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DYNAMIC MONITORING OF THE HISTORIC CENTRE BUILDINGS FOR A SOLAR ELEMENTS ARRANGEMENT (using the example of Chernivtsi)

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Abstract: The possibilities of integrating the solar power elements into formed environment of historic cities are considered in the article. Using the example of a historic city area of Chernivtsi it has been realized a multi-level dynamic monitoring of the buildings and presented the results of preliminary calculations of an energy efficiency of a roof photoelectric elements installation.

Key words: energy (power) efficiency, energy saving, power (energy) updating, reconstruction, historic building, historic monument, monitoring, solar power, photo-voltage, photoelectric elements.

1. Introduction

Energy efficiency is one of the most important aspects in the practice of contemporary architecture by the level of its relevance. Such activity is often in the nature of reflect or declaratory using the distinctive methods and arrangements. So, in this regard, the intervening into a historic building is of concern. The uniqueness of the historic buildings excludes the application of those energy efficiency measures which could influence the exterior of the edifice. Power updating the historic building needs the processing a considerably greater amount of information and carrying on the row of special investigations that enable moving beyond analysis of the problem to concrete effective solutions.

2. Basic Theory Part

2.1. Analysis of the published works and investigations.

For the duration of carrying on the research the relevant works of native and foreign authors, namely Pidhornyy O. L., Kazakov G. V., Khavkhun G. N., Farenyuk H. H., Belyayev V. S., Khokhlova L. P., Tabunshchikov Yu. A., Brodach M. M., Kashchenko T. O., Shuldan L. O., Murgul V. A. and others have been analyzed. The analysis of scientific works [1 – 9] allows make conclusion about the absence of science-based methods of power updating the city historic center buildings in general and those with the application of solar elements in particular.

2.2. Analysis of foreign and native experience

A native experience of photoelectric systems using in a historic formed environment isn't considerable. The analysis of foreign experience of energy effective reconstruction has shown substantially different methods of historic heritage buildings updating [10]. Thus, one of these methods is a *demonstrative* and *accented* method that lies in using the active stylistic forming solutions while performing the reconstruction. The integration of solar elements into the fencing constructions advances as a new artistic accent in a historic building perception and is aimed not so much using the renewable sources of energy as the idea to declare the principles of new energetic policy, new view on generation and consumption of the energy. The cases in point are: the project of

Reichstag building reconstruction performed by British architect Norman Foster in 1999, the XI century church reconstruction in the town Ales, done by the architect Jean-Francois Roger, the reconstruction of the church Groenhof Castel in Flanders (Belgium) implemented by architectural bureau "Samyn & Partners" in 1996 – 99-s.

The second method is ***masking*** – the method of unnoticeable modernization that lies in including the solar energy systems in the exterior of the building with a minimal intervening into an architectural image and the preservation of an authentic building appearance. The examples of this approach are the power updating of the Herz-Jesu Kirche church built in 1901 (Plauen, Germany, reconstruction 2002) as well as a Lutheran church Lutherkirche Meißen built in 1904 (Meissen, Germany, reconstruction 2006).

The third method, namely, *declarative,* provides solar power systems setting in a direct proximity to a historic building or on the roofs of the adjacent buildings. Such approach is mostly oriented to the preservation of cultural heritage buildings and their historic surrounding. A case in point can be the building of Los-an- Goel church in France.

2.3. The purpose and task of the publication

The purpose of this research is a dynamic monitoring of the buildings situated in a central historic part of the town (with the example of Chernivtsi) aimed to create the base of the objects applicable for a power updating. The task of the publication is the analysis of heliosystems placing possibilities on the roofs of the buildings, accompanied by the preliminary calculations of the power efficiency and smart economics.

2.4. Historic information

The first written record of Chernivtsi dates to October, 8, 1408 and was fixed in the charter of Moldavian landlord Oleksandr Dobryi. Chernivtsi is located in the south-west of Ukraine, at the eastern Carpathian foothills on the Prut river bank. This town is rightly considered to be one of the real pearls of architecture.

According to the governmental accounting a historic part of Bukovyna capital commands 602 architectural monuments, of which 25 are of national importance.

Historic building of an old city is a holistic and almost untouched ensemble of the XIX – early XX centuries. Among the architectural monuments of Chernivtsi the architectural ensemble of the Bukovina and Dalmatsia orthodox metropolitans former Residence occupies a special place. It was designated a UNESCO World Heritage sites on the 28th of June 2011 at the 35th session of their Committee.

A total area of Chernivtsi within the administrative boundaries is about 153 square kilometers. The population as at the March, 1 2013 was 260 669 inhabitants. The population density is 1 643inhabitants per km^2 [11].

