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USING AI/ML TO ENHANCE THE OPEX AND CAPEX OF GRID OPERATIONS WHILE IMPROVING RELIABILITY AND REDUCING RISK

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INDUSTRY CHALLENGES

Do you have the immediate answer the following questions?

Health & Monitoring

Asset Replacement: What is the most critical equipment to be replaced in the coming 5 years?

Asset Maintenance: What are your current top 10 urgent maintenance actions for in your fleet?

Asset Performance: What are the 10 lowest performing\at risk assets (e.g. transformers) in your fleet? What is their estimated residual life? What is their probability of failure?

Asset Behavior: Are you familiar with your assets operating characteristics, failure modes and how to prevent & avoid asset failure?

Asset Current State: How up to date is the data and information about your assets?

Strategy & Planning

- Do you have a plan for how you can spend your budget in most effective way?
- How much risk reduction will be achieved in $?
- What will be the asset KPI improvements (Health, Maintenance, Probability of Failure, Risk)?
- If the budgets were reduced what is the impact on the above business objective, can you ensure critical actions are not impacted?
- When is the optimal time to perform maintenance or replace an asset?
- Can the workforce achieve what is required within the allocated time and budget?

AI IN APM SYSTEM

Artificial Intelligence (AI) & Machine Learning (ML) in APM

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Customer/Industry Challenges

- UC1. Early prediction of unhealthy grid assets (transformers) and classification of fault severity in the absence of the grid experts.
- UC2. Improve CAPEX investments in grid assets with more accurate Estimated Residual Life (ERL) models.
- UC3. Improve OPEX investments by reducing field maintenance activities while improving the identification of potential asset failures.
- UC4. Utilize thermal images of grid assets and automatically identify asset components and effectively extract the right insights.

Solution Proposal Using AI & ML

- Identify at-risk assets and classify the grid equipment fault severity based on blueprints developed using algorithms of grid data.
- Asset models that consider additional grid parameters (such as asset design, cooling system, geographic location, loading pattern, aging profile) which today are not considered in the physical models of the ERL of assets.
- Reduce the number of condition parameters required to effectively evaluate the failure of assets by identifying the most relevant data for asset FMEA.
- Automatically process thermal images, recognizing the assets and components to evaluate the thermal signatures without the need of thermographer analysis.

AI & ML in APM

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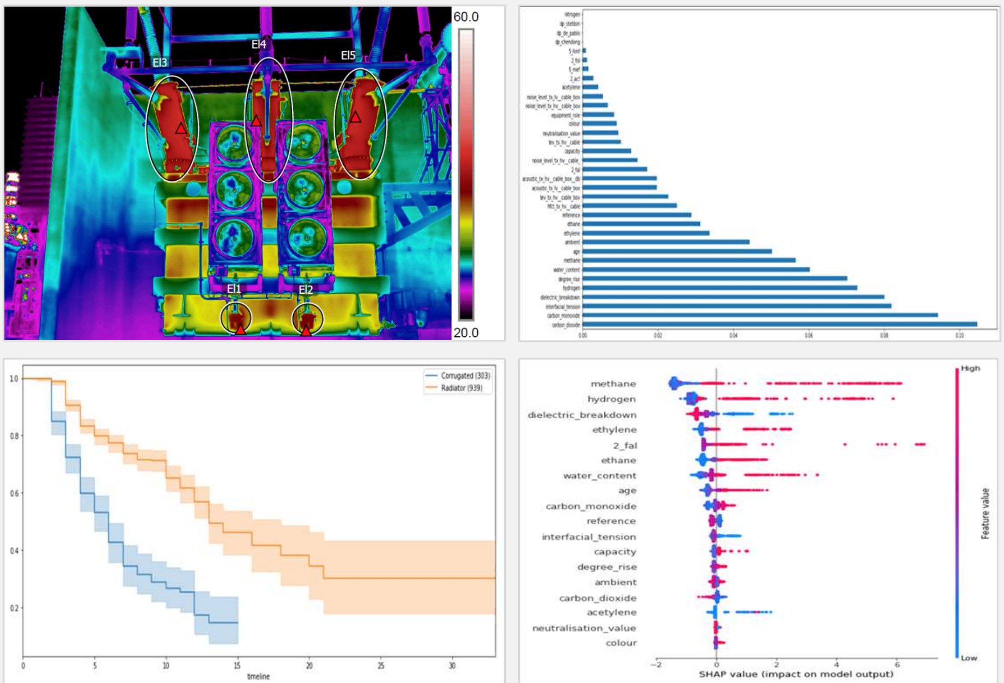
Data Science Integration at all stages of APM to enhance asset insights AND Drive business outcomes



