The PI System's role in Enel's Digitalization

Luca Franceschini
Alvise Rossi

PI System
ENEL

Global Thermal Generation
Global Infrastructure and Networks
Enel Green Power
Argentina
Australia
Brazil
Brazil
Bulgaria
Canada
Chile
Colombia
Costa Rica
Ethiopia
Greece
Guatemala
India
Italy
Morocco
Mexico
Panama
Peru
Romania
Russia
South Africa
Spain
USA
Zambia

Enel Global Power Generation
Global Digital Solution

LUCA FRANCESCHINI

Head of Plant Information Platforms Chapter

Enel Global Power Generation
Global Digital Solution Digital Hub

LUCA.FRANCESCHINI@ENEL.COM

ALVISE ROSSI

Plant Information Platforms Chapter

Enel Global Power Generation
Global Digital Solution Digital Hub

ALVISE.ROSSI@ENEL.COM

Agenda

- The Enel Group
- The Role of PI System platform in the Enel Digitalization
- PI System Platform management
- Data Availability
- Data usage, Experience and success cases
  - Global Thermal Generation
  - Renewable Generation Hydro Wind Solar

The Enel Group

Enel's leadership in the new energy world

1st **network** operator[1]

World's largest private player[2] in **renewables**

Largest retail **customer** base worldwide[3]

 # End users

74 mn

Renewable capacity

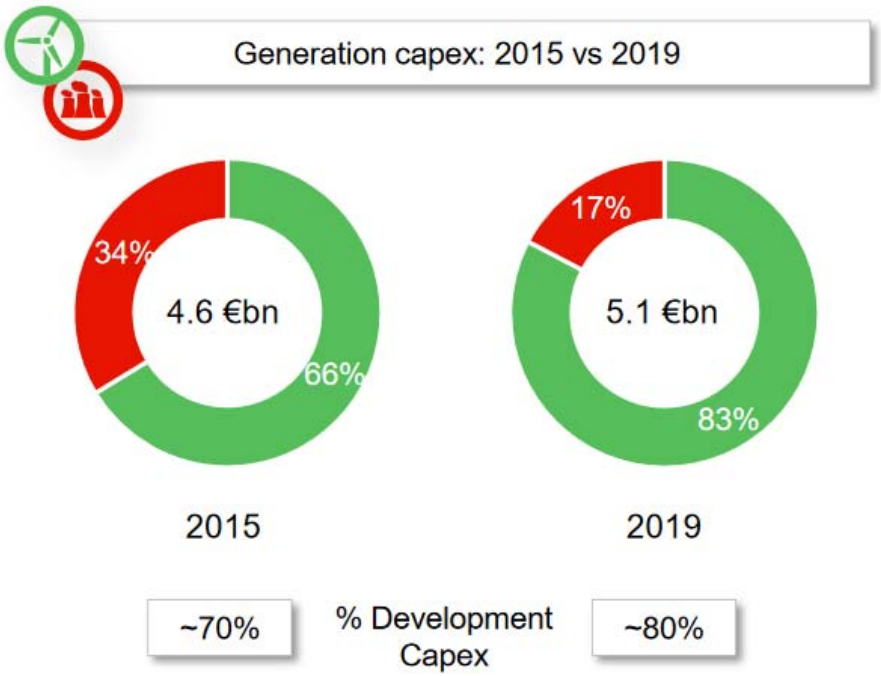
46 GW

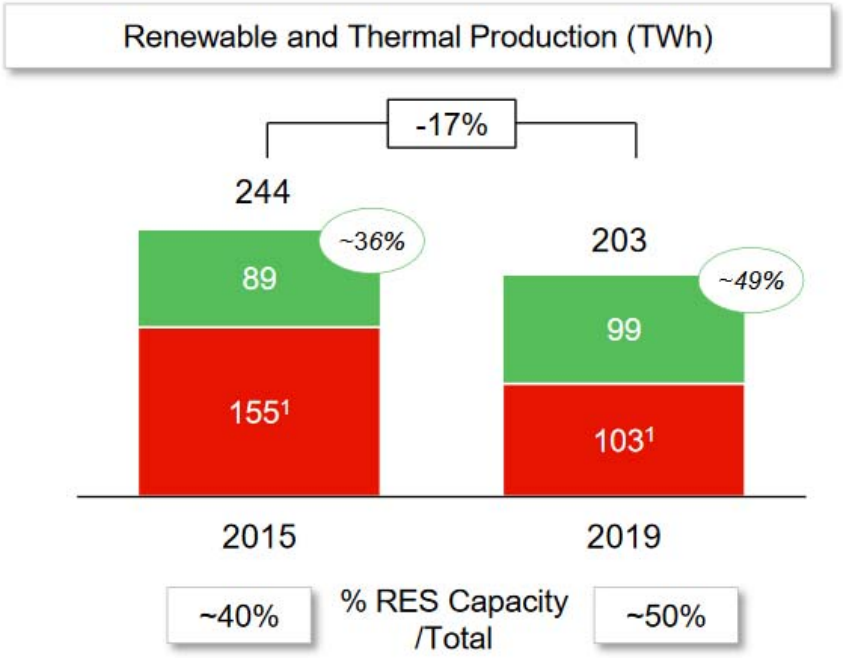
 # Customer

70 mn

1. By number of users. Publicly owned operators not included
2. By installed capacity. Includes managed capacity for 3.7 GW
3. Includes customers of free and regulated power and gas markets

We have focused our capital allocation on renewables...

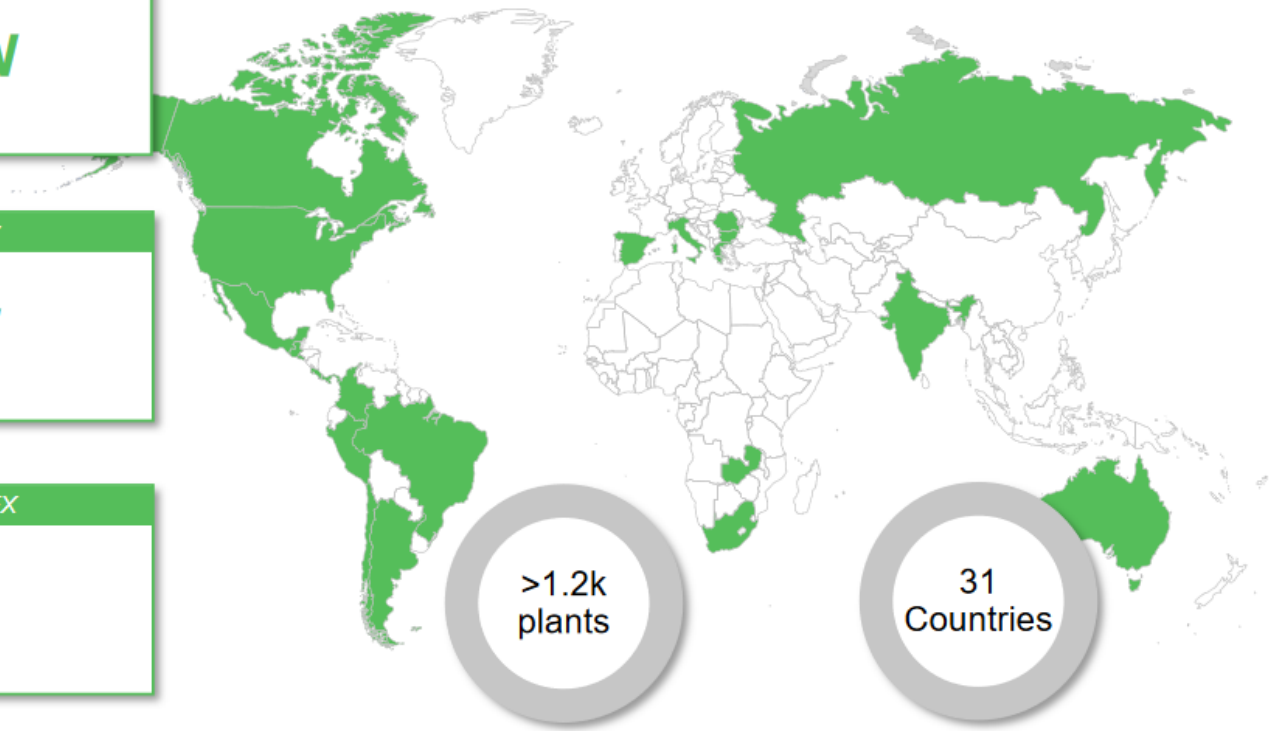




1. Excluding nuke (39.8 TWh in 2015 and 26.3 TWh in 2019)

...to become the world leader in renewables

2015	2019
Installed capacity: 37 GW	Installed capacity[1]: 46 GW
Built capacity: 1 GW	Built capacity: 3 GW
EBITDA/CAPEX: 11%	EBITDA/CAPEX: 11%



