PaaS
SAKURA-IIoT

INNOVINNPROM

Operational Excellence
Maintenance & Repair

Asset Performance Management
SaaS “SAKURA-APM”

This project has received funding from the European Union’s Horizon 2020 research and innovation programme within the framework of the BOWI Project funded under grant agreement No 873155

BOWI

INDUSTRY 4.0

Object of TTE

The volume of fully loaded grain storage is 100,000 tons

SCADA - Automated design system “Route” INNOVINNPROM

PLC – Siemens S7-1500, 1500 DI/DO/AI/AO

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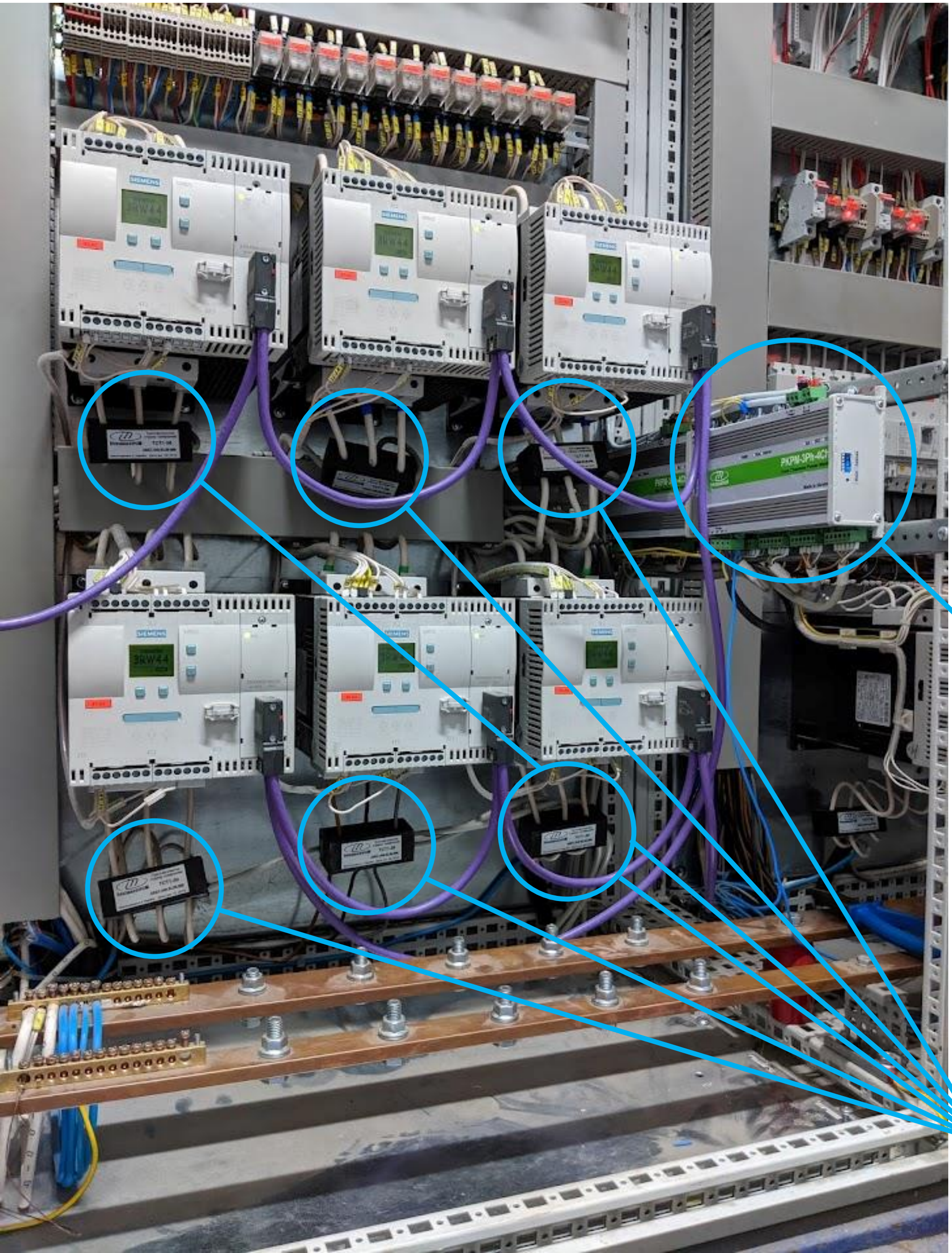
Installation of Equipment Without Reassembly



Installed:

Power Meters 17 units
Transformers 65 units
IoT Gateways 2 units

Total:

65 units controlled equipment
3,000 control channels per second

4 Channel Smart Power Meters
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Innovative 3 Phase Transformers
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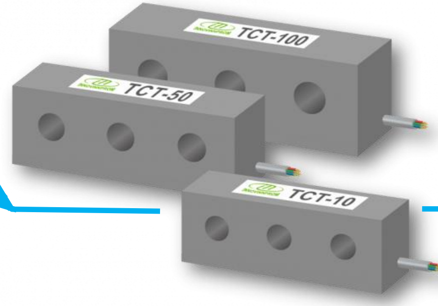

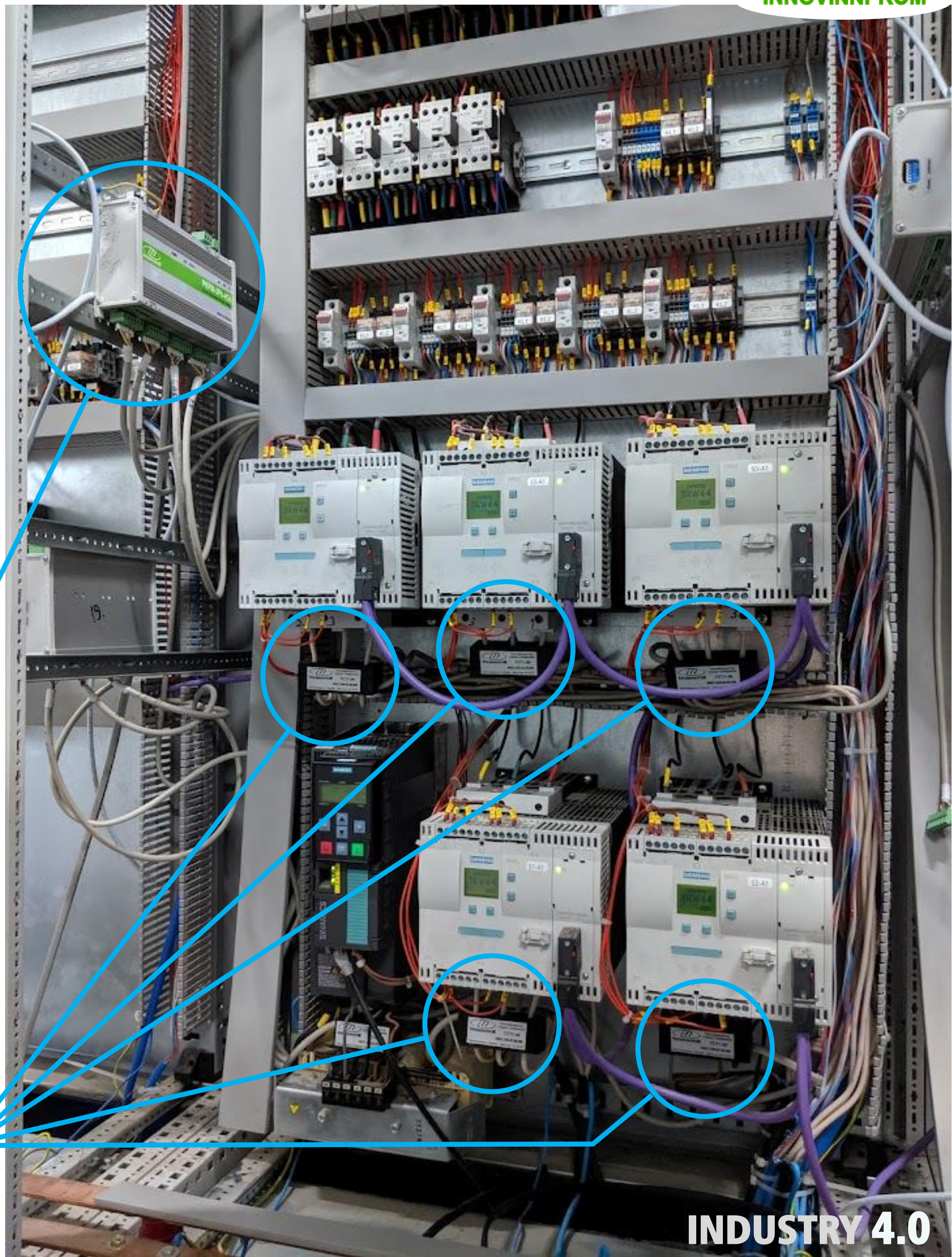

Workspace

ІННОВІННПРОМ

Full Control and Analytics at All Levels - Holding / Enterprise / Production Line / Equipment

INDUSTRY 4.0

- Internet of Things
- Artificial Intelligence
- Machine Learning
- Edge Computing
- Big Data
- Cyber Security
- Digital Twin

