Direct and indirect control of process plants with neural network

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Content of today's lecture

- **NeuronalNetworks! (NNW) AI Solution can improve MVA (WIP) Operations**
- **Presentation of the implemented improvements** through the implementation and operation in a pilot plant

- **Presentation of the AI implementation**
  - Examples of AI Operator
  - Examples of AI Prediction

The AI-Solution can improve MVA (WIP) Operations

Development of AI applications with the following challenges:

- **Volatile incineration process** (e.g. fresh, damp waste versus high-calorie waste)
- **Long dead times**, e.g. in connection with CO generation, are challenges for plant operators and automation
- **Optimization** of several key figures (e.g. waste throughput, energy efficiency, flue gas reduction, reduction of emissions and consumables, etc.)
- **Human plant** operators often control several blocks / lines in parallel
- **High requirements** with regard to plant and data security
- **Limited budget** for additional equipment

The pilot: 27 months of operation in an MVA (since July'19)

The pilot project

waste2energy

>17.000
Hours

First
of its kind

KINRW

First results

+10% ↗
Power Generation & Wastethroughput

-30% ↘
O2-Level

Reduction ↘
Consumables (e.g. oil)

Reduction ↘
Emissions (e.g. CO)

Safety First

TÜV NORD

- ✓ Human operator sits in the control room – No replacement
- ✓ AI operator can be stopped at any time
- ✓ Strict separation from boiler protection
- ✓ No external access possible

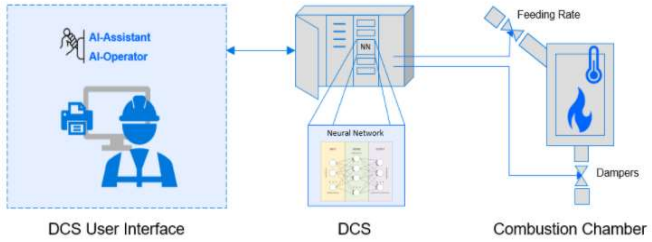
NNW AI solution differs from other AI tools in the energy sector

Focus below

Analyse AI-Tools

- Centralized data analysis
- Mostly cloud-based
- Tools belong to Condition Monitoring, Predictive Maintenance, Combustion Modelling

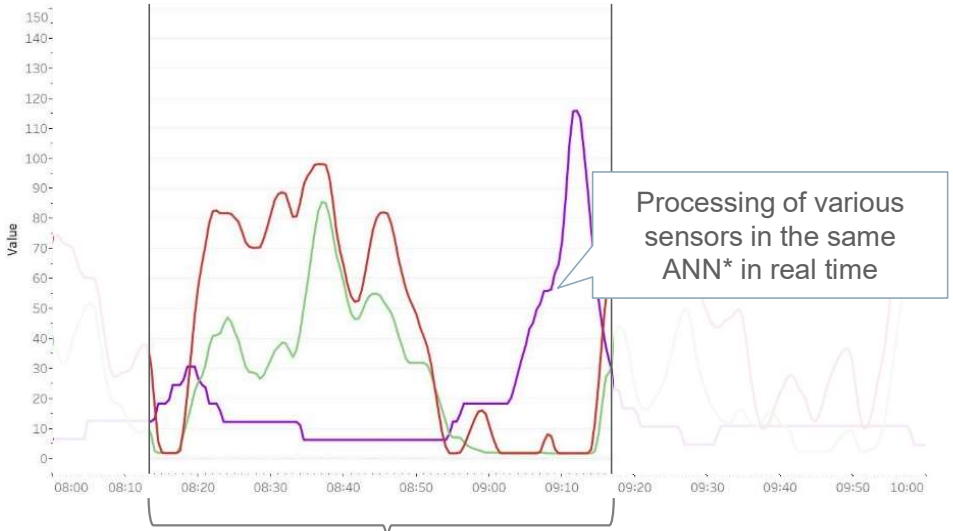
NNW AI-Tools



- The aim is to operate/automate the system
- Directly embedded in the DCS
- No cloud connection due to the local control system in the plant

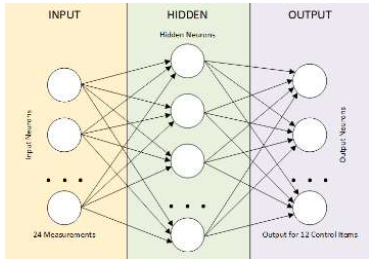
Use of artificial intelligence to analyze process data

