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An Automation System failure analysis with PI System tools for modernization decision-making used at ITAIPU

A proof-of-concept study of data-driven decision-making support

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WORLD LEADER IN CLEAN
AND RENEWABLE ENERGY

ITAIPU Binacional

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ITAIPU BINACIONAL

About the company

- Bi-national: Paraguay and Brazil (**50%** each).
- Total production: +**2,950 TWh, ~100 TWh year, 20 generating units, 14,000 MW of installed power.**
- Distributed royalties: + U$ **11 billions.**
- Attraction as an engineering wonder: **+ 1 Million** visitors.

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Technical Direction – Maintenance Department

Maintenance Mission

- Ensure optimal operating availability of the Hydroelectric Power Plant to meet the needs of Itaipu Binacional customers.
- Deliver energy that stands out in both high Quality and Reliability.
- Carry out well-planned, executed, and controlled maintenance activities.
- Regularly evaluate the balance between Cost and Benefits.

Maintenance Attribution (part of it)

- Oversee the performance analysis for:
  - Power Plant's Equipment and System;
  - Substations;
  - Transmission Lines;
  - Communication Systems;
- Drive studies for permanent improvement of the installed equipment and systems.

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MAIN ASPECTS

Dam and the Automatic Data Acquisition System (ADAS) of the Civil Structure of the Itaipu Hydroelectric Power Plant

Itaipu Hydroelectric Power Plant Dam

Main aspects

- **Construction Material:** The dam is built using a mix of concrete (main dam), rock, and earth.
- **Function & Design:** It serves to dam the water and obtain the 120 m (400 ft) drop that drives the operation of the turbines. Intakes are in the upper part of the main dam, through which the water begins its descent, until the turbine wheel is activated and rotated.
- **Dimensions:** The dam stretches 7,800 meters (~5 miles) in length and stands 196 meters (~650 ft) tall at the main dam.
- **Instrumentation:** The power plant dam contains over 2,000 installed field sensors, and 300 deemed most crucial have been automated, collecting data at specific intervals.
- Their role is to monitor and ensure the structural integrity and safety of the dam.

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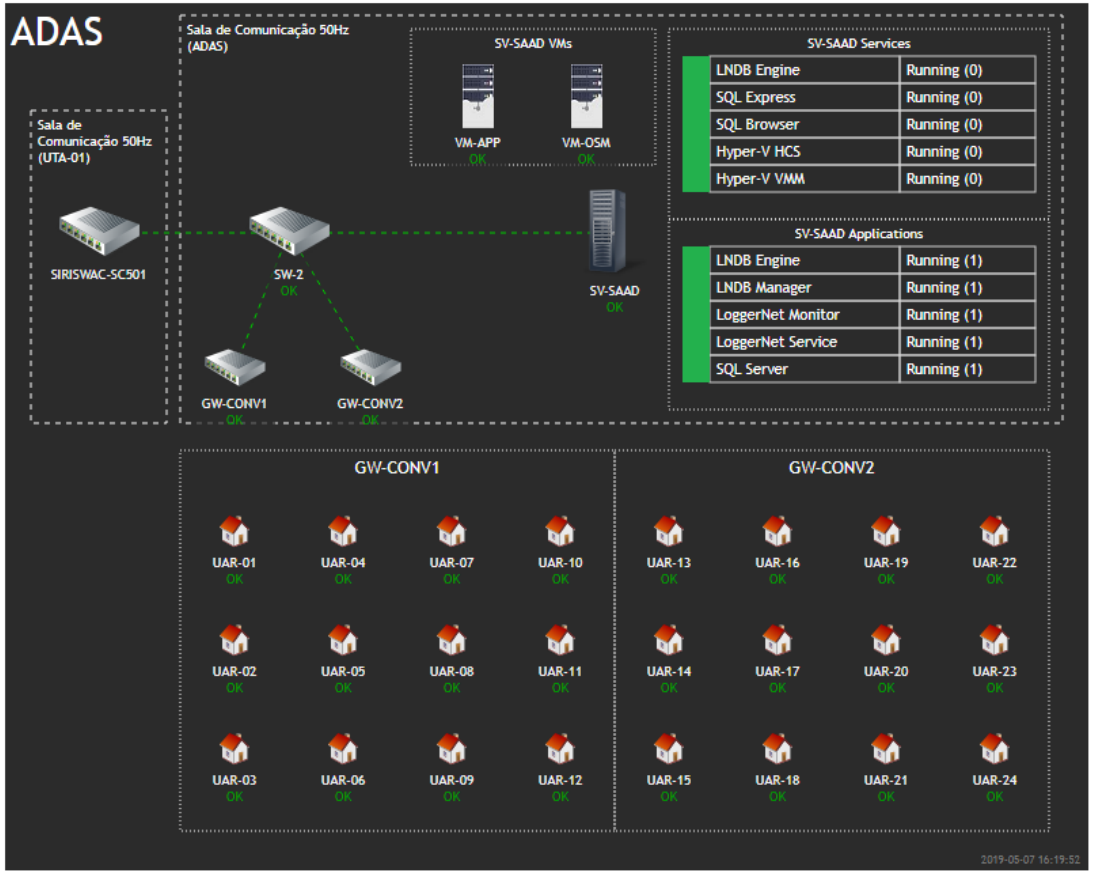
Automatic Data Acquisition System (ADAS) of the Civil Structure of Itaipu Hydroelectric Power Plant

Main aspects

- The system uses a series of Remote Acquisition Units (UAR) located throughout the dam. These UARs send their data directly to a Central Station (CS).
- The data gathered at the Central Station is then made available to the Civil team of Itaipu, providing essential information for analysis and decision-making.
- Following this, the Civil team regularly checks data from the ADAS servers to keep a close watch on the dam's structural health.