The Results of Proof of Concept

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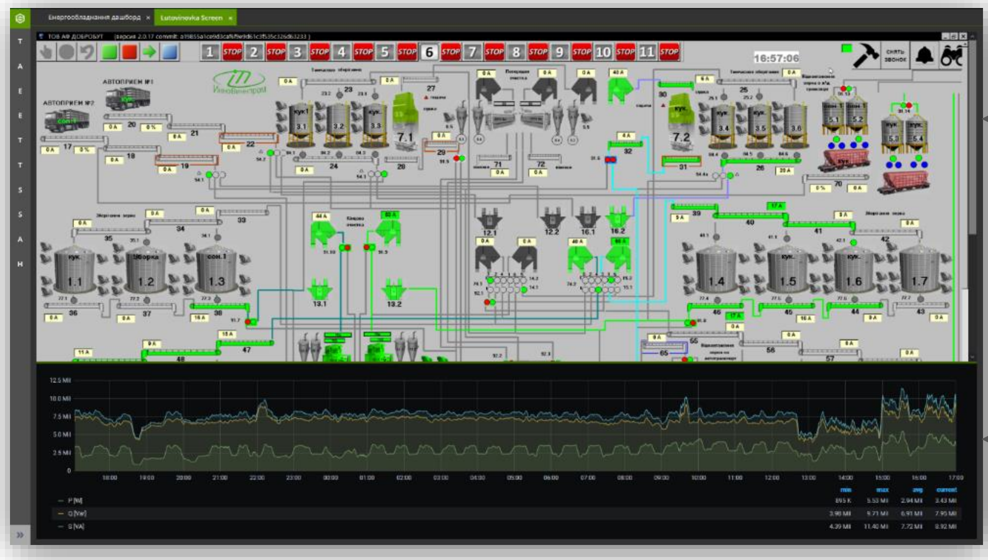
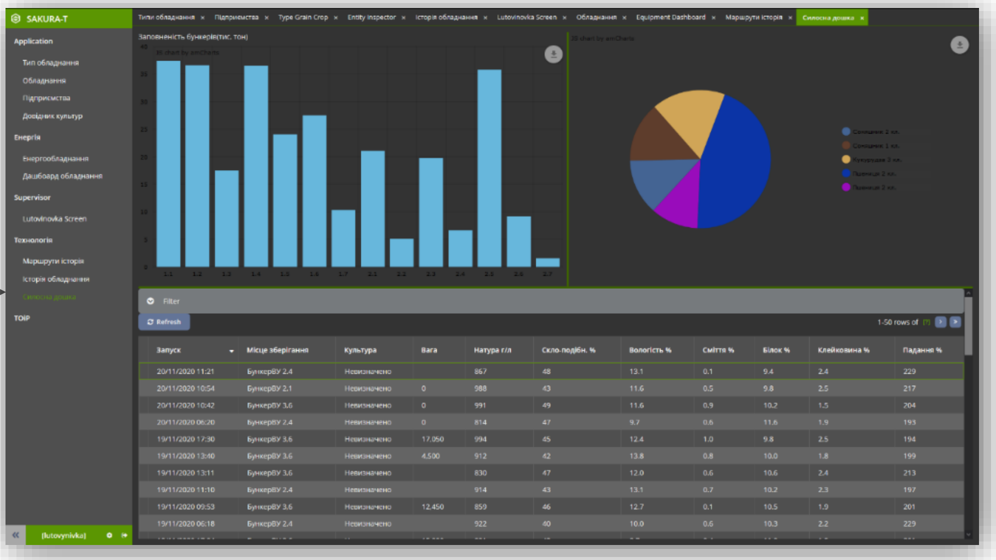


Technology control

Energy efficiency analysis

KPI calculation

Total energy consumption



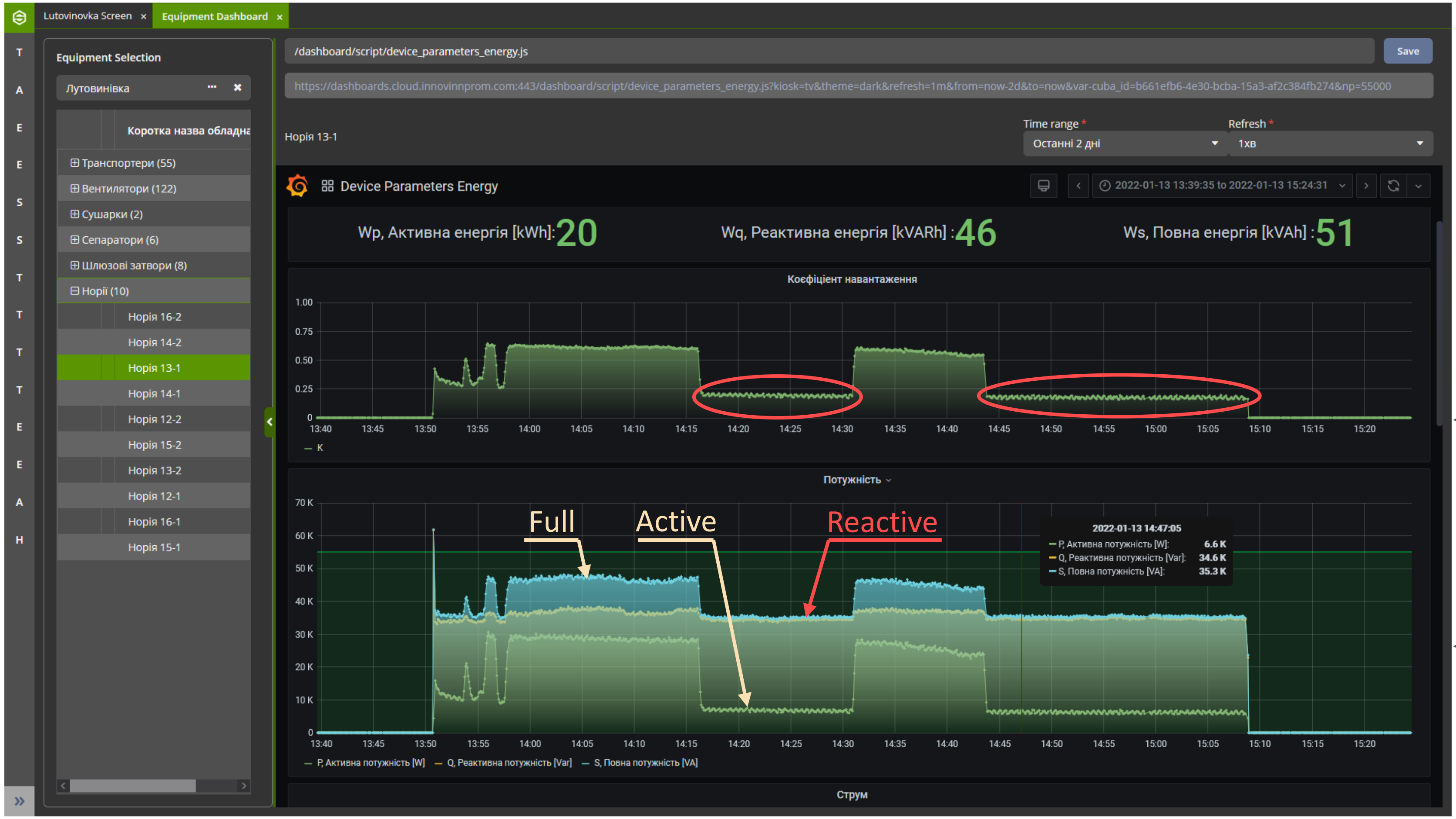
Analysis of technical processes

Control of equipment operation

INDUSTRY 4.0

Problem Discovery and Diagnostics

Example of using one unit of equipment out of 65:



Test operation showed that more than 17% of the company's equipment was used inefficiently. Moreover, if electric motors were idling without load, the energy consumed by them dropped insignificantly. The reason is the high reactive component of energy consumption.
As a result, energy is released into the air, contributing to cable lines over-heating. This is the main reason for excessive energy consumption by the company and excessive wear of equipment.

Equipment efficiency - 25%

during 50% of the technological process

Electricity losses 37 kVA/h

prevalence of the reactive component
direct electricity losses

Result:

More than 25 kVAh was lost during the technological process lasting 1 hour 20 minutes

The task of the SaaS SAKURA-T:

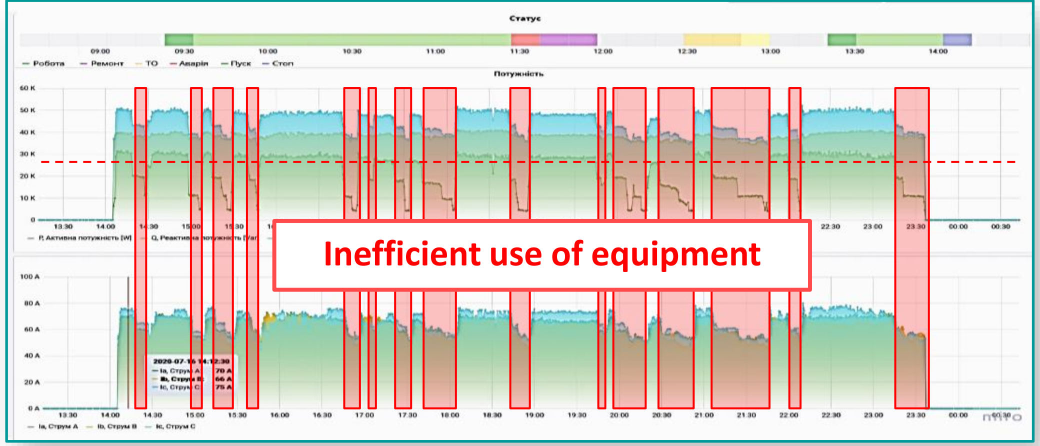
Using AI & ML, automatically detect cases of suboptimal use of equipment and provide appropriate correction commands to SKADA

INDUSTRY 4.0

The Results of Proof of Concept

The period of test operation - from July 2020 to January 2022, only 16 months

	Wp, Active energy [kWh]	Wq, Reactive energy [kVARh]	Ws, Full energy [kVAh]
Consumed during the trial operation	388 238	772 376	934 885
On average, daily	808,83	1 609,17	1 947,68
Inefficient operation at load <40%	66 000,46	131 303,92	158 930,45
Losses, Euros			31 786,09



The table takes into account only electricity losses, excluding:

- ❖ operation of ventilation, aspiration and lighting systems;
- ❖ gas costs for drying products;
- ❖ related operating losses.

