A Comparison Between Computed and Measured Behavior of On-Off Control

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A COMPARISON BETWEEN COMPUTED AND MEASURED BEHAVIOUR OF ON-OFFCONTROL

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Abstract

A comparison is made between simulated, computed and full-scale experiments of on-off control of roomair temperature. The results show that the models describes the process well.

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1 Introduction

The main purpose of this report is to show how useful a model for a process can be. In this case a system with on-off control of room air temperature is studied. The simulated and computed behaviour fits well to the results from fullscale experiments. A more general study is made in Jensen & Ljung, 1973b.

On off control is a very simple control. The output of the process oscillates and in many applications with a reasonable amplitude. With a model is it possible to compute an approximate frequence and amplitude for the oscillations. This is done by simulation with the model in section 2.

Another approach is to use the contionuous transferfunction and the describing function of a relay. This is done in section 3.

Some experiments have been made with room air temperature control of a fullscale testroom.

The controlled process is heating effect to roomair temperature. The heating effect is switched on and off. The experiments are discussed in section 4.

The measured frequence and amplitude are given.

A short comparison is made in section 5 between computed and measured values.

2 Simulation method

A straight forward method to get the period time and the amplitude of the on-off oscillations is to simulate the process in discrete time on a computer. The results are given in table 2.1 from three used discrete time models. The sampling interval was 1 minute. The control signal was determined in a sampling point and kept constant to the next sampling point. The used models are given in Jensen, 1973a.

Table 2.1

Model	Period time minutes	Amplitude °C
1	16	0.39
2	18	0.51
3	20	0.61

3 Frequency method

On off control is easily established by introducing a relay in a closed loop system. The relay is a nonlinear system. This makes it difficult to analyse the closed loop system. There is one approximate method to investigate the oscillations of an on off control system. The Nyquist theorem, a describing function for the relay and the Nyquist curve for a model of the process is used. The describing function tells only how the lowest frequence in the oscillations goes through the nonlinear system.

The input to the relay is assumed to be

$$x(t) = C \cdot \sin \omega t$$

The output from the relay can be computed as

$$y(t) = \frac{4}{\pi} (\sin \omega t + \frac{1}{3} \sin 3\omega t + \dots \frac{1}{3} \sin 5\omega t + \dots)$$

The describing function is in this case just

$$Y_N(C) = \frac{4}{\pi \cdot C}$$

The phase is not affected by the relay.

In the Nyquist theorem the point (0,-1) in the complex plane is compared with the Nyquist curve for the open loop system to study the stability of the closed loop system. Normally the feedback is assumed to be -1.

In this case with a non linear feedback the point (0,-1) is transformed into the curve $-1/Y_N(C)$. This curve covers the whole negative real axis. The Nyquist curves for the studied process will always cut the negative real axis. The transfer functions are of second order and have got a time delay. It can be shown that this gives a soft-self excitation. Further details are given in Åström, 1968.

Three different second order transfer functions have been used and the frequences, the period times and the amplitudes are given in table 3.1 for the most negative cut between the Nyquist curve and the real axis. This gives the lowest frequence. The used transfer functions are given in Jensen, 1973a.

Table 3.1

Model	Delay	Frequency rad/minutes	Period time minute	Amplitude ^oC
1	1	0.46	13.7	0.29
2	2	0.41	15.3	0.39
3	3	0.35	17.9	0.50

4 Experiments

Several control experiments have been made with roomair temperature with a fullscale test room (see Jensen & Ljung, 1973b). The testroom is fully described in Adamson, 1969.

The roomair temperature is controlled by switching the heating effect to two electrical radiators on and off. A process computer (PDP-15) and a process interface (coupler/controller HP 2570A) have been used at the experiments. The control laws are implemented in software on the computer. The sampling interval was one minute. The regulator was approximated by a proportional regulator with high gain and saturation. The room air temperature and the heating effect are shown for two experiments in figure 4.1 and 4.2. Between the 20th and 25th minute outdoorair is fanned into the room. Between the 80th and 140th minute an extra radiator (500 W) is switched on. One experiment takes 200 minutes. The setpoint for the roomairtemperature is 27 ^{o}C.

From other experiments it is also found that the output is oscillating with about 6 - 7 periods per 100 minutes. The amplitude varies from 0.3 ^{o}C to 0.5 ^{o}C.

