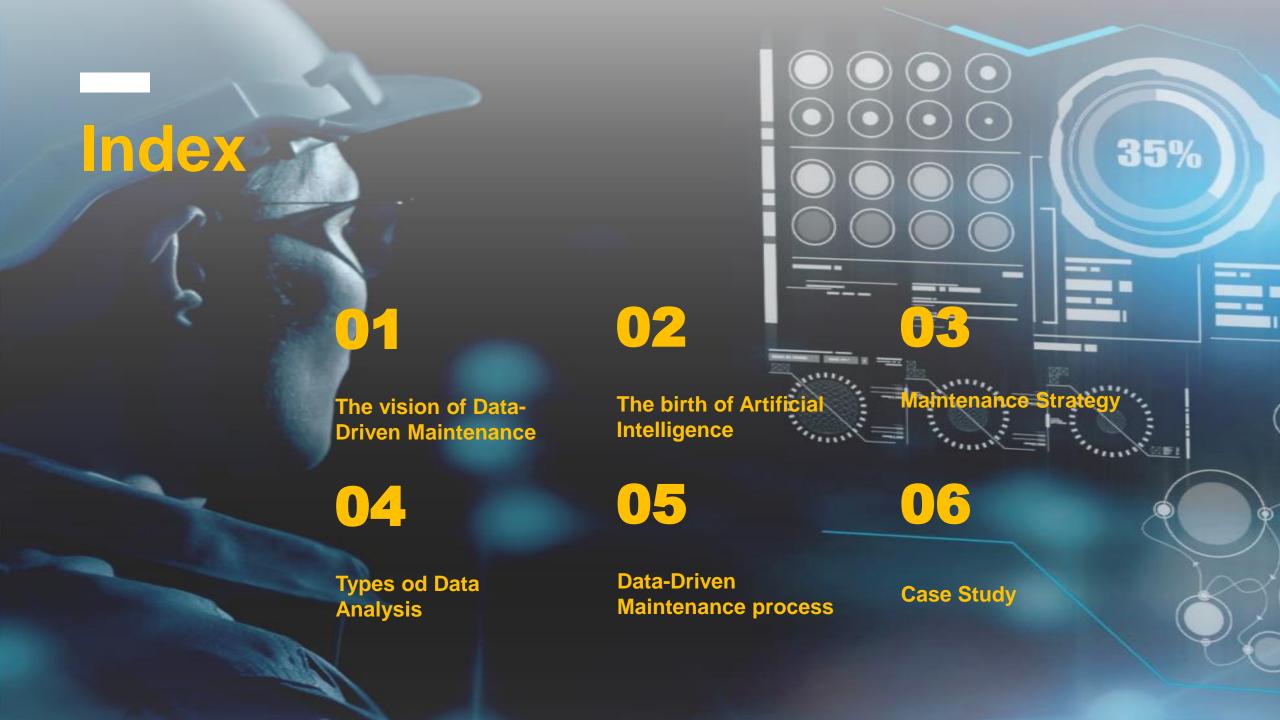
ARTIFICIAL INTELLIGENCE FOR DATA-DRIVEN MAINTENANCE IN THE POWER GENERATION SECTOR:

Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin Constructed with Deep Learning Techniques









APLICACIONES DE LA IA
AL MANTENIMIENTO
BASADO EN DATOS

The vision of DDM

✓ On July 24th, 2019 a new initiative was introduced at the Endesa Open Space to apply Artificial Intelligence aimed to the optimization of the power generation asset management by means of Machine Learning algorithms. This initiative called Data-Driven Maintenance is made up of two main pillars:

 Change the current Maintenance Culture towards a "Digital minset applied to Maintenance" through the development of Data-Driven Maintenance projects and training plant staff in machine learning techniques:



• Digitalization of the Ordinary Maintenance Management through a **Digital Platform** that would respond all the needs of the Plant Maintenance staff.



The dawn of Al

¿What is the purpose of Al?

"To proceed on the basis of the conjecture that every aspect of **learning or** any other feature of intelligence can be in principle be so precisely described that a machine can be made to simulate it".

