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**Research Article**

# COMPARATIVE STUDY OF THE USE OF LATTICE TOWERS VERSUS POLYGONAL MONOPODS IN SNEL SA'S HIGH-VOLTAGE TRANSMISSION NETWORK INFRASTRUCTURE

**[1,*] Léon MWANDA MIZENGI and [1,2]André MAMPUYA NZITA**

[1]Université de Kinshasa (Ecole Régionale de l'Eau, « ERE »), RD Congo.
[2]Université Président Kasa-vubu, RD Congo.

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**ABSTRACT**

The comparative study on the use of lattice towers versus conical monopods in SNEL SA's high-voltage transmission network is of paramount importance in determining the conditions for safety, reliability, operation and maintenance. The main aim is to overcome the growing phenomenon of vandalism, such as the theft of galvanized angles, bolts, copper conductors and earth counterweight wires from electrical infrastructures, which leads to the collapse of lattice towers and the unavailability of SNEL SA's power transmission lines. The use of polygonal monopole towers offers the following advantages: aesthetic, can be installed in urban areas, small footprint, one-day installation, reduced number of parts for assembly, low maintenance costs spread over several years, resistance to acts of vandalism, no natural aggression and environmental impact. The complete construction cost of one kilometer of line (ratio) is 1.25 k€/km for the conical monopod as opposed to 1 k€/km for the lattice tower, i.e. a 20% difference in investment.

***Keywords:*** Comparison, use, lattice tower, conical monopole, SNEL SA High Voltage transmission system or grid.

## INTRODUCTION

The National Electricity Society (SNEL SA) faces major challenges in securing, making reliable and guaranteeing the supply of quality electrical energy to its customers. SNEL SA is confronted with acts of vandalism on high-voltage power transmission infrastructures, such as the theft of galvanized angle irons, bolts, copper conductors and earth counterweight wires from electrical infrastructures, which can lead to the collapse of lattice towers and prolonged unavailability of power transmission lines. SNEL SA's power transmission network currently comprises 9,189.46 km of direct current ± 500 kV INGA - KOLWEZI extra-high voltage lines and alternating current lines at different voltage levels: 400, 220, 132, 120, 70, 55 and 50 kV.

The two ± 500 kV INGA - KOLWEZI direct current lines, which together have 8,523 lattice masts, currently transmit 560 MW from the INGA generating park to the Kolwezi Conversion Station (SCK), to supplement the 470 MW output of SNEL SA's 4 hydroelectric power stations in the former mining province of Katanga. The high demand for electrical power (close to 2,000 MW) from mining companies operating in the southern part of the Democratic Republic of Congo (DRC), the former province of Grand Katanga, is prompting some mining companies to use monopod pylons to combat acts of vandalism on their power transmission lines. No transmission line with lattice towers is immune to this recurring phenomenon. Several strategies are being implemented to eradicate acts of vandalism, including cross-patrolling of high-voltage line corridors, replacement of copper conductors with aluminum alloy ones, replacement of stolen angle irons, use of drones, employment of security companies, etc.

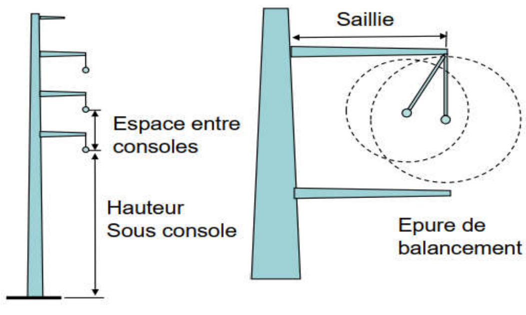
The aim of this study is to demonstrate the economic and technical viability or otherwise of investing in the use of monopole towers versus lattice towers on power transmission lines.

