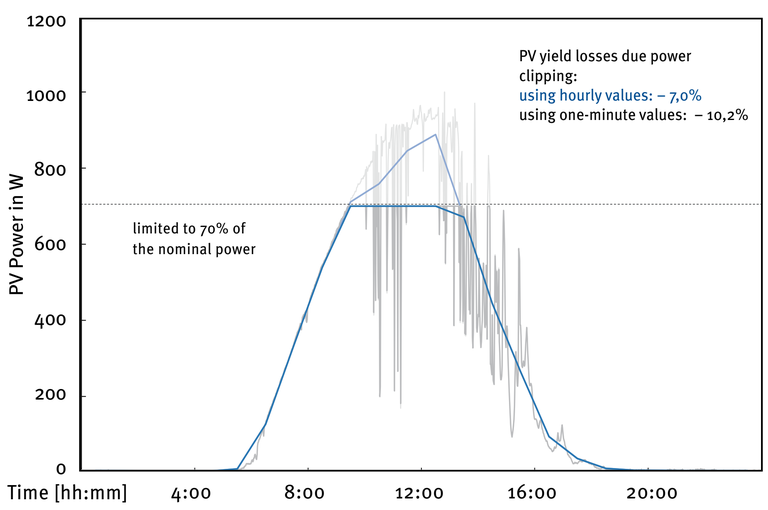
PV*SOL® | Generating irradiance data with one minute resolution for better PV simulations

We present a method to generate time series of global irradiance with a temporal resolution of one minute, based on the combination of irradiance measurements averaged over one hour and probability transition matrices derived from high resolution measurements under similar meteorological conditions. High resolution time series of global irradiance are needed for improved simulations of photovoltaic (PV) systems due to the inherent nonlinear dynamics of these systems, e.g. the dependency of the module efficiency from the irradiance.

Why one-minute values?

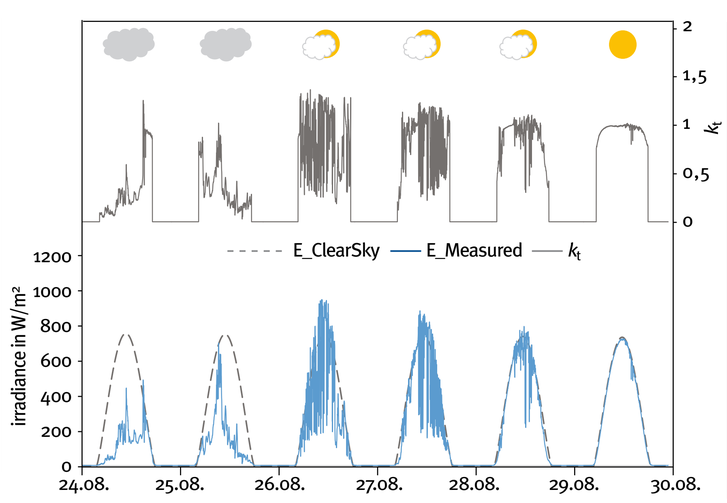
One-minute values are important for the simulation of PV systems. Several effects can not be simulated precisely with hourly averaged values, e.g.

- Maximum power clipping (typically at 70%)
- Inverter undersizing
- Interaction of PV and storage



New Approach

- **Transition probability matrices (TPM) and Markov chains**
  Synthesis of one-minute irradiance data is done by intelligent random processes based on real measurement data on a worldwide scale
- **Very large data base (by BSRN and own measurements)**
  guaranteeing a considerable local and temporal validity
- **Detection of weather situations**
  Algorithm is location independent and hence applicable worldwide



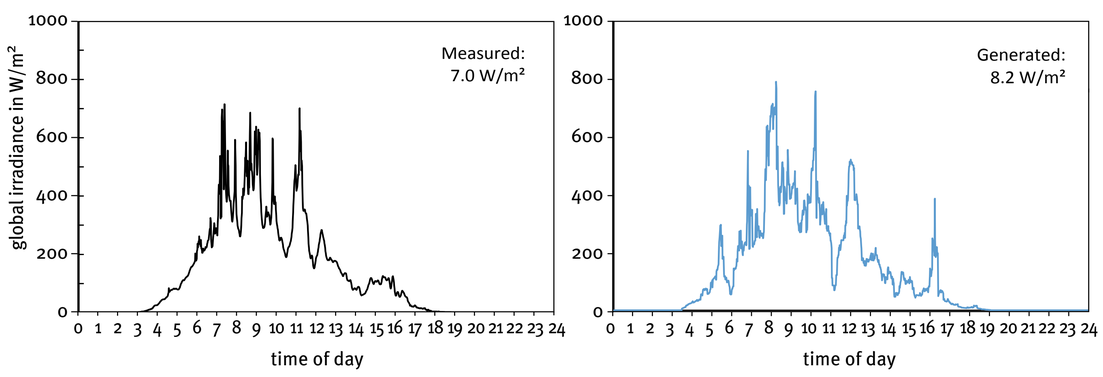
	$k_{t,i+1}$ 0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	…
$k_{t,i}$ 0	0	0	0	0	0	0	0	0	0	
0.01	0	0.8293	0.1707	0	0	0	0	0	0	
0.02	0	0.1034	0.7241	0.1724	0	0	0	0	0	
0.03	0	0	0.0941	0.7529	0.1412	0	0.0118	0	0	
0.04	0	0	0.0101	0.1111	0.7475	0.1111	0.0202	0	0	
0.05	0	0	0	0	0.0592	0.8092	0.1118	0.0132	0.0066	
0.06	0	0	0	0	0.0171	0.1453	0.6496	0.1453	0.0256	
0.07	0	0	0	0	0	0.0115	0.2184	0.4943	0.2529	
0.08	0	0	0	0	0.0148	0	0.0370	0.1407	0.6074	
0.09	0	0	0	0	0	0	0	0.0550	0.1835	
0.1	0	0	0	0	0	0	0	0	0.0233	
…										

