnett.no

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What is the SAMBA project?

- The SAMBA project has been a **3 year R&D project** financially supported by the Norwegian Research Councils Energix program and completed end March 2019.

The Research Council of Norway

With funding from
The Research Council of Norway

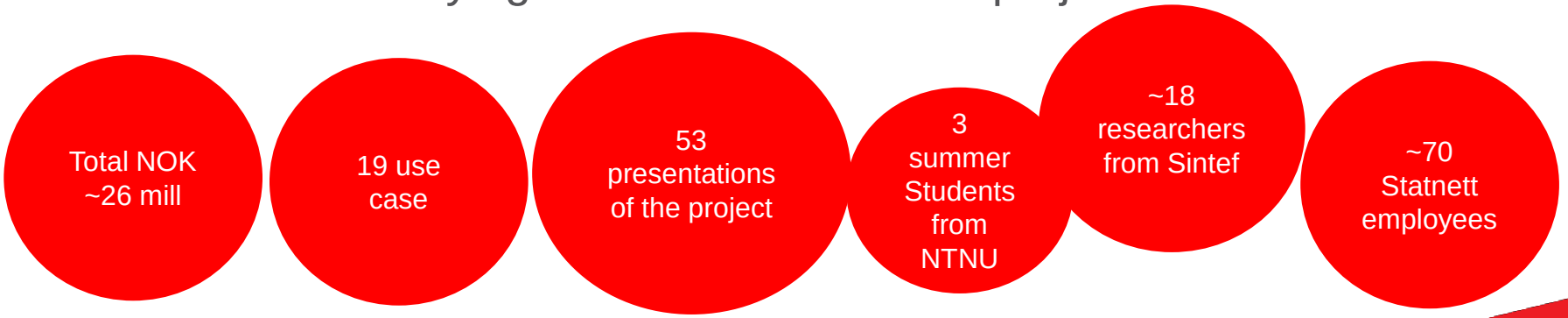
- The partners in this project have been:

Statnett SINTEF IBM ABB GE

The challenges for Asset Management in Statnett

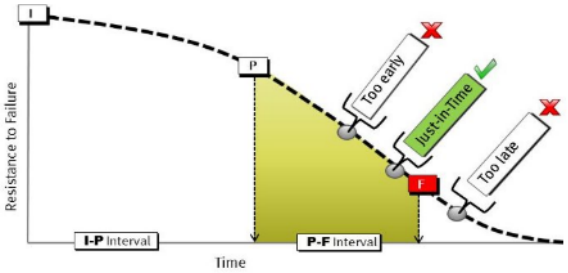
- Aging and increased volume of assets
- Statnett must optimize maintenance and investments
- Statnett has a lot of data about its components, but can utilize these in a better way

Some key figures from the SAMBA project:



Why SAMBA project?

- Predict **now condition** for critical components
- Predict the development **over time** for critical components
- The basis for predictive maintenance
- Optimize the right time for critical component replacement
- Simplify and automated decision processes



