Validation of fault detection methods for district heating customer installations

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Why fault detection of DH installations?

- Two common reasons to increased DH return temperatures:
  - Faults in the customers' internal heating systems
  - Faults in the district heating customer substations
- Many customer installations are poorly performing in some way
  → decreased energy efficiency for the entire DH system
- Customer installations must be well performing in 4GDH systems
- Many DH utilities have no systematic way of finding poorly performing installations
- Important to develop automatic fault detection tools
  - Make use of customer data!

Purpose of the study

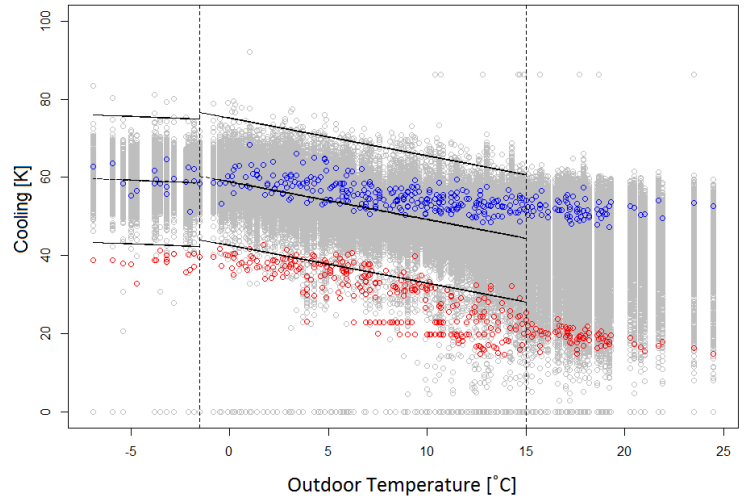
Overall objective:

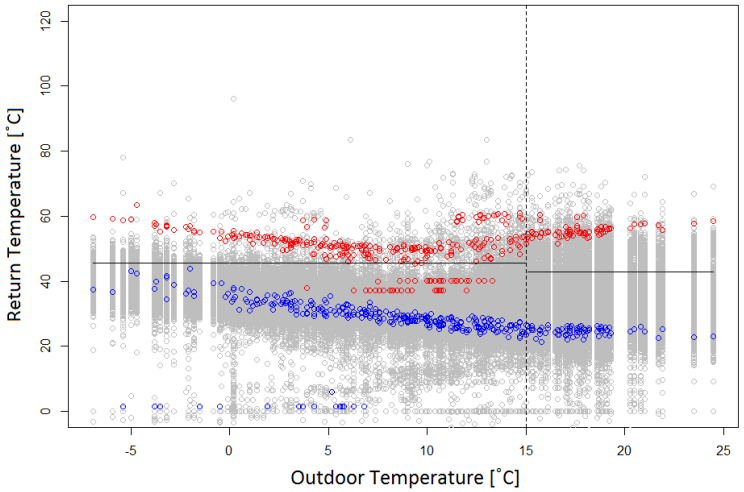
- Evaluate the performance of two previously developed fault detection methods that utilize customer data:
  - Heat load
  - Mass flow
  - Supply and return temperature
  - Outdoor temperature

Objectives:

- Create a fault “key” – data known to contain specific faults
- Investigate what installations are identified by fault detection methods
- Investigate what faults are identified by fault detection methods

Previous studies:
Fault detection method 1 using customer data





- Can we detect faults using customer data?
- Reference case of well performing installations
- Model the average behavior of reference case and create thresholds
- Compare performance to reference case thresholds – **limit checking**

Previous studies:
Fault detection method 2 using customer data

Model behaviour of installation

- Customer data from well performing installations
- Output: mass flow per hour
- Evaluate model performance

