A NEW SOFTWARE FOR MONITORING SOLAR RADIATION USING INFORMATION FROM SATELLITE IMAGES AND FREE DATA SOURCES

Martín Gastón[1], Iñigo Pagola[1], Xabier Nicuesa[1], Ana Bernardos[1], María Vicenta Guisado[1], Iñaki Bernad[1], Marcel Suri[2], Marek Caltik[2], Milan Skuhra[2], Lourdes Ramirez[1]

[1] Solar Thermal Energy Department, National Renewable Energy Centre (CENER). Address: c/ Ciudad de la Innovación 7, Sarriguren, 31621, Navarra (Spain).

[2] GeoModel, Pionierska 15, 831 02 Bratislava, Slovakia.

1. Abstract

To characterize the real solar radiation in sites where Concentrating Solar Power (CSP) plants are going to be settled, local meteorological data have to be measured. Detailed studies demonstrate that even when the measured data have passed most of the standard quality procedures, wrong values could still be labeled as valid in the final data set.

In this paper, a new software for monitoring and validating measurements from meteorological stations is presented. The software has been created in order to handle measurements of solar radiation and meteorological data from several stations easily. All the data from the meteorological stations are georeferenced, and can be accessed via a main window of the web interface.

The software, promoted by CENER, aims to provide control tests to ensure the quality of the measured solar radiation data. These control tests are grouped into four main steps: 1- visual checking; 2- standard Baseline Surface Radiation Network (BSRN) procedures; 3- comparison with the satellite-derived irradiance and 4- comparison of data from several stations. A validation of the methodology for the estimation of global irradiance from satellite images has been made in order to check the viability of the quality test based on it.

2. Introduction

To characterize the real solar radiation in sites where CSP plants are going to be settled, local meteorological data have to be measured. Detailed studies demonstrate that even when the measured data have passed most of the standard quality procedures, wrong values could still be labeled as valid in the final data set. In concentrating solar power plants, these wrong data could be the responsible of a not appropriate design and sizing of the solar field.

In this paper, a new software for monitoring and validating measurements from meteorological stations is presented. The software has been created in order to handle measurements of solar radiation and meteorological data from several stations easily. All the data from the meteorological stations are georeferenced, and can be accessed via a main window of the web interface.

The software, promoted by CENER, aims to provide control tests to ensure the quality of the measured solar radiation data. These control tests are grouped into four main steps:

- Visual checking.
- Standard Baseline Surface Radiation Network (BSRN) procedures (Long and Dutton, 2002).
- Comparison with the satellite-derived irradiance.
- Comparison of data from several stations.

The user web interface to the control software has been developed in collaboration with GeoModel.

3. Methodology and main characteristics

Following the new trends in solar radiation data analysis and to avoid a final data set with not homogeneous zenithal angle distribution, only complete days without missing data are considered as valid or not valid data in the new software.

The first step when monitoring solar data with the developed software is to do a visual check in order to

assign the data as valid or not.

Once the daily data has been pre-assigned visually to valid data, in a second step the procedures 1 (physically possible limits), 2 (extremely rare limits) and 3 (comparisons) of the BSRN are applied. The procedure 4 is the comparison of the measurements with a model, and it will be implemented in the future.

The third step is a new quality control test procedure based on the estimation of solar global horizontal irradiance (GHI) from satellite images. A combination of Heliosat-1 (Diabaté el al., 1988) and Heliosat-2 (Rigollier el al., 2004) methods has been implemented in the software for the estimation of solar global horizontal irradiance from satellite images. Thus, a quality control test is done by comparing the estimated solar global horizontal irradiance and the measured one. In some cases, data which are not measured properly (e.g. because of a misalignment of the Sun tracker or shadowing) could pass all the BSRN quality control tests. This can be detected by comparing the values of solar global horizontal irradiance both measured and estimated from satellite images. The values of measured global horizontal irradiance which differ more than a fixed quantity from the estimated one are labeled for a subsequent check. This fixed quantity can be adjusted for each location.

Finally, comparisons of the solar radiation measurements with free solar radiation data are possible as an additional quality control check.

The meteorological information is managed in a geo-referenced interface and it aims to provide free access for most of the free solar radiation ground measurements. In addition, secure access for private measurement stations is also possible.

Using the software, daily, monthly and annual reports of the solar and meteorological measurements of a specific station can be obtained effortlessly.

4. Validation of the solar global irradiance estimated from satellite images

As it has been in the previous section, a combination of Heliosat-1 (Diabaté el al., 1988) and Heliosat-2 (Rigollier el al., 2004) methods is implemented in the software for the estimation of solar global horizontal irradiance from satellite images, and comparing it with the measured one in a new quality test. A validation of the methodology with measurements is necessary to check the viability of the new quality test.

For the validation of the methodology, the estimation of solar global horizontal irradiance from satellite images has been made for the years 2009 and 2010 using data of the Meteosat Second Generation (MSG) satellite. The frequency of this data is 15 minutes, and it has been used data of the high resolution visible channel.

