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How do we use Digital Twins for nuclear plant monitoring ?

02/06/22 - Aurelien SCHWARTZ – CEO of Metroscope

We build Digital Twins for the monitoring and diagnostics of power plants.
As of November 2021, we equip 65 power plants around the world.

Metroscope is a member of the EDF Group

eDF

Monitoring & Diagnostic Software

Metroscope provides a software to understand faults and energy losses on industrial equipment

- Monitor key parameters

- Monitor deviations

- Automatic detection of energy losses

- Automatic and live fault diagnostic

- Impact on performance

- Interactive features

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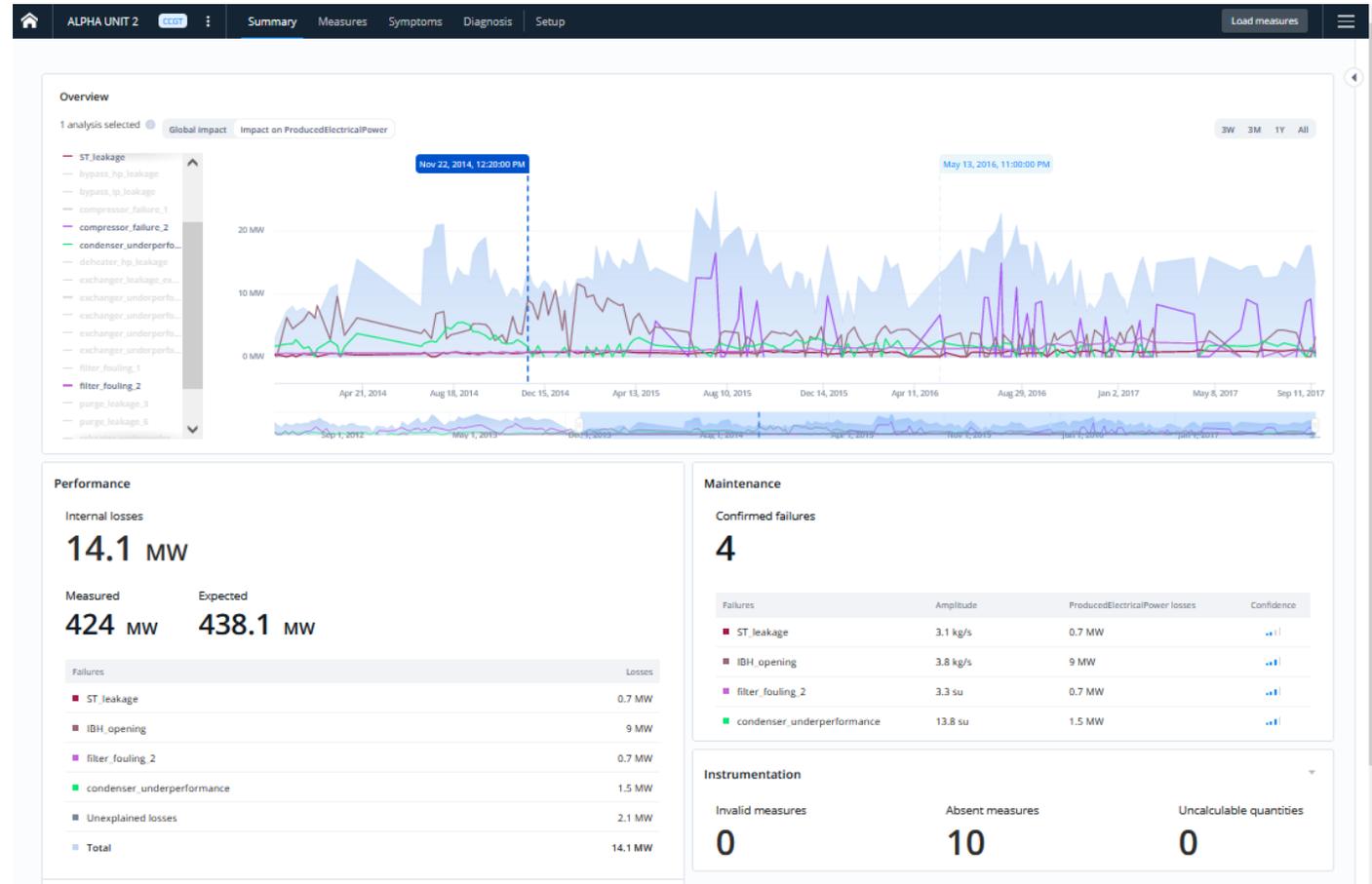
Detect symptoms