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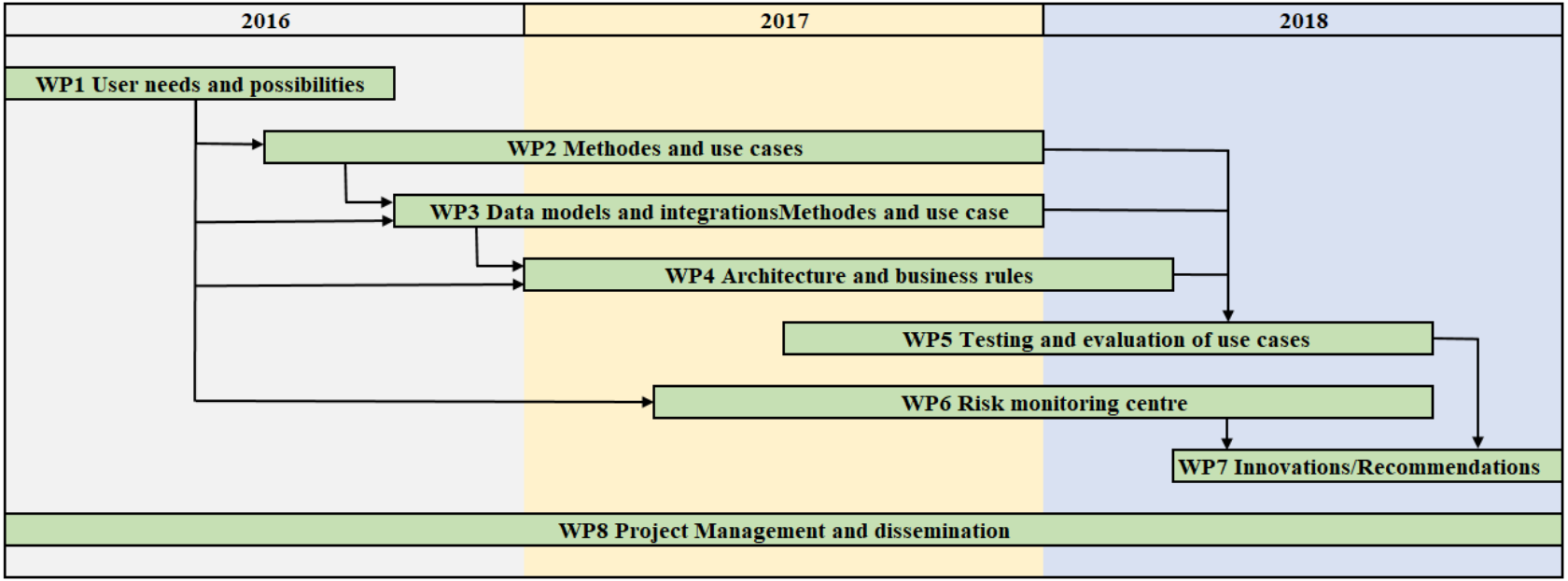
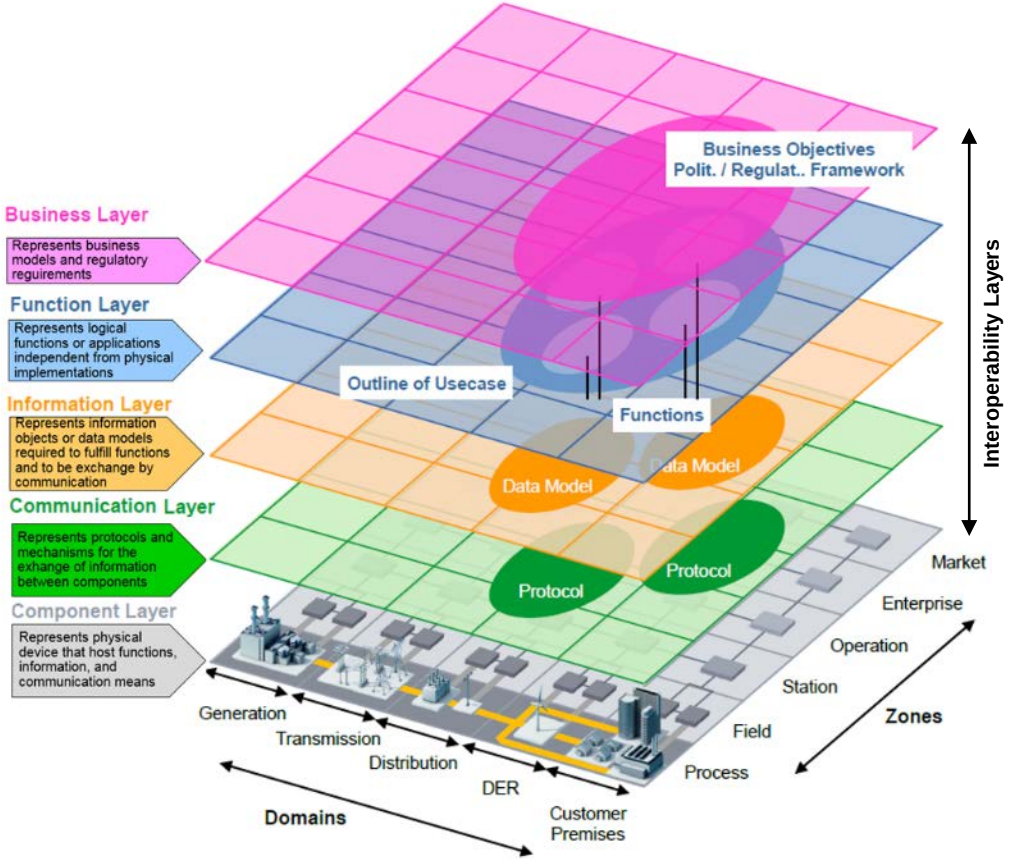
Execution of the SAMBA project



