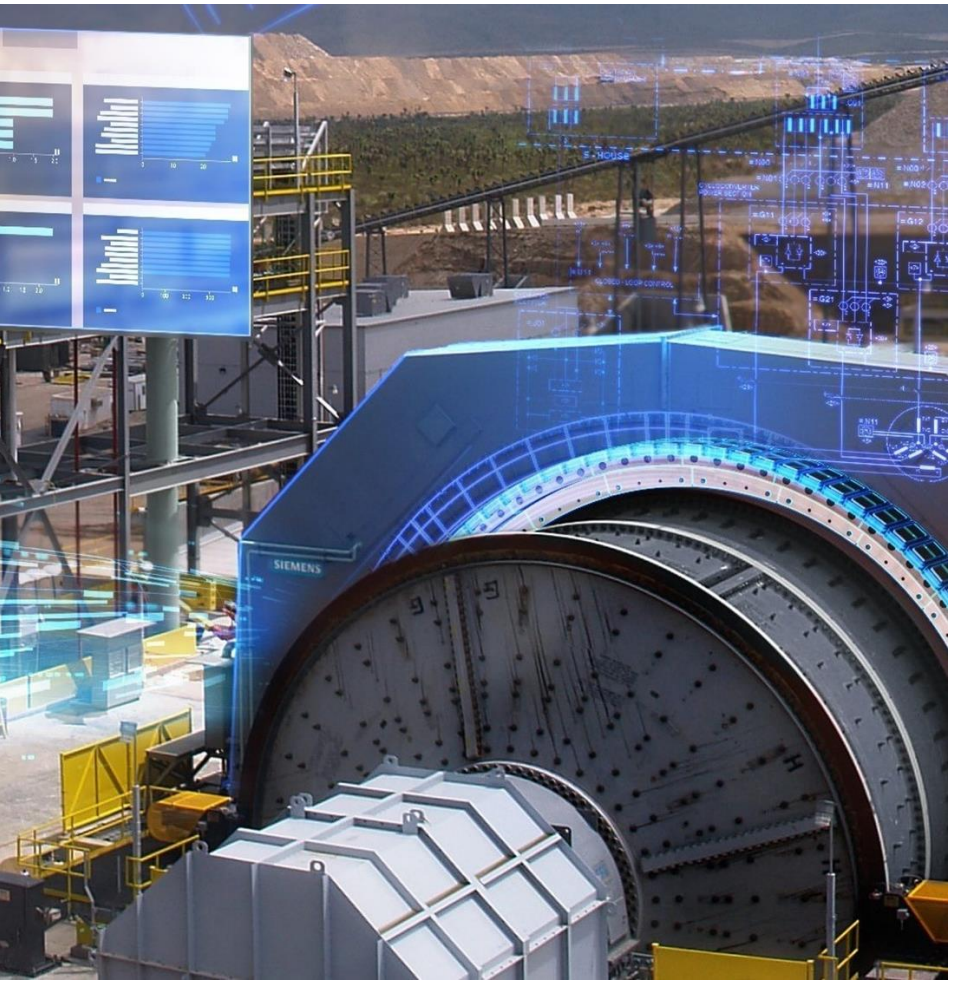
SIMINE Asset Health Analytics Survey

Dr. Dan Fodor, July 2020

siemens.com/mining

Courtesy © Penasquito Gold-Silver Operation in Mexico (Image: Newmont)

SIMINE Asset Health Analytics Survey
Contents



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Customer Voice

Asset Health Analytics for Gearless Mill Drives

- Added Value for Operations
- Technology Pillars

Asset Health Analytics for Belt Conveyors

SmartMining

Demo/ Examples within each Chapter

Customer Voices*) guide our Solution Development

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"Where I see value being added is to have the alarms and event messages shown with detailed explanations and recommended actions"

Superintendent - Electrical, Instrumentation & Process Control, Mexico

Corporate Director of Performance, Chile

"Within the mining industry the challenge is how to adapt technology to improve productivity, reduce costs and increase revenues. Multisystem capacities and teamwork are what allow people to understand that one single action could affect the entire process. That is how the success of digital transformation could be achieved."

Head of Process Control, South Africa

" For future development, we will focus on digitalization and automation of the production processes"

"Raising to the challenge: Increasing equipment utilization"

Managing Director & CEO, Australia

Mine Manager, USA

"We're trying to get more of a predictive vs reactive mode of Operation - Obviously the sooner you know about something you start getting ready for it"

"Increase utilization and reduce shutdowns. We are working with our fleet management and process control companies to check debottlenecking opportunities, because we do have some."

"umm.. I don't think there is any tool to let me see incidents happening in a mine."

"Its Everybody's dream to reduce shutdowns."

Mine Superintendents, USA

Therefore our Asset Health Analytics Solutions focus on (a) Process visibility (b) Predictive and (c) Counteraction information

*) Company & Speaker Name intentionally deleted

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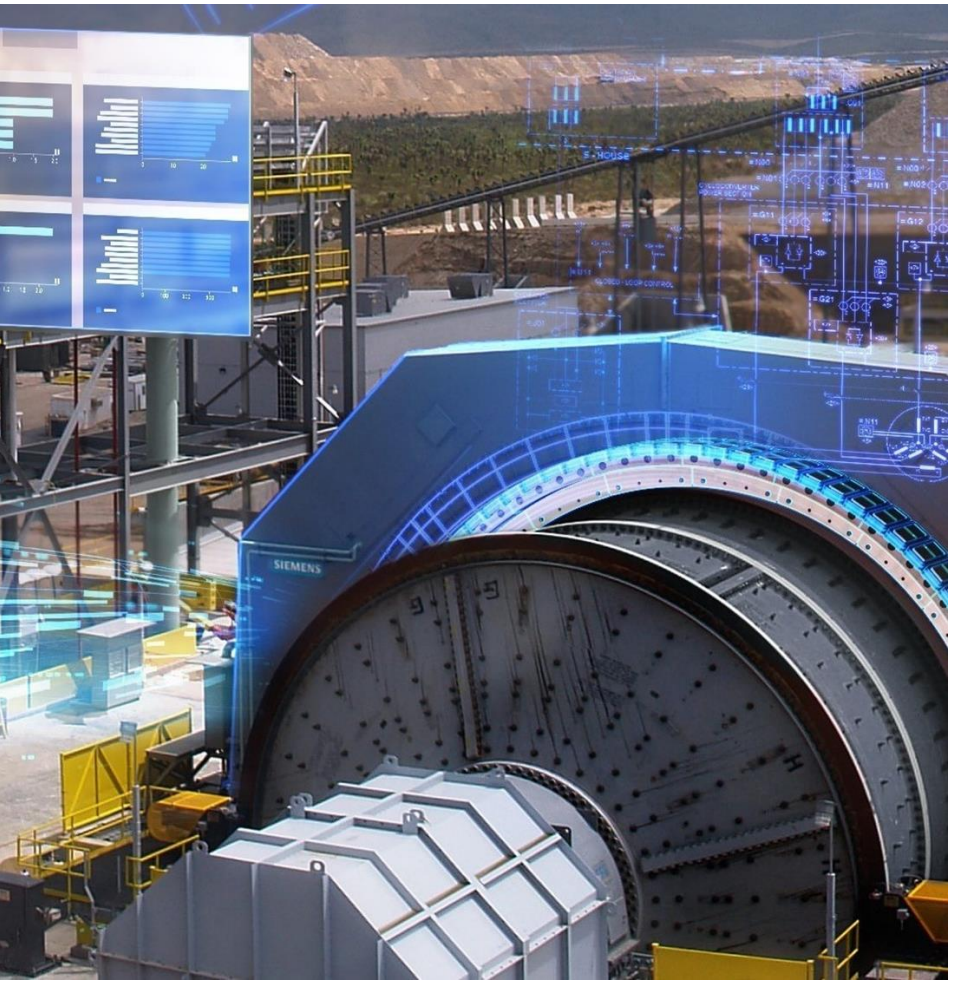

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Customer Voice

Asset Health Analytics for Gearless Mill Drives

- **Added Value for Operations**
- Technology Pillars

Asset Health Analytics for Belt Conveyors

SmartMining

Demo/ Examples within each Chapter

Reasoning – Added Value for Operations

Courtesy © Penasquito Gold-Silver Operation in Mexico (Image: Newmont)

Events leading to unexpected mill misfunction and shutdowns **induce operational losses** up to **several Mio USD per day**

We see **added value** in

- **Early information** that the mill or its components reveal deviations from normal operation
- **Identifying the correct root-cause** and
- **Recommending counteractions**

Goal is

preventing/ shortening unplanned shutdowns

SIMINE Asset Health Analytics for Gearless Mill Drives

(Asset Health Analytics for Pinion Mill Drives and Belt Conveyors in the start phase)

SIMINE Asset Health Analytics Focus
From corrective towards proactive Mode of Operation

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Remote Services

Shorten unplanned downtime
by
enhancing troubleshooting activities

Remote Support
(incl. On-Call Service)

Corrective

Condition Monitoring Services

Minimize planned and unplanned downtimes
by
optimizing maintenance activities

Basic System
(GMD, Pinion Mill Drives, Belt Conveyors)

Options
(Wireless Rotor Monitoring, Vibration)

Corrective / Preventive

Asset Health Analytics

Optimize the asset performance
by
expert support based on asset data

Expert Analysis

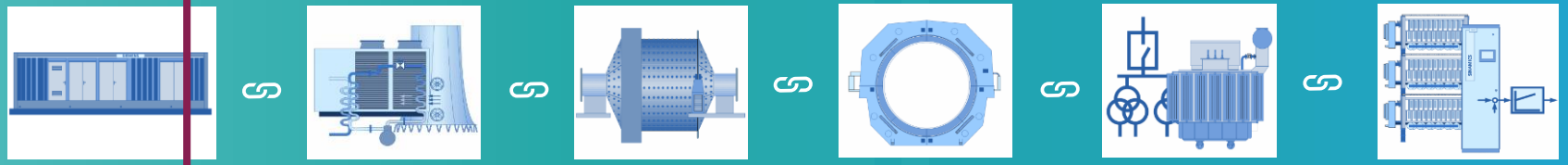
Expert Report

Root-causes

Model calculations

Predictive / Proactive

Asset Health Analytics GMD
Key Components Overview



SIMINE Asset Health Analytics for Gearless Mill Drives
Our Expert Solution to avoid “false Positives”

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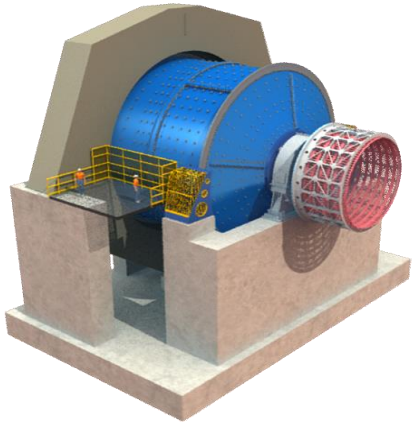
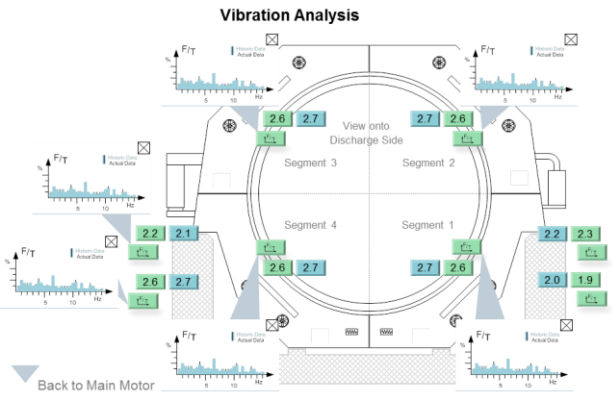
Key Messages

- Our solution is developed by experienced specialists with GMD-specific know-how hence is not a standard Condition Monitoring System
- The user of Asset Health Analytics receives the real root-cause(s)
- Our solution supports with timely information/ recommendations and does not close any loop to Automation system i. e. there is no shutdown induced by Asset Health Analytics
- State-of-the-Art technologies (like modelling/ Digital Twin) are implemented based on decades of own Gearless Mill Drives experience





SIMINE Asset Health Analytics
Value Proposition induced by “Mill Operator Voice”

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Operator Voice

Detect changes in Mill Operation

“As maintenance engineer I want to receive early indication of looming incidents in order to avoid mill misfunction or damages”

Analyze contributors and underlying root-cause(s)

“As maintenance engineer I want to receive an interpretation of anomalies detected in the mill data”

Decision support for action

“As operation manager I need to organize fast countermeasures”

Added Value

Information and transparency: “no surprise”

Understand what happens: ”opportunity to prepare”

Support for “early appropriate counteraction”

