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AI-enabled online monitoring and diagnostics of geothermal power plant

Matteo Galgani (Enel Green Power S.p.A, Italy)

Moresh Wankhede (AVEVA Group plc, UK)

Agenda

- Enel Green Power
  - Mission and Organization
- A Geothermal Power Plant
  - Rancia 2 site
  - Tackling a two-fold operational challenge
- Deploying AVEVA AI solutions
  - Online monitoring and diagnostics
  - Benefits achieved
- Summary and next steps

Enel Green Power (EGP)

RENEWABLE ENERGY FOR A SUSTAINABLE FUTURE

We seek out energy around the globe: in the power of wind and water, in the heat of the sun, in the depths of the earth and, above all, in people.

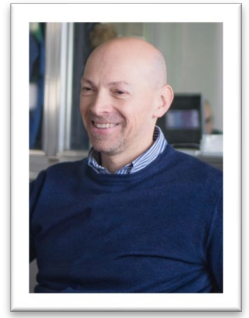
Project Organization

ENEL GREEN POWER

TSS (O&M GEO)

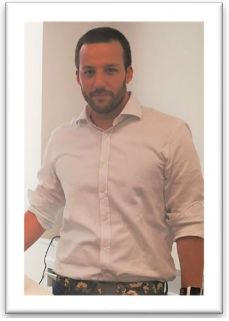
Matteo Galgani

TSS (O&M GEO)



Marco Magrini

Innovation (INN TGX)



Andrea Morandi

Innovation (INN TGX)

Diego Dal Canto

AVEVA

Head (AI CoE)

Mike Reed

Technical Leads

Moresh Wankhede

David Smith

Customer Support

Franceso Petrone

Geothermal energy in EGP

From the hearth of Tuscany

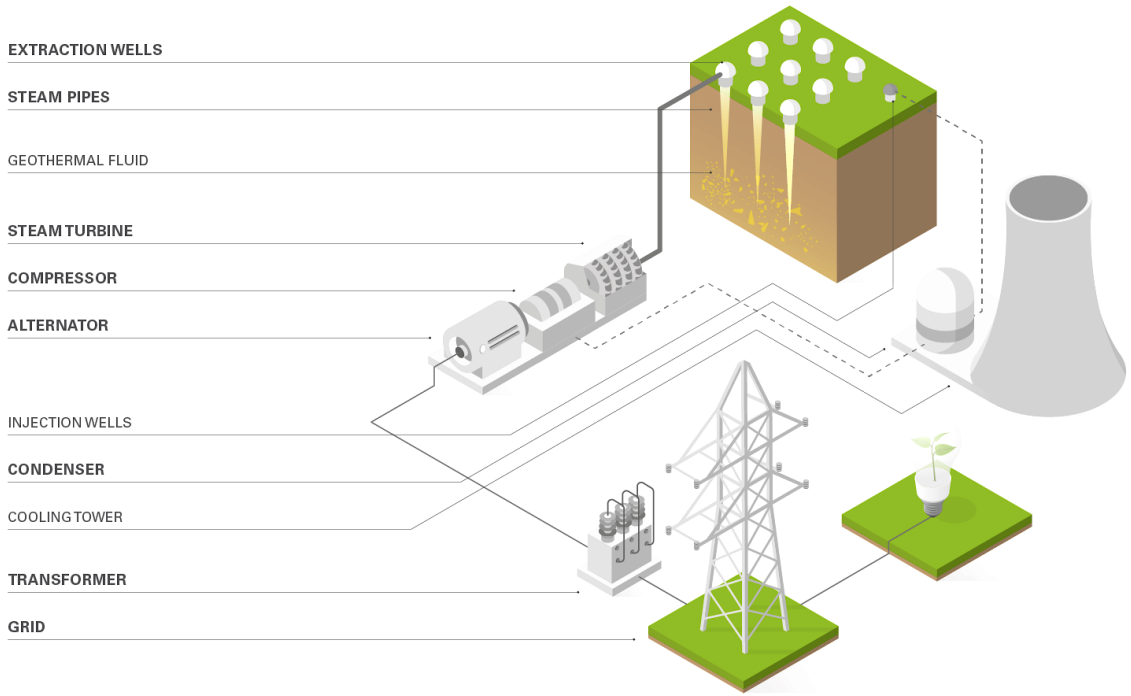
Tuscany is famous principally for food, nature, wine, art and historical cities

But there is also another thing that make Tuscany famous all around the World

GEOTHERMY

How Does Geothermal Energy Work?

Electricity from the heat of the Earth



EGP Geothermal Italy numbers:

- 37 Power Units, approximately **900 MW** capacity
- More than **500 Wells** and 700km of pipelines for fluids
- Plants is normally **tele controlled** by a central room and not manned.
- More than **100k measures** acquired in real time from sensors and field devices

The problem and the challenge

Where did the synergy between AVEVA and Enel Green Power come from?

The problem

Current EGP systems do not allow to develop AI complex algorithms directly on plant time series data and in real time.

The challenge

Adopt a computing platform fully integrated into EGP traditional systems (OSIsoft PI) that allows to design, develop and execute complex AI algorithms and calculations on plant data.

What is this project?

Use AVEVA AI platform for optimizing geothermal plant operations

- **Monitoring and diagnostics** of the main operating parameters of geothermal power plants
- Notification of inefficiencies by automatically sending **personalized alarms**
- Setup of **configuration** parameters through a **simple and intuitive** interfaces

What was developed?

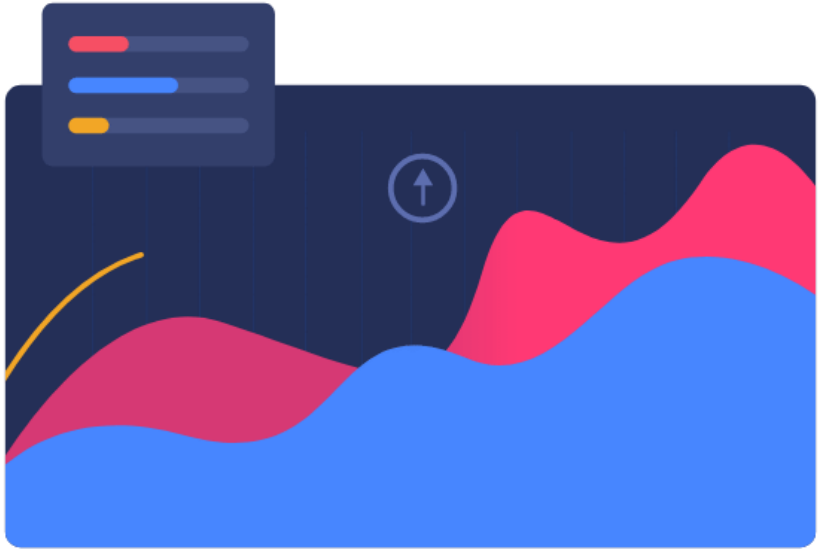
Using AVEVA Predictive Analytics platform and the data of Rancia 2 Power Plant

PLANT SIGNATURE's RULES for inefficiency detection:

Power, Flow rate and Steam temperature, Hot and cold H2O temperature,

Condenser pressure, Specific consumption, EG suction temperature …

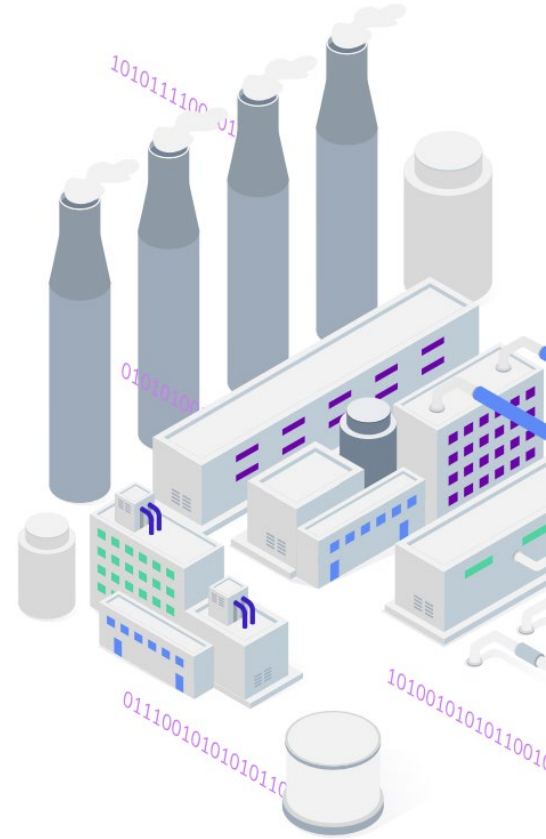
Each state of inefficiency corresponds to a suggestion about the cause