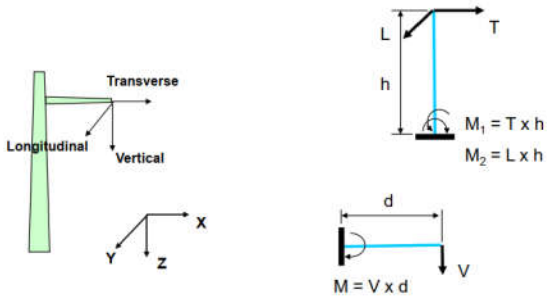
***Corresponding Author: Léon MWANDA MIZENGI,**
1Université de Kinshasa (Ecole Régionale de l'Eau, « ERE »), RD Congo.

## METHODES AND MATERIALS

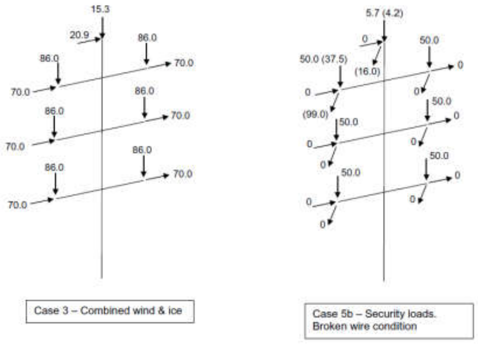
The methodological approach consists of collecting and analyzing data on acts of vandalism perpetrated on electrical power transmission infrastructures, through cases of theft of copper conductors on AC lines over a period ranging from 2016 to 2024, 630 km of copper conductors stolen, the loss of earnings amounting to $27.826,948.40, while the cost of replacing the stolen copper conductors, carried out under our own management, has already reached $10,240,943.26, including the collapse of 125 lattice towers. These two factors led us to request in-depth research from the Transport Department of Société Nationale d'Electricité (SNEL SA). Exchanges with experts from the Société Nationale d'Electricité enabled us to consolidate our scientific knowledge of the literature review. For an experimental part, we used annual statistics.

We're going to look at the various problems involved in calculating the economic-technical viability of using monopole towers versus lattice towers. The geometry of monopole towers is based on electrical distances: distance from the ground, balance of active conductors and distance between phases. The induced forces generate very simply calculated internal forces and moments on the supports.



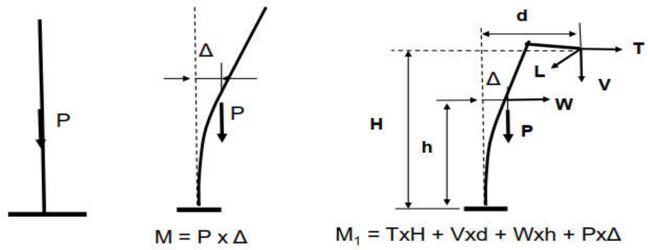



The forces on monopod supports are determined by the choice of active conductors, and are generally provided by customers and calculated in accordance with national standards. they can also be given in two ways: by editing a tree of mechanical loads (vertical, horizontal and transversal forces) directly entered into a calculation program.

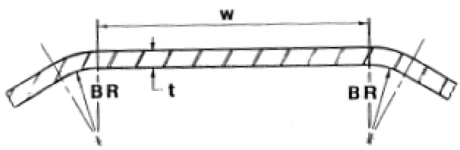



- Spans on both sides of the line;
- Conductor diameter ;
- Wind pressures and directions for different load cases;
- Line angle ;
- Conductor breakage conditions ;
- Line installation conditions ;
- Cable voltage for all load cases.

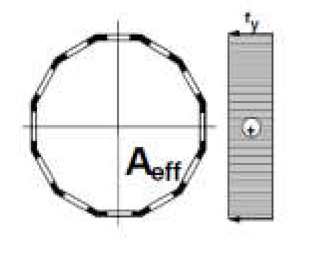
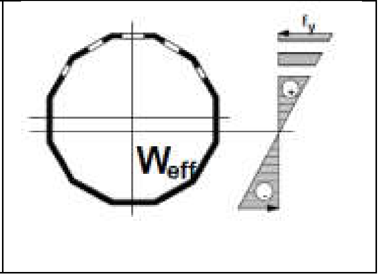
Since monopole towers undergo large deformations, in accordance with all calculation standards, it is mandatory to consider the “P-Δ effect”, which takes into account the instability of the structure.




