# Wind Power Statistics (Offshore) and $H_2$-Evolution

## How a Power Balancer Enhances Availability of Electric Wind Energy

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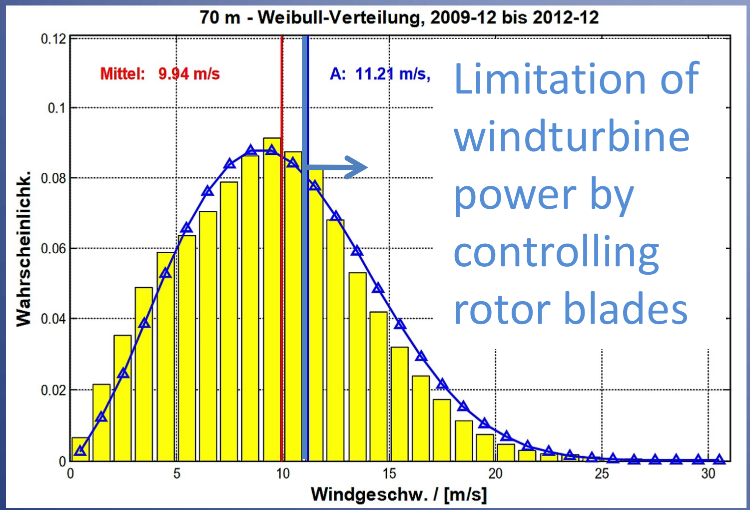
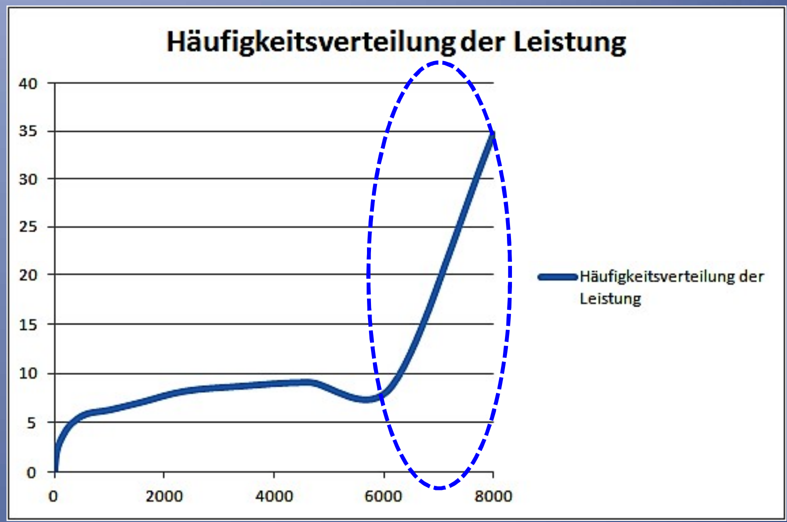
# Wind Power Statistics and $H_2$ Evolution

## * Technical Power-Limit enhances Frequency of Occurence *

## * This is realized today already! *




Example for the frequency of wind speed 1)




Calculated frequency of power based on data shown at left hand

1) Source:
https://www.dwd.de/DE/klimaumwelt/klimaforschung/klimaueberwachung/finowind/finodoku/abschlussbericht_pdf.pdf?__blob=publicationFile&v=3, fig. 11

*Numbers must be treated as an example, because wind speed frequency strongly depends on the site of the windturbine - Power scaled in relative units !*

# Wind Power Statistics and $H_2$ Evolution

## Rare known Fact with Windturbines if Strong Wind is Blowing:

- Because power output of a windturbine increases with (windspeed)^3 onshore and offshore wind farms sometimes suffer a shutdown during stormy weather !
- This is due to a non controllable lesser power demand by the grid 2) especially around 4 am.
- The limited transmission capacity of the grid is a second triggering reason for the shutdown.

2) Power controllability of a windturbine by its rotor blades usually is restricted to an interval between 12m/s and 25m/s windspeed. In this intervall the turbine delivers constant maximum output power.

