EDF eMonitoring for Thermal Power Plants

Presented by Pierre ANDRIEUX – EDF - O&M Performance Team Manager
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AGENDA

EDF A GLOBAL LEADER IN POWER GENERATION

WORLD'S NO.2 ELECTRICITY COMPANY

- EDF Group is particularly well established in Europe, especially France, the United Kingdom, Italy and Belgium.
- A marked increase in the use of renewables is bringing change to its power generation operations, which are underpinned by a diversified low-carbon energy mix founded on nuclear power capacity.

LEADER IN LOW-CARBON POWER GENERATION

- No. 1 in the world for nuclear power generation.
- No. 1 in Europe for renewable energy generation.
- No. 3 in Europe for energy services.

Copyright ou crédit photo

EDF COVERS ALL ELECTRICITY-RELATED ACTIVITIES

- Generation
- Transmission, distribution
- Trading, supply
- Energy services

EDF A GLOBAL LEADER IN POWER GENERATION

edf

EDF GROUP in 2016

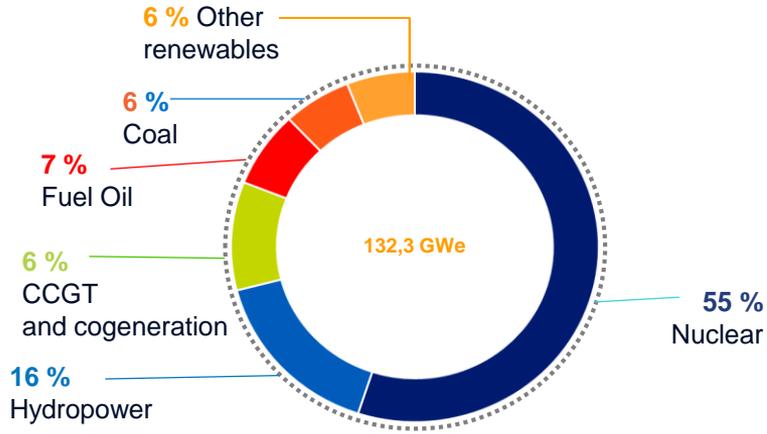- **37 M** customers worldwide

- **155 000** employees

- **€71,2 billion** sales

- **584,7 TWh** electricity generation

EDF A GLOBAL LEADER IN POWER GENERATION
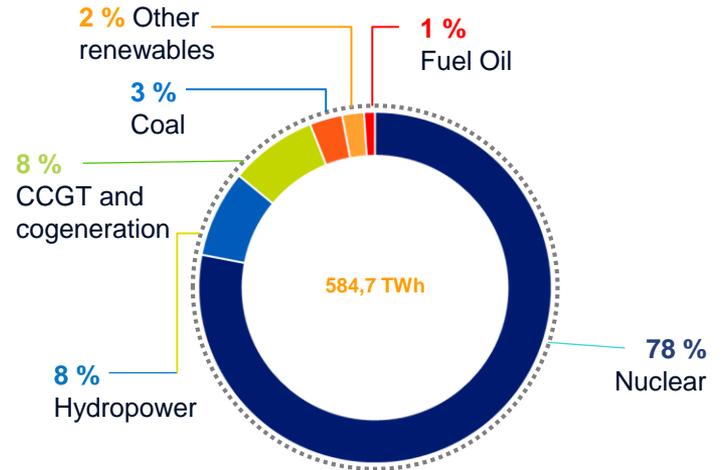
EDF GROUP'S INSTALLED CAPACITY IN 2016

6 % Other renewables
6 % Coal
7 % Fuel Oil
6 % CCGT and cogeneration
16 % Hydropower
132,3 GWe
55 % Nuclear

EDF GROUP'S ELECTRICITY GENERATION IN 2016

2 % Other renewables
1 % Fuel Oil
3 % Coal
8 % CCGT and cogeneration
8 % Hydropower
584,7 TWh
78 % Nuclear

EDF A GLOBAL LEADER IN POWER GENERATION

EDF COMMERCIAL OFFER FOR THERMAL GENERATION BUSINESS

① **STRATEGY**
- Masterplans & Grid Consultancy
- Pre-Development Consultancy

⑦ **ENVIRONMENT**
- Environmental Performance Enhancement
- Environmental Measures
- Waste Management
- Depollution

⑥ **DECOMMISSIONING**
- Final Shutdown Preparation
- Asbestos Removal
- Dismantling

⑤ **TRANSFORMATION**
- Lifetime Extension
- Equipment Upgrading
- Conversion
- Repowering
- Relocation
- Mothballing and Recommissioning

② **CONCEPTION**
- Project Development:
- Feasibility study
- Basic design
- Preparation of tender documents and management of tender

③ **CONSTRUCTION**
- Construction & Commissioning Supervision

④ **OPERATION & MAINTENANCE**
- O&M Management
- Organization Improvement
- Technical Assistance and Performance Improvement
- Training Programs and Skills Development
- **eMonitoring**

① STRATEGY
② CONCEPTION
③ CONSTRUCTION
④ OPERATION MAINTENANCE
⑤ TRANSFORMATION
⑥ DECOMMISSIONING
⑦ ENVIRONNEMENT

AGENDA

eMonitoring – Organization & services

- eMonitoring is a service of remote analyses of power plant process data
- Two services are proposed
  - **Performance** monitoring

    | Detect and analyze the power plant performance degradation | Tool: EtaPRO |

  - **Early Fault Detection**

    | Anticipate the potential equipment faults | Tool: PRiSM |

EMONITORING – ORGANIZATION & SERVICES
EDF Thermal power plant eMonitoring IT figures

32

Units monitored [1]

[1] 19 in mainland France

8

eMonitoring
IT infrastructures
including PI servers

9 GW

monitored

200 000

TAGs

EMONITORING – ORGANIZATION & SERVICES
## EDF THERMAL EMONITORING AROUND THE WORLD SINCE 2004

FRANCE
5038 MW
- Blénod 1 CCGT (1-1-1)
- Martigues 2 CCGT (1-1-1)
- Bouchain 1 CCGT (1-1-1)
- 9 OCGTs
- 3 coal fired units

EFD
- Bouchain 1 CCGT (1-1-1)

SENEGAL
125 MW
Performance monitoring & EFD
- Sendou
1 coal fired power plant

FRENCH GUINEA
EFD
- 1 mobile OCGT

BRAZIL
780 MW
- Norte Fluminense
1 CCGT (3-3-1)

UNITED KINGDOM
1290 MW
- West Burton
3 CCGT (1-1-1)

EFD
- West Burton
3 CCGT (1-1-1)

