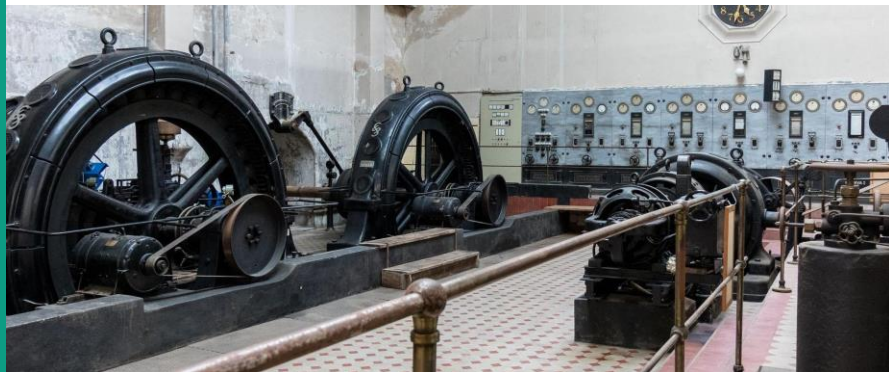


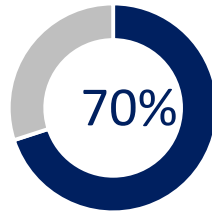
Risk assessment of hydroelectric plant components: common sense and digitalization

RENEXPO[®] INTERHYDRO



About Elettricità Futura

Elettricità Futura is the main electrical energy sector Association in Italy. It encompasses electrical energy generators involved in RES as well as traditional sources, distributors and service providers. It contributes to making today's electrical market more efficient, ready for the future evolutions and challenges



of the **electricity consumed in Italy** is ensured by companies being part of Elettricità Futura

600
OPERATORS

40.000
WORKERS

75.000 MW
INSTALLED CAPACITY

1.150.000 km
ELECTRICAL LINES

We are member of:



eurelectric



Wind[•]
EUROPE



MOTUS 

Elettricità Futura for the future power sector



Promote **decarbonisation** of the European energy mix via the strengthening of the ETS system

Promote **electrification** in the transport and heating and cooling, driving technology evolution



Further develop **Renewable Energy Sources** (RES) using efficient and market-oriented mechanisms, ensuring regulation stability and investments continuity

Reform the **electrical market**, integrating RES and new technologies, and providing clear long-term price signals to all the power plant technologies



Rely upon **digitalisation** and information access to increase customers awareness of their role and options in the liberalised market

Health and Safety for workers and respect of Environment by sharing the best practices and promoting a work culture with the goal of "zero injuries"



What is risk?

Effect of uncertainty on objectives (ISO 31000)

```
graph TD; A[Effect] --> D[Deviation from the expected]; B[uncertainty] --> C[Deficiency of information related to understanding or knowledge of an event, its consequence, or likelihood]; C[objectives] --> E[Financial, health and safety, environmental goals]; C --> F[Strategic, organization-wide, project, product and process];
```

Deficiency of information related to understanding or knowledge of an event, its consequence, or likelihood

