Field Study on Changing Grid Requirements Due to High PV Penetration

Georg Wirth [1] | Andreas Spring [1] | Gerd Becker [1]
Robert Pardatscher [2] | Rolf Witzmann [2]
Johannes Brantl [3] | Michael Garhamer [3]

Motivation

The low voltage grid has to be designed, to handle the occurring maximum load. Considering the demand, this load is not the sum of each household's maximum load as there is very little synchronism of these loads. Decentralized power production has no impact on the grid as long as this power is locally consumed. Apparently there is very little synchronicity and new load patterns occur.

Efficient planning of the low voltage grid demands for indicators of the simultaneity of the feed in and the nominal power of a PV system.

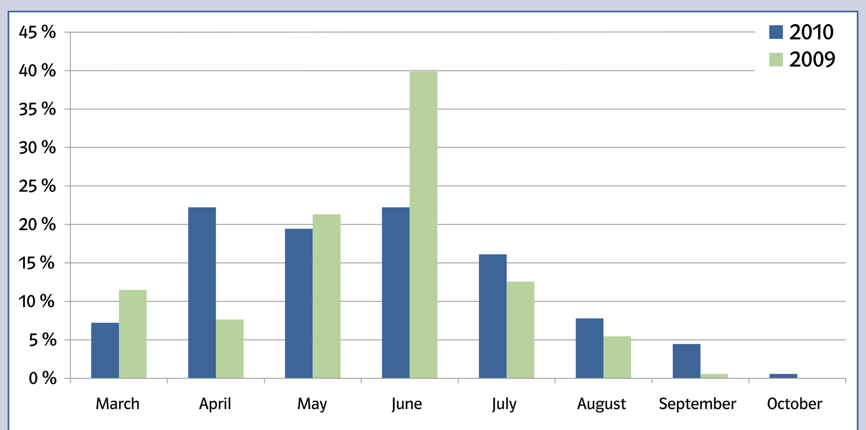

Fig. 1: Relative occurrence of the maximal feed in power of 150 distributed PV systems in Bavaria.

Project

The E.ON Bayern project "The Grid of the Future", which is a cooperation of the TUM and the University of Applied Sciences Munich, analyzes these new load patterns on the grid. Figure 1 illustrates that the day with the maximum feed in power occurs mostly in the summer months, but not necessarily at the sun's zenith in the end of July. This indicates that the highest power production does not necessarily occur on a clear sky day.

Inverter

A limiting factor for the maximum power output of the PV system is the inverter design. Besides a large number of objective technical reasons also financial aspects have to be considered. A study amongst 934 PV systems within the project should show the variability and the final sizing of PV systems in the south of Germany. The overall sizing ratio ($P_{WR\text{-}AC\text{-}Nom}$ over $P_{PV\ STC}$) is 0.89 as shown in table 1 with a rising trend towards larger systems.

Table 1: Average sizing ratio ($P_{WR\text{-}AC\text{-}NOM}$ / $P_{PV\text{-}STC}$)

System Size	Sizing Ratio
Up to 5 kW	0.88
5 kW to 10 kW	0.88
10 kW to 30 kW	0.90
30 kW to 100 kW	0.90
100 kW to 400 kW	0.93
Total	0.89

Maximum Power on a Clear Sky Day

With clear skies in summer the irradiation reaches values around 950 W/m² in Southern Germany. In this case the diurnal cycle of solar radiation has the shape of a bell curve. The generated power of distributed PV systems shows due to the homogeneous weather situation a high simultaneity. All plants in a region feed high power to the grid. Due to the slowly increasing radiation and the high ambient temperature, the high radiation levels come along with high module temperatures and the plant output remains well below the STC performance.

The simulation itself follows an efficiency-based model with typical system parameters as shown in figure 2. The maximum global radiation is calculated with the radiative transfer library libRadtran according to the correlated-k method. The ambient temperature is taken from longterm data series of the German Weather Service.

The results of the simulation show that the highest power output on clear sky days appears in June.

Figure 3 shows the power output of a typical south oriented PV system in W per kW_p. The maximum power in Germany stays below 850 W per kW_p and therefore below the typical inverter limitation.

