Correlation Analysis of Wind Speeds for the Wind Safety Assessment in Off-site Power System

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1. Introduction

According to the "Korea Climate Change Assessment Report 2020," the intensity of typhoons affecting Korea is increasing due to climate change [1]. Typhoons generate strong winds and heavy rain, which can damage the off-site power system of nuclear power plants (NPPs) [2]. The off-site power system consists of the substation, tower, power plant etc. and is distributed across a wide area. When performing a wind safety assessment of a network, a reasonable risk can be derived by considering the correlation coefficient. Therefore, the correlation between maximum wind speed and the transmission tower's response to the distance was derived in this study.

2. Methods and Results

2.1 Method for Deriving Correlation of Wind Speed

Wind speed data was used from the Automatic Weather Station (AWS) data measured from 1991 to 2022 at 30 AWS measurement points provided by Korea Meteorological Administration. The 30 AWS measurement points are shown in Fig. 1. The maximum wind speed data measured at each measurement point during the duration of the typhoon (D± 3days) was used. Using the maximum wind speed data, two measurement points were selected according to the distance from all measurement points, and the correlation was analyzed. A total of 435 correlation coefficients were analyzed, and the correlation coefficient was derived according to the distance of the AWS measurement point.

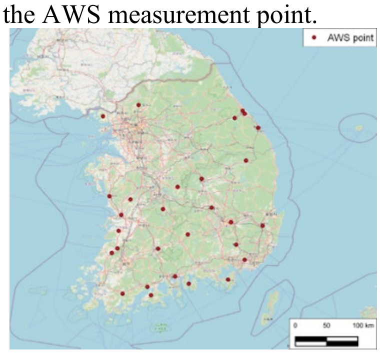

Fig. 1. Location of the measured AWS points

2.2 Method for Deriving Response Correlation of Transmission Tower

A 154 kV model was used for the transmission tower to derive the response to wind. The transmission tower was assumed to be located at AWS branch locations. The roughness and topographic factors were set to 1.0, and the roughness category was set to B. Wind direction and speed are required to perform wind analysis of transmission towers, and the wind load code was used ASCE 7-16 [3]. The wind direction was set at 30° intervals between 0 and 90°. The maximum wind speed data measured at each measurement point during the typhoon (D±3 days) was used for wind speed. The wind analysis of the transmission tower was analyzed with SAP2000. The response of the transmission tower derived the x, y, and z axis from four points, and the points derived from the response are shown in Fig. 2. For the response of the transmission tower, SRSS was applied to all (x, y, and z axis) responses of each point, and the average of the SRSS of all points was used. In addition, the maximum response among the average responses of angles for each wind speed was used. Using the maximum response of the transmission tower, two points were selected according to the distance from all points, and the correlation was analyzed. Afterward, the correlation coefficient was derived according to the distance of the transmission tower.

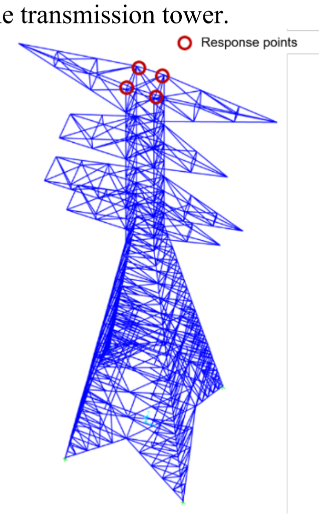

Fig. 2. Transmission tower response derivation points

2.3 Equation and Result for Deriving Correlation Coefficient According to Distance

Each correlation coefficient according to distance was curve-fitted to equations 1-2, equation 1 is a linear function and equation 2 is an incoherence function used in SSI analysis. Where R is the distance and a-g are the fitted parameter.

$$(1)\quad Corr.\ Coef. = a \cdot R + 1$$

$$(2)\quad Corr.\ Coef. = \left[1 + \left(\frac{R \cdot Tanh(d \cdot e)}{a \cdot b}\right)^{f}\right]^{-\frac{1}{2}} \cdot \left[1 + \left(\frac{R \cdot Tanh(d \cdot e)}{a \cdot c}\right)^{g}\right]^{-1/2}$$

Each correlation coefficient according to distance and the curve-fitted correlation coefficient are shown in Fig. 3-4. The correlation coefficient according to the distance of the maximum wind speed and the response to the wind of the transmission tower were similarly derived. In addition, the Root Mean Square Error (RMSE) between the fitted parameters and the correlation coefficient is shown in table 1.

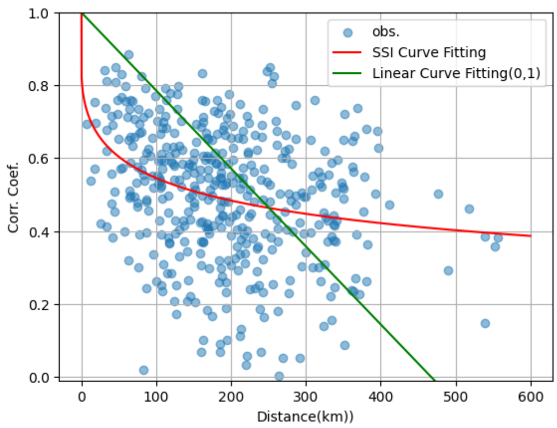

Fig. 3. Correlation of maximum wind speed according to distance

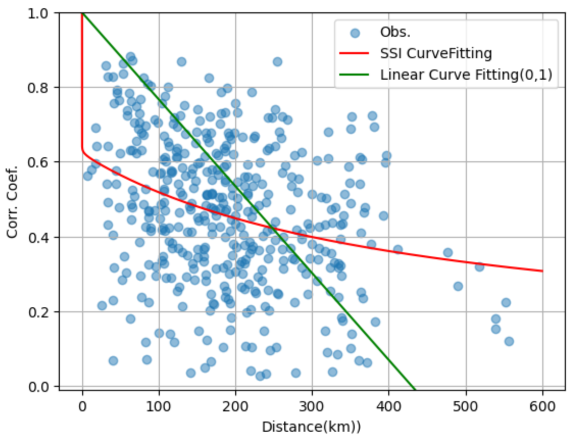

Fig. 4. Correlation of transmission tower response according to distance

Table I: Fitted parameter and RSME

Division	Wind speed Corr. Coef.		Response Corr. Coef.	
	Linear curve	Incoherence function	Linear curve	Incoherence function
a	-2.16e-3	1.70e+1	-2.33e-3	2.97e+0
b	-	2.67e-23	-	3.90e+0
c	-	7.18e+1	-	7.96e+0
d	-	7.29e-24	-	2.08e-1
e	-	1.00e+0	-	1.00e+0
f	-	5.59e-1	-	2.00.e-6
g	-	1.40e-2	-	7.60.e-1
RMSE	0.255	0.171	0.261	0.177

3. Conclusions

Recently, the frequency and intensity of typhoons have increased due to climate change, leading to direct and indirect impacts on off-site power systems in NPP. In this study, to analyze the correlation between the maximum wind speed according to the distance to evaluate the reasonable safety of the off-site power system due to strong winds. In addition, the correlation coefficient analysis of the response of the transmission tower to the wind according to the distance was performed. As a result of deriving the correlation coefficient according to the distance, the correlation coefficient of the maximum wind speed and the correlation coefficient of the transmission tower's response were similar. Therefore, it was concluded that the correlation coefficient based on the derived distance could be applied to conduct a reasonable wind safety assessment for off-site power systems.

4. Acknowledgement

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