ENERGY CONSERVATION IN SUPPLYING HEAT AND COLD TO MULTIFUNCTIONAL BUILDINGS UNDER MULTIZONE SCHEME

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Calculation of the energy conservation value under the conditions of heat and cold supply of multifunctional building under the multizonal scheme is conducted. The case, when heat is transported from the space where there is the access heat to the space where there is heat shortage, is reviewed. The mentioned process is achieved by using reversible heat pumps connected to the common water loop and operating in a parallel mode. Significant energy conservation (40-50%) is achieved especially in transient period (spring, winter).

Key words: ***Power conservation, multifunctional building, heat and cold supply, multizonal scheme, heat pumps.***

Different spaces in the multifunctional buildings can be in significantly different thermal conditions due to the following reason: different heat losses from the space (from the building in the environment and ventilation losses); various internal sourses affecting the space like metabolic heat, heat generated by reregerating units, computers and other devices. When calculating heat, heat losses are estimated and when calculating cooling, heat flow values, are estimated respectively for heating and cooling calculation temperatures. According to these data, individual heat pumps for each space or each zone are selected. As the calculation is run for the worst case, the unit capacities will be taken with maximum reserve. This is associated with the incraese of initial investments and at the same time with the decrease of the unit use coefficients (unit oepration cicles decreases). Together with increasing the tempterature in the environment, as the heat losses in the environment decrease, there might create such a heat balance in particular space when the heat obtained from the internal heat sources exceed the heat losses in the environment, i.e. there will be excess heat into the space. In order to maintain microclimate into the space, reversible heat pump from "heating" mode will be swithed to "colling" mode. According to a standard scheme, the mentioned excess heat as the heat loss will will taken to the environment. In case the reversible heat pumps are connected to the common water loop, then the excess heat is transfered to the ring water loop from where it is possible to use it in another space where there is a demand on heat (lack of heat).

So, in changing the climate conditions, especially in a transient season (spring, autumn), in case of supplying heat-cold to the multizone building, when the reversible heat pumps are connected one common ring loop, heat from the spaces where there is the excess heat will be transferred to the spaces where there is the lack of such heat. As a result we will get significant energy conservation. During certain periods of the year heat balance of the entire building can be achieved with the internal energy reserves so that the energy supply from the external sources is not needed.

When designing heat-cold supply of the multifunctional buildings, in order to avoid selection of the required units with large reserves and unreasonable increase of the initial investments and also for estimating an appropriate value for saving energy necessary for supplying heat and cold, it is necessary to create engineering design method which will involve the heat transfer between particular spaces. Consequently, at the design stage it is possible to estimate future operation costs of the building more accurately and reflect these data in an energy file of the building. Generation of the energy file of the building will help

both construction companies and purchasers (customers) to make proper choise in purchasing and selling the appartments.

In designing heat-cold supply under the standard layout, the estimation of the heat losses and heat flows for cetrain spaces are made and power required for heating and cooling the particular space is calculated respectively for heating and cooling calculation temperature conditions [5]. Heat designing method [6] does not require consideration of the heat flow from internal sources in the building in winter which in most cases is associated with the large reserve of the heat capacities. Ring water loop system on the basis of the reversible heat pumps allows to utilise the excess heat, however in selecting the optimum capacities required for the units, when making engineering desing, it is necessary to take into the account the transfer of heat between the spaces.

Today the most promising scheme of the heat-cold supply of the multifunctional buildings is assumed to be the systems run by the heat pumps [5].

As an example let's review the building for the heat-cold supply of which the reversible heat pumps [1] are in parallel connected to the rind water loop. For theoretical building modelling let's identify two spaces: I and II (figure) within the building. Microclimate is created within the spaces. Ring water loop to which two reversible heat pumps operating in parallel are connected, is maintained. The model is characterized by the following parameters:

Outside air temperature $t_{outside}{}^0C$;

Space air temperature $t_{inside}{}^0C$.

There are the following internal sources of energy generation occur in the spaces I and II: lightening, human heat (metabolic heat), computers and refregirators and other electric devices. Their total effect is respectively (kW) $Q_{inside\ source1}$ and $Q_{inside\ source2}$.

The heat losses (from the building) into the environment are (kW) $Q_{building1}$ and $Q_{building2}$. The heat losses reduced to the space to be heated and one degree of the room air and environemnt temperature difference, respectively are q_1 and q_2 kW/m^2/K. Then, the heat losses from the first space into the environment from external walls, windows, external door, floor, ceilling (transmission losses) equal to:

$$Q_{building1} = q_1F_1(t_{inside} - t_{outside}).$$

Similarly, the heat losses on ventilation (kW) are $Q_{vent.1}$ and $Q_{vent.2}$. Quantities of air flow into the spaces (m^3/sec) are $L_{vent.1}$ and $L_{vent.2}$.

