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Innovative Solutions for Overhead Line Supports

Working Group
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Innovative Solutions For Overhead Line Supports

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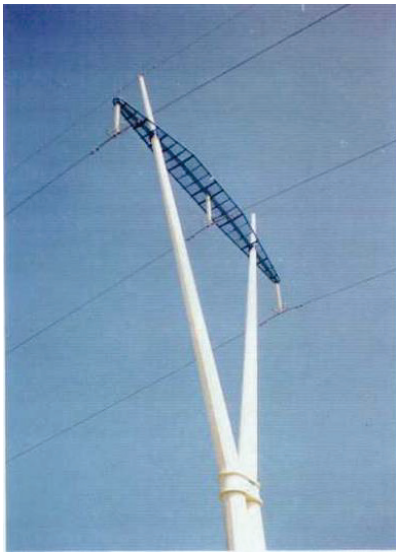

Spain

Working Group

B2-08

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Innovative Solutions for Overhead Line Supports

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The first man to place a log across a stream was probably criticized roundly by his fellow tribesmen for defacing the countryside. Today we proudly show visitors our bridges as scenic wonders-from the stately George Washington in New York to the harp-stringed Golden Gate in San Francisco. When transmission towers are given the same purity of expression given great bridges, they, too, may be acclaimed as Twentieth Century art form.

Of course, there is a difference. We encounter bridges in a personal way: we cross them. On the other hand, our contact with transmission towers is remote. The only thing crossing them is electricity. And so we are conditioned, psychologically, to accept a bridge more easily than a power pole.

The towers shown in this book are both simple and functional in form. Particular care was given to fitting them into their environment. Thus in preparing structures for urban areas, we studied urban surroundings and expressed them in the structures. We devoted similar attention to rural structures.

"SOURCE" Elena Paroucheva

All of us would prefer to place electric power underground or to transmit the power on an invisible beam. But until such techniques prove practical, we hope that the work shown here will serve usefully the dedicated designers and engineers who seek to preserve the integrity of our surroundings.

Henry Dreyfuss
January 1968

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1. INTRODUCTION

Years ago, aesthetics was not a value taken into account in the design of supports for new transmission lines. Towers were not judged as “pretty” or “ugly”; they were just considered essential elements for transmission of electricity. Many thousands of kilometers of transmission lines were, thus, built in all continents, justified by the benefit of the electricity, considered a privilege of modern societies organized in cities and factories with high consumption of energy.

This reality started to change mainly after the 60’s, when the environmental aspects of the lines and the aesthetics of the supports, began to be more and more questioned in the implementation of new designs. These changes can be understood as a result of many factors, such as:

- The existence of thousands of kilometers of lines already built in some countries and/or some regions.
- The evolution of the benefit of electricity, from “a privilege of few societies” to an “acquired right” of the citizens of the twentieth century. Electricity subtly became a “social right”, and an obligation of the governments to provide it.
- 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.
- 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. Nowadays, transmission line projects have to start with an environmental impact assessment, where environmental auditors identify and analyze the impacts on the natural and human environment. New line routes have to find a balance between the need of electricity transmission and the environmental perspectives. As part of these studies, the visual appearance and the aesthetic of the towers began to play an important role in the analysis, once they are the most visible elements on the landscape.

This Technical Brochure, through a research conducted by the Cigré WGB2.08, has the purpose of reporting how these questions have been treated and solved recently around the world. It will also be shown, how aesthetic towers have been used as solution to mitigate environmental impacts.

2. EVOLUTION ON THE SOLUTIONS

2.1 First OHL Tower Aesthetic Studies

The subject of the aesthetic of transmission line towers is not a new issue. During the 60's, designers and power lines engineers had already started to study improvements on their aesthetics.

One of the first remarkable initiatives was the studies reported by H. Dreyfuss & Associates, through a publication of Edson Electric Institute in 1968 [1]. The document contains 47 innovative proposals for Overhead Line Supports with different conductor configurations, with single or double circuits, and using different materials such as steel, concrete or wood. Outstanding aesthetic solutions were suggested, perhaps a little advanced for their time, but with a clear vision of the future (figures 1, 2 and 3).

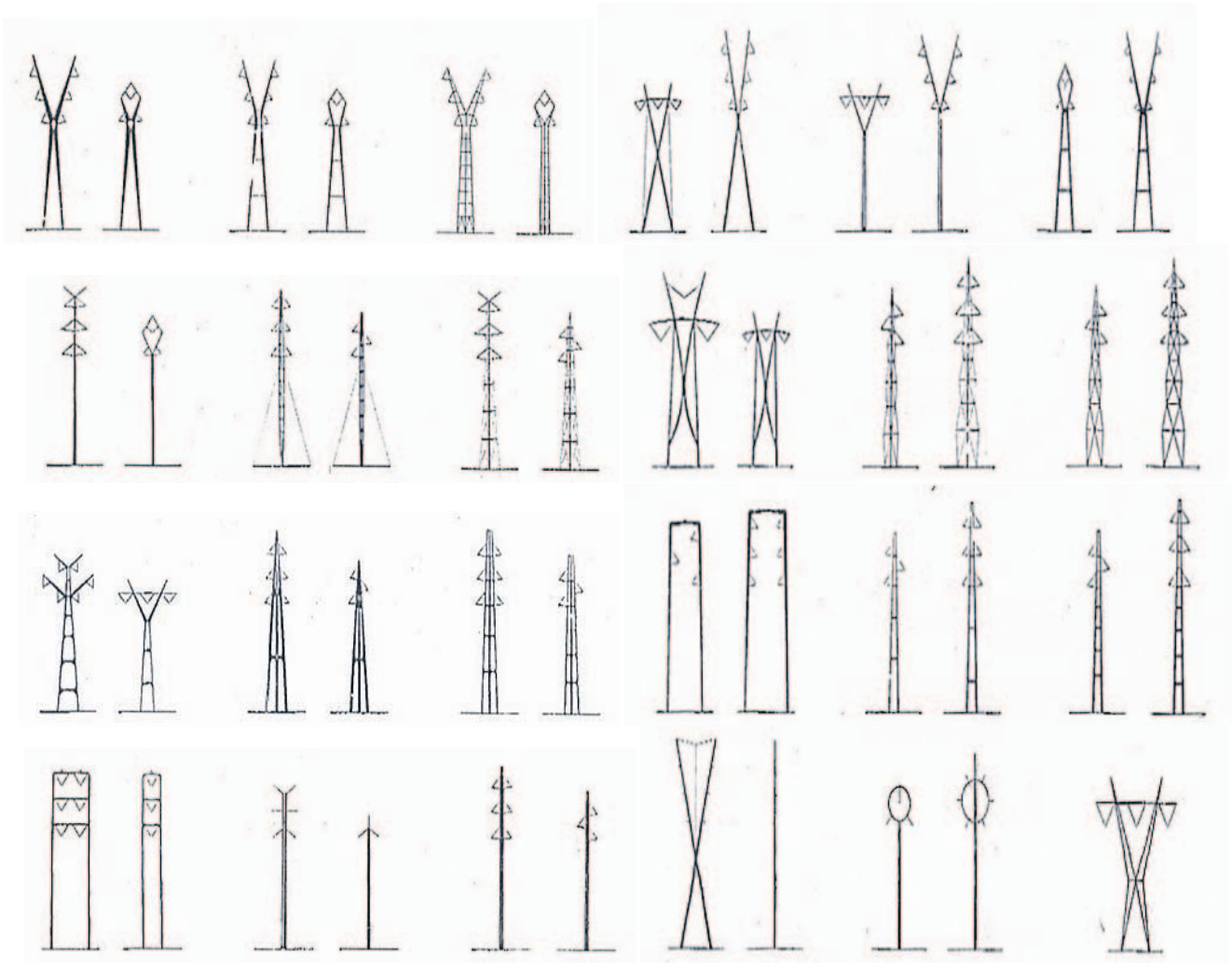


Figure 1 – H.Dreyfuss Pictorial Index

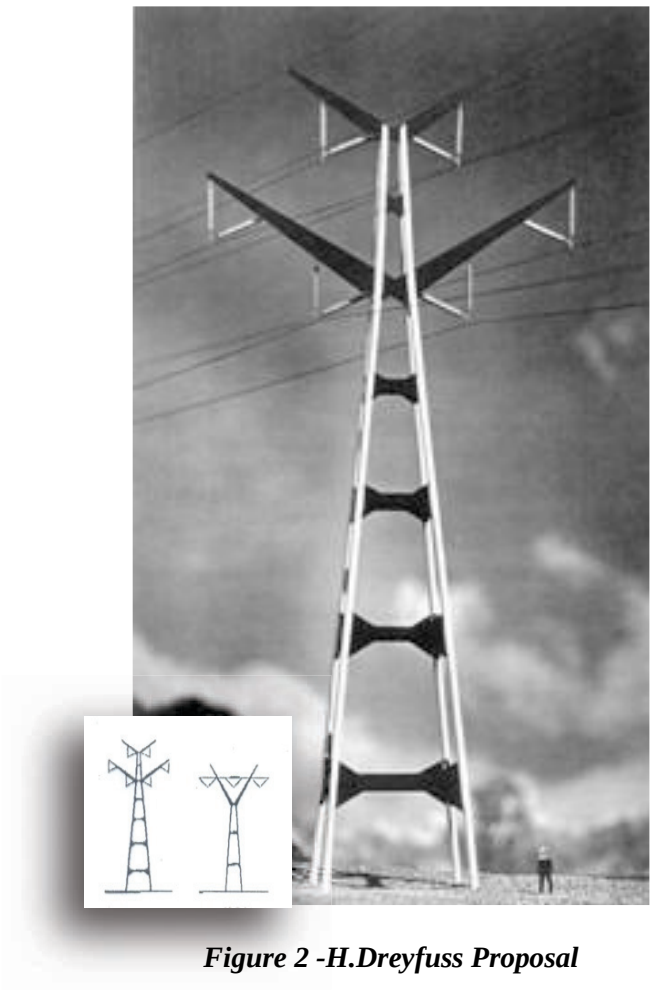


Figure 2 -H.Dreyfuss Proposal

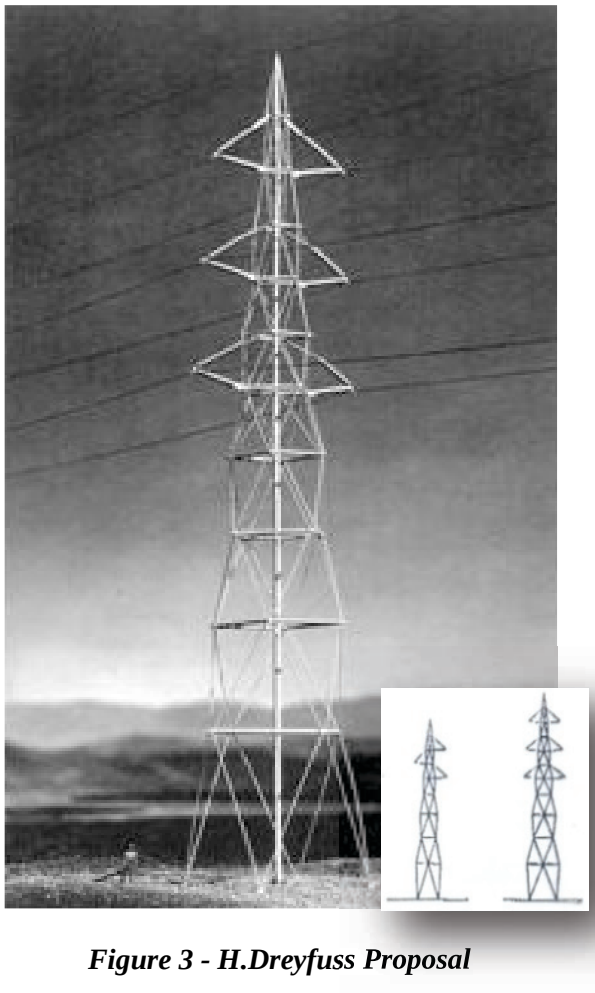


Figure 3 - H.Dreyfuss Proposal

The Dreyfuss' studies were carried out in times when more and more power lines began to cohabitate with citizens and cars on the cities, disputing their urban space. Transmission lines had to bring more power to the downtown of big cities growing vertically, and/or cities expanding horizontally reaching existing servitudes of lines already constructed. For these reasons, in different parts of the world, Utilities have started to think more and more seriously on the aesthetic of the overhead line supports.

2.2 Cigré Studies

Due to the increasing environmental concerns regarding the impact of overhead lines, and consequently the necessity of discussing solutions to mitigate them, the former Cigré SC22, in the beginning of the 80's, created the Working Group 02 focusing on the environmental aspects of the lines. This group finalized its works in 1986 publishing the Technical Brochure "The Environmental Impacts of High-Voltage Overhead Transmission Lines"[2]. Many new ideas and suggestions were presented in that Brochure, showing how it is possible to minimize impact of the overhead lines through creative proposals for land occupation. Later on, in 1999, another Technical Brochure entitled High Voltage Overhead Lines-Environmental Concerns, Procedures, Impacts and Mitigations (Technical Brochure nr. 147), was published by Cigré, enlarging the discussions about OHL routes and corridors, visual impact and mitigation measures[3].

Motivated by the Cigré studies, in 1988, J. da Silva(Cigré former SC22 member) carried out an interesting survey in the Architectural School of the Federal University of Minas Gerais, Brazil, on the environmental aspects of the Overhead Lines. Forty students, splitted in eight small groups, were invited to investigate the visual impact of the overhead transmission lines crossing the outskirts of the city of Belo Horizonte, Brazil, with specific focus on the aesthetic of the towers. The unique demand to them was the visual aspect, the aesthetic, the beauty of the towers, and/or their impact on the landscape. There was no involvement on economy aspects, and no engagement with the necessity of energy transportation.

