Wind Load Assumption of 765Kv Transmission Towers

Jeong-Boo Kim

Abstract

This paper mainly describes the wind load assumption of 765kV transmission towers. We analyzed wind velocity data at meteorological observatories to get the wind velocity of 50 years return period by using Gumbel I type extreme value distribution. By multi-correlative regression analysis method, wind velocity at no observation site was obtained.

Reference dynamics wind pressure map was obtained from above analysis and the wind pressure was classified as three region in high temperature season.

Keywords: Extreme Value Distribution, Gust Velocity, Multi- Correlative Regression Analysis, Reference Dynamic Wind Pressure.

I. Introduction

In 1983, 1987, and 1989 many steel towers of 345kV and 154kV transmission lines collapsed near the eastern and southern coast of Korea peninsular due to anti-tropical cyclone in spring and tropical cyclone in summer.

We have found that the instantaneous wind velocity(gust velocity) was very high comparing with 10-minutes average wind velocity.

To get reference dynamic wind pressure, gust wind velocity map was obtained by analyzing 10-minutes average wind velocity and gust velocity data of the meteorological obserbatories. The reference dynamic wind pressure in the coast area and island was upgraded, respectively.

II. Wind load assumption

1. The distribution wind velocity

We have collected the annual maximum data of 10-minutes average wind velocity in each meteorological observatories.

To determine the wind velocity of 50 year return period from above data, Gumbel I type extreme value distribution can be utilized as follows[1].

$$P(V) = 1 - \exp[\,-\exp(-\pi(V - \overline{V} + 0.45\ \sigma_v / (\sigma_v \sqrt{6})))] \qquad (1)$$

Where P[V] : Probability of the wind velocity which exceeds V

$\overline{V}$: Average value of maximum yearly wind velocity

σ_v : Standard deviation of maximum yearly wind velocity

From equation(1), the wind velocity V_T corresponding to a given return period T can be determined.

$$V_T = \frac{\sqrt{6}}{\pi} \cdot \sigma_v \cdot \ [\,-l_n\{-l_n(1 - \frac{1}{T})\}] + \overline{V} - 0.45 \cdot \sigma_v \qquad (2)$$

Equation (1) and (2) are applicable, if the number of year of observation is larger than 30.

At that time most of our meteorological observatories were installed in less than 20 years before.

In this case, equation (1) and (2) must be revised into general Gumbel I type distribution as follows[2].

$$P(V) = 1 - \exp[\,-\exp\{-a(V-u)\}] \qquad (1)'$$

Where $a = C_1/\sigma_v$

$u = \overline{V} - C_2 / a$

C_1, C_2: Constant as following table 1

$$V_T = u - \frac{1}{a}\, l_n\ \{\, l_n \frac{T}{T-1}\,\} \qquad (2)'$$

Reference wind velocity means 10-minutes average wind velocity at 10m above ground.

Manuscript received September 13, 1994; accepted May 30, 1995.
The author is with Korea Electric Power Research Institute.

