Article
KEPCO Journal on Electric Power and Energy
Vol. 4, No. 2, December 2018
ISSN 2465-8111(Print), 2466-0124(Online)
DOI : 10.18770/KEPCO.2018.04.02.063

# Development of Compact Towers with Insulation Arm in Korea

# 절연암 적용 컴팩트 철탑 개발

Won-kyo Lee[1†], Cheol-Hee Yun[1]

**Abstract**

Lattice towers and tubular steel poles have been commonly used for electrical power transmission in Korea as well as the other countries. They are durable, structurally stable, simple and can easily be constructed in limited spaces. However, residents are opposed to construct transmission lattice towers in their areas because they are not visually attractive, and electrical field occur at the transmission lines. Underground transmissions have been used instead of the traditional towers to resolve these problems, however they are not cost effective to construct and run. Therefore, we have developed compact towers that are more attractive, well blend into the surrounding environment and much more economical than underground transmissions. This paper shows the design of a compact towers with insulation arm, in order to reduce the height of tower and the separation between phases. The compact tower can be installed in a narrow right-of-way. Insulation arms are easily applied to lattice and steel tubular towers instead of steel arms. Compact towers with insulation arm are also considered as a solution to have public acceptance or to create a familiar atmosphere among towers and people. Compact tower compared with a conventional tower, insulation arms reduces the width and height of the tower by 20% and 15% respectively.

*Keywords: Insulation arm, Compact Tower, Tubular, Composite*

## I. INTRODUCTION

Electricity has become indispensable as people need energy that is highly adaptable and controllable. In addition, natural sources of energy are often in areas remote from the user and may not be in the form the user needs. Electrical energy offers efficient conversion from a variety of sources to electricity, easy transport to the user, and reconversion to the form that the user needs. All of this can be achieved in a clean, controllable and efficient manner. Towers for electrical power transmission are usually designed to support the conductors and ground wires. The shape of transmission towers depends on voltage level, number of circuits and number of ground wires. Currently, Aesthetics have not been a great value taken into account in the design for towers. Towers were just considered essential elements for supporting structures in Korea. So, we usually have used lattice towers and tubular steel poles to transmit power because they are durable, structurally stable, simple and can easily be constructed in limited spaces. However, residents are opposed to construct towers in their areas since they are not attractive, and electrical field occur at the transmission lines. Underground transmissions have been used instead of the traditional towers to resolve these problems, however they are very expensive to construct and run.

In the previous CIGRE works, the appearance of the towers already has been taken into consideration when designing towers in other countries. These changes can be understood as results of many reasons, such as the increasing presence of transmission lines in inhabited areas, in such a way, that the towers became familiar elements in the cities, the difficulty of obtaining new urban corridors for bringing more power to central regions of cities especially those with high vertical growth and a greater environmental conscience motivated by the various aggressions to the environment in different regions of the world. All this together made that the environmental aspects had become one of the most important premises in the studies for the implementation of new transmission lines [1].

Nowadays, transmission line projects have to consider an environmental impact assessment, where environmental auditors identify and analyze the impacts on the natural and

Manuscript received July 18, 2018, Accepted October 24, 2018
[1] KEPCO Research Institute, Korea Electric Power Corporation, 105 Munji-Ro Yusung-Gu, Daejeon 34056, Korea
† wonkyo.lee@kepco.co.kr

Table 1. Tower classification of KEPCO standard (DS-1111)

| Tower type | Angle of deviation | Wind span | | Weight span | | Type of insulator set |
|---|---|---|---|---|---|---|
| | | 154 kV | 345 kV | 154 kV | 345 kV | |
| A | 1° | 400 (300) | 450 (300) | 600 (500) | 600 (500) | Suspension |
| SF | 3° | 500 (500) | 600 (500) | 1,200 (800) | 1,200 (800) | Suspension |
| F | 3° | 400 (300) | 450 (300) | 800 (500) | 800 (500) | Suspension |
| Ba | 10° | | | | | Tension |
| Bb | 20° | | | | | Tension |
| C | 30° | | | | | Tension |
| E | 40° | | | | | Tension |
| D | 60° | | | | | Tension |

human environment. New line routes should be balanced between the needs of electricity transmission and the environmental perspectives. As part of these studies, the visual appearance and the aesthetic of the towers began to play a significant part in the analysis, as they are the most visible elements on the landscape. Therefore, we have developed eco-friendly electric transmission towers that are more attractive, well blend into the surrounding environment and much more economical than underground transmissions.

