Вісник Тернопільського національного технічного університету
Scientific Journal of the Ternopil National Technical University
2017, № 1 (85)
ISSN 1727-7108. Web: ***visnyk.tntu.edu.ua***

INSTRUMENT-MAKING AND INFORMATION-MEASURING SYSTEMS

ПРИЛАДОБУДУВАННЯ ТА ІНФОРМАЦІЙНО-ВИМІРЮВАЛЬНІ СИСТЕМИ

UDC 621.31

RESEARCH OF ENERGY POTENTIAL OF SOLAR RADIATION IN TERNOPIL

Volodymyr Andriychuk; Yaroslav Filyuk

Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine

Summary. *Experimental installation for measuring and recording of solar radiation flux density was mounted according to suggested procedures. Analysis for density flux time distribution was performed and surface energy density of solar radiation for the city of Ternopil was calculated. It was proved that the most productive period for electricity photo generation within Ternopil city area is May through September.*

Key words: *solar battery, solar energy, microcontroller, pyranometer.*

Received 20.02.2017

Problem setting. Solar radiation is accessible and inexhaustible source of energy. So far, a lot of research projects dedicated to efficiency and necessity of solar energy [1 – 7]. The usage of solar power stations in Ukraine is a challenging method to gain ecological and regenerative sources of energy. The efficiency of solar energetics depends upon both technical designs and climate conditions. The investigation of energy potential in certain regions is extremely relevant, as it will facilitate installation of solar power stations into national energy system that is why the represented research project is devoted to investigation of solar energy potential in City of Ternopil.

Analysis of resent issues. During the analysis of solar radiation intensity we accepted the assumption that despite monthly aggregates of solar energy on horizontal surface are changing every year their average values are invariable [3].

The [4, 5] represent the data about the volumes of solar energy in those settled areas where the investigations were carried out by Davis Instruments Co meteorological station. The probabilistic characteristics and solar potential distribution laws were calculated for Kropivnitskyy district in [4]. The average values of solar energy for each month from 2012 up to 2015 in City of Odessa were shown in [5] but they are not intrinsic for other inhabited areas.

The issues [6 – 8] represent monthly and annual values of aggregate solar radiation reflecting from horizontal surface of Ukrainian territory according to geographic latitude that were calculated with solar radiation duration and average nebulosity. The calculation results for aggregate, direct and scattered solar radiation on horizontal surface in Ternopil are shown in [9] though it does not contain the experimental data that include the climate specifications of the given area.

Corresponding author: Yaroslav Filyuk; e-mail: filuk.slavik.91@gmail.com

Research objectives include the research of energy potential of solar radiation in Ternopil taking into consideration the atmospheric and climate conditions.

Task setting assumes the elaboration of methods and experimental device to measure the energy potential of solar radiation and its recording during the given time intervals. The calculation of time distribution of ray density and number of solar radiation value per a surface unit on the angle 49^0 against the horizon in Ternopil administrative area.

Presentation of basic material. Ternopil and its vicinities are located $49^0 34'$ degrees north latitude that corresponds to maximal energy potential of 1150 $W{\cdot}h/m^2$ solar radiation. To study the atmospheric influence upon its value there was designed and mounted the measuring device displayed on Figure 1. This device facilitates recording of sun radiation on-line with an interval of 1 min.

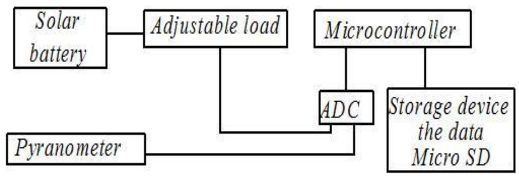

Figure 1. Block diagram of the measuring device

The device contains: microcontroller Atmega 32, which processes and records data from analog-digital convertor (ADC); storage device the data MicroSD; adjustable load; solar battery (SB) ALM-50M; pyranometer.

