Smart Nord

AP5.2: Systemtheorie von Erzeugern und Lasten

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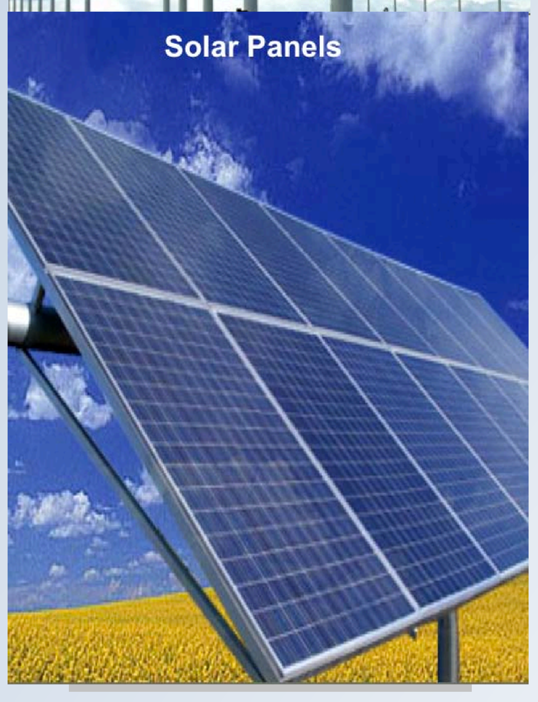
Research Topics and Context



- Study the effect of short term extreme fluctuations of solar and wind powers on the grid dynamics as, e.g., the voltage stability
- Characterization of the strong intermittent solar and wind powers with available high frequency time series
- Stochastic dynamical equation for the solar and wind powers with strong jumps

Methodology

- Drift-diffusion-jump modeling
  - Non-parametric estimation of dynamic equation
  - Jump rate from time series

1) Drift-diffusion-jump processes

$$dx_t = \mu(x_t, t)\, dt + \sigma(x_t, t)\, dw_s + \varsigma\, dJ_t$$

where $\{W_t, t \geq 0\}$ is a scalar Brownian motion.
$\mu(x_t, t)$ is drift function
$\sigma(x_t, t)$ is diffusion function
J_t is a time-homogeneous Poisson Jump process.
The jump has rate $\lambda(x)$
ς is jump sizes are assumed to be normally distributed, $\varsigma \sim N(0, \sigma_\varsigma^2)$

2) Non-parametric estimation of Drift-diffusion-jump processes

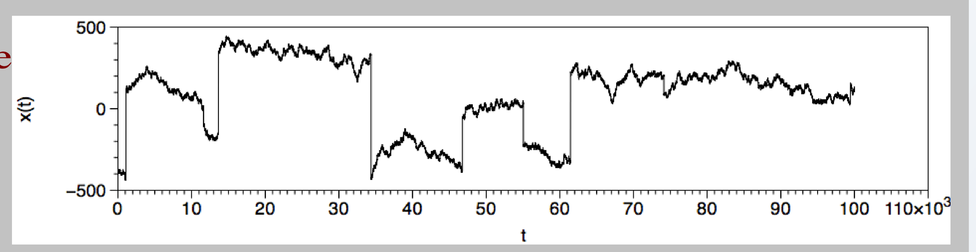
Bandi Theorem: $$M_j = \lim_{\Delta t \to 0} \frac{1}{\Delta t} < (x(t+\Delta t) - x(t))^j \mid x(t) = x >$$

$$\mu(x) = M_1$$
$$\sigma^2(x) + \lambda(x) < \zeta^2 >= M_2$$
$$\lambda(x) < \zeta^j > = M_j, \text{ for all } j > 2$$

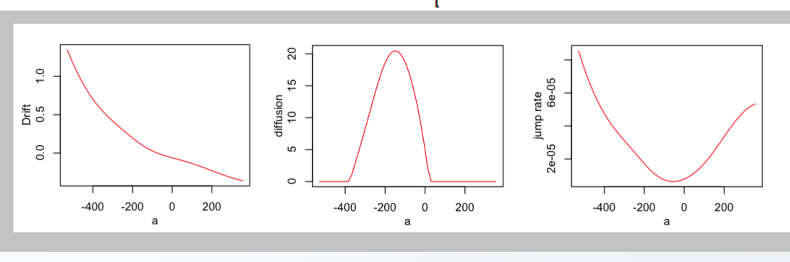
Estimation:

$$\mu(x) = M_1$$
$$s^2 = <\zeta^2> = \frac{1}{n} \Sigma_{i=1}^n \frac{M_6(x_i)}{5\, M_4(x_i)}$$
$$\lambda(x) = \frac{M_4(x)}{3\, s^4}$$
$$\sigma^2(x) = M_2(x) - \lambda(x)\, s^2$$