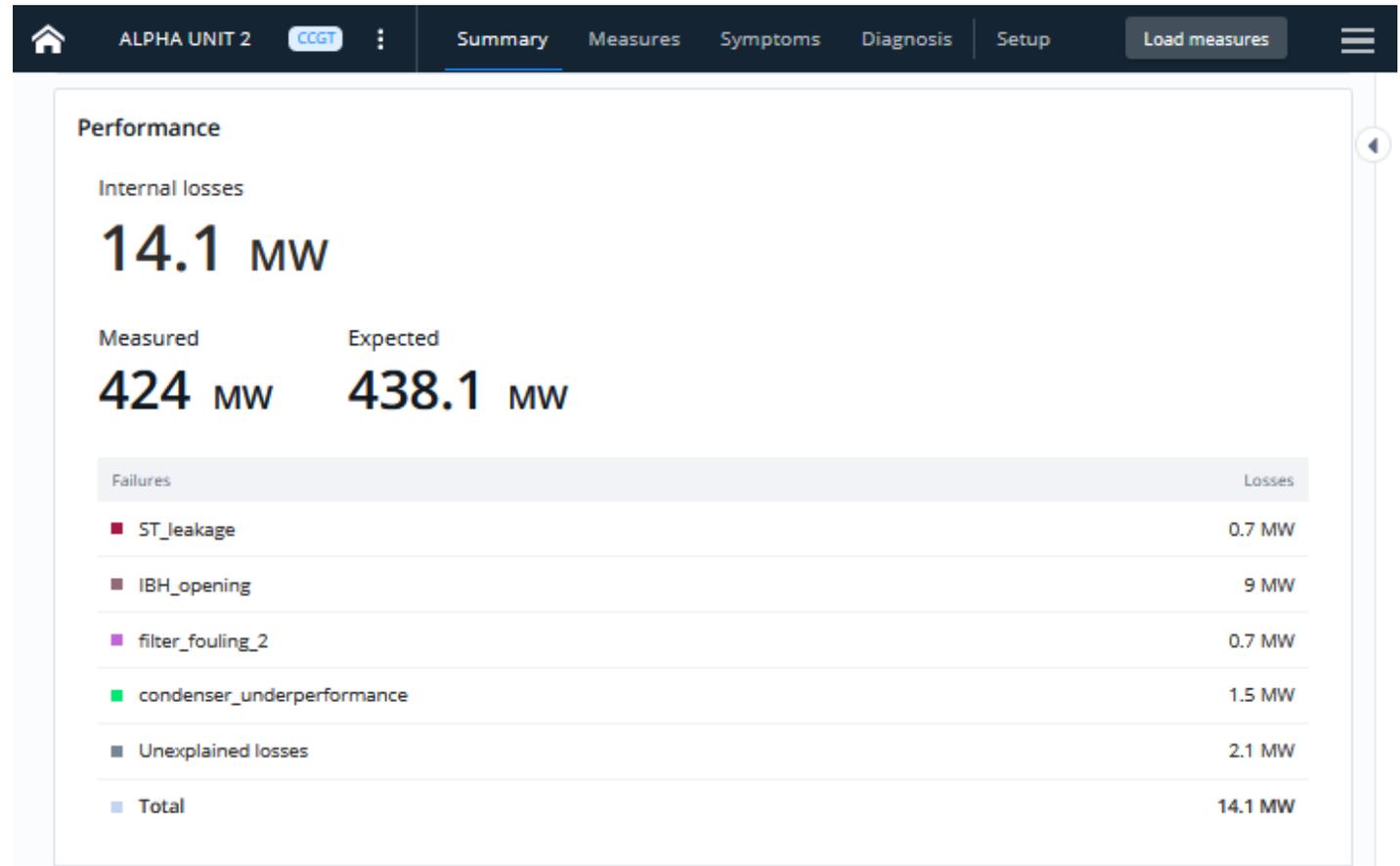Automated detection of abnormal behaviors thanks to the Digital twin

- key parameters (blue line in the picture) are compared to their expected value given by the Digital Twin (green line) over the history

- Visual cues to pinpoint symptomatic behaviors

- Follow and highlight the evolution of the symptom over time.

