# A Numerical Analysis on the Capability of Withstanding Violent Typhoon of Distribution Feeders

Hui-hua Deng[1],Chun-yan Huang[2,*],Shao-hui Huang[3],Jian-hua Chen[1]and Feng-liu Liang[1]

1.Huizhou Power Supply Bureau, Guangdong Power Grid Co., Ltd, Huizhou 516001, China;

2. Guangzhou Power Electric Technology Co., Ltd, Guangzhou 510640, China;

3. Huizhou Electric Power Design Institute, Huizhou 516001, China

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**Abstract:** Distribution feeders are sometimes damaged heavily by typhoon every year in the coastal region. A finite element model of a standard feeder is established by ABAQUS/CAE firstly. Then the deformation under different wind speeds after the wind loading is applied by equivalent inertial acceleration. The paper focus on investigating the deflection of the pole of three kinds of feeders, which cover the effect of foundation soil, strengthened with guy wire and none of both.

## Introduction

As a place appearing typhoon frequently, the coastal area of China suffers to typhoon every year. The grid feeders, especially the overhead distribution lines are destroyed most heavily [1], because of its low wind standing design grade, circuit aging and maintenance shortage. The studies about power grid disaster resistance are mainly focus on the electric transmission feeders [2], few on the theoretical research of distribution lines. The grid companies have put huge resource into the reinforcement and reconstruction on the distribution feeders [3]. Since there are no exact theoretical analysis and numerical simulation, the reinforcing works depend on experience and gained less effect.

Finite element modeling is a numerical analysis method. It can be used to investigate the mechanics response of a whole system under all kinds of loading and has been applied in the static and dynamic analysis of transmission feeders. Liu established the finite element models of 220kV and 550kV overhead transmission lines to simulate the dynamic windage response [4]. The model neglected the pole’s deformation. Aimed at 550kV two-circuit transmission lines, Yan built a tower-line coupling finite element model to study the dynamic response of the system under different ice unloading condition [5]. Lou researched the dynamic windage response of 500kV strain section with eight spans by FEM and harmonic superposition method [6]. Shao discussed the vibration and oscillation of the wire caused by wind [7].

The detail investigation on the anti-wind capability, the inner force and deflection of the RC pole haven’t been reported. This paper presents a numerical analysis on the capability of withstanding violent typhoon of 10kV distribution feeders. A finite element model of a standard strain section is established by ABAQUS [8]. Then the deflection of the pole under different wind speed and three kinds of conditions are discussed.

## Model Building

### Finite Element Model

Base on a standard single circuit overhead line, a pole-wire coupling finite element model is built by ABAQUS/CAE. In the model, the pole, high tensile steel wire, pole arm and wire are divided into 5760 solid elements (C3D8R), 382 truss elements (T3D2), 200 beam elements (B32) and 1202 truss elements (T3D2), respectively. The constraint relationship between the insulator and the wire is coupling, and that between insulator and pole arm is fixation.

## Loading Simulation

The loading of a distribution line includes the gravities of wire, pole arm and RC pole, and the wind loading that the wire and pole subjected. The gravity should be applied to the model by gravitational acceleration, and the wind loading can be applied after be translated to equivalent gravitational acceleration.

## Size and Parameters

The RC pole discussed in this paper is a M Grade high strength pole, whose size is: height 12m, base diameter 350mm, top diameter 190mm, wall thickness 60mm, burial depth 2m. The concrete grade is C60. In the concrete, arranges 19 □9 high-tensile wire, with standard value of strength 1470MPa, tensile strength 1040MPa, compressive strength 410MPa, and elasticity modulus 205GPa. The wire's type is JL/GIA-150/20, diameter 16.67mm, cross sectional area 164.5mm2, equivalent density 3339.8kg/m3, integrated elastic coefficient 73GPa, intensity strength of conversion 283.5MPa. The span of the circuit is 60m. The cross arm uses Steel Q345, type ∠75×6. Diagonal bracing uses Steel Q235, type∠50×5, elasticity modulus 201GPa. The guy wire is steel strain GJ50, which is advised by South China Grid's Typical Design Guide.

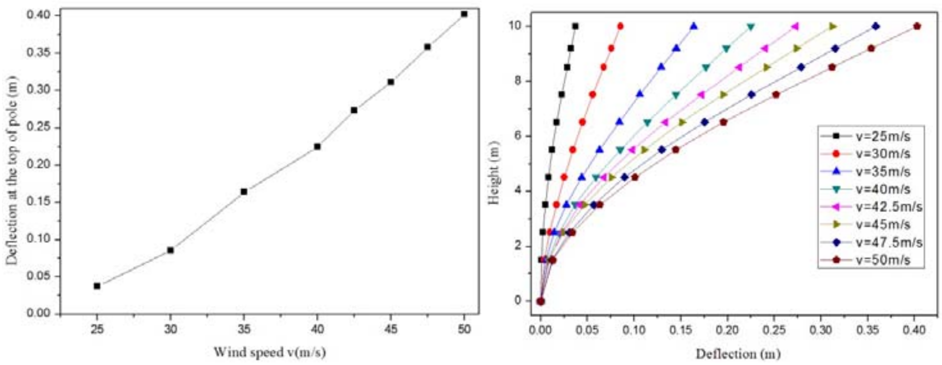
# Calculation Results

In the following study, the pole's deflection under different wind speed and three kinds of conditions are discussed. After just a little modification needed to be made to the model built in Section 1, a new model suited to the investigation can be obtained.