1. Including managed capacity by 3.7 GW

The PI System's role in Enel's Digitalization

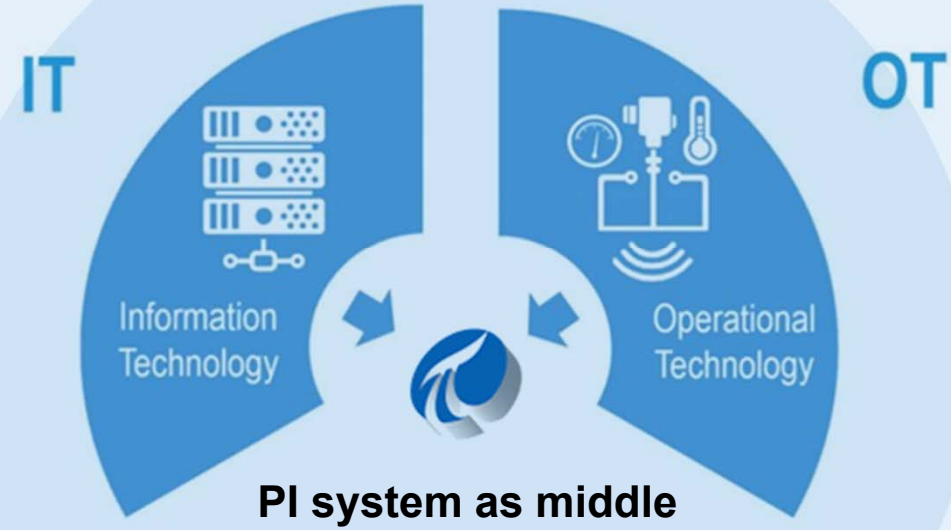
IT+OT=IOT, Information Operational Technology

IT (information technology) systems and OT (operational technology) systems integration

IT and OT technologies physical separation

Different teams with different goals

Analytics capabilities vs real time data delivery



PI system as middle layer for IT and OT DATA integration

Plant Data

Plant Data Gathering

The PI System represents main Enel worldwide Platform for data collection process directly from the plant, providing a structured BD to guarantee a high level of availability and quality of the data gathered

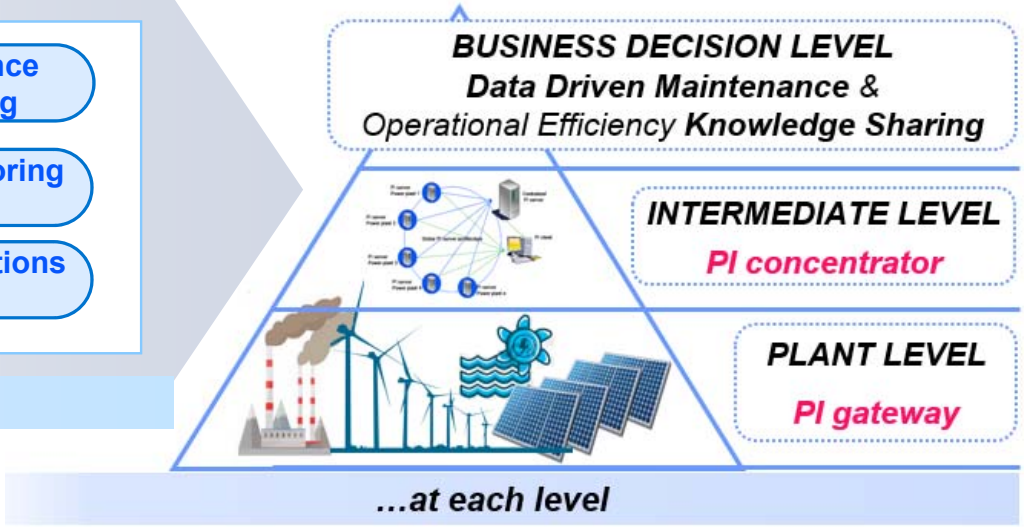
SUPPORTED PERIMETER

- ***Global Applications***
- ***Local Applications***

MAIN ACTIVITIES

- Predictive Analysis
- Performance Reporting
- Big Data Analysis
- Plant Monitoring System
- Monitoring rooms
- Plant Operations System

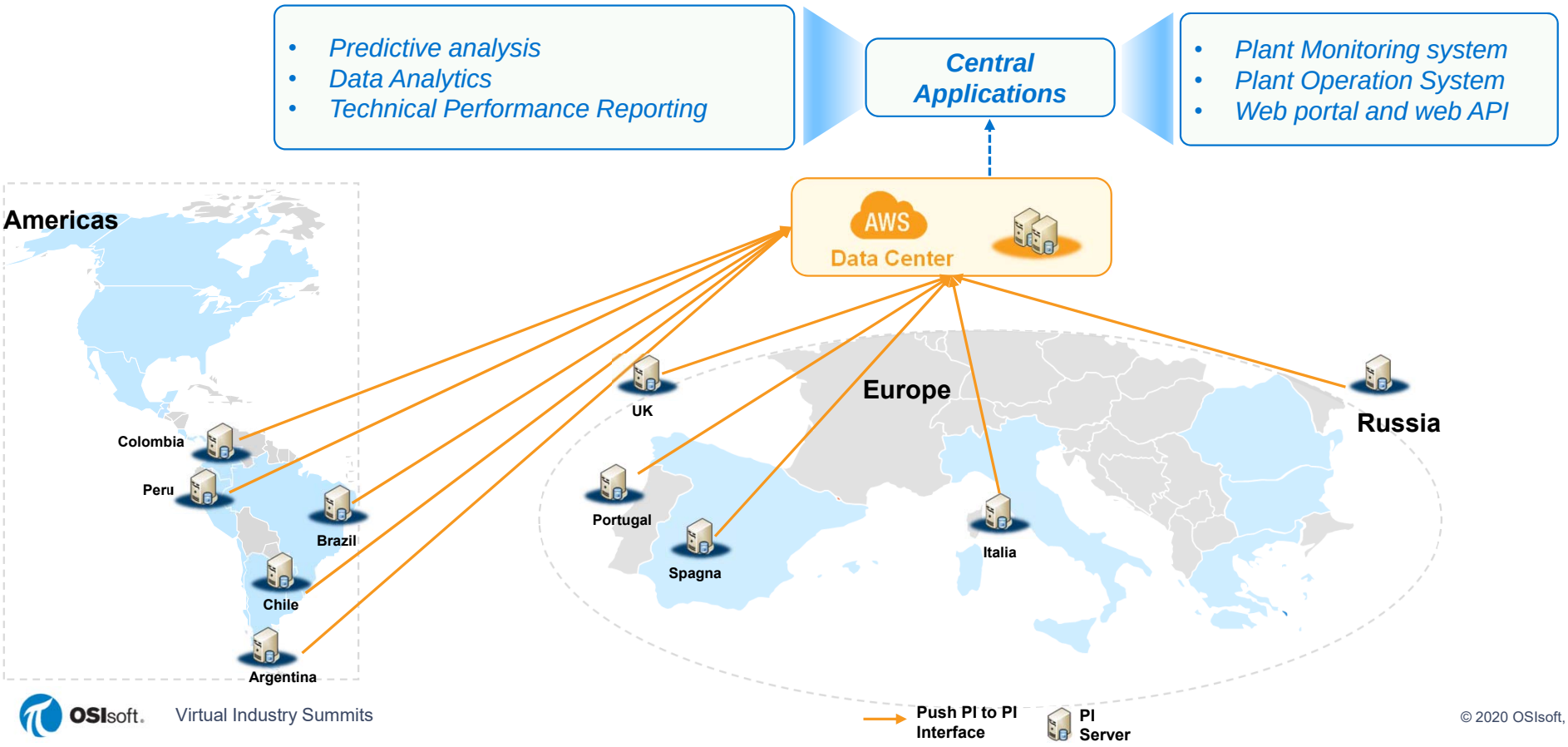
Data as key driver for advanced Analysis & Monitoring…



