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A web-based remote monitoring of solar energy measurements and data storage system design for renewable energy center of Karabuk University

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ABSTRACT

Solar data of long periods are required for the related regions so that solar system applications could be optimally sized and economically installed. Solar data must be continuously stored to foreknow how much electricity could be met from solar energy for daily or different seasonal demands. In this study, a solar radiation measurement, data acquisition, and storage system were designed. A monitoring web site offering the user solar data with different analysis is also designed to access data from remote points. Instantaneous and previous data are accessible with different analysis on the web page at http://yemmer.karabuk.edu.tr/lab/. Spectral data of solar energy are increasingly becoming important with developing spectrally selective technologies such as solar detoxification, photovoltaic, solar thermal etc. Hence five different wavelength bands (UV, Green, Visible, IR, Global) of solar spectrum is continuously measured and stored as minutely averages. In this way solar energy potential of Karabuk region emerges.

1. Introduction

Energy consumption in world is growing day by day depend on development of technology and fast industrialization. This energy demand is also being increased by fast population growth. Thus world energy consumption has increased about 50 % at last 20 years. Furthermore fossil fuels that supplies about 85% of world energy demand are nonrenewable energy sources causing permanent destruction in nature and environmental pollution [1]. High carbon dioxide emission which is mostly caused by fossil fuels is major reason of climate change and will threat world's future. The energy crisis that the world faces and negative impacts of energy sources that have been used have turned the view of scientists to renewable energy sources [2].

However solar energy has a special place among the renewable energy sources. Solar energy amount that comes earth surface in one year is more about 15000 times than energy that can be generated by power plant that uses fossil fuels, nuclear power plant and hydroelectric power plant [3]. Solar energy is also environmentally friendly and some like endless.

To assess this huge energy source, technologies converting solar energy to different energy forms which are suitable to be used by human being were found. Photovoltaic technology directly converting solar energy to electrical energy and its applications are increasingly developing. While solar energy applications are planning, not only superficial knowledge (just observations made by meteorologist or model results using data of limited number measurement stations) is required but also detailed knowledge (daily and hourly basis monthly and yearly average values of long-term measurements) for solar energy potential about the site where applications will be made is required. While solar insolation reaching top of the atmosphere is nearly constant during the year, solar insolation falling onto earth surface varies with local atmospheric conditions, micro climate, surface shape and time of the day and year. Moreover different insolation values can be observed for same time slots of years. Hence solar insolation values should be continuously monitored to determine solar energy potential of the site for economic and optimal application reasons. Measurements should be long-term and stable [4]. In [5] detail information about solar energy measurements can be found.

In addition to meteorological organizations, researchers also work to detect solar energy potential on their regions. In 1999, Mukaro and Carelse designed and implemented a microcontroller based data acquisition system for solar radiation and environmental monitoring [6,7]. Balan et al. have implemented a solar energy measurement system for detecting solar energy potential on their region. Solar radiation values measured by a commercial pyranometer are stored in database. Instantaneous data and previous data can be queried on the internet [8]. Some researchers focused on measuring meteorological data like solar radiation, temperature, humidity in a specific

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region using wired or wireless communication [9-13]. A series of papers [14-17] reported monitoring of photovoltaic power generation and performance of PV solar plant.

In this study, a solar radiation measurement, data acquisition, storage and web based remote monitoring system were designed. The monitoring web site offers the user solar data with different analysis and gives ability to access data from remote points. Instantaneous and previous data are accessible with different analysis on the web page at http://yemmer.karabuk.edu.tr/lab/. The difference of this study is that not only global radiation is measured but five different spectral region of solar spectrum are also measured by pyranometers designed by our renewable energy laboratory. A flexible interface giving ability user to query historical data with different forms was also designed. Throughout the paper, operating system of solar energy measurement laboratory of Karabuk University renewable energy engineering research and application center was explained.

1. General structure of the system

Measurement station and solar measurement laboratory were established at the roof of Karabuk University Engineering Faculty (located at latitude of 41°12′48.55″N and longitude of 32°39′15.26″E, Karabuk, Turkey). Five different spectral radiation measurements are made by the station. Five pyranometers have been placed horizontally to ground. Signals coming from pyranometers are collected with microcontroller based data acquisition card communicating with the computer via USB. Measurement values which are sampled and digitized in the microcontroller are transferred to computer on which an interface program is running. Digitized values are converted to solar radiation values by multiplying calibration coefficients and then stored in database. An internet page has been designed to share measurement results with researchers and also with public to increase awareness about solar energy. Any user on the internet can see instantaneous data and observe measured radiation values throughout present day with a chart. Owing to database, users can query previous data chart at daily, monthly and yearly average form. In Figure 1 general flowchart of the system is shown.