1. Polygonal sections are subject to local warpage when considered as non-compact. There are two ways of taking this phenomenon into account:
2. The ASCE method: Tests were carried out on various polygonal cross-sections to establish relationships between permissible stress and W/t ration, where W is the width of a cross-section side and t is the thickness of the cross-section

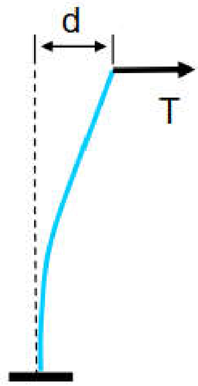



3. The second method, in accordance with EN 50341, is based on Eurocode 3 part 1.1 chapter 5 for non-compact “class 4” sections, where effective section characteristics are calculated. Aeff & Weff

| Aeff under axial force | Weff under the bending moment |
|---|---|
|   |   |

## GENERAL PRINCIPLES

Les pylônes monopodes sont beaucoup plus soumis à la déformation que les pylônes à treillis :




**Problématiques :**

Essentially aesthetic (banana shape)
People are surprised by this shape, even if the pylon has been correctly dimensioned.

Visible when Deformation >> Top diameter

Deformation (deflection) should only be considered for daily load cases: little (or no) wind, normal temperature, without weighting coefficient.

- **Deformation**

**Permissible values :**

What is commonly accepted in terms of the arrow?

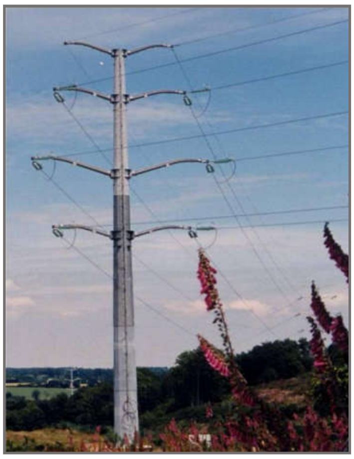
SNEL SA limits deformation to 6% of the height of monopod towers for alignment towers, and to 4.5% for towers with strong ELU (Ultimate Limit States) angles.

Selon la norme EN 50341-1 : 7.4.4 États limites d'aptitude à la fonction (chapitre 4) (se référer également aux NNA).

Appropriate limiting values of deformations and deflections shall be agreed between the client and the designer.

1) It is recommended that the deflection under a second order analysis at the ultime limit state does not exceed 8 % of the height of the pole above ground level.

**Max 8% ELU**



Ce pylône 2 x 220 kV

Height: 40 meters

Number of sections : 7

Load : 42 tonnes

Calculated with a deflection limit of 4.5% ELU

- **Comparison of different arrow limits:**

**Calculations for a type ON1H-40 tower Height 56,7 meters**

| Item | Version 1 | Version 2 | Version 3 | Version 4 |
| --- | --- | --- | --- | --- |
| Deflection limit | 2% Worst Load Case | 4% Worst Load Case | 2% Every Day Stress | 4% Worst Load Case |
| Top deformation | 1125 mm = 2% | 2257 mm = 4% | 995 mm = 1,8% | 2029 mm = 3,6% |
| **Type of tower steel** | **ASTM gr 65 448 Mpa** | **ASTM gr 65 448 Mpa** | **ASTM gr 65 448 Mpa** | **EN S355** |
| Diameter | 2257 mm | 2100 mm | 2050 mm | 2200 mm |
| **Number of elements** | **7** | **6** | **6** | **6** |
| thickness | 22 mm to 10 mm | 15 mm ro 8 mm | 15 mm to 8 mm | 16 mm to 8 mm |
| Worst stress ratio | 1,94 (steel S235 would be OK) | 1,02 | 1,00 | 1,01 |
| Design governed by | Deformation | Deformation and stress | Deformation | Deformation |
| Tower weight | 68,7 Tons | 41 Tons | 40,5 Tons | 45,8 Tons |

For this tower, the 4% deflection limit of the worst-case load, and 2% EDS lead to very close dimensioning (V2 and V3).

