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OPTIMIZATION OF THE POWER AND CONTROL PARAMETERS OF HVAC SYSTEMS IN CONDITION OF THE UNSTEADY DUTIES

N. Parfentjeva, O. Samarin, S. Paulauskaitė

1. Introduction

As we know, the main problem faced by the specialists in the HVAC systems is ensuring the required comfort of internal meteorological conditions in the operating zone of rooms with minimal expenses for energy and materials [1]. Therefore, the design of building HVAC systems always assumes certain optimisation of specified engineering decisions. However, this problem becomes very important in our time due to the substantial increase of requirements for economical efficiency of the HVAC systems and the maintenance of given parameters of indoor air in variable external and internal exposures [2, 3]. It results in a need for new approaches to calculations, design, the operation of HVAC systems and their automatic control systems (ACS).

2. Method and results of investigations

One of the most promising techniques which allows to achieve a substantial decrease in the maximal capacity of HVAC systems (in comparison with traditional methods) is a joint consideration of transients possible to use their own thermostability of rooms, partially (and sometimes fully) to maintain a given thermal condition by the correlation of unit-step responses of the shown objects which are, in essence, the unified systems. In this case, it is possible to decrease the design-basis capacity of HVAC systems and to simplify the controllers using a lead of heat disturbances by action of HVAC systems controlled by ACS with PD or even P-control algorithm. Simultaneously, it becomes expedient to pass the maintenance function of the daily average internal air temperature t_a to the qualitative control of central heat (cold) supply. Then the local ACS will only compensate the difference between the set-point temperature and t_a, and the proposed procedure of optimising the capacity of HVAC systems. And control parameters are developed just for such conditions.

The given procedure is based on an assumption that common thermostability P_{com} of the system «room-HVAC and ACS-systems» combines room admittance P_{room} and a control action of ACS K_c [4].

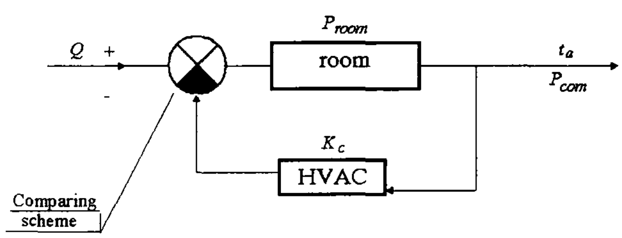

Fig 1. The automatic control circuit of the indoor microclimate

This immediately follows from the opposing-parallel connection of units corresponding to a room and HVAC systems in the circuit of automatic control of the indoor microclimate (Fig 1). Therefore HVAC system will compensate only that part of heat disturbance Q, which cannot be balanced due to internal damping in the system. It is possible to show that this part can be expressed by amplitude of disturbance A_q and the generalised coefficient of assimilation of variable excess heat K_{ass}. The latter is a further development of the concept of assimilation coefficient, which was first introduced [5] with reference to the compensation of radiant disturbances by convective actions of HVAC systems but without reference to the automatic control of them. Then, the installation power of HVAC systems Q_{ins} combines the compensated part of disturbance and the average duty over the period Q_{av}:

$$Q_{ins} = Q_{av} + K_{ass} \cdot A_q. \qquad (1)$$

In the most general case, the assimilation coefficient depends on the requirements to maintain the indoor temperature, ie on its acceptable amplitude A_{ta}, the thermostability of a room, the amplitude of heat disturbance q_r and compensating action of HVAC systems $q_{r,hvac}$:

$$K_{ass} = A \cdot (1 - B \cdot R_d) \cdot B_0, \qquad (2)$$

where $R_d = A_{ta} \cdot \frac{P_{room}}{A_q}$ is the dynamic control coefficient of HVAC systems $B_0 = f \cdot (q_{r1} \cdot q_{r,hvac})$ is the measure of assimilation of radiant heat disturbances. A and B are parameters characterising the control algorithm. To some extent the form of specified control algorithm also affects K_{ass} (because of its influence on values of A and B), and it is possible to show that the maximal effect from, the specified, like this measures take place using proportional and derivative controllers with PD-control algorithm with specially fitted derivation period T_d. The latter depends mainly on averaged head inertia of room $D_{av} = \frac{\Sigma DF}{\Sigma F}$ and allows to compensate the time lag of room response to heat disturbance:

$$T_d = 1{,}17 \cdot (3{,}5 - D_{av}), hrs; \qquad (2a)$$

but not less than 1,17 and not more than 2,93 hours at 24-hours period of variations of heat disturbance. In this case A=B=1, and K_{ass} takes a minimally possible value for the given system which is equal to $(1 - R_d) \cdot B_0$. Nevertheless, using a simpler and routine P-algorithm it is possible to achieve results, rather closely spaced to the optimal ones (especially when HVAC system is the heating one). The parameters A and B in this case differ from 1: A increases (maximal magnitude is equal to 1,25), and B decreases up to 0,9-0,95.

