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Characterisation of the rapid fluctuation of the aggregated power output from distributed PV panels

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Figure 2: The SYSLAB experimental power system at DTU, Risø Campus.


Figure 1: Typical clouds at a sunny day in Denmark.

Even at a good day in Denmark, clouds will typically partly shadow for the sun, resulting in fluctuating power generation from PV panels. At the DTU Risø Campus, PV power panels connected to our experimental power system facility SYSLAB are distributed over 1 km at three sites. The large and rapid power fluctuations caused by these passing clouds is a challenge for the power system – for the control, the power quality and the stability. However, the fluctuations of the aggregated power from the distributed PV panels are clearly reduced.

I. Experimental Set-up

SYSLAB is a very flexible, experimental power system at DTU Risø Campus (Figure 2). PV power is connected to the SYSLAB power system at three sites (117, 319 and 725) distributed over 1 km (Figure 4). The very flexible SYSLAB power connection set-up makes it possible to connect the PV panels at the three sites to a dedicated power line and connect the power line to the national grid (Figure 3). The SYSLAB monitoring system measures the power for each PV installation and the aggregated power at the grid connection with a time resolution of 1 sec.

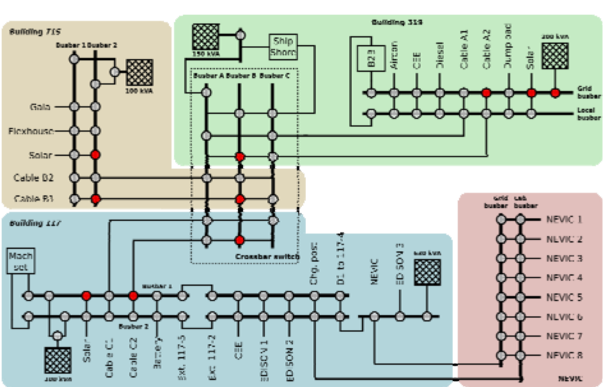
Figure 3: The flexible power connection of SYSLAB.

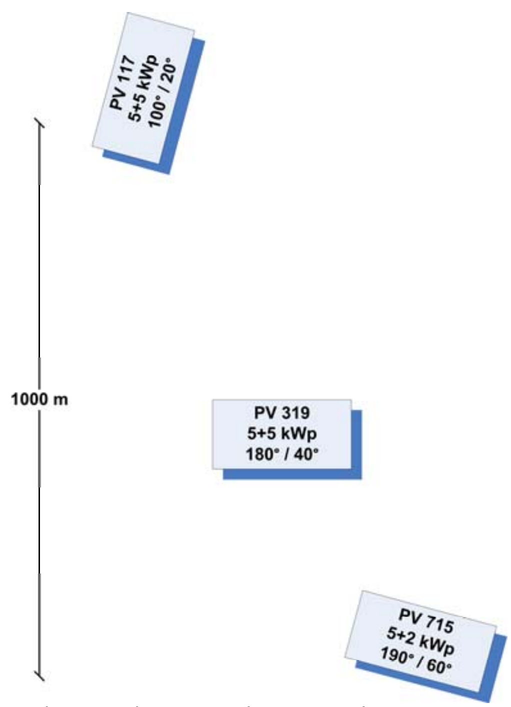

Figure 4: The PV panels connected to SYSLAB.

The large and rapid power fluctuations (on 2012-06-01) from one of the PV installations are presented in Figure 5. The variation over the day of the maximum power from the three PV

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panels is presented in Figure 6. For comparison, the power outputs from each of the PV panels and for the aggregated value are presented as normalized power relative to the maximum power during the day. The three panels have different profiles during the day due to their different orientations and tilt-angles (Table 1).

Site	Orientation	Tilt	Technology	Nominal power
715	190°	60°	poly-crystalline mono-crystalline	2 kWp 5 kWp
319	180°	40°	poly-crystalline thin film	5 kWp 5 kWp
117	100°	20°	poly-crystalline thin film	5 kWp 5 kWp

Table 1: PV installations in SYSLAB (2012).

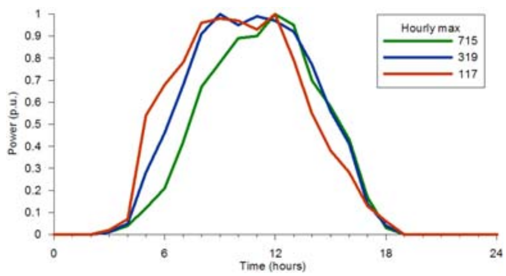

Figure 6: The hourly maximum power for the three PV installations over the day.

