*Journal of Science and Technology*
*ISSN: 2456-5660 Volume 7, Issue 07 (July -2022)*
*www.jst.org.in* *DOI:https://doi.org/10.46243/jst.2022.v07.i07.pp27- 35*

# Designing Efficient HVAC Systems Best Practices for Optimization

**SYED JUNAID UDDIN[1], MOHAMMED TAHER[2], RAZA AHMED KHAN[3]**
**Department of Mech**
**Nawab Shah Alam Khan College of Engineering and Technology (NSAKCET)**

***To Cite this Article***
**SYED JUNAID UDDIN[1], MOHAMMED TAHER[2], RAZA AHMED KHAN[3], "Designing Efficient HVAC Systems Best Practices for Optimization"** *Journal of Science and Technology, Vol. 07, Issue 07, July 2022, pp27-35*

***Article Info***
*Received: 23-05-2022 Revised: 21-06-2022 Accepted: 05-07-2022 Published: 15-07-2022*

**Abstract**

When it comes to developing technical solutions for different types of buildings that are energy efficient, this publication is seen as the most viable avenue. Starting with the first design calculations, this journey is initiated. As a building's components, the heat and mass balances provide the groundwork for making HVAC systems that are both efficient and affordable. In addition to calculating mass and heat, a thorough investigation of the building's geometric dimensions and thermal performance envelope is required. This research takes a look at a unique approach to calculating the heat load of HVAC systems. Improvements in the estimation of building heat losses are shown by the approach under consideration. The suggested technique is used to calculate transmission heat losses using the elemental approach. Various methods of accounting for the infiltration component are shown in the technique for determining ventilation heat losses. A method for integrating the many components of thermal energy use into a unified mathematical framework is laid forth. An analysis of the approach of optimising heat loads under harsh operating circumstances is presented. The study presents the results of calculations and additional methods for using correct methods in building design. As a conclusion, this article suggests a few things.

*Keywords:* Heat losses ; Heat gains ; Extreme mode ; Matrix method ; Building energy simulation ; Levelling peak loads

## 1. Introduction

Consumption is a way of life for all of us. Indicative of a country's educational level and the quality of life inside, the satisfaction of its citizens' most fundamental wants has been raised to the level of a national ideal. Improvements in the country's fuel and energy infrastructure always lead to an increase in the "comfortable" part of people's daily lives. However, the high humanistic role of engineering systems is unavoidable due to factors such as hot summers and cold winters, challenging climatological conditions in various cities and towns across the globe, pollutions, the human need to breathe clean air, and the limits of human thermoregulation.
Parallel tendencies may be seen in both the HVAC industry and the scientific community at large. The true goals are confirmed by the macroeconomic process of artificially separating markets with their own normative database. The global growth of nations is not something that the general public is concerned about. The idea of durability is being phased out, but only gradually. But structures aren't commodities; they're abodes for the most part. China and Russia are able to experience it to its fullest because of their challenging climates [1].
This is happening as people's "appetites" for comfort continue to rise. The ideal interior climatic parameters are more demanding and include things like air temperature, average surface temperature in the building, relative humidity, air mobility, and gas impurity composition. Because of this, the engineering methods used to generate microclimates are more complicated. Eventually, this causes the energy bills to rise.

## 2. Path of optimization

We must be able to adapt if we want to keep our capacity to progress. This may be accomplished by coordinating engineering systems and their modes of operation, as well as by using multivariate selection of kinds of engineering systems based on logic

*Journal of Science and Technology*
*ISSN: 2456-5660 Volume 7, Issue 07 (July -2022)*
*www.jst.org.in* *DOI:https://doi.org/10.46243/jst.2022.v07.i07.pp27- 35*