Eight reports were produced revealing interesting perspectives from the vision of the common citizen, and in this particular case, also from qualified citizens with an already acquired capability of making critical analysis in terms of aesthetic. From this exercise, the following comments were considered relevant, being interesting to be noted:

- *"To be honest, we should assume that we have never paid attention to this matter before".*
- *"In our cities, in general, there are many other constructions that have worse visual impact than the towers".*
- *"From the architectural point of view, the transmission lines are characterized by the presence of the vertical element".*
- *"Concerning the visual aspect of the transmission lines, all attention should be given to the towers. They should be treated as if they were sculptures".*
- *"Looking a little bit closer and paying more attention, we could verify that there are beautiful and ugly towers".*
- *"The towers cannot be ignored in the context: They should be camouflaged or exhibited".*
- *"There are green and brown insulators. The green insulators are more beautiful".*
- *"In special locations in the cities, the towers should be painted with live colors: lemon-green, shock-pink, blood-red, electric-yellow, etc." (Figure 4)*
- *"Some towers could be used to decorate the cities like in Christmas Season by dressing them with chains of lights. Some others could also be used to support cable cars in parks and in other recreational areas". (Figure 4).*
- *"The majority of the towers we found were latticed ones, but there are others from a more compact type.*
- *"From the aesthetical point of view, the most interesting tower we found was that from the compact type with box section like poles! They are slender, having an agreeable aspect and requiring a reduced base area to be settled".*
- *"It is a pity, but we were informed that, as a general rule, the architects don't participate in the transmission line projects".*
- *"A sample of the population should be consulted about the preferable type of towers to be specified. We think that, if they were involved, they could accept more easily the existence of the transmission lines".*

Figure 4 – Architeture School Students' Proposals

2.3 First Initiatives

The first practical initiatives in terms of "aesthetic towers" were not so ambitious and, basically, oriented by the following principles:

- To compact the lines and the supports as much as possible,
- To reduce the number of structural elements on the towers,
- To try to put them invisible or camouflaged in the landscape.

The compact solutions like the monopoles, the portal and V guyed, the chainette and the "cross-rope suspension - CRS", were solutions that have fulfilled with those objectives (Figure 5).
Thousands of kilometers of lines were constructed around the world using these solutions, which aesthetic principles were based on simplicity, slenderness, symmetry, invisibility, reduced number of structural elements, transparence.

Monopole Support
Brazil

Portal Guyed
Sweden

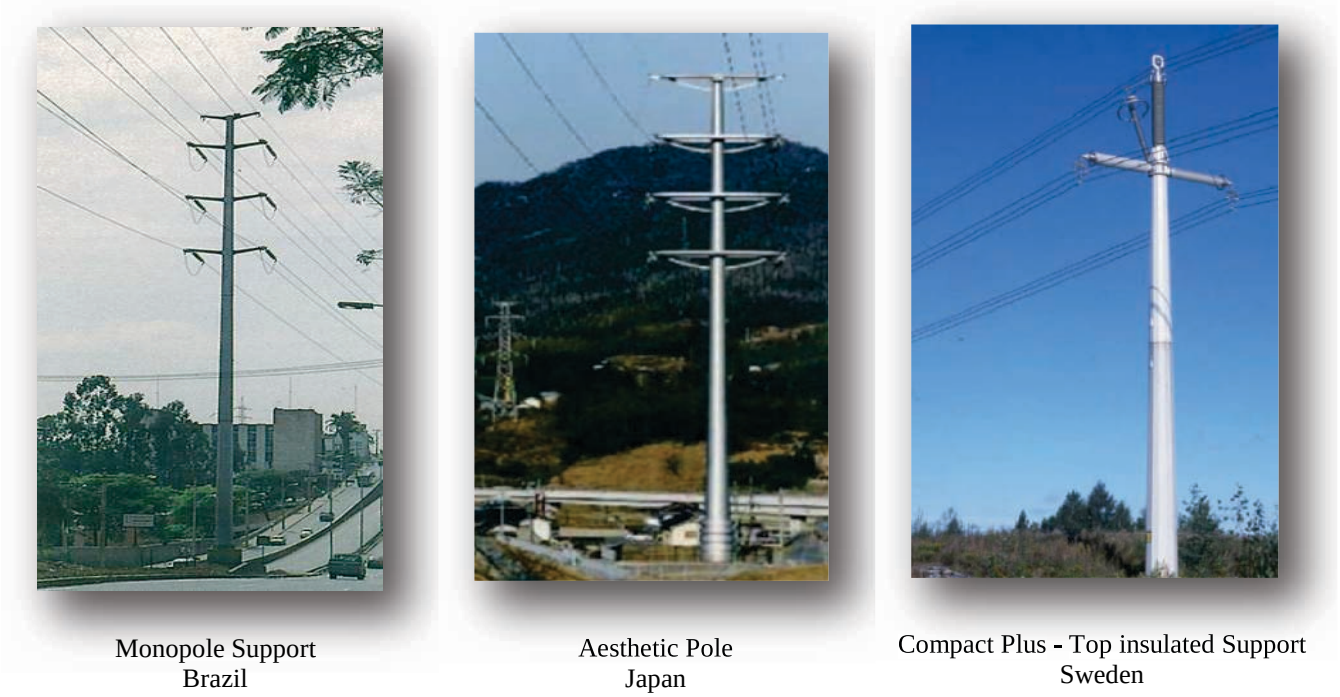
Invisible Cross rope
Argentina

Figure 5 – First Aesthetic Solutions

3. THE OVERHEAD LINE MONOPOLE SUPPORTS

The most attractive solution for urban or suburban OHL towers has been the monopole supports. They have been extensively used in all over the world, having adaptations and characteristics according to local necessities.

There are many reasons for the extensive use of monopoles as the main aesthetic solution. Among them it can be noteworthy: the simplicity, the slenderness, the low visual impact, the elegance, the beauty and the reduced area for settlement. As a summary, they are attractive solutions having appropriate painting system to fit them into special environmental circumstances (Figure 6).



Monopole Support
Brazil

Aesthetic Pole
Japan

Compact Plus - Top insulated Support
Sweden

Figure 6 – Monopole Solutions

3.1 Main Characteristics

Currently, the steel poles are made from carbon steel, mainly from high strength low alloy quality, being shaped in modulus from 9 up to 12m length and with continuously variable polygon cross sections. Depending on the dimensions involved (height and pole base width), the cross section used can be from the square (or rectangular) to the dodecagonal or circular type (Figure 7). The most common joints used are from the “overlapping splices” type, more suitable for suspension or light angle poles. The flanged joints are currently used for the heavy angle or dead-end poles (Figure 7).

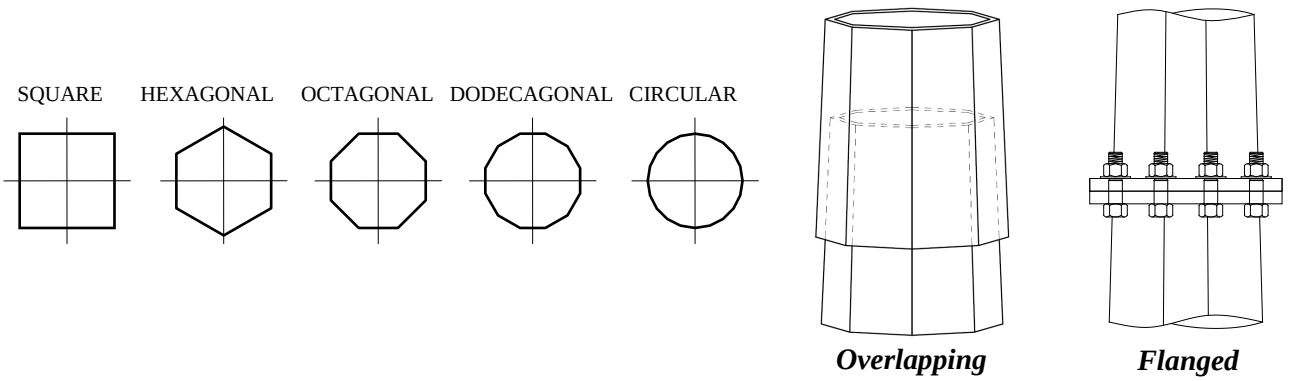


Figure 7 – Typical Pole Cross-Sections & Joints

The finishing types are specified basically to meet two needs: the corrosion protection and the aesthetic. For this purpose, the poles can be only externally painted with complete sealed joints, or hot-dip galvanized. The first solution provides an excellent aesthetic finishing, while the second one excellent protection. Therefore, some clients usually specify both finishing procedures, hot-dip galvanizing plus painting to obtain both advantages. For this, it is mandatory to use an appropriate “shop primer” over the galvanized coating in order to create a sufficient / necessary anchorage surface.

As far as the pole foundations are concerned, they have been constructed using two different principles: the “direct embedment” or the “flanged base plate with anchor bolts”. The directly embedment on densed sand box, is a very economic solution mainly when designed for light suspension poles. The flanged base plate proposal is specially recommended for angle/dead-end poles, since the “two nuts adjustable system” helps to adjust the pole top deflection (Figure 8).

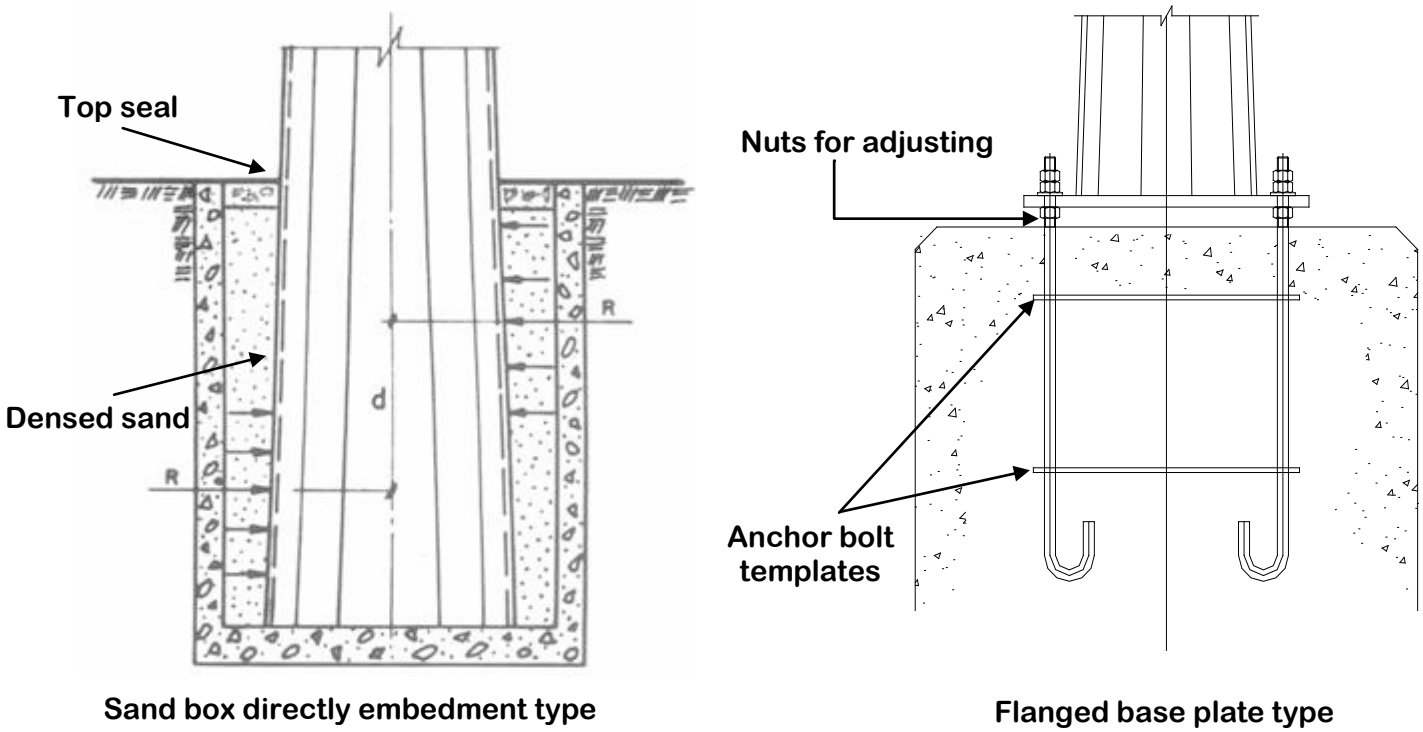


Figure 8 – Typical PoleFoundation Details

3.2 Structural Characteristics

From the structural analysis point of view, it is important to observe that the monopoles are very flexible structures with high level of elastic deformation (up to 5% of the height or even more) especially when compared with similar latticed towers. For this reason, it is recommended that the calculations should be carried out through “physical and geometric non linear” analysis. Second order effects, may be of great relevance in the case of structural analysis for monopoles. To limit pole top deflection, however, can be very expensive. For this reason, to reach both aesthetic and economic targets, it is suggested to verify the pole top deformation at the following stages:

- At EDS condition: maximum top deformation equal or smaller than 1.5 to 2% of the pole height,
- At Ultimate Stage: 4 to 5% of the pole height.

Figure 9 illustrates how deformable are the monopoles during the prototype tests.

Figure 9 - Pole deflections during Tests

4. THE CIGRE WGB2.08 STUDIES

During the 90's, the aesthetic of the OHL towers became a real issue in some regions, and the first "landscape towers" were installed. New approaches and techniques were applied envisaging a better public acceptance. Aiming to collect all those new ideas, the Cigré WGB2.08 created a new Task Force entitled "Innovative Solutions for Overhead Line Supports". The main objective of this new TF was to collect all the initiatives around the world on aesthetic towers, and to produce a Brochure that could be a reference book. Contributions were received from 17 countries: Australia, Brazil, Canada, Denmark, Finland, France, Iceland, Italy, Japan, Norway, Romania, South Africa, Spain, Sweden, Switzerland, United Kingdom and United States(Figure 10). All contributions were equally received as innovative and aesthetics. An interesting databank was created showing the great variety of aesthetic solutions adopted in different parts of the world. The solutions collected can be seen on the Annex A attached to this Brochure.

Figure 10 – SCB2.08 Country Contributors

5. ADVANCED INNOVATIVE SOLUTIONS

Analyzing the solutions reported on the data bank, it could be identified that the so called "aesthetic proposals" already adopted by the Utilities, follow three basic principles: to design aesthetic solutions for unique places, for a single line, or standard aesthetic solutions. Examples of these trends can be found, for example, in Finland, in Denmark and in France.