Goal: Predictive/ proactive Mode of Operation

SIMINE Asset Health Analytics
Example Mill Vibration Analysis

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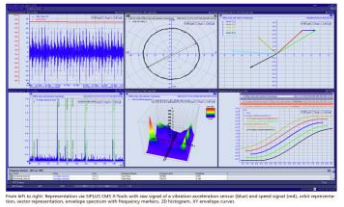
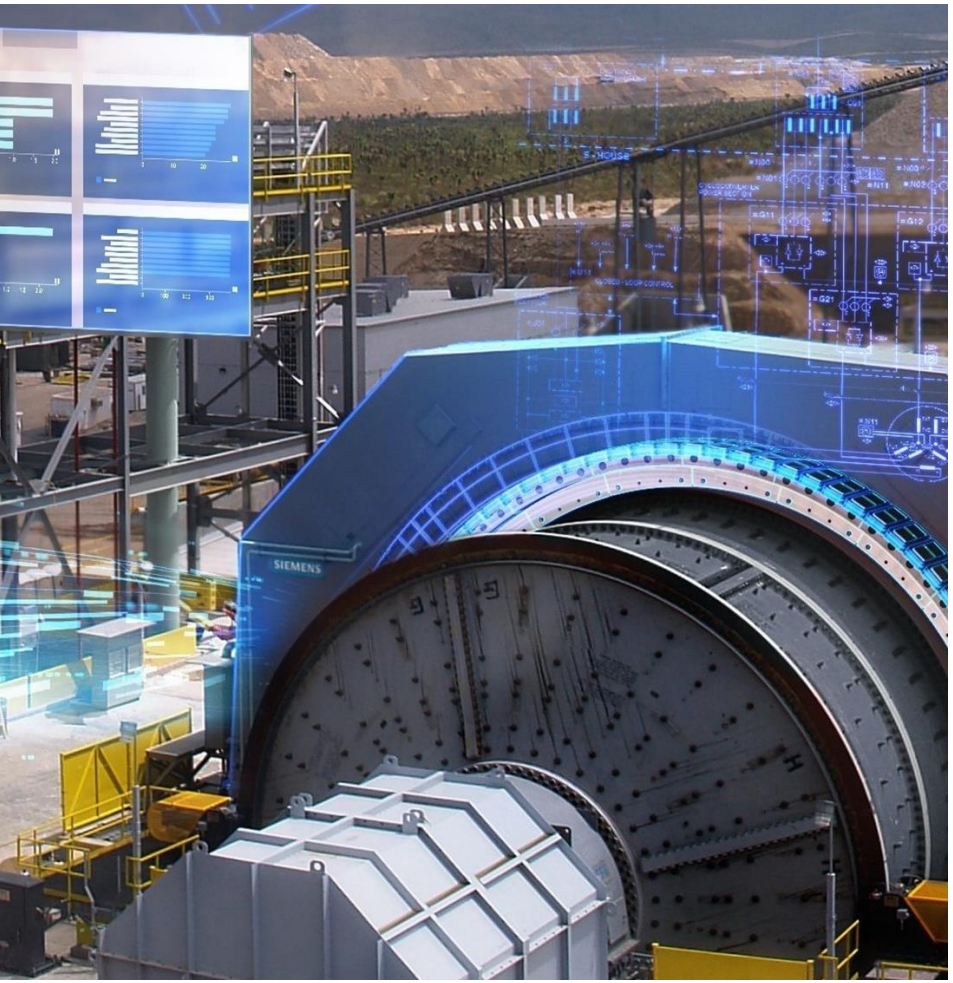
Functionality & Challenge ↓	Information & Recommendation ("Deliverables") ↓	
Real-time monitoring ("CMS") **What happens/ happened?**	Increased motor stator vibration over time	Notifications and warnings Online dashboards
Data analysis **Why did a change happen?** – **What triggered the change/ anomaly?** – **Which is the root-cause?**	Reduced torque in stator fixation bolts on motor foundation	 Data assessment
Forecast Anomaly detection, fault prediction **What will happen?**	Mill vibration will reach the warning level in "x days, weeks…" if no change Notification ⓘ SHUTDOWN RISK	Reports Online dashboards
Recommendations Prescript action like equipment check, maintenance, service… **What should be done?**	Inspect and plan re-torque of fixation bolts If required, realign Notification ⓘ ORGANIZE SERVICE	Online dashboards Remote support

SIMINE Asset Health Analytics Survey
Contents



Courtesy © Penasquito Gold-Silver Operation in Mexico (Image: Newmont)

Customer Voice

Asset Health Analytics for Gearless Mill Drives

- Added Value for Operations
- **Technology Pillars**

Asset Health Analytics for Belt Conveyors

SmartMining

Demo/ Examples within each Chapter

SIMINE Asset Health Analytics – Three Technology Pillars

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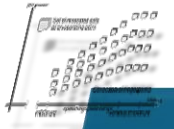
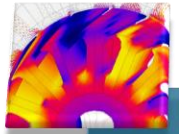
Asset Health Analytics for grinding mills



Fingerprint Analysis

- Collection of fingerprints (measured data sets) from start-up as reference for later operation
- Comparison actual/ reference



Mathematic Modelling

Digital Twin

- Calculation of (e.g. motor temperature) models
- Comparison w/ real values and deduction of trends

Artificial Intelligence

- Beyond limits of mathematics
- Train AI-models with operational experience

Asset Health Analytics for Gearless Mill Drives – Example Vibrations Fingerprint Analysis (Siemens Patent pending)

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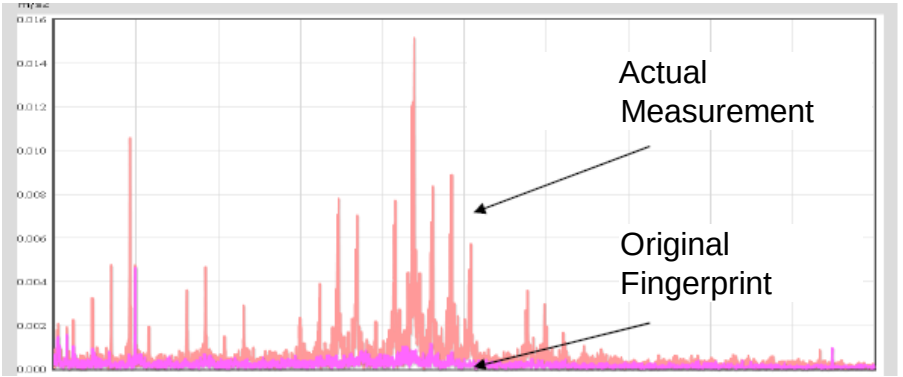
Basics

- Original Fingerprints are
  - obtained by measurements during mill start-up
  - validated by Siemens specialists
  - stored (On-Cloud or On-Premise)
  - used as reference for comparison and analysis during the whole mill lifetime
- Analysis example – Comparison of Actual Measurement with Original Fingerprints

Vibrations

- Changes in level and frequency of vibrations might indicate abnormalities (selection):
  - Loosening of internal fixation bolts and/or
  - Loosening of fixation on foundation and/or
  - Deterioration of foundation
  - …



Asset Health Analytics for Gearless Mill Drives – Example Temperature Fingerprint Analysis (Siemens Patent pending)

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Comparing two slightly different operation points results in an increase trend (Fig. 1)…
… and leads to the false root-cause: problem in motor cooling system (heat exchangers, fans, etc.)

Correct root-cause is revealed by the consistent comparison (same operation point)…
… and leads to correct conclusion (Fig. 2): winding temperature constant, no change trend

Fig. 1

Stator winding segment 1
(average temperature)

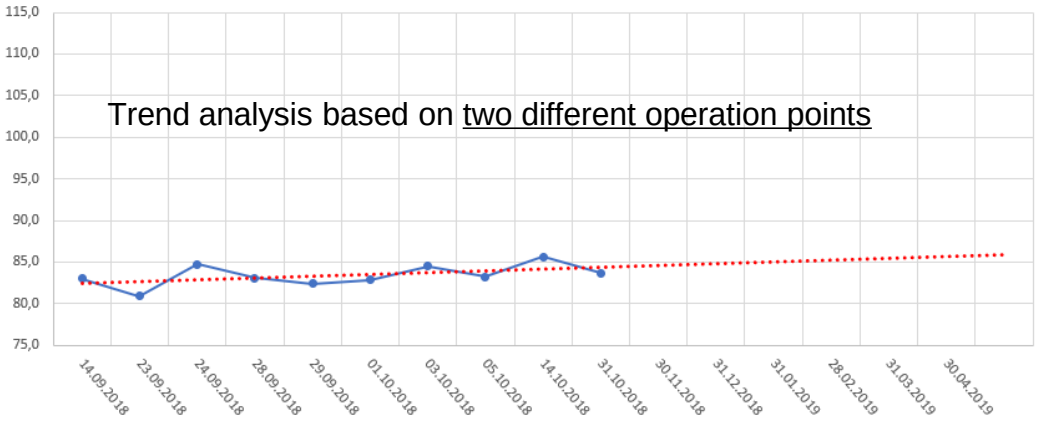
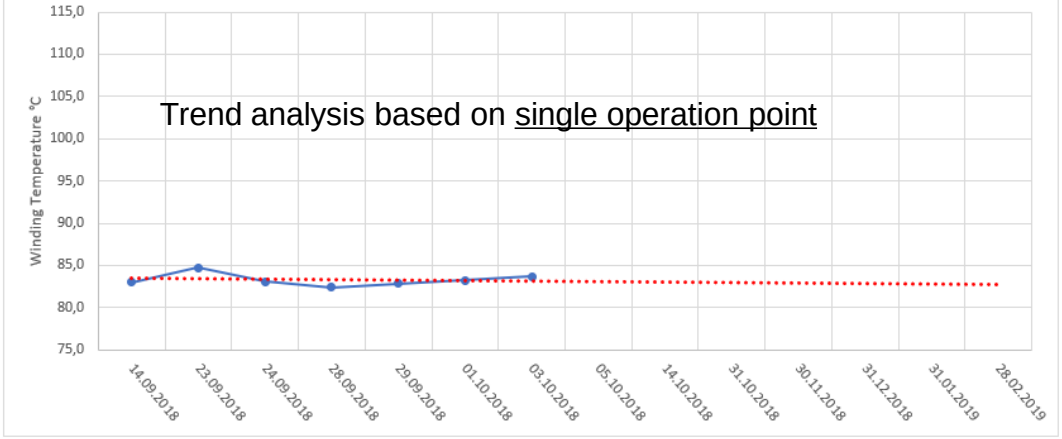


Fig. 2

Stator winding segment 1
(average temperature)



Expert Analytics to avoid “false Positives” – Example follow

Asset Health Analytics for Gearless Mill Drives – Example Digital Twin based Winding Overheating

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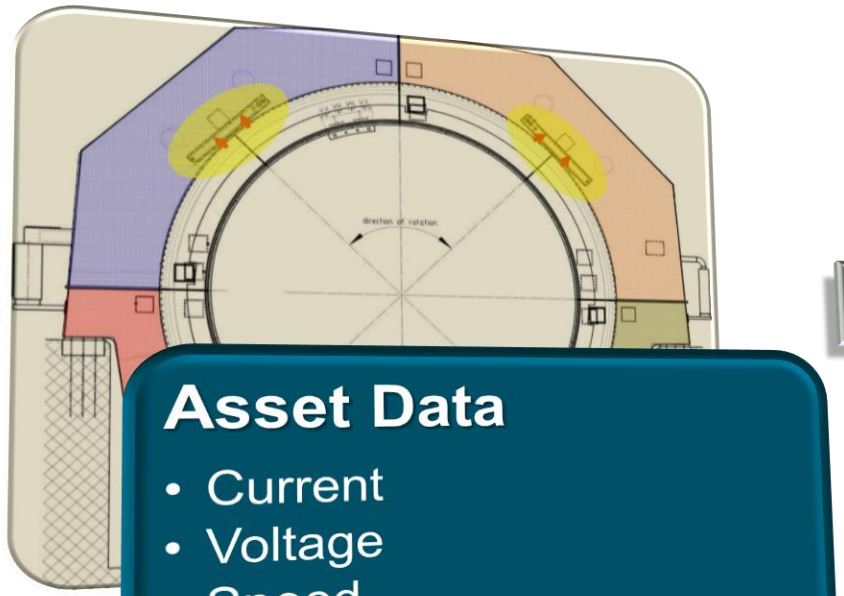
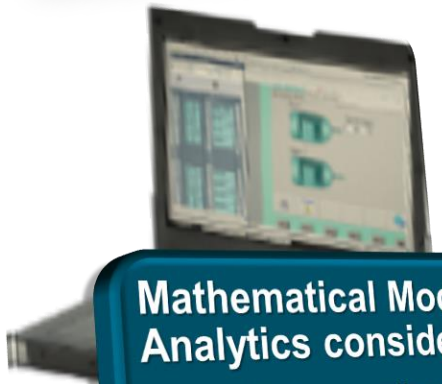


Asset Data
- Current
- Voltage
- Speed
- Power
- Temp. cooling water
- Temp. cooling air

Digital Twin



Mathematical Model Analytics considering
- Asset Data as well as
- Cooling characteristics
- Motor characteristics
- Temp. rotor/stator windings
- Winding characteristics

OKAY
winding temperatures equal to calculated values

ABNORMAL
winding temperatures higher than calculated
Maintenance required during next scheduled downtime

IMMEDIATE ACTION
Backup info like
Root-cause
Recommendations
Maintenance suggestions
and other

Asset Health Analytics for Gearless Mill Drives – Example Digital Twin Winding Overheating

