

“Acciona’s Condition Monitoring Platform for Predictive Maintenance”

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Alberto Casas (Optimization) and Aaron Villegas (TIC)

1	ACCIONA Energía	2	3	4
		Life Extension Projects	Big Data Platform for Condition Monitoring	Business Case



ACCIONA Energía

WHO WE ARE

ACCIONA ENERGÍA:



A GLOBAL OPERATOR IN RENEWABLE ENERGIES
with a unique profile in the sector

THE BIGGEST COMPANY IN CLEAN ENERGIES
not related to conventional utilities

Oriented towards demonstrating the **TECHNICAL AND ECONOMIC VIABILITY** of a sustainable energy system for the world based on renewables

REFERENCE 100% RENEWABLE COMPANY
as a developer, partner or vendor of services worldwide

Experience in the entire value chain

Project
Development

Engineering &
Construction

Wind Turbine
manufacturing

O&M

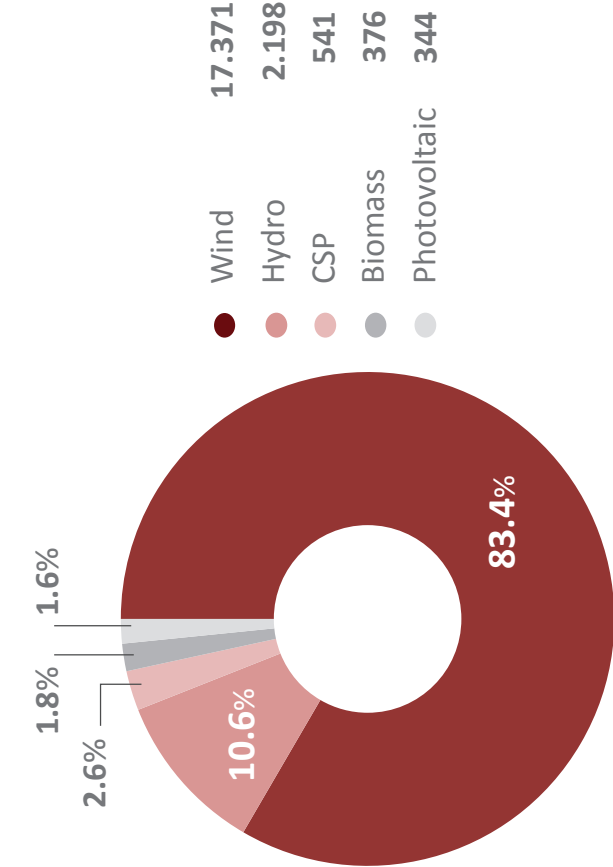
Energy Management
and Trading

100% RENEWABLES

CLEAN ENERGY EQUIVALENT TO THE CONSUMPTION OF 6 MILLION HOMES

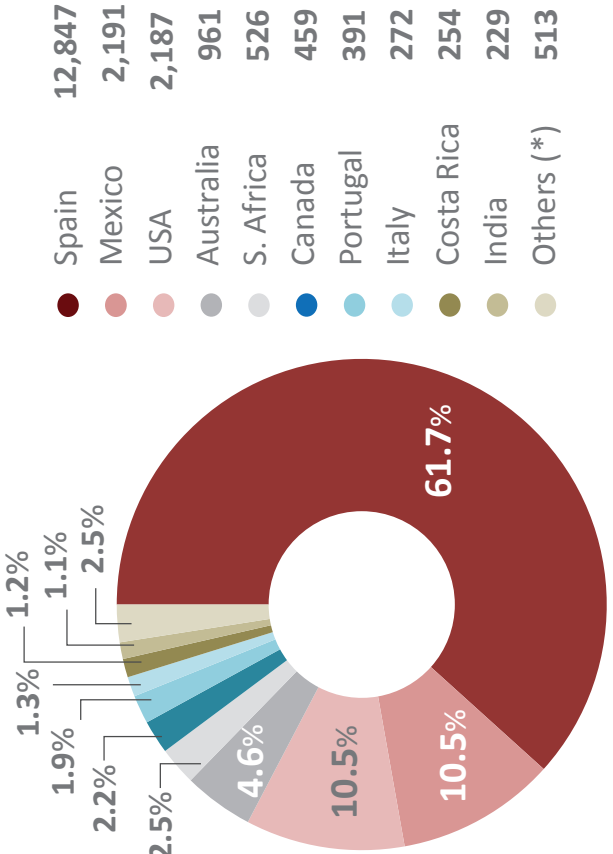
GENERATION BY TECHNOLOGY 2016

(percentage and total - GWh)



GENERATION BY COUNTRY 2016

(percentage and total - GWh)



TOTAL: 20,830 GWh

*Others: Poland, Croatia, Chile, Greece and Hungary

INNOVATIVE

CECOER: THE BIGGEST RENEWABLES CONTROL CENTER IN THE WORLD



13,568 MW MANAGED

for AE and customers in 18 countries

21 TWh+ RENEWABLES PRODUCTION

managed by the control center

8,000+ MULTI-TECHNOLOGY WIND TURBINES

and more than 100 facilities in other technologies

97% AVAILABILITY RATE

24/365 surveillance

EXCELLENCE IN OPERATION AND GRID INTEGRATION

with the highest quality and safety



LIFE EXTENSION PROJECTS

- Diagnosis (Health)
- Prognosis (Prediction)
- Prescription (Recommendations)

Smart
Maintenance

Life Extension,
Overhauls,
Upgrades

Turbines for Life
Program

Tecnology: Big Data, Machine Learning & Artificial Intelligence

Short – Medium Term

Technology: Physical predictive models (Materials Science) and hybrid models

Long Term

Partners

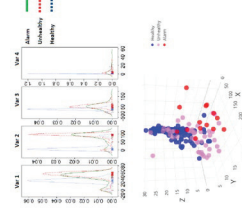
Main Shaft



plain concepts



SMART:VE.



Gearbox

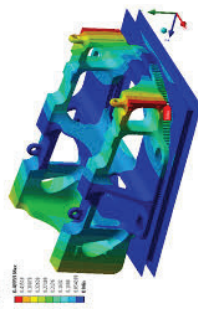
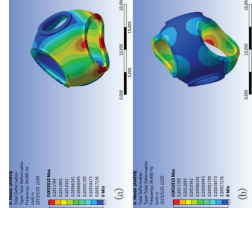


plain concepts

Damage Class 3
Major Defect
(Re-inspect in 6-12 months)



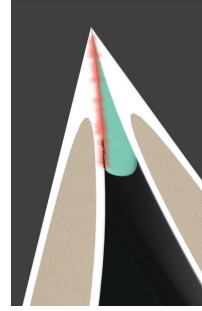
Frames / Foundry



Blades

Bladerna

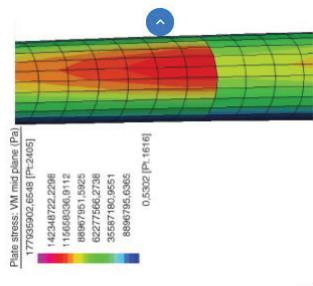
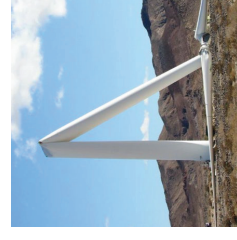
BLADE ENABLER



Tower



UNIVERSIDADE DA CORUÑA



LAST AWARDS

Wind • CONFERENCE & EXHIBITION EUROPE 2019 2-4 APRIL BILBAO

ACCIONA HAS BEEN RECENTLY AWARDED IN THE WIND EUROPE CONFERENCE, WITHIN THE POSTER CATEGORY IN O&M:

“Turbine’s Advanded Life Extension by means of Artificial Intelligence”

PO.096

Turbine’s Advanced Life Extension by means of Artificial Intelligence

Juan I. Cárdenas, Mattia Beretta, Jordi Cusido (Smartive)
Gunther Auer, Enrique Harte (Acciona)



Abstract

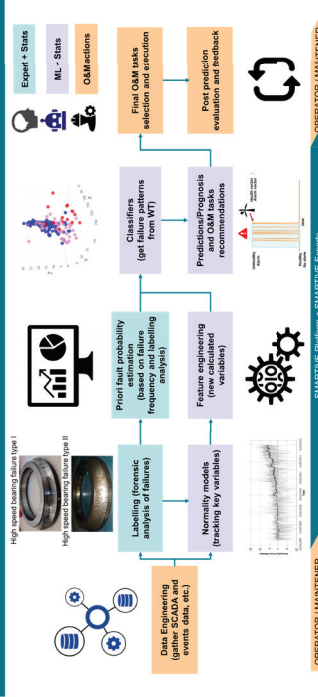
ACCIONA has a very ambitious program “Turbines for life” whose objective is to improve operations applying procedures coming from the aeronautical sector to achieve the goal of keeping the turbines spinning for their entire life cycle.

SMARTIVE is a company specialized into failure predictions by means of algorithms and data analysis. We support ACCIONA in their ambition. We work with algorithms to predict failures. The past two years we have worked in different projects building prediction modules obtaining outstanding results. Together with ACCIONA we have tested the system in 100 wind turbines.

Objectives

- Demonstrate that expert knowledge together with powerful machine learning and AI algorithms produce the best results for failure prediction using SCAOA data.
- Evaluate the hypothesis that fault signatures present in historical data are useful to detect current faults and anticipate future failures.
- Show that taking care of the health of SCAOA data as well as forensic analysis of historical data are essential steps to build AI algorithms and Big-data strategies to get value from data.

Methods



Results

- Test setup:**
- Training Data: 2014 to 2015
 - Test data: 2016
 - 3 Wind farms and technologies
 - 100 WTs (50 G47 + 16 AW3000 + 34 AW1500)
 - Daily predictions with 30 days of anticipation
- Results:** 10 out of 13 detected events (77%)
- GRGX failure: 5 out of 6 (83%)
 - Generator failure: 5 out of 7 (71%)



Conclusions

The obtained results were achieved thanks to the collaboration of people from two different backgrounds: operation and maintenance and computer scientist. The fusion of expert knowledge, data analysis and machine learning tools to extract the most information from different and complementary sources of data has been the best strategy to implement a predictive maintenance system in ACCIONA's wind farms.

References

- M. Schilling and J. K. S. "Comparative analysis of neural networks and regression-based models for wind turbine failure prediction." *Wind Energy*, vol. 15, no. 1, pp. 1-15, 2012.
- C. A. J. A. "A new approach for wind turbine condition monitoring based on SCAOA data." *Proc. 2017 IEEE Big Data Control Conf. (Big Data Control)*, vol. 1, pp. 285-292, 2017.
- J. C. "A new approach for wind turbine condition monitoring based on SCAOA data." *Proc. 2017 IEEE Big Data Control Conf. (Big Data Control)*, vol. 1, pp. 285-292, 2017.
- A. B. "A new approach for wind turbine condition monitoring based on SCAOA data." *Proc. 2017 IEEE Big Data Control Conf. (Big Data Control)*, vol. 1, pp. 285-292, 2017.

MEET US AT (IB53)





ACCIONA'S BIGDATA AND IA PLATFORM FOR CONDITION MONITORING BASED ON DATA ANALYTICS

WHY CMS BASED ON DATA ANALYTICS?