5.1 Solutions for unique places: The Finnish Experience

In Finland, there are good examples of unique tower solutions for specific places. The first landscape towers were constructed in the early 90's by Fingrid Plc, the national grid operator in Finland. The company wanted to get better public acceptance for the lines and, in some cases, to use them as landmarks in public places. Fingrid hired for that purpose a well-known interior architect, Prof. Antti Nurmesniemi to look at structures from a designer's point of view. The idea of Nurmesniemi was not to hide the towers into the environment but, quite the opposite, to exhibit them. He wanted to show that transmission line structures are not only functionally necessary objects but can also be visually attractive and, in some cases, seen almost like pieces of art.

First landscape towers were installed in 1994, in the Southwest of Finland coast in the city of Turku. It was a series of six towers, the design of which was matched with the gabled one-family houses of the residential area nearby. Colour schemes were inspired by the surroundings (Figure 11).

Figure 11 - 1994: ”Yellow beak” - Hiversalo, Turku. A. Nurmesniemi

Few years later, a multi-level junction in Espoo was provided with a unique landmark and piece of environmental art: a series of three 400 kilovolt towers, referred to as “Espoon sinikurjet” (Blue cranes of Espoo) on account of their blue colour, (Figure 12).

Figure 12 - 1995: "Blue Cranes", Espoo.Studio Nurmesniemi.

After this, towers adapted to the surroundings were erected at the cities of Virkkala (Figure 13), Tuusula(Figure 14), Jyvaskylan (Figure 15), Hameenlinna(Figure 16), Porvoo (Figure 17), Vantaa (Figure 18) and Oulu(Figure 19) [4].

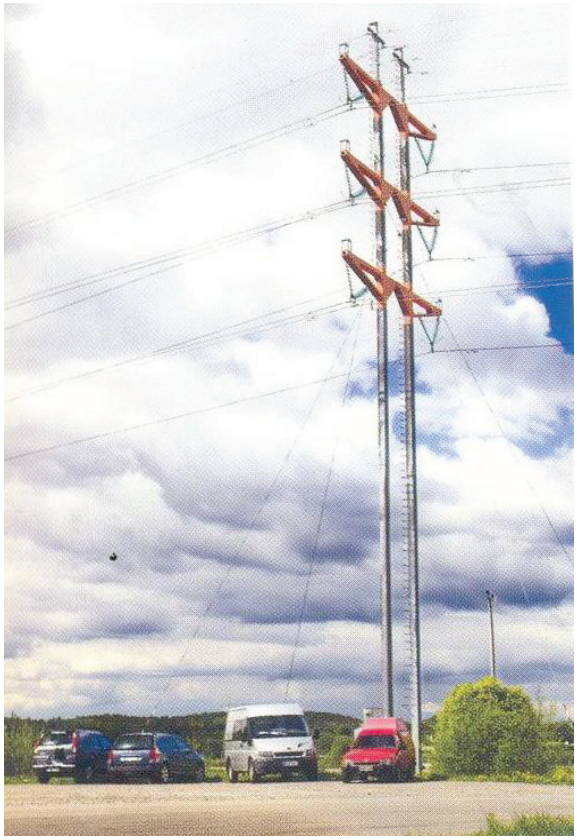


Figure 13 - 1995:Petäjävesi, Virkkala. B. Selenius

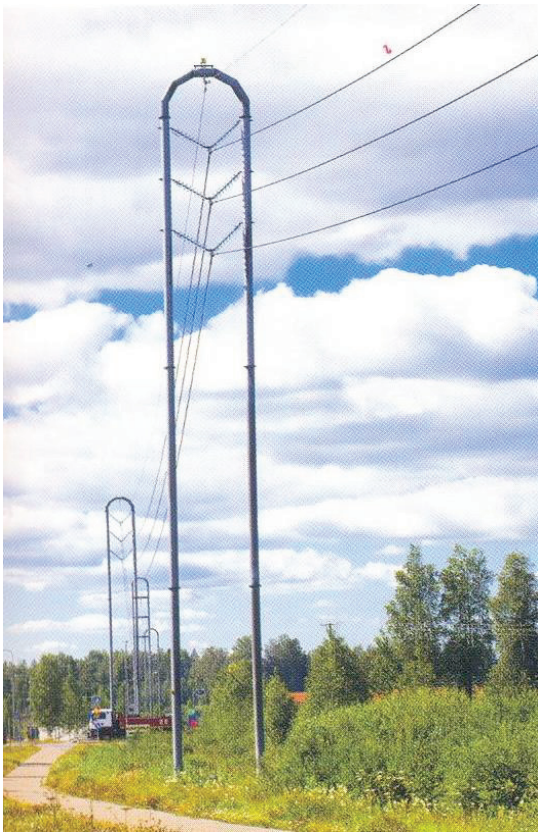


Figure 14 - 1996: Tuusula. IVO Power Engineering.

Figure 15 - 1998: Jyvaskylan, J. Valkama

Figure 16 - 2000: "Antinportti", Hämeenlinna. Studio Nurmesniemi.

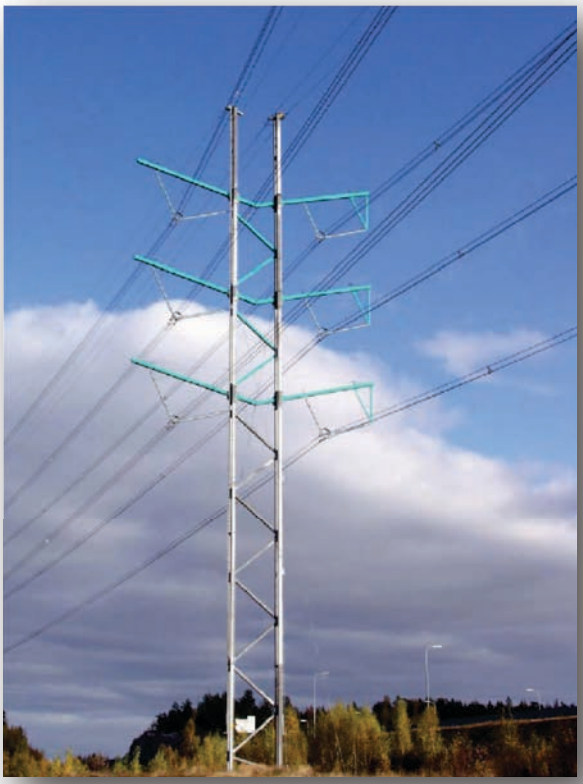


Figure 17 - 2000: Ilola, Porvoo. Studio Nurmesniemi.

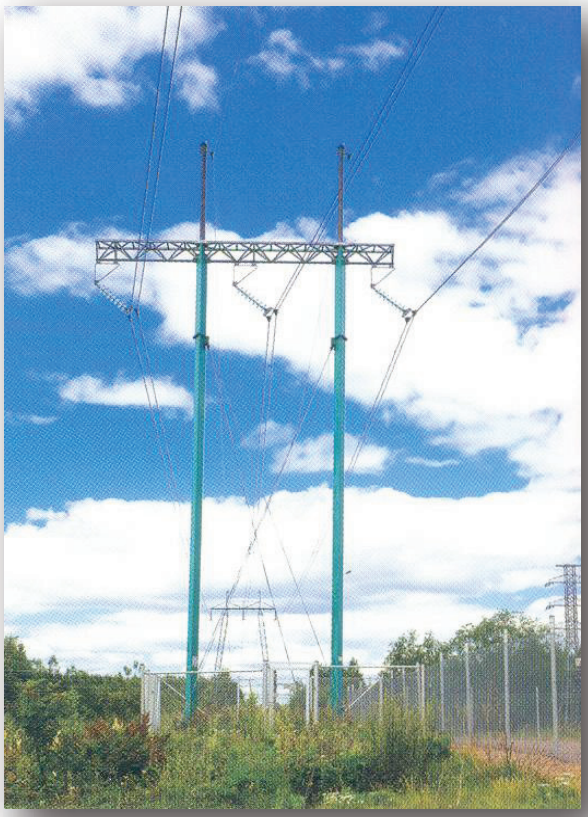


Figure 18 - 2001: Rekola, Vanta,. J. Valkama.

Figure 19 - 2003: Oulu, Kuivasjarvi.

5.2 Solutions for specific lines

The most common approach for reaching environmental friendly power lines, is to propose an aesthetic solution for a specific line (or just a segment of the line) which crosses a sensitive region.
A good example of that, is the 400kV connection line between the cities of Aarhus and Aalborg in Denmark. Another remarkable case is the transmission line Salmisaari-Meilahti in Helsinki, Finland.

5.2.1 The Danish Experience

According to [5], *"Eltra is the system operator for the western part of Denmark and owner of 400 kV grid. In March 2001, Eltra received a license to construct a new 400 kV connection between the cities of Aarhus and Aalborg, finalizing a major 400 kV ring (Figure 20).*
This connection consists of overhead lines (117 km) with intermediate sections of underground cables (14 km). A minor part of the connection (27 km, shown on the map in green) is placed going through a rural area with few technical installations. For this part the Danish Minister for Energy decided to demand a new type of tower based on a design competition.

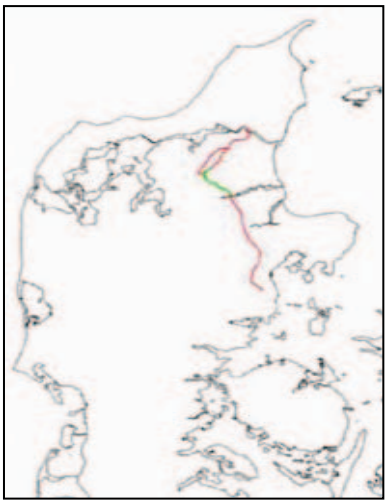


Figure 20 - New 400kV line

Figure 21 - The Winning entry – Erik Bystrup

The winning entry, selected from among 48 entries, was based on a tower with a cylindrical shaft of weathering steel and a tower top constructed as a lattice structure built of very few tubular members, all in stainless steel (Figure 21).

The overall design strategy for the new 400kV tower was to design a tower which, unlike the existing Donau towers, did not add visual "noise or interference" to the landscape. It is a tower consisting of few elements and simplicity in the design. A tower that would be read as aesthetic, calm, and repetitive elements strolling through the landscape contours. (Figure 22).
To achieve this, a hierarchy on how a technical installation is perceived in the landscape was developed:

- *At a distance, only the body of the poles is visible, standing quietly measuring out the landscape.*
- *A little closer the insulators, the high voltage strings and the lattice top become visible.*
- *Close on the tower the details of the lattice top, the joints, the connections and the electrical components become visible.*

Figure 22 - Transition from Donau- to design-towers

To support this hierarchy a choice of materials for the different elements was suggested:
Weathering steel for the shaft and Stainless Steel for the lattice top (Figure 23).

Figure 23 - The lattice top

Figure 24 - Shafts in the landscape

Thus, in colour and texture the weathering steel becoming to the soil and the Stainless Steel lattice top becoming part of the sky.
Together these materials would strengthen each other giving character to both elements and underline the design strategy.
Due to local public opposition, the weathering steel for the shaft was abandoned and replaced with hot dip galvanized steel. (Figure 24).

The new 400 kV tower accomplishes a variety of assignments in one unique design:

- *Creating a continuous visual appearance, thus,*
- *Minimizing the visual impact on the landscape.*
- *Angle tower capabilities allow a harmonious, ”bent” alignment of overhead line and landscape.*
- *Due to a straight-forward and inexpensive foundation method, the tower leaves a minimal footprint.*
- *Fitting lattice tubes with cast stainless steel joints allows faster in site assembling.*
- *The overall design allows a reduction of the magnetic fields.*

One of the main adjustments of the winning entry was to change the vertical strings to V-strings in order to be able to use the same tower as a suspension tower and as a running angle tower for minor angles, to lower magnetic fields and to achieve a narrow right of way (Figure 25, 26).

The tower head is constructed as a lattice structure of stainless steel tubes welded together. The joints of the tubes are casted in stainless steel. Developing the moulds for the castings and executing the castings were difficult tasks due to the complicated geometry.

Figure 25 - Suspention V-string

Figure 26 - Angle tower

A tower family with 3 types of supports was developed:
- Suspension tower
- Running angle tower for max. 5º deflection
- Angle tension tower for 5 to 45º line angle

A prototype of the suspension tower was constructed and mechanically tested up to 105% of the maximum design loads (Figure 27).

Figure 27 – Prototype under test

5.2.2 The TL Salmisaari-Meilahti, Helsinki

The towers for the transmission line between Salmisaari and Meilahti are located in the sea area in front of the urban Helsinki district (Figure 28).

Figure 28 - TL Salmisaari-Meilahti, Helsinki

The line is 3.5 km long, and it includes nine new towers being 5 of them, the ones located on the sea area, landscape towers designed by Prof. A. Nurmesniemi (Figures 29, 30, 31).