3. Results and Discussion

The reduction of a power consumption of the historic buildings is a complicated and expensive process. The thermos-modernization of the historic and cultural buildings-monuments with the warmth keeping of the fencing constructions can't be considered in relation to the availability of protected facades and interiors at the same time. Therefore, the generation of additional energy within a building circuit (contour) that will reduce its consumption from the urban systems can be considered as an acceptable measure. In this case the building is both a consumer and a producer of the energy.

The analysis of world experience suggests that the least expensive and, for all it, the most abundant solution in conditions of historic building is the installation of photoelements on the roofs of the buildings.

The building of historic city centers is in the condition of a permanent reconstruction. Considerable part of residential buildings of Chernivtsi historic center had been built by 1940. Above a third part of them hasn't been repaired in major way yet. Most buildings are characterized by extremely low energy-efficiency indicators. In recent years there has been a process of an active compaction of Chernivtsi central district buildings. As the consequence of a housing stock increase is forecasted increase of energy consumption.

Complex protective zone of Chernivtsi within a central historic region has the area of 292.33 ha (Fig. 1). The roofs of this zone became the first objects of the monitoring.

We have created a base of objects excluding all the buildings that are the architectural and historic monuments of national and local importance (Fig. 2).

Within this territory it has been worked up about 2400 buildings of the background and inferior historic building with a total area of roofs of 620000 m^2 (Fig. 3).

The second stage of the monitoring was the determination of the main geometric characteristics of the building roofs and identification of the south oriented fragments as well (Fig. 4).

Fig. 1. Complex protective zone of Chernivtsi within a central historic area

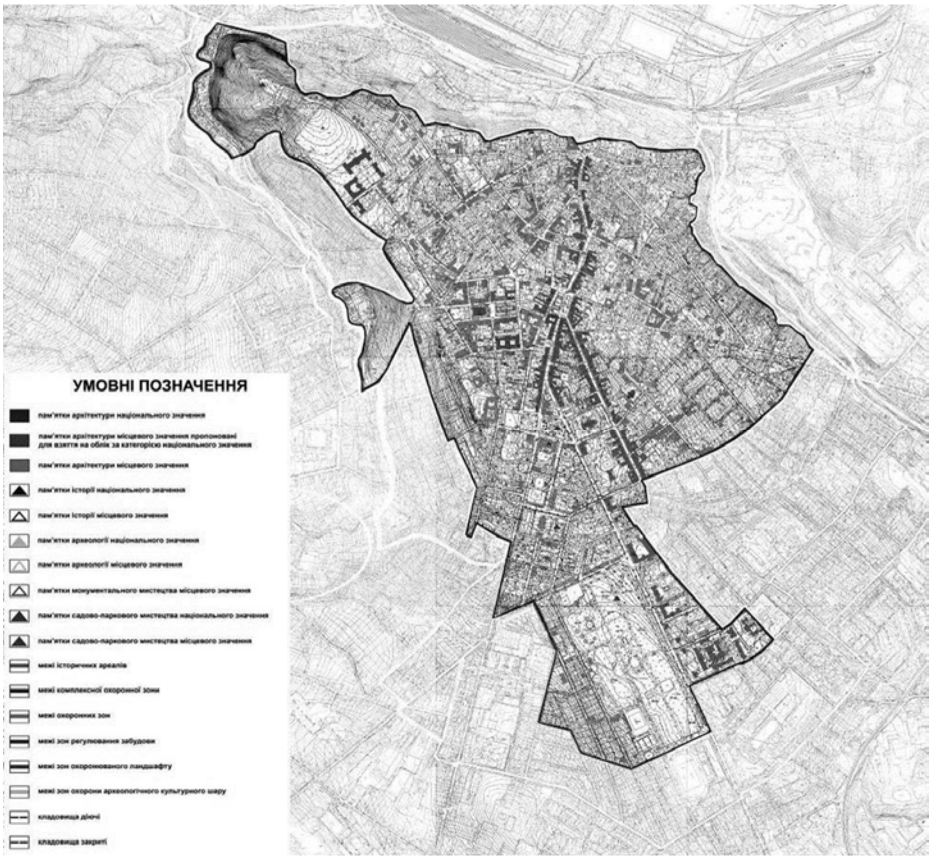

Fig. 2. Monuments of history and architecture (from the authors' archives)

Fig. 3. The buildings included in monitoring

Fig. 4. The fragments of south oriented roofs of buildings, included in the monitoring

The criteria in this case were defined by the deflection from the south within 30^{o} (at which the losses caused by solar rays were minimal) and a minimal area of fragments that is suitable and reasonable for placing the photoelectric panels. Expediency in this case was determined from the point of view of panels fragment placement on the plane with the total power of not less than 1 KW-hr taking into the account the main losses.