Compact towers with insulation arms are considered as a solution to needs for eco-friendly electric transmission towers. Compact towers compared with a conventional tower, insulation arms reduce the width, height and weight of the tower. So, KEPCO 154 kV Compact tower which is included in fabrication of sample tower and tower testing has developed and the results are presented in this paper.

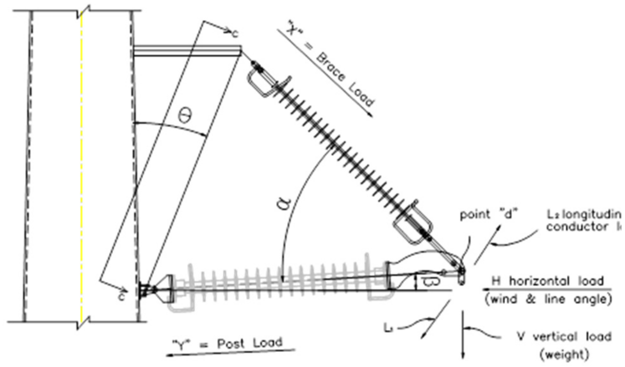
## II. MAIN CHARACTERISTICS FOR COMPACT TOWERS

In this paper, Compact electric transmission towers were oriented by the following principles:

- To meet the design condition of KEPCO standard (DS-1111) to replace existing towers.
- To support bundle (154 kV) and 4-conductors (345 kV) configurations with double circuits.
- To use self-supporting structure (not considering guyed structure).
- To try to put them to be landmark or camouflaged in the landscape.
-

Table 1 shows tower classification of KEPCO standard (DS-1111). Tower type can be categorized according to deviation angle of the line. Depending on the deviation angle of the line, the respective tower is chosen. The tower types (A, SF, F) are tangent tower. The tower types (B, C, E, D) are angle tower.

The standard span that is determined by economic considerations on towers and concrete foundations [2][3]. The numbers refer to the standard span of lattice towers and the small numbers in brackets refer to tubular steel poles. For increased facility safety, fabrication, and transportation, the standard spans of tubular steel poles are selected to be smaller than the standard spans of lattice towers.




$$\text{Post Load (Y)} = \frac{V \times \cos(\alpha - \beta)}{\sin\alpha} + \frac{H \times \cos(\alpha - \beta)}{\sin\alpha} \quad (1)$$

$$\text{Brace Load (X)} = \frac{V \times \cos\beta}{\sin\alpha} + \frac{H \times \sin\beta}{\sin\alpha} \quad (2)$$

Fig. 1. Pivoting horizontal-vee.

Currently, we have used lattice towers that can be erected easily in very inaccessible locations especially mountainous areas as the tower members can be easily transported. The structure can easily be modified to achieve the desired shape and configuration. Self-supporting lattice structures are generally used. Lattice towers are light and cost effective under voltage levels of 154 kV and 345 kV electric transmission line. However, residents are opposed to construct transmission lattice towers in their areas because they are not attractive. So, we need the more attractive solution for resident necessities. Until now, we proposed the tubular steel poles for the low visual impact and the reduced area for settlement. Tubular steel poles have been widely used in Korea.

Tubular steel poles are made from carbon steel, mainly from high strength low alloy quality, being shaped in modules from 9 up to 12 m length and with continuously variable polygon cross sections. Depending on the dimensions involved, the cross section used can be the dodecagonal or circular type. Flanged joints are commonly used for the connecting modules.

The deflection of tubular steel poles is calculated by a non-linear analysis of the deflection of load application points [4]. The maximum deflection shall not exceed 8% of the height of tubular steel poles at 1.5 times the normal consistency (all conductor intact load condition in high temperature). In case of the condition for the average temperature with no wind, It shall not exceed 2% the height of tubular steel poles.

## III. COMPACT TOWER WITH INSULATION ARM

### A. Design Approach

To develop eco-friendly transmission towers, we have designed to compact transmission tower with insulation arm with the technical basis of the composite insulators which are replacing conventional steel cross arm. This will contribute a great reduction in the width of right-of-way [5]. Compared with a conventional vertical string of suspension insulators