Financial, health and safety, environmental goals

Strategic, organization-wide, project, product and process

Deviation from the expected

Digitalization: the magic word of XXI century

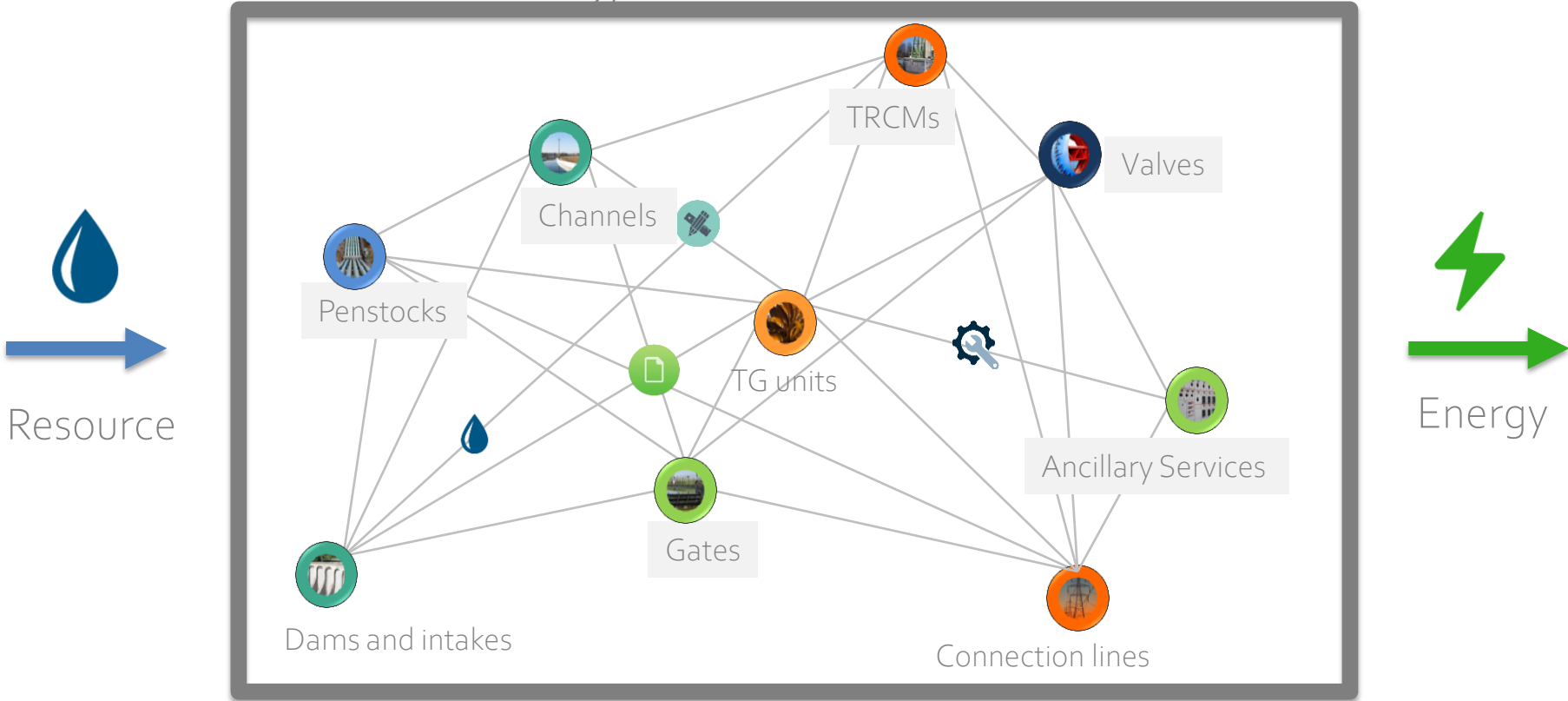


What do I mean by digitalization with reference to HPPs

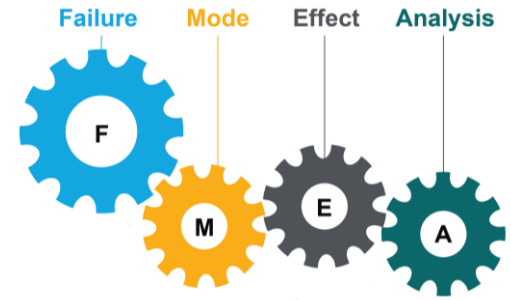
Definition: software and hardware to improve operation and maintenance of HPPS



Hydroelectric plant: a set of components functionally connected to turn the water resource into energy



A (not entirely) new approach



1. Identify the ways a product can fail
2. Identify the potential causes of the failure
3. Estimate the potential consequences
4. Estimate the risk associated to a specific failure mode
5. Prioritize the failure mode (and actions)
6. Identify possible controls to reduce risk
7. Verify the effect of the controls

Severity

x

Occurrence

x

Detection

=

RPN



STEPS

- Define the team
- Define the analysis level

- Identify and describe the plant
(components/functions, interconnections,
maintenance)

- Identify and describe failure modes, causes and effects

- RPN: Risk Priority Number

- Identify actions and
priorities

1 - Organize

2 – Recognize

3 - Analyze

4 Quantify

5 - Act



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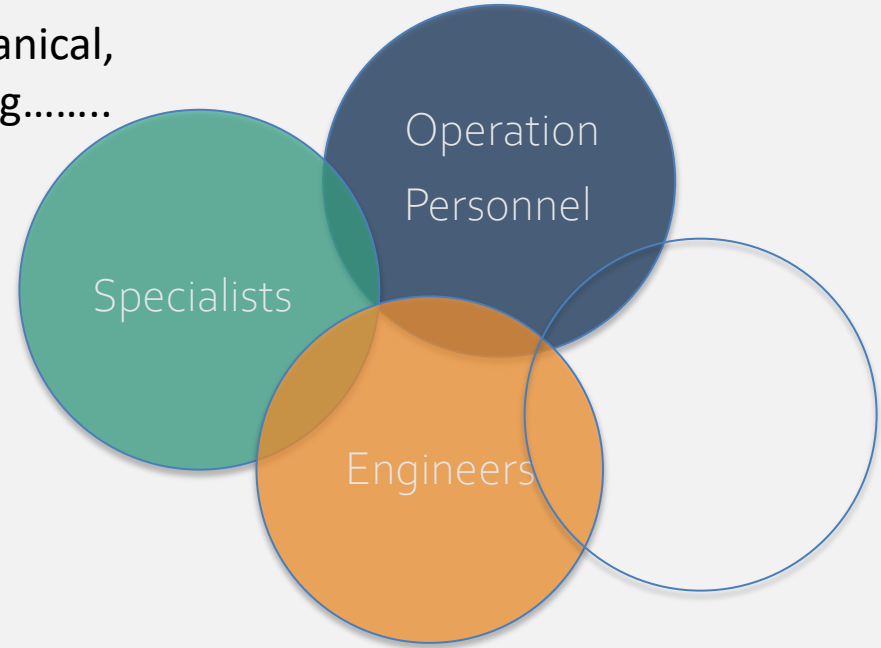


Multidisciplinary Team

Hydrology, hydraulic, geology, structural, mechanical, electrical, geotechnical, automation engineering.....



