1. System description

The experiments will be carried out with an US residential air condition system with variable speed compressor located in E1K-N74, Danfoss Nordborg.

**Compressor:** variable speed compressor. 15-70hz. The compressor speed change is always with a ramp of 2.7hz/S. There is no step change from speed one to speed two. A specific function is enabled to secure the oil return to the compressor. When the compressor is running at the speed lower than 40hz for half hour, the compressor speed will be increased to 40hz for a 80 seconds period in order to guarantee proper lubrication of the mechanical parts of the compressor. The compressor speed then decreases to the original speed and will be maintained at that level until the next lubrication procedure starts.

**Expansion valve:** step motor driven valve. The opening of the valve from 0 to 100% takes 16 seconds. The valve takes 16 second closing from 100% to 0%.

**Condenser:** finned tube

![Figur 1: Outdoor coil](image)

**Evaporator:** finned tube. Interlaced
Figur 2: Indoor coil

Benchmark data

Tabel 1: Benchmark data - components and refrigerant

<table>
<thead>
<tr>
<th>Nominal capacity (TR)</th>
<th>3 ton for the system components except the compressor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor Unit</td>
<td>YORK CZB03611B</td>
</tr>
<tr>
<td>Indoor Unit</td>
<td>YORK FC36C3XN1A</td>
</tr>
<tr>
<td>Indoor Fan</td>
<td>LINDAB IRE400F</td>
</tr>
<tr>
<td>Compressor</td>
<td>VRJ035UK (This is a 4 ton compressor)</td>
</tr>
<tr>
<td>Drive</td>
<td>Performer VSD 4 TR cooling capacity</td>
</tr>
<tr>
<td>Expansion Device</td>
<td></td>
</tr>
<tr>
<td>Indoor</td>
<td>UKV18D51 (valve)</td>
</tr>
<tr>
<td></td>
<td>UKV-A102 (coil)</td>
</tr>
<tr>
<td>Expansion Device</td>
<td></td>
</tr>
<tr>
<td>Outdoor</td>
<td>UKV18D51 (valve)</td>
</tr>
<tr>
<td></td>
<td>UKV-A102 (coil)</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R410A</td>
</tr>
<tr>
<td>System charge</td>
<td>2,8 kg</td>
</tr>
</tbody>
</table>
2. Benchmark configuration and controller instrumentation

![Diagram of benchmark configuration]

The upper box shows the outdoor unit (i.e. compressor + condenser) while the lower block contains the indoor unit (which is essentially the evaporator and the expansion valve). Since the considered system is designed so that it also works in a heat pump mode some additional valves (to reverse the refrigerant flow) are added. The figure shows various temperature sensors (denoted by TT) and pressure sensors (denoted by PT). Additionally, there are sensors that measure the flow (refrigerant and air) in the benchmark.
Controller instrumentation

Figure 4 illustrates the controller instrumentation and the related sensors. Description of the sensors is given in the following:

Po : refrigerant pressure at the evaporator (in the paper is denoted by Pe)
To: sensor measurement of the refrigerant boiling temperature (in the paper denoted by Te)
S2 : Measurement of the refrigerant (in gas form) at the outlet of the evaporator (in the paper it is denoted by To)
S21: Is the same as S2: the sensor is placed further on the same pipe (after S2).
S22: is the same as S2 (and S21). S22 is place after S21
S4 : Is the temperature of the air after the evaporator (Ta in the paper)
OD : Opening degree of the expansion valve (in the control signal)
F : Mass flow measurement (measuring \(\dot{m}_i\))
Pc: The measurement of the condensation pressure (also Pc in the paper)
Tamb: Measurement of the ambient (room) temperature
ON/OFF switch: provides info about the state of the compressor (is not available at the moment)
3. Code implementation and data acquisition

At the moment, the benchmark can only be run with Minilog. Minilog has its own sensors (temperature, pressures etc.).

In addition a Matlab/XPC target has been set up. The XPC system uses separate measurement devices that are installed in parallel with the ones that are used by Minilog (Though only the measurements that are relevant for SH control on the evaporator). The sensors for the same measurement (evaporator outlet gas temperature) might be placed in the different places for the the Minilog and XPC.

4. Evaluation criteria of test results

A control strategy for super heat control based on only one temperature sensor will probably not settle at a constant level (i.e. the measured signal may have a cyclic nature). Therefore the results of the one sensor solution strategy and the strategy based on full available information can not be compared directly. Several evaluation criteria for comparison are proposed below and the definitions of these criteria are different for the two solutions (See figure 5 and 7, are for the one sensor solution. Figure 6 and 8 are for the solution based on full available info). However, using these criteria for comparison can give an idea of how the one sensor solution performs.

- **Stable average superheat \( \text{SH} \):** Under a specific condition, \( \text{SH} \) is defined as the average superheat after the system stabilizes until next disturbance occurs (In figure 5 and 6, from time b to next time disturbances or compressor switching occur. In figure 7 and 8, from time C to the time disturbances or a compressor switching occurs). It is important to use average superheat due to the expected nature of the solution strategy based on one temp. sensor.

- **Flooding period \( tf \):** the longest time period that the system is flooded after the system is switched (compressor) on, or a disturbance has occurred. In some other cases, there can be several flooding periods. Flooding period \( tf \) will be the longest flooding period among all the flooding periods after a disturbance or system operation condition changes. In order to take measurement offsets into consideration. Flooding is defined as \( T_{sh} < T_{low} \). In these experiments, \( T_{low} \) is specified as 2.5C, which means that when superheat is lower than 2.5C, the evaporator is considered to be flooded

- **Number of flooding \( N_f \):** the times of flooding during a specific period (from the time when the disturbance occurs to the next time disturbance occurs).

- **Stabilizing time \( ts \):** For the benchmark case (see figure 6 and 8), \( ts \) is defined as the time that superheat takes to reach and stay within a range (5% in this case) about the stable average superheat \( \text{SH} \) (Defined above) after the system is switched (compressor) on, or the disturbances occurs. For the one sensor method (see figure 5 and 7), \( ts \) is defined as the time from the disturbance or compressor switching happens to the time, that superheat goes to a new stable cycle period.

- **\( T_{sh,\text{max}} \):** the maximum superheat after the disturbances occur, or the system is switched (compressor) on.
- $T_{sh,\text{min}}$: the minimal superheat after the disturbances occur, or the system is switched (compressor) on.

![Diagram showing $T_{sh,\text{max}}$, $T_{sh,\text{min}}$, and $T_{sh}$ variation](image)

**Figure 5:** sketch of $T_e$, $S_2$ and superheat variation after disturbance occurs, the one sensor solution. The disturbance occurs at time $a$, and stabilizes at time $b$.
Figure 6: sketch of superheat variation after disturbance occurs, the benchmark solution. The disturbance occurs at time $a$, and stabilizes at time $b$. 

$$T_{sh}$$

$$T_{sh,max}$$

$$T_{sh,min}$$

$T_{sh}$

$T_{ref}$

$T_{Low}$

$t$

$0$

$a$

$b$

$tf$

$ts$
Figur 7: sketch of superheat variations after compressor starts up, one sensor solution. The super heat stabilizes at time c.
Figur 8: Sketch of superheat variations after compressor starts up, benchmark solution. The super heat stabilizes at time $t_5%$. The initial superheat is $T_{sh,\text{max}}$ and $T_{sh,\text{min}}$. $T_{sh}$ stabilizes below the reference $T_{\text{ref}}$. The time $t_f$ and $t_s$ are the initial and final settling times, respectively.