36. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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SOLAR RADIATION MONITORING SYSTEM

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Abstract

The paper is presenting a solar radiation monitoring system, based on two scientific pyranometers and an on-line computer data acquisition system. The values of total and diffuse solar radiation are stored on a server, in a mysql database, using high precision, original data acquisition equipment and different original software applications. A flexible web based interface, was developed to interrogate the database and to extract relevant data, based on different user selected periods. Average values for the solar radiation components are computed, together with total solar radiant heat for the user selected periods. The results are presented in the form of relevant and suggestive tables. The paper presents also relevant results, discussions and conclusions concerning an important and useful tool, to evaluate the local solar energy potential.

Key words: *Solar, Radiation, Monitoring, Data Acquisition, Software, Database, Heat*

Introduction

In the context of our day's relatively acute energy crisis, the scientific world is reconsidering the approach through all types of renewable energies. Between those, the solar energy is representing one with the highest potential, all over the world, because for a very long period of time, the Sun can be considered a huge free source of free energy, being also the unique energy source able to entertain the life on Earth. The life of the Sun is estimated at the following 4-5 billions of years.

The incoming solar radiant energy, per square meter, at the outside limit of the earth atmosphere, is named solar constant, being determined by satellite technologies measurements, at the value of 1350..1366W/m^2. From the outside limit of the atmosphere, until Earth surface, the intensity of the solar radiation is decreased by several known effects

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(reflection, dispersion, absorption, etc.) and at the ground, the solar radiation presents very different values, depending:

÷ geographical position (latitude, longitude, altitude);
÷ meteorological conditions;
÷ presence or absence of pollution;
÷ etc.

There are two types of solar radiation manifested at the ground level: direct radiation and diffuse radiation, the addition between the two representing the total solar radiation.
The presented solar radiation monitoring system was designed to measure and to allow the calculation of all the three type of solar radiation (total, diffuse and direct), in Cluj Napoca, Romania.

Methods

In order to measure the total and the diffuse radiation intensity, were used two CMP3 pyranometers from the company Kipp & Zonen. One was used to determine the total solar radiation intensity and one (shadowed), was used to determine the diffuse solar radiation intensity. Figure 1 presents a pyranometer 3D model and figure 2 presents the working principle of a pyranometer.