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CHALLENGE & SOLUTIONS

Creating valuable data insights for the Automatic Data Acquisition System (ADAS) of the Civil Structure of Itaipu Hydroelectric Power Plant

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ITAIPU implements Automation System failure analysis for modernization projects

Challenge

- Provide state-of-the-art on-line monitoring and analytics capabilities for the Automatic Data Acquisition System (ADAS) of the Civil Structure of the ITAIPU hydroelectric power plant
- Require a data-centric decision-making process for modernization projects

Solution

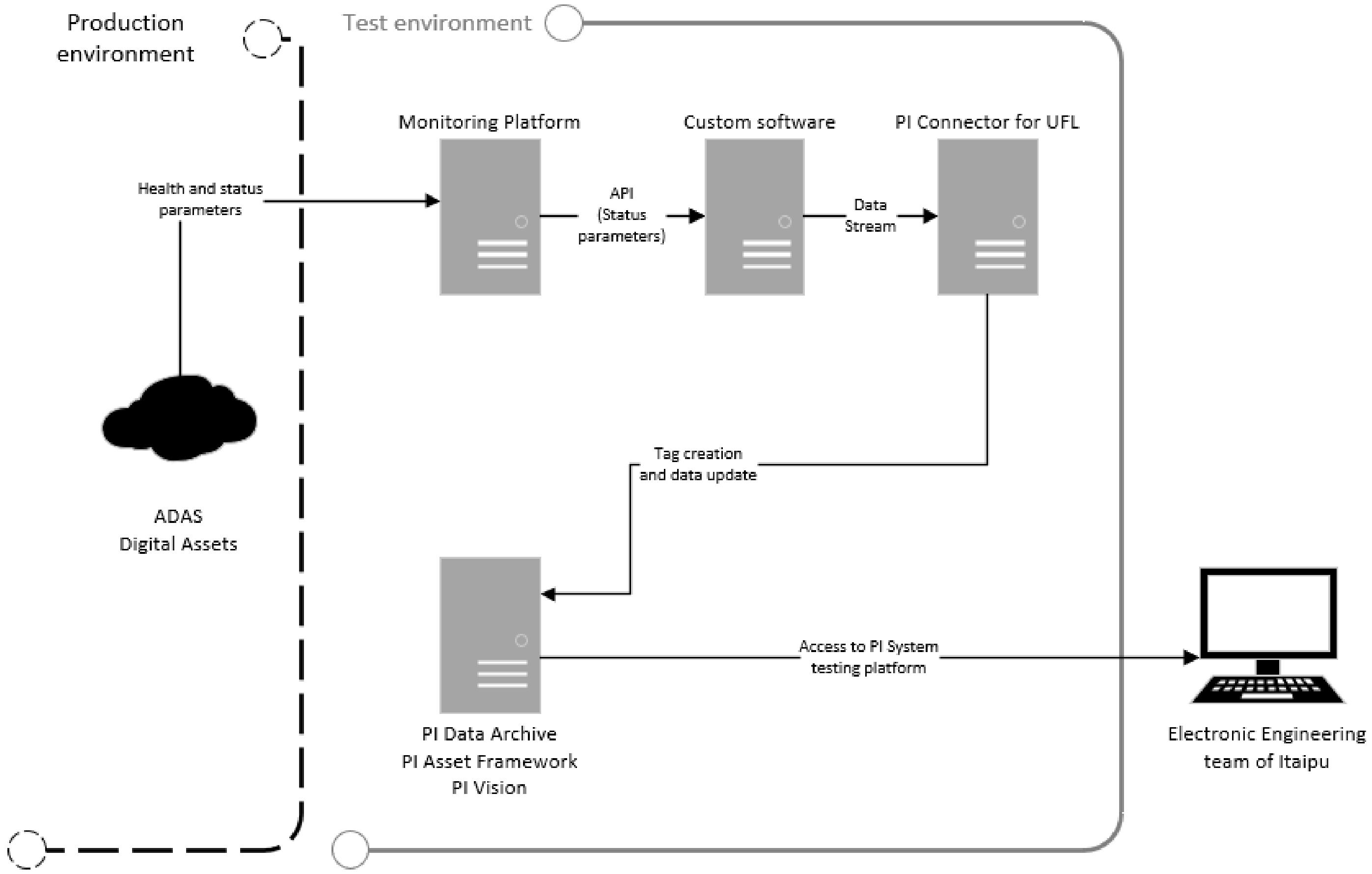
- Deploy the AVEVA™ PI System™ as an advanced foundation for Integration with Networking Monitoring Platform
- Implement Condition Based Maintenance & Advanced Analytics for KPI calculations.

Results

?