…at each level

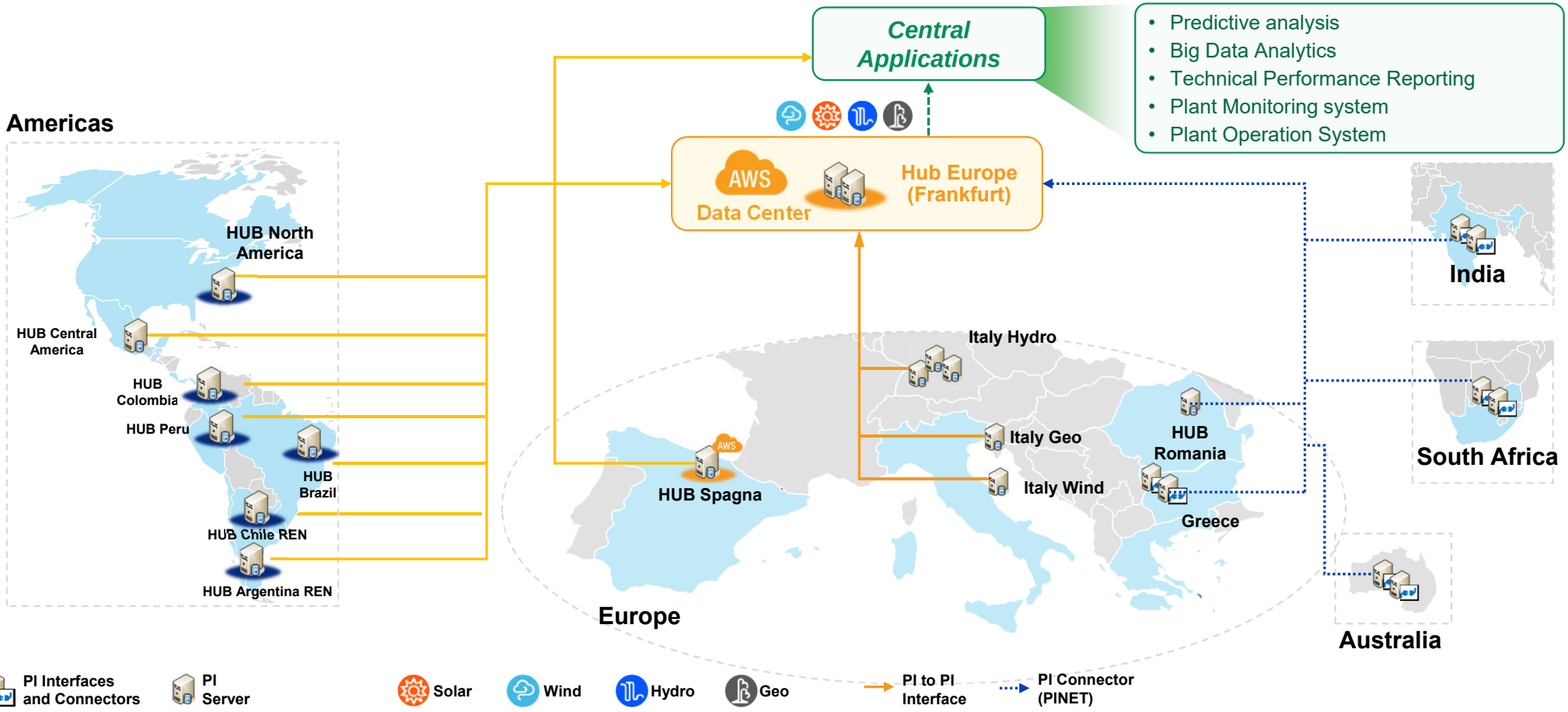
PI System in Enel Global Thermal Generation

Global PI System Infrastructure Project



PI System in Enel Global Renewable Generation

Global PI System Infrastructure Project



Plant Data

Plant Data Gathering

The PI System represents main Enel worldwide Platform for data collection process directly from the plant, providing a structured BD to guarantee a high level of availability and quality of the data gathered

PI SYSTEM INTEGRATION AS-IS SCENARIO *(Integration base level: core data are acquired)*

COUNTRY	Hydro	Wind	Solar	Geo	Thermal	COUNTRY	Hydro	Wind	Solar	Geo	Thermal	COUNTRY	Hydro	Wind	Solar	Geo	Thermal
Argentina	100%				100%	Greece	100%	100%	100%			Peru	100%	100%	100%		100%
Australia			100%			Guatemala	100%					Romania		100%	100%		
Brazil	90%	100%	100%		100%	India		100%				South Africa		100%	100%		
Bulgaria		100%				Italy	99%	100%		100%	100%	Spain	99%	78%	100%		100%
Chile	100%	77%	100%	100%	100%	Mexico	100%	89%	100%			Portugal					
Colombia	99%		100%		100%	North America	90%	87%	100%	100%		Russia					100%
Costa Rica	100%					Panama	100%		80%			Zambia			100%		

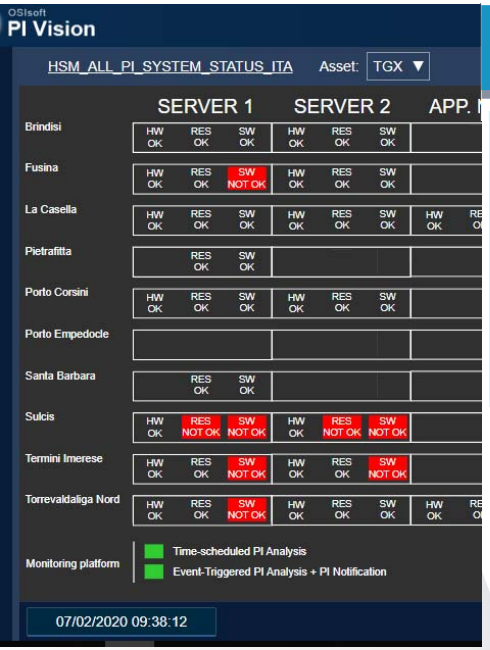
14

Tech not present in that country

PI System Platform management

PI System Platform

Monitoring



PI SYSTEM PLATFORM MONITORING AND FAULT MANAGEMENT

- **Design** and make a **unique monitoring tools for PI HW** and **SW components within the PI framework** (leveraging the current existing tools: PDA, HSM, etc):

TICKETING

- **Ticketing: automatic and semiautomatic assignment** of **troubleshooting activities**, with activity tracking

NOC SERVICES

- **Definition of system configurations** and **architectures** needed to enable **monitoring services provided by OSI** (NOC)
- **Definition of which units** should **cooperate with the NOC engineers** to **solve issues**, in case they need some internal support

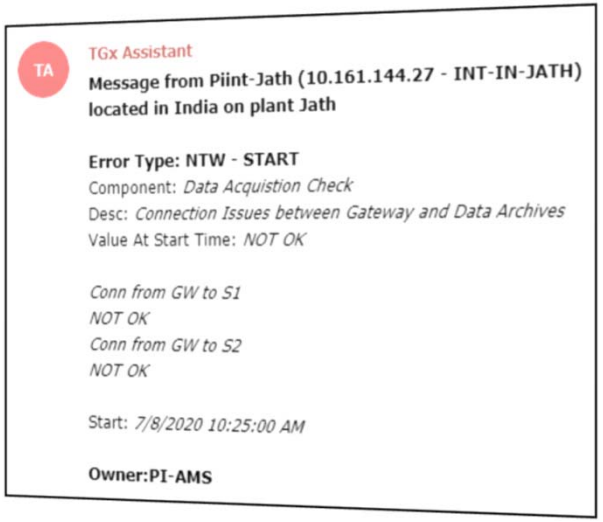
PI System Platform

Monitoring

INTERNAL PI SYSTEM PLATFORM MONITORING → PI-HSM

HOW:

- Configure a direct alert system based on TELEGRAM chat with maintenance team
- TO DO: Configure PI-HSM in order to open automatic Service Now incidents with the same information reported on the Telergam alerts



PI System Platform

Monitoring

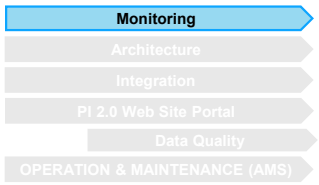
INTERNAL PI SYSTEM PLATFORM MONITORING → PI-HSM

HOW:

- Configuring PI Vision display with more information about the alerts receive from TELEGRAM
- Reduce the needs of maintenance the monitoring system by limit the installation of monitoring components on not PI-dedicated machine (non accessible form the Global PI Team)
- Focus on DATA AVAILABILITY: DATA QUALITY will be assured by a dedicated tool

PI System Platform

Monitoring



TICKETING MANAGEMENT

MISSION: Configure an automatic (or semiautomatic) assignment of troubleshooting activities, with activity tracking

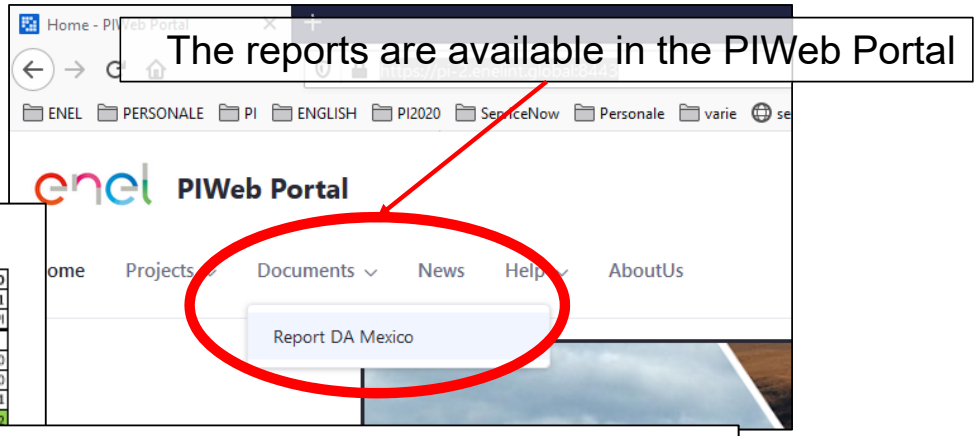
HOW:

