

Predictive Maintenance Solution for Refinery

www.moh.gr | March 30, 2022 | Smart Factory Conference 2022



Refinery



185,000 BSD

barrels of crude oil per
stream day

11.54

rating on the
Nelson Complexity Index

2,600,000

m³ of storage capacity

12.1 million MT

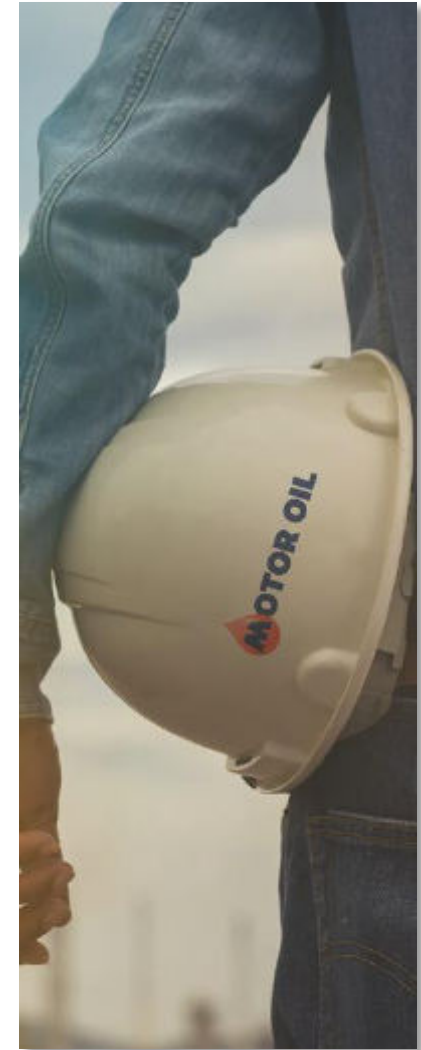
production of refinery products
(FY19)

3,000 Vessels

berthed at the port facilities
annually

220 Trucks

served per day at the truck
loading terminal



Predictive Maintenance Roadmap

Proof of Concept (3,5 weeks)

Systems

- SAP HANA Platform
- SAP Analytics Cloud

Operational Data

- 3 Compressors
- 11 sensors (pressure, temperature, vibration)
- 4 years data
- Trip & Alarm Thresholds

Implementation Steps

- Data Quality Check
- Data Analysis
- Operating Conditions & Data Melt-Down
- Engineering Rules
- Predictive Target Definition

Results

- 80.5 % accuracy in predictions of trip threshold exceedance events
- 99.7 % accuracy in predictions of no trip threshold exceedance

e-Data Value Workshop

PoC

Pilot

Evaluation

Scale-Up

2020

2021

2022

SAP e-Data Value Workshop (2 days)

- Learn about SAP Solutions (SAP Industry point of View, BTP & Customer Cases)
- Identify Current Challenges & Future opportunities
- Discover Use Cases
- Prioritize Use Cases
- Define Roadmap

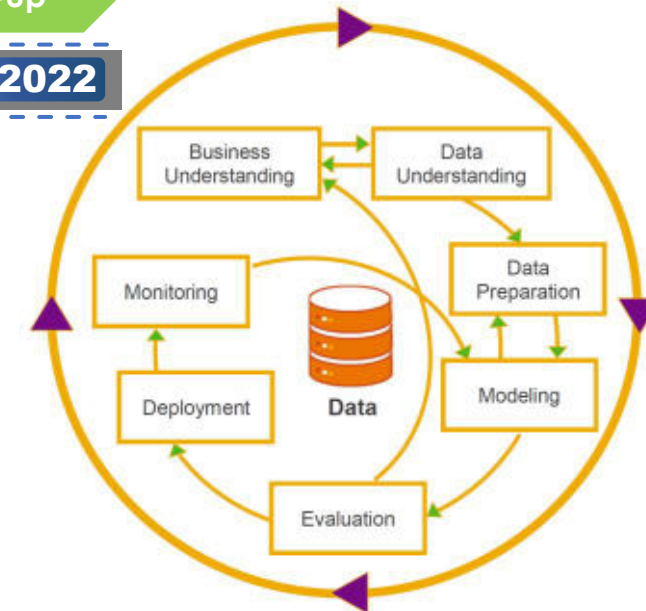
Pilot (3 months)