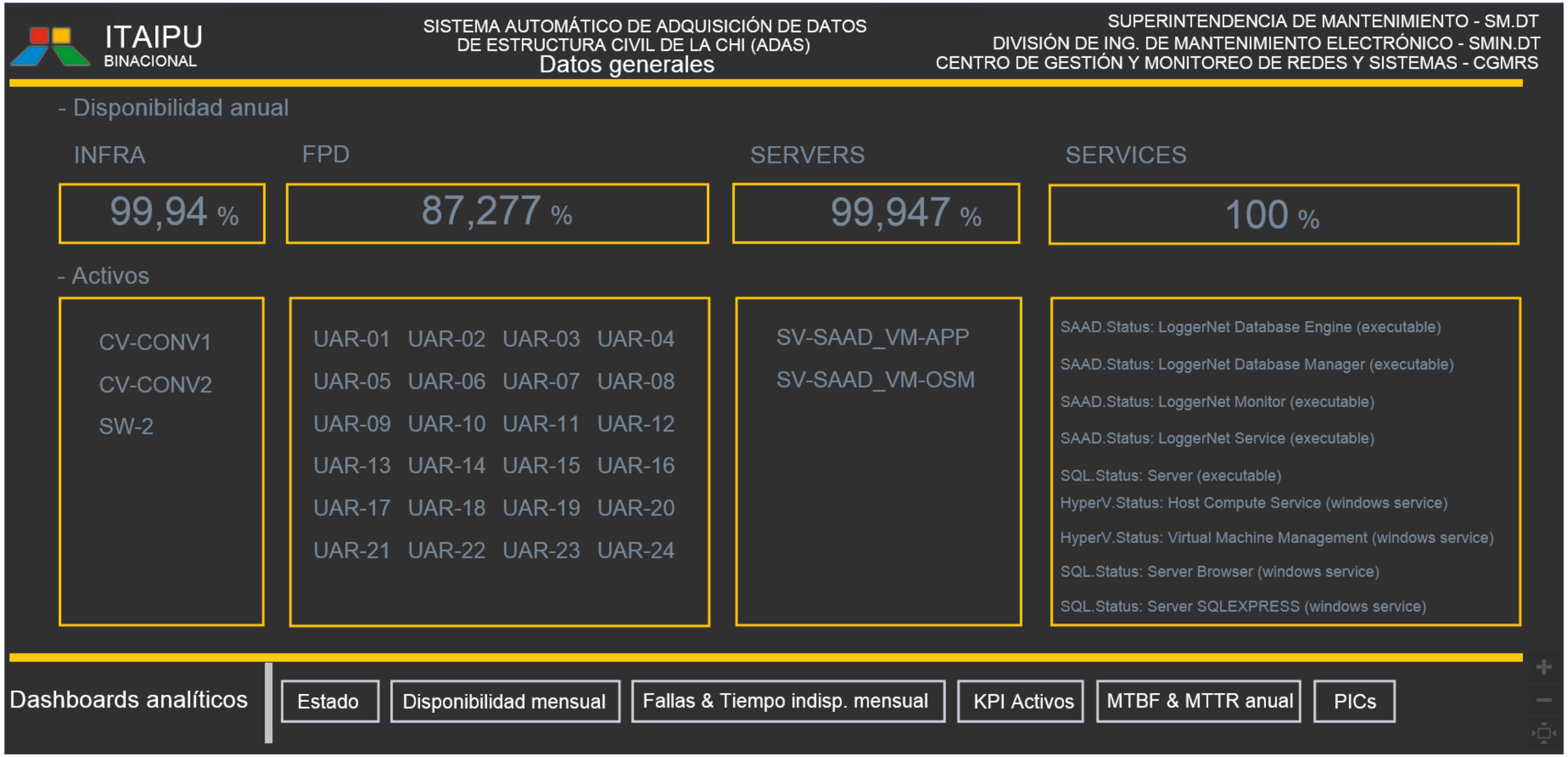
Solution

Implemented architecture for the proof-of-concept



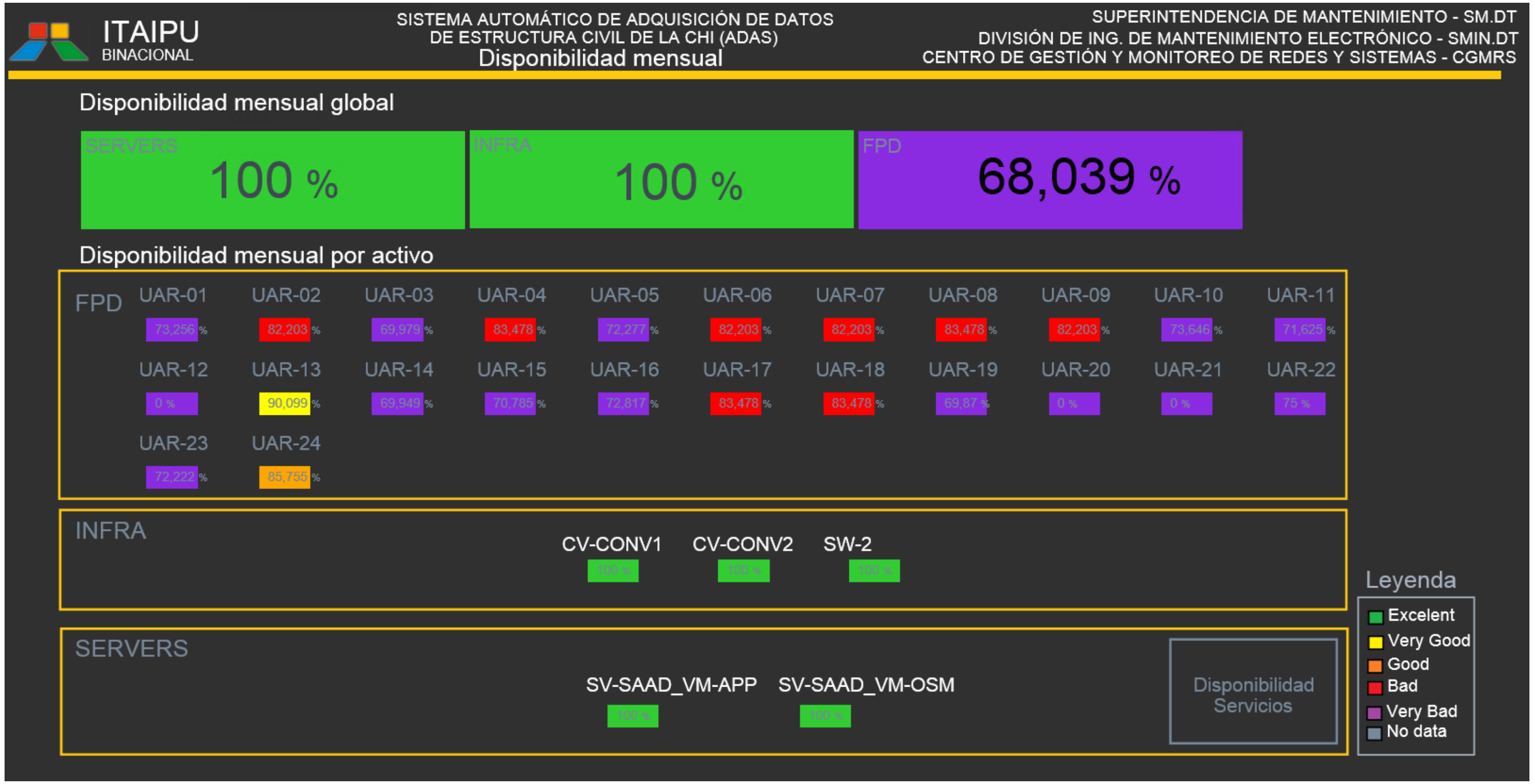
Solution - Implementation details of KPI