- Using Telegram chats (grouped by Geographical area) where Local Maintenance Team and Global PI team will receive the HSM alerts
- By receiving e-mail alerts from NOC for the PI components monitored
- Write a detailed Management Procedure in order to define who and how have to take care of the maintenance necessary after an fault alert
- Start to manage all the fault as Service Now incidents

Data Availability

Data availability report for solar power plant

This report represent the availability of the PI System infrastructure and the availability of the architecture in the power plant needed <u>to gather the real time data on PI system.</u>



PI AVAILABILITY REPORT (V1.0)

Country		MESSICO
Power Plant		Villanueva 1
PI server		\\MCA-PI
Period under analisys		
START		7/7/2020
END		7/8/2020
DURATION (days)		1
PI Buffer	OPCUA_Villanueva1.PIServer.EKIO01PIS01.BufferedEvents	2
PI availability	'MCA-PI.PIServerAvailability.stCal'=0	
PI INT	'MXSVLN1.ScadaAvailability.stCal'=0	
TOTAL PI INFRASTRUCTURE	'MCA-PI.PIServerAvailability.stCal'=0 and 'MXSVLN1.ScadaAvailability.st	
SCADA Availability	'MXSVLN1.Scada.CommSt.stCal'="NON FAULT" and 'MXSVLN1.Pyranom	
DAY DURATION	'MXSVLN1.Pyranometers.stCal' >0.1	
Critical %		
Alert %		
GU number		
Cab Comm Fail %		
Data Availability %		
TOTAL data availability %		

PI Buffer	Average number of samples stored in the PI buffer. If this value is great significant. If this number is greater than 10,000, a network problem is
PI availability	This parameter report the AF and PI availability on the period under an

DURATION

DATE 7/7/2020 7/8/2020 1d

Technology	Country	Plant Name	GU Name	GU Nominal Power (kW)	Log Interval	Cab Comm % (for each GU)	Data Availability % (for each GU)	TOTAL DATA AVAILABILITY (for each GU)
PV	MEXICO	DON JOSE	Cab1		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab2		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab3		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab4		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab5		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab6		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab7		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab8		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab9		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab10		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab11		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab12		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab13		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab14		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab15		1d	98%	98%	98%
PV	MEXICO	DON JOSE	Cab16		1d	1%	2%	2%
PV	MEXICO	DON JOSE	Cab17		1d	98%	98%	98%

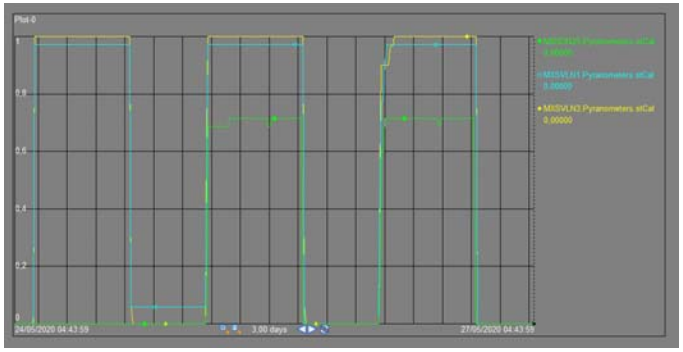
Data availability report for solar power plant

Objectives

Development of a **Data Quality tool** to enable the **analysis of data variations and availability** (every 15 minutes) throughout the **entire transmission cycle from the sensor** installed on the plant to the PI System and **supporting data quality analysis and KPIs monitoring**

Real-time identification of cabin failures to detect data losses

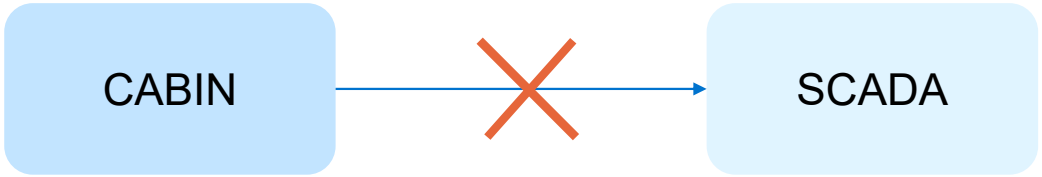
Identification and analysis of the Plant Production Phase through pyranometers

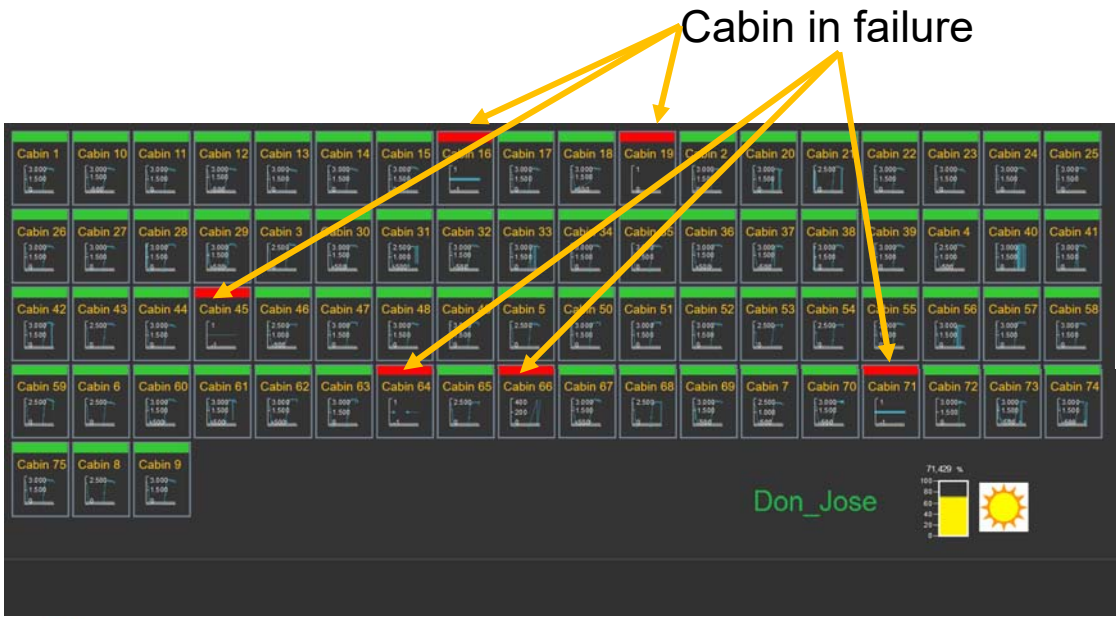


Don Jose, Villanueva I and Villanueva III plants (Mexico) finalized the PI infrastructural development through the creation and implementation of PI tags & implemented the PI Vision Dashboard

Data availability report for solar power plant

Data losses between a cabin and the SCADA server





Algorithm

1. In the production phase the electrical tags have to change their values with the time
2. We select all the electrical tags for each cabin and we check if
   - We are in the production phase
   - If we don't acquire exception/sample in the last two hours

If the check result if true for both the test we determinate a TLC problem between the cabin and the SCADA: **probably we are losing data from that cabin and it's necessary to check immediately what's happening**

Data usage,
Experience and success cases

Global Thermal Generation

Remote Predictive diagnostic Monitoring center

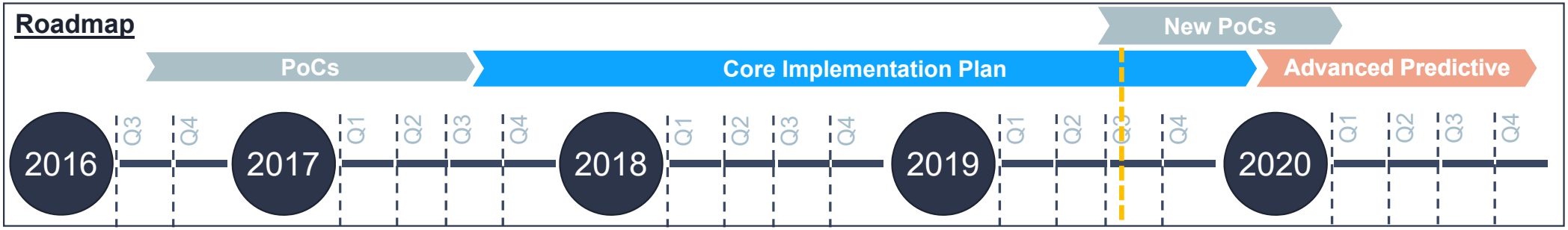
Goals:

- Line up energy production to the best international standards
- Reach the best results in terms of **availability**, **efficiency**, **quality** and **security** in our power plants
- Power Plant support to solve Operation and Maintenance related issues
- Take actions to Improve the Operation and Maintenance tasks
- Allow for failure analisys and provide for technical support while minimizing Outage

Remote Predictive Diagnostic

Roadmap

Roadmap



Innovation

- Continuous diagnostic tools scouting, managing pilots deployment, evaluating benefits and main outcomes, with the aim to select the best ones.

