PIACER
Piattaforma Progettazione Gestione
Comunità Energetiche Rinnovabili

Reggio Emilia

# SYSTEM DIAGNOSTICS

## Tool per la diagnosi del sistema di generazione e distribuzione dell'energia di CER

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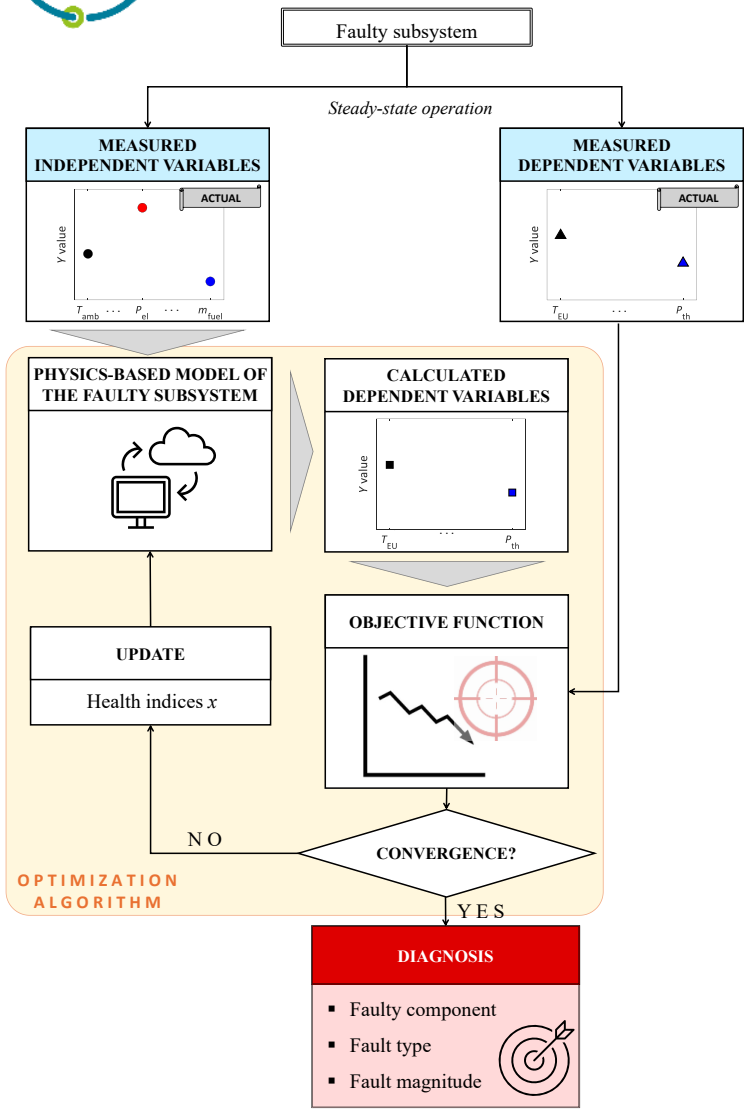
IN4 innovazione ingegneria integrazione industria