¿What is the goal of Al?

"The goal is to make machines use language, develop abstractions and concepts, solve problems usually reserved for people, and improve".

¿What is Prescriptive AI?

It is a type of Artificial Intelligence that is designed to provide recommendation, solution, or actions to optimize a specific process or outcome. It usually uses machine learning algorithms and other advanced technologies to analyze large datasets and generate recommendations based on the data.

¿What is Generative AI?

It is a type of Artificial Intelligence that can **create original content—such as text**, images, video, audio or software code—in response to a user's prompt or request.









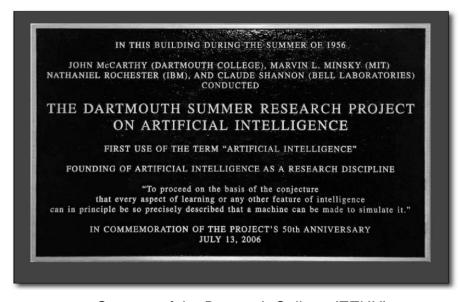


John MacCarthy

Marvin Minsky

Claude Shannon

Nathaniel Rochester

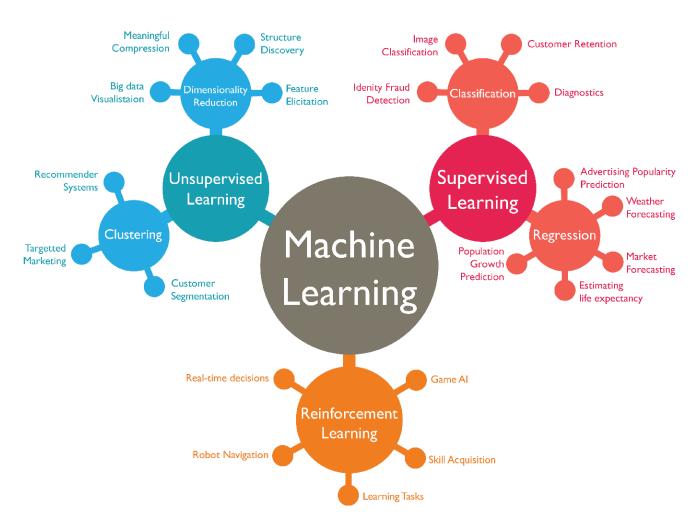


Campus of the Dartmuth College (EEUU). Summer workshop August 31rst 1956

APLICACIONES DE LA IA AL MANTENIMIENTO BASADO EN DATOS



Machine Learning



APLICACIONES DE LA IA AL MANTENIMIENTO



endesa

Maintenance strategy

Evolution of Maintenace Strategy

Irst Generation

Corrective **Maintenance**

Takes place after failure has already occured

Passive in nature

2nd Generation

Preventive Maintenance (PM)

> Occurs at predetermined intervals

Active in nature

3rd Generation

Predictive Maintenance (PdM) and CBM

> Occurs at predetermined intervals

Proactive in nature

Next Generation

Prescriptive Maintenanace

Precription of mitigation solutions for optimum results

Proactive in nature

Traditional reliablity engineering

Prognostics and Health Management

Data-Driven Maintenance (DDM)

Maintenance strategy

Types of Data Analysis

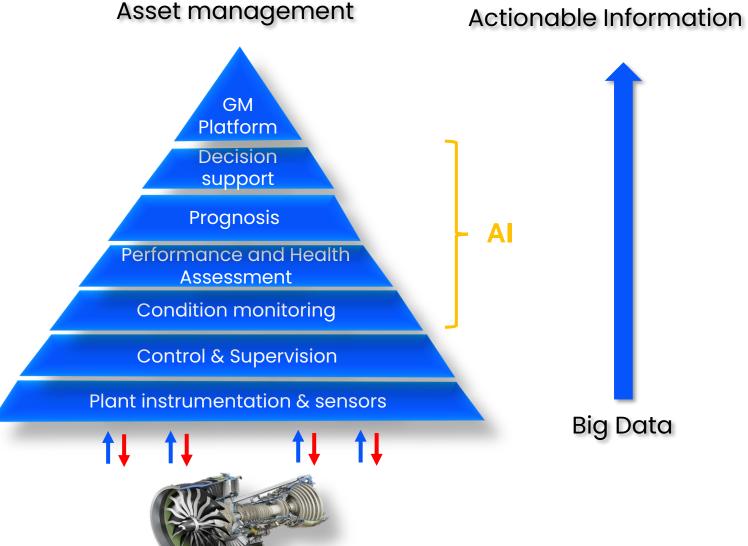
APLICACIONES DE LA IA
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Precriptive analysis: answers the question, "what should be do about it?