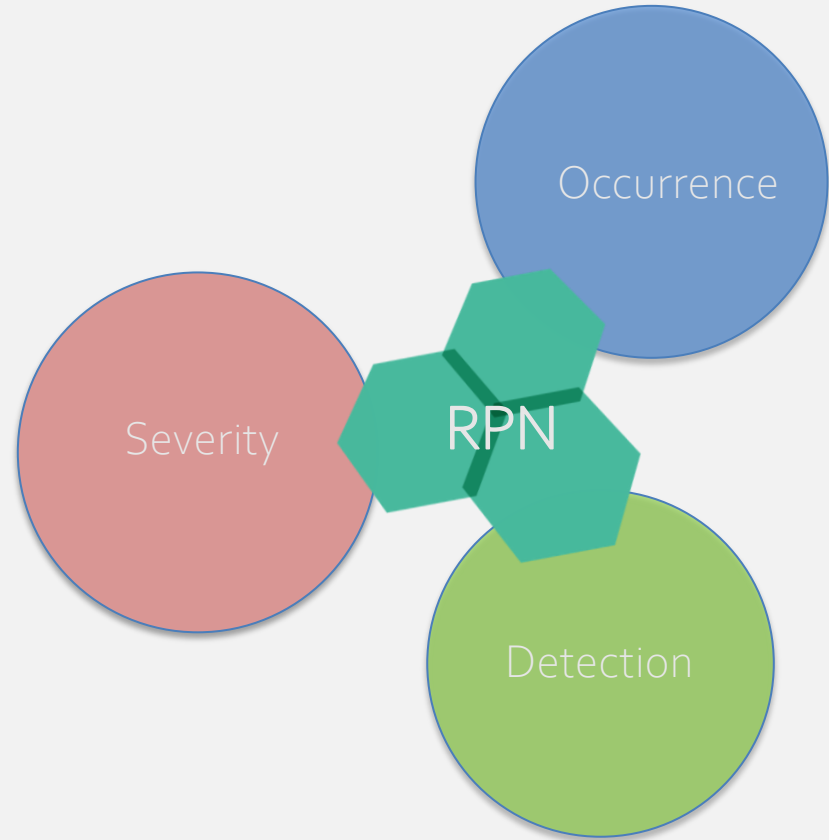
EVALUATOR/CLIENT





Define the criteria to assign
the scores and the relevant
warning thresholds

EVALUATOR/CLIENT



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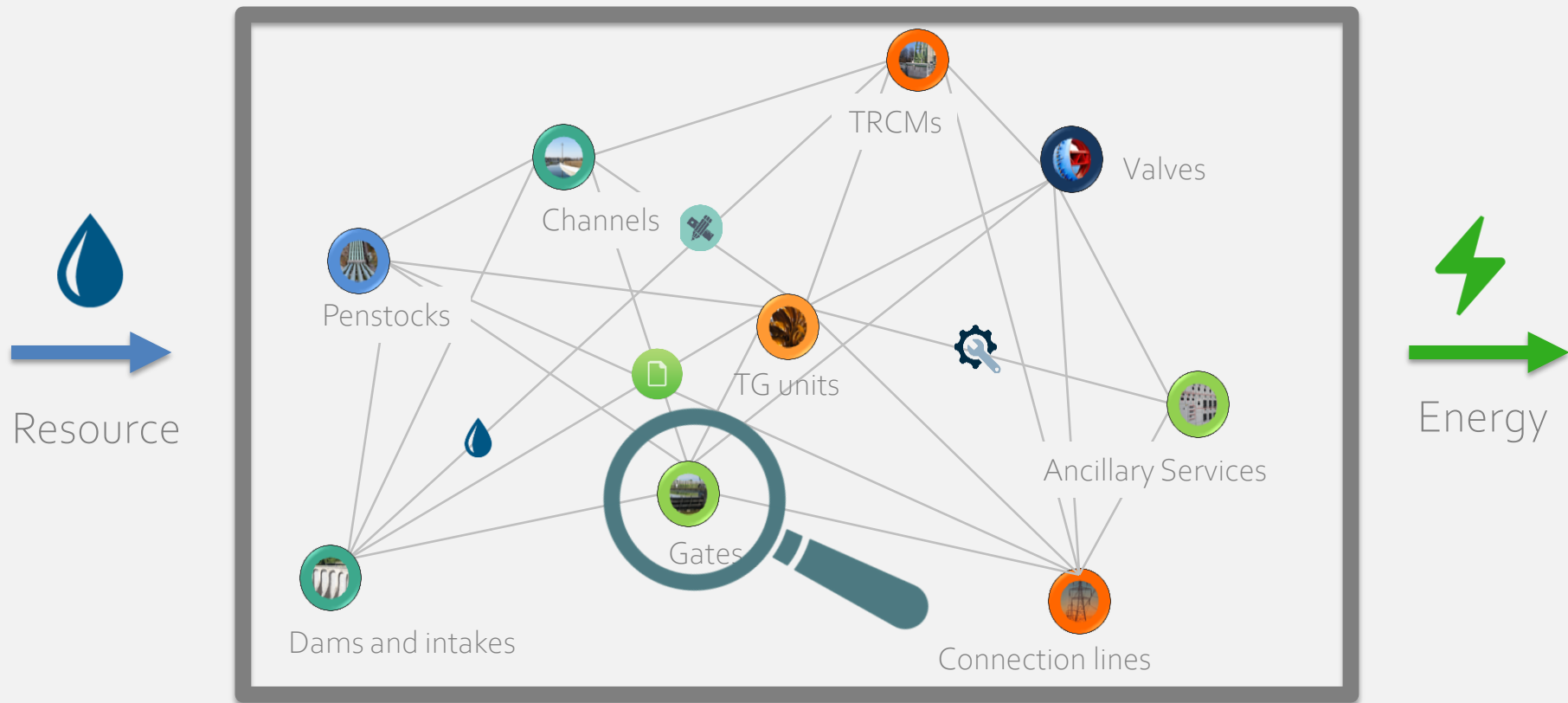
3 - Analyze