Example



$s^2 = 82020$



Results

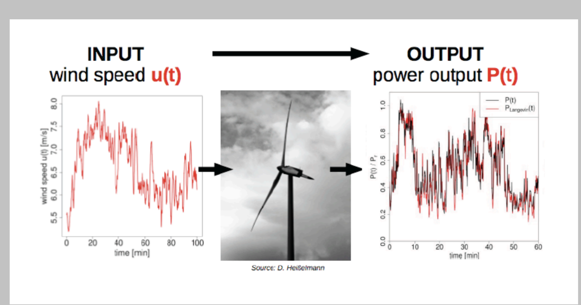
Stochastic Dynamic

1) Characterization of non-Gaussian behavior of solar irradiance and wind power increments via random multilplicative processes

2) Modeling of wind power with Langevin dynamics

$$\frac{dP}{dt} = D^{(1)}(P \mid u) + \sqrt{D^{(2)}(P \mid u)}\; \Gamma(t)$$

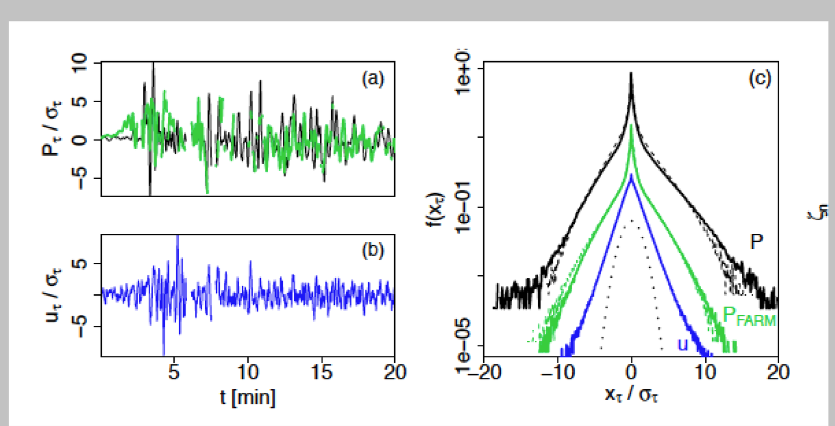
P. Milan, M. Wächter, and Joachim Peinke, Phys. Rev. Lett. 2013.



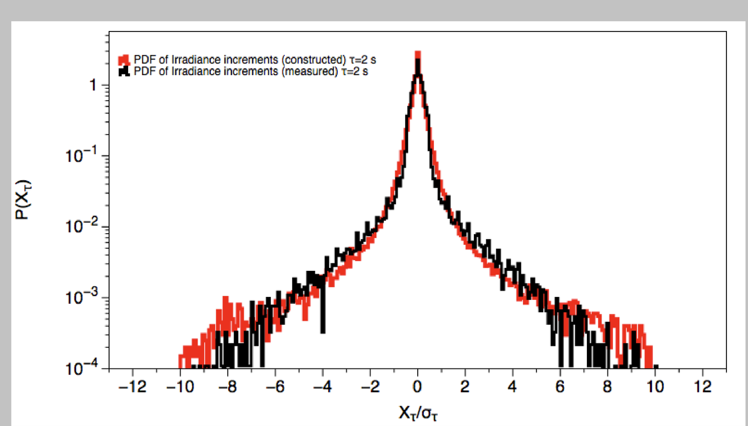
3) Improving the Langevin modeling with Drift-diffusion-jump model

Extreme Events

The calculated PDF increments with some delay scale parameter s: $X_\tau = X(t+\tau) - X(t)$
where X(t) = irradiance or wind Power data.