Annual availability by group of assets of the same type



Solution - Implementation details of KPI

Monthly availability by asset and by group of assets of the same type



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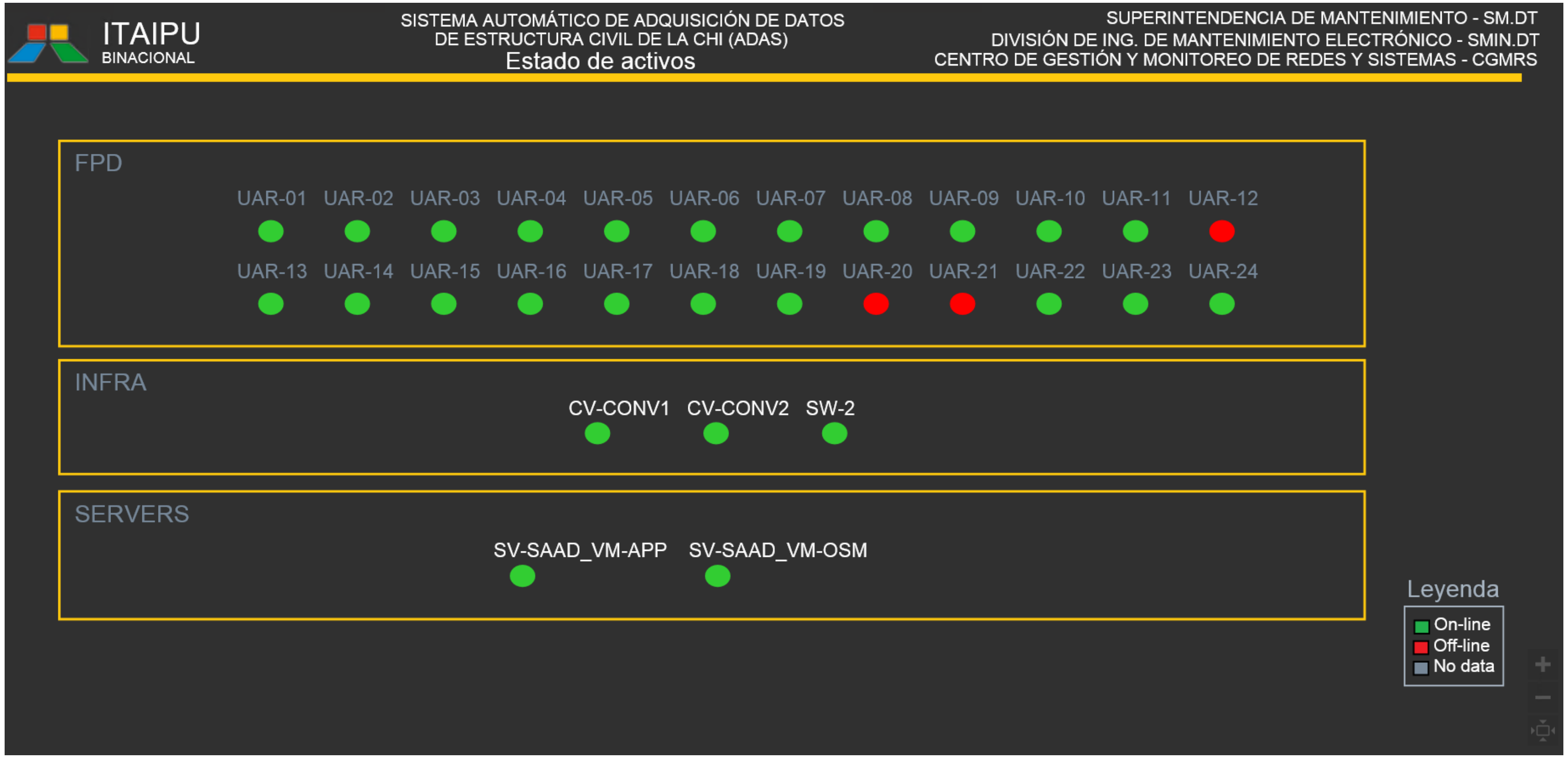
Solution - Implementation details of KPI

On-line status of the System assets



Solution - Implementation details of KPI

Monthly number of failures and downtime per asset

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SISTEMA AUTOMÁTICO DE ADQUISICIÓN DE DATOS
DE ESTRUCTURA CIVIL DE LA CHI (ADAS)
Estadística mensual

SUPERINTENDENCIA DE MANTENIMIENTO - SM.DT
DIVISIÓN DE ING. DE MANTENIMIENTO ELECTRÓNICO - SMIN.DT
CENTRO DE GESTIÓN Y MONITOREO DE REDES Y SISTEMAS - CGMRS

-FPD

Cantidad de fallas

Name	Value
UAR-01|Month_FailureCount	10
UAR-02|Month_FailureCount	9
UAR-03|Month_FailureCount	9
UAR-04|Month_FailureCount	9
UAR-05|Month_FailureCount	12
UAR-06|Month_FailureCount	8
UAR-07|Month_FailureCount	8
UAR-08|Month_FailureCount	10
UAR-09|Month_FailureCount	10
UAR-10|Month_FailureCount	12
UAR-11|Month_FailureCount	10
UAR-12|Month_FailureCount	0
UAR-13|Month_FailureCount	9
UAR-14|Month_FailureCount	7
UAR-15|Month_FailureCount	10
UAR-16|Month_FailureCount	10
UAR-17|Month_FailureCount	12
UAR-18|Month_FailureCount	7
UAR-19|Month_FailureCount	9
UAR-20|Month_FailureCount	0
UAR-21|Month_FailureCount	0
UAR-22|Month_FailureCount	8
UAR-23|Month_FailureCount	8
UAR-24|Month_FailureCount	10

Tiempo de indisponibilidad [h]

Name	Value
UAR-01|Month_UnavailabilityDuration	20,667
UAR-02|Month_UnavailabilityDuration	20,417
UAR-03|Month_UnavailabilityDuration	21,5
UAR-04|Month_UnavailabilityDuration	20,417
UAR-05|Month_UnavailabilityDuration	21,25
UAR-06|Month_UnavailabilityDuration	20,167
UAR-07|Month_UnavailabilityDuration	20,25
UAR-08|Month_UnavailabilityDuration	20,75
UAR-09|Month_UnavailabilityDuration	20,333
UAR-10|Month_UnavailabilityDuration	21,333
UAR-11|Month_UnavailabilityDuration	21,083
UAR-12|Month_UnavailabilityDuration	696
UAR-13|Month_UnavailabilityDuration	21,25
UAR-14|Month_UnavailabilityDuration	20,917
UAR-15|Month_UnavailabilityDuration	20,833
UAR-16|Month_UnavailabilityDuration	21,083
UAR-17|Month_UnavailabilityDuration	21,5
UAR-18|Month_UnavailabilityDuration	20,833
UAR-19|Month_UnavailabilityDuration	20,167
UAR-20|Month_UnavailabilityDuration	696
UAR-21|Month_UnavailabilityDuration	696
UAR-22|Month_UnavailabilityDuration	20,833
UAR-23|Month_UnavailabilityDuration	20,583
UAR-24|Month_UnavailabilityDuration	20,833

-SERVERS

Cantidad de fallas

Name	Value
SV-SAAD|Month_FailureCount	32
SV-SAAD_VM-APP|Month_FailureCount	0
SV-SAAD_VM-OSM|Month_FailureCount	0

Tiempo de indisponibilidad [h]

Name	Value
SV-SAAD|Month_UnavailabilityDuration	12,5
SV-SAAD_VM-APP|Month_UnavailabilityDuration	0
SV-SAAD_VM-OSM|Month_UnavailabilityDuration	0

Estadística anual

-INFRA

Cantidad de fallas

Name	Value
GW-CONV1|Month_FailureCount	28
GW-CONV2|Month_FailureCount	29
SW-2|Month_FailureCount	29

