



Comparison of optimum tilt angles of solar collectors determined at yearly, seasonal and monthly levels



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ABSTRACT

The amount of energy that is transformed in solar collector depends on its tilt angle with respect to horizontal plane and orientation of the collector. In this article the optimum tilt angle of solar collectors for Belgrade, which is located at the latitude of 44°47'N is determined. The optimum tilt angle was found by searching for the values for which the solar radiation on the collector surface is maximum for a particular day or a specific period. In that manner the yearly, biannual, seasonal, monthly, fortnightly, and daily optimum tilt angles are determined. Annually collected energy per square meter of tilted surface is compared for ten different scenarios. In addition, these optimum tilt angles are used to calculate the amount of energy on the surface of PV panels that could be installed at the roof of the building. The results show that for observed case study placing the panels at yearly, seasonal and monthly optimum tilt angles, would yield increasing yearly amount of collected energy by factor of 5.98%, 13.55%, and 15.42% respectively compared to energy that could be collected by putting the panels at current roofs' surface angles.

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1. Introduction

The amount of solar energy that is converted in solar collector depends on tilt angle of collector with respect to horizontal surface and orientation of the collector. Although in recent study [1] authors show that the tilt angle is nearly irrelevant that is the difference of plant yield is just 6% for tilt angles between 0° and 70°, these results are counterintuitive and as authors claim themselves the further investigations considering other locations and time periods are needed to clarify this issue. The tilt angle of a solar energy system was investigated for different applications: evacuated tube solar water heaters [2,3], hybrid power system [4], PV generation [5], solar cooker [6], mirror-augmented PV system [7], and many others.

The most efficient solar energy yield can be obtained by using Sun-tracking devices. There are number of studies showing that tracking systems enable significant amount of solar energy compared to fixed systems. Abdal lah [8] found that tracking systems increase total daily energy collection of about 43.87% as compared with fixed system. A very detailed review of energy gain of different trackers is done in Mousazadeh et al. [9]. In that paper authors report boost of collected solar energy by means of tracking system in the range of 10–100% depending on different periods of time and

geographical conditions. Tomson [10] reported increasing of seasonal energy yield by 10–20% by using the two-positional tracking system that positions collectors in the morning and in the afternoon. Chang [11] found substantial gains of 51.4%, 28.5% and 18.7% from the extraterrestrial, predicted and observed radiations respectively by using a single-axis tracking system.

However, Sun-tracking systems are quite expensive, energy intensive and are not recommended for using for small solar panels [9,10]. The other approach to increase amount of collected energy is to place collectors at optimum angle. There are number of studies that were carried out in order to find the optimum tilt angle of solar collectors around the world (Carbondale, Illinois [12], Izmir in Turkey [13], Sanliurfa, Turkey [14], Dhaka [15], 30 cities in China [16], Madinah, Saudi Arabia [17], Jordan [18], Helwan, Egypt [19], Brunei Darussalam [20], Syria [21], Cyprus [22], Burgos, Spain [23], Brisbane, Australia [5] and many more).

Many researchers proposed various schemes for optimizing the tilt angle of solar collectors for different latitudes. Some of them gave even set of 12 equations for calculating optimum tilt angle for each month [24,25]. However, although during last two decades, researchers have made efforts for estimation of local optimum tilt angles, no definite value, or method is accepted by all researchers and reported optimum angles for the same latitude differ for more than 15° : $(\phi + 15) \pm 15$ [26], $\phi - 10$ [27], $\phi \pm 10$ [28].

In this paper optimum tilt angles of solar collectors for Belgrade, Serbia are found at yearly, biannual, seasonal, monthly, fortnightly

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