Systems

- SAP Data Provisioning Agent
- SAP HANA Platform
- SAP Analytics Cloud

Operational Data

- 5 Process Critical and non-redundant Compressors
- 86 sensors (pressure, temperature, vibration)
- 4 years data
- Trip & Alarm Thresholds



Scope Definition



Scope Definition

Monitor process critical compressors

Analyze Historical Data & Learn from Past Events

Forecast equipment sensors behavior and predict alarm & trip limits exceedance

Early notification about upcoming abnormal events

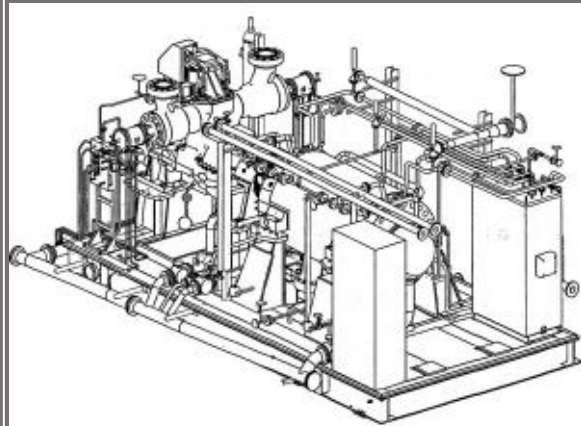
Avoid unexpected shutdowns



Mechanisms

Root cause analysis – Real time system health monitoring

Sensor level timeseries forecasting (24 hours)



Root Cause Analysis vs Time Series Forecasting



Root Cause Analysis

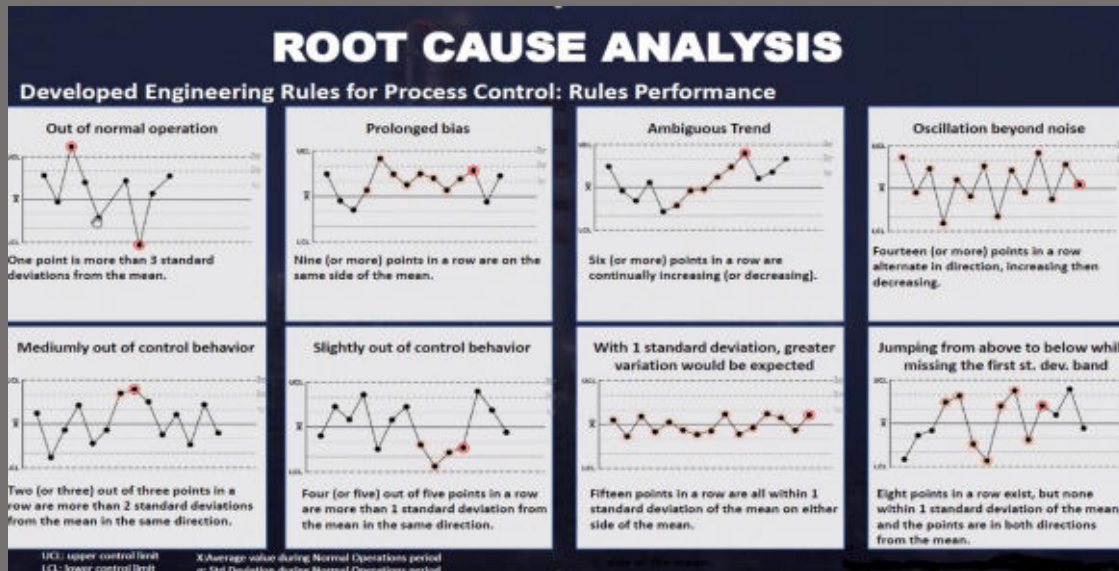
Define normal values of each tag learning from periods of normal operation