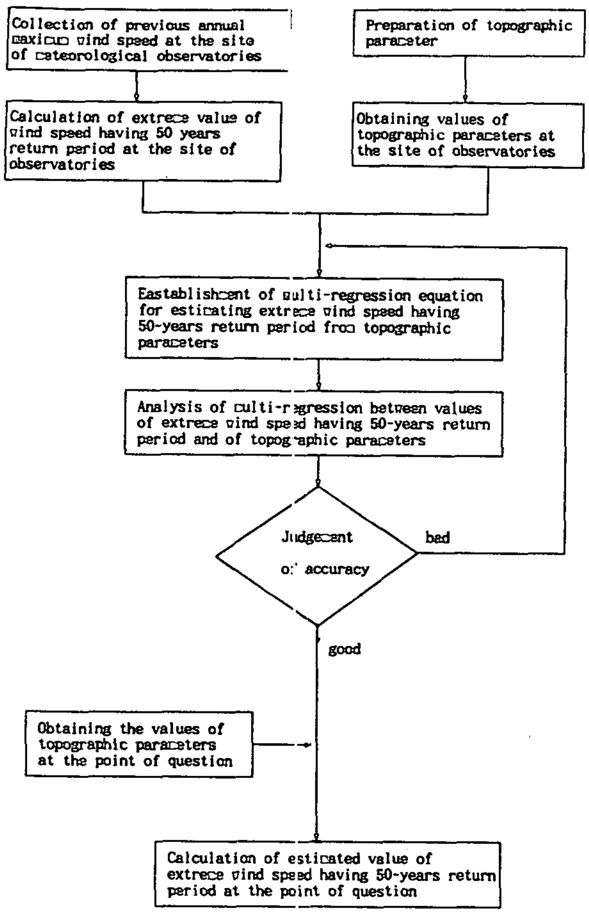


Fig. 1. Flow chart of multi-correlative regression analysis.

Table 1. value of the constant C_1 and C_2.

Number of year of observation	C_1	C_2	C_2/C_1
10	0.9497	0.4952	0.5214
15	1.0206	0.5128	0.5024
20	1.0628	0.5236	0.4927
25	1.0915	0.5309	0.4864
30	1.1124	0.5362	0.4820
40	1.1413	0.5436	0.4763
50	1.1607	0.5485	0.4726
∞	$1.2826 = \frac{\pi}{\sqrt{6}}$	0.5772	0.4500

2. Multi-correlative regression analysis in no observation place

Meteorological observatories are generally located in the suburbs of large city, but transmission towers are generally located in the mountaninous area or in the place from where the observatories are very far away. The wind velocity in no observation place must be known to assum wind load.

We divided our country at 16km interval longitudinally and latitudinally respectively

At the cross-point 18 terrain factors were investigated from 1:50,000 and 1:200,000 scale map.

Multi-correlative regression analysis method was used to obtain the wind velocity at the cross-point as follows.

$$[V] = [P]\ [A] \tag{3}$$

$[V]$: wind velocity matrix of 50 year return period

$[P]$: terrain factor matrix

$[A]$: Regression coefficient matrix

Fig. 1 shows the flow chart of the multi-correlative regression analysis procedure.

3. Reference dynamic wind pressure

(1) Gust factor

In old days, only 10-minutes average wind velocity was recorded at meteorological station, recently 10-minutes average wind speed and instantaneous wind velocity(gust velocity) are simultaneously recorded. The strength of tower must withstand the gust velocity.

Maximum monthly instantaneous wind velocity and 10-munutes average wind velocity from meteorological data were analyzed to get the gust factor as follows.

$$G = V_1 / Vm \tag{4}$$

Where G : gust factor

V_1: maximum monthly instantaneous wind velocity

V_m: maximum monthly 10-minutes average wind velocity

The analysis result of the gust factor follows as table 2. The higher 10-minutes average wind speed is, the less the gust factor is as seen in table 2.

Table 2. Gust factor.

10-minutes average wind velocity	Gust factor
less than 20 m/sec	1.50 Vm
20 ~ 30 m/sec	1.70 - 0.01 Vm
30 ~ 40 m/sec	1.55 - 0.005 Vm
greater than 40 m/sec	1.35 Vm

(2) Reference gust velocity

If we know 10-minutes average wind velocity at every cross point by multi-correlative regression analysis and gust factor, we can calculate gust velocity by the equation (4).

Reference gust velocity means the wind velocity measured at 10m above the ground and average measuring time is 3 to 5 seconds.
Fig. 2 shows our reference gust velocity map of 50 years return period(YRP) in high temperature season (April-November).

