TRANSIENT RESPONSE OF THE AIR HANDLER-ROOM SYSTEM IN AIR CONDITIONING APPLICATIONS

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Abstract **– The paper studies the relationship between the choice of rated power of large capacity air conditioning systems and their ability to cope with the cooling load of the space. A mathematical model for the air handler – room system is developed and the simulation results are presented.**

***Keywords*:** *Air conditioning, air handler, transient response.*

1. INTRODUCTION

Rated power of large capacity air conditioning systems influences the energy consumption and on the other hand the space temperature, in other words the space comfort. Any mismatch between the cooling load and the rated capacity of system has obvious effects: if the rated capacity is too low then the air conditioning system cannot ensure the comfort conditions; on the other hand, a too high capacity will result in unnecessary energy consumption and expenses.

This article presents a mathematical model of the system consisting of the air handler and room based on lumped parameter approach. The equations of the model are implemented in a Matlab script and simulations are run. The transient response of the system is assessed for various values of the air handler rated capacity taking into account values of the cooling load typical for North Africa climate.

The cooling agent is water and it is supplied at constant temperature and flow rate. The cooling of the room is achieved by mixing the air in the room with the air that circulates through the air handler at constant flow rate.

2. DEVELOPMENT OF THE MODEL

2.1. The equations of the model

A schematic diagram of the system is shown in figure 1. The cooling agent (water) is assumed to be supplied at constant temperature. The system is modeled by the following set of energy balance and heat transfer equations:

Room:

$$M_{air}c_{air}\frac{dt_a}{d\tau} = Q(\tau,t_a) - G_{air}c_{air}(t_a - t_{a2}) \quad (1)$$

Air handler:

$$t_{a2} = \frac{\left[t_{c1} + \dfrac{t_a\left(1 - N_h/N_c\right) - t_{c1}}{\exp(N_h - N_c)}\right]}{1 - \dfrac{N_h/N_c}{\exp(N_h - N_c)}} \quad (2)$$

$$t_{c2} = t_{c1} + N_h/N_c \cdot (t_a - t_{a2}) \quad (3)$$

The following nomenclature was used:

M_{air} - mass of indoor air;

c_{air} - specific heat capacity of air;

t_a - temperature of indoor air;

Q - cooling load;

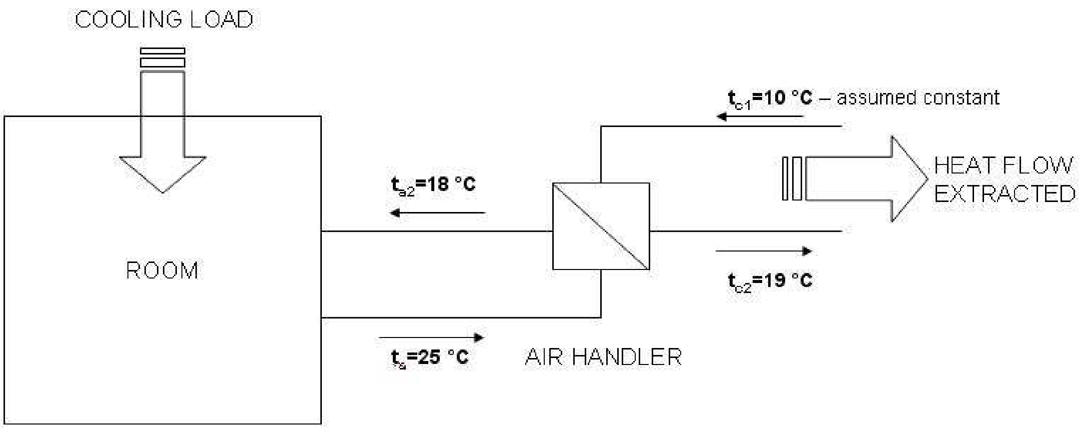

Figure 1. Schematic diagram of the system

G_{air} - air flow rate through the air handler;

t_{a2} - temperature of the chilled air;

t_{c1} - temperature of the cooling agent from the cold supply;

t_{c2} - return temperature of the cooling agent;

U - air handler overall heat transfer coefficient;

A - air handler heat transfer surface area;

$N_h = UA/(G_{air}c_{air})$ - number of transfer unit for the hot fluid (air);

$N_c = UA/(G_w c_w)$ - number of transfer unit for the warm fluid (water);

The first step in assessing the transient response of the system was the sizing of the air handler. For this purpose, standard conditions were chosen and the heat transfer surface area was evaluated. The LMTD method was employed in sizing the air handler with the following standard values of the characteristic temperatures:

Indoor air temperature 25 °C;
Chilled air 18 °C;
Cooling agent 10 °C;
Return temperature of the cooling agent 19 °C.