NETHERLANDS
870 MW
- Sloe
2 CCGT (1-1-1)

BELGIUM
Innovation VIB360
(Diesel motor health assessment)
- EDF Luminus – Diesel generators

IVOIRY COAST
370 MW
Performance monitoring & EFD
1 CCGT

KSA
OE eMonitoring
- Saudi Electricity Company

KSA
OE eMonitoring
- ARAMCO / NOMAC

CHILE
Performance monitoring & EFD
- El Campesino
1 CCGT (1-1-1)

ISLAND ENERGY SYSTEMS
190 MW
- 5 OCGTs

EFD
- Diesels motors

TURKEY
320 MW
Performance Monitoring
- Çan
2 CFB coal fired power plants

CHINA
2000 MW
EFD
- Fuzhou
2 coal fired power plant

VIETNAM
715 MW
- Phu-My
1 CCGT (2-2-1)

NEW CALEDONIA
110 MW
Performance Monitoring
- Prony
2 coal fired power plant

EMONITORING – ORGANIZATION & SERVICES

EDF THERMAL eMonitoring around the world SINCE 2004

- **2015**
  - BRAZIL : EFD for Norte Fluminense
- **2016**
  - FRANCE : Bouchain (Performance eMonitoring)
- **2017**
  - FRANCE : Bouchain (EFD)
  - TURKEY : MENR (Performance eMonitoring)
  - BELGIUM : EDF Luminus (Acyclismes eMonitoring)
  - SENEGAL : SENDOU (EFD & Performance eMonitoring)
  - KSA : Consultant for SEC Generation Operation Centre

Monitored Capacity (MW)
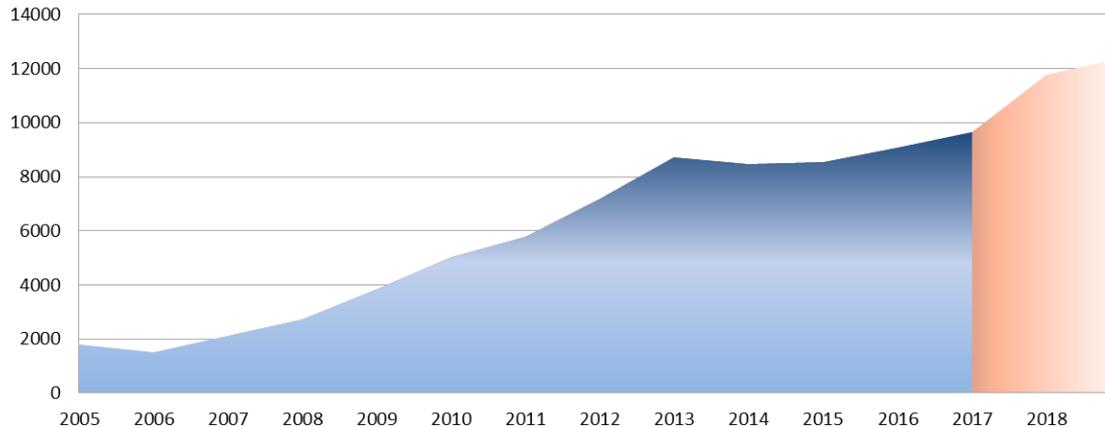
EMONITORING – ORGANIZATION & SERVICES

- The eMonitoring center is located at EDF-CIT in Paris La Défense.
- With a dedicated team:
  - Of about 14 people
  - Close to EDF-CIT's process and equipment experts
  - Benefiting from the support of the other experts of the EDF Group (EDF-DTG, R&D...)
  - Within a 3 level organization
  - Independent from the manufacturers
  - Working on weeks day with office hour and cannot replace the real time operators checks
- A centralized monitoring enables to:
  - Capitalize the alerts on all units
  - Standardize and share the best practices and initiatives
  - Propose pilot sites for developments and speed up their deployment on the other units

EMONITORING – ORGANIZATION & SERVICES

THREE LEVEL ORGANIZATION

Power plant: level 1
Real-time operation
Operation and Maintenance of the production asset

eMonitoring center: level 2
Periodical and almost real-time monitoring and analyses
Analyses thanks to modern tools to perform equipment health and performances assessments

Experts CIT, CIST, DTG: level 3
On-demand expert assessments on the process or on equipment
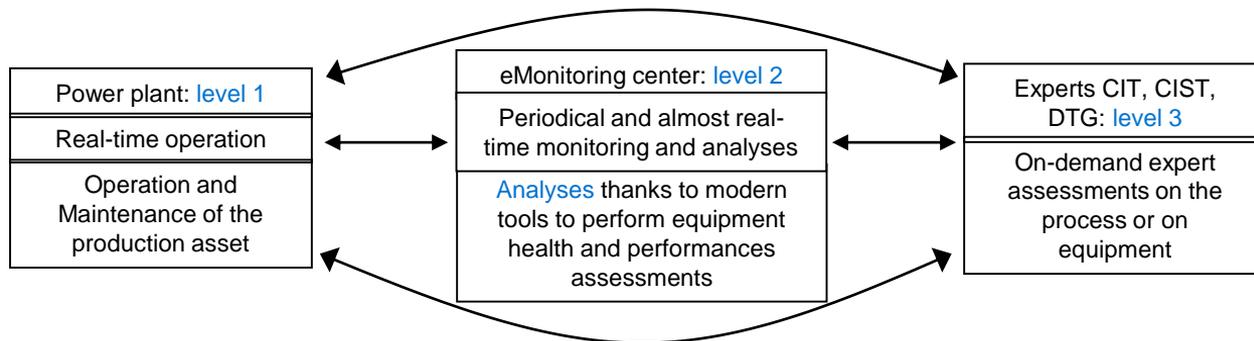
Expertise fields (EDF):

- Thermodynamics, Gas Turbines, Static machines (HRSG, condenser...), Rotary machines (Steam turbines, pumps,...), Generators, Transformers, Ancillary system, Chemistry

Specific deliverables adapted to each power plant:

- Analyses and recommendations formalized in periodical reports
- Periodical phone meetings
- Additional or on-request studies led, if necessary, with the support of our experts
- Alerts, on the process or on a system, in case of deviation and/or prominent risk for the equipment

AGENDA

EMONITORING – PERFORMANCE

Performances Monitoring report

- – **1 Sheet per main theme**
    - • Overall performances
    - • Gas turbine
    - • HRSG/Boiler
    - • Steam Turbine
    - • Condenser / Cooling Tower
    - • Auxiliary Consumptions

- – **On each Sheet**
    - • Trend of parameters
    - • Filtered average values over the monitored period
    - • Recommendations

