Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 129 (2015) 195 – 200

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Industrial Engineering

Using solar optical fibers for public buildings illumination in the South Urals

Kirpichnikova I.M., Volkova O.S., Maliugina A.A.*

South Ural State University, 76, Lenin Avenue, Chelyabinsk, 454080, Russian Federation

Abstract

The article shows the problem of energy shortage and justifies the necessity of energy-saving activities to be applied in the lighting of buildings. The analysis of solar radiation throughout the year and the length of daylight availability in Chelyabinsk region is made. Based on the analysis of designs and technical characteristics of solar optical fibers their use in newly constructed buildings and social facilities is justified, disclosing the terms of using solar optical fibers in the Urals conditions. The data on the changes of the natural lighting in the room, depending on the time of the day, cloudiness, and the location of the buildings to the cardinal points is produced, the expediency of the combined lighting systems "solar optical fiber+ light-emitting diode" application, which will significantly reduce the lighting costs, is illustrated.

Peer-review under responsibility of the organizing committee of the International Conference on Industrial Engineering (ICIE-2015)

Keywords: energy efficiency, solar optical fibers, illumination (lighting), solar radiation, light-emitting diodes.

1. Introduction

The priority trend of social and economic development of the Chelyabinsk region is the development of medicine, education, sports, culture and arts, which leads to the construction of major sports complexes, swimming pools, schools, kindergartens, medical centers, clinics, exhibition centers, museums and other public buildings.

Modern buildings have not only an interesting design, but also provide maximum comfort for guests: well-chosen lighting, ventilation and air conditioning, heating systems - resulting in an overall increase in electricity consumption in the region. But Chelyabinsk region already experiencing energy shortages (South Ural power plants

* Corresponding author. Tel.: +79226366140; fax: +7 351-2679894.
E-mail address: ionkim@mail.ru

Peer-review under responsibility of the organizing committee of the International Conference on Industrial Engineering (ICIE-2015)
doi:10.1016/j.proeng.2015.12.032

can provide electricity demand is only 80%). [1]. In addition, the annual growth of tariffs for energy in the region is about 4%. [2]. All of the above makes think seriously about energy efficiency. Since the share of energy consumption for lighting in public buildings is 30-50%, the introduction of energy-saving-measures in these systems is especially important.

2. Rationale for the use of solar optical fibers

2.1. Traditional light sources

The traditional methods of energy efficiency increasing of lighting systems include:

- Replacement of artificial light sources others with greater light output and lower power consumption (for example, replacing incandescent lumps with fluorescent and fluorescent with light-emitting diode);
- Light flow of artificial light sources control using a variety of dimmers, light sensors, motion sensors and etc.

Energy-saving light sources, in addition to high luminous efficiency, low power consumption, long life time, has a number of disadvantages:

- Pulsing the light flux;
- Ultraviolet radiation;
- The presence of mercury in gas discharge lamps;
- The poor quality of some of the manufacturers of lamps.

All this leads to deterioration in health and limitation of the use of these light sources in public buildings, especially in children and medical institutions.

An alternative source is the use of natural light by using the solar optical fibers.

2.2. Solar optical fibers

Solar optical fiber is the light conducting device transmitting light at a distance by multiple reflections within the hollow structure having a reflective surface.

Advantage of solar fibers is that they can:

- To replace the source of artificial lighting during daylight hours;
- To reduce the heat inflow from the artificial lighting and thus the cost and power of conditioning equipment and operating costs;
- To receive the full spectrum of lighting (for the transmission of the completeness of colors of the interior space, as well as increasing operability and reduce fatigability, which causes the artificial light sources);
- To increase the level of comfort in the buildings;
- To include in the system a source of artificial lighting (for the dark time of day), adjust the brightness of the transmitted light or turn it off completely [3,4,5].

Thus, the installation of solar optical fibers in public buildings will not only reduce energy costs but also reduce the harmful effects of artificial lighting sources on human health.

2.3. Goals and objectives of the study

Objective: to investigate the possibility of using solar optical fibers in public buildings in the South Urals.