Remote Predictive Diagnostic Center

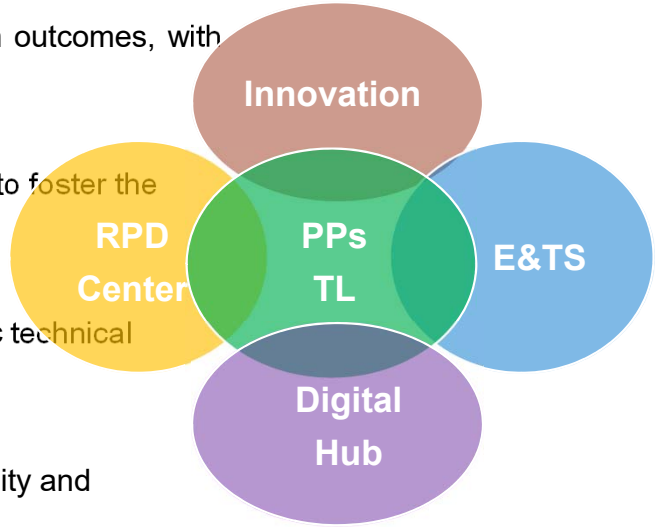
- Support tools selection, use the tools and contribute to validation and benefits evaluation, in order to foster the rolling out activities and to get the highest value once the solution is implemented.

Technical Support and Powerplants

- Support in the identification of most critical equipments and problems, and interpretation of specific technical issues in the framework of 2nd level diagnostic analysis.

Digital Hub

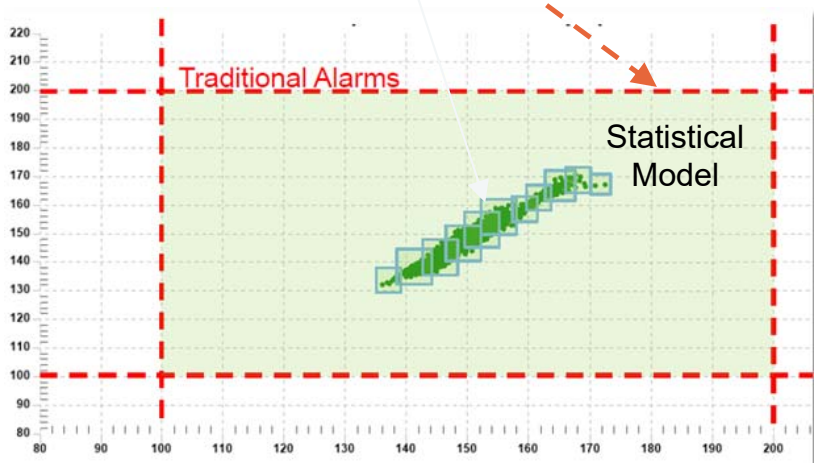
- Data collection in a proper way from the plant to the Cloud level in order to ensure availability, quality and reliability.



Predictive Diagnostic

Diagnostics based on statistical analysis

The diagnostic system alerts work differently than traditional alarms from DCS used in the typical working status



1. Historical process data collection to allow for the development of statistical models
2. Statistical models provide for ideal data values that the real time measures should assume during the machinery normal working condition
3. Models identify possible evolving anomaly conditions and raise alerts
4. Reliable and temporally extended historical data base is strictly required to properly “train” the models under all possible working conditions

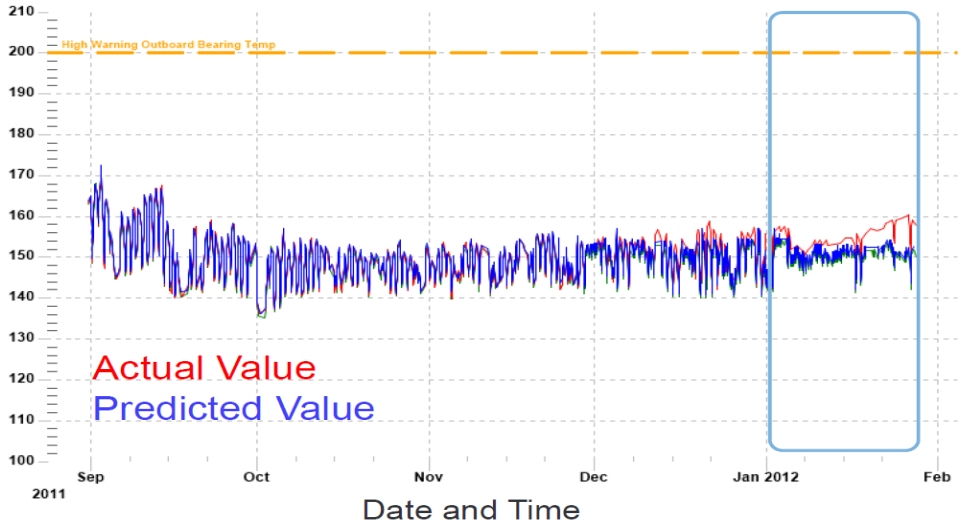
How the statistical diagnostic works

The diagnostic system alerts work differently than traditional alarms from DCS used in the typical working status

Actual Value
- The original signal
- The value of an equipment sensor at that time

Predicted Value
- Created by model leveraging all signal values
- Sensor's expected value

Deviation
- Delta: (Actual Value – Predicted value)
- A signal's distance from expected performance

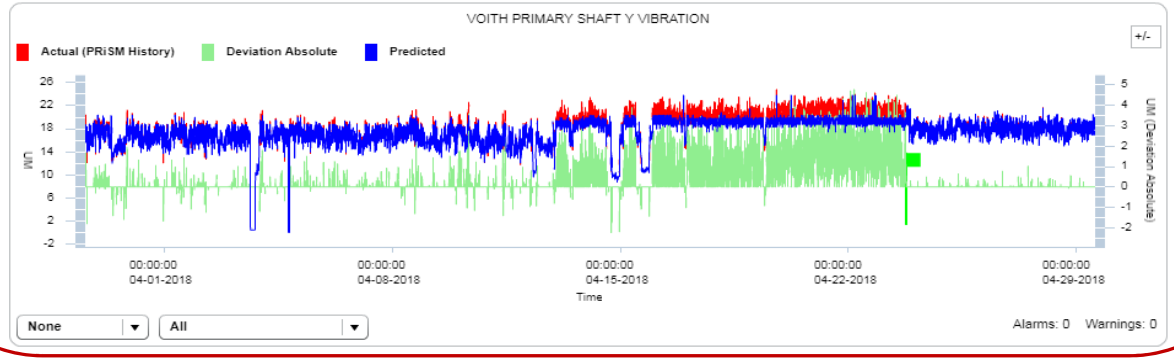


The diagnostic alerts are configured on the deviation values.

Example of detected catch

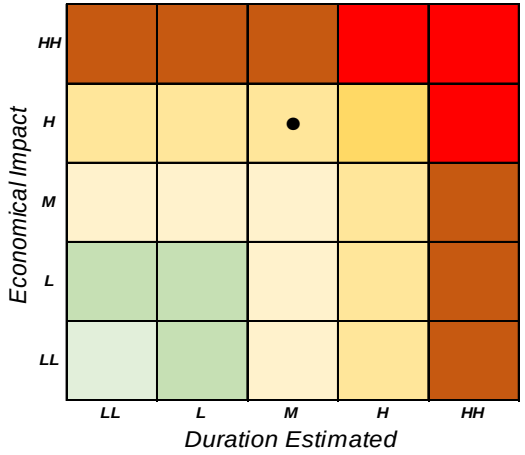
BOCAMINA 2 – Feed water Pump Coupling – bearing loosening

- Detected anomaly behaviour of both vibration measurements of primary shaft coupling, mainly VOITH PRIMARY SHAFT Y VIBRATION.
- Analysis carried out by power plant technicians confirmed a different behavior of the equipment for some frequency vibration, caused by a play between coupling device of bearing n.8 of Voith Primary Shaft. **Power plant made maintenance activity, taking advantage from a scheduled outage.**



Estimated Impact

Predictive Module	Feedwater System
Equipment	Feed Water Pumps

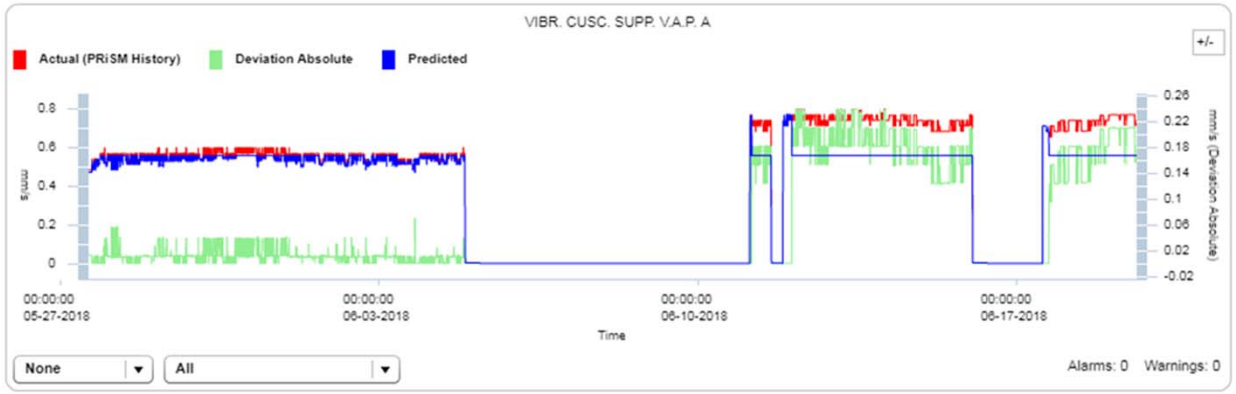


Global Unit Code	BOCA-ST02-CO-A&B
Net Maximum Capacity	324,1MW
Equivalent Duration	175,3 Hrs Eq
Total Economical Estimation	
Lost Production Opportunity	
Restoring Cost	
Estimated EUOF Impact	2%