The measured data used in the validation correspond to three different locations. Two of them are locations in the Southwest of Spain, which is an important place in the terms of CSP plants. The other location is the CENER BSRN station in Sarriguren, which is located in the North of Spain. The measurements related to the two locations in the Southwest of Spain are available in a minute frequency, but 15 minute means have been calculated to match the estimated solar global horizontal irradiance from satellite images. The measurements related to the CENER BSRN station in Sarriguren correspond to a second frequency, and 15 minute means have also been calculated to match the estimated values. For this location measurements are available from July of 2009, when the station started to store data.

After the synchronization of the measured solar global horizontal irradiance with the estimated one, nocturnal data have been filtered excluding them of the validation.

The comparison parameters which have been calculated in the validation for each location are:

- RMD: Relative Mean Difference, which is the mean difference (absolute value of estimation minus measurement), divided by the arithmetic mean of measurement.
- BIAS: mean value of estimation minus measurement.
- Correlation coefficient.

The results of the validation are shown in Table 1:

Tab. 1: Comparison parameters of the methodology validation

	RMD (%)	BIAS (W/m^2)	Correlation
Southwest Spain nº1	13.4	-6.0	0.948
Southwest Spain nº2	12.7	4.5	0.946
CENER BSRN station	24.5	-31.4	0.897

As can be seen in Table 1, the results of the satellite derived global horizontal irradiance are better for the locations in Southwest of Spain than for the CENER BSRN station. This could be caused because of the meteorological conditions in the North of Spain where the CENER BSRN station is located, as they are very different from the conditions in the South of Spain. As a result, it has to be noted that it is necessary to analyze and validate the satellite derived estimations of solar irradiation for each location separately when referring to energy production.

Figure 1, Figure 2 and Figure 3 show the comparison between the measured solar global horizontal irradiance and the estimated from satellite images for the two locations in the Southwest of Spain and the CENER BSRN station.

