Interim report – WP10

Smart Components

Reporting months: July 2018 – June 2019

Photo: By & Havn / Ole Malling

Jan Eric Thorsen/ Lars Sloth Larsen/Henrik Høj Madsen/Kevin Smith/Torben Ommen
Danfoss / DTU BYG /DTU MEK
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Work package aims and objectives

The work package demonstrates and analyses the technical and economic feasibilities of smart control of specific components and systems with main functions to provide heat and cooling services in buildings – including space heating, hot tap water heating and food cooling. The components and systems include:

1) WP10.1: Heat Booster Substation based on ultra-low temperature district heating (ULTDH), providing domestic hot water for multifamily or commercial buildings, including heat pump for providing domestic hot water and heating
   and:
   A Circulation Booster, boosting the DHW circulation water from 50°C to 55°C.

2) WP10.2 Remote controlled valves for regulation of a water based building space heating.

3) WP10.3 Utilisation of spare heat pump (compressor)capacity in supermarkets.

Overall progress of the work towards WP Objectives

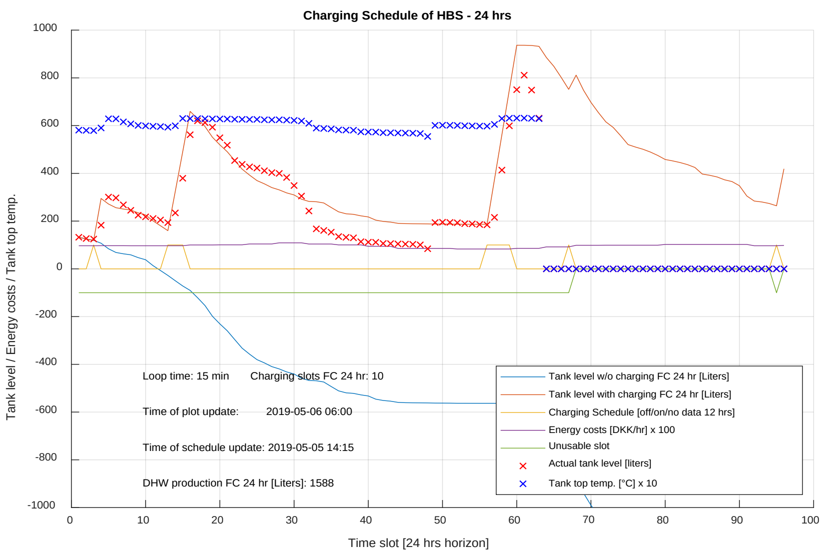
WP10.1:
The **Heat Booster Substation** (HBS) is installed in Aarhusgade 140 - Havnehuset, a multifamily building with 22 individual flats. The HBS was installed February 2018. The HBS is a district heating (DH) substation operating at an ultra-low temperature DH (ULTDH) supply temperature of 35-45°C. The concept includes a main electric heat pump, boosting the DH supply temperature to a level where domestic hot water (DHW) can be produced by means of an instantaneous heat exchanger. Besides this, the HBS maintains the DHW circulation temperature by means of a small heat pump. A DH storage tank is accumulating the energy, and this storage tank makes it possible to shift the charging time of the tank, independent on the DHW tapping occurrence. Hereby the service of load shift flexibility is provided in relation to electricity and DH.

Based on the experience made (12 months of operation), it can be concluded that the HBS unit is successfully installed, tested and operating. The DHW is produced at 55°C, DHW circulation is raised continuously from 50-55°C, with a DH supply temperature of 45°C and a DH return temperature of typically 30°C. The share of electric energy consumption for DHW and DHW circulation service is 14%, at the average produced DHW volume of 1.700 liters pr. day. Whereas the DH share is the remaining 86%. Due to the variation of DHW draw off pr. day over the year, the electric share varies e.g. from 12%, at a produced DHW volume of 2.500 liters pr. day, to 17% at a produced DHW volume of 1.000 liters pr. day. Note that electric share is based on DHW as well as DHW circulation production.

The daily average DHW load shift potential is 75 kWh/day for the 22-flat building, hereof electricity accounts for 7 kWh/day and thus DH accounts for the remaining 67 kWh/day. On a yearly basis it’s at least on the same level as the load shift potential for the heating system of the building. Regarding capacity flexibility, this is 3 kW electric and 30 kW DH realized for e.g. a period of 1 hr. and 10 min. before the morning DHW peak and before the evening DHW peak in average over the year.