Tiempo de indisponibilidad [h]

Name	Value
GW-CONV1|Month_UnavailabilityDuration	15,199
GW-CONV2|Month_UnavailabilityDuration	15,399
SW-2|Month_UnavailabilityDuration	11,3

-SERVICES

Cantidad de fallas

Name	Value
HyperV.Status: Host Compute Service (windows service)|Month_FailureCount	0
HyperV.Status: Virtual Machine Management (windows service)|Month_FailureCount	1
SQL.Status: Server Browser (windows service)|Month_FailureCount	0
SQL.Status: Server SQLEXPRESS (windows service)|Month_FailureCount	2

Name ▼	Value
SQL.Status: Server (executable)|Month_FailureCount	0
SAAD.Status: LoggerNet Service (executable)|Month_FailureCount	0
SAAD.Status: LoggerNet Monitor (executable)|Month_FailureCount	0
SAAD.Status: LoggerNet Database Manager (executable)|Month_FailureCount	0
SAAD.Status: LoggerNet Database Engine (executable)|Month_FailureCount	0

Tiempo de indisponibilidad [h]

Name	Value
HyperV.Status: Host Compute Service (windows service)|Month_UnavailabilityDuration	0
HyperV.Status: Virtual Machine Management (windows service)|Month_UnavailabilityDuration	0,33337
SQL.Status: Server Browser (windows service)|Month_UnavailabilityDuration	0
SQL.Status: Server SQLEXPRESS (windows service)|Month_UnavailabilityDuration	0,33329

Name	Value
SAAD.Status: LoggerNet Database Engine (executable)|Month_UnavailabilityDuration	0
SAAD.Status: LoggerNet Database Manager (executable)|Month_UnavailabilityDuration	0
SAAD.Status: LoggerNet Monitor (executable)|Month_UnavailabilityDuration	0
SAAD.Status: LoggerNet Service (executable)|Month_UnavailabilityDuration	0
SQL.Status: Server (executable)|Month_UnavailabilityDuration	0

- Disponibilidad media global [%]

Name	Value
ADAS|INFRA_Average_Month_Availability	98,355
ADAS|SERVERS_Average_Month_Availability	98,586
ADAS|SERVICES_Average_Month_Availability	99,957
ADAS|FPD_Average_Month_Availability	86,104

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Solution - Implementation details of KPI

Annual mean time to repair and mean time between failures per asset

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BINACIONAL

SISTEMA AUTOMÁTICO DE ADQUISICIÓN DE DATOS
DE ESTRUCTURA CIVIL DE LA CHI (ADAS)
Análisis Estadístico Anual

SUPERINTENDENCIA DE MANTENIMIENTO - SM.DT
DIVISIÓN DE ING. DE MANTENIMIENTO ELECTRÓNICO - SMIN.DT
CENTRO DE GESTIÓN Y MONITOREO DE REDES Y SISTEMAS - CGMRS

-FPD

MTBF [h]

Name	Value
UAR-01|Year_MTBF	65,04
UAR-02|Year_MTBF	108,67
UAR-03|Year_MTBF	30,534
UAR-04|Year_MTBF	101,13
UAR-05|Year_MTBF	56,257
UAR-06|Year_MTBF	107,34
UAR-07|Year_MTBF	103,53
UAR-08|Year_MTBF	102,31
UAR-09|Year_MTBF	99,976
UAR-10|Year_MTBF	58,514
UAR-11|Year_MTBF	44,976
UAR-12|Year_MTBF	795,27
UAR-13|Year_MTBF	115,87
UAR-14|Year_MTBF	30,641
UAR-15|Year_MTBF	29,907
UAR-16|Year_MTBF	36,074
UAR-17|Year_MTBF	106,04
UAR-18|Year_MTBF	111,44
UAR-19|Year_MTBF	30,113
UAR-20|Year_MTBF	8.748
UAR-21|Year_MTBF	8.748
UAR-22|Year_MTBF	74,45
UAR-23|Year_MTBF	58,126
UAR-24|Year_MTBF	106,04

MTTR [h]

Name	Value
UAR-01|Year_MTTR	18,06
UAR-02|Year_MTTR	30,323
UAR-03|Year_MTTR	8,6027
UAR-04|Year_MTTR	28,006
UAR-05|Year_MTTR	15,656
UAR-06|Year_MTTR	29,712
UAR-07|Year_MTTR	28,656
UAR-08|Year_MTTR	28,327
UAR-09|Year_MTTR	27,68
UAR-10|Year_MTTR	16,284
UAR-11|Year_MTTR	12,56
UAR-12|Year_MTTR	685,17
UAR-13|Year_MTTR	32,298
UAR-14|Year_MTTR	10,496
UAR-15|Year_MTTR	8,4123
UAR-16|Year_MTTR	10,108
UAR-17|Year_MTTR	29,363
UAR-18|Year_MTTR	30,845
UAR-19|Year_MTTR	8,4567
UAR-20|Year_MTTR	7.430,8
UAR-21|Year_MTTR	0
UAR-22|Year_MTTR	20,663
UAR-23|Year_MTTR	16,166
UAR-24|Year_MTTR	29,357

-SERVERS

MTBF [h]

Name	Value
SV-SAAD|Year_MTBF	213,36
SV-SAAD_VM-APP|Year_MTBF	437,4
SV-SAAD_VM-OSM|Year_MTBF	486

MTTR [h]

Name	Value
SV-SAAD|Year_MTTR	0,37196
SV-SAAD_VM-APP|Year_MTTR	3,1975
SV-SAAD_VM-OSM|Year_MTTR	2,6389

-INFRA

MTBF [h]

Name	Value
GW-CONV1|Year_MTBF	265,09
GW-CONV2|Year_MTBF	257,29
SW-2|Year_MTBF	249,94

MTTR [h]

Name	Value
GW-CONV1|Year_MTTR	4,1288
GW-CONV2|Year_MTTR	4,0132
SW-2|Year_MTTR	3,7857

-SERVICES

MTBF [h]

Name ▲	Value
HyperV.Status: Host Compute Service (windows service)|Year_MTBF	8.748
HyperV.Status: Virtual Machine Management (windows service)|Year_MTBF	4.374
SQL.Status: Server Browser (windows service)|Year_MTBF	8.748
SQL.Status: Server SQLEXPRESS (windows service)|Year_MTBF	2.915,8

