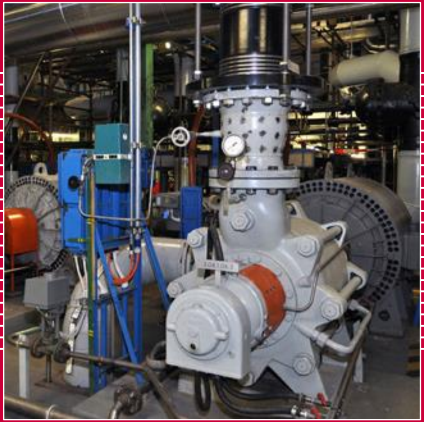
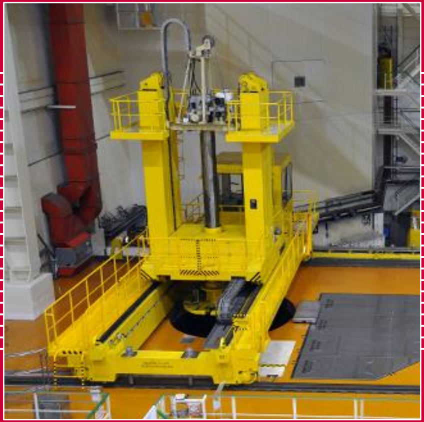
NPP Thermal Performance Monitoring and Optimization System

VVER 2019 Recent & Future

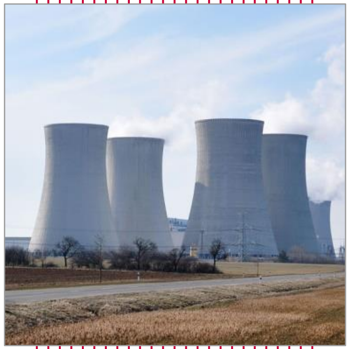
11 – 12 November 2019, Prague, Czech Republic





CONTENT

- Thermal Monitoring & Optimization System challenges
- Thermal Monitoring & Optimization System (O&M) – three pillars
- Advanced measured data processing (DVR)
- Models for diagnostics and optimization
- Diagnostics Examples – condenser, cooling tower
- Optimization example – cooling circuit optimization
- Conclusion, benefits



MY VIEW = WHAT IS POWER PLANT PERFORMANCE IMPROVEMENTS

WHEN WE ARE TALKING ABOUT POWER PLANT PERFORMANCE = WE ARE TALKING ABOUT THERMAL POWER PLANT PERFORMANCE

THERMAL POWER PLANT PERFORMANCE RESTORING OR INCREASING = POWER PLANT OUTPUT TO THE GRID INCREASING

POSSIBILITIES / CHALLENGES

- Reactor power output increasing by improving accuracy of reactor thermal output calculation; data reconciliation
- Early warning of critical equipment performance degradation; turbine, condenser, cooling tower, etc.; equipment model = expected state for given condition
- Loss MW finding; cycle isolation
- Improvements of main control loops; cooling water flow optimization

THE PRESENTATION IS NOT ONLY ABOUT GENERAL IDEAS BUT ALSO ABOUT REAL EXAMPLES TAKEN FROM REAL LIFE (, AND TO SHOW THAT IT IS POSSIBLE)

THERMAL MONITORING & OPTIMIZATION SYSTEM – CHALLENGES

TRUE ANSWER TO THREE QUESTIONS

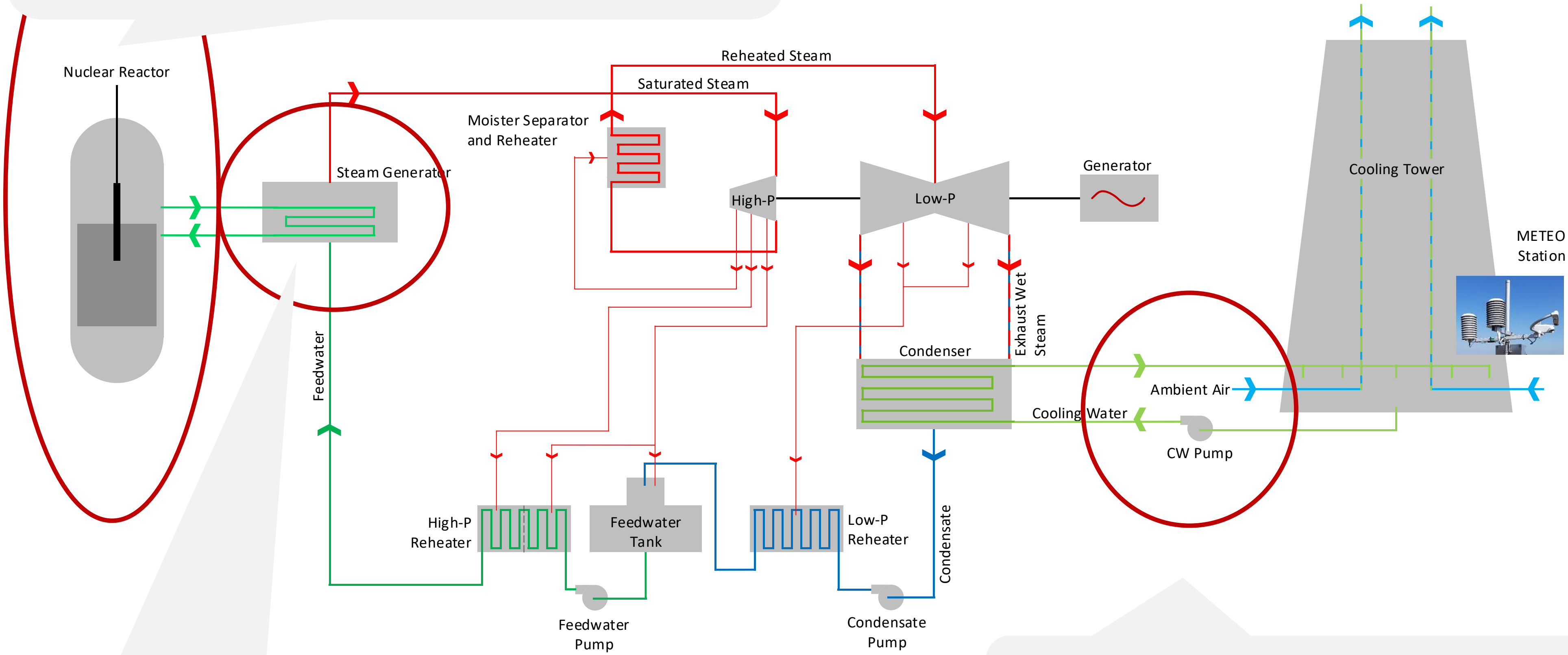
- Do we have really true information about equipment health and overall thermal cycle performance?
- Do we know current equipment health?
- Do we provide loss megawatt hunting and / or find out all possibilities to improve performance of thermal cycle?

MANY NPPs HAVE BEEN MORE THAN 30 YEARS OF OPERATION

= OBSOLESCENCE ISSUES

THERMAL MONITORING & OPTIMIZATION SYSTEM – CHALLENGES (1)

Nuclear reactor
- Accuracy in terms of output < 0,5 %
- Reactor thermal output uprate ↑ 0,1 – 0,2 %



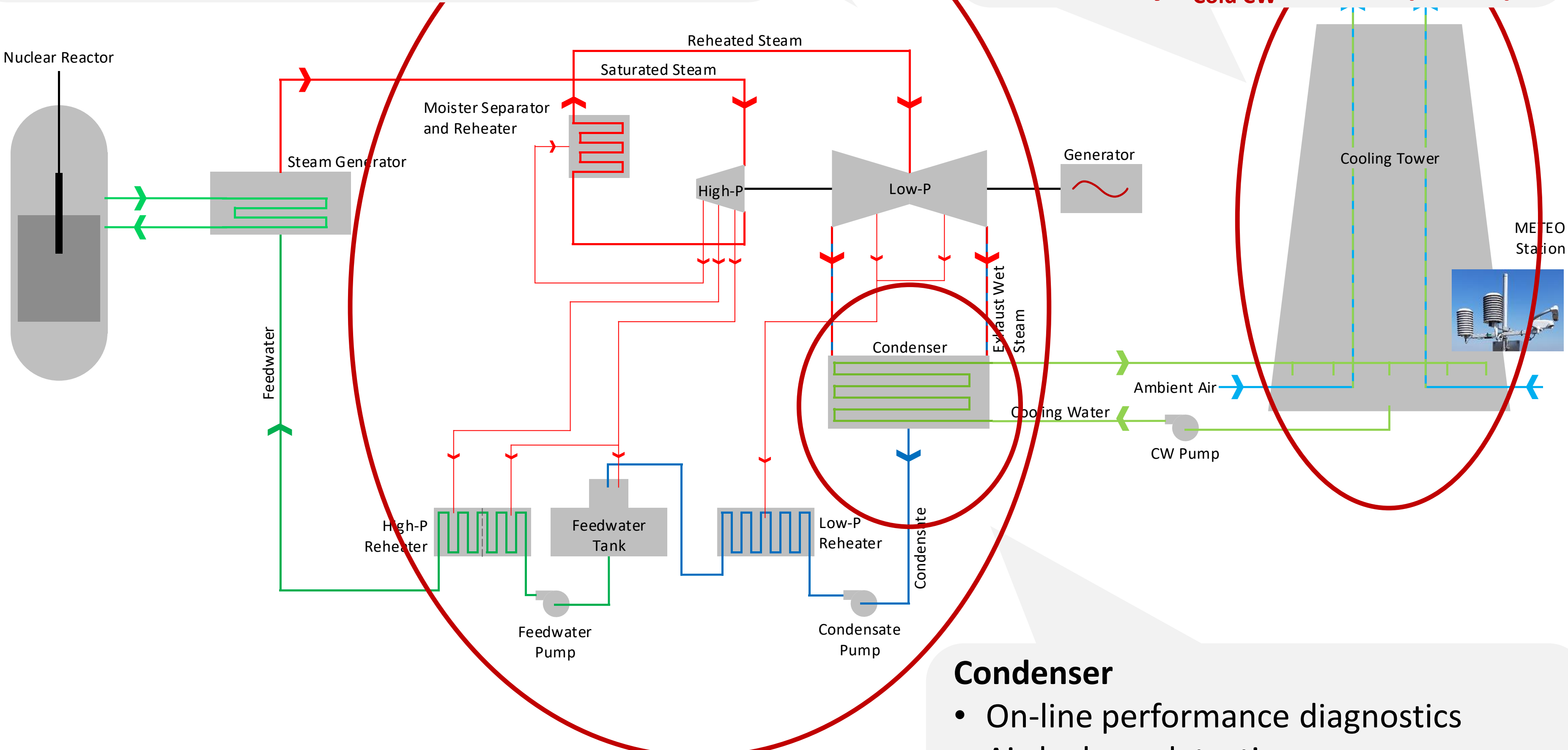
Blow down flow
- Accuracy in terms of output < 3,0 %