25/11/2026

# Goal




## FAULT DETECTION

- *Is there a fault?*
- *Which is the faulty component?*

## FAULT IDENTIFICATION

- *What is the fault signature?*
- *What is the fault magnitude?*

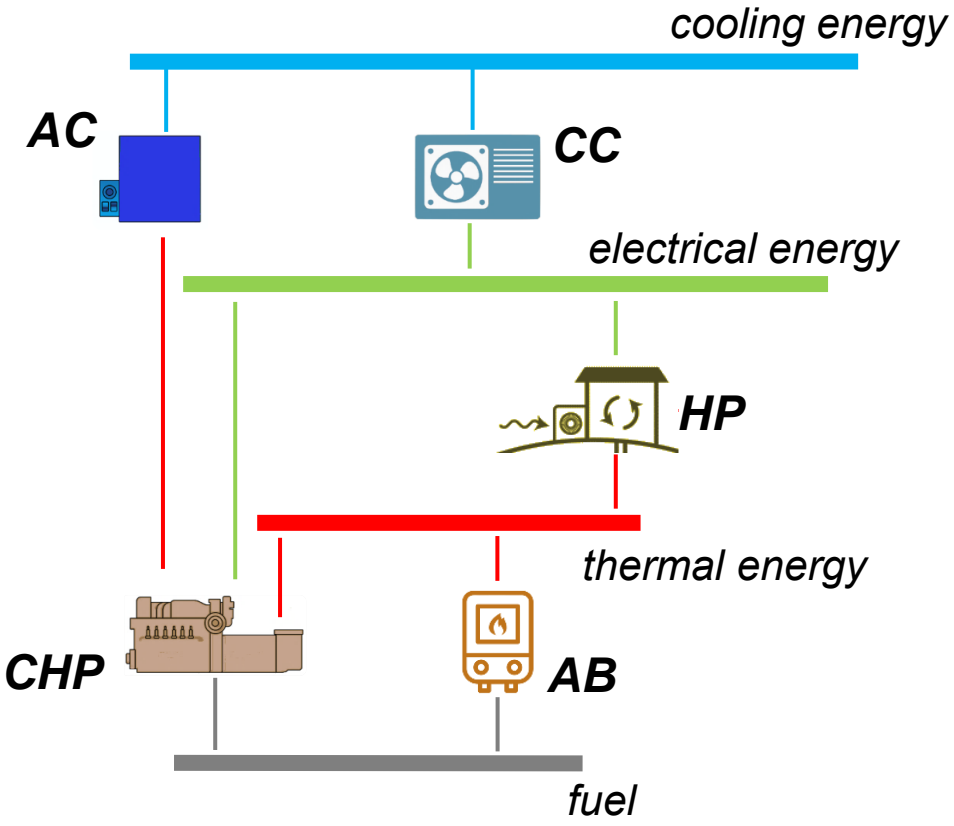
## HEALTH INDEX

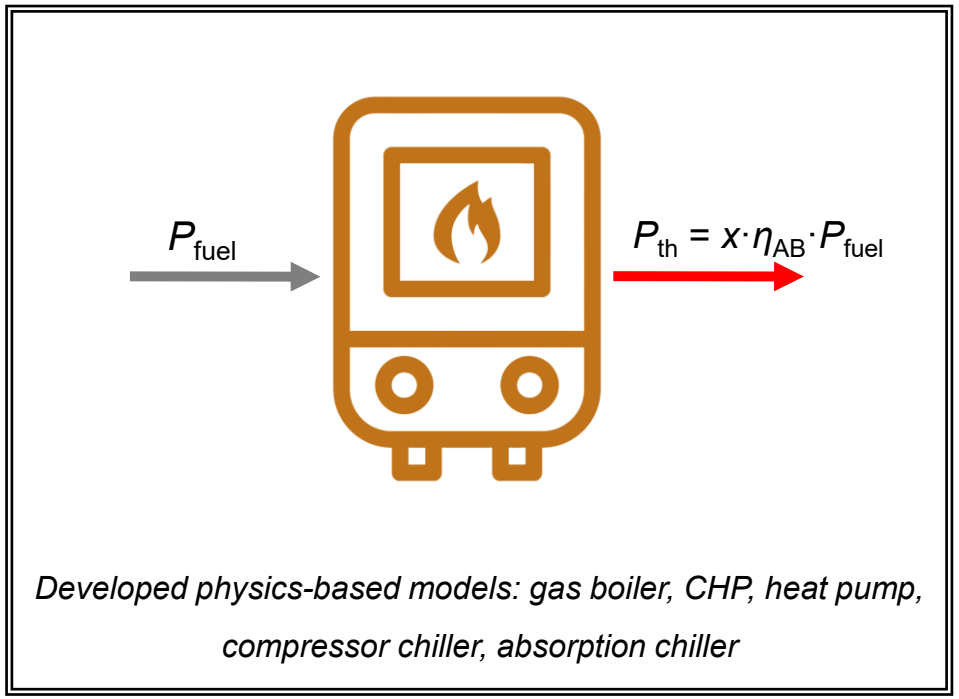
x = 1
HEALTHY

x < 1
FAULTY

# TOOL PER LA DIAGNOSI DEL SISTEMA DI GENERAZIONE DELL'ENERGIA

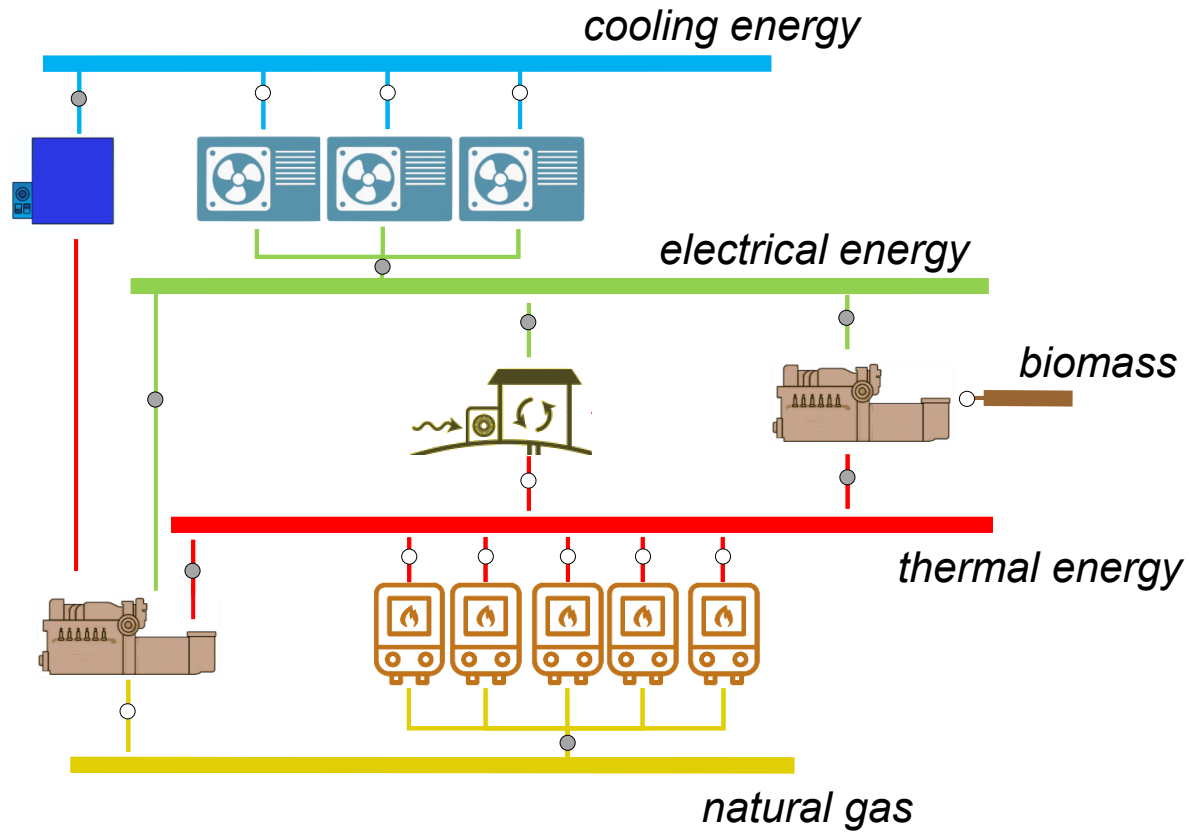
# Physics-based approach




*Developed physics-based models: gas boiler, CHP, heat pump, compressor chiller, absorption chiller*

## Campus of University of Parma




Data provider

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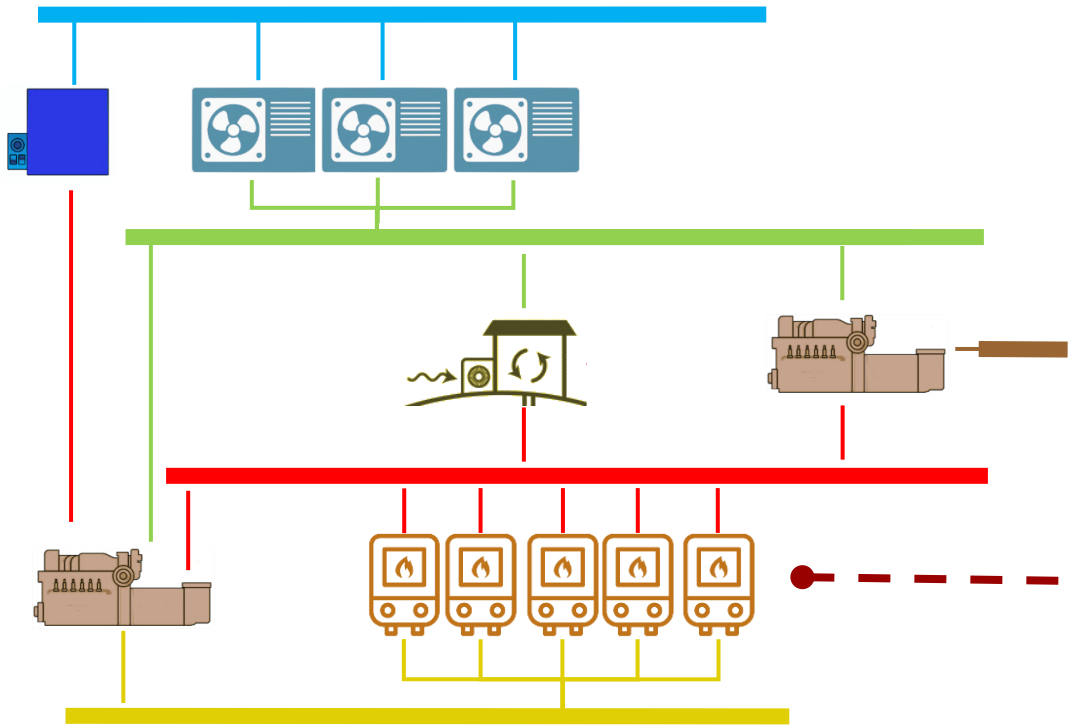
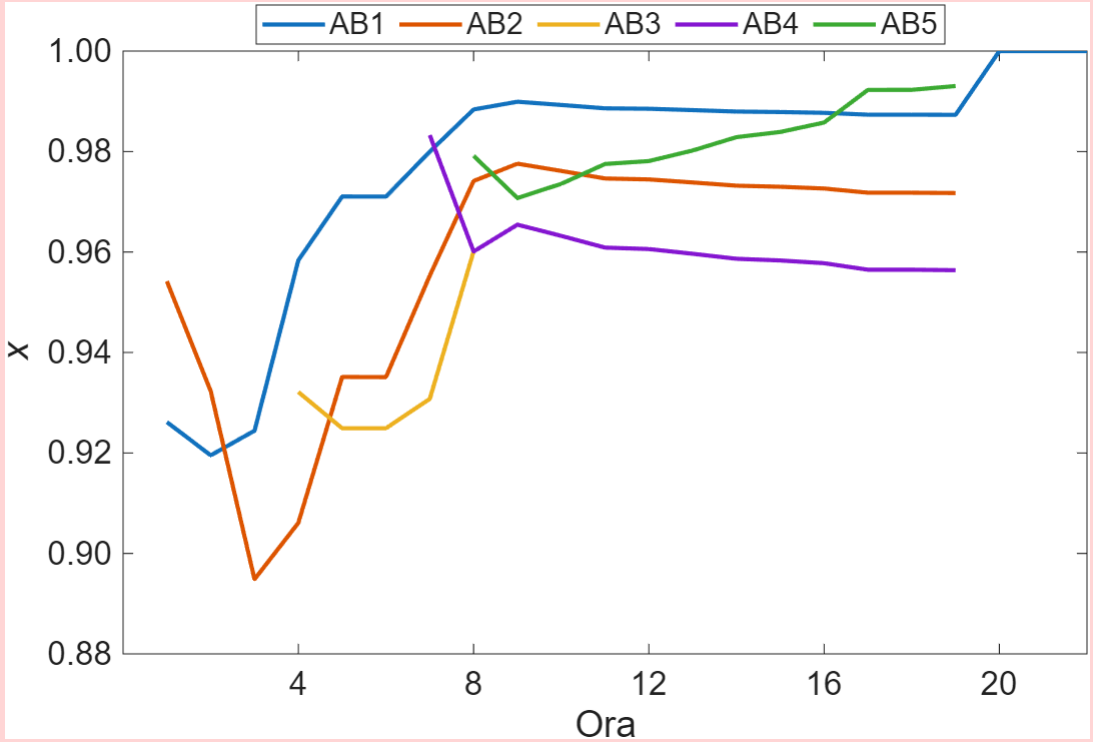
- Independent variable
- Dependent variable