# Wind Power Statistics and $H_2$ Evolution

## Preventing Windturbine from Shutdown by Clipping Grid Fed Power by a Free Controllable Bypass-Load

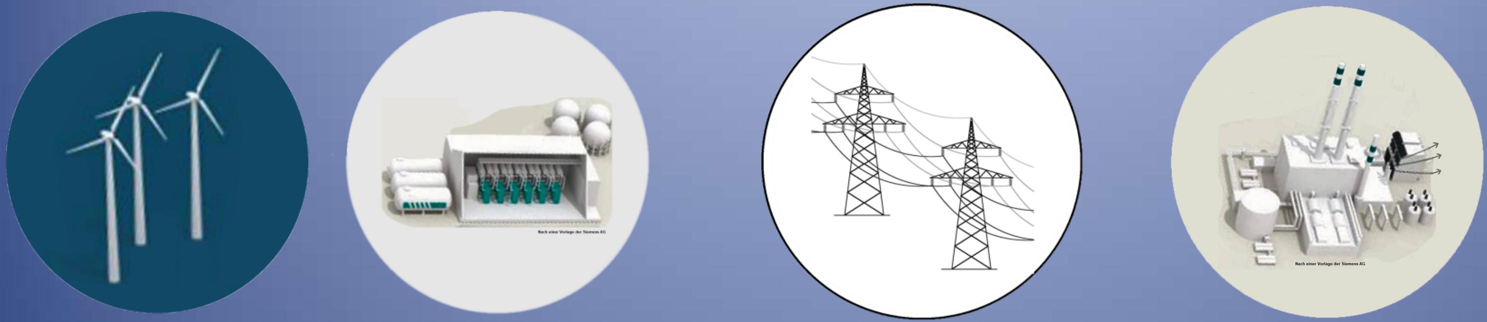
- Possible workarounds to avoid the regrettable necessity of a shutdown are
  - Build long transmission lines from wind farms to power stations and dynamically reduce the output power of the latter during strong wind – if technical possible and economic reasonable,
  - Use a big controllable load nearby the wind farms to bypass grid fed power. Usually a „Power Balancer“, e. g.$H_2$-Evolution, is choosen for this purpose 3), – $H_2$ is less valuable 4) than ready to use electric power, but easier transportable in big scale and storable,
  - May be both possibilities together …
  - See the simplified schematic on next page.

3) https://new.siemens.com/global/de/produkte/energie/erneuerbare-energien/hydrogen-solutions.html

4) But compare this to the „value“ of a shutdown …

# Wind Power Statistics and $H_2$ Evolution

## Simplified schematic for using a „Power Balancer“




*) Symbolic Shutdown Switch

https://www.tennet.eu/de/news/news/netzbetreiber-stellen-investitionsantraege-fuer-power-to-gas-projekte/

