Solar energy data for the typical technical and economical calculation for solar installations

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Abstract*: In this article the available climatic data for typical technical and economical calculations for different type of solar application are analysed. Such type of calculation is based on statistically performed data for long time period of observation. Due to the big range of slope and orientation of absorbed elements surfaces of solar equipment there is need to perform solar data geometrically to the needed slope and orientation. Different models of geometrical conversion of solar radiation is analysed in this work. A computer program is created t delivery solar radiation for different applications.*

Keywords: *Solar energy, climatic data, technical and economical assessment.*

1. INTRODUCTION

The performance of solar systems depends upon local climatic conditions. From this point of view they are very different from conventional domestic heating system and system for hot water. Two sets of climatic data are needed to conduct analysis of the thermal solar systems. The first is the 'normals' of daily air temperature distributions for a typical day in each month of the year. These are required to calculate heat loses of solar elements during the working period. The heat loses should not be taken from tables of heating degree day figures, as they will vary according to the solar gains, wind speed, effective temperature of the sky, internal gains of the building etc.

The second set of climatic data is required to assess gains of the houses or the solar collectors due to absorption of solar radiation. They are affected by such climatic and geographical factors as the amount of cloudiness, the atmospheric clarity, local altitude and latitude, reflective characteristic of the environment and other. Because of these factors it is difficult to make accurate assessment of the solar radiation. Additional problem is the requirements of geometrical calculations for solar radiation, because the solar energy depends on the angle of incidence upon absorption surface. This angle veer during the day and year and it is necessary to use simulation calculations to assess the technical efficiency of solar equipment.

The assessment of the efficiency of thermal solar installations is in relation with observing potentiality of the available solar radiation for the region which is being explored. The main difficulty in observing this quantity is determined by the great number of variable factors that influence on the regime of entering solar energy upon the earth surface. That is the reason why it is necessary to observe solar radiation in statistically aspect on the base of long-term meteorological researches.

Determination of the area of the absorbed surface is a basic task in projecting of solar applications. One of the possible approaches for solving this task is to use long-term simulating calculations with the help of mathematical models for different type of solar installations. With such simulations it can be defined the annual or seasonal efficiency of installations when there is a certain collector field (absorptive surface). As we simulate variants with different in size collector field, we can define the optimal size of solar installation in reference to the surface of solar collectors. The main problem here is to find the accurate typical data for climatic parameters (solar radiation, ambient temperature, wind speed and other).

2. AVAILABLE METEOROLOGICAL DATA

In Bulgaria, the average annual period of sunshine is about 2100 hours. In some of its regions it may reach 2500 hours, which corresponds to 1400 ÷ 1600 kWh/m^2 annually on the horizontal surface. The assessment of long-term observations from more than 40 meteorological stations in Bulgaria has shown that the country can be divided into three “solar zones” [1].

For design purposes it is best to use a full year’s data or full seasonal data if the process is seasonal one, and if data are available for many years it is necessary to select the best set. Klain [4] suggests the concept of a design year, which using many years data, selects for every month the radiation closest to the all year average for this month. Monthly average temperatures are used as a secondary criterion where necessary. The set of month’s daily distribution of solar radiation and ambient temperature constitutes the design year data. These quantities are often estimated in hour-by-hour time period.

Radiation data are the best source of information for estimating the incident solar gain. However, the network collecting solar radiation in Bulgaria is still very scarce; complete radiation data are available only from Sofia and partially from any other places. The main concern is therefore, to use empirical relationship to estimate radiation from hours of sunshine or cloudiness. Data on average hours of sunshine are available from over 40 stations in Bulgaria. Many papers have been written on the sunshine based models to estimate solar radiation on horizontal surface [4,5]. Well-known Kimbal-Angstrom-Page model was used to calculate total radiation on horizontal surface through the day. On the base of this model, design year data for the solar radiation is received, for stations with available sunshine hours data. Temperature distribution data are available for many places in Bulgaria

As a basic source of information in defining solar radiation there are long-term measurements of summary solar radiation, related most frequently to horizontal surface. Such data about our country exist only about Sofia region (2,3). About other regions of the country actinometrical observations for a longer period of time do not exist yet.

Another source of information for assessment of the potentiality of solar radiation is data about the duration of sun-shining. These data with accuracy could be used for indirect determination of the course and distribution of solar radiation. The most common and accurately checked correlations for determination of the summary solar radiation on horizontal surface together with using data about duration of sun-shining are the equation of Masson, Angstrom, Sivkov and others [4].

Very often it is necessary to define solar radiation on inclined and differently orientated surfaces. It is known that the quantitative determination of direct solar radiation on inclined surface is a question of geometric dependencies. The question about diffuse radiation is more complicated since this radiation enters from different parts of the sky, but not from the sun disc. The unevenness in the atmosphere state determines significant anisotropy in the intensity of the diffuse solar radiation which appears especially in differently inclined and orientated surfaces.