The quantities of the resolved air are equal to, respectively, the quantities of the flown air: $L_{vent.1} = L_{resolved1}$ and $L_{vent.2} = L_{resolved2}$; refregirator coefficient of the heat pumps running on colling mode is ε_1 and heat transofrmation coefficient - φ_1. Respectively, refregirator coefficient of the heat pumps running on heating mode is ε_2 and heat transofrmation coefficient - φ_2.

Total heat Q_1 and Q_2 losses in I and II spaces are:

$$Q_1 = Q_{building1} + Q_{vent.1} \text{ and } Q_2 = Q_{building2} + Q_{vent.2}.$$

Say that there is the excess heat in I space and heat shortage in II space. The heat balances in the spaces will have the following form:

$$Q_{inside\ source1} - Q_1 = \Delta Q_1 > 0 \text{ and } Q_{inside\ source2} - Q_2 = \Delta Q_2 < 0.$$

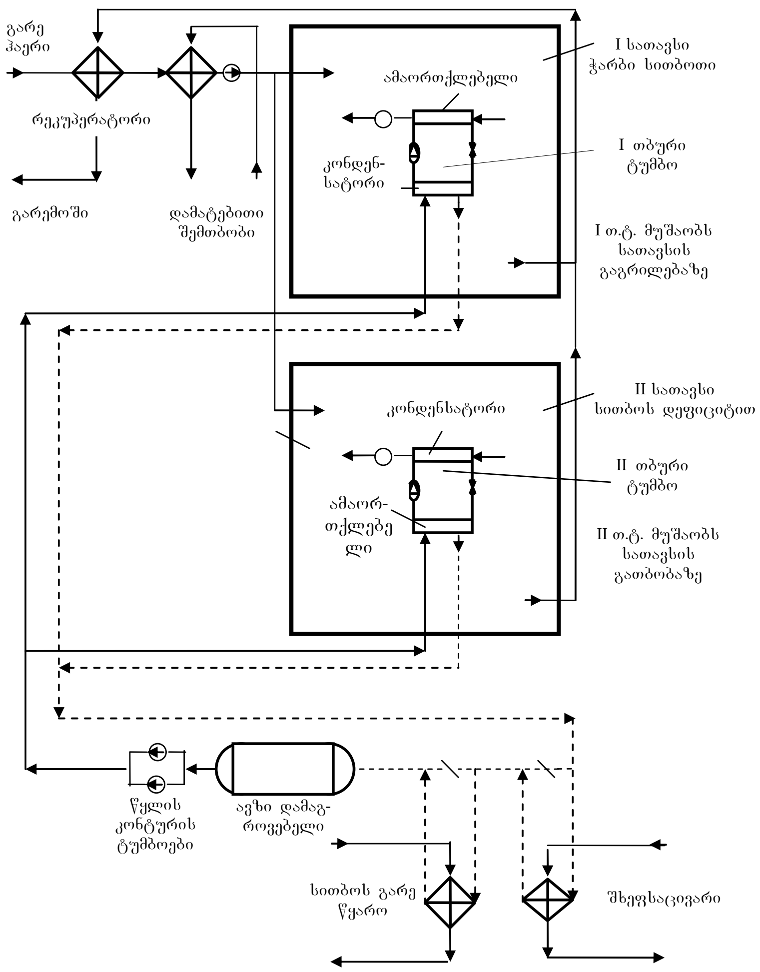

Figure. Model of energy transfer from one spalce to the another using heat pumps

In order to create the microclimate in I space, the reverse heat pump will operate in cooling mode and the heat pump of II space will operate in heating mode.

Air conditioning system consists of the following units: heat pump – "air-water" type, primary loop-air-cooling agent, secondary loop-colling agent-water. Primary air is taken from the outside. Air in a central ventilation calorifer heats to t^0C. By insufficient heating $\Delta t = (t_{inside} - t)^0$C. Air in the space gets with t^0C and gets mixed with the space air with the temperature $t_{inside}{}^0$C. The quantity of heat are $Q_{vent.1}$ and $Q_{vent.2}$ required for heating the flowing air having t^0C temperature to $t_{inside}{}^0$C equals to :

$$Q_{vent.1} = L_1 .c. \rho. (t_{inside} - t) \text{ and } Q_{vent.2} = L_2 .c. \rho. (t_{inside} - t) ,$$

where C (kJ/kg.K) ρ (kg/m^3) is air mass heat capacity and density.

The heat losses from the building is calculated with the formulas:

$$Q_{building1} = q_1F_1(t_{inside} - t_{outside}), \text{ and } Q_{building2} = q_2F_2(t_{inside} - t_{outside}),$$

where q=0.003 kW (m^2/k) is specific heat loss from the building restricting structures into the environment reduced to 1m^2 of the space to be heated and 1^{0}C of temperature difference between room and environment. F_1 and F_2 – respectively spaces to be heated.