- – **Cross comparison of similar equipments**

SHEET 10: U10 PLANT OVERALL PERFORMANCE

	Average
CAPACITY	
BL Corrected Capacity[1] (MW)	424.3
Performance tests (MW)	436.8
Guaranteed value (MW)	435.4

	Average
HEAT RATE	
BL Corrected Heat Rate[1] (kJ/MWh)	6140
Performance tests (kJ/kWh)	6106
Guaranteed value (kJ/kWh)	6107

	Average
POWER DEGRADATION	
BL Cycle Capacity Degradation (%)	1.13
BL Cycle HR Degradation (%)	1.85
Plant Efficency (%)	57.2
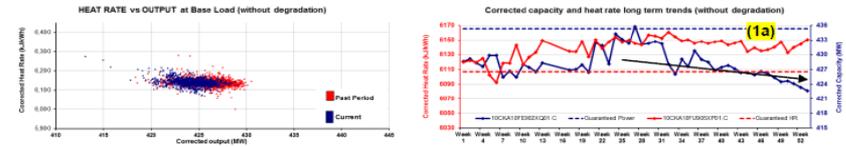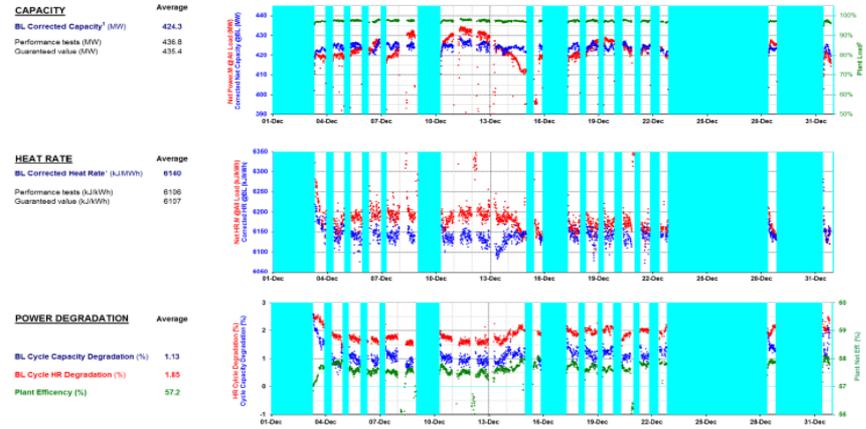
1. Corrected capacity and heat rate are the measured plant net output and heat rate corrected to design conditions using the correction curves revised by EDF-CIT for operation at base load (GT IGV Full Open).
2. Plant instantaneous net power / Plant guaranteed capacity in actual conditions

GT	HRSG	ST	CONDENSER
LOW RISK	NORMAL	LOW RISK	NORMAL
Abnormal use of the HCO due to high vibrations of the steam turbine shaft		High vibrations of the steam turbine shaft	

EMONITORING – PERFORMANCE CATCHES

Gain on Power production due to cooling tower fouling in CCGT Power Plant
- Site alert after fast increase of Delta temperature of cold water outlet, fouling suspected

Estimated impact
$\cong$ 8°C (cold end)
$\cong$ 13 MW on ST power

- Change of cooling tower cells packing , discovered filled with mud
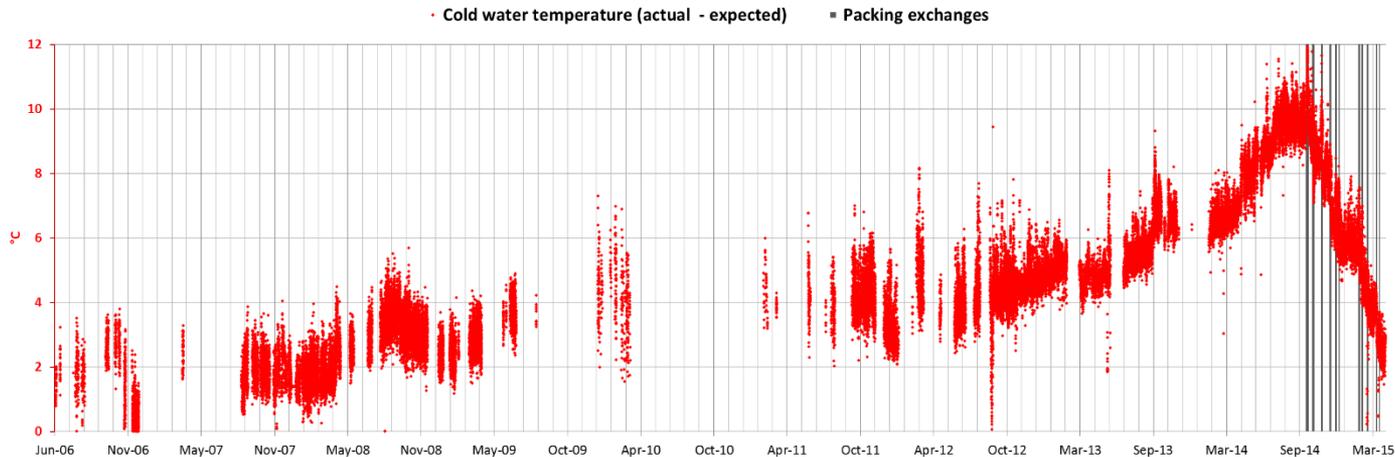
EMONITORING – PERFORMANCE CATCHES

- Improvement of condenser backpressure due to actual decrease of cold end temperature
- Power capacity increase **by 13 MW (~ 40-50 k€ / day) validated with the client**
- Cooling tower beams were found damaged to overweight caused by the accumulation of mud

EMONITORING – PERFORMANCE
EDF Thermal eMonitoring based on local PI Data Archive

On site infrastructures

Remote Access + Datalink

EDF-CIT
LEVEL 2
eMonitoring

Blénod (1)

APPS
DATA

Martigues (2)

APPS
DATA

PI DataLink

Bouchain (1)

APPS
DATA

PI DataLink

Cordemais (4)

APPS
DATA

PI DataLink

Le Havre (1)

APPS
DATA

PI DataLink

Vaires/Marne (13)

APPS
DATA

PI DataLink

Porcheville (4)