circuits.
The optimization path begins with enhancing the precision of engineering system design calculations. To begin, it is a comprehensive database of mass and heat balances. When working with precise calculations, it is recommended to minimize the amount of data points used as references. What is the bare minimum of necessary benchmarks? There is a collection of defining circumstances (2-4 modes) throughout the transitional times, as well as the polar opposites of the warm and cold seasons. Taking these hourly and systemic balances into account is the suggested approach, but only for a limited set of common cases (the extreme days). Every piece of information needed to calculate the power of various HVACR-devices will be located. Additionally, the collaboration of various HVACR-systems will be evaluated using a well defined range of parameter adjustments.
Choosing the right kinds of engineering systems, along the given route, is also a rational option. This decision is made at the same time that the mass and heat balances are being built along the optimization route. The appointment of premises is, of course, the most important issue. Decisions on the layout of the area are therefore being processed. Here we are also seeing a localized enhancement of structural remedies. However, it is important to consider the effects of the HVAC systems' interaction in the early design phases as well. Because of this, we must include these details when calculating balances. Furthermore, we need to decide on passive energy-saving measures to adopt at this point. The projected payback duration of such an occurrence, even with the discount, has a genuine impact in most circumstances; it is exhaust air heat recovery. The buildup of heat and "cold" (which always results in reduced capital expenses) is happening. Last but not least, this route involves optimizing technical and economic aspects when designing engineering system parts (such as ducts, pipes, diffusers, and radiators). Designers must put in a lot of time and effort to implement all of these precautions. But look at the outcome you can achieve! Lastly, the first year of the building's exploitation phase is when control algorithms of engineering systems should be established. During their first year of existence, babies rely on "the parents" for support while they develop their bodies. Much like living things. In this particular instance, it also ensured the cost-effective documentation of every genuine building characteristic and its lifespan. A departure from the use of hourly weather data is warranted in this instance.

## 3. Compilation of the heat and mass balances

The main components of these balances are the heat losses and gains, flows of supply and exhaust air.

In terms of heat losses, there are:

- Transmission heat losses with a detailed application of an elemental approach [2] (we consider all thermal bridges, including and linear, and point thermal bridges);
- Ventilation heat losses (infiltration component is accounted depending on the type of ventilation systems and their balances with using the logic laws of conjunctions and disjunctions).

Moreover, forming mass balances can be performed with this criterion. For example, we can take into account the infiltration part when selecting of air supply valves and fanlights of natural ventilation systems.

In terms of heat gains, there are:

- Solar radiation heat gains (as you know even on a cold cloudy day there is some guaranteed share of diffuse solar radiation);
- Various domestic heat gains (the accuracies degree of calculations of heat gains from people, lighting, electronics can be changed).

To create a complex picture, we add into heat balance the heat load required to provide domestic hot water supply. In addition, we can consider the additional cost of electricity as needed. In case, when it solved the problem of determining the annual operating costs and the payback period of energy efficiency engineering measures.

The heat balance components fixed in the regulatory documents of Russia [3] and the world [4, 5] are virtually identical.

## 4. Work progress on a real example

The object that is selected for the visual presentation of our calculations is a commercial and office building with a restaurant. It is the three-story building with a cellar. In the cellar there are mainly auxiliary and technological premises, and bank branch. On the first floor there is retail space. On the second floor there is the shopping area and a restaurant. On the third floor there is an office area.

Fig. 1. Location of the object.

The object is located near from Moscow (about 2 km from capital, see fig.1).

Moscow climate characterized by cold winters and rather hot summers. A few parameters adopted as design values can be seen in tab. 1.

Table 1. Moscow climatic characteristics

| Moscow climatic characteristics | Cold season | Warm season |
|---|---|---|
| Air temperature (design, at winter: the coldest five days temperature), °C | -28 | 26 |
| Amplitude of the air temperature (daily maximum), °C | 6,3 | 10 |
| Relative humidity, % | 85 | 74 |

Effective work progress based on the selection and calculation of the peak modes. But it is impossible to get a complete picture of the simulated modes without qualitative solutions for engineering systems. So, logical choice of engineering systems carried out in parallel with the calculation of extreme days. Logical operations in this paper is not carefully considered. The set of conditions is based on the requirements of the internal parameters of indoor climate. And, it is taking into account the additional conditions. For example, it is impossible to simultaneously heat or cool a single room. At the same time, engineering systems should ensure the simultaneous heating and cooling for different areas of the building, and as well as year-round hot water supply. Collected conditions placed in logical equations. Then we solve them and get the best version applied engineering systems. At this stage, it is possible to compare different energy efficiency measures for payback. In the comparison, we can use advanced solutions for systems using solar energy [6].