Predictive analysis: answers the question, "what might happen in the future?

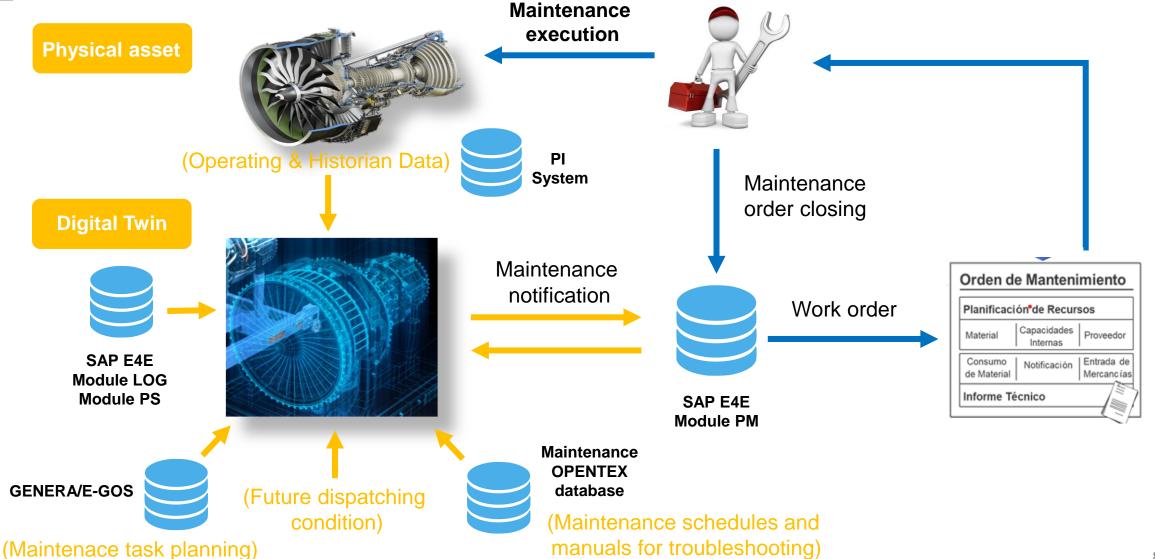
Diagnostic analysis: answers the question "why did it happen?"

Descriptive analysis: answers the question, "what happened?"



