VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Violeta MISEVIČIŪTĖ

EVALUATION OF POSSIBILITIES FOR PROCESSES INTEGRATION IN VENTILATION EQUIPMENT

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Scientific Supervisor

Prof Dr Habil Vytautas MARTINAITIS (Vilnius Gediminas Technical University, Technological Sciences, Energetics and Power Engineering – 06T).

Consultant

Prof Dr Egidijus Saulius JUODIS (Vilnius Gediminas Technical University, Technological Sciences, Energetics and Power Engineering – 06T).

The dissertation is being defended at the Council of Scientific Field of Energetics and Power Engineering at Vilnius Gediminas Technical University:

Chairman

Prof Dr Habil Rimantas KAČIANAUSKAS (Vilnius Gediminas Technical University, Technological Sciences, Energetics and Power Engineering – 06T).

Members:

Prof Dr Habil Benediktas ČĖSNA (Vilnius Gediminas Technical University, Technological Sciences, Energetics and Power Engineering – 06T),

Assoc Prof Dr Arnas KAČENIAUSKAS (Vilnius Gediminas Technical University, Technological Sciences, Mechanical Engineering – 09T),

Dr Robertas POŠKAS (Lithuanian Energy Institute, Technological Sciences, Energetics and Power Engineering – 06T),

Prof Dr Habil Stasys ŠINKŪNAS (Kaunas University of Technology, Technological Sciences, Energetics and Power Engineering – 06T).

Opponents:

Prof Dr Habil Gintautas MILIAUSKAS (Kaunas University of Technology, Technological Sciences, Energetics and Power Engineering – 06T),

Prof Dr Habil Petras VAITIEKŪNAS (Vilnius Gediminas Technical University, Technological Sciences, Environmental Engineering – 04T).

The dissertation will be defended at the public meeting of the Council of Scientific Field of Energetics and Power Engineering in the Senate Hall Vilnius Gediminas Technical University at 2 p. m. on 30 January 2012.

Address: Saulėtekio al. 11, LT-10223 Vilnius, Lithuania.
Tel.: +370 5 274 4952, +370 5 274 4956; fax +370 5 270 0112;
e-mail: doktor@vgtu.lt

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

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Mokslinis vadovas

prof. habil. dr. Vytautas MARTINAITIS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, energetika ir termoinžinerija – 06T).

Konsultantas

prof. dr. Egidijus Saulius JUODIS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, energetika ir termoinžinerija – 06T).

Disertacija ginama Vilniaus Gedimino technikos universiteto Energetikos ir termoinžinerijos mokslo krypties taryboje:

Pirmininkas

prof. habil. dr. Rimantas KAČIANAUSKAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, energetika ir termoinžinerija – 06T).

Nariai:

prof. habil. dr. Benediktas ČĖSNA (Vilniaus Gedimino technikos universitetas, technologijos mokslai, energetika ir termoinžinerija – 06T),

doc. dr. Arnas KAČENIAUSKAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, mechanikos inžinerija – 09T),

dr. Robertas POŠKAS (Lietuvos energetikos institutas, technologijos mokslai, energetika ir termoinžinerija – 06T),

prof. habil. dr. Stasys ŠINKŪNAS (Kauno technologijos universitetas, technologijos mokslai, energetika ir termoinžinerija – 06T).

Oponentai:

prof. habil. dr. Gintautas MILIAUSKAS (Kauno technologijos universitetas, technologijos mokslai, energetika ir termoinžinerija – 06T),

prof. habil. dr. Petras VAITIEKŪNAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, aplinkos inžinerija ir kraštotvarka – 04T).

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Adresas: Saulėtekio al. 11, LT-10223 Vilnius, Lietuva.
Tel.: (8 5) 274 4952, (8 5) 274 4956; faksas (8 5) 270 0112;
el. paštas doktor@vgtu.lt

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Introduction

Topicality of the problem. Buildings consume about 40 % of final energy used in the European Union and emit approximately the same amount of carbon dioxide. The biggest part of primary energy is used in building engineering systems (up to 90 %) in the viewpoint of a lifecycle.

As the demand of final energy increases, the resources of primary energy decrease. The demand of energy will rise, as the forecast shows, owing to the number of people, the level of comfort as the reason for spending more time in the buildings. Intensive use of energy is related to the inefficient use of processes in the building engineering systems.

Commonly active and passive microclimate systems for the building are designed without the consideration of the integration of the processes during their design phase. Each system is designed without proper estimation of the influence they have on each other. The integration of conventional processes used for industrial processes covers basic research tasks for heat exchangers, closely linked to optimization and identification methods. The integration of processes is described as an action which is aimed at joining the streams of different building engineering systems. The results of the solution to this problem have a considerable effect on the creation of an algorithm for the evaluation of the integration of the processes.

According to the research review, Pinch analysis was first applied for integrating the building engineering systems. Solving the problem of optimization of building engineering systems performance from the viewpoint of efficient energy use, energy demand, parameters, and the pattern of change or the pattern of control impact change for engineering systems are determined. Entirely classical methods are insufficient to solve the tasks that are suitable for the research of traditional systems as they are becoming bigger and more complex. The technique for the integration of industrial processes could be applied to small scale energetic systems, especially if there are various energy streams in building processes. Better energy use indicators in building engineering systems may be achieved through the rational integration of streams, i.e. by formatting an effective heat exchangers network. It is noted that modes of these systems in comparison with industrial systems are related to variable outdoor air parameters.

Object of research – the integration of ventilation equipment in public buildings and the processes in them as well as other engineering systems‘ waste heat streams.

Aim and tasks of the work. The main aim of this work is to evaluate the possibilities of applying the method of the integration of processes in order to define and improve the thermodynamical effectiveness of the public building engineering systems‘.

The tasks of the work are:

1. To define the problematic building engineering systems, their equipment and processes from the viewpoint of energy efficiency.
2. To define the characteristics of project-based solutions of the building ventilation systems which require energy supply.
3. To assess the possibilities and properties to use conventional methodology for the integration of processes – Pinch analysis – for the building engineering systems.
4. To create the algorithm to define the thermodynamically optimal integrated solution of building engineering systems, combining the thermodynamical and Pinch analyses.