CMS: CONDITION MONITORING SYSTEMS FOR O&M OPTIMIZATION



As operator our scope is to

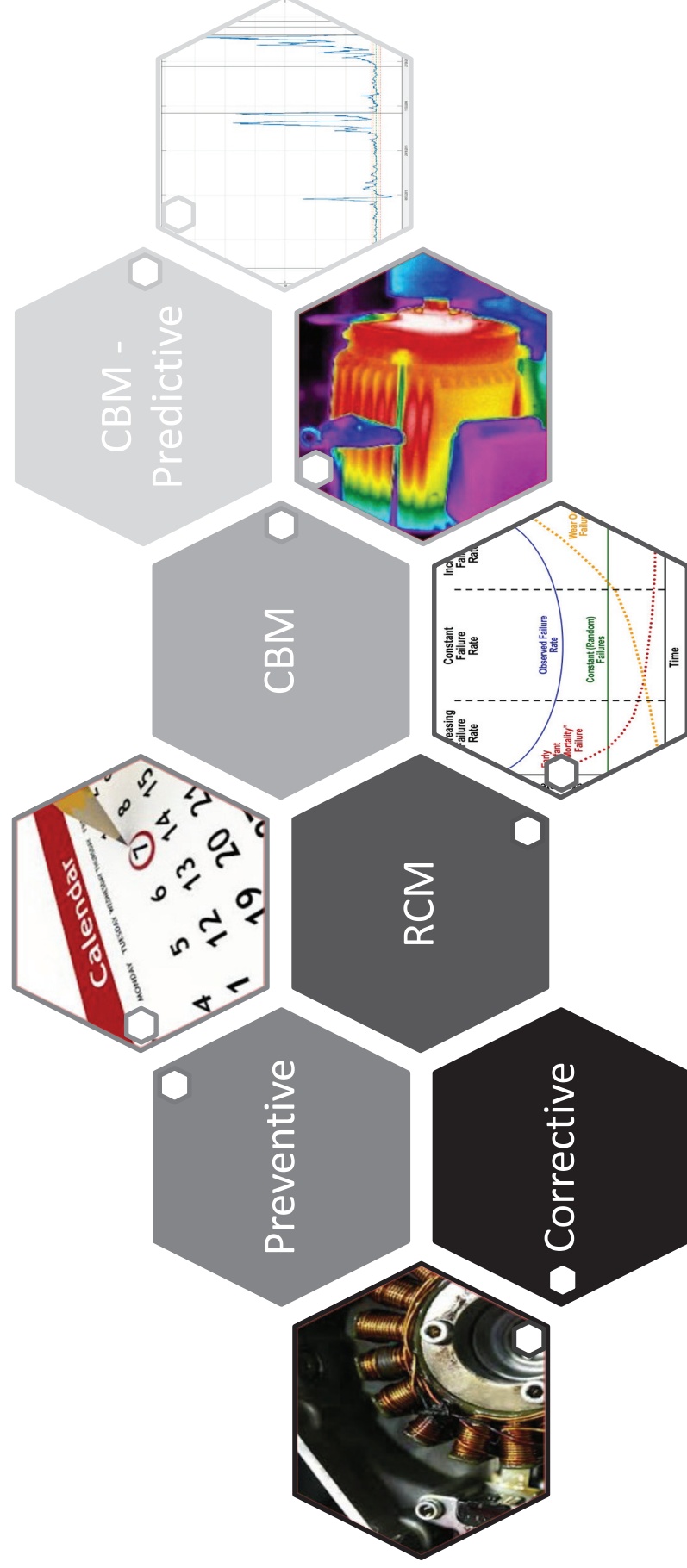
“Maximize the **Profitability** and the **Asset Life**”

More Production + Less Costs & Maximize Life Extension

(↑ Availability & ↑ Efficiency) + (↓ Impact & ↑ Maintainability) & ↑ Life Extension

DATA ANALYTICS IN MAINTENANCE

CMS: CONDITION MONITORING SYSTEMS FOR O&M OPTIMIZATION

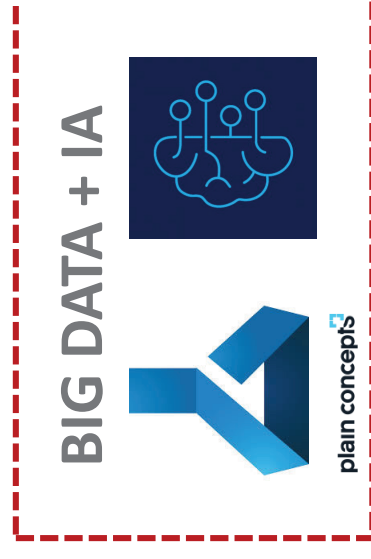


“Do it – Do it Now – Do it Simple”

ARCHITECTURE DESCRIPTION

Benefits of this architecture:

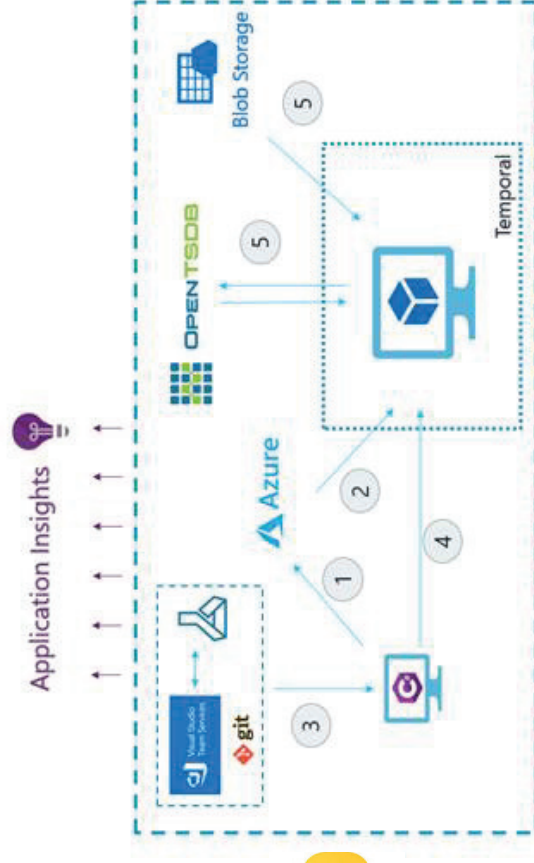
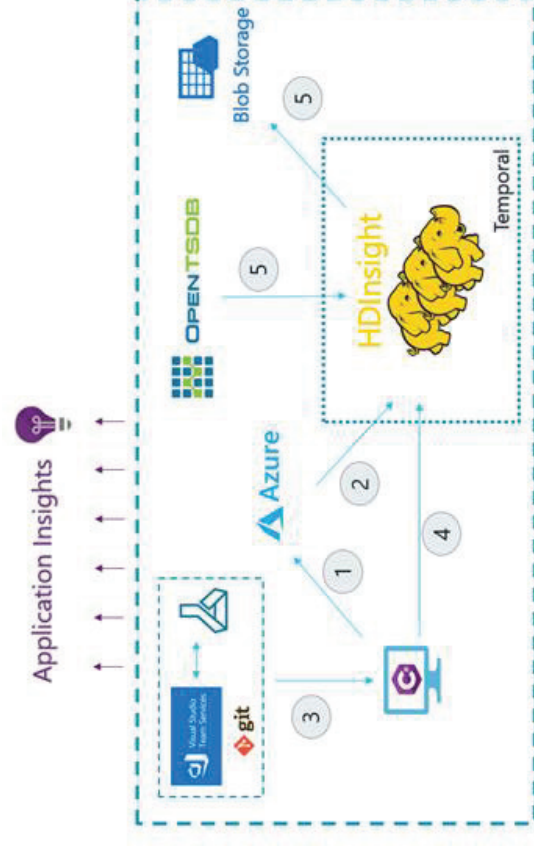
1. Reduction of Training time
2. Infrastructure cost reduction
3. Daily Condition estimation

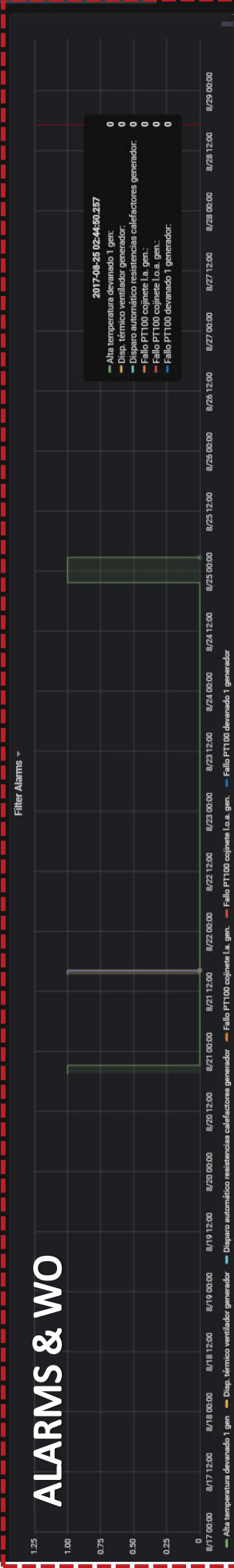
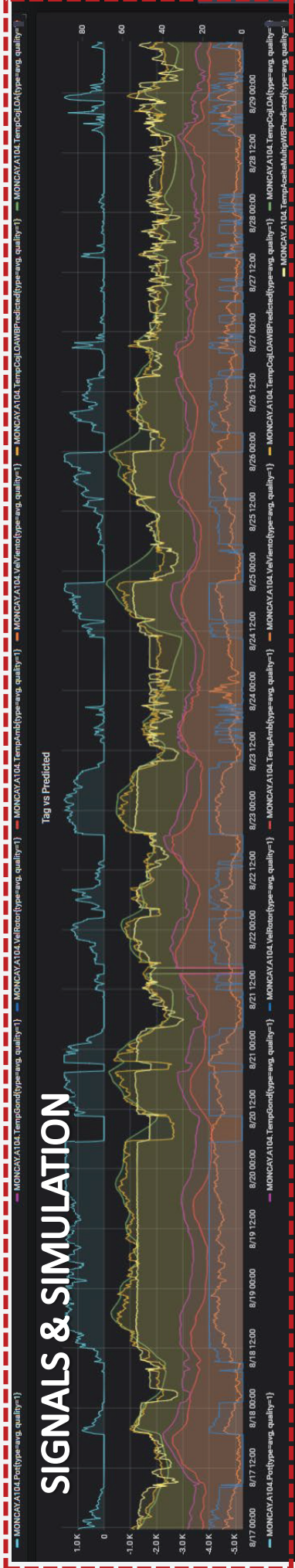


