Probability of lightning strikes to wind turbines in Europe during winter months

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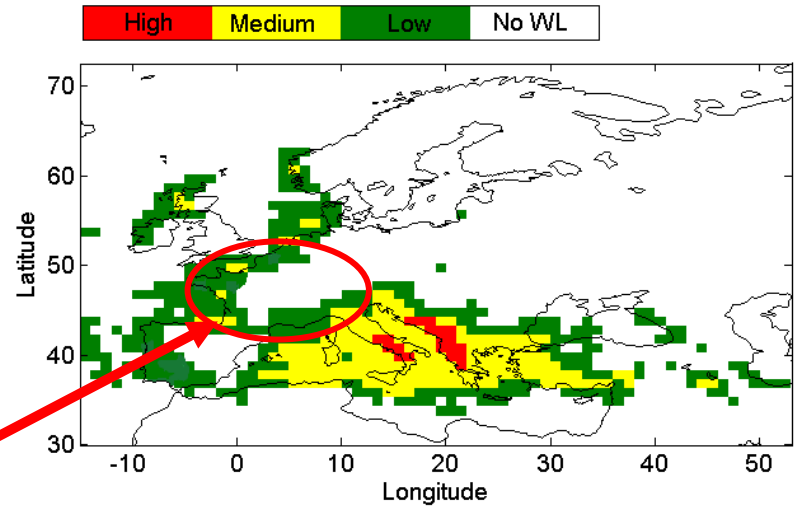
IEC 61400-24 IEC: 2019 Wind energy generation systems - Part 24: Lightning protection

For wind turbines placed in certain geographical areas where they are exposed to high numbers of upward lightning particularly during winter it may be relevant to increase the required durability of air termination systems (e.g. receptors) with regard to flash charge to more than lightning protection level I, Q_{flash} = 300 C, as this parameter decides the wear (melting) of materials and therefore influences the need for maintenance of air termination systems, spark gaps etc. (ie components subject to erosion due to arcing). In locations exposed to winter lightning charge levels may reach Q_{flash} = 600 C due to upward winter lightning. In addition the exposure and thereby the number of incidents between maintenance needs to be considered (see Section 7 and Annex B for further information. Table D.2 provides test current parameters for winter lightning).

Table B.2 - Range of upward lightning activity as a function of winter lightning activity for wind farm located in flat terrain

Winter lightning activity level	Percentage of upward lightning
High activity	80 – 99%
Medium activity	40 - 90%
Low activity	20 - 50%
No activity	10 - 40%