Data Collection

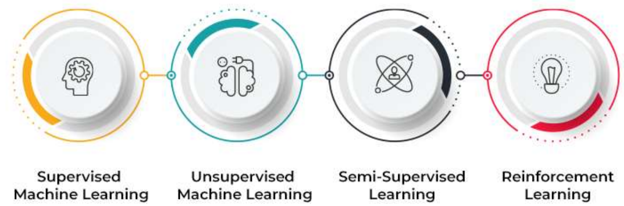
Data Processing

Health Condition Assessment

Diagnostics
Prognostics
Failure Prediction

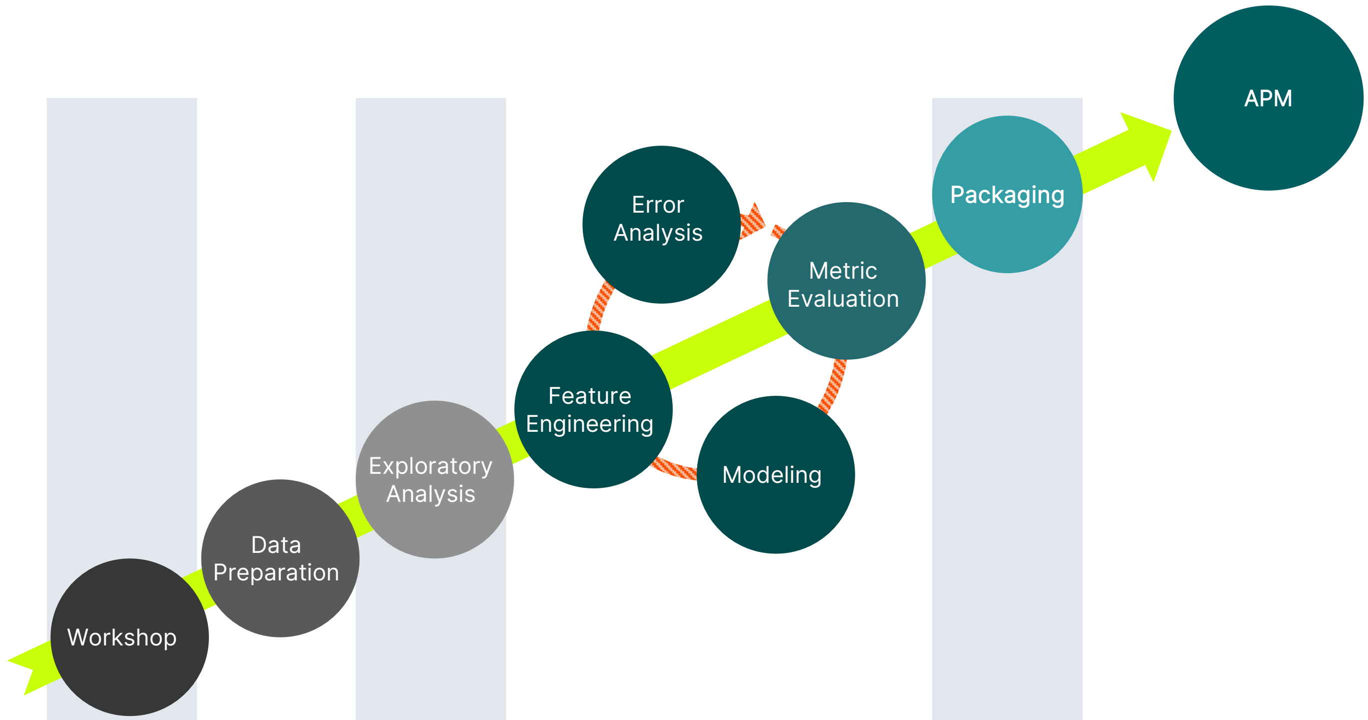
Reliability

Decision Support



Data Science and an Analytical Approach

- GE Vernova has analyzed available AI/ML technology and developed algorithms with high accuracy and repeatability.
- AI/ML algorithms were applied to typical use cases of the power industry and the results were analyzed.
- We are prototyping use cases with selected customers and their data.
- Once validated, the use cases will be productized within GE Vernova's eAPM software.



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USE CASES

USE CASE 1

Early prediction of unhealthy grid assets (transformers) and classification of fault severity in the absence of grid experts

Data List

Time Series Data	
Acetylene (C_2H_2)- PPM	Oil Temperature (°C)
Ethylene (C_2H_4)- PPM	Water Content (PPM)
Methane (CH_4)- PPM	Water Content Corrected to 20°C (PPM)
Carbon Dioxide (CO_2)- PPM	C_2H_2/C_2H_4
Carbon Monoxide (CO)- PPM	C_2H_2/CH_4
Ethane (C_2H_6)- PPM	C_2H4/C_2H_6
Hydrogen (H_2)- PPM	C_2H_6/CH_4
Nitrogen (N_2)- PPM	CH_4/H_2
Oxygen (O_2)- PPM	CO_2/CO
Combustible Gas – PPM	

Static Attributes
Transformer Status
Voltage Ratio High Voltage
Voltage Ratio Low Voltage
Water Content (PPM)
Water Content Corrected to 20°C (PPM)
YOM (Year Of Manufacturing)
Oil Type
Sample Point
Transformer Power Rating (kVa)
Origin

Expert Conclusion (Training Target):

Overall Health & Severity Classification

- Class 0 – normal
- Class 1 – minor defects
- Class 2 – several defects
- Class 3 – critical (shutdown)

Preliminary Insights

A. Classify whether a transformer is healthy (0) or not (1-3).

	Predicted 0	Predicted 1
True 0	4752	339
True 1	272	4166

Accuracy is **94.26%** on test data.

B. Classify transformers according to Severity Index Level (1-3).

	Predicted 1	Predicted 2	Predicted 3
True 1	3686	13	3
True 2	29	194	49
True 3	8	28	153

Accuracy is **96.39%** on test data.

* These are ensemble-based models for classification. These models combine the predictions of several base estimators built with a given learning algorithm in order to improve generalizability/robustness over a single estimator.

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USE CASES

USE CASE 2

IMPROVE CAPEX investments in grid assets with more accurate ERL models

Remaining Useful Life (RUL) of Power Transformers

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We used survival analysis, which was traditionally developed in the medical profession to measure the lifespans of individuals.

Survival analysis is used in different areas:

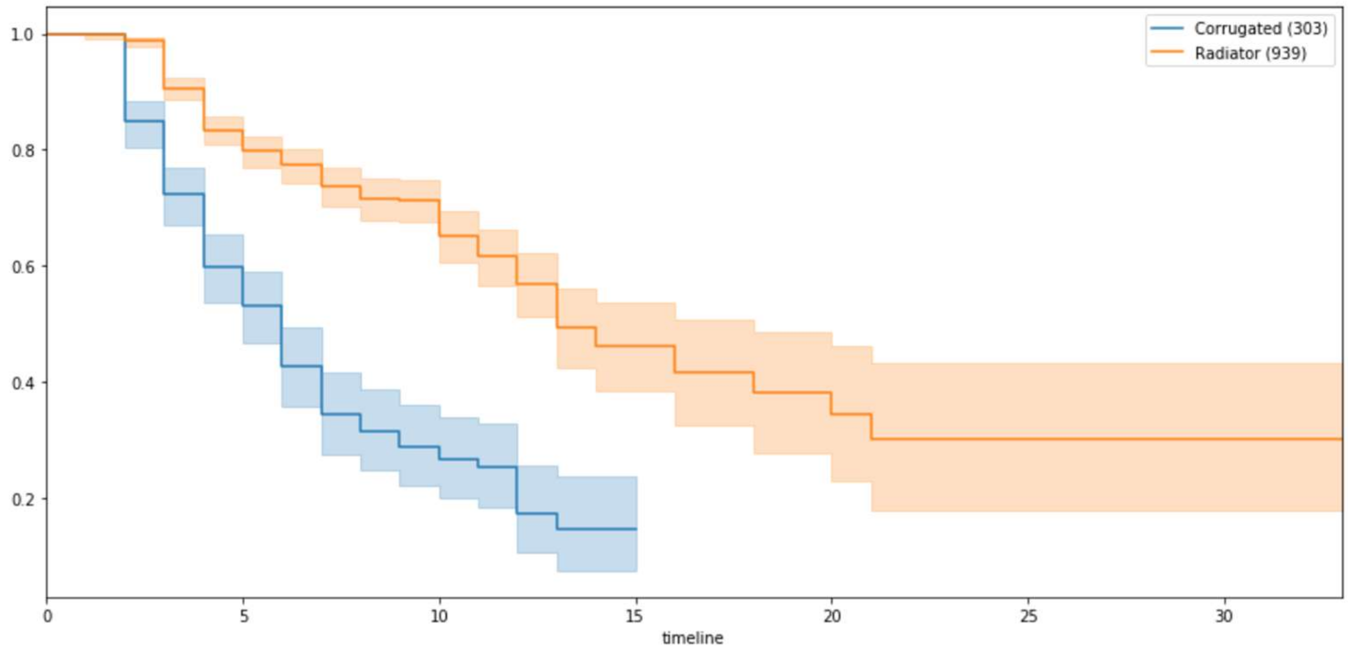
- CUSTOMER ANALYTICS
- MARKETING ANALYTICS
- ACTUARIES
- PREDICTIVE MAINTENANC

Applying the same concept to the lifespan of power transformers, we asked the question:
How long will this transformer operate normally until encountering a defect?