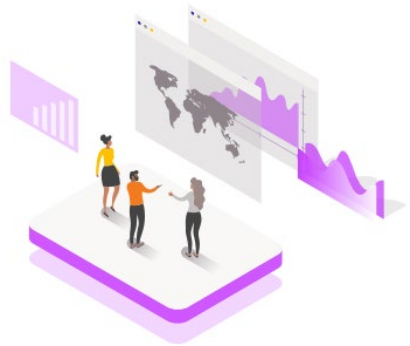


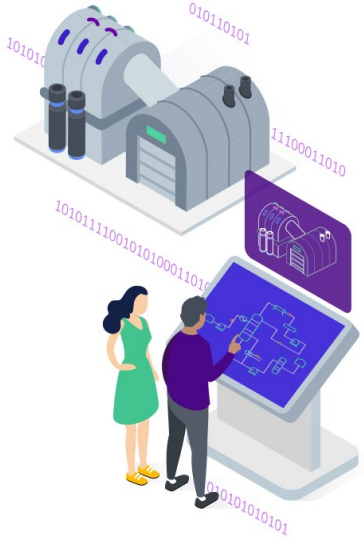
What has happened? What will?

Deploying AVEVA’s AI solutions for sustainable outcomes

Using AVEVA Predictive Analytics and PI System



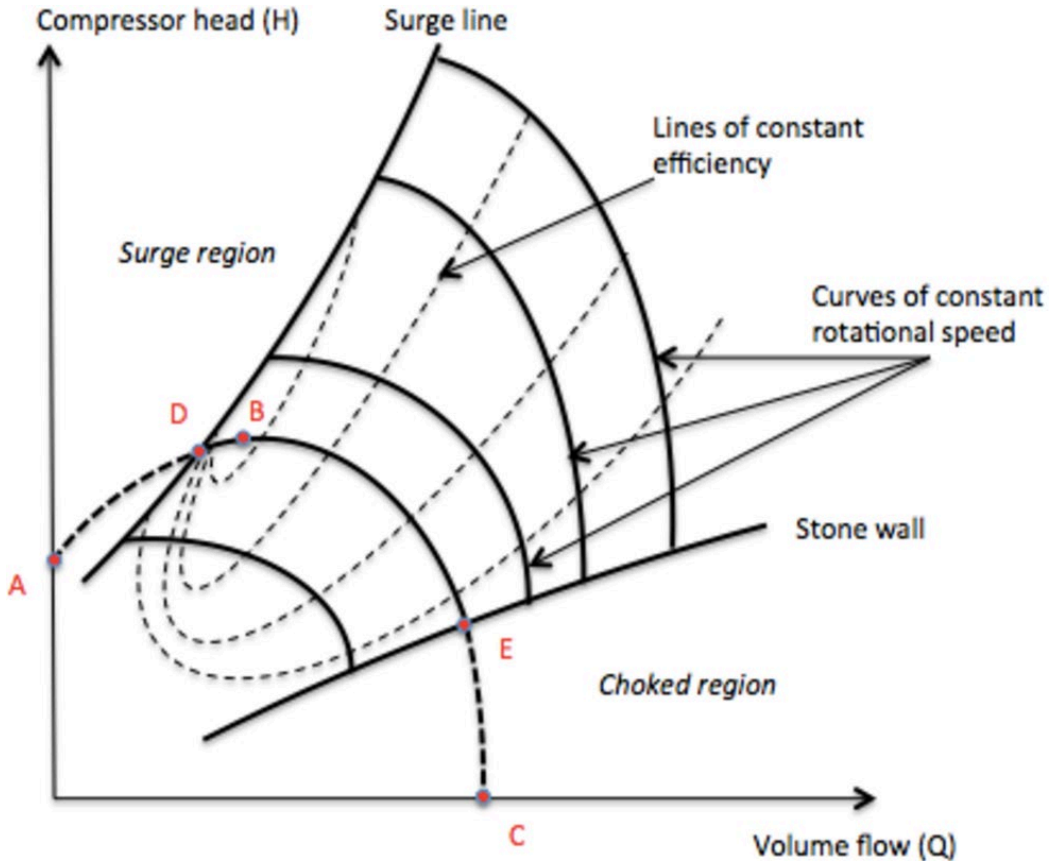




Green Power

Rancia 2 Reliability Monitoring

Gas Compressor Surge Detection



- Integrally geared gas compressor driven by HP steam turbine shaft
- Two anti-surge recycle valves modulate flow to the compressor
- Compressor surging is **unpredictable**, hence operated away from surge condition
  - **reduces operational efficiency**
- And if surge suddenly occurs, difficult for the operators to intervene in time

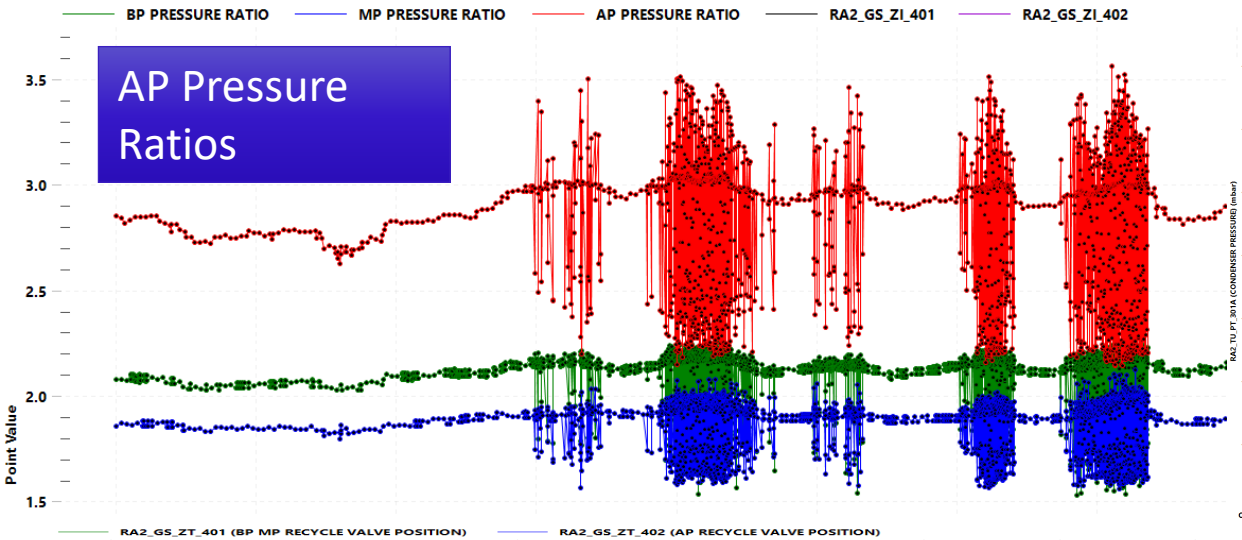
a deep surge can cause plant to stop

Early detection of surge event crucial to operate at higher efficiency and avoid plant shutdown

