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OPTIMAL POSITION OF SOLAR COLLECTORS: A REVIEW

Abstract: *Solar energy is the most abundant, inexhaustible and clean of all the renewable energy resources till today. The power from the sun intercepted by the earth is about 1.8×1011 MW, which is many times larger than the present rate of all the energy consumption. Solar energy has received much more attention in building energy systems in recent years.*

During the first years of the twenty-first century, extensive efforts have been undertaken to alleviate global warming of the earth caused by emission of CO2 in atmosphere. These emissions are generated by intensive burning of fossil fuels to satisfy the growing energy needs of humanity. The emissions may be mitigated when part of energy needs is satisfied by using non-polluting energy sources such as solar energy, instead of fossil fuels. Also, another important advantage of the usage of solar energy is that it does not pollute the environment with nitrogen oxides and sulfur dioxide.

In households, the high amount of DHW (domestic hot water) is used for shower, tap, cloths-washing machines, and dish-washing (machines). It is customary to use electricity for heating of DHW. Most of electricity is produced by using coal with high greenhouse emission, it is important and the most rewarding to use solar energy for DHW heating instead of electrical energy. Accordingly, worldwide, the most rewarding application of solar energy is when it replaces electrical energy for heating of DHW in households.

The solar collector has to take the optimal position that will guarantee the highest generation of heat. This paper gives a review of research with the objective of presenting, classifying and analysing the different criteria by which the authors observed an optimal position of the solar collector. In addition, it is important to have a high efficiency of conversion of solar energy to heat. Then, the highest amount of avoided primary energy, avoided electrical energy, avoided exergy, and decrease in CO2 emissions may be expected.

Keywords: *domestic hot water, azimuth angle, slope angle, orientation, optimization*

1. INTRODUCTION

During the first years of the twenty-first century, extensive efforts have been undertaken to alleviate global warming of the earth caused by emission of CO_2 in atmosphere. These emissions are generated by intensive burning of fossil fuels to satisfy the growing energy needs of humanity. The emissions may be mitigated when part of energy needs is satisfied by using non-polluting energy sources such as solar energy, instead of fossil fuels. Also, another important advantage of the usage of solar energy is that it does not pollute the environment with nitrogen oxides and sulfur dioxide.

In Serbian households, the high amount of DHW is used for shower, tap, cloths-washing machines, and dish-washing (machines). It is customary to use electricity for heating of DHW. As around 70% of electricity is produced by using coal with high greenhouse emission, it is important and the most rewarding to use solar energy for DHW heating instead of electrical energy. Accordingly, in Serbia and worldwide, the most rewarding application of solar energy is when it replaces electrical energy for heating of DHW in households [1]. In addition it is important to have a high efficiency of conversion of solar energy to heat. Then, the highest amount of avoided primary energy, avoided electrical energy, avoided exergy, and decrease in CO_2 emissions may be expected.

The solar collector has to take the optimal position that will guarantee the highest generation of heat. This paper gives a review of research with the objective of presenting, classifying and analysing the different criteria by which the authors observed an optimal position of the solar collector.

Therefore, it is important to have a high efficiency of conversion of solar energy to heat. Then, the highest amount of avoided primary energy, avoided electrical energy, avoided exergy, and decrease in CO_2 emissions may be expected.

As studied by different authors [2-5], general rules of thumb can be stated for the installation of solar flat plate collectors. For maximum annual energy availability, the slope of the collector should be equal to the angle of latitude for low latitude countries ($\delta < 40°$), increasing to latitude plus 10° for higher latitude countries ($\delta >$ 40°). For a latitude of 45° N, the variation of the total energy received s a function of slope showed that the changes in total annual energyreceived are less than 5% for slopes of 20° more or less than the optimum [6-8]. Calculations of total annual energyfor $\delta = 45°$, for surfaces of slopes of 30° and 60°, as a function of surface azimuth angle showed a small reduction in annual energyfrom the optimum (tilting towards the south). The generalization made in the literature was that the collectors facing 10-20° east or west of south should make little difference in the annual energy received. These literatures are mostlyconcentrated on higher latitude countries.

2. METODOLOLOGY

The slope angle (β) of any collector is defined as the angle between the plane of the collector and the horizontal. The azimuth angle (Ɣ) is defined as the displacement angle between the projection on a horizontal plane of the normal to the collector surface and due north. The incidence angle, e, is the angle between the direct radiation on a surface and the normal to that surface. For maximum direct radiation, the incidence angle should be a minimum. Fig. 1 shows these angles.

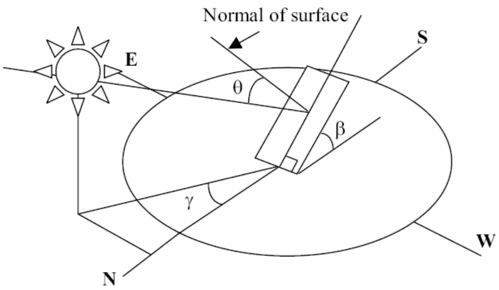

Figure 1 - Major angles in solar applications [9]

3. OPTIMAL POSITION

The orientation of a collector can be described with the help of its slope and azimuth angles. These two parameters can varied in special computer codes in order to find the optimal orientation.