Alongside with measurement of radiation density with pyranometer this device facilitates measuring of electricity volume obtained from solar battery. For this purpose, we used SB of ALM-50M with resisting adjustable load. Electric circuit of the given section of the device is displayed on Figure 2. The voltage from SB output was fed to load resistance R_{load}, bleeder R_1, R_2 and R_{shunt}. According to decrease of voltage on R_{shunt} we determined the load current and the voltage on SB output was measured by means of bleeder R_1, R_2. The bleeder used high-Om resistance that enabled eliminating the influence upon measurement results. The power of generated electric current was determined as a product $P=UI$. The load resistance was selected in order to be relevant to the mode of maximal SB capacity.

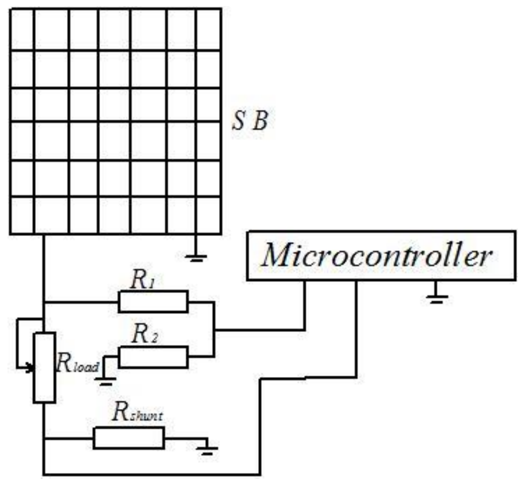

Figure 2. The electrical circuit for voltage and current measuring of the SB

To measure the density of energy flux of solar radiation we used the pyranometer, it electric circuit is shown on Figure 3. The presented device consists of photo-receiver of mono-crystal silicon D_1, linked to short circuit, electric converter A та and booster of signal B. This device was calibrated with flux density indicator for solar radiation Solar Power Meter DT-1307. The measurement was carried out at tilting angle of photo-receiver against the horizon $\alpha = 49^0$, which is optimal for Ternopil latitude. All experiments were made in accordance with ГОСТ28977-91. The data were recorded on bulk storage and processed in Maltab software.

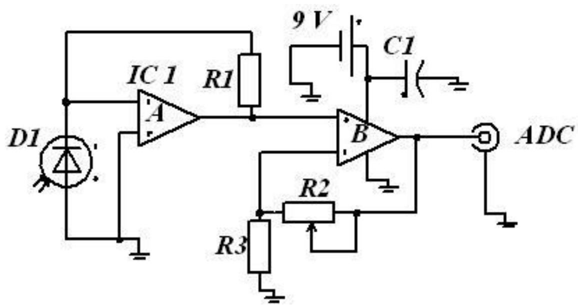

Figure 3. The electrical circuit of pyranometer

Research results. The studying of energy flux density distribution started on May/01/2016 at Faculty of Applied Information Technologies and Electric Engineering, 46 Mykulynetska. The photo-detector and solar battery were located on the upmost terrace of campus building #7 to avoid artificial shadowing and ensured the maximally objective measurement results. Figure 4 represents values of solar radiation density during May/2016. The same graphs were made for other months including December/2016.

