FIELD STUDY ON CHANGING GRID REQUIREMENTS DUE TO HIGH PV PENETRATION

G. Brantl 1 | A. Speier 1 | G. Wirth 1
R. Kallmeyer 2 | M. Witzmann 2
J. Heinen 2 | M. Hagemann 2

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.

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 \( \frac{P_{\text{AC, Nom}}}{P_{\text{PV, STC}}} \) is 0.89 as shown in table 1 with a rising trend towards larger systems.

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 photovoltaic systems shows due to the homogenous weather situation a high simultaneity. All plants in a region feed high power to the grid. Due to the slowly increasing radiation and 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 orientated PV system in W per kW. The maximum power in Germany stays below 850 W per kW, and therefore below the typical inverter limitation.

Conclusion
The maximum feed in power of a typical photovoltaic system is limited by the inverter by a factor of 0.85. For large PV plants this factor is slightly higher. On a clear sky day in Southern Germany a typically 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.

Table 1: Average sizing ratio \( \frac{P_{\text{AC, Nom}}}{P_{\text{PV, STC}}} \)

<table>
<thead>
<tr>
<th>System Size</th>
<th>Sizing Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kW to 5 kW</td>
<td>0.88</td>
</tr>
<tr>
<td>5 kW to 10 kW</td>
<td>0.88</td>
</tr>
<tr>
<td>10 kW to 30 kW</td>
<td>0.85</td>
</tr>
<tr>
<td>30 kW to 100 kW</td>
<td>0.90</td>
</tr>
<tr>
<td>100 kW to 400 kW</td>
<td>0.90</td>
</tr>
<tr>
<td>Total</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Fig. 1: Relative occurrence of the maximal feed in power of 150 distributed PV systems in Bavaria.
Fig. 2: Block diagram of the simulation model.
Fig. 3: Maximum feed in power of a typical south orientated PV system for Germany in W per kW installed STC power.
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 (red) and a maximum clear sky day (black). The light blue line indicates a simulation with the nominal power and its movement.

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