3.1 Optimal slopes

The variation of annual diffuse, direct and total solar energy depends on slope angle. When slope angle is positive, the orientation of the surface is toward to the equator, and when is negative, the orientation is toward the pole. Bari [9] shows that the peak total occures at 6^0 slope, corresponding to an azimuth angle of 180^0. The peaks of the direct and diffused components are located on different slopes. The peak of the diffused component occurs at 0^0, i. e. horizontal, whereas the paek of the direct component occurs at 6^0.

3.2 Optimum azimuth angle

For maximum annual energy, the collectors should be tilted towards the equator, i. e. towads the south in the northern hemisphere and north in the southern hemisphere. At Iqbal [8], when the slope is optimum variation of surface azimuth angle does not have significant effect on the received solar energy. Therefore, for low latitude countries, the collectors’ azimuth angle can be oriented in any direction provided the tilt angle is optimum. For higher latitude countries, this night not be trued.

4. SUMMARY OF CRITERIA

During operation, solar collector has to take the optimal position that will guarantee the highest generation of heat. The solar collector takes the north-south direction and the objective is to find the optimum solar collector tilt. In literature, there is a lot of research with this objective. Based on the extraterrestrial solar radiation, Gunerhan and Hepbasli determined the optimum tilt angle of solar collectors for building applications [10], and Chang calculated the optimal tilt angle of a solar collector in the northern hemisphere [11]. By using the equations for the global solar radiation by an empirical model, Nijegorodov and Jain calculated optimum slope of a north-south aligned absorber plate from the north to the south poles [12], Chang calculated the optimal tilt angle of a solar collector in the northern hemisphere [11], and Moncos calculated the optimum tilt angle for solar collectors in Assiut, Egypt [13]. By determining the sunshine duration, Chang roughly estimated the optimal tilt angle of a solar collector in the northern hemisphere [11]. Based on the incident angles of the direct solar radiation, Skeiker calculated the optimum tilt angle and orientation for solar collectors in Syria [14]. By taking into account position of the sun at the sky and using the model of ASHRAE, Bari calculated the optimum orientation of domestic solar collectors for the low latitude countries [9]. By using the measured values of the global solar radiation, Ibrahim calculated the optimum tilt angle for solar collectors used in Cyprus [15]. By searching for values for maximum of the total radiation for a specific period by using measured data for global and diffuse radiation, Yakup and

Malik calculated the optimum tilt angle and orientation for solar collector in Brunei Darussalam, [16]. Based on the measured monthly average incident solar radiation, Hartley et al calculated optimized the angle of inclination of a solar collector [17]. Based on the monthly horizontal radiation, Tang and Wu reported the optimal tilt-angles for solar collectors used in China [18]. Based on the measured data for solar radiation by meteorological station, Shariah et al. optimized the tilt angle of solar collectors for the SDHW system where maximum solar fraction was used as an indicator for the optimum tilt angle [19] which is the case in the presented investigations. [20], Skerlic reported an investigation of the energy performance for variable tilt lat-plate solar collectors in Belgrade, Serbia. The investigated solar collectors are SC#2, SC#4, and SC#12. These solar collectors are placed at roofs of houses in north-south direction. The used weather data were from the meteorological station. These investigations use computer codes in EnergyPlus and GenOpt software with the application of Hooke-Jeeves search algorithm. For the different variable tilt SCs, the investigations yield their optimum tilts that maximize the solar fraction, avoided electricity, and avoided fossil energy by the SDHWS. In addition the research will study the deficit in the solar fraction when the tilt in practice is not optimal. After that the values of the avoided electricity are compared for all cases in order to show the real need for SC#2, SC#4, and SC#12 in practice. [21] Talebizadeh, reported investigation, the optimum slope and azimuth angles for hourly, daily, monthly, seasonally and yearly bases were found using the Genetic Algorithm (GA) respectively. The percentages of heat gain of a solar collector under these optimum angles were obtained. Furthermore, the importance of solar radiation components on the performance of solar collectors and photovoltaic panels were investigated by predicting the optimum slope angle and the input solar energy in different combinations of the solar components.

5. CONCLUSION

The performance of solar water systems not only depends on the solar energy absorbed by the collector, but it also depends on factors such as thermal energy lost from the collector to the surroundings byconduction, convection and infrared radiation, tube spacing inside the collector, the geometry of the collector, material properties etc. However, one of the criteria to improve the efficiency of the collector is to increase the absorbed radiation by the collector [2-4], which emphasizes the importance of proper orientation of the collector.

For value for money, the collector should be oriented properly so as to receive maximum solar radiation. A survey conducted in many cantries in world showed that almost all the collectors are not properly installed. They are mounted on the roof, so the roof's slope is the slope of the collector and the roof's azimuth angle is the collector's azimuth angle.

A computer program, developed to investigate the effect of slope and azimuth angle of the collector on the annual energyreceived, showed that the average loss of energyof these collectors is 10-35%. In some cases, the loss is as high as 50%. This clearly indicates lack of knowledge of both the suppliers and the consumers in this field.

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