For engineer calculations the hypothesis about isotropy of the diffuse radiation with observing variable character of the solar radiation, brings satisfying results. What is more, the maximal rate of diffuse radiation from the summary solar course does not increase 30%, which significantly reduces the influence of incorrectness from supposing isotropy.

Using the hypothesis for isotropy brings the influence of the incline and the orientation of the accepting surface to establishing different correlations between the two components of the diffuse radiation – radiation from the sky vault and reflected from the ground surface radiation. These correlations also are brought to certain geometric dependencies, but they are different from the dependencies related to the direct radiation. Therefore, when it is known only summary solar radiation, it is necessary to be divided in direct and diffuse. This could be accomplished, for example, using the equations of Lui and Jordan [2] and Page [3].

When the solar radiation is calculated with the data about duration of sun-shining, it is preferable to use empirical dependencies about the direct and the diffuse radiation, in which we should admit the geographic place of the region and the atmosphere state. For example, the direct solar radiation intensity on a surface perpendicular to the sun rays could be defined from the expression:

(1) $$I = I_{sc} C \cdot A \cdot \exp(-B/\sin(h))$$

Where I_{sc} is a “solar constant” – 1380 W/m2,

C –corrective coefficient of the distance earth – sun,

A, B – coefficients, admitting the influence of the atmosphere pollution on the passing sun rays,

h – height angle of the sun.

The direct solar radiation on the inclined surface therefore is:

(2) $$Q_D = I \cdot \cos(\theta)$$

where θ is the angle of falling sun rays. [1].

The diffuse radiation on horizontal surface could be defined from the equation [1]:

(3) $$Q_d = I_{sc} C \cdot \sin(h) \cdot T_d$$

where for the coefficient of passing scattered radiation through the atmosphere T_d in an experimental way it is established the correlation:

(4) $$T_d = 0.271 - 0.2939 A \exp(-B/\sin(h))$$

On a surface inclined under an angle ***S,*** the total diffuse radiation could be defined from the equation:

(5) $$Q_{ds} = \frac{1+\cos(S)}{2} Q_d + \rho \frac{1-\cos(S)}{2} (I \cdot \sin(h) + Q_d)$$

where ρ is a coefficient of reflection of solar radiation from the soil.

On the base of the dependencies (1), (3) and (4) and on the existing data about solar radiation (for the region of city of Sofia) and the data about the duration of sun-shining for 35 meteorological stations in this work it is achieved an assessment of the potentiality of the solar radiation on the territory of Republic of Bulgaria. The data about the solar radiation are referred to the period 1970 – 1985 [2,3] and the data about the duration of sun-shining – to the period 1960 – 1985 [2].

When we constitute the algorithm for calculating the solar radiation there have been used the following suppositions:

- because of the insignificant difference in the day duration in southern and northern parts of the country, we can reckon that the special distribution of sun-shining about the total territory is determined only by the distribution of cloudiness;

- as far as the geographic length about the territory of the country varies in narrow limits (41 - 43 deg), solar radiation distribution is determined mostly by the duration of sun-shining. This means, for example, that the summary solar radiation in an absolutely sunny day, as well as diffuse radiation in a cloudy day is the same for the whole country (excluding regions with more polluted atmosphere). Apart from that, instead of calculated on equations /1-3/ data about the direct and the diffuse radiation for different regions, it can be used relevant data from calculations about the region of the city of Sofia.

Taking into account the previous suppositions, the distribution of solar radiation is determined by the relative duration of sun-shining for the certain day interval:

$$f_h = \frac{sum \cdot of \cdot monthly \cdot sunshine \cdot duration \cdot for \cdot apropriate \cdot hour \cdot in \cdot dasy}{number \cdot of \cdot days \cdot in \cdot month}$$

Average monthly solar radiation for appropriate hour interval can be expressed by:

(6) $$q_s = f_h \cdot q_t + (1 - f_h) \cdot q_d$$

where $\boldsymbol{q_t}$ is the summary solar radiation for the certain hour interval in conditions of a cloudless day; $\boldsymbol{q_d}$ – diffuse radiation for the certain hour interval in conditions of a cloudy day.

The question about defining solar radiation on differently inclined and orientated surfaces can be observed as defining $\boldsymbol{q_t}$ and $\boldsymbol{q_d}$ for the certain incline and orientation. As it was previously pointed it can be observed as geometric transformations of the data about direct and diffuse radiation determined in advance.

