TEST SETUP FOR AN ACTIVE CONTROLLED HEAT PUMP INSTALLATION

Dirk Vanhoudt[1], Johan Desmedt[1] and Johan Van Bael[1]

[1]VITO, Boeretang 200, 2400 Mol (Belgium)

1. Introduction

Energy efficiency in building is becoming more and more important; a recent Directive of the European Parliament and Council (European Parliament and Council, 2010) stated that from 2021 onwards all new buildings should be ‘nearly zero-energy buildings’. This implies that both efficient heating techniques and on-site production of renewable energy becomes more and more prominent. Heat pumps, in combination with on-site photovoltaic electricity production can play an important role in this transition toward an energy efficient building envelope. The major obstacle of powering heat pumps for heating with photovoltaic electricity is the imbalance in time between heating demand and the availability of solar electricity. In future smart electricity grids, active control is needed whereby the heat pump is switched on when electricity is available. The heat produced at moments of low heat demand is stored in thermal storage buffers.

2. The test setup

2.1. Description of the installation

The hydraulic scheme of the heat pump is shown in Figure 1. The installation consists of a domestic water to water heat pump (“HP”: 11 kW) and two short-term thermal storage vessels: one for domestic hot water storage (“DHW”: 300l) and one for space heating storage (“HHW”: 400 l).

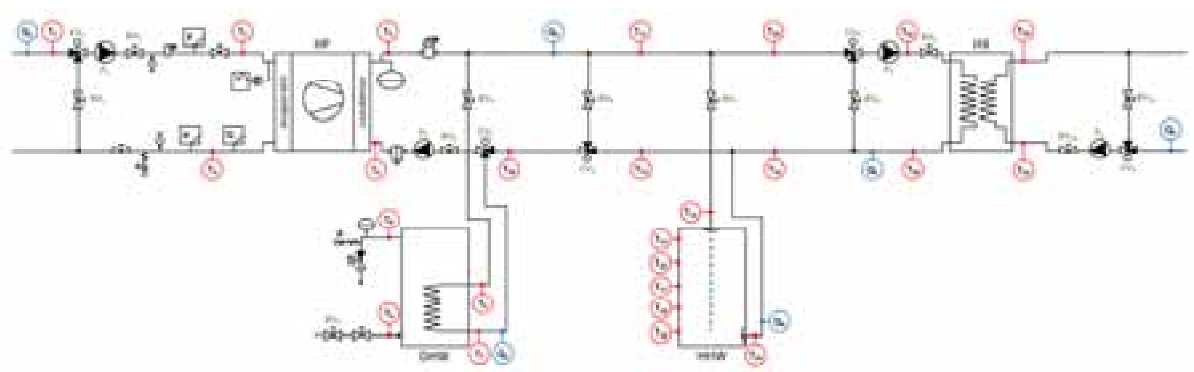

Figure 1: Hydraulic scheme of the heat pump installation

The evaporator of the heat pump is coupled to the existing lab infrastructure. Water at a certain temperature T1 (e.g. 25°C) and a certain flow rate Q1 is delivered to the evaporator. By mixing this flow with the return flow of the evaporator by means of tempering valve CV1, the supply temperature to the evaporator (T2) can be controlled. This makes it possible to emulate temperature profiles of the well of the heat pump (e.g. ground water at 10°C).

By means of control valve CV2, the heat pump can supply heat to either the domestic hot water buffer or the space heating system and heat storage. In heating mode, the outlet temperature of the heat pump is controlled by tempering valve CV3. CV4 controls the supply temperature to the heating supply system. The heating of the building is emulated by means of a heat exchanger (HX), coupled to the lab infrastructure at the secondary side. By adjusting CV5, the power of the heat exchanger is changed. This enables to simulate the heat demand of a certain building. Domestic hot water draw profiles are emulated by controlling a solenoid valve on top of the DHW-buffer.

To monitor the installation, 25 PT100 temperature sensors are installed (in red on Figure 1) as well as five flow meters (in blue on Figure 1). All measuring signals are logged to a server via a PLC. A Labview user interface is implemented to control the installation. Once inserted the heating demand and hot water demand profile of the building, the interface allows to run automatic test cycles during nights and weekends. A picture of the lab setup is shown in Figure 2.