Smart Grid Reference Architecture

- Use case
  - Use case is a list of actions or event steps that define the interaction between roles and a system to achieve a goal
- Template from IEC standard 62559-2



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

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Selection of use case for SAMBA

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, A3.6
A3.2 Technical-economic analysis of maintenance and reinvestment	A3.1, C3.5
A3.3 Registration and analysis of historical costs	-
A3.4 Visualization of condition/risk for stations and overhead lines	A3.1
A3.5 Condition assessment through sample testing	L3.2
A3.6 Registration and storage of condition information	T1.1-T1.12, CB1.1-CB1.10, L1.1-L1.8, C1.1-C1.8
A3.7 Risk monitoring of critical equipment	A3.1, O2.2
A3.8 Identification of renewal needs for stations	A3.1, A3.7
A3.9 Benchmarking	

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

Responsible	No. of use cases
Sintef	13
ABB	3
GE	3

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 Geograhical 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 Decommissioning 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 assessment of cable
C3.2 Condition assessment of accessories
C3.3 Condition assessment of oil filled termination
C3.4 Health index
C3.5 Investment and capacity analysis

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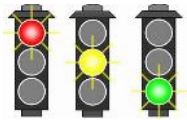
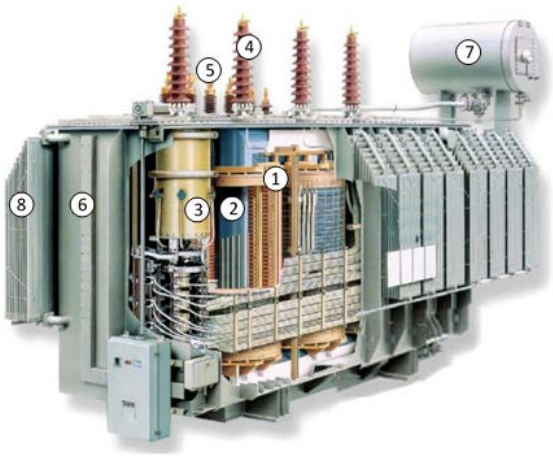
Transformer- AHI (Asset Health Index)

- 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

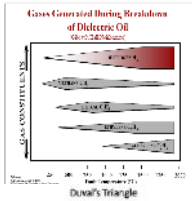


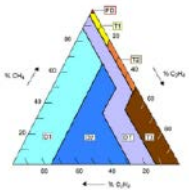


1) Winding with paper insulation. 2) Core. 3) Tap changer. 4) HV bushing 5) LV bushing. 6) Tank. 7) Oil expansion tank. 8) Cooling arrangement.

Transformer monitoring and inspections

- DGA. Continuous monitoring
- Oil condition. (Annual sampling)
- Temperature, PT100, fiber-hot spot
- Inspection, condition





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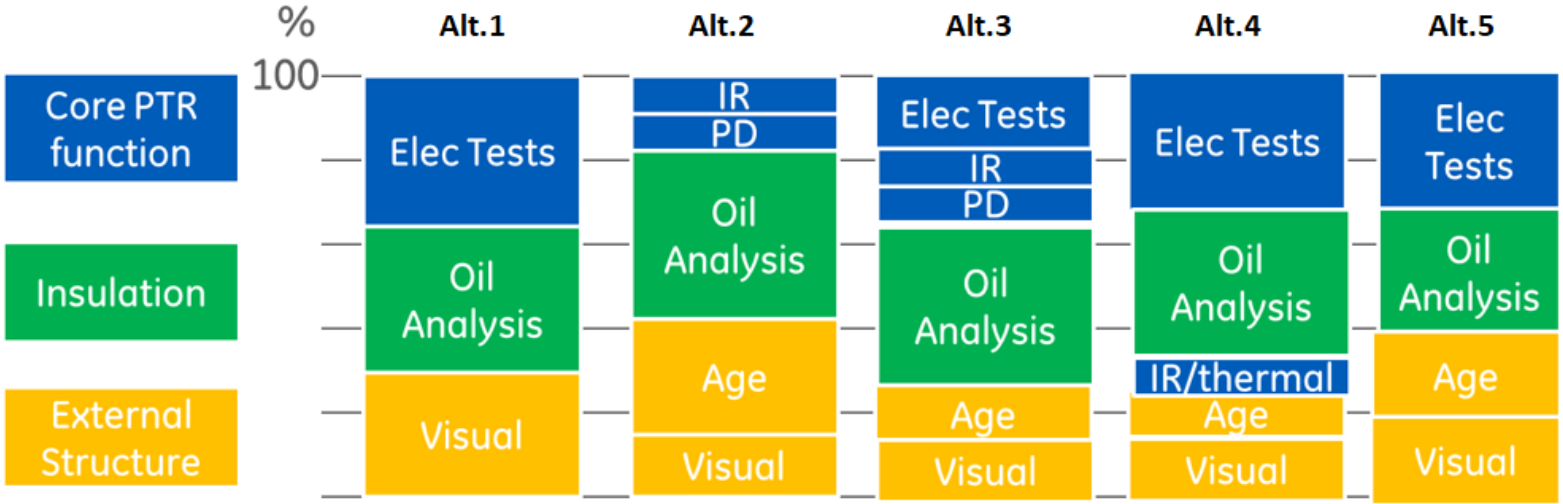
Aging model (AHI)