There is no point in using a high-strength steel for a very tight deflection limit .....(V1)

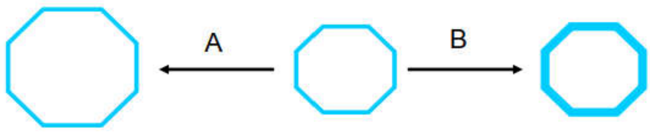
If the deflection limit is reasonable, a high-strength steel will limit the weight (V2/V4).

A reasonable arrow limit should be given in Every Day Stress (V3)

- **Contraintes**

Different types of steel: the stress is calculated taking into account weighting coefficients and then compared with the yield strength or the permissible buckling stress.Même sous chargement extrême, la contrainte reste dans le domaine élastique.

- High-strength steels reduce tower weight and costs;
- In the USA, Valmont Structures International uses 65 ksi steels for its towers (ASTM A572 GR65);
- In China, Valmont Structures International uses 65 ksi (448 MPa) and 50 ksi steels (A572 & Q345);
- In Europe, Valmont Structures International uses 355 Mpa, 460 MPa and 500 MPa steels.
- Steels manufactured to EN10025 S355J0 and J2 are readily available in Europe. Optimisation




**Increase Diameter (Diam) or Thickness (Ep)?**

- Increase Diam is more efficient
  - Stress proportiona to Diam² x Ep x Re
  - Stiffness proportional to Diam³ x Ep x E
  - Weight proportional to Diam x Ep
- Keep Diam/Ep reasobable
  - Too large Diam/Ep introduces local warpage
  - Reduce cross-sectional stress (reduced Re/Fb)

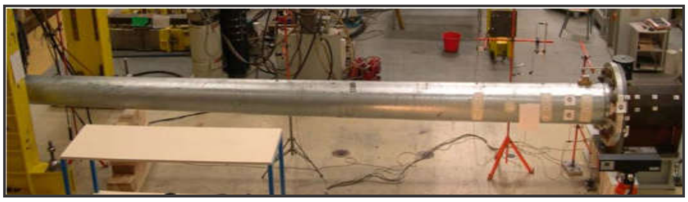
**General principles:**

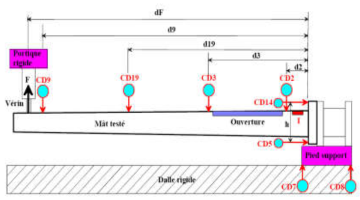
The aim of a full-scale trial is to validate :

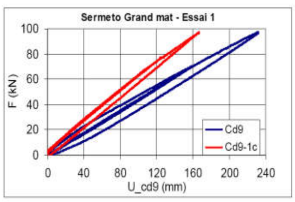
- Calculation methods ;
- Technichal manufacturing .

Tests are carried out in accordance with IEC 60652. Generally, the tower is loaded up to its design load, including weighting coefficients.. Deformations are measured and compared with theoretical values. The elastic integrity of the tower is verified (no or little residual deflection).

The size test can be performed horizontally or vertically.





