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Actual and design wind loads for overhead transmission lines in the Central European part of Russia

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Abstract. This paper reveals an impact of the climatic loads on the sustainable operation of power grid facilities. An overview is provided considering various international standards related to the design of overhead transmission lines. The aim of the research was to analyze and compare the actual and design values of wind loads for transmission lines located in the Central European part of Russia and operated by the power grid company "Rosseti Center and Volga Region". An analysis of wind load dynamics has been carried out considering the territory of 9 subjects of Russia and 1983-2022 timeframe. The actual climate data were computed according to the direct measurements of the weather stations. Nomograms of the maximum annual wind speeds are formed utilizing the first limiting Gumbel distribution for two climatic regions of the research area. The retrospective wind loads values were compared against the design values. The results of the study show that climate standards should be updated more frequently as it is the case nowadays, in particular, it relates to revision of existing wind loads or recalculation of wind speed correction factors for the near future.

1. Introduction

Impacts of the climatic factors and their changes on the reliability, stability and operability of electric power systems are studied for various countries: Europe [1, 2], the USA [3, 4], China [5, 6], Russia [7, 8, 9]. The high relevance of this topic is linked to increased requirements towards energy security, including challenges linked with decentralization of infrastructure facilities. Reliability of electricity supply in Russia is likely to be even more vulnerable as compared to other parts of the world due to a sufficiently large area of the country. In terms of the real situation, following the results of the autumn-winter period 2021-2022, a national power grid operator in Russia – Public joint-stock company (PJSC) "Rosseti", has reported a sharp increase in the number of dangerous weather events, observed on the territory the company was operating – by 30% compared to 2020-2021, and there were environmental factors that caused most of the outages. According to the annual reports of PJSC "Rosseti" subsidiaries for 2019-2021, more than 50% of accidents in the power grid occur on overhead transmission lines (next – OTL), meaning these objects are the most vulnerable compared to the rest, and the main causes of damage include the wire clashing and the trees fall due to wind gusts.

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It is generally assumed that the reliability of power grid facilities depends, among other things, on the climatic load values assumed at the time of design. In the framework of a comparative analysis of international [10], European [11, 12], Canadian and US [13, 14] standards for the design of OTL have established that the main parameter to be taken into account in all regulatory documents is the factor of wind loads, and only then icy impacts, and extreme temperatures. Also, reference documents used for design are mainly based on a deterministic approach [15], in which it is necessary to periodically revise the boundary (maximum) values for various types of external climatic loads.

In Russia, there are also methodological approaches that take into account the degree of climatic factors influences when making design calculations of OTL and its elements, which is reflected in regulatory documents [16, 17]. For example, as one of the main climatic factors affecting OTL and their elements, in accordance with PUE-7 [16], wind loads are allocated to such objects as: supports, wires and insulators. Also, in accordance with SP 20.13330 [17], the wind load is a combination of four components: the main load, peak values, resonant vortex excitation, aerodynamically unstable oscillations. However, for [17], it was found impossible to determine the averaging period on which actual standard values of wind loads were calculated and a low spatial resolution of visual assessment tools – climate zoning maps.

In general, all the international documents suggest utilizing almost identical approaches to determining initial data and wind loads. Necessary, we should be aware that there could be some issues due to climate non-stationarity linked with the climate change (namely in wind loads) what could impact on the reliability during designing the power grid infrastructure. The aim of the study is to fulfill a comparative assessment considering actual and design values of wind loads for OTL on the example of a branch of the largest power grid company in Russia PJSC "Rosseti".

2. Methods and materials

As the research area was chosen the territory of the power grid complex of PJSC "Rosseti Center and Volga Region", located in the central European part of Russia and covering the following areas: Kaluga, Tula, Ryazan, Vladimir, Ivanovo, Nizhny Novgorod, Kirov regions, as well as the Republic of Mari El and Udmurtia. Map and a brief description of the research area are shown in Figure 1.