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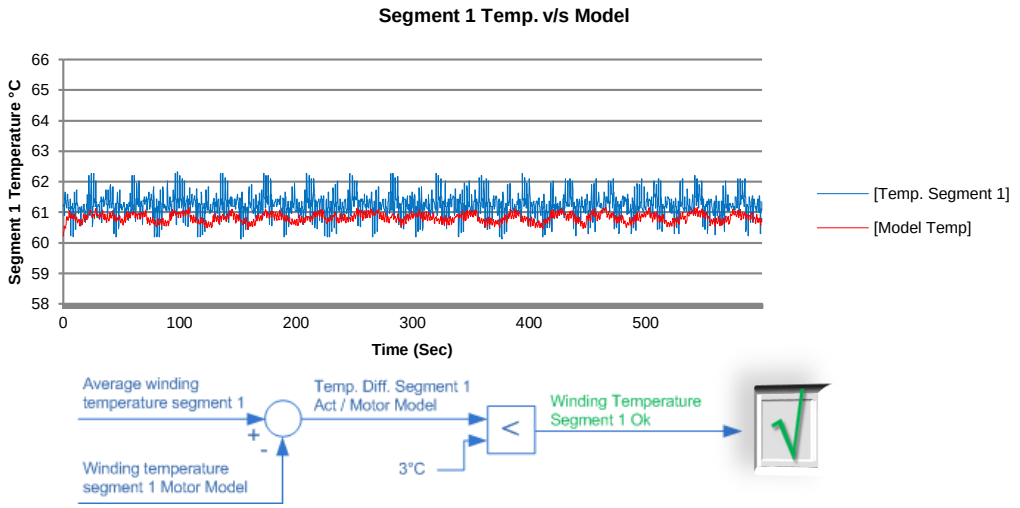
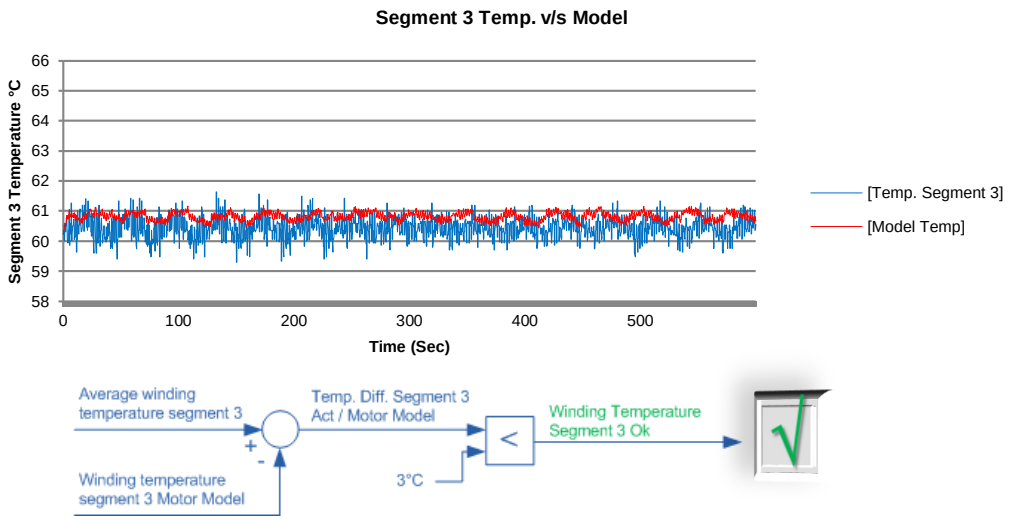
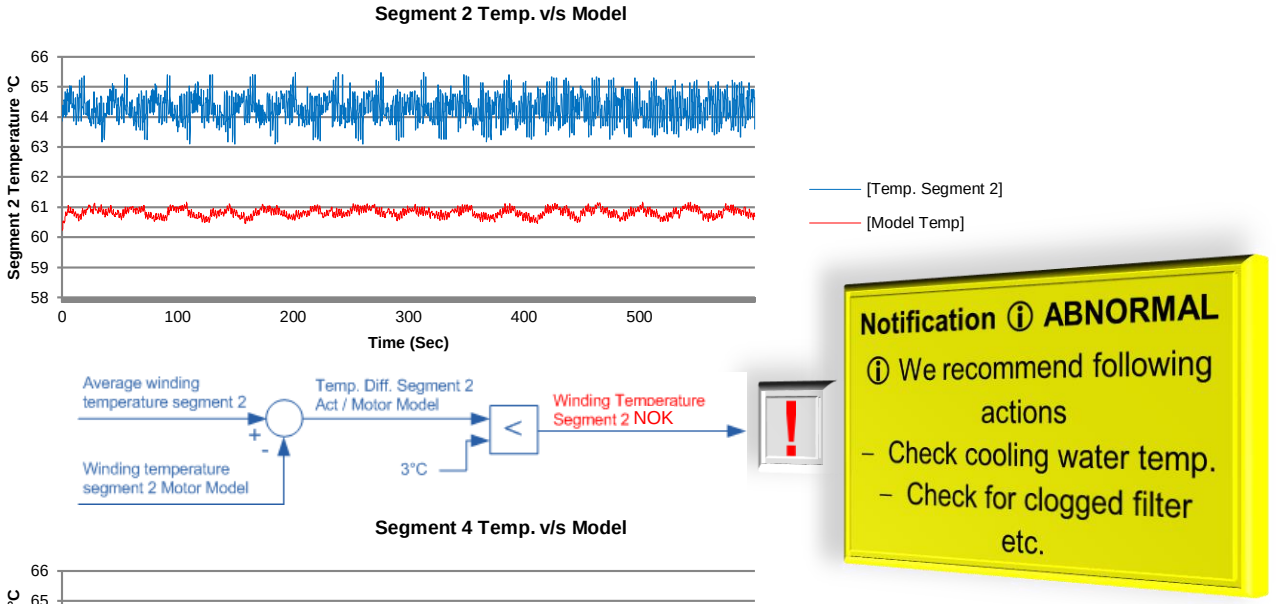
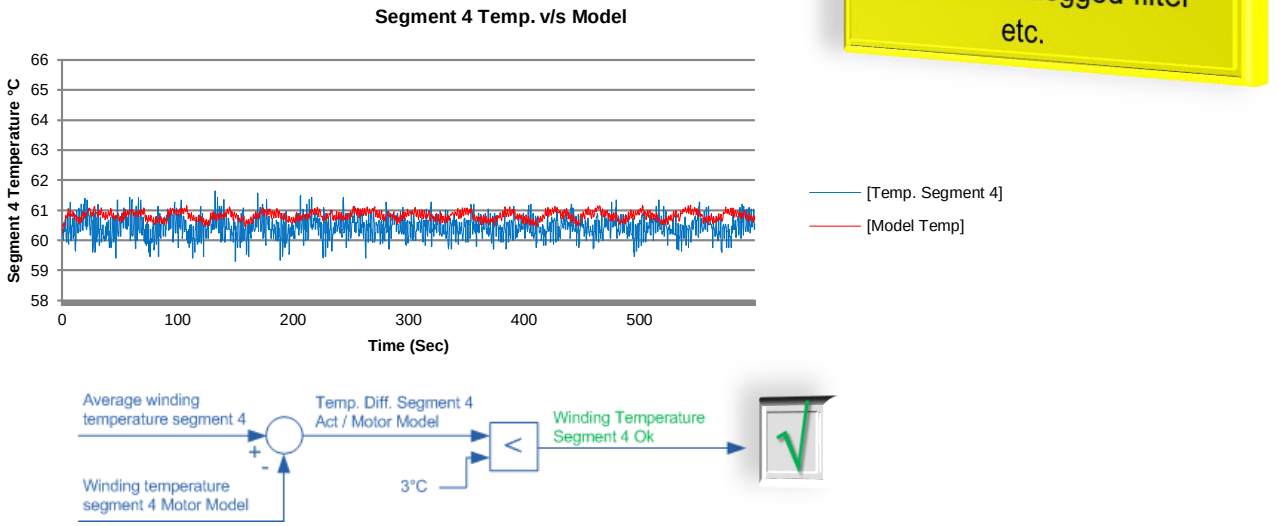
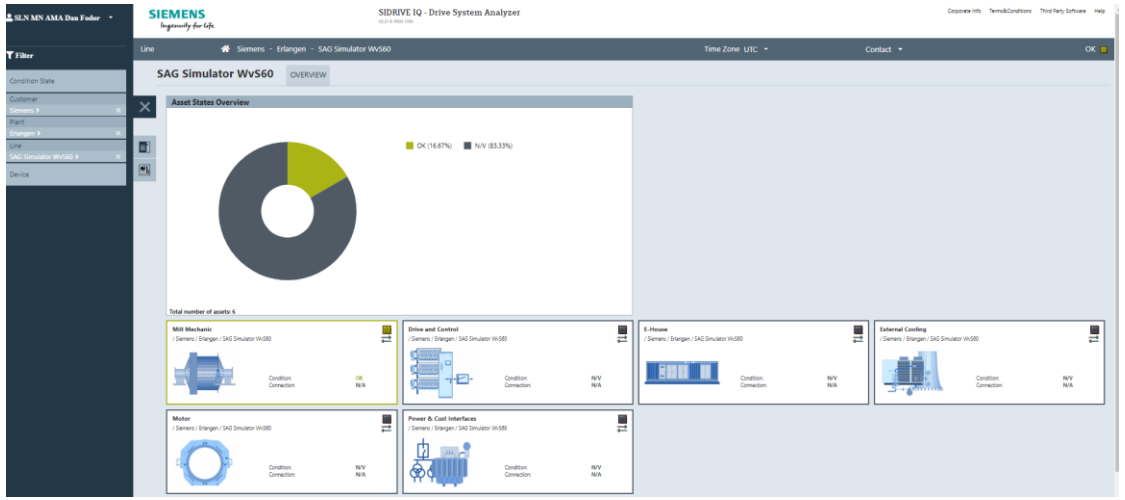


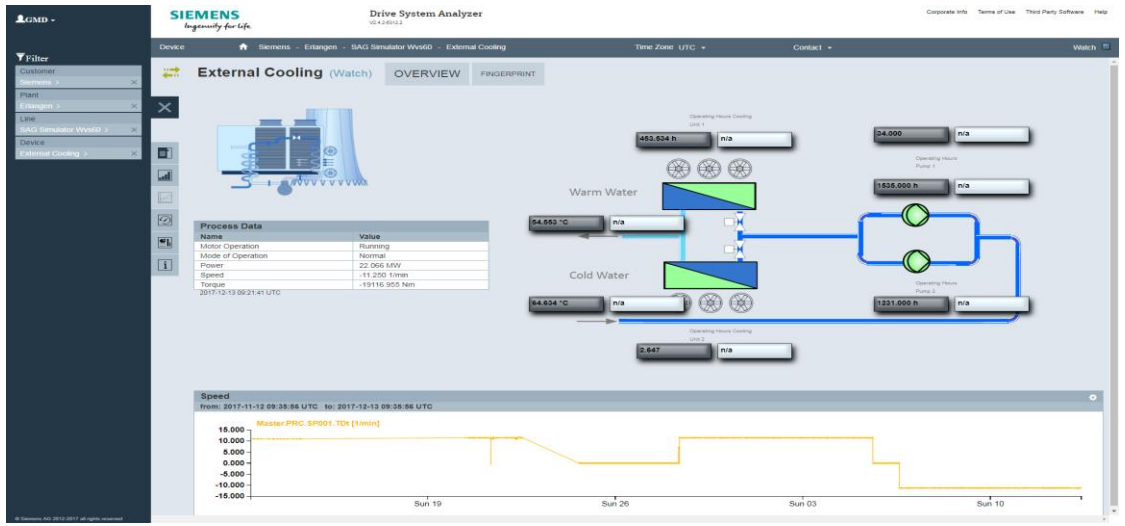






SIMINE Asset Health Analytics for Gearless Mill Drives – Example Dashboards, intuitive Status Overview as well as technical Insights





Intuitive overview of the 6 key components

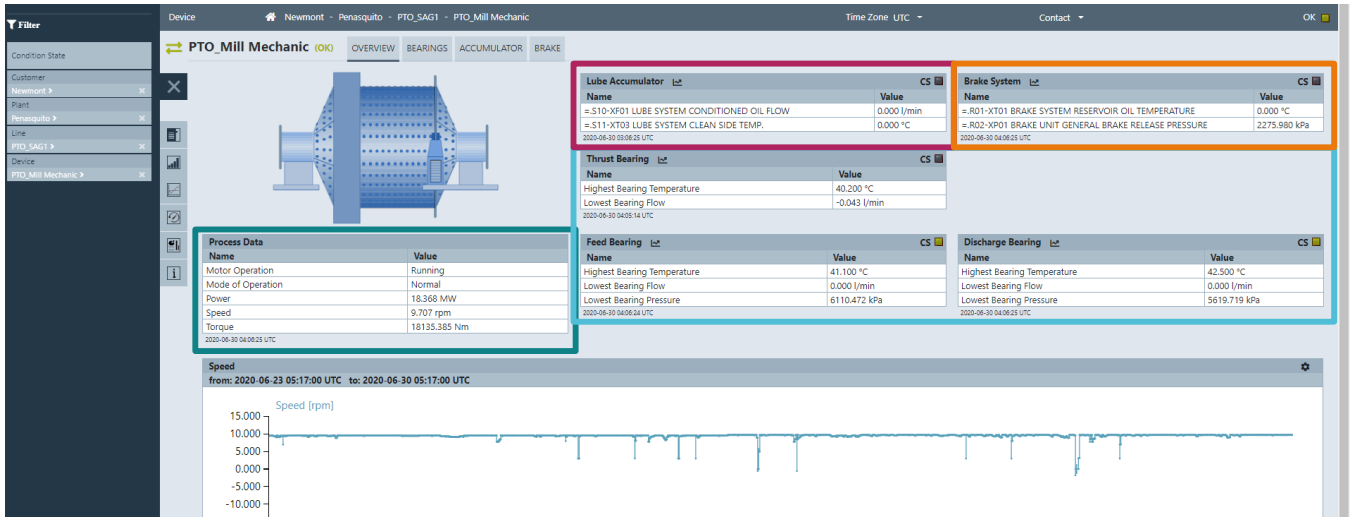
- Mill Mechanic w/ bearings / accumulator / brake
- Drive & Control
- E-house
- External Cooling
- Ring Motor
- Power & Interfaces w. switchgear / circuit breaker / excitation

Intuitive status display

Example technical insights component status “Chiller”

- Ambient & water temperatures / operating hours pumps & cooling unit

SIMINE Asset Health Analytics for Gearless Mill Drives – Example Technical Insights Mill Mechanic



Parameter values
are correlated and displayed
with associated Fingerprints & Process Data

- Lube accumulator (oil flow, temperature)
- Brake (oil temperature, release pressure)
- Bearings (temperature, oil flow/ pressure)
  - Thrust
  - Feed
  - Discharge
- Bearing pads 1 to 4 (temperatures)

SIMINE Asset Health Analytics for Gearless Mill Drives – Example Fingerprints Motor Air-gap, “OKAY” and “NOT OKAY” Status