The research problem:

Evaluate the effectiveness of the use of solar optical fibers with regard to:

- Climatic features of South Urals;
- The amount of solar radiation reaching the surface, for different areas of the Chelyabinsk region;
- Lighting of buildings;
- Design features of optical fibers.

3. The climatic characteristics of the Chelyabinsk region

The climate in Chelyabinsk region is continental, which is determined by the position of the territory on the mainland. The main features of the climate are the long cold winter with frequent snowstorms, dry and hot summers with droughty periods.

The average value of total solar radiation over the region is 1150kW·h / m^2 per year. By the magnitude total annual solar energy arriving on a horizontal surface, the region is divided into five areas [6]. Average annual duration of sunshine in the region is 12 hours. The duration of sunshine varies in the region around 2000 hours per year. Thus, only 50% of the days in a year are sunny, other days are cloudy (Table. 1).

The length of daylight varies throughout the year and ranges from 7 hours in January to 17 hours in June (Figure 1). Moreover sunrise starts at 10:30 in January and at 5:30 in July, and sunset at 17:30 takes place in January and at 22:30 in July [9].

Table 1. An example of a table. Table 1. Zoning of the Chelyabinsk region [7, 8].

Magnitude	V. Ufaley, Kyshtym	Chelyabinsk, Chebarkul	Plast, Chesma	Troitsk, Varna	Bredy, Kartaly
The mean values of total solar radiation H, kW • h / m^2	1050	1100	1150	1200	1250
The average duration of sunshine S, h	70.2	67.9	71.4	72.5	79.1
The percentage of sunny days per year,%	48.7	47.1	49.5	50.3	54.9

A special feature of winter in the region is the presence of stable snow cover, on average, from November to April. The duration of snow cover from 160-170 days in mountainous areas up to 140-150 days in the south. The average height of snow cover in the region is 30-40 cm [10].

4. The research of the premises illumination

One of the main factors of a comfortable stay of people indoors is to maintain standardized illumination in it, which is achieved by natural and artificial lighting. The construction of most buildings in the Chelyabinsk region has natural side lighting, an area which does not exceed 30% of the area of the outer wall.

We conducted a research - the lighting dependence inside the buildings of the following factors:

- The location of the outer wall of the room from the cardinal point;
- The distance to the wall with windows;
- Cloudiness.

Measurements were taken directly from the window aperture.

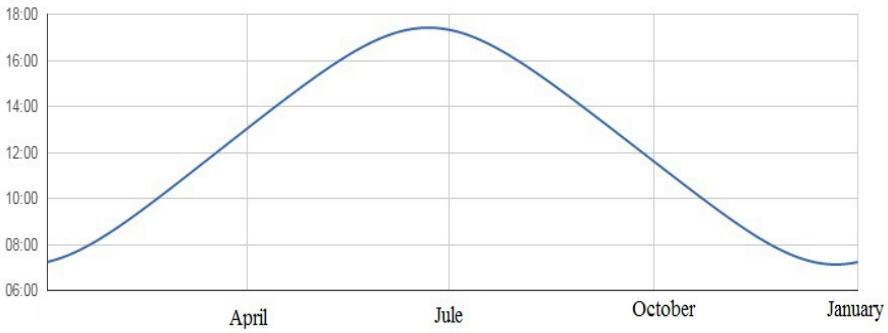

Fig. 1- The duration of the daylight in Chelyabinsk during the year

Research time: in July 2015, the average duration of daylight for the Chelyabinsk city is 16 hours, sunrise at 6:00, sunset at 22:00. Comparison of illumination changes from the location of the outer walls of buildings with windows, showed that the average illumination of the southern side to 3.73 times higher than the northern(Figure 2).