The rectangular single-crystal panels of conventional size have been accepted as a photoelement. After working up the most iterated geometric shapes concerning the possibility to be made up by the panels of such total capacity it has been defined that the area of the fragment must be not less than 17м^{2}.The area losses were estimated by the reduction coefficient of К=1,5.

The analysis by these criteria identified 1330 roof fragments with the total area of 131057 square meters.

Chernivtsi city is situated at 48th latitude (the coordinates are 48^{o} 17’ 27" north latitudes and 25^{o} 56’04" east longitudes), therefore while installing the photo elements it is desirable one should use the angle of 48^{o} with the correction at the mean position of the Sun between the winter and spring equinoxes.

Inclination angle of roof planes of the central area buildings ranges within 20-40^{o}. While doing calculations it has been decided to use an average value of 30^{o} in the first approximation as well as a static variant of panel installation which provides the lowest cost and the simplest assembling the elements. At the same time the power losses were estimated at least of 40 %. Due to the previous conclusions concerning forecasted power of every fragment enabled us to create the hierarchy of fragments’ value, to reveal numerical values in every design power segment.

The segment that ranges from 1 to 10 KWT-HR (Table 1***a***) is the most numerous and is presented mostly by the low-rise residential buildings. The segment that ranges from 10 to 20 KWT-HR (Table 1***b***) characterizes multi-family housings. The segment from 20 to 30 KWT-HR (Table 1***c***) is an exclusive characteristic of the public buildings. The public buildings with the flat roofs are belonged to the last segment (Table 1***d***).

Table 1

Distribution according to the power segments
(number of the buildings, area and value of the roof fragments, predicted total power)

a	***Power segment from 1 to 10 KWT***										***sum***
At the power within, KWT-HR	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10		
Fragment area	15.1–30.2	30.2–45.3	45.3–60.4	60.4–75.5	75.5–90.6	90.6–105.7	105.7–120.8	120.8–135.9	135.9–151		
Number of the buildings	179	193	184	157	144	101	81	60	62		**1161**
Predicted total power, KWT-HR	268.5	482.5	644.0	706.5	792	656.5	607.5	510	589		**5256.5**
b	***Segment from 10 to 20 KWT***										***sum***
At the power within, KWT-HR	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	
Fragment area	151–166.1	166.1–181.2	181.2–196.3	196.3–211.4	211.4–226.5	226.5–241.6	241.6–256.7	256.7–271.8	271.8–286.9	286.9–302	
Number of the buildings	42	27	21	14	16	10	4	4	3	1	**142**
Predicted total power, KWT-HR	441	310.5	262.5	189	232	155	66	70	55.5	19.5	**1801**
c	***Segment from 20 to 30 KWT***										***sum***
At the power within, KWT-HR	20–21	21–22	22–23	23–24	24–25	25–26	26–27	27–28	28–29	29–30	
Fragment area	302–317.1	317.1–332.2	332.2–347.3	347.3–362.4	362.4–377.5	377.5–392.6	392.6–407.7	407.7–422.8	422.8–437.9	437.9–453	
Number of the buildings	3	3	2	2	2	0	1	2	2	2	**19**
Predicted total power, KWT-HR	61.5	64.5	45	47	49	0	26.5	55	57	59	**464.5**
d	***Segment from 35 and more KWT***										***sum***
At the power within, KWT-HR	36–37	40–41	54–55	65–66	85–86						
Fragment area	544–559	605.08	907.82	1085.44	1427.77						
Number of the buildings	2	1	1	1	1						**6**
Predicted total power, KWT-HR	73	40.5	54.5	65.5	85.5						**319**

4. Conclusions

1. Energy-saving is an urgent subject under consideration for Ukrainian architects. The analysis of the investigations and publications has suggested the absence of a scientifically-grounded methodology for energy renovation of the buildings belonged to historic city centers in general and those that are provided with solar elements in particular.

2. A widespread list of methods and measures may not be used in a historic building without reserve. The solutions should be based on special research accompanied by processing a significant amount of data taking into account the uniqueness of the objects that belong to a historic and cultural heritage. The authors have carried on a dynamic monitoring of the historic area buildings from the example of Chernivtsi.

3. During a five-level dynamic monitoring there have been defined the peculiarities of historic buildings and the criteria of objects selection in a historic area of 292.33 ha as well as created the base of buildings suitable for placing the solar elements. About 2400 houses of background and small value historic building with a total roof area of 620000 $м^2$ have been picked out. A considerable improvement of a city center power consumption without concerning the important historic monuments can be achieved due to the arrangement of the solar elements just on the roofs of an “inferior” building.