Investigate model performance for faulty data

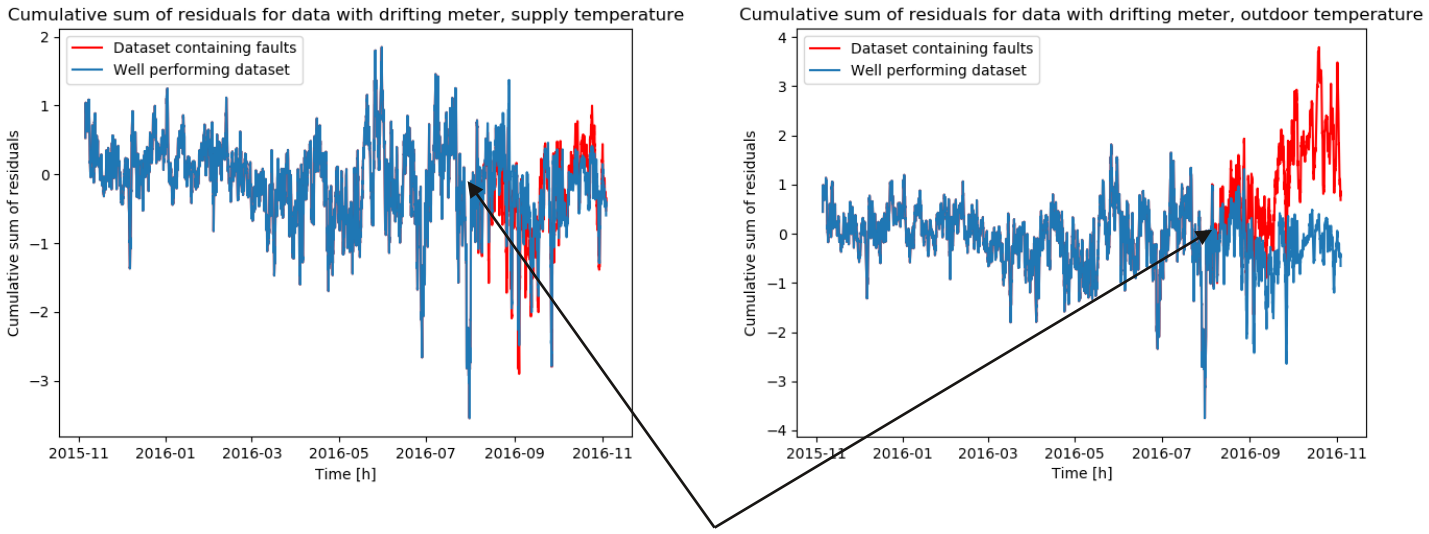
- Introduce model to data known to contain faults
- Drifting temperature sensors and faulty temperature sensors
- Evaluate model performance

Compare model predictions to real data

- Investigate residuals between real data and predicted data
- Does the model behave differently for faulty data?
- Does the model behave differently for all faults?

Previous studies:
Fault detection method 2 using customer data

- Model performance changed for faulty data
  - But not significantly for all faults!



Problem formulation

Overall objective: Evaluate the performance of the two previously developed fault detection methods that utilize customer data