APLICACIONES DE LA IA
AL MANTENIMIENTO
BASADO EN DATOS

Data-Driven Maintenance process

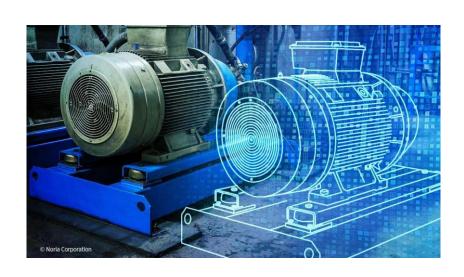


Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

Global Maintenace Twin: GMTWIN

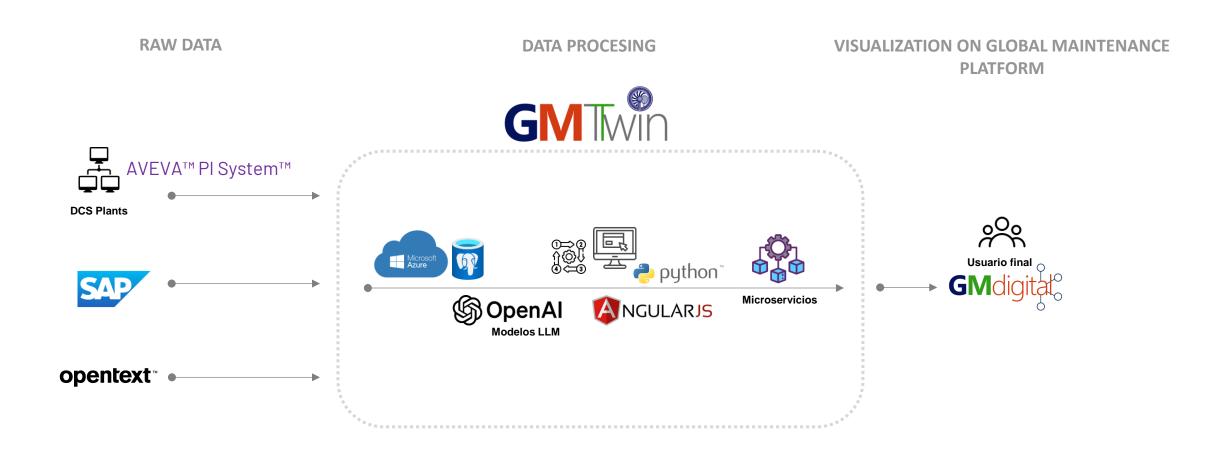


- Maintenance management of the circulating water pumps (CWP) of a Combined Cycle Power Plant at Granadilla (Tenerife, Spain).
- Two Virtual Digital Twin developed to emulate the normal behaviour of the CWPs in the absence of malfunctions.
- Early anomly detection module of the CWP failure modes.
- Risk assessment (Time to Failure and Severity).
- Maintenance resource planning.
- Generative AI designed to provide recommendation, solution, or actions to optimize the operation and maintenance of the CCWs.



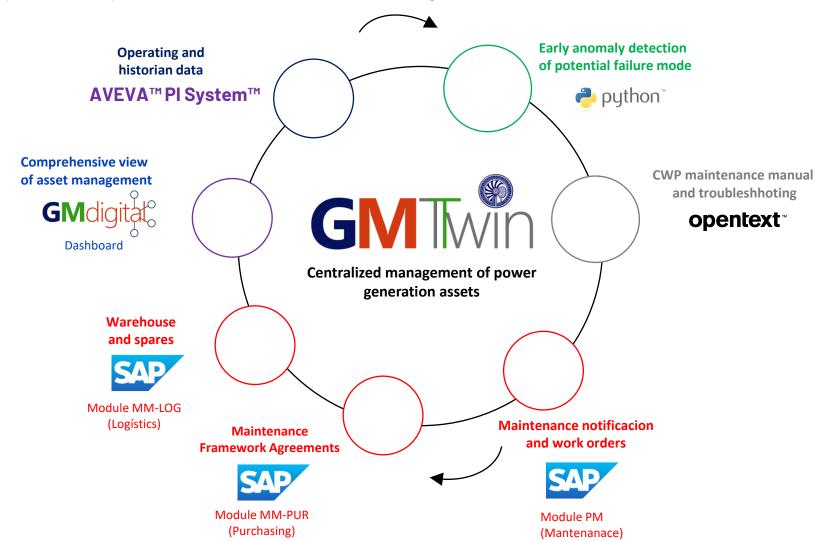


Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin





Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin







Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

Historical operation data and real-time data.

Operating hours and start-ups of the equipment.

ed learning

and supervised learning for fault detection. recommendation of maintenance interventions, determination of maximum permitted risk and calculation of equipment degradation.

Time series study

The objective is to build the same models described for the case DLNN. The environment gives a reward to penalize how far the prediction is from the real value and gives a new state, which is the new

entrance data.

Smart search within manuals the OpenText storage unit, on maintenance reports and manuals of the and generation units and related equipment

Φ

Maintenace

Smart search on maintenance notifications and work orders of previous equipment failure and planned maintenance.

planning

resourc

Information on contracts associated with the equipment and their availability.