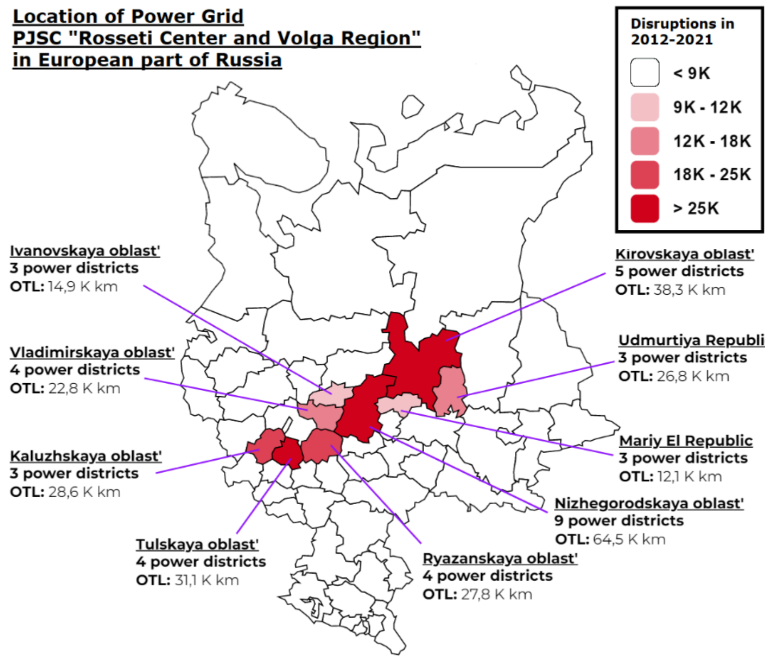

Figure 1. Spatial distribution of power supply disruption on the considered territory. Calculated by the authors according to official reports of PJSC "Rosseti Center and Volga region" power grid.

In accordance with the Russian technical regulations [16, 17], the basis for zoning by wind pressure is the values of maximum wind speeds with a 10-minute interval of averaging speeds at a height of 10 m with repeatability of 1 every 25 years. Accordingly, such a repeatability of the maximum annual values of wind loads is equivalent to the probability of not exceeding 0.96. We have calculated this value using two approaches. The first one has relayed on the climatic zoning maps values while the second one used statistical information on maximum annual wind speeds based on observations data.

To assess the dynamics of wind load variability on the considered area, the values of wind speeds were calculated based on statistical data published by Russian Research Institute of Hydrometeorological Information–World Data Centre with a 3-hour measurement interval for the period from 1983 to 2022 for more than 60 weather stations. To estimate the probabilities of not exceeding the design wind loads, an analysis was carried out which based on empirical integral probability distribution functions and their approximation using the first Gumbel limit distribution. We calculated the highest values of maximum wind speeds averaged over a 10-minute time interval for each year of the analyzed statistical series. The obtained values were ranked in ascending order, and the accumulated probability was estimated for each year included in the time range, according to the equation (1):

$$F'(V) = \frac{m}{n+1} \tag{1}$$

where m – the ordinal number of the ranked series member; n – the number of row members.

The values of mathematical expectation $\bar{V}$ and standard deviation σ were calculated for each statistical series. At the second stage, the limiting Gumbel distribution was used to approximate the accumulated probabilities of maximum values of wind speeds per year using the equation (2):

$$F(V) = e^{-e^{-\alpha\cdot(V-\beta)}} \tag{2}$$

where $F(V)$ – probability of not exceeding the maximum wind speed; $\alpha = \frac{\sigma_n}{\sigma}$, $\beta = \bar{V} - \frac{\overline{y_n}}{\alpha}$ – the distribution parameters; $\sigma_n = \sigma_{10} = 0.9497$ and $\overline{y_n} = \overline{y_{10}} = 0.4952$ – auxiliary (design) values.

For each climatic region, retrospective values were calculated considering the maximum wind speed with different levels of non-excess $F(V_i) = \{0.96, 0.98\}$, which correspond to the periods of phenomena repeatability, respectively, 1 time in 25 and 50 years, according to the equation (3):

$$V_i = \bar{V} - \frac{\overline{y_n} + \ln(-\ln(F(V_i))}{\alpha} \tag{3}$$

The results of our computations were further presented as nomograms with various levels of phenomena repeatability based on the statistical processing results considering time-series of the maximum annual wind speeds distribution function.