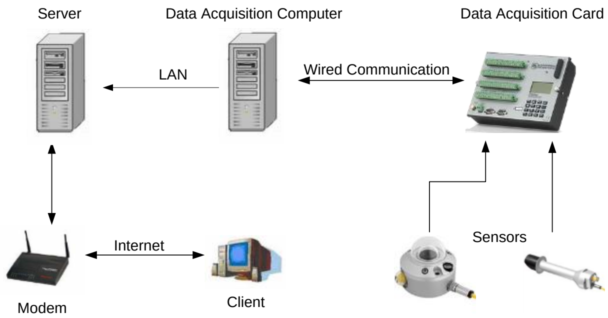


Figure 1. Block diagram of the measurement system

2.1. Measured wavelengths and pyranometers

Spectral data of solar energy are increasingly becoming important with developing spectrally selective technologies such as solar detoxification, photovoltaic, solar thermal etc. In Solar Energy Measurement Laboratory, pyranometers responding different spectral regions of solar energy are used. Hence energies in ultraviolet (280-400 nm), visible (400-700 nm), infrared (700-1100 nm), green (500-578 nm) and total (280-2500 nm) regions of the spectrum are measured. Pyranometers shown in Figure 2 have been designed and realized in Karabuk University. Calibration coefficients of the pyranometers are obtained under the standard lamp.

Figure 2. Horizontally placed pyranometers.

To validate measurement of designed pyranometers, the response of global pyranometer on a randomly selected day was compared with a commercial pyranometer which has accuracy of ± 5% (SP215 Apogee Instuments) measurements. The response of two pyranometers is very similar as shown in Figure 3.

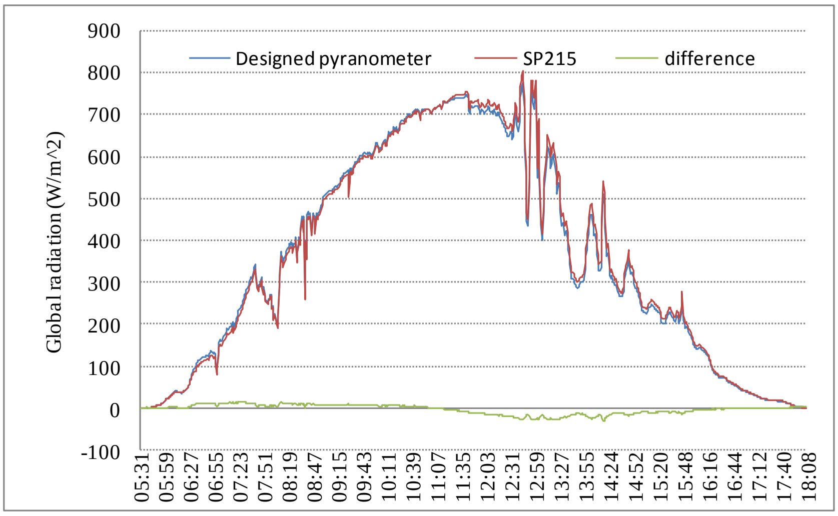


Figure 3. Comparison of global solar energy data measured with designed pyranometer and commercial pyranometer on 25.03.2013.

2.2. Data acquisition card

Analog (0-5 VDC voltage) signals are produced by trans-impedance amplifier circuit placed in the pyranometer. These signals are taken to computer via a data acquisition card having 13 analog channels of 12 bites, communicating to the computer with USB interface. Analog signals are converted to 12-bit digital numbers and sent to the computer in certain intervals by microcontroller.

2.3. Data transfer and storage

The interface program written in C# programming language takes data that are sampled, digitized and sent by microcontroller and then stores them into database. The screen shot of interface program is shown in Figure 4.