Name ▲	Value
SAAD.Status: LoggerNet Database Engine (executable)|Year_MTBF	8.748
SAAD.Status: LoggerNet Database Manager (executable)|Year_MTBF	4.374
SAAD.Status: LoggerNet Monitor (executable)|Year_MTBF	4.374
SAAD.Status: LoggerNet Service (executable)|Year_MTBF	8.748
SQL.Status: Server (executable)|Year_MTBF	17.496

MTTR [h]

Name ▲	Value
HyperV.Status: Host Compute Service (windows service)|Year_MTTR	0
HyperV.Status: Virtual Machine Management (windows service)|Year_MTTR	0,25001
SQL.Status: Server Browser (windows service)|Year_MTTR	0
SQL.Status: Server SQLEXPRESS (windows service)|Year_MTTR	526,84

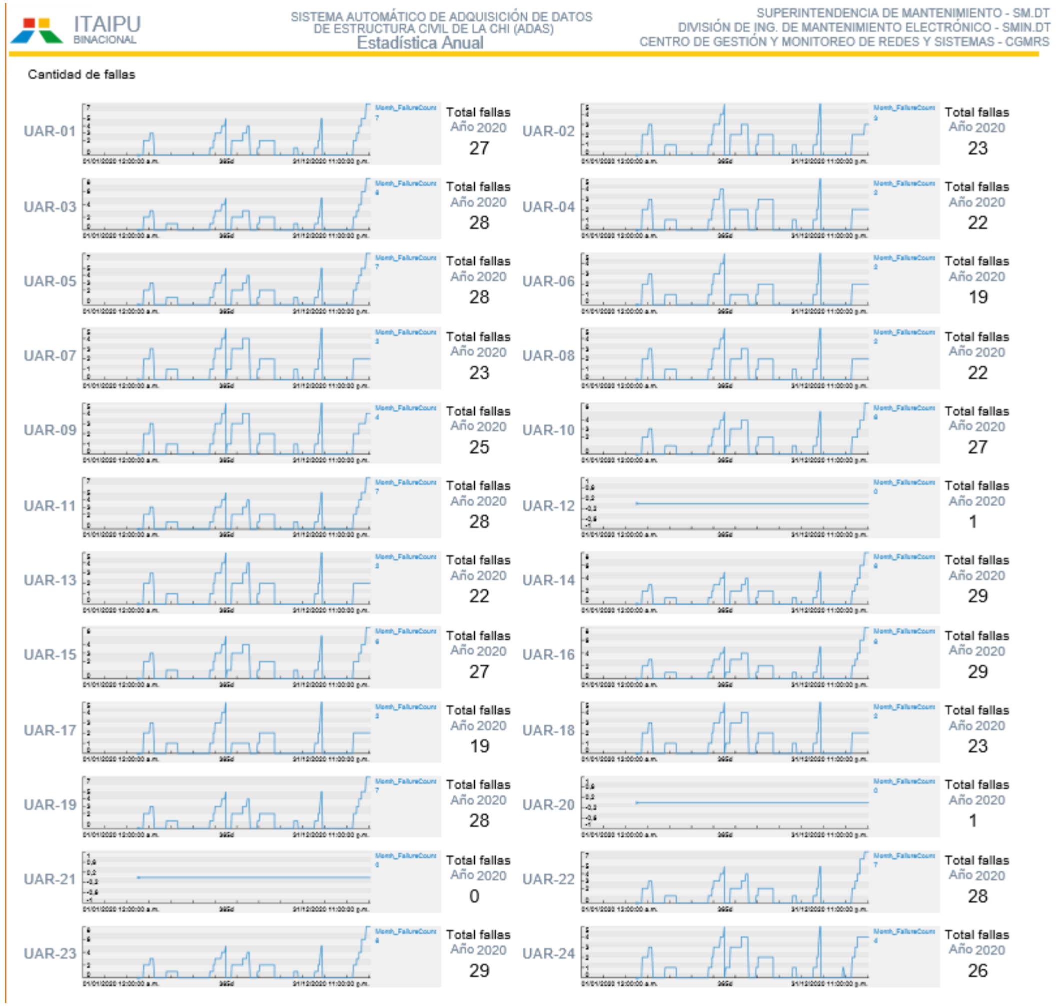
Name ▲	Value
SAAD.Status: LoggerNet Database Engine (executable)|Year_MTTR	2,6498
SAAD.Status: LoggerNet Database Manager (executable)|Year_MTTR	46,125
SAAD.Status: LoggerNet Monitor (executable)|Year_MTTR	185,48
SAAD.Status: LoggerNet Service (executable)|Year_MTTR	2,6498
SQL.Status: Server (executable)|Year_MTTR	3.163,1

- Disponibilidad media global [%]

Name	Value
ADAS|FPD_Average_Year_Availability	76,027
ADAS|INFRA_Average_Year_Availability	99,81
ADAS|SERVERS_Average_Year_Availability	99,766
ADAS|SERVICES_Average_Year_Availability	88,369

Solution - Implementation details of KPI

Number of failures in remote stations in a period of twelve months



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Results

Results, benefits and efficiencies gained

- Detected downtime events were verified on field by the Maintenance team and the causes identified. This process gave feedback to the team on the improvement of the monitoring strategy and in the determination of the status of assets, through de IT Monitoring Platform, which serve as data source for this work.

- Definition and implementation of Key Performance Indicators for the ADAS System digital assets.