3. Results and discussion

The analysis was carried out considering changes in wind load to assess an impact on OTL across the considered areas in accordance with the best international and Russian practices over the past 40 years to determine the trend direction within various ranges of wind speeds. Based on the available data from more than 60 weather stations located in the research area, 4-time intervals with a ten-year shift were formed (1983-1992; 1993-2002; 2003-2012; 2013-2022), to estimate a change in the maximum wind speed during each decade as compared with a previous time interval. That has allowed to establish changes of patterns in wind load. Table 1 contains the results on distribution of the average annual values of maximum ($\overline{V_{MAX.10}}$) wind speeds according to 3-hour observations for the considered regions.

The obtained results indicate that there is the heteroscedasticity of wind speed values has been found for both the considered climatic regions using the wind pressure values for each subsequent time interval. Namely, an increase in the standard deviation has been found for annual maximum wind speeds which leads to an imbalance both low and high wind speeds, and this process increases over time.

The nomograms in the Fig. 2 demonstrate approximation of the maximum annual wind speeds according to the function of Gumbel distribution by equation (3) for the considered two climatic regions. The calculation results indicate that there has been a decrease in maximum wind speeds for any levels of repeatability for climatic region No. I, in terms of wind loads, since 1983, within each subsequent time interval. In the case of region No. II, the reverse situation is found, namely, there is an increase in annual maximum wind speeds for each subsequent time interval, and this is especially noticeable for the phenomena repeatability 1 time in 25 and 50 years. These conclusions are consistent with the distribution of previously obtained in this work values of maximum wind speeds for 3-hour observations, and also confirm one of the main conclusions of our studies [7, 8] about an increase in the range (imbalance) of wind speeds for territories with high wind pressure.

Table 1. Annual values of maximum wind speeds according to 3-hours observations on the study area $\overline{V_{MAX.10}}$, m/s

Climate district	Russian subject (part of PJSC “Rosseti Center and Volga region”	Period			
		1983-1992	1993-2002	2003-2012	2013-2022
I	Kaluga, Tula, Ryazan, Vladimir and Ivanovo regions, Republic of Udmurtia	24.4±1.9	23.0±2.0	24.2±1.8	23,3±1.8
II	Nizhny Novgorod and Kirov regions, Republic of Mariy El	25.2±1.9	24.7±2.1	25.4±2.4	25.3±2.6

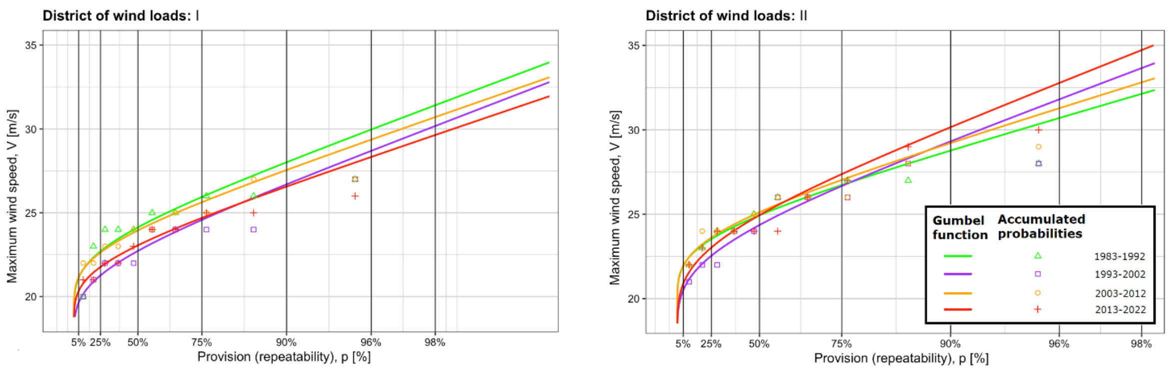

Figure 2. Graphs of Gumbel distribution functions of maximum wind speeds for I and II climatic districts of considered regions by wind loads.

Table 2 shows the results of a comparative assessment regarding retrospective values of wind loads for OTL for PJSC “Rosseti Center and the Volga region”, in accordance with the retrospective data defined as weather stations observations and design values calculated according to the maps of climatic zoning [16] for a probability of not exceeding 96% (repeatability 1 once in 25 years). It was found that even initially calculated values of maximum wind speeds did not correspond [17]. For the current realities (2013-2022), in turn, for both climatic region No. I and region No. II, the annual maximum wind speeds are 13% higher than the corresponding design values.