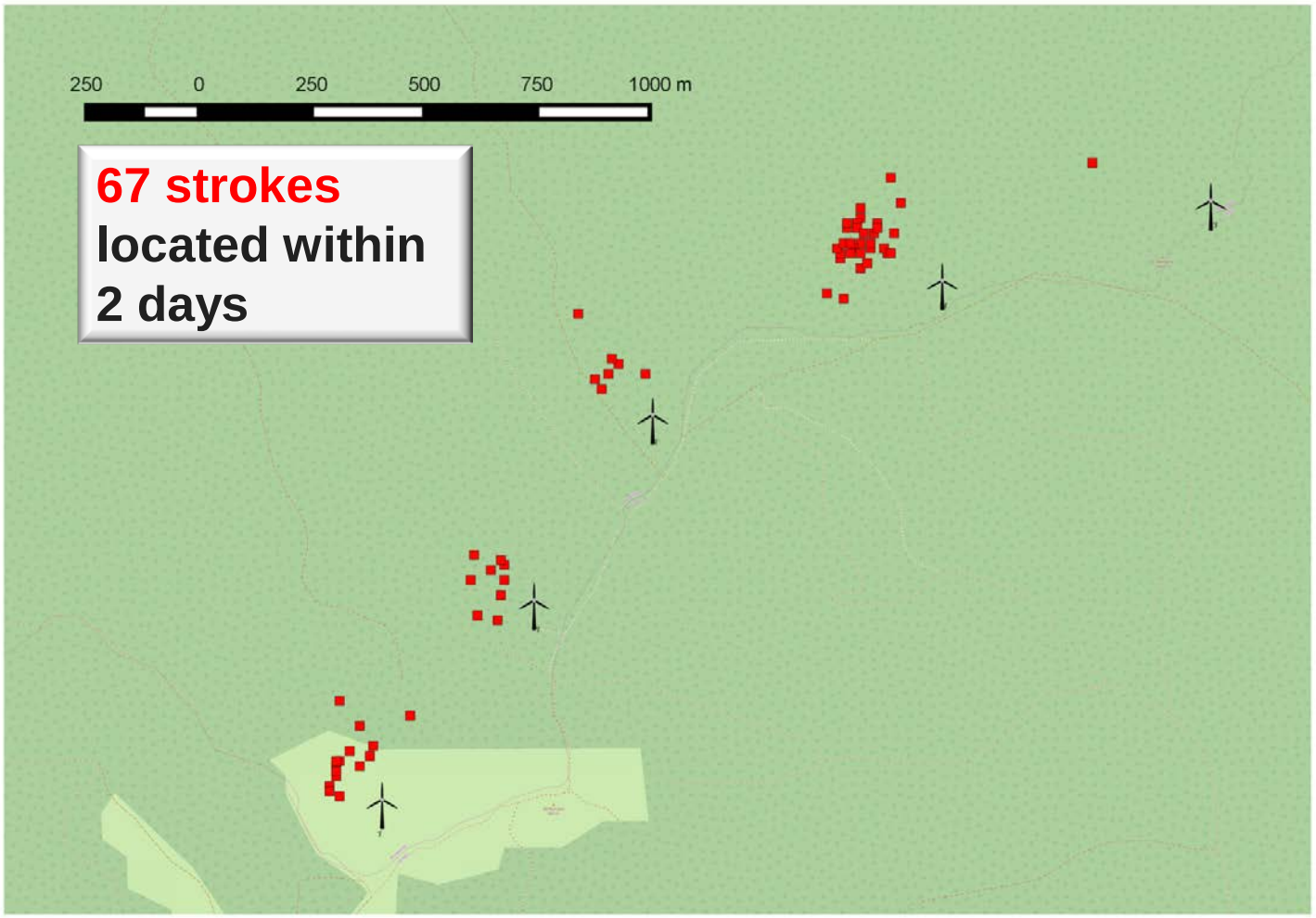
According to map in IEC 61400-24 mostly low activity of winter lightning is expected in Cental Europe

Upward lightning initiated by tall objects

- Objects of a heights >100 m on flat ground can trigger upward lightning
- Today's wind turbines have heights of up to 200 m and more and therefore trigger upward flashes, especially during the cold season (winter lightning)
- At Gaisberg Tower in Austria about 50% of the upward flashes are of the ICC_{Only} type and are not detected by lightning location systems [1] - we can assume a similar percentage for all upward lightning at similar latitude and meteorological conditions

[1] Diendorfer, Gerhard, Hannes Pichler, and Wolfgang Schulz. "LLS detection of upward initiated lightning flashes." Proc. 9th Asia-Pacific International Conference on Lightning (APL). 2015