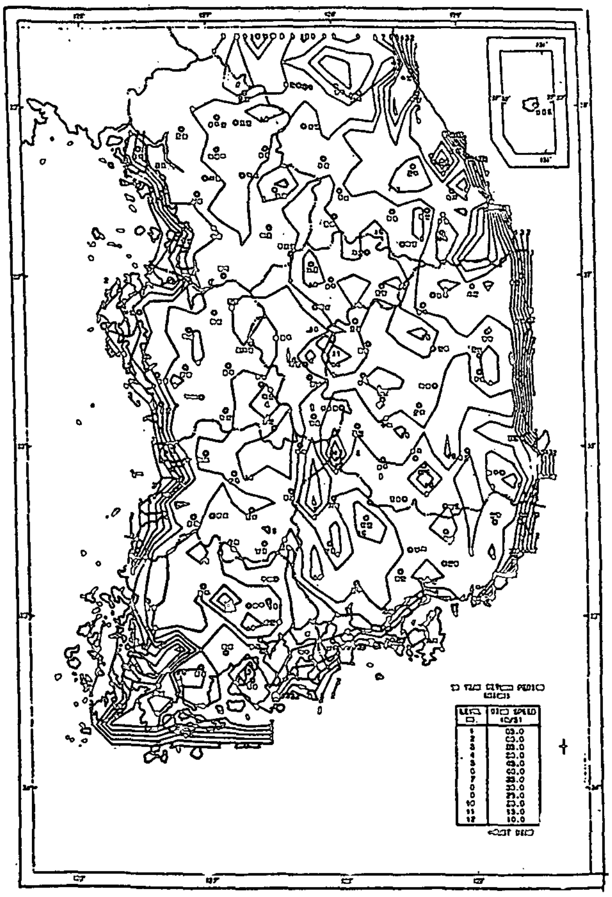


Fig. 2. Gust wind velocity map of 50 YRP in high temperature season((HTS).

(3) Reference dynamic wind pressure

Reference dynamic wind pressure can be calculated from gust velocity and air density, as following equation.

$$q = 1/2\ \rho\ V^2_{G10} \quad (5)$$

Where ρ : air density (kgf s^2/m^4)
V_{G10} : gust velocity at 10m above the ground
q : reference dynamic wind pressure (kg/m^2)

Air density in high temperature season was calculated as 0.1195 from minimum average atmospheric pressure and temperature in meteorological observatories from 1951 to 1980.

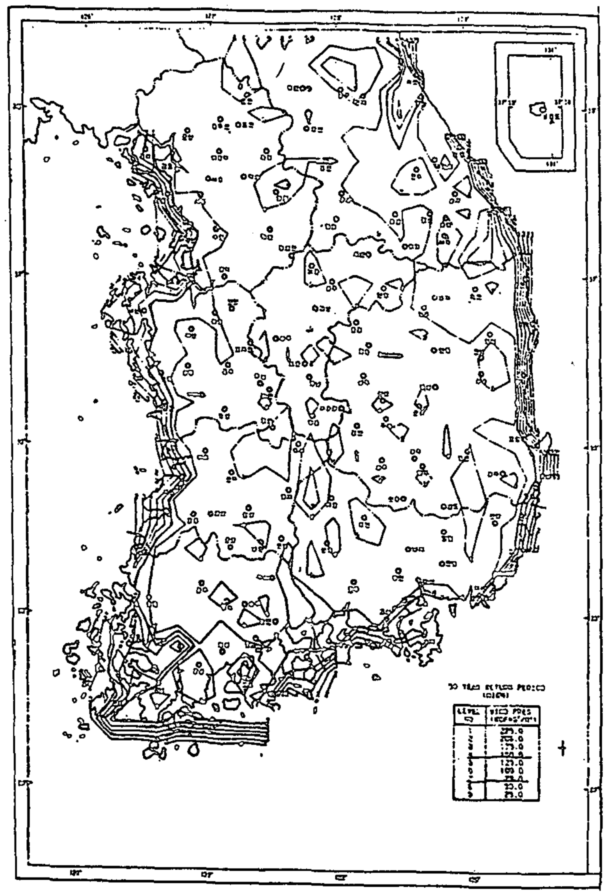


Fig. 3. Reference dynamic wind pressure map of 50 YRP in HTS.