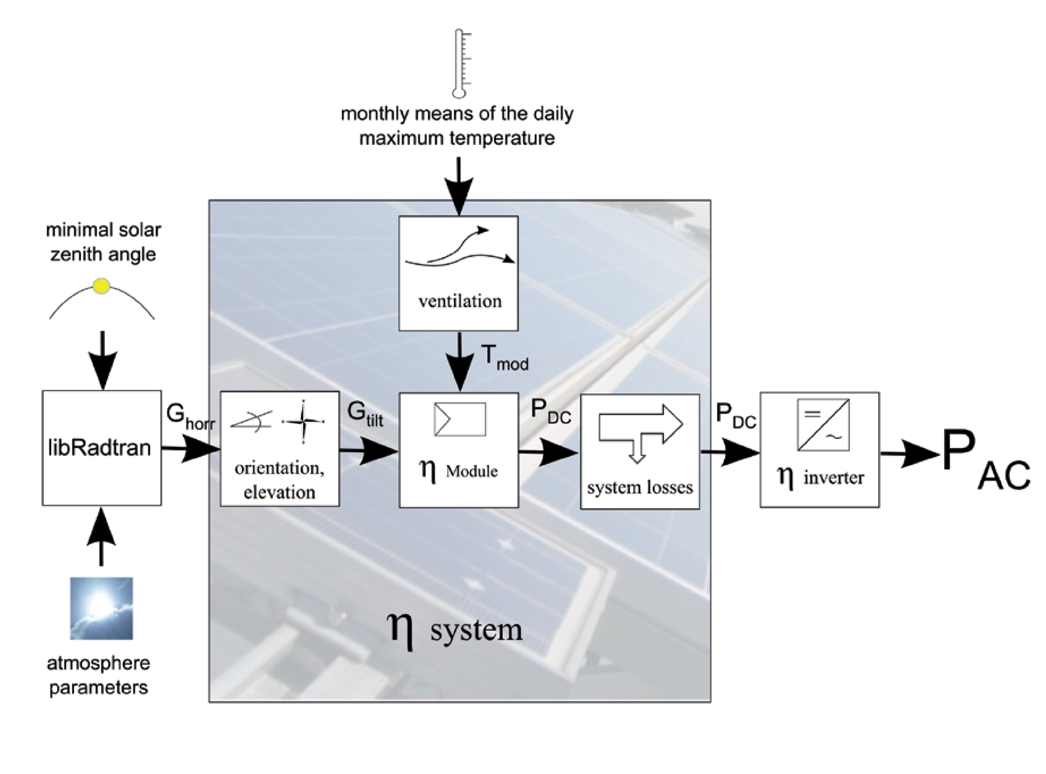

Fig. 2: Block diagram of the simulation model.