Cooling water flow
- Accuracy in terms of output < 1,0 %

THERMAL MONITORING & OPTIMIZATION SYSTEM – CHALLENGES (2)

Turbine
- On-line and Off-line performance diagnostics
- Testing after service or reconstruction
- Testing after changes of control strategy
- **Sensitivity in terms of output < 2,0 MW (1,0 MW)**

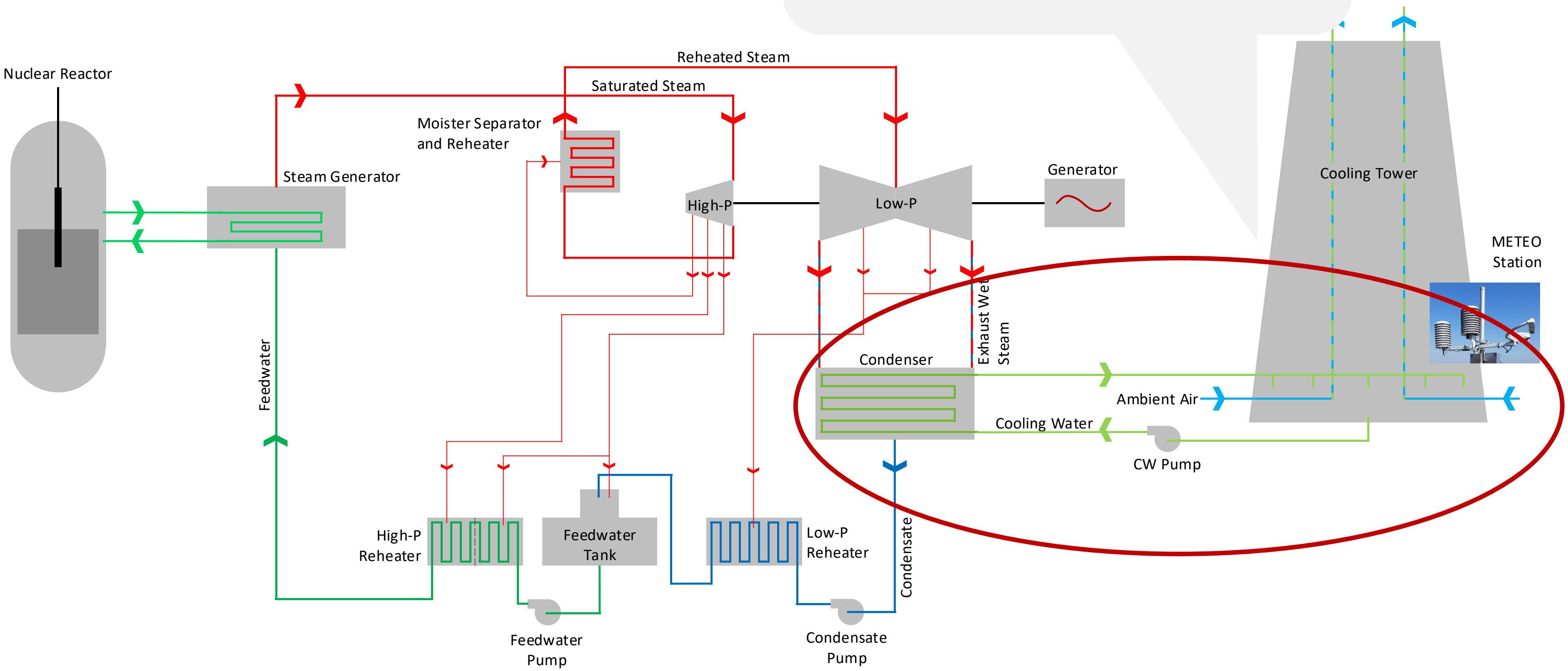
Cooling Tower
- Off-line performance diagnostics
- Detection of fill and eliminator fouling and damage
- **Sensitivity $T_{Cold\ CW}$ < 0,4 °C (0,2 °C)**



Condenser
- On-line performance diagnostics
- Air-leakage detection
- Surface fouling detection
- **Sensitivity P_{Steam} < 0,2 kPa (0,1 kPa)**

THERMAL MONITORING & OPTIMIZATION SYSTEM – CHALLENGES (3)

Cooling Circuit
- Cooling water flow optimization
- **1000 MW Unit power output ↑ 1 – 2 MW**



M&O – THREE PILLARS

Thermal Performance Monitoring and Optimization System

- **Robust Data Reconciliation**
- **Highly Accurate Models**
- **Feature-Rich HMI**

M&O – BENEFITS BY ADVANCED DATA PROCESSING AND MODELS

Supervision & Diagnostics

Optimization Control

KPI Expected values by MODEL calculation

DATA RECONCILIATION & Gross errors detection

Raw Data from DCS / PLS PREPROCESSING and FILTERING

Process optimization & prediction

- 1 to 2 MW power output uprate for 1000 MW unit / twin unit
- Accurate power output planning

Equipment supervision & diagnostics

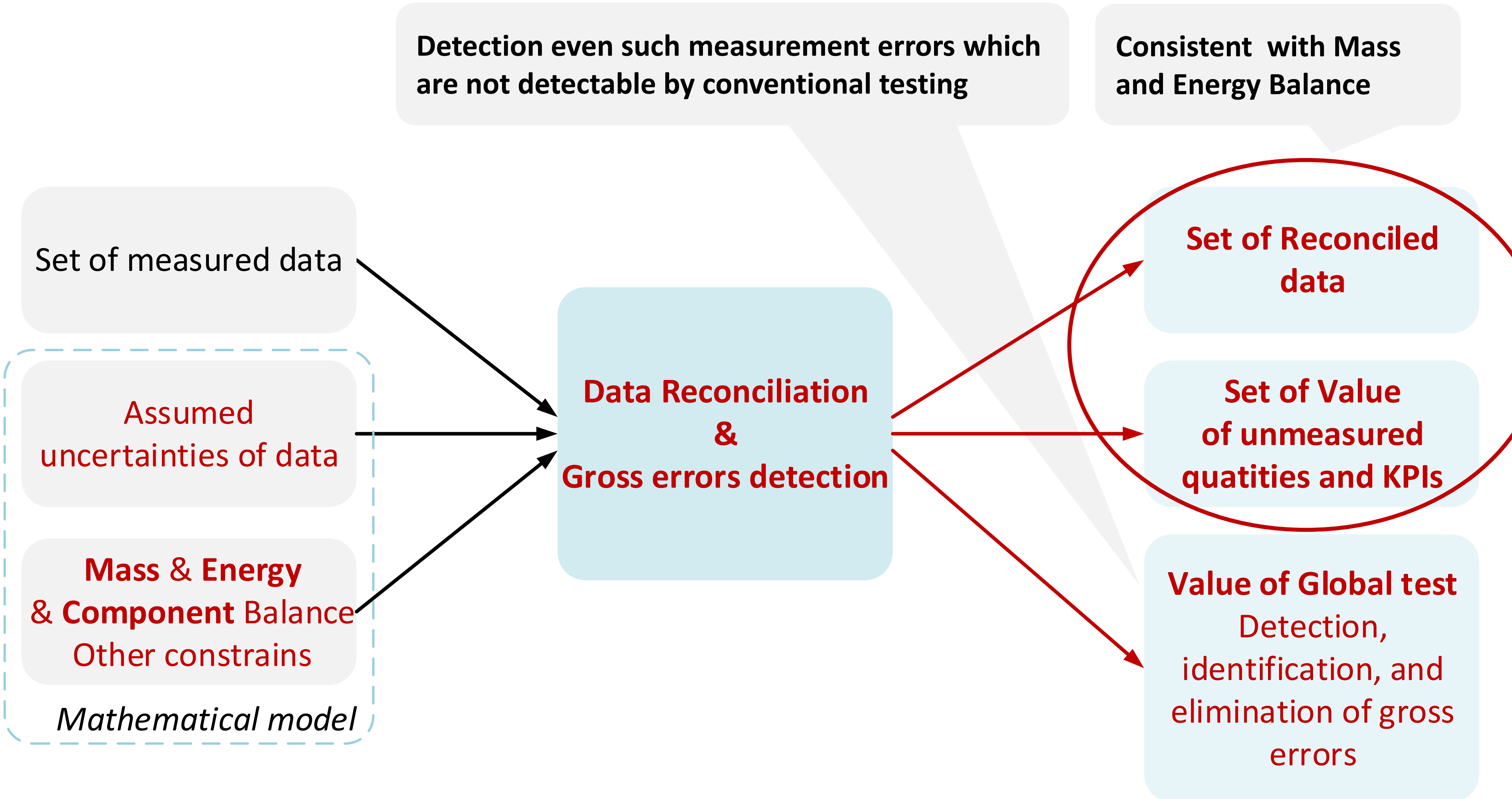
- On-line equipment health evaluation, early fault Detection
- Process performance supervision, lost MW hunting, predictive maintenance support