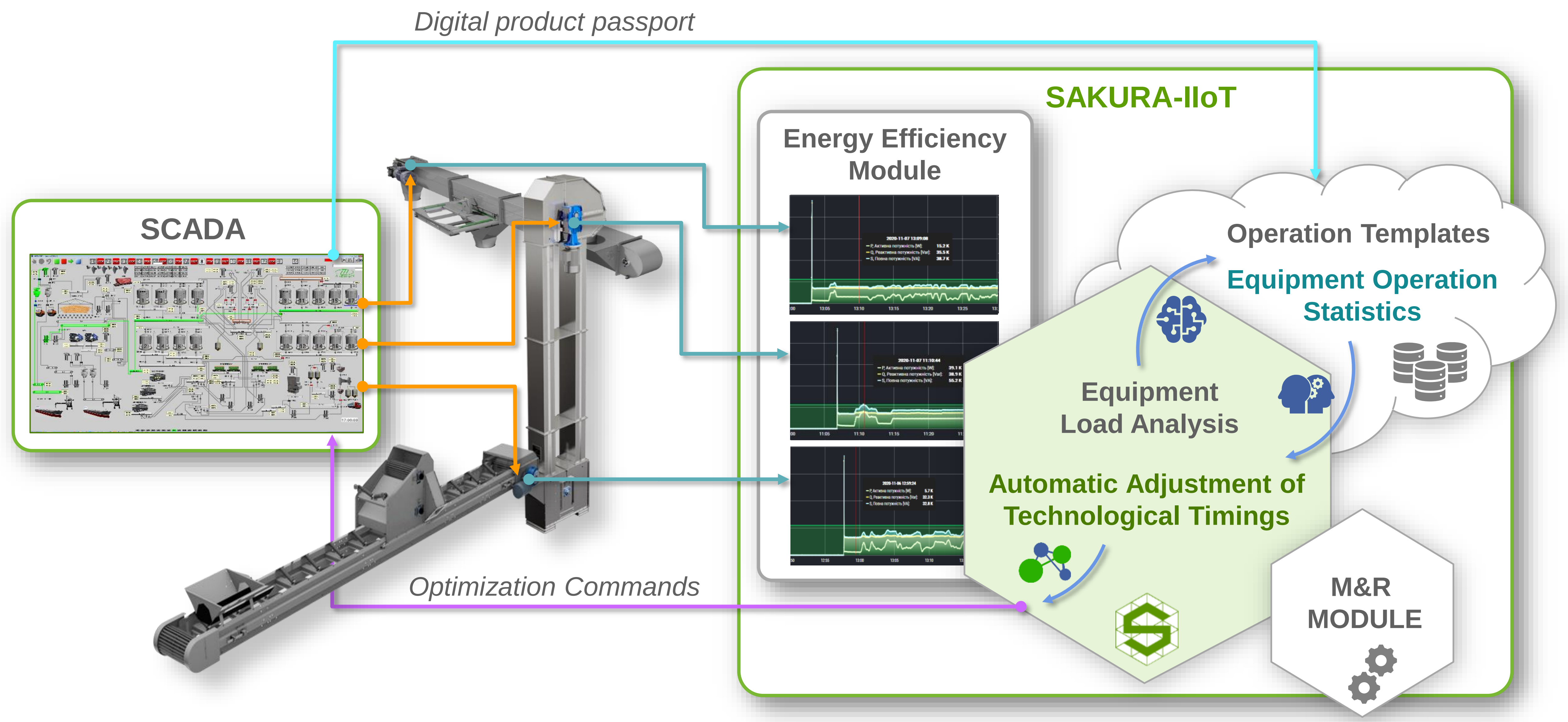
Altogether, total losses can be 3 ... 5 times higher.

The task of AI & ML:

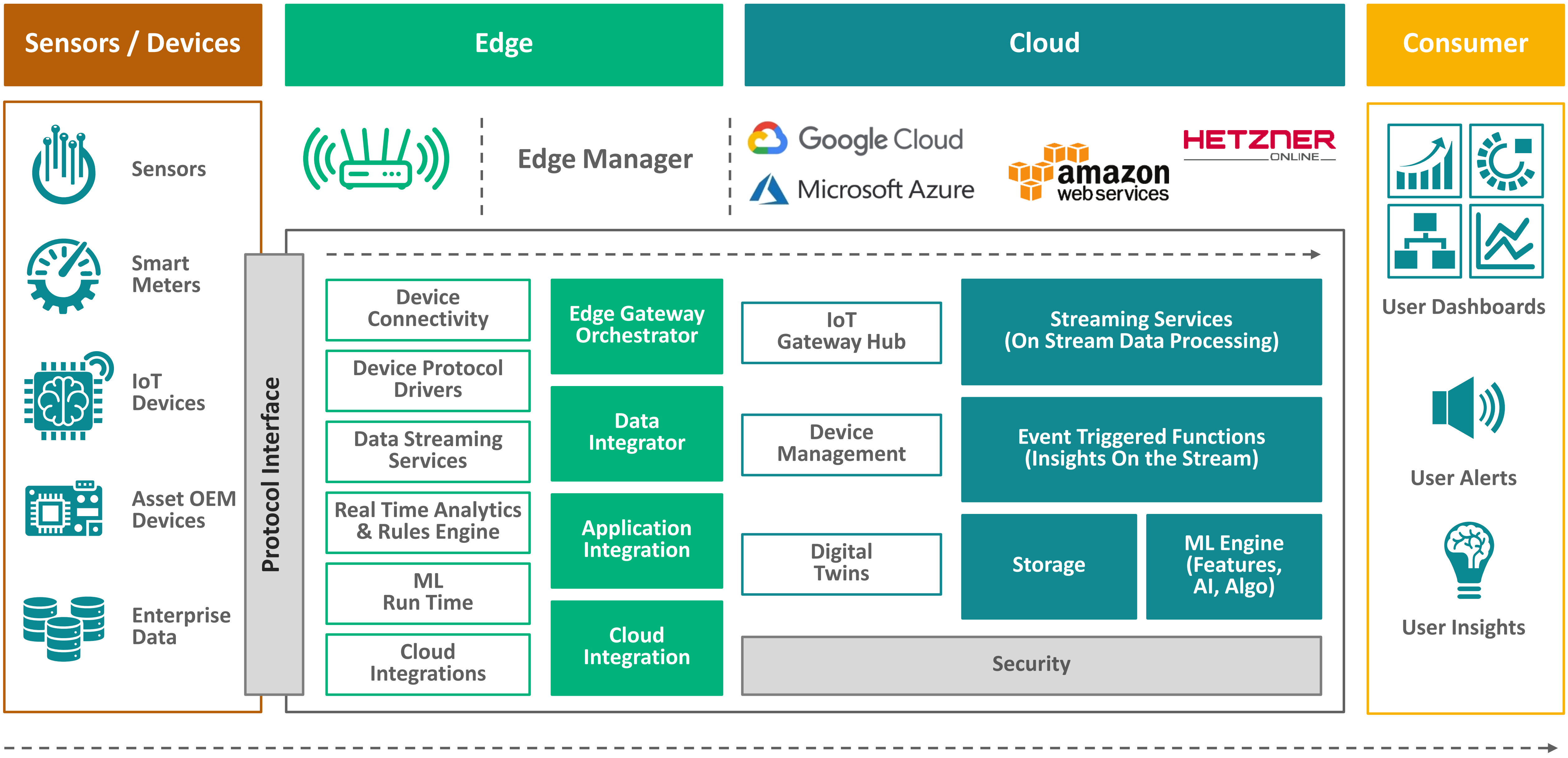
- ❖ Optimization of technological delays
- ❖ Product life cycle control
- ❖ Adjustment of technological parameters depending on product quality
- ❖ Forecasting the cost of energy resources
- ❖ Recognition and correction of human errors

The result of the implementation of SAKURA-T in addition to financial costs will reduce emissions of pollutants.