# Example of application



## AB health index



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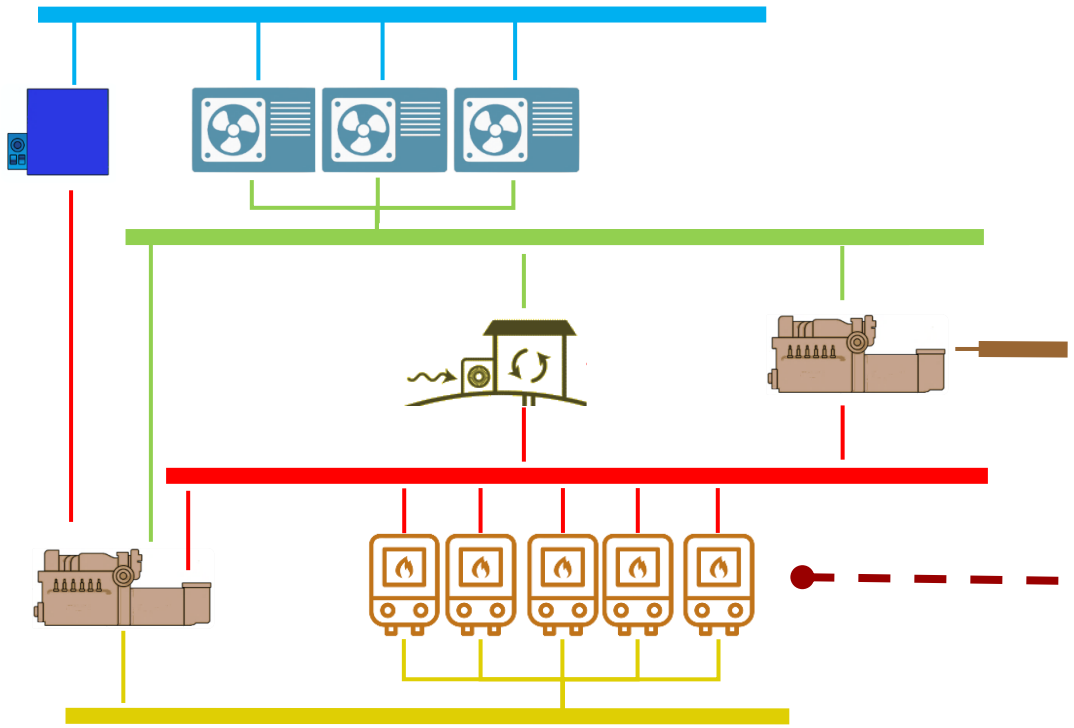

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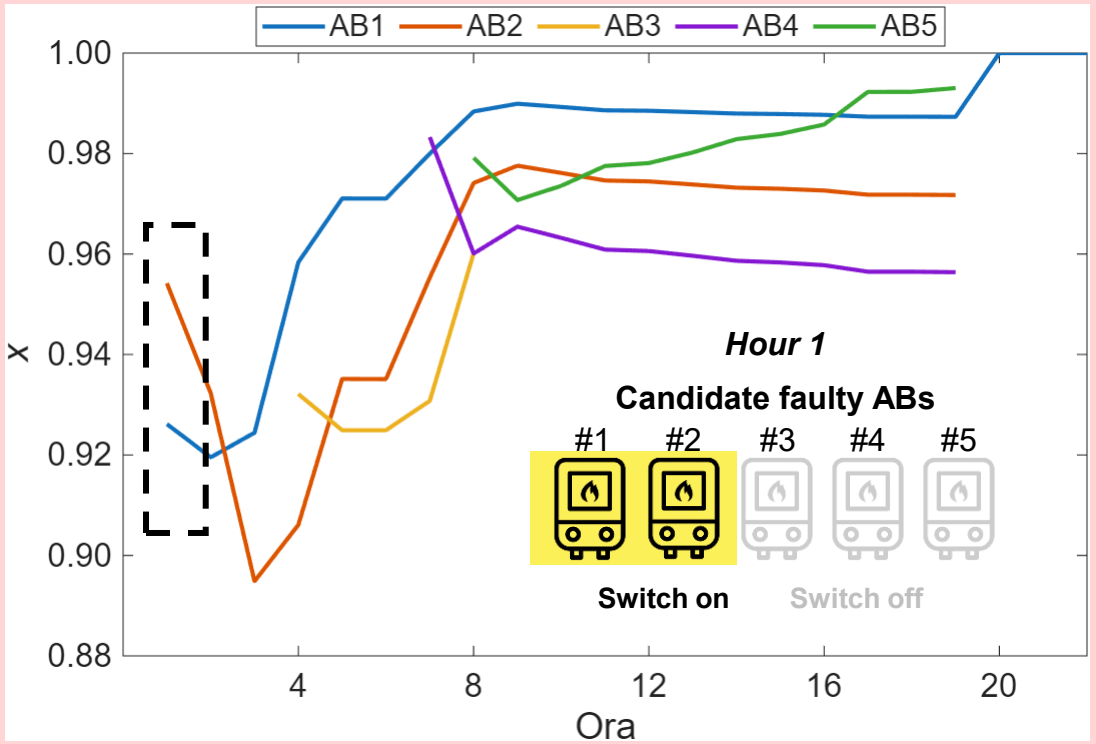
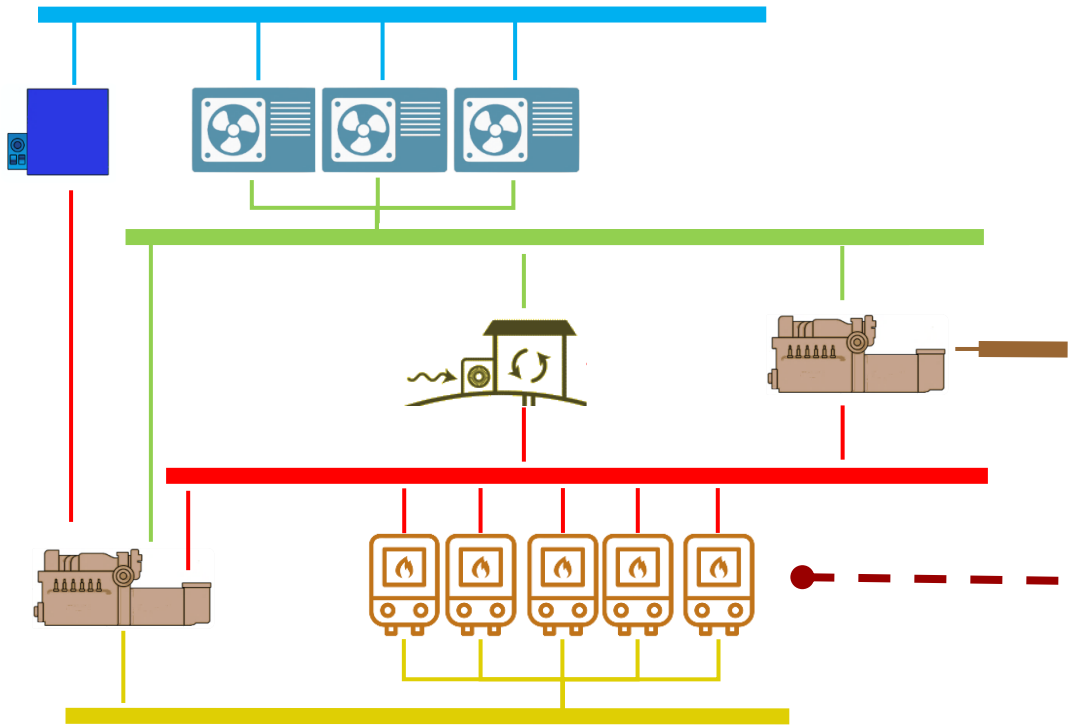
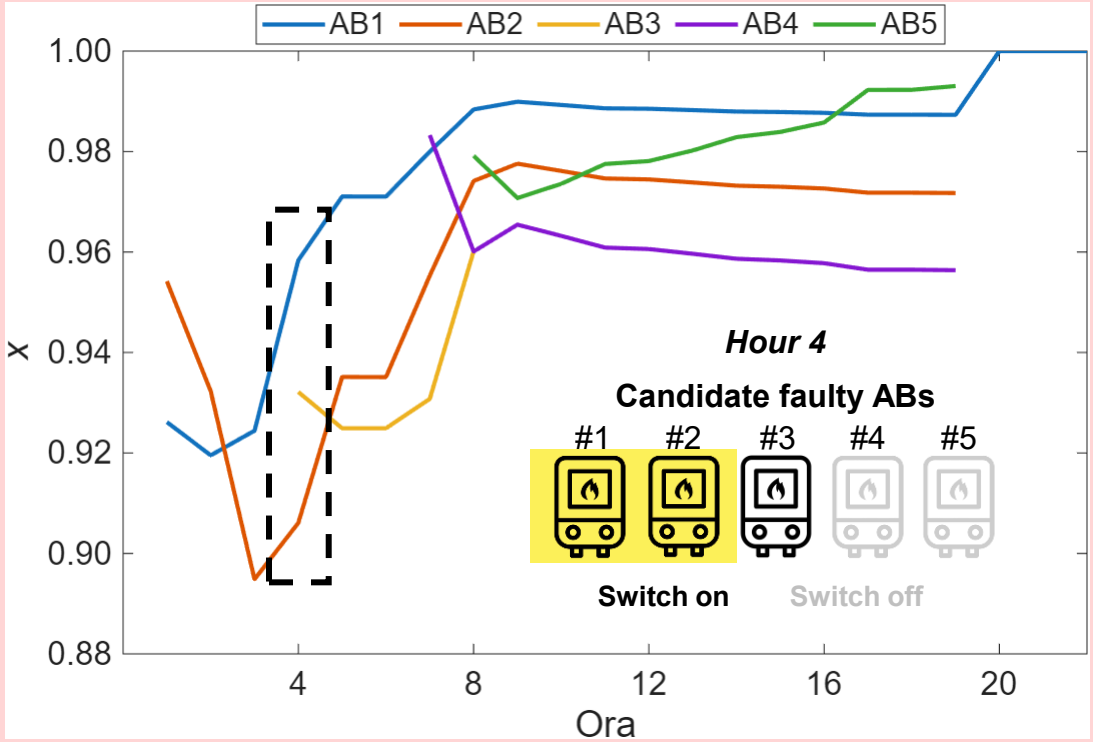