2.2. Cooling load and meteorological conditions.

A room with a 250 cubic meter volume was chosen for simulations. The climate conditions considered in this study are specific to North Africa. TRNSYS simulations were run for the room considered in order to evaluate the cooling load, defined as the heat flow that must be removed from the room in order to keep a previously set temperature. In other terms, the cooling load can be defined as the heat flow that enters the room at a certain temperature. Obviously, the cooling load depends on the indoor temperature. As a result, the cooling load depends both on time and on indoor temperature. A number of five values of the indoor temperature ranging from 23 °C to 28 °C were used for computing the cooling load. An hourly TRNSYS simulation throughout a year was employed and a maximum value of the cooling load of approximately 15 kW was found.

3. RESULTS AND DISCUSSION

A Matlab script was developed that solves the initial value problem (1) with the initial condition $t_a(\tau = 0) = 25$ combined with the algebraic equations (2) and (3).

The simulations took into account the operating principle of the system. The system is controlled by the indoor temperature value in a straightforward way: if the indoor temperature is above 24.5 °C the system is switched on, otherwise it is switched off.

Prior to running the simulations the sizing of the air handler was done. Four variants of air handler sizing were chosen. The values of the heat transfer surface area for each variant are listed in table 1.

Variant	Rated capacity [kW]	Surface area [m^2]
1	4.5	5.4
2	5.0	6.0
3	7.5	9.0
4	10.0	12.0

Table 1. Variants of air handler sizing

The values of the cooling load from TRNSYS simulation for the sizing variant 1 are shown in figure 1.

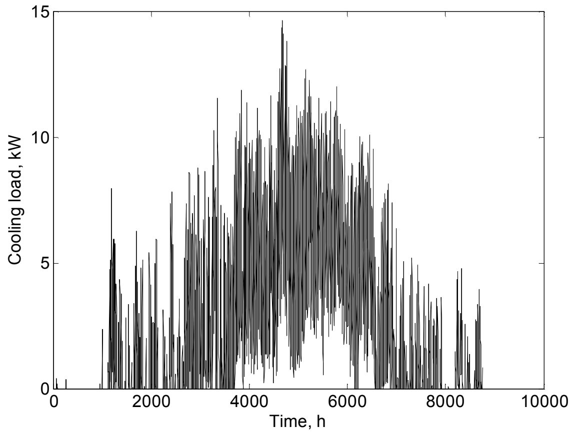

Figure 2. Cooling load (sizing variant 1)

The evolution of indoor temperature, chilled air temperature and cooling agent return temperature in time for sizing variant 1 are shown in figure 3.

The heat flow extracted from the room is shown in figure 4. Most of the values of the heat flow

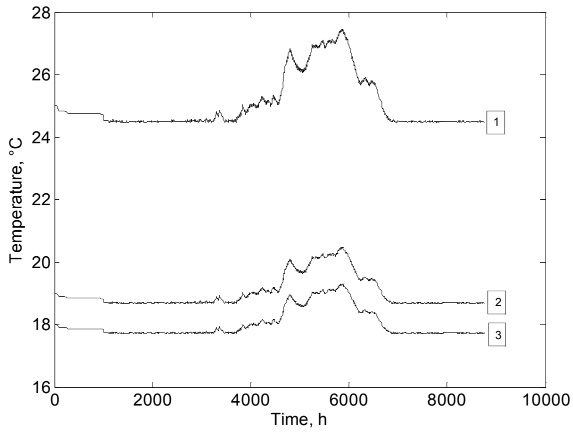

Figure 3. Indoor temperature (1), chilled air temperature (2) and cooling agent return temperature (3)

