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The monitoring of monthly, seasonal and yearly optimum tilt angles by Raspberry Pi card for Bilecik city, Turkey

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Abstract

Solar energy is extracted from photovoltaic (PV) panels by semiconductor materials used in the system. However, the PV panel efficiency is low. Moreover, inaccurate determination of optimum fixed tilt angle of the panels, some environmental factors such as dirt and dust and solar radiation level and temperature variations depending on the seasonal changes decrease the panel efficiency. In the study, PV panels were placed at 10º, 20º, 30º, 40º, 50º and 60º tilt angles and the monthly, seasonally and yearly optimum tilt angles for Bilecik city were determined. Therefore, it was determined at which tilt angle the maximum power is extracted from PV panels. The record and the storage of the voltage, current and the power data obtained from PV panels is provided by Raspberry Pi card. Moreover, the obtained data is open to access on the internet by a web server set up on Raspberry Pi. Therefore, the data can be watched live in any computer with an internet access. Annual measurements were performed by the designed system and the data was recorded with the date and time data.

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Keywords: PV panel; Raspberry Pi; tilt angle; microcontroller; yearly

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1. Introduction

The need for electricity has increased due to rapidly improving technology and increasing population with the industrial revolution. Today, mostly fossil fuels such as oil, natural gas are used in obtaining electrical energy. Some renewable energy sources such as solar, wind, geothermal and biomass have been used recently as an alternative to fossil fuels since they give harm to the environment and they will be exhausted in the near future. There have been many investments on energy sector recently and obtaining electrical energy from solar energy has become more attractive [1, 2].

The systems used to obtain electrical energy from solar energy are called as photovoltaic (PV) systems. In PV systems, solar energy is directly converted to electrical energy by the semiconductor materials used in the system. However, the efficiency of PV panel is low depending on the semiconductor materials. There are many factors affecting the PV panel efficiency. The location of the PV panel is the most important parameter affecting the efficiency. Sun lights should fall on the PV panels with direct angle in order to have a power at maximum level [3–5]. Therefore, solar tracking systems are used. However, the drawbacks of the power tracking systems are that the devices such as motor, driver, etc. used in the system consume energy continuously and they have high cost. Therefore, the panels are placed monthly seasonally and annually at optimum fixed tilt angles to benefit from sun light at maximum level. In fixed tilt angle systems, the angle varies according to the geographic position of PV panels. As a result, the monthly, seasonally and annually variations of PV panel optimum tilt angles are determined by experimental studies [6, 7].

In literature, Ulgen [8] carried out a study for Izmir city, Turkey and determined that the optimum tilt angle for solar collectors varies between 0–61˚ throught the year. He indicates that the tilt angles of the solar collectors should be 55.7˚ for winter, 18.3˚ for spring, and 4.3˚ for summer and 43˚ for autumn. He presented that annually average tilt angle of fixed systems is 30.3˚. In the study conducted by Beringer et al. [9] eight PV panels are placed between 0°–70° by 10° increase. The optimum tilt angle for winter and summer seasons are found to be between 50°–70° and 0°–30°, respectively. The annual optimum tilt angle is found to be equal to the tilt angles of summer period. Jafarkazemi and Saadabadi [10] found the annual optimum tilt angle as 22°. This value is very close to the latitude angle found by Abu Dhabi. The monthly optimum tilt angle varied between –9 and 52° starting from June to December months. Khorasanizadeh et al. calculated the monthly, seasonal, semiannual and annual optimum tilt angles for Tabass city, Iran. The monthly tilt angle was found to be 0° for June and July and 64° for December months. The annual tilt angle was calculated as 32° and this value is very close to the latitude angle of Tabass city. Kacira et al. [11] conducted a study for Sanlıurfa city and presented that the monthly optimum tilt angle of the city varies between 13°–61° through the year.

In this study, PV panels with same properties were placed at 10º, 20º, 30º, 40º, 50º and 60º tilt angles and the voltage data was measured and recorded in the computer environment. The monthly, seasonal and annual optimum fixed tilt angle was determined for Bilecik city. Firstly, the obtained analog data was converted to numerical data by a microcontroller. The average of the numerical data was taken in every 10 minutes by Raspberry Pi and was stored on a SD card placed on Raspberry Pi and in computer environment as well. Then, the current, voltage and power values of PV panels could be watched alive by the web server set up on Raspberry Pi in every hour of the day. Only the voltage values of PV panels could be measured in the system. The current and power values of the PV panels are calculated by an algorithm written by Phyton programming language. The measurements were conducted between May 2015 and April 2016. The data was taken hourly between 06:00 and 21:00. The daily average voltage, current and power values are shown in line chart, the daily voltage and current values of each panel placed at different angles are shown in bar chart and the annual power values expressed in percentages are shown in a bar chart.

This paper is organized as follows: Section 2 presents the designed system. In Section 3 and 4, hardware development and architecture of the system are presented, respectively. In the results section, the annual power values of the panels expressed in percentages placed are given and the monthly, seasonal and annual optimum tilt angles are determined.