Various models for the calculation of aging (AHI)



Transformer- AHI

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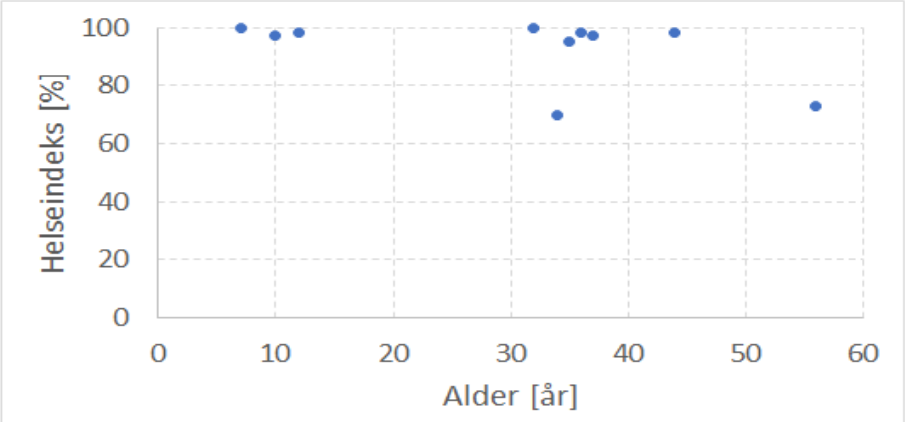
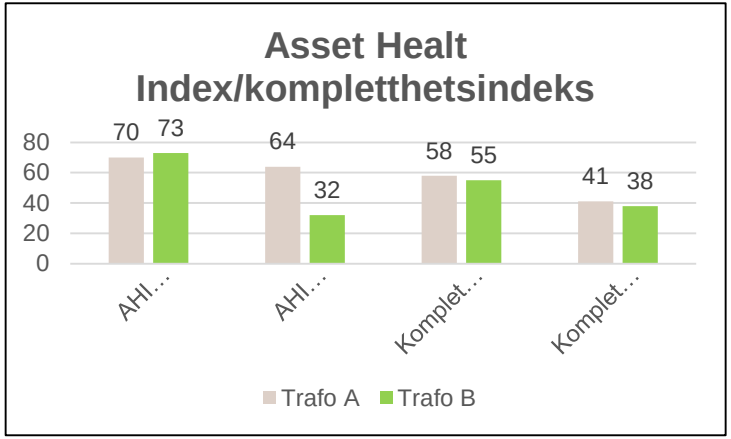
Sintef AHI

Driftsmerking	Alder	Helseindeks (%)	Kompletthetsindeks
T2	32	100	73 %
T2	37	97	75 %
T1	36	98	75 %
T51	7	100	55 %
T12	10	97	95 %
T1	12	98	85 %
T3	35	95	75 %
T2	34	70	58 %
T2	56	73	55 %
T4	44	98	75 %

Leverandør A AHI

Root	Region	Subregion	Make	Age, Yr	AHI, %	CPLI-H, %
GRID	WEA	STATNETT	ABB	55.9	32	38
GRID	WEA	STATNETT	NATIONAL...	34	64	41
GRID	WEA	STATNETT	NIJMEGEN	1.7	93	41
GRID	WEA	STATNETT	NIJMEGEN	1.7	94	41





Asset condition transformer

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Asset Management

Risk analysis and prioritization

Alarms to AHC

Risk handling

Action operation

Action maintenance

Sensor strategy for AM

Example of a health index (CornEd 2015, from IEC MSB workshop)

Individual condition parameters (CM)

Overall condition (CM)

Age

Doble test

Transformer oil quality

Transformer DGA

Loading (M)

Month 1 ..... Month n

Rating WO / Age / Power factor / F(IFT, electric str., acid, color) compared to limits / F(H2, CH4, C2H6, C2H4, C2H2, CO, CO2) compared to limits / overload ratio

Score × weight

Trend increase rate > limit?