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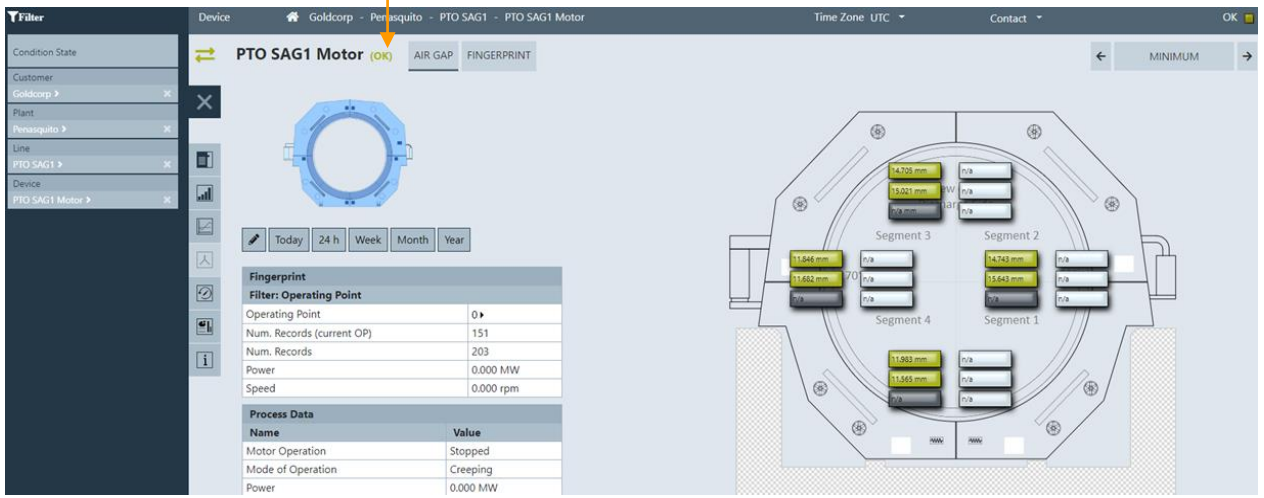
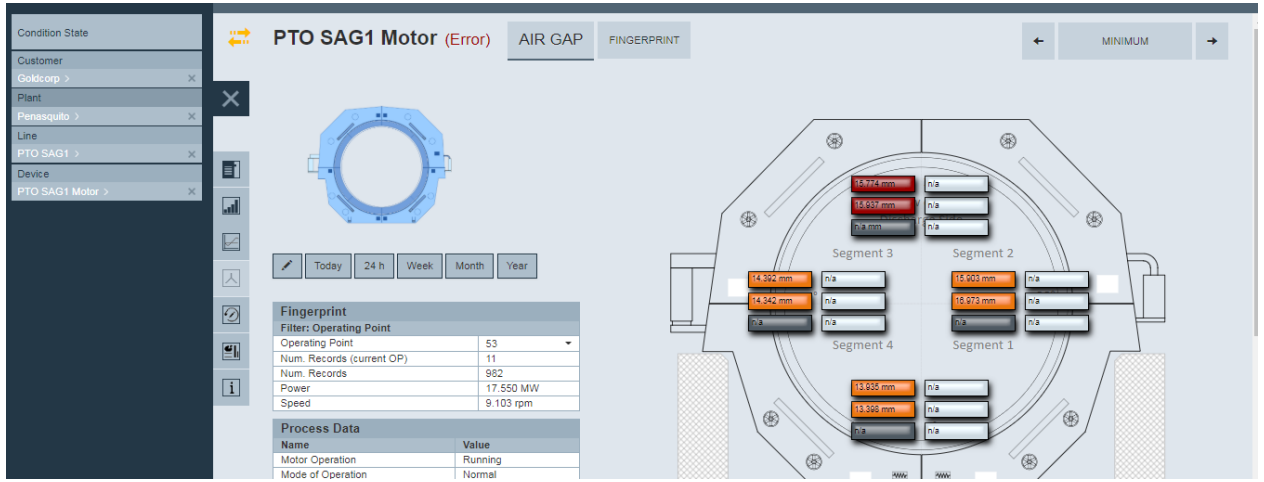
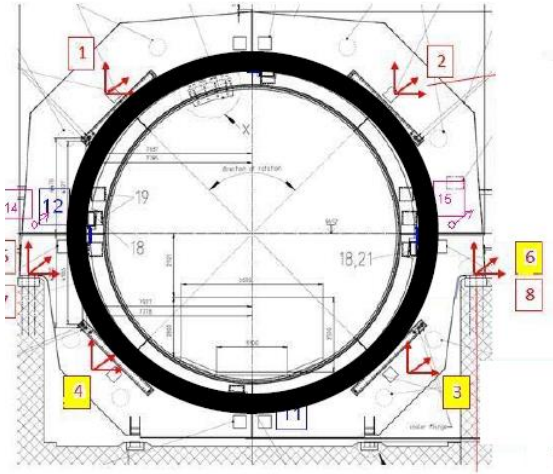
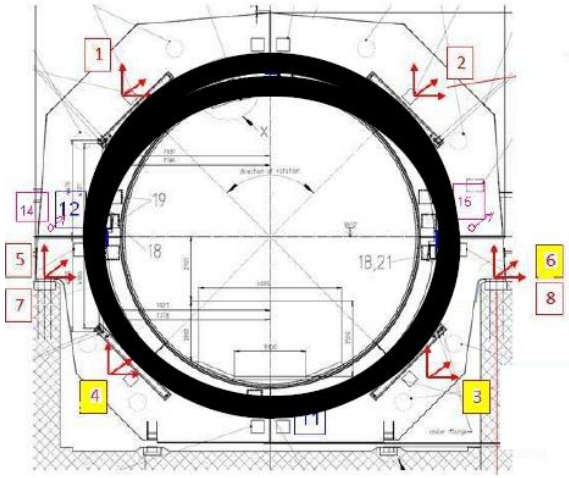
Asset State









Fingerprints application

- Inner circle in first year of operation is ideal round, with tolerances according to the design
- Interesting are eventual long-term stator deformations
- After five to ten years, the circle might change to an oval
- Early detection is crucial

SIMINE Asset Health Analytics for Gearless Mill Drives Example – Service Report answering „What will happen?“

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Fingerprints- and Digital Twins- based Analysis and Trends reveal preventive Actions

Service Expert Report

Asset Health Analytics

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2 Summary Expert Analysis – Status and Trends

This section shows a summary of the mill status. The Asset Health Analytics considers 6 main assets to be analyzed: Motor, Mill Mechanic, Drive and Control, E-House, External water-cooling system and Power and customer interface.

Table 2 shows the legend for the assets summary status, shown in Table 3.

Table 2 Table Legend

Trend – In Comparison to last/previous report	
↑ - Intensity of anomaly has increased	No action required
→ - Intensity at constant level	Action recommended
↓ - Intensity of anomaly has decreased	Action required
n.a. – not applicable	

2	Mill Mechanic			
2.1	High pressure system	→	All values are within the normal operation range.	✓
2.2	Low pressure system	n.a.		
2.3	Accumulator system	n.a.		
2.4	Feed side Pads temperature	→	All values are within the normal operation range.	✓
2.5	Discharge side Pads temperature	→	All values are within the normal operation range.	✓
2.6	Feed side Pads oil flow	n.a.		
2.7	Discharge side pads oil flow	n.a.		
2.8	Feed side Pads pressure	→	All values are within the normal operation range. Trends must be analyzed during the next months. For more detail please refer to 9.4.	✓
2.9	Discharge side Pads pressure	→	All values are within the normal operation range. Trends must be analyzed during the next months. For more detail please refer to 9.5.	✓
2.10	Thrust bearing oil flow	n.a.		

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4 Mill Operation

Within the reported time frame (01.08.2018 to 31.10.2018) the mill was operated 41.28% of all time within the power/speed range 8.56-9.84rpm / 16.79-20.65MW. The remaining time the mill was operated out of this range (very low load).

The normal operation range is used for further analysis. The distribution of mill operation time in this range is shown in Figure 1.

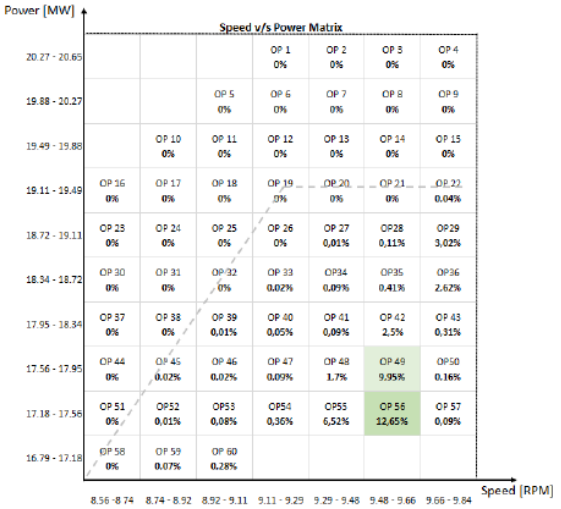

Figure 1 Mill Operation

The most ran operating point (OP) was the number 56 with 12.65% of the time. This operating point represents a speed between 9.48 – 9.66 [RPM] and a power between 17.18 – 17.56 [MW].

For analysis purposes, the most active operating point will be used to evaluate the mill status.

SIMINE Asset Health Analytics for Gearless Mill Drives Example – Service Report answering „What will happen?“

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Fingerprints- and Digital Twins- based Analysis and Trends reveal preventive Actions

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5 Mill Eccentricity

Using the airgap measurements, the mill eccentricity is analysed.

Figure 2 and Figure 3 shows the trend of the mill eccentricity at the operation point 56 (see Figure 1) between the 01.08.2018 until the 31.10.2018 and the exact dates when the mill operated at this operation point.

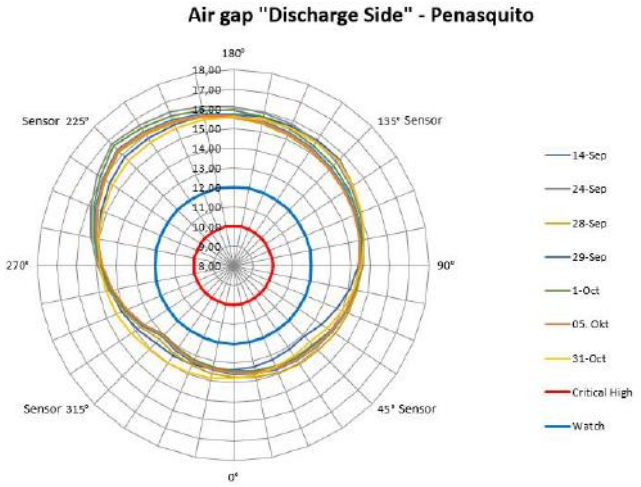

Figure 2 Air gap measurements discharge side

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6 Stator winding temperature and trend prediction

In this section, using the fingerprint concept of the Asset Health Analytics system, the winding temperature is measured at the operating point 56 shown in Figure 1 and the winding temperature trend is analysed.

Using the trend the Asset Health Analytics system provides a prediction of the winding temperature behaviour for the future operation. If the winding temperature prognosis trend reaches 105°C and 110° a warning condition message and critical condition message will be generated respectively.

Each measurement point shown in Figure 4, Figure 5, Figure 6 and Figure 7 represents the average motor winding temperature when the mill was running at the operation point 56.

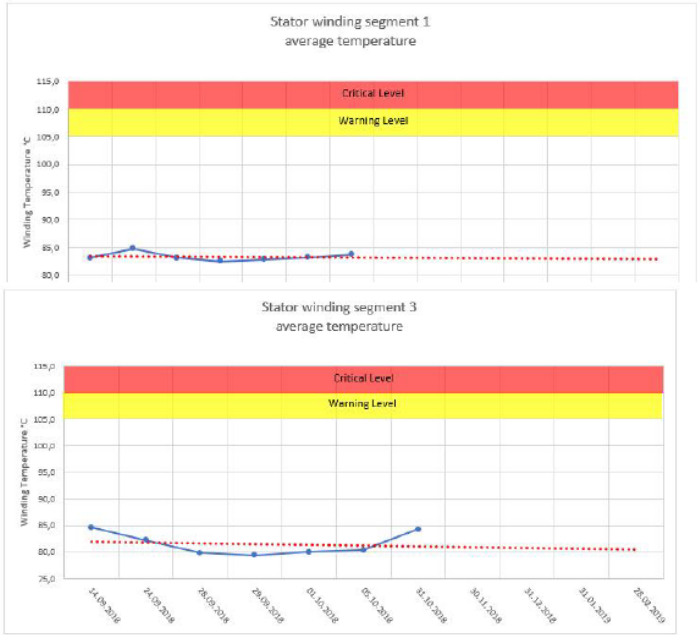

Figure 6 Stator winding average temperature segment 3

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7 Stator winding temperature compared to motor temperature model

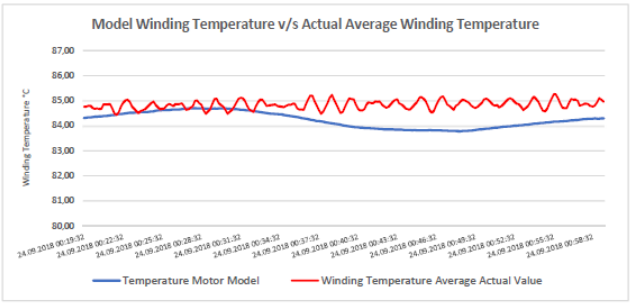

Figure 9 Motor winding temperature, model v/s actual value

9.1 Thrust Bearing temperature

Figure 15 shows the trend of the thrust bearing temperature at the operation point 56 between the 01.08.2018 and the 31.10.2018.