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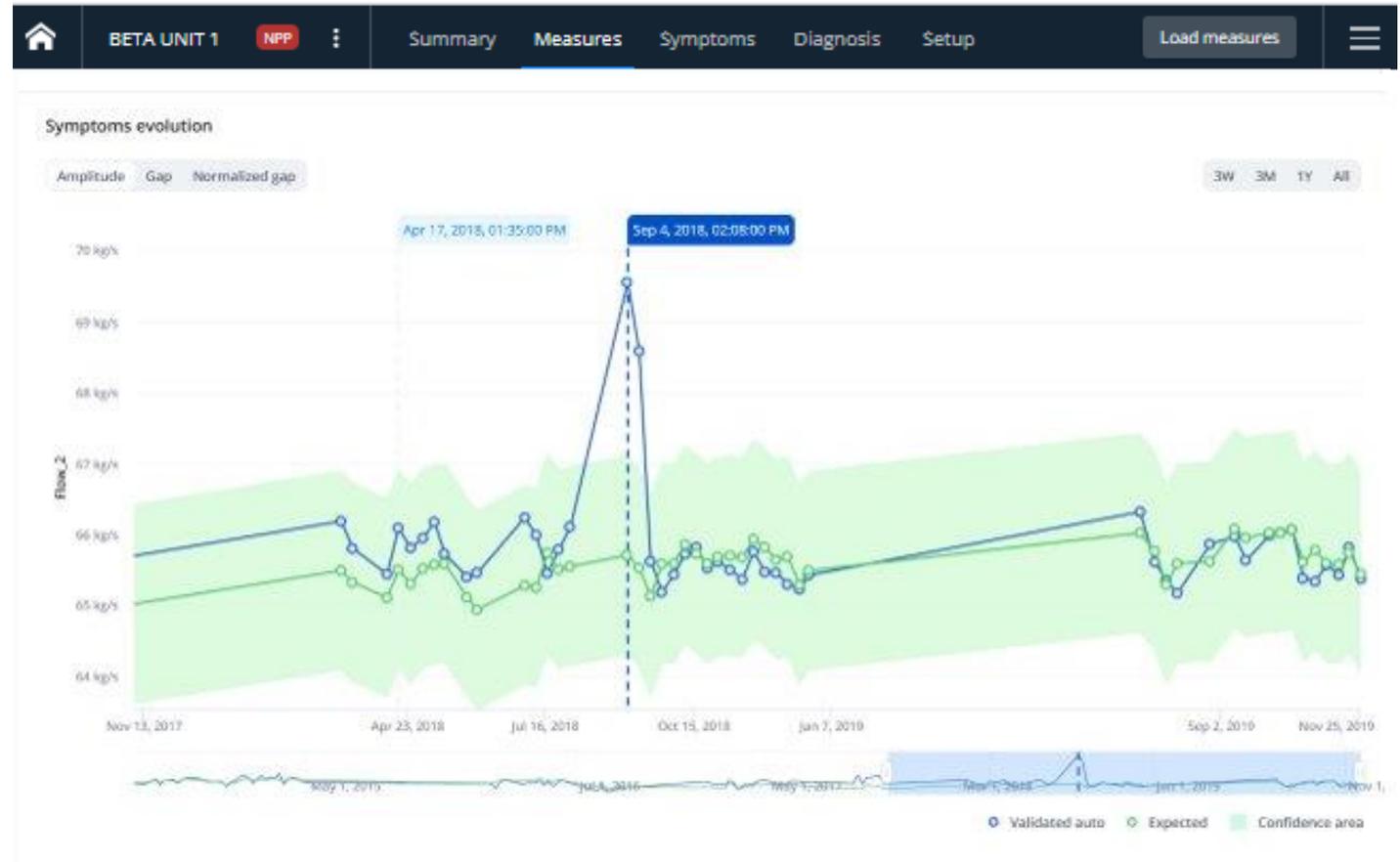
Understand root causes

Diagnostics results from provided after trying thousands of faults scenario in the Digital Twin

- automatic identification of faults and their magnitude

- automatic quantification of specific impact on the overall performance

- associated level of confidence for each fault

ALPHA UNIT 2 CCGT | Summary | Measures | Symptoms | Diagnosis | Setup | Load measures

Performance

Internal losses

14.1 MW

Measured | Expected
424 MW | **438.1** MW

Failures	Losses
ST_leakage	0.7 MW
IBH_opening	9 MW
filter_fouling_2	0.7 MW
condenser_underperformance	1.5 MW
Unexplained losses	2.1 MW
Total	14.1 MW

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Key Principles

- The digital twin is encapsulated in our software and governed by an inferential engine in charge confronting the twin to the process data

- Any fault impairing the process is automatically located and classified by order of likelihood. Its magnitude is quantified and its impact on generation is qualified

$$diagnostics = P(faults \mid symptoms)$$

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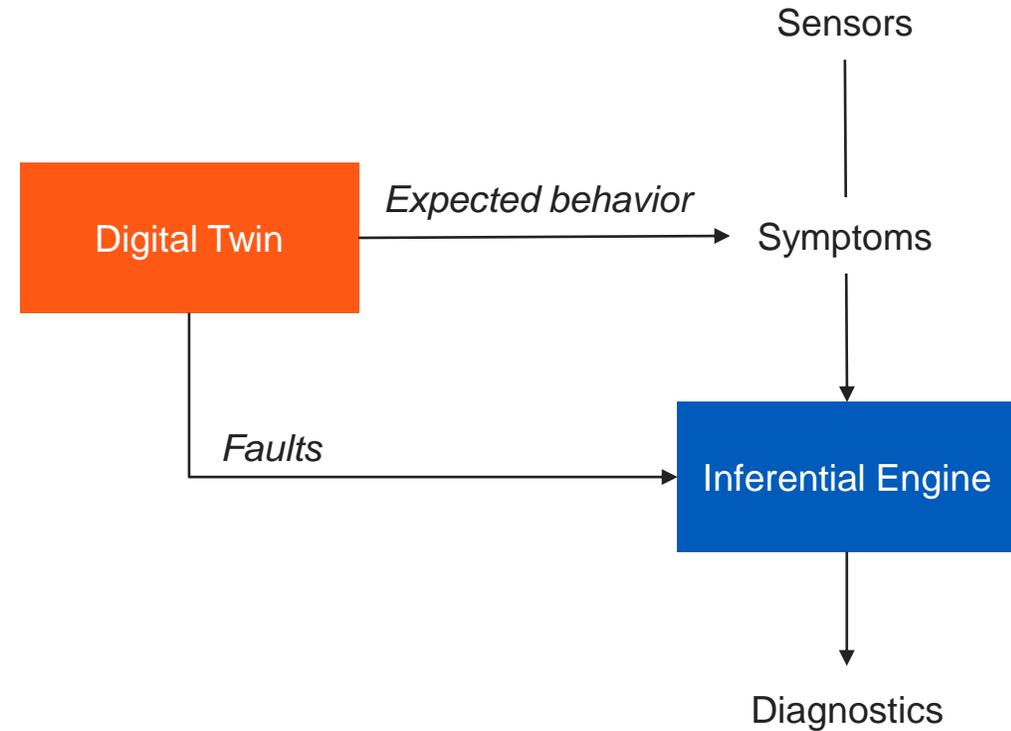
"A digital twin is a digital representation of a real-world entity or system "
Gartner 2021