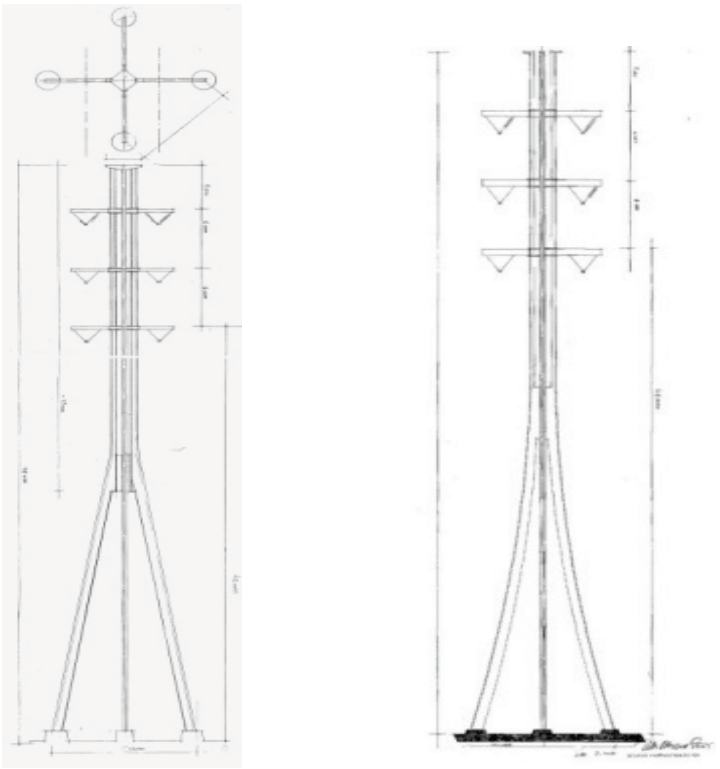


Figure 29 - First pencil drawings

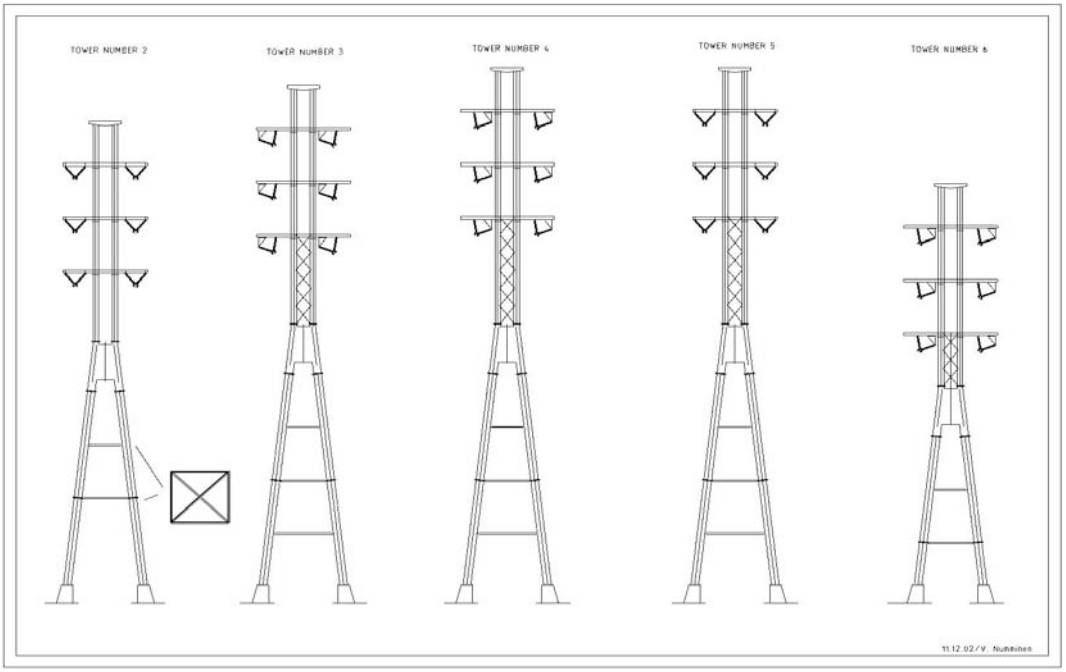


Figure 30 – Tower CAD drawings

Figure 31 - A photo montage of the transmission line

Due to the line's central location, it was the wish of the client, Helsinki Energy, to use these environmentally amenable structures. Design and construction of foundations are generally very difficult in offshore sites. In this line, two offshore towers were based on piled foundations. The longest piles used had 21 m with 610 mm of diameter. The tension capacity was secured by drilling and

grouting the bar (length of 5 m) into the rock. After the concrete hardening, the tension capacities of the piles were tested. The foundations themselves were made in the traditional way: with “pad and chimney” and casting in dry circumstances. In order to keep the water away from the foundation works, and to enable the underwater constructions, a steel coffer was used. A temporary bridge was constructed for moving piling machine and the coffer to the place of the tower. Special attention was paid on the positioning of the anchor bolts (16 pcs/tower leg). The profiles used on the fabrication of the landscape towers were not of a standard type. Suitable manufacturing method had to be chosen. A half oval profile was made from two pieces which were fabricated by using a trimming press. Half profiles were welded together using a submerged arc welding against backing. The maximum length of tower parts was designed not to exceed 12 m (Figure 32).

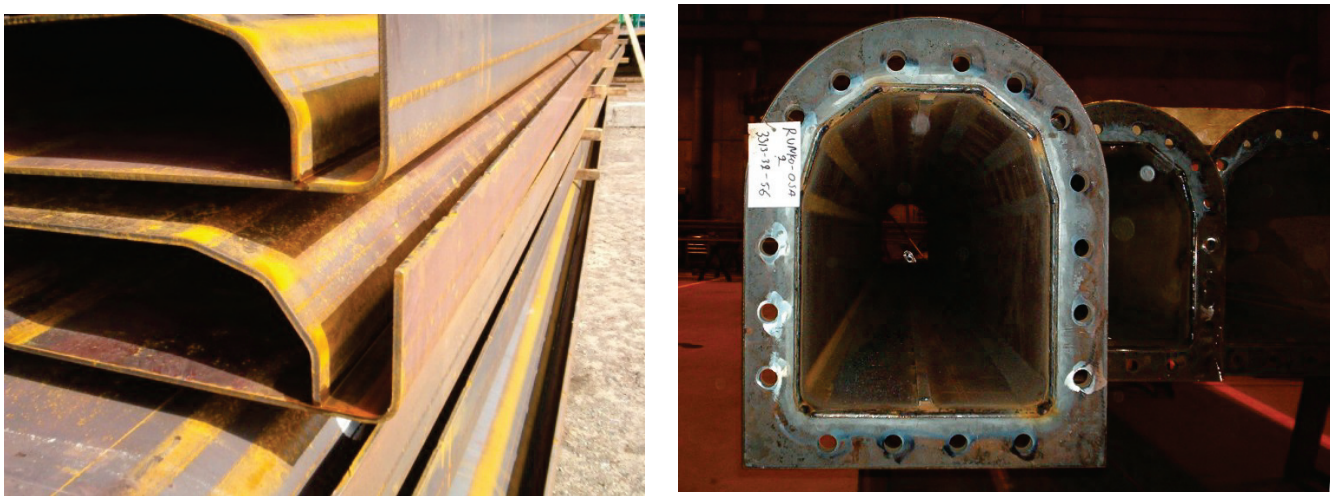


Figure 32 – Towers Manufacturing

The erection of the towers had to be designed in such a way that the weight of the single parts did not become too heavy. All joints between body parts were bolted with flange connections. Special lifting and guiding devices had to be designed in order to get two leg parts assembled together (Figures 33, 34).

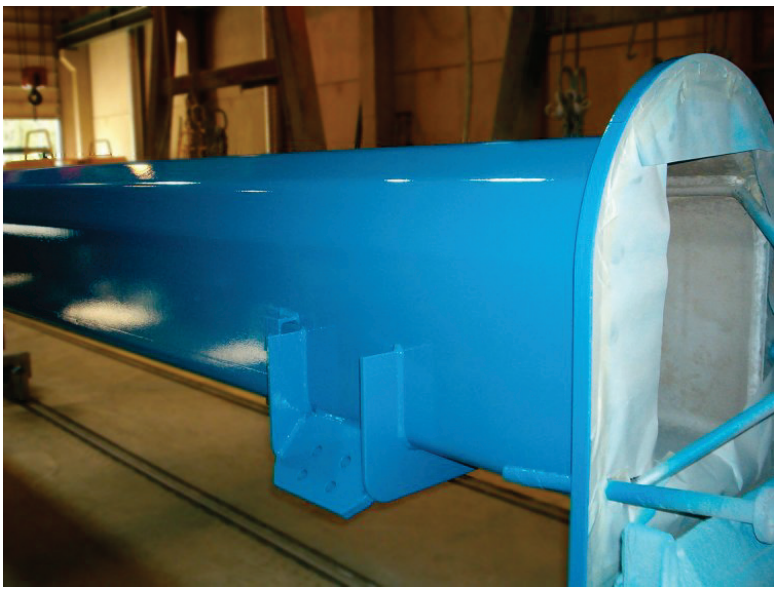


Figure 33 – Towers Finishing

Figure 34 - Body parts Assembly

Upper parts were lifted as single modules while an additional frame had to be designed so that the members could be assembled to body parts (Figures 35, 36).

Figure 35 – The Interesting Result

Figure 36 – Tower Top Detail

5.3 Standard Aesthetic Solutions - The French Experience

To develop “standard aesthetic tower solutions” is one of the approaches used by RTE, the French Transmission Grid Operator, for the integration of Overhead Lines into the environment. Aiming to reach this objective, RTE has promoted two experiences for development of innovative supports: the architects and the tower manufacturers design competitions.

The first architects design competition was carried out in 1994 and had, as main target, to develop standard aesthetic solutions for 400kV Overhead Line Towers, to be used when and where it would be necessary. As per [6], the specifications were very limited without any restriction, for example, to the selection of materials to be used or phase arrangements. The only exception was the attendance to the electrical clearances. The objective of this first experience was to give, as much freedom as possible to the creativity of the designer. In most of the cases, the proposals were made by architects in association with technical engineers. At the end of the process, eight competitors were selected among 121 candidates and two winners appointed. The jury was composed by RTE representatives, as well as members of the fields of architecture, design and environment. The competition process lead to the definition of two standard aesthetic tower families: the “Roseau (reed)” and the “Fougère (fern)”.

The “Roseau”, designed by M. Mimram, is a slender structure, exploring the verticality of the support element. An original technology was used based on open-work modules of casting material for the lower part of the tower (Figure 37). Eleven Roseau type towers have been installed in France so far.

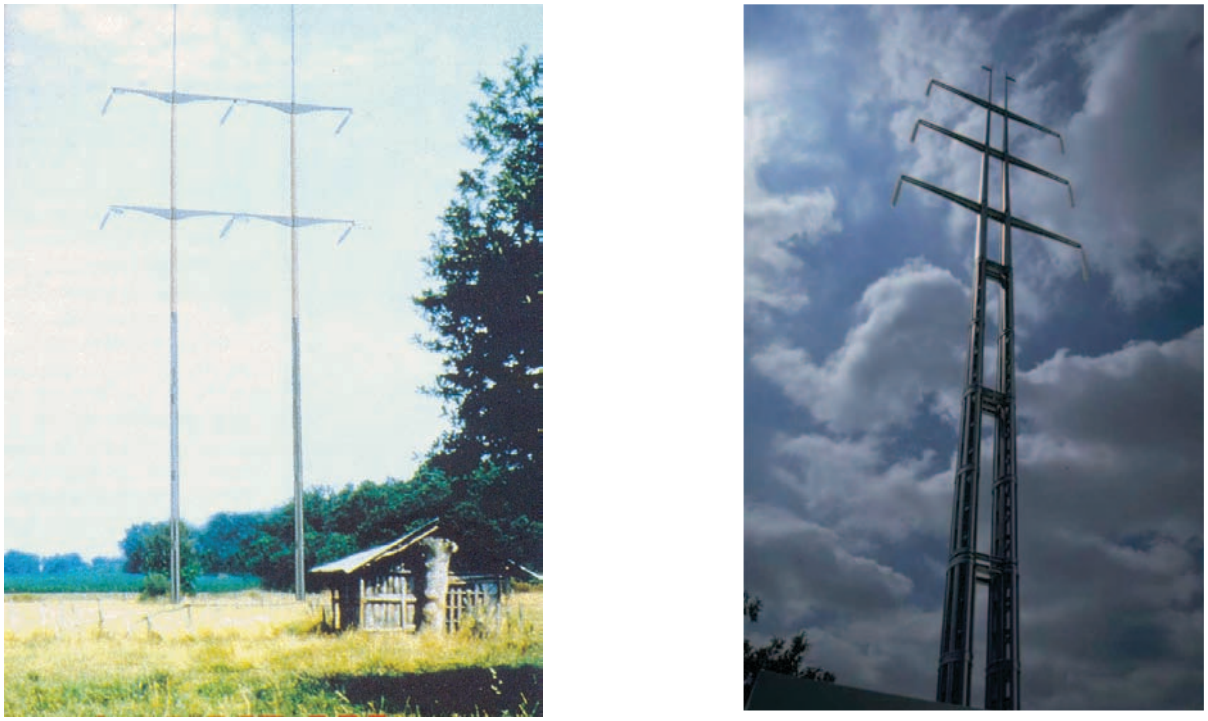


Photo montage ***Real***

Figure 37 - The “ROSEAU” Tower – M. MIMRAM

The “Fougère” type support was designed by I. Ritchie and K. Gustafson (RFR Architects), and consists of a tube tower whose originality lies on the distribution of conductors in a horizontal position spread over two independent structures in the shape of an “f”. In this solution the architects were looking for a very pure form (Figure 38). Two Fougère towers have already been installed in France.

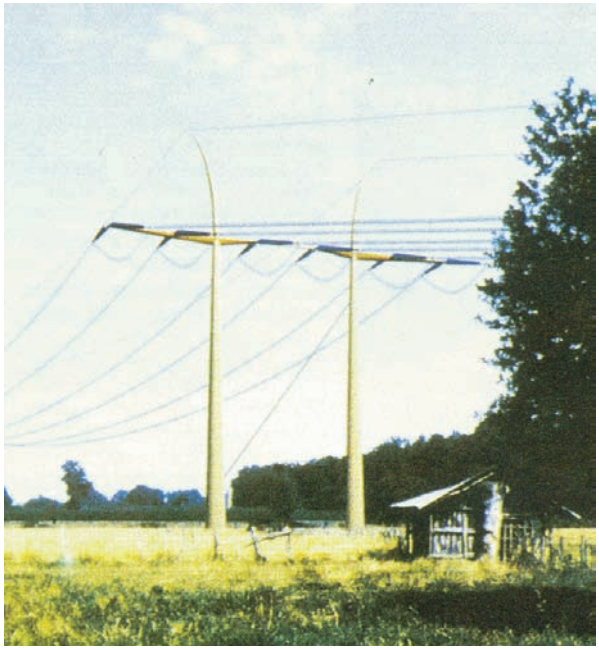


Photo montage

Real

Figure 38 - The "FOUGERE" Tower - I. Ritchie, K. Gustafson

The main advantage of this first RTE experience was the great innovation in shapes obtained. As disadvantages, it can be appointed the difficulty to transform a concept into industrial product, the time taken for development and tests, and the high costs involved. All these lead to limit the use of that aesthetic towers to exceptional sites.

The second experience was proposed only among support manufacturers and performed along 2004/2005. Differently from the architects' competition of ten years ago, in this case, the functional specifications were more restrict. It were defined the position of the phases, the number of circuits (single or double), the materials to be used and suggestions of silhouette. The main objective of this experience was to obtain a tower design on the basis of technical solutions, thus, avoiding industrialization difficulties. This way, the proposals were expected to come from the industry, either OHL manufacturer or pylon suppliers. The advantages of that procedure were basically the use of tested/existing solutions, with little industrialization difficulties, reduced development times and at reasonable costs.