AI & ML for Energy Efficiency Optimization



Architecture in a Typical Manufacturing Scenario



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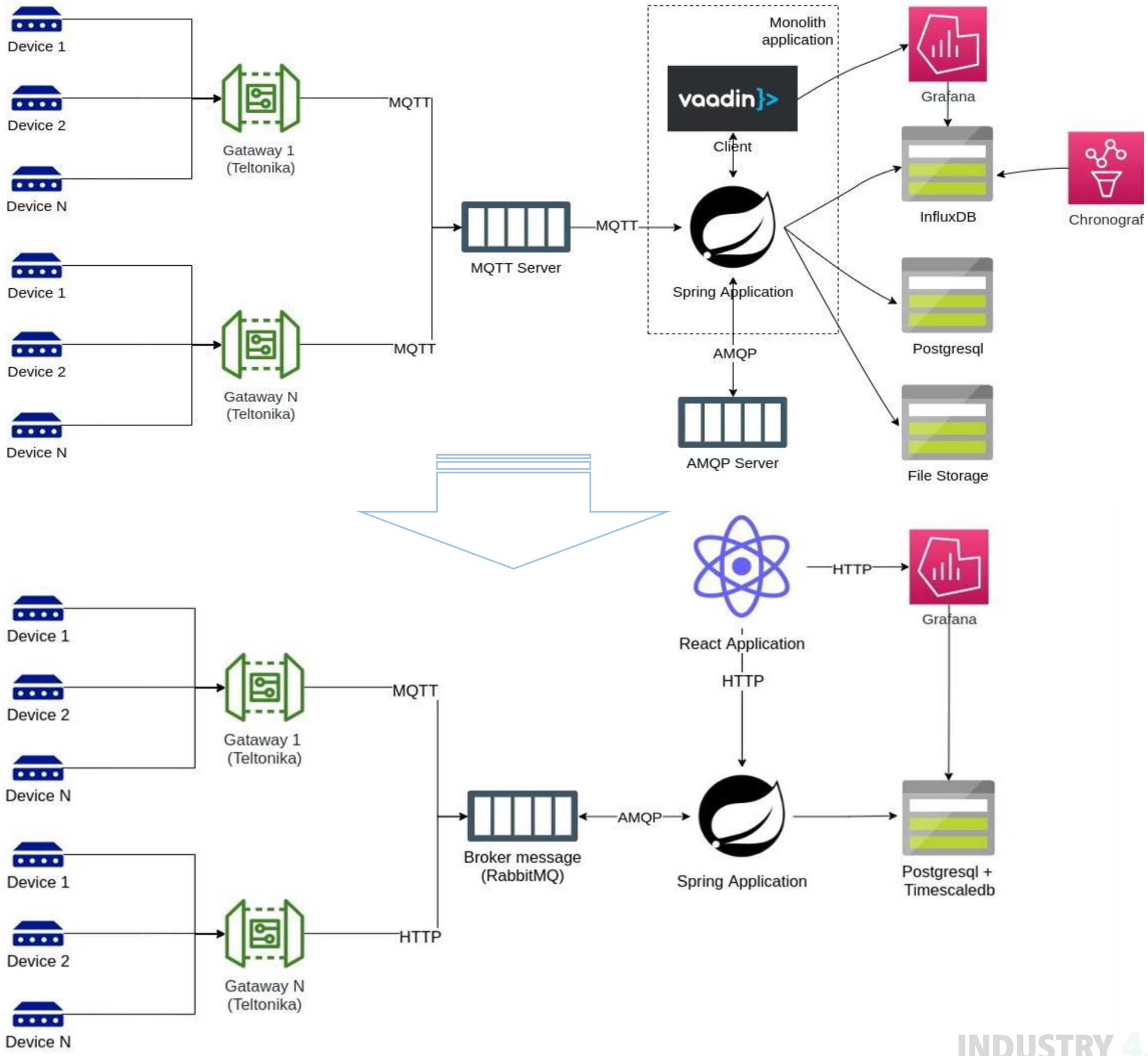
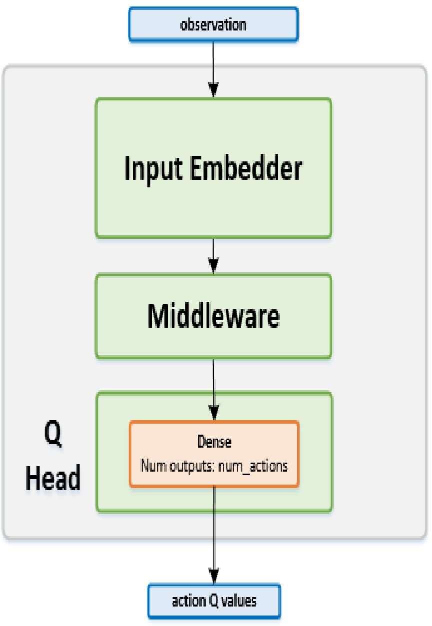
Optimize the Technology Stack

1. The monolithic application was divided into a client and a server.
2. Moved the client part from Vaadin to React. This provides more opportunities for development, simplifies maintenance, allows for easier configuration of horizontal scaling.
3. Due to the Timescale DB extension for Postgre SQL, we excluded the time series database (Influxdb) and the administration tool (Chronograf).
4. Moved the Mqtt server to Rabbit MQ, due to the Rabbit-MQTT plugin.
5. PostgreSQL is used to store files.
6. We increased the fault tolerance of the application due to the introduction of a two-way queue in RabbitMQ.

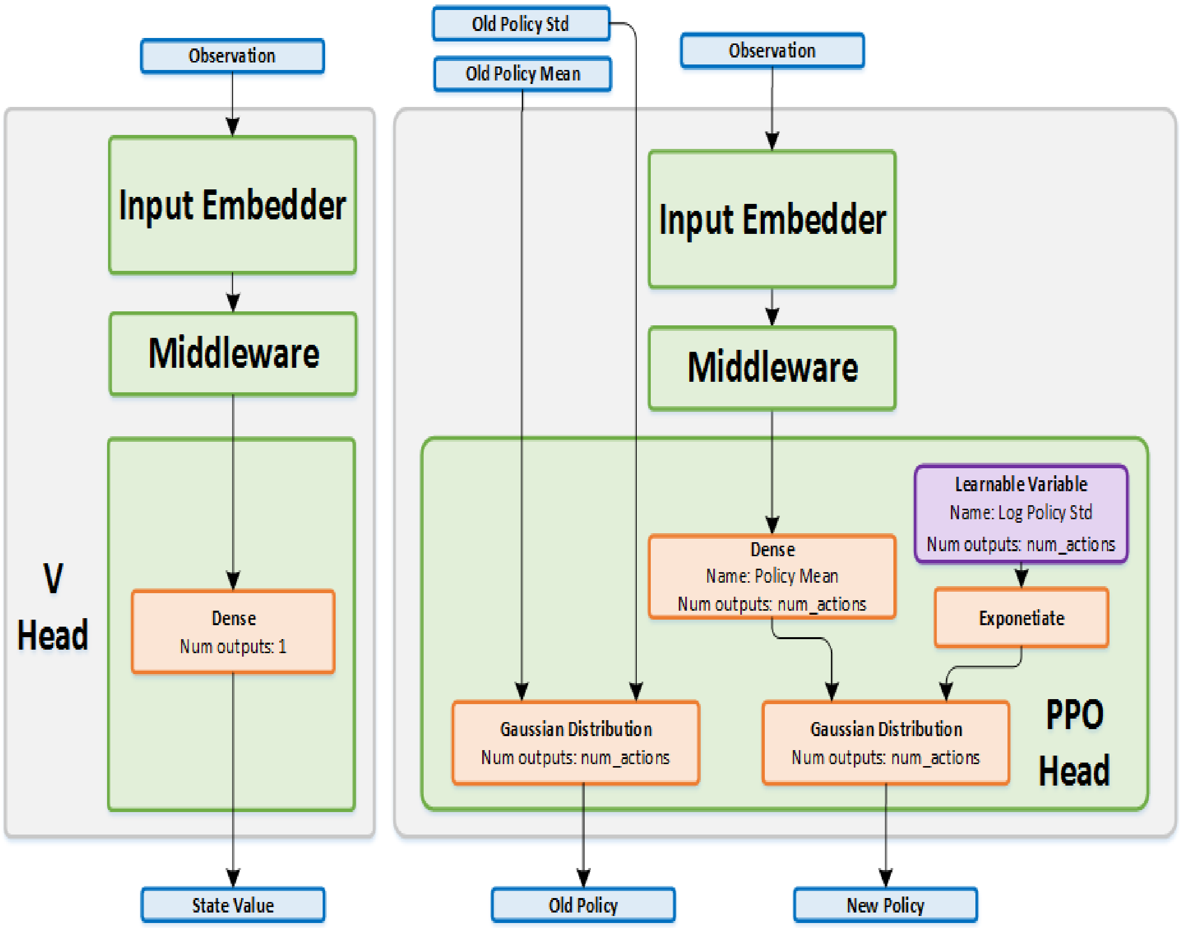


Analysis of Analogues for the Optimization of the TP Using Intelligent Information Technology