ALDIS located strokes to WT during a winter storm on 1. 4. 2015 and 2.4.2015

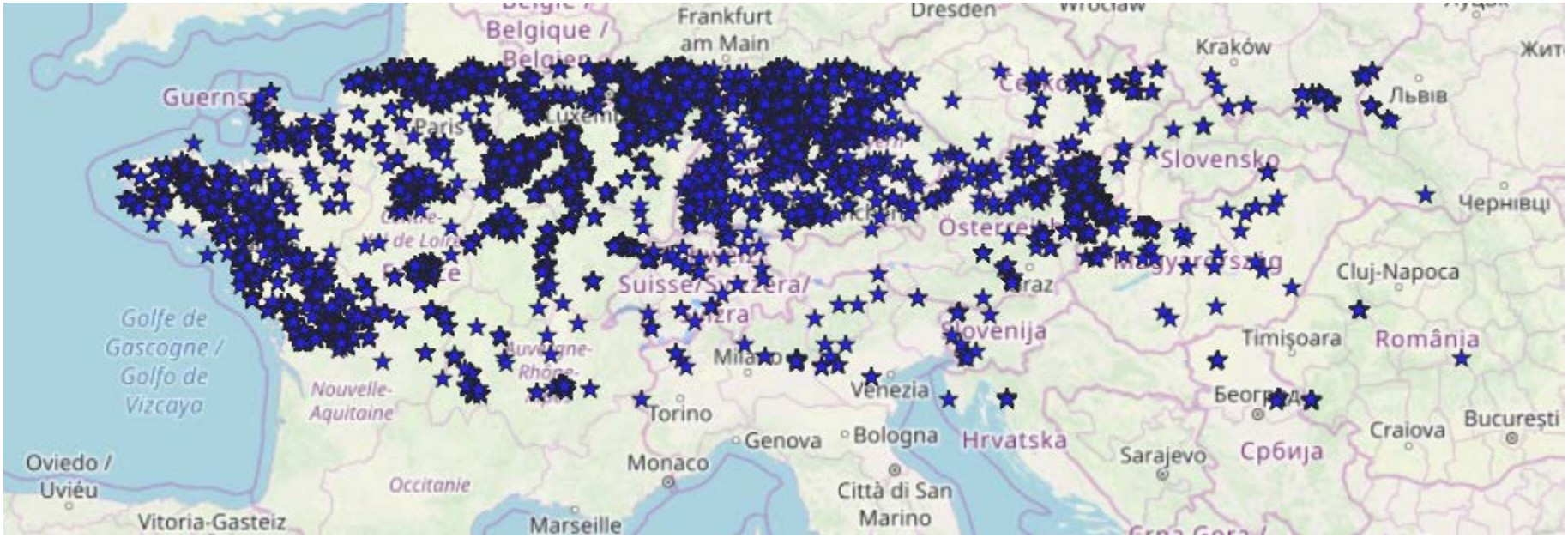


27.4.2016 Rotor blade damaged by lightning

LLS located pos. stroke with ~100 kA peak current

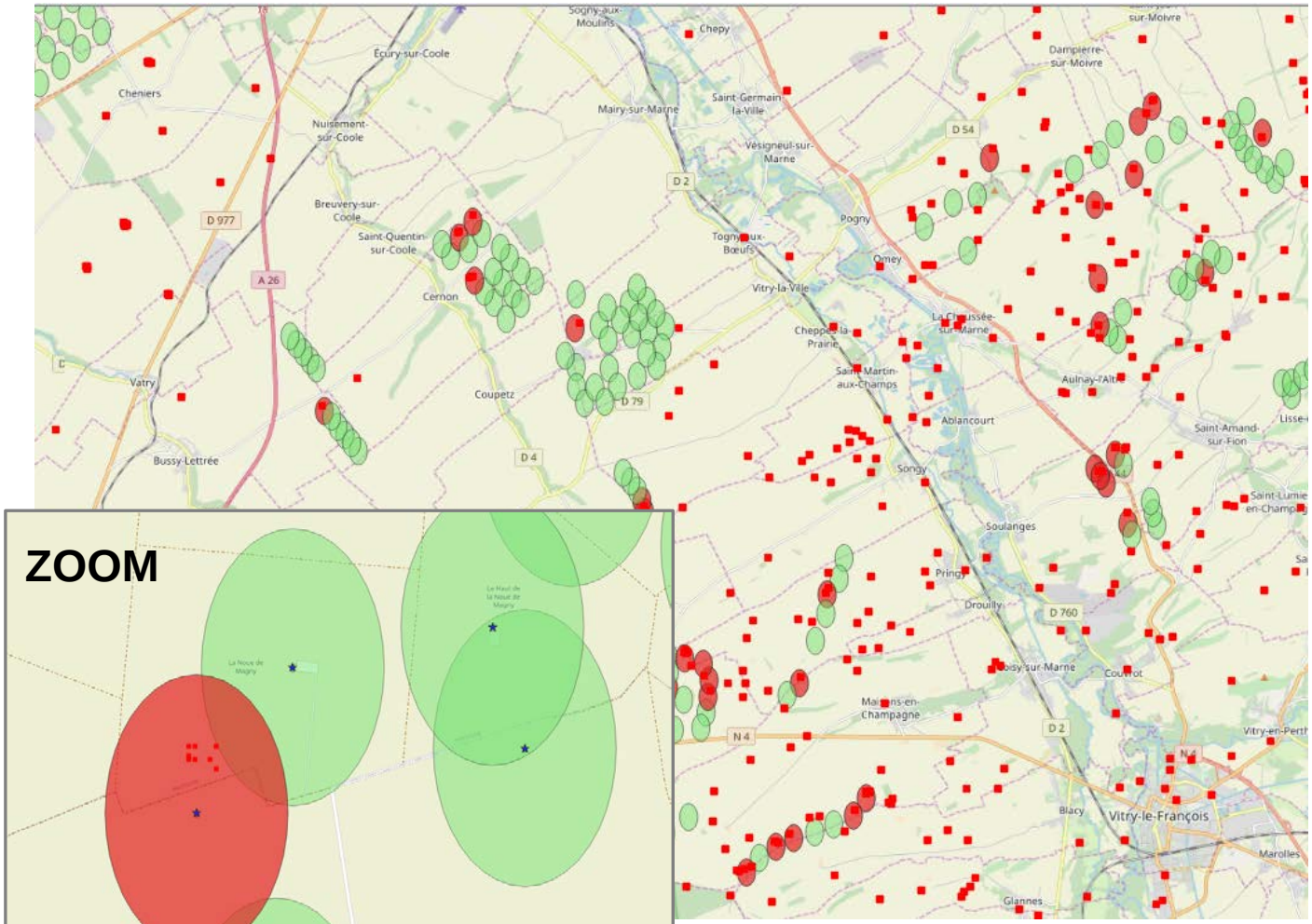
https://www.maz-online.de/Lokales/Brandenburg-Havel/rieisge-truemmer-nach-absturz-von-rotorblatt-in-windpark-bei-lehnin

45°N - 50°N – about 10.000 WT are installed



★ **Wind turbine locations (WT) taken from Open street map (OSM)**

0.003° area (~300 m) around each WT and located strokes in winter months (10-2017 till 04-2018)