Example of detected catch

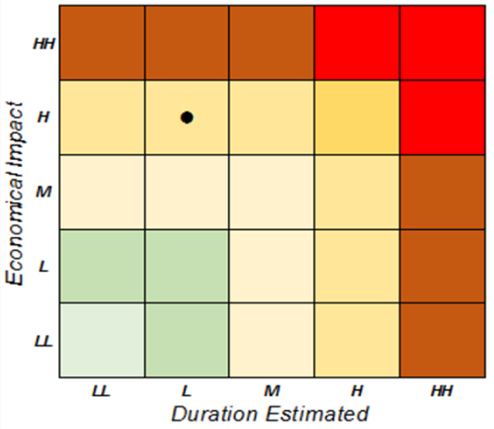
TORRENORD 4 – Air Primary Fan – bearing support loosening

- OMR for mechanical model of Unit 4 Air Fan exceeded limits, mainly due to support bearing vibration increasing.
- E&TS colleagues checked locally the dynamical behaviour of the asset, confirming a different behavior of the equipment for some frequency vibration, caused by a support bearing loosening. **Power plant technicians made maintenance activity.**



Estimated Impact

Predictive Module	Boiler Air And Gas Systems
Equipment	Air Fans



Global Unit Code	TNOR-ST04-CO-A&B
Net Maximum Capacity	615MW
Equivalent Duration	107 Hrs Eq
Total Economical Estimation	
Lost Production Opportunity	
Restoring Cost	
Estimated EUOF Impact	1,22%

Data usage,
Experience and success cases

Renewable Generation

Hydro
Wind
Solar

Ongoing integration projects

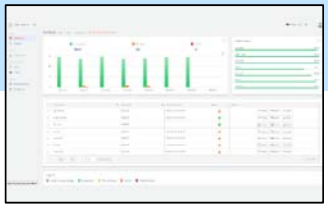
Applications that rely on PI data for Data Driven maintenance

Technology	Projects
	Wind: 3 projects ongoing
	Solar: 2 projects ongoing
	Hydro: 2 projects ongoing
	Battery: 1 project ongoing

Predictive

Solar Predictive

Predictive Maintenance Solution for Solar aimed at define inverter tech inefficiencies & failures through irradiance & power values analysis and allows the visualization and monitoring of the plant status and criticalities



String Monitoring (Solar)

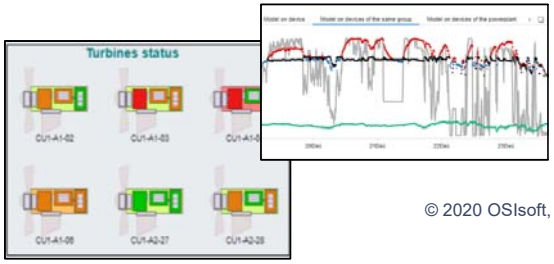
Near real-time fault detection model by building an ad-hoc algorithm internally thanks to DH (DCC) & O&M experience, in order to record its output on PI concentrators & enable visualization by the CR operators

Presagho (Hydro)

Development of predictive alarms and ticketing systems to manage tickets generated by the predictive maintenance & analyses

Iceberg(Wind)

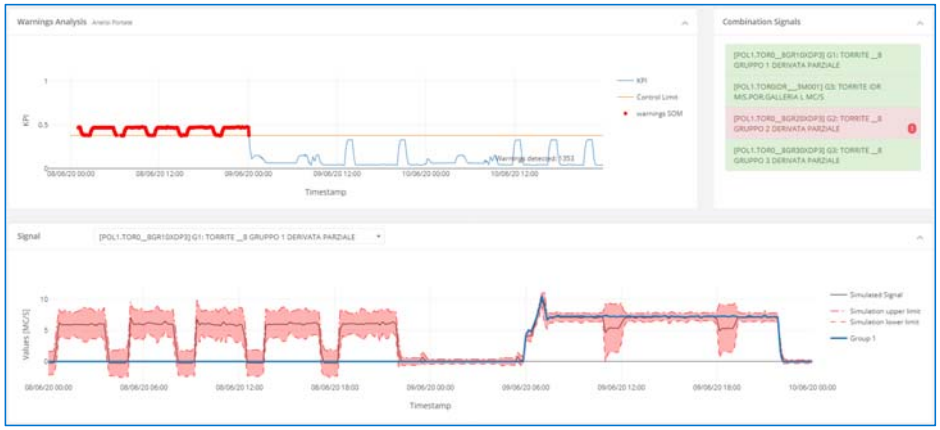
Predictive Maintenance and Advanced Data Analytics for Maintenance Optimization



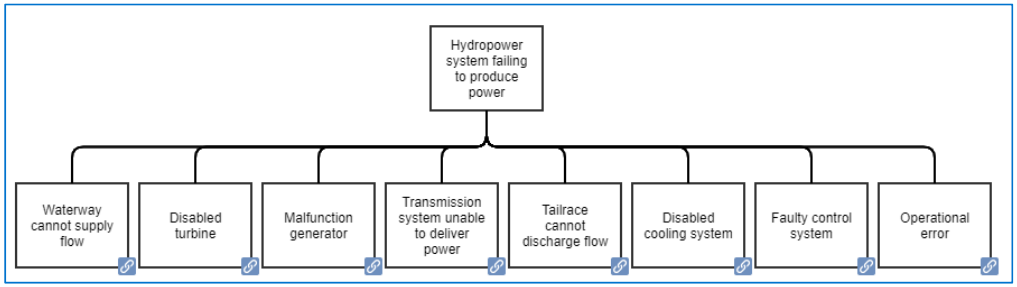
E-Maintenace 2.0

Hydro Predictive Platform

General Overview	Plants general info
Plant Overview	Active power and water flow time-trends
Data Exploration	Specific signals time-trend
Quality Check	Descriptive analysis on available data
Efficiency Analysis	Unit-Combinations efficiency analysis
Analytics	Predictive info from data analytics models (predefined inputs)
Operator Analytics	Predictive info from data analytics models (user-defined inputs)
Events	Recap of warnings in calendar pages