Information on spare parts in stock for the equipment at Endesa warehouse.

Actions and/or recommendations to optimize the asset management of power generation.

Power Plant Asset High level status, alerts, selective notification and actionable information to support plant staff decision making on asset management.

power o View

Comprenhensive

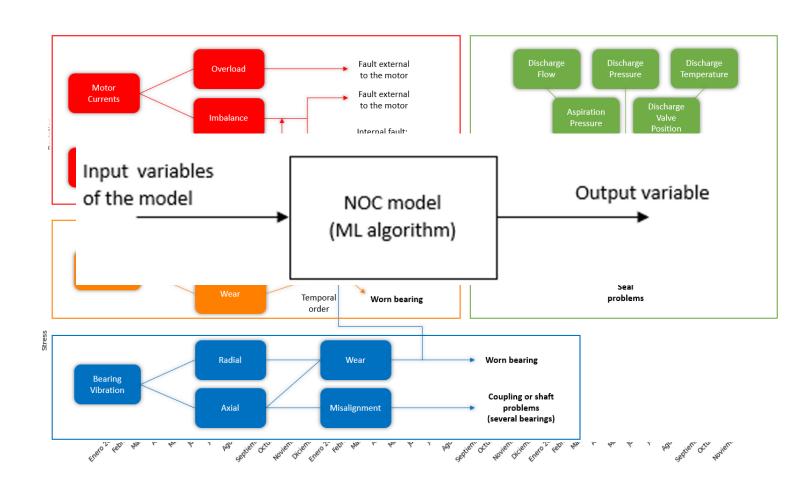
data operating on-line and Historical





Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

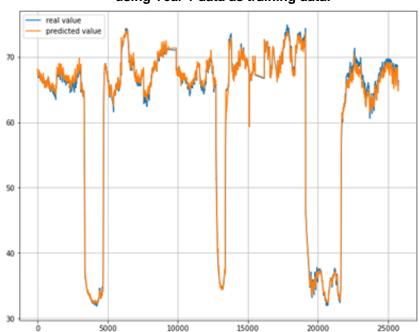
- Failure Mode, Effects and Analysis (FMEA).
- Normal Behaviour Model based on Deep Learning Neural Networks (DLNN) and Deep Reinforce Learning (DRL).
- Monitoring of main parameters under actual working conditions.
- Assessment of the risk of failure.



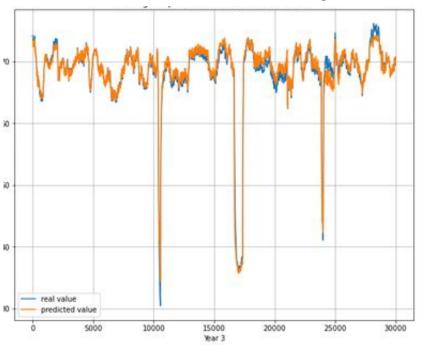


Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

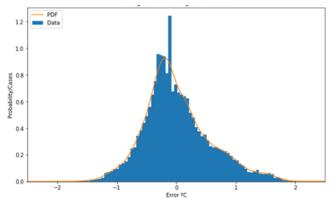
Actual and predicted values for the bearing temperature using Year 1 data as training data.



Actual and predicted values for the bearing temperature of the dataset Year 3 not used in training



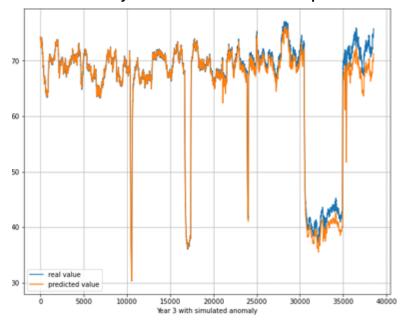
Error observed between actuak and predicted values for the bearing temperature using Year 1 data