Methodology of research. Systematic, thermodynamical (exergy) and processes integration (Pinch) methods are applied in the work. A systematic analysis enables us to define systems’ elements and their interconnections. The exergy analysis allows to perform a thermodynamically-based assessment of different quality of energy. The analysis of process integration (Pinch analysis) permits to use the procedures applied in industrial processes to define thermodynamically optimal network of heat exchangers.

Scientific novelty

During the preparation of this work these new results for power engineering science were obtained:

1. The methods which interconnect the finding of a solution of energy efficient building engineering system with the suppositional combination of stream parameters are applied in process integration. Patterns of integrating ventilating equipment as the energy intensive facilities are presented.
2. The Pinch method, which up to now has been used for industrial processes, was applied for the first time to optimize heat recovery in the network of ventilation system heat exchangers, to find the combination of streams and to integrate the processes in building engineering systems.
3. By means of the methodology prepared in this work, the necessity for integration of new or existing building engineering systems is

evaluated, determining the solution for the better seasonal thermodynamical (exergy) efficiency of the system.

Practical value. The results of the research may be used to solve the problems of the design of the heat exchangers of various building engineering systems, to define the optimal parameters for workable heat exchangers or their networks, the patterns of change, heat exchangers or the network of their operation dependency on the time in the combined climate zone buildings. The parameters of streams which perform in heat exchange may be known or found.

Defended propositions

1. Even though the Pinch method is increasingly used for the integration of industrial processes, it is practically unused for the processes in building engineering systems, although owing to its methodological basics and aim together with the thermodynamical (exergy) analysis, it should be applied in finding efficient integrated solutions of building engineering systems.
2. The properties of process integration in building engineering systems are settled by the change of the locality seasonal outdoor air temperature, the solution of the heat recovery unit of ventilation systems and their effectiveness. These properties define the temperature for determining the optimal network of heat exchangers and selecting the minimal temperature difference for heat exchangers.
3. The results obtained from the process integration and exergy analysis of building engineering systems have shown that the process integration has influence on the thermodynamical efficiency of the system and that integrated systems consume less exergy in comparison with the non-integrated ones.
4. The suggested algorithm is meant for evaluating the complex integrity of processes in building engineering systems. This algorithm may be applied in the minimization of exergy streams used in buildings so it may be applied while designing the engineering systems of a building. The process integration encourages to use low potential heat streams (it is often waste heat in buildings), and this allows us to use the heat streams found in buildings rather than the traditional heat streams supplied by high parameters.

The scope of the scientific work. The scientific work consists of the general characteristics of the dissertation, 4 chapters, general conclusions, a list of literature and a list of publications. The total scope of the dissertation is 108 pages, 62 pictures and 7 tables.

1. Survey of the research works of processes integration in building engineering systems

This chapter covers the review of process integration in building engineering systems, the analysis of process integration, ways of optimizing in mentioned systems, methods for process integration and their properties.

In this work process integration is defined as a combination of processes in building engineering systems. The integration of processes in building engineering systems may be attained by combining new systems or (and) creating new systems.

Public buildings and their engineering systems consume from 32 % to 50 % of energy. Up to 38 % potential of energy saving exists in these buildings. The air tightness of modern buildings determines the increase of ventilation in the buildings, therefore an amount of energy for ventilation may reach up to 50 % of energy used in the building.

The techniques of the integrity of building engineering systems are explored in different ways, besides, they commonly deal with new and renewable energy resources used for the installation in the existing or design systems.

Generally, energy (heat, electricity or both) production systems are less integrated while building engineering systems. Process integration is necessary in building engineering systems as there are possibilities to create combinations of systems and new systems that use natural resources more efficiently from the point of view of energy quality.

Thermal processes from the viewpoint of energy transformation are inefficient processes. They use high parameter (temperatures) streams for the processes performed, whereas the same result may be obtained using lower parameter streams. According to the process integration frequency, these processes are the ones that are commonly integrated.

One of the goals for the efficient use of energy in building engineering systems is minimization of exergy streams. According to the fact that the biggest part of the world's energy is used for heating and cooling of buildings, it is necessary to search for the ways to minimize exergy streams in the mentioned systems to increase the efficiency of the use of energy.

The analysis of the methods used for process integration has shown that the exergy and Pinch analysis methods are acceptable as a tight interrelationship exists between them: the parameters are used for the analysis and simple application in the research of building engineering systems. The results obtained using the methods of the log-mean temperature difference (LMTD) and the number of transfer units (NTU) for the analysis of heat exchangers is equal, whereas the NTU method in comparison with the LMTD is simpler. The exergy and Pinch analysis may define in more detail the indicators for efficient energy use of the systems of heat exchangers or the systems which use them.

2. Properties of processes integration use in building engineering systems

The most energy intensive processes in building engineering systems are related to energy transformation equipment: heat exchangers and heaters. Therefore, these elements are explored in this work. Most attention is paid to heat exchangers used in ventilation systems as the hand potential for energy saving or increasing the thermodynamical efficiency of the systems lies here.

The mechanical ventilation systems are generally used to ventilate public buildings. As the base case for the analysis of ventilation systems, the system with heat recovery is chosen. The different ventilation systems with various heat exchangers (Fig. 1) were explored. The ventilation system with plate rotary heat exchangers (on the top in Fig.1) is the most often used. New improved schemes used for heat recovery with run around coil heat exchanger have the advantage of using waste heat (on the bottom in Fig. 1).