TRAINING

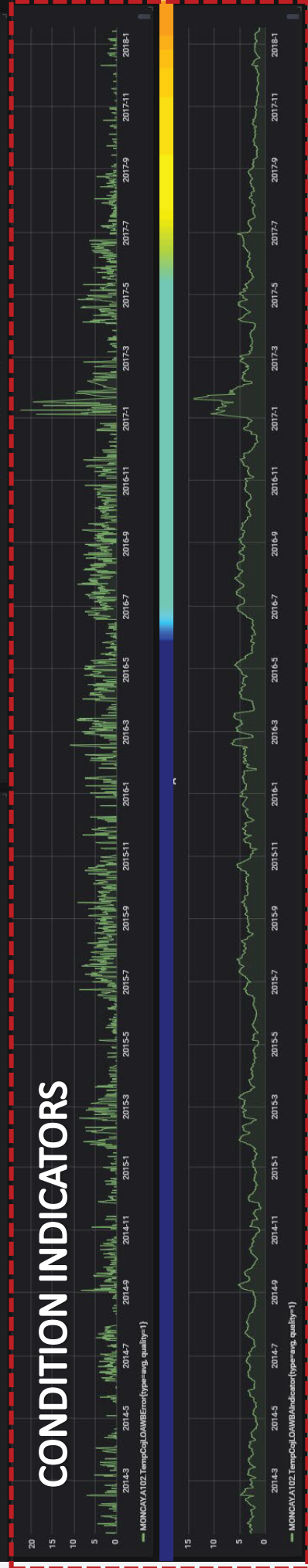
AND

PREDICTION



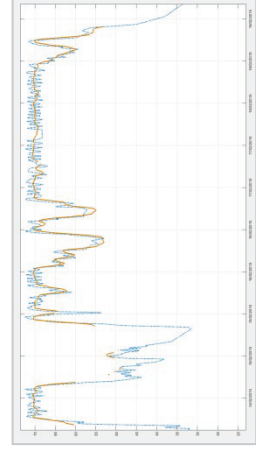


Panel Title				Panel Title			
RawName	StartAlarmTime	EndAlarmTime	Description	Code	Duration	MaintenanceFlag	
A.1.4	2017-08-25T00:44:50.257Z	2017-08-29T00:10:15.383Z	Info: Initializing Run State	5.56 K	5.25 Mil	0	
A.1.4	2017-08-28T22:42:44.667Z	2017-08-28T22:42:44.667Z	Info: Idle State	5.56 K	93.69 K	0	
A.1.4	2017-08-28T22:41:10.877Z	2017-08-28T22:41:10.877Z	Info: Controlled Stop State	5.56 K	100.00	0	
A.1.4	2017-08-28T22:32:51.067Z	2017-08-28T22:41:10.877Z	Info: Untwisting State	5.56 K	499.81 K	0	
A.1.4	2017-08-28T22:32:30.173Z	2017-08-28T22:32:51.067Z	Info: Curtailment State	5.56 K	20.90 K	0	
A.1.4	2017-08-28T22:32:30.067Z	2017-08-28T22:41:10.777Z	Máquina funcionando en estela	786.00	520.71 K	0	
A.1.4	2017-08-28T22:29:24.417Z	2017-08-28T22:32:30.173Z	Info: Initializing Run State	5.56 K	185.76 K	0	



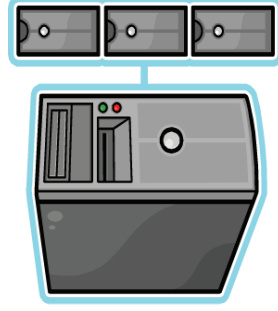
METHODOLOGY DESCRIPTION

STEP I: NORMAL BEHAVIOR MODELS



Operational
Data

Step I: Normal
Behavior Model



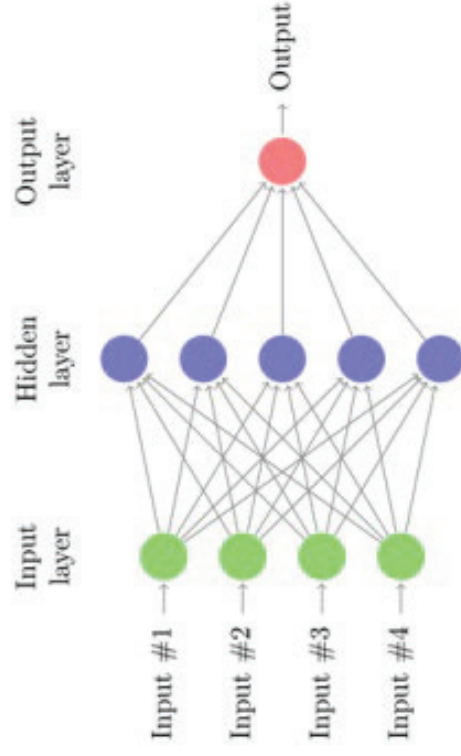
Data Base
(CECOER + GEMAO)

METHODOLOGY DESCRIPTION

STEP 1: NORMAL BEHAVIOR MODELS WITH NEURAL NETS (NN)

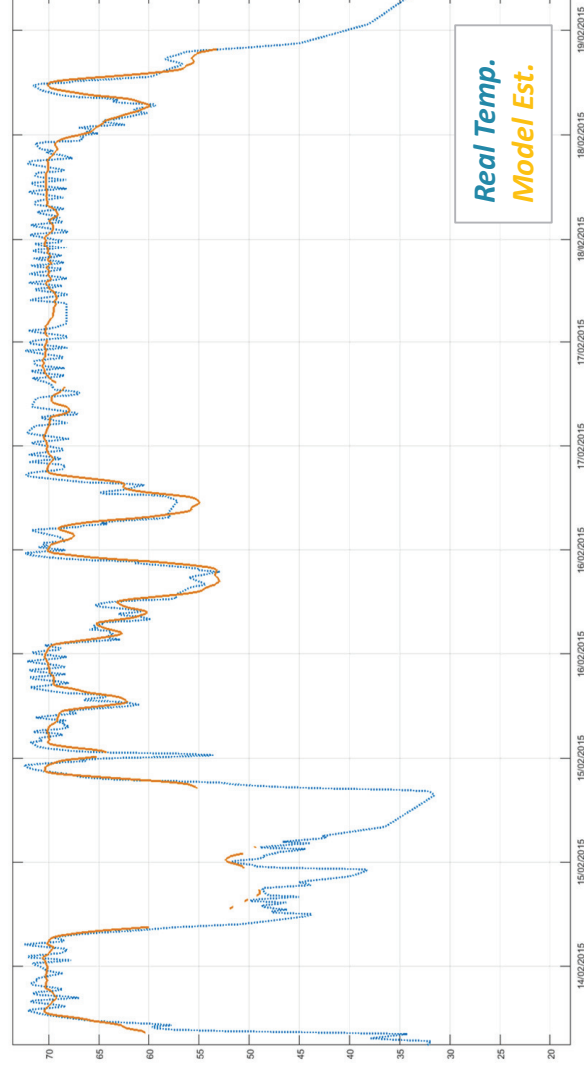
Gearbox high Speed Bearing Temperature

Model Vs Real



Inputs:

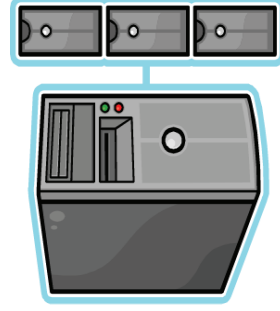
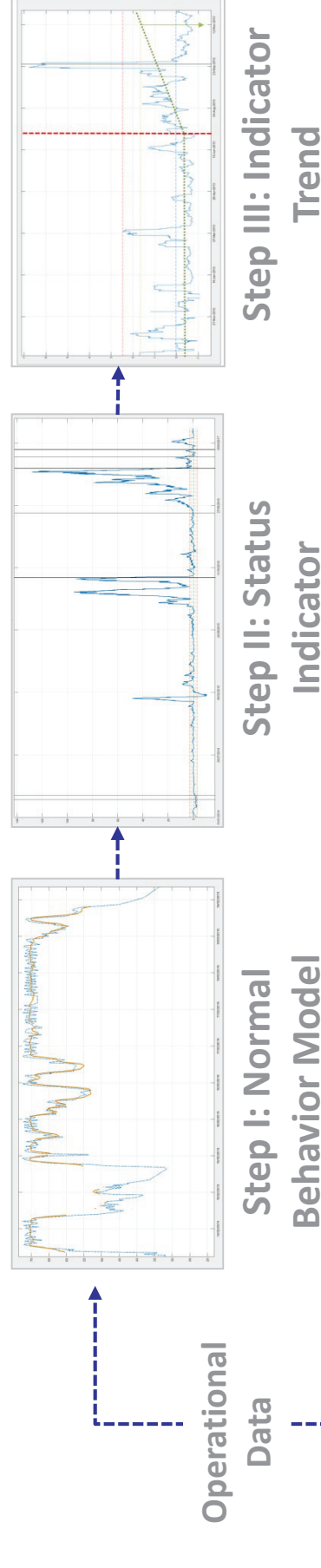
- Wind Speed (m/s)
- Environmental Temperature (°C)
- Power (kW)
- Main Shaft revolutions (r.p.m.)



Output : Gearbox High Speed bearing Temperature(°C)

METHODOLOGY DESCRIPTION

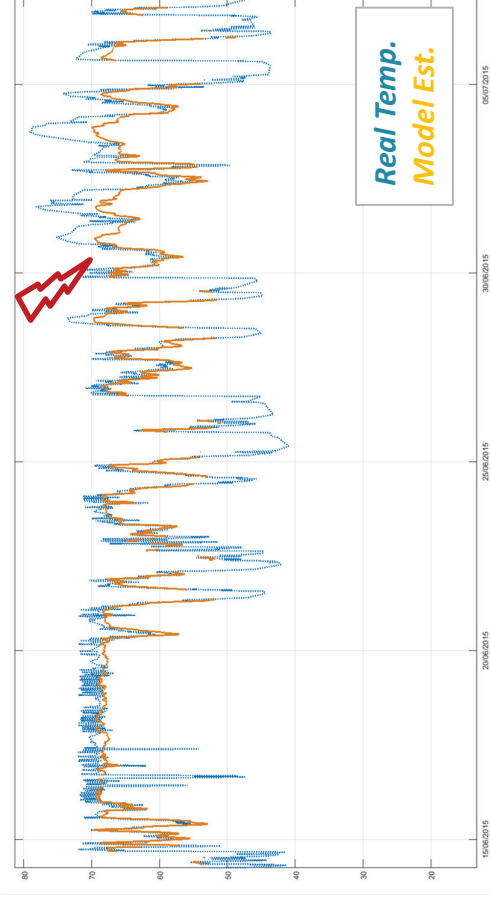
STEP II & III: STATUS INDICATOR AND INDICATOR TREND



Data Base
(CECOER + GEMAO)