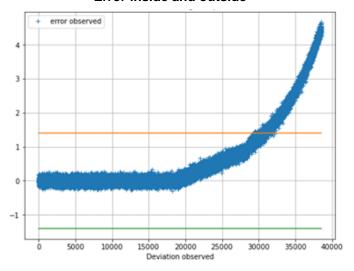


Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

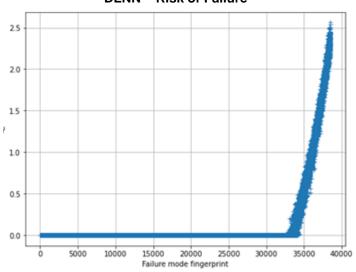
Actual and predicted values by the DLNN digital twin. An anomaly is detected at the end of the period



Error inside and outside



DLNN - Risk of Failure

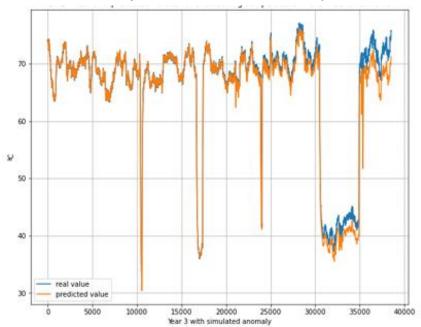




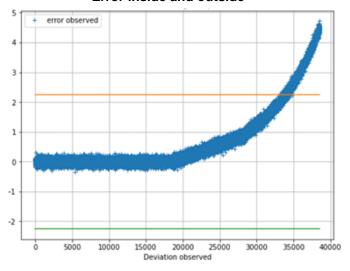


Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

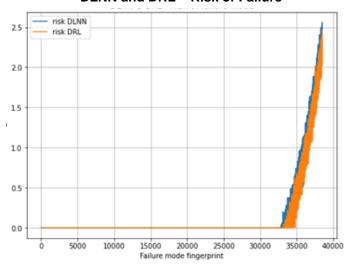
Actual and predicted values by the DRL digital twin. An anomaly is detected at the end of the period