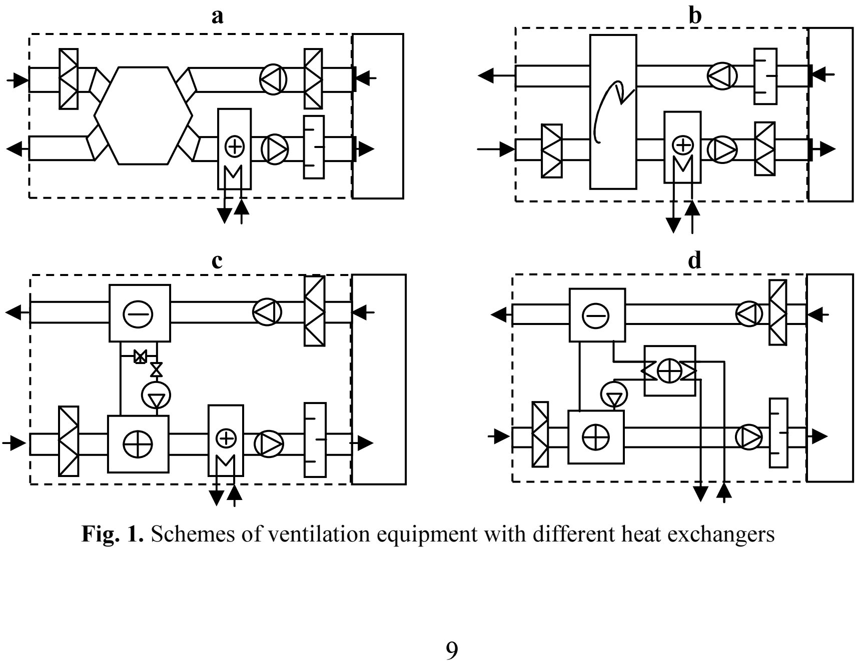

Fig. 1. Schemes of ventilation equipment with different heat exchangers

The reliability of the data is one of the steps required in the Pinch analysis. These data may be obtained from the climatic and building energy management systems (BEMS) if the existing system is explored. The unknown data may be evaluated from the heat balance equation. The proper data for the Pinch analysis are represented in Fig. 2.

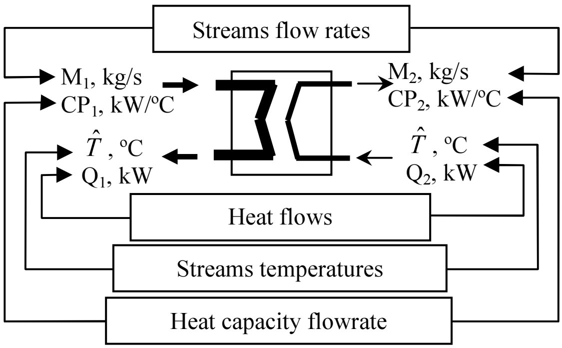

Fig. 2. Data for processes integration analysis

If new building engineering systems are designed, such data as thermal capacities and stream temperatures may be predicted.

This chapter also describes the indicators (climate conditions, dependency on it) which have influence on energy consumption in building engineering systems.

The sequence of the Pinch analysis applied in thermal industrial processes is presented. The ways of data extraction are presented if existing or new systems are examined. The application of waste heat in process integration in building engineering systems is explored.

The main waste heat sources in the building are supplied to and return from the heating system heat stream, return domestic hot water, technological or sewage water, heat pump, cool tower and waste heat of a chiller. Some of these waste heat sources are explored in this work. The most applicable is the use of return heat stream of the heating system.

3. Analysis of ventilation systems processes integration results

This chapter covers the analysis of the results of process integration in ventilation systems. According to the simplified air handling unit scheme with rotary heat exchanger, the temperature for the maximal exergy demand for air heating is determined. This temperature definitely depends on climatic conditions and is equal to 3 °C for the public building in the moderate climatic zone.

The relation between the minimal temperature difference and temperature effectiveness of a heat exchanger was determined and may be written by the equation (1):

$$\Delta\hat{T}_{\min} = f(\varepsilon_t) \leq \frac{\hat{T}_3 \cdot (1-\varepsilon_t) - \hat{T}_1 + \hat{T}_4 \cdot \varepsilon_t}{\varepsilon_t + 1} \tag{1}$$

where ε_t – the temperature effectiveness of a heat exchanger; $\Delta\hat{T}_{\min}$ – the minimal temperature difference; $\hat{T}_1$ – the temperature of the outdoor air; $\hat{T}_3$ – the temperature of the extracted air from the room; $\hat{T}_4$ – the temperature of the exhaust air from an air handling unit.

This minimal temperature difference for heat exchangers used for heat recovery is recommended close or equal to 5 °C as a bigger difference influences the disappearance of a heat exchanger.

According to the Pinch analysis, process integration is assessed in terms of different schemes of air handling units and waste heat combinations. The analysis has shown that simple plate or rotary heat exchangers should not be analyzed using process integration as the possible achieved result could be obtained using the heat balance. So the use of run around coil heat exchangers was proposed for the research of the possibilities to use waste heat for process integration in air handling units as well as in building engineering systems.

The scheme for process integration in building engineering systems was arranged and adopted for the analysis of these systems (Fig. 3). The hot streams (H1, H2) are represented in the upper side from the left to the right (above horizontal dotted line), cold streams (C1, C2) conversely. The vertical dotted line represents the Pinch point for hot streams (PPH) and for cold streams (PPC). The basic network of heat exchangers (presented by the line connecting circles) may be the same as in the rectangle (Fig. 3). The Roman number (at the top of the circle) is the number of the heat exchanger, the numerical value (at the bottom of the circle) – its capacity (Fig. 3).