The main disadvantage, as compared with the architects' competition, is that, the creativity is reduced and, as a consequence, the innovation is much more limited, resulting in shapes and formats more traditional. With this procedure, a new wood support was developed for using in the 225kV OHL of RTE named as "The Arverne". The prototype tower was a proposal from Transel - Linuhonnun team, and 78 pylones were installed in France in 2005 (Figure 39).

Figure 39 - The "ARVERNE" Tower - Transel, Linuhonnun

6. OVERHEAD LINE TOWERS INTO ARTWORKS

The various experiences carried out in the world with aesthetic towers were, generally, very successful in terms of public acceptance. Those initiatives motivated the Utilities that had lines in sensitive areas, to expand the concepts and the use of "landscape towers". Since the 90's, slowly, the towers were evolving from OHL Supports to "Urban Electrical Sculptures", as envisaged by H. Dreyfuss' Studies and Da Silva's architecture students Consultation, in 1968 and 1988 respectively (see items 3.1 and 3.2).

6.1 Finnish Sculptures

In Finland, according to [7], "*the transmission line towers designed by Studio Nurmesniemi represent a straightforward design approach. The towers have an important downright vital purpose as a part of the electricity transmission system, and their design naturally stems from proper functionality. In large objects, an aesthetic appearance often means eliminating details; this is also the case with these towers. The towers adapted to their background scenery and to the built-up environment represent technical aesthetics at its best.*"

After the well succeeded first experiences, landscape towers have continued to be designed and constructed. As examples, Figures 40, 41, 42, 43, 44 and 45, show new solutions in the cities of Lempäälä, Vihti, Vaasa, Espoo, Helsinki, Eurajoki, that are really sophisticated sculptures used as towers to support conductors [4].

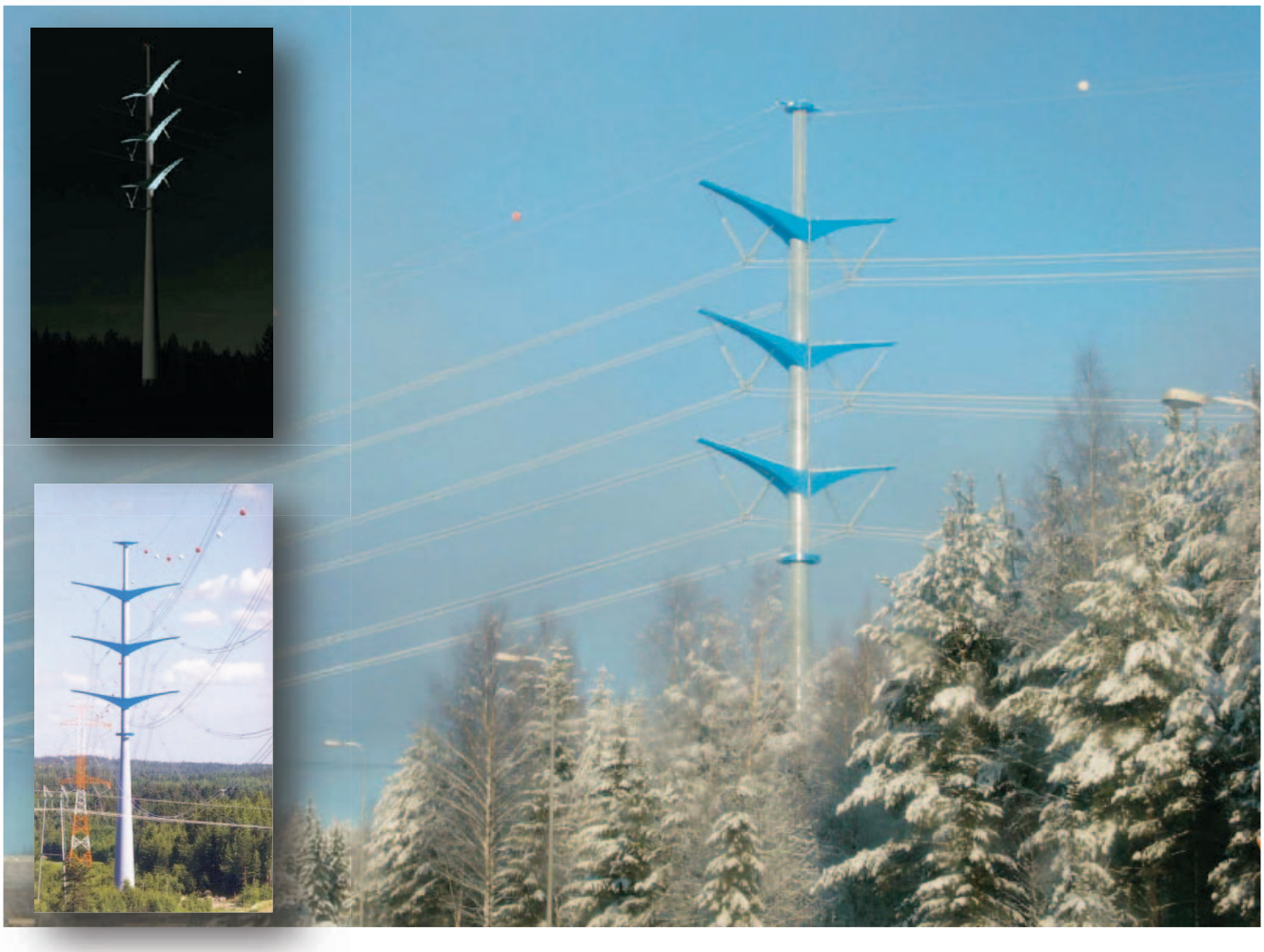


Figure 40 - Lempäälä.Konehuone / J. Valkama

Figure 41 – Nummela, Vihti. Konehuone/J. Valkama.

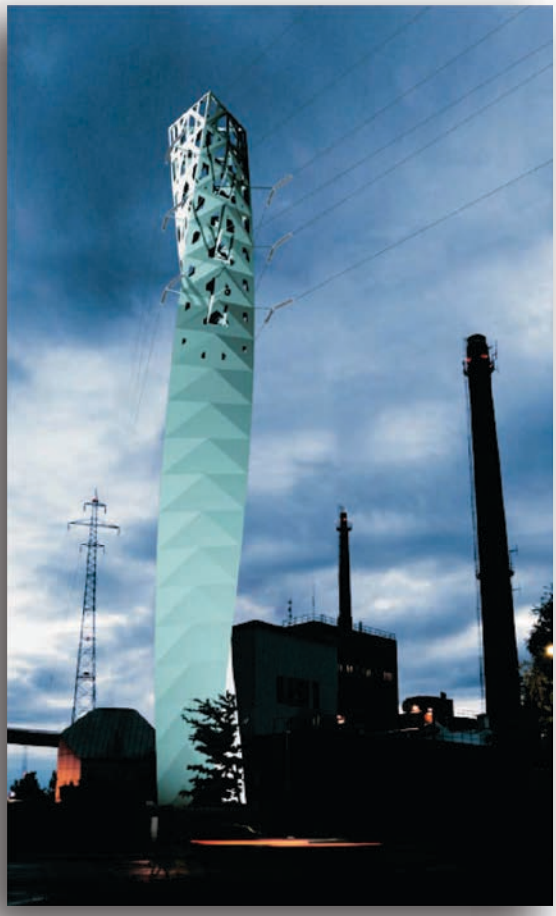


Figure 42 - Vaasa, Palosaari. Konehuone/J. Valkama

Figure 43 - Espoo, Suurpelto. Konehuone/J. Valkama.

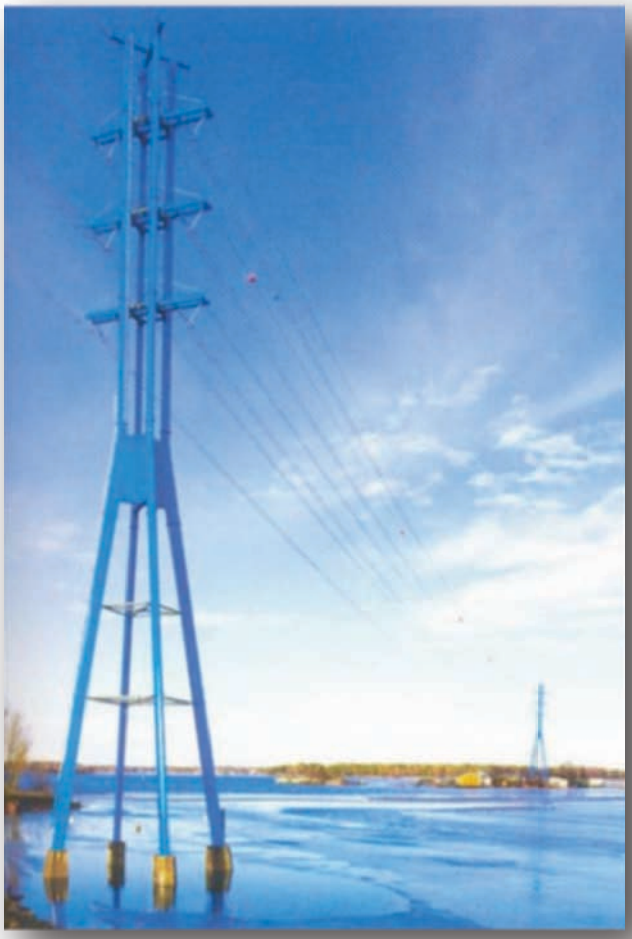


Figure 44 – "Antti's Steps", Helsinki.
A. Nurmesniemi & J. Valkama

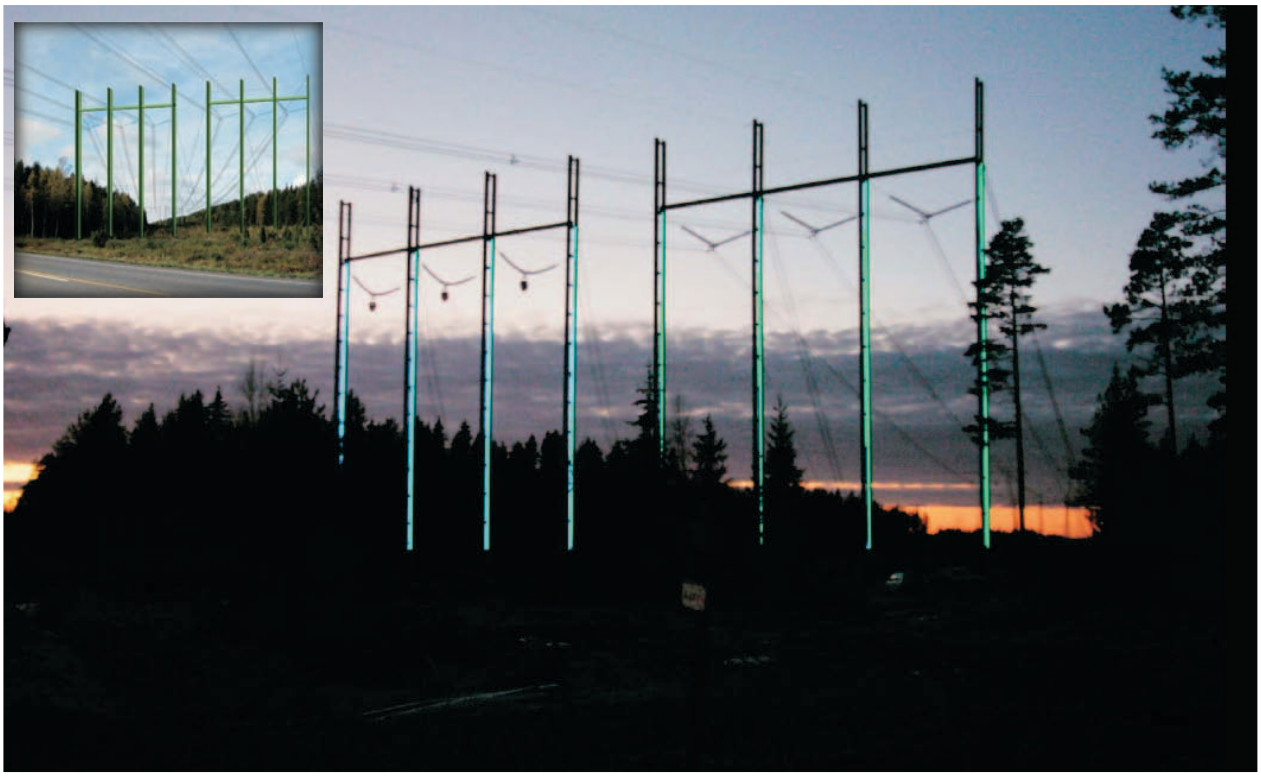


Figure 45 - Eurajoki. Konehuone/J. Valkama.

6.2 French Initiatives

In France, to mitigate overhead line impacts, EDF/RTE has adopted the philosophy of “the best integration into the environment at a reasonable cost”. Currently, such integration is achieved by means of:

- The best route selection for the line,
- Aesthetic towers when necessary,
- Specific paintings or artistic treatment of lattice towers.

6.2.1 Architect / Designers’ Tower Competition

For developing “aesthetic towers”, as seen in item 6.3, RTE has promoted architects/designers’ competitions. As per [6], from the first competition carried out in 1994, when as much freedom as possible was given to the proponents, eight solutions were chosen as most innovative and aesthetics among 121 proposals. The photomontage of them can be seen on figures 46, 47, 48, 49, 50, 51, 52, 53.