Usecase – Unit X

Name   Unit X
Design   Pressurized Water Reactor
Manufacturer   Framatome
Power Gen   900 MW
Initial operation   1980
Location   Europe

Digital Twin of Unit X - Model

UNIT X nominal model simulates the generation of the plant from the steam generator to the alternator
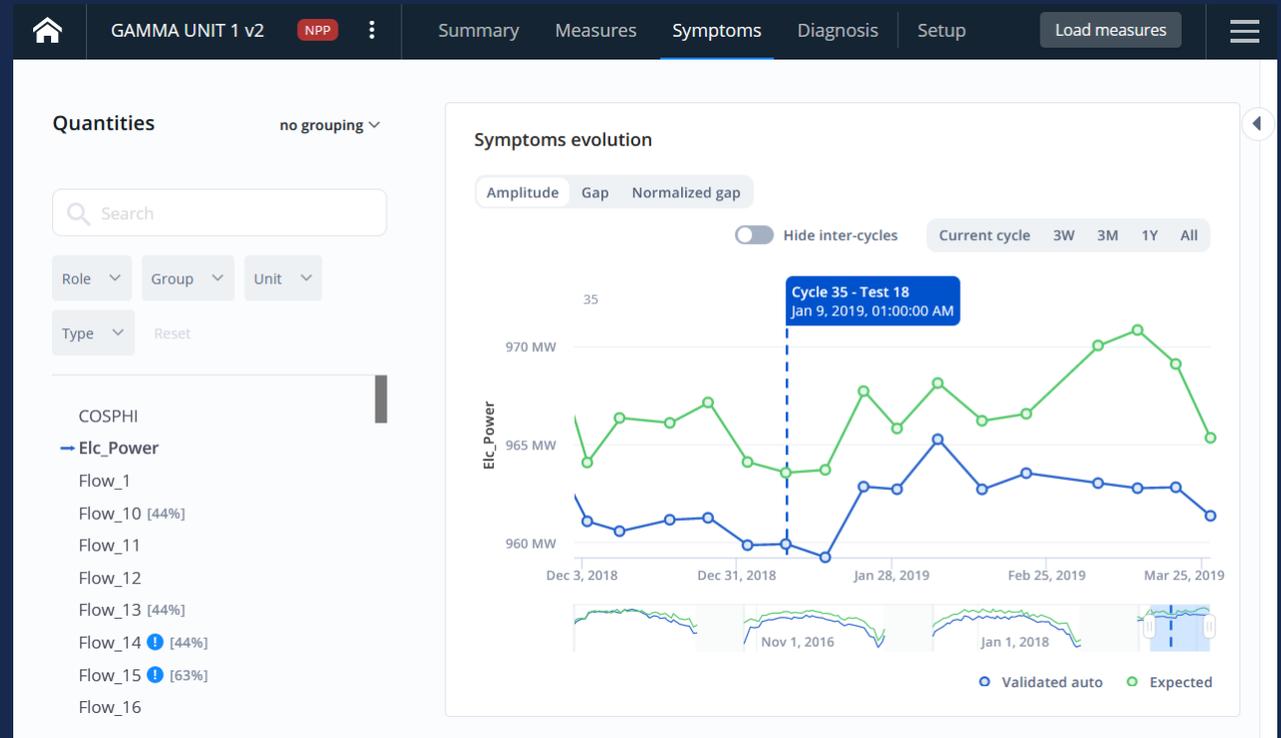
- 12 000 physical equations embedded
- 135 components
- 95 measurements
- 5 years of data history

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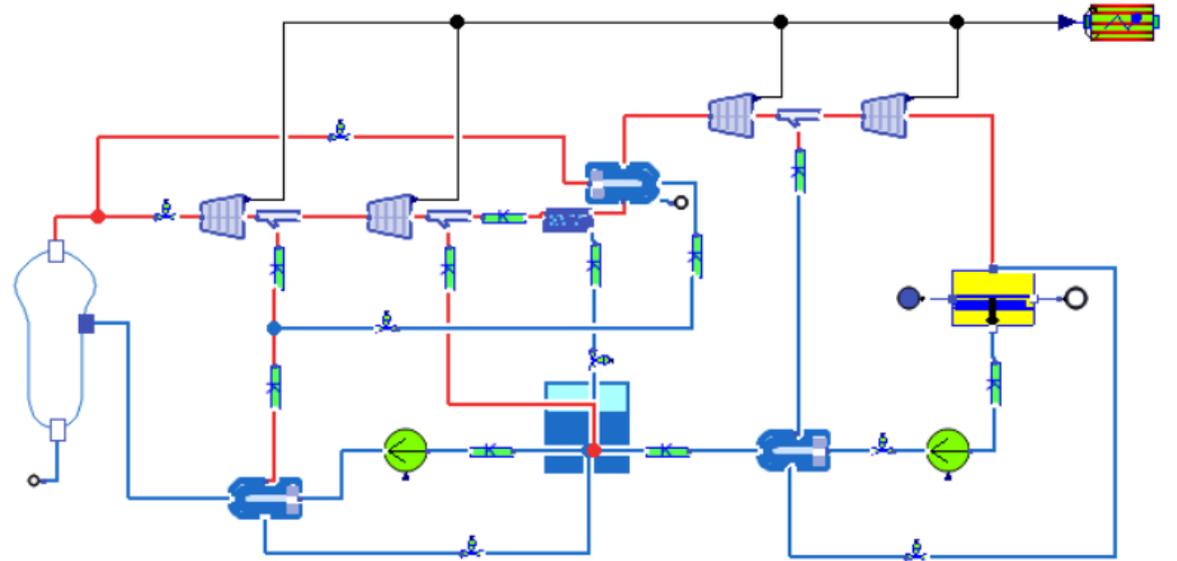
Monitoring of Unit X - Performance