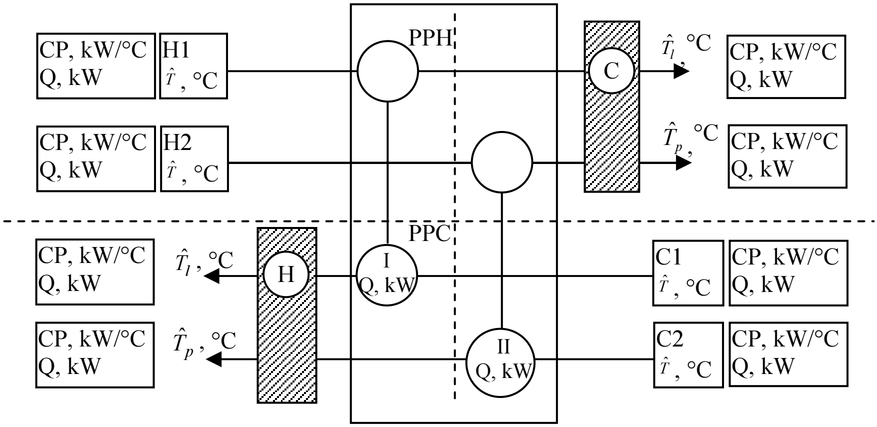

Fig. 3. Principal scheme of Pinch analysis for processes integration – net diagram of heat exchangers network

The disposable streams (H1, H2, C1, C2) and their initial temperatures presented in small rectangle. The final temperatures of streams may be obligatory $\hat{T}_p$ or voluntary $\hat{T}_l$. The first ones should be strictly maintained as the other ones may differ from the selected for the analysis. The selection of the voluntary temperature can affect the use of additional heating (H) or cooling (C) equipment. If the heat exchangers can not to satisfy the process final temperature these equipment should be used. They should be placed exactly in the respective place of the hatched area (Fig. 3). The numerical values in the left columns of the scheme (Fig. 3) mark heat capacity flowrate (on the top) and the heat flows (on the bottom) above Pinch point. These values on the right columns present the same quantities below the Pinch point.

In this work the scheme presented in Fig. 3 is adopted to be used for heat exchangers' network formation by integrating processes in building engineering systems.

Using the temperature obtained for the maximal exergy demand, the process integration is performed for the different combinations of waste heat. When the total heat exchangers' thermal transmittance is the minimal, the optimal result is presented in Fig. 4. The network of heat exchangers covers four heat exchangers those perform heat exchange in the air handling unit.

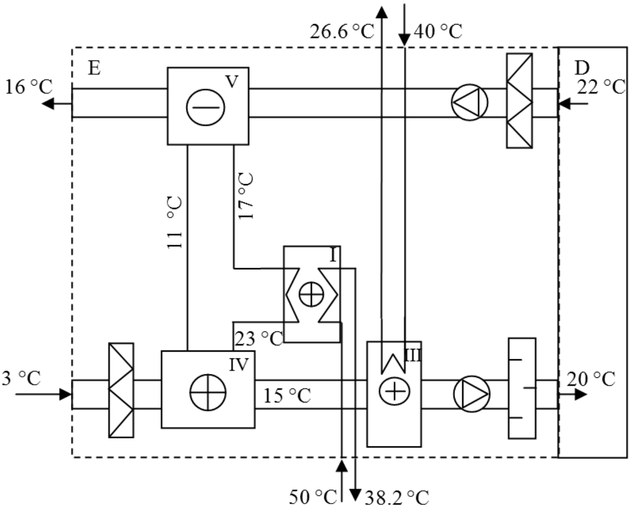

Fig. 4. Air handling unit with run around coil heat exchanger after the processes integration

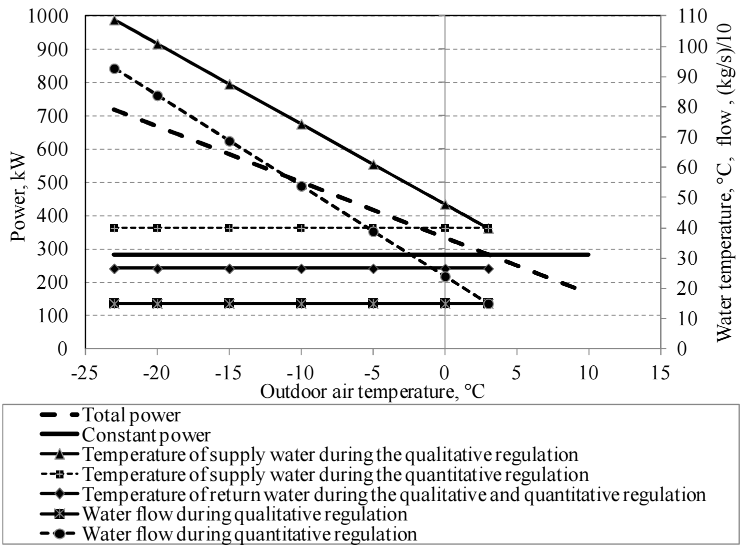

Fig. 5. Heat demand at various outdoor air temperatures

Suggestions for the performance of the air handling unit at other outdoor temperatures are presented. The regulation of the water flow of III heat exchanger is organized using qualitative (Fig. 5) or quantitative regulation of the flow. According to the data obtained in Fig. 5, the energy and exergy demand for non-integrated and integrated systems are evaluated and compared (Fig. 6).

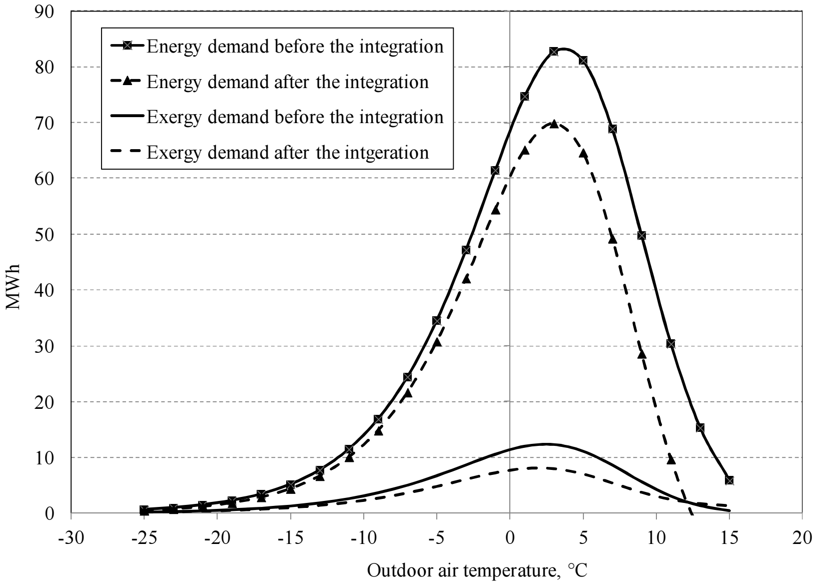

Fig. 6. Energy and exergy demand before and after the integration at various outdoor air temperatures

The total energy demand before the integration in comparison with its demand after the system integration differs 1.26 times. The total exergy demand is bigger 1.45 times before the integration. The difference between the demand of energy and exergy in both cases, i. e. the integrated and non-integrated systems, may be explained by means of the mixed regulation used for the water flow of the non-integrated ventilation systems water in the heat exchanger after the heat recovery unit (Fig. 1, c scheme). The reason for energy overuse may be related to the quite great duration of the hot period temperatures.

