Investigation of time-dependent turbulence on small wind turbines: a comparison with the turbulence model of IEC 61400.

IEA Wind TCP Task 41 , Daniel Österreicher

FH University of Applied Sciences TECHNIKUM WIEN

Agenda

- Introduction
- Energy Research Park Lichtenegg
- Problem and aim of the work
- Method
- Results
- Interpretation and comparison of results
- Effects on planning and operation
- Conclusion

Introduction

- SWT Worldwide (WWEA 2022):
  - Plants: 1,165,046
  - Total capacity: 1,295 MW
- SWT Austria (2018):
  - Plants: 359
  - Total capacity: 1.72 MW
- Demand for small wind turbines on the rise

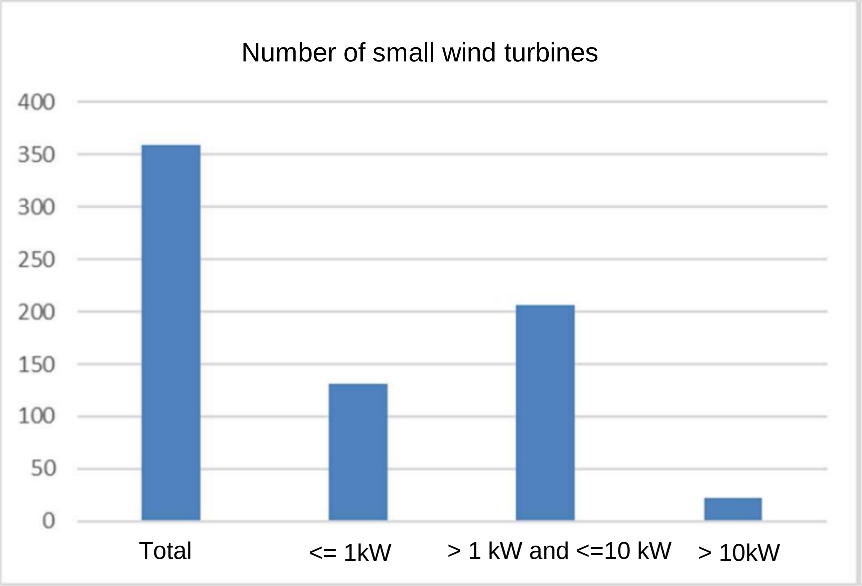

Figure 1: Number of small wind turbines in operation in Austria as of 31.12.2018 (Leonhartsberger et al. 2018).

Energy Research Park Lichtenegg

- Operated by a joint venture
  - UAS Technikum Wien
  - EVN AG
  - Solvento energy consulting GmbH
  - Energiewerkstatt e.V.

- Independent measuring and testing of small wind turbines

- Mean wind speed of 5.0 – 5.3 m/s

- Part of several research projects
  - Newest: SmallWind4Cities

Figure 2: Energy Research Park Lichtenegg

Problem

- Small wind turbines are systems prone to vibrations
- Causes of vibrations
  - Wind-induced turbulence
  - Mechanical forces

- Consequences:
  - Resonant vibrations
  - Material fatigue
  - Plant failures

Figure 3: Damage caused by vibrations and at the Lichtenegg Research Park.

(Leonhartsberger et al. 2019)

Aim of the work and scientific question

- Investigation of turbulence in the energy research park Lichtenegg
- Comparison with the Normal Turbulence Model (NTM) of IEC 61400-1.

Scientific question:

“What influence do the time-dependent turbulence events in the Energy Research Park Lichtenegg have on small wind turbines and can they be adequately described with the NTM according to IEC 61400-1 and what influence do these turbulence events have on the dynamic loads and the planning of small wind turbines?”

Method

- Basic research:
  - Literature from textbooks
  - Standard IEC 61400-1
  - Scientific research projects

- Data available
  - Wind measurement data from the years 2017 – 2020
  - 1 Minute average values

- Data analysis and graphical representation
  - MATLAB
  - Visplore
  - MS Excel