Figure 2: Picture of the heat pump installation

2.2. Standard control strategy

First tests were carried out with a standard heat pump control algorithm in order to get a good understanding of the characteristics of the system and to get a reference situation to compare to. In this control strategy, if the water in the DHW-buffer needs heating, the heat pump prioritizes this. If not, the heat pump switches to heating mode. In this mode, first the set point of the supply temperature of the heating system is calculated by the ambient temperature and a heating curve: the lower the ambient temperature, the higher the supply temperature. Then the outlet temperature of the heat pump is determined, based on the lowest ambient temperature of the last three days and the heating curve. Once the set temperatures are known, the difference between the set temperature of the heat pump and the actual outlet temperature is evaluated and integrated (degree minutes control). When this value exceeds an upper limit, the heat pump is switched on. The heat pump is switched off again once the degree minutes exceed a lower limit.

An important notion in a smart grid context is flexibility. By this we mean how long the start-up of the heat pump be delayed in the presence of heat demand, or how long the heat pump can work in absence of a heat demand. Of course the flexibility is dependent on the capacity of the buffers. One can say that tests with this standard control strategy reveal the maximum flexibility of the system, since the heat pump is only switched on when the HHW buffer is empty and switched of when the buffer is fully loaded.

2.3. Smart control strategy

In the next steps intelligent control algorithms were developed, in order to switch on the heat pump when the electricity of solar panels is available. Of course, the heat pump does not know whether or not the electricity available is coming from renewable energy sources like solar panels. To cover this, a software package called Intelligator was developed to set up a virtual electricity market between the various electricity producing and consuming components of an intelligent energy network.

As a first attempt, a priority is determined based on the state of charge of the two buffers. The priority is a value between 0 and 100 which indicates how crucial it is for the buffers to get heat: when the buffers are about empty the priority will be close to 100. When they are almost full, the priority will be low. This priority is then transferred to Intelligator. In this way, the heat pump makes a bid on the electricity available from renewable energy sources together with other device which require electrical energy (e.g. washing machines, electrical boilers...). On the other hand, the solar panels on the roof of the VITO-office provide a priority based on the amount of PV-power available. By combining supply and demand the software decides whether or not to switch on the heat pump.

At the submission of this paper, this rather simple algorithm is finalized and implemented. Later, more complex business cases can be implemented, e.g. peak shaving, variable connection power of the building, or optimal use of renewable electricity. In these business cases, besides the state of charge of the buffers, also weather predictions and user behaviour will be included. The installation will also be extended to more sophisticated forms of short term energy storage (e.g. in PCM) and to seasonal storage in the ground.

3. State of the research

The first tests were performed to check the stability and robustness of the control algorithms. Next, two situations will be tested in the lab. First is a single household house in a very cold winter week. Second is a moderate winter week for the same house. To implement this, the heat demand profile for heating and sanitary hot water is needed as an input. These profiles were calculated by means of Type 56 in the building simulation software TRNSys. The resulting profiles are then applied to the heat exchanger and the solenoid valve of the DHW-buffer. Temperatures and flow rates are recorded and stored. These tests will be performed both with a standard control algorithm and a smarter control algorithm.

The cases with a standard control algorithm are performed to serve as a reference situation. The purpose of these tests is to assess which fraction of the energy consumed by the heat pump is coming from renewable energy sources. By performing the same tests with the intelligent control algorithm, the difference in this fraction can be calculated.

4. Conclusions

We developed a test setup for an active controlled heat pump installation. This installation makes it possible to simulate the behaviour of the heat pump in real conditions. The objective of this test setup is to develop a heat pump which is utilised as much as possible when renewable energy such as solar photovoltaic power is available.

As a reference case, the heat pump will be tested with a standard control algorithm based on degree minutes control. These tests revealed the maximum flexibility of the system in a cold winter week and a moderate winter week. Afterwards, a first control algorithm was developed to combine the heat pump with solar photovoltaic panels. To date however, the results of the tests are available yet.

Next steps in the project are the development of more complex control algorithms, by which other business cases can be developed (e.g. peak shaving or variable connection power of the building).

5. References

European Parliament and Council, 2010, Directive 2010/31/EU on the energy performance of buildings. To be consulted at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF, last accessed on 22 March 2011.