For the considered building heating system uses a surface heating panels, which pipes are hardwired into floor slabs. The ventilation system is divided sequentially for «propulsion» air handling units and «fan-coil» fans. Moreover, these electronically commutated «fancoil»-fans are connected with carbon dioxide sensors in the premises. As the cooling system, there are channel fancoil blocks. Chiller of the cooling system has a remote condenser that is the decorative fountain in the area around the building, which is calculated as a spray pond.

Should be noted to the fact that the building is provided with an increased level of comfort (including due to the increased radiation surface temperatures in the buildings, produced by floor-ceiling heating systems with high radiation part of heat transfer).

## 5. Compilation of the heat balance for the cold season (extreme mode)

We simulate the most disadvantageous design situation within 24 hours (day and night). All other days can show hidden (possible) potential to reduce energy consumption, and can not participate in the design loads on HVAC systems.

To construct the graph of the winter mode, we use a number of climatological data: the temperature of the coldest five-day week with a coverage ratio of 98%, the data on the amplitude of the minimum daily temperature for the coldest month. Calculation of the transmission component is done using a matrix method [7, 8], which takes into account all of linear and point thermal bridges of enclosure structures for all premises.

For example, we use specific heat transfer of enclosure $H_{tr}$, *W/°C*, (1) to calculate transmission heat losses:

$$H_{tr} = K \cdot A = \left[ \Sigma(A_i \cdot U_i) + \Sigma(L_j \cdot \psi_j) + \Sigma(N_k \cdot \chi_k) \right], \qquad (1)$$

where: $K$- heat transfer coefficient of external enclosures, *W/(m² °C)*;
$A$ - total area of external enclosures, $m^2$;
$A_i$ - area of the flat structural element (of $i$-th type), $m^2$;
$L_j$ - length of the linear thermal bridges (of $j$-th type), *m*;
$N_k$ - number of the point thermal bridges (of $k$-th type), *units*;
$U_i$ - heat transfer coefficient of the $i$-th uniform part of the enclosing structure, $W/(m^2\,^oC)$;
$\psi_j$ - specific heat losses through the $j$-th linear thermal bridge, $W/(m\,^oC)$;
$\chi_k$ - specific heat losses through the $k$-th point thermal bridge, $W/\,^oC$.

This method also allows to calculate and infiltration component, and actual ventilation component of ventilation heat losses [9]. Matrix method takes into account the orientation of the all facades and windows and the air pressure

*Journal of Science and Technology*
*ISSN: 2456-5660 Volume 7, Issue 07 (July -2022)*
*www.jst.org.in* *DOI:https://doi.org/10.46243/jst.2022.v07.i07.pp27- 35*

on the sides of all enclosures. Calculation of various additional factors linked to technical solutions. For example, about the device air curtains at the entrance. Calculation of the ventilation component being based on the use of heat recovery units under actual use (all settings are linked, and, if necessary, can be specified).

Accounting of diffuse solar radiation, the value of which even on a cloudy day would come into the rooms, also introduced in the calculation. For ventilation systems accounting of operation modes of the building: and the shopping halls, and office spaces.

The maximum design peak load for this example is about 383 kW. This point shows the maximum design value for the selection of boilers and heaters. More information about the components of the heat balance of buildings («cold period») you can see in fig.2 and tab.2.