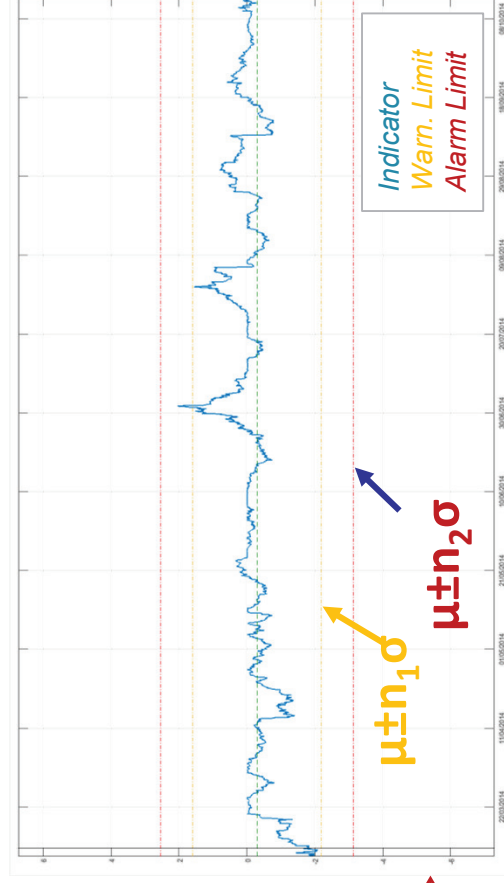
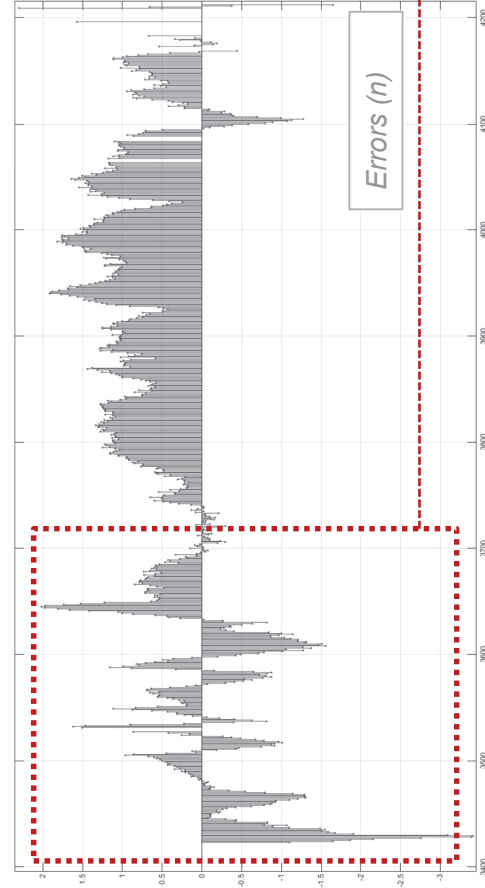
METHODOLOGY DESCRIPTION

STEP II & III: STATUS INDICATOR AND INDICATOR TREND (INDICATOR CONCEPT)



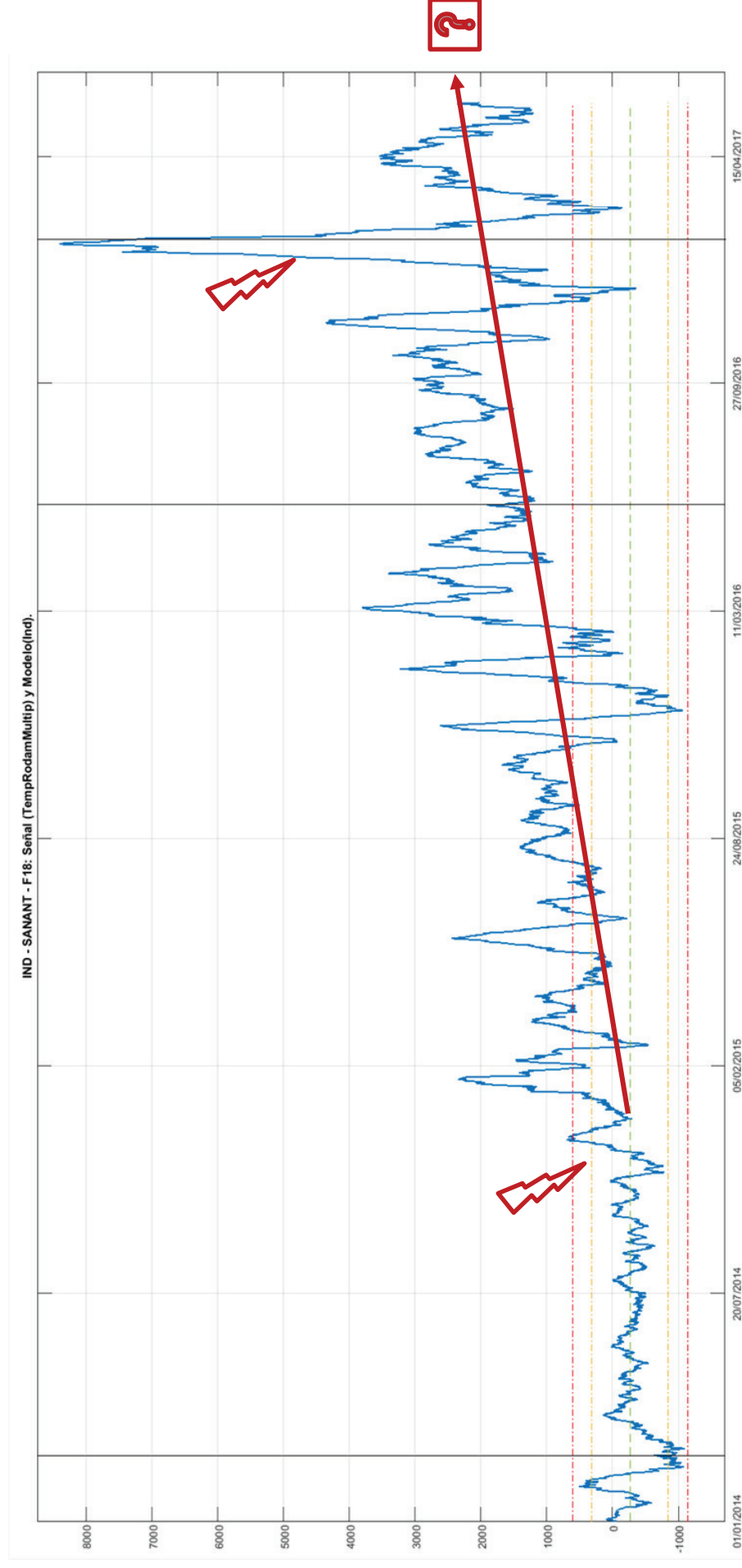
The moving mean error
along time

$$Ind = \frac{\sum_{n=t-T}^t Error(n)}{T}$$



METHODOLOGY DESCRIPTION

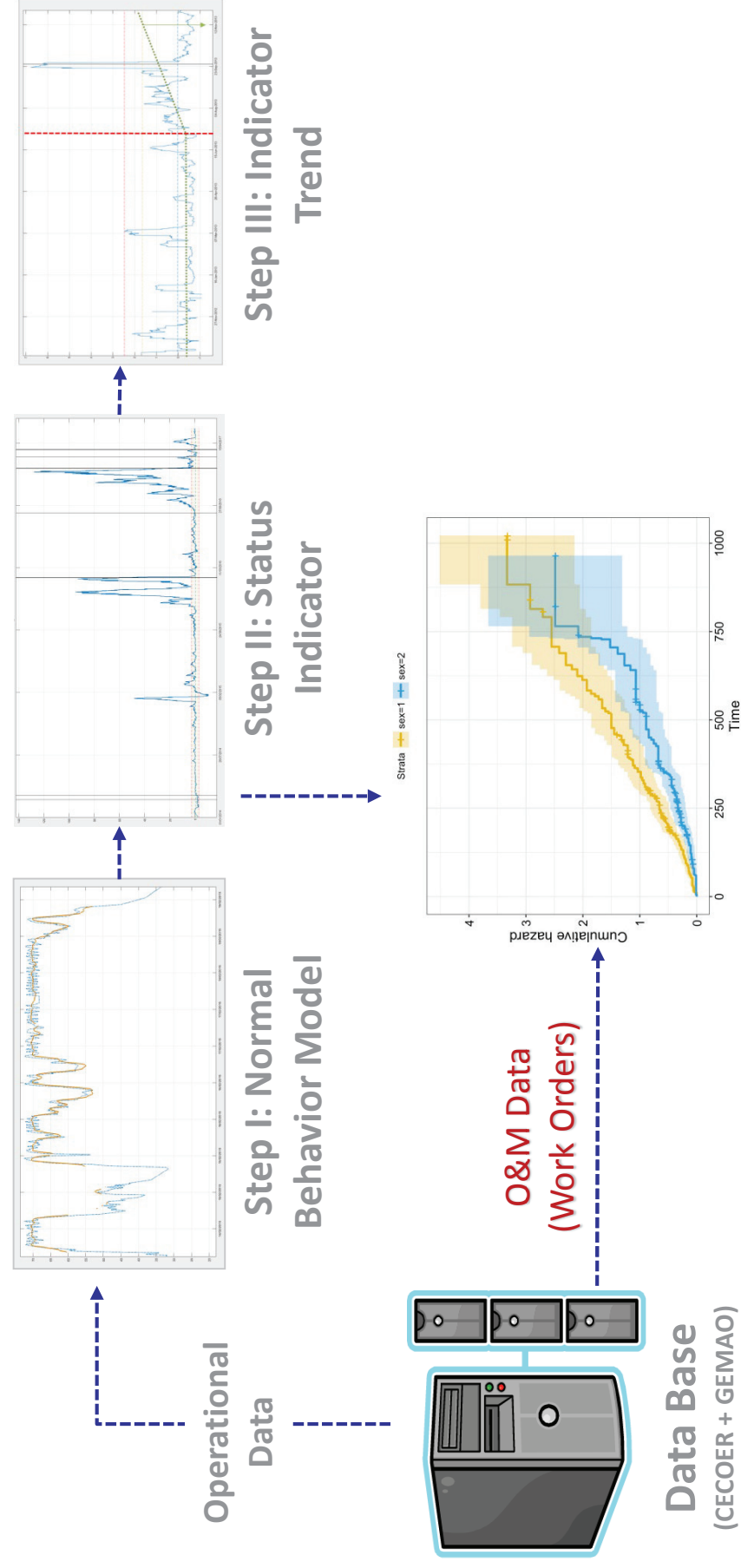
STEP II & III: STATUS INDICATOR AND INDICATOR TREND (SIMPLE INDICATOR)



When the gearbox failure will come?

