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CLOUD PASSING FORECASTING FOR PV POWER PLANT OUTPUT POWER SMOTHING

Primož SUKIČ[1], Gorazd ŠTUMBERGER[1]

Content

Photovoltaic power plants can cause step changes in the output power due to fast moving clouds. That could lead to voltage fluctuations and stability problems in the connected distribution electricity network. These effects can be reduced effectively by electricity network reinforcements or by battery energy storage system that smooth the output power fluctuations. These two solutions are effective but very costly. For house scale photovoltaic power plants of several kWp, both solutions represent a considerable percentage of investment. However, similar results can be achieved by a programed smooth reduction of the photovoltaic power plant output power based on the cloud passing forecasting. Low cost hardware Internet of Things (IoT) modules incorporated in a cloud passing forecast system could be a much cheaper alternative compare to battery storage system or network reinforcement. This paper proposes a low-cost IoT based solution for intra-minute cloud passing forecasting. Used low cost hardware is Raspberry PI Model B 3, Omni Vision OV5647 camera, optical circular polarizing (CPL) filter and natural density (ND) filter (Figure 1). All used hardware cost less than 70 €.

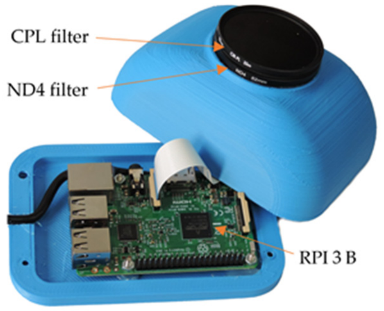

Figure 1: Used hardware

The existing professional systems for solar irradiance and cloud passing forecasting can provide accurate forecast but only at high costs. Their price can easily exceed the price of small house scale photovoltaic power plants [1].

The algorithm applied in the proposed cloud passing forecasting system differs from the existing ones. It uses the green and the blue colors for cloud recognition and reduction of flare problems. The image processing is limited to a narrow area around the sun, which is sufficient for intra minute cloud passing forecasting and can be performed with a low computational effort. The recognition of clouds is based on the ratio between the green and the blue colors GBR (Green Blue Ratio) digital filter instead of well-known RBR (Red Blue Ratio) filter [2], [3].

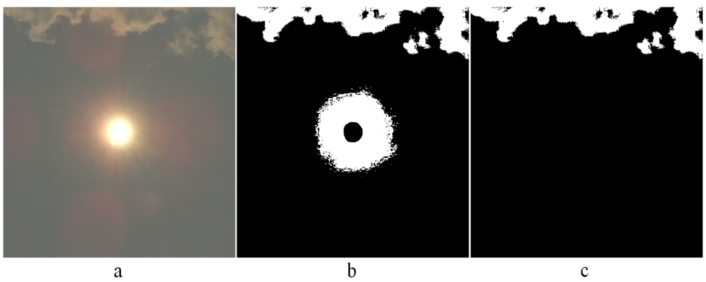

Figure 2: Cloud recognition

The prediction of cloud movement is required only during the part of the day where the moving clouds could influence the output power of a PV power plant substantially. For the prediction of cloud movement within one minute, the photo is cropped down to a relatively small area around the sun where the cloud recognition is performed (Figure 2). In order to make the executive code for the prediction of cloud movement, suitable for implementations on low-cost IoT modules, the applied algorithms are minimized regarding the required computational effort. The pixels representing the cloud closest to the sun in the cloud recognition matrix are identified first. In order to do this, the checkpoint matrix is defined, containing 128 checkpoints. Its elements are distributed in 4 radially equidistant layers, measured from the center of the sun (Figure 3). Each layer contains 32 angularly equidistant points. The pixels representing the cloud closest to the sun in the cloud recognition matrix are identified first. The sequences of the processed images of the sky, shown in Figure 4, are used to demonstrate the operation of the proposed cloud passing forecasting system.