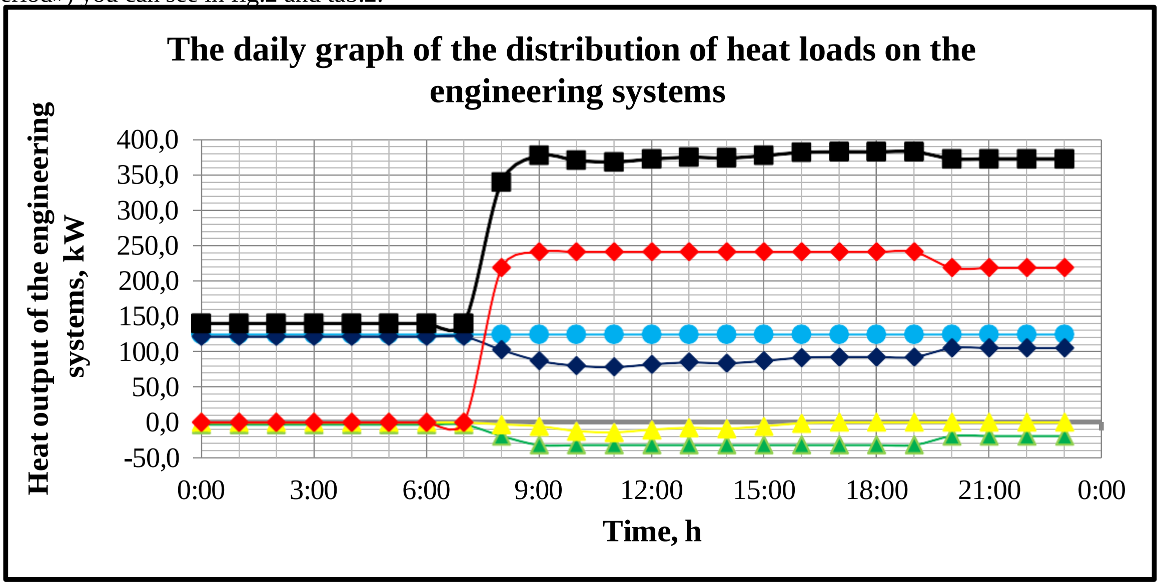


Fig. 2. The daily graph of the distribution of heat loads on the engineering systems.

Table 2. Keys to the graph of CP («cold period»).

| | |
|---|---|
| | Domestic heat gains |
| | Solar heat gains |
| | Transmission and infiltration heat losses |
| | The resulting load on the heating system |
| | Actual ventilation heat losses |
| | Total (hot water supply inc.) |

**6. Compilation of the heat balance for the warm season (extreme mode)**

As the design value, we take sunny day with the maximum heat gain from solar radiation.

For the warm season and, consequently, for the maximum «summer» peak load in the calculation of the heat balance transmission component is introduced which occurs when the outdoor temperature exceeds the temperature of indoor air. Thus, the model takes into account the changing nature of the outdoor temperature, and consequently heat transfer losses and gains for 24 hours.

To optimize cooling and air-conditioning systems load arising due to the ventilation part delegated to the air cooler of the central air handling units. «Cooling» power for the central air conditioning and for the local fancoils is assigned to the chiller. The remote condenser is used as a decorative fountain in the area around the building. The decision of the customer and designers in this case has been optimized for the needs of refrigeration system.

The maximum peak load for this mode is about 278 kW. This point shows the maximum design value for the selection of chiller and cooling systems elements. More information about the components of the heat balance of buildings («warm period») you can see in fig.3 and tab.3.

It should be noted that the effect of heat absorption of enclosing structures did not consider. This is due to a significant coefficient of facades glazing. The large value of this coefficient eliminates the offset of the temperature maximum of premises. Moreover, the physical nature of the phenomenon of heat absorption does not increase the overall size of the «cooling» load, especially when there is a large amplitude of the outdoor temperature (during the day).