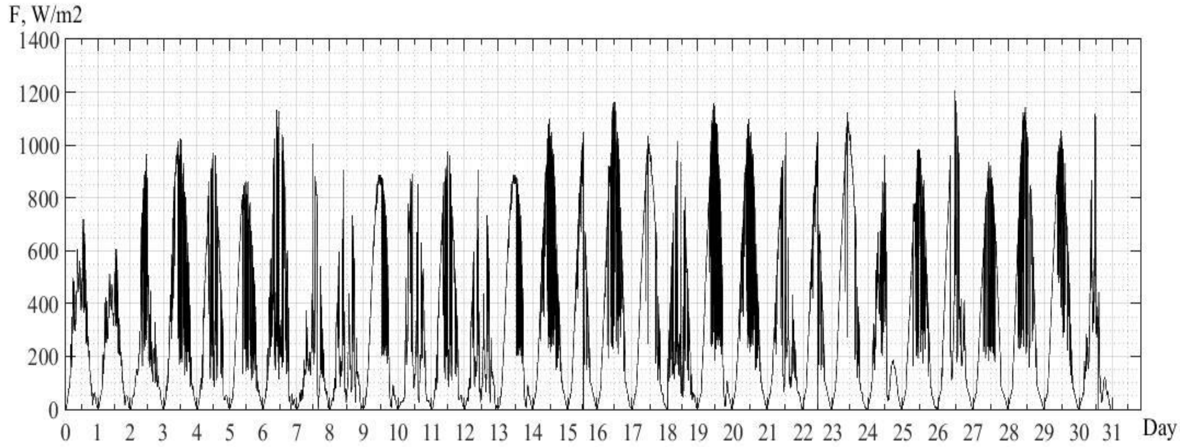

Figure 4. Graph of solar radiation density flux changes during May 2016

As it was noted above, the time interval of 1 min. was selected for recording, within which the alteration value of energy flux did not exceed ±10%. In order to determine the energy of solar radiation the statistical processing of measurement results was carried out in the form of identification of time distribution of radiation flux density. With this purpose we imposed the discrete flux values altering with an interval of 10 W/m^2. The results were processed with Matlab software an averaged with the least squares method. Figures 5a an 5b display the distribution of density for energy flux of solar radiation in May and June 2016. As the graphs show, the distribution of density of solar radiation up to 200 W/m^2 has the time interval from 300 to 1400 *min*., and the energy fluxes more than 200 W/m^2 are divided within time interval from 50 to 300 *min*. Time distribution of energy fluxes from 0 to 200 W/m^2 is described by exponential law for May $F=334e^{-0.0022\tau}$, and June $F=324e^{-0.0024\tau}$.

During July, August and September the time distribution of energy flux is the same as in May and June but the fluxes from 800 to 900 W/m^2 are marked with longer action time that is reflected with their maximal values on graphs. The time correlation between energy fluxes from 0 to 200 W/m^2 of these months can be described by exponential law $F=250e^{-0.0024\tau}$.

Fall – winter period on Ternopil latitude is characterized with the decreases time of fluxes' action with the energy more than 200 W/m^2. The time distribution of density of solar radiation in October 2016 is shown on Figure 5e. The same dependencies were spotted in November and December. The time distribution for energy fluxes that are less than 200 W/m^2 is described equation $F=274e^{-0.0001\tau}$.