4. With a view to further monitoring it has been left over 1330 roof fragments with the total area of 131057 $м^2$ according to the clearly defined criteria as well as carried on the evaluation of their appropriateness for the photo-elements installation and power segments distribution. The preliminary energy results have been calculated and a maximal predicted power capacity has been determined on the level of 7840 KWT-HR. It offers grounds for substantiating a smart economics of the photo-elements installation as well.

5. A multilevel dynamic monitoring enables to forecast the energy modernizing prospects of the historic city center buildings and to plan the following steps.

References

[1] Pidhornyy O. L. Heometrychne modelyuvannya nadkhodzhennya sonyachnoyi radiatsiyi na rizni poverkhni // Prykladna heometriya ta inzhenerna hrafika: Zb.statey.Vyp. 54. K.: KIBI, 1993. S. 10–13.

[2] Kazakov G. V. Printsipy sovershenstvovaniya gelioarkhitektury. L'vív: Svítoch, 1990. 152 s.

[3] Khavkhun G. N. Primeneniye sistem ispol'zovaniya solnechnoy energii v arkhitekture rekreatsionnykh zdaniy (na primere prirodno-klimaticheskikh usloviy USSR). Dis. k.arkh. K., 1987. 135 s.

[4] Farenyuk H. H. Teplova nadiynist ohorodzhuval'nykh konstruktsiy ta enerhoefektyvnist' budynkiv pry novomu budivnytstvi ta rekonstruktsiyi: avtoref. dys. d-ra t.n.: 05.23.01. Poltava: PNTU im. YU. Kondratyuka, 2009. 36 s.

[5] Belyayev V. S., Khokhlova L. P. Proyektirovaniye energoekonomichnykh i energoaktivnykh grazhdanskikh zdaniy. M.: Vyssh.shk., 1991. 255 s.

[6] Tabunshchikov YU.A., Brodach M.M. Matematicheskoye modelirovaniye i optimizatsiya teplovoy yefektivnosti zdaniy. M.: AVOK PRESS, 2002. 194 s.

[7] Kashchenko T. O. Pidvyshchennya enerhoefektyvnosti zhytlovykh budynkiv na osnovi optymizatsiyi yikh formy. Avtoref. dys. k-ta arkh.:18.00.02/ KNUBA. – K., 2001. – 19s.

[8] Shuldan L. O. Pryntsypy arkhitekturno-typolohichnoho vdoskonalennya shkil'nykh budivel z urakhuvannyam enerhozaoshchadzhuvannya. – Dys. kand. arkh.:18.00.02. Lviv, 2007. 212 s.

[9] Murgul V. A. Vozmozhnosti ispol'zovaniya solnechnoy energii dlya energosnabzheniya zhilykh zdaniy istoricheskoy zastroyki Sankt-Peterburga i uluchsheniya kachestva gorodskoy sredy / V. A. Murgul // Mezhdunarodnyy elektronnyy nauchno-obrazovatel'nyy zhurnal “Arkhitektura i sovremennyye informatsionnyye tekhnologii”. 2013. [Online]. Available: http://www.marhi.ru/ AMIT/2013/1kvart13/murgul/murgul.pdf.

[10] Shuldan L. O., Al'-Akhmmadi S. A. Intehratsiya solyarnykh elementiv v arkhitekturu istorychnykh budivel (tekhnichni aspekty) // Visnyk Nac.u-ntu LP? 2016.

[11] Ofitsiynyy portal Chernivets'koyi mis'koyi rady. [Online]. Available: http://chernivtsy.eu/portal/i/p/news/histor-zone.

[12] Histor-zon [Online]. Available http://city.cv.ua/portal/i/p/news/histor-zone.jpg

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ДИНАМІЧНИЙ МОНІТОРИНГ БУДІВЕЛЬ ІСТОРИЧНОГО ЦЕНТРУ ДЛЯ РОЗМІЩЕННЯ СОЛЯРНИХ ЕЛЕМЕНТІВ
(на прикладі міста Чернівці)

Анотація. *У статті розглянуто можливості інтеграції елементів сонячної енергетики в сформоване середовище історичних міст. На прикладі історичного ареалу міста Чернівці здійснено багаторівневий динамічний моніторинг будівель, подано результати попередніх розрахунків енергетичної ефективності встановлення фотоелектричних елементів на дахах.*

Ключові слова: *енергоефективність, енергозбереження, енергетична модернізація, реконструкція, історична забудова, пам'ятка архітектури, моніторинг, сонячна енергія, фотовольтаіка, фотоелектричні елементи.*