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MODELLING, IDENTIFICATION AND TEMPERATURE CONTROL OF A HOUSE

BALAN, R[adu]; HANCU, O[limpiu]; LAPUSAN, C[iprian]; STAN, S[ergiu] - D[an]; DONCA, R[adu] C. & MURESAN, V[lad]

Abstract: *This paper presents a simple solution for thermal modeling of a house which includes experimental identification of the parameters of the model, using a less expensive and noninvasive measurement system (indoor and outdoor temperatures and thermal energy consumption). It is used a simplified zone thermal model which has two dynamic temperature nodes roughly representing the air and a lumped structure node. Such data are used to simulate the thermal behavior of the house, to estimate the energy consumption and to obtain solutions to reduce energy consumption. In simulation, the control of the thermal system is performed using a model predictive control algorithm.*
Key words: *modelling, identification, temperature control, model based predictive control*

1. INTRODUCTION

Reducing and optimization of the energy consumption in the residential sector is an important issue in the context of the global warming effect (www.dehems.org, 2010). This paper presents a simple solution for thermal modeling of a house which includes experimental identification of the parameters of the model. Such data are used to simulate the thermal behavior of the house, to obtain solutions to reduce energy consumption and to change the behavior of the occupants. In simulation, the control of the thermal system is performed using a model predictive control algorithm.

2. THE THERMAL MODEL OF THE HOUSE

In this paper it is used a simplified zone thermal model which was originally introduced in (Crabb et al., 1987). The model has two dynamic temperature nodes roughly representing the air and a lumped structure node. Two dynamic heat balance equations are used (Zhang et al., 2005):

$$C_a \frac{dT_a}{dt} = Q - K_i(T_a - T_w) - K_f(T_a - T_o) \quad (1)$$

$$C_w \frac{dT_w}{dt} = K_i(T_a - T_w) - K_o(T_w - T_o) \quad (2)$$

where: T_a (ºC) is air temperature, T_w (ºC) is mean wall temperature, T_o (ºC) is outside air temperature and Q (kW) is heat input to the air node.

The proposed system is dedicated only for the measurement of the heat consumption and to give suggestions for the occupants (it is preferable to do not change the existing control system; the system is designed to be as little as possible non-invasive). From this reason, to test through simulation an algorithm for parameters identification of the model (1), (2), it is possible to proceed as follows:

- it is considered that the process is of the form (1), (2) with parameters (C_a, C_w, K_f, K_i, K_o) known and constant;
- the existing control system will be simulated;
- the estimations of the parameters (C_{ae}, C_{we}, K_{fe}, K_{ie}, K_{oe}) will be obtained using the input-output data.

3. THE CONTROL ALGORITHM

In this paper it is used a type of a model based predictive control algorithm. The basic idea of the algorithm is the on-line simulation of the future behavior of the control system, by using a few candidate control sequences (Balan et al. 2004, Balan et al. 2006). Then, using rule based control these simulations are used to obtain the 'optimal' control signal. The main idea of the algorithm is to compute for every sample period:

- the predictions of output over a finite horizon (N);
- the cost of the objective function,

for all (hypothetic situation) control sequences:

$$u(.) = \{u(t), u(t+1), .., u(t+N)\} \quad (3)$$

and then choose the first element of the optimal control sequence.

For a first look, the advantages of the proposed algorithm include the following:

-the minimum of objective function is global;
-this algorithm can be easy applied to nonlinear processes;
-the constraints can easily be implemented.

The drawback of this scheme is an unrealistic computational time. Therefore, the number of sequences must be reduced. This will lead to some difficulties in finding the global minimum of objective function. Choosing the sequences has to be made with attention, thus through simulation to be obtained information more helpful for computing the control signal. The control algorithm uses next sequences:

$$\begin{aligned} u_1(t) &= \{u_{\min}, u_{\min}, .., u_{\min}\}, \quad u_2(t) = \{u_{\max}, u_{\min}, .., u_{\min}\} \\ u_3(t) &= \{u_{\min}, u_{\max}, .., u_{\max}\}, \quad u_4(t) = \{u_{\max}, u_{\max}, .., u_{\max}\} \end{aligned} \quad (4)$$

where $u_{\min}$ and $u_{\max}$ are the accepted limits of the control signal, limits imposed by the practical constraints. These values can depend on context and can be functions of time.

4. PARAMETERS IDENTIFICATION

For every step of sampling it is measured only next values: $T_a(t), T_w(t), T_o(t)$ and $Q(t)$.

These data are memorized for a number of n_{sim} previous steps of sampling. Therefore at each sampling step will be possible to simulate the evolution of the process, using as initial data the information of $(t - n_{sim} \cdot T)$ sampling. The simulation will use the current values of estimated parameters ($\hat{C}_{ae}$,

$\hat{C}_{we}$, $\hat{K}_{fe}$, $\hat{K}_{ie}$, $\hat{K}_{oe}$). It is chose a performance index to compare the evolution of the measured internal temperature $T_a(t)$ and measured energy consumption $Q(t)$ by the evolution obtained by simulation based on estimated parameters ($\hat{C}_{ae}$, $\hat{C}_{we}$, $\hat{K}_{fe}$, $\hat{K}_{ie}$, $\hat{K}_{oe}$). It is used a bank of models (i.e. sets of parameters (C_{ae}, C_{we}, K_{fe}, K_{ie}, K_{oe})). All models will be test in simulation to find the best of them (based on a performance index). Also it is used a specific algorithm to introduce or remove a model in/from the bank.

