Project: Digital twins for large-scale heat pump and refrigeration systems

EUDP
The Energy Technology Development and Demonstration Programme

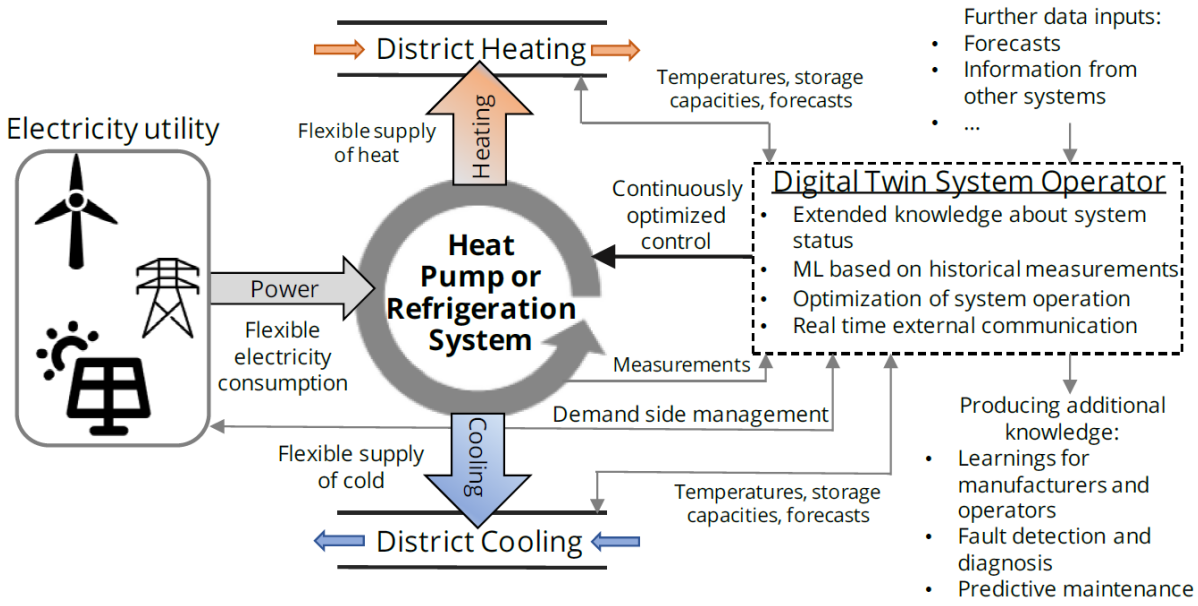

Figure 1: Diagram of the digital twin system operator.

Summary of IoT case

Digital twins can be described as adaptable models that are able to adjust their structure based on measured data from the system they represent. This project aims to reduce the effort to develop digital twins for large-scale heat pump and refrigeration systems. The target groups are supermarket refrigeration systems as well as heat pumps for district heating systems.

The digital twins developed in the project are expected to have a modular and reusable structure. This will be used to provide services such as advanced system monitoring, operation optimization as well as fault detection and diagnosis. The data used to develop and implement the adaptable models may be retrieved from wired sensors as well as from IoT-based sensors.

Digital twins are conceived as a combination of two modelling frameworks, namely physics-based and data-driven models. The first type includes simulation models that incorporate mass and energy balances, and empirical correlations of heat transfer coefficients and pressure drops. On the other hand, data-driven models are comprised of statistical models and machine learning. Such models will be especially useful to describe performance degradation of components, predict system performance and optimize set points as well as operation schedules.

Two large-scale heat pump systems are applied as case studies to develop and test the digital twins. These systems have rated heating capacities of approximately 4 MW and 1 MW and are used for supply of district heating. One system use seawater as heat source and ammonia and water as working fluids in separate cycles. These cycles include reciprocating and turbo compressors, respectively. The second case study is an ammonia system with reciprocating compressors that uses industrial excess heat as heat source.

Measured data from the case study heat pumps is retrieved from data collection systems used for monitoring and control. Currently, the digital twins that are under development in this project use measured data from wired sensors only. However, it is expected that future

Figure 2 - Seawater and NH_3 heat pump system at Aarhus Ø (AVA) used for case study I.

applications of such models will also include data from wireless sensors based on IoT.

After the project is finalized, it is expected that the frameworks developed during the project will be applied in multiple heat pump and refrigeration systems. It is estimated that the digital twins will be implemented as a software that use measurements from existing monitoring and control systems, e.g. SCADA systems.

Learnings and results

- Dynamic simulation models of the case study heat pump systems were developed, which are expected to provide an accurate description of their performance.
- Predictive maintenance and operation optimization are estimated to be potential outcomes from the implementation of the digital twins developed in the project. This can be used as a basis for creating digital twin-based services. As an example of this, a framework for performing continuously set-point optimization has been developed for case study I.
- Advanced fault detection and diagnosis services provided by digital twins will be included in a framework to assess the potential of heat pumps for flexible operation.
- It is projected that the effort to develop new digital twins for large-scale heat pump and refrigeration systems will be reduced as a result of this project.

FACTS ABOUT THE IOT CASE

IoT category: Optimize heat pump operation, predictive maintenance, and performance monitoring

Goal: Reducing the effort for creating digital twins in order to improve services for large-scale heat pumps and refrigeration systems

Beneficiary: End-use and operator.

Analysis method Numerical simulations and data analysis.

Modelling requirements: Design system specifications and real-time measured data for the development and adjustment of dynamic simulation models (made in Dymola) and data-driven models.

Data required: Operational data from heat pumps, weather forecast and electricity prices

Data interface: No specific requirements yet.

Transmission protocol for data: No specific requirements yet.

Quality-of-Service: Real-time and hourly for online monitoring and control.

Technology Readiness Level: TRL 5.

Project participants: DTI, DTU, TLK-Thermo GmbH, AK Centralen, Superkøl, Danfoss, Affaldvarme Aarhus, TU Braunschweig

Time schedule: 2020-2024

Link to webpage: http://digitaltwins4hprs.dk/

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