Define historical actual events in machine level

Compare tag behaviors 1 week before actual events to what is normal

Discover abnormal behaviors

Define abnormal behaviors that led to machine abnormal event



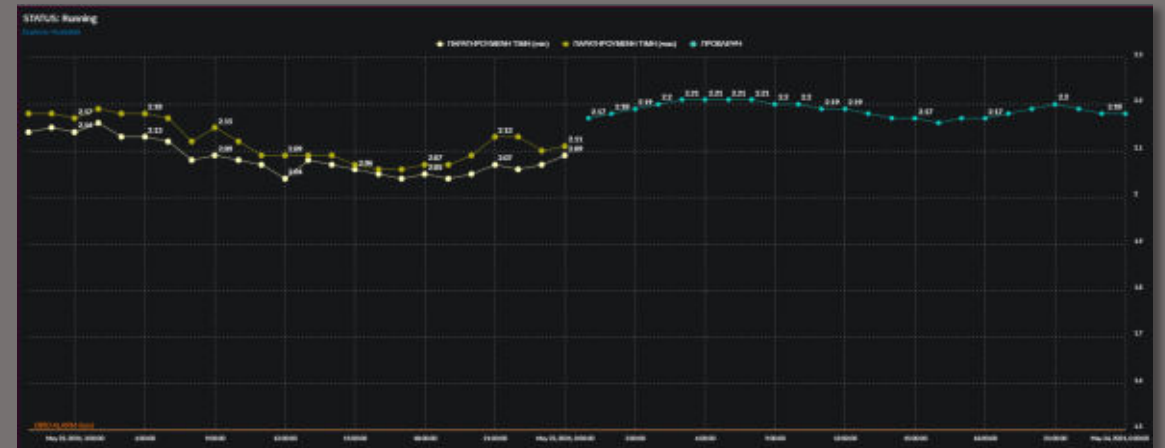
Time Series Forecasting

Define periods of normal operation for each machine

Examine ML algorithms for each tag

Define suitable ML algorithm for each tag

Measure Forecasting Accuracy using MAPE (Mean Absolute Percentage Error)