Accurate expected KPI value calculation by MODELS

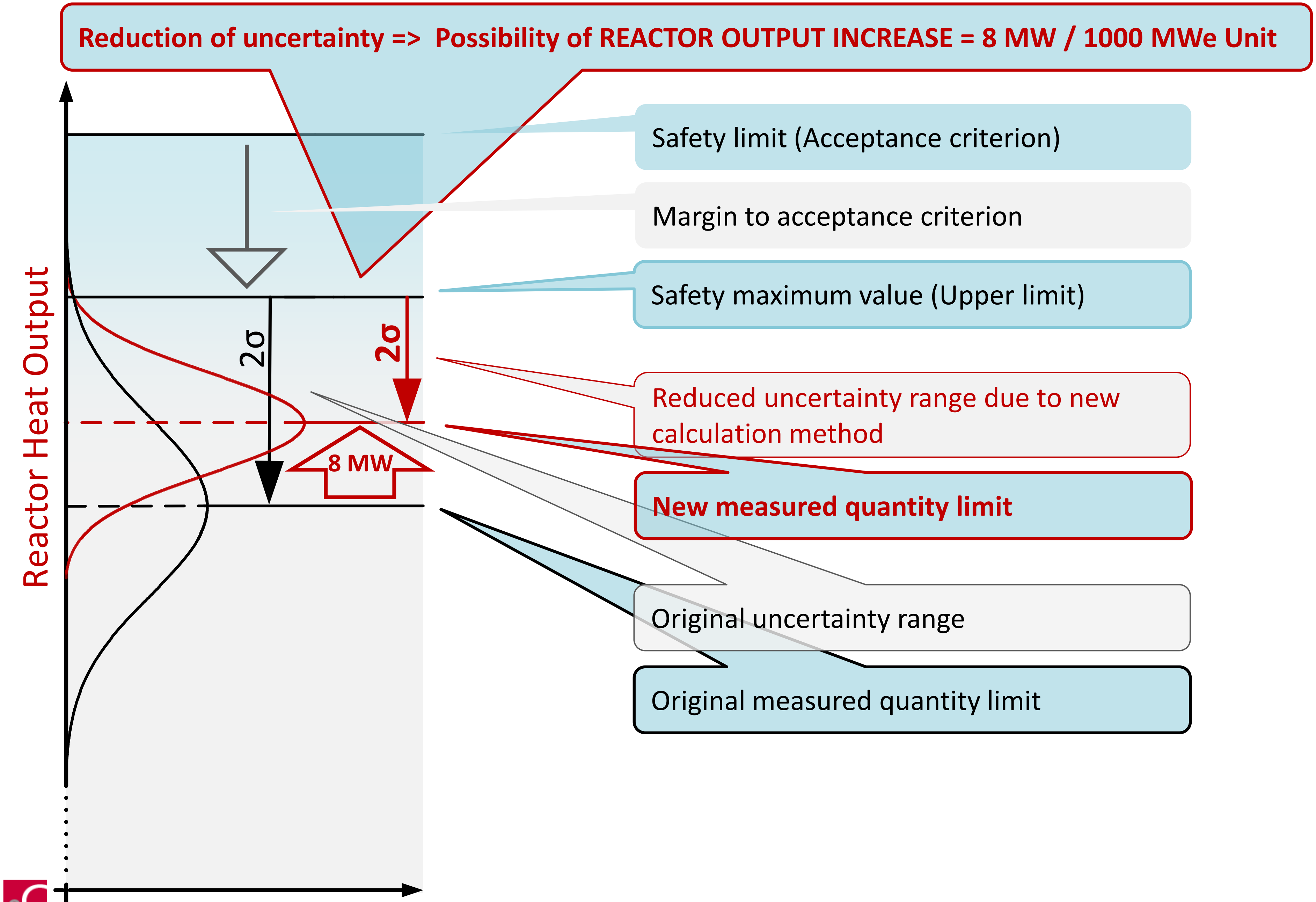
Better accuracy, better confidence in data

- Identification and elimination of measurement errors
- Measurement accuracy improvements
- Unmeasured quantities and KPI calculation