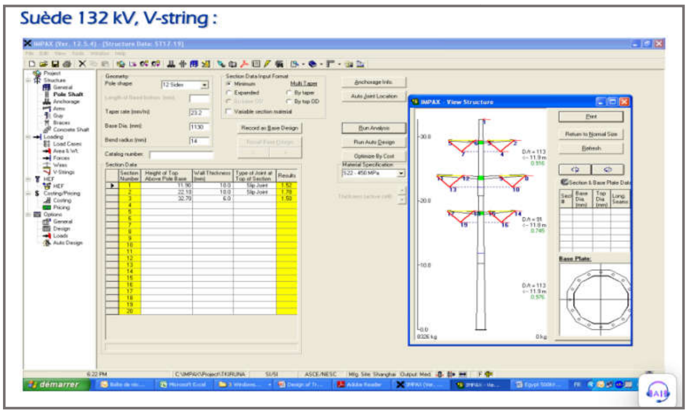

- **Calculation software**

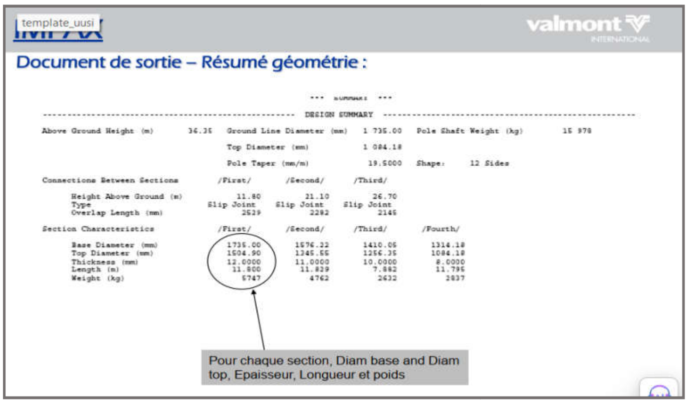
Impax is a Valmont software package dedicated to the construction of electricity transmission towers:

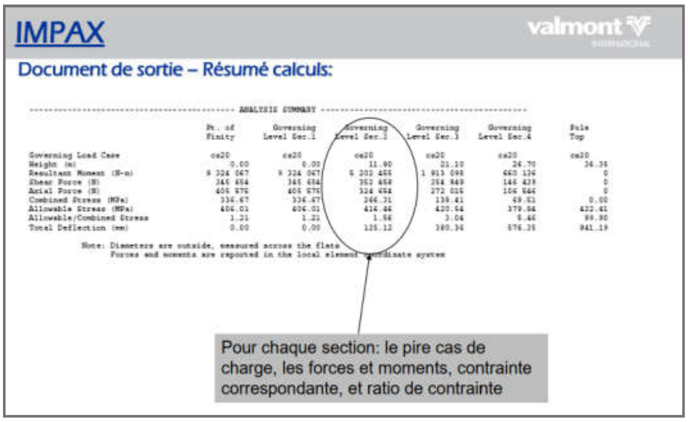
- Impax is a Finite Elements calculation program ;
- Impax can calculate Isostatic and Hyperstatic structures ;
- Impax includes all polygonal and circular sections ;
- Impax includes all steels used worldwide.

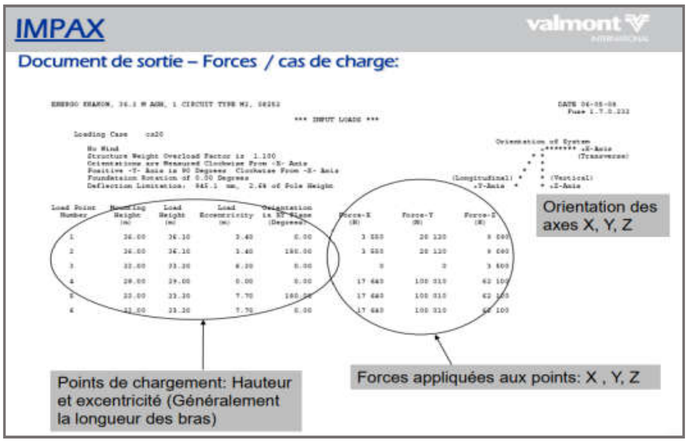
Impax's calculation of footings is based on the results of a multitude of full-scale tests. The diamond shape of the footing optimizes stress in this important structural element.