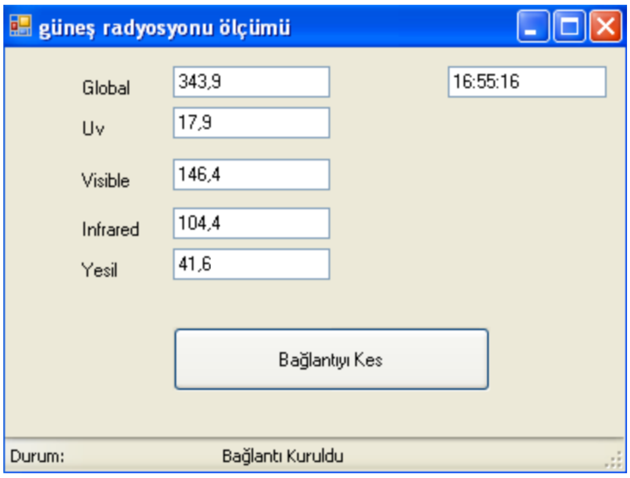


Figure 4. The screen shot of interface program

Interface program takes measurements at every 3 seconds. These measurements are converted to solar insolation values multiplying by the calibration coefficients related to measured wavelengths. The average values of the measurements taken during one minute are stored into database together with date-time information. Hourly average values are calculated and stored into database at the end of every hour. The flowchart of interface program is shown in Figure 5.