To accomplish the necessary calculations of the summary solar radiation for differently inclined and orientated surfaces, there have been used computer program SOLAR. With their help it can be determined the daily course of the summary solar radiation as well as the daily, monthly and annual sums of the solar radiation. Such calculations have been performed for the 35 meteorological stations on the territory of Bulgaria, for which there exist data about the duration of sun-shining. The results about the city of Sofia were compared with the existing data from the measurements of solar radiation as well as the results achieved through using the equation of Lui and Jordan [4]. It has been achieved a good correlation between the different data and the results.

The analysis of the accepted results reveals that it is useful to divide hypothetically the territory of Bulgaria into three "solar" zones[1].

The assessment of the radiation balance for the territory of Bulgaria reveals that for the summer season (31.03 – 31.10), the optimal incline angle of the absorbing surfaces is about 30^o , and the incident solar radiation on $1m^2$ is from 900 to 1200 kWh/m^2 season. For the winter season (31.10 – 31.03) the optimal angle is about 55^o, and the incident solar radiation is from 300 to 390 kWh/m^2 season. The annual summary solar radiation with an angle of incline 30 is from 1200 to 1500 kWh/m^2 year.

3. PROGRAM SOLAR

It is developed a software system SOLAR for modeling and simulation calculations of installations for thermal transformation of solar energy. The algorithm and the organization of the interface of the program provides a universal approach for adding new devices for exploring, including an opportunity for variation of parameters for the elements in the system.

The organization of the programming system contains three basic functional parts [2] (Fig. 1). As a basic infrastructural part of the system it appears the module of controlling simulation cycles in time and providing necessary climatic parameters in relation to discretion of the processes in time. In this time it is included the deliverance of data about the solar radiation and the air temperature for different geographical regions. In this functional part it is included special solar radiation' processor, which recalculate solar radiation for given slope and orientation of the received surface, and optical parameters for solar radiation penetration through the transparent covers.

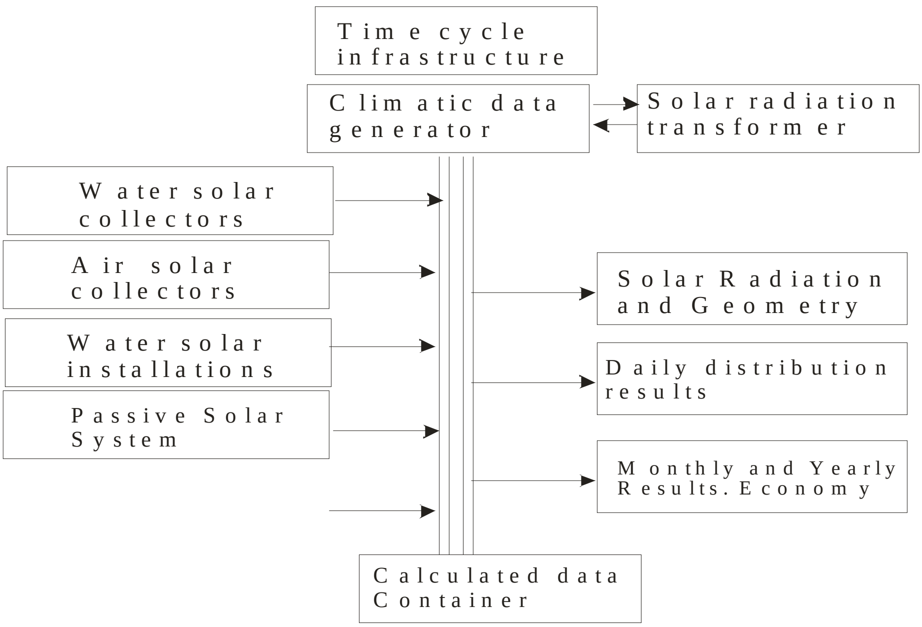

Fig. 1. Scheme of the program algorithm

The second functional part of the programming system is a set of programming modules for simulating heat and mass exchanging processes in different thermo-technical devices for utilizing solar energy. They are organized as separate programming structures according to the common infrastructural part of the programming system.

The third part of the programming system organizes the preservation of results from the calculations and a preparation of the necessary data. It is worked out a universal system for showing results for different periods of the simulation interval. Technical and economical estimations for solar systems can be generated on the base of received results from simulation calculations.

4. CONCLUSIONS

On the base of the existing data about solar radiation (for the region of city of Sofia) and the data about the duration of sun-shining it is achieved an assessment of the potentiality of the solar radiation on the territory of Republic of Bulgaria. A software product has been performed for simulation analyses of devices for thermal transformation of solar energy. It has modular structure for completing different installation schemes and it gives the opportunity to generate long-term assessments of thermal efficiency of devices. Program system can be successfully used not only for projecting purposes, but also for solving exploring tasks.

5. REFERENCES

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