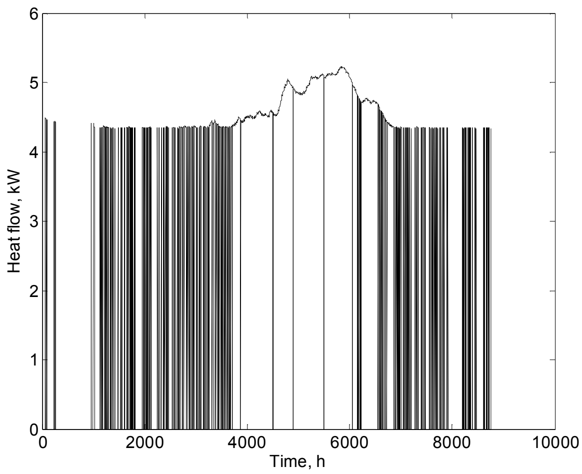

Figure 4. Heat flow extracted from the room (variant 1)

evacuated from the room are close to the rated cooling capacity of the air handler (4.5 kW). However, at the increase of the cooling load, the air handler faces a larger load than sizing assumptions. During these periods a significant increase of the indoor temperature is noticed due to the mismatch between the cooling load and the heat flow that the air handler extracts from the room.

Another observation for sizing variant 1 is that the system must in operation for long periods (for example, between 4000 and 6000 it is switched on almost continuously).

In figure 5 the values of the indoor temperature for all sizing variants are shown. Variant 3 (which is about half the maximum value of the cooling load in terms of rated cooling capacity) is capable of maintaining the indoor temperature at values lower than 25 °C.

It can be noticed that the system has a much shorter continuous operation interval than in the case of sizing variant 1. The maximum length of the continuous operation interval 4600 – 4800 h occurs at the maximum value of the cooling load as in the plot

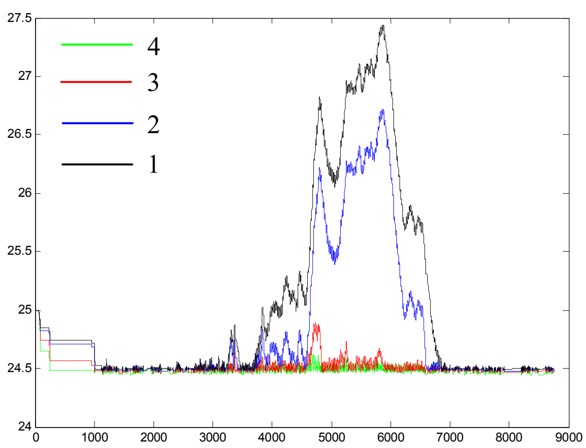

Figure 5. Indoor temperature for each sizing variant

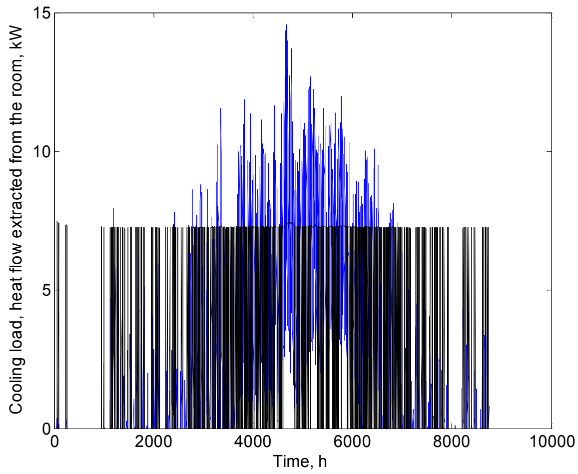

Figure 6. Heat flow extracted from the room (black) and the cooling load (blue) for sizing variant 3.

in figure 6.

Even though the rated cooling capacity is approximately half the maximum value of the cooling load, the system sized according to variant 3 is capable of maintaining the indoor temperature below 25 °C, as it is shown in figure 7.