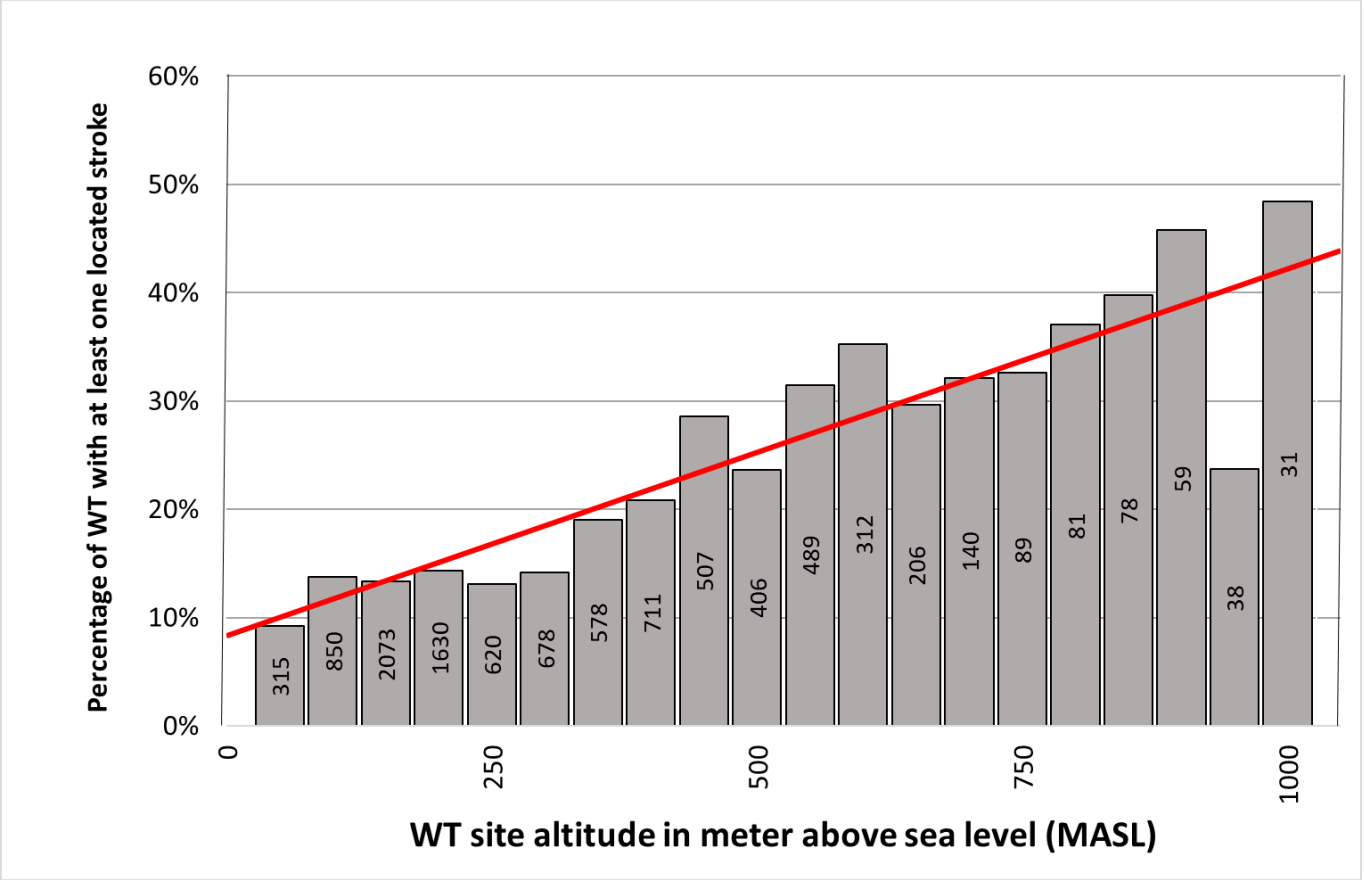
300 m radius around WT

One or more strokes are located within 300 m radius around this WT

Results for winter 2017/18 and 2018/19

Total number of WTs	10.225		
		Percentage	Max. number of strokes to a single WT
WTs with stroke in winter 2017/2018	1.131	11,1 %	51
WTs with stroke in winter 2018/2019	913	8,9 %	33
WTs struck in both winters	101	1,0 %	56

Effect of WT site altitude (ASL)



Clear trend of increasing probability of upward lightning to WT with increasing altitude of installation site above sea level

Summary

- In the considered area of 45°- 50°N, at least one stroke was detected in the immediate vicinity in about 10% of the WT during cold season (winter lightning). Does not correspond to map given in IEC 61400-24.
- Fast majority of these strokes was most likely caused by upward flashes triggered by the tall WTs.
- ICC_{Only} type flashes (approx. 50% of all upward flashes) are not detected by LLS and it can therefore be assumed that actually the percentage of the WT that experienced a flash every cold season is even more in the range 10% - 20%.
- There is an increasing chance of triggered flashes from WT with increasing WT installation site altitude