Analysis of process data with artificial intelligence (ANN*)



Processing of various sensors in the same ANN* in real time

Consideration of a period of time (e.g. Is -80 min)



ANN

Strengths ANN*

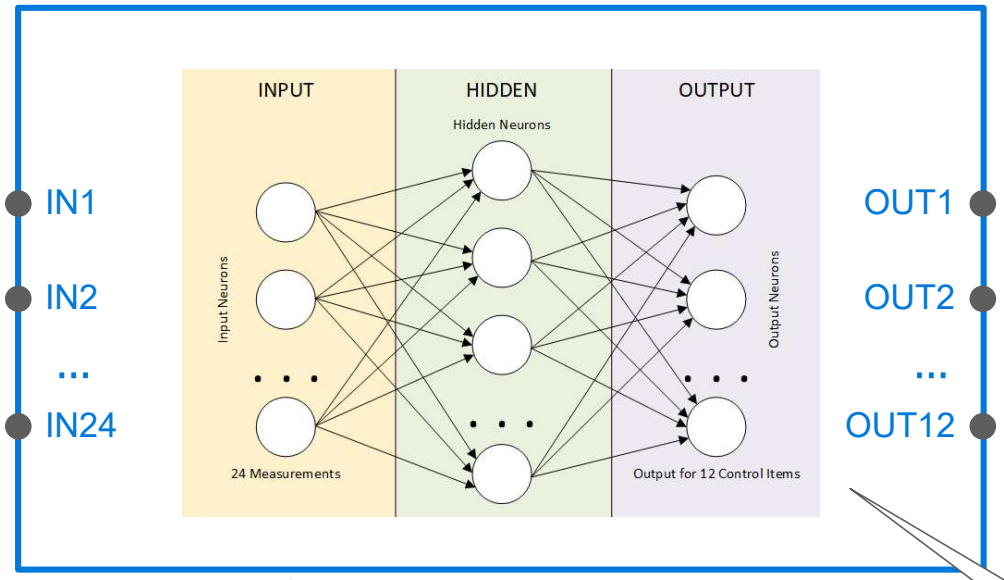
- **Detecting correlations**
- **Pattern recognition**
- **Recognition of dead times (time-shifted relationships)**

* Artificial Neural Network

AI processes complex relationships

The neural network learns the process image

- 24 measured values
  Use of relevant sensor data
- 80 minutes history
- Includes values derived from measured values, e.g. gradient and curvature



Implemented as a **function block** in the DCS

Plant **safety system** is not changed

No cloud – high **data security**

Control by AI

- 12 learned control outputs
- Max/Min Values Learned
- Continuous control without delays
- AI can operate the system in 24/7 mode
- AI can handle dead times

CUDA C/C++

Different operating modes are possible

AI-Prediction

AI anticipates the process

Operator controls the system

AI-Assistant

AI recommends actions

Operator controls the system

AI-Operator

AI controls the system

Works like an autopilot

Operator monitors AI

Example: AI-Assistant/ AI-Operator - 1

Project Setup

Type	**MVA (WIP)**
Fuel	waste (350,000 t/a)
Automation	Manual operation
Location GER,	Lower Saxony

Challenges & goals of the pilot project:

- Older boiler with low automation
- Old sensors (tw. over 25 years old)
- Older boiler design leads to suboptimal air distribution
- Long dead times
- Higher waste throughput possible if steam production is equalized

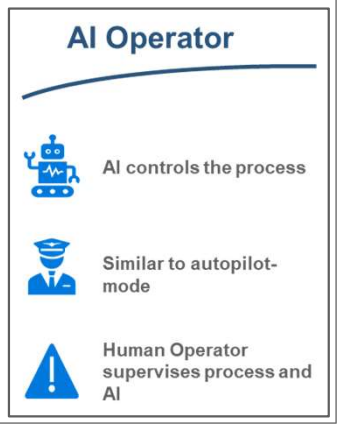
Solution

Step 1: AI-Assistant

- Recommendations for the air flaps; Optimization of air distribution
- Recommendations for the setpoint of the load
- Operator control