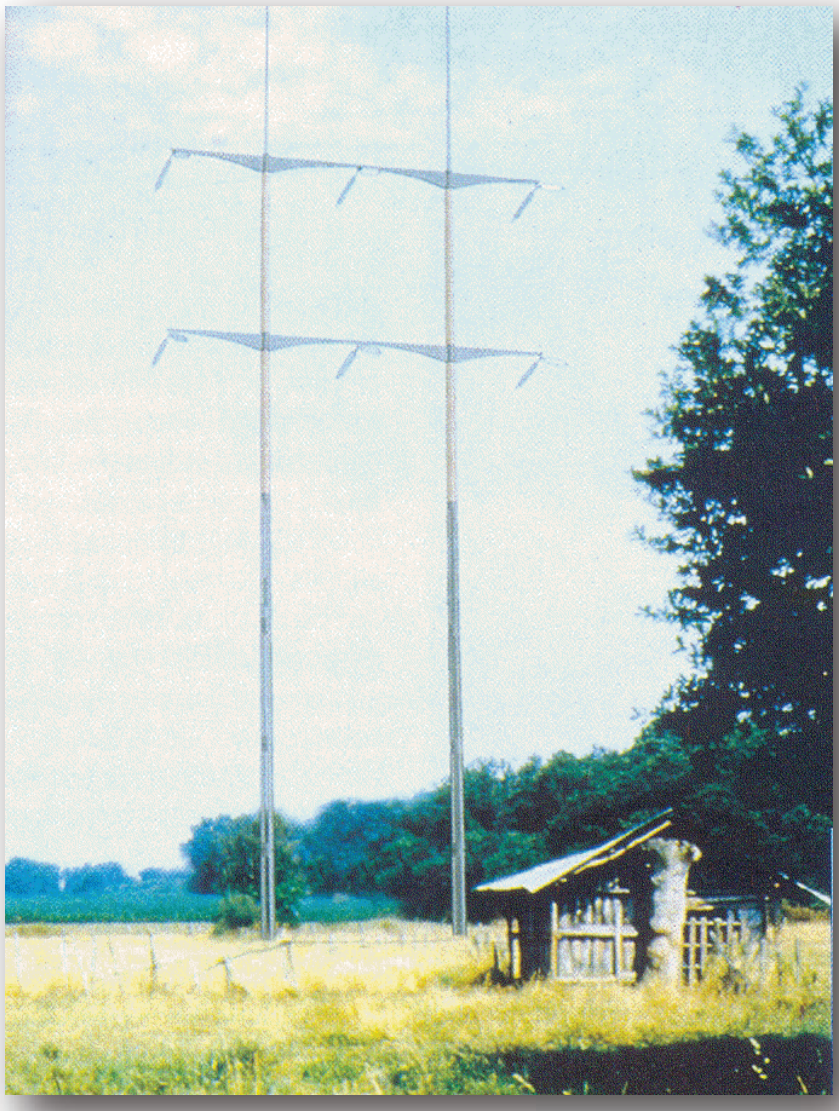


Figure 46 - Well-Thought Reeds.Marc Mimram

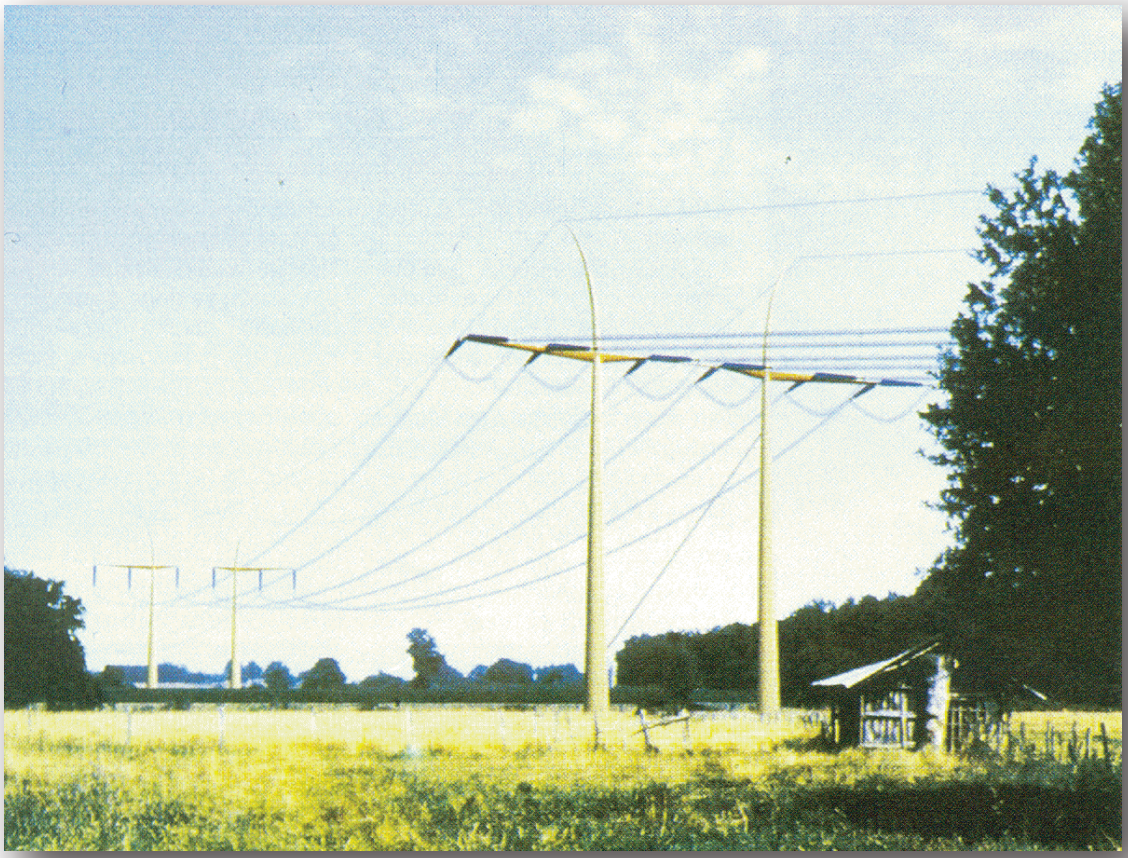


Figure 47 - "f"s All The Way-Ritchie, RFR, Gustafson

Figure 48 - Slender Stabile. Deslaugiers, RFR,Gerpa Team

Figure 49 - "Ecosystem. Wilmotte, Technip, Petit-JeanTeam

Figure 50 - Card Game.Perrault, Ove Arup Team

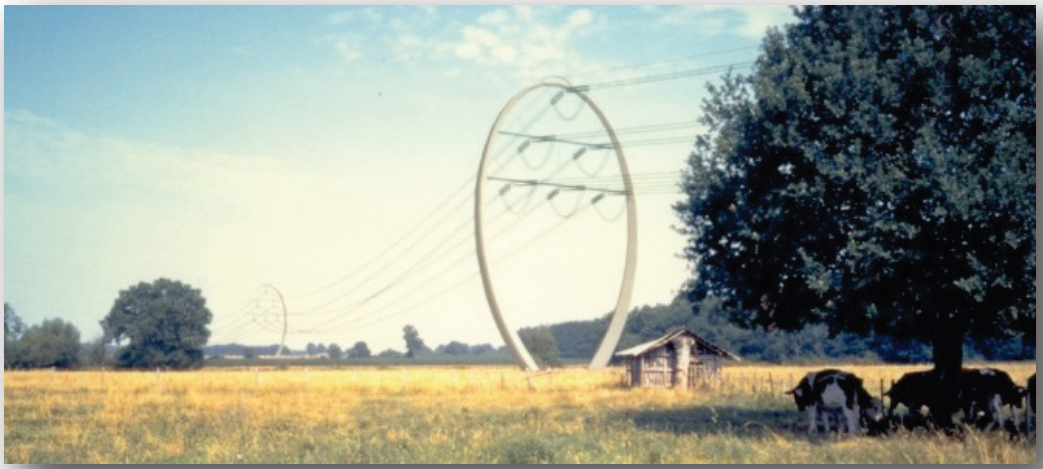


Figure 51 – Swan Neck.Euro RSCG Design,Tallon,Bet Jean Muller International Team

Figure 52 - The Heron Aesthetics.Giugiaro Design Team

Figure 53 – Haute Couture.Starck,Meda, Arsene-Henry and Triaud, de Miranda Team

Looking at these solutions chosen by the Selection Committee, it can be perceived that they are more "sculptures" than towers and, not by a coincidence, at the end of the selection process, the two winners (Figures 46 and 47) were exactly those more OHL Towers oriented. "Artworks" and "Engineeringworks" were side by side on the definition of the "Standard Aesthetic Solutions" in France.

6.2.2 Networks into Artworks

A new technique has been recently utilized by RTE for improving the aesthetic of the transmission Lines: The artistic treatment of lattice towers by Elena Paroucheva.

The works of E. Paroucheva aim at emphasizing the above ground networks such as, energy transmission and distribution, renewable energy windmills, cellular relay–antennas, lighting–highways, stadiums, public spaces, etc. Instead of trying to hide the support elements of these facilities in the landscape, she transforms them into “artworks”[9]. Generally, she applies two kinds of techniques: “Art Installations” and “Sculptures”. The “Art Installations” solutions treat the transformation of existing infrastructures elements or buildings in the environment. They are investigated according to their reception areas and allow the modification of their visual aspect into artistic works (Figure 54).

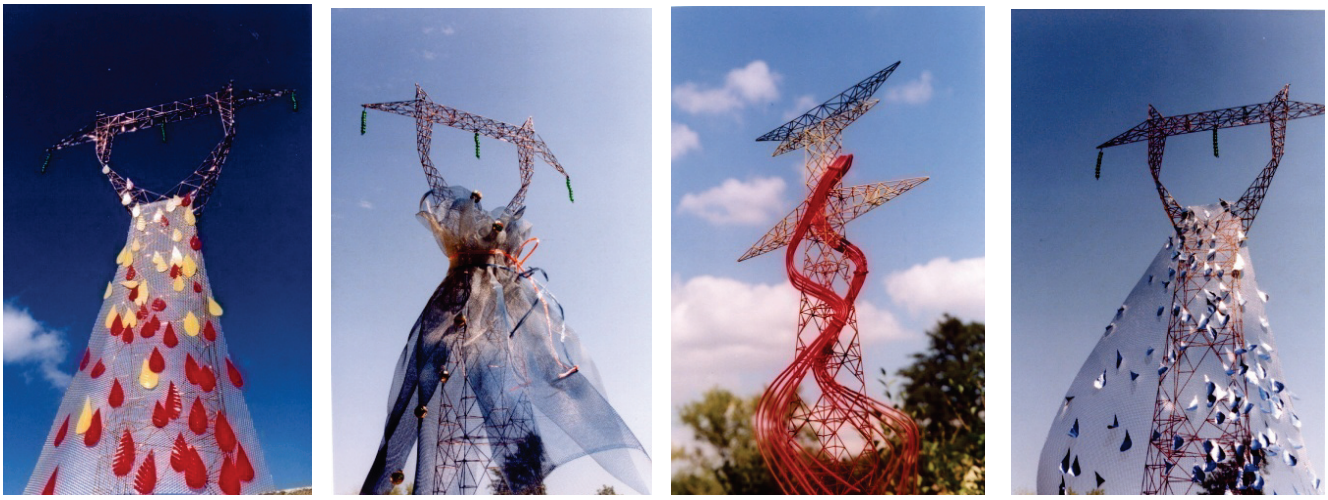


Figure 54 - Art Installations on Overhead Line Supports

The “Sculptures” explore new forms of towers to be implanted in the landscape, in both urban and rural areas (Figure 55).

Figure 55 - Towers Sculptures

The sculptures use "symbolically" the same modules of metallic constructions for the conception of “pylons – sculptures”, “antennas – sculptures”, “wind energy – sculptures” and “lighting – sculptures”(Figures 56 and 57).

Figure 56 - Sculptures- Electric Tower Models

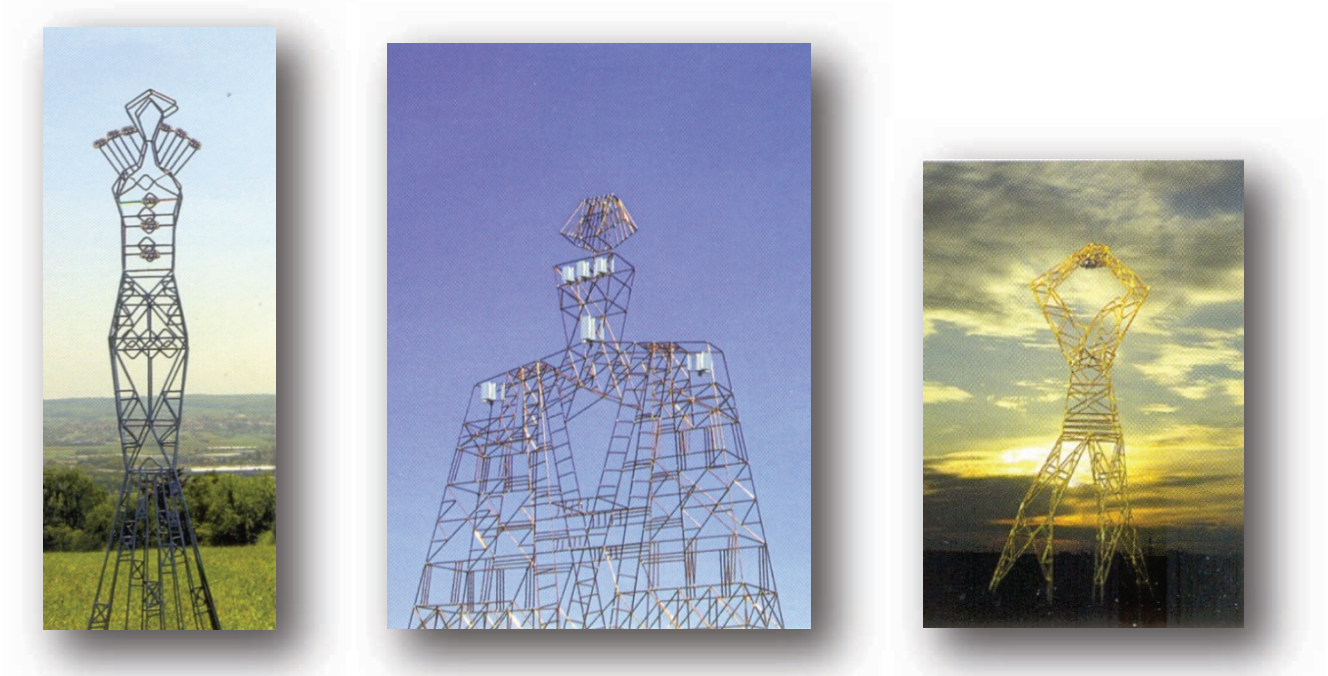


Figure 57 - Sculptures- Cellular Antennas

In the city of Amnéville les Thermes, France (figure 58), "SOURCE", the artwork of E. Paroucheva, has transformed 1.3kms of an existing segment of line into a monumental piece of art[10].
At its inauguration in 1950, the 225 kV "Amnéville-Montois" line, crossed a former heap of steel in Lorraine. Afterwards, a tourist and thermal centre has been developed around the line creating, thus, a complaint from the population and the 5 million tourists that currently visit the city per year.