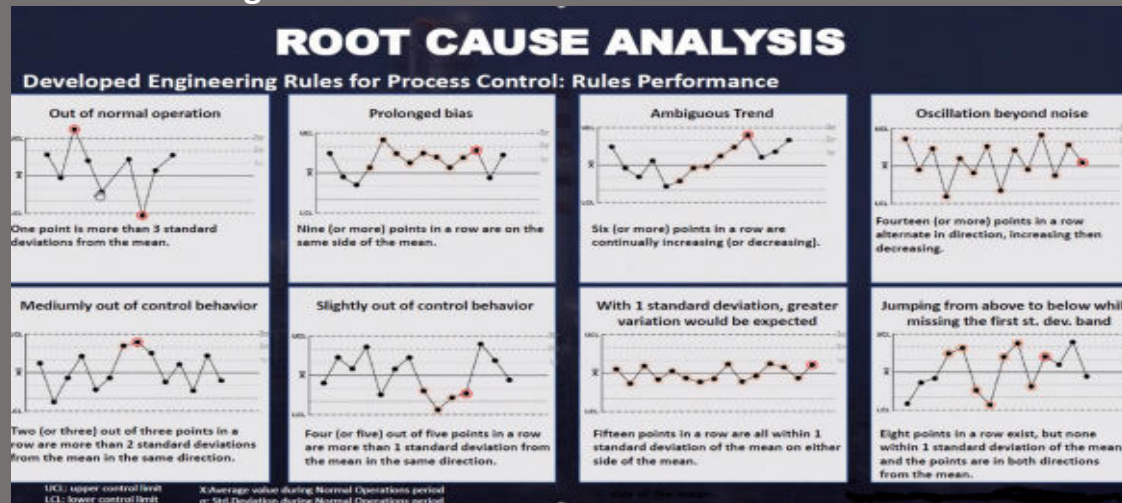


Root Cause Analysis vs Time Series Forecasting



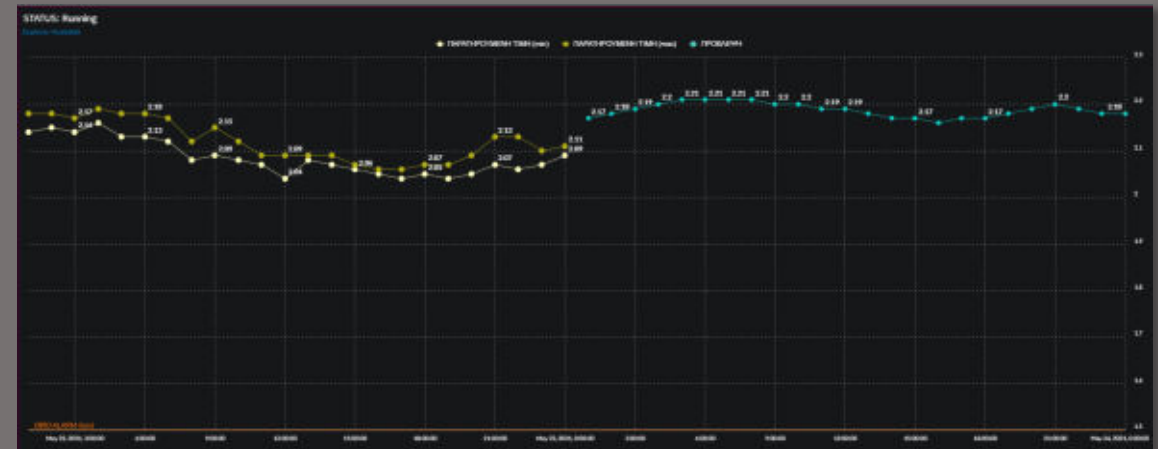
Root Cause Analysis Benefits

- Equipment view as one unit – holistic view
- Equipment Abnormal Events mechanism - decomposition & understanding
- Equipment deep-dive analysis, hidden patterns discovery and gain insights about correlations and coalitions
- Early warning for unexpected behaviors - Abnormal Event indicators
- Earlier Warnings



Time Series Forecasting Benefits

- Tag performance real-time monitoring
- Future Tag performance estimation and Abnormal Events predictions
- Significant Abnormal Events predictability at Equipment Group level
- The Algorithm learns from the system itself (self-educated process)