By definition, assimilation coefficient is always less than 1, the thermostability of a room is never equal to zero. It is assumed, however, that the radiant fraction in heat emission (assimilation) of HVAC system Q_{HVAC} does not exceed the corresponding fraction in heat disturbance, so the condition $\hat{A}_0 < 1$ is satisfied conforming to the known point [5] that it is more preferable to use a convective way of compensation of radiant heat excess. In the specific case, when the resources of a room are sufficient for maintaining the designed internal conditions within required limits that takes place when $R_d \geq 1$, assimilation coefficient is equal to zero, and the automatic control by deviation from the average value is not required. Otherwise, the gain $K_1 \left[\frac{Wt}{K}\right]$ of proportional term of the controller should be determined. This gain is related to the assimilation coefficient and provides, with the specified value of T_d, the required control action of ACS:

$$K_1 = C \cdot K_{ass} \cdot \frac{A_q}{A_{ta}}; \qquad (3)$$

where C is a parameter characterising control algorithm. When using proportional algorithm realised by P-controllers, $C = 1$; when using the optimal PD-algorithm, C decreases, and the least magnitude takes place for rooms with predominantly «light» enclosure and is equal to 0,75.

Certain original ideas, being concerned with the described approach to calculation of the power of HVAC systems, were advanced earlier [6], but here they are used in a somewhat different form and interpretation. We should specially emphasize that the problem determining the minimally necessary HVAC power proves to be correlated with the calculation of heat inertia of a room and the unit-step responded of specified ACS. In this case obtaining savings is complex in character so far, as it is reduced not only to decrease of overall dimensions of the equipment but also to shortening the flow rate of the hot (cold) fluids (including the air flow) as well as the diameters of pipelines and air ducts and energy expenditures to move the fluids in the pipelines. Moreover, there is an increase in the coefficient use of installation equipment power because of shortening the gap between maximal and average duty of HVAC systems. In essence, for an advanced optimisation of HVAC systems it is feasible a more complete way for using passive (structural and volume-layout) HVAC elements for maintenance of the required parameters of indoor atmosphere and so the decrease role is active. HVAC terms, and hence an opportunity of energy saving (in comparison with traditional approaches).

It is possible to determine the dimensions of the achieved saving in the given case on the basis of the following characteristic example. Calculations have been carried out for the room with a floor area of 16 m^2 with maximal heat excess $Q_{\max} = 1500 \cdot Wt$, so that A_q is also equal to $750 \cdot Wt$. It was 9 hrs-duration $Q_{av} = 750 \cdot Wt$, so that A_q is also equal to 750 Wt. It was assumed, that the increase of excess heat was connected predominantly with solar radiation, thus the radiant fraction in them $q_r = 0{,}8$. The other 20% reach by convection window surfaces. As HAC system the air convective cooling system was specified, ie $q_{r,hvac} = 0$. Characteristics of the enclosure correspond to a regular room in a building with silicate brick walls, gypsum-concrete bulkheads and hollow reinforced concrete ceilings. In this case the thermostability of the room $P_{room} = 460 \cdot \frac{Wt}{K}$, when the floor height is equal to 2,7 m, and value $B_0 = 0{,}57$.

Then using P-control algorithm for HVAC systems and rather stringent requirements to the amplitude of the indoor temperature (equal to 1 °C), the sufficient installation power of the equipment $Q_{ins} = 940 \cdot Wt$ that corresponds to the magnitude $K_{ass} = 0{,}25$. It takes only 63% of the maximal duty of the room and 16% less than the magnitude found from existing procedure of calculation in the unsteady thermal regime of a room [5] with no regard to the effect of automatic control upon the power of HVAC systems and equating in essence, the coefficient K_{ass} to the value B_0. When using the optimal PD-control algorithm, the required power decreases up to $915 \cdot Wt$, and the difference increases up to 39% and 19% correspondingly, that can be provided using the parameters of ACS $K_1 = 190 \cdot \frac{Wt}{K}$ and $T_d = 2{,}9 hrs$.

The pattern of transient processes in the system «room-HVAC and ACS-systems» is shown in Fig 2. When extending the feasible range of variation of indoor temperature up to 1,65 deg. to both directions from the average one, the installation power acquires the minimally feasible magnitude which is equal to $Q_{av}(940 \cdot Wt)$.