The air density in low temperature season (December-March) was calculated as 0.131.
Fig. 3 shows reference dynamic wind pressure map of 50 years return period in high temperature season. Fig.4 shows the area classification according to Fig.3 [3].
Table 3 shows reference dynamic wind pressure according to Fig. 4.

Table 3. The classification of reference dynamic wind pressure.

Area		Reference dynamic wind pressure(kg/m^2)	Reference wind velocity(m/sec)		
			10-minutes average	Gust	Gust factor
H	I	175	40.0	54.0	1.35
T	II	150	36.6	50.0	1.37
S	III	115	31.7	43.7	1.38
L T	Heavy snow area	45	-	26.3	-
S	Others	60	20.2	29.5	1.46

HTS : High Temperature Season
LTS : Low Temperature Season

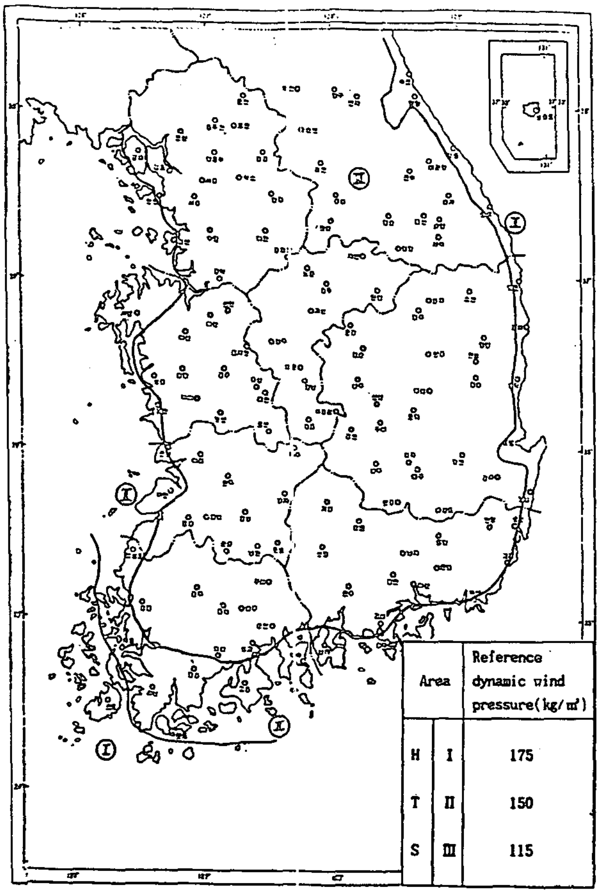


Fig. 4. Area classification recording to reference dynamic wind pressure.

4. Design dynamic-wind pressure

Design dynamic-wind pressure on conductor is assumed as follows[2].

$$q = q_o \alpha \beta K_1 K_2 \qquad (6)$$

Where q : design dynamic-wind pressure
q_o : reference dynamic-wind pressure
α : increasing coefficient of structure scale
β : decreasing coefficient of structure scale
K_1 : coefficient of structure
K_2 : coefficient of shielding

We do not consider the increasing coefficient of conductor height in the dynamic wind pressure of conductor, but we consider the effect of tower height in calculation of wind pressure on tower as follows.

$$\alpha = \left(\frac{h}{h_o}\right)^{\frac{1}{n}}$$

Where h : height of above ground
h_o : standard height, 10m
n : index representing increasing degree of height
n = 4

We assume K_1 is 1.15 in 765kV tower to increase the reliability in the design. This is equivalent to wind velocity of 100 years return period.

5. Ice and snow load

Ice and snow thickness as following table 4.

Table 4. Ice and snow thickness.