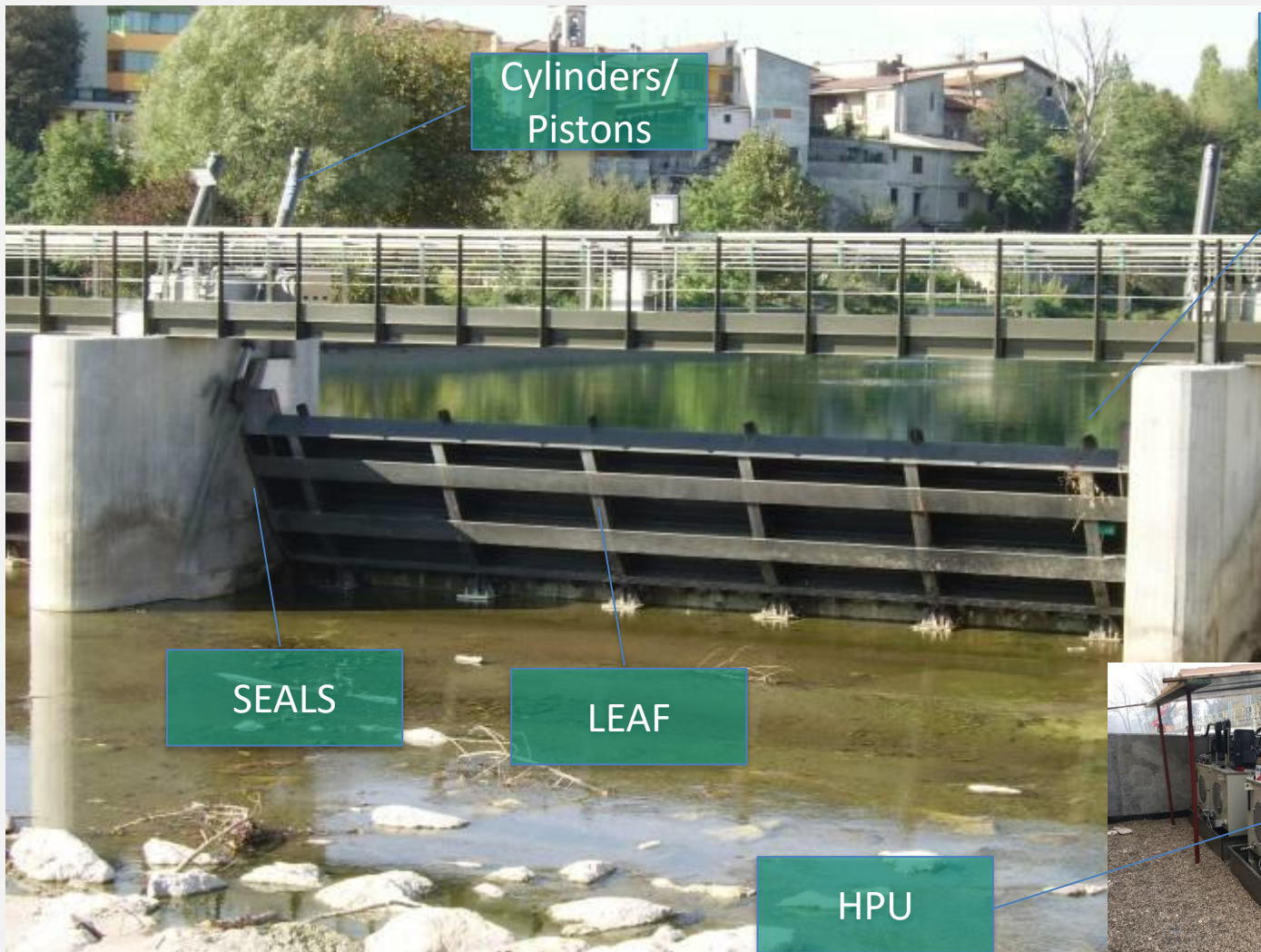
4 Quantify

5 - Act



Hydroelectric plant: a set of components functionally connected to transform the water resource into energy