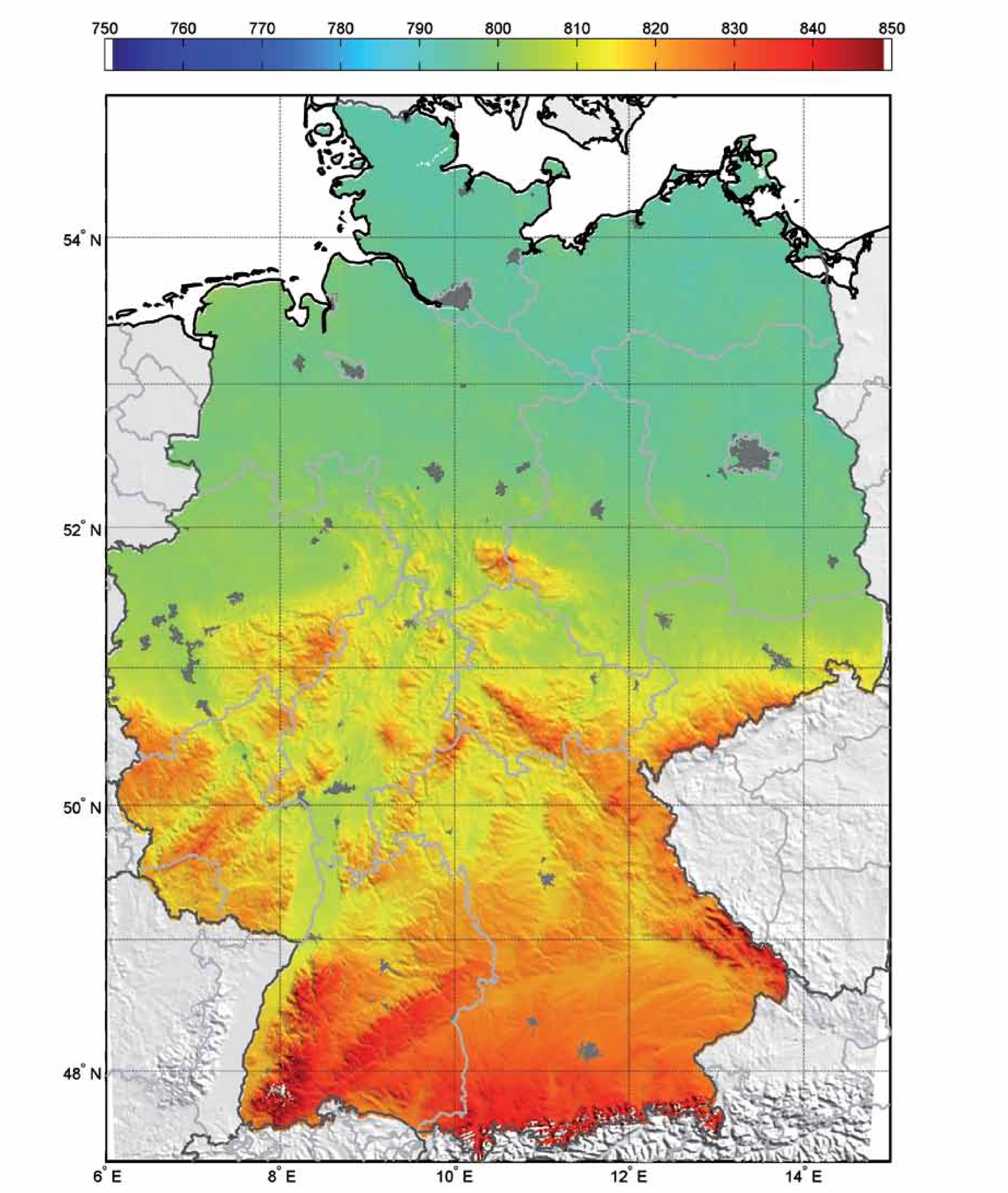

Fig. 3: Maximal feed in power of a typical south orientated PV system for Germany in W per kW_p installed STC power.

Maximum Power on a Cloudy Day

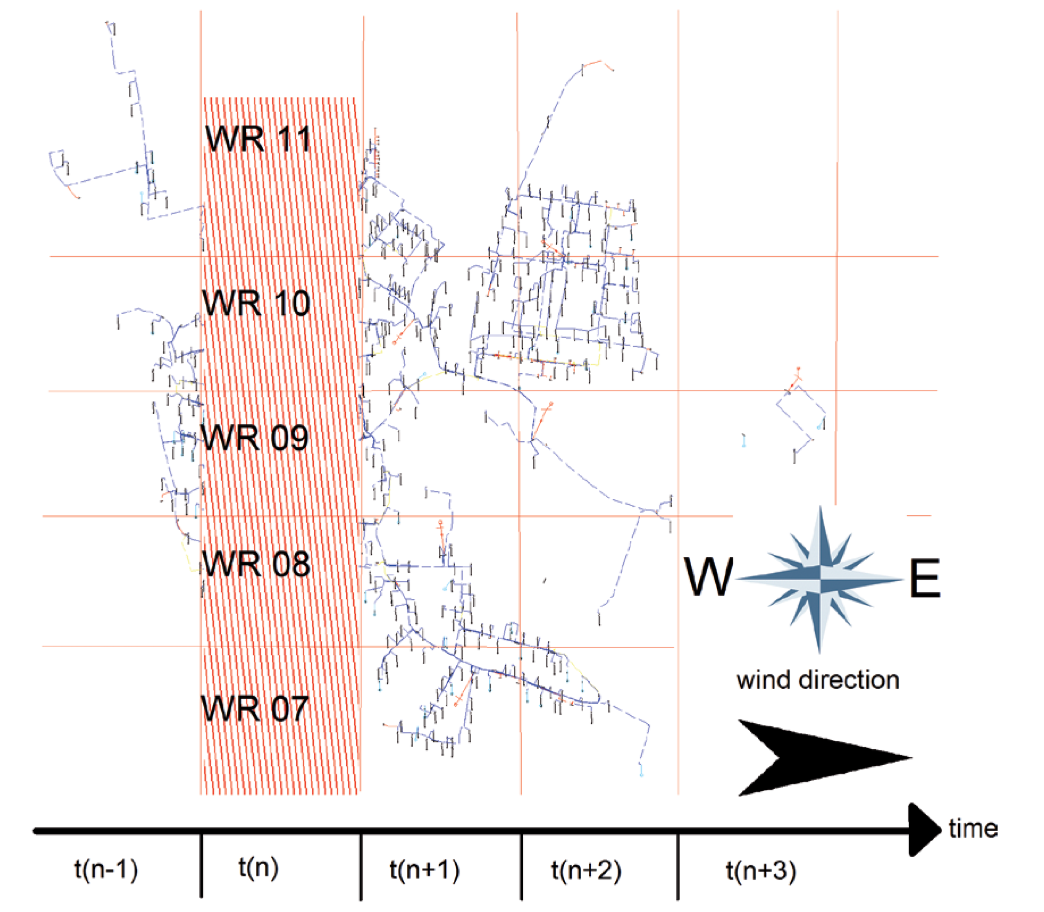

Fig. 4: The analyzed low voltage grid with the allocated load profile and its movement.