Σ

Σ(Score ×weight)/N

X

Adjusting Factor

A = 1.00
B = 0.95
C = 0.85
D = 0.75
E = 0.50

Health Index	Condition
85 – 100	Very Good
70 - 85	Good
50 - 70	Fair
30 - 50	Poor
0 - 30	Very Poor

Transformer 1…n

AHI

RCM

Condition inspection:

- Surface/painting
- Gasket condition
- Control wires
- Local readings
- Oil leaks
- etc.

Risk handling

Impact on human safety
Economic impact
Impact on reliability
Impact on the environment

Risk impact/requirements

Needs for replacement
Needs for refurbishment
Operational restrictions

Technical / Economic Analysis

Costs in the period of analysis

CENS (failure)
Repair after failure
CENS (reinvestments)
Reinvestments/maintenance

Should we maintain or reinvest and when?

Solution chosen on the basis of risk assessment

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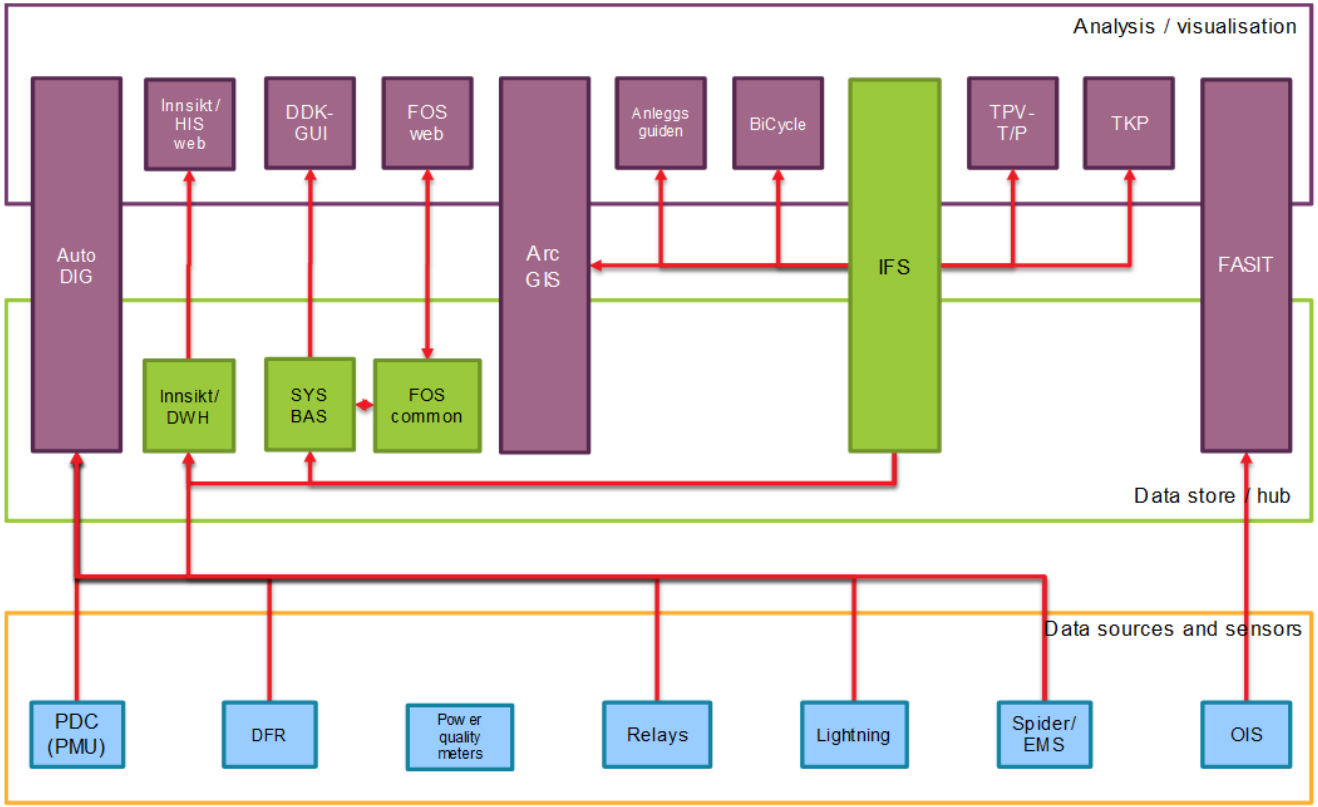
Todays ICT solution vs. future ICT needs in AM