Block diagram DQN



Block diagram PPO

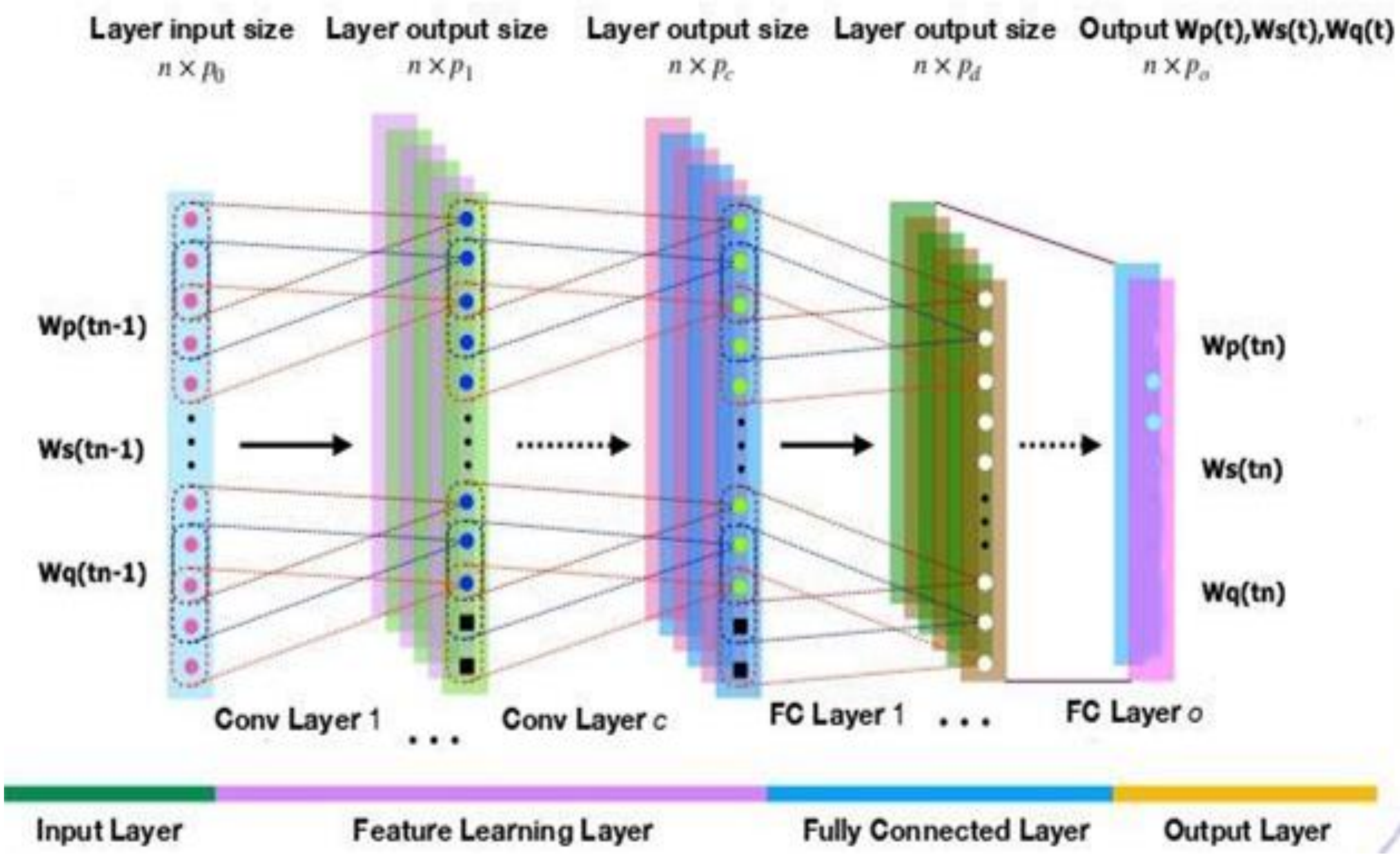


Comparative table of analogues for the optimization of the TP using intelligent information technology

Parameter	DQN (Deep Q Network)	A2C (Advantage-Actor-Critic)	PPO (Proximal Policy Optimization)
Recurrent policies	NO	YES	NO
Multi processing	NO	YES	YES
Discrete (Action/Observation)	YES/YES	YES/YES	YES/YES
Box (Action/Observation)	YES/NO	YES/YES	YES/YES
MultiDiscrete (Action/Observation)	YES/NO	YES/YES	YES/YES
MultiBinary (Action/Observation)	YES/NO	YES/YES	YES/YES

The best option is intellectual method **A2C with reinforcement learning**

Architecture Neural Networks of Typical Nodes of Grain Elevator Route Devices



Prediction of three output parameters at once based on the same three input parameters, the same outputs of the previous node at the previous moment in time by one **convolutional neural network** (CNN) with a complex architecture CNN model

Choice of Information Technology for Optimization of Production at the Grain Elevator

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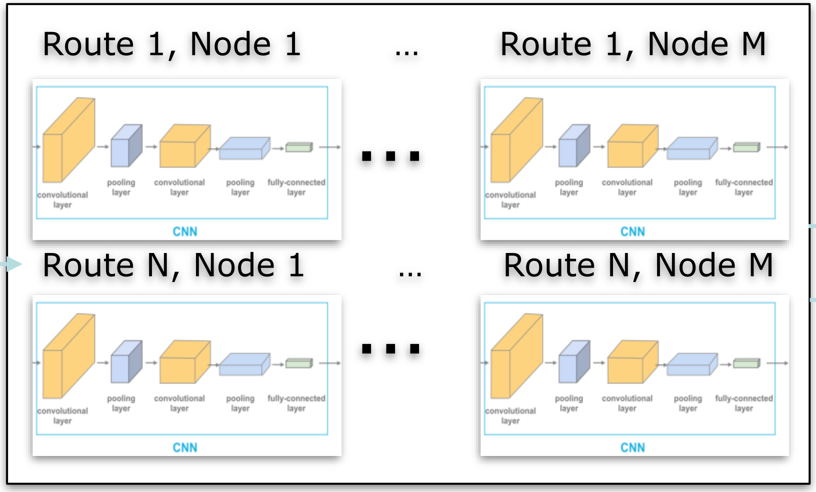
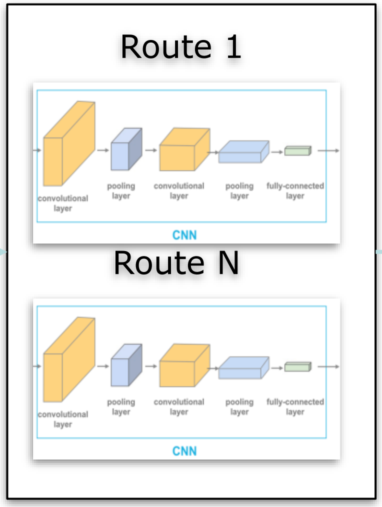
DATA

Routes with CNN model for each node



Routes with CNN model for each route



Option 1. IT for optimization of routes with RL

Option 2. Calculation output of all models

Option 3. Calculation output of all models

Option of IT	N	T
1	Small	Middle
2	Small	Big
3	Small	Small - optimal
1	Big	Small - optimal
2	Big	Big
3	Big	Middle

N - number of routes
T - duration of calculations for optimization

Experiments showed that under real conditions, in most cases, the number of possible combinations of route variations between given input and output bunkers is small, so it was decided to implement option 3.

It was option 3 that ensured the optimal duration of calculations, which is important for the operator

Construction of Intelligent Simulator for Simulation and Visualization of the Grain Elevator Technological Cycle and Optimization of its Routes and Equipment Parameters