Data Analytics Outcome

Root Cause Analysis

Events
Explained-
Predicted 

Response
Time 

Time Series Forecasting

Events
Explained-
Predicted 

Expected
MAPE 

K-5701

77%

120 – 20 hours

65%

2-15%

K(T)-3301-B

96%

120 – 20 hours

70%

1-17%

K(T)-2201

100%

120 – 20 hours

65%

3-20%

K(M)-3201

95%

120 – 20 hours

63%

1-18%

K-7502

N/A

N/A

N/A

1-9%

Tool Design & Insights

Landing Page - Dashboard

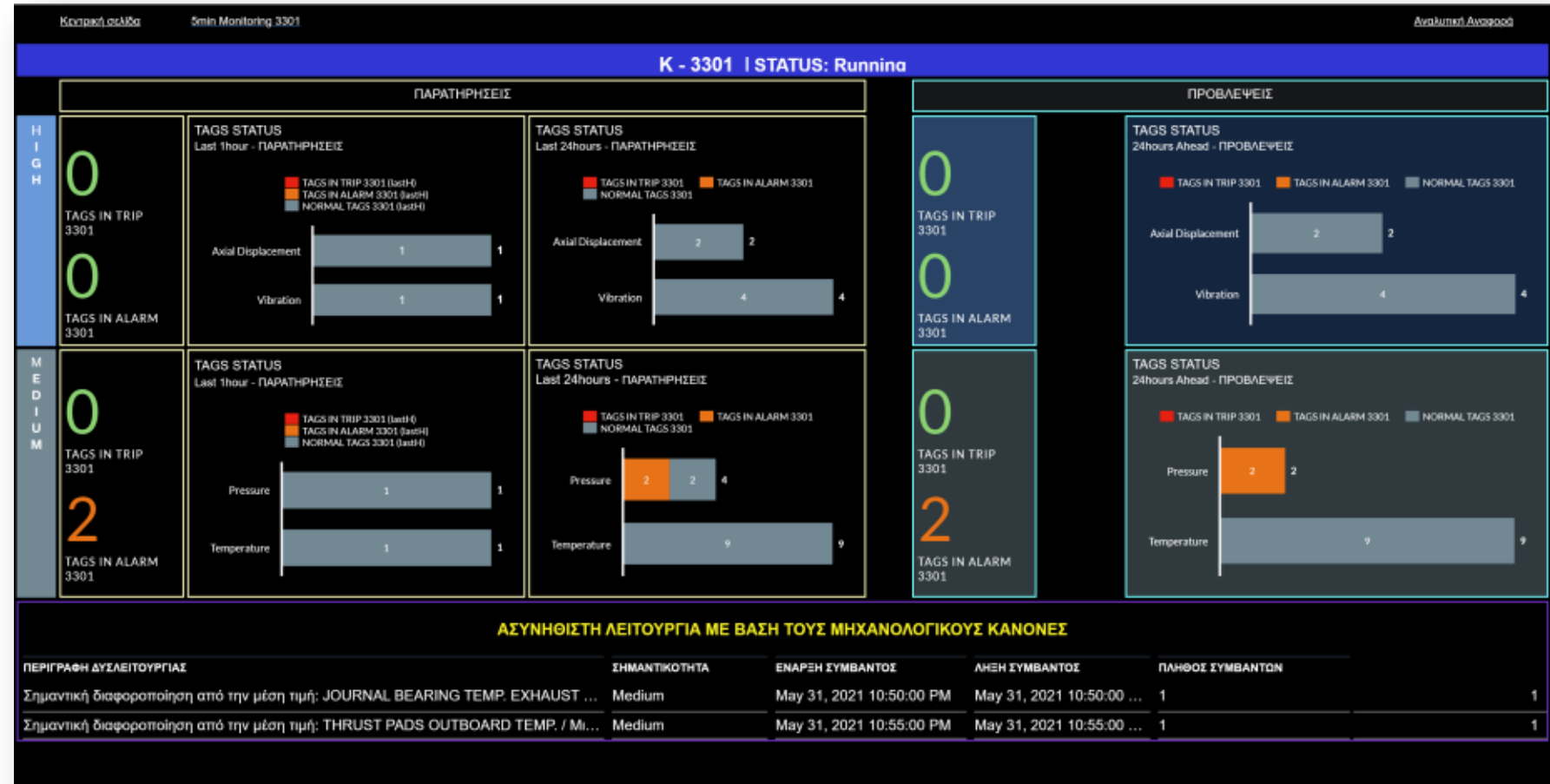
- 360° view
- Last & Next 24 hours
- Operating status
- Normal operations
- Actual & Predicted Trip instances
- Actual & Predicted Alarm instances
- Abnormal behavior
- Hyperlink to details



Tool Design & Insights

Machine Screen

- Group by Sensor Type
- Group by Criticality
- Actual events
- Predictions
- Abnormal behavior