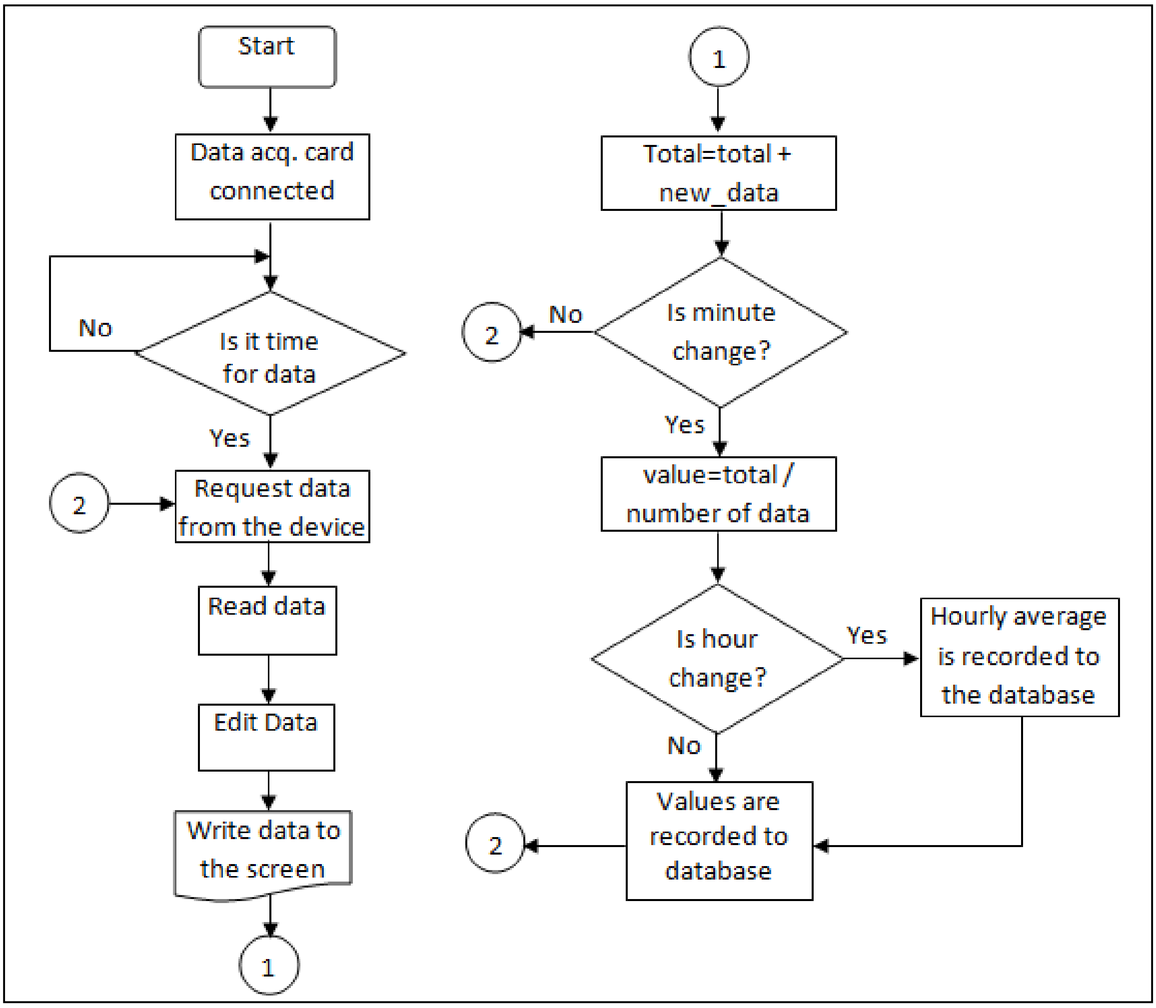


Figure 5. Flowchart for interface programme

2.4. Database

A database is used to store measurements. There are two tables to store minutely and hourly average values in the database that are formed using SQL server database management system. In Figure 6 the table on the left hand side shows the minutely average stored data whereas the table on the right hand side shows the hourly average of stored data. As shown in Figure 6, each record has four columns as ID, wavelength showing what the measurements belong to, measurement value, hour and date. In this way a new measurement can be easily added to the table.

id	wavelength	measurement	hour	date
1688351	global	624,2	11:41	2012-09-24
1688352	ultraviole	35,2	11:41	2012-09-24
1688353	infrared	185,3	11:41	2012-09-24
1688354	green	47,8	11:41	2012-09-24
1688355	visible	246,9	11:41	2012-09-24

id	wavelength	measurement	hour	date
33084	guneslenme	27	07-08	2012-09-24
33083	visible	34,3	07-08	2012-09-24
33082	green	6,3	07-08	2012-09-24
33081	infrared	34,6	07-08	2012-09-24
33080	ultraviole	4	07-08	2012-09-24
33079	global	111,9	07-08	2012-09-24

Figure 6. Tables formed in database

For security of recordings, data are simultaneously stored into two different computers; computer in the laboratory to which data acquisition card is connected, and server computer in the information technologies center of the university. Database on the server computer is used to disseminate the measurement results via internet.

2.5. Data presentation

A web page is prepared to disseminate the measurements with different analysis to see solar potential of Karabuk throughout the year. The address of this website is *http://yemmer.karabuk.edu.tr/lab*. The website has two windows; one for instantaneous data, and the other one for historical data with different analysis.

The instantaneous data window shows current measurements and their daily trends and is updated with period of one minute. The window showing instantaneous data is shown in Figure 7.

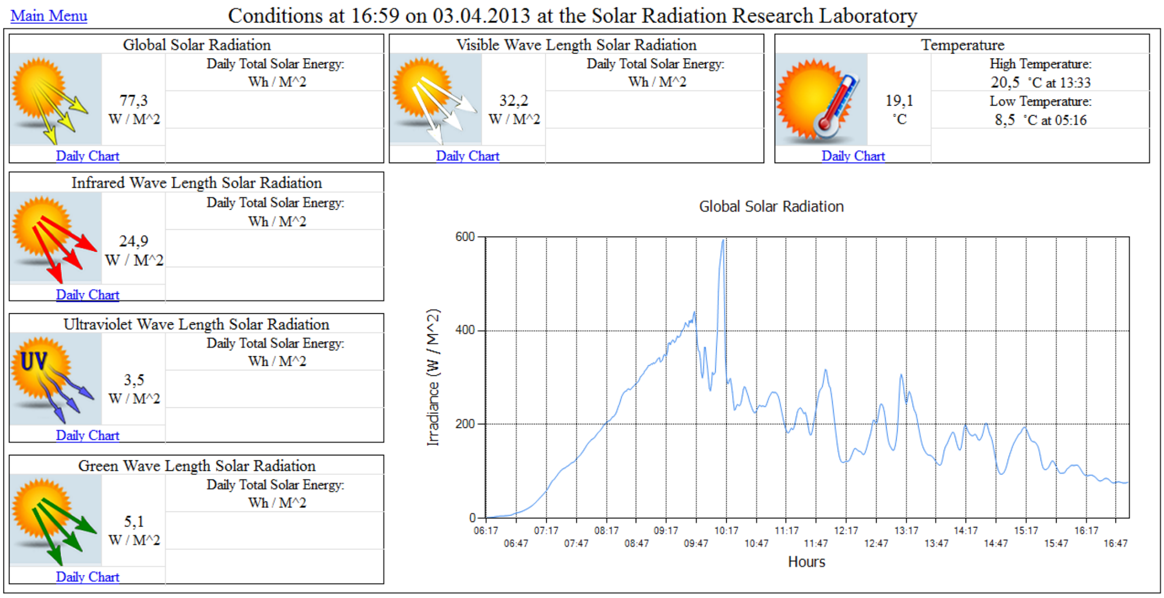


Figure 7. Window showing instantaneous data and its daily trend.