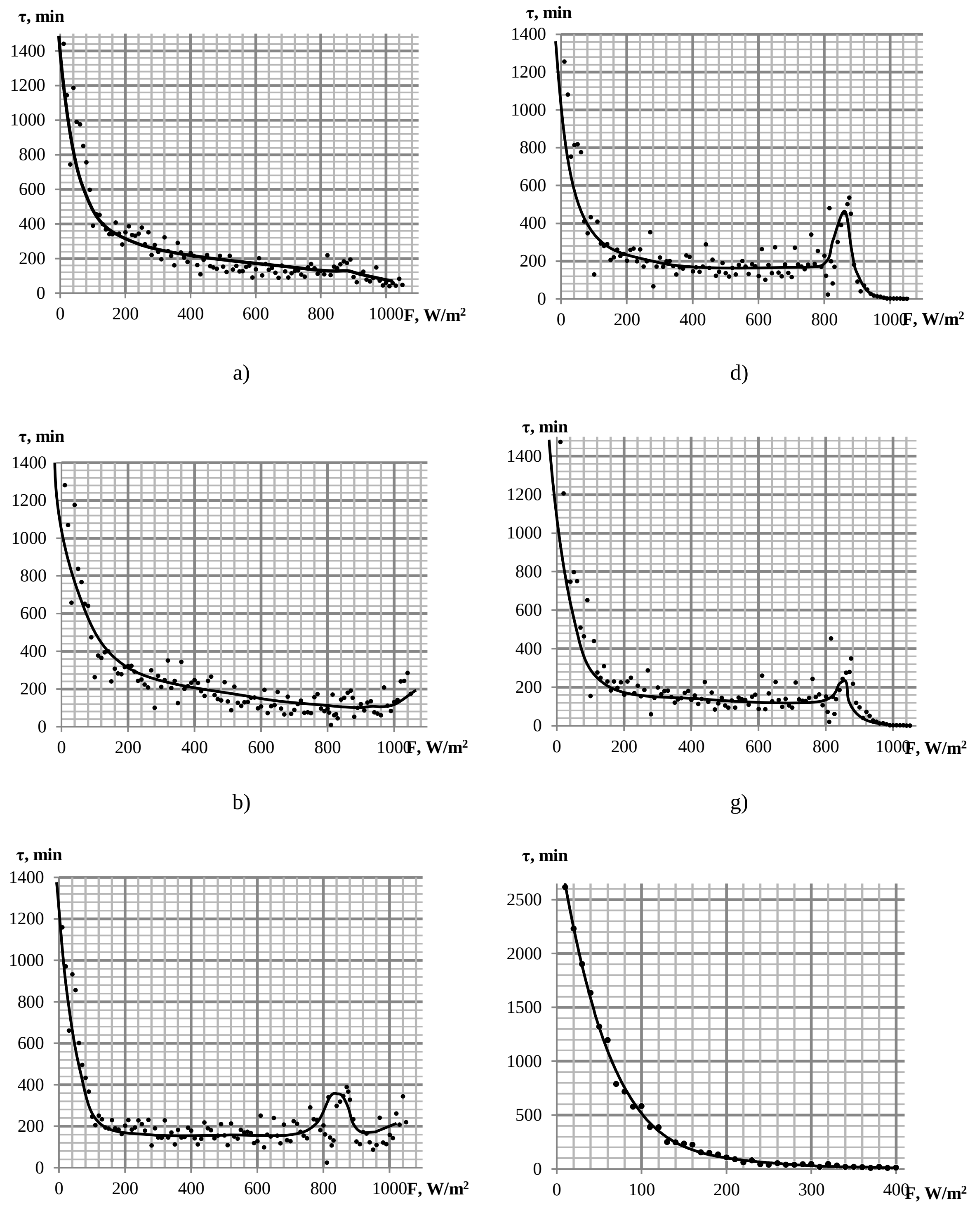

Figure 5. Monthly density distribution of solar radiation energy flux:
a) May; b) June; c) July; d) August; g) September; e) October.

There were also carried out the analysis of daily distribution of density of solar radiation that facilitated diversifying of days due to atmospheric transparency.

Figures 6 – 8 represent the graphs of distribution of flux density of solar radiation for sunny or cloudless day, misty (average cloudiness) and gloomy day in May 2016. Having based on the graphs we calculated the radiation energy for sunny E=6,03 $kW{\cdot}h/m^2$, misty

E=2,8 $kW \cdot h/m^2$ and gloomy day E=1,54 $kW \cdot h/m^2$. There also was calculated the number of sunny, misty and gloomy hours and their share during month, their values were put into Table 1. The same calculations were made for other months. The value of measured E and maximal energy E_{max} are displayed in Table 1. The influence of climate conditions upon the value of solar radiation energy was estimated with the parameter $\eta = (E/E_{max}) \cdot 100\%$.

Simultaneously with measurement of density of energy flux of solar radiation we determined the number of generated SB during each month of studied period that are represented in Table 1.

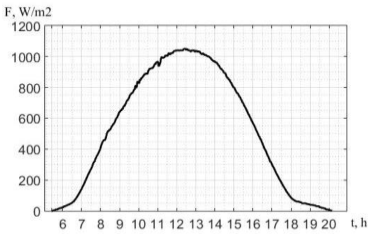

Figure 6. Graph of solar radiation density flux changes in sunny day of May 2016

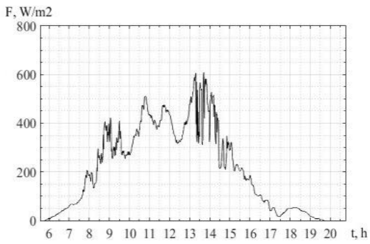

Figure 7. Graph of solar radiation density flux changes in misty day of May 2016

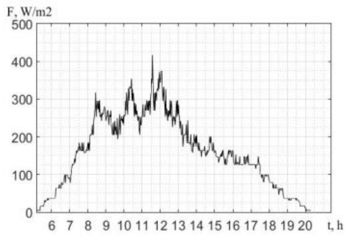

Figure 8. Graph of solar radiation density flux changes in gloomy day of May 2016