Area classification	Ice		Snow	
	Thickness (mm)	Density	Thickness (mm)	Density
General area	9	0.9		
Heavy snow area			20 40(Above 800m altitude of east coast)	0.6 0.6

6. The load assumption of 765kV tower

In our country, there are many mountains and it is very difficult to get right of way because our population density is very high.

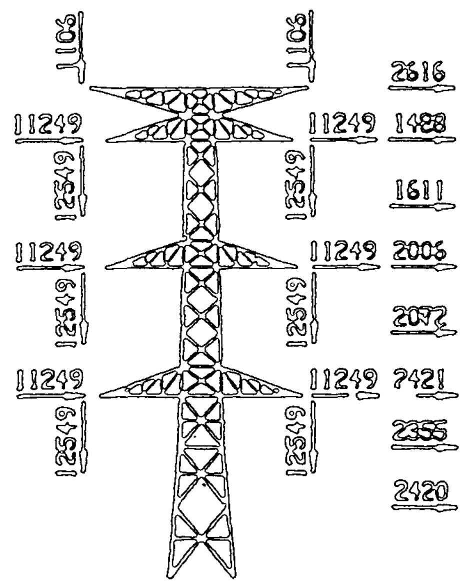


Fig. 5. The load assumption of high temperature season.

Korea Electric Power Corporation decided to build one double-circuit 765kV line of vertical arrangement configuration instead of two single-circuit 765kV lines of horizontal configuration.

We had preliminary design of 765kV transmission tower and had loading test.

In the corona performance study, six conductor bundle of ACSR 483mm^2 per phase was selected and two ground wire of 200mm^2 of AW was selected.

Wind span was assumed as 400m.

Weight span was assumed as 700m.
The insulation string length in suspension tower is about 7m. Maximum switching overvoltage is assumed as 1.9 p.u. The minimum clearance is determined as 4.9m.

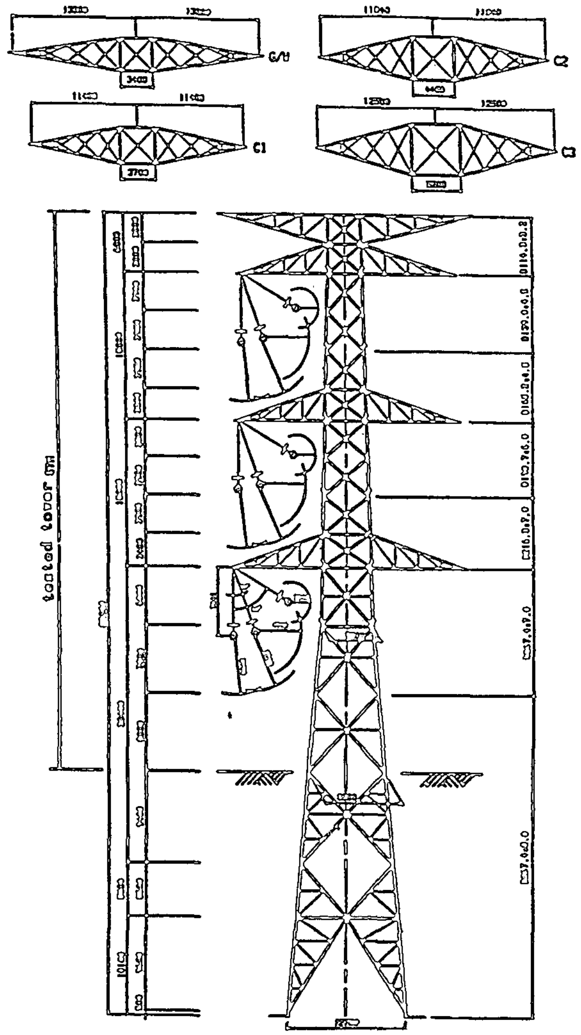


Fig. 6. 765kV steel tublar tower(suspension type).