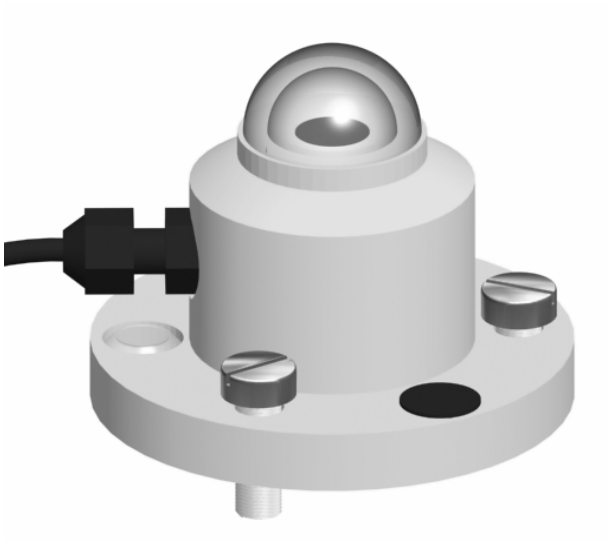

Fig. 1. 3D model of a pyranometer

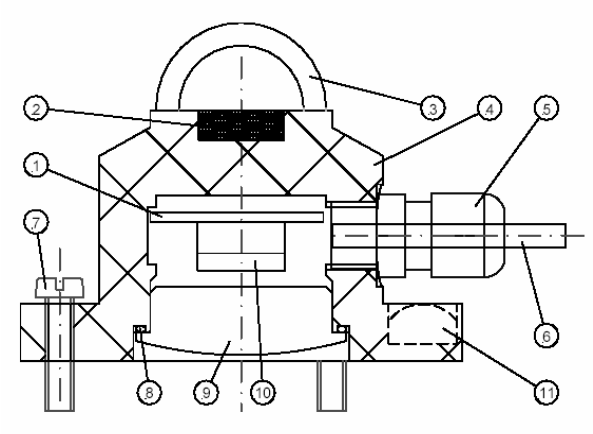

Fig. 2. Working principle scheme of a pyranometer
1 – printed circuit board; 2 – solar radiation sensor; 3 – glass dome; 4 – body;
5 – electrical cable connector; 6 – electrical cable; 7 – screw for horizontal level fixing;
8 – fixings; 9 – access for cable connection; 10 – screwed electrical connector;
11 – water babble.

Some used pyranometers specifications are presented in table 1.

Table 1. Specifications of the used pyranometers

Specification	**Value**
Response time (95%)	18s
Zero offsets - thermal radiation (200W/m^2) - temperature change (5K)	 ±15W/m^2 ±5W/m^2
Non stability change / year	±1%
Non linearity (0…1000W/m^2)	±2.5%
Directional error (at 80° with 1000W/m^2)	±20W/m^2
Temperature dependence of sensitivity	±5% (-10…+40°C)
Tilt error at 1000W/m^2	±2%
Sensitivity	5…15µV/W/m^2
Operating temperature	-40…+80°C
Spectral range	310…2800nm
Maximum irradiance	2000W/m^2
Expected daily accuracy	±10%

The scheme of the original data acquisition and solar radiation monitoring system, developed at the Technical University of Cluj Napoca, is presented in figure 3.

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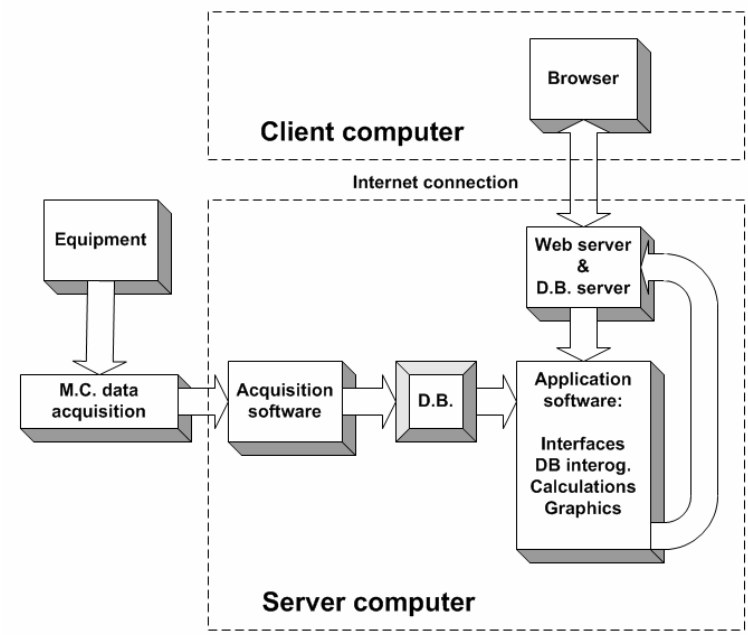

Fig. 3. Working principle scheme of the data acquisition and monitoring system

The on scheme indicated equipment is represented by the two pyranometers, connected to the original data acquisition and monitoring system.

The values of total and diffuse solar radiation intensities are captured by a microcontroller MC, using the original electronic conversion module CONV and original software, as indicated in figure 4.