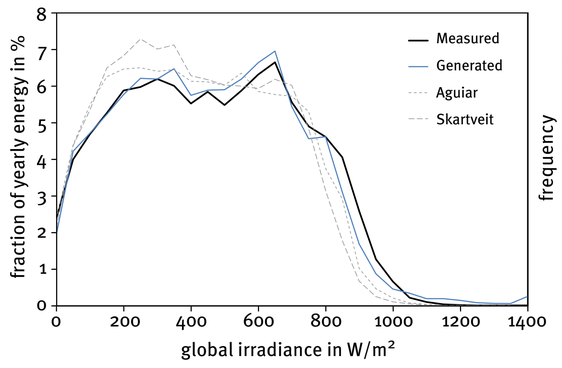
Results

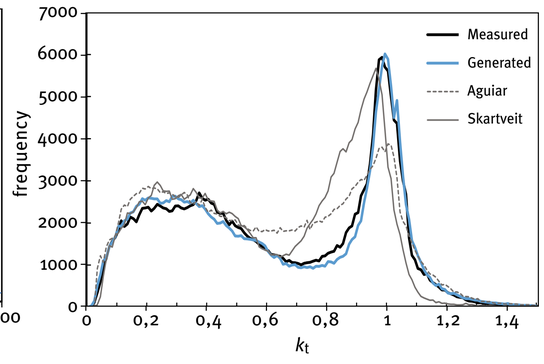
The new algorithm is able to reproduce the frequency distributions of the global irradiance much better than previous algorithms (e.g. by Aguiar and Skartveit). Low and mid irradiance values are not underestimated, a very good congruence is shown at high irradiance values.
The typical bimodal character of the kt frequency distributions is reproduced very well for locations with strong cloudiness as well as for sunnier locations with pronounced clear sky peak at kt near 1.

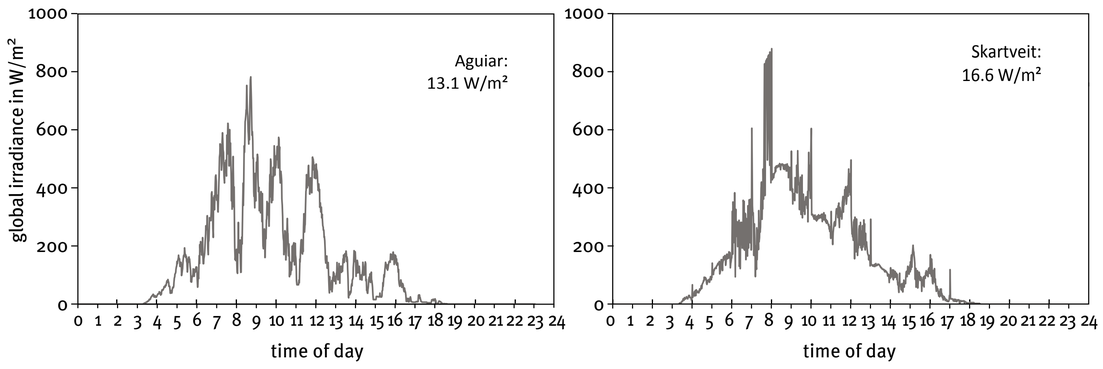
The reproduction accuracy for sunny days is very high. For less sunny days as well the new algorithm generates sequences of irradiance, that agree very well with measured data in terms of variability and temporal patterns.

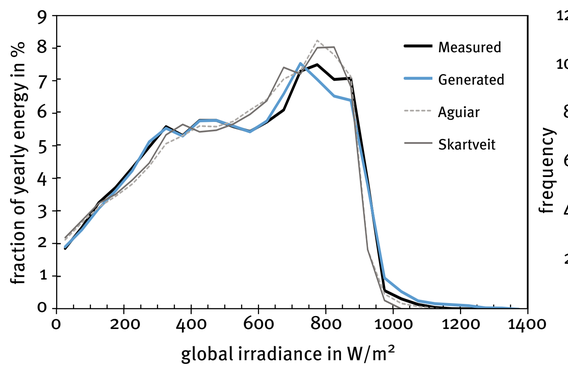
	RMSE of irradiance in %		RMSE of k_t in counts	
Model	**Lindenberg**	**Carpentras**	**Lindenberg**	**Carpentras**
Aguiar	0.530	0.549	596	801
Skartveit	0.684	0.575	862	962
New	0.210	0.237	207	248

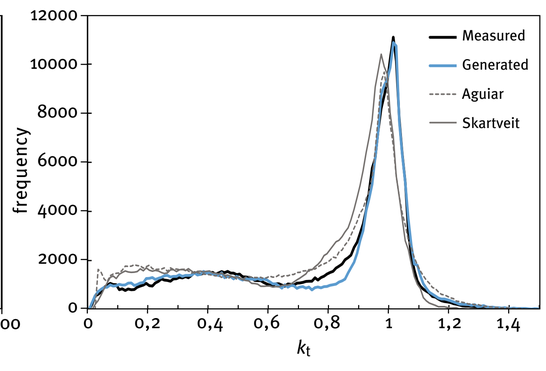












Conclusion

An improved method to generate one-minute time series of global irradiance has been presented that was developed on the basis of a large worldwide measurement dataset. It combines the advantages of conventional algorithms and adds new elements like the differentiation of weather conditions. It could be demonstrated that with the new approach it is possible to synthesize one-minute values of high statistical quality and realistic temporal variability.

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