Cylinders/
Pistons

Level
sensors



Control
panel

Energy
supply



SEALS

LEAF

HPU

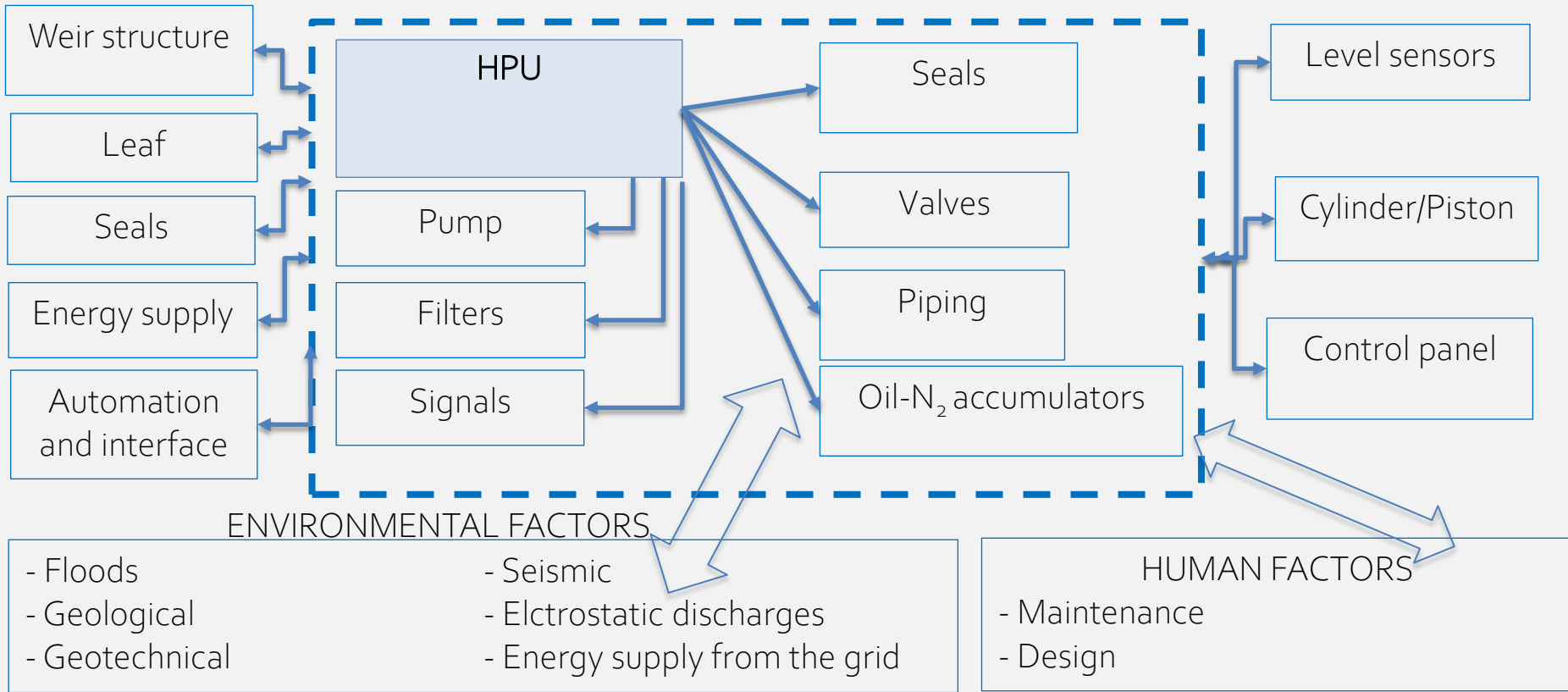


System: Plant XYZ

Sub-system: Spillway channel

Component: Flap gate

Element: HPU



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Function	Failure Mode	Failure Mode Severity	Effect	Effect Severity	Cause	Occurrence	Detection Controls	Detection	RPN
Valves/Pressure and flow control	Pressure drop in the system/Pressure too low to move the gate	6	Impossibility to raise the gates	6	Pump in default	7	Pressure and flow switches	5	210
					Leakages from pipes	4	Pressure and flow switches	5	120
					Valves configuration wrong	3	Pressure and flow switches	5	90
					Missing maintenance	4	Pressure and flow switches	5	120
					Missing electric energy for long periods of time		Pressure and flow switches	5	60
					Excessive head losses		Pressure and flow switches	5	60
					Filter clogged		Pressure and flow switches	5	210
					Valves configuration wrong		Pressure in the HPU	5	105
Filter / guarantee clean oil	Oil dirt	4	Valves clogging	4		7	Clogging indicator		252
			higher wear of the components	4		6	Clogging indicator		216
						2	Clogging indicator		72
Tank and pipes/ contain the oil in the circuits	Oil leakages	7	Oil leakages in the environment	7	joints failure	7		1	490
			Excessive oil consumption	5	pipes failure	5		10	350
Oil nitrogen accumulators / guarantee energy reserve to move the gate in case of blackout and stabilisation of pressures		5	Impossibility to raise the gates	5	Missing pressure in the system	5		10	250
					Undersized/Malfunctioning accumulators	1		10	50

Which are the functions?

Which are the effects?

How severe?

How often does it happen?

Which are the causes?

How "good" is my control?

What can go wrong?

Which are the controls?

System
Subsystem
System Indenture

Example
HPU
Example > Spillway channel > Flap Gate > HPU

Indicators



Severity (S)

How severe are the effects?

1 – No effect

to

10 – Danger without warning



Occurrence (O)

How frequently does it happen?

1 – Extremely unlikely

to

10 – Certain



Detection (D)

How easily can I detect the failure?

1 – Almost 100% detected

to

10 – Extremely difficult



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The Judgment Parameter



$$\text{RISK PRIORITY NUMBER (RPN)} = \text{Severity} \cdot \text{Occurrence} \cdot \text{Detection}$$

The higher the RPN value, the greater the need to intervene to decrease the value of one or more of the three factors



RANKING RPN

<i>Lower Bound</i>	<i>Upper Bound</i>	<i>Color</i>	<i>ACTIONS</i>
1	300		Acceptable Risk - No Action
301	520		Monitoring campaigns (spot or continuous) in order to get better knowledge of the components
521	1000		Risk not acceptable - Actions aimed to reduce the risk are necessary