Pretrained Models Bank

**Module of the SAKURA with Information Toolbox
of the Intellectual IT
for Grain Elevator Optimization**

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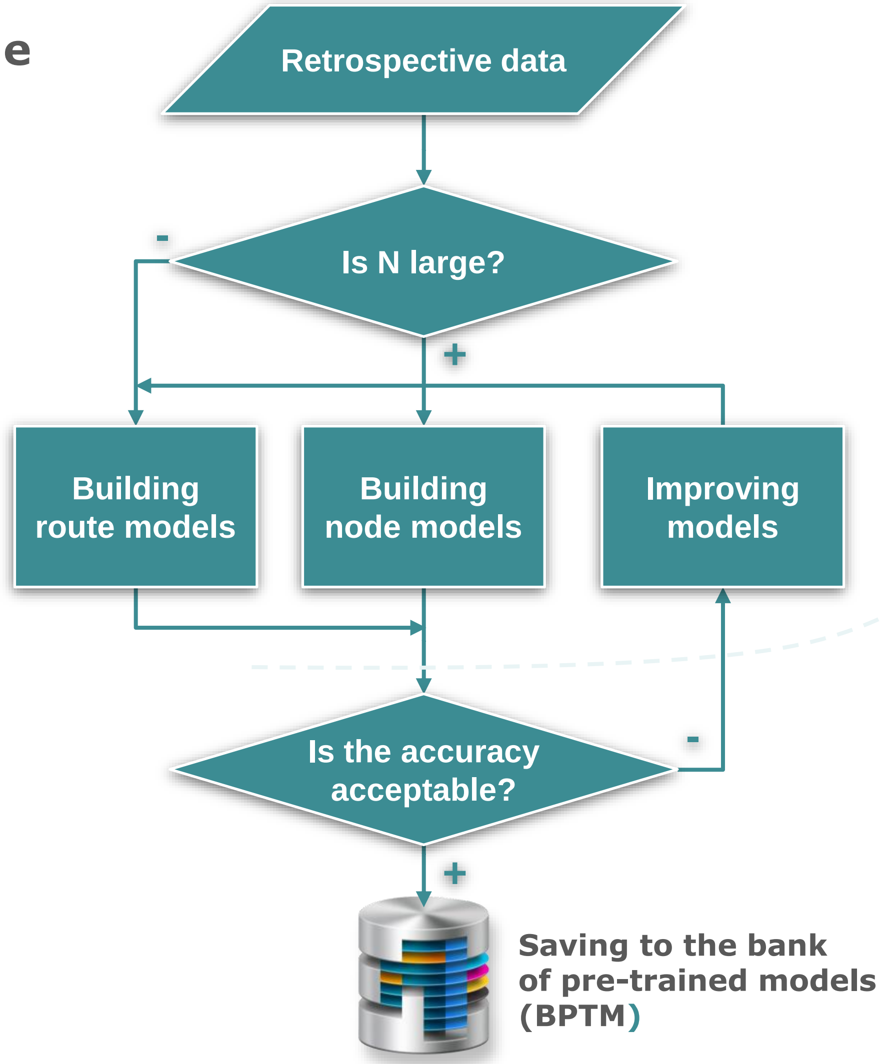
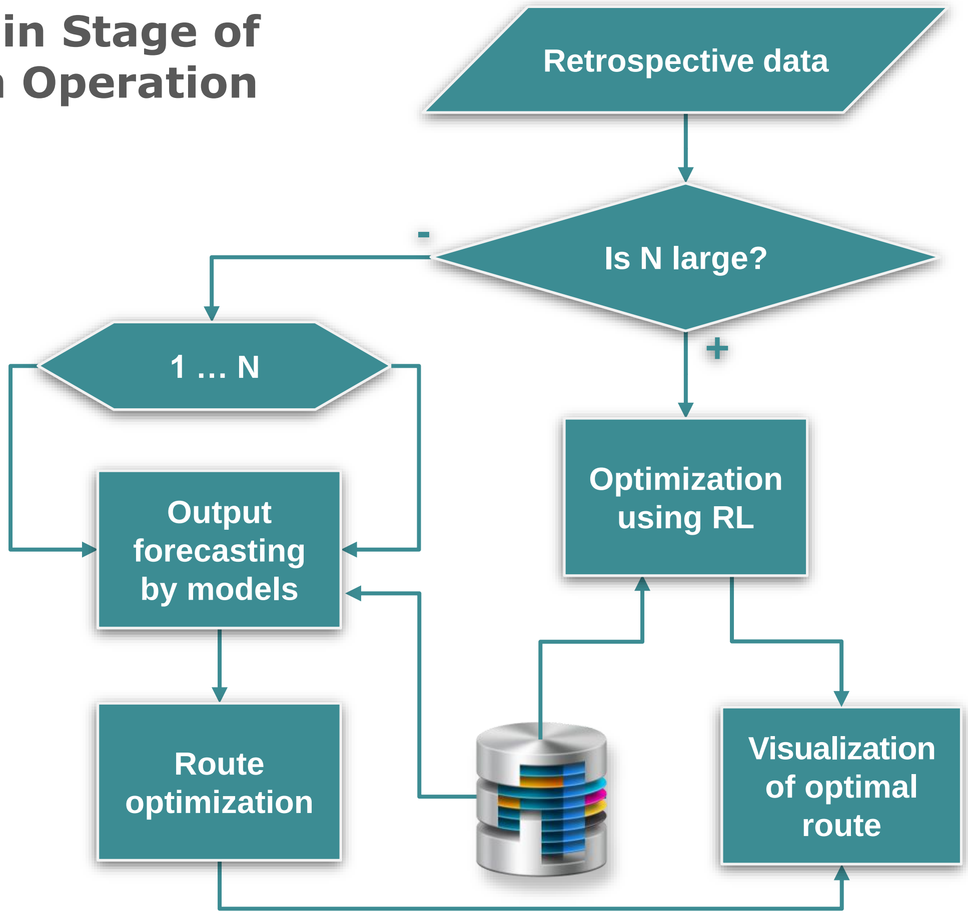
Construction of Algorithms for Optimizing Grain Elevator Routes Based on New Data Using Machine Learning Technologies with Reinforcement

Stage 1
Creation of the Pretrained Models Bank



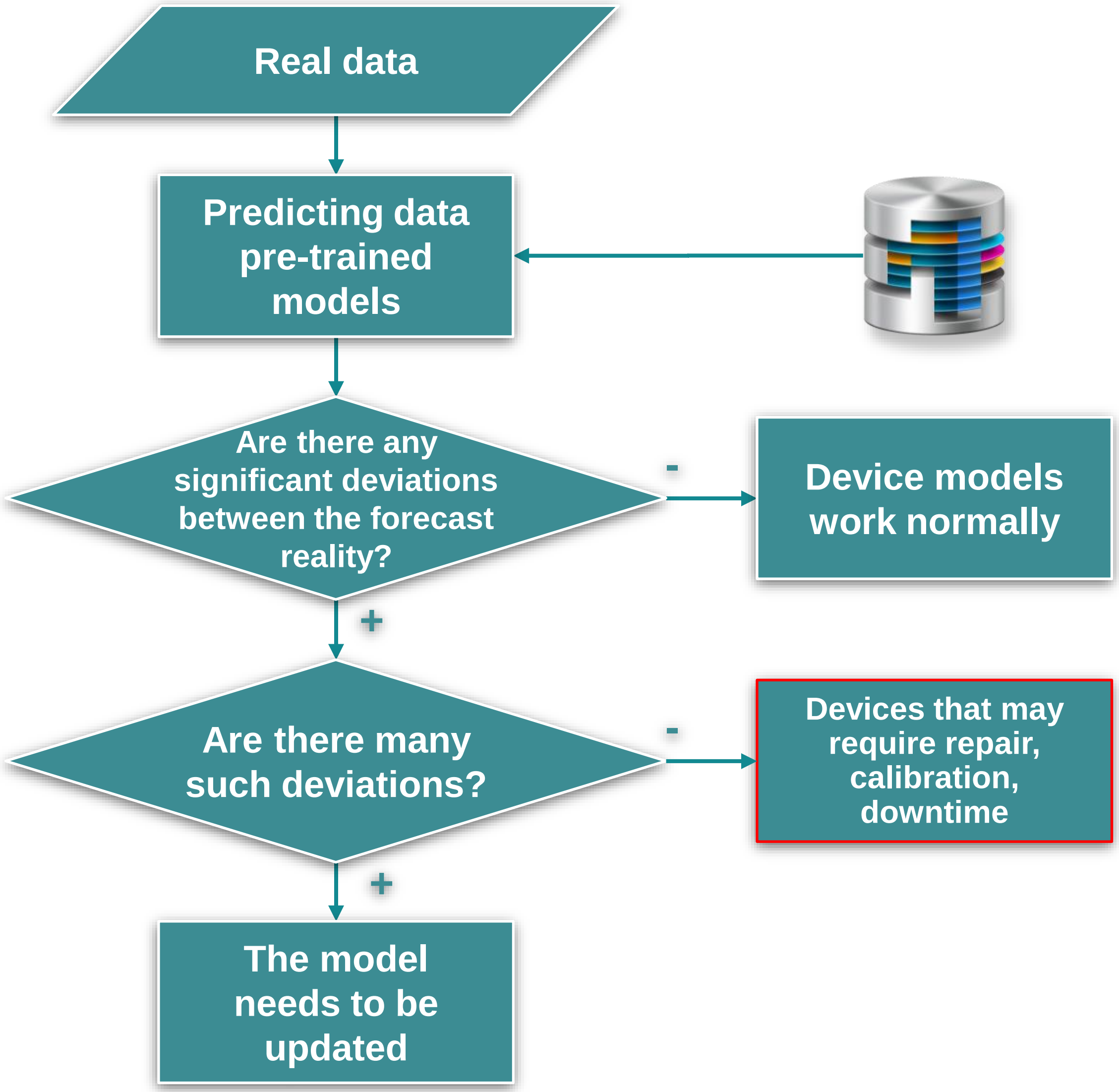
Stage 2
The Main Stage of System Operation



Implementation of Algorithms for Automatic Detection of Devices that May Require Repair, Calibration, Downtime, etc.

After each completion of the movement of the grain along the route, the forecast of the output data is compared with the same data at the output of the route that was selected.

Depending on the result of the comparison, a certain **algorithm** makes a conclusion about whether it is worth updating the models of the devices or the route and whether it is worth checking which devices of this route **may require repair, calibration, downtime**

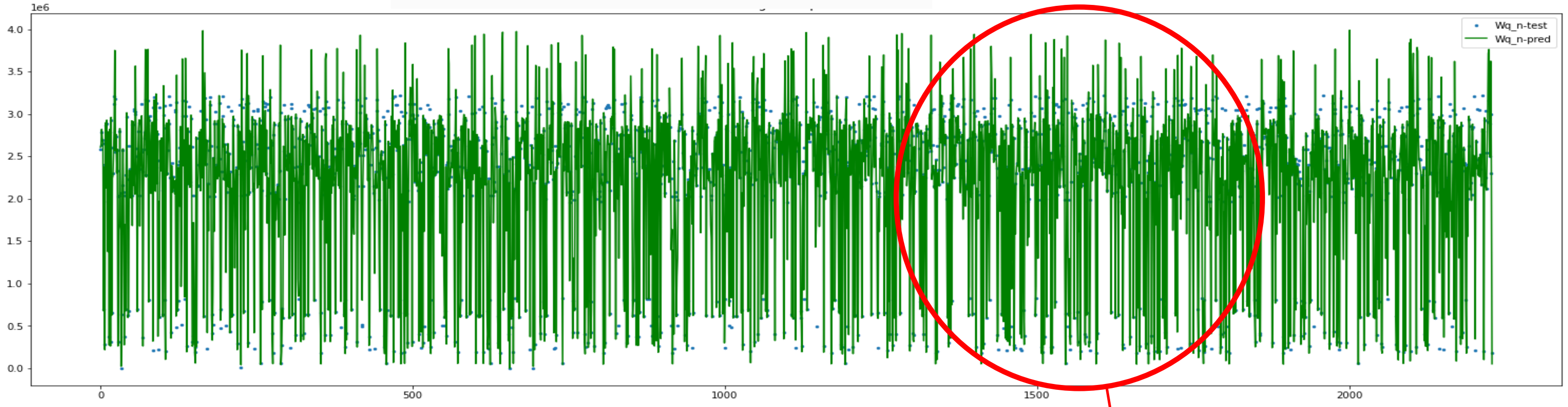


Creating Trained Neural Network Model for Grain Elevator Route Based on Real Data