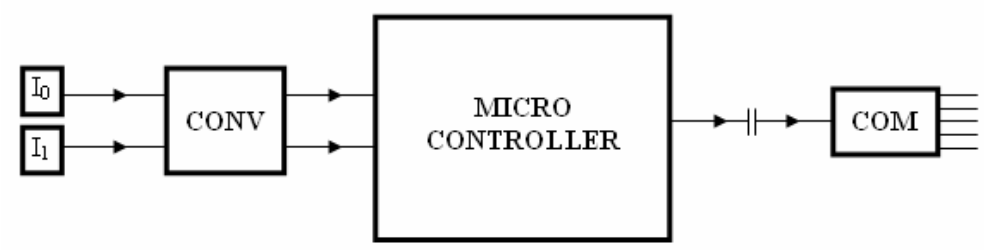

Fig. 4. Principle scheme of the data acquisition system using a microcontroller

The two electrical pyranometers output tensions, proportional with the solar radiation intensities, are converted into the effective's values of the total and diffuse solar radiation intensities, in the electronic conversion module and then are registered into the

microcontroller memory. This is also realising the transmission of the recorded values to an IBM compatible PC, using the COM serial interface. The total solar radiation intensity is noted with I_0, and the diffuse solar radiation intensity is noted with I_1.

The presence of the PC used as a server computer, as indicated in figure 3, is compulsory because it was highlighted the at distance monitoring.

The monitoring application, involve many software components:

÷ Storing the values of the solar radiation intensities into a database;

÷ Multiple criteria selection of the stored data;

÷ Display of the data on a web based virtual monitoring panel;

÷ Graphical representation of the selected database stored information.

The database indicated by D.B. on figure 3, designed to store the values of measured solar radiation intensities is of MySQL type and allow the interrogation via internet. The structure of the database table used data storing is presented in figure 5.

	Field	Type	Collation	Attributes	Null	Default	Extra
☐	id	int(11)			No		auto_increment
☐	data	datetime			Yes	NULL	
☐	pyr0	int(11)			Yes	NULL	
☐	pyr1	int(11)			Yes	NULL	

Fig. 5. The structure of the MySQL database table

It can be observed that each record receive a unique code named id and the stored information are: date and time of the measurement, into the field data, and the two values of total respective diffuse solar radiation intensity, into the fields pyr0 and pyr1.

Two of the most important original software components of the data acquisition and monitoring application, are the “Acquisition software” and “Database interrogation”. The principle flow chart diagrams of the two software components are presented in figures 6 and 7.

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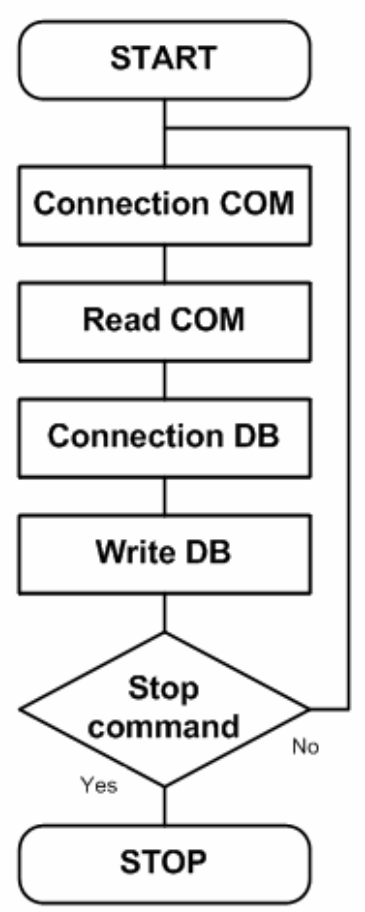

Fig. 6. Principle flow chart of the "Acquisition software" component

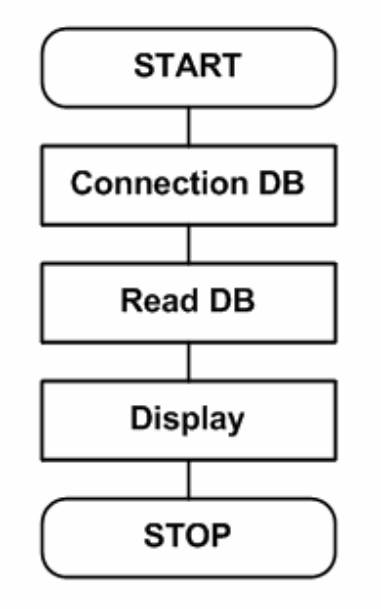

Fig. 7. Principle flow chart of the "Database interrogation" component

The "Acquisition software" component is continuously operating, reading and storing into database the instant measured values of the total and diffuse solar radiation intensities, with a time step of 1 minute.