4. Algorithm for processes integration in building engineering systems

This chapter covers the algorithm, recommendations and comparison of the research results with other research in the area of process integration in buildings' engineering systems.

As the research review has shown, the energy demand for ventilation systems is growing as stricter restrictions for building envelope thermal characteristics are determined. The algorithm (Fig. 7) for the minimization of exergy in these systems by integrating processes in the air handling unit is created.

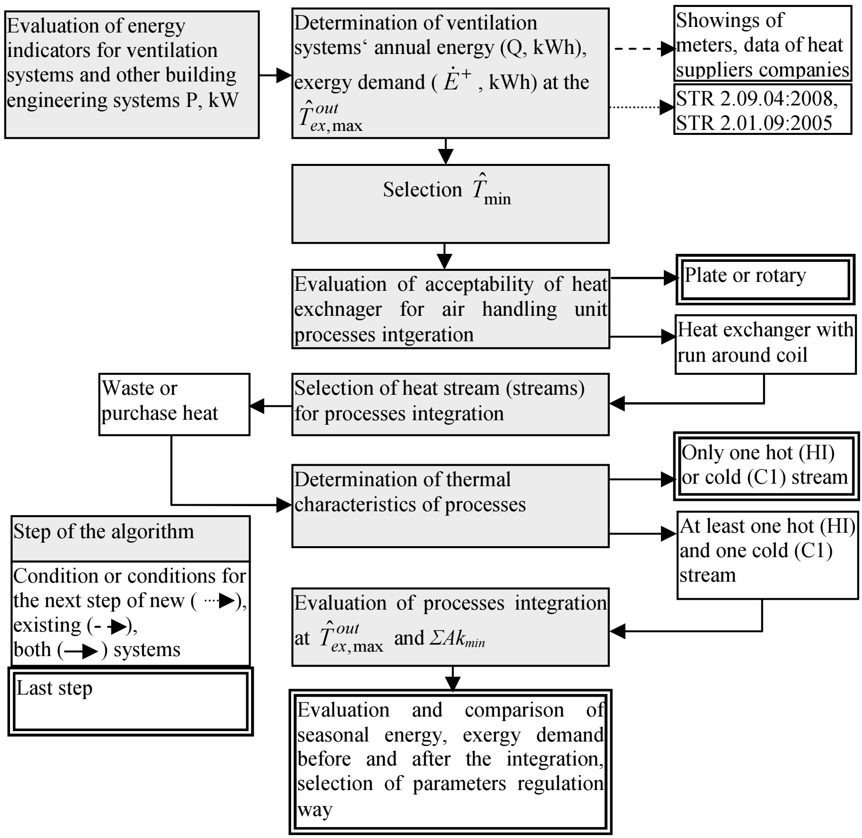

Fig. 7. Algorithm for processes integration in building engineering systems

The created algorithm for process integration in building engineering systems (Fig. 7) may be applied to integrate public as well as the processes in industrial buildings' engineering systems.

Outdoor air temperature that satisfies the maximal exergy demand is marked by $\hat{T}^{out}_{ex,\max}$, the minimal temperature difference – $\hat{T}_{\min}$ and the total minimal thermal transmittance of heat exchangers ΣAk_{min}.

The recommendations for process integration in building engineering systems are described. These recommendations may be applied or used as a simplified evaluation of process integration in the ventilation system as well as in other buildings' engineering systems.

Comparison of the results with other researchers' and research. The comparison of the results obtained by applying exergy and process integration methods with the results of other researchers' Biekša (2008) and Torio *et al.* (2009) have shown the agreement of the results related to the intensive energy used in ventilation elements: heat recovery units and heaters. The comparison has also shown that the area of building engineering systems was first analyzed by means of the Pinch method for process integration in the above-mentioned systems.

General conclusions

1. The review of the research in process integration field showed that there is a limited number of investigations in process integration in the field of building engineering systems and they are not applied in engineering practice. Therefore, the possibilities of the method used for process integration are analyzed in this work.
2. After performing the analysis of the research review and the comparison of the received results from the exergy analysis, it was determined that thermal processes and elements in ventilation equipment in which these processes are performed (heat exchangers, heat recovery units and heaters) are the most exergy intensive.According to research it was found that selection of a heat recovery unit used in ventilation equipment determines demand and possibilities of processes integration in ventilation equipment. The additional heat exchanger for one-stage plate heat recovery unit may be selected according to energy balance without application of processes integration procedures.
3. According to the research, it was found that the selection of a heat recovery unit used in ventilation equipment determines the demand and possibilities of process integration in ventilation equipment. The additional heat

exchanger for one-stage plate heat recovery unit may be selected according to the energy balance without applying process integration procedures.

4. It was found that the selection of the minimal temperature difference between streams is especially important for process integration procedures, at marginal case for the ventilation equipment. According to the equations of the heat transfer and temperature effectiveness for heat exchangers, the dependence of the effectiveness of a heat recovery unit on the minimal temperature difference is determined. The close to 5 °C difference, lower than recommended for industrial systems (about 15 °C) is suggested for process integration in ventilation equipment.

5. Ventilation system consumes the maximum amount of thermal exergy during the heating season at the determined outdoor air temperature. In order to minimize the exergy expenditures the network of heat exchangers is optimized at this temperature. This outdoor air temperature for Lithuanian climatic conditions is about 3 °C.

