ISSN 2519-2817 online
ВЕСТНИК ДОНБАССКОЙ НАЦИОНАЛЬНОЙ АКАДЕМИИ СТРОИТЕЛЬСТВА И АРХИТЕКТУРЫ
Научно-технические достижения студентов строительно-архитектурной отрасли
Выпуск 2024-4(168)

EDN: WJTRWG
УДК 620.92

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POTENTIAL FOR UTILISATION OF SOLAR IRRADIATION IN HEAT SUPPLY SYSTEMS ON THE TERRITORY OF DONBASS

Abstract. The problem of efficient utilisation of energy resources is one of the key issues in the modern energy industry. Annually increasing consumption of thermal energy requires more and more hydrocarbon fuel. One of the ways to solve this problem is the use of alternative energy sources. The most accessible and reliable source of alternative energy is the Sun. The use of solar energy will reduce the consumption of hydrocarbon fuels without reducing thermal energy production. The thermal potential of the solar irradiation as a source of thermal energy for solar thermal systems in Donbass has been analysed. Factors affecting the efficiency of solar energy collection are considered, such as local climatological features, the time of 24-hour day and the season, the angle of inclination and orientation of the absorbing surface.

Keywords: alternative energy sources, solar energy, solar irradiation, hot water supply, central heating supply.

PROBLEM FORMULATION

The problem of efficient utilisation of energy resources is one of the key issues in the modern energy industry. Annually increasing consumption of thermal energy requires more and more hydrocarbon fuel, the reserves of which are not unlimited.

OBJECTIVE

Reducing the consumption of thermal energy from the combustion of fossil fuels through the use of alternative energy sources, in particular solar energy.

BASIC MATERIAL

Rising energy prices and increasing negative impact on the environment make us reconsider our attitude towards irrational use of traditional energy resources and pay attention to alternative energy sources. In the future, energy supply should be based on equipment operation on renewable energy sources, which are available everywhere and practically have no limitations. Undoubtedly, the most accessible and reliable source of energy is the Sun [1].

When utilisng solar energy, it is important to understand how much of the sun's irradiation can actually be utilized.

The intensity of solar irradiation outside the Earth's atmosphere is practically unchanged and amounts to 1 367 W/m^2 [2]. During its passage through the atmosphere, solar irradiation decreases due to various atmospheric phenomena. Clouds are the main atmospheric phenomenon that determines the amount of solar radiation reaching the Earth's surface. Cloud cover reflects a certain part of solar radiation, while another part is absorbed by it. A significant amount of irradiation is scattered in the atmosphere and clouds, creating scattered irradiation. Eventually most of the irradiation, about 1 000 W/m^2, reaches the Earth's surface, where it is also partially reflected and partially absorbed by it. The reflection of direct irradiation from the Earth's surface also contributes to the creation of scattered irradiation. Various anthropogenic and natural phenomena also reduce the amount of solar radiation that reaches the Earth's surface [1, 3].

The sum of direct and diffuse solar irradiation is called total solar irradiation. The share of diffuse radiation in the total radiation is on average about 50 % per year in Donbass somewhat less in summer and more in winter [1].

From the point of view of solar energy utilisation, an important factor is the irradiation power measured on a particular surface (Table 1) [4]. To determine the amount of solar radiation actually converted into heat energy, it is necessary to take into account the duration of irradiation of a given surface by the Sun (Table 2) [5].

Table 1 – Monthly total solar radiation on to the horizontal plane kWh/m², for Donetsk

Month												Σ
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
29,7	46,7	82,5	118,1	163,6	174,4	183,3	155,3	114,7	69,2	27,5	19,4	1 184,4

Table 2 – Number of sunny days for Donetsk

Number of days	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
clearly	3	4	7	11	13	16	20	23	19	16	11	4
cloudy	5	5	9	8	12	11	9	7	7	9	7	7
overcast	23	19	15	11	6	3	2	1	4	6	12	20

The amount of solar energy falling on the Earth's surface changes due to the movement of the Sun. These changes are determined by the time of the day and the time of the year. Usually more solar radiation reaches the Earth at midday than in the early morning or late afternoon, because at midday the Sun is high above the horizon and the path length of solar irradiation through the Earth's atmosphere is shorter. Consequently, less solar radiation is scattered and absorbed by the atmosphere, and thus more of it reaches the Earth's surface. As a consequence of the change of seasons, the length of the day changes in summer and winter, which, in turn, depends on the geographical latitude of the area [1].

The city of Donetsk has coordinates 48 °N. Taking into account the angle of inclination of the Earth's axis, it means that on the 21-st of June the Sun is at noon at an angle of 65,4° to the horizon and the duration of daylight is 16 hours 4 minutes. At noon on December, 21 the angle is 18,6° and the daylight hours are reduced to 8 hours 23 minutes [6].