ADVANCED MEASURED DATA PROCESSING, ADDITIONAL LEVEL FOR DATA VALIDATION

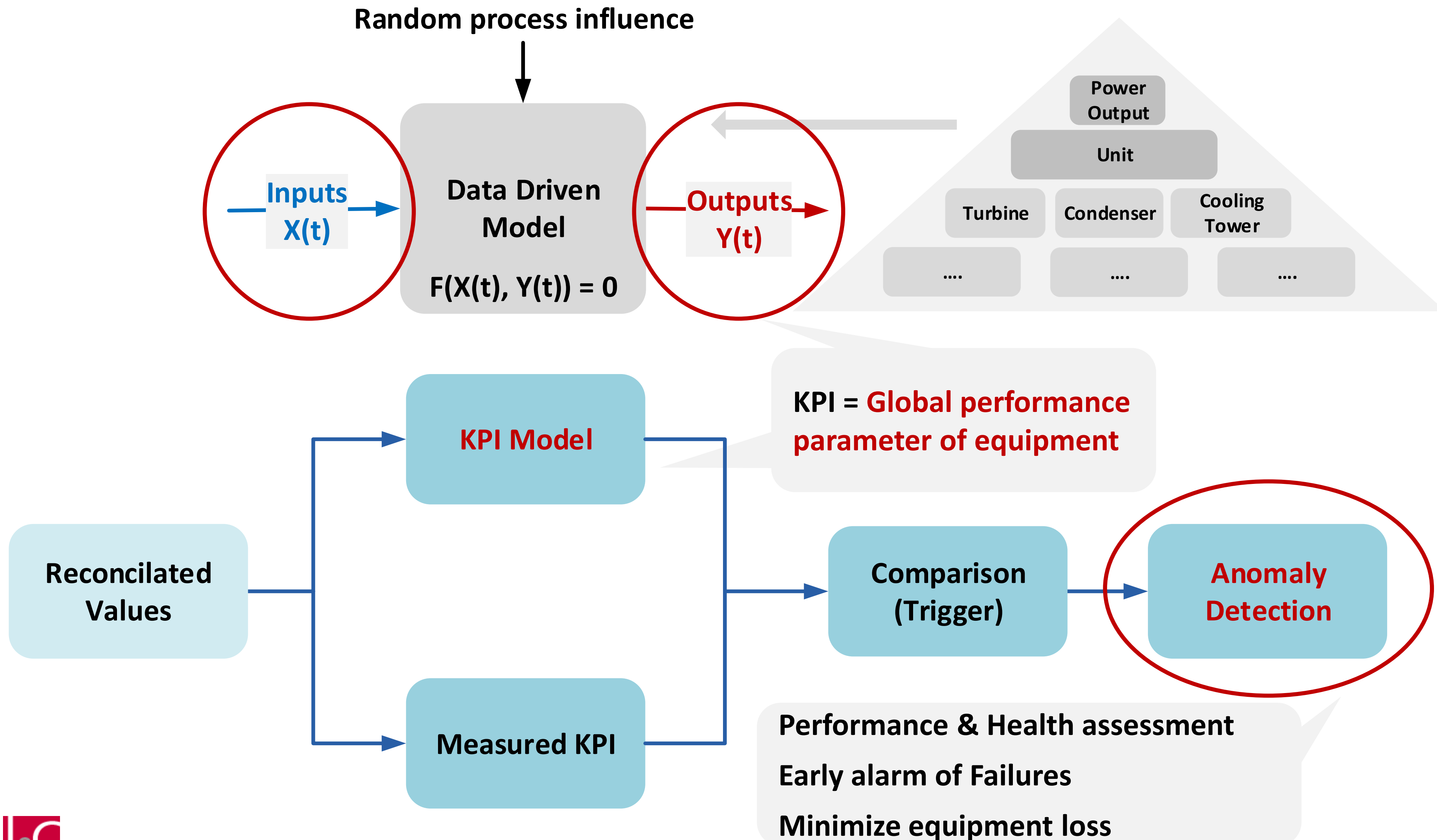


ACCURACY EXAMPLE – REACTOR POWER OUTPUT ON-LINE CALCULATION

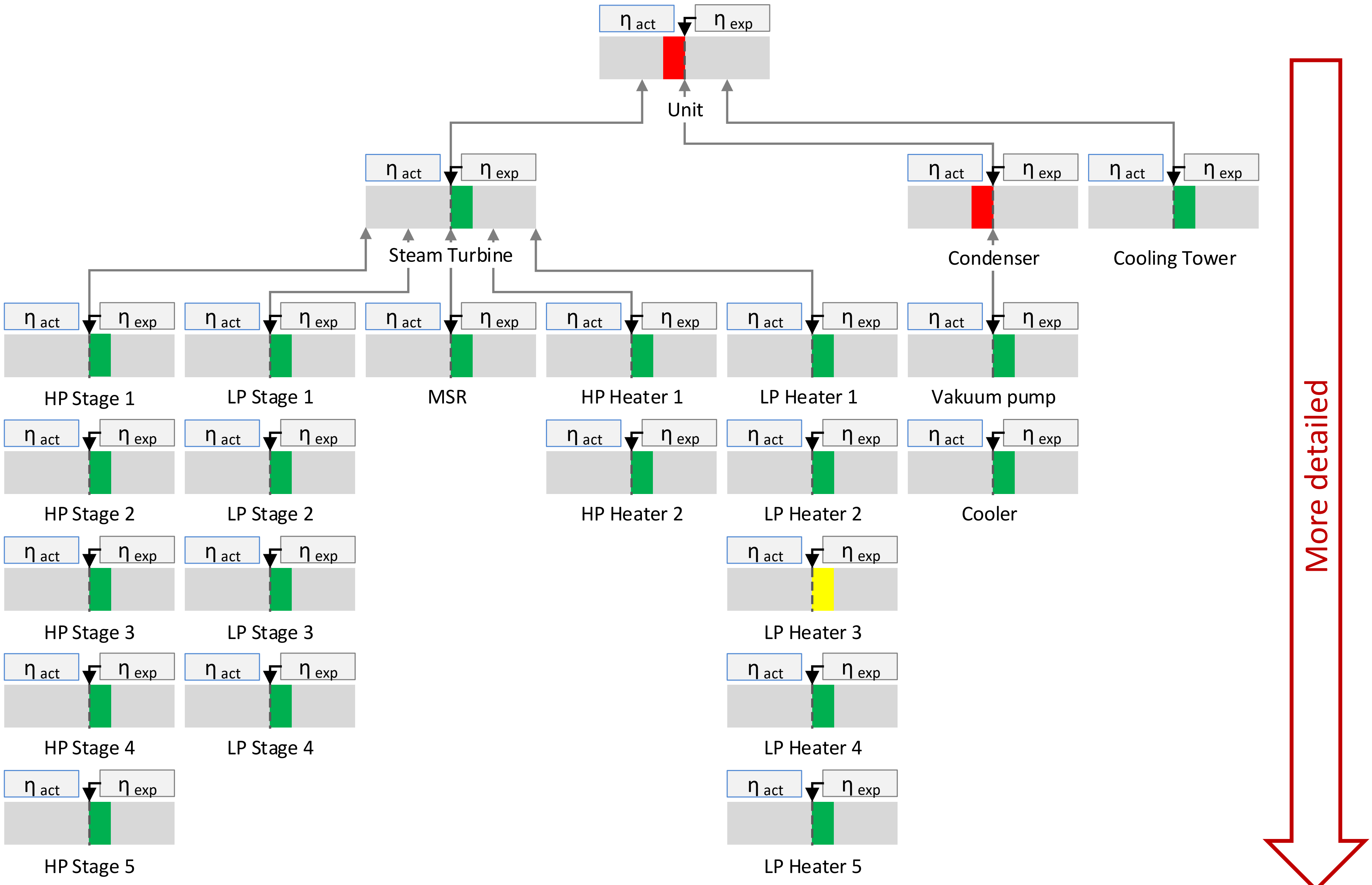


MODELS FOR DIAGNOSTICS AND OPTIMIZATION

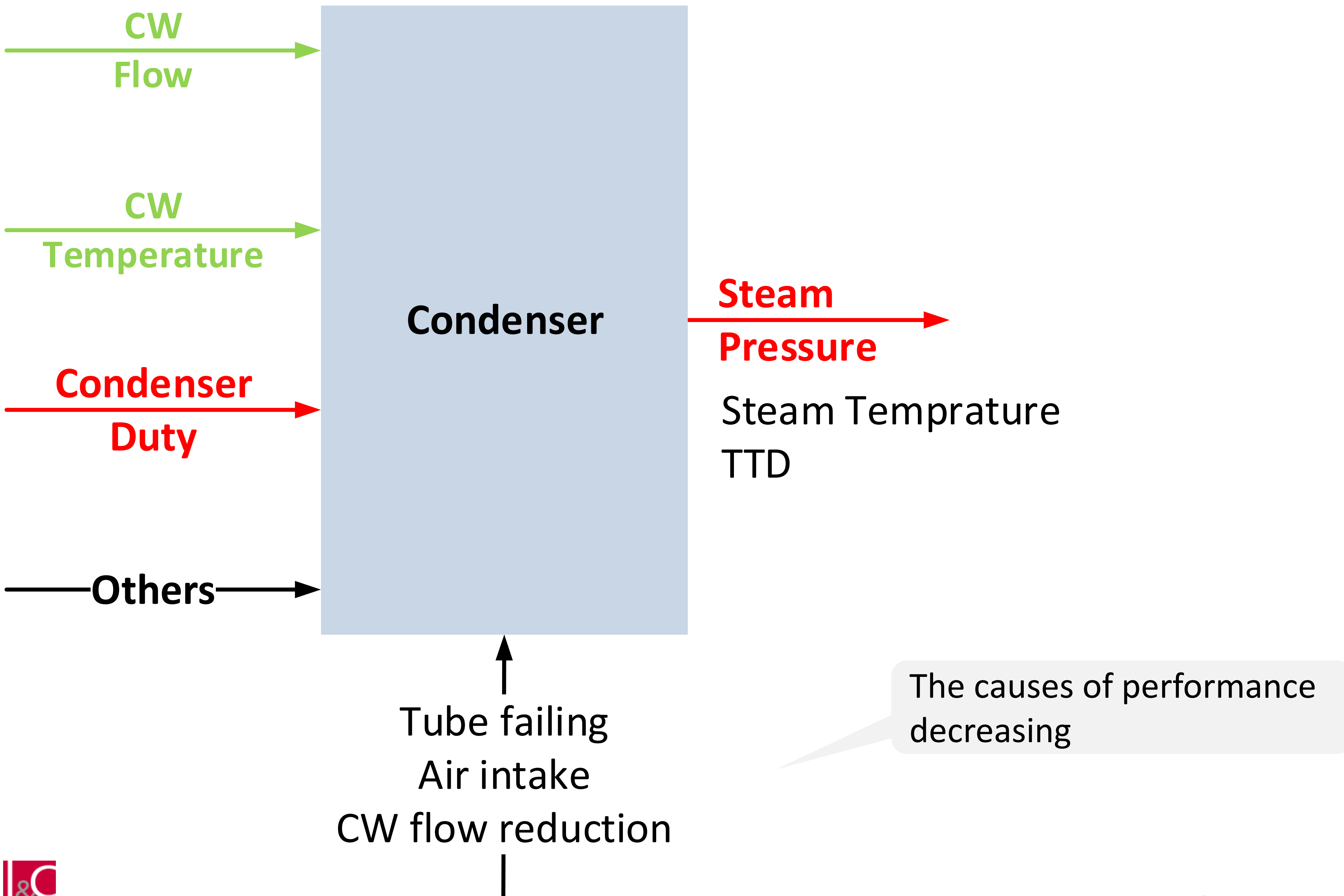
Regression Triplet = Data + Model + Method