Table №1

The number of hours and solar energy

Month	Cloudy hours	%	Gloomy hours	%	Sunny hours	%	E, $kW \cdot h/m^2$	E_{max}, $kW \cdot h/m^2$	η, %	E_{SB}, $kW \cdot h$
May	151,4	34	115,1	26	174,7	40	142,95	187,18	77	4,65
June	144,2	32	105,4	24	196,3	44	148,6	181,16	82	4,82
July	131,9	28	95	20	240	52	157	188	83	5,1
August	130	28	90	19	245	53	151	188	80	4,9
September	135	33	83	20	190	47	115	169	68	3,73
October	205	72	50	18	28	10	53,7	63,08	85	1,74
November	192	73	54	20	16	7	32	40,7	78	1,03
December	171	74	23	10	37	16	28	42,4	66	0,91

Conclusions. There was suggested a methodology and mounted the experimental device to measure and record the density of solar radiation flux.

The authors calculated the time distribution of energy flux density for solar radiation during May – December 2016 in City of Ternopil and determined the volume of solar radiation energy during each month. There was also carried out the analysis of climate conditions influence upon the volume of solar radiation energy and calculated the number of sunny, misty and gloomy hours and their percentage during each month.

It was shown that the most productive for photo-generating of electric power in Ternopil is the period from May to September.

References

1. Malyarenko V.A., Timchenko S.P., Yakovlev A.I. Vozobnovlyaemaya e'negretika ukrainy: sostoyanie, problemy razvit. Svitlotekhnika ta elektroenerhetyka, no. 3, 2011, pp. 63 – 66. [In Russian].
2. Vozniak O.T., Yaniv M.Ye. Enerhetychnyi potentsial soniachnoi enerhetyky ta perspektyvy yoho vykorystannia v ukraini. Visnyk Natsionalnoho universytetu "Lvivska politekhnika". Seriia: Teoriia i praktyka budivnytstva: zbirnyk naukovykh prats, no. 664, 2010, pp. 7 – 10. [In Ukrainian].
3. Holyk O.P., Zhesan R.V. Analiz danykh meteorolohichnykh sposterezhen za intensyvnistiu soniachnoi radiatsii v Kirovohradskomu rehioni z metoiu stvorennia systemy avtomatychnoho keruvannia avtonomnym enerhopostachanniam na osnovi soniachno-vitrovykh ustanovok. Zbirnyk naukovykh prats Kirovohradskoho natsionalnoho tekhnichnoho universytetu. Tekhnika v silskohospodarskomu vyrobnytstvi, haluzeve mashynobuduvannia, avtomatyzatsiia, no. 22, 2009, pp. 164 – 172. [In Ukrainian].

4. Kravchenko V.P., Kravchenko Ye.V., Bodnar I.V. Instrumentalne vyznachennia insoliatsii v raioni m. Odesy. Enerhetyka: ekonomika, tekhnolohii, ekolohiia, no. 1, 2016, pp. 20 – 27. [In Ukrainian].
5. Kozyrskyi V.V., Martyniuk L.V. Intensyvnist soniachnoho vyprominiuvannia, spriamovanoho na pokhylu poverkhniu. Naukovyi visnyk Natsionalnoho universytetu bioresursiv i pryrodokorystuvannia Ukrainy. Seriia: Tekhnika ta enerhetyka APK. Vol. 174, no. 1, 2012, pp. 112 – 119. [In Ukrainian].
6. Fylenko V.V. Do pytannia vyznachennia diisnykh helioenerhetychnykh resursiv. Problemy mashinostroeniya. Vol. 18, no. 1, 2015, pp. 67 – 72. [In Ukrainian].
7. Zhelykh V.M., Omelchuk O.V., Shapoval S.P., Venhryn I.I. Enerhetychnyi potentsial soniachnoi radiatsii na terytorii Ukrainy. Visnyk Natsionalnoho universytetu “Lvivska politekhnika”. Seriia: Teoriia i praktyka budivnytstva: zbirnyk naukovykh prats, no. 823, 2015, pp. 117 – 121. [In Ukrainian].
8. Koval V.P., Ivasechko R.R., Kozak K.M. Enerhetychna efektyvnist system pozytsionuvannia ploskykh soniachnykh panelei. E'nergosberezhenie. E'nergetika. E'nergoaudit, no. 3, 2015, pp. 2 – 10. [In Ukrainian].