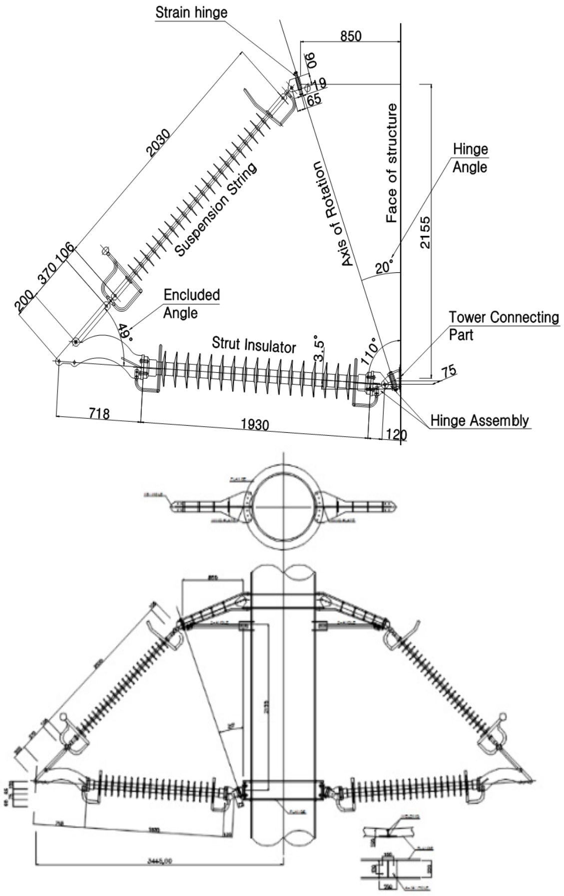



Fig. 2. 154 kV Pivoting horizontal-vee.

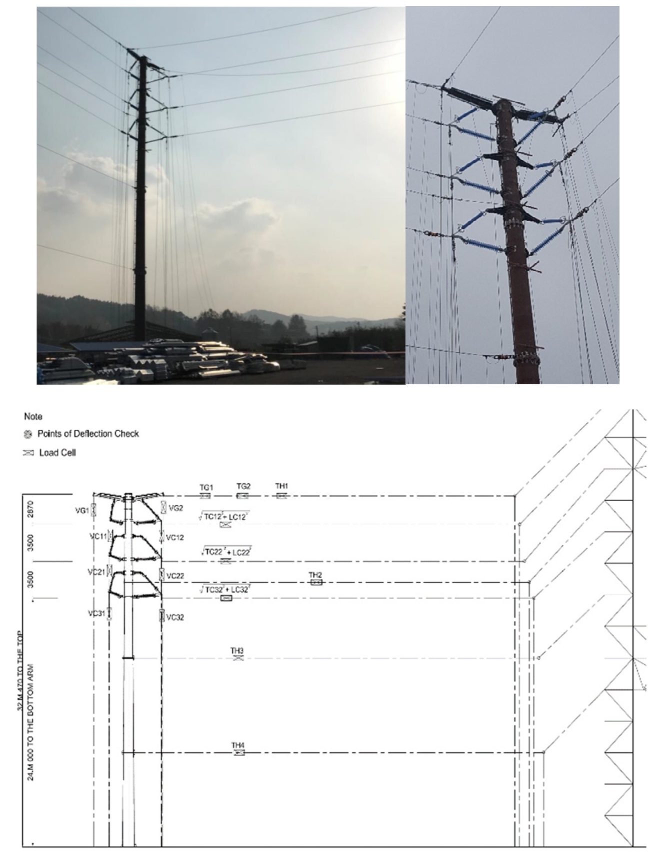



Fig. 3. Tower test for 154 kV compact tower (Landscpe, Rigging diagram).

mounted on a tower arm, a horizontal insulating cross-arm allows the use of a shorter tower and a reduction in the minimum required line-to-ground (tower body) clearance. This is well-known for one of the most attractive solutions to line compaction [6].

B. Mechanical loads for 154 kV Compact tower

Mechanical loading characteristics for composite insulator assemblies are very dependent on the type of attachments at the support structure for the assembly. We can choose the braced insulator assemblies to meet KEPCO design standard on structures for transmission. Especially 'pivoting horizontal vee' applied to compact transmission tower.

Fig. 1 shows a figure of a typical horizontal vee with applied loads and the resulting loads in the two insulator components. The post member Y has an articulated attachment to the pole at point 'c' and the brace, also articulated, is attached to a fixed short stub-arm at point 'c' to provide an inclined axis of rotation (θ) for the insulator assembly. Loads in the brace and post components of the assembly depend on the applied loads, the magnitudes of the included (α) and inclined (θ) angles. The compression load in the post (Y) and the tension load in the brace (X) insulator components are shown in Eq. (1) and (2) in Fig. 1 [4].

C. Design for 154 kV Compact tower

According to KEPCO design standard on structures for transmission, we can decide the magnitudes of the assembly included angle α of 49°, and inclined angle θ of 20° as shown in Fig 2. The maximum tension working loads for the individual post and suspension are all under 6,800 kgf (including safety factor).