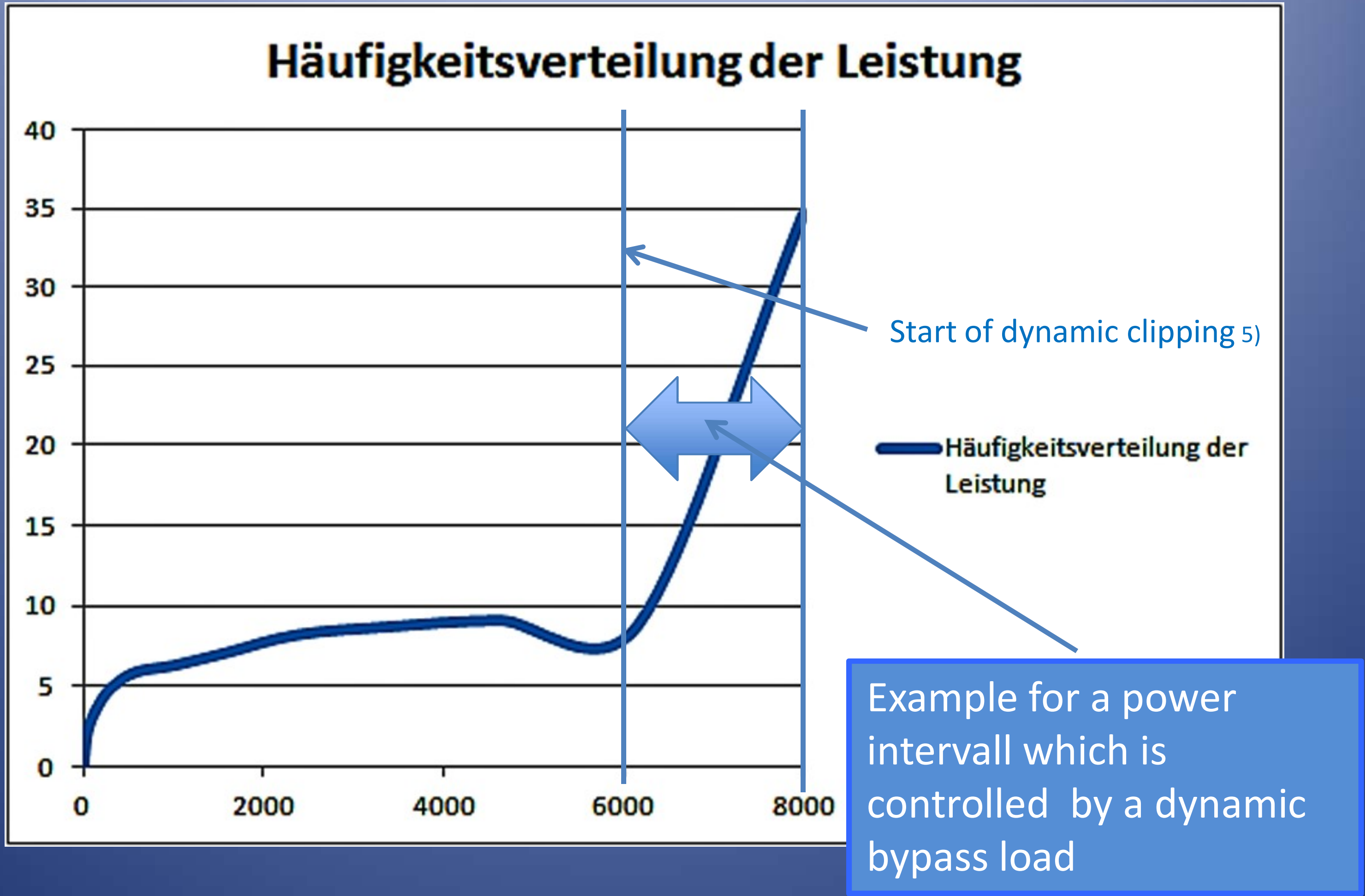
# Wind Power Statistics and $H_2$ Evolution

## Benefit of a Bypass Load to the Wind Farm

- Power balancing a wind farm enhances overall produced electric energy, because the necessity of shutdowns will be reduced.
- Power balancing also reduces the peak power requirements of dedicated transmission lines.
- Economic success of power balancing results from two sources:
  1. The benefit of reduced peak power requirements of transmission lines,
  2. The value of additional available grid fed electrical energy while avoiding a shutdown and
  3. the value of the produced hydrogen.

# Wind Power Statistics and $H_2$ Evolution

## Suitable Power Intervall for Clipping Grid Fed Power by $H_2$-Evolution




5) For simplification, this value is arbitrarily choosen as a constant. Real values will be dynamically generated by the dispatch management and obey to the load curve of power consumption, see Appendix 2 at page 10.

# Wind Power Statistics and $H_2$ Evolution

Simplified estimation of the amount of electric energy gained, while clipping the grid fed wind power by $H_2$-Evolution

1. Calculate the sum of produced electric energy if too much power due to weak demand and stormy weather causes a shutdown at 6000RU: 14626 Energy Units.
2. Calculate the sum of produced electric energy for the left and for the right intervall (were power will be balanced by $H_2$-Evolution from 6000RU to 8000RU): 32708 Energy Units. => We got a benefit of 18082 Energy Units (+55%) !
3. Calculate the sum of consumed power for the $H_2$-Evolution plant: 6027Energy Units. This energy will be transformed to hydrogen and gives an additional benefit.