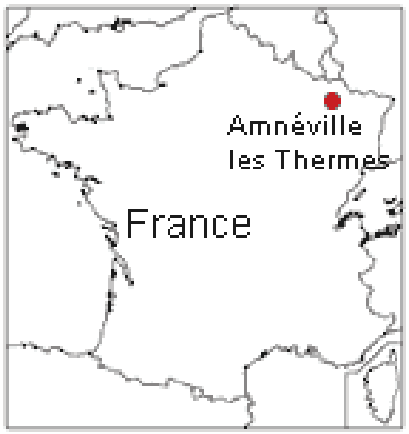


Figure 58 - Amnéville-les-Thermes Location

In 2003, an agreement was signed between RTE and the City of Amnéville-les-Thermes, for the implementation of an artistic treatment of the line. Rather than burying the line and removing the towers, the choice made was exactly the opposite, to highlight them in the landscape. The artist E. Paroucheva was then contacted and her artwork "SOURCE" implemented, transforming the existing transmission line and its 4 support towers in “dressed illuminated creatures” (Figure 59).

Figure 59 – E. Paroucheva’s Studies

The technique has utilized guy wires and stay cables and tubes of stainless steel over the high-voltage structures, comprising 3 km of steel cables, 2.71 km of stays, 525m of plastic canvas, 576m of stainless steel tubes, 384 fixations and 40 floodlights controlled by satellite.

The 4 towers of the segment of line crossing the village, numbers 10, 11, 12 and 13 were nominated, "Source - light", "Source – water", "Source – energy" and "Source - flame" respectively.

The realization of the works has comprehended casting foundations, painting of the pylons, assembling of the guy wires and the dressing of the towers up down to their feet. Each installation has been highlighted by monochrome illumination on the ground, ordered by satellite to illuminate the work at nightfall (Figure 60).

Figure 60 - Erection of the artwork of "Source"

Figure 61 shows the four towers of the "Amnéville-Mortois OHL" before and after they were treated by the works of "Art Installations", while the figures 62, 63, 64, 65 and 66 exhibit the complete works and the results.

Figure 61 - "Art Installations" Works on "Amnéville-Mortois OHL"

Figure 62 – Aesthetic Works on Amnéville-Mortois OHL

Figure 63 – "Source Lumière" – Pylon n° 10

Figure 64 - "Source Energy" – Pylon nº 12

Figure 65 – "Source Water" – Pylon nº 11

Figure 66 - "Source Flame" – Pylon nº 13

6.3 Icelandic Studies

Another interesting initiative that results in outstanding proposals of "electrical sculptures" for OHL Supports, was that carried out in Iceland by Landsnet. Again, this was done through a competition among architect/artist and engineer/designer teams. According to [8], *"the competitors' goal was to look for new types of towers, that would blend well into the environment and, thus, minimize the visual impact that the line towers undeniably have. In addition, emphasis was placed on minimizing electrical and magnetic fields. The Selection Committee has considered that, the majority of the proposals received for the competition, have fully addressed these goals. In addition, the Selection Committee has also found the competitors' diverse approaches regarding the appearance and visual impact of the transport structures especially interesting. The competitors have chosen to either, glorify the towers, or blend them carefully into the landscape and urban areas. It is the Selection Committee's view that both approaches have their place, and the competitors have succeeded well in showing the diversity of possibilities.*

The competitors' goal was to obtain new ideas on types and appearances of a tower or towers for 220 kV high-voltage lines. Landsnet emphasized that specific consideration should be given to the visual impact of towers (or lines), and that the competitors make proposals on the appearance of towers that would take this into account as much as possible, regarding towers or lines both near urban areas and in unsettled regions.

It was left up to the competitors whether all the towers would have a new look, particular towers and selected environments would have a new or altered look, or whether the appearance of known types of towers would be altered, one way or another. In addition, it was left up to the competitors whether the tower/towers were blended well into the landscape in rural and urban areas, or the tower/towers would stand out at specific sites".

The main goal of the competition was that an idea for a new type of tower/towers would emerge, an idea on the overall appearance of line routes, and that a proposal would emerge on a tower/towers that could be developed further with respect to environmental impact, the electromagnetic field, lifetime and costs."

A total amount of 98 proposals were received from different regions of the world. The eight winner solutions (in real order) selected are shown in the figures 67, 68, 69, 70, 71, 72, 73 and 74, where it can also be seen the Selection Committee's arguments justifying their choice.

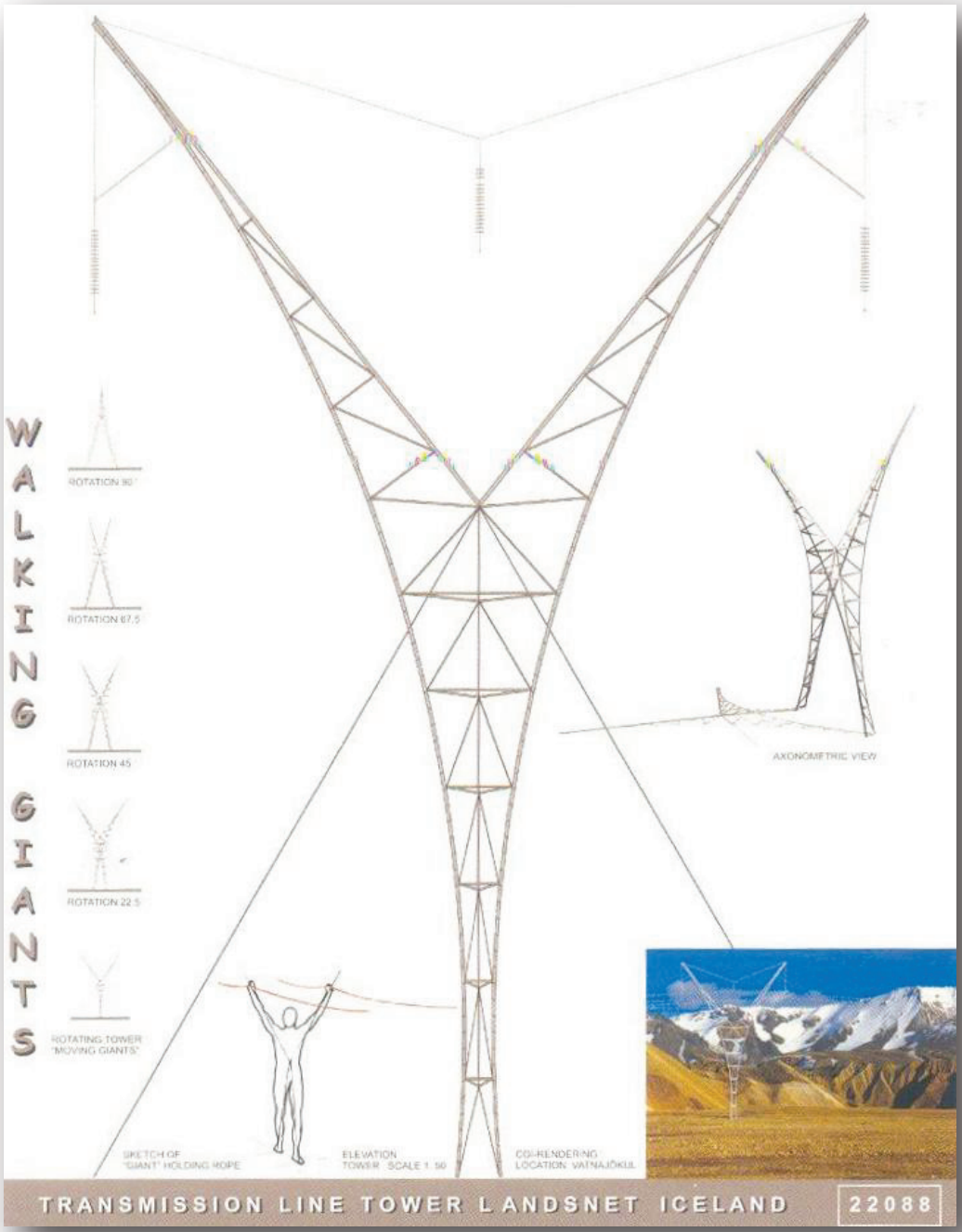


Figure 67 – "Walking Giants" –The Winner

S. Krehn

Comment: Extremely beautiful and living support structure. "The walking giant" takes its basic structure from the human body without becoming particularly anthropomorphized. The beauty springs from utility, but the artistic purpose is not far ahead. The proposal nevertheless suffers from limited installation, which is entirely out of step with the precious content.

Technical opinion: A technically possible solution that needs further development regarding the hanging of insulator suspensions and Guy wires.

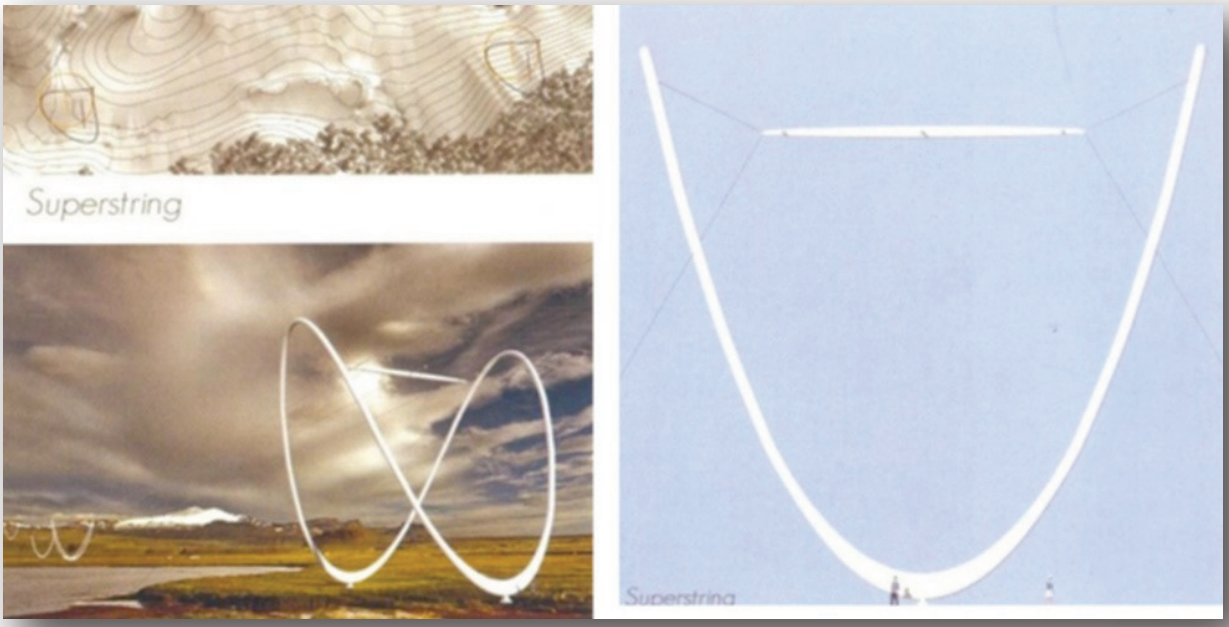


Figure 68 – "Superstring"
Yong-ho Shin
Comment: A very dynamic and innovative form of support structure and extremely exquisite connection between crossbars and the main support structure. These towers are prominent structures with artistic value. The artistic implementation could go well in demarcated areas.
Technical opinion: Technically doable

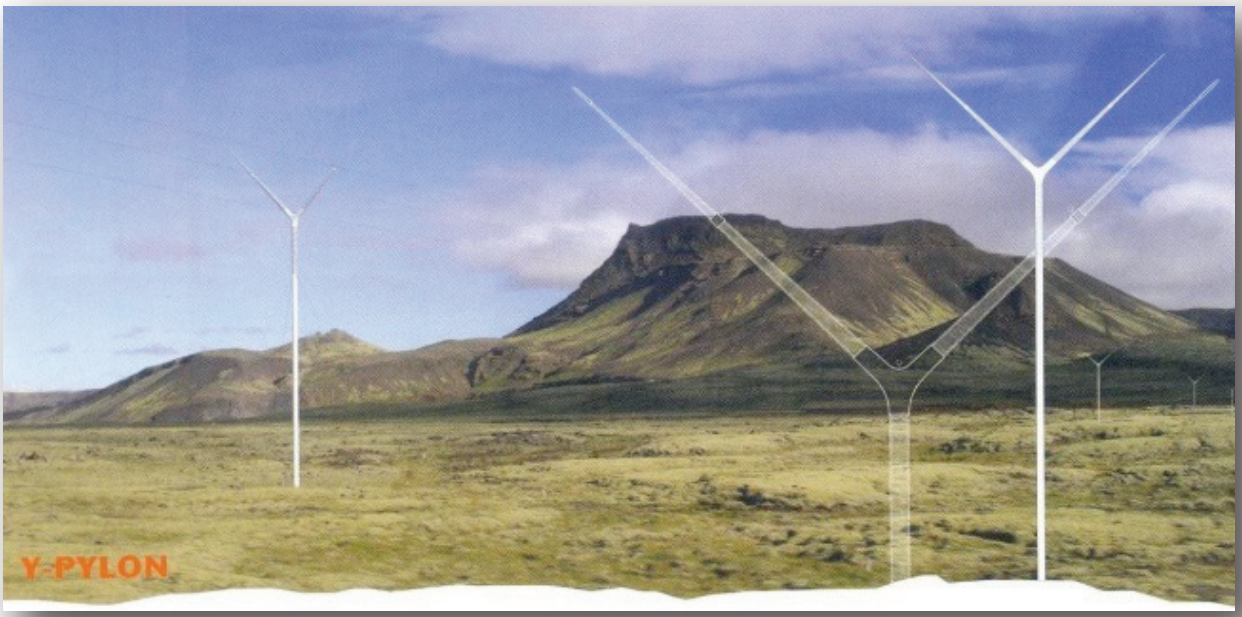


Figure 69 – Landscape Tower Proposal
Bystrup Archtects and Designers
Comment: An especially well implemented proposal. The proposal provides for the insulators being utilized as part of the support structure. Such an arrangement would have a revolutionary impact on the development of high-voltage line towers. Falls technically short regarding implementation of insulators.
Technical opinion: For the tower to meet electrical requirements, the core must be made of insulating material. Today it is not possible to manufacture a sufficiently strong core with respect to the strength required for the stress that must be expected.