Using a bank of models and the presented algorithm it will be obtained some obvious advantages:

- significantly improves the speed of the identification of the model parameters;
- most important aspect: the risk for a divergent identification process decreases very much;
- the risk of a local minima decreases also very much;
- in the case of nonlinear systems method, the method permits to obtain piecewise models;

Difficulties:

- the computing time increases;
- to find optimal solutions for introduction/removed of a model in the bank; if the model which is inserted is too much closer to one existing model from the bank then the method effectiveness decreases.

5. SIMULATION EXAMPLE

We will consider the next values of the process parameters:

$C_a = 1400$, $C_w = 2200$, $K_f = 0.02$, $K_i = 1.4$, $K_o = 0.02$

and the initial estimate:

$C_{ae} = 2500$, $C_{we} = 500$, $K_f = 0.05$, $K_i = 2$, $K_o = 0.1$.

The results are presented in Fig. 1 (parameter identification) and Fig. 2 (the evolution of temperatures $T_a(t)$, $T_w(t)$, $T_o(t)$, control signal $Q(t)$ and also control signal estimation $Q_e(t)$).

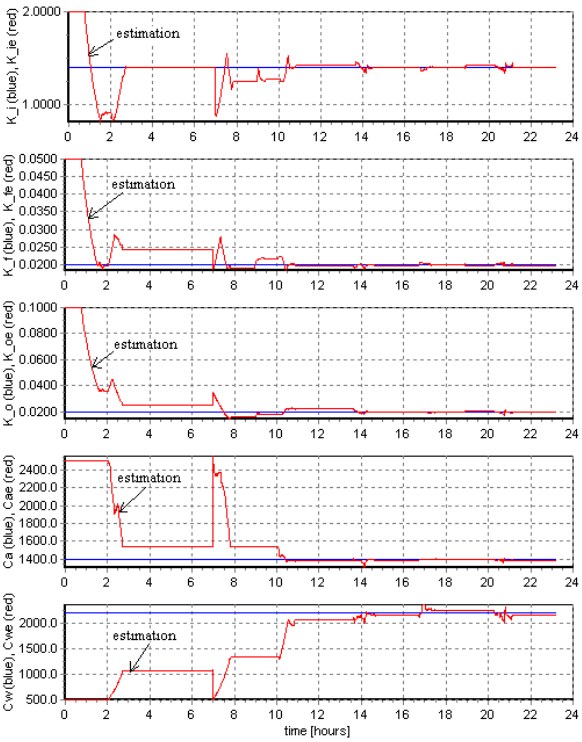

Fig. 1. Parameter identification

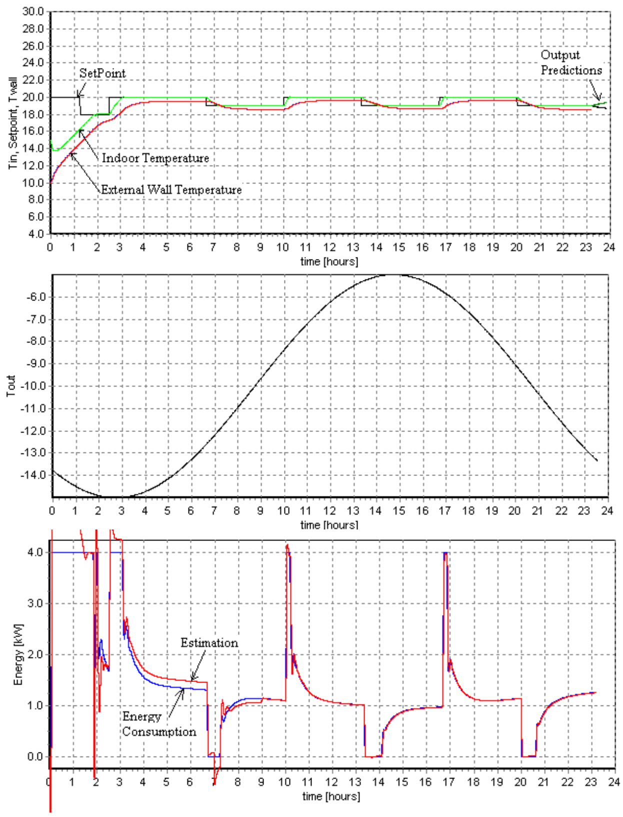

Fig. 2: Measured, control and estimate signals

6. CONCLUSIONS

This paper presents a simple solution for thermal modeling and temperature control of a house which includes experimental identification of the parameters of the model, using a less expensive and noninvasive measurement system (indoor and outdoor temperatures and thermal energy consumption).

7. ACKNOWLEDGEMENTS

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