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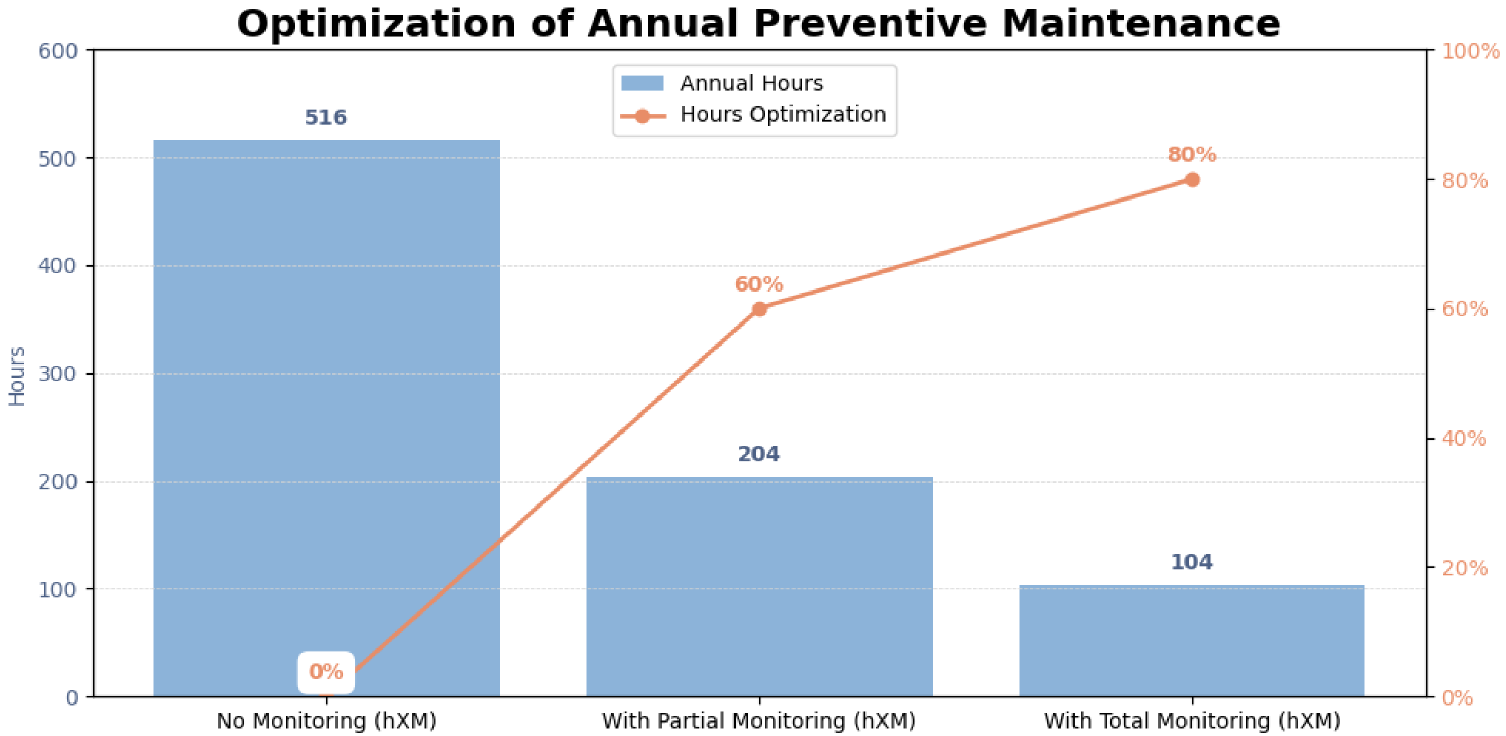
Results

Results, benefits and efficiencies gained

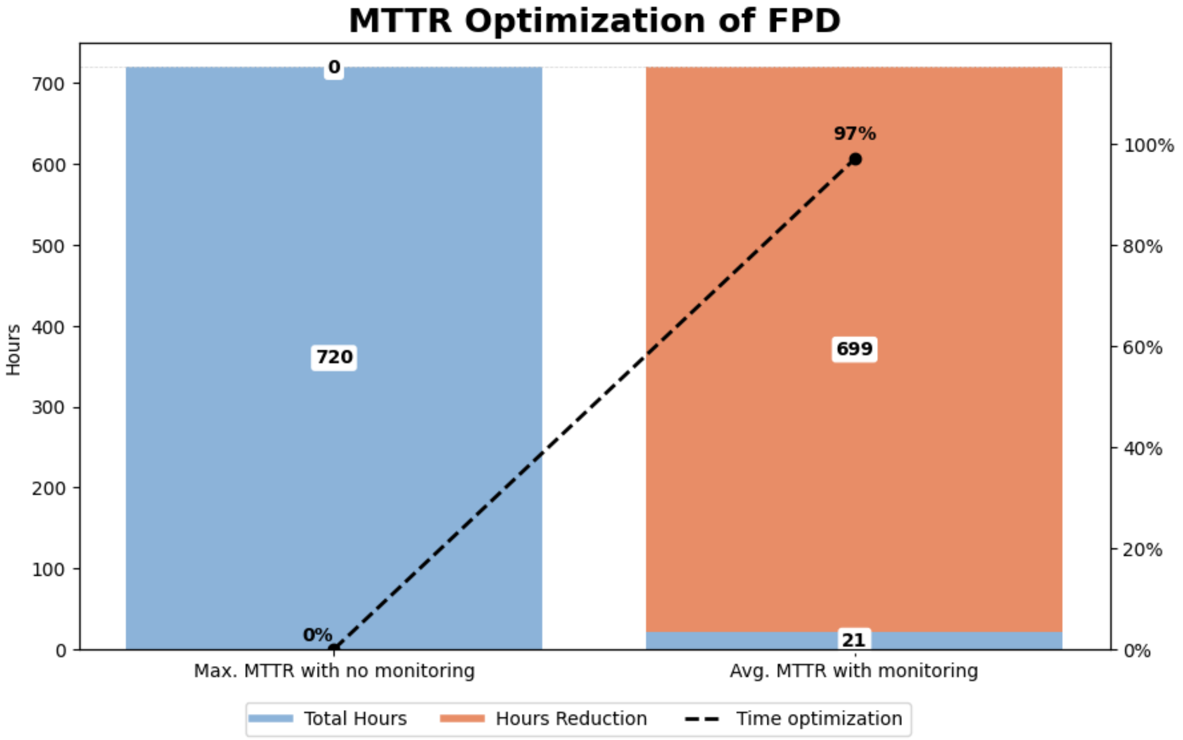
- **60%** reduction of the required time for the Maintenance team to execute the preventive maintenance on the System in a year, which represents a saving of 208 hours.



Results

Results, benefits and efficiencies gained

- Reduction in the MTTR (Mean Time to Repair) to an average of 21 hours per month, achieving an optimization up to **97%** per month of the MTTR of the Field Process Devices, which represents a reduction of 699 hours per month in average.