Time based evaluation for year 2020

Month [-]	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00
1	0,12	0,12	0,11	0,11	0,11	0,11	0,10	0,10	0,10	0,12	0,12	0,13
2	0,14	0,13	0,14	0,14	0,15	0,13	0,14	0,13	0,13	0,14	0,15	0,15
3	0,12	0,12	0,12	0,12	0,11	0,11	0,12	0,13	0,15	0,16	0,16	0,16
4	0,11	0,11	0,10	0,10	0,10	0,10	0,12	0,14	0,16	0,16	0,17	0,17
5	0,12	0,12	0,12	0,11	0,12	0,12	0,14	0,14	0,15	0,16	0,16	0,16
6	0,11	0,11	0,12	0,12	0,11	0,11	0,12	0,12	0,13	0,14	0,15	0,15
7	0,10	0,09	0,10	0,10	0,10	0,09	0,10	0,12	0,14	0,15	0,15	0,16
8	0,10	0,10	0,11	0,11	0,11	0,10	0,10	0,12	0,12	0,14	0,15	0,15
9	0,11	0,11	0,11	0,11	0,11	0,11	0,10	0,11	0,13	0,14	0,14	0,15
10	0,12	0,12	0,10	0,11	0,12	0,12	0,12	0,11	0,13	0,13	0,14	0,14
11	0,11	0,11	0,12	0,11	0,11	0,11	0,12	0,12	0,12	0,12	0,12	0,12
12	0,10	0,11	0,10	0,10	0,11	0,11	0,11	0,10	0,10	0,10	0,10	0,10

Month [-]	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
1	0,13	0,13	0,12	0,12	0,11	0,11	0,11	0,11	0,10	0,11	0,10	0,11
2	0,15	0,15	0,15	0,14	0,14	0,13	0,14	0,15	0,14	0,14	0,13	0,14
3	0,16	0,15	0,15	0,14	0,14	0,13	0,12	0,12	0,12	0,13	0,12	0,13
4	0,16	0,16	0,16	0,15	0,14	0,13	0,11	0,10	0,11	0,10	0,10	0,10
5	0,16	0,15	0,15	0,15	0,15	0,14	0,13	0,12	0,12	0,11	0,12	0,12
6	0,15	0,15	0,15	0,15	0,15	0,14	0,14	0,14	0,13	0,12	0,11	0,12
7	0,16	0,16	0,16	0,15	0,14	0,14	0,14	0,13	0,11	0,11	0,11	0,10
8	0,15	0,15	0,15	0,15	0,14	0,13	0,13	0,11	0,09	0,10	0,10	0,10
9	0,15	0,15	0,14	0,14	0,13	0,13	0,11	0,10	0,10	0,10	0,12	0,11
10	0,14	0,13	0,13	0,13	0,12	0,11	0,12	0,12	0,12	0,12	0,12	0,11
11	0,12	0,12	0,13	0,14	0,14	0,13	0,13	0,12	0,13	0,12	0,11	0,11
12	0,10	0,11	0,12	0,13	0,13	0,13	0,12	0,13	0,10	0,10	0,11	0,11

Time [h]

Figure 4: Heatmap of turbulence intensity in Lichtenegg for the year 2020, at measurement height 19m

Comparison with IEC 61400-1

- Standard deviation as 90 % quantile of wind speed

- Steeper increase of standard deviation

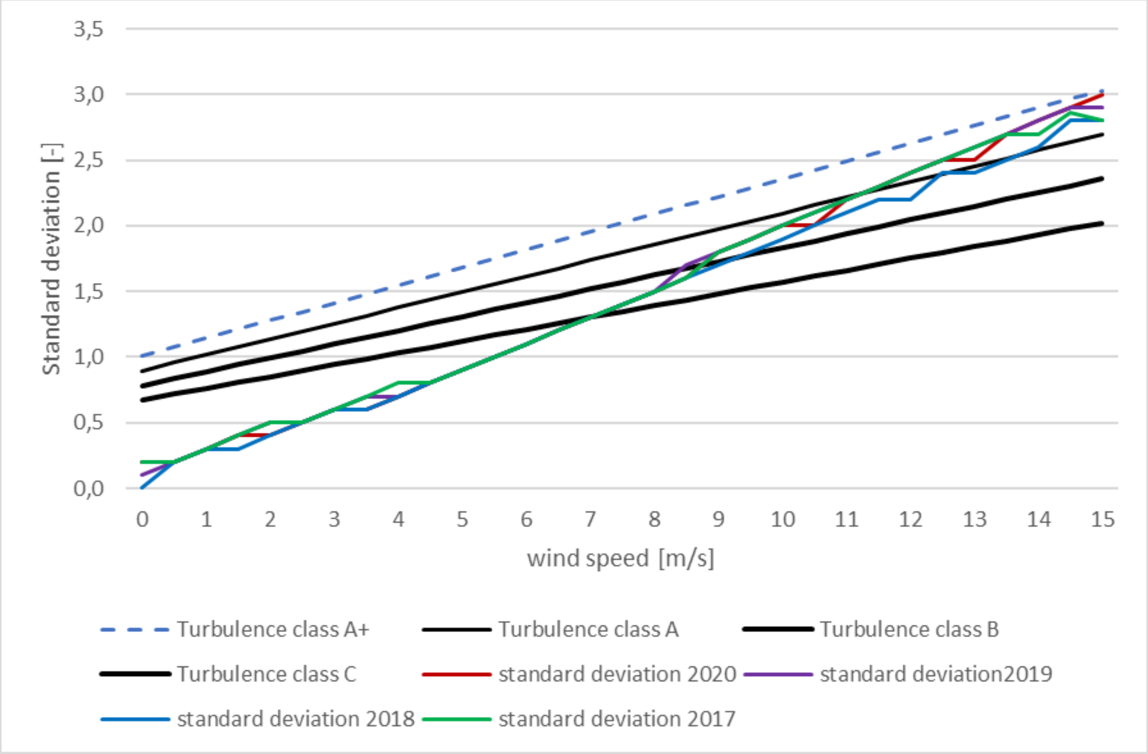

Figure 5: Standard deviation in Lichtenegg for the years 2017 - 2020.