# Example of application



## AB health index



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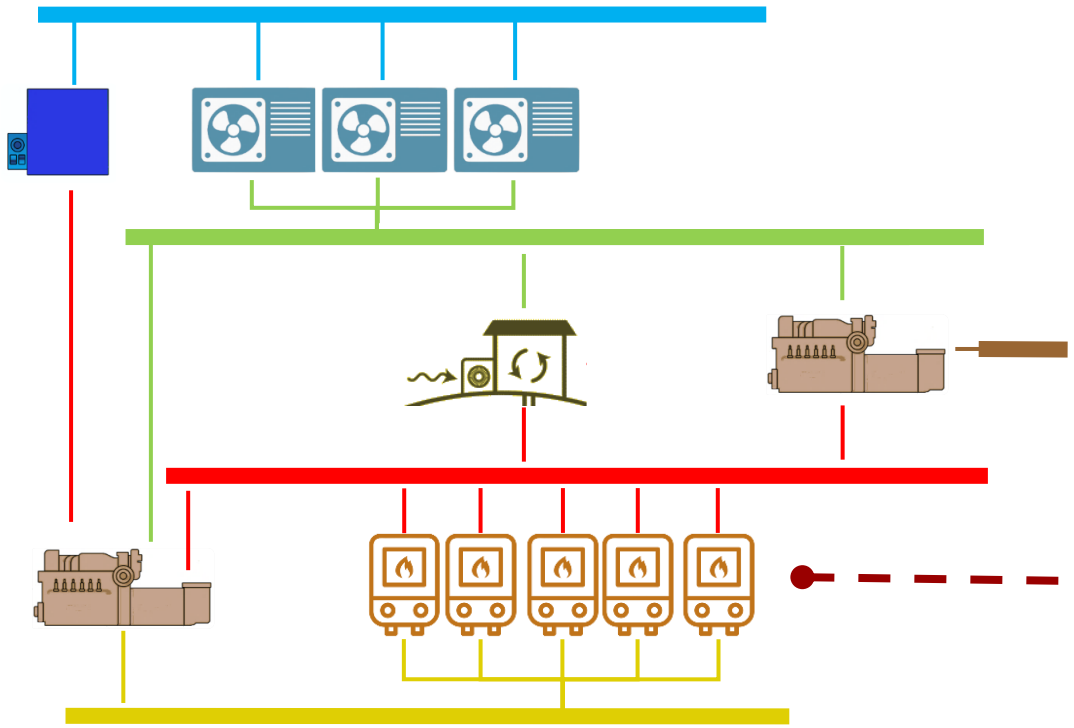

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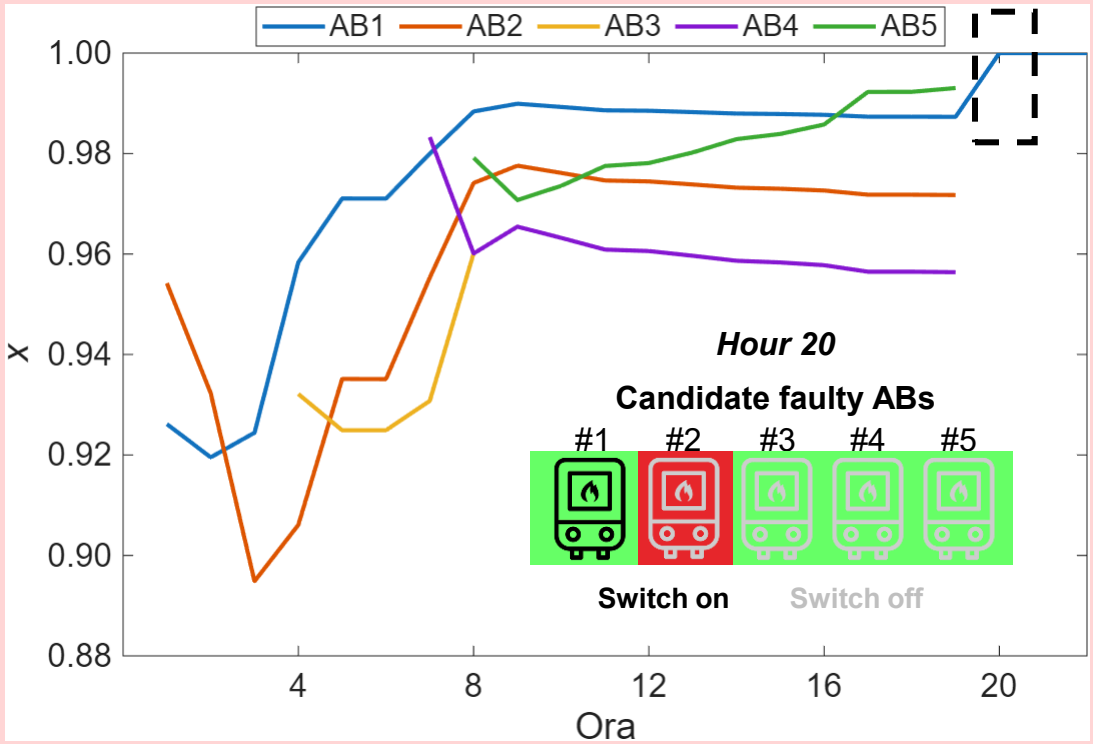
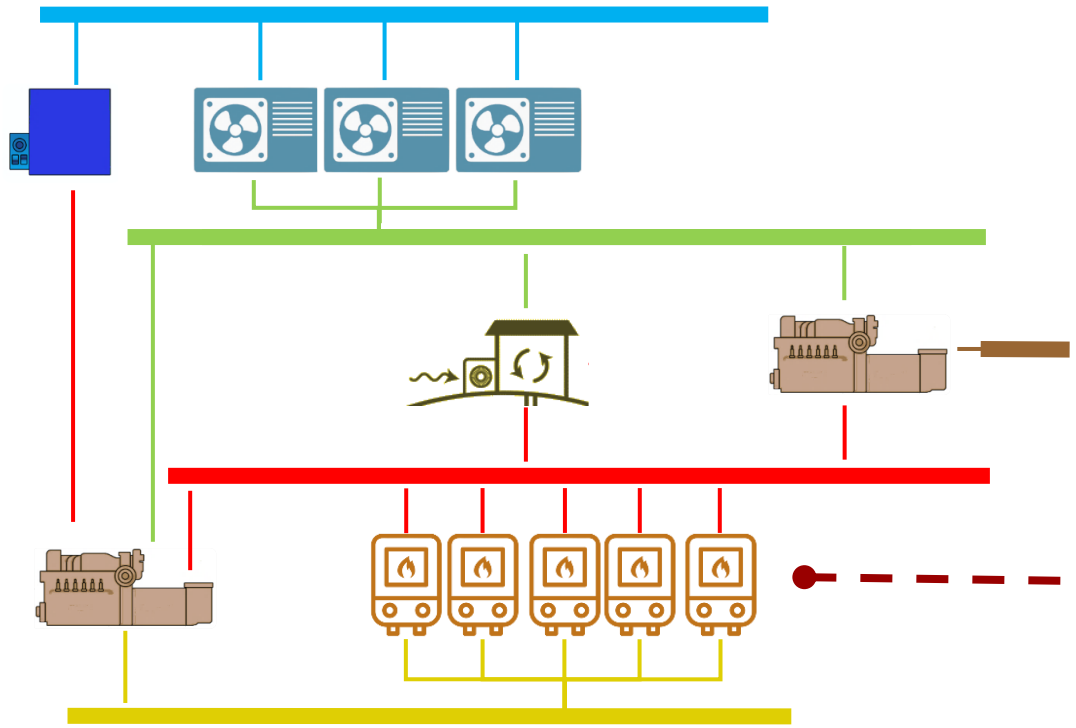