The display of the recorded data, based on multiple criteria selection of the stored data is realised on a web based virtual monitoring panel, using the interface presented in figure 8.

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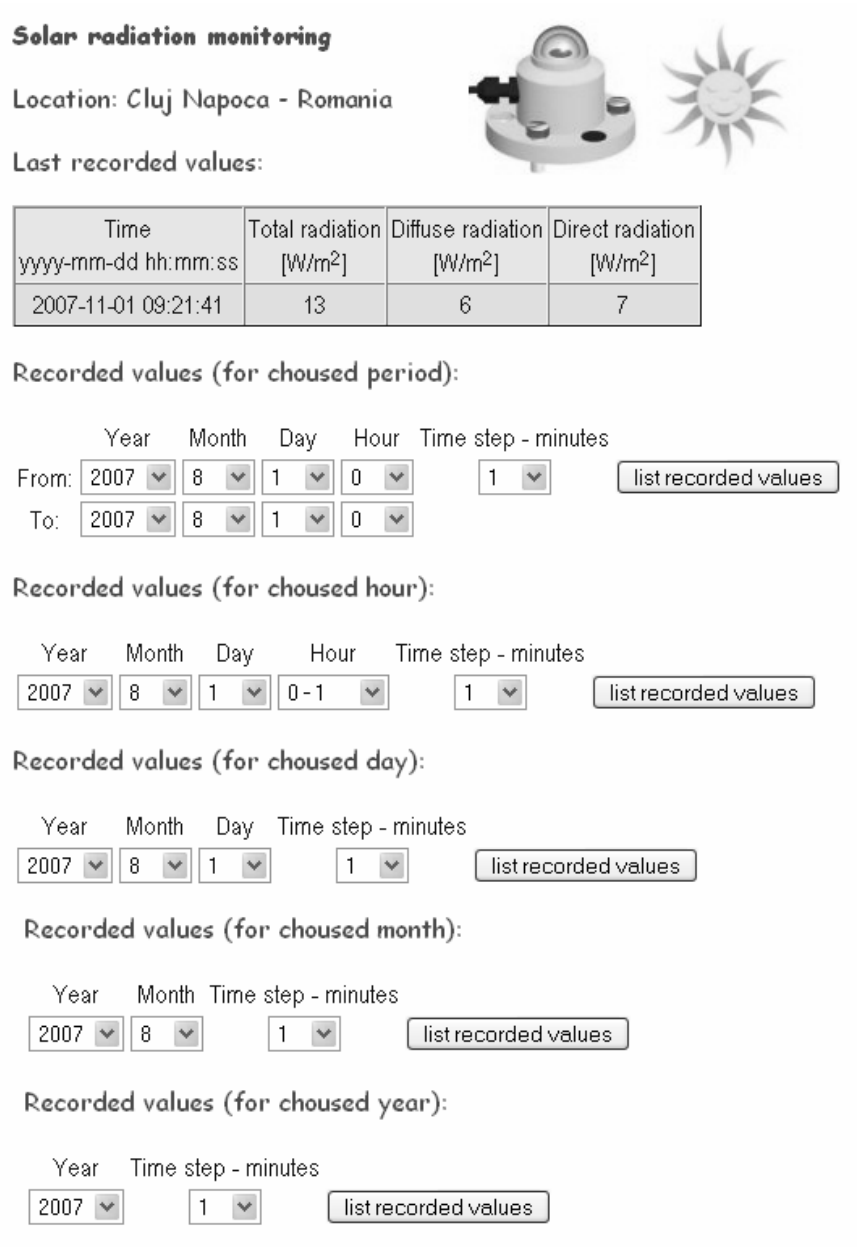

