Intra-hour classification of direct normal irradiance for two sites in Spain and India

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1. Introduction

The magnitude of the direct normal irradiance (DNI) depends on seasonal differences due to the sun-earth geometry, and atmospheric extinction processes caused by aerosols and clouds. The most relevant source for intra-hour variability in the DNI are clouds. Suitable sites for concentrating solar power (CSP) plants have an annual average DNI above approx. 2000 kWh/m². Not only the average DNI but also the temporal and spatial DNI variability on the field has a considerable impact on the dispatched electricity [1]. A classification method based on eight distinct variability classes for 1 minute resolved DNI on an hourly basis is introduced by [2]. In this work, the approach presented by [2] is adapted for an intra-hour application, which is more suitable for CSP applications. Here, we discuss the impact of the considered time window on the classification. Furthermore, the impact of the spatial solar field DNI on the variability classification was studied, using spatially resolved DNI maps of a camera based nowcasting system [3].Moreover, we present the results of a variability classification study, including data of a complete year (2017) for a NETRA facility near New Delhi and the Plataforma Solar de Almería (PSA).

2. Intra-hour Adaptation of DNI variability classification method

The utilized variability approach from [2] uses eight classes: Class 1 describes clear sky conditions; class 2 and 3 describe nearly clear sky conditions with a stronger variability and comparatively lower average DNI in the case of class 3. Class 4 shows a strong temporal variability but with an overall high average DNI, whereas class 5 describes less variable conditions with a lower average DNI. Class 6 resembles class 4 with a strong temporal variability, but with a significantly lower average DNI. Nearly complete overcast situations with some ramps are described by class 7 and fully overcast situations by class 8.

The DNI variability indices thresholds from [2] are scaled down to a 15 min time window to achieve a classification that is more suitable for CSP plants. A further reduction of the time window is not feasible, since a clear distinction between the classes becomes more difficult. The motivation for the reduced temporal resolution can be seen in Fig. 1 (left). The DNI of a day with highly variable and stable time windows is depicted together with the assigned variability class. A new assessment of the variability takes place with every new time stamp (1 min resolution), considering the prevailing DNI of the last 60 min (15 min, respectively). It is clear that the 60 min approach is often too inert for an inter-hour consideration. This is particularly evident in the time windows from 11:54 to 12:38 and from 13:21 to 13:59 which show clear sky conditions (marked yellow in Fig. 1). The 60 min approach misses these clear conditions for the first 12 minutes completely before dropping to class 3. The 15 min approach reacts 2 minutes after the start of the clear window and drops from class 5 to class 1 within 14 minutes.

For CSP plants, the field average of the DNI is more relevant than the DNI at a singular point within the solar field. Therefore, we investigated if the DNI variability class of point like measurement is well-correlated to the class of the field average. We used a quadratic area of 2 km² and a data set of 30 days. DNI maps with spatial information are provided by a camera based nowcasting system [3]. Only DNI maps which describe the current situation are used for this study. The scatter density plot depicted in Fig. 1 (right) shows good agreement between the point like measurement based classification and the classification based on spatial solar field average DNI. The relative frequency of the matched classes is described by the color. All bins in one column add up to 100%. A perfect match is achieved for 94.9% of all timestamps. For 4.5%, we observe a mismatch by a single class. A stronger mismatch is observed only in 0.6% of the time stamps. We thus consider it reasonable to use a singular point measurement for variability classifications even for the time window of 15 min and industrial field sizes.

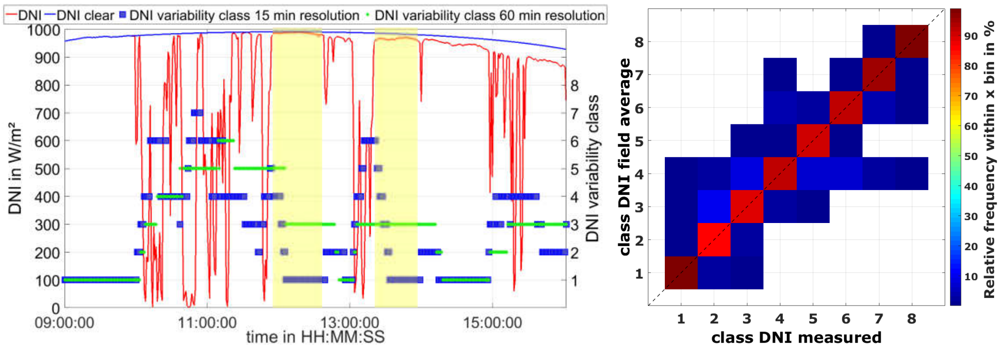

Fig. 1: (Left) DNI and variability classification with 60 min and 15 min resolution; (Right) scatter density plot comparison of DNI variability classifications point measurements to spatial field averages

3. Evaluation of a year–long data set from a NETRA facility near New Delhi and the PSA

Two data sets, each containing a full year (2017), from a NETRA site near New Delhi and the PSA are processed. The comparison between the 60 min and 15 min approach for both sites is illustrated in the histograms (Fig. 2). Different classifications are observed in 35% (NETRA) respectively 32% (PSA) of the processed time stamps comparing the 60 min and 15 min approach. It is noteworthy, that the classes 4 and 6 with strong variability are rarely assigned by the 60 min approach. A strong over representation of the less variable classes 5 and 7 can be observed instead. Clearly, the distribution is influenced by the real time application, which classifies the current conditions for each time stamp (1 min resolution). The scatter density plot for the NETRA data illustrates the shift between the classes due to the used temporal approaches (Fig. 2 right). Only by comparing the class distribution, it can be seen that the PSA seems to be the more suitable site for CSP compared to the NETRA site. Due to the hazy conditions at the NETRA site, real clear sky conditions (class 1 and 2) a comparatively rare events. Instead the more variable classes 3 and 5 show the highest occurrence followed by the overcast classes 7 and 8.

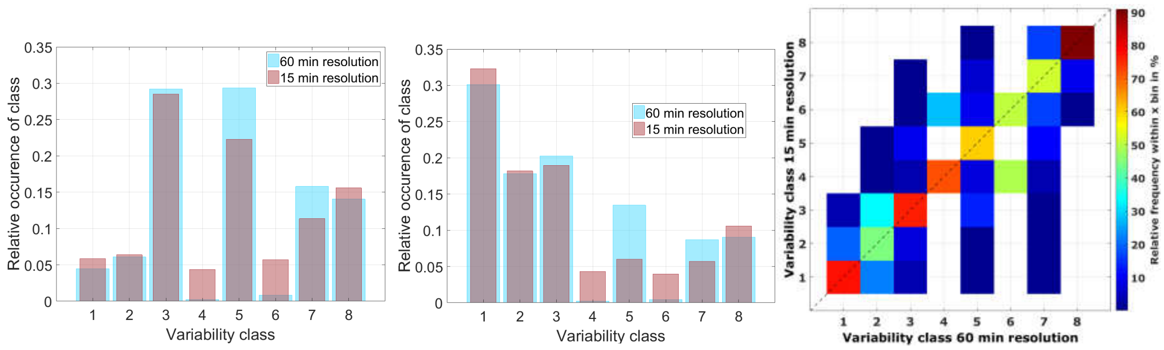

Fig. 2: (Left) histogram with class probability (NETRA); Center) histogram with class probability (PSA); (Right) scatter density plot 60 min versus 15 min classification (NETRA)

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