On the 9th of January 2019

- UNIT X was performing at **959.9 MW**

- The Digital Twin calculates that the plant should be performing at **963.5 MW**

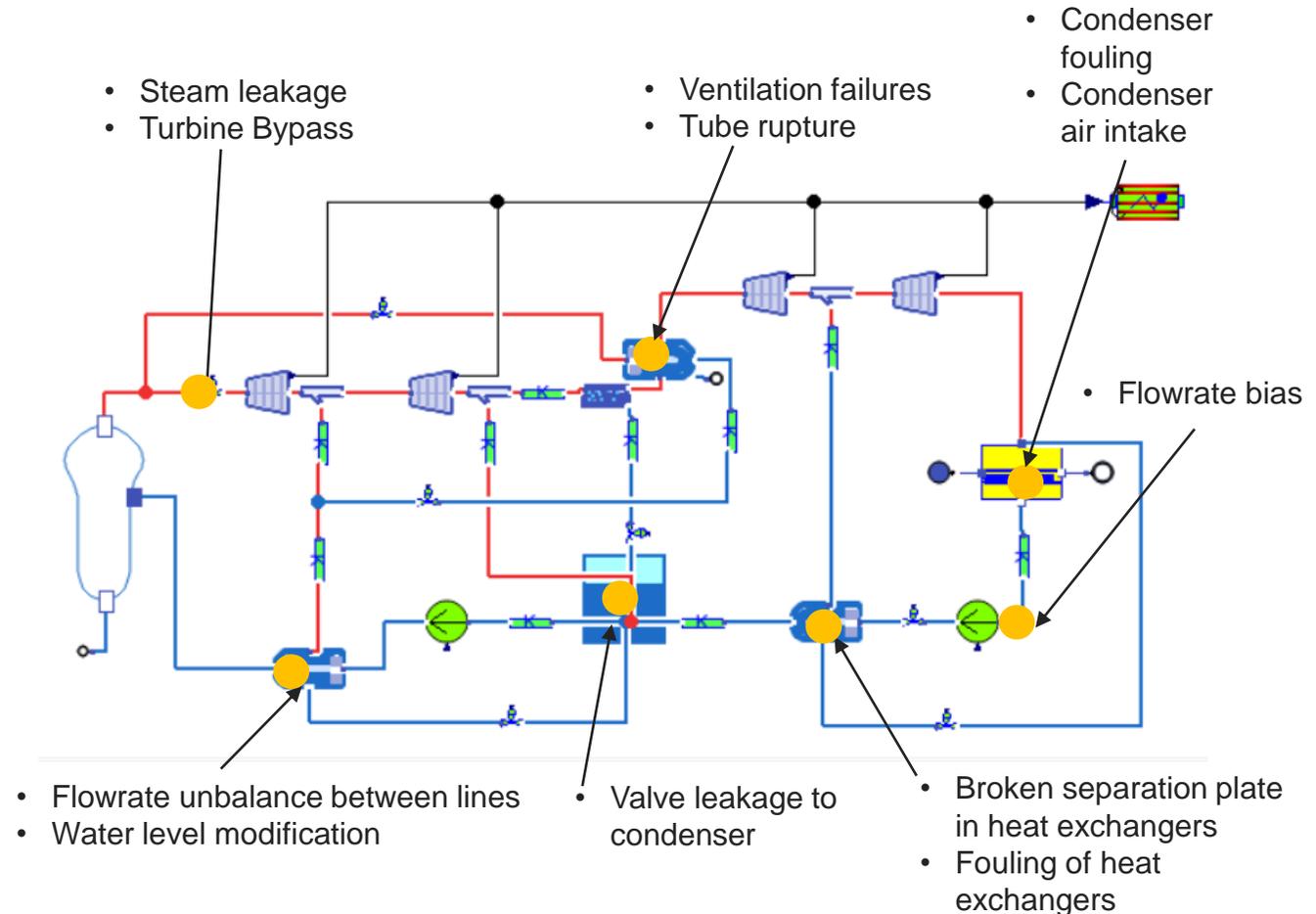- **3.6 MW are missing due to internal losses**

Digital Twin of Unit X - Faults

75% of faults happen on the secondary side

Over 80 faults embedded in the Digital Twin

- Flowrate bias
- Steam leakage
- Turbine bypass
- Valve leakage to condenser
- Heat exchanger tube rupture
- Heat exchanger broken separation plate
- Heat exchanger water level mis-regulation
- Heat exchanger fouling
- …

- Steam leakage
- Turbine Bypass

- Ventilation failures
- Tube rupture

- Condenser fouling
- Condenser air intake

- Flowrate bias

- Flowrate unbalance between lines
- Water level modification

- Valve leakage to condenser

- Broken separation plate in heat exchangers
- Fouling of heat exchangers

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The Inferential Engine

What is the most likely faults scenario to explain the current symptoms?