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# Wind Power Statistics and $H_2$ Evolution

## Appendix 1: Tables of Data used for the Numbers

Assuming operating hours from frequency of occurence 100% => 8700h/y

**Beispiel Winddaten (Offshore Nordsee) und produzierte elektrische Energie**

| Windgeschwindigkeit v [m/s] | Dynamik der Leistung [RE] | Häufigkeit der Leistung [%] | Anteilige jährliche Betriebsstunden [h] | Anteilig produzierte elektrische Energie [RE] | Produzierte elektrische Energie n. Begrenzung auf 6000 [RE] | Im Balancer verbrauchte elektrische Energie [RE] | Produzierte elektrische Energie mit Abschalten [RE] |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0,0 | 0,00 | 0,0 | 0,0 | 0,0 | 0,0 |
| 1 | 5 | 0,7 | 60,90 | 0,3 | 0,3 | 0,0 | 0,3 |
| 2 | 37 | 2,2 | 191,40 | 7,1 | 7,1 | 0,0 | 7,1 |
| 3 | 125 | 3,5 | 304,50 | 38,1 | 38,1 | 0,0 | 38,1 |
| 4 | 296 | 4,9 | 426,30 | 126,3 | 126,3 | 0,0 | 126,3 |
| 5 | 579 | 5,9 | 513,30 | 297,0 | 297,0 | 0,0 | 297,0 |
| 6 | 1000 | 6,3 | 548,10 | 548,1 | 548,1 | 0,0 | 548,1 |
| 7 | 1588 | 7,1 | 617,70 | 980,9 | 980,9 | 0,0 | 980,9 |
| 8 | 2370 | 8,2 | 713,40 | 1691,0 | 1691,0 | 0,0 | 1691,0 |
| 9 | 3375 | 8,7 | 756,90 | 2554,5 | 2554,5 | 0,0 | 2554,5 |
| 10 | 4630 | 9,1 | 791,70 | 3665,3 | 3665,3 | 0,0 | 3665,3 |
| 11 | 6162 | 8,8 | 765,60 | 4717,7 | 4717,7 | 0,0 | 4717,7 |
| 12 | 8000 | 8,3 | 722,10 | 5776,8 | 4332,6 | 1444,2 | 14626 |
| 13 | 8000 | 6,8 | 591,60 | 4732,8 | 3549,6 | 1183,2 | |
| 14 | 8000 | 5,3 | 461,10 | 3688,8 | 2766,6 | 922,2 | |
| 15 | 8000 | 4,2 | 365,40 | 2923,2 | 2192,4 | 730,8 | |
| 16 | 8000 | 3,2 | 278,40 | 2227,2 | 1670,4 | 556,8 | |
| 17 | 8000 | 2,4 | 208,80 | 1670,4 | 1252,8 | 417,6 | |
| 18 | 8000 | 1,7 | 147,90 | 1183,2 | 887,4 | 295,8 | |
| 19 | 8000 | 1,1 | 95,70 | 765,6 | 574,2 | 191,4 | |
| 20 | 8000 | 0,7 | 60,90 | 487,2 | 365,4 | 121,8 | |
| 21 | 8000 | 0,5 | 43,50 | 348,0 | 261,0 | 87,0 | |
| 22 | 8000 | 0,3 | 26,10 | 208,8 | 156,6 | 52,2 | |
| 23 | 8000 | 0,1 | 8,70 | 69,6 | 52,2 | 17,4 | |
| 24 | 8000 | 0,0 | 3,48 | 27,8 | 20,9 | 7,0 | |
| 25 | 0 | 0,0 | 1,74 | 0,0 | 0,0 | 0,0 | |
| | | | | | | | |
| Summe | | 100,1 | 8705 | 38736 | 32708 | 6027 | |

*Numbers should be treated as an example, because wind speed frequency strongly depends on the site of the windturbine - Power and energy scaled in relative units !*