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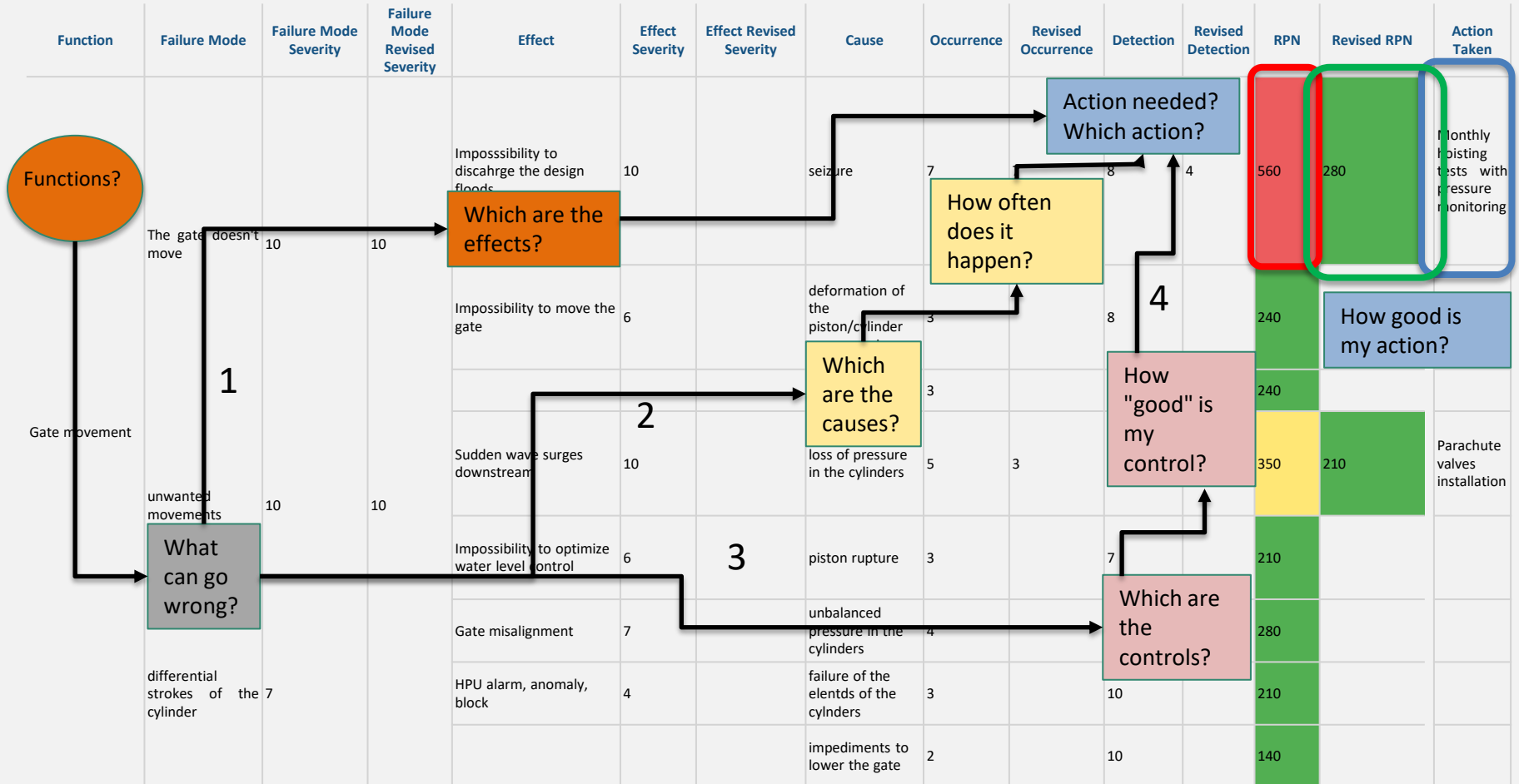
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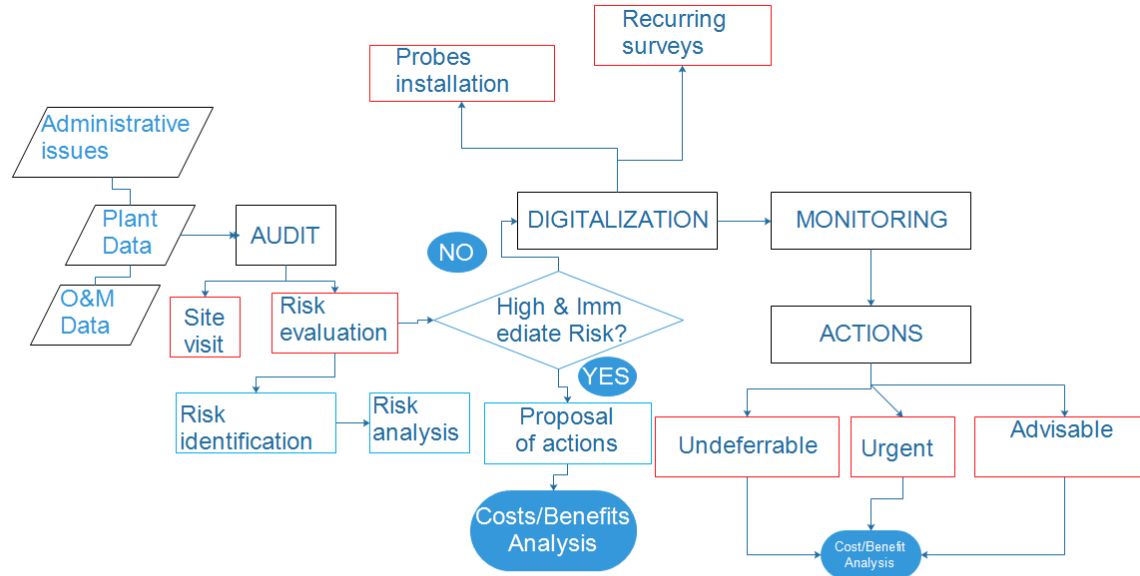


But what does digitalization have to do with risk assessment?