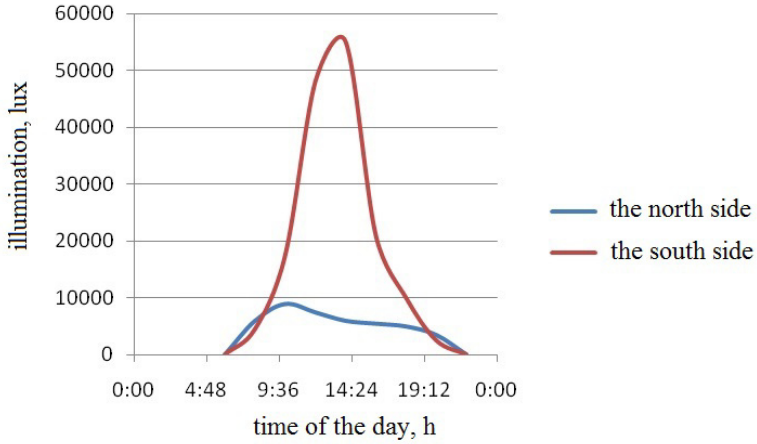

Fig. 2- Changing the lighting in the room, depending on the time of the day and buildings location by cardinal points

Dependence the research of indoor illumination from the distance from the source of natural light (see Fig. 3) shows that the luminance decreases, and a distance of 5 m from the window, this value is an average of 13.3 times. In addition, the standardized lighting 200 lux for public buildings at a distance from the windows of 4 m or more can not be achieved at any time of the day, and at a distance of 3 m is achieved only until 12:00.Research of the effect of clouds showed that illumination indoors is reduced by 3.9 times in comparison with the clear day. Considering that in the Chelyabinsk region less than half the days in a year are clear, this fact is necessary to include in the design of lighting buildings systems. Thus, our studies indicate that in buildings with natural side lighting, it is not enough light during the day and artificial lighting is required.

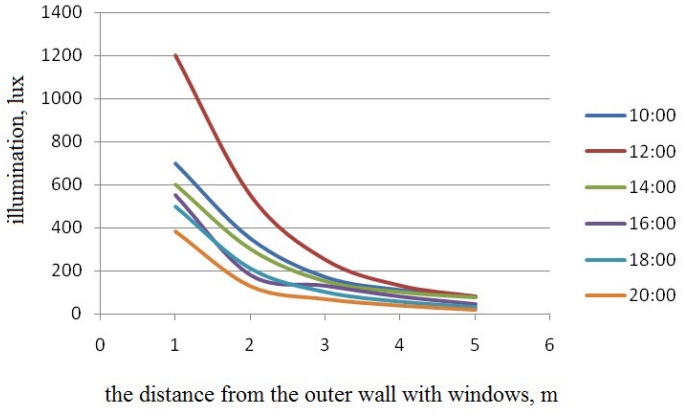

Fig. 3. - The dependence of the illumination indoors from the distance from the outer wall with windows

We propose to increase the number of sources of natural light by installing solar optical fibers.

Analysis of Chelyabinsk region climate and our studies have shown that the use of optical fibers will increase the solar illumination indoors to standardized, subject to the following conditions:

- The location of the optical fibers domes on the south side of the building or on the roof;
- The dome has to collect not only the direct rays, but also scattered since more than the half of the days in a year are cloud;
- The dome should be placed above the height of the snow cover, i.e, higher than 40 cm.

5. Choosing the design of solar optical fibers for the premises illumination

Today, solar optical fibers produce dozens of foreign companies. In Russia, widely spread only two: Solatube (USA) and Allux (Czech Republic).

After studying design features of fibers of these firms, we chose the European company as more appropriate to the conditions of the South Urals. The Allux fiber dome is made of polycarbonate, which allows it to remain transparent to ultraviolet rays over the lifetime. The dome shape is a hexahedral prism, which allows absorbing the maximum amount of light even on a cloudy day. Special “winter” design of optical fibers is not subject to condensation inside the fiber and prevents its freezing in the winter period of operation. The hollow Allux optical fiber inside has a mirror coating, consisting of a number of optical and protective layers coated on the base sheet of aluminum by chemical vacuum spraying that allows it not to burn up under the action of ultraviolet light and does not crack when the temperature drops.

Modern structures of solar lighting systems have additional accessories, such as daylight regulator, which shuts off the light in the room, or reduces its amount or kit for night-time, containing an artificial light source, thereby reducing the number of lamps. Most often incorporated energy-saving lamps in them. The reflecting fiber length depends on the diameter of the cylinder. Thus, the manufacturer offers optical fibers with a diameter up to 400 mm length of the cylinder up to 10 m and with a diameter of 600 mm and more - up to 25 m [11].