RUL

Survival Analysis Results

Cooling Type



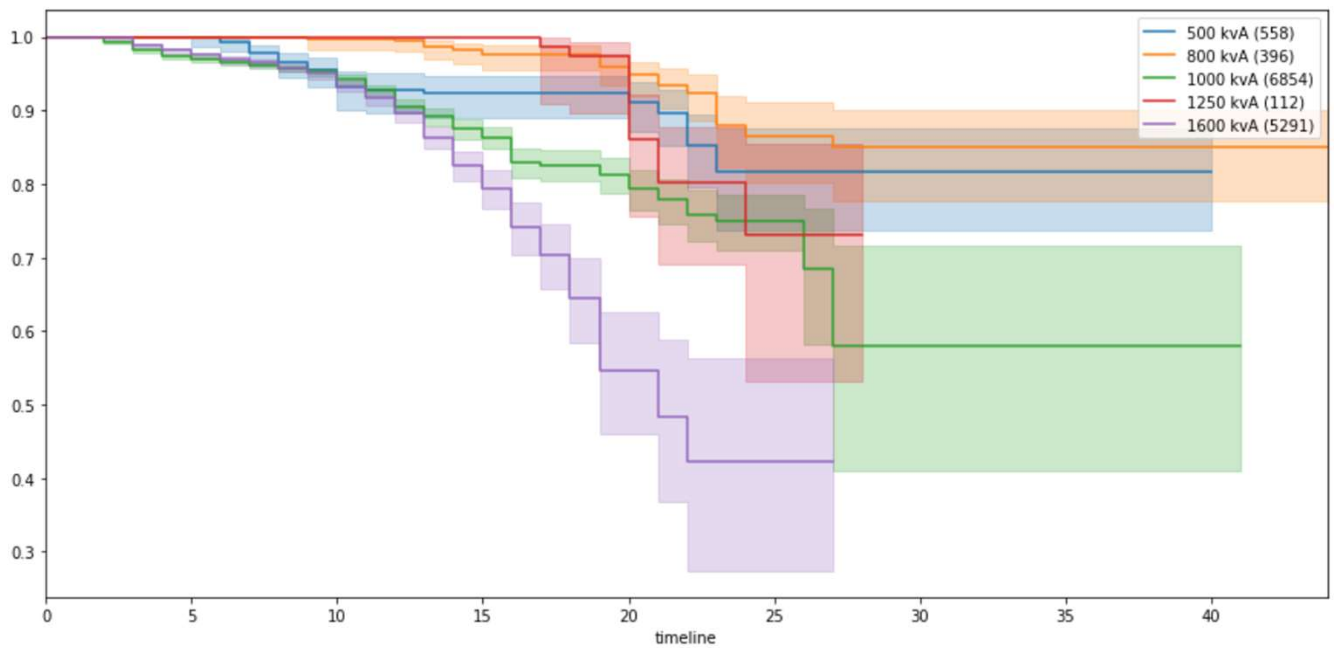
Transformers with radiators are more reliable than transformers with corrugated cooling fins.

- After 10 years of operating life, the survival probability for a radiator type is around 60%, while only 25% for a corrugated type.
- After 14 years of operating life, less than 20% of corrugated transformers have not experienced a defect.
- After 35 years, 30% of radiator transformers have not experienced a defect.

RUL

Survival Analysis Results

Ratings



The higher the rating, the lower the survival probability through time.

After 25 years:

- Rating = 500 kVA has a survival probability of 82%.
- Rating = 1,000 kVA has a survival probability of 75%.
- Rating = 1,600 kVA has 45% chance to survive.

USE CASES

USE CASE 3

IMPROVE OPEX investments by reducing field maintenance activities while improving the identification of potential asset failures