# Example of application

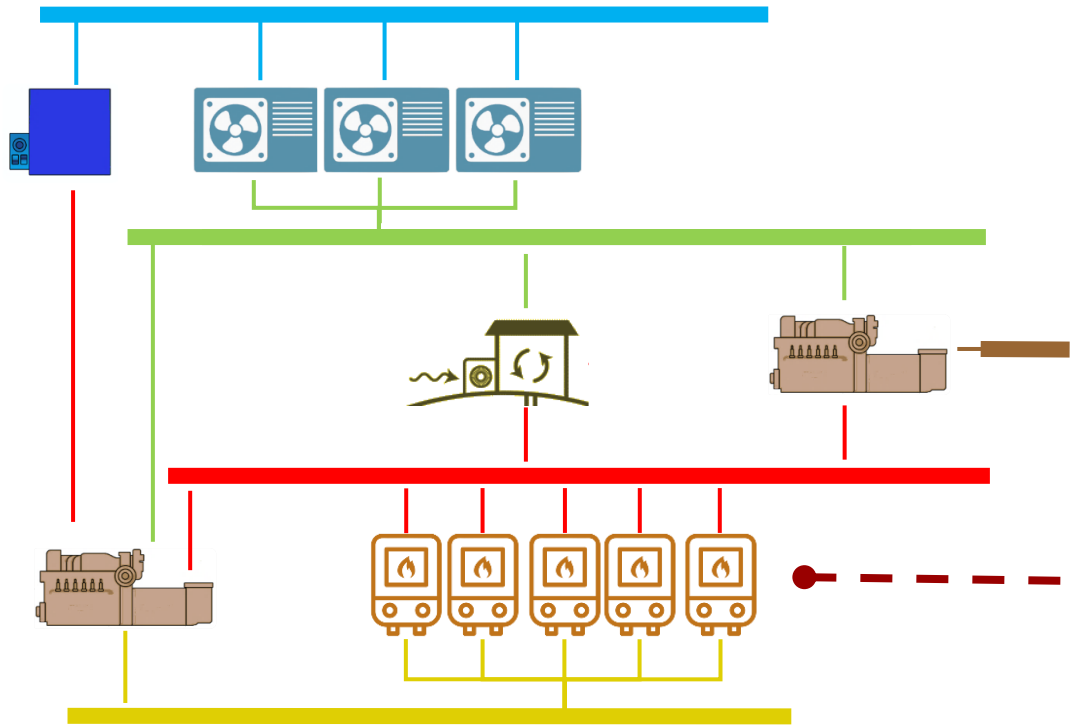


**AB health index**

***Identification of the fault magnitude***



# Example of application



## AB health index

***Identification of the fault magnitude***

#2

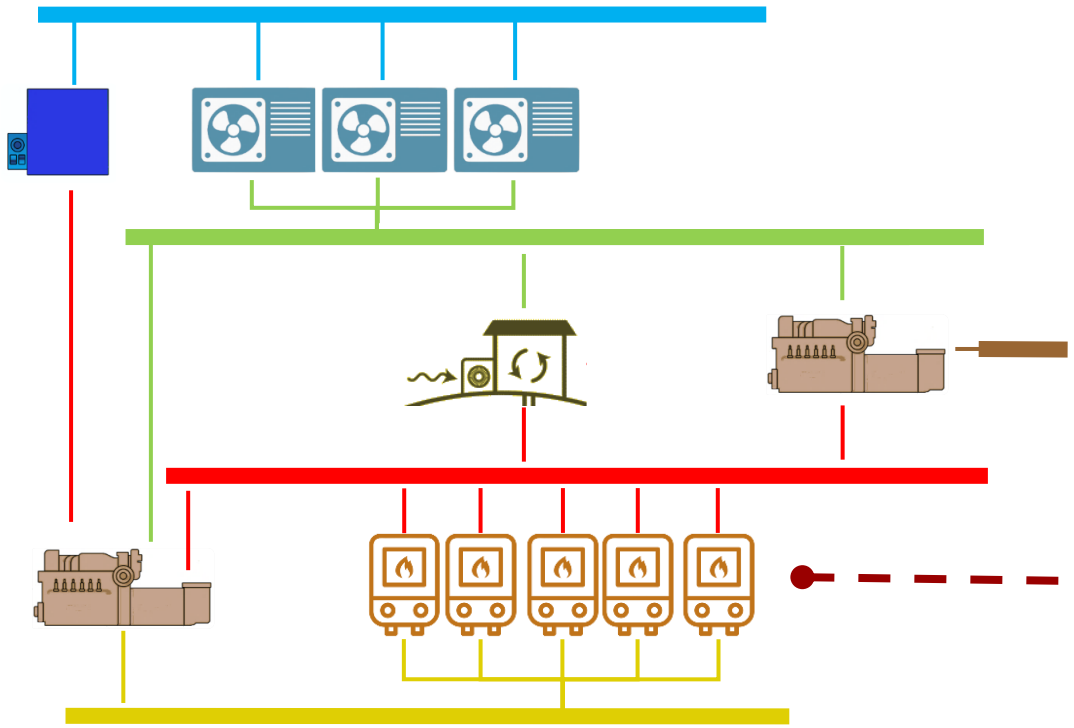


$x_{calc} = 0.85$

$x_{actual} = 0.85$



# Example of application



**AB health index**

***Identification of the fault magnitude***

#2



$x_{calc} = 0.85$

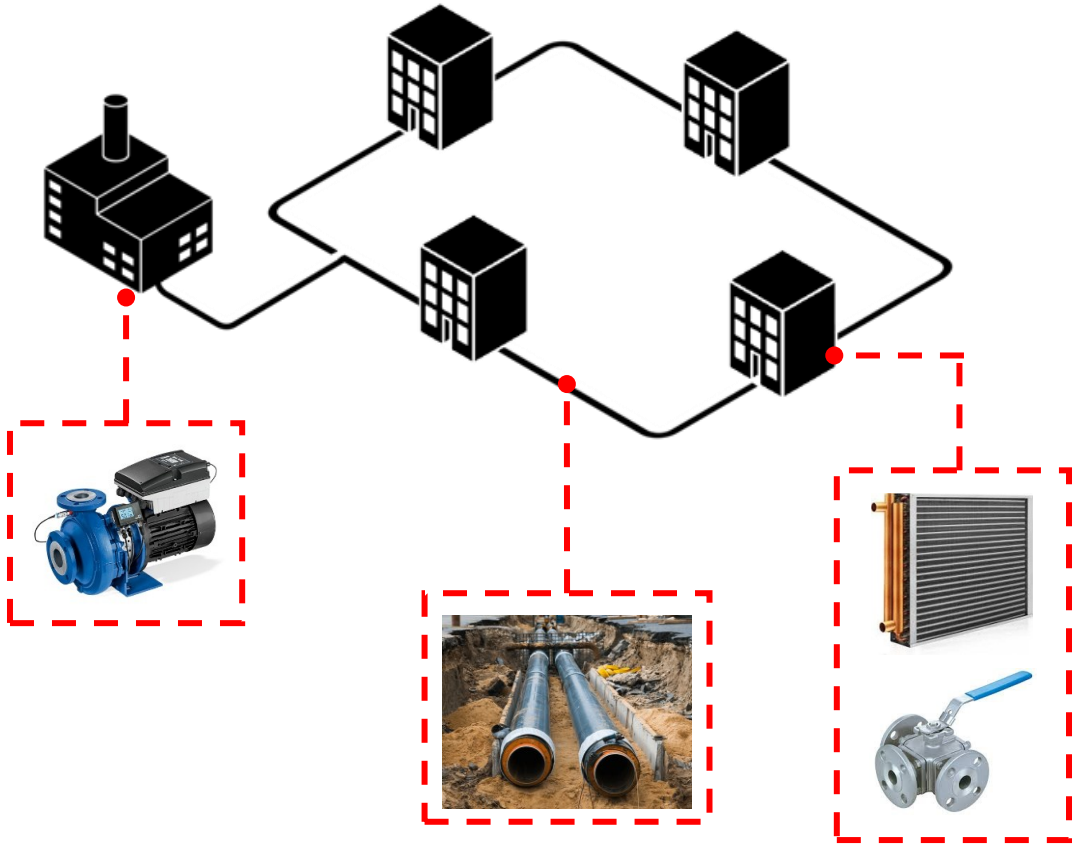
$x_{actual} = 0.85$

**FAULT DETECTED & IDENTIFIED**

# TOOL PER LA DIAGNOSI DI RETI DI TELERISCALDAMENTO

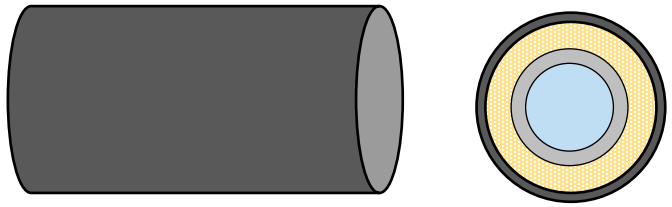
# Detectable faults

| Faulty component | Fault signature |
|---|---|
| Pump | ▪ Head reduction |
| Pipe | ▪ Leakages<br>▪ Anomalous heat losses<br>▪ Anomalous pressure losses |
| Valve | ▪ Incorrect opening<br>▪ Leakages |
| Heat exchanger | ▪ Leakages<br>▪ Anomalous heat losses<br>▪ Anomalous pressure losses |



# Physics-based approach

## *Distribution network model*



- Mass conservation equation
- Energy conservation equation
- Momentum conservation equation

## Health indices

$$\sum x_{\mathbf{leak}} \dot{m}_{\text{in}} - \sum \dot{m}_{\text{out}} - \dot{m}_{\text{in,sub}} = 0$$



$$R_{\text{th}} = x_{\mathbf{th,loss}} \left( \frac{1}{\pi L D_{\text{int}} k} + \sum \frac{1}{2\pi L \lambda} \ln \frac{D_{\text{ext}}}{D_{\text{int}}} \right)$$