Error inside and outside



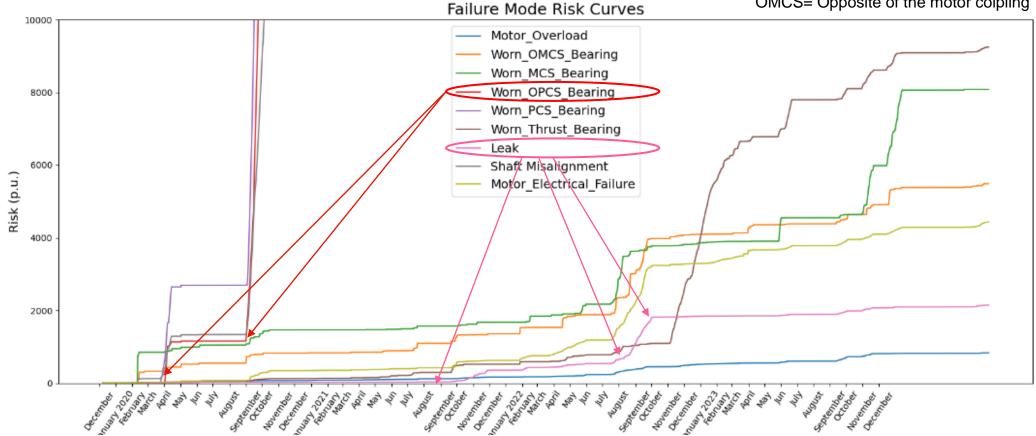
DLNN and **DRL** – Risk of Failure





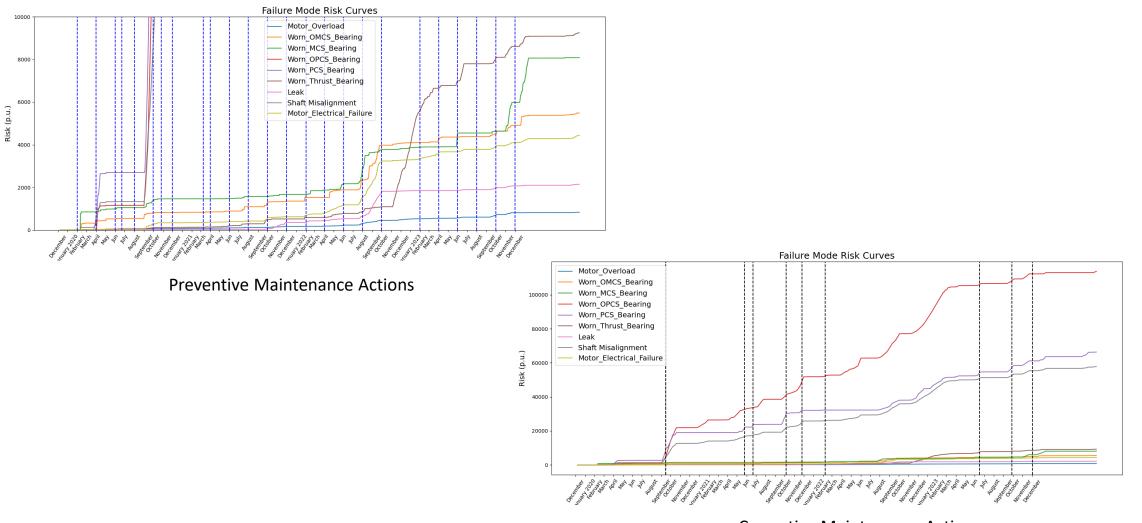
Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin

OPCS= Opposite of the coupling pump PCS= Pump coupling side MCS= motor coupling side OMCS= Opposite of the motor coipling





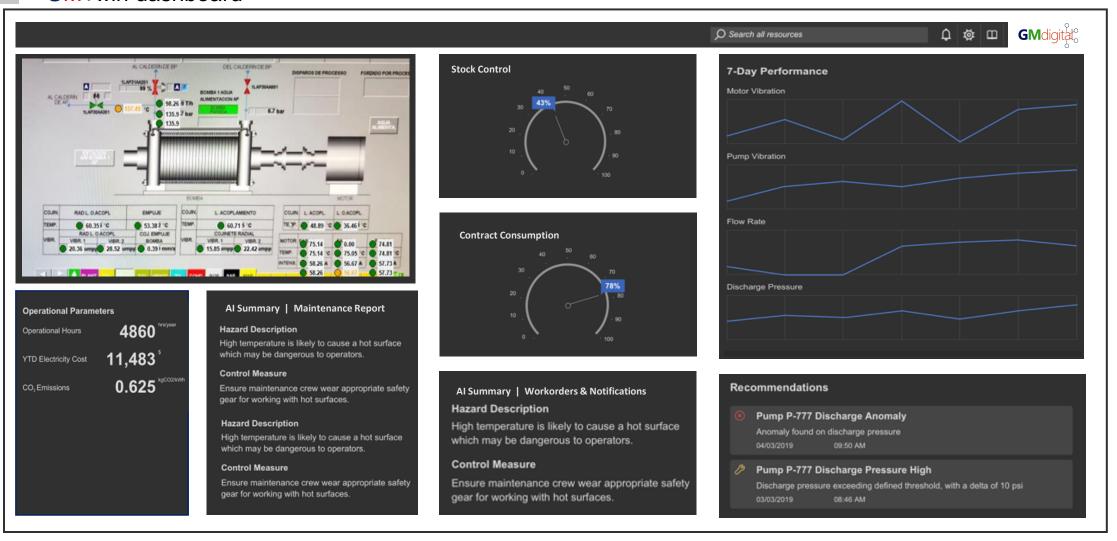
Case study: Anomaly Detection of a CCGT Cooling Water Pump Based on its Virtual Digital Twin



APLICACIONES DE LA IA AL MANTENIMIENTO BASADO EN DATOS

Data-Driven Maintenance (DDM)