- Performs a Root Cause Analysis through a continuous probabilistic approach

- Using Bayesian networks

- Testing thousands of faults scenarios

- While giving special care to uncertainties.

faults

symptoms

Diagnostics = P(faults | symtoms)

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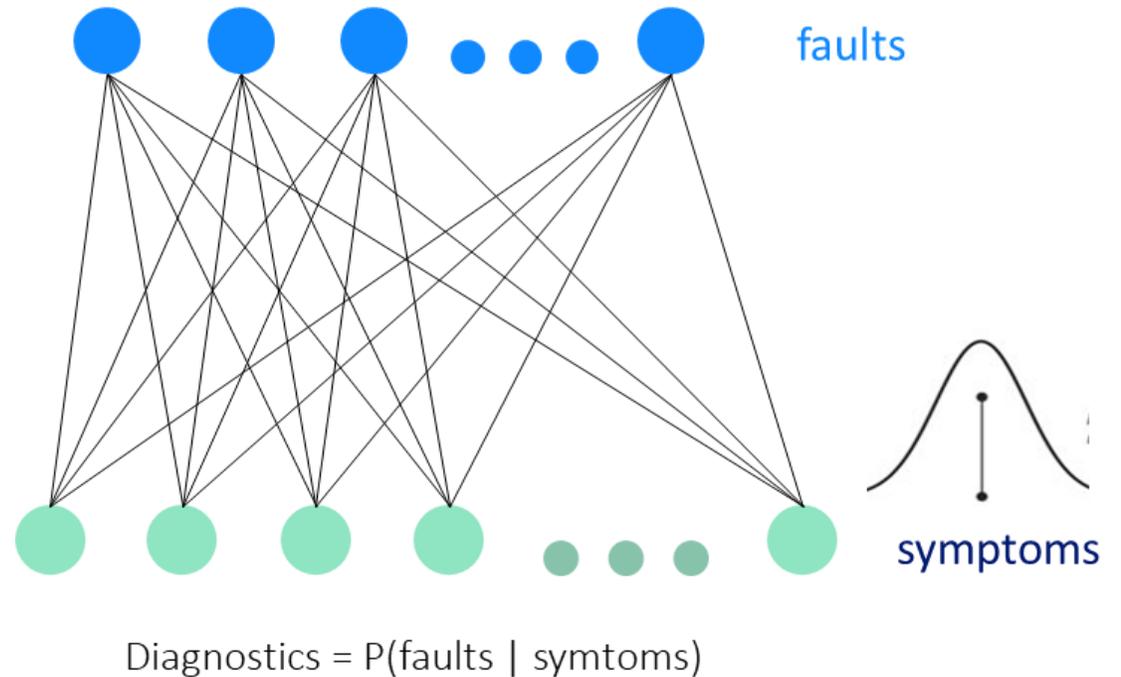
Diagnostics Example