METHODOLOGY DESCRIPTION

STEP IV: SURVIVAL ANALYSIS



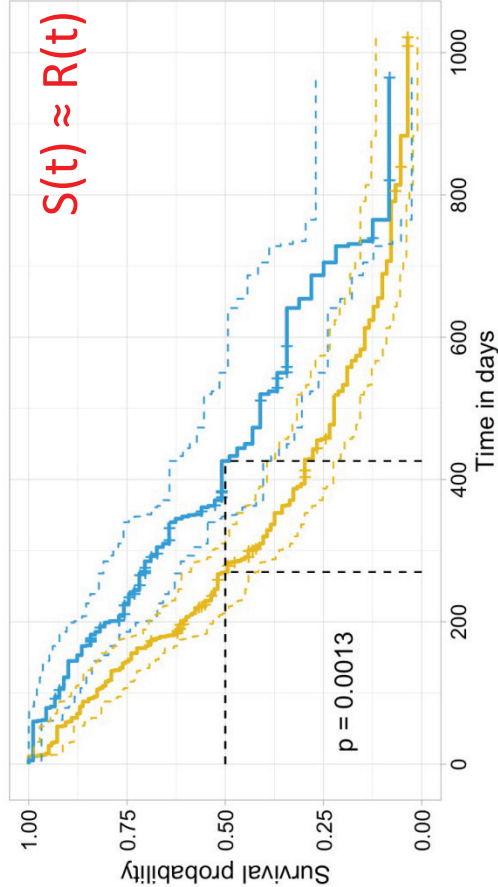
METHODOLOGY DESCPTION

STEP IV: SURVIVAL ANALYSIS (FROM MEDICAL TO INDUSTRIAL FIELD)

From: Medicine

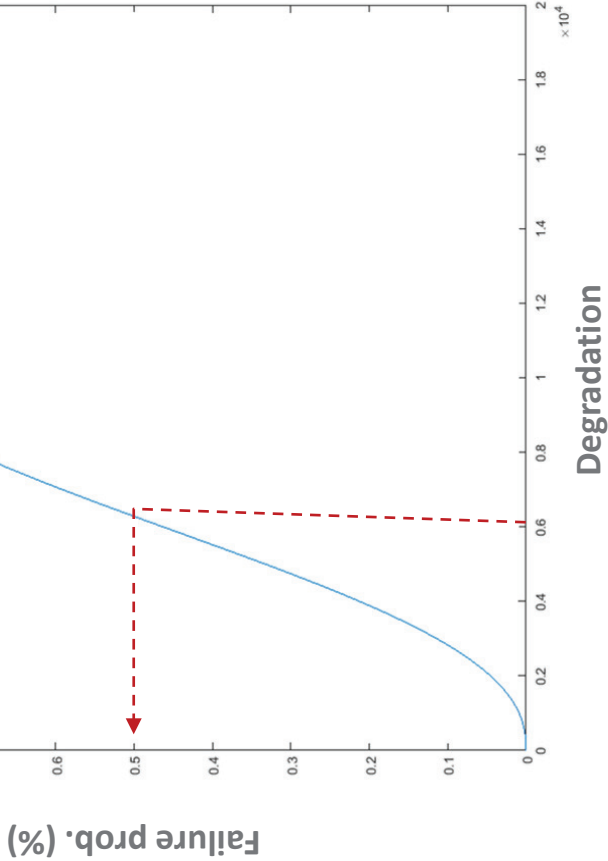
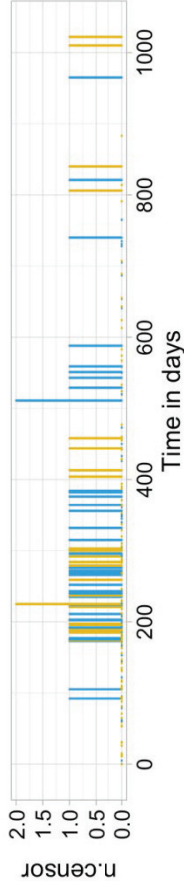
to

Industry



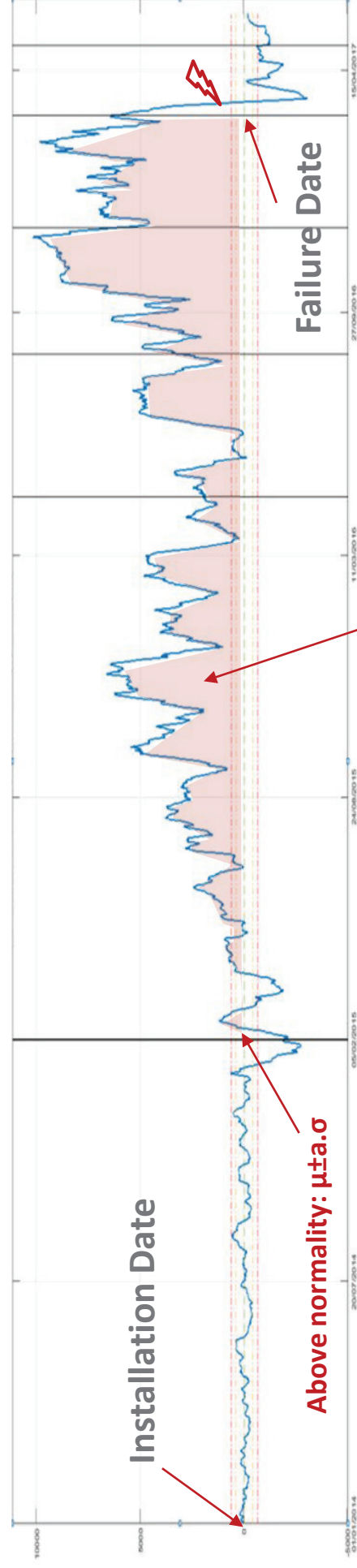
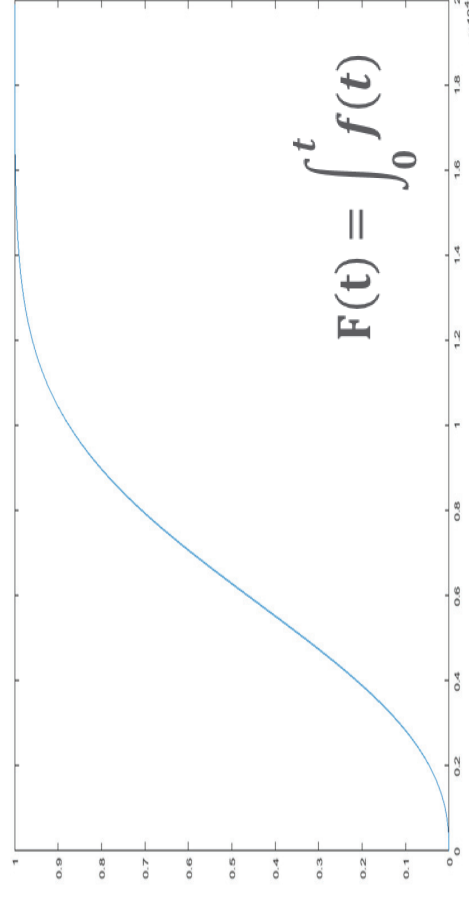
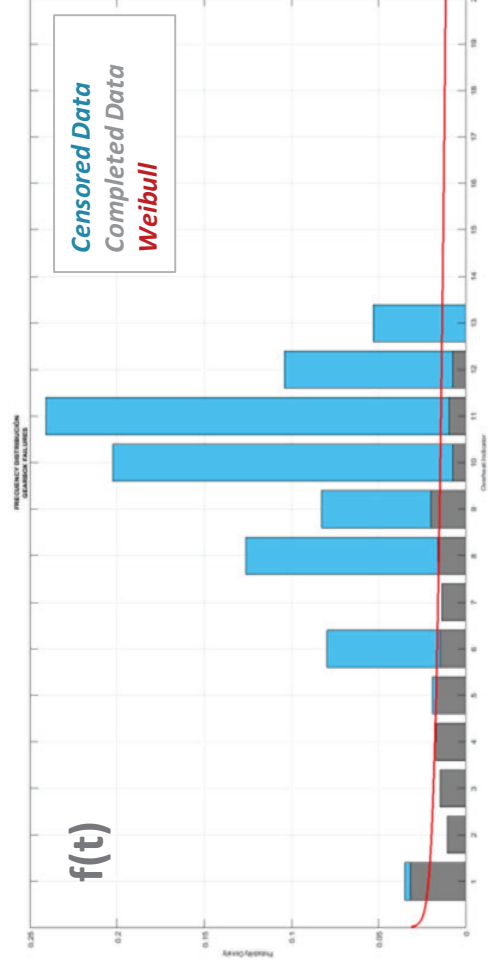
Number at risk by time: n (%)

Strata	38 (100)	78 (57)	31 (22)	13 (9)	6 (4)	2 (1)
Male	30 (100)	66 (73)	26 (29)	11 (12)	2 (2)	0 (0)
Female						



METHODOLOGY DESCRIPTION

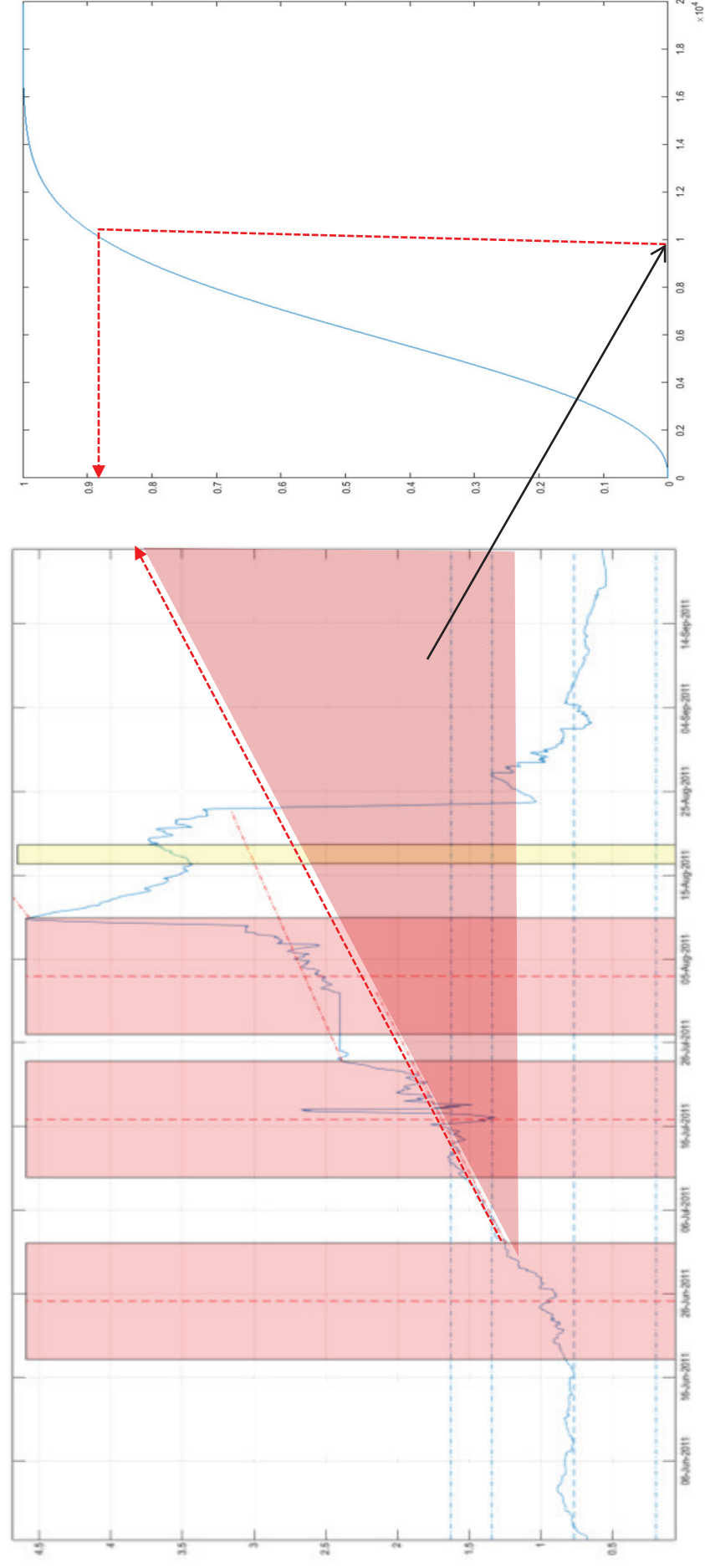
STEP IV: SURVIVAL ANALYSIS (FROM MEDICAL TO INDUSTRIAL FIELD)



$$failure_{n-completed} = \sum_{Installation\ Date}^{Failure\ Date} Ind > \mu + a.\sigma$$