GMTwin dashboard

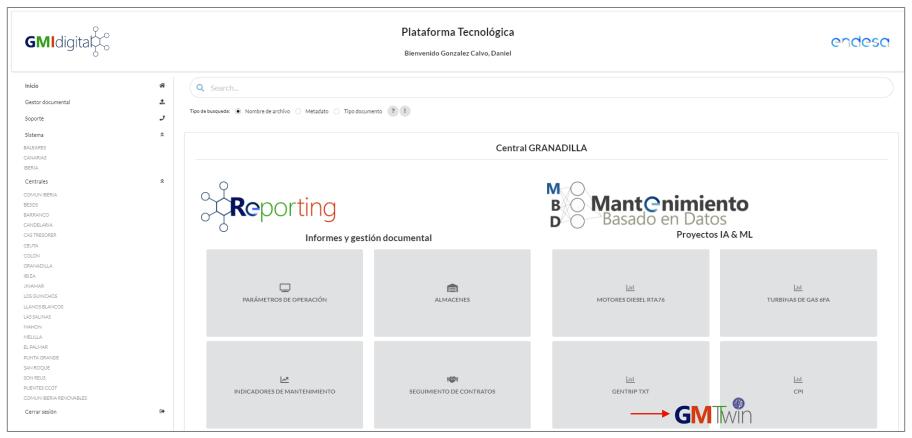


APLICACIONES DE LA IA AL MANTENIMIENTO BASADO EN DATOS

Data-Driven Maintenance (DDM)

Global Maintenance digital platform GMd





Mantenimiento Basado en Datos

APLICACIONES DE LA IA
AL MANTENIMIENTO
BASADO EN DATOS

Al versus humans - who does it better?



endesa



Data-Driven Maintenance

Mantenimiento
Basado en Datos

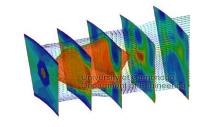
CÁTEDRA
APLICACIONES DE LA IA
AL MANTENIMIENTO
BASADO EN DATOS

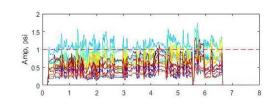


Applications of DDM

1.- Combustion diagnostic algorithm

Anomaly detection of combustión dynamics (DLN combustors)

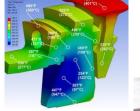




2.- 6B GT rotor replacement based on condition by means of a Digital Twin

Digital twin of the thermal-stress behaviour of a 6B gas turbine rotor components.



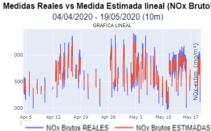




3.- Failure pattern analysis in diesel engines

Failure pattern analysis and prediction environmental events of RTA76 diesel engines.





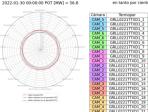
Temperaturas turbina GAS5, última semana: 58 - 69 MW 2022-01-30 00:00:00 POT [MW] = 56.8

Nº de veces que el valor se sale de la media +- la desviación de la muestra

4.- Exhaust Temperature Analysis of 6FA Gas Turbines

Anomaly detection of combustión issues by means of thee xhaust temperatura evolution





Data-Driven Maintenance

Applications of DDM



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APLICACIONES DE LA IA
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5.- Optimisation of compressor performance in 6FA Gas Turbines

Digital Twin of the 6FA gas turbine compressor for their efficiency optimization and off-line water washing interval definition.

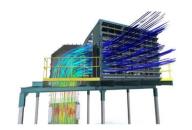
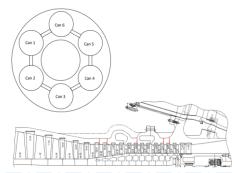




Gráfico comparativo de RENDIMIENTO DEL COMPRESOR

6.- Definition of maintenance intervals according to the actual dispatch of the 6FA gas turbine

Proprietary algorithm for calculating the hours and starts for the 6FA Gas Turbines maintenance definition based not only on the operating hours and starts, but also on the dispatch load





Optimización de intervalos entre revisiones

7.- Natural Language Processing (NLP) and Maintenance Management.

Transformation of natural language into formal language, which computers can process for maintenance management purpose.





8.- Digital Maintenance Platform

Web platform for digitalization of the regular maintenance management.