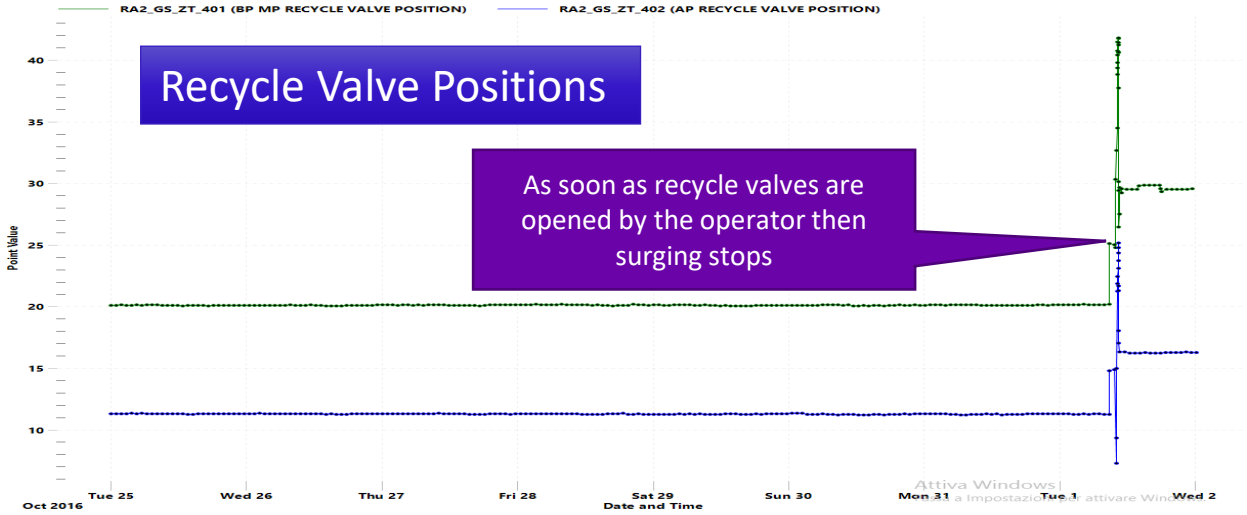
Rancia 2 Reliability Monitoring

Event type	Time_start	Time_end	year
SURGE	28/10/2016 22:00	29/10/2016 09:34	2016
SURGE	29/10/2016 23:22	30/10/2016 08:12	2016
SURGE	31/10/2016 00:35	31/10/2016 08:55	2016

