To assessment of heat saving in automation of buildings heating systems

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Abstract. The paper considers the problem of estimating the magnitude of heat savings in the automation of building heating systems. Its authors propose a fairly simple method for determining the relative efficiency of the heat losses of a building in various temperature regimes. The plausibility of the savings data available in the literature is analyzed. The research provides approximate estimates of the savings for real situations. The practical value of combined heating systems using, in particular, renewable and non-traditional energy sources is estimated. It is indicated that the cost of heat to maintain a given temperature mode is determined by the physics of the heat exchange process of the building, so they are the same with any heating system. As a result, the combined system has no advantages over other types of heating systems in terms of heat consumption.

1. Introduction

It is known that the development of issues related to the automation of heating systems, their improvement and, consequently, energy saving, is one of the most pressing problems of the present time. Quite a lot of papers have been devoted to solving this problem [1-8], quite interesting and important results have been obtained. In particular, in papers [4, 8] an adaptive control system was proposed, which ensures high quality of maintenance of a given thermal mode of the building (TMD). The system implements a combined control principle with setting the weather compensator according to operational data; in the system, due to feedback, such thermal disturbances as heat gains from people, from working equipment, due to solar radiation, increased heat losses due to wind, and all errors in the implementation of the main disturbance compensation channel - the outdoor temperature. This structure of the control system makes it possible to achieve the highest quality of maintenance of a given TMD and the maximum possible energy saving value under the current conditions; it is only necessary to properly solve the problem of its parametric tuning.

When solving automation problems, the question of what are the savings re-serves, how to estimate the amount of heat savings obtained by automating the heating systems of buildings [9-14] is always significant and important. The data given in the literature on this subject are rather contradictory, both quite real [15-17] and quite unimaginable numbers of savings [18] are reported. It is argued that there are solutions that bring a fabulous economic effect. At the same time, on closer examination, as a rule, it turns out that all this is wrong and the effect, in fact, is not confirmed by anything. This paper
discusses such statements and proposes a fairly simple version of a theoretical estimate of the heat savings in the automation of heating systems. The use of such a method can be useful both at the stage of preliminary study of design solutions, as well as when choosing a new TMD and setting up an automation system on it.

2. The proposed method for evaluating the efficiency of heating automation.

If the TMD is specified, then all other conditions being equal, the heat losses of the building are the same regardless of how specifically and with the help of which heating system this mode is realized. These heat losses must be precisely compensated for by the delivery of heat to the building by the heating system. If this is not the case, then the TMD will change and will be different. Therefore, the heat consumption for the implementation of the specified TMD can be estimated from the heat loss of the building.

As it is widely known, the loss of heat by the building (the heat flux lost by the building) can be estimated by the well-known formula of N.S. Ermolaev

\[ Q = q_v \cdot (t_{IV} - t_{VN}) \cdot V, \] (1)

where \( Q \) – heat losses of a building of the \( V \) volume at temperatures \( t_{IV} \) and \( t_{VN} \) respectively, indoor and outdoor air, \( q_v \) – specific thermal characteristic of the building.

Consider two modes of heating: the old mode (bad mode, possible with automatic, but not working, or poorly tuned) and improved mode, implemented with the help of a high-quality automatic control system for heating the building, while we assume that the air exchange is the same in both modes.

Heat loss of the building under the old heating mode will be denoted by before \( Q_{before} = q_v \cdot (t_{IV}^{before} - t_{VN}) \cdot V, \) here \( t_{IV}^{before} \) – temperature of the internal air under the old heating mode (before the mode is improved). Heat losses of the building with a new (improved) heating mode will be denoted by after \( Q_{after} = q_v \cdot (t_{IV}^{after} - t_{VN}) \cdot V, \) here \( t_{IV}^{after} \) – indoor air temperature with improved heating mode. If the basic mode is taken to improve the heating mode, then at 80% savings, as reported in [18], it should be that

\[ \frac{Q_{before} - Q_{after}}{Q_{after}} = 0.8; \] (2)

\[ \frac{Q_{before}}{Q_{after}} = \frac{q_v \cdot (t_{IV}^{before} - t_{VN}) \cdot V}{q_v \cdot (t_{IV}^{after} - t_{VN}) \cdot V} = \frac{t_{IV}^{before} - t_{VN}}{t_{IV}^{after} - t_{VN}} = 1.8. \] (3)