II. Results

Detailed examples of the power fluctuations are presented in Figure 7 around 10 o'clock with passing clouds causing dips in the power generations, and in Figure 8 around 12 o'clock with passing holes in the clouds causing spikes in the power generations.

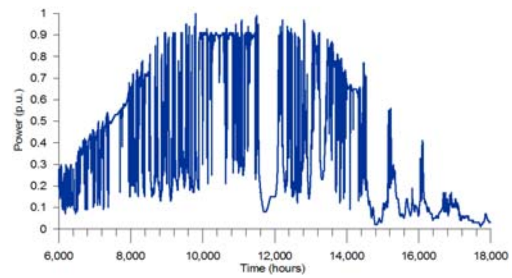

Figure 5: The fluctuations of the power from one of the PV installations.

Even with the relative short distances between the PV panels, it is very clear that the power fluctuations to some degree are uncorrelated, reducing the relative fluctuations of the aggregated power.

In Figure 7 around 9:55 a cloud passed the PV-117 panel without affecting the PV-319 and PV-715 panels. Around 10:00 other clouds passed PV-715 and to some degree the PV-319 panel, but with almost no impact on the PV-117 panel.

In Figure 8 around 12:05 holes in the clouds are passing the PV panels, resulting in large, but to some degree uncorrelated fluctuations. The relative fluctuations of the aggregated power (the power to the grid) are a lot less.

III. Conclusion

In Denmark, a distribution of PV panels over only 1 km will have a significant impact on the rapid power fluctuations of the aggregated power generation from the panels caused by passing clouds.

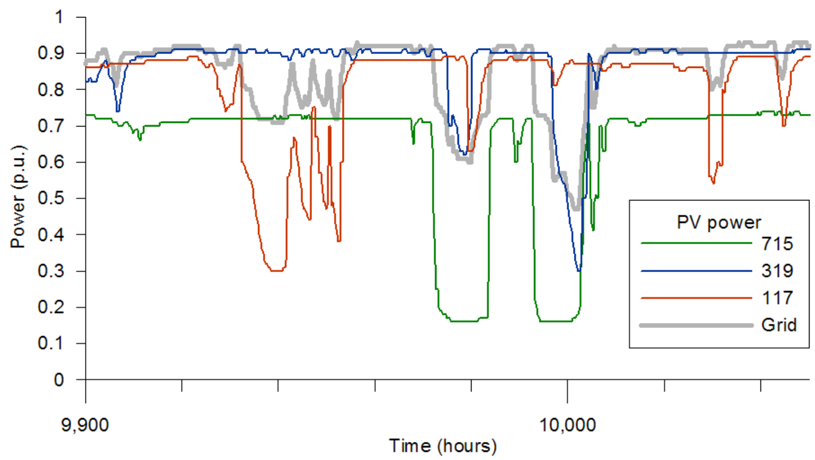

Figure 7: Details of power dips. (Approx 1 minute between the time marks)

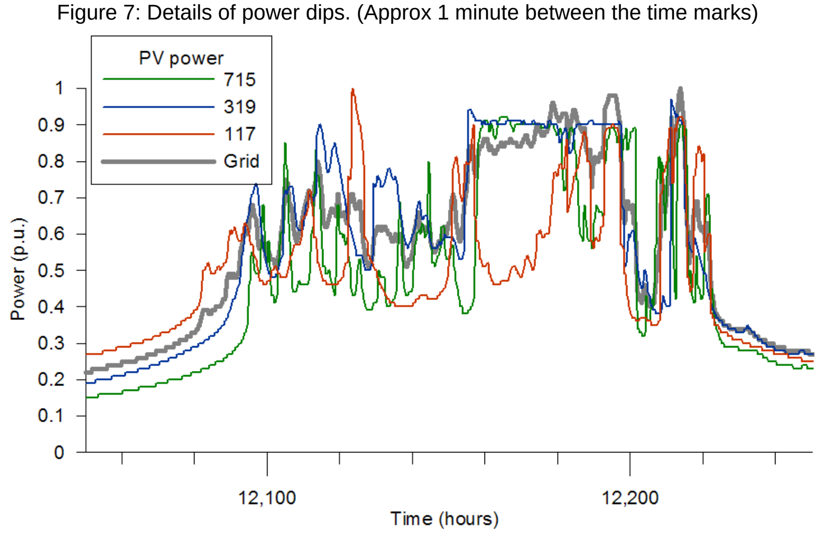

Figure 8: Details of power spikes. (Approx 1 minute between the time marks)