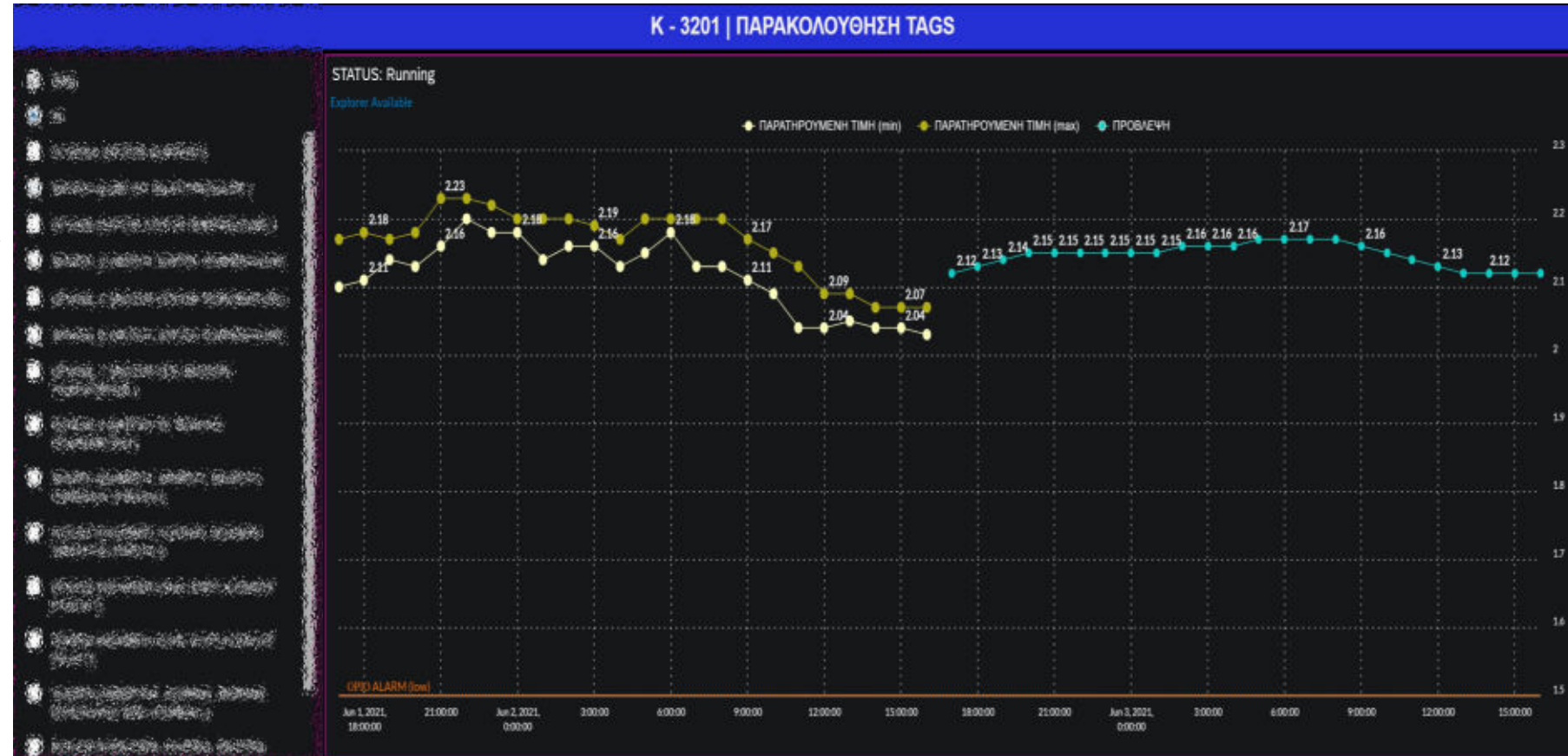
ΑΣΥΝΗΘΙΣΤΗ ΛΕΙΤΟΥΡΓΙΑ ΜΕ ΒΑΣΗ ΤΟΥΣ ΜΗΧΑΝΟΛΟΓΙΚΟΥΣ ΚΑΝΟΝΕΣ

ΠΕΡΙΓΡΑΦΗ ΔΥΣΛΕΙΤΟΥΡΓΙΑΣ	ΣΗΜΑΝΤΙΚΟΤΗΤΑ	ΕΝΑΡΞΗ ΣΥΜΒΑΝΤΟΣ	ΛΗΞΗ ΣΥΜΒΑΝΤΟΣ	ΠΛΗΘΟΣ ΣΥΜΒΑΝΤΩΝ
Σημαντική διαφοροποίηση από την μέση τιμή: JOURNAL BEARING TEMP. EXHAUST ...	Medium	May 31, 2021 10:50:00 PM	May 31, 2021 10:50:00 ...	1
Σημαντική διαφοροποίηση από την μέση τιμή: THRUST PADS OUTBOARD TEMP. / Mi...	Medium	May 31, 2021 10:55:00 PM	May 31, 2021 10:55:00 ...	1