Fig. 8. Web based interface of the virtual monitoring panel

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The web based interface, presented in figure 8, cad be displayed on any internet connected computer, indicated as “Client computer” on figure 3. The interface will be displayed in the web browser of that computer. This element suggests that the presented solar radiation monitoring system was designed and realized into client-server architecture.

The interface present the last recorded values of the solar total, diffuse and calculated direct radiation intensities and offer the following selection criteria option, for the recorded data:

÷ Recorded values for a free chosen period, indicated by: year, month, date and hour of the beginning and ending time for the selected period;
÷ Recorded values for a free chosen hour, indicated by: year, month, date and the selected time interval, for the selected period;
÷ Recorded values for a free chosen day, indicated by: year, month and date;
÷ Recorded values for a free chosen month, indicated by: year and the selected month;
÷ Recorded values for a free chosen year, indicated by the selected year;

For each option, it can be selected also the time step, in minutes, for witch the database stored date to be displayed. The possible values for the time step, depending of the selected criteria are: 1, 5, 10, 15, 20, 30, 60 minutes.

Each selection criteria can be activated by pressing one of the buttons marked bt “list recorded values”.

Additional to the selected data following each criteria, the activated software components will also dysplay the following computed values:

÷ Direct solar radiation intensity, calculated as difference between the total and the diffuse solar radiation intensities;
÷ Average values for the solar radiation intensities (total, diffuse and direct), for the whole selected period of time;
÷ Average values for the solar radiation intensities (total, diffuse and direct), for the day time periods (with Sun on the sky) in the whole selected period of time;

Total values of radiant solar heat (total, diffuse and direct).

Results and discussion

Some results, displayed by the different software component of the solar radiation monitoring system, are indicated as examples.

Figure 9 presents the values of the solar radiation intensities, recorded in august 17, 2007, between 14…15 hours, with a time step of 10 minutes. It was a completely sunny day, the sky was practically clear the whole day, and it can be observed that the recorded values are higher than 800W/m^2.

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Solar radiation monitoring

Location: Cluj Napoca - Romania

home

Recorded values:

Year: 2007 Month: 8 Day: 17 Hour: 14 - 15
Time step: 10 minutes

Time yyyy-mm-dd hh:mm:ss	Total radiation [W/m^2]	Diffuse radiation [W/m^2]	Direct radiation [W/m^2]
2007-08-17 14:00:01	855	60	795
2007-08-17 14:00:51	851	58	793
2007-08-17 14:10:04	853	58	795
2007-08-17 14:10:55	862	56	806
2007-08-17 14:20:08	853	55	798
2007-08-17 14:20:58	855	53	802
2007-08-17 14:30:12	830	52	778
2007-08-17 14:40:16	827	52	775
2007-08-17 14:50:19	827	52	775

Fig. 9. Values of the solar radiation intesity, recorded in august 17, 2007, between 14:00…15:00, with a time step of 10 minutes

Figure 10 presents average values of the solar radiation intensities, recorded in august 17, for the whole 24 hours selected period of time.

Average values for solar radiation - 24 hours:

Total radiation [W/m^2]	Diffuse radiation [W/m^2]	Direct radiation [W/m^2]
295.28	41.73	253.55

Fig 10. Values of the solar radiation intesities, recorded in august 17, for the whole 24 hours selected period of time

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Figure 11 presents average values of the solar radiation intensities, recorded in august 17, for the day time period (with Sun on the sky) in the whole 24 hours selected period of time.

