Controlling wind-solar power in Germany

H. Lustfeld

March 15, 2022

Peter Grünberg Institut (PGI-1), Forschungszentrum Jülich, Germany, email: h.lustfeld@fz-juelich.de

DOI: https://doi.org/10.21203/rs.3.rs-1142831/v1

- electric power consumption in Germany $\approx 60\ GW_{el}$
- but 80% power consumption are nonelectric, (energy for transportation, warm water, space heating and in part for process heating)
- therefore: 'Energiewende': $60\,GW_{el} \dashrightarrow 300\ GW_{el}$

Problem, needed: controlled wind-solar power generation of 60 GW_{el} $\{300\ GW_{el}\}$.

JÜLICH Forschungszentrum

database: power data over 7 years (2015 - 2021) from ENTSO-E

01.01.2021 00:00 - 01.01.2022 00:00 - CET		
	Germany (DE)	
Time	Day-ahead Total Load Forecast [MW]	Actual Total Load [MW]
00:00 - 00:15	43567	45170
00:15 - 00:30	43371	44835
00:30 - 00:45	42884	44519
00:45 - 01:00	42803	44265
01:00 - 01:15	42096	43713
01:15 - 01:30	41824	43157
01:30 - 01:45	41426	42556
01:45 - 02:00	41051	42326
02:00 - 02:15	40781	41798

Germany (DE) / 01.01.2021 00:00 - 01.01.2022 00:00 - CET			
MTU	Solar Actual Aggregated [MW]	Wind Offshore Actual Aggregated [MW]	Wind Onshore Actual Aggregated [MW]
	D	D	D
00:00 - 00:15	0	337	4232
00:15 - 00:30	0	352	4098
00:30 - 00:45	0	404	3819
00:45 - 01:00	0	433	3723
01:00 - 01:15	0	419	3771
01:15 - 01:30	0	410	3689
01:30 - 01:45	0	379	3559
01:45 - 02:00	0	361	3439
02:00 - 02:15	0	318	3372

averaged power (GW) and scaling

year	2015	2016	2017	2018	2019	2020	2021
el. power demand $\bar{P}_d$	57.1	57.2	57.7	57.9	56.4	55.1	57.7
w-s volatile power $\bar{\hat{P}}_v$	12.8	12.7	15.8	17.1	18.9	20.0	18.3

Scaling factor s_f required!

Scaling: s_f selected such that $\bar{\hat{P}}_v \cdot s_f = \bar{P}_v = \bar{P}_d$

- energy demand: $E_d(t) = \int_0^t P_d(t')dt'$
- volatile energy generation: $E_v(t) = \int_0^t P_v(t')dt'$
- stored energy: $E_s(t) = \int_0^t P_s(t')dt'_s$

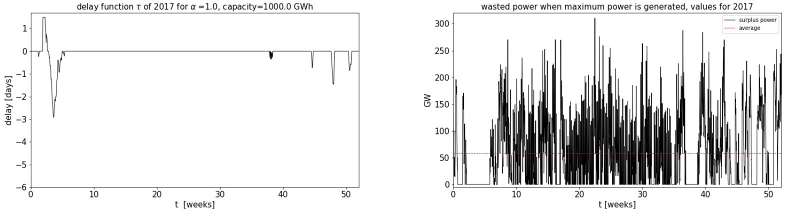
Together, Ansatz:

$$\boxed{E_d(t+\tau) + E_s(t) = (1+\alpha) \cdot E_v(t) - E_{disc}(t)}$$

with

- τ = delay function, simulates smart meters
- $\alpha \cdot E_v(t)$ =surplus energy
- E_{disc} ='discarded' energy

$$E_d(t+\tau) + E_s(t) = (1+\alpha)\cdot E_v(t) - E_{disc}(t)$$



Three characteristic numbers

- n_λ=range of smart meters: $n_\lambda = 4.4$ [days]
- n_δ=days out of prescribed range: $n_\delta = 6$ [days]
- n_σ=days for which smart meters are active: $n_\sigma = 36$ [days]

Conclusion

based on i) precise (partly scaled) data over 7 years (2015-2021), ii) surplus of power, iii) smart meter and iv) characteristic numbers ($n_\lambda, n_\delta, n_\sigma$) our approach predicts:

1. Germany's present electric power demand of $\approx$ 60GW can be supplied by wind-solar power alone.
2. Formidable volatility suppressed by storage capacity of 0.3TWh - 1TWh.
3. $\approx$ 100% surplus of wind-solar power devices required.

extrapolation to 300 GW case:

- I formidable volatility suppressed by storage capacity of 1.5TWh - 5TWh.
- II almost every roof and possibly a significant part of facades have to be covered with solar cells.
- III 270 000 windturbines of type (6MW, 200m height) are required(area of Germany 360 000 km^2)