Green Power



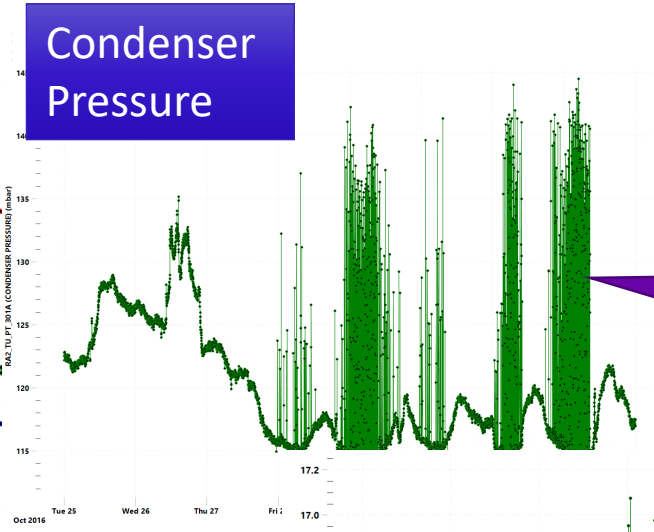
AP Pressure Ratios



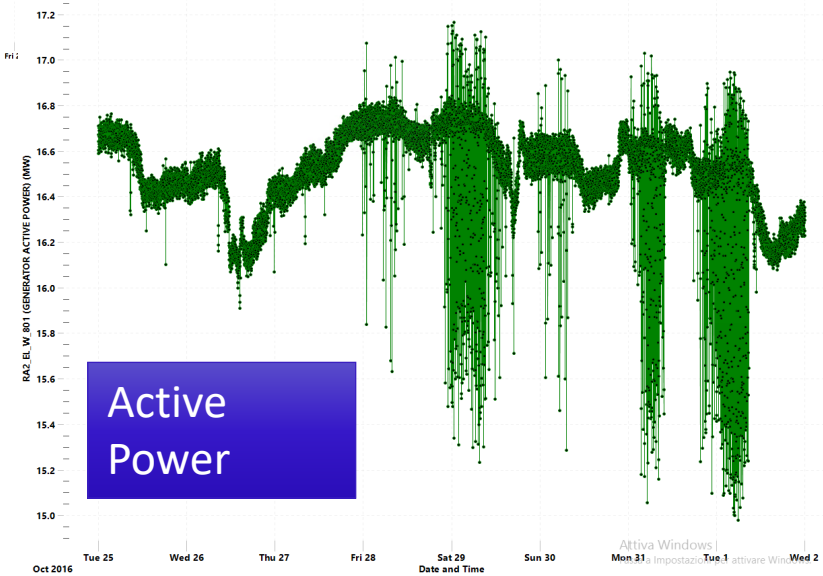
Recycle Valve Positions

As soon as recycle valves are opened by the operator then surging stops

Condenser Pressure



Consequent fluctuations in condenser pressure directly affecting active power



Active Power

AVEVA

Rancia 2 Reliability Monitoring

Event type	Time_start	Time_end	year
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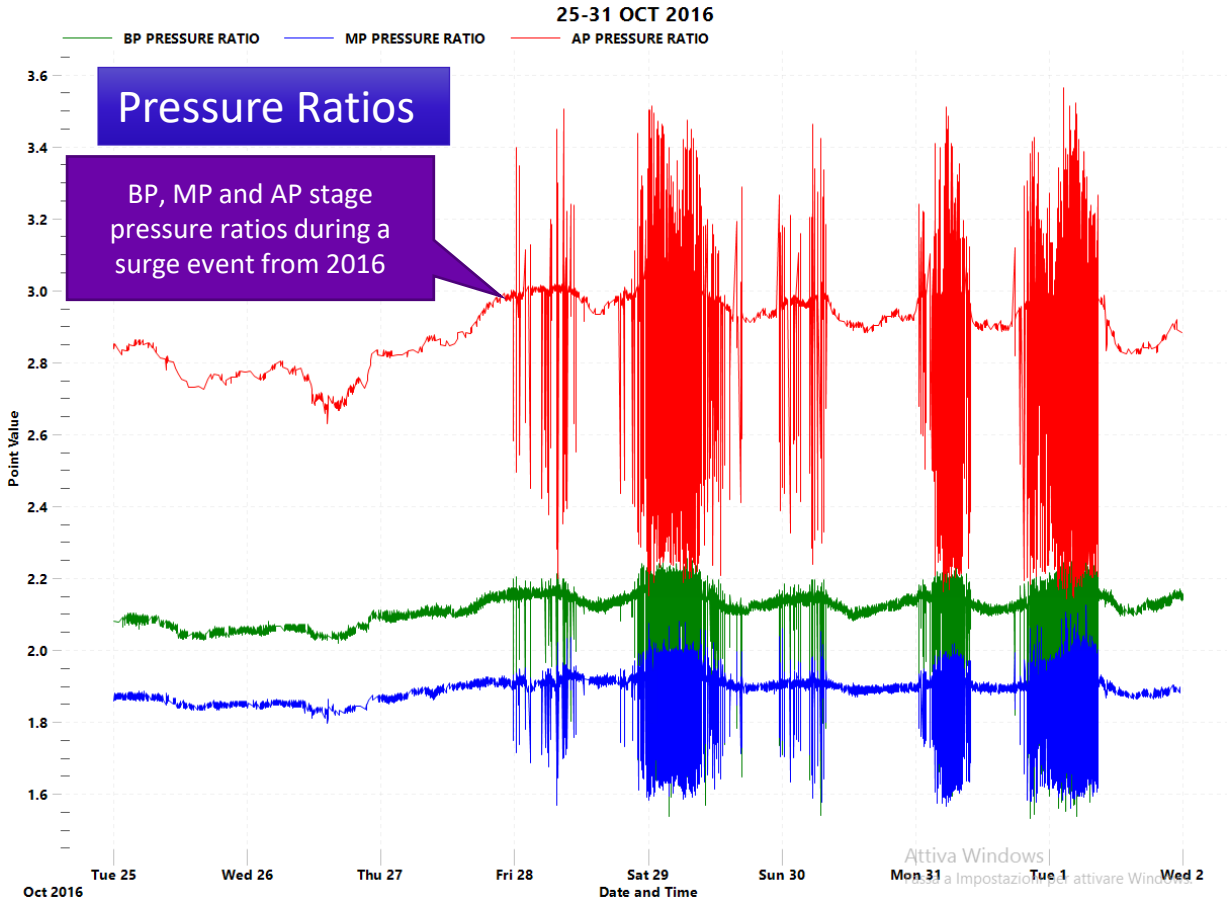
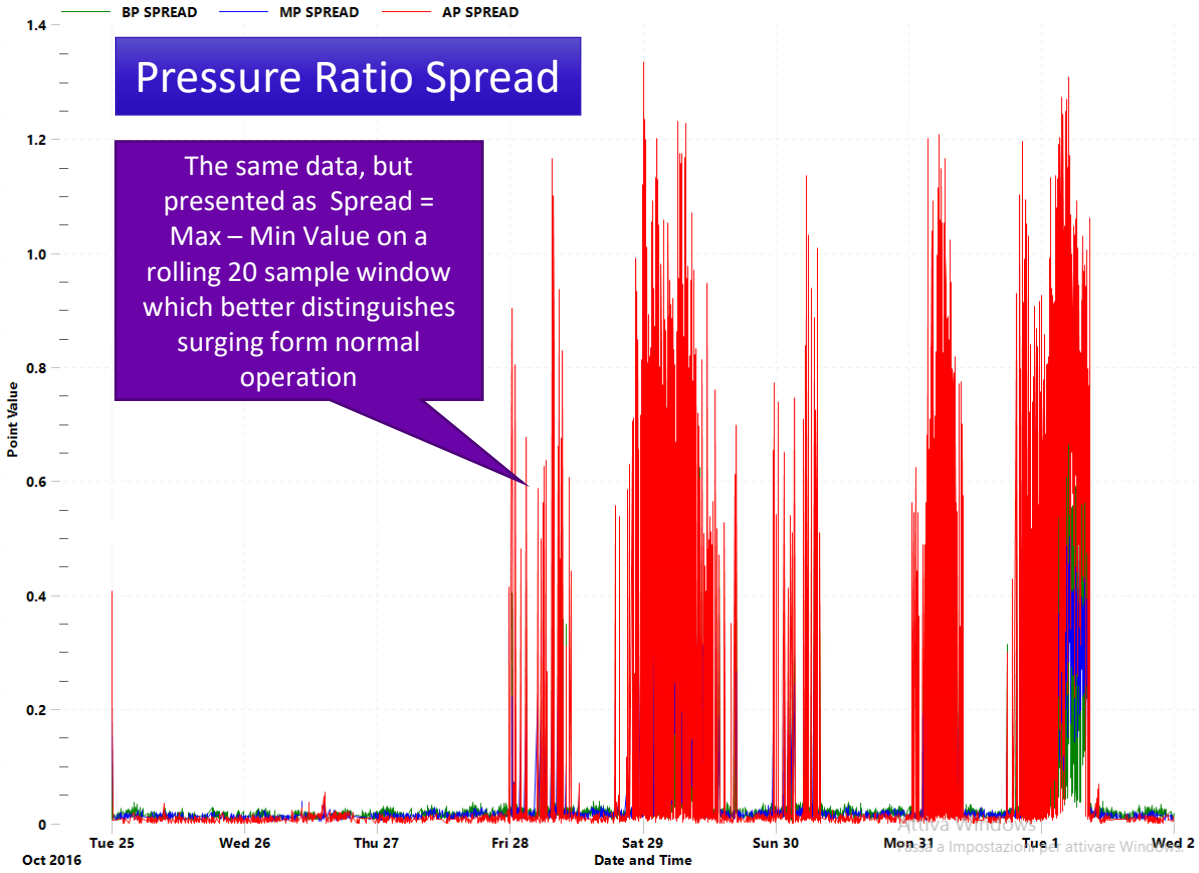
Green Power





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Rancia 2 Reliability Monitoring

Online observations: Surge events April-July

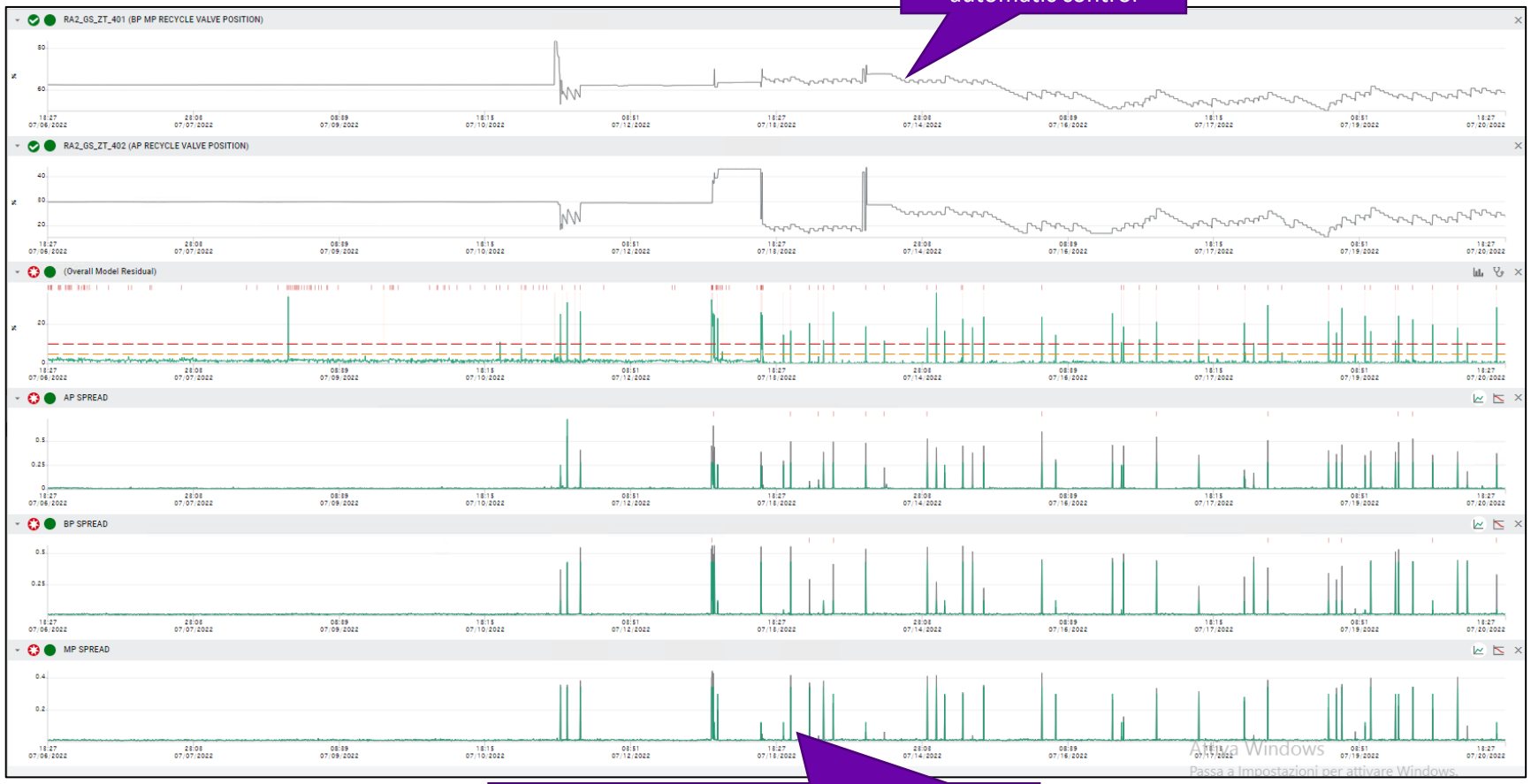
In addition to analysing historical cases, the surge detection model was run on-line. Here we see one particular surge event which was caught by the model in mid April 2022. The model clearly distinguishes the onset of surge first apparent 9th April into 10th.