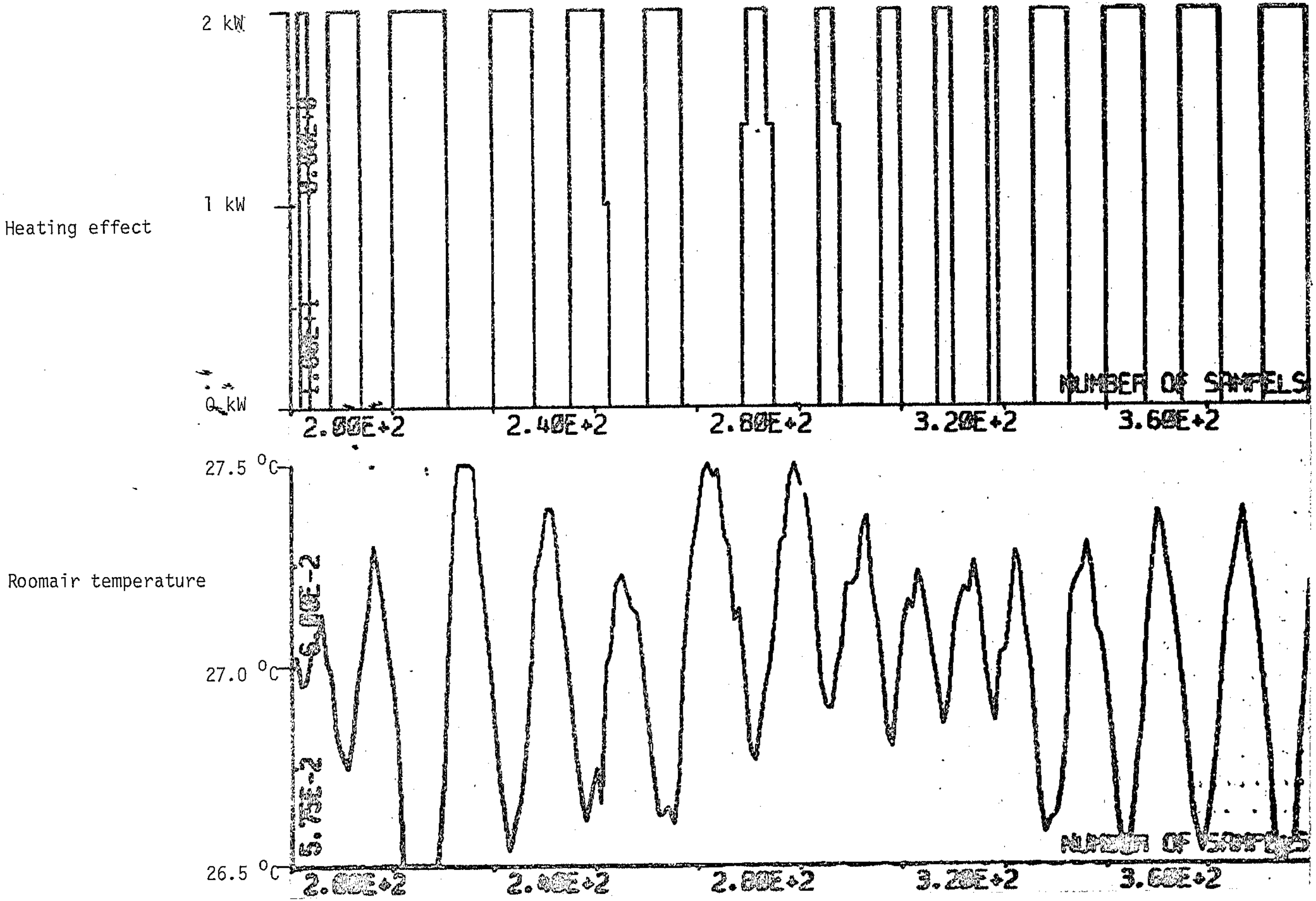

Figure 4.1 On-off experiment

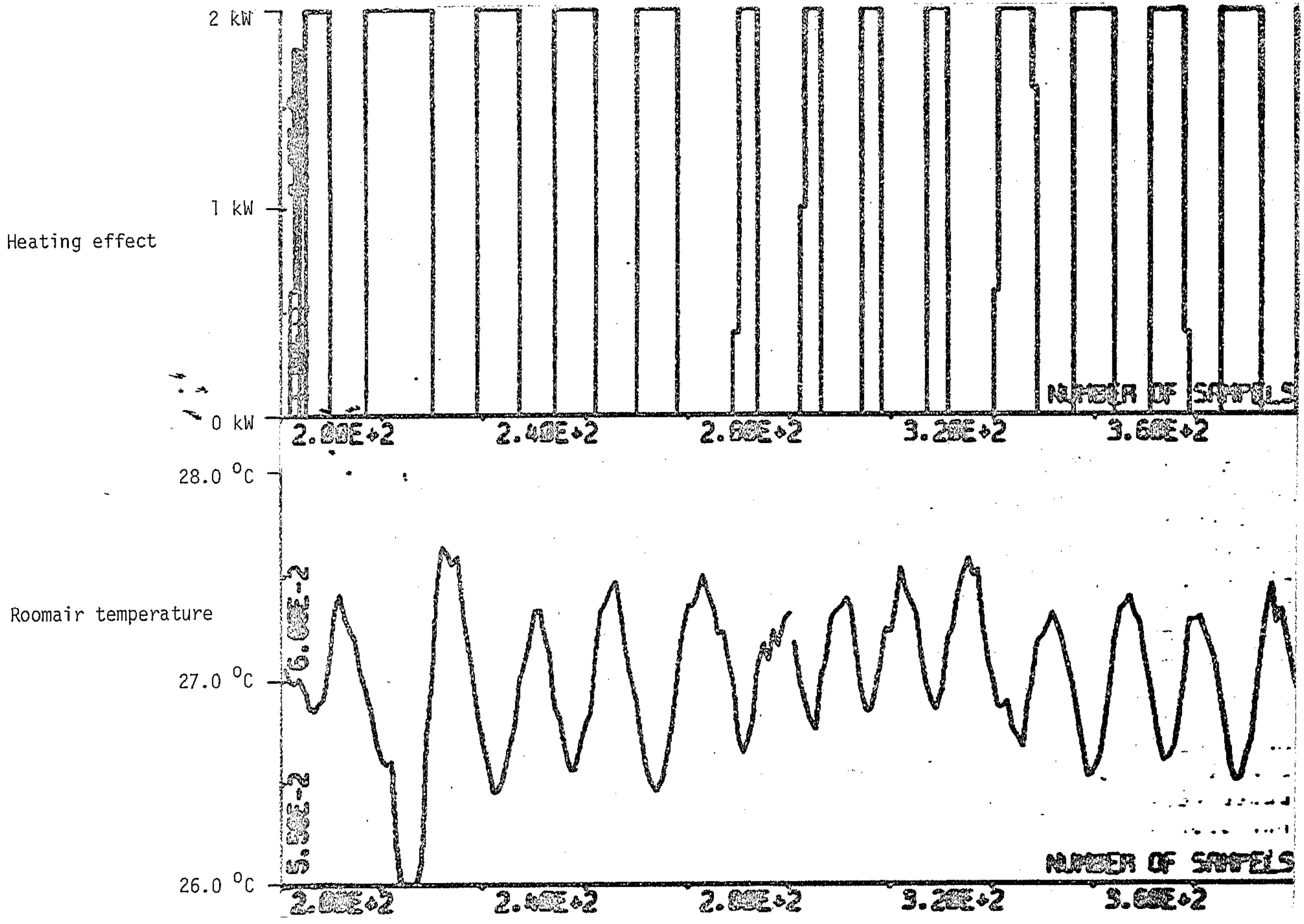

Figure 4.2 On-off experiment

5 Comparison

The simulated, computed and measured values of amplitude and periodtime are given in table 5.1 for the on off oscillations.

Table 5.1

Model	Method	Amplitude ^{o}C	Period time minutes
1	simulation	0.39	16.
2	"	0.51	18.
3	"	0.61	20.
1	frequency	0.29	13.7
2	"	0.39	15.3
3	"	0.50	17.9
-	measured	0.3 - 0.5	14. - 16.

The figures in table 5.1 show that the models describe the process well. Both the amplitude and the periodtime are about the same as the measured. It should be notified that the frequence method only is an approximate method and a relay generates overtones with rather large amplitudes which have been neglected in the analysis. The main comclusion from the result is that the model describes the process well.

6 References

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