[1] University of Maribor, Faculty of Electrical Engineering and Computer Science, Koroška 46, Maribor, Tel.: +386 2220-{7179|7075}, {p.sukic|gorazd.stumberger}@um.si, feri.um.si

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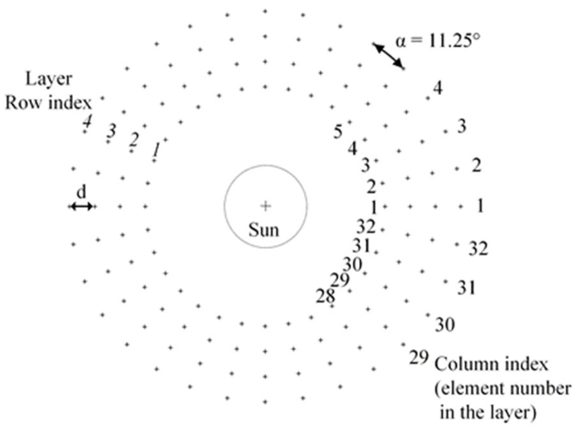

Figure 3: Checkpoints around the sun and checkpoint matrix indices

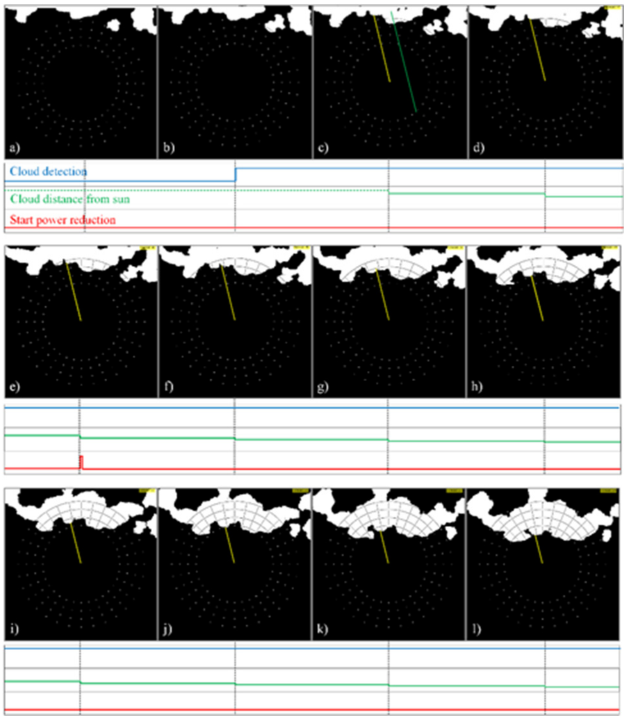

Figure 4: Moving clouds that cover the sun: A time sequence of processed cloud images

The experimental results (Figure 5) show that the proposed cloud passing forecasting system can provide sufficiently accurate prediction of cloud movement in the vicinity of the sun. In the full paper, its output signal will be used to reduce the output power of an operating PV systems smoothly and slowly.

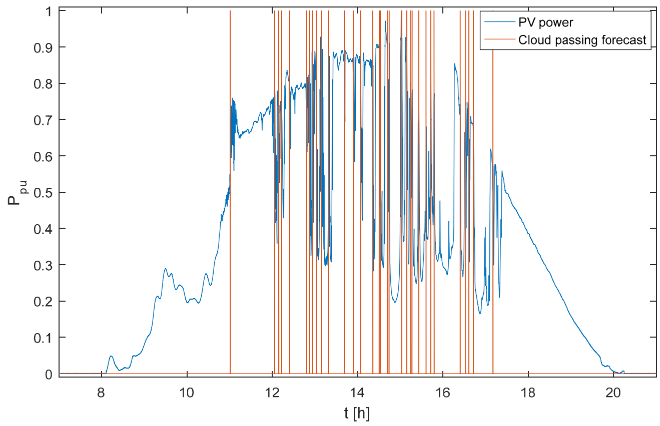

Figure 5: Output power measured on the test PV power plant and the output signal of the proposed cloud passing forecasting system

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