WHY DIGITALIZE?

1. Improve condition monitoring $\Rightarrow$ Optimize maintenance $\Rightarrow$ Cut costs
2. Reduce manual work $\Rightarrow$ Remote control and monitoring $\Rightarrow$ Cut costs
3. Improve control of power plant $\Rightarrow$ Reduce restrictions / optimize production $\Rightarrow$ Increase profit

Transition to digitalization



1. Plant audit
2. *Identification of the risks*
3. Identification of the parameters to monitor
4. *Implementation of the monitoring system*
5. Check of the parameters trend
6. *Maintenance program*

Risk based maintenance

a) run to failure: operation till the next fault

All the maintenance works generally advisable to avoid the failure

b) maintenance based only on the current plant condition

c) preventive maintenance

d) predictive maintenance

Attempt to predict which works are really crucial for a reliable operation

Risk based maintenance



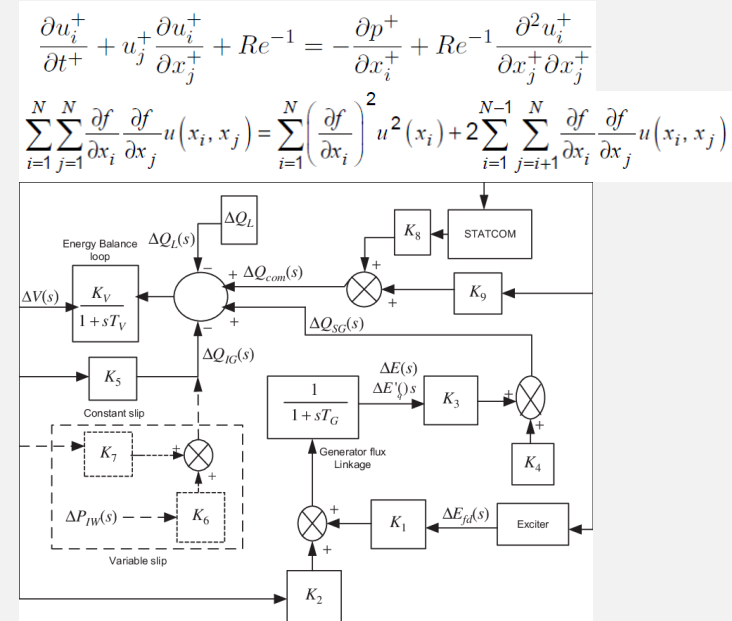
Run to failure operation

No control on rivets and
penstock shell in 70 years

Predictions

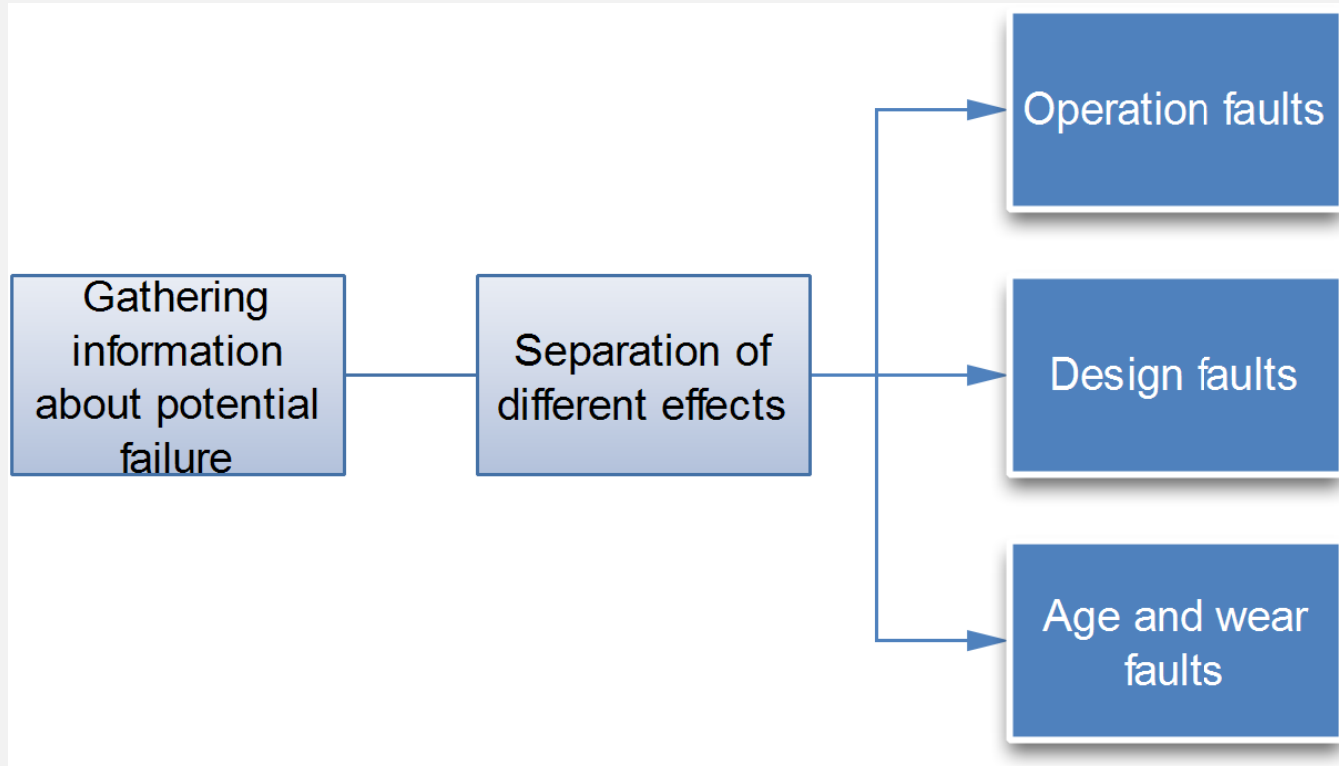


50% success



50% failure

Predictions



Predictions



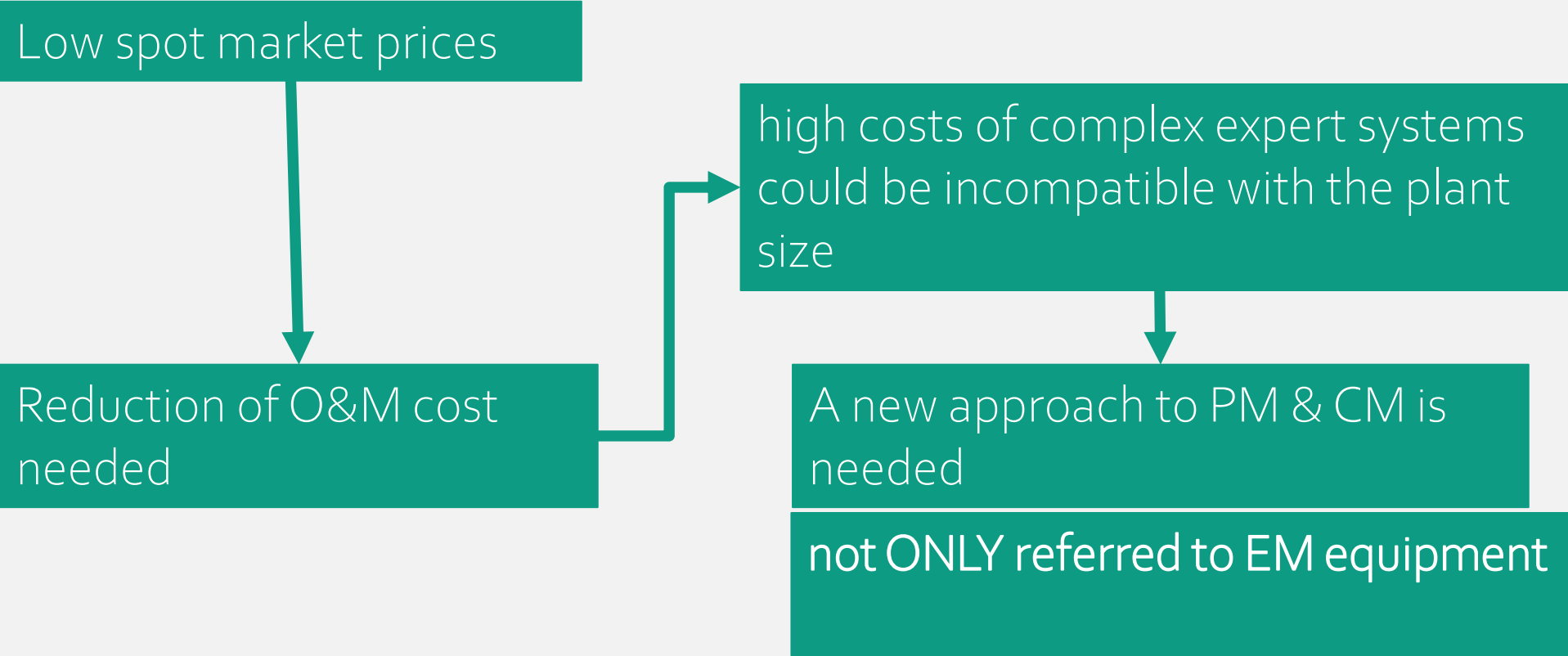