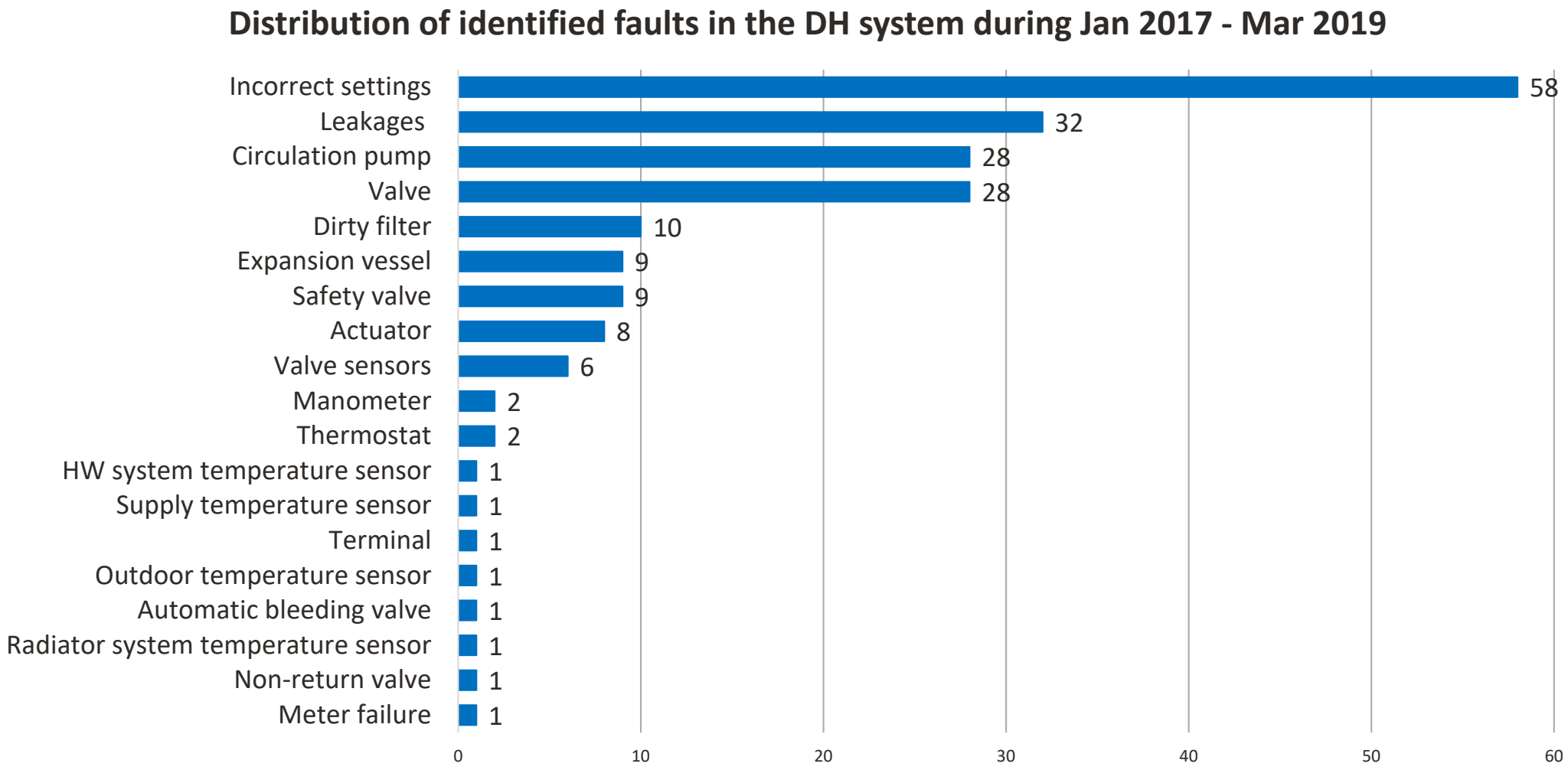
1. Investigate what faults are represented in data set
   - What faults are *possible* to identify in customer data?
2. What installations are identified using the fault detection methods?
3. What faults are identified using the fault detection methods?

Method:
Data and known faults

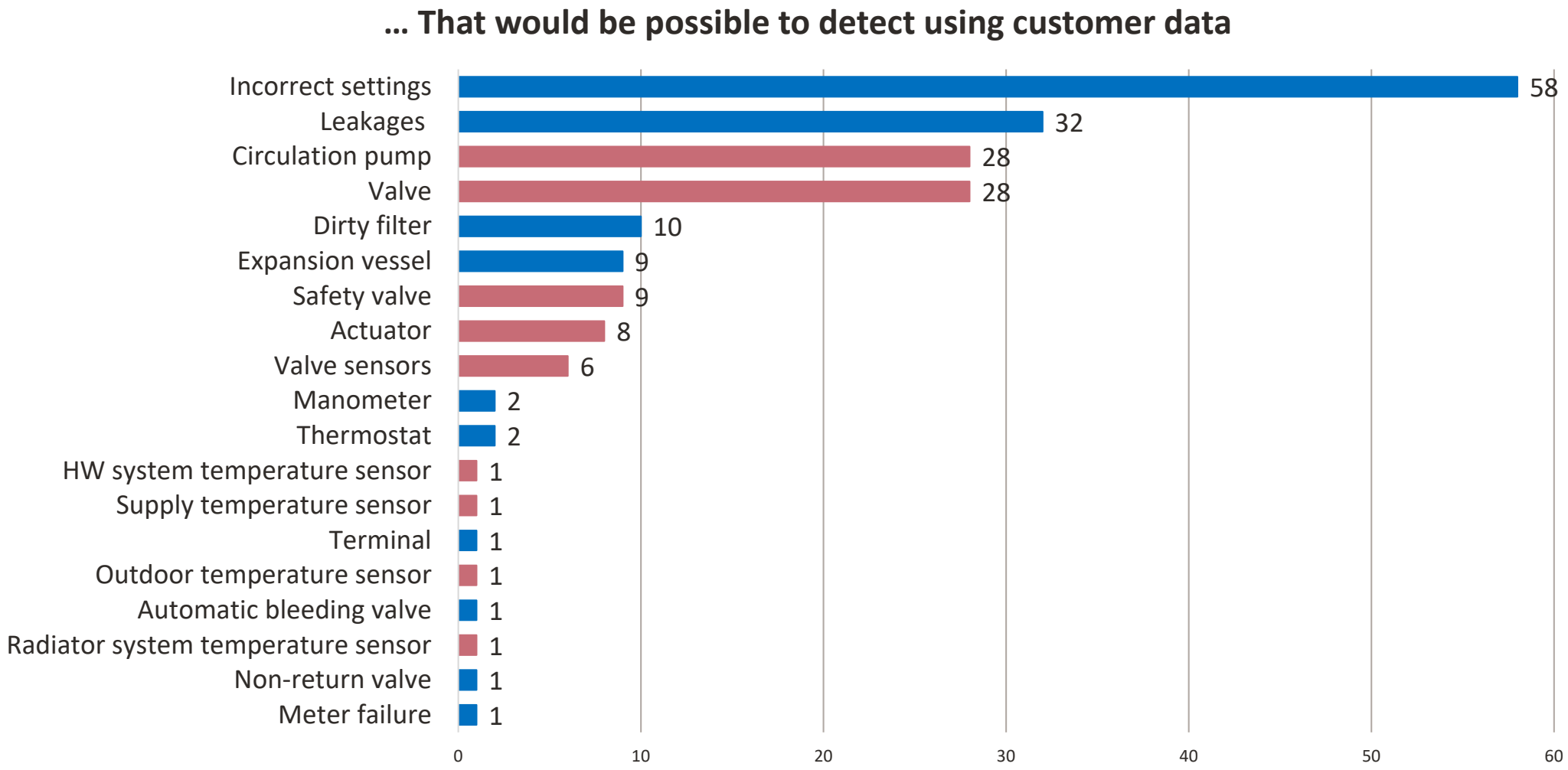
Objective: Create a fault “key”