On the 9th of January 2019

- The Digital Twin identified a **Tube rupture** in a Feedwater Reheater

- Initial detection on Dec 23 with a magnitude of 3kg/s

- Fixed by maintenance teams at the end of Feb, with a magnitude of the leak of 15 kg/s
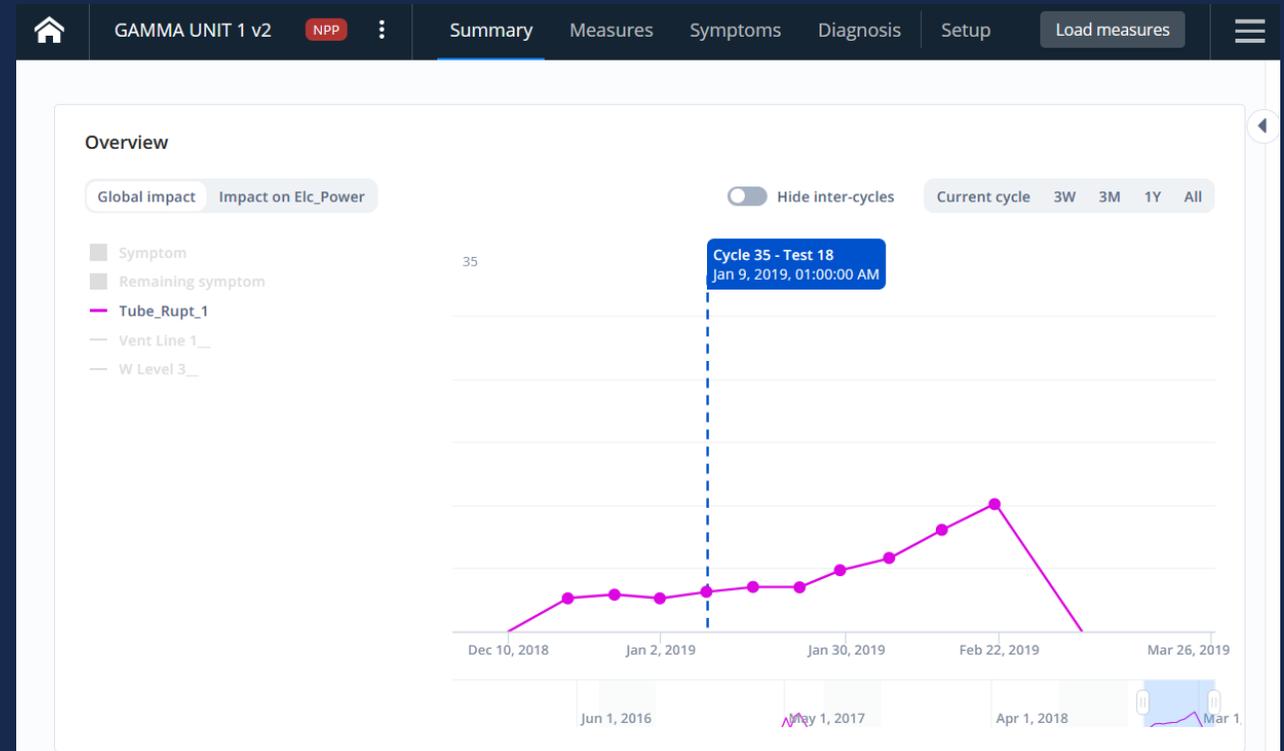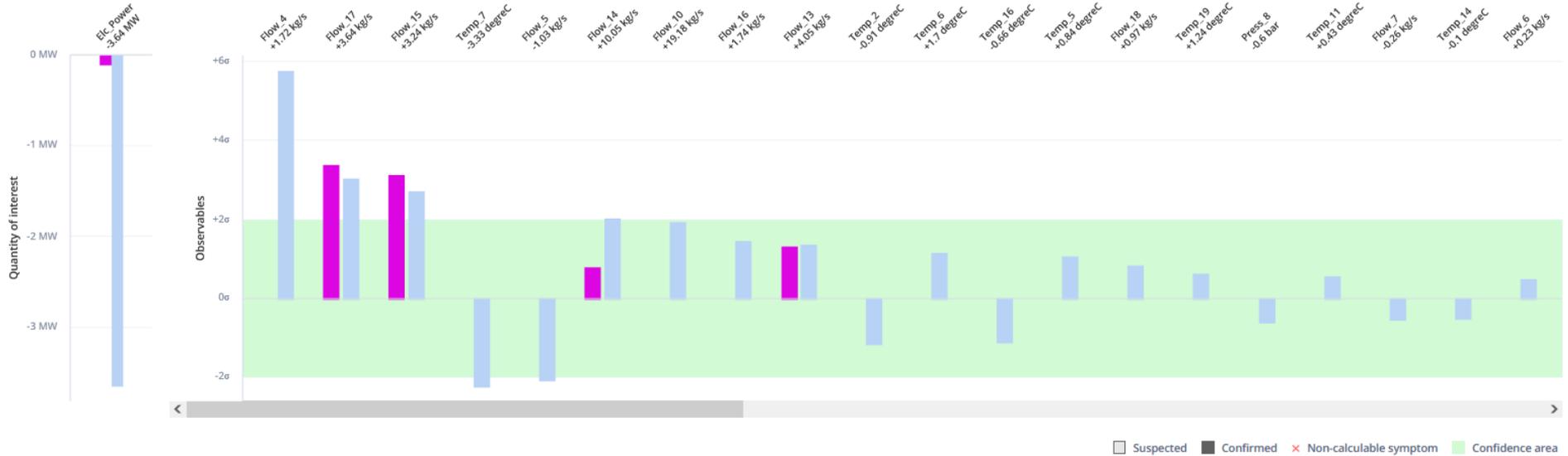
Signature of the tube rupture
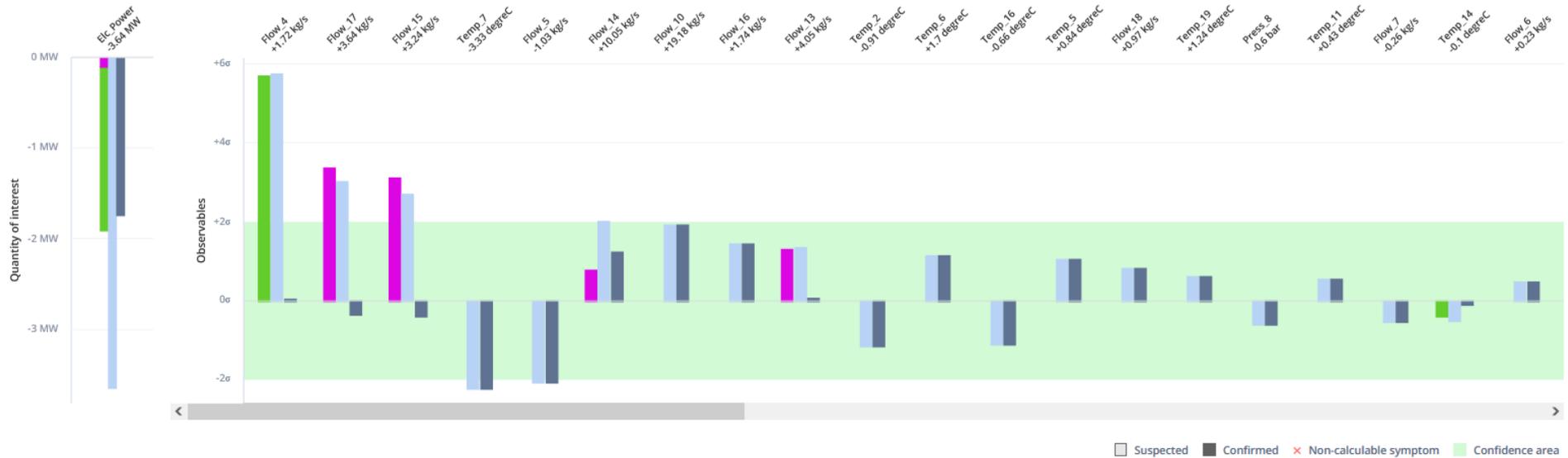
Full diagnostics on Jan 09