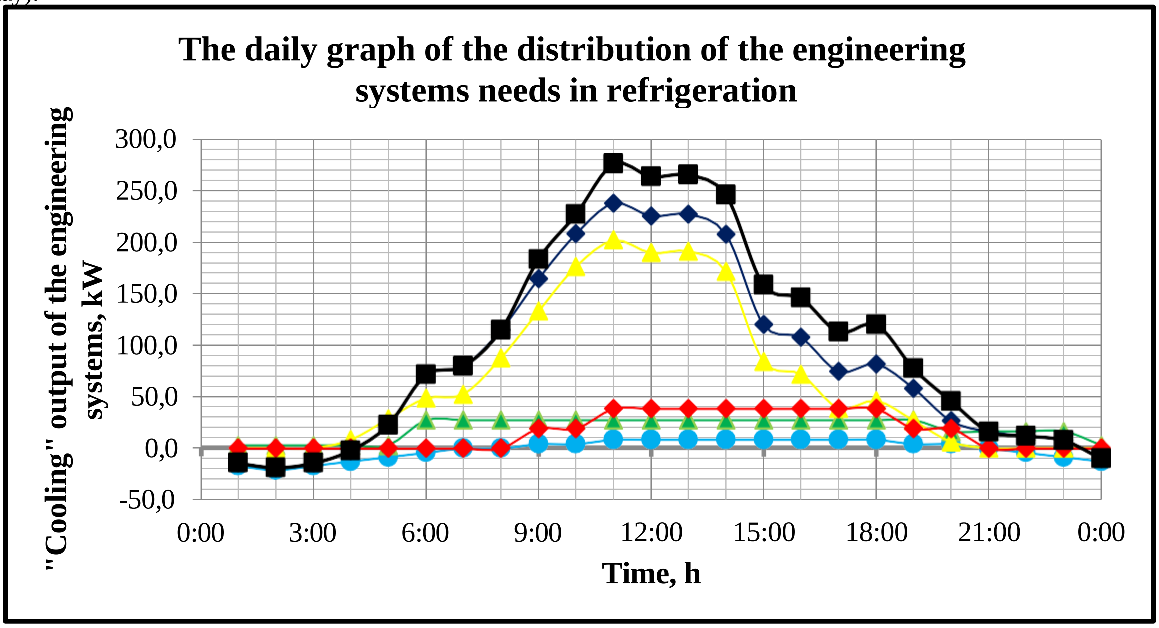


Fig. 3. The daily graph of the distribution of the «cooling» needs of the engineering systems.

Table 3. Keys to the graph of WP («warm period»).

| | |
|---|---|
| (green) | Domestic heat gains |
| (yellow) | Solar heat gains |
| (light blue) | Transmission heat gains/ losses |
| (dark blue) | Resulting load on the air-conditioning system (local part) |
| (red) | Ventilation heat gains/ losses (central part) |
| (black) | Total (hot water supply inc.) |

## 7. Compilation of the heat balance for the intermediate season (extreme mode)

For the correct determination of the different modes of engineering systems operation it is also necessary to consider the intermediate case. In Russia, this case is fixed by regulations. It is the case when the outdoor temperature is 8 Celsius degrees (for most types of buildings). Supply part of the ventilation systems still needs to be heated at this outside air temperature. The quantity of the direct and diffuse solar radiation has already reached significant values. In addition, the daily amplitude of the outdoor temperature can exceed 10 Celsius degrees. This means a significant

*Journal of Science and Technology*
*ISSN: 2456-5660 Volume 7, Issue 07 (July -2022)*
*www.jst.org.in* *DOI:https://doi.org/10.46243/jst.2022.v07.i07.pp27- 35*

change of transmission and some infiltration heat losses in this period of the year (change of direction). Moreover, we should take into account some additional stock in heating-cooling loads that we have during the transition of the optimal parameters of the microclimate from the cold season to a warm season and vice versa.

The maximum peak load for this mode (and for heat, and for cooling needs) is about 274 kW. This is comparable to extreme «warm mode». This point shows the maximum total amount of energy consumption of engineering systems and allows detecting the limits of collaboration cooling and heating systems. A little more information about the components of the heat balance of buildings («intermediate period») you can see in fig.4 and tab.4.

Black line schematically shows the general «cardinality» costs of the engineering systems.