- Data set: 2 048 unique installation IDs
  - Data from Jan 2017 – Mar 2019, hourly data
  - Heat load, mass flow, return and supply temperature, outdoor temperature
- Identified faults known to occur in data set: 200 installation IDs
  - Investigated service records, customer data bases, etc.
  - May be that the data contained more unknown faults

Results:
Known faults in the DH system



Results:
Known faults in the DH system



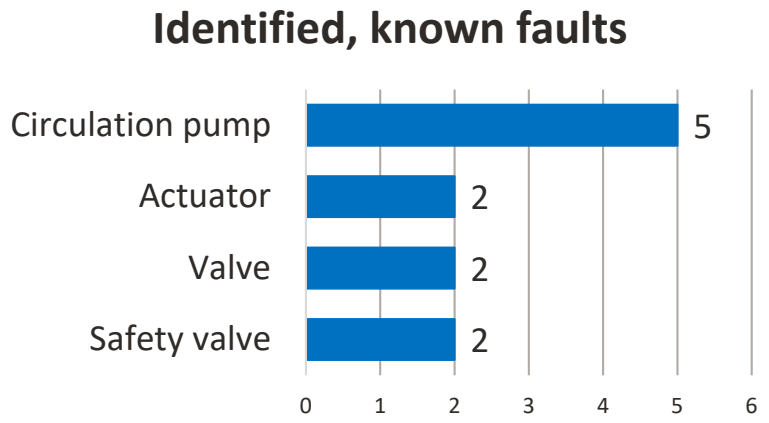
Method:
Evaluation of fault detection methods

Objective: Investigate detected installations and faults

- Reference case data: January 2017- March 2019
- One year of data was analyzed using a sliding window
- Result were collected and compared
  - Identified installation *known* to have contained faults during the period
  - Investigated the installations *not known* to have contained faults
    - Further investigation of service records, customer data bases, etc.

Results:
Evaluation of fault detection methods

- 135 installations were identified in the analysis
- 11 of the installations *known* to contain faults were identified
- 124 installations *not known* to contain faults:
  - Heat exchanger
  - Low delta T
  - Missing values



Conclusions and future work

- Fault detection methods capable of detecting poorly performing installations
- Not all faulty installations were detected – methods need further evaluation

- Further analysis:
  - Shorter analysis period
    - Identify *when* a fault has appeared/has been corrected
- Investigate more installations
  - Discussions with service technicians
  - Visits to customer installations to evaluate performance

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