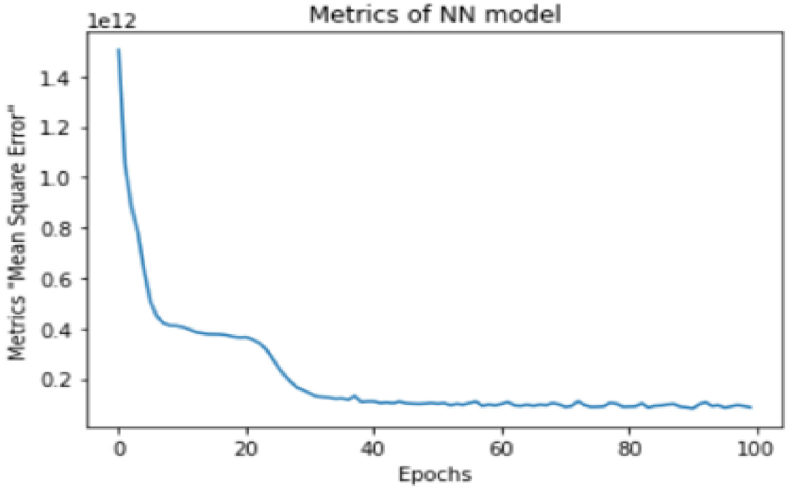
ML of NN model:

```
Layer (type)                Output Shape              Param #
=============================================================
dense (Dense)               (None, 256)               1280
_____________________________________________________________
dense_1 (Dense)             (None, 128)               32896
_____________________________________________________________
dense_2 (Dense)             (None, 64)                8256
_____________________________________________________________
dense_3 (Dense)             (None, 32)                2080
_____________________________________________________________
dense_4 (Dense)             (None, 3)                 99
=============================================================
Total params: 44,611
```

NN Regressor predicting:

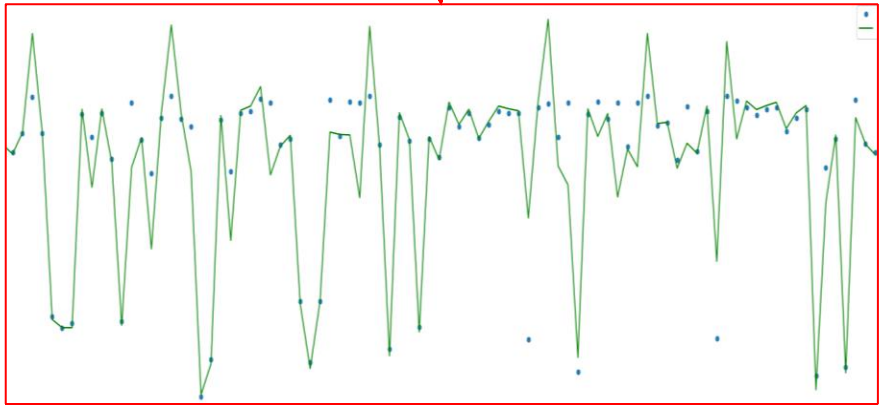


Metrics of NN model:



Probability achieved:

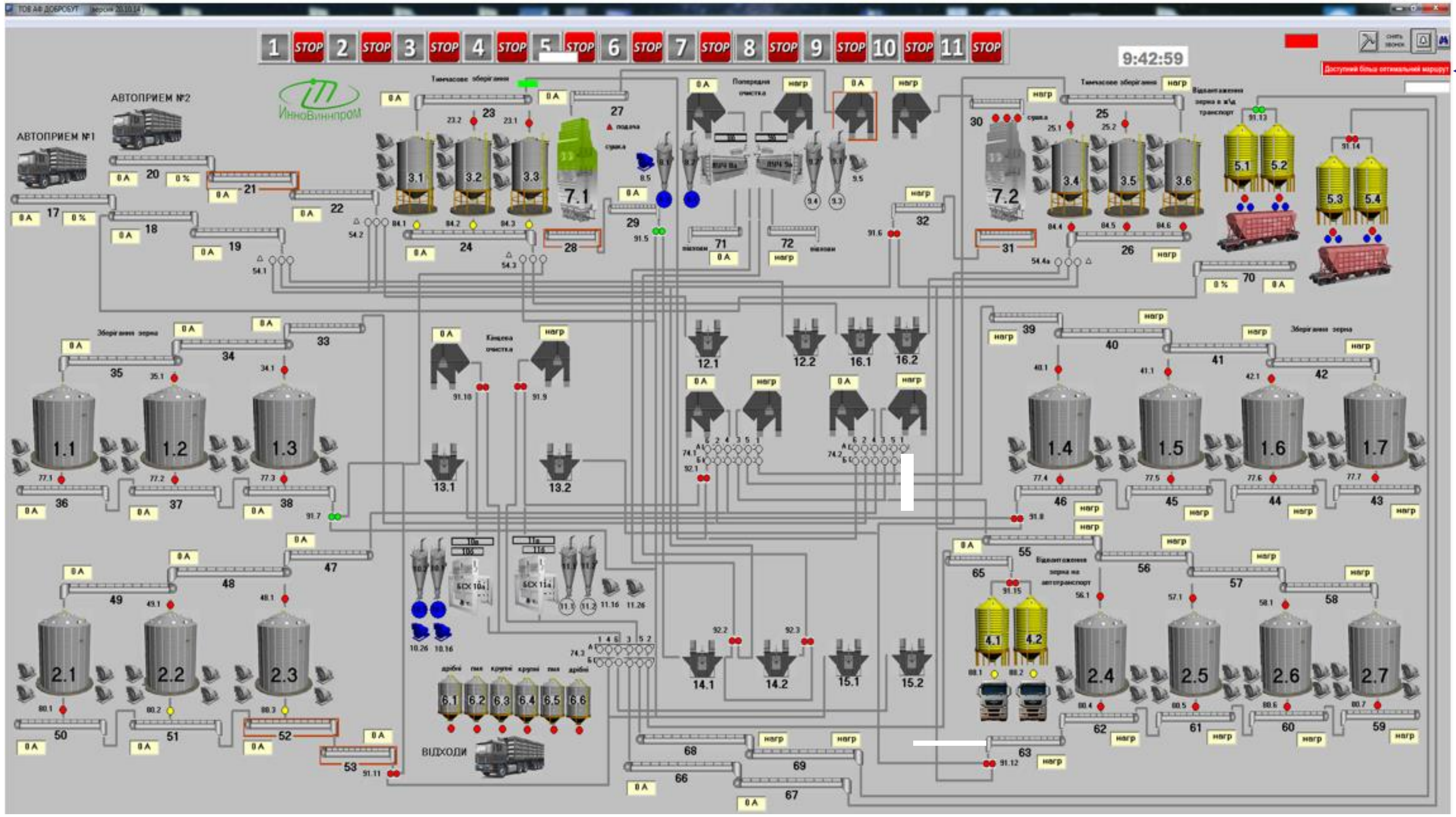
```
Route 0 prediction
Wp_n Relative error: 9.646%
Wp_n r2score : 0.8129453521752672
----------------------------------
Route 1 prediction
Wq_n Relative error: 9.425%
Wq_n r2score : 0.8476444593901902
----------------------------------
Route 2 prediction
Ws_n Relative error: 9.447%
Ws_n r2score : 0.8420825194985004
```



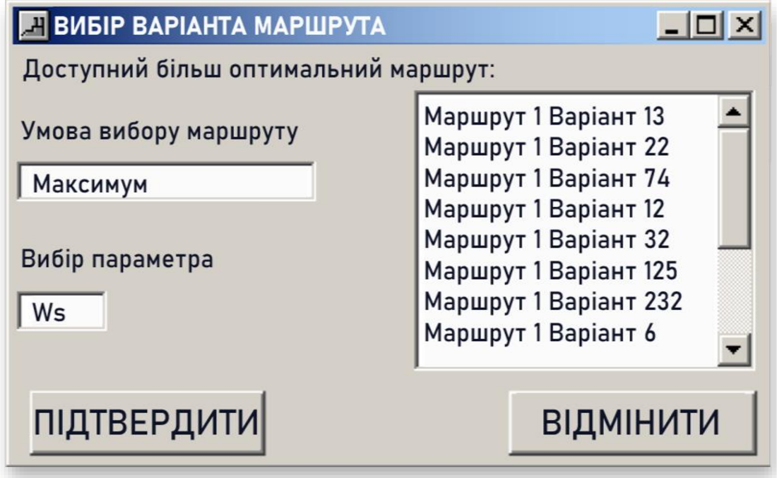
60 % Training | 20 % Validation | 20 % Testing

INDUSTRY 4.0

Selection of the optimal routes using intelligent simulator



НЕОПТИМАЛЬНИЙ МАРШРУТ



The menu for selecting routes and options, configuring the search for optimal routes

For the convenience of the personnel, we have left the SCADA interface familiar to elevator operators unchanged. Only in the upper right corner was added a menu for choosing the optimal route (route option).