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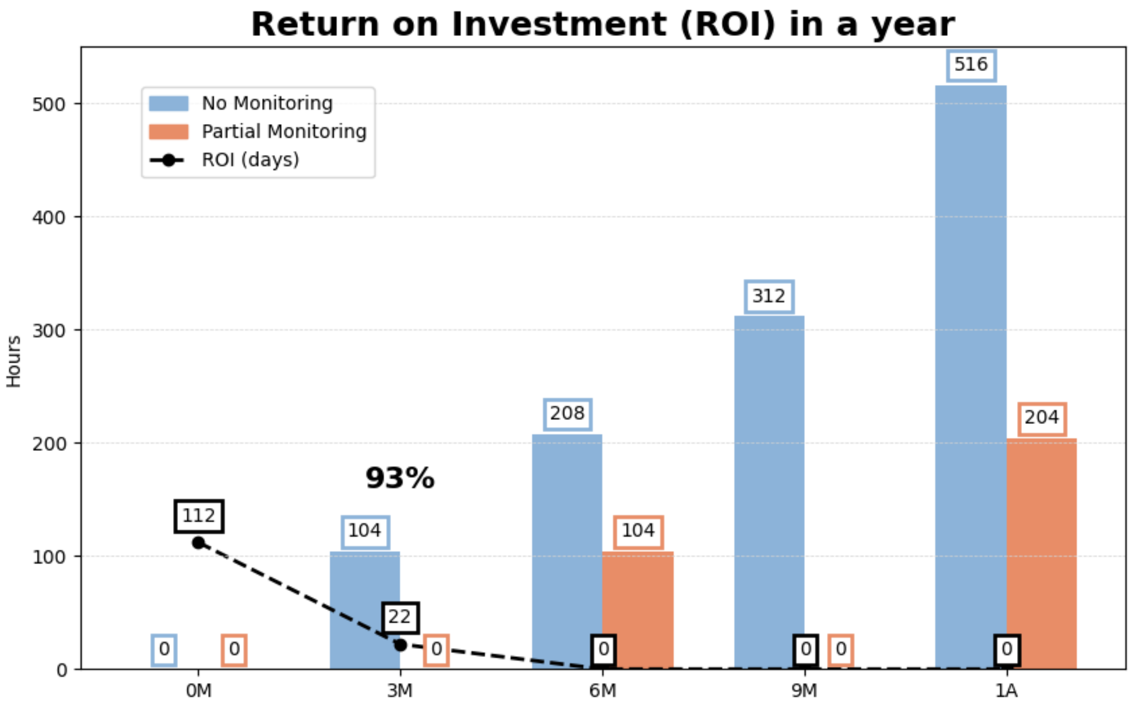
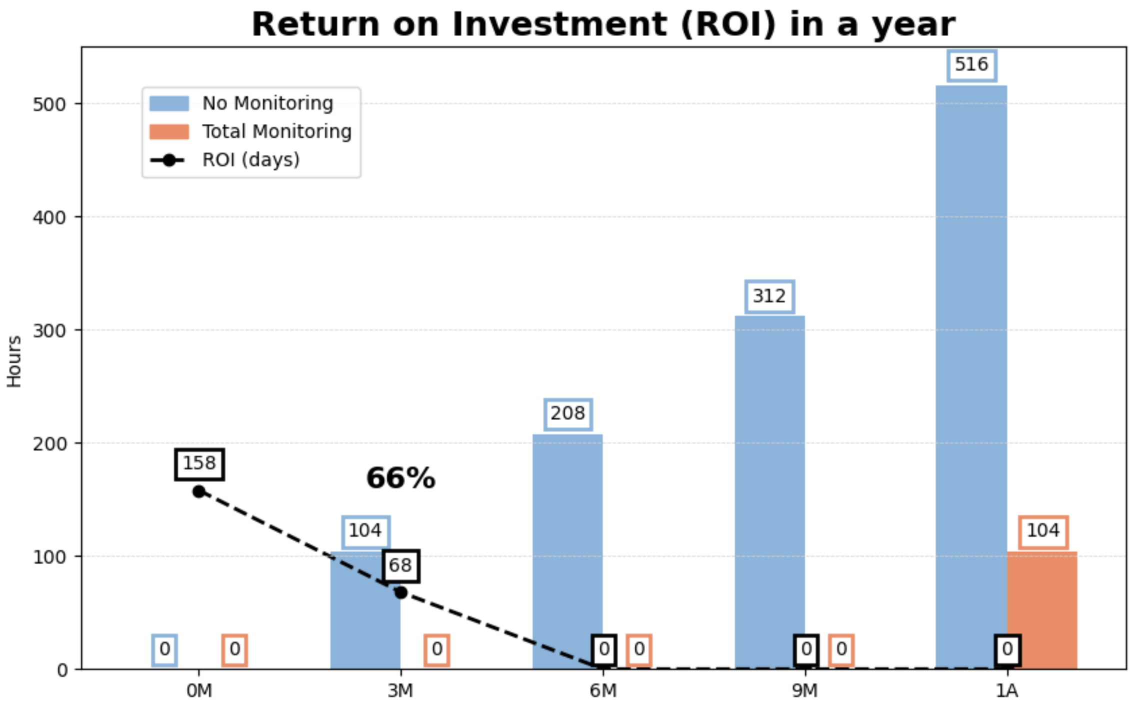
Results

Results, benefits and efficiencies gained

- ROI implementing partial monitoring:



- ROI implementing total monitoring:



Conclusions

- The failure analysis study implemented in digital assets, considering performance indicators, was adequate to get relevant information of overall health of the evaluated System.

- The PI System tools were helpful for data acquisition from the Monitoring Platform, for the historization, structuration and analysis implementation, and for the development of displays.

- The KPI implemented on the evaluated system was enough to identify the group of assets with higher downtime and support the decision-making process for the modernization of the System.

- The defined methodology in this work has helped the standardization for future use in other Automation Systems.

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Power Generation | PARAGUAY and BRASIL

ITAIPU implements Automation System failure analysis for modernization projects

Challenge

- Provide state-of-the-art on-line monitoring and analytics capabilities for the Automatic Data Acquisition System (ADAS) of the Civil Structure of the ITAIPU hydroelectric power plant
- Require a data-centric decision-making process for modernization projects

Solution

- Deploy the AVEVA PI System as an advanced foundation for Integration with Networking Monitoring Platform
- Implement Condition Based Maintenance & Advanced Analytics for KPI calculations.

Results

- Implementation of Key Performance Indicators (KPIs) for digital assets of ADAS System
- Improvement and optimization of the execution time of corrective and preventive maintenance
- The ITAIPU Maintenance team used the KPIs to support the request for the modernization of the assessed System, aiming to improve the availability of data regarding the civil structural health of the dam.

Future work

- Make a Workshop or a Proof-of-Concept (PoC) to evaluate other PI System tools that may retrieve health status data from digital assets;
- Propose the inclusion of failure analysis and health assessment on digital assets for other Automation Systems;
- Define a roadmap to predictive and condition-based maintenance.

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“Data is a precious thing and will last longer than the systems themselves.”

Timothy John Berners-Lee, Computer Scientist, Inventor of World Wide Web.

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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. The company is headquartered in Cambridge, UK.

Learn more at www.aveva.com

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