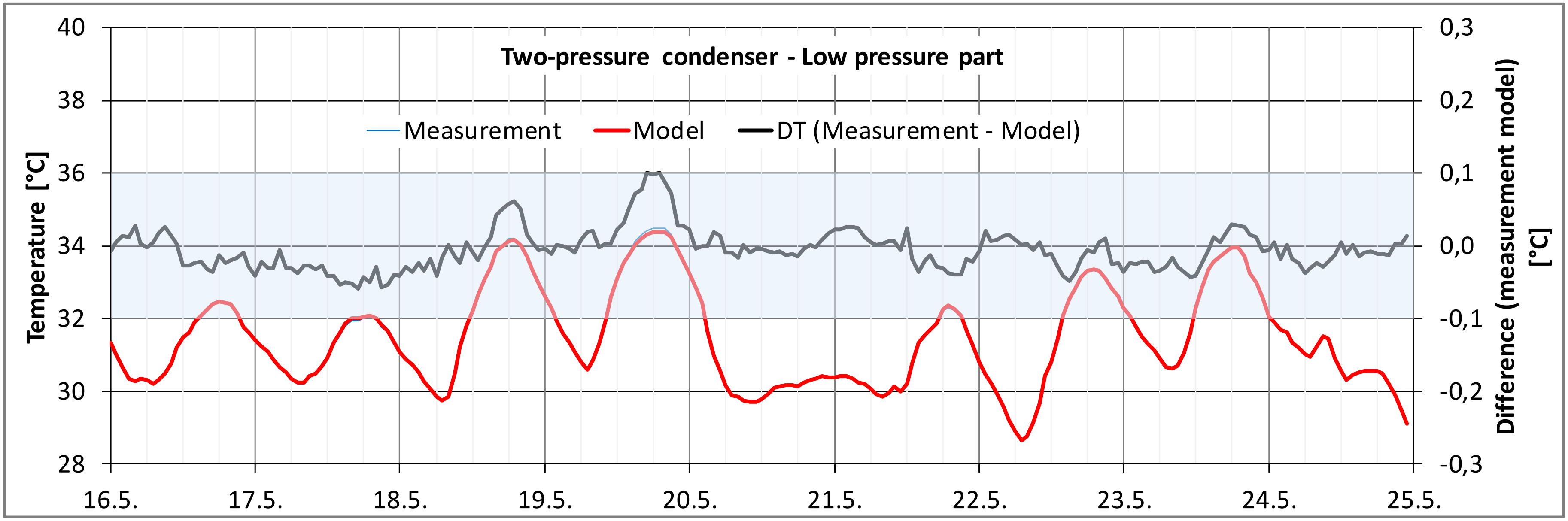
IDENTIFYING THE ORIGIN OF PERFORMANCE DEVIATION BY KPI

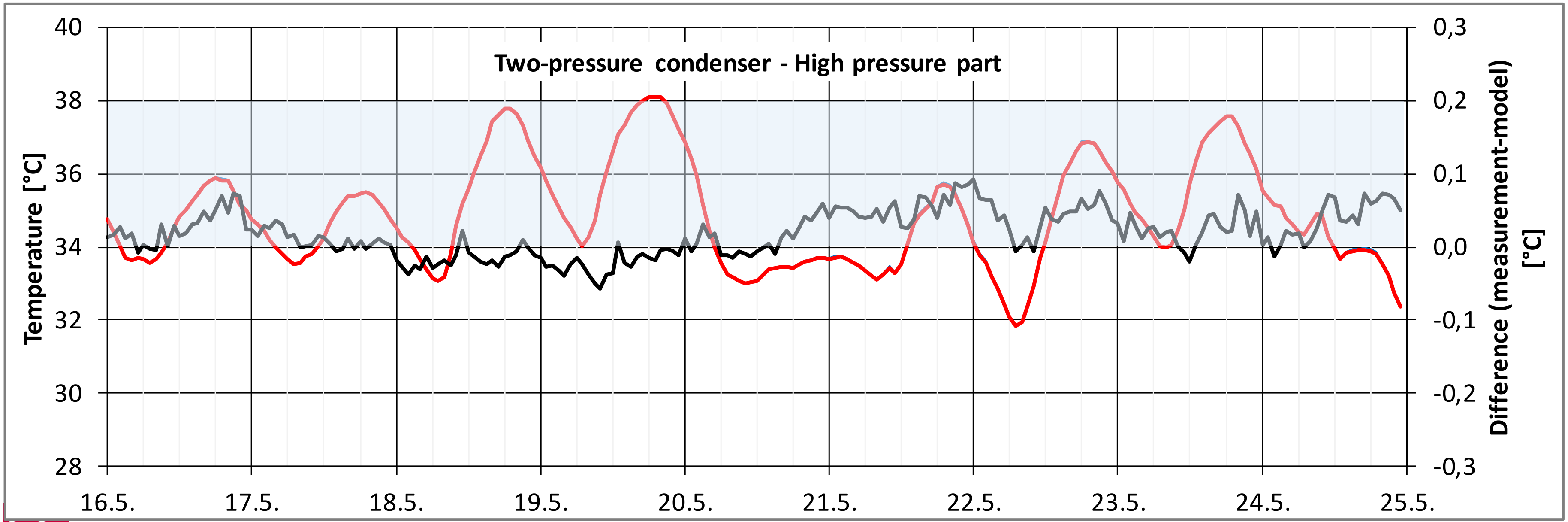


SURFACE CONDENSER MODEL

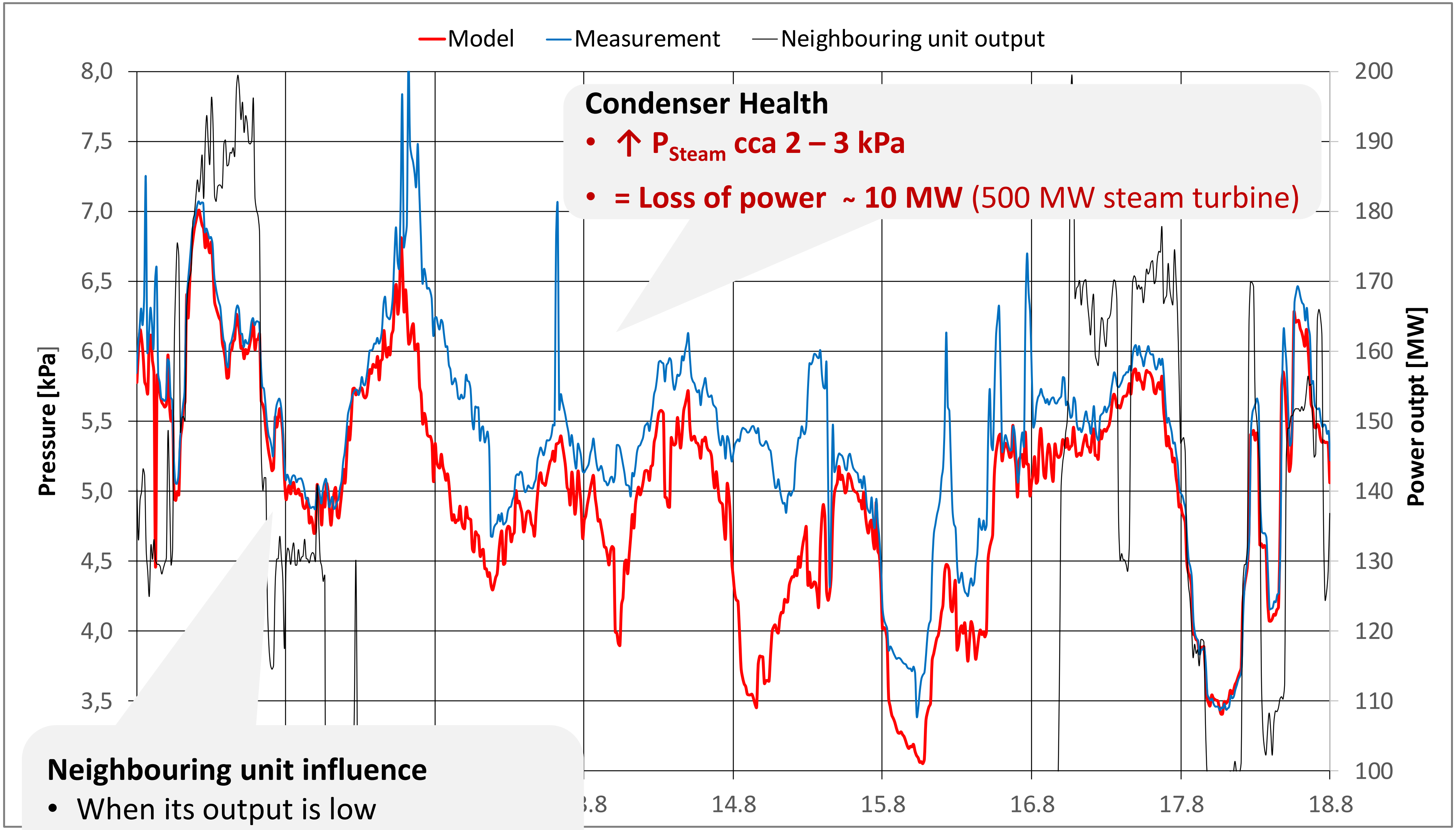


ACCURACY EXAMPLE – SURFACE CONDENSER MODEL





SURFACE CONDENSER – AIR LEAKAGE DETECTION EXAMPLE



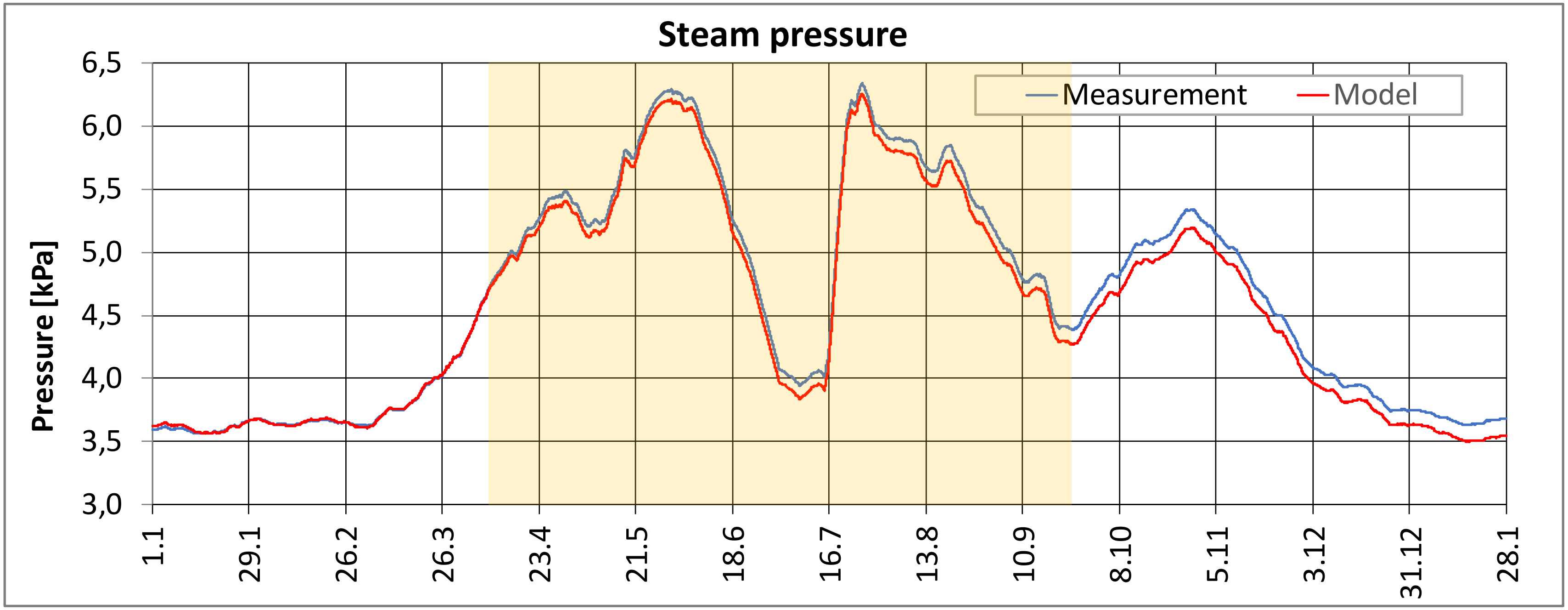
Condenser Health

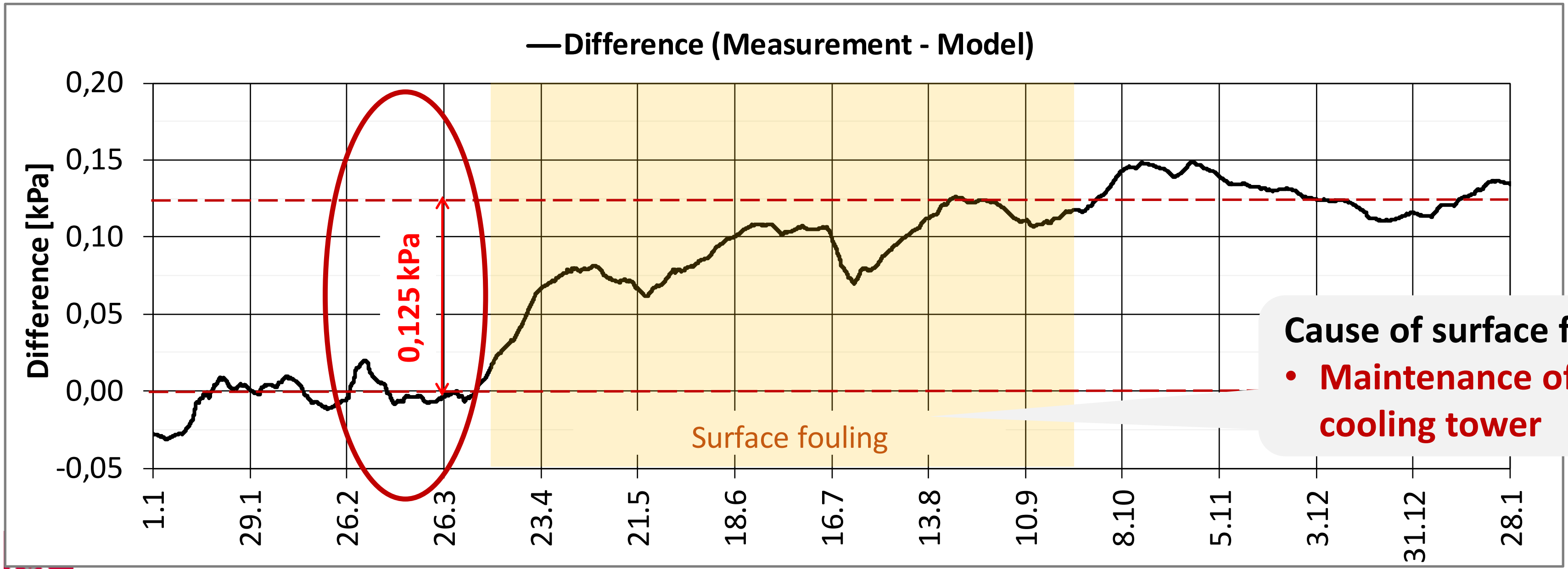
- **↑ P_{Steam} cca 2 – 3 kPa**
- **= Loss of power ~ 10 MW** (500 MW steam turbine)

Neighbouring unit influence

- When its output is low
- Air intake is occurring due to interconnection of both units