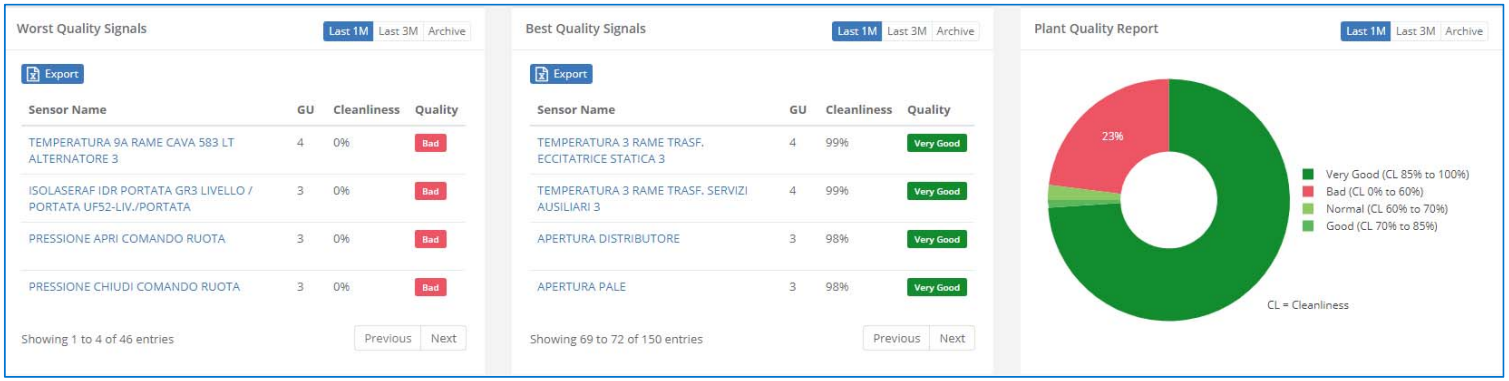


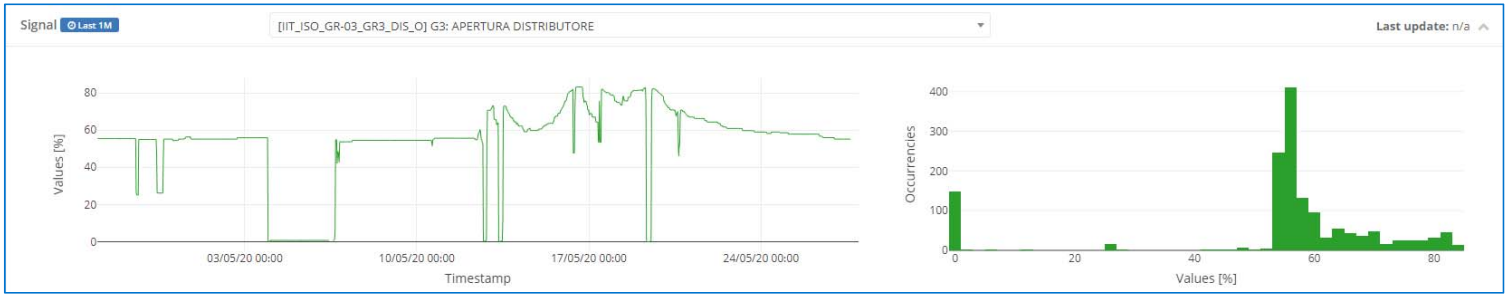
- Interactive user interface
- **Configurator for predictive models**
- Advanced signal analysis
- Natively linked to **failure modes**



Data Quality for Hydro project

- Direct window on the PI system





Automatic calculation of data cleanliness

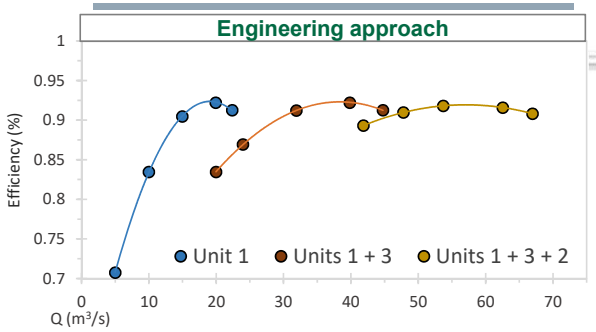
- Integrated tool
- Overall plant data quality
- «Cleanliness» index
- Analysis of signal timeseries for each PI tag
- Statistical distribution
- Focus on missing,out of bounds, **frozen and outlier values** using classification / AI / deep learning.

STRONG FOCUS ON DATA QUALITY TO REDUCE FALSE POSITIVE

Success case: EGP journey to data driven

- Hydro operational efficiency - from data to real accountable value

Human is the best



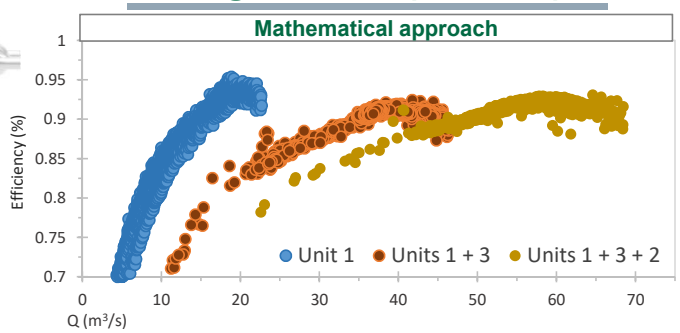
A priori or heuristic approach:
engineering model validated with test field data

Engineering approach
good start point as reference, but limited vision

Mathematical approach
powerful and faster, but risk of false positive excess

We integrated powerful mathematical approach with the engineering and machinery knowledge, in order to leverage on our strong skills in both fields

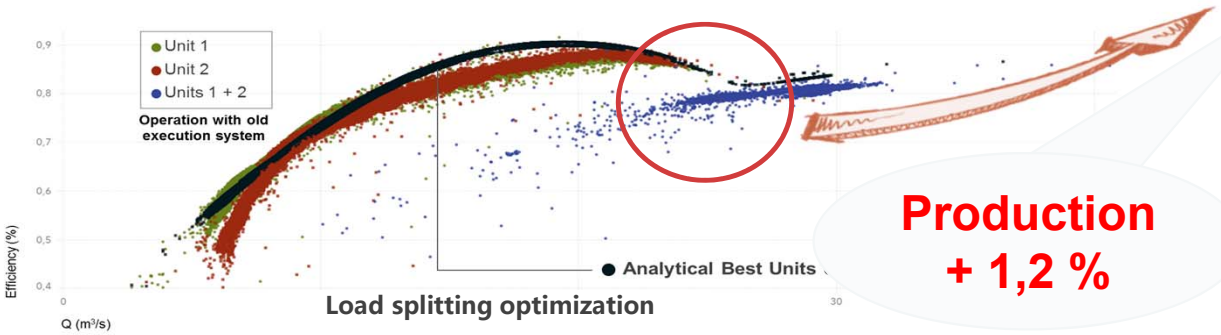
Algorithms (PI Data)



A posteriori approach:
collect real time data from PI and apply algorithms

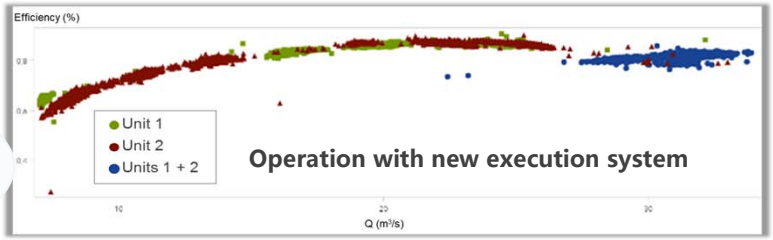
Value creation (1 HPP real case)

+ 1,2% ADDED PRODUCTION (1,3 GWh) IN 1 YEAR



Load splitting optimization

Production + 1,2 %



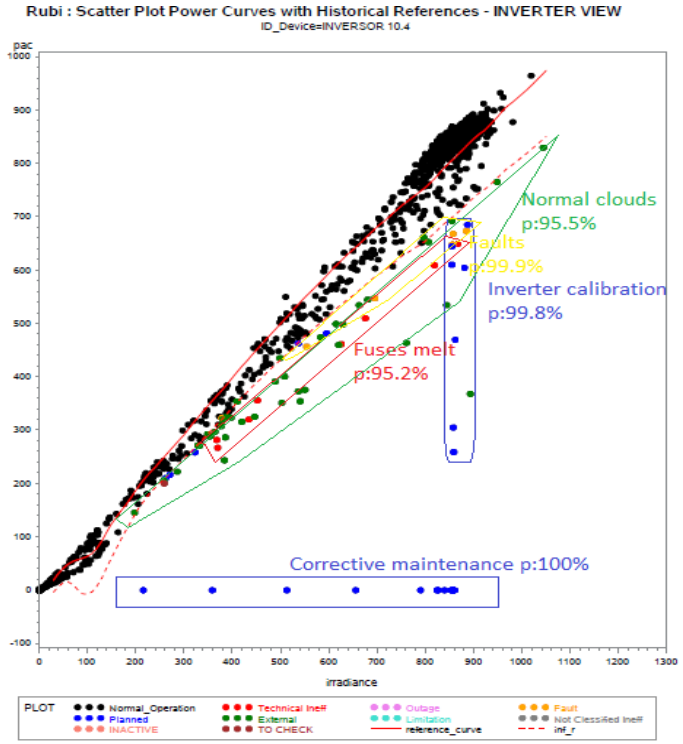
THANKS TO DATA ANALYSIS WE CAN EXTRACT MORE VALUE FROM OUR OPERATING ASSETS

AUTOMATIC LOG BOOK FOR SOLAR PP

AUTOMATIC CLASSIFICATION OF INEFFICIENCIES

Faults early detection in solar plants requires more than 8 hours of continuous hard work & extensive knowledge for the loss production classification (inefficiencies) in inverters.
AI + RPA is sought to incorporate technology and decrease the failure rate.

It combines a machine learning process to improve its evaluation and a Big Data process with 2 algorithms that compete with each other, the function objective is to improve its precision.