Step 2: AI-Operator

- Automation of air flaps and automation of the oad setpoint
- Operator can switch the AI operator on/off at any time
- Positive feedback from the AI Operator by the Operators



Example: AI-Assistant/ AI-Operator - 2

Project Setup

Type	**Circulating fluidized bed**
Fuel	Sewage sludge (200,000 t/a) dewatered, coal
Automation	Manual operation
Location	GER, NRW

Challenges & Goals:

- Keep the temperature in the combustion chamber of the CFB furnace constant at about 890°C
- Increase in sewage sludge throughput and steam production
- Avoidance of:
  - Support burner insert
  - Unavailability in case of temperature limit violation

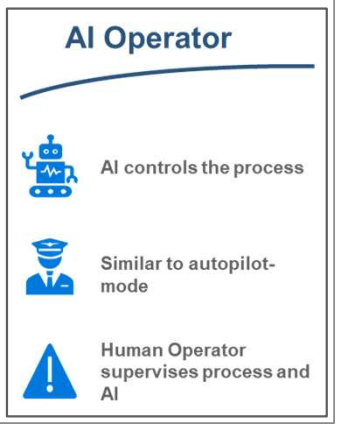
Solution

Step 1: AI-Assistant

- Recommendations for optimal control of vortex air and the return flue gas
- Operator control

Step 2: AI-Operator

- Automation of the frequency converter for the vortex air and the control flap of the return flue gas
- The Operator can switch the AI-operator on/off at any time



Example: AI-Assistant/ AI-Operator - 3

Project Setup

Type	**Gas-fired power station**
Fuel	Gas
Automation	Fire-Rate-Control
Location	GER, Bayern

Challenges & goals of the pilot project:

- NO2 can only be influenced directly by the firing process
- Control of the combustion air to achieve optimum CO, NO2 and O2

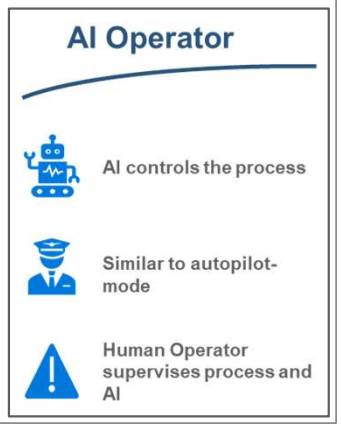
Solution

Step 1: AI-Assistant

- Recommendations for the Lambda correction (fuel/air ratio) to achieve optimum CO, NO2 and O2 at full load
- Operator control

Schritt 2: AI-Operator

- Automate the Lambda Correction
- The Operator can switch the AI-operator on/off at any time



Different operating modes are possible

AI-Prediction

AI anticipates the process

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AI-Operator

AI controls the system

Works like an autopilot

Operator monitors AI

Example: AI-Prediction – 1 and indirect control

Project Setup

Type	**BMHKW (Biomass)**
Fuel	Wood (160.000 t/a)
Automation	Fire-Rate-Control
Ort	GER, NRW

Challenges & Goals:

- Too high boiler ceiling temperatures lead to caking in the boiler, which can damage the grate, when falling down
- However, temperature must remain above 850 degrees C
- Temperature fluctuations are difficult for the Operator to predict

Solution

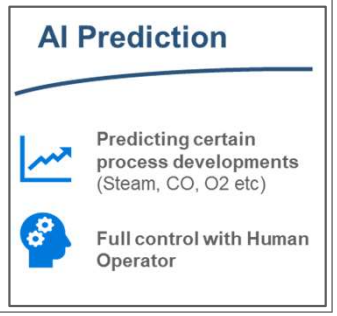
Step 1: AI-prediction to support the Operator

Boiler ceiling temperature prediction

- Using this information, the Operator can proactively control the combustion and operate the temperature more evenly
- Optimization of combustion temperature
- **This is the concept of indirect control!**

Step 2: AI-operator (planned)

- Training of the AI operator on the basis of the optimized manual operation with the help of AI Prediction!