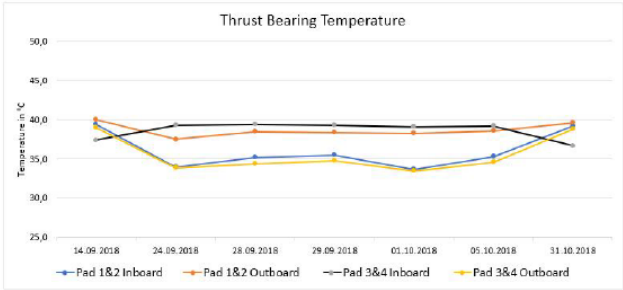

Figure 15 Thrust bearing temperature trend

SIMINE Asset Health Analytics for Gearless Mill Drives
On-premise Solution under Development (Release E 2020)

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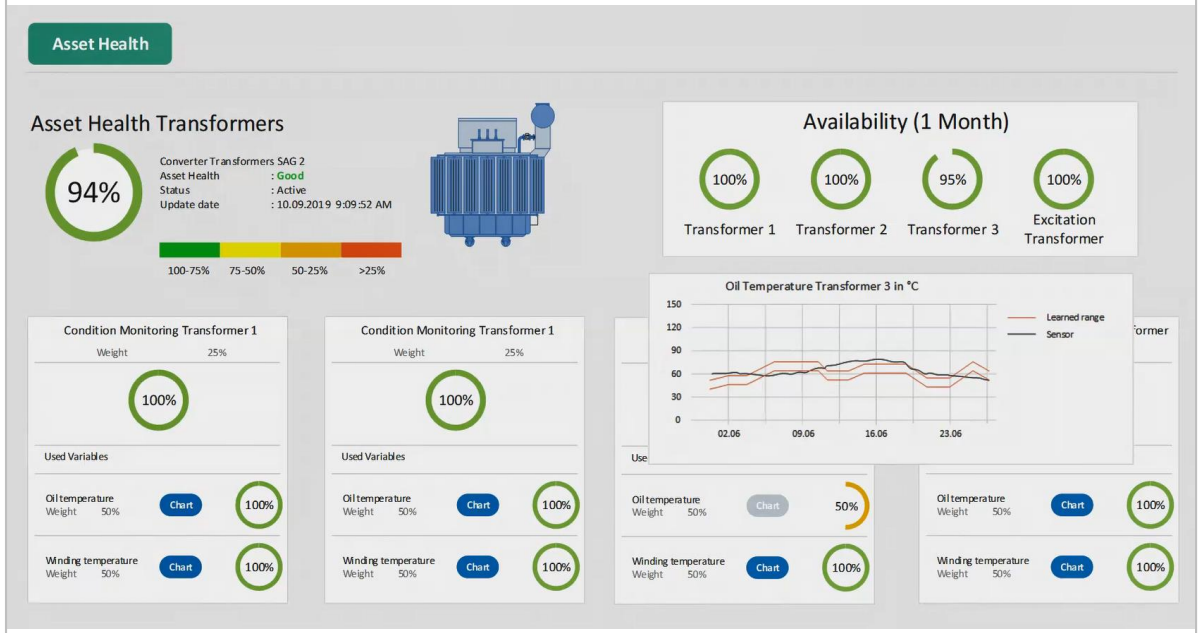
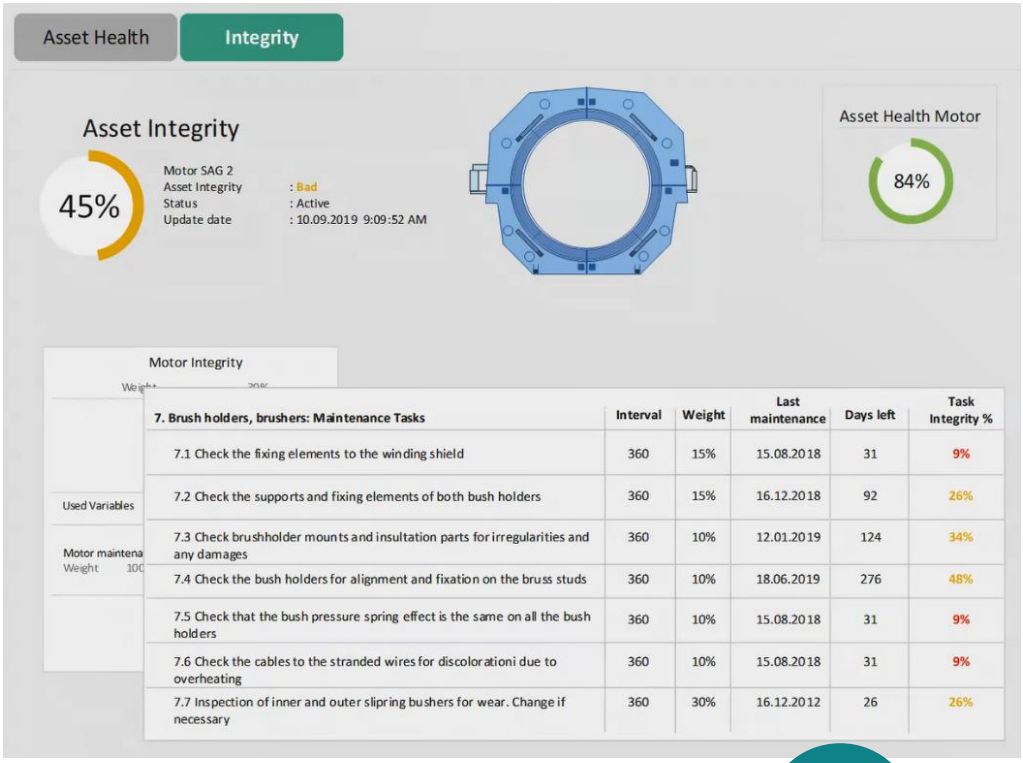
Asset Health



- **Asset health reflects operational conditions** and is determined based on **anomaly detection** of critical measurements e.g. oil temperature and winding temperature of transformers

- **Asset integrity reflects maintenance conditions** and is calculated based on **expected maintenance** tasks and intervals for every component



7. Brush holders, brushers: Maintenance Tasks	Interval	Weight	Last maintenance	Days left	Task Integrity %
7.1 Check the fixing elements to the winding shield	360	15%	15.08.2018	31	9%
7.2 Check the supports and fixing elements of both bush holders	360	15%	16.12.2018	92	26%
7.3 Check brushholder mounts and insultation parts for irregularities and any damages	360	10%	12.01.2019	124	34%
7.4 Check the bush holders for alignment and fixation on the bruss studs	360	10%	18.06.2019	276	48%
7.5 Check that the bush pressure spring effect is the same on all the bush holders	360	10%	15.08.2018	31	9%
7.6 Check the cables to the stranded wires for discolorationi due to overheating	360	10%	15.08.2018	31	9%
7.7 Inspection of inner and outer slipring bushers for wear. Change if necessary	360	30%	16.12.2012	26	26%

Asset Integrity

SIMINE Asset Health Analytics for Gearless Mill Drives
Wrap-up Value Proposition (Status Information only Examples)

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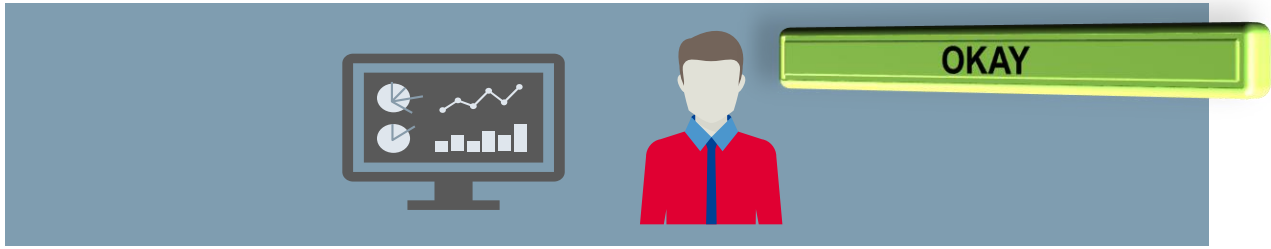
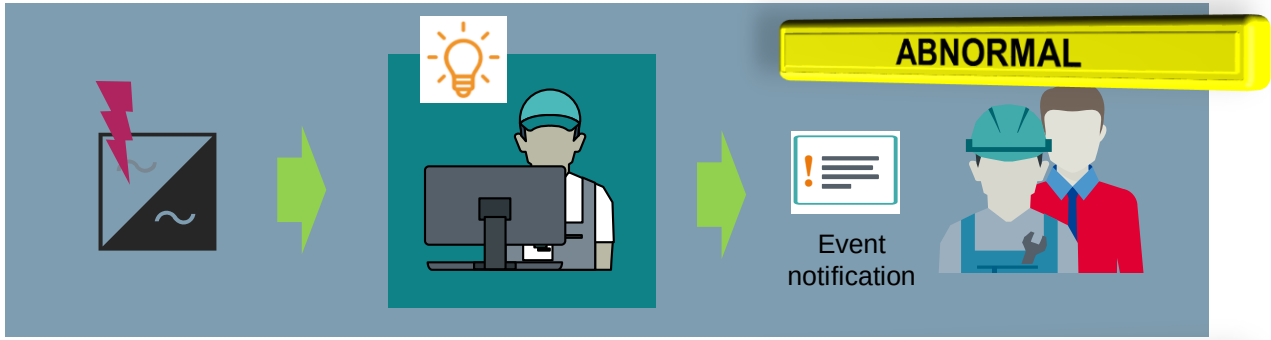
Operational transparency, "no surprise"
- Mill status and trends
- Overview and detailed component views

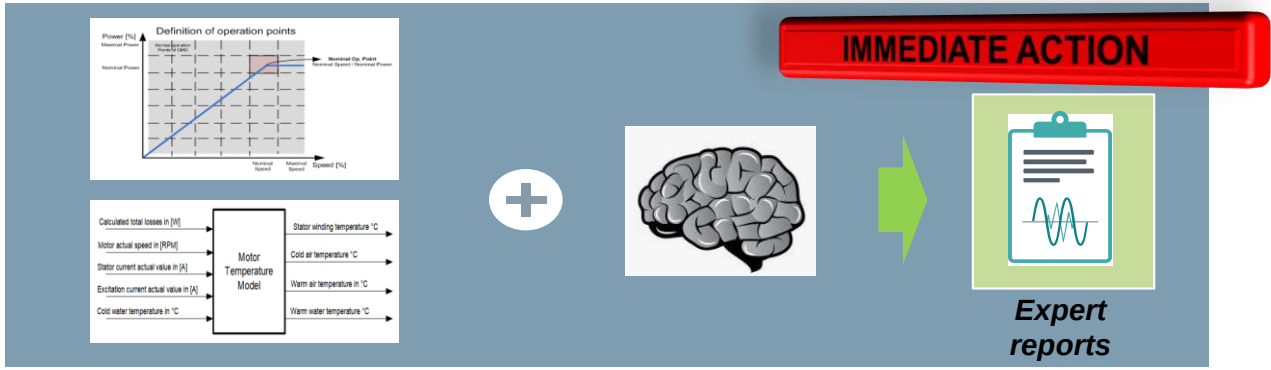


Continuous Condition Monitoring and Expert Analytics identify relevant deviations:

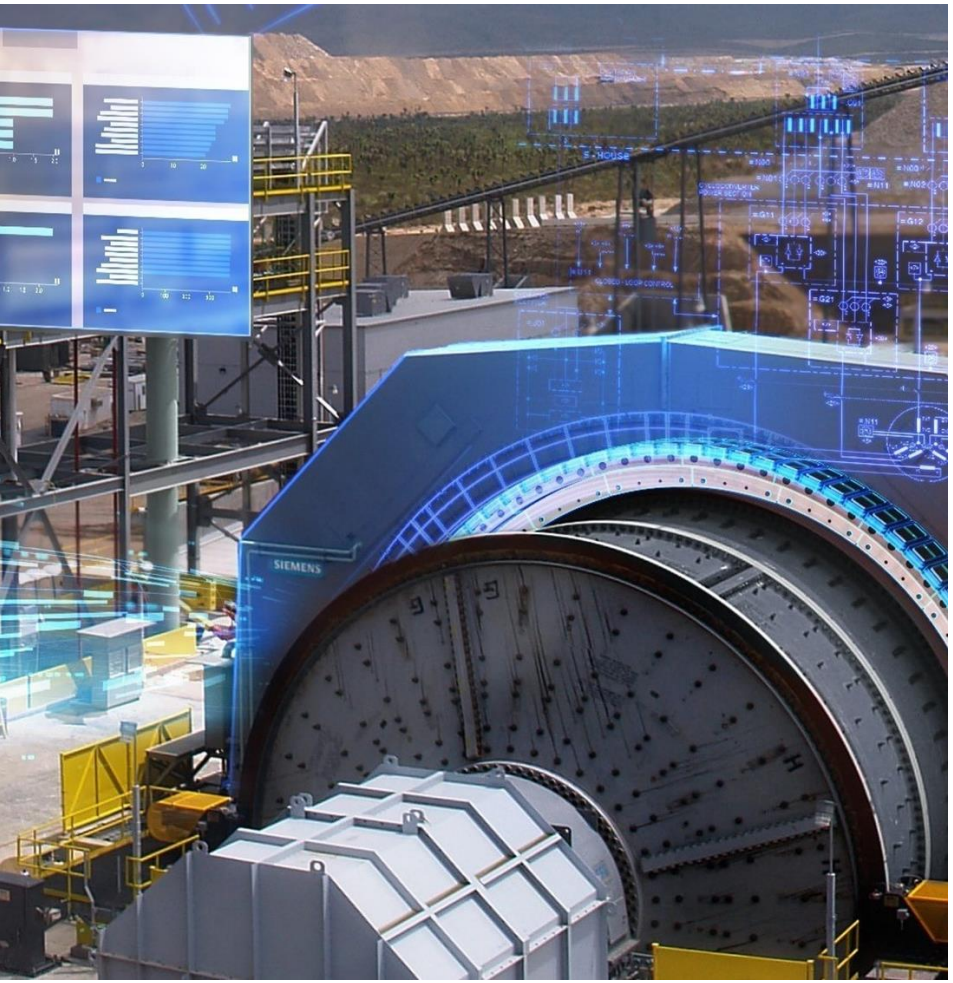
Understand what happens, "opportunity to prepare"
Event analysis *(short term)* to identify event including notification