Feature Improvement

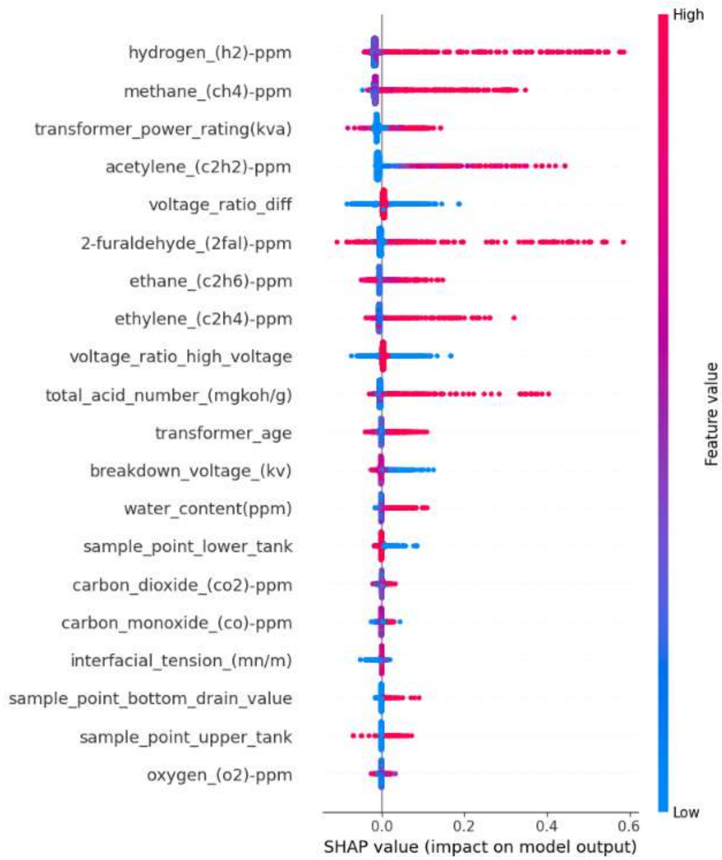
Benefits

Reduces the number of measurements/tests to be done on the field

Identify features which mainly contribute to and decide the transformer severity index

Reduce analytics matrix, save time, increase performance, and improve processes

Top Influencing Parameters



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Users can also have a detailed view about the list of top-influencing features for a given transformer class 3 in eAPM diagnostics

Top-Influencing Parameters

- High Hydrogen
- High Methane
- High Acetylene
- High 2-FAL
- High Ethane
- High Ethylene

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USE CASES

USE CASE 4

Utilize thermal images of grid assets and automatically identify asset components and effectively extract the right insights

Transformer IR Photo Analytics

Implementation plans per phase

1. Automatic detection of subcomponents from the standard and IR pictures:
    - Distribution transformers (DTR) such as main tank, radiators, and cable boxes.
    - Power transformers (PTR) such as main tank, conservator, cooling system, and bushing.
2. Detect hotspot anomalies on thermal pictures and trigger a warning limit:
    - Hotspot for the different transformer components (classification is hot/cold/normal).

Transformer IR Photo Analytics

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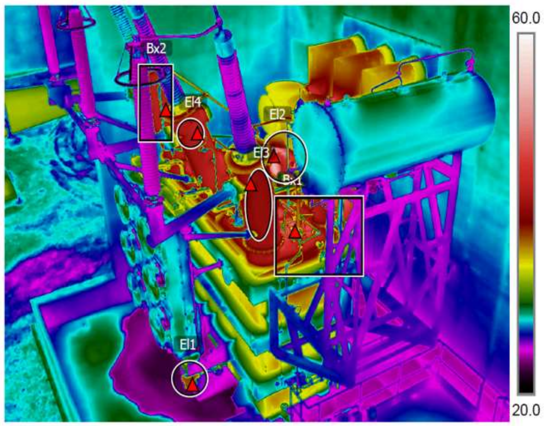
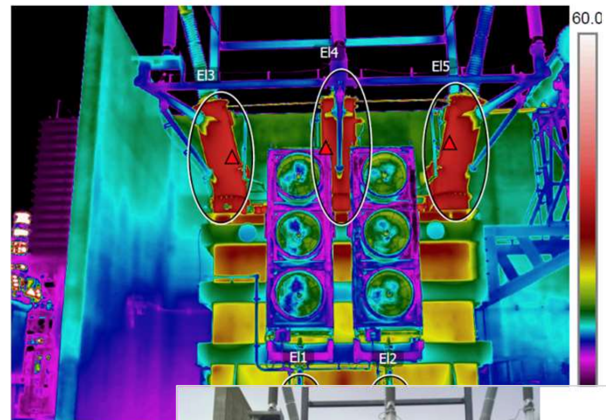


Measurements		
Bx1	Max	50.6 °C
Bx2	Max	44.7 °C
El1	Max	39.3 °C
El2	Max	55.1 °C
El3	Max	42.5 °C
El4	Max	44.5 °C

Parameters	
Emissivity	0.95
Refl. temp.	27 °C



Measurements		
El1	Max	39.3 °C
El2	Max	39.4 °C
El3	Max	44.4 °C
El4	Max	43.5 °C
El5	Max	43.8 °C

Parameters	
Emissivity	0.95
Refl. temp.	27 °C

Comments:

Here we see the temperature on the cover with the box 1 (50.6ºC) This temperature is considered in this study as the maximum top oil temperature. The cooler piping can't be used here as the stainless steel doesn't offer this possibility with IR camera.