METHODOLOGY DESCRIPTION

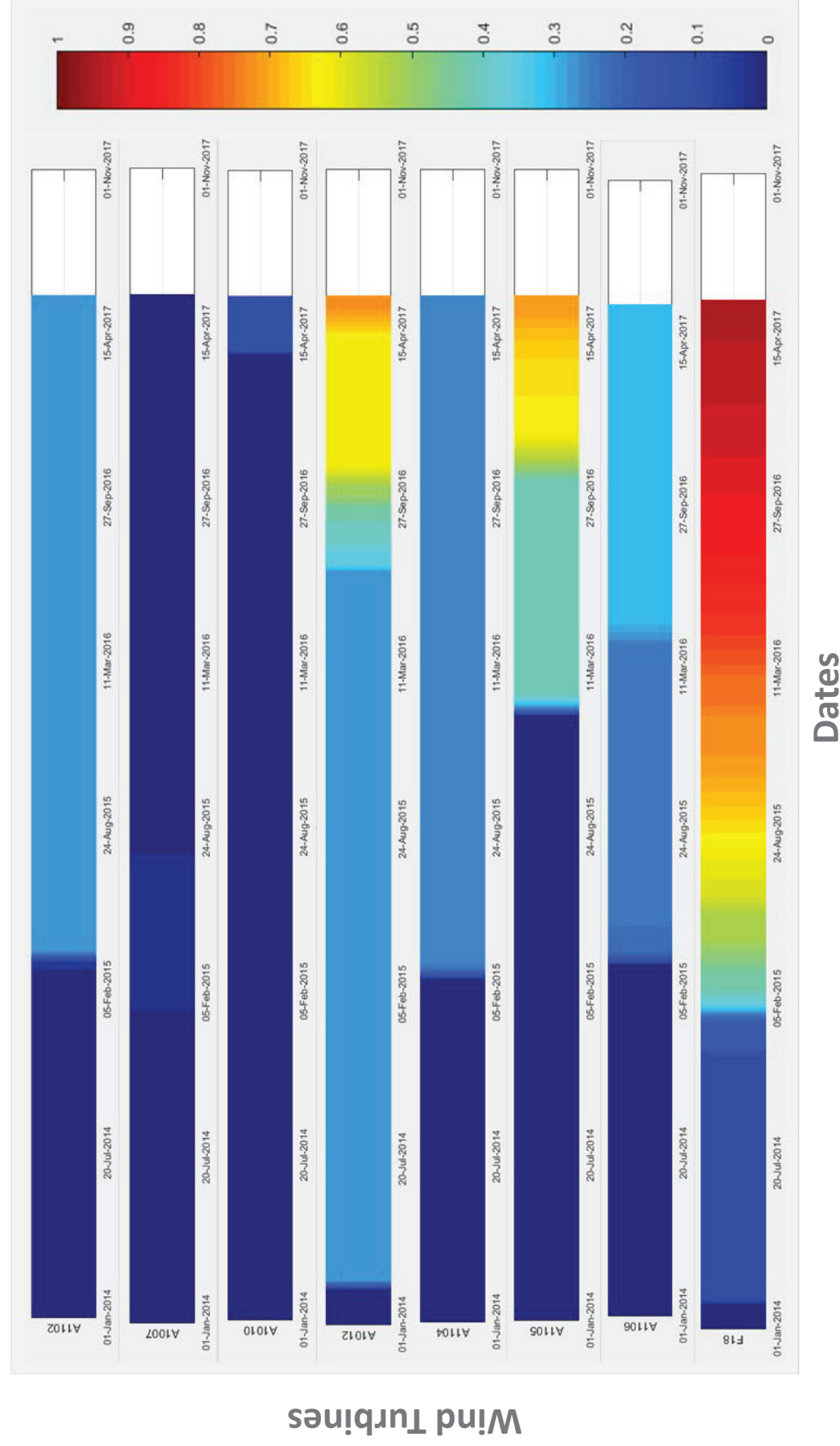
STEP III and IV: REMAINING LIFE (CHANGE POINT TECHNIQUE)*



Estimated failure Date (with 90% probability of failure)

METHODOLOGY DESCRIPTION

STEP V: FAILURE PROBABILITY AND REMAINING LIFE (SCORECARD)

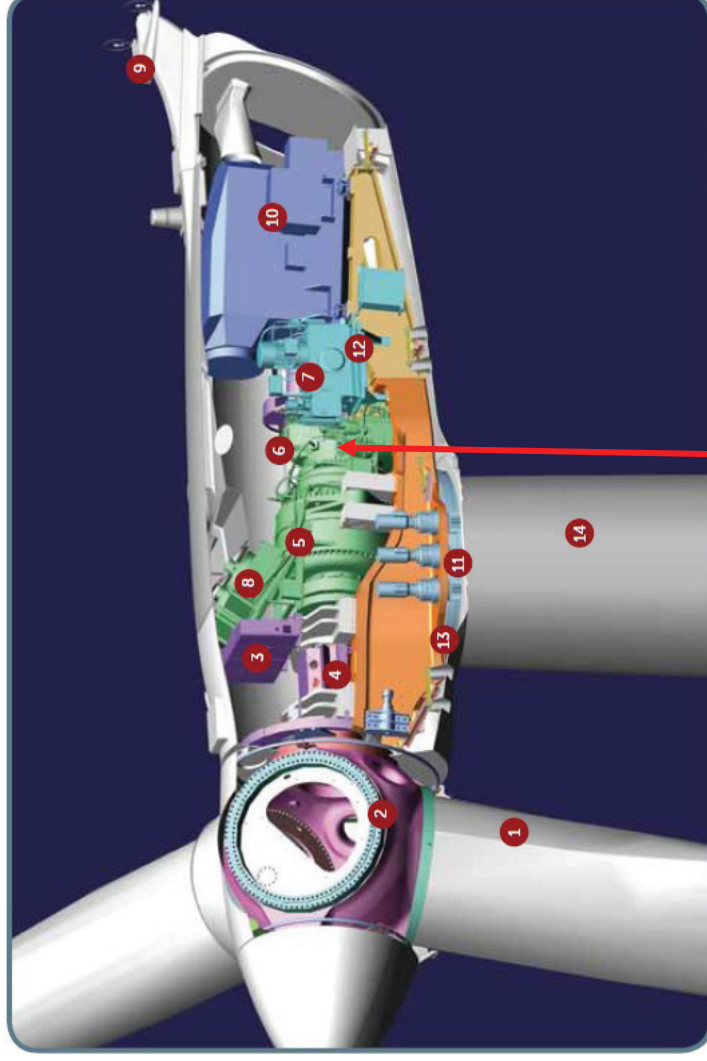




BUSSINES CASE

PILOT INTRODUCTION

CMS FOR GEARBOX FAILURE PROBABILITY AND REMAINING LIFE ESTIMATION



Gearbox condition monitoring using the
High Speed Bearing Temp.

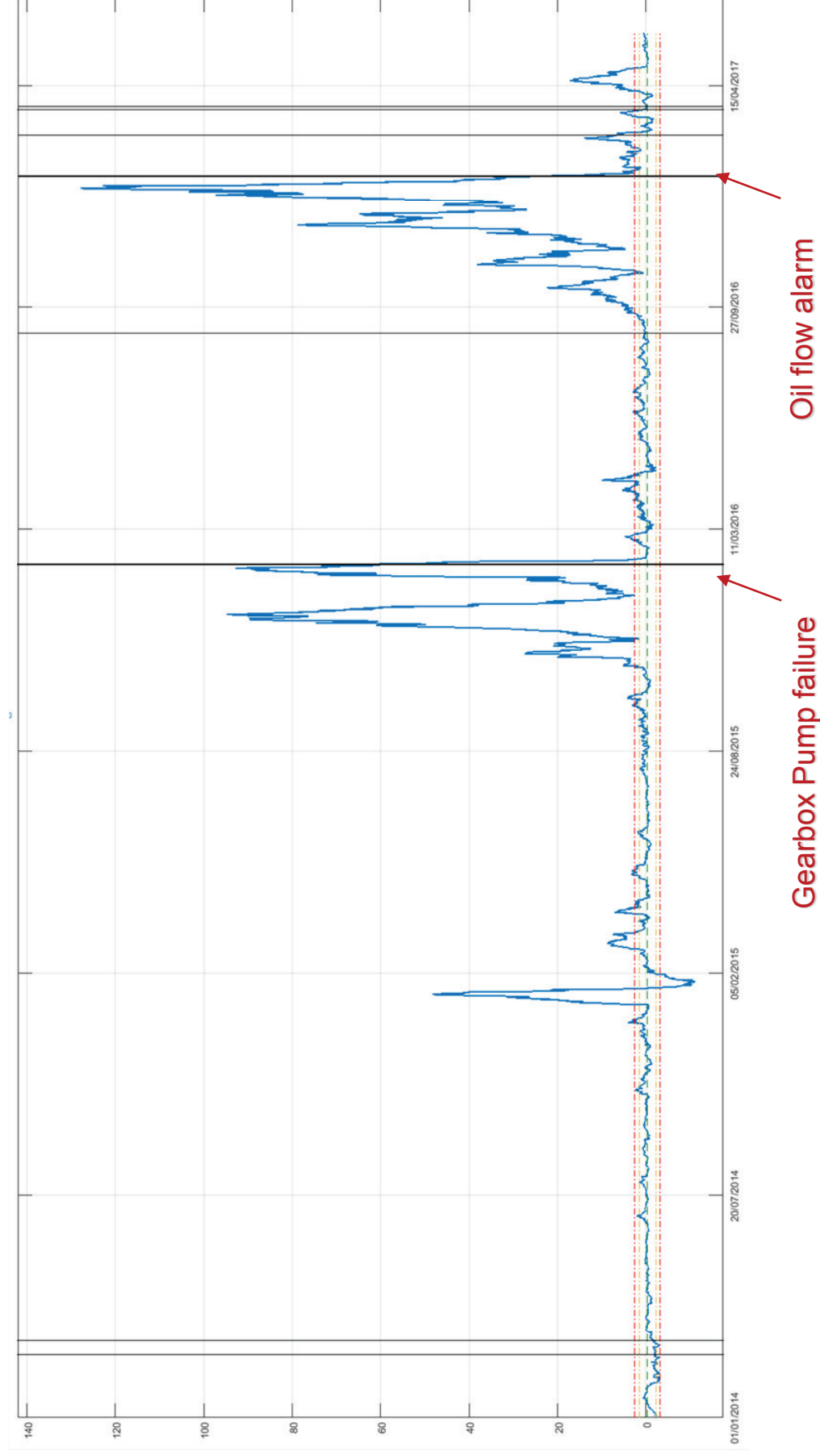
Back Testing validation:

- 1.- Short term failures detection using the AF indicator before Gearbox WO's.
- 2.- Long term failures and RUL using the estimation of failure probability ($F(t)$) before Gearbox replacements*.