Rancia 2 Reliability Monitoring

Realizing a solution for increased operational efficiency

- As seen from the online surge detection model, Enel's new control scheme seems successful; with increased frequency of pressure ratio fluctuations indicating successful avoidance of any significant surge event

AVEVA deployed an AI solution to clearly detect onset of Surge before it becomes significant and enabling increased operational efficacy



Rancia 2 Performance Monitoring

Tracking Key Performance Indicators(KPI) signatures

5.5.2. Pressione Assoluta al Condensatore Attesa (mbarA)

La pressione assoluta al condensatore è calcolata tramite la temperatura dell'acqua fredda in ingresso al condensatore. È ricavata dall' equazione polinomiale del tipo:

$$Pressione\ Assoluta\ al\ Condensatore\ Attesa = a_2 \cdot (Temperatura\ Acqua\ Fredda)^2 + b_2 \cdot (Temperatura\ Acqua\ Fredda) + c_2 \quad (14)$$

Dove i coefficienti a_2, b_2 e c_2 provengono dalla curva di Firma di Impianto relativa al Sistema Estrattore Gas/Condensatore descritta nel paragrafo 7.2, mentre la *Temperatura Acqua Fredda* nel paragrafo 5.1.5.

6.6. PRESSIONE ASSOLUTA CONDENSATORE

6.6.1. Logica di Controllo

Il controllo della Pressione Assoluta al Condensatore (5.1.7) viene effettuato tramite il confronto con la relativa pressione Attesa (5.5.2), ricavata dalla Firma di Impianto del Sistema Estrattore Gas/Condensatore (7.2):

- Cella Gialla: la Pressione al Condensatore misurata è superiore a quella Attesa di 9 mbar
- Cella Arancione: la Pressione al Condensatore misurata è superiore a quella Attesa di 13 mbar
- Cella Rossa: la Pressione al Condensatore misurata è superiore a quella Attesa di 17 mbar
- Cella Viola: la Pressione al Condensatore misurata è inferiore a quella Attesa di almeno il 30%.

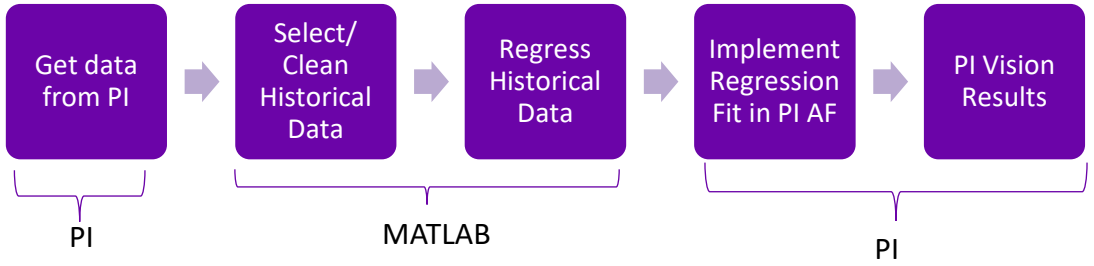
6.6.2. Lessons Learnt

La Pressione Attesa deriva dalla Temperatura dell'Acqua Fredda (vedi 7.2), quest'ultima è il principale parametro che determina il vuoto al Condensatore, quindi uno scostamento tra i due valori, Atteso e Misurato, può evidenziare che:

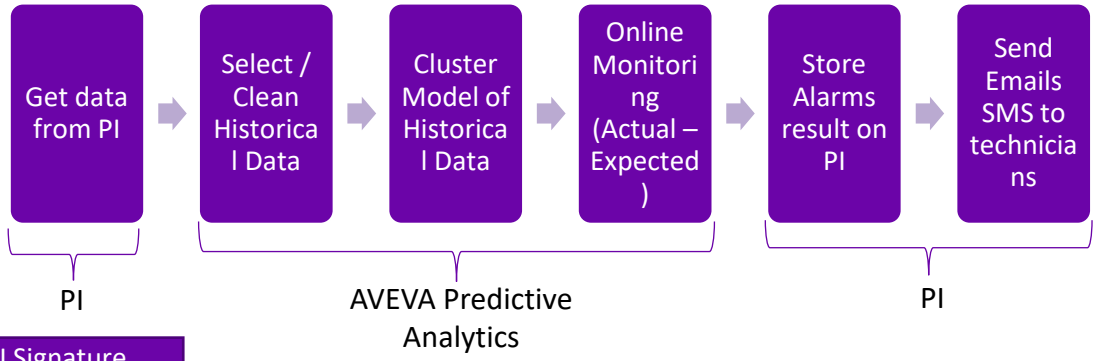
- Cella Gialla/Arancione/Rossa: il sistema condensatore/estrattore gas non riesce a fare il vuoto correttamente, pertanto:
  - Verificare appostamento valvole antipompaggio (controllare se il controllo è manuale o automatico)
  - Verificare eventuali rientranze d'aria
  - Verificare la pressione di spinta compressore (potrebbe essere superiore al valore normale a causa di eventuali intasamenti della linea di espulsione gas)
  - Verificare intasamento demister del condensatore
  - Verificare intasamento demister del refrigerante intermedio
  - Verificare il corretto funzionamento del misuratore di Temperatura dell'Acqua Fredda
  - Verificare il corretto funzionamento del misuratore Pressione Assoluta al Condensatore
- Cella Viola:

Example KPI Signature Procedure at Enel: Condenser Pressure as function of Cold Water Temperature