APPS
DATA

PI DataLink

Data

GAP !
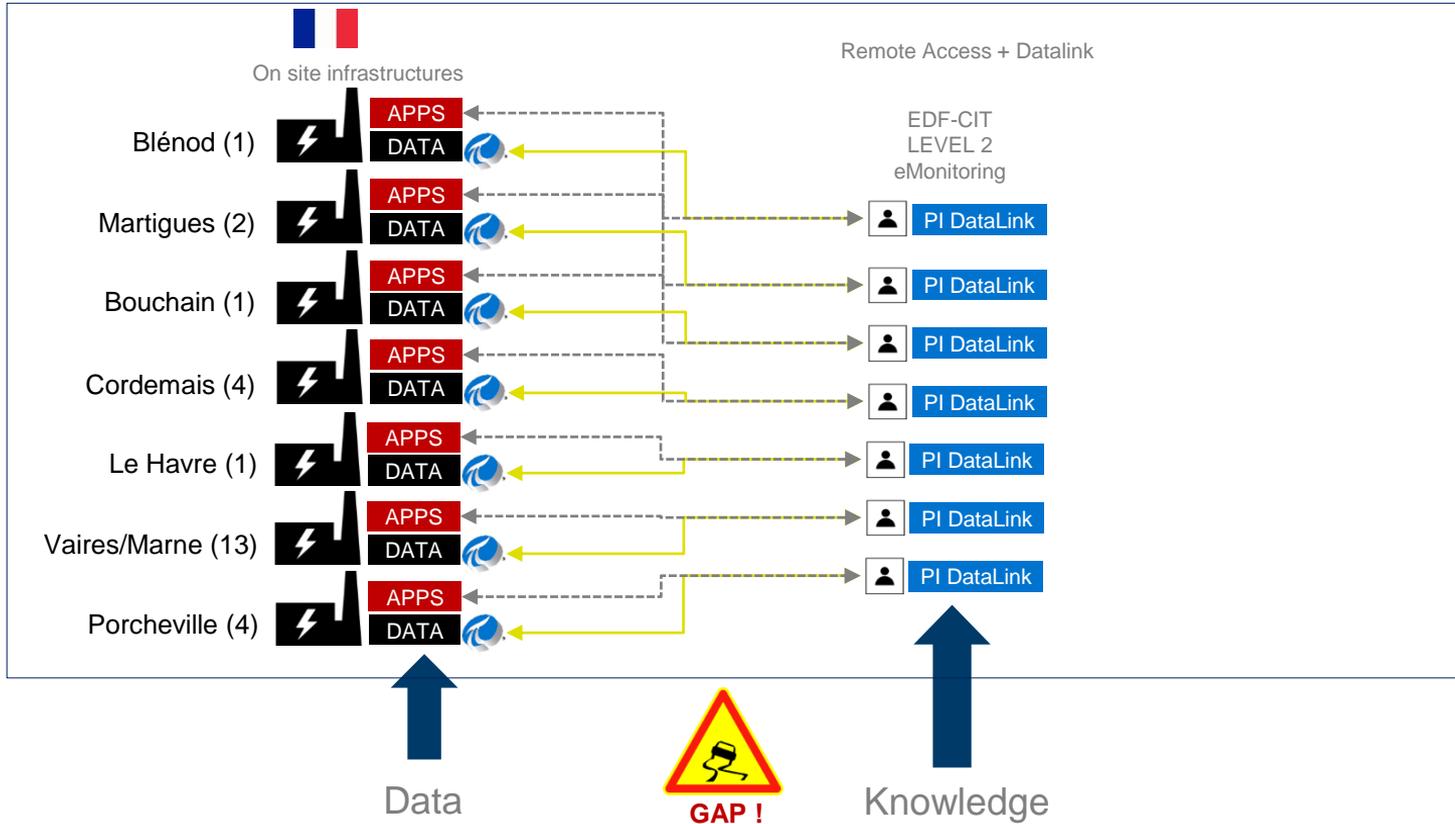
Knowledge

EMONITORING – PERFORMANCE
EDF Thermal eMonitoring based on centralized PI DA and AF
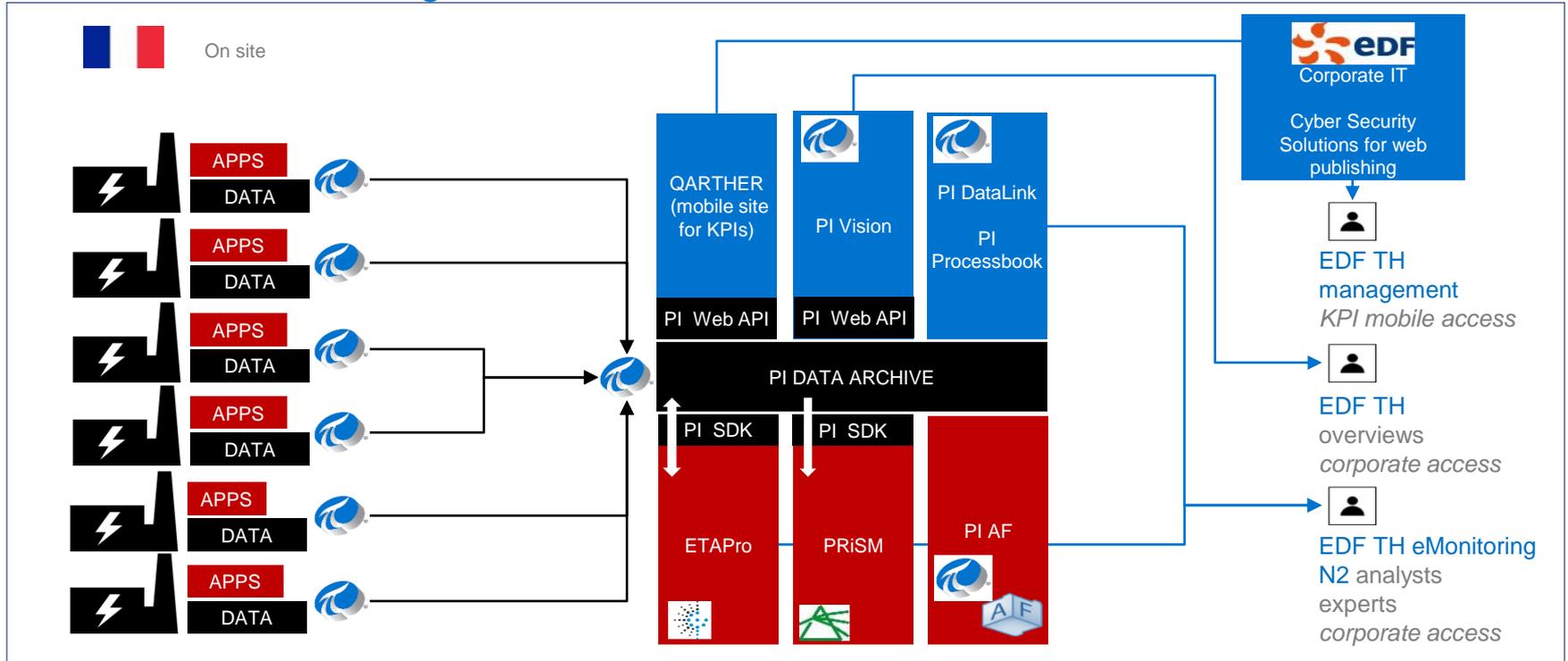
Evolution :
Knowledge, Data, and data Processing at the same place