SURFACE CONDENSER – SURFACE FOULING DETECTION EXAMPLE

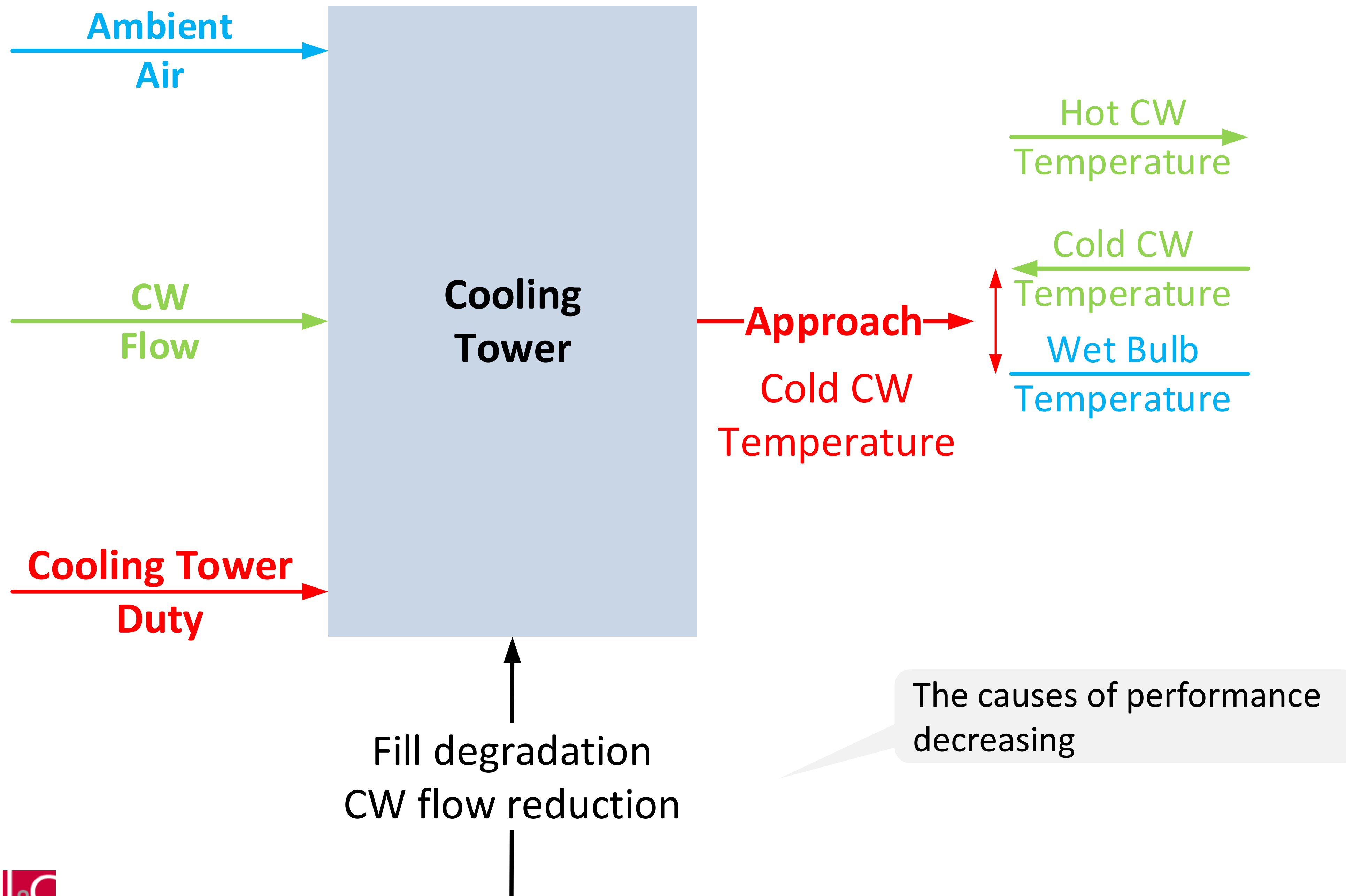




Cause of surface fouling

- **Maintenance of connected cooling tower**

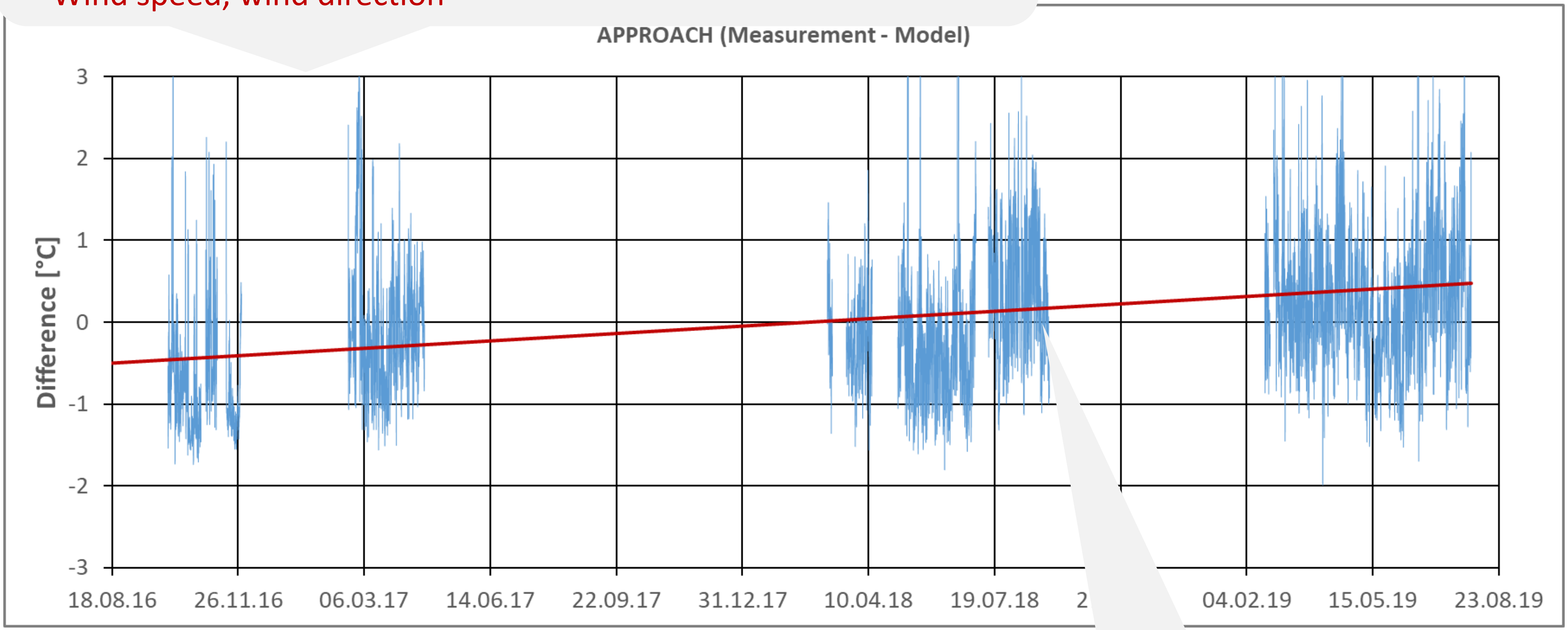
COOLING TOWER MODEL



COOLING TOWER – DETECTION OF FILL FOULING EXAMPLE

Clear view is affected by

- Cooling circuit dynamics (water accumulation in basin)
- Measurement of wet bulb temperature (1 km far away from tower
- Wind speed, wind direction



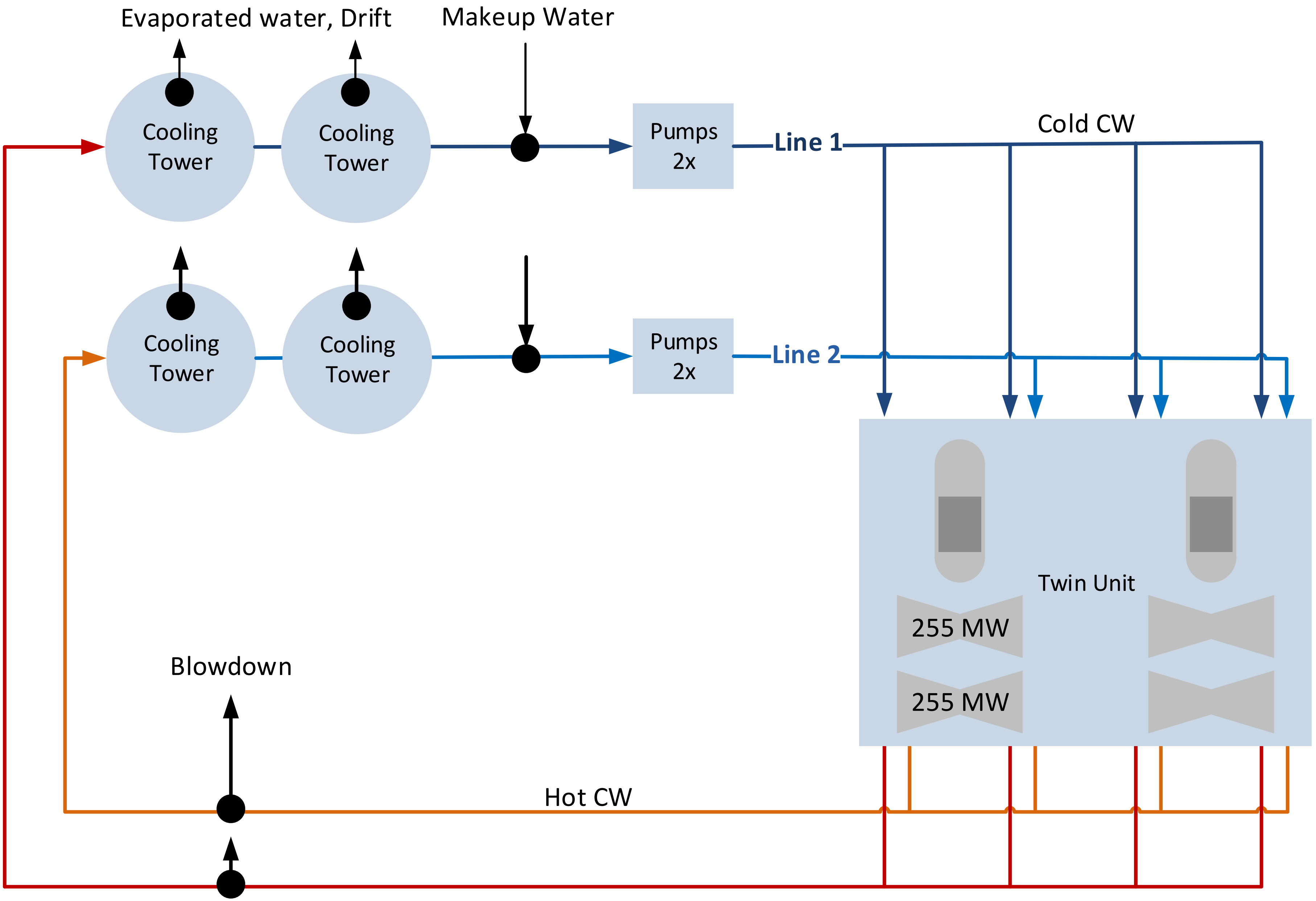
WHAT WE CAN SEE

- Decreasing cooling tower performance 1 °C (approach ↑)
- = 3 MW loss /1000 MW turbine
- **Input for predictive maintenance**