Existing Method: Regression

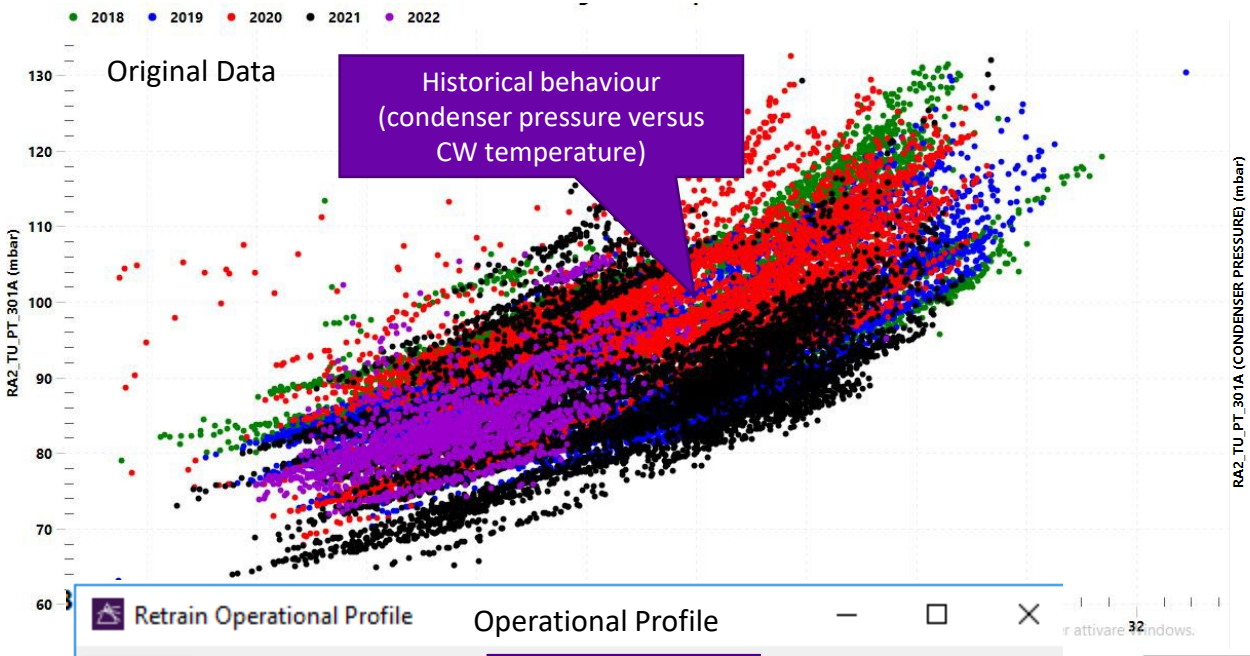


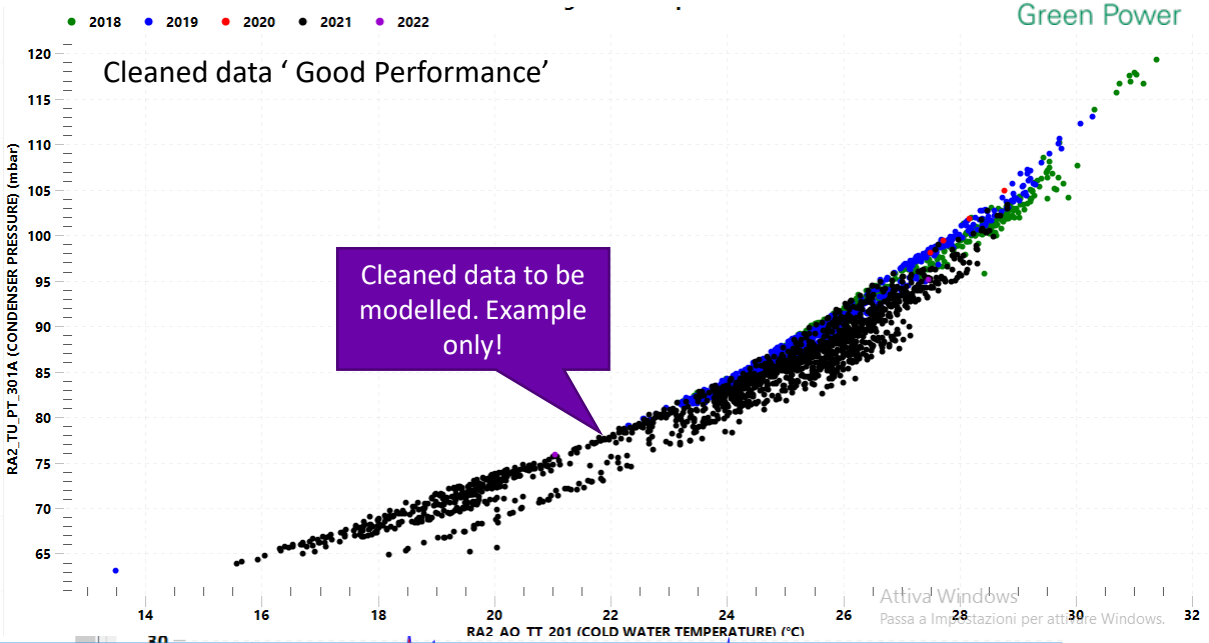
AVEVA AI Solution: Predictive Analytics Clustering

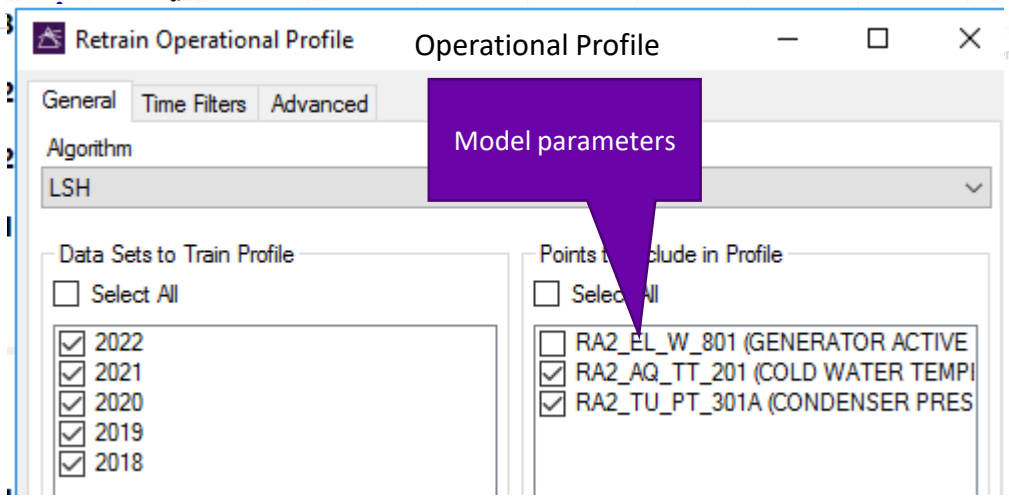


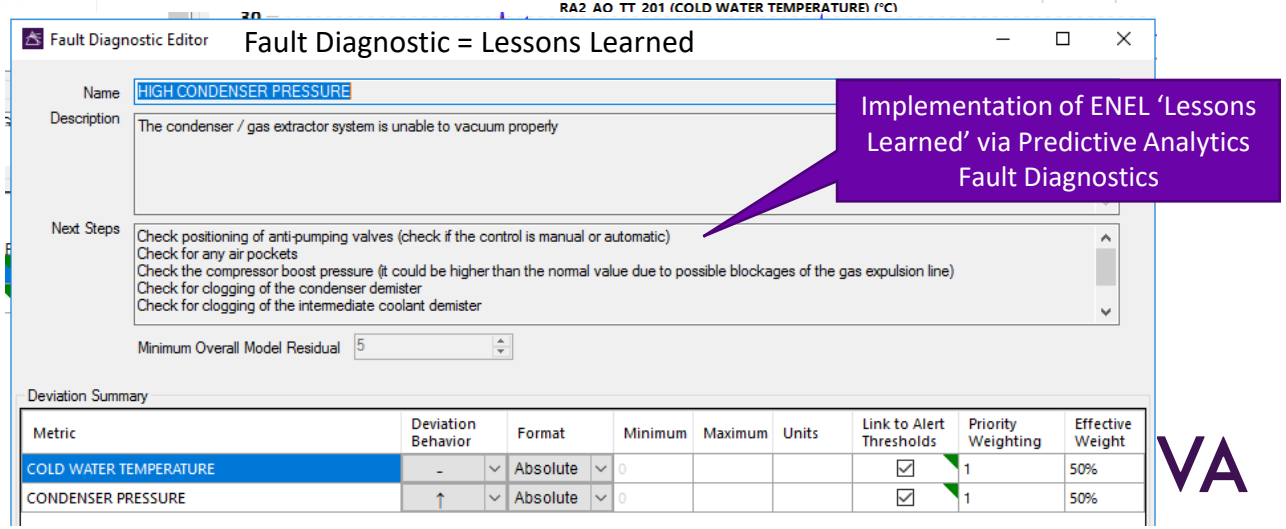
Continuous monitoring of KPI movement is crucial for proactive decision-making by operations staff