Comments:

Here we see the bottom oil temperature on the pump (39ºC) we are going to use this temperature as the bottom oil for the analysis. The temperature on the HV turrets is 44ºC

Hotspot Detection for Cooling System

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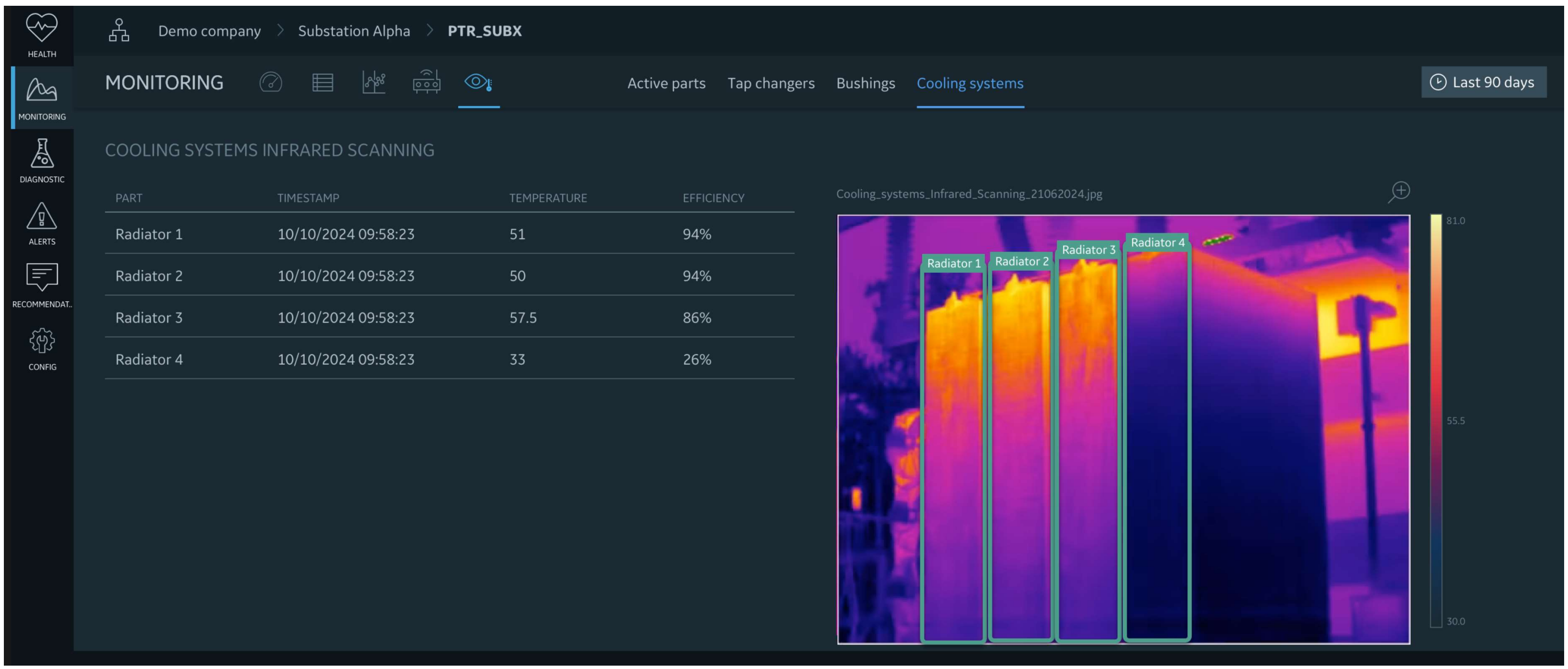

Q+A

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