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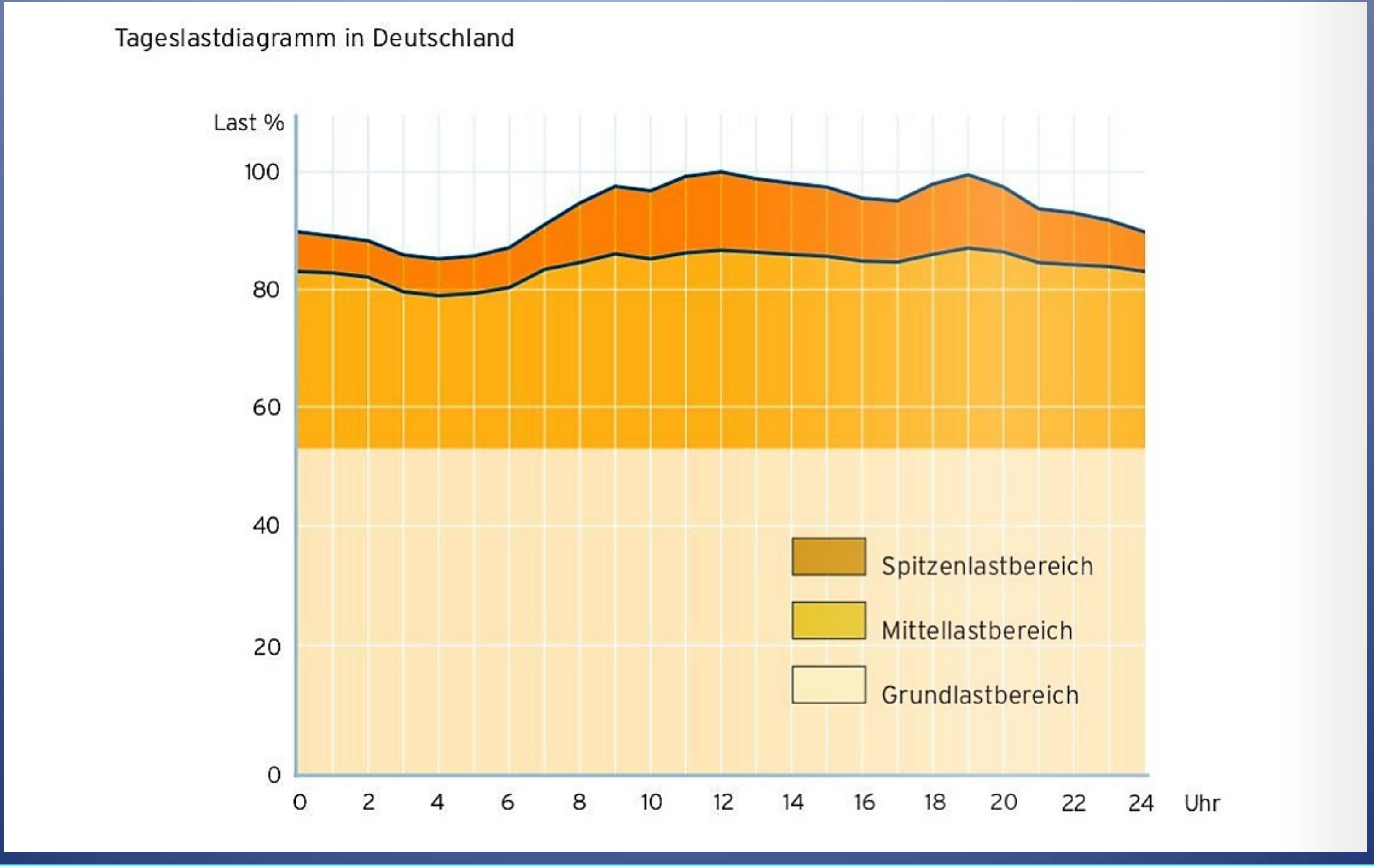
## Appendix 2: Example for a daily load curve (Germany) 6)




6) Source: https://www.yumpu.com/de/document/read/2477468/energie-aus-wasserkraft-strom-erzeugen-nach-bed-16502255/8 - page 8