Example: AI-Prediction – 2 and indirect control

Projekt Setup

Type	**MVA (WIP)**
Brennstoff	Müll (447.000 t/a)
Automation	Fire-Rate-Control
Location	GER

Challenges & Goals:

- Fresh, damp waste will be delivered around 8:00 a.m.
- The Fire-rate-control interprets the data incorrectly, it will heap the grate
- This regularly leads to steam drops
- Oil use is required to reach combustion temperature again

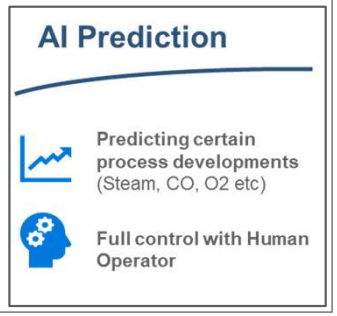
Solution

Step 1: AI-Prediction Tool

- Prediction of steam production
- Based on the forecast, measures can be taken to avoid the steam drop
- Avoidance of steam drops, maintaining temperature and more efficient combustion
- **This is the concept of indirect control!**

Step 2: AI-Operator (planned)

- Training of the AI operator on the basis of the optimized manual operation with the help of AI Prediction!

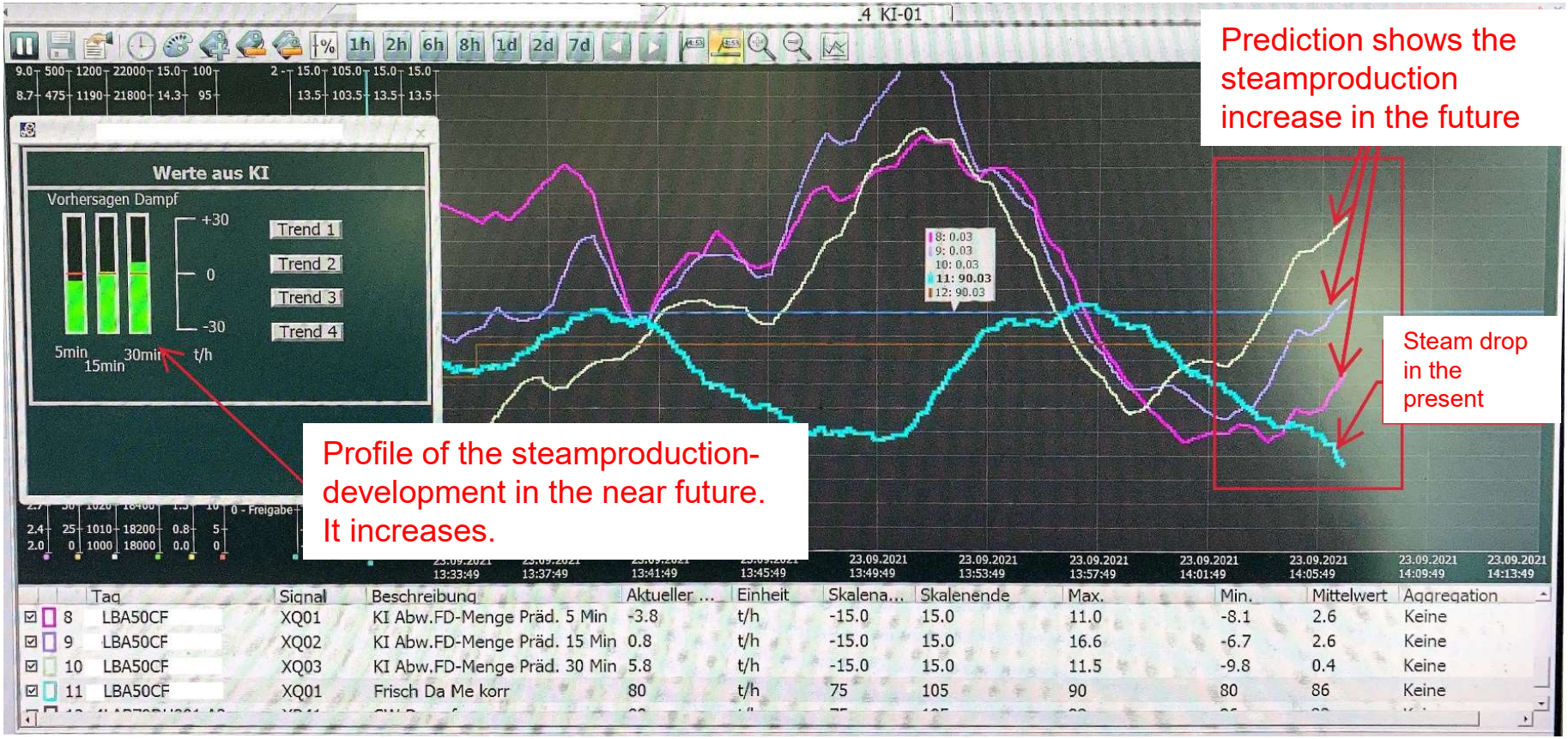


AI Prediction

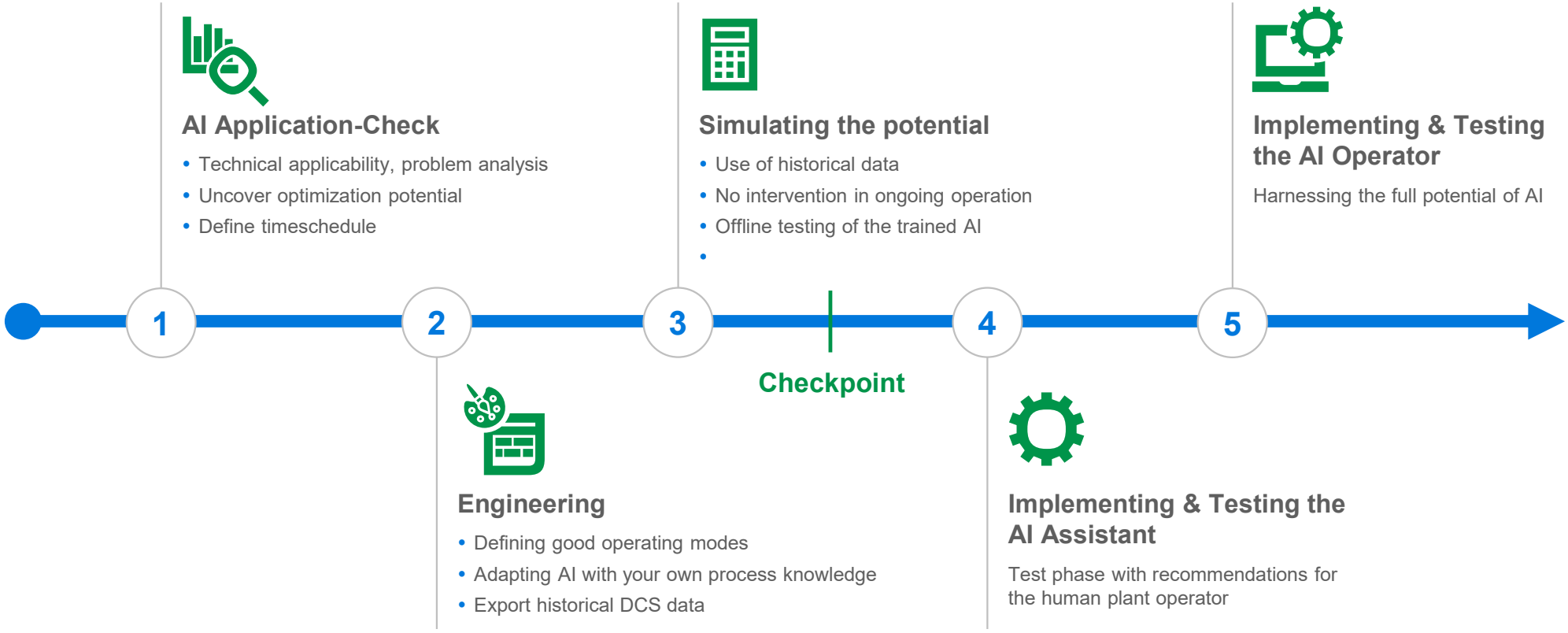
Predicting certain process developments (Steam, CO, O2 etc)

Full control with Human Operator

Example: AI-Prediction – 2 and indirect control



5 simple steps to a successful AI project



We have developed our AI for different use cases

Project References (Excerpt)

Grate furnace: Waste / Biomass	• Reduction of emissions and increase the steam production and waste throughput through **optimization** of the **incineration process** • Reduction of boiler contamination / extension boiler operating period by reducing boiler temperature • **Prediction of steam drops** • **Prediction of CO peaks**
Fluidized bed	• **Control of combustion air**
Gas boiler	• Increase of maximum performance **by trimming combustion air** (Gas boiler)

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