Comparison with IEC 61400-1

- Mean turbulence intensity Lichtenegg:
  - 2020: 14 %
  - 2019: 14 %
  - 2018: 13 %
  - 2017: 14 %
- Reference value of turbulence intensity in the NTM:
  - Category A+: 18 %
  - Category A: 16 %
  - Category B: 14 %
  - Category C: 12 %

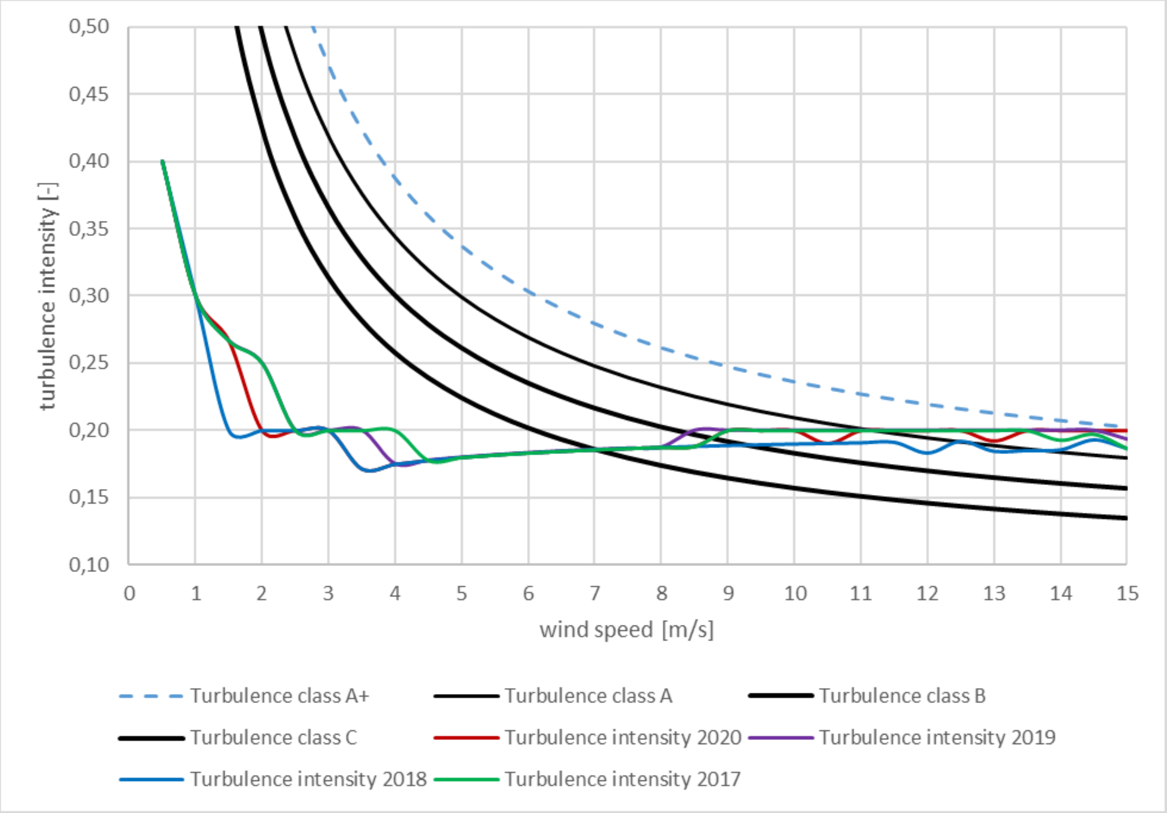

Figure 6: Turbulence intensity in Lichtenegg for the years 2017 - 2020.