➔ EFFICIENCY

EMONITORING – PERFORMANCE
EDF Thermal eMonitoring business TARGETS INSIDE MAINLAND FRANCE

Assets

25 EDF units   CCGT (4)
Coal (3)
TAC, Fioul, diesel

Challenges

Less thermal units in France

More complex analysis

IT Solution

Centralized data storage
for
Mutualized data analysis tools

Benefits

Less EXCEL based analysis and reporting
Supervision of Data Quality
➔ More time for business analysis

EMONITORING – PERFORMANCE
Using PI Event Frames: vibration increase

©EDF – Florent Doncourt - Blenod

- **Request for vibration analysis from CCGT Blénod:**
  - « What is the evolution of the maxima of the vibration of the circulating pump 22 during its startups since the COD (October 2011)? »

- **How to find all startups automatically since 2011?**
  - Simple modelling of a circulation pump
  - Creation of a analysis type « Event Frame Generation »

EMONITORING – PERFORMANCE
Using PI Event Frames: vibration increase on pumps

- for vibration analysis from CCGT Blénod:
  - « What is the evolution of the maxima of the vibrations of the circulation pump 22 during its start-ups since the COD (October 2011)? »

- How to extract only useful information to answer the request ?
  - Extraction of results in PI Datalink

➔ Necessary time for answer : 2 hours

EMONITORING – PERFORMANCE
Using PI Event Frames: Chemistry Monitoring

- Context
    - Monitoring of Pressure Equipment required by internal inspection service
    - Chemists on site perform monthly report
        - By hand
        - Or semi automatic (**VBA**)

- Problem : semi automatic version stopped working
    - Evolution of IT environment
    - 1 day of never ending computation

- ➜ Opportunity to update/create the semi automatic report
    - Standard calculation for every power plant (EDF doctrine)
    - With PI on every plant and PI Asset framework available

EMONITORING – PERFORMANCE
USING PI EVENT FRAMES: CHEMISTRY MONITORING

- Transfer of EDF chemistry expertise into PI AF
  - Only 1 template to create
  - A second one for visualization
  - One table import in library for TAG configuration

- 1 semi automatic report in PI Datalink
  - Project to completely automate report generation
  - 2 minutes to create (from opening Datalink to the result)

- Only 1 configuration table needed to monitor a new power plant

- Facilitate the exchanges between chemists, eMonitoring engineers and IT engineers

Monthly report build in one minute instead of VBA bugs and a formerly day long process

EMONITORING – PERFORMANCE
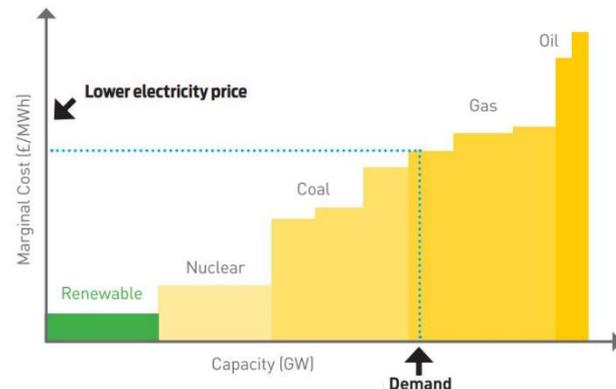## USING PI EVENT FRAMES: FUEL CONSUMPTION AT STARTUP

- Coal fired power plant can be marginal in Merit Order
  - Startup costs are to be challenged
  - Fuel (gas, coal, heavy fuel oil) consumption is the main contributor

- PI Event Frames detects and categorizes fuel consumption
  - Successful/Unsuccessful startups
  - Support
  - Cold/Warm/Hot startups

…still under construction
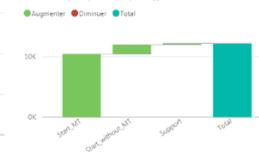
EMONITORING – PERFORMANCE
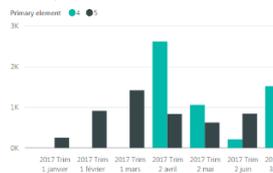## USING PI EVENT FRAMES: PERFORMANCE DASHBOARD

- eMonitoring builds and analyzes a lot of performance indicators

- We provide dashboards for our client build with PI solutions
  - Main indicators for decision-makers
  - Robust and uniform calculation
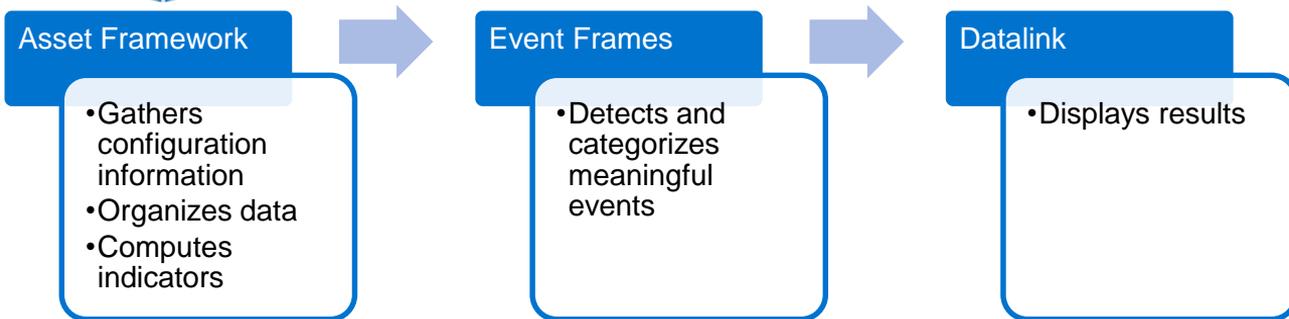
Périmètre	Charge	Indicateur	Unité	Rapport du 04/17 au 07/17	Dernier Rapport	Attendu par le modèle	Dernier essai de performance	Ecart au modèle	Ecart au dernier essai de performance	Valorisation de l'écart au modèle
Informations sur la tranche	PMD	Puissance Nette	MW	597,79	594,56		586,92	-10,87		k€/h
		Rendement Net Corrigé (PCS)	%	31,80	31,80	20,79	26,17	-11,01	-5,63	k€/h
		Rendement Net Corrigé (PCI)		33,46	29,91	21,88	27,53	-11,58	-5,93	
		Temps de fonctionnement	h	129:28:44	56:18:49					
		Energie produite	GWh	78,83	34,04			-78,83		
		Energie combustible consommée (PCS)		212,92	90,87			-212,92		
	MT	Rendement Net Corrigé (PCS)	%	24,89	26,17	18,48	27,56	-6,40	2,67	k€/h
		Rendement Net Corrigé (PCI)		26,18	27,53	19,44	28,99	-6,74	2,81	k€/h
Chaudière		Rendement	%	99,42	99,50	11,17	89,10	-88,25	-10,32	
		Consommation d'eau par MWh produits (TAV)	t/MWh	0,04	0,03	0,04		0,00	-0,04	k€/h
TAV		Consommation spécifique TAV	kj/kWh	#DIV/0!	#DIV/0!	9427,12	8291,00	#DIV/0!	#DIV/0!	
Condenseur		Vide Corrigé	mbar	20,78		0,00	3,00	-20,78	-17,78	
Auxiliaires	PMD	Puissance moyenne	MW	90,75	45,56	8,68	30,00	-82,07	-60,75	
Dépollution		NOx	mg/Nm3	65,42	76,75		60,00		-5,42	
		SOx		89,81	149,98		80,00		-9,81	
		Poussières		1,35	1,04		3,00		1,65	