Estimate, what at such economy should be temperature of internal air at an old mode of heating. From the above equation it follows that

\[ t_{IV}^{before} = 1.8 t_{IV}^{after} - 0.8 t_{VN}. \] (4)

We believe that in the new improved mode, the temperature of the internal air is normative and equal to \( t_{IV}^{after} = 20^\circ C, \) then at \( t_{VN} = -20^\circ C \) the temperature of the internal air in the previous mode should be equal to \( t_{IV}^{before} = 52^\circ C, \) and at \( t_{VN} = -10^\circ C \) only \( t_{IV}^{before} = 42^\circ C. \) It is clear that such a "overturn" is absolutely not real (and, as a result, there is no real saving of heat) and it cannot be "removed" simply by opening the windows, it is necessary to open the windows.

If such a heat saving (80%) is achieved by a decrease of \( t_{IV} \) (for example, at night in public and administrative buildings), then the new reduced temperature should be calculated according to the same formula (3), but only allowed with respect to \( t_{IV}^{after} \)
Here at before \( t_{VV} = 20^\circ C \) and \( t_{VN} = -20^\circ C \) it should be that \( t_{VV}^{after} \approx 2^\circ C \), and if \( t_{VN} = -10^\circ C \), then \( t_{VV}^{after} \approx 6^\circ C \), only in this case 80 percent heat savings will be achieved. However, we note that it is impossible to reduce \( t_{VV} \) [9] below 12\(^{\circ}C\), condensate will fall out on the internal surfaces of the walls, and in this case such a saving of heat cannot be achieved either.

If the basic mode is taken as usual, the old (previous) mode, i.e. if we assume that before \( t_{VV}^{before} \), \( t_{VN}^{before} \), then in this case absolutely absurd values are obtained \( t_{VV}^{before} \). Similar unbelievable results are obtained for the values \( t_{VV}^{after} \), if the intermittent heating mode is implemented. Indeed,

\[
Q_{before}^{after} - Q_{before}^{before} = 0.8
\]

(6)

\[
t_{VV}^{after} = 0,2t_{VV}^{before} + 0,8t_{VN}^{before}
\]

(7)

That is why at before \( t_{VV} = 20^\circ C \) (it was the normative mode of heating) and \( t_{VN} = -20^\circ C \) should be that \( t_{VV} = -12^\circ C \), and if \( t_{VN} = -10^\circ C \), then \( t_{VV} = -4^\circ C \).

Let us now estimate what real numbers of heat savings should be in heating buildings.

In real conditions, under normal (normative) air exchange, there are cases when the temperature of the indoor air in the heated rooms reaches \( 29 \pm 30^\circ C \). If we assume that after a qualitative solution of the problem of automation of the heating system, the temperature of the internal air becomes equal to before \( t_{VV} = 20^\circ C \), then the economy of heat will be

\[
Q_{before}^{after} - Q_{before}^{before} = \frac{\left(t_{VV}^{before} - t_{VN}^{before}\right) - t_{VN}^{after}}{t_{VV}^{before} - t_{VN}^{before}} = \frac{30 - 20}{30 - t_{VN}^{before}}
\]

(8)

At \( t_{VN} = -20^\circ C \) it will be only 20\%, and at \( t_{VN} = -10^\circ C \) it is 25\%.