Rancia 2 Performance Monitoring





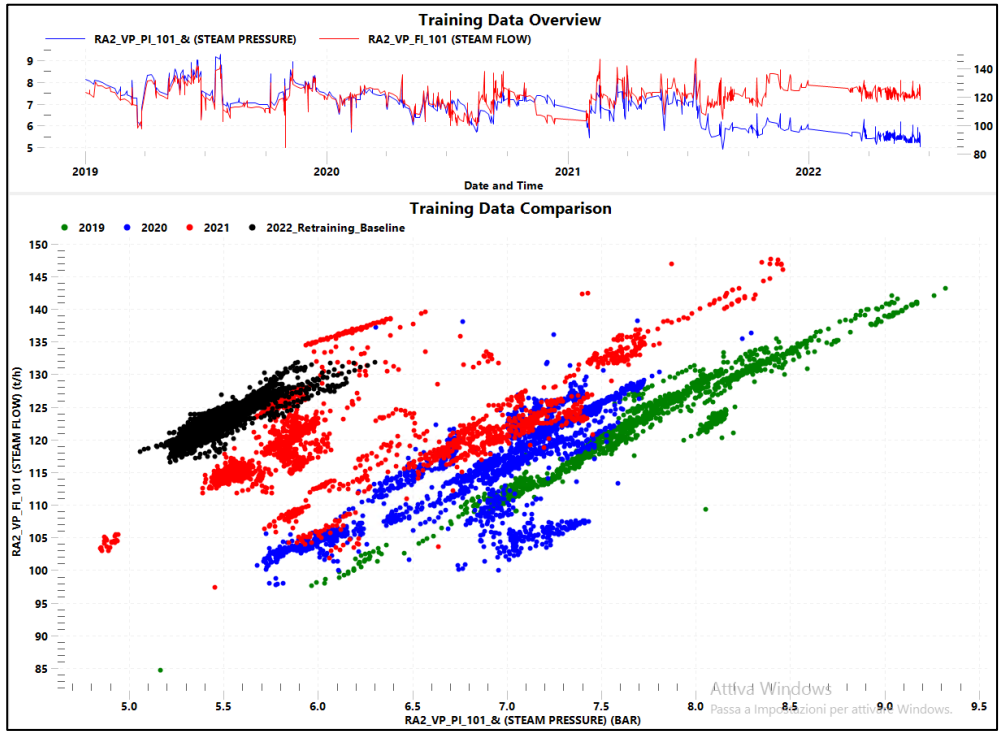


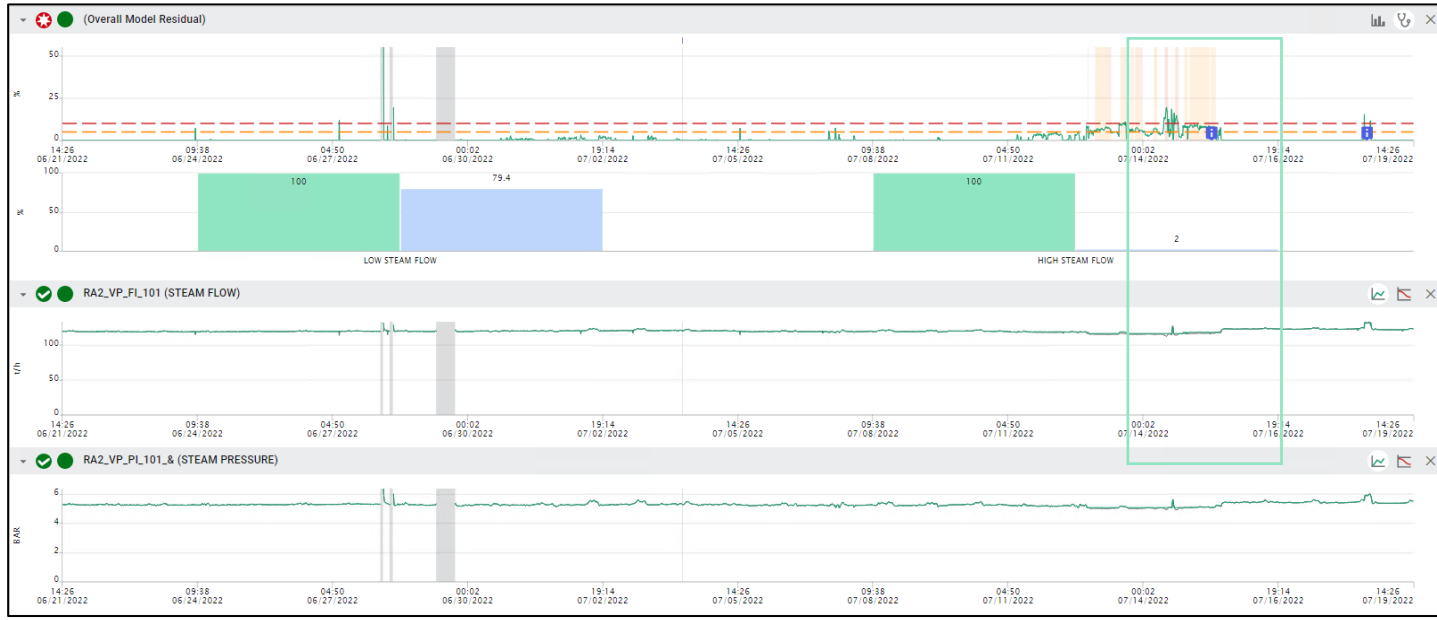


Rancia 2 Performance Monitoring

Rancia 2 Performance Monitoring

KPI: Steam Flow (univariate analysis)



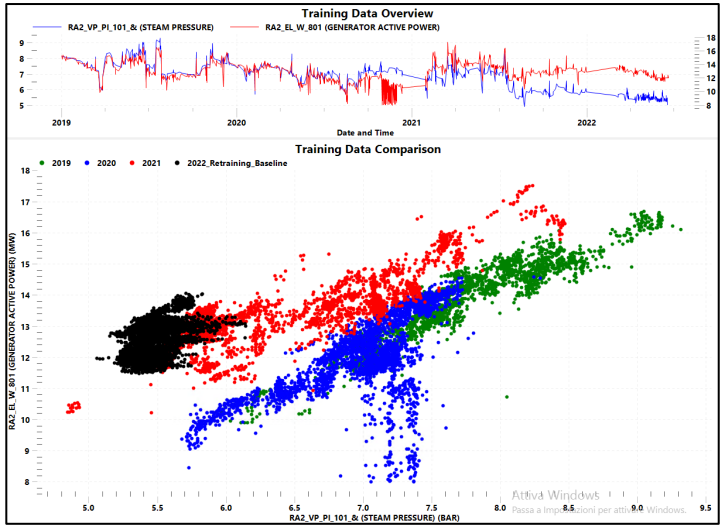


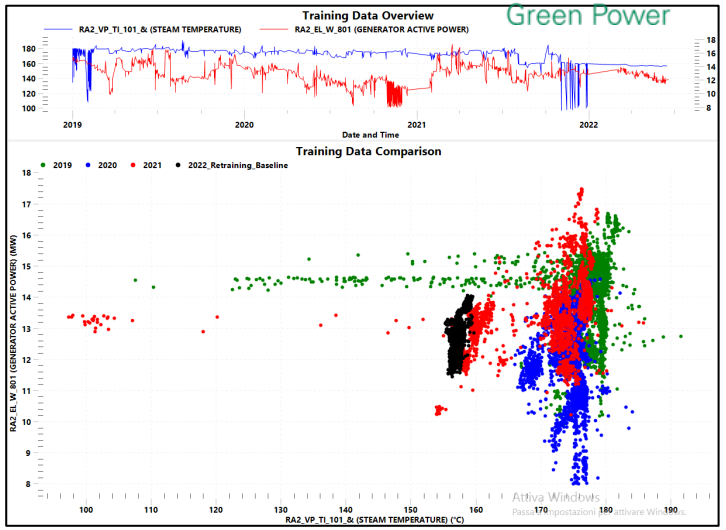
- Significant degradation in steam pressure since 2019, although the steam flow is maintained.
- With the model baselined on 2022 data, one excursion noted during the on-line monitoring period; where steam pressure drops to ~5.0 bar and the steam flow drops correspondingly