6. The performed process integration in the analysis of building engineering systems applying the exergy and Pinch methods has derived that the possibilities for process integration in building engineering systems also depend on the amount of heat streams and temperature potential. The combination of several low temperature streams allows us to achieve a rational energy and exergy use in comparison with the use of one stream or overmuch temperature streams. Waste heat streams in the buildings which have the initial temperature close to 40 °C are preferable for process integration compared to other the temperature of which is higher than pointed.

7. The analysis of the energy and exergy demand obtained before and after the process integration has shown that the seasonal demand of energy and especially of exergy is bigger in an non-integrated system in comparison with an integrated system. In the examined case the energy demand is 1.26 and the exergy demand is 1.45 times bigger.

8. The created algorithm for process integration in the building engineering systems may encourage to design more efficient engineering systems from the viewpoint of energy which use primary energy resources more efficiently. It is recommended to form a diagram of the temperatures of the heat streams in buildings for a more detailed evaluation of the possibilities for process integration in the analysis of building engineering systems. This diagram may be used for the evaluation of heat streams for a purposeful use of process integration in building engineering systems.

List of Published Works on the Topic of the Dissertation
In the reviewed scientific periodical publications

Misevičiūtė, V.; Martinaitis, V.; Šiupšinskas, G. 2011. Cases of ventilation equipment thermal transmittance processes integration, *Mokslas – Lietuvos ateitis* 3(5): 89–97 (in Lithuanian). ISSN 2029-2341. (ICONDA).

Martinaitis, V.; Biekša, D.; Misevičiūtė, V. 2010. Degree-days for the exergy analysis of buildings, *Energy and buildings* 42(7): 1063–1069. ISSN 0378-7788. (ISI Web of Science).

In the other editions

Misevičiūtė, V.; Martinaitis, V. 2011a. The case of heat exchangers of ventilation's system integration by applying Pinch method, in *Proceedings of the Conference "Heat Energy and Technology", held in Kaunas on 3-4 February, 2011* [Konferencijos "Šilumos energetika ir technologijos", įvykusios Kaune 2011 m. vasario 3–4 d., Mokslinių pranešimų medžiaga] (in Lithuanian). ISBN 978-609-02-0179-4.

Misevičiūtė, V.; Martinaitis, V. 2011b. Analysis of ventilation system's heat exchangers integration possibilities for heating season, in *Proceedings of the 8th International Conference "Environmental Engineering", held in Vilnius on 19–20 May, 2011.*Selected papers. Vol II. Water Engineering. Energy for Buildings: 781–787. ISBN 978-9955-28-828-2.

Misevičiūtė, V.; Martinaitis, V. 2008a. Dependence of exergy efficiency of recuperative heat exchanger on dimensionless temperature, in *Proceedings of the 5th Conference of Young Scientists on Energy Issues "CYSENI 2008", held in Kaunas on 29 May, 2008.* Lithuanian Energy Institute: 57–63. ISSN 1822-7554 (CD).

Misevičiūtė, V.; Martinaitis, V. 2008b. An exergetical analysis of counter flow heat exchanger of ventilation system, in *Proceedings of the Respublican Conference "Building Engineering Systems", held in Vilnius on April 24–25, 2008* [Respublikinės konferencijos" Pastatų inžinerinės sistemos", įvykusios Vilniuje 2008 m. balandžio 24–25 d. Mokslinių pranešimų medžiaga]. Vilnius: Technika, 20–24 (in Lithuanian). ISBN 978-9955-28-257-0.

About the author

Violeta Misevičiūtė was born in Trakai, on 4 of August 1983.

First degree in Energetics, Faculty of Environmental Engineering, Vilnius Gediminas Technical University, 2005. Master of Science in Energetics, Faculty of Environmental Engineering, Vilnius Gediminas Technical

University, 2007. In 2007–2011 was working at Vilnius Gediminas Technical University. In 2007–2011 – PhD student of Vilnius Gediminas Technical University. At present – Assistant in Building Energetics Department of Vilnius Gediminas Technical University.

PROCESŲ INTEGRAVIMO VĖDINIMO ĮRENGINIUOSE GALIMYBIŲ VERTINIMAS

Mokslo problemos aktualumas. Pastatai sunaudoja apie 40 % galutinės energijos sunaudojamos Europos Sąjungoje (ES) ir išskiria apytikriai tiek pat anglies dvideginio. Gyvavimo ciklo požiūriu didžioji pirminės energijos dalis (iki 90 %) suvartojama pastato inžinerinėse sistemose.

Didėjant galutinės energijos sunaudojimui, senka pirminės energijos ištekliai. Prognozuojama, kad dėl gyventojų skaičiaus, komforto lygio augimo bei dėl to sąlygojamo ilgesnio buvimo pastate, energijos poreikiai ir toliau didės. Intensyvus energijos naudojimas taip pat glaudžiai susijęs su neefektyviu pastato inžinerinėse sistemose vykstančių procesų naudojimu.

Dažniausiai projektuojant pastatui inžinerines sistemas neatsižvelgiama į tai, kad procesai tose sistemose būtų integruojami jau pradinėje pastato projektavimo fazėje. Kiekviena sistema projektuojama pastatui deramai neįvertinant kiekvienos iš jų įtakos viena kitai. Tradicinė procesų integracija naudojama pramonės procesuose apima pagrindinius šilumokaičių tyrimo klausimus ir yra susijusi su optimizavimo metodais. Šiame darbe procesų integracija suprantama kaip veiksmas, kuriuo siekiama apjungti skirtingose pastato inžinerinėse sistemose esančius šilumos srautus. Šios problemos sprendimo rezultatai turi didelę reikšmę kuriant procesų integracijos pastato inžinerinėse sistemose vertinimo algoritmą.