The window showing historical data can be queried in several different forms as daily data, monthly data, yearly data and periodical data. The daily data page is shown in Figure 8.

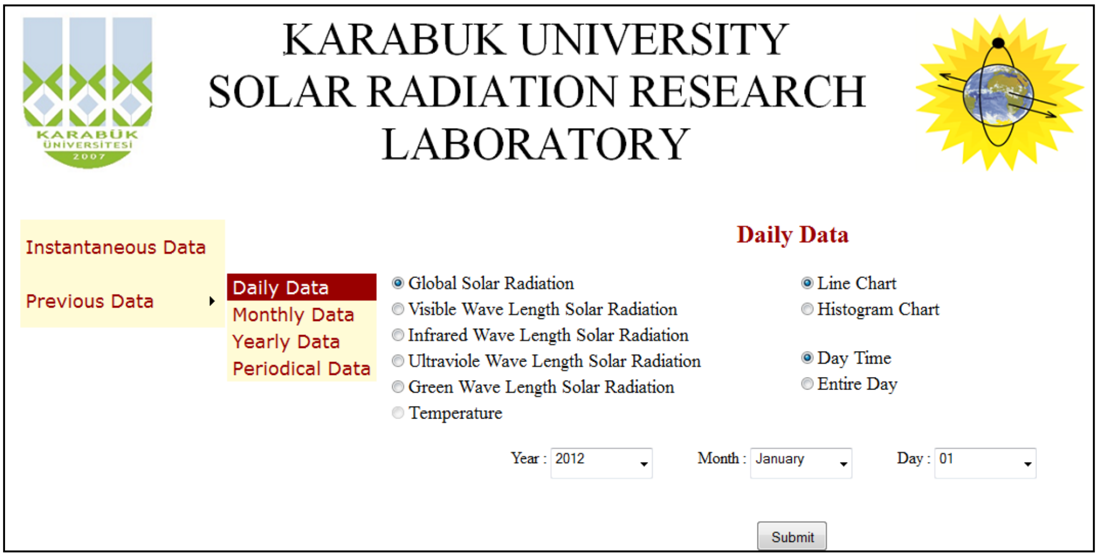
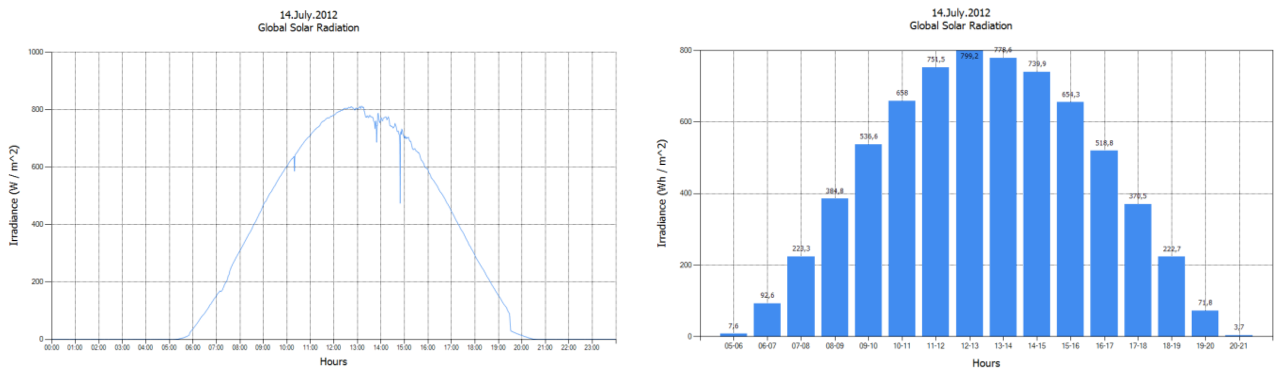