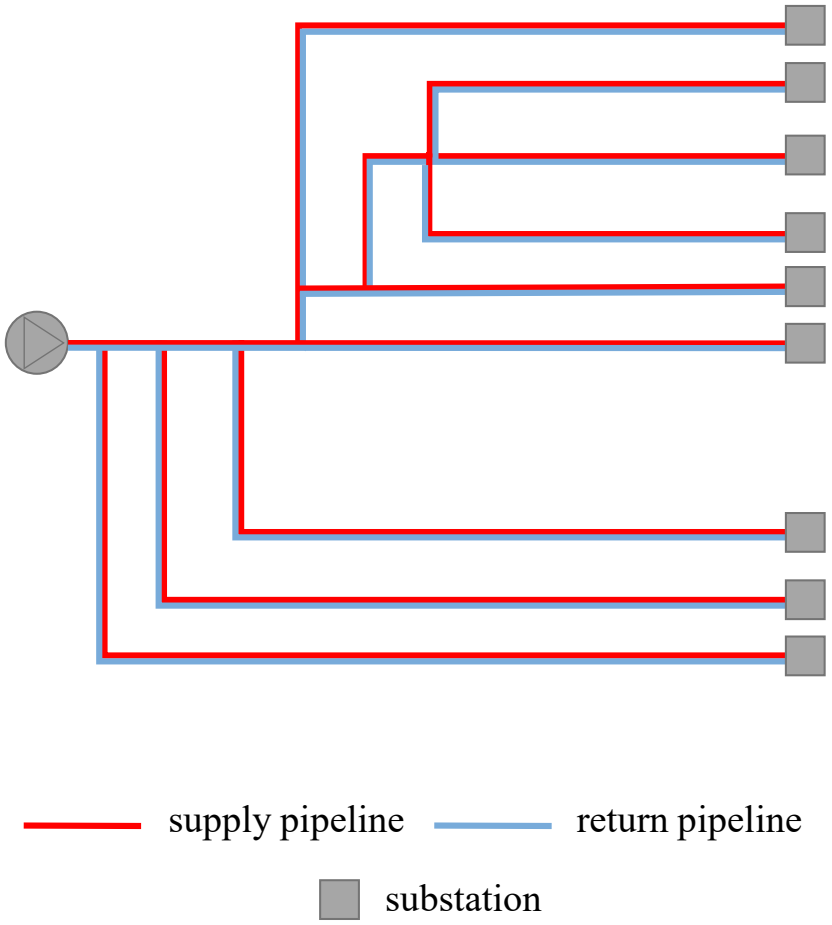


$$\Delta p = x_{\mathbf{p,loss}} R_{\text{p}} \dot{m}^2$$



# Case study

## District heating network of the Campus of University of Parma




*Data provider*

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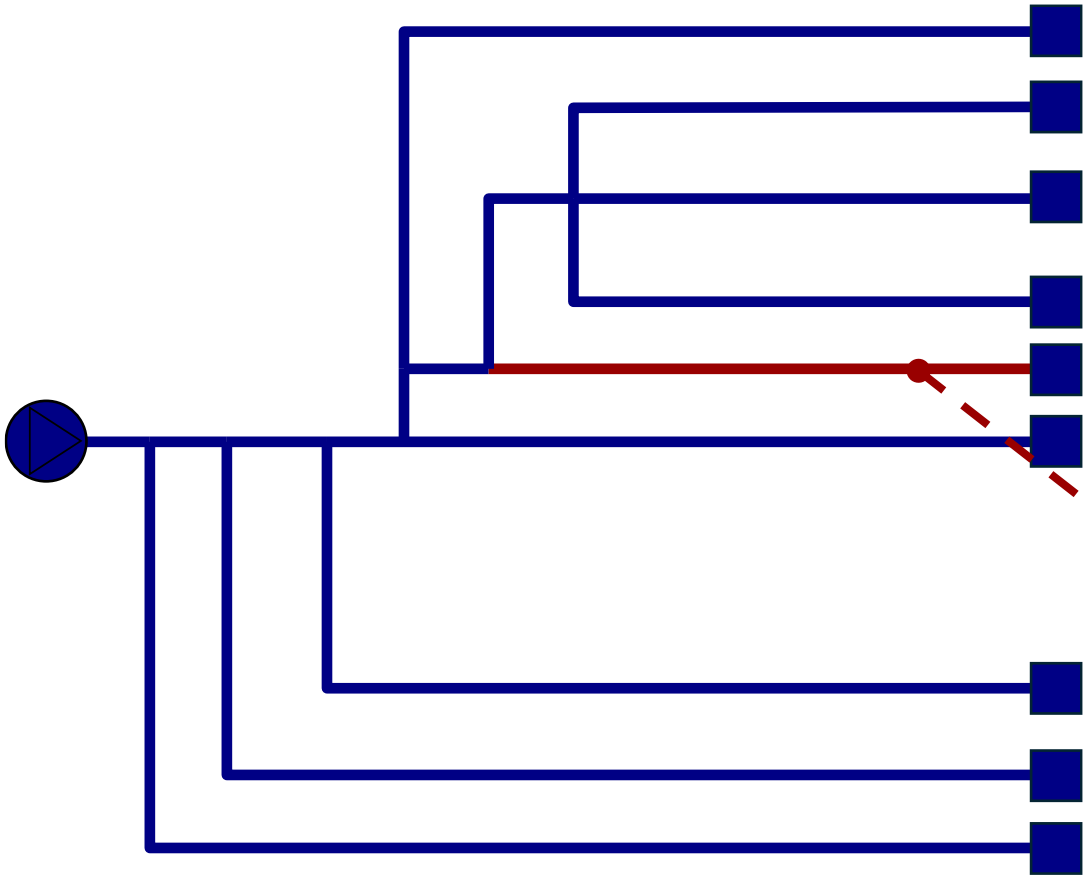
# Example of application