A normalized increment time series for = 8 sec (a) of power output P (black line) and PFARM (bold green line); (b) of wind speed u (blue line); (c) increment PDFs for P (upper black), PFARM (middle green) and u (lower blue) in lin-log scale. The results of the stochastic model in equation (1) are displayed for P and PFARM by the thin dashed curves.

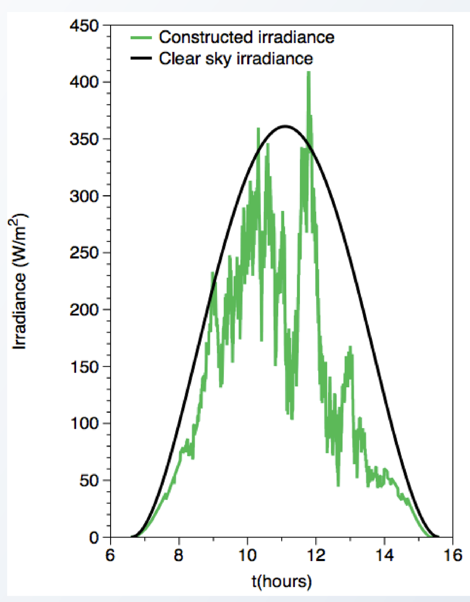


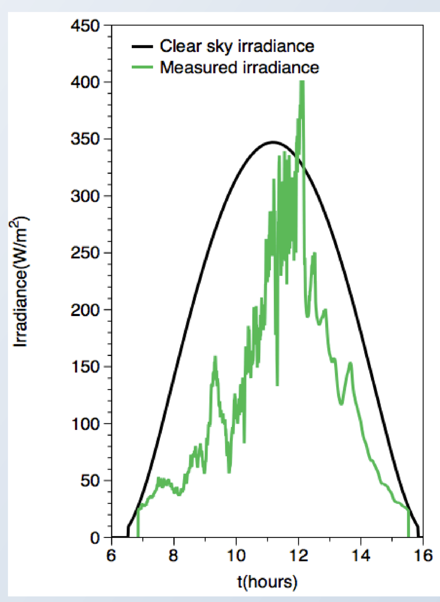
The increments' PDFs for the irradiance data, from 2sec. The black curve are the PDFs based on the irradiance measurement, while red curve is the PDF for constructed time series.

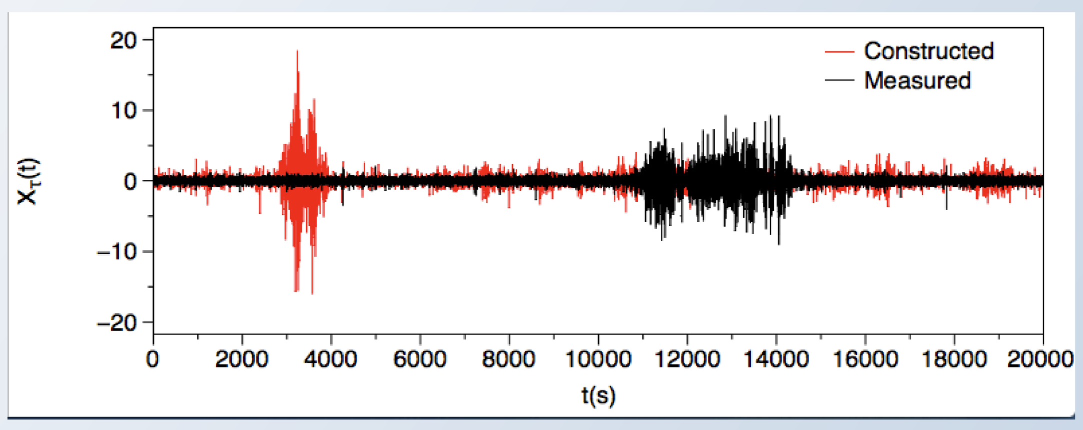
A non-Gaussian PDF with fat tails on small scales indicates an increased probability of occurrence of short-time extreme irradiance fluctuations.

Outlook and Open Questions

- Dynamical drift-diffusion-jump models for
  - Solar irradiance
  - Wind power
- Definition of extreme events in the grid
  - Influence of strong jump in stability of grid
  - Feeding of grid with estimated dynamical process







- Spatial inhomogeneity
  - Study the synchronization
  - Multifractality of sources
  - Intermittency of load

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