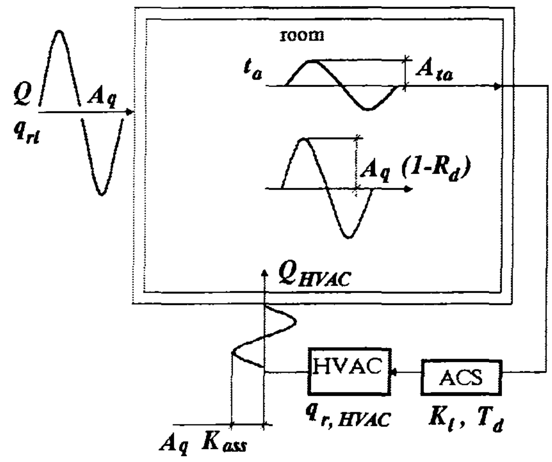

Fig 2. The pattern of transient processes in the system «room-HVAC and ACS-systems» in condition of the unsteady duties

It is necessary that all the shown reasoning hold true in any behaviour of the heat exposure variations (not only in the regular ones). Under unit-step disturbances the count of amplitudes shall be performed not from the average magnitudes but from the reference ones (before disturbance). Besides, the thermostability of the room cannot be calculated by traditional procedures, because it proves to be variable. The corresponding measure can be defined using data [7] depending on the specified duration of a setting time.

3. Conclusions

The given procedure of the optimisation of the HVAC power and ACS parameters to a sufficient extent takes into account the main factors effecting the unsteady thermal conditions of room. It is a simple and convenient way for engineers and it fully corresponds to the concept of creation of Buildings with Efficient Use of Energy [2]. Besides, it is suitable for comparing alternative schemes of the basic HVAC decisions even in the producing survey stage, and that causes its main usefulness in practice.

References

1. В.П. Титов. Учет нестационарных тепловых процессов в помещении // Водоснабжение и санитарная техника, 1994, № 3, с. 11 – 13.
2. В.Н. Богословский. Три аспекта концепции ЗЭИЭ и особенности переходного периода // Сб. докл. конф. НИИСФ, 1997, Т. 1, с. 7 – 9.
3. Ю.А. Табунщиков. Расчеты температурного режима помещения и требуемой мощности для его отопления или охлаждения. М.: Стройиздат, 1981. 84 с.
4. О.Д. Самарин. Расчет нестационарного теплового режима помещения в условиях автоматического регулирования систем кондиционирования микроклимата // Сб. докл. конф. НИИСФ, 1997, Т.1, с. 67 – 71.
5. Е.Г. Малявина. Учет аккумулирующей способности помещений при определении тепловой нагрузки на систему кондиционирования воздуха // Проектирование отопительно–вентиляционных систем, ЦНИИС. Реф. сб., № 2, М., 1973, с. 63–72.
6. Ю.Я. Кувшинов. Энергосбережение при кондиционировании микроклимата гражданских зданий. Автореф. дис. ... д–ра техн. н. М., МИСИ, 1989. 24 с.
7. О.Д. Самарин. О рациональном режиме начального прогрева помещения // Известия вузов. Строительство, 1997, № 3, с. 83 – 85.

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ŠILDYMO, VĖDINIMO IR ORO KONDICIONAVIMO SISTEMŲ GALIOS IR VALDYMO PARAMETRŲ OPTIMIZAVIMAS NESTACIONARAUS REŽIMO SĄLYGOMIS

N. Parfentjeva, O. Samarin, S. Paulauskaitė

Santrauka

Kaip žinia, pagrindinis šildymo, vėdinimo ir oro kondicionavimo sistemų – mikroklimato kondicionavimo sistemų (MKS) – specialistų uždavinys yra reikiamų mikroklimato parametrų užtikrinimas patalpos darbo zonoje minimaliomis materialinėmis ir energetinėmis sąnaudomis. Ypač svarbi ši problema kylant MKS ekonomiškumo ir nustatytų aplinkos parametrų užtikrinimo reikalavimams esant kintamiems vidiniams ir išoriniams poveikiams. Tai reikalauja naujo požiūrio į MKS sistemų skaičiavimą, projektavimą, eksploatavimą ir automatinį reguliavimą.

Siekiant sumažinti maksimalią MKS galią perspektyvu kompleksiškai nagrinėti dinaminius procesus, vykstančius patalpoje, mikroklimato kondicionavimo sistemoje ir automatinio reguliavimo sistemoje (ARS). Be to, siejant minėtų objektų dinamines charaktristikas į vieningą sistemą reguliaraus režimo sąlygomis pasirinktai tempetatūrinei aplinkai palaikyti, iš dalies galima išnaudoti patalpos savąjį šiluminį pastovumą.

Pasiūlyta metodika, kurioje daroma prielaida, kad bendras sistemos “patalpa – MKS – ARS” šiluminis pastovumas susideda iš patalpos šiluminio pastovumo rodiklio ir ARS valdančio poveikio, dėl ko MKS turi kompensuoti tik dalį šilumos poveikių patalpoje. Ši dalis išreiškiama poveikių amplitude ir apibendrintu kintančių šilumos išsiskyrimų koeficientu.

Pateikta MKS galios ir ARS parametrų optimizavimo metodika, įvertinanti pagrindinius faktorius, darančius įtaką nestacionariam patalpos šilumos režimui, yra pakankamai paprasta. Ji gali būti taikoma principiniams MKS sprendimams palyginti.

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