▶ Focus on the selected analysis (Cycle 35 - Test 18 - Jan 9, 2019, 01:00 AM) ⓘ

Decreasing | A-Z

Flag selected quantities
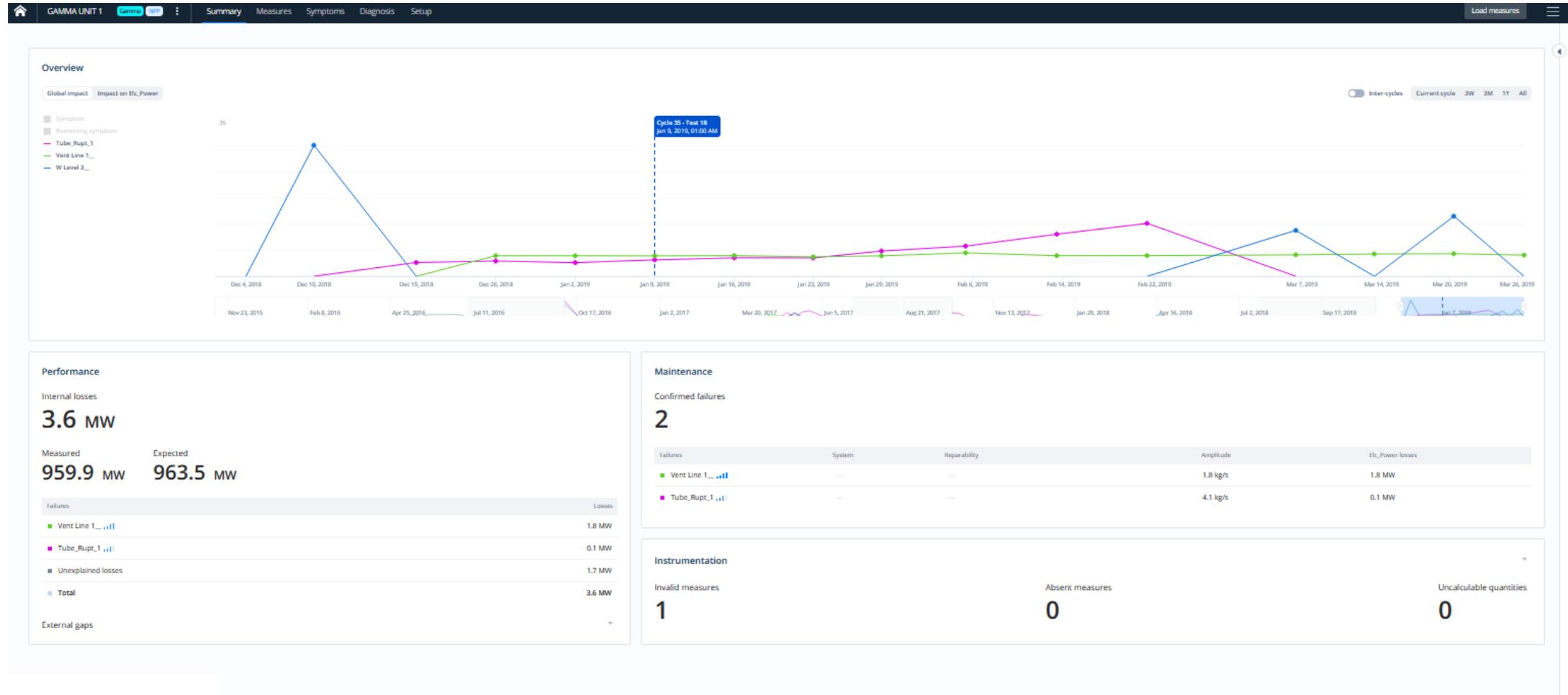
- Symptom
- Remaining symptom
- Tube_Rupt_1
- Vent Line 1__

☐ Suspected   ■ Confirmed   ✕ Non-calculable symptom   ☐ Confidence area

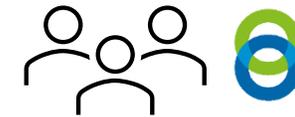metroscope

Full diagnostics on Jan 09

Users

- More than 300 active users worldwide

- Accessible and usable by as many people as possible

- 80% users display MTS results outside of their division

Corporate
asset management, fleet supervision

M&D Center
engineering teams supporting the operations

On-site teams
maintenance, operations, peformance, metrology

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Key Figures

65 Units
equipped worldwide

2000 GWh Losses
detected in 2021, approx 980 000 tons of CO_2

>90 % reliability
according to our customer's experience

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Thank you for your attention