Tool Design & Insights

Sensor trends

- Actual Values (Last 24h)
- Forecasting (Next 24h)
- Alarm, Trip limits
- Combine multiple Sensor Measurements



Tool Design & Insights

Reporting & Email

- Analysis Outcomes
- Actual Abnormal Events
- Email Notifications
- Filtering capabilities

[IMPORTANT][ALERT_NOTIFICATION] NEW ABNORMAL EVENTS

Refinery Predictive Maintenance
To: Michalopoulos Dimitrios

Maintenance (New Technology)
Follow up: Completed on Monday, May 18, 2021
This message was sent with high importance.

Abnormal_Report_Historical.csv 1.6 KB
Forecasting_Report_Historical.csv 12 KB

Translate message to English | New translate from Greek

γεια σου! Παραμένεις.

Α Πρόγραμμα Προβλεπτικής Συντήρησης, έχει καταγραφεί ουσιώδης υπερφόρτωση των Alarm Ορίων.

Αναμένει να βρείτε την καταγραφή των συμβάντων.

Ιαρατηρηθέντα γεγονότα (Actuals)

Machine Group	Πλήθος Tags
K-2201_KT-2201	2
K-5201_A_KM-5201.A	1
K-5701	2

Προβλεπόμενα γεγονότα (Predicted)

Machine Group	Πλήθος Tags
K-2201_KT-2201	3
K-3201_A_KM-3201.A	3
K-5301_B_KT-5301.B	1
K-7502_ST-7501	1

In extensions:

EVENT REPORT & EMAIL NOTIFICATION											
ΠΑΡΑΤΗΡΟΥΜΕΝΑ ΣΥΜΒΑΝΤΑ											
MACHINE_GRP...	EMAIL NOTIFICATION	TAG	ΕΞΟΦΛΙΣΜΟΣ	ΣΗΜΑΝΤΙΚΟΤΗΤΑ	ALARM ΟΡΙΟ (ΠΑΡΑΒΙΑΣΗ)	ΚΟΙΤΙΝΟ ΤΡΙΠ ΟΡΙΟ	ΕΝΑΡΣΗ ΣΥΜΒΑΝΤΟΣ	ΛΗΞΗ ΣΥΜΒΑΝΤΟΣ	ΠΑΡΑΤΗΡΗΣΗ (MIN)	ΠΑΡΑΤΗΡ... (MAX)	ΠΛΗΘΟΣ ΣΥΜΒΑΝΤΩΝ
	2021-05-17 02:45:01.128000000	22P169	High	High	7.8	6.5	2021-05-16 15:40:00	2021-05-17 01:05:00	7.74	7.8	9
	2021-05-16 19:45:00.941000000	22P169	High	High	7.8	6.5	2021-05-16 15:40:00	2021-05-16 18:10:00	7.74	7.8	8
	2021-05-16 09:00.844000000	22P169	High	High	7.8	6.5	2021-05-16 15:40:00	2021-05-16 17:55:00	7.74	7.8	7
	2021-05-16 17:45:01.033000000	22P169	High	High	7.8	6.5	2021-05-16 15:40:00	2021-05-16 16:50:00	7.76	7.8	3
	2021-05-16 16:45:00.892000000	22P169	High	High	7.8	6.5	2021-05-15 16:50:00	2021-05-16 15:40:00	7.79	7.8	2
	2021-05-15 17:45:00.790000000	22P169	High	High	7.8	6.5	2021-05-15 16:50:00	2021-05-15 16:50:00	7.79	7.79	1
	2021-05-13 18:00:00.602000000	22P169	High	High	7.8	6.5	2021-05-12 17:30:00	2021-05-13 15:15:00	7.71	7.8	10
	2021-05-13 16:00:00.852000000	22P169	High	High	7.8	6.5	2021-05-12 15:50:00	2021-05-13 13:50:00	7.71	7.79	6
	2021-05-12 19:00:01.106000000	22P169	High	High	7.8	6.5	2021-05-12 00:40:00	2021-05-12 17:30:00	7.74	7.8	8