* The failed gearboxes considered in this study presented the same failure mode: broken teeth in gears

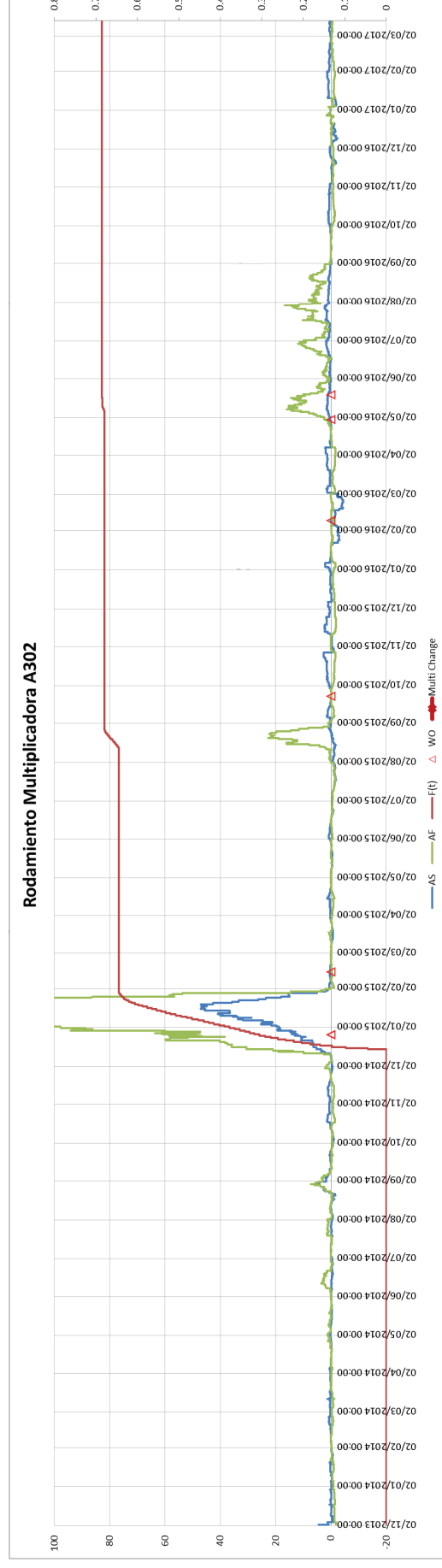
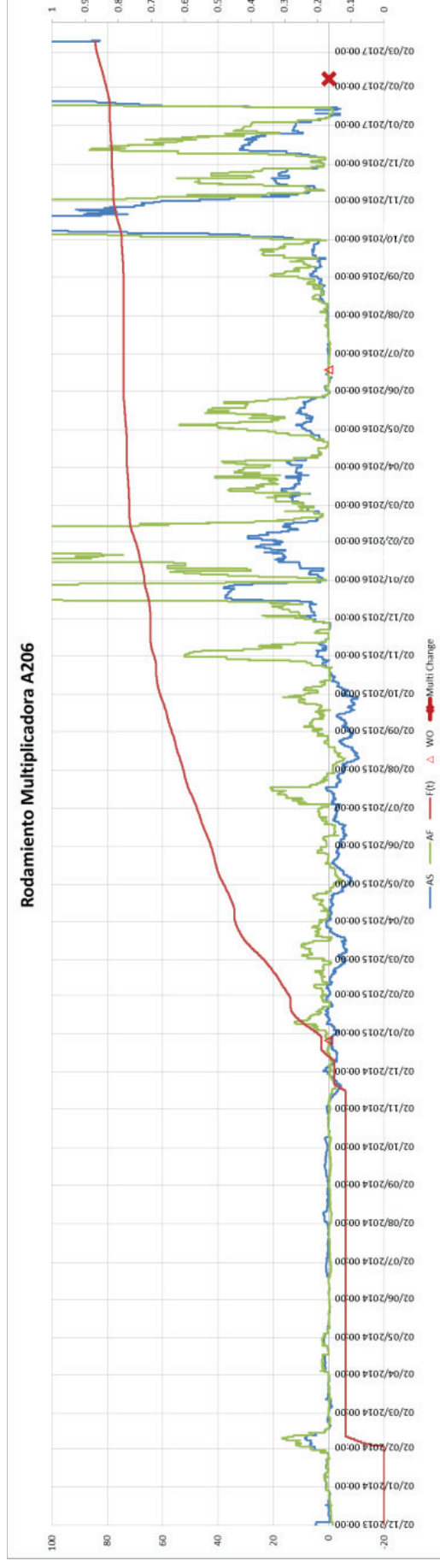
METHODOLOGY CONCLUSIONS

SHORT TERM FAILURES DETECTION USING THE AF INDICATOR BEFORE GEARBOX WO'S.



METHODOLOGY CONCLUSIONS

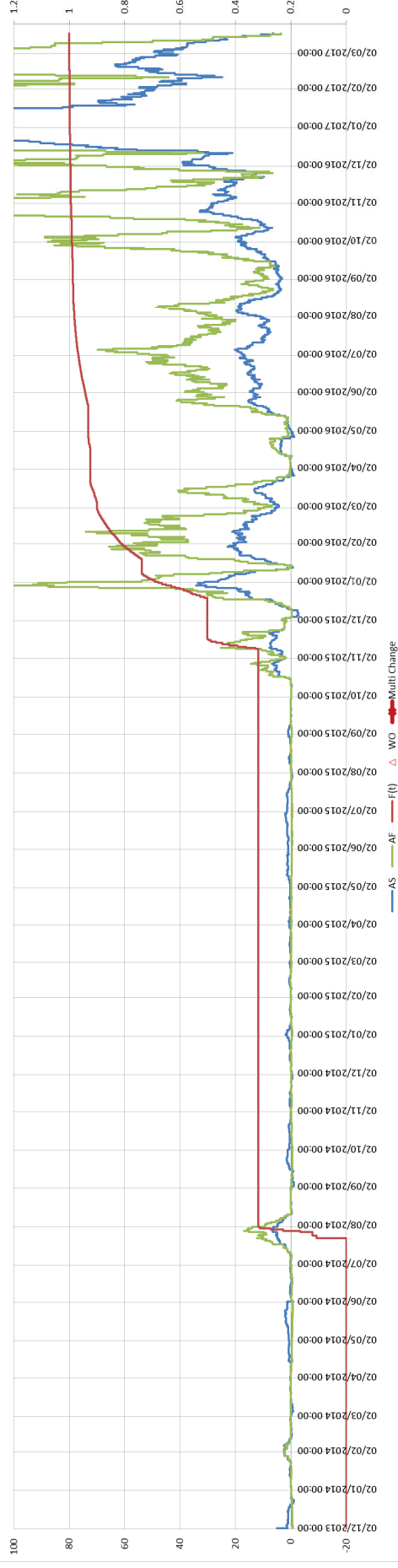
LONG TERM FAILURES AND RUL USING THE ESTIMATION OF FAILURE PROBABILITY ($F(T)$) BEFORE GEARBOX REPLACEMENTS



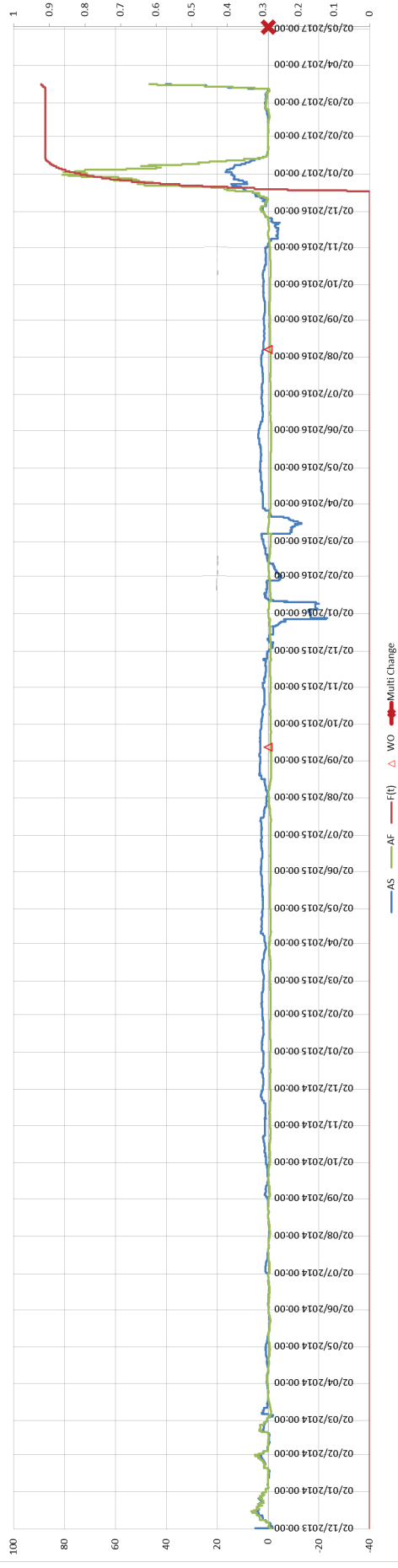
METHODOLOGY CONCLUSIONS

MAIN CONCLUSIONS OBTAINED FROM METHODOLOGY IMPLEMENTATION

Aceite Multiplicadora A305

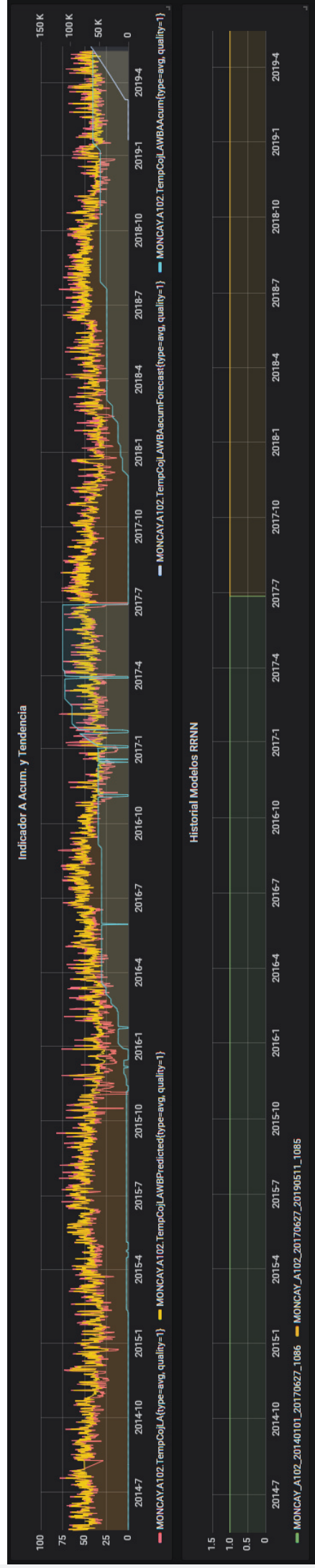
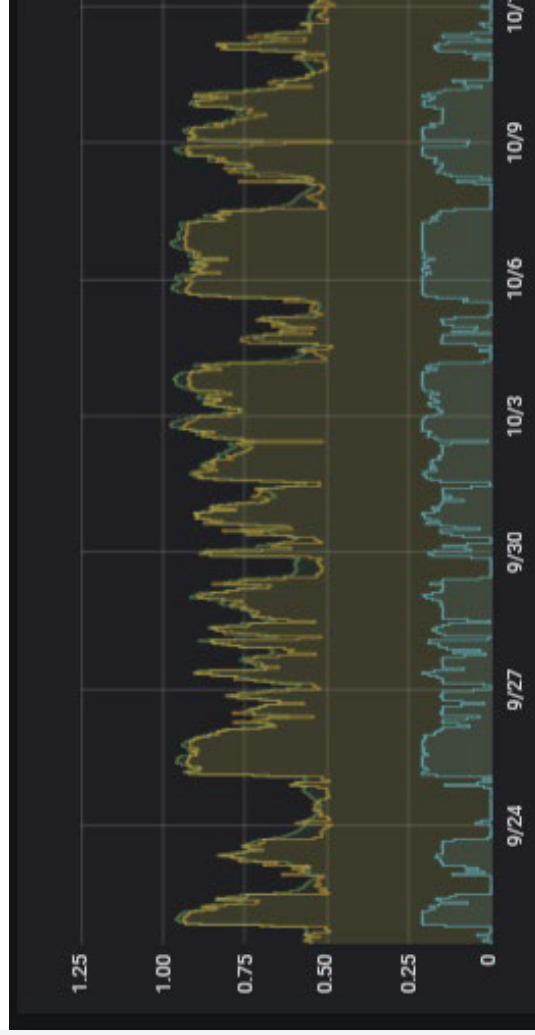