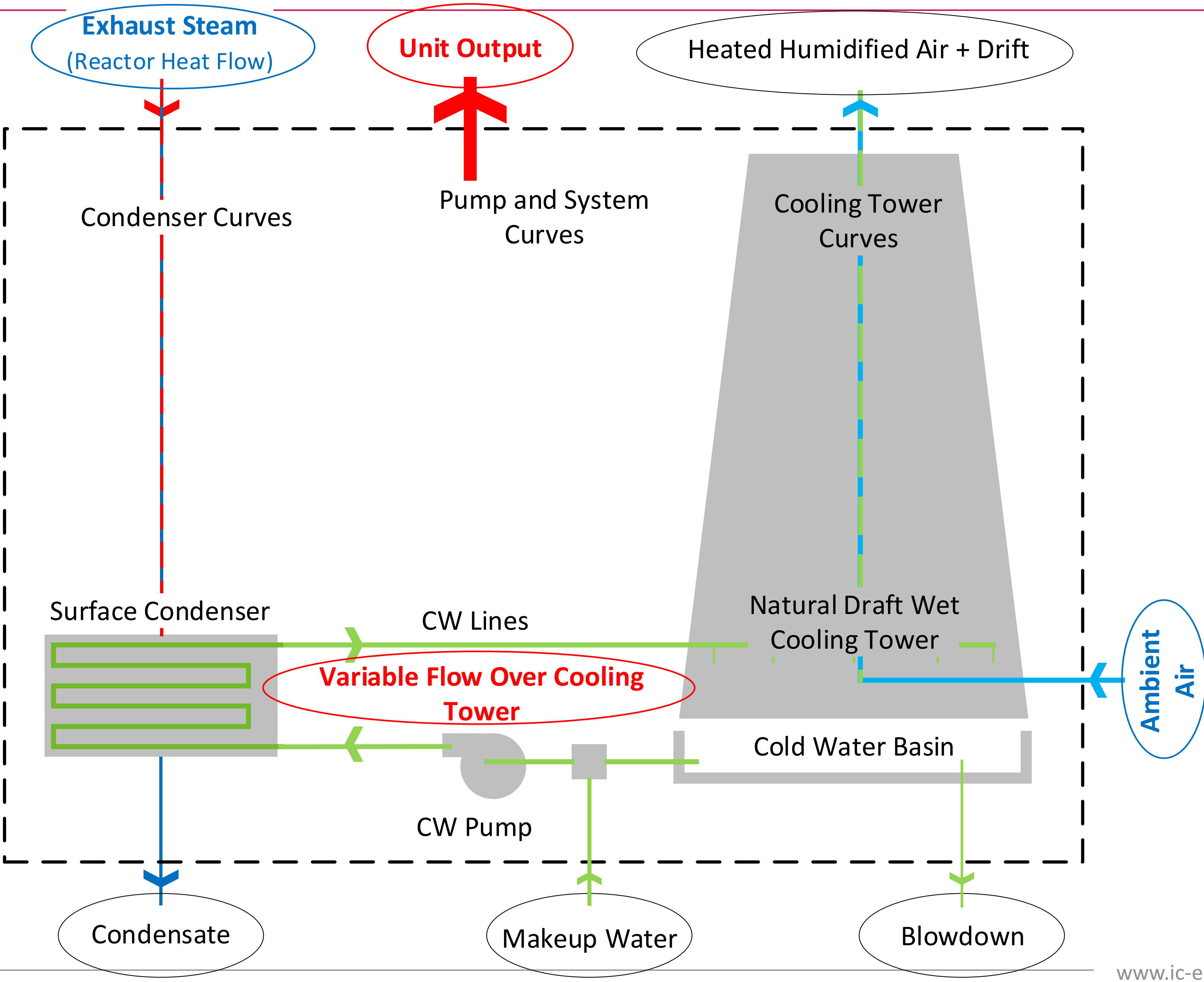
Cause of performance decreasing

- **Fill (bio)degradation**

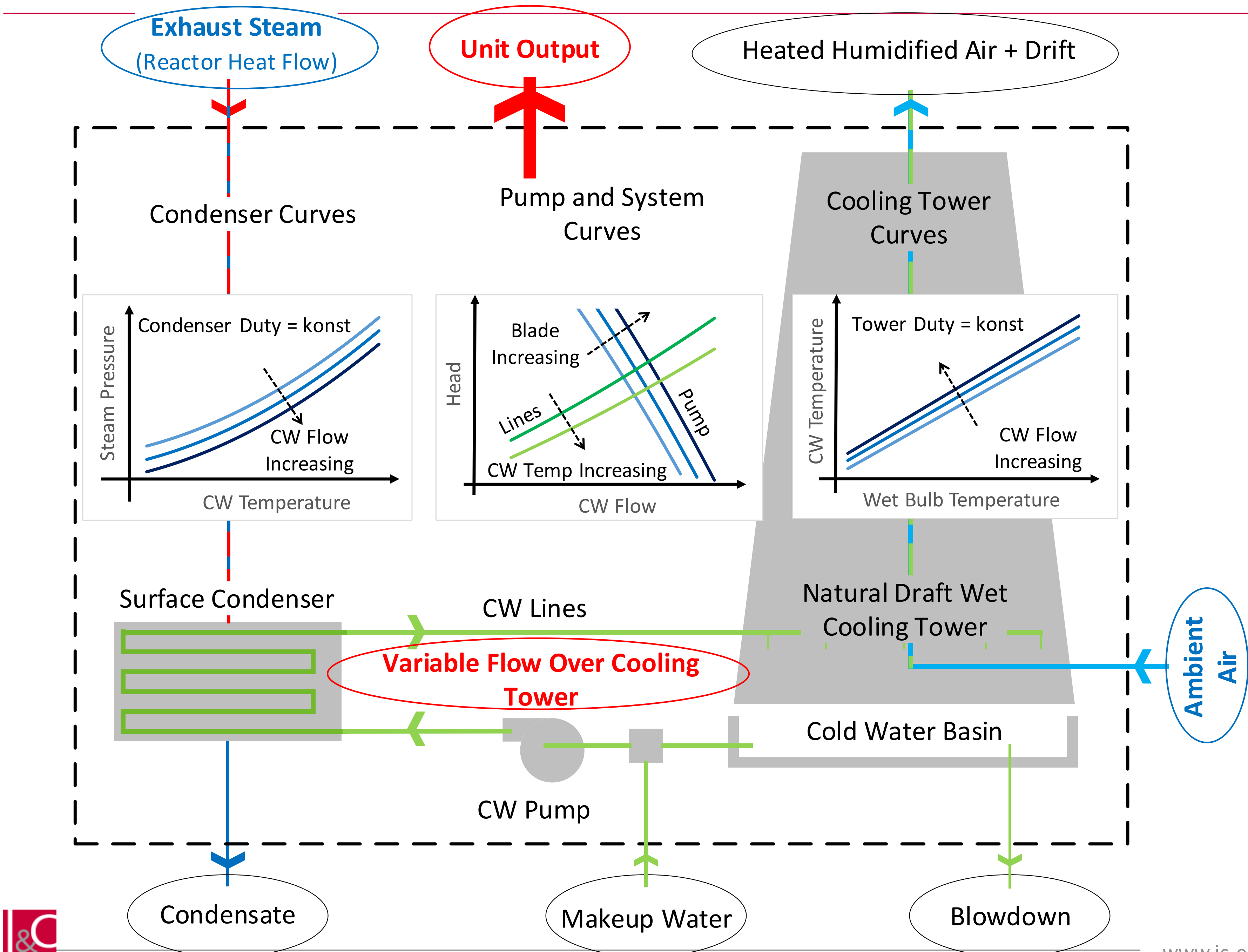
STEAM TURBINE COLD END OPTIMIZATION EXAMPLE



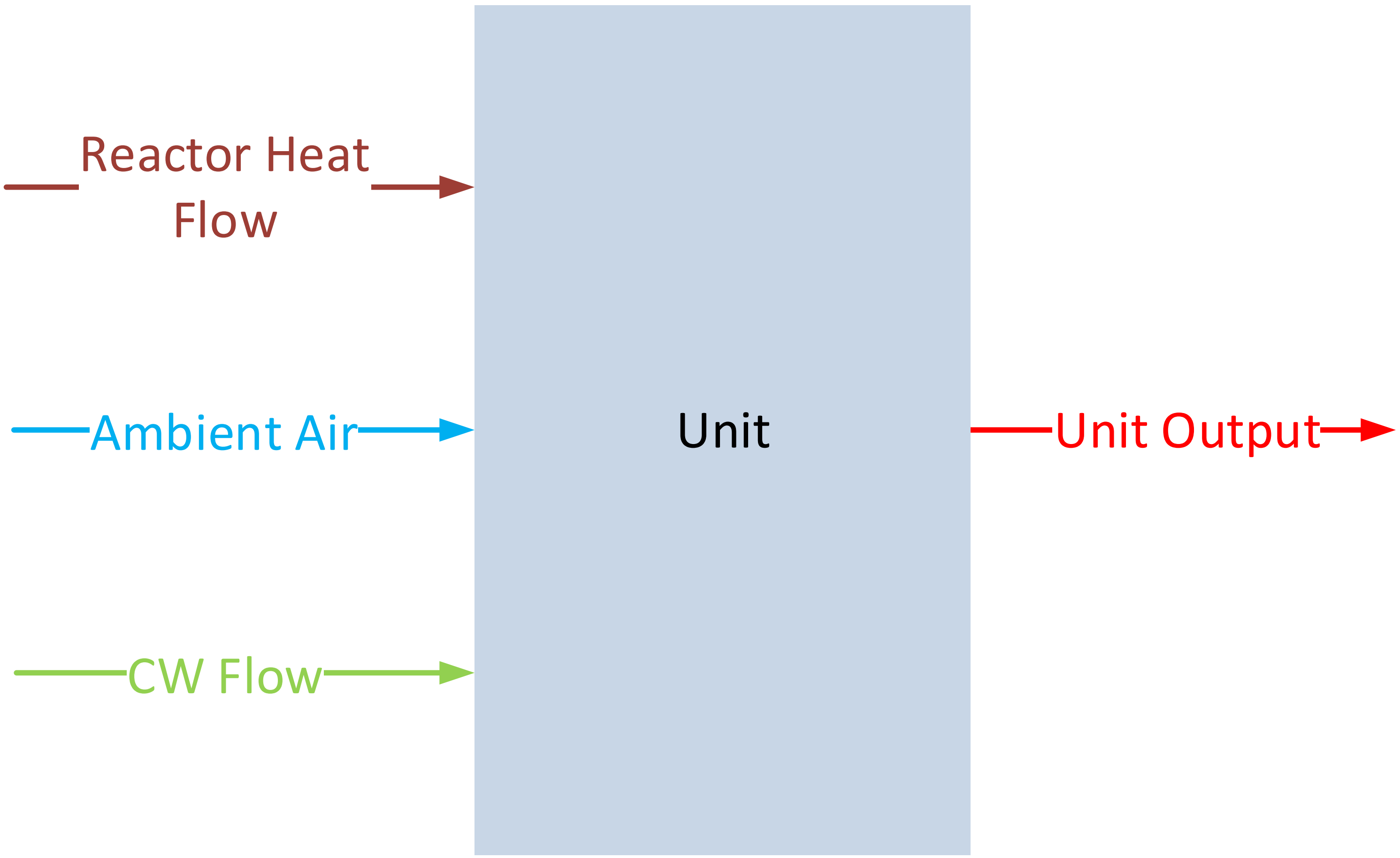
Overall Unit Performance Depends on Performance of the Main Equipment and their Mutual **Relationship**