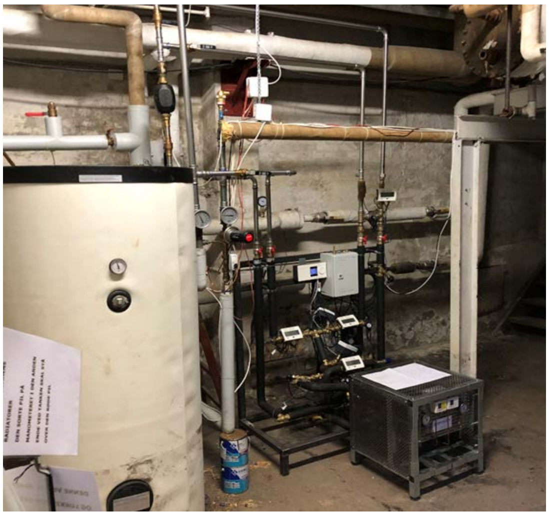
Regarding fuel shift flexibility, which is obtained by varying the evaporation temperature of the main heat pump, tested in the range corresponding to a DH return temperature from 20°C to 30°C, this result in 2 kWh pr. day, thus the electric consumption can vary from 6 to 8 kWh for an average day, with the corresponding DH variation from 66 to 68 kWh/day. The Fuel shift flexibility is regarded as minor.

A prognosis and economic based scheduling of the HBS charging is implemented, optimizing for lowest energy costs, latest possible charging and observing the constrains of min. and max. charging level of the tank.



A number of feasibility studies have been made for the HBS concept compared to the LTDH concept with different energy sources, showing that under the current tariffs system the concept is very limited economically feasible. For a new urban development area, like Nordhavns Levantkaj, the HBS concept could become relevant. This type of area could be designed for ULTDH, where the DH energy input should be the DH return water from the existing DH system. This temperature is typically in the range 35-45°C, and thus relevant for the HBS concept. Still adjustments to the current energy price structures will be needed. Also, where the source of energy for DH is at low temperature level, e.g. solar thermal, geothermal, industry surplus and data centres, the concept of HBS in combination with underfloor heating is relevant to consider. Further, the value of the load shift potential, temperature dependent DH energy prices both flow and return and the electric energy prices will determine if the HBS concept is feasible in each individual case.

The **Circulation Booster** (CB) was installed in Strandboulevarden 3 in December 2018, a multifamily building with 15 spacious apartments. The CB is boosting (heating) the DHW circulation water from 50°C to 55°C in two steps, by means of a direct heat exchange and a heat pump booster, using DH at normal temperatures (70 – 100°C) as the energy source.



Based on the experience made (6 months of operation), it can be concluded that the CB ihas been successfully installed, tested and operating. The DHW circulation is boosted continuously from 50-55°C, with a DH supply temperature in the range from 70-100°C. The share of electric energy consumption for the CB concept is 17% at a representative DH flow temperature of 80°C. The representative DH return temperature from the CB is 23°C. (This is a reduction of approx. 20°C compared to reference situation which was the challenge to be addressed). Within the range of DH flow temperatures 70 – 100°C, the electric share is in the range 20- 15% of the energy needed to boost the DHW circulation. The remaining energy source is DH, with a share of 80 – 85%.

Load shift is not possible for this concept, since the CB is running continuously, and energy storage devices are not obvious for this concept.

Fuel shift is possible, to a minor degree, realized by influencing the condenser outlet temperature, and thus influencing the balance of heat from the condenser and the direct heat exchange. No tests are so far made in this regard.

A number of economic scenarios have been made, focussing on different bonus structures related to reduced DH return temperature and electric energy costs. The current tariff structure does not give a feasible economic case for the CB concept. But considering a more progressive bonus scheme for providing a low DH return temperature, the market potential could be interesting in the segment of existing buildings and partly also new buildings with DHW circulation systems. This is also supported by having the simple retrofit demands in mind and driven by the argument that a low DH return temperature is the precondition for a low DH flow temperature, as specified by the 4th generation DH concept.

WP 10.2 (Smart Control of building heating service)

We did increase the number of connected flats up to 8. Due to private WI-FI setup the data logging is not stable, but still to be used for the purpose. The passed heating season did not provide measurements that could be used for analyzing the load shift. Therefore, the load shift part and the offering of a flexibility service to e.g. the DH utility has not been possible to obtain.

WP 10.3 Utilization of spare heat pump capacity

A system efficiency measurement algorithm (COP=coefficient of performance) has been finalized and is ready for integration in the product. However due to product reprioritization it is not expected to be released in a product before ultimo primo 2020. However, the algorithm can be executed offline on data collected from the Meny Supermarket and can hence be demonstrated and used as for analyzing and optimizing the system energy efficiency.
Further activities are ongoing together to develop control strategies for ensuring energy optimal cooling and heat production in the supermarket control system. These are still at an early stage and is not expected to be rolled out before 2020.