Support for early appropriate counteraction
Decision support for *(short term)* action
Prescriptive analysis *(long term):* analysis of mill status, inclusive expert reports with service recommendations



SIMINE Asset Health Analytics Survey
Contents



Courtesy © Penasquito Gold-Silver Operation in Mexico (Image: Newmont)

Customer Voice

Asset Health Analytics for Gearless Mill Drives

- Added Value for Operations
- Technology Pillars

Asset Health Analytics for Belt Conveyors

SmartMining

Demo/ Examples within each Chapter

SIMINE Asset Health Analytics for Belt Conveyors
Value Proposition

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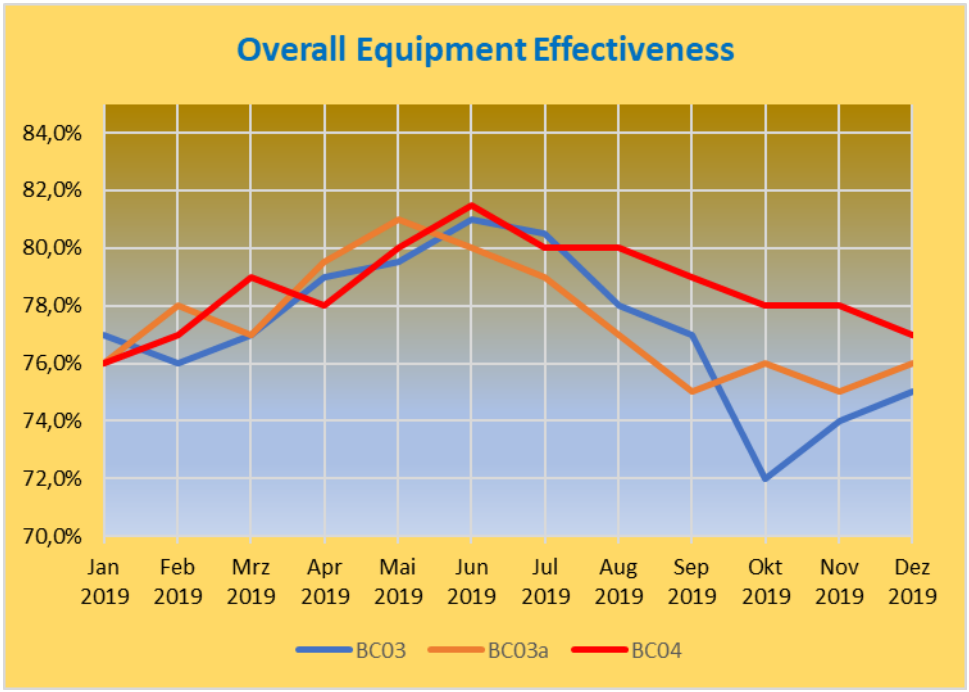
- **Early detect events** that cannot be predicted exclusively through mathematic models and simulation
- **Monitor operational status** e.g. belt misalignment or cord/ edge damage etc.
- **Economics improvement** based on **K**ey **P**erformance **I**ndicators, **O**verall **E**quipment **E**ffectiveness, components lifetime etc.

Example OEE- based analysis



Influences of e. g. ambient temperatures (seasons) or specific events (like BC03 in Autumn 2019) on operating performance can be identified and evaluated

SIMINE Asset Health Analytics for Belt Conveyors
Intuitive Use at all Levels

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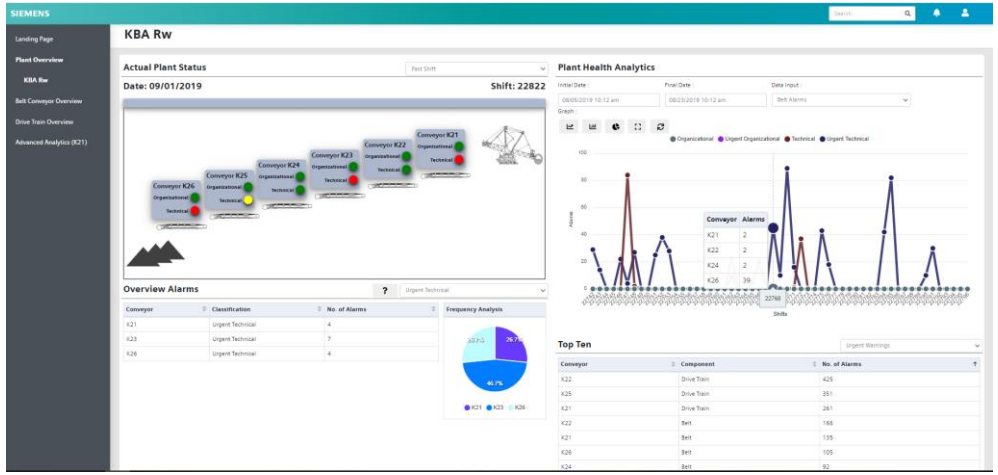
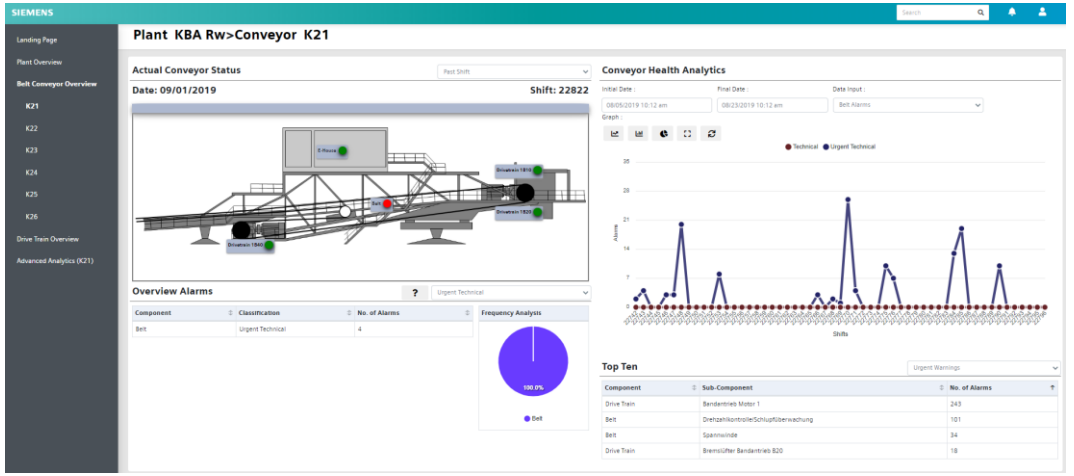
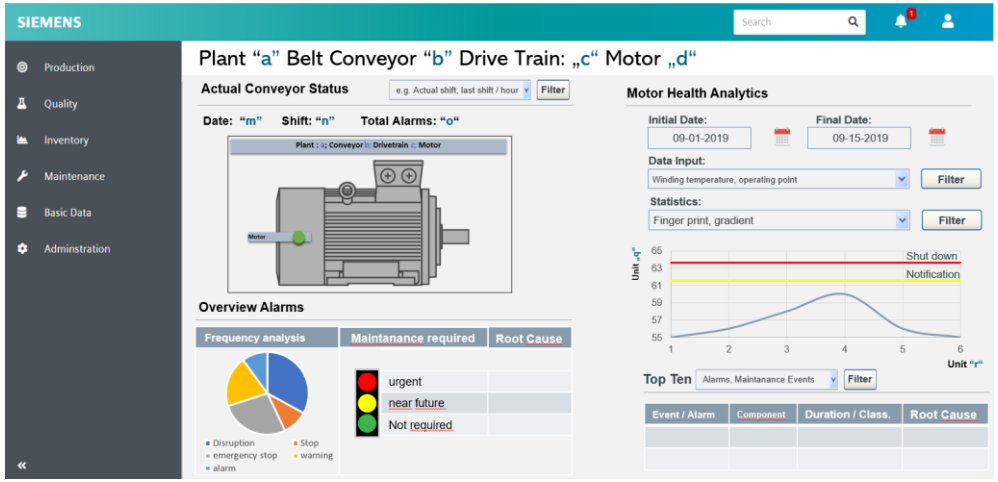
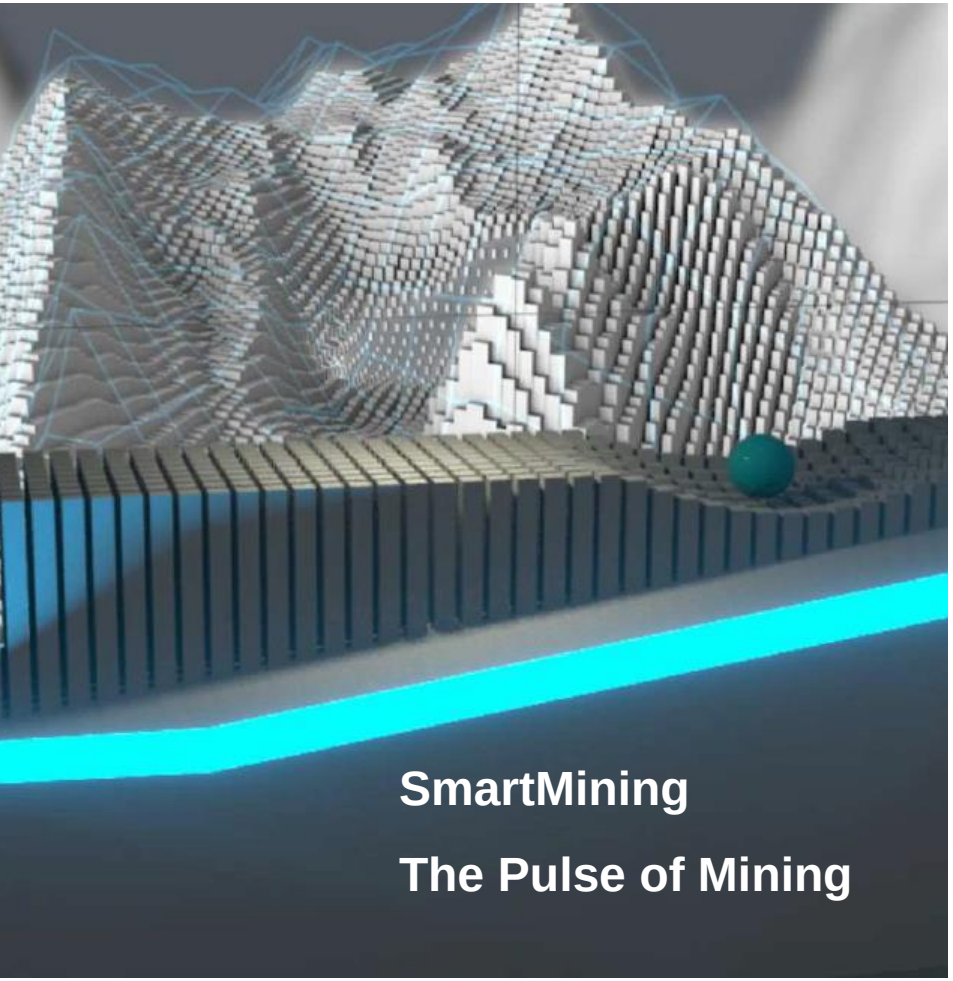






SIMINE Asset Health Analytics Survey
Contents



Customer Voice

Asset Health Analytics for Gearless Mill Drives

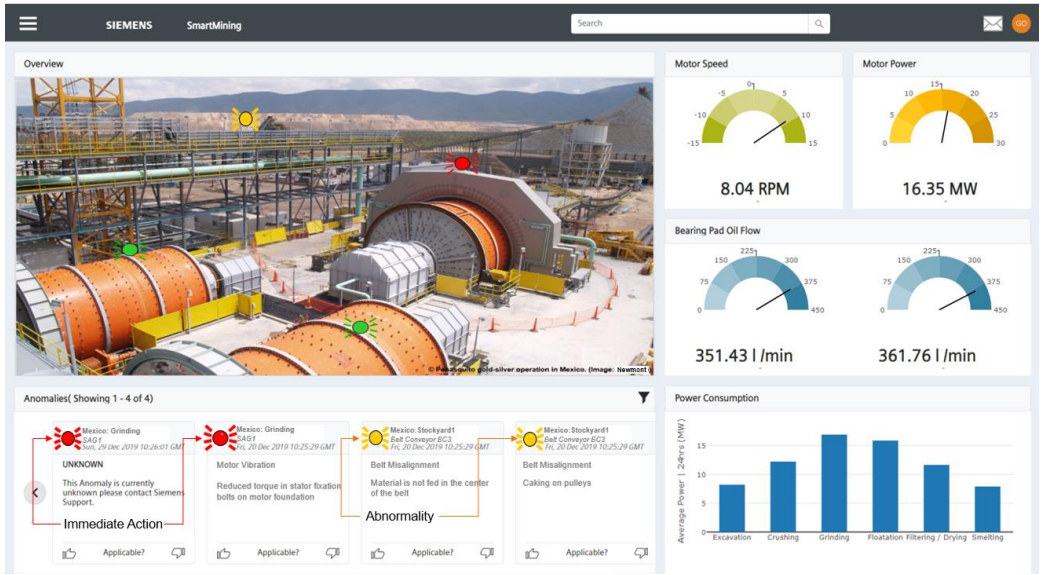
- Added Value for Operations
- Technology Pillars