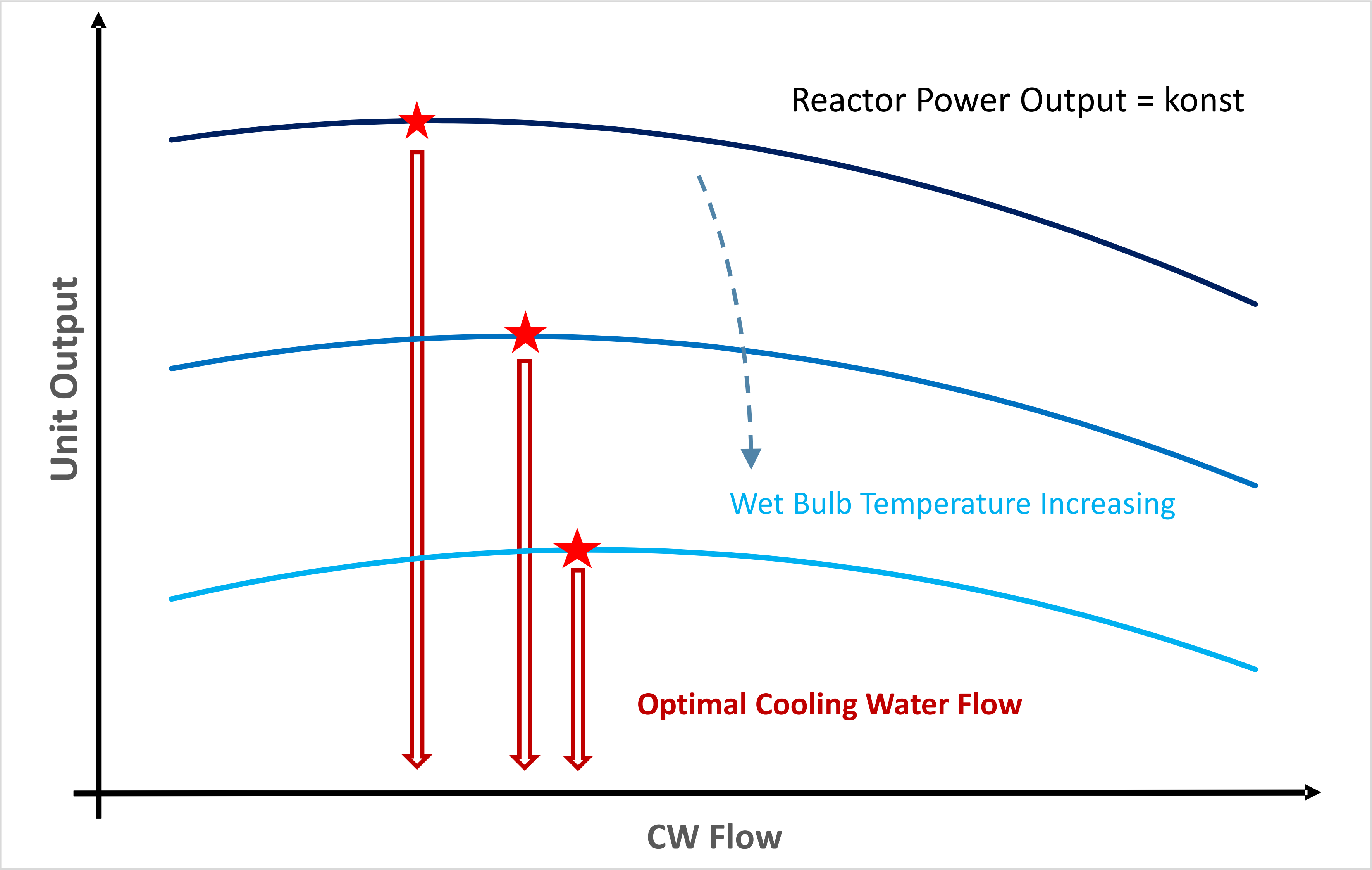
Overall Unit Performance Depends on Performance of the Main Equipment and their Mutual **Relationship**



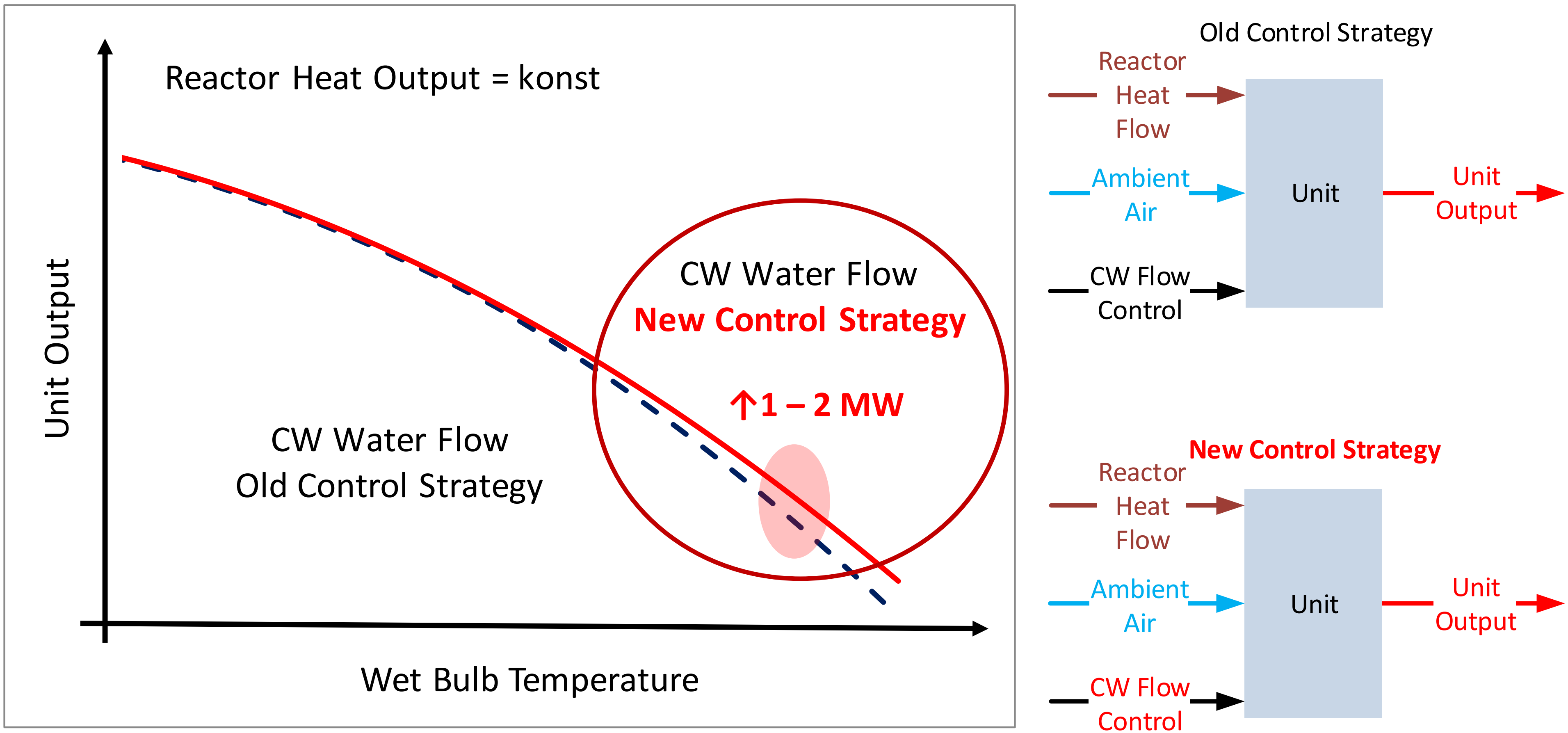
STEAM TURBINE COLD END OPTIMIZATION



STEAM TURBINE COLD END OPTIMIZATION



STEAM TURBINE COLD END OPTIMIZATION RESULT



CONCLUSION – BENEFITS

BETTER CONFIDENCE IN DATA

- Gross errors of measurement Detection, identification, and elimination
- Data truthfulness enhancement (= precision + accuracy)

DEEP VIEW INSIDE THE THERMAL PROCESS; transformation data into usefulness information

- Unmeasured quantities calculation
- KPI (=Key performance indicators) calculation
- Knowledge of power plant staff enhancement

BETTER SUPERVISION & DIAGNOSTICS

- On-line equipment and processes health assessment
- Early warning of equipment failures
- Lost megawatts finding
- Inputs for predictive maintenance

THERMAL PROCESS OPTIMIZATION & PREDICTION

- Unit power output increasing
- Accurate unit power output planning

CONCLUSION – MODEL ACCURACY BENEFITS

Equipment	Detection Starting	Reliable Detection	**Output Loss**
Condenser	↑ 0,1 kPa	↑ 0,2 kPa	↑ 0,5 kPa -> 5 MW loss /1000 MW turbine
Turbine	↑ 1,0 MW	↑ 2,0 MW	= loss detection
Cooling Tower	↑ 0,2 °C	↑ 0,4 °C	↑ 1,0 °C -> 3 MW loss /1000 MW turbine

Thank you for your attention

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