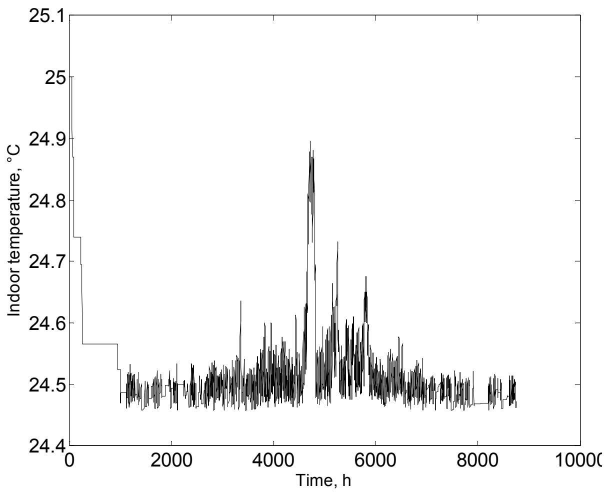

Figure 7. Indoor temperature for sizing variant 3

The operation interval is an important issue in assessing the economic efficiency of the system. In table 2 are listed the operation intervals for each variant

Variant	1	2	3	4
Operation interval, h	4245	4075	2991	2253

Table 2. The operation interval for each sizing variant

The heat flow extracted from the room is compared to the cooling load for variants 1, 2 and 4 in figures 8, 9 and 10.

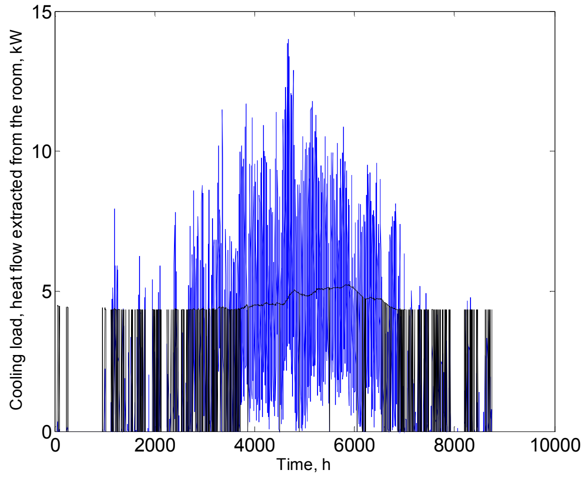

Figure 8. Heat flow extracted from the room (black) and cooling load (blue) for variant 1.

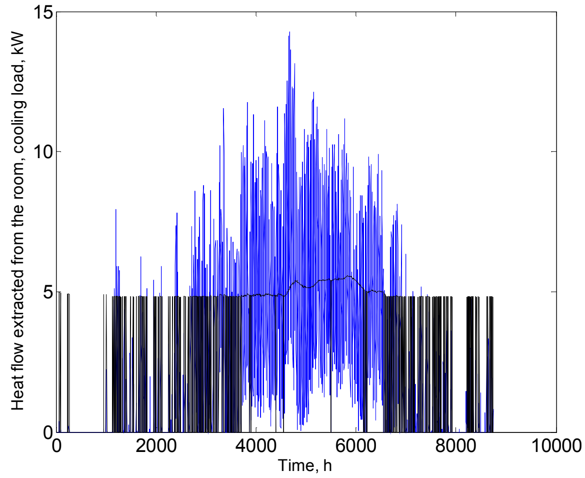

Figure 9. Heat flow extracted from the room (black) and cooling load (blue) for variant 2.

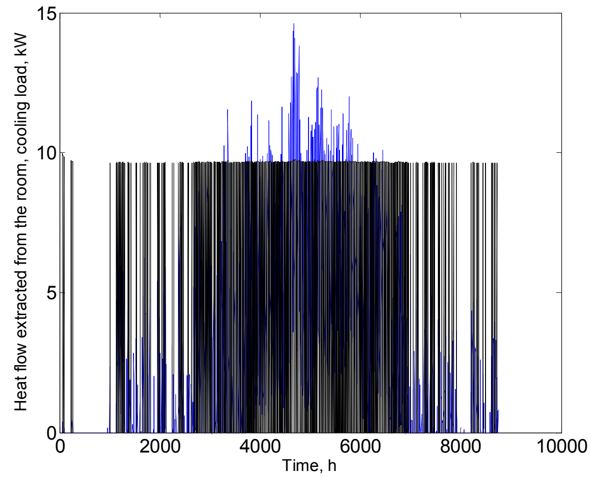

Figure 10. Heat flow extracted from the room (black) and cooling load (blue) for variant 4.

4. CONCLUSION

The transient thermal response of the system consisting of the room and air handler was examined. Four sizing variant were chosen and the transient thermal response of the system was assessed. For a cooling load maximum value of approximately 15 kW it was found that a value of the rated capacity of the air handler of 7 kW ensures a value of the indoor temperature less than 25 °C.

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