As mentioned earlier, the deflection of tubular steel poles is calculated by a non-linear analysis of the deflection of load application points. The maximum deflection shall not exceed 8% of the height of tubular steel poles at 1.5 times the normal consistency (all conductor intact load condition in high temperature). In case of the condition for the average temperature with no wind, It shall not exceed 2% the height of tubular steel poles. A structural analysis has been conducted to meet KEPCO design standard on structures for transmission by PLS-POLE program and then we made and tested a 154 kV compact tower to verify the combination of KEPCO design standard and detail work.

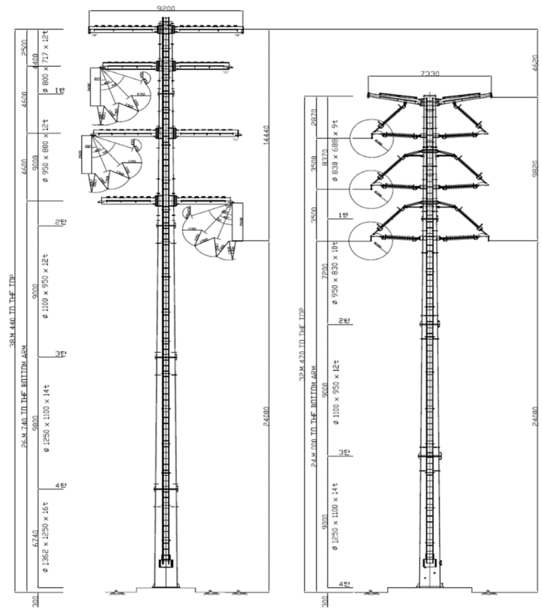
D. Tower test for 154 kV Compact tower

In accordance with IEC 60652 Loading Tests on Overhead Line Structures, we tested 154 kV Compact tower based on tubular steel pole with ACSR 410 $mm^2$×2B. Test facility consists of 2 Units of Gantry Type Tower, Longitudinal Tower - 1 Unit (19,000 Ton - M) and Transverse Tower - 1 Unit (16,000 Ton - M). The landscape and rigging diagram of tower test is shown in Fig. 3.

Tower test was carried out on 3 November 2017, The Tower test was completed successfully. The 154 kV compact tower design was verified by the test. In particular, it is confirmed that the measured deflection occurs within the design criteria through the load condition at 1.5 times the normal consistency and the maximum deflection shall not exceed 5% (1.6 m) of the height of tubular steel poles.

### E. KEPCO 154 kV Compact tower

KEPCO 154 kV Compact tower compared with a conventional vertical string of suspension insulators mounted on a tower arm, a horizontal insulating cross-arm allows to reduce the width and height of the conventional tower by 20% and 15% respectively. These allows the use of 19% lighter tower as shown in Fig. 4.



(a) (b)

| 154 kV 2B A2 – 24 m | | | |
|---|---|---|---|
| Dimension | Tubular Pole | Compact Pole | Size reduction ratio |
| Width (m) | 9.2 | 7.3 | -20.6% |
| Height (m) | 38.4 | 32.4 | -15.6% |
| Weight (kg) | 14.13 | 11.31 | -19.9% |

Fig. 4. 154 kV Tublar steel pole. (a) Conveintional tower, (b) Comapact tower.

## IV. CONCLUSIONS

In urban areas (or even rural areas sometimes), Compact solutions have been installed in different parts of the world, aiming to reach public acceptance. The construction of new lines arouses more environmental and aesthetic concerns. With the growing demand, there will be more requests for alternative design solutions for visually attractive eco-friendly towers. There will be more options to design and construct electricity transmission towers. Local residents would be more pleased with good-looking transmission towers.

## REFERENCES


[1] Working Group SC B2.08 CIGRE, "Innovative Solutions for Overhead Line Supports" (Technical Brochure 416, June 2010, pages 1-58).

[2] KEPCO Design Standard on structures for Transmission (DS-1111, 2013).

[3] W. Dreyer, "Special features in the design of transmission tower lines as imposed by electrical conditions" (Journal of the American Institute of Electrical Engineers, 1923).

[4] ASCE, "Design of Steel Transmission Pole Structures", (ASCE/SEI 48-11, 2011).

[5] Anthony C. Baker, "Braced Insulator Assemblies" (IEEE T&D Conference and Exposition, Chicago, IL April 2008).

[6] Y. F Gao, "Electric Field and Electromagnetic Envrionment analyses of a 500 kV Composite Cross Arm", (IEEE Conf. Electr. Insul. Dielectr.Phenomena (CEIDP), pp.399–402, 2015).