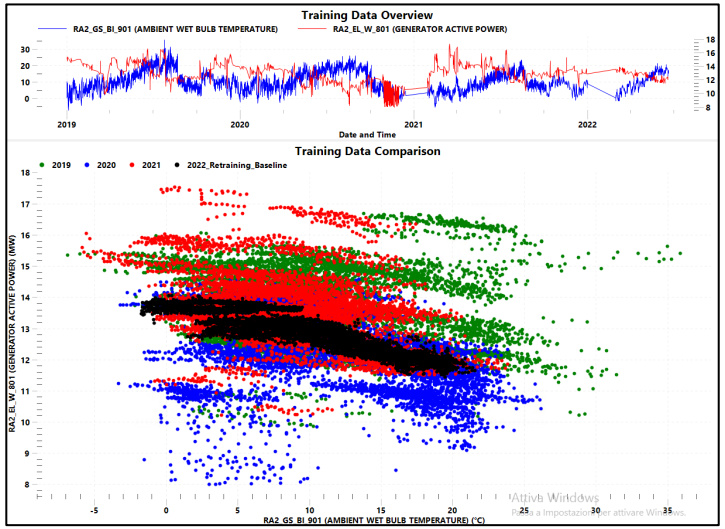
Rancia 2 Performance Monitoring

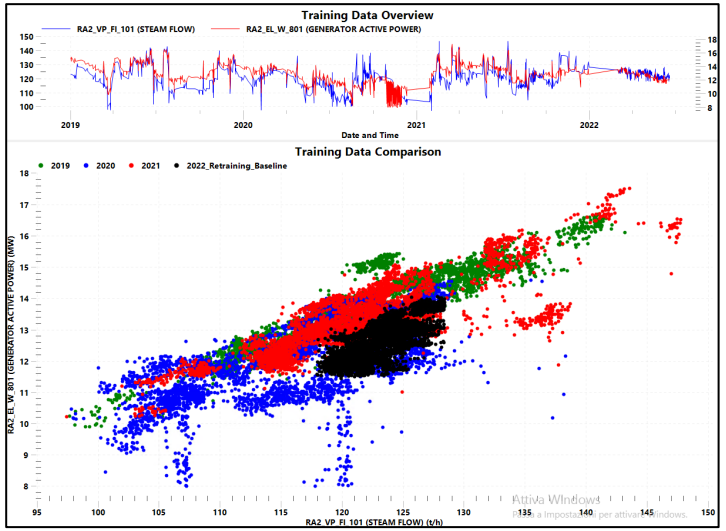
KPI: Generator Gross Active Power (multivariate analysis)

- Generator Gross power is tracked in relation to Steam Pressure and temperature, Wet Bulb Temperature and Steam Flow.
- In 2022 the pressure of the steam is lower than in previous years and consequently for a given steam flow the output of the plant is reduced.







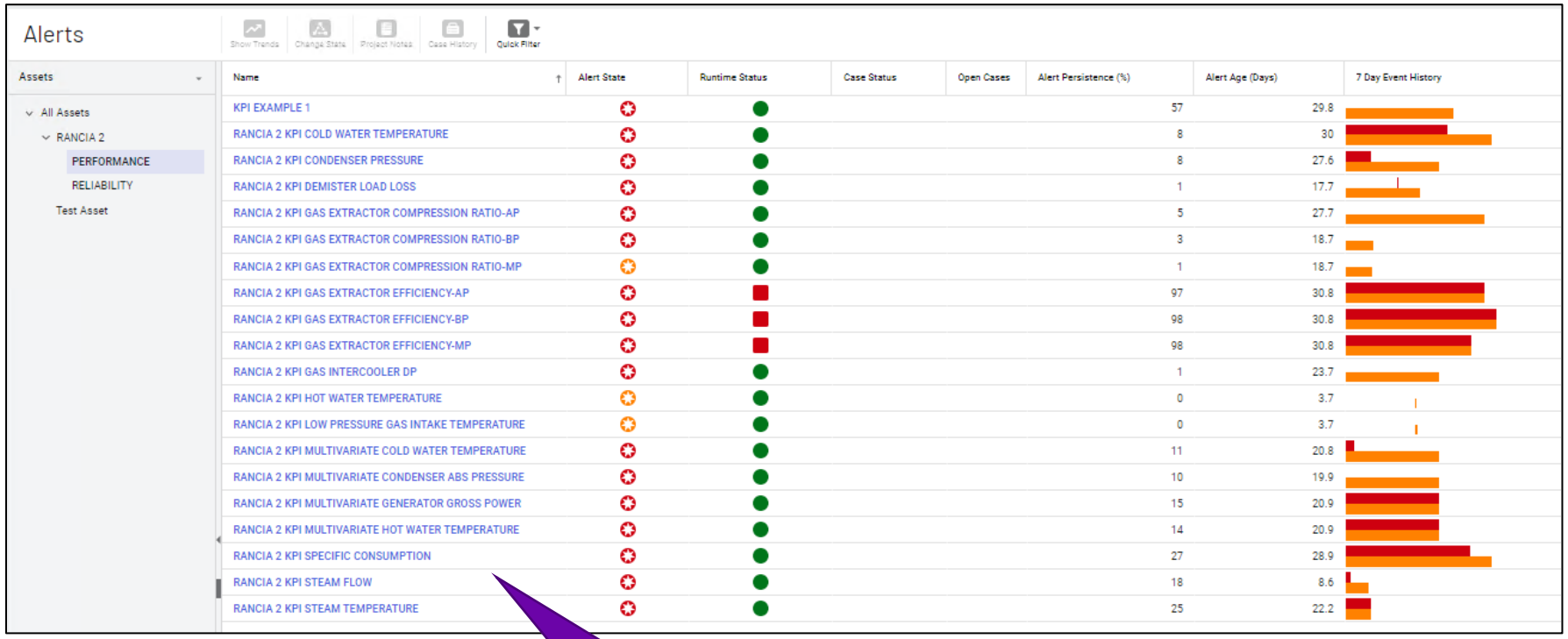


Rancia 2 Performance Monitoring

Realized a solution for increased operational autonomy

Each KPI Performance monitoring was configured with the following information:

- Historical behavior 2019 – 2021
- Selected benchmark behavior 2022 used to train the model
- Online model results June – July 2022
- Observations and insights



Performance KPI models built for all univariate plus multivariate cases

AVEVA deployed an AI solution to enable easier monitoring of performance KPI's for Enel's operations team

The lesson learned, the barriers, the risks

- High value of the acquired data: The huge amount of data acquired has great potential that can be used to increase productivity
- High effort to structure data for analysis: The process in which we filter, and label data is not effortless
- Knowledge of the process required for the development of AE and machine learning algorithms: Independent work between plant engineers and data scientists is impossible
- Design a high-scalability central system for complex calculations: Search for the solution that best integrates with the traditional platforms used in Enel Green Power
- Geothermal energy is a niche market: Academic articles and benchmarks to follow to innovate the limited process. We often run the risk of being pioneers
- The importance of ensuring a robust and informative measurement chain: Complex algorithms need robust inputs to work well and be used with confidence

Summary

World-leader in geothermal power

Green Power

Challenge

- Providing state-of-the-art **AI-enabled real-time monitoring and diagnostics** capabilities for 18MW Rancia 2 geothermal plant, which is at the forefront of geothermal power field in Tuscany, Italy

Solution

- Deployed a variety of latest **AVEVA Predictive Analytics** models for reliability and performance monitoring of power plants critical equipment

Benefits

- **Increased operational efficacy** and **reduced costs** through early detection of critical events
- **Enhanced operational autonomy** and **ease of use** through active KPI tracking and proactive decision-making

AVEVA

Matteo Galgani

Engineer

- Enel Green Power S.p.A
- matteo.galgani@enel.com

Moresh Wankhede

Senior AI Solutions Engineer

- AVEVA Group plc
- moresh.wankhede@aveva.com

Questions?

Please wait for the microphone.

State your name and company.

Please remember to…

Navigate to this session in the mobile app to complete the survey.

Thank you!

enel Green Power

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Over 20,000 enterprises in over 100 countries rely on AVEVA to help them deliver life's essentials: safe and reliable energy, food, medicines, infrastructure and more. By connecting people with trusted information and AI-enriched insights, AVEVA enables teams to engineer efficiently and optimize operations, driving growth and sustainability.

Named as one of the world's most innovative companies, AVEVA supports customers with open solutions and the expertise of more than 6,400 employees, 5,000 partners and 5,700 certified developers. With operations around the globe, we are headquartered in Cambridge, UK and listed on the London Stock Exchange's FTSE 100.

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