Degradation
due to age

Incorrect
operation

Original sin



Why digitalization



What hinders widespread diffusion of digitalization?

- cost intensive (esp. for owners of a single plant)
- difficulty to monetize the benefits of the method
- lack of historical data for small plants



- tailor-made solution
- step by step implementation process
- low initial costs
- possibility to extend the system once the owner has experimented the pros

CONCLUSIONS

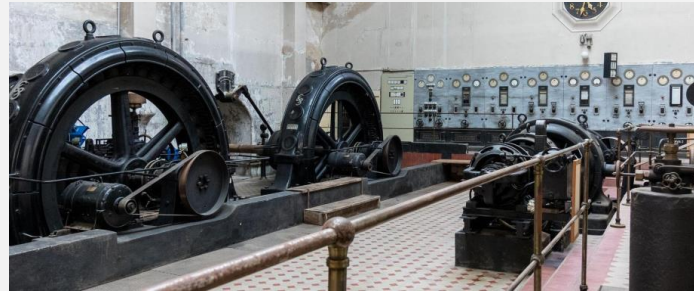
Digitalization in a wider sense can't refer only to EM equipment
Static equipment can fail as the dynamic one and even more.
Risk analysis should drive the digitalization

A global model of the whole plant is fundamental.
Risk analysis should be part of the model

Site-specificity makes difficult the causation among monitored parameters, failures and the statistical analysis

Nonetheless, a frequently updated knowledge of the plant condition allows to regularly check the residual value of the asset, that plays an important role in the balance of the Company.

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Thank you for your attention