Figure 8. Daily data page

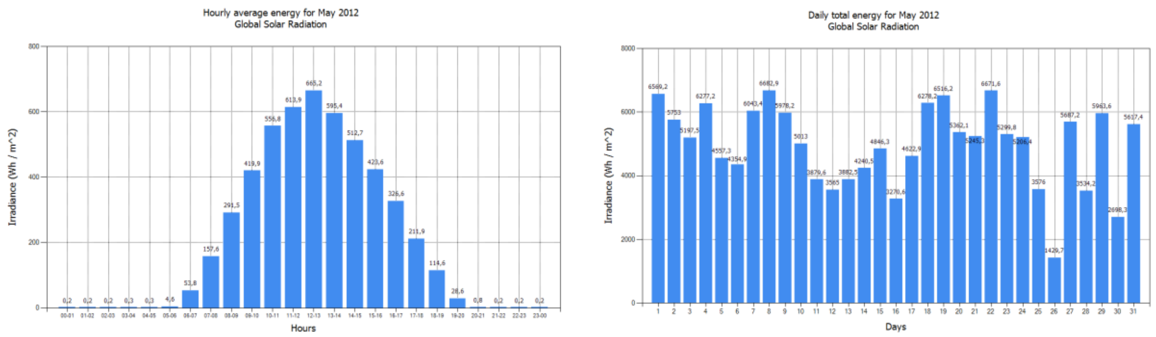
If a user wants to observe any daily measurements, it should be firstly selected that what wavelength measurements are needed and what date it is. As shown in Figure 9, daily data page also offers user to select graph type with two options; line graph showing minutely measurements throughout the day or histogram graph showing averaged values of minutely measurements over one hour.



(a) (b)

Figure 9. (a) line graph, (b) histogram graph for daily trend.

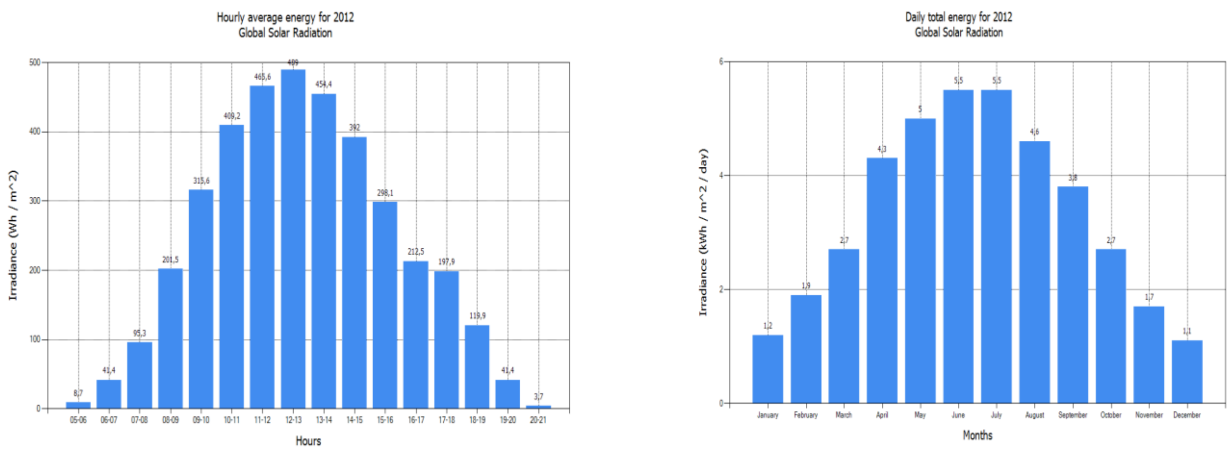
If monthly data are wanted to be observed, the user is prompted with two different analysis; monthly basis hourly average as shown in Figure 10a or daily total radiation throughout the month as shown in Figure 10b. Monthly basis hourly average shows how much average radiation there are for a certain hour of selected month. This type of analysis may be used for a solar plant to estimate whether solar energy potential can meet energy demands for a certain hour of a month.



(a) (b)

Figure 10. (a) Monthly basis hourly average radiation for selected month, (b) daily total solar energy trend for a selected month.