General evaluation of progress for WP10:

The progress for the 3 subtasks differs. Related to WP10.1 we are fulfilling the deliveries. For WP10.2 we are fulfilling to a certain degree, basically influenced by missing data evidence that we can realize load shift for the water-based heating system. For WP10.3 we are in the situation that the heat Recovery Unit is so far not in operation, thus we cannot fulfill the deliveries. WP10.3 has been delayed in several rounds firstly due to difficulties in finding an appropriate supermarket and secondly due to unexpected process time in getting approvals and agreement in place for installing, operating and delivering the heat recovery unit.

Status and activities in the WP tasks

WP10.1:
The basic objective of WP10.1 is fulfilled, anyhow since there are remaining resources in WP10, then DTU-CEE and DTU-BYG are working on improving the MPC based control concept for the Heat Booster Substation (besides to focus on when to charge the DH tank, also optimize on charging temperature, DH evaporator outlet temperature and source for circulation HP). Further, data are continually logged with the aim to get a stronger data foundation for mapping the performance of the concept.

WP10.2: So far, no useful data showing load shift potential for the water based heating system has been logged. See comments above.

WP10.3: HRU not yet installed.
Due to delays as explained in the section above the HRU is not yet installed.
The HRU is expected to be installed during august which means MP6 is expected to be delivered end of August and MP7 end of October.

Deliverable status

D #	Deliverable title	Planned completion month	Status **1** = on schedule **2** = completed **3** = delayed
D10.1c	[Report (public) Heat Booster Substation for Domestic Hot Water and Booster for Domestic Hot Water	May 2019	**3**
D10.2c	[Report (public)] Smart control of water based building heating services	January 2019	**3**
D10.3a	Control Concept Development	December 2018	**2**
D10.3b	Test Concept in Field	January 2019	**3**
D10.3c	[Report (Public)] Smart utilisation of spare heat pump capacities	May 2019	**3**

D10.1c: Expected June 2019, review is completed, only WPL group approval is missing.
D10.2c: Missing usable data from last heating season, Delivery time unclear at the time being. The outcome of a WP10 project extension is influencing this.
D10.3b: HRU not up running in supermarket, expected completed August 2019
D10.3c: See D10.3b, expected October 2019.

Dissemination

J.E. Thorsen et. al.: Load Shift Experience with ULTDH Substation for Multifamily Building, 4th International Conference on Smart Energy Systems and 4th Generation District Heating Aalborg, 13-14 November 2018

J.E. Thorsen, T. Ommen: Field experience with ULTDH substation for multifamily building, THE 16th INTERNATIONAL SYMPOSIUM on District Heating and Cooling, Hamburg, October 2018

J.E.Thorsen et. al.: ULTDH substation for Multi Family Building, EuroHeat&Power Magazine English Edition I/2019

W.Meesenburg et al. Economic feasibility of ultra-low temperature district heating systems in newly built areas supplied by renewable energy. Submitted for review, Energy.

WP10 has been presented at several events and towards a number of delegations at Danfoss.

MSc-thesis: H.Gunnarsson, Modeling and experimental analysis of booster heat pump, DTU, December 2018.

BSc-thesis: R.J.Knudsen, Optimering af drift af supermarkedskøleanlæg integreret med fjernvarme. DTU, Januar 2019.

Next steps

General:
Continue using demonstrations, Show Room and promoting ELN project towards delegations and customers. Finalize deliverables with sufficient experience and data from field test.

WP10.1: Operate Heatbooster Station in various modes, continue logging data for evaluation.

WP10.2: Implement and test (in case of project extension) algorithm for automatic load shift based on external parameters.

WP10.3: Get HRU installed and test system efficiency (COP) algorithm by DTU-MEK. Support input to UC#27, test spare heat pump capacity to the extent possible.

Quality Assurance

Status of deliverable		
Action	By Jan Eric thorsen	Date 12.06.2019
Sent for review		
Reviewed	Brian Elmegaard	Date 14.06.2019
Approved	WPL Group	Date 21.06.2019

Author	Reviewer	Approver
J.E. Thorsen	B. Elmegaard	WPL Group

The project "EnergyLab Nordhavn – new urban energy infrastructures" develops and demonstrates future energy solutions. The project utilizes Copenhagen's Nordhavn as a full-scale smart city energy lab and demonstrates how electricity and heating, energy-efficient buildings and electric transport can be integrated into an intelligent, flexible and optimized energy system. The project participants are: DTU, City of Copenhagen, CPH City & Port Development, HOFOR, Radius, ABB, Balslev, Danfoss, Nerve Smart Systems, METRO THERM, Glen Dimplex and the PowerLab facilities. The project is supported by EUDP (Energy Technology Development and Demonstration Programme), grants 64014-0555 and 64015-0055 and runs from 2015-2019.

Version Control

Version	Date	Author	Description of Changes
1	12.06.2019	J.E. Thorsen	First draft (missing inputs)
2	14.06.2019	B. Elmegaard	Review inputs
3	xx.xx.xxxx		WPL comments and approval