Interpretation and comparison of the results

- Stability of the atmosphere has a great influence on turbulence
  - day-night, summer-winter periods as well as heat periods

- Lichtenegg is not an isolated case where the NTM does not work
  - La Ventosa, Mexico (H
  - Coastal Region of Benin
  - Port Kenedy

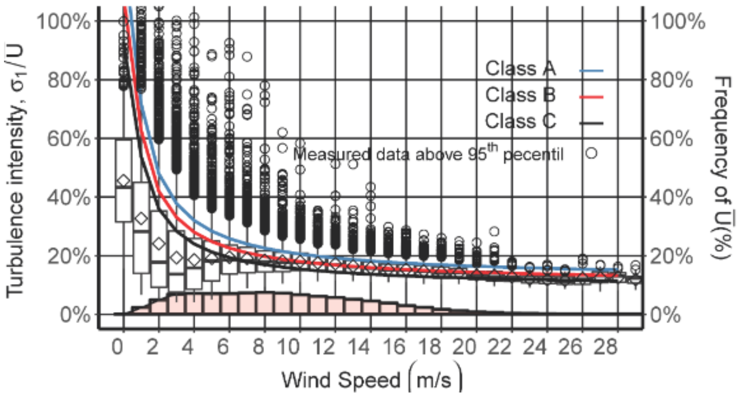

Figure 7: La Ventosa: Comparison to the IEC61400-1 (Lopez et al. 2018)

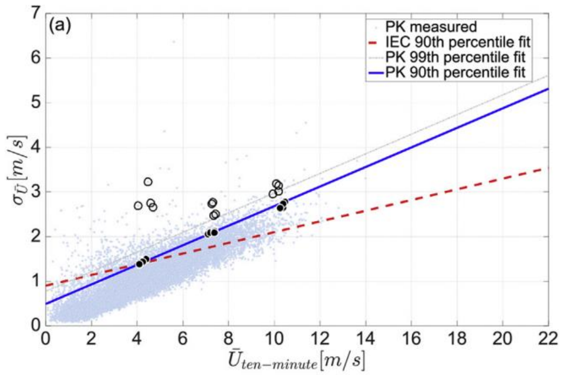

Figure 8: Port Kenedy Comparison to the IEC 61400 (Kc et al. 2020)

Effects on the planning and operation

- Turbulences
  - Important planning factor
  - Dependent on the stability of the atmosphere
  - Dependent on the time of the year and day

- Rotor blades are most affected
  - Highest vibrations in the rotor blade root
  - Expected lifetime is reduced by months and year

- Solutions
  - More flexibility of the rotor blades
  - More stability of the rotor blade root

Conclusiones

- IEC 61400-1
  - NTM does not adequately describe the turbulence in Lichtenegg
  - Not applicable for low altitude sites (installation height<20 m)

- Potential use of different models
  - Function of roughness
  - Wind shear coefficient

- Significance for the industry
  - Need for an accurate turbulence model
  - Detailed site analysis (regional and local)
  - Sufficient measurement data
  - Focus on rotor blade stability and flexibility

Thank you for your attention!

FH University of Applied Sciences TECHNIKUM WIEN

Bibliography

- Gasch, R., Bade, P. hrsg., 2005, Windkraftanlagen: Grundlagen, Entwurf, Planung und Betrieb. 4., vollst. überarb. und erw. Aufl. Wiesbaden, Teubner
- Hau, E., 2016, Windkraftanlagen: Grundlagen, Technik, Einsatz, Wirtschaftlichkeit. 6. Auflage. Berlin, Springer Vieweg
- Kelley, N., Jonkman, B., 2008, The Stable Atmospheric Boundary Layer: A Challenge for Wind Turbine Operations. AGU Fall Meeting Abstracts
- Leonhartsberger, K., Hirschl, A., Schidler, S., Priglinger, B., Peppoloni, M., Österreicher, D., Baumann-Stanzer, K., Stenzel, S., Lotteraner, C., Duer, T., Leeb, K., Strohkendl, K., Tiefgraber, C., Stökl, A., Lachinger, F., 2019, SmallWindPower@home. Wien, Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie
- Leonhartsberger, K., Peppoloni, M., Hirschl, A., 2018, Kleinwindkraftreport Österreich 2018. Wien, Technikum Wien GmbH, Institut für Erneuerbare Energie
- Lopez, C., Rodríguez, O., Campos-Amezcua, R., Cruz, G., Jaramillo, O.A., Mendoza, J., 2018, Wind Turbulence Intensity at La Ventosa, Mexico: A Comparative Study with the IEC61400 Standards. Energies, Band 11, Nummer; 3007
- OVE, Ö.V. für E. hrsg., 2020, OVE EN IEC 61400-1.; https://lesesaal.austrian-standards.at/action/de/private/details/667596/OVE_EN_IEC_61400-1_2020_01_01; 2.3.2022
- WWEA, W.W.E.A., 2022, Knowledge Base – WWEA Small Wind Platform.; https://smallwind.wwindea.org/knowledge-base/; 15.3.2022
- ZAMG, 2020, https://www.zamg.ac.at/cms/de/klima/news/zweitwaermster-februar-der-messgeschichte