Average values for solar radiation - day time (sun on the sky) - 16.33 hours.:

Total radiation [W/m^2]	Diffuse radiation [W/m^2]	Direct radiation [W/m^2]
518.22	73.24	444.98

Fig 11. Values of the solar radiation intesities, recorded in august 17, for the day time period (with Sun on the sky)

It can be observed that it could be calculated the day time period. The average value of the total radiation intensity is 518.22W/m^2 comparing with the value of 295.28W/m^2 corresponding to the whole 24 hours considered period.

Figure 12 presents the total values of radiant solar heat (total, diffuse and direct), calculated for the day of august 17, 2007.

Total values for heat:

Total heat [Wh/m^2]	Diffuse heat [Wh/m^2]	Direct heat [Wh/m^2]
8464.67	1196.33	7268.33

Fig. 12. Total values of radiant solar heat (total, diffuse and direct), calculated for the day of august 17

The results of the different software component of the presented monitoring system are very accurate and consistent. These types of data are to be recorded for a long period of time (many years) and are going to be analysed in order to evaluate the local potential of the solar energy, to be used in thermal collectors or in PV panels. At the moment of this paper realising, there are available data for three month: august, september and november 2007. Even for this short period of time, the stored data relevates interesting ideas, but for consistent conclusions of this type, a longer period of time is needed, probably at less for one year, to include also a summer period of time.

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Conclusions

The presented solar monitoring system is representing an original, complex and usfull hardware and software tool, able to offer all the needed information, to evaluate the local potential of the solar energy, to be used in thermal collectors or in PV panels.

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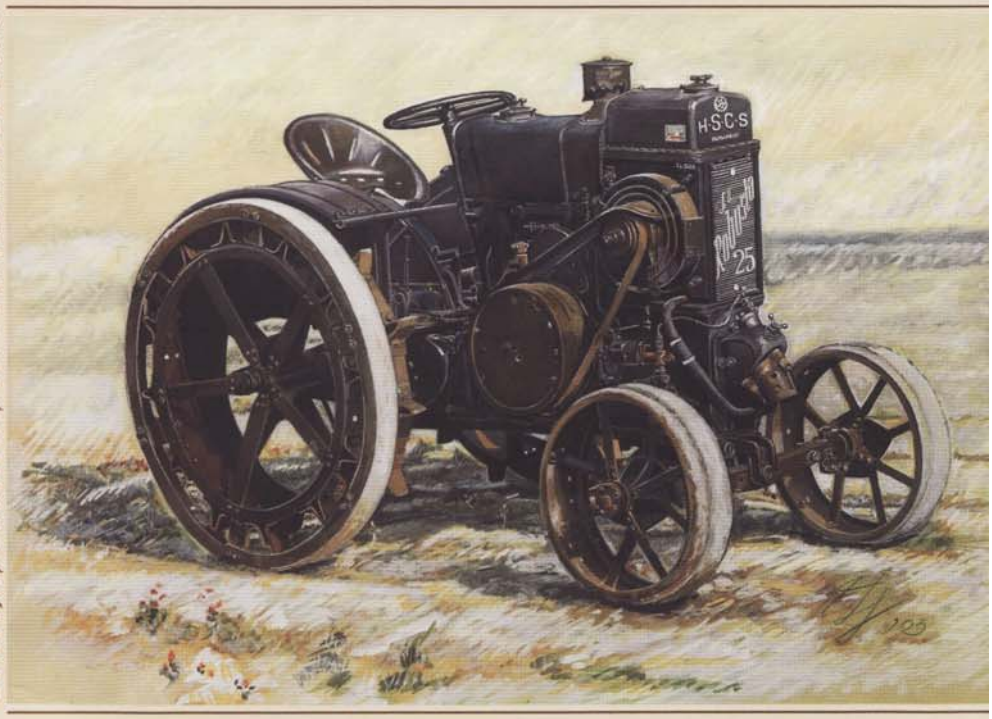

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