ΔQ_1 aexcess heat abstraction in the space with the heat pumps and its transfer to the water loop are required for cooling the first space/room. Power consumed on the abstraction $\frac{\Delta Q_1}{\varepsilon_1}$ and the heat transferred to the water loop $\Delta Q_1 + \frac{\Delta Q_1}{\varepsilon_1} = \Delta Q_1 \cdot \frac{\varphi_1}{\varepsilon_1}$,

where ε_1 and φ_1 are the cooling and heat transformation coefficients of the heat pump run under the cooling mode in accordance with [2,3].

There is the lack of heat $Q_2 - Q_{\text{შიდა წყ.2}}$ in the second space which can be compensated from the first space on the account of the excess heat transferred to the water loop from the first space.The heat pump of the second space will operate under the heating mode and will take heat from the water loop

$$\Delta Q_1 \cdot \frac{\varphi_1}{\varepsilon_1} + \Delta Q_1 \cdot \frac{\varphi_1}{\varepsilon_1} \cdot \frac{1}{\varepsilon_2} = \Delta Q_1 \cdot \frac{\varphi_1 \varphi_2}{\varepsilon_1 \varepsilon_2} = \Delta Q_1 n$$

and supply to the first space, where $\frac{\varphi_1 \varphi_2}{\varepsilon_1 \varepsilon_2} = n$.

Total balance of the first and second spaces will have the following form:

$$\Delta Q_1 n = Q_2 - Q_{\text{შიდაწყ2}},$$

i.e.

$$Q_{\text{შიდა წყ.1}} - Q_{\text{შენ.1}} - Q_{\text{ვენტ.1}} = Q_{\text{შენ.2}} + Q_{\text{ვენტ.2}} - Q_{\text{შიდაწყ.2}}.$$

In a detailed way:

$$Q_{\text{შიდა წყ.1}} \cdot n - qF_1(t_{\text{შიდა}} - t_g) \cdot n - L_1 c\rho(t_{\text{შიდა}} - t) \cdot n = qF_2(t_{\text{შიდა}} - t_{\text{გ}}) + L_2 c\rho(t_{\text{შიდა}} - t) - Q_{\text{შიდაწყ.2}}$$

As a result of simple convertions will get the calculation expression of the final preheating temperature of the air:

$$t = t_{\text{შიდა}} + \frac{(q_1F_1n + q_2F_2)(t_{\text{შიდა}} - t_g)}{C\rho(L_1n + L_2)} - \frac{Q_{\text{შიდაწყ.1}}n + Q_{\text{შიდაწყ.2}}}{C\rho(L_1n + L_2)} \quad . \tag{1}$$

In a private case, when both spaces have similar architecture, $F_1 = F_2 = F$, ventilation air consumptions $L_1 = L_2 = L$ are equal too and specific heat losses into the environment are equal $q_1 = q_2 = q$. In such case, will obtain:

$$t = t_{\text{შიდა}} + \frac{q \cdot F}{C\rho L} \cdot (t_{\text{შიდა}} - t_{\text{გ}}) - \frac{Q_{\text{შიდაწყ.1}}n + Q_{\text{შიდაწყ.2}}}{C\rho L(n+1)} \quad . \tag{2}$$

Coefficient $\frac{\varphi_1 \varphi_2}{\varepsilon_1 \varepsilon_2} = n$ determined by cooling and heating transformation coefficient of the heat pumps run under different modes participates in the calculation formula of the final preheating temperature of the air. The size of this complex in which the heat pumps connected to the ring water loop have to operate is defined for particular conditions.

Estimation of power conservation based on the accepted method was run for multifunctional complex, Niba-Invest (Vazha Pshavela I, turning #1/43, Tbilisi). The author of this unique project is the well known Italian architect Massimiliano Fuksas. Penetron type materials are used for complex dampproofing of the four-level underground section (foundations and walls) [4]. Construction of the stage I of the project is at final stage and construction of 160m height building is planned for the stage II.

Priority during designing process was given to more effective use of the energy resources consumed on the power supply of the building using innovative solutions. One of the examples of the innovative solution is the use of closed water loop reversible heat pumps for the heat-cold supply of the building providing the energy conservation and protection of the environment from pollution.

According to the calculations run it is accepted that the elaborated closed water loop scheme of the heat-cold supply of the multifunctional building [1] based on the reversible pumps provides the energy conservation of up to 40% and reduction of heating gas to 8950 t CO_2/sec under the conditions of maintaining very comfortable climate within the building. Total power of the heat pumps is selected within the range of 70-75% of the calculation power and the coverage of the peak load (the duration of which is short) is economically reasonable with electric heating coils of the heat pumps.

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