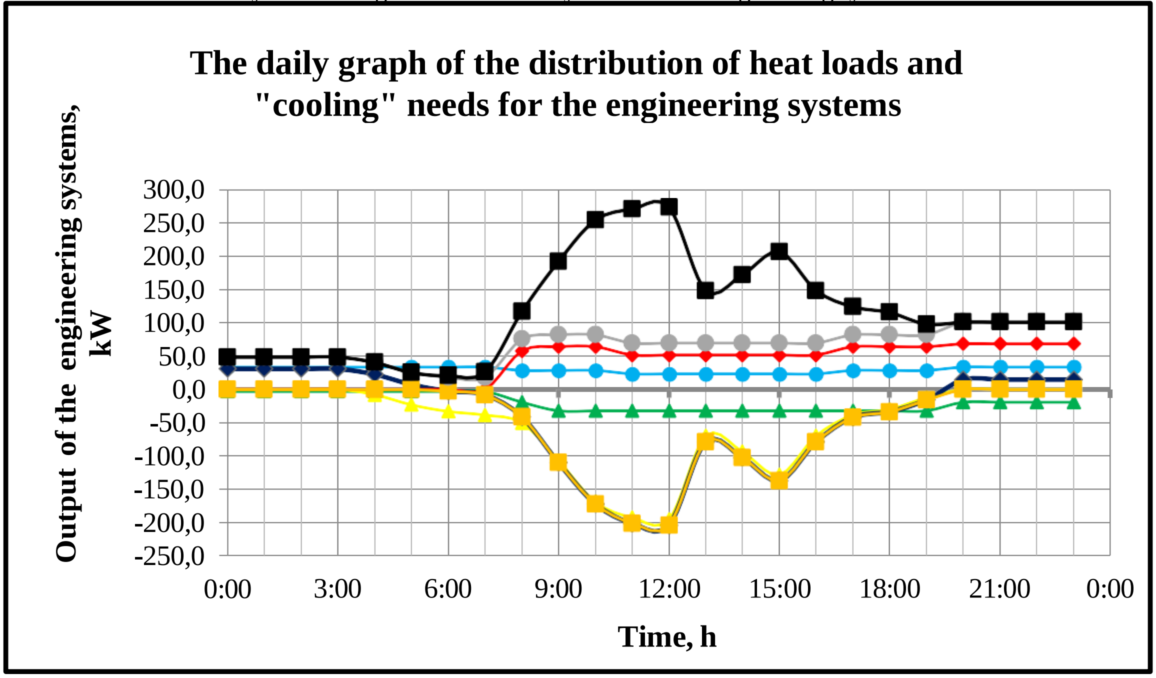


Fig. 4. The daily graph of the distribution of heat and «cooling» needs of the engineering systems.

Table 4. Keys to the graph of WP («warm period»).

| | |
|---|---|
| (green) | Domestic heat gains |
| (yellow) | Solar heat gains |
| (light blue) | Transmission heat losses |
| (dark blue) | Resulting load on the air-conditioning system (local part) |
| (red) | Needs for central cooling of the supply air |
| (grey) | Total (for heat supply, hot water supply inc.) |
| (orange) | Total (for refrigeration) |
| (black) | Total |

**8. Additional modes – check**

Additional modes are not required for the considered object. Considered modes completely describe all regimes of the complex working of the engineering systems for this building in the area of construction with the maximum outputs during the year.

Generally, the amount of modes required for the calculation is determined by climatological characteristic of the area. It may be another day of the intermediate season with cloudy weather. In such a case, there can be significant heating loads. It is also possible that there are simultaneous loads of heating and cooling systems for different premises of the building. This is true for buildings located in areas with rather long winters (like Moscow).

Also, it is necessary to prevent the simultaneous operation of heating and cooling systems for one room. It also allows determining the necessary performance range for selection control devices and elements of automation systems.

**9. Matrix method. Operational energy costs**

The matrix method for compiling the thermal balances of the building premises - is an approach, where the heat flow characteristics of the building premises presented as a concentrated parameters and distributed in a strictly organized matrices. These matrices use many data on the various components of heat balances. Strict location of the data allows collecting all the mass and heat balances for areas isolated.

Matrices can successfully take into account the transmission component in terms of heat transfer through the internal enclosures. With matrices it is easy to use operations of logical addition and multiplication for calculation of the ventilation component of the heat losses. Matrix method provides simultaneous and separate calculation of heat balances for each premises of the building. This method is the work with real big data.

Matrices of the hourly layout of the maximum modes by using degree-days data solve the problem of the definition of operational energy costs for each month.

**10. Application of the heat and «cold» accumulation systems. Levelling peak loads**

As far as technical solutions go, heat and "cold" accumulators are among the most intriguing options for drastically cutting costs. Using the same machinery for accumulators, heat supply, and refrigeration is the best option. Since water is required as a coolant, this restricts the kinds of engineering systems that may be used. But it's a green solution. During the intermediate stage, the needed load capacity for the item in question was determined by conducting a thorough analysis of the various operating modes of engineering systems. The accumulation systems made use of twenty tanks, each with a capacity of five hundred liters. Vehicles transporting power tanks use a cross-flow system equipped with vehicles-off valves. Because of this, these "rechargeable water-batteries" may serve dual purposes: powering HVAC systems and cooling systems separately. Power tanks are supplied by four main pipelines, even when they are working simultaneously. The home hot water demands of a day are also met by these tanks. The floor slabs are subjected to a dispersed load by virtue of the modest tank capacity. The UEC, or unified energy center, sits atop these buildings. All HVACR-system components are kept below two meters in height. This contributes to the building's visual attractiveness.

It is possible to include the daily load under the worst circumstances using constructed heat balances. That way, we may find ways to accumulate. The decision-maker is primarily accountable for the winter load because of the specific dependability requirements.