Asset Health Analytics for Belt Conveyors

SmartMining

Demo/ Examples within each Chapter

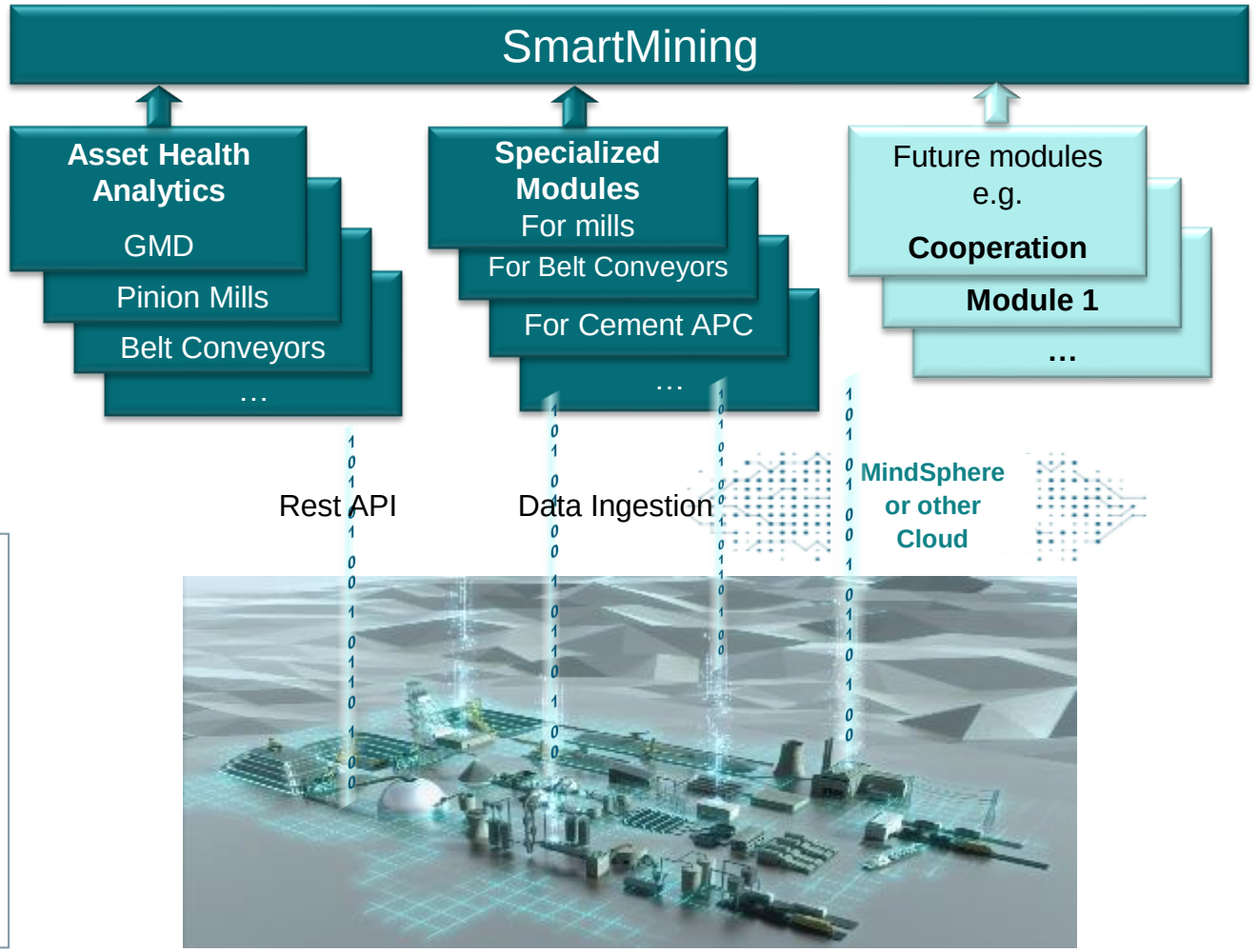
SmartMining Platform for Grinding or Transportation Process or for entire Mine Location



Our SIMINE Asset Health Analytics solutions are expandable to higher levels

e.g. **grinding process, transportation process or entire mine location**

through integration in Siemens SmartMining platform



Process Control System PCS7 / DCS systems -Historian / 3rd Party system

SIEMENS SmartMining

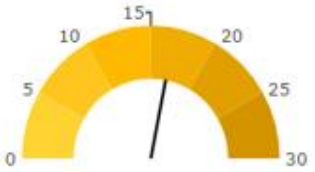
Search GO

Overview

Motor Speed

8.04 RPM

Motor Power



16.35 MW

Bearing Pad Oil Flow

351.43 l /min

361.76 l /min

Anomalies(Showing 1 - 4 of 4)

Mexico: Grinding
SAG1
Sun, 29 Dec 2019 10:26:01 GMT

UNKNOWN

This Anomaly is currently unknown please contact Siemens Support.

Applicable?

Mexico: Grinding
SAG1
Fri, 20 Dec 2019 10:25:29 GMT

Motor Vibration

Reduced torque in stator fixation bolts on motor foundation

Applicable?

Mexico: Stockyard1
Belt Conveyor BC3
Fri, 20 Dec 2019 10:25:29 GMT

Belt Misalignment

Material is not fed in the center of the belt

Applicable?

Mexico: Stockyard1
Belt Conveyor BC3
Fri, 20 Dec 2019 10:25:29 GMT

Belt Misalignment

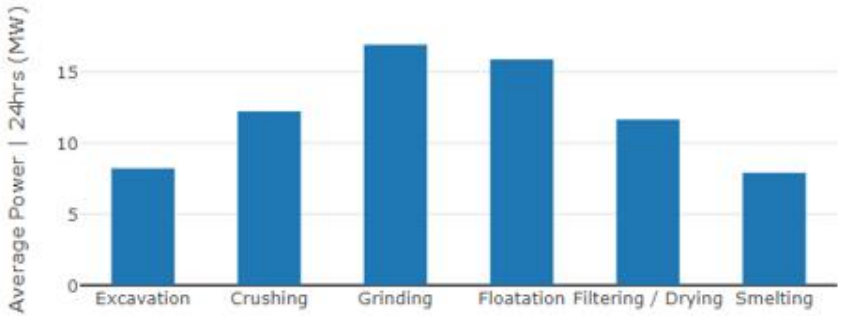
Caking on pulleys

Applicable?

Immediate Action

Abnormality

Power Consumption



Example of SmartMining Microservice – Events, Root Causes and recommended short/long- Term Actions

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Event	Reason (Possible cause) (samples only)	Counter-measures (short-term) (samples only)	Preventive measures (long-term) (samples only)
Mis-alignment of belt	Material is not fed in the center of the belt	Change the conditions in the feeding station	Install off-track detectors (misalignment switches) behind the feeding station
	Caking on pulleys	Increase the efficiency of the belt cleaner	Increase the inspection interval for the belt cleaner
	Alignment of idler-stations are wrong	Check the idler-stations	Increase the inspection interval for the idlers (e.g. use thermal camera)
	Wind or rain influence the local friction conditions between belt and idlers	Install covers or hoods on the conveyor	

- **Identified risky changes** appear on the screen with details and relevant signals
- **Root cause(s) and counteraction(s)** corresponding to the change(s) are displayed
- Own expert classified changes can be **permanently added**

SIMINE Asset Health Analytics for Grinding Mills
Our expert Solution to avoid “false Positives”

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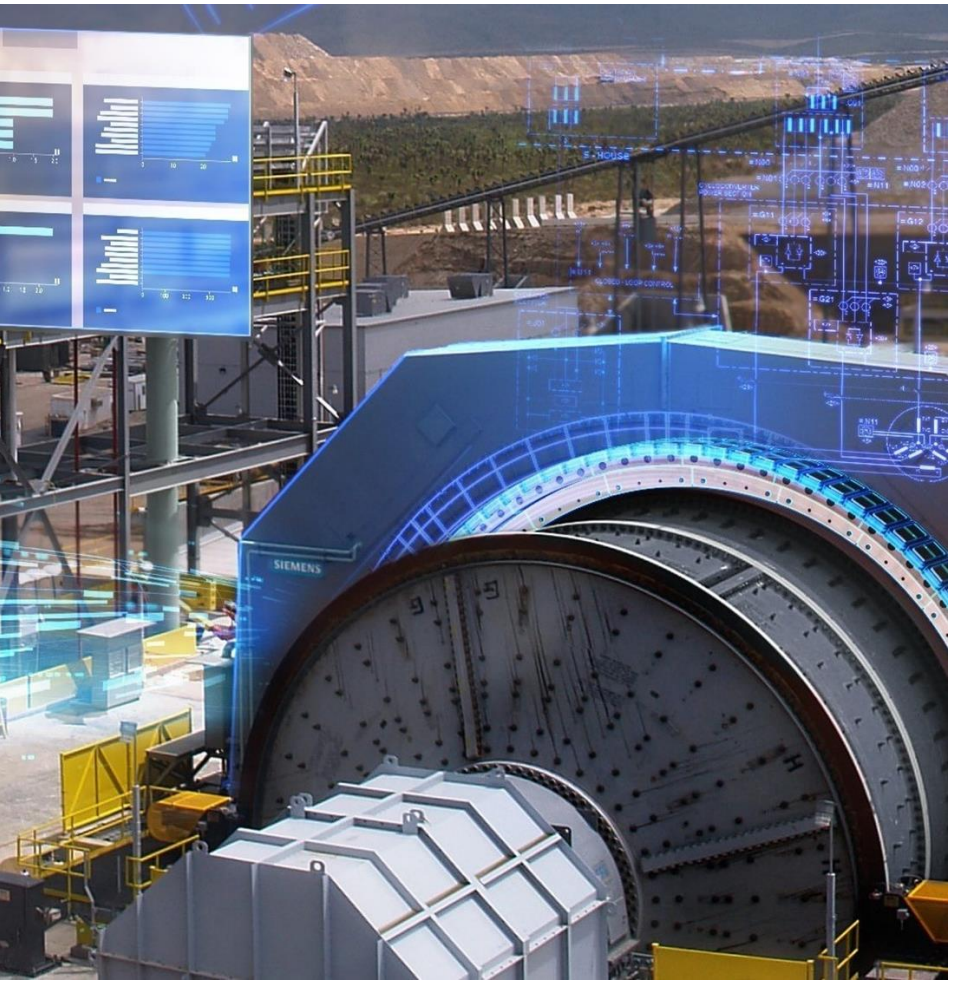

Courtesy © Penasquito Gold-Silver Operation in Mexico (Image: Newmont)

Example

Example Fingerprint Analysis – Abnormality “Winding Temperatures increase during Sommer Months”. Which is the Root-Cause?

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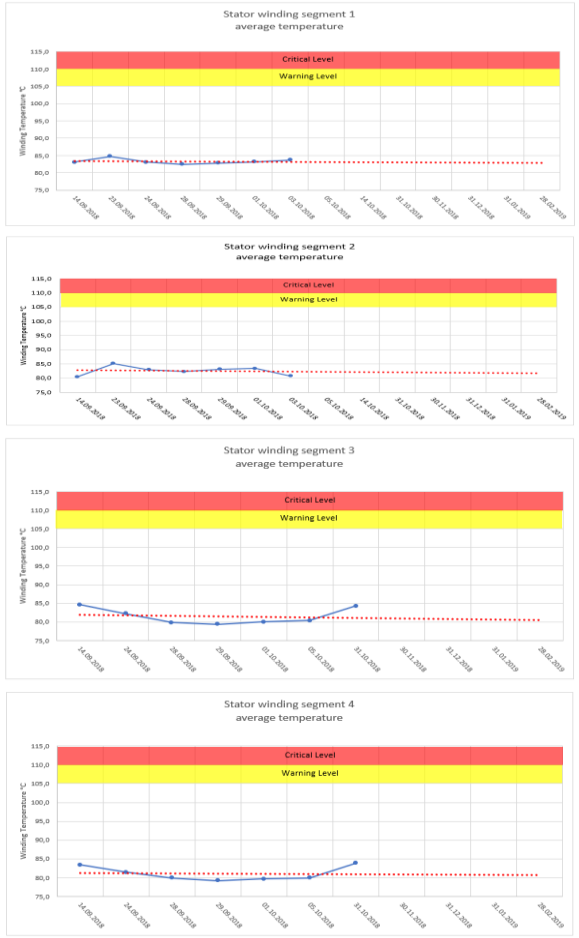
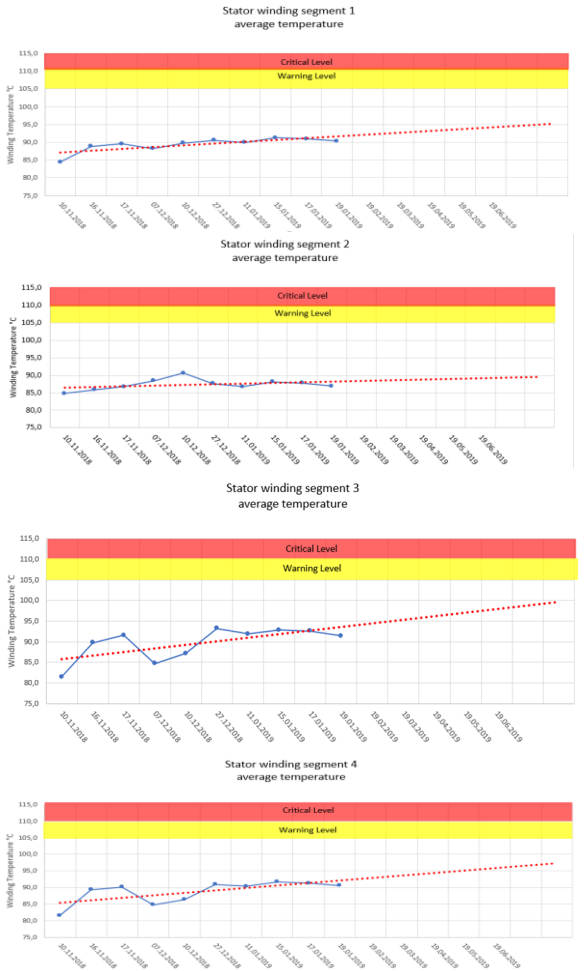
01.08.2018–31.10.2018



01.11.2018–28.02.2019



Example of Expert Analytics to avoid “false Positives”