KPI 2. Reducing the Percentage of Inefficient Use of Grain Elevator Equipment

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Target value of KPI: **from 17% to 10%**

Reached value of KPI: **10%**

Period	Active Energy Wp, [kWh]	Reactive Energy Wq, [kVARh]	Total Energy Ws, [kVAh]	Power Factor cos φ	Inefficiency %
October 2020 - January 2021	**54 554,13**	**119 744,93**	**137 975,99**	**0,45**	**30,8**
October 2021 - January 2022	**107 403,55**	**177 044,77**	**218 273,11**	**0,54**	**16,9**
October 2022 - January 2023	**93 260,02**	**146 739,53**	**174 222,06**	**0,59**	BOWI **9,2**

Due to the fact that the energy consumed by the elevator cannot be an indicator for evaluating energy efficiency, the Power factor (averaged cos φ) was chosen as the main parameter.

*A number of practical experiments were conducted on weighing at key points of the elevator the amount of grain products moved during the reference period of time. At the same time, the reference average value of the Power factor at the maximum permissible load and throughput of the equipment was **0.65**. We used this value as 100% efficiency.*

The Inefficiency value of 16.9% was achieved as a result of the application of IoT technologies thanks to the administrative influence and optimization of SCADA, the value of 9.2 thanks to the application of AI technologies.

KPI 3. Reducing of Energy Consumption of Technological Equipment of Grain Elevator

Target value of KPI: **from 17% to 10%**

Reached value of KPI: **15 … 5%**

TTE showed that during the design and construction of the elevator, the designers made a mistake by choosing motors of excessive power for the equipment. During TTE, we did not manage to achieve significant results through the use of information and operational technologies, **a maximum of 1...2%**. The reactive power component remained practically constant, as it significantly exceeds the active energy component.

However, we managed to find a way to solve the problem - this is the installation of vector frequency converters. Another effective, but expensive way is to replace the engines with more modern engines of lower power.

We installed vector frequency converters and performed a number of experiments that showed that at any load of the test unit of equipment (transporter No. 36) the Power factor was within **0.95...0.98**. That is, it was possible to reduce energy consumption **to 2...5%.**

KPI 4. Reducing of Technological Delays and Downtime of Grain Elevator Equipment

Target value of KPI: **from 5% to 3%**

Reached value of KPI: **3%**

The planned KPI level was achieved in the following ways:

1. According to the results of the analysis of the operation of the equipment (time of acceleration of the engines, time of supplying the product to the next unit of equipment, etc.), we at SKADA reduced the time of switching on and off the routes.
2. Real-time monitoring of the load (product availability on transport equipment) made it possible to automatically detect cases of equipment operating in idle mode and equipment problems that could cause an unplanned stop on the route.

- The load is normal
- Partial load, inefficient work
- Equipment operation in idle mode

Executive summary of TTE

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The support of BOWI helped us achieve the following results :

- Keep the team and continue working against the background of a significant economic downturn.
- Significantly optimize the technology stack
- Update the version and add new features to the system software.
- Develop new version and upgrade SCADA and PLC software.
- Obtain and analyze large arrays of grain elevator equipment operation data.
- Select and test algorithms for the use of neural networks.
- Conduct experiments on the use of artificial intelligence to optimize the efficiency of technological processes.

Many mentoring meetings from Centre 4.0 KPI DIH have been held. As a result, SMEs are fully satisfied with the received support which included assistance in setting up technical processes, technical and business consulting, etc. PIAP DIH helped a lot during TTE planning with technical and business advices.

BOWI Technology Application Roadmap

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Task number 1 — Planning
- TAR
- Ethical deliverable
- Requirements specifications
- Updated presentation

Task number 2 — Mid term evaluation targets
- Data processing algorithms
- Digital Twin of SCADA
- Frontend and backend software
- Neural network software

Task number 3 — Final evaluation and demonstration
- SKADA version update
- Neural network training
- Conducting experiments
- Business analysis

Task number 4 — Demonstration of system
- Final Report
- Video of TTE results
- Public presentation
- Cooperation with the client

Task number 5 — Business development
- Implementation Plan
- Business plan
- Business analysis
- Cooperation with the client

Team

ВНТУ

INDUSTRY 4.0

The New Project team


Mykola Bevz
Busines Analyst


Sophia Kravchenko


Sergii Khmil
Busines Analyst


Andrii Lukhverchyk
Principal Engineer


Alexey Bondarchuk
TechLead/DevOps


Oleh Mazuruk
Software Developer


Slava Bobrov
QA Engineer

Software Developer


Serhii Muzyka


Vitalii Mokin
Data Scientist in Nestlogic


Dratovanyi Mykhailo
Software Developer


Andrey Yasholt
Software Developer


Alexander Reznik
SCADA Developer


Yurii Fedorenko
PLC Developer


Oleksandr Radovets
Firmware Developer

SaaS “SAKURA-APM”

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INNOVATIONS

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Operational Excellence

Reduction of air emissions

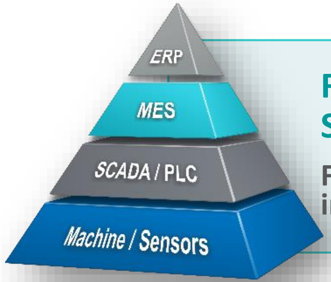
Energy efficiency

Digital product passport

Customer Intimacy

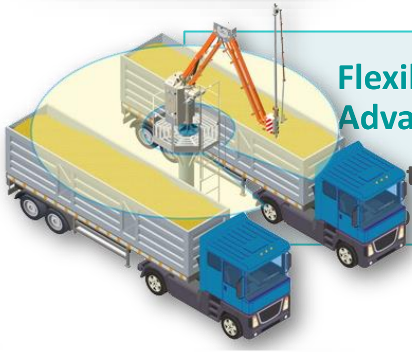
Innovations in better adaptation

30 years of experience



Reasonable Simplification

Four systems into one



Flexible robotics Advanced robotics

tic grain sampling
lexes

Environmental impact analysis

Round-the-clock control

PaaS SAKURA-IIoT INNOVINNPROM

SaaS

SACURA-APM
Asset Performance Management

SaaS

SACURA-ENEF
Energy monitoring system

SaaS

SACURA-M&R
Maintenance & Repair

SaaS

SACURA-ECO
Environmental control

ROUTE-ADC
Agro-Industrial Enterprises SCADA

- Industrial Internet of Things
- Big Data & Data Sharing
- Cloud Computing
- Autonomous Factories
- Digital Twins
- AI & ML

SaaS

SACURA-Business
ERP/PLM/MES

Shared databases

Open Source

Support for all OT and IT protocols

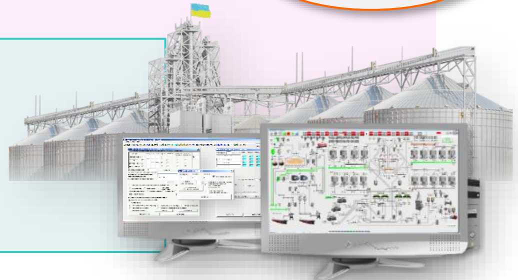
Application of modern IT technologies

Ability to integrate cheaper IoT devices and sensors

Cooperation with DIH and universities

Improving the system

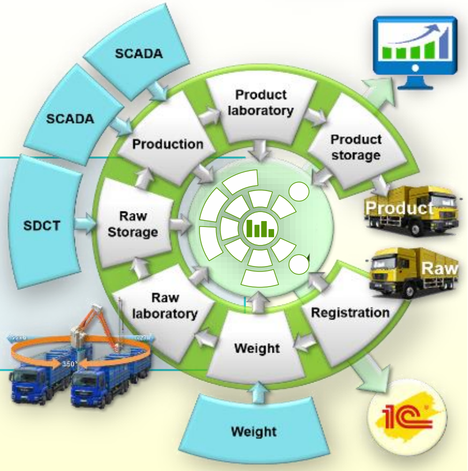
Adding new features and capabilities



Automated Design System "ROUTE" for SCADA

Transfer to cloud services

Provision of services as SaaS



Quantitative and qualitative accounting system

The Best Industry Solutions

of INNOVINNPROM are adapted to the conditions of the region

INDUSTRY 4.0

Industrial Internet of Things platform PaaS SAKURA-IIoT

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- Internet of Things
- Artificial Intelligence
- Machine Learning
- Edge Computing
- Big Data
- Cyber Security
- Digital Twin

PaaS SAKURA-IIoT

SaaS **SACURA-Business**
ERP/PLM/MES

SACURA-APM
Asset Performance Management

SaaS **Enterprise-ENCO**
Enterprise Control

SaaS **SACURA-ENEF**
Energy Efficiency

SaaS **SACURA-OPEX**
Operational Excellence

SaaS **SACURA-M&R**
Maintenance & Repair

SaaS **SACURA-ECO**
Environmental control