Kaip rodo atlikta tyrimų apžvalga, šiame darbe pastato inžinerinėms sistemoms integruoti pirmą kartą pritaikyta Pinch analizė. Sprendžiant pastato inžinerinių sistemų veikimo optimizavimo uždavinius efektyvaus energijos vartojimo požiūriu, nustatomi inžinerinių sistemų energijos poreikiai, parametrai, jų kitimo arba valdymo įtakos dėsningumai. Tokiems uždaviniams spręsti nepakanka vien tik klasikinių metodų tinkamų tradicinėms sistemoms nagrinėti, nes sistemos tampa didesnės ir sudėtingesnės. Todėl pramonės objektams taikomas būdas procesams juose integruoti gali būti perkeliamas į mažesnio mastelio energetines sistemas, ypač tuomet, kai pastate yra skirtingų procesuose dalyvaujančių energijos (šilumos) srautų. Šiuos srautus racionaliai apjungiant, t. y. formuojant iš jų efektyvų šilumokaičių tinklą, galima būtų pasiekti geresnių energijos naudojimo pastato inžinerinėse sistemose rodiklių.

Pažymėtina, kad šių sistemų veikimo režimai, skirtingai nuo pramoninių sistemų, susiję su nuolatos kintančiais išorės oro parametrais.

Tyrimų objektas – viešosios paskirties pastatų vėdinimo sistemų įrenginiai ir procesų juose kartu su atliekiniais šilumos srautais kitose inžinerinėse sistemose integracija.

Darbo tikslas ir uždaviniai. Šio darbo pagrindinis tikslas – įvertinti procesų integravimo metodo taikymo galimybes viešųjų pastatų inžinerinių sistemų termodinaminiam efektyvumui nustatyti ir gerinti.

Darbo uždaviniai

1. Nustatyti pastato inžinerinių sistemų energinio efektyvumo požiūriu problemines sistemas, įrenginius ir procesus.
2. Nustatyti pastato vėdinimo sistemų, kurioms reikalingas energijos tiekimas, projektinių sprendimų ypatybes.
3. Įvertinti tradicinės procesų integravimo metodikos – Pinch analizės – naudojimo pastato inžinerinėms sistemos galimybes bei nustatyti ypatybes.
4. Sukurti algoritmą termodinamiškai optimaliam pastato inžinerinių sistemų integruotam sprendiniui rasti derinant termodinaminės ir Pinch analizės metodus.

Tyrimų metodika. Darbe taikomi sisteminės analizės, termodinaminės (eksserginės) analizės ir procesų integravimo (Pinch) analizės metodai. Sisteminė analizė leidžia nustatyti sistemų elementus bei jų tarpusavio ryšius. Eksserginė analizė leidžia atlikti termodinamiškai pagrįstą skirtingos kokybės energijos rūšių vertinimą. Procesų integravimo (Pinch) analizė leidžia panaudoti pramoniniams procesams taikomas procedūras termodinamiškai optimaliam šilumokaičių tinklui nustatyti.

Mokslinis naujumas

1. Pritaikyti procesų integracijos metodai, susiejantys energiškai efektyvių pastato inžinerinių sistemų sprendinių radimą su inžinerinėse sistemose numatomų naudoti šilumnešių parametrų deriniais. Pateikti vėdinimo, kaip perspektyvoje energijai imliausių įrenginių, integravimo pavyzdžiai.

2. Vėdinimo sistemų šilumogrąžių tinklui optimizuoti, jų šilumnešių deriniams rasti ir procesams pastato inžinerinėse sistemose integruoti pirmą kartą pritaikytas Pinch metodas, kuris iki šiol buvo taikomas tik pramoniniams procesams.

3. Darbe parengta metodika įvertinama, ar galima integruoti ir kaip integruoti tiek projektuojamas, tiek esamas pastato inžinerines sistemas, randant tų sistemų didesnio sezoninio termodinaminio (ekserginio) naudingumo sprendinį.

Praktinė vertė. Tyrimų rezultatai gali būti naudojami įvairių pastato inžinerinių sistemų šilumokaičių tinklo projektavimo uždaviniams spręsti, rasti eksploatuojamų šilumokaičių arba jų tinklų optimalius parametrus, jų kitimo dėsningumus, šilumokaičių arba jų tinklo veikimo laike priklausomybę mišrioje klimatinėje zonoje esančių viešosios paskirties pastatų grupei, kai žinomi arba ieškomi šilumos srautų, dalyvaujančių pastato inžinerinėse sistemose, parametrai.

Ginamieji teiginiai

1. Vis plačiau pramonės procesuose taikomas Pinch analizės metodas pastato inžinerinių sistemų procesams praktiškai nenaudojamas, nors dėl savo metodinių pagrindų ir tikslo kartu su termodinamine (eksergine) analize turėtų būti naudojami efektyvių, integruotų pastato inžinerinių sistemų sprendinių radimui.
2. Procesų integracijos ypatybes pastatų inžinerinėse sistemose suformuoja sezoninė vietovės lauko oro temperatūrų raida, vėdinimo sistemose naudojamų šilumogrąžių sprendiniai ir jų efektyvumas. Šios ypatybės apsprendžia temperatūros, prie kurios Pinch analizės procedūromis nustatomas optimalus šilumokaičių tinklas ir minimalaus temperatūrų skirtumo šilumokaičiuose, pasirinkimą.
3. Gautieji procesų integracijos ir eksergines analizių pastato inžinerinėse sistemose rezultatai rodo, kad procesų integracija leidžia rasti didesnio sistemos termodinaminio naudingumo sprendinius, o integruotos sistemos naudoja mažiau eksergijos lyginant su neintegruotomis.
4. Pasiūlytas algoritmas skirtas siekti procesų integralumo pastato inžinerinėse sistemose ar jam įvertinti. Šis algoritmas gali būti pritaikytas pastate naudojamų eksergijos srautų minimizavimui, todėl jis gali būti pritaikytas projektuojant pastatų inžinerines sistemas. Tokia procesų integracija inicijuoja naudoti žemų potencialų šilumos srautus (pastate dažniausiai atliekinės), o tai leidžia efektyviau išnaudoti pastate esančius šilumos srautus nei naudojant tradicinius aukštų parametrų tiekiamos šilumos srautus.

Darbo apimtis. Darbą sudaro bendra darbo charakteristika, 4 skyriai, bendrosios išvados, literatūros sąrašas ir publikacijų sąrašas. Bendra disertacijos apimtis – 108 puslapiai, 62 iliustracijos, 7 lentelės.