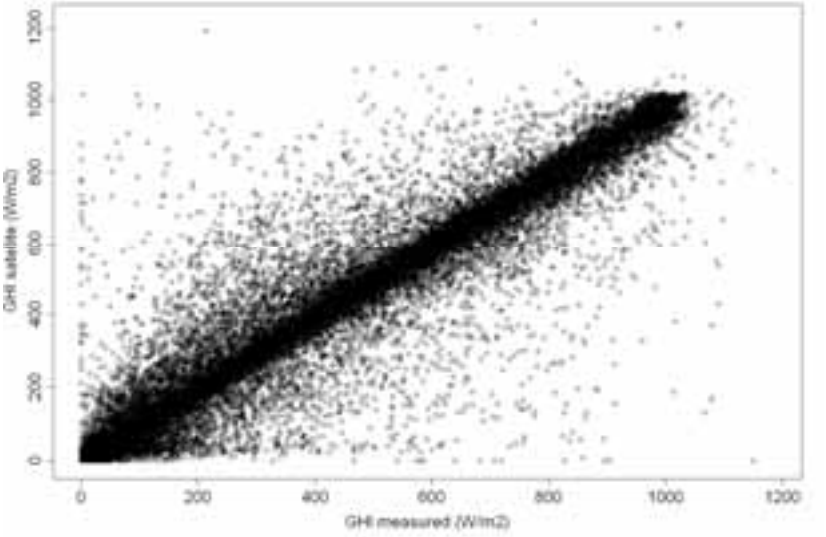

Fig. 1: GHI measured vs. GHI estimated for Southwest location nº1

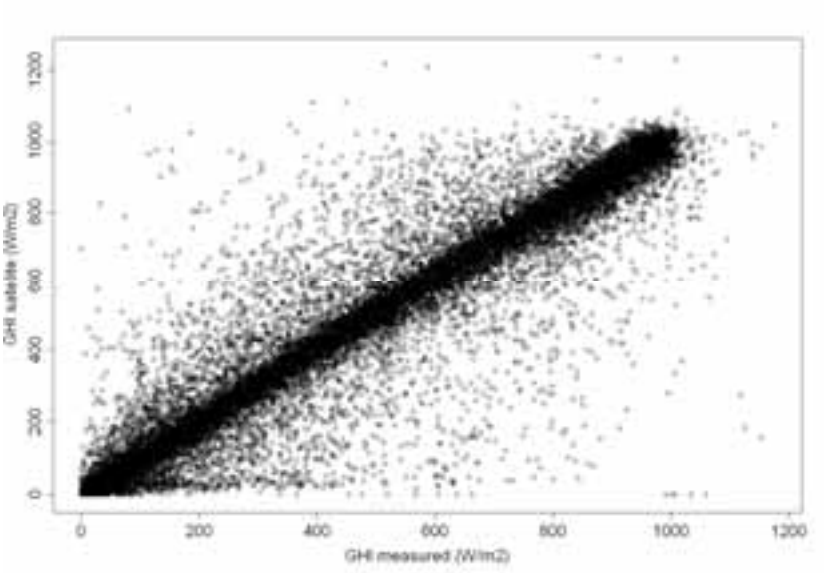

Fig. 2: GHI measured vs. GHI estimated for Southwest location nº2

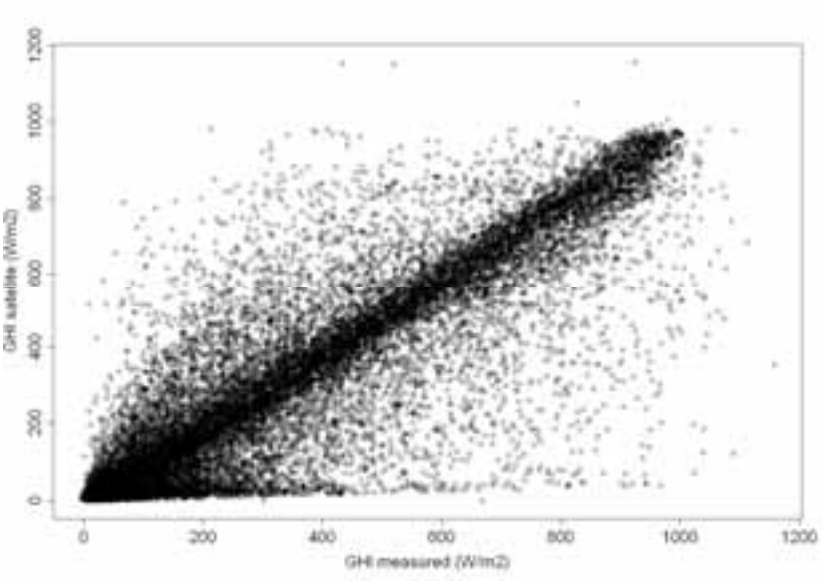

Fig. 3: GHI measured vs. GHI estimated for CENER BSRN station

As can be seen in Figure 1, Figure 2 and Figure 3 the results for the CENER BSRN station seem to be more dispersed than the results for the two locations in the Southwest of Spain. That is, the difference between measured solar global horizontal irradiance and satellite estimated is bigger for the CENER BSRN station.

5. Screenshots

In Figure 4, the main window of the user web interface of the new software is presented. It is an interactive map where the different stations can be selected. It provides information about the state of the stations according to the results of the different quality tests.

Fig. 4: Main window of the new software for monitoring solar radiation

Figure 5 shows an example of the daily report for a specific station, providing a plot of the global horizontal irradiance, diffuse horizontal irradiance and direct normal irradiance. It also provides the daily values of global, diffuse and direct irradiation.

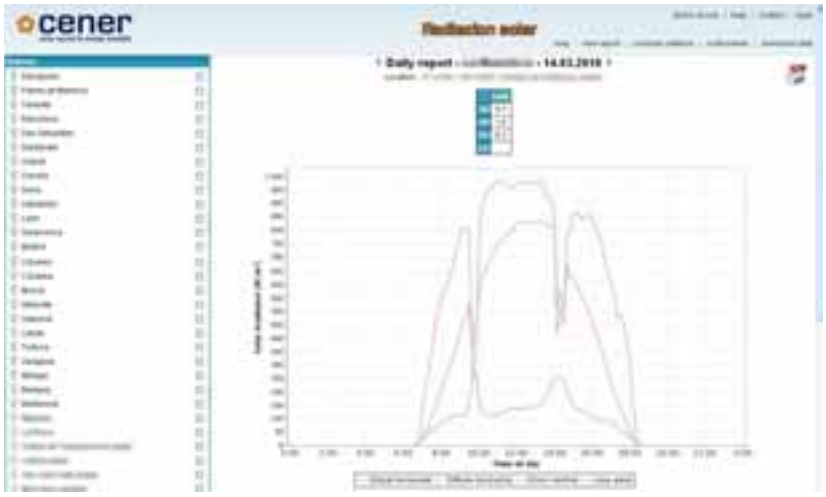

Fig. 5: Daily report of the new tool for monitoring solar radiation

6. Conclusions

A new software for monitoring and validating measurements from meteorological stations has been developed.

The software has been created in order to handle measurements of solar radiation and meteorological data from several stations easily. All the data from the meteorological stations are georeferenced, and can be accessed via a main window of the web interface.

The new developed software aims to provide control tests to ensure the quality of the measured solar radiation data. These control tests include visual checking, standard Baseline Surface Radiation Network procedures, comparison with satellite-derived irradiance and comparison of data from several stations.

A combination of Heliosat-1 and Heliosat-2 methods has been implemented in the software for the estimation of solar global horizontal irradiance from satellite images. This methodology has been validated using data of the years 2009 and 2010 from the Meteosat Second Generation satellite and measurements from three locations, two of them in the Southwest of Spain and the CENER BSRN station in the North of Spain.

The results of the satellite derived global horizontal irradiance are better for the locations in Southwest of Spain than for the CENER BSRN station. This could be caused because of the meteorological conditions in the North of Spain where the CENER BSRN station is located, as they are very different from the conditions in the South of Spain.

It has to be noted that it is necessary to analyze and validate the satellite derived estimations of solar irradiation for each location separately when referring to energy production.

Using the software, daily, monthly and annual reports of the solar and meteorological measurements of a specific station can be obtained effortlessly.

7. References

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