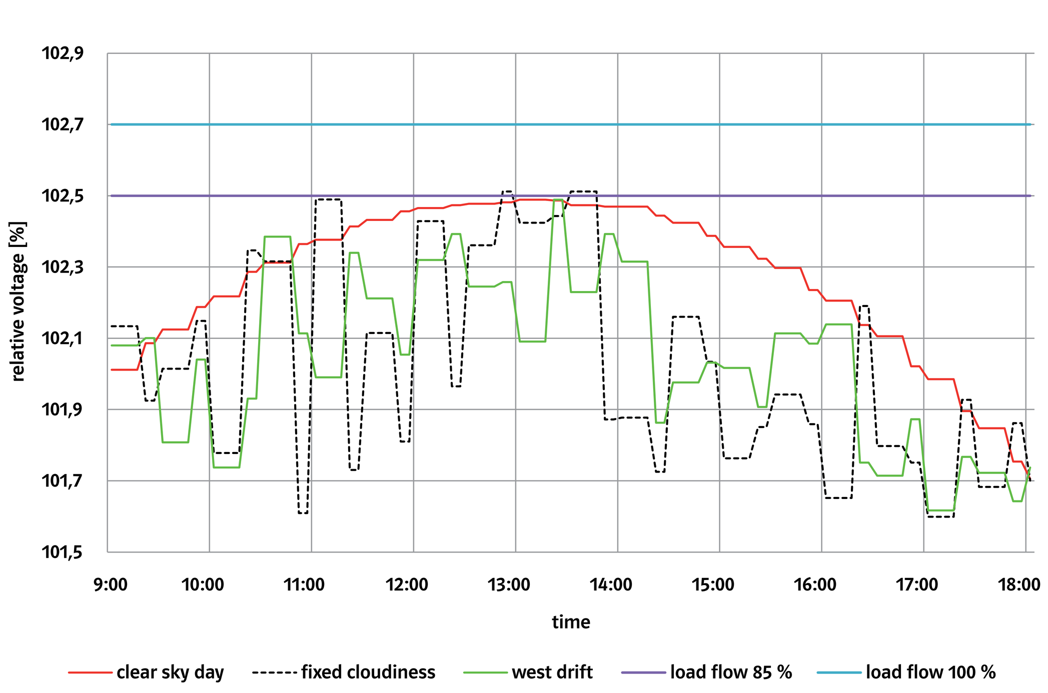

Fig. 5: Relative voltage on a cloudy day (green), a theoretic day without smoothing (black), and a maximum clear sky day (red). The light blue line indicates a simulation with the nominal power and the purple line indicates 85 % of the nominal power.

Cloud reflections cause increases of the global radiation up to values above the solar constant. These irradiation enhancements meet low cell temperatures due to the thermal time constant of the PV module. The resulting power peaks are limited by the maximum inverter output power. The simultaneity of this phenomenon is due to the cloud movement lower as the one of clear skies.

To examine this more closely, detailed operating data of a large-scale photovoltaic power plant are taken and transferred, according to figure 4, to a low voltage grid which spreads out over an equal area. To visualize the smoothing, the rigid curve shows the resulting voltage with the same load profile at all PV systems. In the simulation a slow west drift was adopted and the size of the inverters chosen according to table 1.

The results of the simulation, as required by DIN 50160, are 10 minute average values of the relative voltage on all knots. Figure 5 shows the results of a load curve calculation for different cloud conditions. The real cloudy sky (green) is much more even than the theoretic fixed cloudiness (black) and exceeds never the 85 % limit. At the same time, it is obvious that cloudy days are more critical for local grids than clear sky days.

Conclusion

The maximum feed in power of a typical photovoltaic system is limited by the inverter by a factor of 0.89. For large PV plants this factor is slightly higher. On a clear sky day in Southern Germany a typical optimally oriented PV system feeds less than 0.85 times its installed STC power to the grid. Cloud reflections cause peaks of the global radiation up to values above the solar constant. The maximum feed in power of the PV system and the impact on the grid is higher on these days, but still a reduction factor of 0.85 can be applied. Therefore it is recommended to consider small PV systems with 85 % of the installed STC power in grid calculations.

(1) Munich University of Applied Sciences · Department of Electrical Engineering · Working Group of the Solar Technology Lab · 80323 Munich · Germany
Phone: +49(0)89/1265-3483 · Fax: +49(0)89/1265-3403
http://www-lse.ee.hm.edu · georg.wirth@hm.edu
(2) TUM – Technische Universität München · Fakultät für Elektrotechnik und Informationstechnik
Fachgebiet Elektrische Energieversorgungsnetze
80290 München
(3) E.ON Bayern AG · 93049 Regensburg