Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2023

Wind tunnel tests of a transmission tower under combined yaw and tilt angles

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1. Introduction

Steel lattice transmission towers, which are used to carry electricity over long distances, can be damaged by natural disasters like typhoons. Previous typhoon incidents have shown that these towers are highly susceptible to damage. For example, during Hurricane Sandy in 2012 and Hurricane Irene in 2011, more than 200 transmission towers failed. Loss of off-site power may occur due to transmission tower collapse.

Electric transmission towers are crucial infrastructure that have been designed and constructed according to established design codes. However, failures of transmission towers during extreme wind events are still frequently reported. This is particularly true for towers located on mountain slopes, where the wind may not be horizontal but may have an angle of attack on the tower face, as shown in Figure 1. The tower must be able to withstand both the horizontal and vertical components of the wind load, as well as the added force from the angle of attack. Designers must take into account these factors when designing transmission towers in order to ensure their stability and safety in all conditions.

This study aims to investigate the aerodynamic forces acting on transmission tower subjected to combined yawed and tilted wind. The aerodynamic forces acting on the tower model are measured in the wind tunnel by varying the horizontal and vertical angles. The test results and discussions are summarized in the paper.

Fig. 1. Towers in mountain slope

2. Tests and Results

The tests were conducted in the KOCED Wind Tunnel Center at Jeonbuk(Chonbuk) National University, Korea. Test section of the closed-circuit wind tunnel is 5.0 m wide, 2.5 m high, and 20 m long, and the maximum speed of wind is 31 m/s. The turbulent intensity and flow uniformity are less than 0.6% and 1%, respectively. All tests were conducted in uniform flow.

A scaled model was constructed duplicating the details of a full-scale tower of 44.8m high shown in Fig. 2. Geometric scale of the model was 1:25 considering the test section size. The blockage ratio is less than 1% at all yaw and tilt angles. As shown in Figure 2, the test model and the 6-axis loadcell were seated on a supporting system capable of changing the tilt angle.

Fig. 2. Tilted model in the wind tunnel

As shown in Figure 3, within a tilt angle of 20 degrees, the decrease in longitudinal and transverse aerodynamic coefficients is insignificant within a tilt angle of ±20°. However, the aerodynamic coefficient may decrease by up to 7% at a tilt angle of ±30°. Concludingly, the effect of the tilt angle on longitudinal and transverse aerodynamic coefficients can be insignificant up to a tilt angle of ±20°, and the effect become greater when the tilt angle is more than ±20°.

The aerodynamic coefficients in gravitational direction, C_{Fz}, are shown in Figure 4. In the figure, the tilt angle is negative for yaw angle from -0° to -90°, and is positive for yaw angle from 0° to 90°. It is clear from the Figure 4(b) that C_{Fz} increases linearly with the tilt angle. The C_{Fz} at tilt angle of -30° has been increased by up to -1.1 from that at tilt angle of 0°. This is significant large load corresponding to about 39% of the maximum longitudinal aerodynamic force.

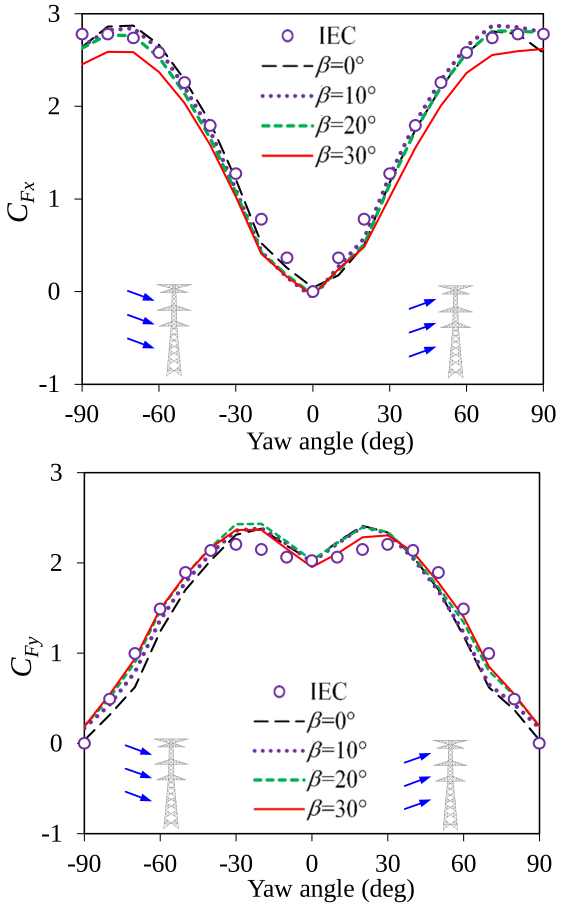
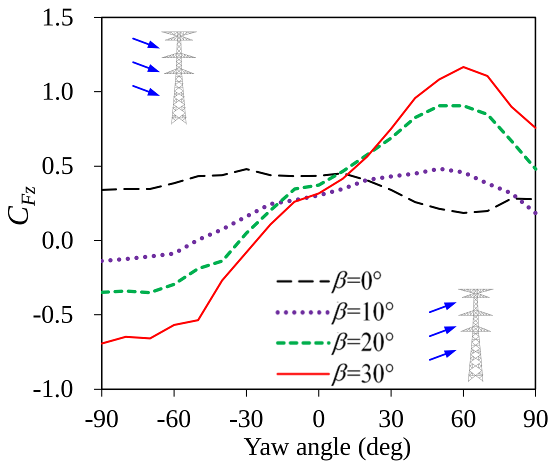
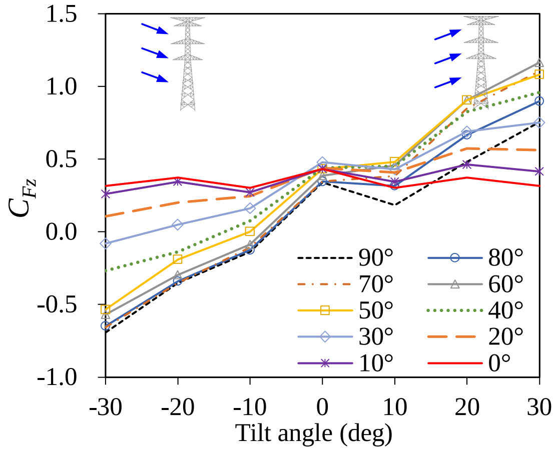


Fig. 3. Aerodynamic coefficients under different tilt angles and yaw angles.



(a) Tilt angle from 0° to 30°



(b) Yaw angle from 0° to 90°

Fig. 4. C_{Fz} under different tilt angles and yaw angles.

3. Conclusions

The wind tunnel test results suggest that the effect of the tilt angle on the longitudinal and transverse aerodynamic coefficients is not significant within the tilt angle range of ±20°. However, if the tilt angle exceeds this range, there may be a reduction of up to 7% in the coefficients. The lift aerodynamic coefficients in the direction of gravity have a linear relationship with the tilt angle, which means that they increase steadily as the tilt angle increases. At the tilt angle of ±30°, there is a significant increase in the lift aerodynamic coefficients, which corresponds to 39% of the maximum longitudinal aerodynamic force.

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ACKNOWLEDGEMENT

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 2022B10200040).