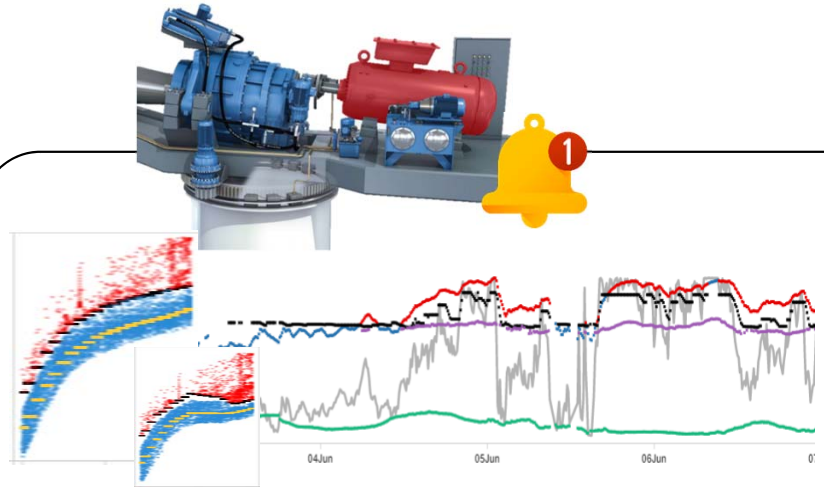
RESULTS

KPI	Results
EA improvement	99.30% June 99.17% May 99.11% April 97.71% March
Savings April to June	(2.0 GWh)

PI in Wind Technology

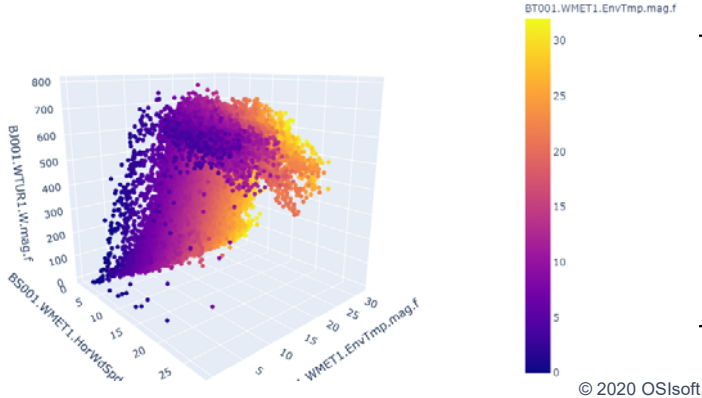
Main activities based on SCADA Data

WIND IN NUMBERS:
~ 7.000 turbines
~ 12.000 MW
~ 20÷800 tags per WTG



- Predictive Maintenance Algorithms
- Near real-time anomaly/fault detection and notification

- Multi-Variable Performance Analysis
- RCA and Continuous Improvement monitoring



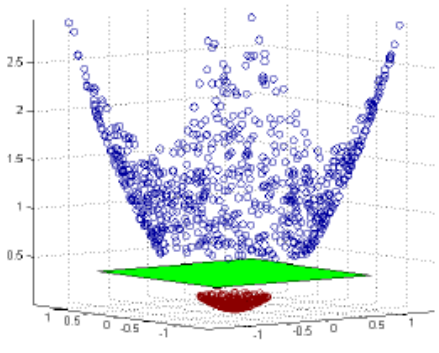
Solar Predictive

Short term forecasting of inverters failures and inefficiency

Software solution aimed to detect inverter technical inefficiencies through analysis and monitoring of plant status using PI System data acquired

Machine learning and neural networks to process

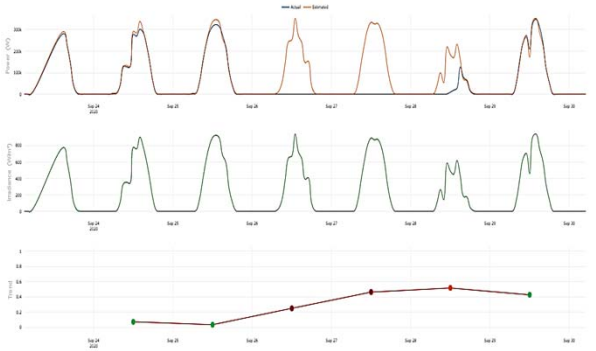
- Environmental measurement
- Inverter physical quantities



System modelled and trained for detecting specific failures pattern

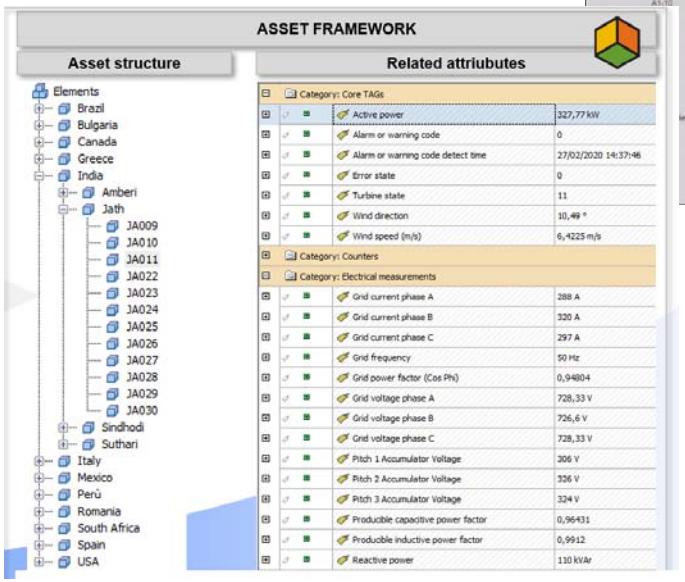
A responsive web dashboard allows users to

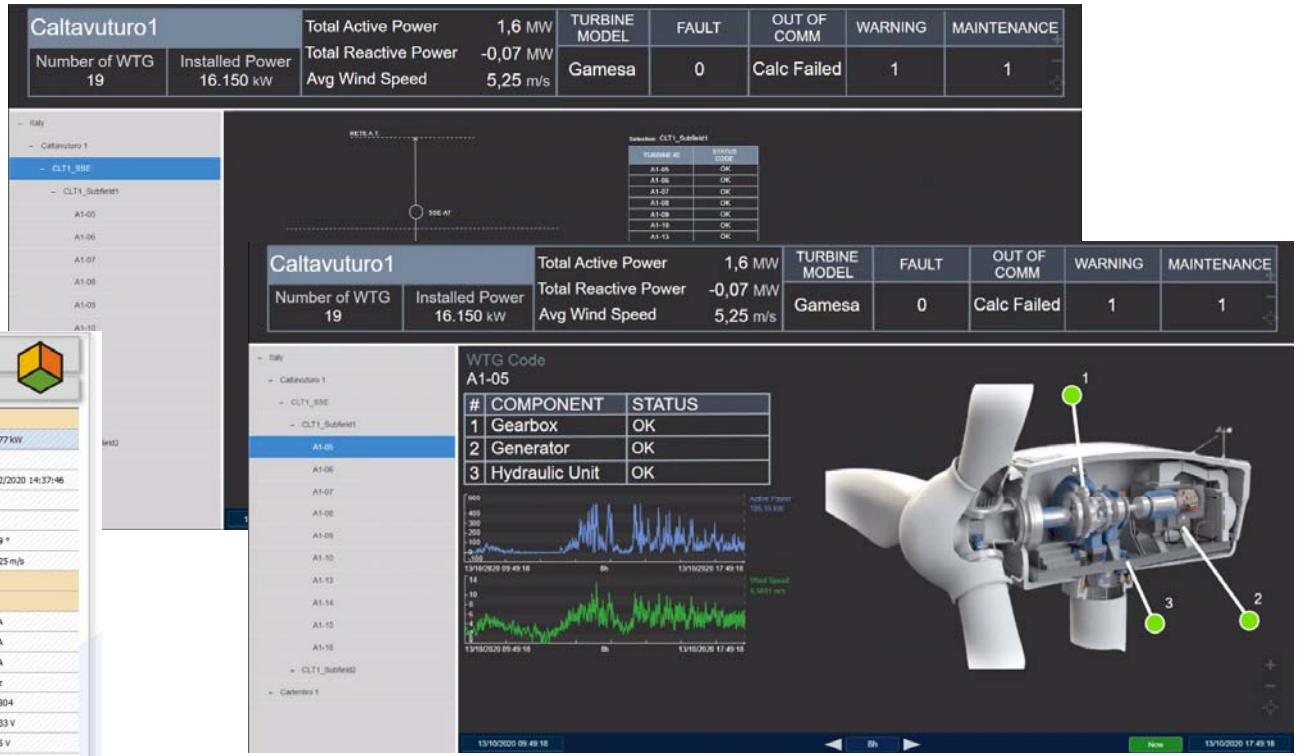
- Visualize and analyze data
- Keep warnings and alerts under control



Monitoring room

PI AF for:
- Plant and asset hierarchy
- Calculation
- Alarm and Event management





PI Vision and web component for:
- browsing
- displays
- Trends and alarms

Power Generation

The PI System's role in Enel's Digitalization

Challenge

Providing state-of-the-art real-time monitoring and analytics to many OT and IT colleagues to enable data driven decisions.

Solution

Deployed the latest OSIsoft PI technology including PI AF and PI Vision as an advanced foundation for Process Monitoring, Condition Based Maintenance, Advanced Analytics and other functions with a globally standardized approach.

Enel is a long-time EA (Enterprise Agreement) customer and leverages OSIsoft services as a true partner.

Benefits

Increased production and operational efficiency, reduced costs, 'data to the people'.

Cost controlled for OT-IT integration and true digitalization.
Significantly accelerated 'Time to Value' for Advanced Analytics & Machine Learning projects.

Thank you