AF | SDK (PI)

Asset Framework
- Gathers configuration information
- Organizes data
- Computes indicators

Event Frames
- Detects and categorizes meaningful events

Datalink
- Displays results

eDF

AGENDA

eMonitoring – EARLY FAULT DETECTION

PRiSM software as EFD tool

eMonitoring – EARLY FAULT DETECTION

Overall Model Residual

Upper bound

Lower bound

Moderate relative deviation

High relative deviation

Spread

Compressor outlet pressure

Compressor outlet temperature

Turbine inlet temperature

Gas turbine power

- Alarm,
- Trip,
- equipment deterioration
- performances loss

Prediction bounds

EARLY FAULT DETECTION - main catches

Early detection of GT cooling blades degradation in a CCGT power plant

28/10
- Site alert after important step up increase of vibration sensors on GT compressor bearing

28/10
- Diagnostics by EDF: unbalance evolution after suspected material loss
- Recommandation: GT shut down for boroscopic inspection

10/11
- Material loss confirmed by boroscopic inspection
- Planification of corrective action with LTSA supplier

10/12
- GT supplier confirms restart of the GT in safety conditions
- Maintenance has been anticipated

Estimated gain ~400 k€

Step up increase of both vibration sensors of the bearing

Wed 22

Date and Time

GT cooling blade degradation

eMonitoring – EARLY FAULT DETECTION
EDF Thermal eMonitoring business TARGETS Outside Mainland FRANCE

Assets

7 Client's units

Challenges

New world wide eMonitoring Clients

Integration of IIoT and Cloud opportunities

IT Solution*

*including opportunity of OSIsoft connected services despite constraint at this step of having one PI interface on one server for each client

ONE centralized PI Data Archive

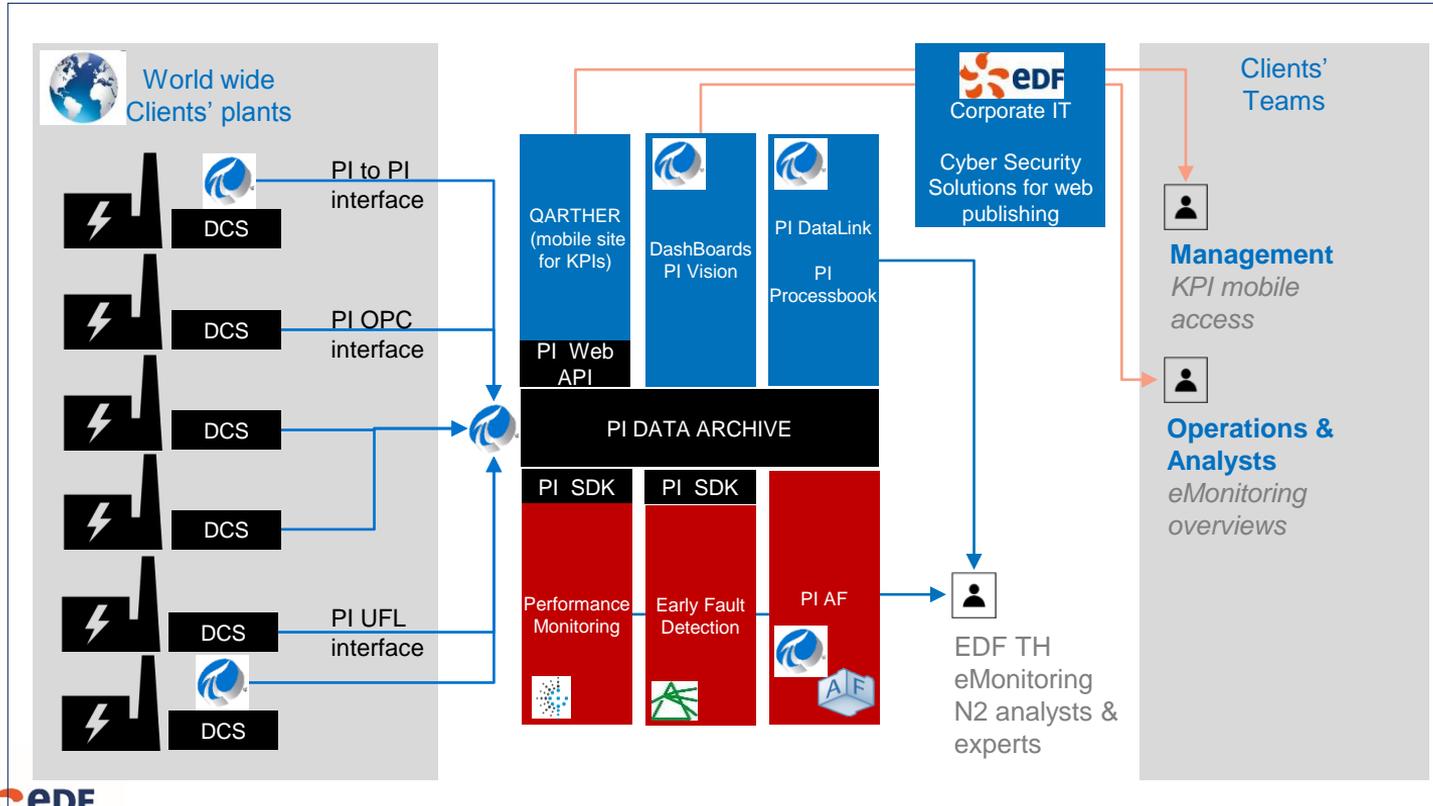Simplified data acquisition* (PI to PI , PI OPC , PI UFL)