Pirmajame disertacijos skyriuje atlikta literatūros disertacijos tema analizė susijusi su procesų integracija pastato inžinerinėse sistemose, metodų skirtų procesų integracijai palyginimas.

Antrajame skyriuje nagrinėjami vėdinimo įrenginiai. Nustatomos procesų integracijos taikymo, pastato inžinerinėms sistemoms, ypatybės.

Trečiajame skyriuje tiriamos procesų inžinerinėse sistemose integracijos galimybės ir atliekama procesų integracijos vėdinimo įrenginiuose rezultatų analizė.

Ketvirtajame skyriuje siūlomas algoritmas procesams pastato inžinerinėse sistemose integruoti.

Bendrosios išvados

1. Atlikta tyrimų procesų integracijos srityje apžvalga parodė, kad labai ribotas skaičius jų nagrinėja integraciją pastato inžinerinėse sistemose, o inžinerinėje praktikoje jie netaikomi. Todėl šiame darbe nagrinėjamos procesų integracijos metodo taikymo minėtose sistemose galimybės.
2. Atlikus tyrimų apžvalgos analizę bei ekserginės analizės metu gautų rezultatų palyginimą, nustatyta, kad imliausi eksergijai yra vėdinimo įrenginyje vykdomi šiluminiai procesai bei elementai, kuriuose tie procesai vykdomi: šilumokaičiai, šilumogrąžiai ir šildytuvai.
3. Tyrimais nustatyta, kad vėdinimo įrenginyje naudojamo šilumogrąžio pasirinkimas lemia procesų vėdinimo įrenginyje integracijos poreikį ir galimybes. Plokštiniam vienpakopiam šilumogrąžiui papildomas šilumokaitis parenkamas pagal energijos balansą, netaikant procesų integravimo procedūrų.
4. Nustatyta, kad procesų integracijos procedūroms, o ribiniu atveju ir galimybėms vėdinimo įrenginyje, ypač svarbus yra minimalaus temperatūrų skirtumo tarp šilumnešių pasirinkimas. Remiantis šilumogrąžio šilumos perdavimo ir temperatūrinio efektyvumo lygtimis nustatyta priklausomybė tarp šilumogrąžio temperatūrinio efektyvumo ir minimalaus temperatūrų skirtumo. Procesams vėdinimo įrenginyje integruoti siūloma pasirinkti artimas 5 °C, t. y. mažesnes nei pramoninėse sistemose rekomenduojamas, apie 15 °C minimalaus temperatūrų skirtumo, reikšmes.
5. Maksimalus šiluminės eksergijos kiekis suvartojamas, kai vėdinimo sistema veikia visą šildymo sezoną, esant tam tikrai nustatytai lauko oro temperatūrai. Todėl, siekiant minimizuoti eksergijos sąnaudas, vėdinimo

sistemos šilumokaičių tinklas optimizuojamas esant šiai temperatūrai. Ši temperatūra, Lietuvai būdingoms klimatinėmis sąlygomis, yra apie 3 °C.

6. Atlikus procesų integracijos inžinerinėse sistemose analizę, taikant eksserginį ir Pinch metodus, gauta, kad procesų integracijos pastato inžinerinėse sistemose galimybės ir rezultatai taip pat priklauso nuo naudojamų šilumos srautų kiekio ir temperatūrinio potencialo. Kelių srautų su žemesnėmis temperatūromis derinimas leidžia pasiekti racionalesnį energijos ir eksergijos panaudojimą lyginant su vieno srauto naudojimu arba su pernelyg aukštų temperatūrų šilumnešių naudojimu. Atliekinės šilumos srautai pastate turintys pradinę temperatūrą artimą 40 °C yra tinkamesni procesų integracijai už tuos srautus, kurių temperatūra aukštesnė už nurodytą.

7. Energijos ir eksergijos poreikių, gautų prieš procesų integraciją ir po jos, analizė parodė, kad sezoniniai energijos ir ypač eksergijos poreikiai neintegruotoje sistemoje yra didesni nei integruotoje. Nagrinėjamu atveju energijos poreikiai 1,26, o eksergijos net 1,45 karto didesni.

8. Sukurtas algoritmas procesams pastato inžinerinėse sistemose integruoti gali padėti projektuoti energijos požiūriu efektyvesnes inžinerines sistemas. Išsamesniam procesų integracijos pastato inžinerinėse sistemose galimybių vertinimui rekomenduojama sudaryti viso pastato šilumos srautų temperatūrinę diagramą, kuria naudojantis galima būtų įvertinti, kokius šilumos srautus tikslinga naudoti procesų integracijai pastato inžinerinėse sistemose.

Trumpos žinios apie autorių

Violeta Misevičiūtė gimė 1983 m. rugpjūčio 4 d. Trakuose.

2005 m. įgijo energetikos bakalauro laipsnį Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos fakultete. 2007 m. įgijo energetikos mokslo magistro laipsnį Vilniaus Gedimino technikos universiteto Aplinkos inžinerijos fakultete. 2007–2011 m. dirbo Vilniaus Gedimino technikos universiteto Pastatų energetikos (iki 2009 m. Šildymo ir vėdinimo) katedros asistentu. 2007–2011 m. – Vilniaus Gedimino technikos universiteto doktorantas. Šiuo metu dirba asistentu Vilniaus Gedimino technikos universiteto Pastatų energetikos katedroje.

Violeta MISEVIČIŪTĖ

EVALUATION OF POSSIBILITIES FOR PROCESSES INTEGRATION IN VENTILATION EQUIPMENT

Summary of Doctoral Dissertation
Technological Sciences, Energetics and Power Engineering (06T)

Violeta MISEVIČIŪTĖ

PROCESŲ INTEGRAVIMO VĖDINIMO ĮRENGINIUOSE GALIMYBIŲ VERTINIMAS

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Vilniaus Gedimino technikos universiteto
leidykla „Technika“,
Saulėtekio al. 11, 10223 Vilnius,
http://leidykla.vgtu.lt
Spausdino UAB „Ciklonas“
J. Jasinskio g. 15, 01111 Vilnius