Given that the average duration of daylight for the year in the South Urals is 12 hours, the use of combined lighting systems: "optical fiber + light-emitting diode" will significantly reduce energy costs, while allowing a person to feel comfortable in the dark time of the day. Figure 4 shows the duration of light-emitting diodes switching-on in the system "optical fiber + light-emitting diode" during the year for the 12-hour working day from 10:00 to 22:00.

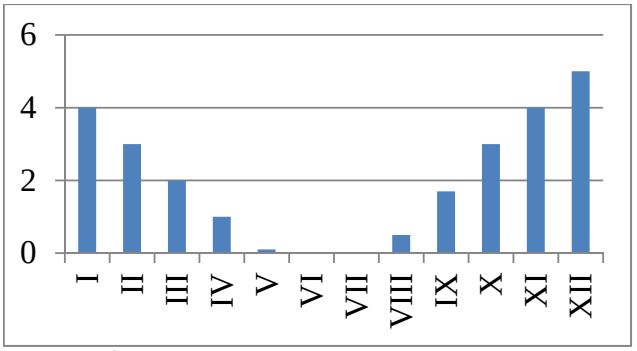

Fig. 4- The duration of the light-emitting diode bulbs operation incorporated in solar optical fibers, h

Thus, making natural illumination of public buildings with solar optical fibers with the set of light-emitting diodes for working in the dark time of the day, will reduce the time of energy consumption to an average of two hours a day, therefore, save energy up to six times.

6.Conclusions

- The increasing energy consumption for newly constructed public buildings lighting requires a search for new energy-saving technologies and devices.
- Research of the changes of the natural lighting in the room, depending on the time of the day, cloudiness, and the location of the buildings to the cardinal points revealed that the lighting does not correspond to standardized, therefore, the installation is required for additional artificial lighting.
- If the average total solar radiation in the South Urals is 1150kW· h / m^2 and the duration of the daylight in average is 12 hours per year, the most expediency is the use of the dome solar optical fibers installed on the south side of the roof or buildings.
- The use of combined lighting systems "solar optical fiber+ light-emitting diode", significantly reduce energy costs, while allowing a person to feel comfortable in the dark period of the day.

References

[1] L.A. Saplin, Jekonomicheskoe obosnovanie ispol'zovanija netradicionnyh vozobnovljaemyh istochnikov jenergii v Cheljabinskoj oblasti, Polzunovskij al'manah. 1 (1999) 88–101.
[2] Information on http://www.tarif74.ru/htmlpages/Show/Tarifypotrebitelyam/Tarifynaelektricheskuyuenergiy
[3] A.V. Salomatin, Ju.N. Kazakov, Nauchnoe obosnovanie novyh tehnologij ustrojstva solnechnogo osveshhenija v zdanijah, Jenergosovet. 6(31) (2013).
[4] Information on http://www.solatube.su/o-tehnologii-solatube/preimushhestva-sistemyi-osveshheniya-solatube/
[5] Information on http://www.solarway.su/index.php
[6] L.A. Saplin, S.K. Sher'jazov, O.S. Ptashkina-Girina, Ju.P.Il'in, Jenergosnabzhenie sel'skohozjajstvennyh potrebitelej s ispol'zovaniem vozobnovljaemyh istochnikov, Cheljabinsk, ChGAU, 2000.
[7] Information on http://voshod-solnca.ru.html
[8] I.M. Kirpichnikova, O vozmozhnosti ispol'zovanija vozobnovljaemyh istochnikov jenergii v Cheljabinskoj oblasti, Vestnik Jenergosberezhenija Juzhnogo Urala. 2 (2007) 58–68.
[9] L.A. Saplin, Utochnennaja metodika rascheta solnechnoj jenergii na primere Cheljabinskoj oblasti, Vestnik Cheljabinskogo agroinzhenernogo universiteta. 26 (1998) 121–125.
[10] Agroklimaticheskie resursy Cheljabinskoj oblasti, Gidrometeoizdat, Leningrad, 1977.
[11] Information on http://www.allux.cz/cz.