ΠΡΟΒΛΕΠΟΜΕΝΑ ΣΥΜΒΑΝΤΑ											
MACH...	EMAIL NOTIFICATION	ΕΞΟΦΛΙΣΜΟΣ	ΣΗΜΑΝΤΙΚΟΤΗΤΑ	ALARM ΟΡΙΟ (ΠΑΡΑΒΙΑΣΗ)	ΠΡΟΒΛΕΨΗ (ΠΑΡΑΒΙΑΣΗ ALARM)	ΕΝΑΡΣΗ ALARM ΣΥΜΒΑΝΤΟΣ	ΠΛΗΘΟΣ ALARM ΣΥΜΒΑΝΤΩΝ	TRIP			
	2021-05-17 13:45:00.782000000	High	High	7.8	7.79	2021-05-18 09:00:00	3	NaN			
	2021-05-17 12:45:00.977000000	High	High	7.8	7.77	2021-05-17 12:00:00	4	NaN			
	2021-05-17 11:45:01.709000000	High	High	7.8	7.51	2021-05-17 11:00:00	4	NaN			
	2021-05-17 10:45:01.044000000	High	High	7.8	7.46	2021-05-17 10:00:00	4	NaN			
	2021-05-17 09:45:00.830000000	High	High	7.8	7.75	2021-05-17 09:00:00	4	NaN			
	2021-05-17 08:45:00.753000000	High	High	7.8	7.76	2021-05-17 09:00:00	4	NaN			
	2021-05-17 07:45:00.835000000	High	High	7.8	7.76	2021-05-17 09:00:00	4	NaN			



Results & Benefits for Motor Oil Hellas

PdM Project Principles



**System Decomposition
& Understanding**



**Continuous Health
Monitoring**



**System Performance
Prediction**



**Findings & Alerts
Communication**



Cost Savings



- Early Abnormal event notification allows planned and short-duration Machine Shutdowns reducing maintenance costs and downtime
- Machine part maintenance rather than part replacement reduces maintenance costs

Safety



- Severe events prevention
- Effectively address identified risks

Effective Planning



Real-time Machine Health monitoring and timely Abnormal Events predictions drive well-planned actions with the most appropriate and qualified personnel

Valuable Insights and Domain Knowledge



Unobserved correlations and interactions reveal Abnormal Events mechanisms

Next Steps



New Scope Definition

Increase number of equipments

Increase number and type of sensors that we monitor

Combine data from multiple process related equipments

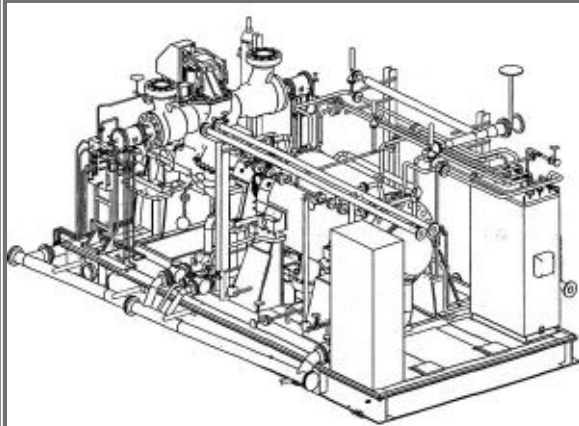
Combine data from quality factors related to the process (e.g. crude oil composition)



New Mechanisms

Deviation from normal level of correlation

Root cause analysis that can be re trained based on new incidents



QA