## Model 1

Model 1 is the simply model shown in Fig.1, which neglect the foundation soil and wind guy wire. The restrain condition at the section of ground is defined as fixed. Fig.1 shows the deflection of the pole under different wind speeds, which change from 25m/s to 50m/s.

It can be known from Fig.1(a) that the deflection of the pole's top linearly increase with wind speed. Fig.1(b) shows that when wind speed equal or greater than 35m/s, i.e., the typhoon level, the deformation enlarges rapidly.




(a) Deflection of the pole's top (b) Pole deflection curve

Figure 1. Deflection of Model 1

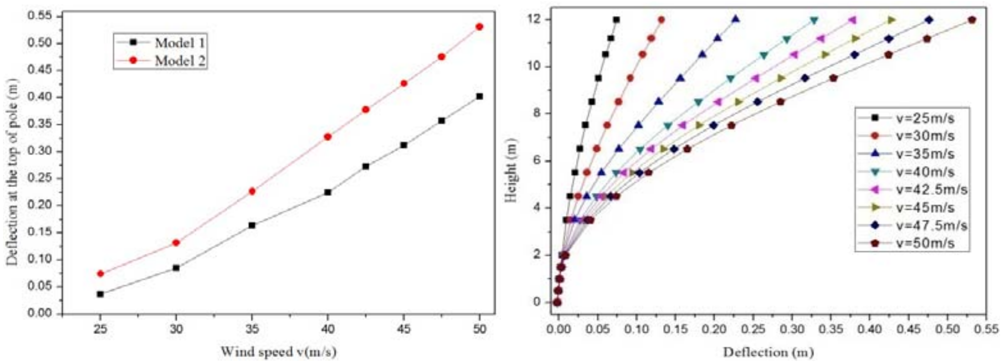
## Model 2

In Model 2, we consider the influence of the foundation soil in a 1m radius around the root of the pole. The constitutive relation employs Mohr-Coulomb model. Assuming the soil common clay, the soil is divided into 1440 solid elements (C3D8R). The specific parameters are given in Table 1.

Table 1. The soil parameters

| Soil property | Modulus of compression $E_S$/[MPa] | Poisson's ratio $\mu$ | Desity $P$/[kg·m$^{-3}$] | Cohesion $C$/[KPa] | Internal friction angle $B$/[°] | Dilatancy angle $\varphi$/[°] |
|---|---|---|---|---|---|---|
| Clay | 18 | 0.3 | 1880 | 107 | 35 | 17.5 |

The calculation results of the pole's deformation are shown in Fig.2. It can be concluded from Fig.2(a) that under the same wind speed the top deflection of Model 2 are greater than that of Model 1. The increment are about 6~13cm， since the deformation of the soil have superimposed effect on the pole. Comparing with Fig.1(b), the pole deflections in Fig. 2(b) are greater, and the zero point lies in 1.2m below the ground. If the common clay is replaced with soft plastic clay, the aggravate soil compression will leads the pole deformation to further increasing. So, the worse foundation soil means the greater chance for pole toppled than broken.

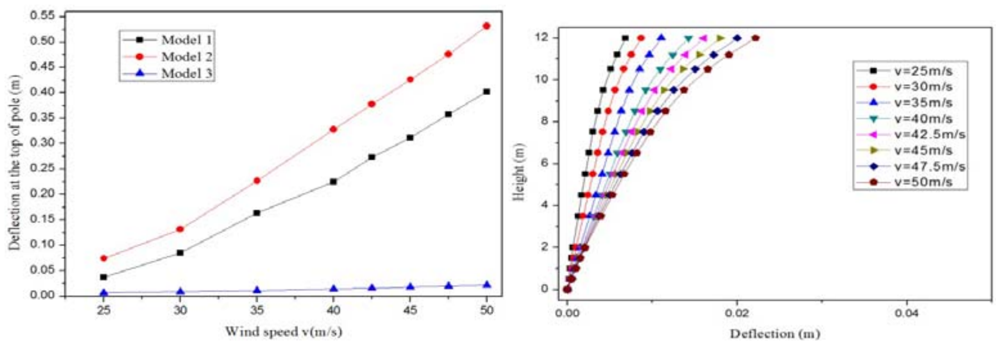



(a) Deflection of the end (b) Pole deflection curve

Figure 2. Deflection of Model 2

## Model 3

Model 3 is strengthened by guy wire. The guy wire, 30° angle to the pole, made of GJ50 steel strand, is installed at the hoop of the diagonal bracing of the cross arm. The calculation results are shown in Fig.3. It can be known from Fig.3(a) that the top deflections increase a little when the wind speed rise. Comparing to the curves in Model 1 and Model 2, the deflection of Model 3 is kept in a low level. Fig.3(b) indicates that the pole deflection curve has a turn at the section where the guy wire installed. Even at the violent typhoon speed of 50m/s, the maximum displacement is only 0.022m. The obvious and great reinforcement effect is verified.




(a) Deflection of the end (b) Pole deflection curve

Figure 3. Deflection of Model 3

## Conclusions

The paper made a numerical study on the capability of withstanding violent typhoon of 10kV distribution feeders. A coupling finite element model of a standard stain section is established by ABAQUS. The deflections of the pole under three kinds of condition and different wind speed are investigated. The results indicate that: (1) the deformation of the foundation soil has superimposed effect on the pole deflection. If the soil property is poor, the pole tends to topple. (2) installing guy wire can decrease the maximum displacement of the pole obviously and increase the capability of anti-wind of the feeder. The research results can provide reference to the reinforcement design of distribution feeders.

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