ADVANCED DATA ANALYTICS FOR FAULT DETECTION AND OPTIMIZED OPERATION IN DISTRICT ENERGY CONCEPTS

On the use of semantics, machine learning and optimization

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Current situation
Transformation of energy supply systems for districts

- Raising complexity of energy supply infrastructures
- Limited manpower for the operation phase of buildings and districts
- Need for new concepts for energy optimized districts enabling:
  - the integration of a high amount of local renewable energy
  - interactions between people, buildings and heating and power networks

We need digital methods to increase the degree of automation in the operational management of buildings
Digital methods for energy optimized buildings and districts

Enabling smartness
Digital methods for energy optimized buildings and districts

Enabling smartness
Semantic interoperability
Foundation to take benefit of data

- Data amount and availability in buildings are steadily increasing
- Ideally, this data should be structured on the basis of standardized data models:
  - to interoperate heterogeneous applications
  - to process data automatically
- In reality:
  - It often looks like that:
Semantic interoperability
Solution pathways

- Unified semantics as base to cope with existing systems and to automate analysis
- Enable the usage of BIM and Ontologies

- Labeling of systems
  1. Building
  2. Zone
  3. System
  4. Subsystem_1
  5. Subsystem_2
  6. Medium
  7. Position
  8. Kind
  9. Datapoint

Available data points:
- BUI_WERK_WTH__OA__MEA_T
- BUI_WERK_WC.H__HW_SUP.SEC_MEA_T
- BUI_WERK_WC.H__HW_RET.SEC_MEA_T
- BUI_WERK_WC.H.NO PU__HW_SUP.SEC_SIG_CTRLSIG
Semantic interoperability

Solution pathways

- Automated identification of sensor types through meta data inference

VL-Temperatur HK-Z1

Combined Machine learning architecture
Semantic interoperability
Solution pathways

- Semantics as base for automatization
  - Automatically trigger simple checking rules

\[
T_{\text{SUP,PuON}} = T_{\text{SUP}} (P_{\text{SIG}} > 0)
\]

\[
T_{\text{SUP,PuOFF}} = T_{\text{SUP}} (P_{\text{SIG}} = 0)
\]

\[
\text{if } T_{\text{SUP,PuOFF}} > T_{\text{SUP,PuON}}: \quad \text{fault} = \text{True}
\]

Available data points:

- BUI_WERK_WTH_ _ _ _OA_ _ _MEA_T
- BUI_WERK_WC.H_ _ _HW_SUP.SEC_MEA_T
- BUI_WERK_WC.H_ _ _HW_RET.SEC_MEA_T
- BUI_WERK_WC.H.NO_PU_ _ _HW_SUP.SEC_SIG_CTRLSIG
Digital methods for energy optimized buildings and districts

Enabling smartness
Fault Detection and Diagnostics

Principle

System information:
- System type
- Available sensors
- Control strategy
- ...

Information about errors, e.g.:
- Length / period
- Affected component
- Error type
- Impact
- Remedying
Fault Detection and Diagnostics
Methods

- Fault Detection & Diagnosis
  - Manual
    - Rule Based
      - Visual evaluation of measurement data
    - Monitoring of static or dynamic thresholds
  - Automated
    - Model Based
      - Measurement Data
        - Black-Box
      - Simulation Based
        - Grey-Box
        - White-Box
          - Artificial Neuronal Networks, Clustering, Decision Trees, Regression, Qualitative Models, Parameter Estimation, Bayesian Approach and Physical Models, ...

Optimization
Diagnostics
Semantics
Fault Detection and Diagnostics

Clustering

- Density-based clustering (DBSCAN)
- Training on error-free data -> data are assigned to clusters
- Outliers correspond to incorrect data
Fault Detection and Diagnostics

Qualitative models

- Approximate description of system behavior
- Use of qualitative values e.g. "a lot" or "little"
- The qualitative behavior of the process is represented by a quantized system
Fault Detection and Diagnostics

Qualitative models

Example: fault detection in supply temperature of thermal activated slabs
Fault Detection and Diagnostics
Method combination and feedback system

- Use of two complementary methods (e.g. clustering and decision trees)
- Continuous user feedback is used to adapt the methods

Fault Detection and Diagnostics

Method combination and feedback system

- Benefits:
  - Initially only error-free training data necessary
  - Expert knowledge can be integrated
  - Error detection improves during use
  - Required feedback decreases

Fault Detection and Diagnostics

Example Rathaus im Stühlinger - Freiburg

Very precise detection of increased supply air temperatures in an AHU by learning from user feedback.
Digital methods for energy optimized buildings and districts

Enabling smartness
Optimization

Complex energy supply system - overview

- CHP
- HT
- MT
- LT
- Boiler (2)
- Heat pump (3)
- Absorber (2)
- Ice storage
- Cold storage

HT demand
MT demand
LT demand
Cooling demand
Optimization

Complex energy supply system - optimization tasks

1) Optimize heat generators

2) Optimize heat sources
Optimization

Complex energy supply system - methods

- System modelling and calibration
- Use of weather and occupancy forecast models
- Objective function definition: minimize costs, emissions while ensuring thermal comfort
- Optimization method selection: iterative, heuristic
- Communication/Integration with Building Management Systems
Digital methods for energy optimized buildings and districts

Conclusion and outlook

- Digital methods are key enabler for energy and cost efficiency in complex district and building energy systems
- Unified data models and semantics are essential to inter-operate complex systems
- Analytics methods and connectivity technologies are mature for implementation and test in field
- New business and incentives models need to be developed to enable scalable solutions with high replication potential
Vielen Dank für Ihre Aufmerksamkeit!

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