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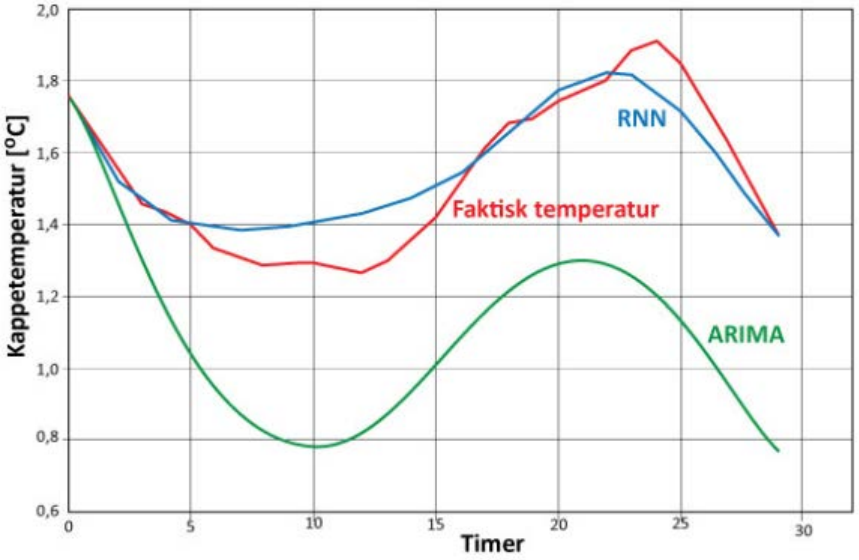
Innovations

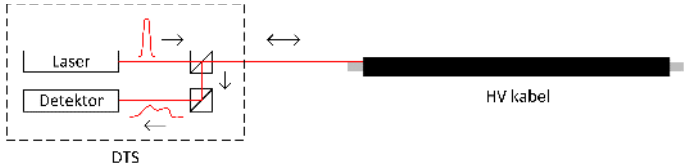
Statnett use case identification	Circuit breaker failure model	Risk monitoring function	Voltage transformer failure prediction
Multivariate analysis of transformer gasses	Overview of historical data availability	Cable and transformer temperature prediction	Asset reinvestment analysis testing
Reactor breaker reignition identification	Health index transformers	Line connector condition assessments	ICT asset management architecture investigation

Innovation

Cable temperature prediction

- Tested on Statnett data
- Possible to predict temperature in cable
- Goal: Used in operation and detection of abnormal conditions





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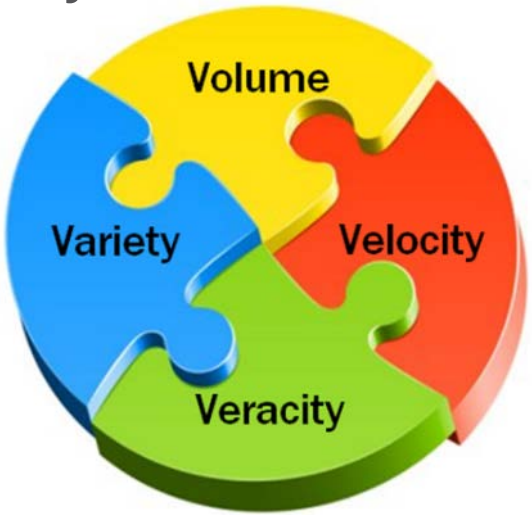
Recommendations

Improve data quality and availability

- Data **V**olume
- Data **V**elocity
- Data **V**ariation
- Data **V**eracity



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What is the benefit of the SAMBA project?

Statnett has achieved:

- An ICT architecture suitable for asset management
- Demonstrate the need for sensors, measurements and data quality
- Expertise for condition monitoring models for power components
- Basis for development of Asset Health

Effective **Smart** **Safe**

Potential savings for Statnett

- Saving ~ 30 - 40% by going from preventative to predictive maintenance

- Annual savings by postpone the replacement of a transformer is approx. NOK ~ 0.5 million

Tank you for your attention!

Statnett homepage: https://www.statnett.no/en/about-statnett/research-and-development/results/