If yearly data are wanted to be observed, the user is prompted with two different analysis; yearly basis hourly average as shown in Figure 11a or monthly basis daily total radiation throughout the year as shown in Figure 11b. Yearly basis hourly average shows how much average radiation there are for a certain hour of a average day of a year. This is calculated averaging hourly radiation values throughout the year. Monthly basis daily total radiation shows how much average radiation there are for a average day of a month.



(a) (b)

Figure 11. (a) yearly basis hourly average, (b) average daily radiations for months throughout the year.

The web page also offers user to select a period of time on which data are wanted to be analyzed. In this case user enters a time period in 'Periodical data' section and then is asked with two options to analyze the data as hourly average or daily average.

3. Results

In this study a data acquisition, storage and web based monitoring system for solar radiation measurement in Karabuk have been designed and implemented. Historical solar radiation measurement data can be monitored with different analysis on the internet by researchers and public. Thus solar potential of Karabuk region will be determined with long-period measurements. These measurements enable us to optimally and economically size solar projects to be established in Karabuk, and to estimate how much energy demand can be met from a solar plant for a specific hour or day of year. We also aim adding new sensors such as for wind speed and direction, pressure, humidity and for rain to collect all the meteorological data about Karabuk.

References

[1] U.S. Energy Information Administration, "International Energy Outlook 2010", DOE/EIA, 0484, Washington, 9-21, 2010.
[2] Islam, M.D., Alili, K., I., Ohadi. M., "Measurement of solar-energy (direct beam radiation) in Abu Dhabi, UAE", Renewable Energy, 35, 515–519, 2010.
[3] Serrano, E., Rus, G., García-Martínez, J., "Nanotechnology for sustainable energy", Renewable and Sustainable Energy Reviews, 13, 2373–2384, 2009.
[4] National Renewable Energy Laboratory, "Shining on: A Primer on Solar Radiation", http://rredc.nrel.gov/solar/pubs/shining/intro_shining.html, 2013.
[5] Myers, D.,R., "Solar radiation modeling and measurements for renewable energy applications: data and model quality", Energy, 30, 1517–1531, 2005.
[6] Mukaro, R., Carelse, X., F., "A microcontroller-based data acquisition system for solar radiation and environmental monitoring" IEEE Transactions on Instrumentation and Measurement, 48(6), 1232-1238, 1999.
[7] Mukaro, R., Carelse, X., F., Olumekor, L., "First performance analysis of a silicon-cell microcontroller-based solar radiation monitoring system" Solar Energy, 63(5), 313–321, 1998.
[8] Balan, M. C., Damian, M., Jäntschi, L., "Preliminary Results on Design and Implementation of a Solar Radiation Monitoring System", Sensors, 8, 963-978, 2008.
[9] Koutroulis, E., Kalaitzakis, K., "Development of an integrated data-acquisition system for renewable energy sources systems monitoring", Renewable Energy, 28(1), 139–152, 2003.
[10] Juca, S., C., S., Carvalho, P., C., M., Brito, F., T., "A Low Cost Concept for Data Acquisition Systems Applied to Decentralized Renewable Energy Plants", Sensors, 11(1), 743-756, 2011.
[11] Papadakis, K., Koutroulis, E., Kalaitzakis, K., "A server database system for remote monitoring and operational evaluation of renewable energy sources plants" Renew Energy, 30, 1649–69, 2005.
[12] Benghanem, M., "A low cost wireless data acquisition system for weather station monitoring", Renewable Energy, 35, 862-872, 2010.
[13] Rosiek, S., Batlles, F.J., "A microcontroller-based data-acquisition system for meteorological station monitoring" Energy Conversion and Management, 49(12), 3746–3754, 2008.
[14] Dursun, M., Yilmaz, E., "Design and application of internet based solar pump and monitoring system", Journal of Applied Science, 8, 2859-2866, 2008.
[15] Benghanem, M., Maafi, A., "Data Acquisition System for Photovoltaic Systems Performance Monitoring" IEEE Transactions on Instrumentation and Measurement, 47(1), 30-33, 1998.
[16] Gagliarducci, M., Lampasi, D.,A., Podesta, L., "GSM-based monitoring and control of photovoltaic power generation" Measurement, 40(3), 314–21, 2007.
[17] Forero, N., Hernandez, J., Gordillo, G., "Development of a monitoring system for a PV solar plant", Energy Conversion and Management, 47, 2329-2336, 2006.