If we consider the mode of intermittent heating, then applying the same formula (8) for this case, we find that for before \( t_{VV} = 20^\circ C \), \( t_{VN} = 12^\circ C \) and \( t_{VN} = -10^\circ C \) it will be only 26.6\%, and at \( t_{VN} = -20^\circ C \) it is 20\%. Figure 1 shows the curves showing the magnitude of the relative heat savings, calculated by formula

\[
Q_{before}^{after} - Q_{before}^{before} = \frac{\left(t_{VV}^{before} - t_{VN}^{before}\right) - t_{VN}^{after}}{t_{VV}^{before} - t_{VN}^{before}} = \frac{30 - t_{VN}^{after}}{30 - t_{VN}^{before}}
\]

(9)

for \( t_{VN}^{after} = 18^\circ C \) (upper curve), \( t_{VN}^{after} = 20^\circ C \) (average curve), \( t_{VN}^{after} = 22^\circ C \) (lower curve).

As can be seen from Fig. 1, the maximum saving in heat during "overheat" cannot be exceeded and this is only possible at the end of the heating season, if the internal air temperature.

It is clear that the above estimates refer to stationary heating modes, in addition, when considering the mode of intermittent heating, it was assumed that the rate of "heat" premises before the start of the work day is the same, which is usually determined by the installed power of the heating system.

We also note that the heat consumption for ventilation is reduced to a form analogous to equation (1). Therefore, in formula (1), under it follows, in fact, to mean the sum of the actual specific thermal property of the building and the specific heat consumption for ventilation [19]. But since in all
subsequent formulas this quantity is reduced, all the estimates obtained for relative efficiency remain
the same.

3. Evaluation of the efficiency of combined heating systems using different energy sources.
Concerning combined heating systems [18,20] using different energy sources, the following can be
noted. As it seems to us, in [18] the task of improving the thermal (temperature) mode of buildings
(TMD) is not solved, but an attempt is made to prove that by managing the combined heating system,
it is possible to achieve significant heat savings in the implementation of the well-known TMD, which
is absolutely impossible.

Indeed, as already noted above, the heat loss of a particular building is determined by its TMD and
the outside air temperature, these heat losses are the same, regardless of which heating system is
implemented by this TMD. These heat losses in accuracy must be compensated for by the delivery of
heat to the building by the heating system, and it is absolutely not important whether it is water, or
electric, combined or not. If this is not the case, then the TMD will change and will be different.
Therefore, by heat!!! at realization of the given TMD there can be no economy in principle. The
benefit here can only be in monetary terms, if the tariffs for "water" and "electric" or some other Gcal
are different, and, for example, so that "night electric" Gcalorie is much cheaper than "water" one.
However, even here it is not so, at the moment in Chelyabinsk, the "water" Gcalorie for the population
costs 1211.33 rubles, "Night electric" Gcalorie 1478.13 rubles.

![Figure 1](attachment:image.png)

**Figure 1.** Dependence of heat savings on outdoor temperature

It should also be noted that when realizing, for example, the intermittent heating mode, the
temperature of the indoor air can be quickly raised to a predetermined value by an air heating system
with electric heaters, which can cause the illusion that in this case there is a saving heat. But even here
it is not so, since the temperature of the inner surfaces of the enclosing structures will be low, this is a
discomfort, and it is impossible to declare the economy of heat due to the deterioration of the
microclimate.

Therefore, the combined heating system in the implementation of a given TMD in terms of heat
costs has no advantages over any other heating system, unless, of course, the quality of the solution of
the automation task of both systems is the same. If, however, taking into account the increased capital
costs for its creation, then the question of the practical value of such heating systems can be considered quite closed at this time.

Of course, the theoretical values of the effects obtained should be clarified from the data of real measurements.

4. Conclusions.
The problem of estimating the amount of heat savings in the automation of building heating systems using wireless sensor networks for determining the temperature of the internal air is considered. A fairly simple method for determining relative efficiency is proposed. The practical importance of combined heating systems, including different energy sources.

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