Aceite Multiplicadora A402

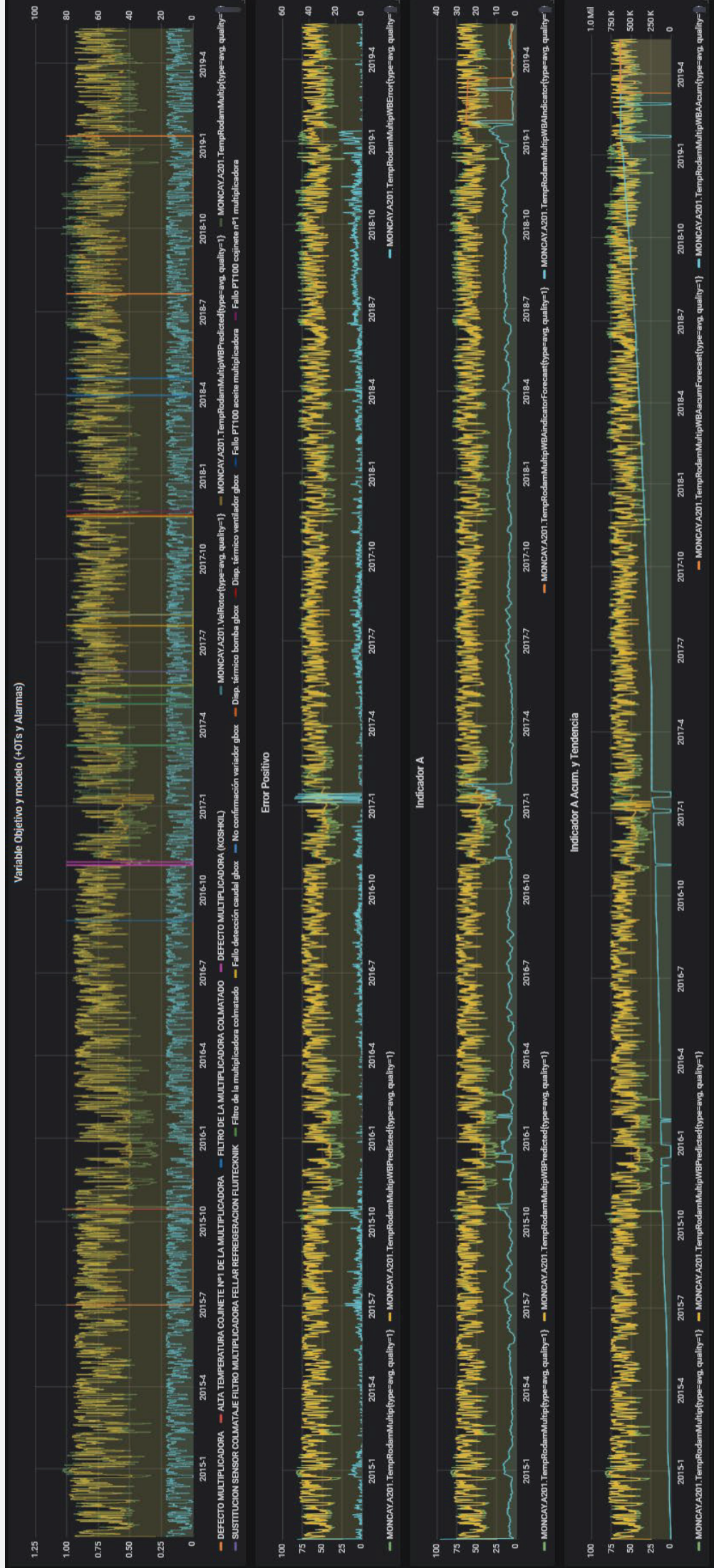


METHODOLOGY CONCLUSIONS

SOME EXAMPLES INTO THE PLATFORM



METHODOLOGY CONCLUSIONS



PILOT RESULTS

CONFUSION MATRIX: FAILURE PROBABILITY AND REMAINING LIFE (SCORECARD)

Case Study:

- **Fictitious Wind Farm** with 56 Wind Turbines, with a total of 23 Degraded Gearboxes**.
- F(t) fitted with 21 completed data.
- Failure F(t) above 80%



NOTE: Negative: The equipment do no present malfunction
Positive: The equipment present malfunction

79% of successful evaluations*

* http://www.fisterra.com/mbe/investiga/pruebas_diagnostics/pruebas_diagnostics.asp#sensibilidad

** The failed gearboxes considered in this study presented the same failure mode: broken teeth in gears



CONCLUSIONS

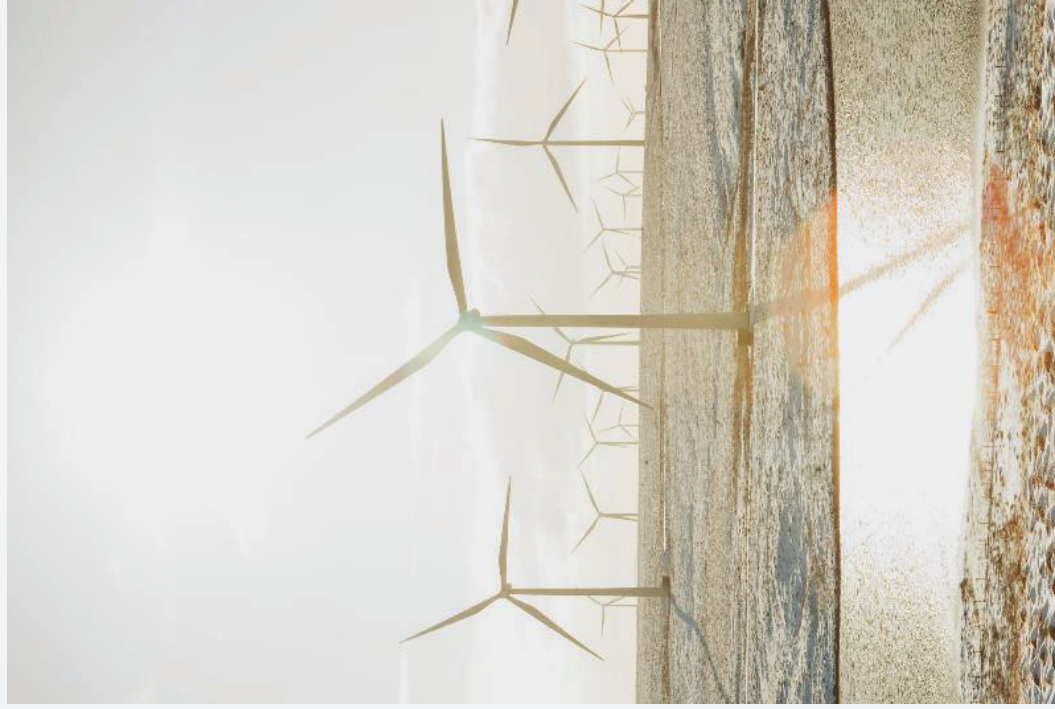
METHODOLOGY CONCLUSIONS

MAIN CONCLUSIONS OBTAINED FROM METHODOLOGY IMPLEMENTATION

- The methodology has shown good performance ratios (79%).
- Wind Brain Platform allows:
 - **Detect** mal functions.
 - **Evaluate** the effectiveness of the WO.
 - Identify the origin of mal functions (**root cause analysis**).
- With Data Analytics we are **improving** our O&M processes and therefore **reduce** Cost of Energy.

NEXT STEPS

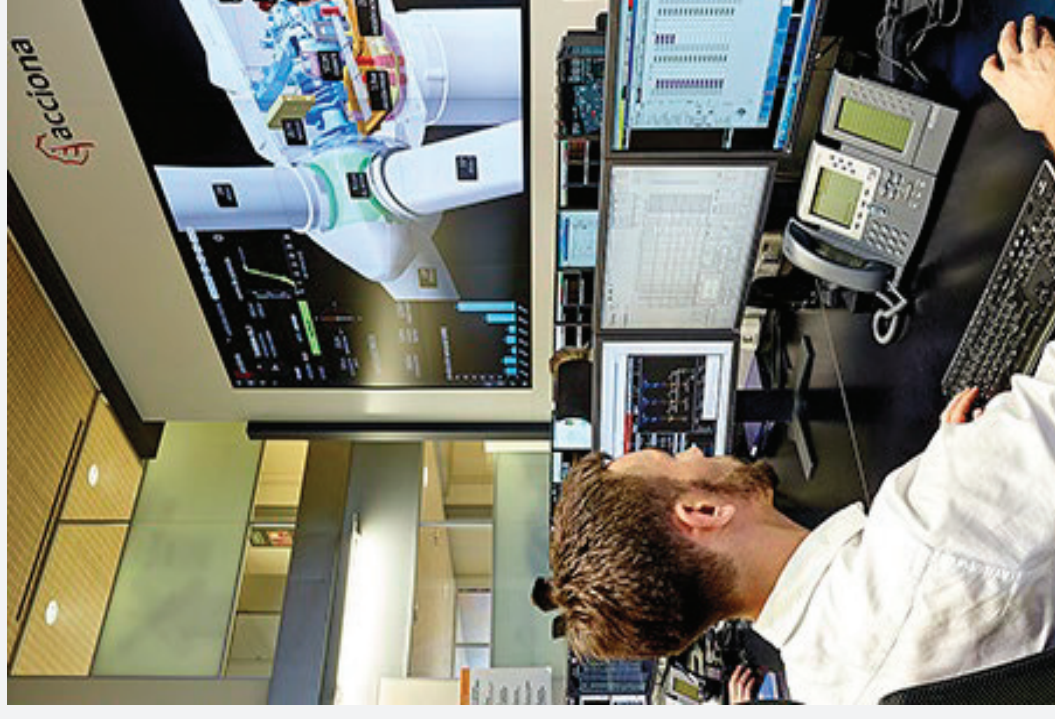
Extend the model creation to the whole operated fleet



Develop additional detection and diagnose features



Commercialize the Condition monitoring to third parties



IF YOU HAVE ANY QUESTION DO NOT HESITATE TO CONTACT US:

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Alberto Casas Olcoz: alberto.casas.olcoz@acciona.com