Benefits

Simplified eMonitoring offer (reduce number of tools)

Choice of the expert tools is 100% on EDF side (no SaaS)

EMONITORING – EARLY FAULT DETECTION
CENTRALIZED PI FOR CONNECTED EMONITORING SERVICES

World wide Clients' plants

PI to PI interface

DCS

PI OPC interface

DCS

DCS

DCS

PI UFL interface

DCS

DCS

QARTHER (mobile site for KPIs)

PI Web API

DashBoards PI Vision

PI DataLink

PI Processbook

PI DATA ARCHIVE

PI SDK

PI SDK

Performance Monitoring

Early Fault Detection

PI AF

eDF Corporate IT

Cyber Security Solutions for web publishing

Clients' Teams

Management
KPI mobile access

Operations & Analysts
eMonitoring overviews

EDF TH eMonitoring N2 analysts & experts

SIMPLICITY FOR THE CLIENT

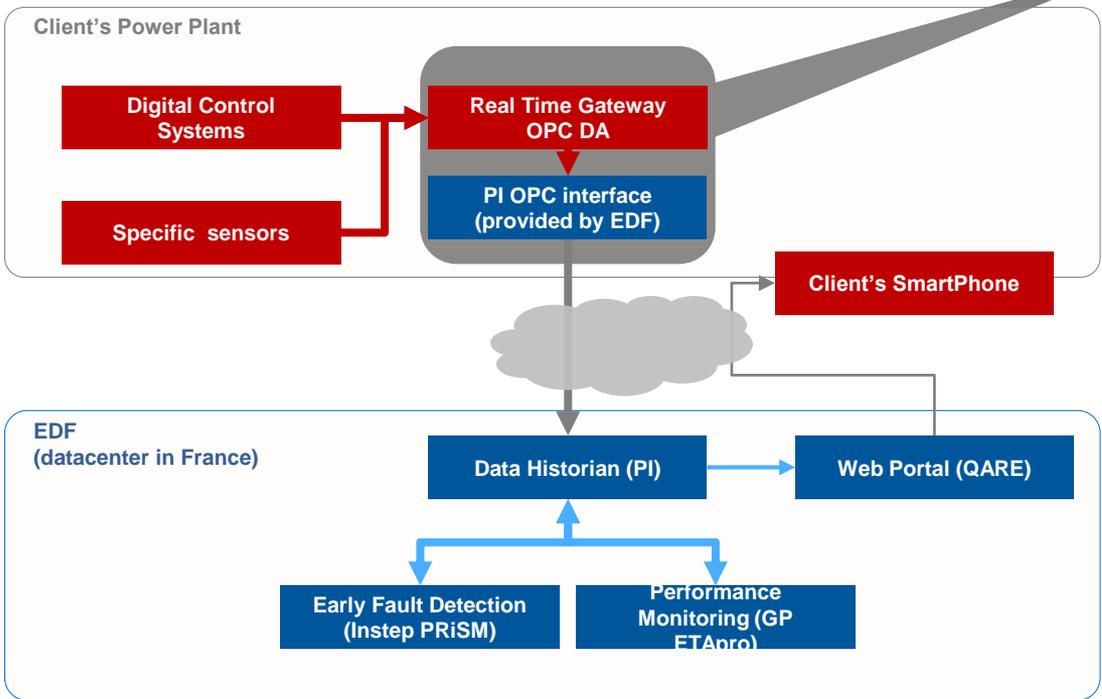no specific tools

SIMPLICITY FOR EDF

generic solutions

not sharing expert tools

EMONITORING – EARLY FAULT DETECTION
SIMPLIEST IT « CONNECTED SERVICES » INFRASTRUCTURE FOR CLIENTS

Focus on a simplified architecture schema

Issues are here :
- Firewall configuration
- OPC Configuration

Minimum requirement : a clear RACI*

Responsible
Accountable
Concerned
Informed

Client's Power Plant

Digital Control Systems

Specific sensors

Real Time Gateway OPC DA

PI OPC interface (provided by EDF)

Client's SmartPhone

EDF (datacenter in France)

Data Historian (PI)

Web Portal (QARE)

Early Fault Detection (Instep PRiSM)

Performance Monitoring (GP ETApro)

AGENDA

eMonitoring – EXPERIENCE FEEDBACK

- Thank to different technical and economic assumptions, the eMonitoring is able to estimate the avoided costs associated to performance monitoring and early fault detection in four categories :
  - ➢ **Avoided power loss**
  - ➢ **Avoided fuel over-consumption**
  - ➢ **Avoided unavailability**
  - ➢ **Avoided material Impact**
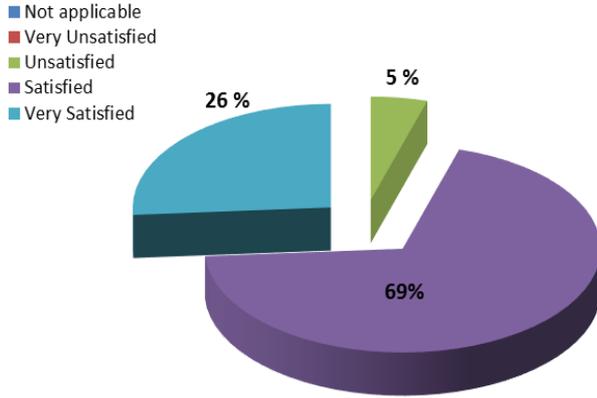
> 85 main detections since 2011

 # 30 M€ of avoided costs, split over the last 6 years

 # 5 M€ of avoided costs per year due to eMonitoring

EMONITORING – EXPERIENCE FEEDBACK

Result of the 2016 survey

Legend:
- Not applicable
- Very Unsatisfied
- Unsatisfied
- Satisfied
- Very Satisfied