Thus, an integration operation has been completed. Applying the heat accumulation will put 356 kW of demand on the boilers. Saving 27 kW is achieved even in the coldest, most extreme setting! The volume of the tanks-accumulators was chosen for this value. We also factored in the cooling requirements and adjusted them for the selected "batteries" during the hot season in severe mode. It has been determined that the 249 kW-chiller is necessary. It is feasible to decrease the size of the spray pond that serves as the distant condenser in this scenario (via accumulation). Along with this, the amount of green space around the structure also expanded! The ratio of the "batteries" required when heating and cooling systems are operated in tandem was determined by integrating data based on the heat balance over the intermediate time of the year. The operating load was lowered to 30 kW throughout the year. The typical dimensions of HVAC, refrigeration, and air-conditioning systems have been shrunk.

The analysis is based on the integration in this section of the job progress. Add up all the daily loads, and you get the building's energy requirements and its accumulation restrictions. Also, the system's accumulators cut down on energy use even further. While structures are in operation, we never tap into the hidden reserve that we lose. Boilers and chillers work more efficiently with energy accumulation for medium modes than without it.

**11. A little bit about the complex optimization**

At the level of city planning is important to take into account the peculiarities of development of fuel and energy complex of the area. Features of the object for fuel supply, district heating supply and electro supply should be considered when selecting the types of engineering systems for buildings.

Firstly, we must make some additions to the accompanying electrical loads that are needed for the operation of engineering systems (engines of pumps, fans and compressors) and implement their values in the heat balances.

When we solve the energy problems in relation to a particular location, we can easily see when we need to move the loads in the direction of increasing electrical energy consumption or heat. Alternatively, we can provide the fuel supply to the building itself. Then the value of the correct choice of engineering systems is increasing! Moreover, now it is possible to link it with the energy capacity of the country, with the features of the development and transportation of fuel and energy even for the first ideas of building cities.

Considered retail and office center was near the special threads of the gas pipeline and rather close to electrical power lines. Due to the nature of tariffs in Russian Federation for the energy provision of this building it was very cost-effective to create its own energy center.

**12. Basic idea**

The energy design optimization route is detailed and laid out in theses. A thorough evaluation of the project's requirements is required for a good construction, and this includes: - calculating the premises' heat balances using the matrix approach;
- Putting together all-out everyday modes;
- Using the datasets that have been produced, determine the energy usage.

Logic operations are included at each level of the computation to produce a genuine and accurate report. For principled decision-making and parameter optimization in engineering systems, these processes are helpful. Converting matrices to big data is an option if needed. For the energy design of the entire city.

**References**

[1] "Building climatology" (SP 131.13330.2012). Revised SNIP 23-01-99*, Moscow, 2013.
"Thermal performance of the buildings" is referenced in SP 50.13330.2012. Moscow, 2012, revised SNIP 23-02-2003.
[3] "Heating, ventilation and conditioning" is detailed in SP 60.13330.2012. Moscow, 2012, revised SNIP 41-01-2003.

(4) The European Standard EN ISO 13790:2008. Assessing a building's energy efficiency: determining how much power is required to heat and cool a given area. year 2008.

[5] Energy efficiency and resource needs for building heating systems: a method for 2007 (EN ISO 1531

6). In 2013, A. Walker published Solar Energy: Technologies and the Delivery of Building Projects with Wiley in New Delhi.

[7] The authors of the article "Improving the accuracy of the calculation of thermal capacity of heating systems when designing the buildings with high-energy efficiency" (Gagarin V., Neklyudov A.Y., 2015, Г. 39, № 2, С. 79-87) discuss methods to improve the precision of thermal capacity calculations in certain contexts.

[8] V.G. Gagarin and A.Yu. Nekludov, Taking Enclosure Thermal Bridges into Consideration When Calculating Heating System Demand for the Issue 6, pages 3–7 of Building, Zhilishchnoe Stroitel'stvo [Housing Construction], 2014. This is being spoken in Russian.

[9] The use of the matrix approach to determine the ventilation component of the building's thermal load on the heating system was discussed in a 2014 article by Gagarin and Neklyudov in the journal Promyshlennoye i grazhdanskoye stroitel'stvo (Industrial and Civil Engineering), volume 7, issue 7, pages 21–25. This is being spoken in Russian.