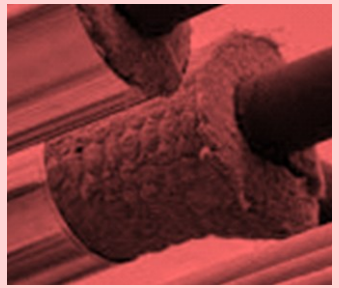


**FAULT ALERT**

## PIPE #11 (substation 5)



$x_{leak}$ = 1.00

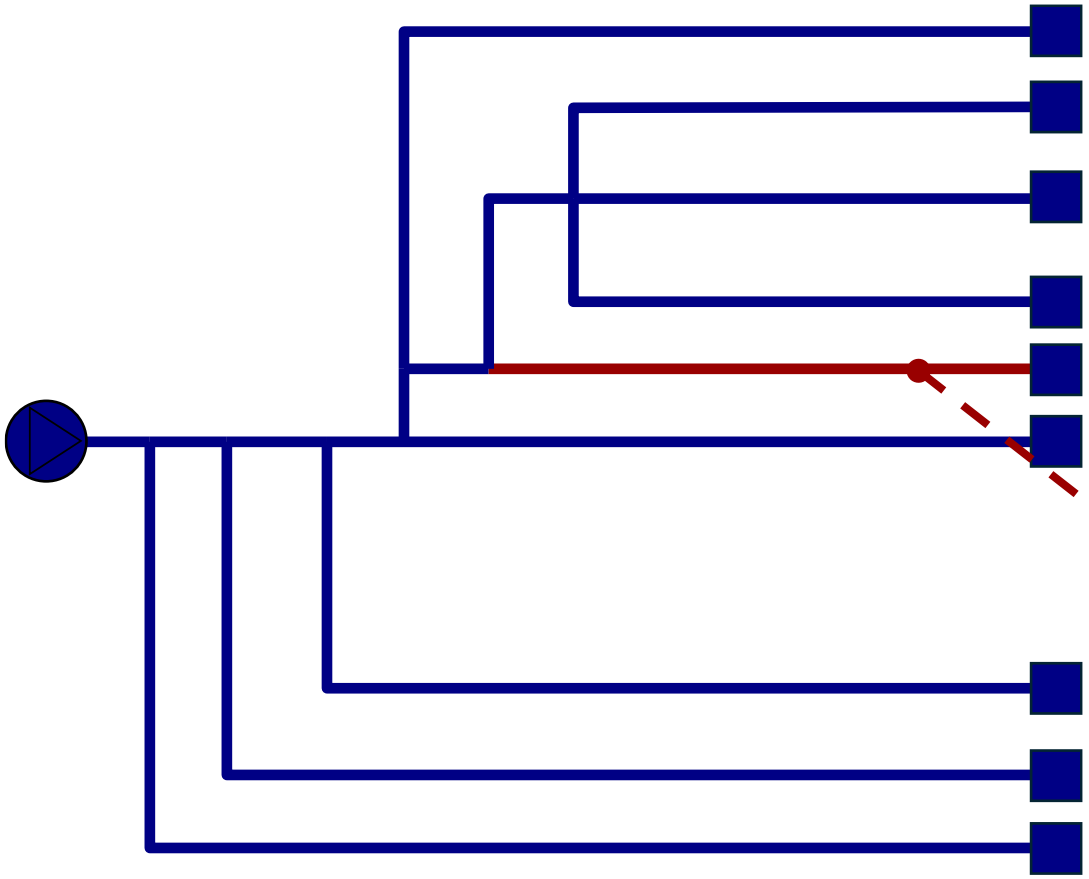


$x_{th.loss}$ = 0.02



$x_{p.loss}$ = 1.00

# Example of application

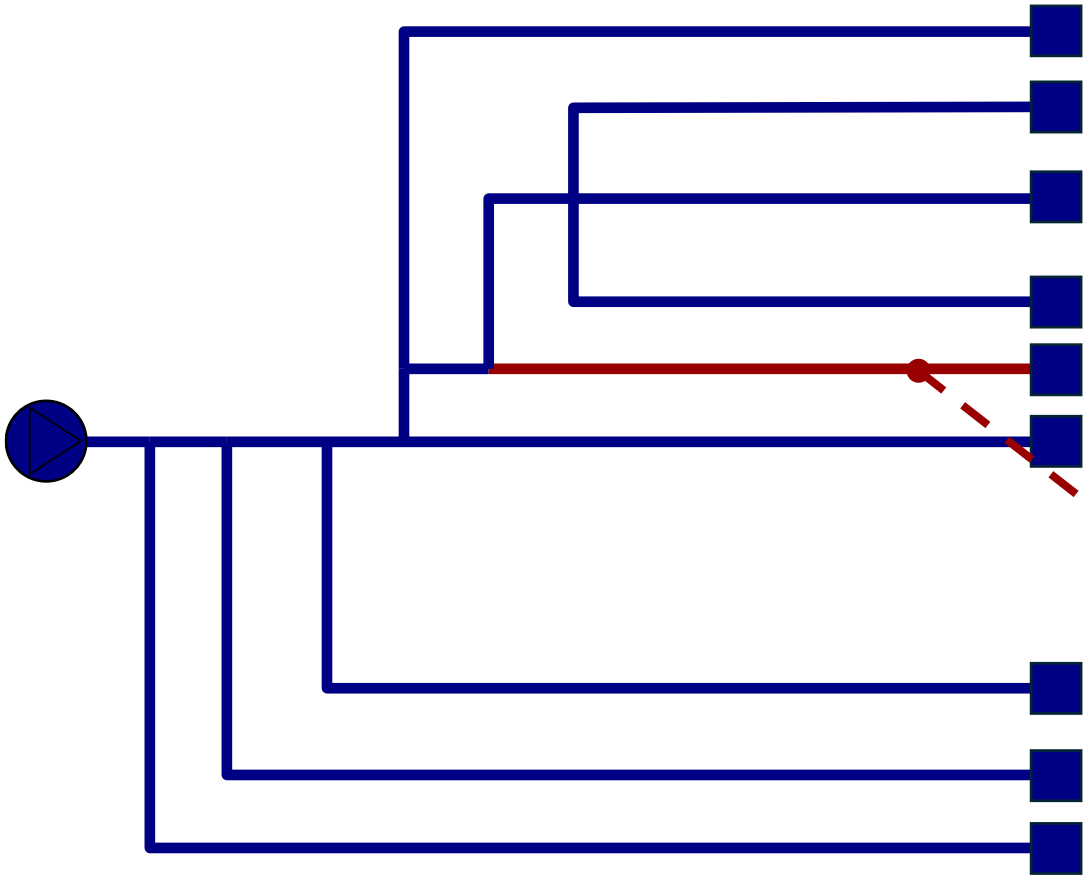




$x_{th.loss} = 0.02$

| $\lambda_{ins}$ [W·m$^{-1}$·K$^{-1}$] | |
|---|---|
| Calculated | 1.9 |

# Example of application

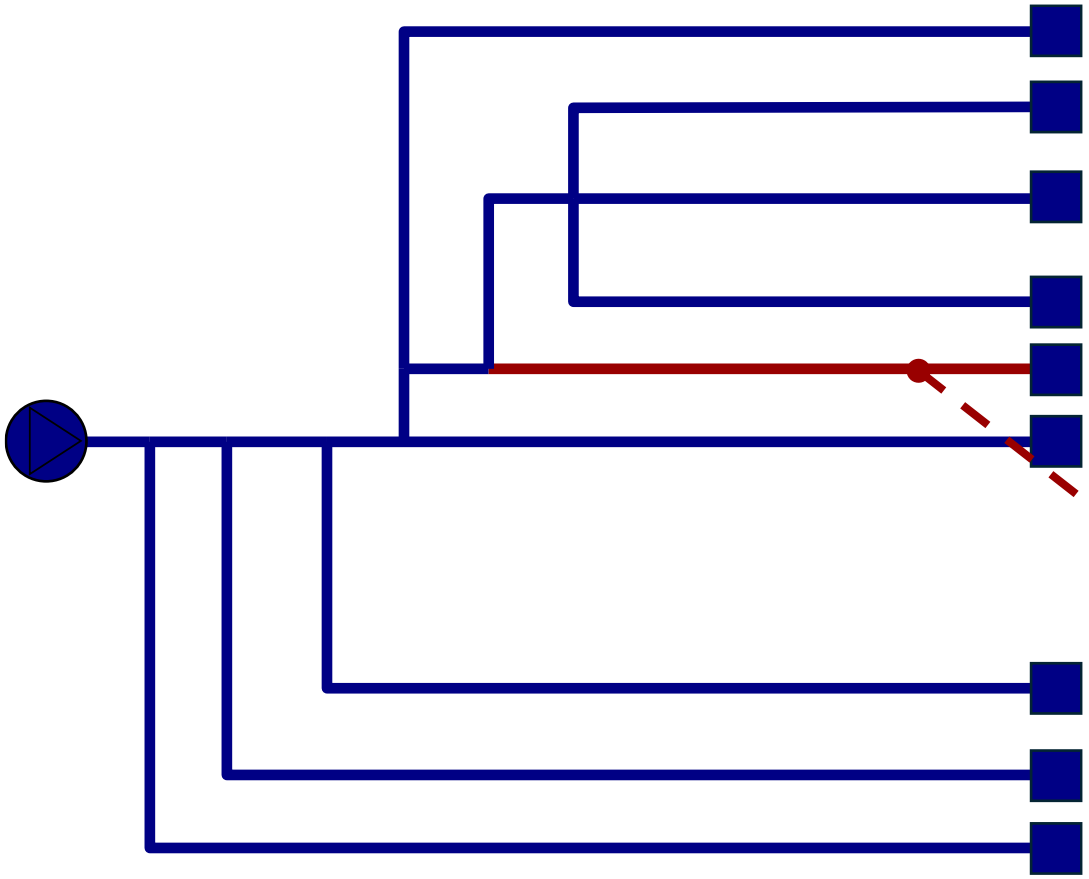




$x_{th.loss} = 0.02$

| $\lambda_{ins}$ [W·m$^{-1}$·K$^{-1}$] | |
|---|---|
| Calculated | 1.9 |
| Healthy | 0.04 |

# Example of application

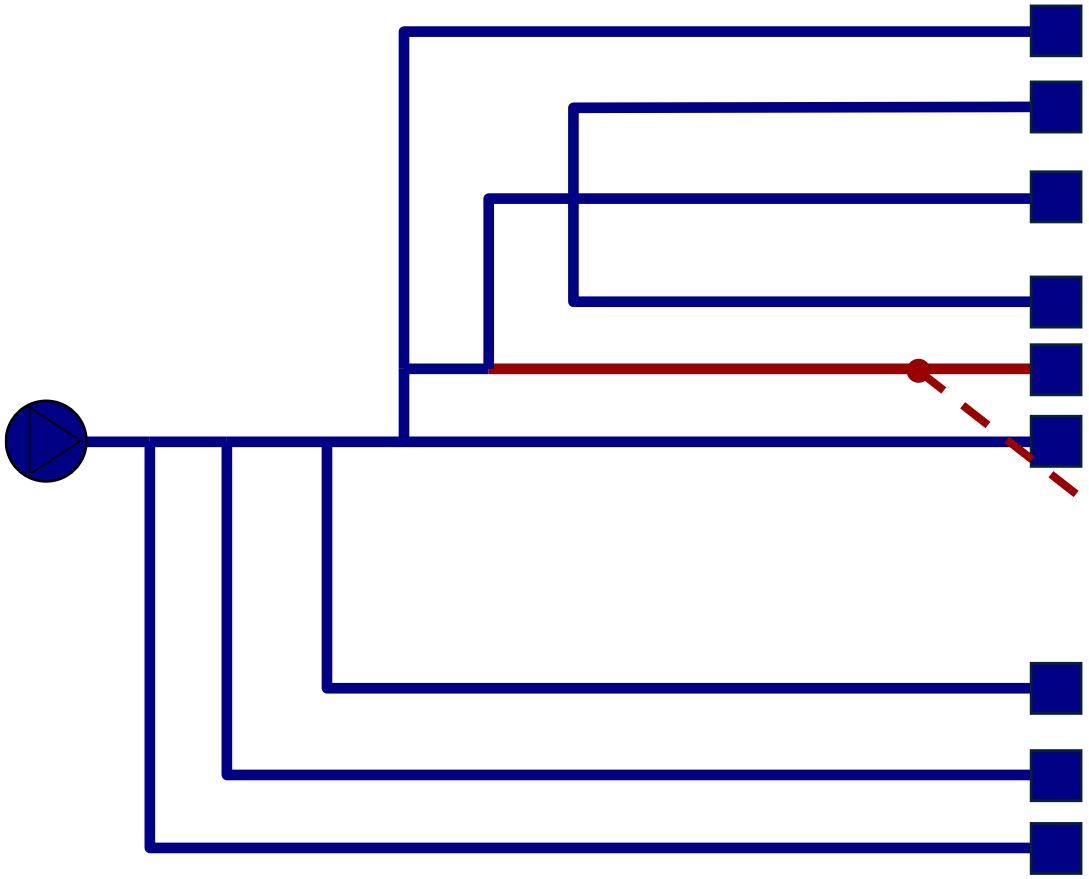




$x_{th.loss} = 0.02$

| $\lambda_{ins}$ [W·m$^{-1}$·K$^{-1}$] | |
|---|---|
| Calculated | 1.9 |
| Healthy | 0.04 |
| Actual | 2.0 |

# Example of application



**FAULT DETECTED & IDENTIFIED**



$x_{th.loss}$ = 0.02

| $\lambda_{ins}$ [W·m$^{-1}$·K$^{-1}$] | |
|---|---|
| Calculated | 1.9 |
| Healthy | 0.04 |
| Actual | 2.0 |

# Conclusions

## PROS

- Diagnostic tool for the diagnosis of RECs
- Diagnostic tools fully validated
- Suitable for real-word applications
- Low computational time
- Robust against measurement noise

## CONS

- In-depth knowledge of REC configuration



*Reduction in energy and economic costs associated with faults*



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# Thank you!

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