- 5 %
- 26 %
- 69%

Evolution of customer satisfaction

- Participation rate
- Satisfaction rate

❑ Some customers verbatim

« We are satisfied with eMonitoring service which is indispensable part of the plant operation. The quality of the reports was improved. »
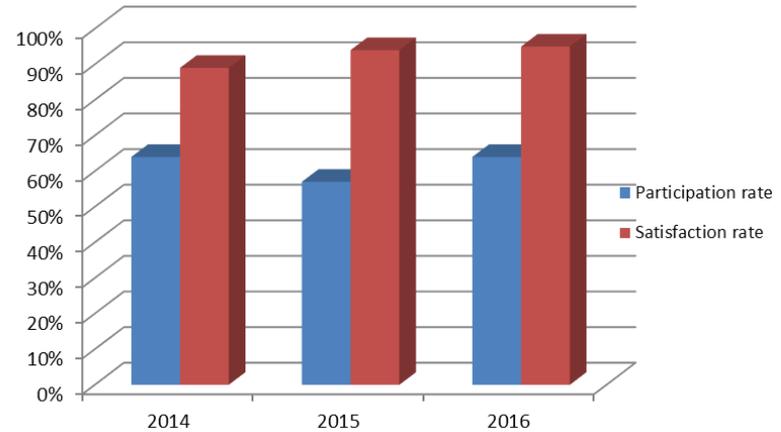
Phu-My

«Very satisfied»

Martigues

« Satisfied but even we need to improve the service together… »

Sloe

« The eMonitoring service is a complement of the work we are performing at the plant and allows us to evaluate how we are doing it and how we improve it. »

NORTE FLUMINENSE

AGENDA

1. EDF A GLOBAL LEADER IN POWER GENERATION
2. EMONITORING ORGANIZATION AND SERVICES
3. EMONITORING PERFORMANCES
   EMONITORING PERFORMANCES CATCHES
4. EMONITORING EARLY FAULT DETECTION
   EARLY FAULT DETECTION MAIN CATCHES
5. EMONITORING EXPERIENCE FEEDBACK
6. EMONITORING DEVELOPMENT

MOBILE ACESS TO REAL TIME KPI

100 % Management of the mobile site dashboard from a dedicated AF database

EMONITORING DEVELOPMENT

Thermal Services Business

• EDF Assistance to Saudi Electricity Company for their Generation Optimization Centre project

• CHILE – Octopus CCGT Project

• eMonitoring offers on going to :
- • PAKISTAN – CCGT
- • CHINA – Supercritical Coal Power Plant
- • IVOIRY COAST - CCGT
- • OMAN – CCGT
- • EGYPT – CCGT
- • KSA – Assistance for development of GOC
- •…

SERVICE PACKAGES
A number of solutions are available for the packaging of eMonitoring services:

eMonitoring	On Line Monitoring consultancy	O&M Supervision & eMonitoring
Performance monitoring and early fault detection for power plant units.	Consultancy work for clients to help them develop, build, commission and operate their own On Line Monitoring.	The eMonitoring service is combined with each O&M supervision contract of 3 years or more.

CONTACT INFORMATION

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Questions

Please wait for the **microphone** before asking your questions

State your **name & company**

Please remember to…

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감사합니다

Danke

谢谢

Merci

Gracias

Thank You

ありがとう

Спасибо

Obrigado

Case Study – Foreign Object Damage in a Steam Turbine

COMPANY and GOAL

EDF eMonitoring is a service of remote analysis of power plant process data to :

- Detect and Analyze the power plant performance degradation
- Anticipate the potential equipment faults

CHALLENGE

Analyze a brutal change of pattern during CCGT operation

- 10 bar increase noted at the HP section of the Steam Turbine
- Boiler safety valves lifted

SOLUTION

Use of dedicated eMonitoring tools and methods for Root Cause Analysis

- Analyses based on PI Data (long term and short term trends on key parameters)
- EDF Steam Turbine experts involved in the diagnostic

RESULTS

Conclusion led to a Foreign Object Damage (FOD) in the HP block

- Suspicion of Pin Ball Effect
- Confirmed by boroscopic inspection on site
- Reduced unavailability for the client (720 k€ of avoided cost)

Case Study – IP drum level regulation valve passing

Training Data
décembre 2015 à novembre 2016

COMPANY and GOAL

EDF eMonitoring is a service of remote analysis of power plant process data to :

- Detect and Analyze the power plant performance degradation
- Anticipate the potential equipment faults
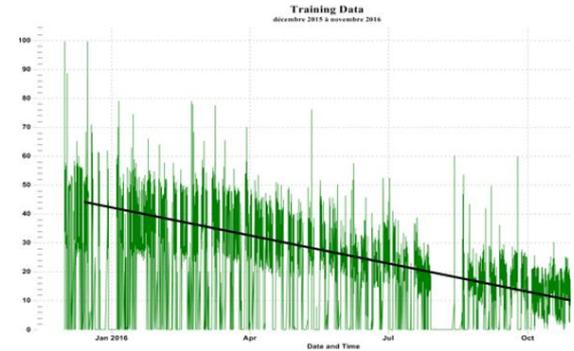
CHALLENGE

Detection of a slow degradation of an equipment

- Progressive closing of the IP regulation valve for the same feed water flow

SOLUTION

Use of Early Fault Detection models based on training data from normal plant operation

- Analysis of the contributors of the alarm on the global deviation of the model

RESULTS

Conclusion led to a leaky feed water valve

- Suspicion of valve degradation : water passing on the line
- Confirmed by valve inspection on site
- 3 days of unscheduled unavailability avoided (775 k€ of avoided cost)

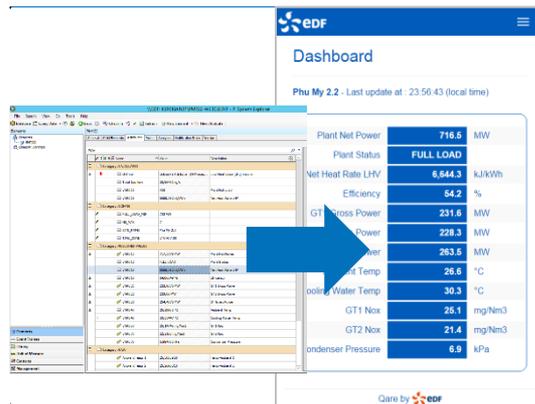# Benefits of Data Centralization for EDF Thermal eMonitoring Business

COMPANY and GOAL

EDF eMonitoring is a service of remote analysis of thermal power plant process data to :
- Detect and Analyze the power plant performance degradation
- Anticipate the potential equipment faults

EDF would like to offer this service to other electricity producers

CHALLENGE

Build low cost solution

Monitor data quality

Standardize offer

- Formerly installed on premises, eMonitoring Tools were expensive to maintain
- As data remain in the Power Plant, the data quality is not continuously monitored

SOLUTION

Centralized DataCenter

PI connected services

Generic Interfaces

- Data is centralized in one PI server
- OSIsoft provides the interface between local DCS or DCS
- EDF IT dept. provides secured publication on internet/mobile site

RESULTS

Packaged eMonitoring Service Offer for commercial team

2 New Clients in 2017

- Pricing of the service if more simple due to standardized solution an less on-site work to do
- Time to market is faster, as most of applications are already running in the datacenter