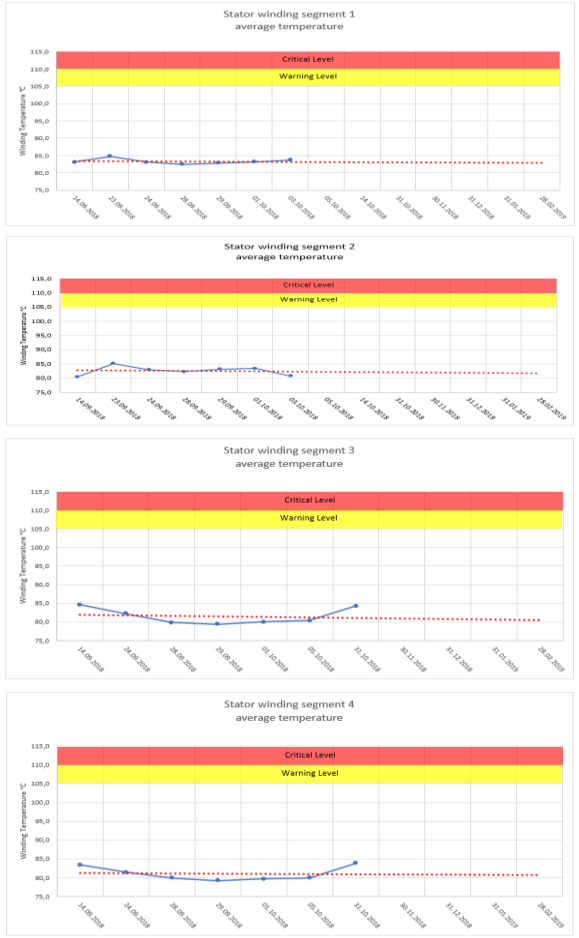
„First shot“ explanation of the root-cause:

There is a possible problem in the motor cooling system i.e. with the motor fans or heat exchanger

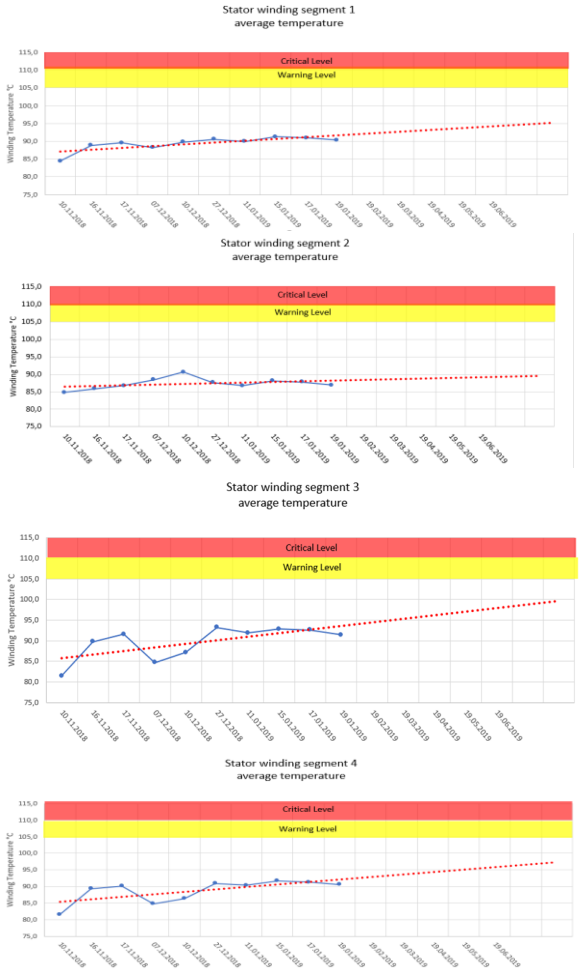
Siemens “Expert Analysis” based explanation needs additional information, therefore…→

Winding Temperatures increase during Sommer Months. Which is the Root-Cause? Let us analyze the external cooling as well

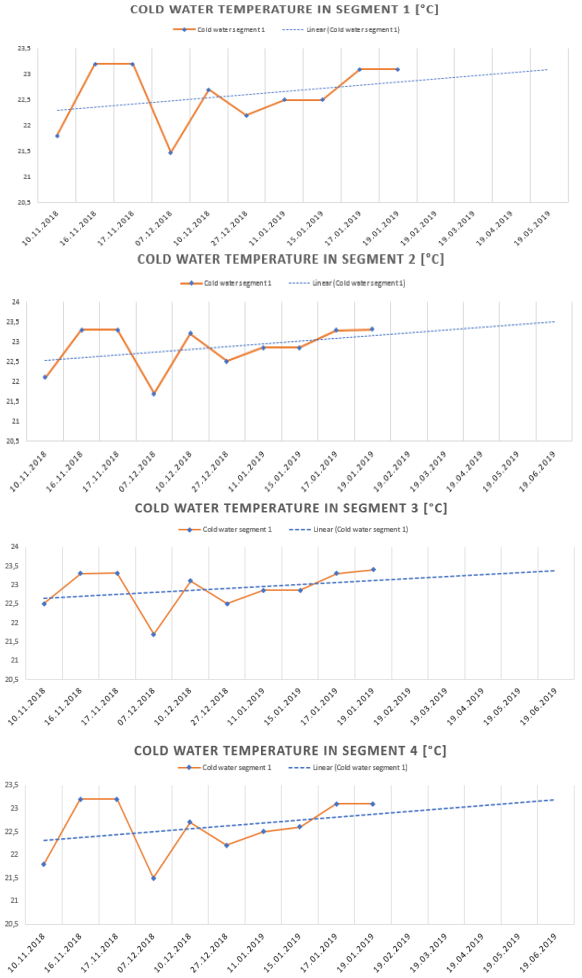
01.08.2018–31.10.2018



01.11.2018–28.02.2019



01.11.2018–28.02.2019



Abnormality “Winding Temperatures increase during Sommer Months.” – Which is the Root-Cause?

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Summary of the Facts

- Winding temperatures are constant during Spring[1)] months but increase during Summer months
- First root-cause explanation is a possible problem in the motor cooling system (i.e. motor fans or heat exchanger)
- **Siemens “Expert Analysis”** needs additional information, therefore the external cooling system is analyzed as well
- In the external cooling system, cold water temperature increases during the Summer months as well
- Siemens Asset Health Analytics support information for immediate action:
  - There is no problem with the motor cooling system
  - Suggestion to the customer: check the chiller (motor external water cooling system) due to increased inlet cold water temperature

1) Seasons acc. Chile location

Example Fingerprint Analysis – Did we solve the problem? Yes, we did, as the following months confirmed

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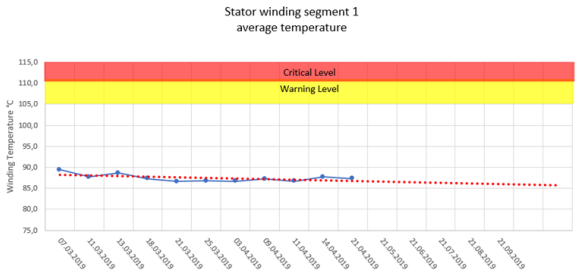
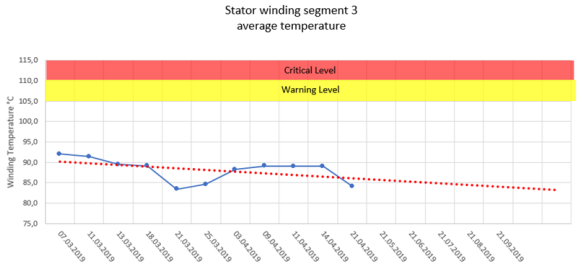
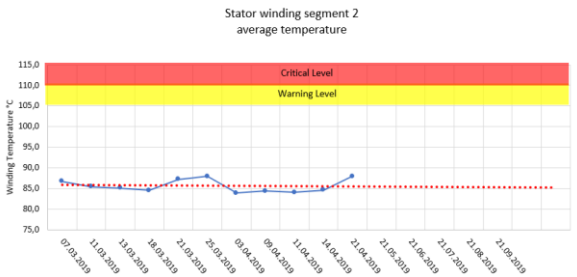
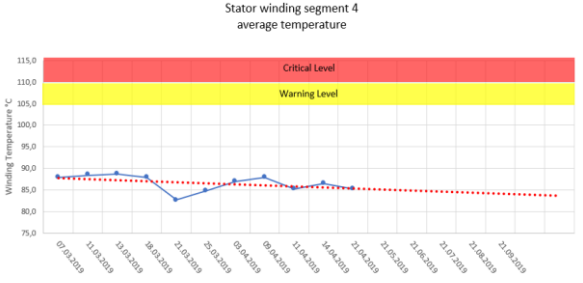
01.03.2018–30.05.2019







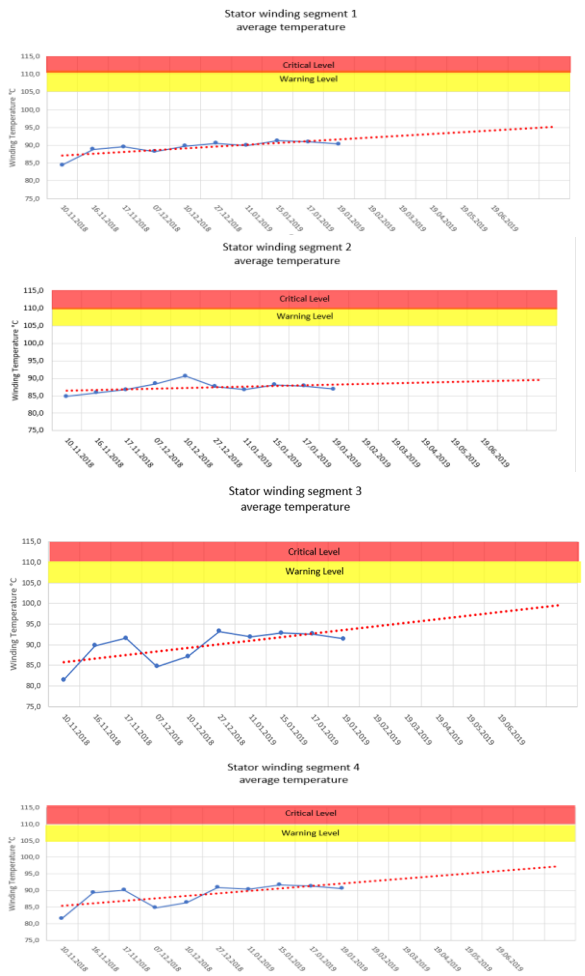


Motor winding temperatures got back to normal in the months after

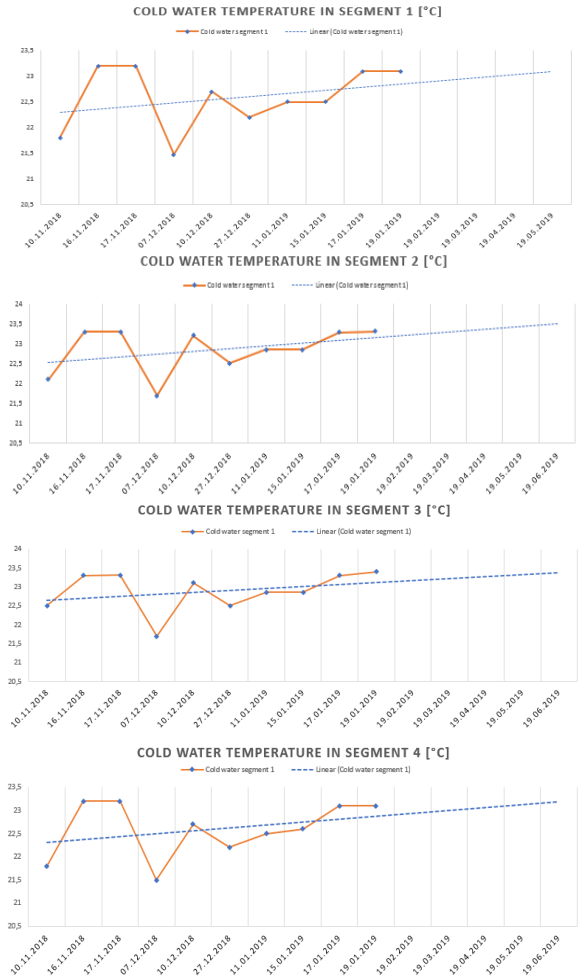
Hence: Health Analytics from Siemens Experts to avoid “false Positives”

Example Fingerprint Analysis (Siemens Patent pending)
Did we avoid here a “false Positive”? Yes, we did.

01.11.2018–28.02.2019



01.11.2018–28.02.2019



In our example, the **„false Positive“ root-cause for** Winding temp. increase is:

- **External cooling is OKAY** (induced by “Motor cooling has malfunction”)

	Identified	NOT Identified
External Cooling OKAY	**False Positive**	**False Negative**
External Cooling NOT OKAY	**True Positive**	**True Negative**

Takeaways
SIMINE Asset Health Analytics

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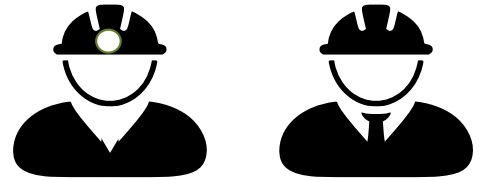
Our SIMINE Asset Health Analytics solutions are…

- … available for Gearless Mills, Pinion Mills, Belt Conveyors and Mine Winder
- … focused on process visibility, predictive and counteraction information
- … based On-Cloud or On-Premise as specified by the user
- … expandable to higher levels (e.g. grinding, transportation process or entire mine location) through integration in Siemens SmartMining platform
- … supporting miners for having
  - “no operational surprise”
  - ”opportunity to prepare against unexpected”
  - “early indication for counteractions”



Many Thanks for Your Attention!
Questions

Dr. Dan Fodor

Head of Portfolio Management and R&D
Siemens AG

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dan.fodor@siemens.com