Evaluation of the influence of the Saharan dust events on the solar radiation components in southestern Spain

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Abstract: Atmospheric aerosols have a strong impact on Earth's climate. However, the quantification of their influence is far from being completely achieved. This work evaluating the Saharan dust events occurred frequently in the south of the Iberian Peninsula, which produce changes in the amount of solar radiation reaching the surface of Earth to the various components of solar radiation, due to scattering and absorption that producing these particles. Being able to quantify the loss of solar radiation received helps to know how the energy production vary when an event of Saharan dust occurs so the operators of renewable power plants can get an idea of the amount of energy that can be lost in order to make a forecast for the production during the event.
Keywords: aerosol, Saharian dust, radiation, DNI, GHI,

INTRODUCTION

One of the most important environmental problems nowadays is the impact caused by the combustion of fossil fuel causing emissions of oxides of carbon, sulphide and nitrogen. It is therefore necessary to use renewable energies in order to mitigate these emissions and their harmful effects. Among all renewable energies in this case we will focus on the study of solar energy because of its importance and development today.
Solar energy is the main source of life on Earth. With the exception of geothermal energy, all renewable energy derived directly or indirectly from solar energy. Directly in the case of light and heat produced by solar radiation (which lesser impact being generated in the environment), and indirectly in the case of wind, hydro, tides, waves and biomass, among others [1].

Solar thermal power plants (STPP) are considered to have a significant importance for the transition from conventional to sustainable energy production [2]. The Spanish legal foundation offers the operators of STPP two possibilities to sell its electricity production: the tariff and the premium model. The tariff model consists of a fixed price independent of day and time. To improve competitiveness, the operator is allowed to feed in the renewable electricity with priority to any other conventional electricity generator. The premium model has been introduced in order to motivate the operators of renewable energy plants to act on the liberalized market like the conventional power plant managers. This means they have to place their energy bids in a day-ahead market, announcing the hour of energy production, the energy amount and the price

One problem is that the availability of renewable energy sources such as wind and solar is not continuous as it is affected by meteorological factors, leading to energy production patterns highly variable in space and time. Generally we not know the state of the atmosphere, such as aerosols can influence the climate in a lot of processes, as produce warming by absorbing the radiation incident in the atmosphere can cause cooling or partially reflect it and is highly variable in space and time depending on the time of day,

whether there is a clear atmospheric situation, if there is contamination etc. In addition the size of the aerosol have a very important role in the formation of different types of clouds as they facilitate the process of condensation of water vapor in the atmosphere function. Because of all these factors when working with solar energy would need to have a rough understanding of the components of solar radiation for this approximate models the behavior of the solar radiation is used.

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II. INSTRUMENTATION

In this work two instruments which are briefly described below are used.

Sun photometer CE318-4 CIMEL is an instrument which allows measurements made atmospheric aerosol in the atmospheric column. Provides measurements of the AOD at different wavelengths. It consists of a sensor head, a robot, a battery and an electronic box to control the system. From the observations of the photometer has been carried out to determine the presence or absence of events of Saharan dust over Granada, and the study of these events ancient dust.

Two pyranometers (CM-11 Kipp & Zonnen), one of them measuring global solar irradiance from 0.305 to 2.800 microns and the other mounted on solar tracking platform for measuring diffuse solar irradiance.

III. METHODOLOGY

To start the study, the first thing to address is when exactly there has been a Saharan dust event over the southeast of the Iberian Peninsula more specifically on the city of Granada occurs. To know this we will use the CALIMA website (www.calima.ws). CALIMA detected a total of 112 days in 2014 with Saharan dust intrusions on the southeastern part of the Iberian Peninsula. Once we located the days that Saharan dust events occur through the data provided by the CALIMA proceed to filter out days with a significant amount of clouds. To do so, we inspect visually the components of the radiation for each day.

After this first selection of cases, to confirm that the event has actually taken place, we must consider which are the values of AOD measured that specific day, because when an intrusion of dust in the atmosphere occurs values AOD increases abruptly with the consequent reduction in the scattering Angström exponent values [3] [4] [5] [6]. Using the results obtained in other studies we select the events where there is a combination of large AOD (440 nm) values above 0.2 with small Angström exponent values under 1 as a signature of the contribution of coarse mineral dust particles to the aerosol load [4] [7] [8] [9].

Once we select the day on which the event of Saharan dust has happened and is a strong event, we proceed to the selection of a period of days before and after the event days in which the values of AOD obtained are analyzed to choose one of those days as a background day, that will be the day we use to compare the results with the day of the event. This day has to be as clear as possible. Then we performed the comparison between the day of the event and the background day for the periods of the day in which there are no clouds, getting a series of measures of AOD, Angström exponent and reduction of solar radiation for DNI component and for GHI component.

IV. RESULTS AND DISCUSSION

There are many cases used for the study but in all these cases are not useful the vast majority of them, either because the number of data points to that day is not enough, or because the conditions are not optimal for the analysis. Once the selection of Saharan dust events is performed using the CALIMA are chosen those days when clouds flow is minimal and proceed to the selection of those days where the results are more optimal.