Список використаної літератури

1. Маляренко, В.А. Возобновляемая энегретика Украины: состояние, проблемы развития [Текст] / В.А. Маляренко, С.П. Тимченко, А.И. Яковлев // Світлотехніка та електроенергетика. – 2011. – № 3. – С. 63 – 66.
2. Возняк, О.Т. Енергетичний потенціал сонячної енергетики та перспективи його використання в Україні [Текст] / О.Т. Возняк, М.Є. Янів // Вісник Національного університету «Львівська політехніка». Серія: Теорія і практика будівництва: збірник наукових праць. – 2010. – № 664. – С. 7 – 10.
3. Голик, О.П. Аналіз даних метеорологічних спостережень за інтенсивністю сонячної радіації в Кіровоградському регіоні з метою створення системи автоматичного керування автономним енергопостачанням на основі сонячно-вітрових установок [Текст] / О.П. Голик, Р.В. Жесан // Збірник наукових праць Кіровоградського національного технічного університету. Техніка в сільськогосподарському виробництві, галузеве машинобудування, автоматизація. – 2009. – Вип. 22. – С. 164 – 172.
4. Кравченко, В.П. Інструментальне визначення інсоляції в районі м. Одеси [Текст] / В.П. Кравченко, Є.В. Кравченко, І.В. Боднар // Енергетика: економіка, технології, екологія. – 2016. – №1. – С. 20 – 27.
5. Козирський, В.В. Інтенсивність сонячного випромінювання, спрямованого на похилу поверхню [Текст] / В.В. Козирський, Л.В. Мартинюк // Науковий вісник Національного університету біоресурсів і природокористування України. Серія: Техніка та енергетика АПК. – 2012. – Вип. 174(1). – С. 112 – 119.
6. Филенко, В.В. До питання визначення дійсних геліоенергетичних ресурсів [Текст] / В.В. Филенко // Проблемы машиностроения. – 2015. – Т. 18. – № 1. – С. 67 – 72.
7. Желих, В.М. Енергетичний потенціал сонячної радіації на території України [Текст] / В.М. Желих, О.В. Омельчук, С.П. Шаповал, І.І. Венгрин // Вісник Національного університету «Львівська політехніка». Серія: Теорія і практика будівництва: збірник наукових праць. – 2015. – № 823. – С. 117 – 121.
8. Коваль, В.П. Енергетична ефективність систем позиціонування плоских сонячних панелей [Текст] / В.П. Коваль, Р.Р. Івасечко, К.М. Козак // Энергосбережение. Энергетика. Энергоаудит. – 2015. – № 3. – С. 2 – 10.

УДК.621.31

ДОСЛІДЖЕННЯ ЕНЕРГЕТИЧНОГО ПОТЕНЦІАЛУ СОНЯЧНОГО ВИПРОМІНЮВАННЯ В ТЕРНОПОЛІ

Володимир Андрійчук; Ярослав Філюк

Тернопільський національний технічний університет імені Івана Пулюя, Україна, Тернопіль

Резюме. *Запропоновано методику та змонтовано експериментальну установку для вимірювання та записування густини потоку сонячного випромінювання. Проведено аналіз часового розподілу густини потоку та розраховано поверхневу густину енергії сонячного випромінювання для Тернополя. Визначено вплив кліматичних умов на величину енергії сонячного випромінювання. Показано, що найпродуктивнішим для фотогенерації електричної енергії на території Тернополя є період від травня до вересня.*

Ключові слова: *сонячна батарея, сонячна енергія, мікроконтролер, піранометр.*

Отримано 20.02.2017