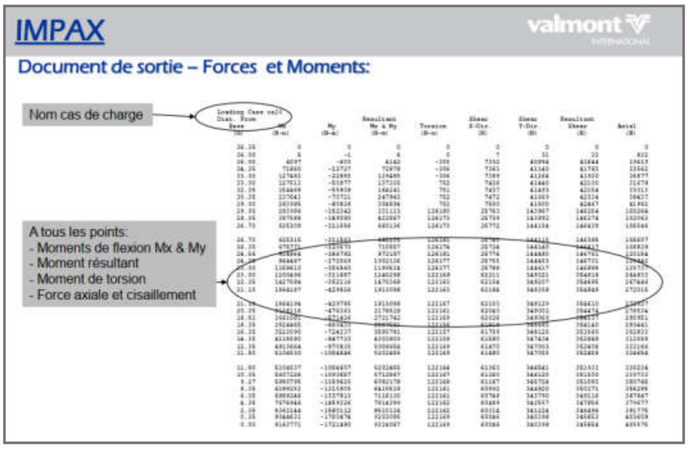
Test results are also used to calculate the connection of arms (brackets) to composite insulators or to chains of arched tempered glass insulators.

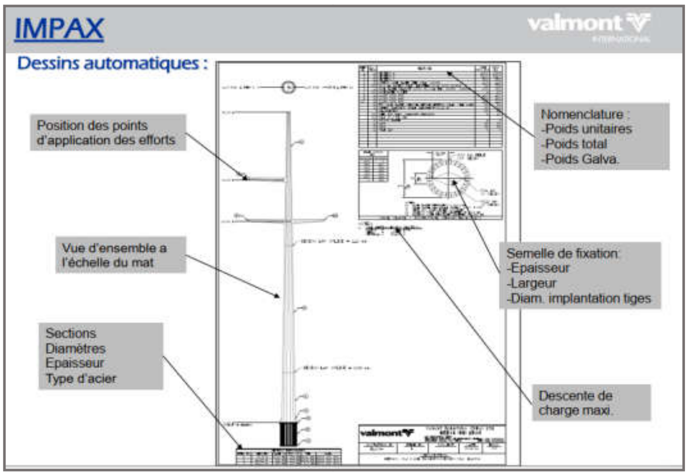


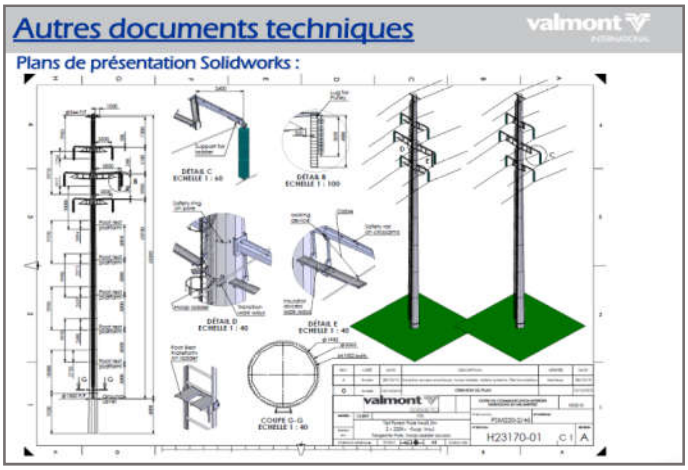



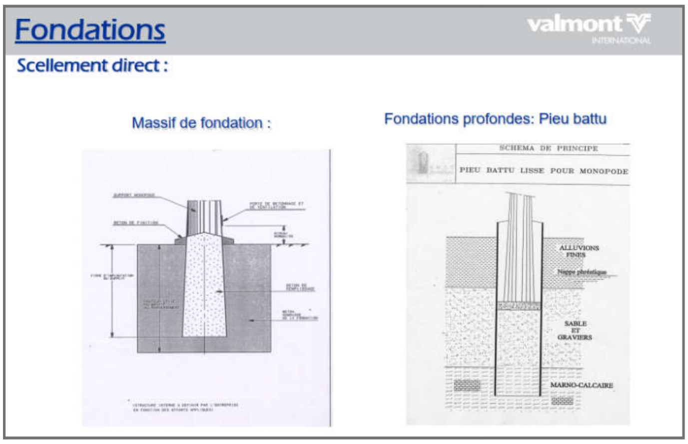



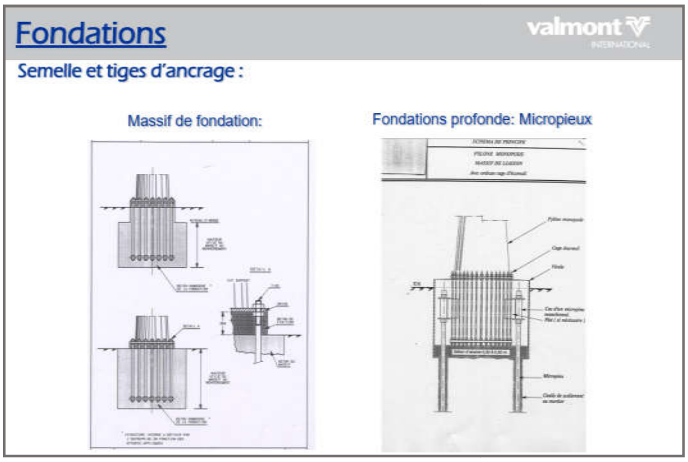



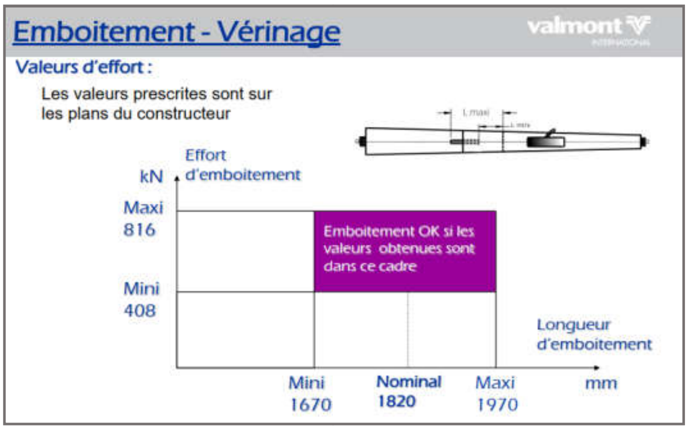












- **Floor area :**

| | | **220 kV Double Circuit** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Lattice tower** | | | **Monopod tower** | | | **Monopod versus Trellis in (%)** |
| Height below console | Use | Réf. Tower | Size at GL | Floor area (m²) | Monopod | Size at GL | Floor area (m²) | Floor area |
| 30 m | Low-angle alignment | G4 NT B3x | 6,63m x 6,63m | 48,40 | S2 KNT H6 Y | Diam 1,95 | 3,80 | 8% |
| | Medium-angle anchoring | G4 AS B3x | 7,13m x 7,13m | 55,921 | S2 AS H6 Y | Diam 2,98 | 8,90 | 16% |
| | High-angle anchoring | G4 SOS1 B3x | 7,13m x 7,13m | 55,921 | S2 AS H6 Y | Diam 3,66 | 13,4 | 24% |
| | | **160,24** | | | **26,10** | | | **16%** |

- **Comparison :**

| | Monopod (tubular) towers | Lattice towers |
|---|---|---|
| | Aesthetics | Utilities |
| Location | Suburban areas | Campaign |
| Floor area | Diameter 1 m à 2 m | Carré 10 m x 10 m |
| Installation | ½ à 1 day | 1 sweek |
| Number of pieces | 50 | > 1000 (with bolts) |
| Typical weight | 14 tons (3T à 30 T 90 kV) | 10 tons |
| | Resist Terrorism | No monopods |
| | Vandal-resistant (South Africa) | No |
| | Avalanche-proof (Norway, Iceland) | No |
| Cost of complete line per km (ratio) | 1.25 k€/km | 1 k€/km |

**Key figures:**

- Weight: 7 to 10 times heavier;
- Special transport: 20 m length and heavy load;
- Lifting:
  - large telescopic cranes;
  - damaged by shocks;
  - not possible for remote locations.

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