In total 29 cases they have been selected, in which was calculated the various components of solar radiation, AOD values of exponent Ångström values and relationship between the maximum and minimum zenith angle with the percentage loss of solar radiation. Of all the cases that have been studied we will further focus on the 2nd of September in which an intrusion of Saharan dust over the city of Granada occurs (confirmed by the results of CALIMA), and compare measurements of solar radiation, AOD and Ångström exponent of that day with the measured the 6th of September, in which day the sky is clear, it will be our background day.

The results we have obtained in this case can be summarized in the following ways, for the DNI we can see a significant difference between the DNI that measured along the background day and the day of the event .For solar zenith angles greater the difference between the radiation of background day and the day on which the event occurs will be greater. For the GHI, the difference between the GHI that measured along the day for background day and the day of the event it is not as significant. AOD values increase compared to the days in which the atmosphere is clean, then in the case under analysis shows that the measured values AOD for the day 2 of September 2014 are higher than the values for the 6 of September 2014 as expected. The Ångström exponent values are lower for the day in the event of dust compared to the day when the sky clear this occurs. In our case it becomes to fulfill this condition, confirming that the loss of solar radiation when an event occurs Saharan dust is relatively significant and remains almost constant throughout the day.

Analyzing all the results obtained the dust events occurred in June 19 occurs the dust event with the mean values of AOD are higher than for other events (around 0.47) indicating that this would be a very strong event, because this measure gives us an idea of the amount of particles that are introduced into the atmosphere when an event occurs dust. By contrast the day August 17 would be one of the weakest recorded events as the measured values for AOD are 0.22. In other cases the measured average values are greater than 0.25.

For the mean values obtained to Angstrom parameter we can observed highly variable results. On September 2nd that in which that the measured value is the smallest,

around 0.22, it could indicate that the particle sizes are large but they are also mixed with small particles

The values obtained for the difference between the day of the event and the background day in % for most cases exceeding 0.10% reaching values of up to 0.35%. For the DNI the maximum value obtained will be 47.41% for the difference between day 6 and day 19 June indicating that the loss of direct solar radiation between a day on which an event occurs and the background day is considerably high. In the case of global solar radiation, the difference between day 6 and day 19 June is the maximum value obtained with a 15.25%. The minimum value recorded for the DNI will be 7.94% for the difference between day 17 and day 16 May and for the case of the GHI the difference between days 15 and June 13 will be 2,06%. These differences are not very significant but are sufficient to demonstrate the loss of radiation that when a dust event occurs.

The difference in radiation measurement for the day of the event with respect to day background will be increased to values larger AOD, i.e. the loss of DNI can be approximated by a linear fit ($\Delta DNI = 123{,}45(AOD) - 18{,}94$) to the measured for mean AOD value on the day of event. In the case of the GHI it occurs just as we discussed earlier but in this case the linear fit is slightly worse, in this case the value is $\Delta GHI = 42{,}37(AOD) - 7{,}60$.

For some of the cases have shown the difference of radiation received both for the GHI to the DNI, as a function of zenith angle. It is confirmed that the loss of radiation received in both cases is greater as the zenith angle increases and is higher in the case of the DNI.

CONCLUSION

Changes that occur for solar radiation when an intrusion of Saharan dust occurs are substantially higher for the DNI than for the GHI component. In the first case the values obtained in% are in most cases higher than 20% reaching values above 40%. However the values obtained for the GHI component in all case do not exceed the 15%.

When the zenith angle increases the differences in the DNI they will also increase, so that for zenith angle around 80º (angles near the horizon) exceed 30% reaching values above 60%. For this angle it is when the solar power plants begin to operate. For small angles around 15º (sun located near the zenith) most of the values are above 20% reaching values above 26%. For the GHI also satisfied that for large angles the radiation difference is bigger so that most of the values are above 15% reaching values above 24% .For small angles values are around 3% reaching values above 7%, well below the values obtained for the DNI.

Analyzing the loss of radiation as a function of the measured AOD for the day of the event values has come to the conclusion that it could create a linear model for the city of Granada as a function of the measurements made during 2014, that is, taking the values of AOD measured for a particular day by linear regression previously calculated can get to obtain an estimate of the amount of radiation DNI may be lost when an event of Saharan dust occurs over the city of Granada. The model is equally applicable for measuring radiation GHI, but for this case will be different linear regression calculated.

The methodology explained in this work, along with the models obtained could be very useful for operators of renewable energy plants in order to anticipate the losses,

just by knowing the value of AOD measured during an event of Saharan dust to estimate and quantify the radiation loss.

ACKNOWLEDGMENTS

This study has been made possible thanks to the work of the members of the GFAT who took the measurements. I would like to express my profound personal gratitude to Alberto Cazorla Cabrera the supervisor of this study, to have shown a particular patience, devotion and availability during all the processes of the research.

Last but not least, I would like to thank my parents, friends and my colleagues: M.Barreiro, J.A. Casquero, P.Ortiz, L.Palacios and A.Perez for your help at all times, your infinite patience and your support, without you this would not have been the same.

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