Table 2. Retrospective and design values of the maximum wind speed with a various probability of not exceeding (provision) $\overline{V_{MAX.10}}$, m/s

Provision (repeatability)			96% (1 time in 25 years)				98% (1 time in 50 years)			
Period			1983-1992	1993-2002	2003-2012	2013-2022	1983-1992	1993-2002	2003-2012	2013-2022
District	I	Retrospective	29.9	28.7	29.4	28.3	31.4	30.2	30.7	29.6
		Design	25				–			
	II	Retrospective	30.7	31.8	31.3	32.8	32.1	33.6	32.8	34.7
		Design	29				–			

4. Conclusion
Quantitative assessment considering the main causes of technological disruptions at power grid facilities has revealed multifaceted and nonlinear connections in the structure of empirical data related to disruptions and the observed weather conditions. A number of shortcomings has been identified in the technical documents regulating the requirements for the OTL structural reliability that in the medium term may affect the reliability of projected and reconstructed power facilities.

In conformity with results demonstrating the increase of annual maximum wind speeds with each subsequent decade for areas with a higher wind load, it is necessary to take into account that during the next decades, the actual wind exposure may exceed design standards and pose a danger to new power grid facilities.

Thus, it may be recommended to update climate standards more often compared to how it is currently happening, to revise existing wind loads or recalculate correction factors for the wind speed based on retrospective data to account for the climate non-stationarity in a more accurate and timely way.

5. References
[1] Goncalves A, Marques M C, Loureiro S, Nieto R and Liberato M 2023 Disruption risk analysis of the overhead power lines in Portugal *Energy* **263** 125583
[2] Panteli M and Mancarella P 2015 Influence of extreme weather and climate change on the resilience of power systems: Impacts and possible mitigation strategies *Elec. Pow. Syst. Res* **127** pp 259–270
[3] Watson P, Spaulding A, Koukoula M and Anagnostou E 2022 Improved quantitative prediction of power outages caused by extreme weather events *Weat. & Clim. Extr.* **37** 100487
[4] McMahan B and Gerlak A 2020 Climate risk assessment and cascading impacts: Risks and opportunities for an electrical utility in the U.S. Southwest *Clim. Risk Manag.* **29** 100240
[5] Wang J, Li H N, Fu X, Dong Z Q and Sun Z G 2022 Wind fragility assessment and sensitivity analysis for a transmission tower-line system *J. Wind Eng. & Ind. Aerodyn.* **231** pp 1–10
[6] Fu X, Li H N, Li G, Dong Z Q and M Zhao 2021 Failure analysis of a transmission line considering the joint probability distribution of wind speed and rain intensity *Eng. Struct.* **233** pp 1–13
[7] Loktionov O A, Kondrateva O E and Fedotova E V 2022 Analysis of prerequisites for changing wind load standards for electric grid facilities *4th Int. Youth Conf. on Radio Electron., Elect. & Power Eng.* (Moscow, Russian Federation) pp 1–5
[8] Klimenko V V, Kondratyeva O E, Tereshin A G, Fedotova E V, Loktionov O A and Voronkova E M 2021 Wind regime change over the Russian territory and the accident rate of overhead power lines *Dokl. Phys.* **66** pp 80–87
[9] Loktionov O A, Kondrateva O E, Fedotova E V and Borovkova A M 2019 Power lines vulnerability of Moscow region from climatic environment factors *1st Int. Youth Conf. on Radio Electron., Elect. & Power Eng.* (Moscow, Russian Federation) pp 1–4
[10] IEC 60826 2003 Design criteria for overhead transmission lines
[11] CIGRE No. B2-10974 2022 Design of overhead lines in a changing climate
[12] EN 50341 2012 Overhead electrical lines exceeding AC 1 kV - Part 1: General requirements
[13] CAN/CSA-C22.3 No. 608626-06 2019 Design criteria of overhead transmission lines
[14] ANSI C2 / NESC 2012 National Code of Rules for the safety of electrical Installations
[15] Cradden L C and Harrison G P 2013 Adapting overhead lines to climate change: Are dynamic ratings the answer? *Energy Policy* **63** pp 197–206
[16] PUE7-7 2003 Rules for the installation of electrical installations (in Russian)
[17] SP 20.13330 2016 Loads and actions (in Russian)

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