Fig. 6 shows the skeleton of steel tubular tower of suspension tower.
The height is 82m. The vertical distance between arms is 15m. The length of arm is 25m. The minimum conductor height is 22m.
Fig. 7 shows the buckling state of two main posts and braces by compression load (at 115% loading condition)
We consider the safety factor of the material to be 1.2 or 1.3 in 765kV transmission tower.

III. Conclusion

We classified reference dynamic wind pressure in three categories. Gust velocity in land is relatively lower than coastal area. We upgraded the reference dynamic wind pressure in coastal area and Jeju-island, but we have not obtained the exact ice and snow load. We need to measure ice and snow thickness in heavy snow area.

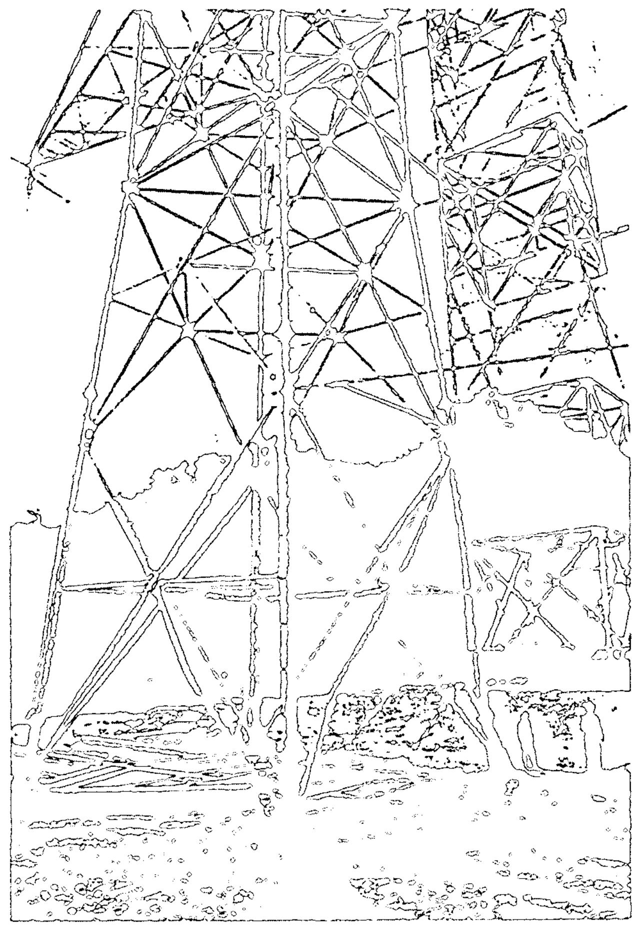
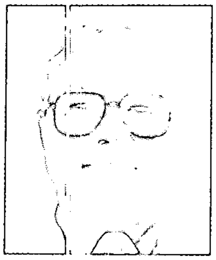


Fig. 7. The buckling state of two posts and braces by the compression load(at 115% load).

Reference

[1] JIEE, "The Tower Design Standard of the Transmission Line," JEC-127, Appendex 11, pp24, 1979.
[2] Technical Report IEC826, "Loading and Strength of Overhead Transmission Line," pp. 193, 1991
[3] J.B. Kim, D.W Jung, "Design Dynamic Wind Pressure Assumption of Transmission Line," *The journal of the Korean Institute of Electrcal Engineers*, Vol.36, No.10, pp.37~45, 1987.



Jeong-Boo Kim was born in Kyung-book Province, Korea on November 14, 1943. He received BS, MS and Ph. D. degree in Electrical Engineering from Seoul National University in 1971, 1985 and 1990 respectively. In 1971, he joined Korea Electric Power Corporation. He has engaged in the study on insulation coordination, reactive power planning, transmission line design, corona & field effects of power system and the corrosion control & protection of underground pipe-type oil filled cable. Dr. Kim is a member of the Institute of Electrical Engineers of Korea and IEEE. He is a member of study committee 22 of CIGRE.