The values of the total solar irradiation given in the normative literature refer to a horizontal surface. In the case of an inclined solar collector surface, the angle of incidence of the sun's rays changes, which in turn affects the intensity of irradiation and the amount of energy absorbed. In order to maximize the efficiency of solar radiation absorption by the solar collector, it is necessary to select the optimal angle of inclination, taking into account the geographical location and the time of season [7]:

– for year-round solar installations, the optimum angle of inclination is equal to the geographical latitude of the location;

– for solar installations operating in the non-heating period, the optimum angle of inclination is 15° less than the geographical latitude of the location;

– for solar installations operating during the heating period, the optimum angle of inclination is 15° greater than the geographical latitude of the location.

The average values of daily total solar radiation on the inclined plane depending on the mode of operation of the solar installation for Donetsk are given in Table 3 [8].

Table 3 – Averaged values of daily total solar radiation, kWh/m², on an inclined plane for Donetsk

Number of days	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
clearly	3	4	7	11	13	16	20	23	19	16	11	4
cloudy	5	5	9	8	12	11	9	7	7	9	7	7
overcast	23	19	15	11	6	3	2	1	4	6	12	20

Another key point that should be taken into account when determining the amount of solar radiation absorbed is the orientation of the absorbing surface. For the territory of Donbass, the most effective orientation of the surface will be in the southern direction. Figure illustrates the effect of orientation and inclination of the absorbing surface on the level of incident radiation in comparison with horizontal placement of the absorbing surface.

ISSN 2519-2817 online
Вестник Донбасской национальной академии строительства и архитектуры

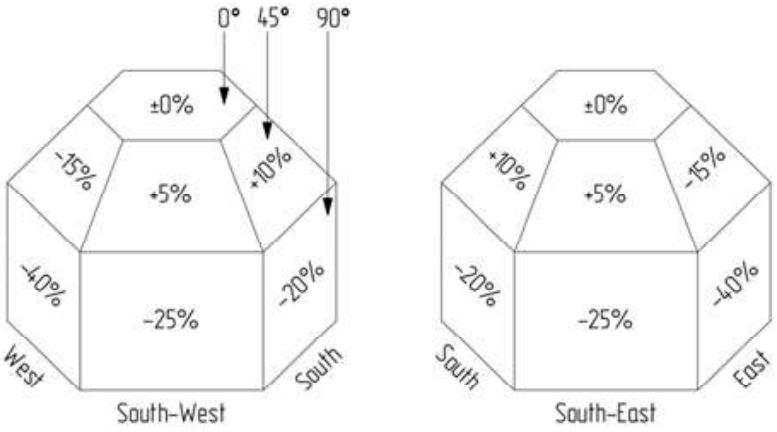

Figure – Effect of the angle of inclination and orientation of the absorbing surface on the value of total solar radiation.

Between the south-east and south-west directions with inclination angles between 25° and 70°, a zone can be identified where the solar collector efficiency will be optimal [1].

CONCLUSION

Based on the study of available solar radiation resources on the territory of Donbass, it can be concluded that there is a significant potential for the use of solar energy in heat supply systems on this territory. Realization of this potential can lead to significant savings of traditional fuels due to their partial substitution by solar energy.

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Получена 02.05.2024
Принята 24.05.2024

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ПОТЕНЦИАЛ ИСПОЛЬЗОВАНИЯ СОЛНЕЧНОГО ИЗЛУЧЕНИЯ В СИСТЕМАХ ТЕПЛОСНАБЖЕНИЯ НА ТЕРРИТОРИИ ДОНБАССА

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Аннотация. Проблема эффективного использования энергоресурсов является одной из ключевых в современной энергетике. Ежегодно увеличивающееся потребление тепловой энергии требует все больше

углеводородного топлива. Одним из путей решения этой проблемы является использование альтернативных источников энергии. Самым доступным и надежным источником альтернативной энергии является Солнце. Использование солнечной энергии позволит сократить потребление углеводородного топлива без снижения выработки тепловой энергии. В данной статье проведен анализ теплового потенциала солнечного излучения в качестве источника тепловой энергии для гелиотермальных установок на территории Донбасса. Рассмотрены различные факторы, влияющие на эффективность сбора солнечной энергии, такие как местные климатологические условия, время суток и время года, угол наклона и ориентация поглощающей поверхности.
Ключевые слова: альтернативные источники энергии, солнечная энергия, солнечное излучение, горячее водоснабжение, централизованное теплоснабжение.

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