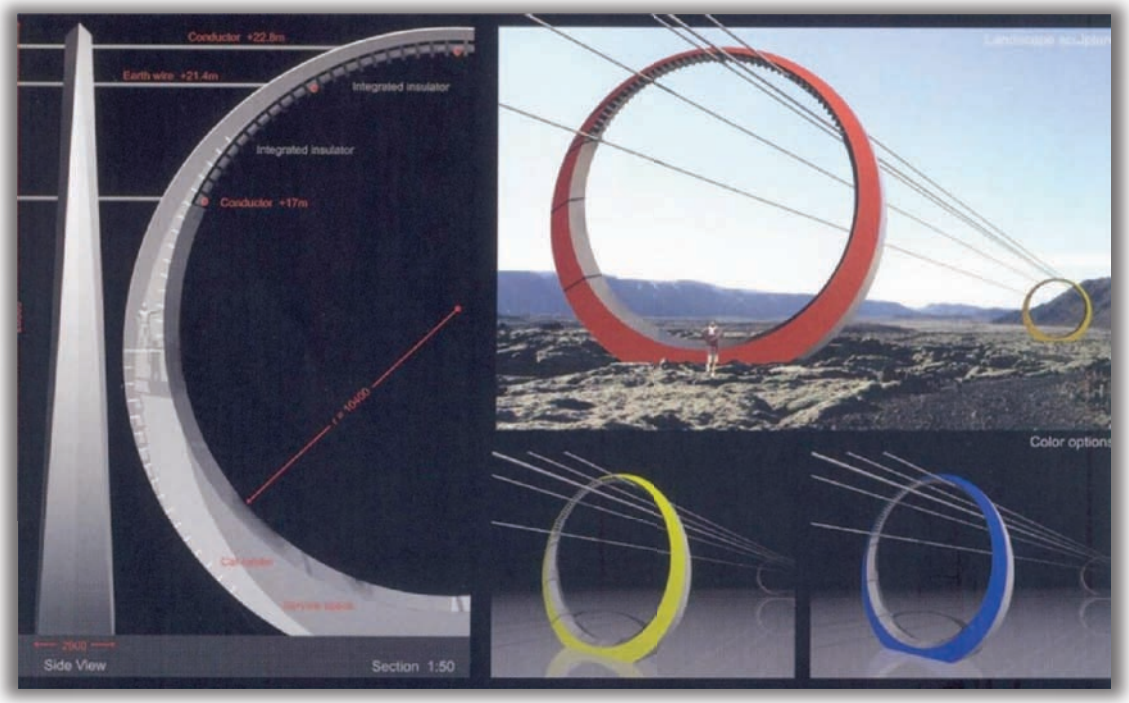


Figure 70 - Landscape Tower Proposal

T. Leung

Comment: Simple, innovative and strong proposal. Offers extensive possibilities for emphasizing line routes in selected locations.

Technical opinion: The insulation system is not realistic and must therefore be further developed as to how power lines go through the tower and are not isolated from it. The support structure also requires development.

Figure 71 - Landscape Tower Proposal

Hornsteinar arkitektar ehf

Comment: Very good presentation. Towers well formulated as a convincing line support structure. It would fit well into the environment visually.

Technical opinion: Technically developed solution.

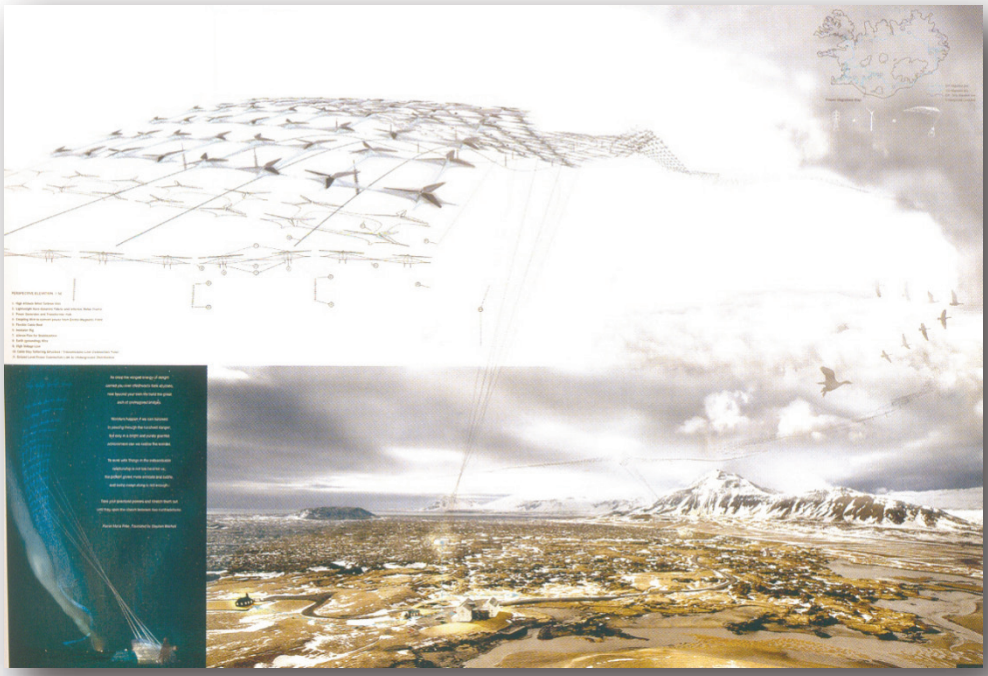


Figure 72 - Landscape Tower Proposal
J. Winchester

Comment: Revolution, vision or science fiction? There is no possibility of orienting oneself to how realistic this proposal is within the time we are given. The proposal is nevertheless admirable, and it is clear that resolving energy and environmental affairs in an idealized oscillation was very much on the author's mind.

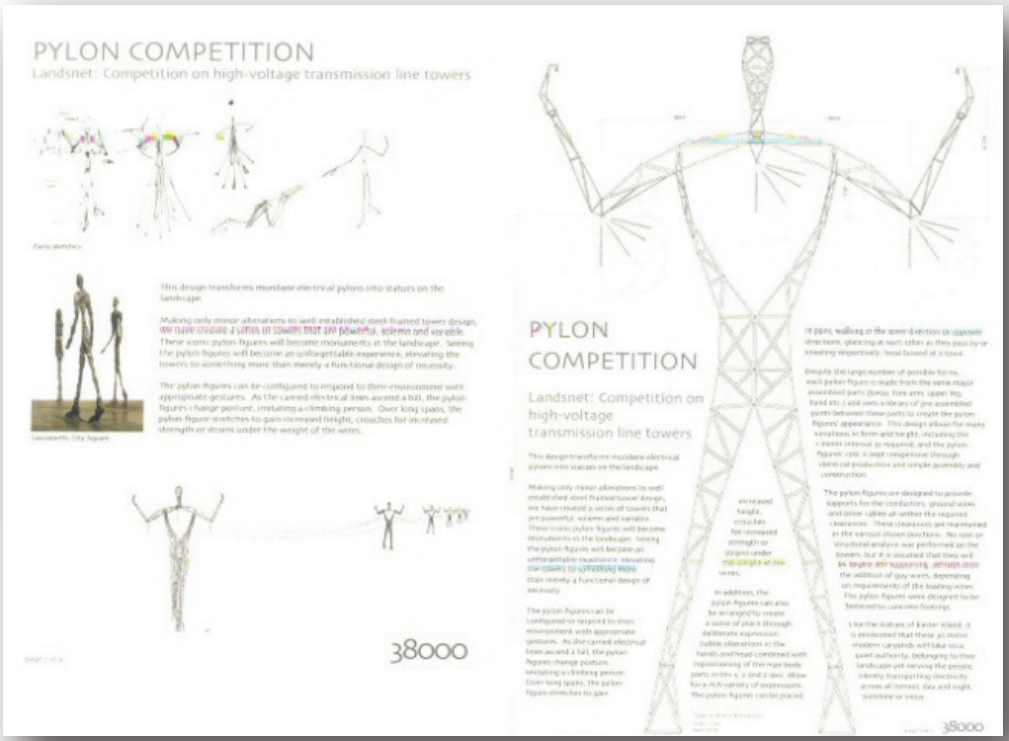


Figure 73 - Landscape Tower Proposal
T. Shine

Comment: An ingenious Idea as a reference to giants in folktales and robots in modern times.
Technical opinion: Technically possible. The support system requires more work.

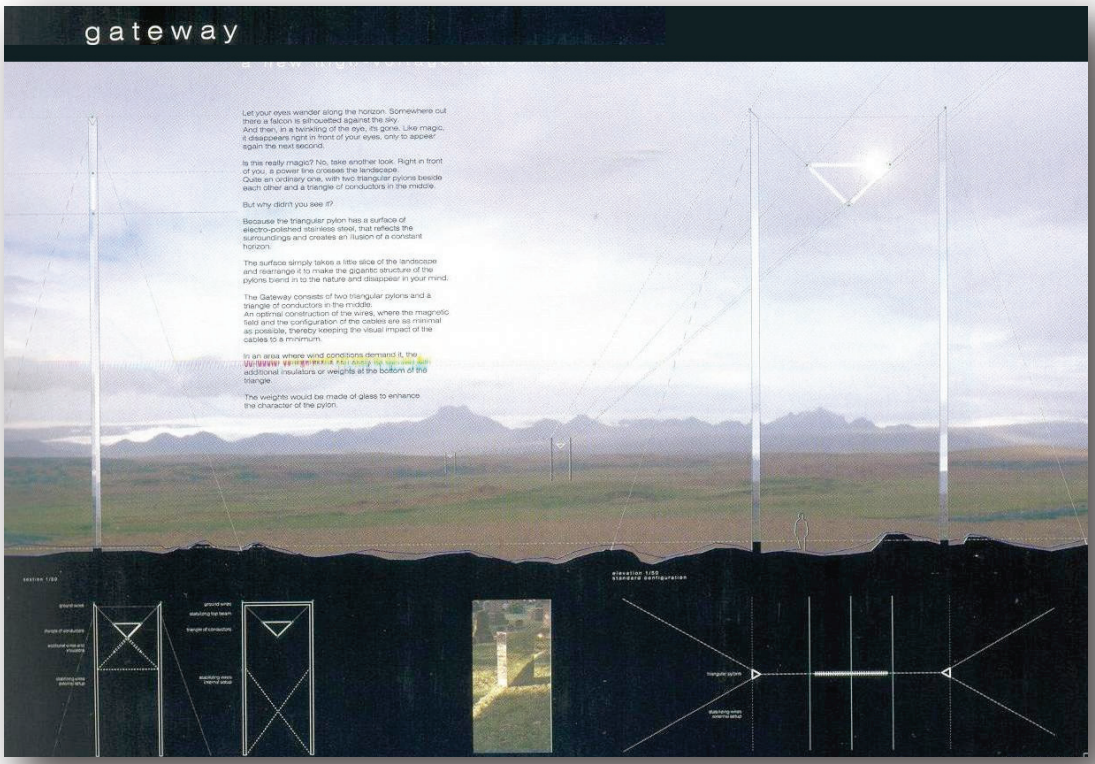


Figure 74 - Landscape Tower Proposal
Bystrup Architects and Designers

Comment: Singularly simple but thoroughly thought-out proposal. Each tower would have a strong artistic impact on viewers, not least at close quarters. The delicate design makes the towers nearly invisible from a distance except perhaps on bright, sunny days when the steel glint.
Technical opinion: Technically possible.

7. ANALYSIS OF THE SOLUTIONS

Analyzing the aesthetic solutions collected, and the arguments justifying them, interesting aspects can be reported. Firstly, it can be observed an increasing environmental concern in almost all new OHL projects around the world. This is valid for short or long lines, and for both, urban and rural landscapes. There are, however, different policies regarding the OHL Lines and the environment in different regions or countries.
In the case of long lines, normally crossing rural areas, cost is an absolute relevant issue which targets of economy cannot, currently, be reached with aesthetic towers. In these cases, premises for environmental friendly supports are, as already mentioned before, the invisibility, the transparence, slenderness, compaction, camouflaged structures, all together driven by cost reduction (Figure 75).

Figure 75 – Tower Solutions for long OHL

In urban areas (or even rural ones sometimes), aesthetic solutions have been more and more been used in different parts of the world, aiming to reach public acceptance. As seen in chapter 6, to achieve this, different policies have been implemented such as to design “unique landscape towers” for specific places, sometimes for a line or a segment, and even to design “standard aesthetic solutions”(Figures 76,77).

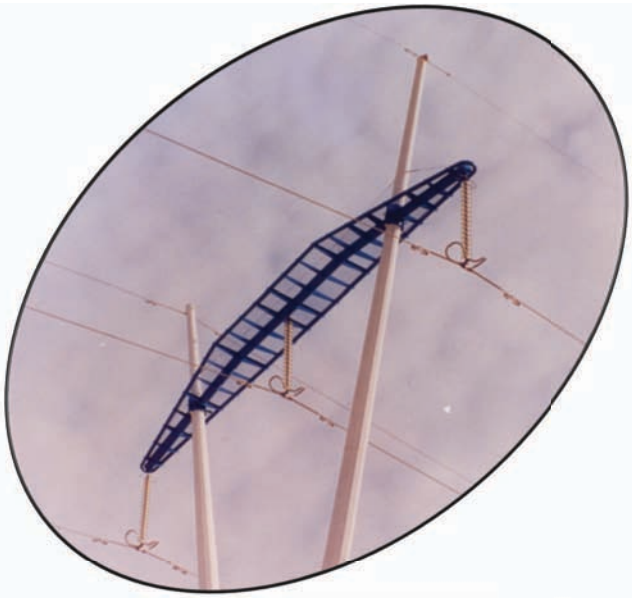


Figure 76 - 1992 Seville Expo Tower - Spain

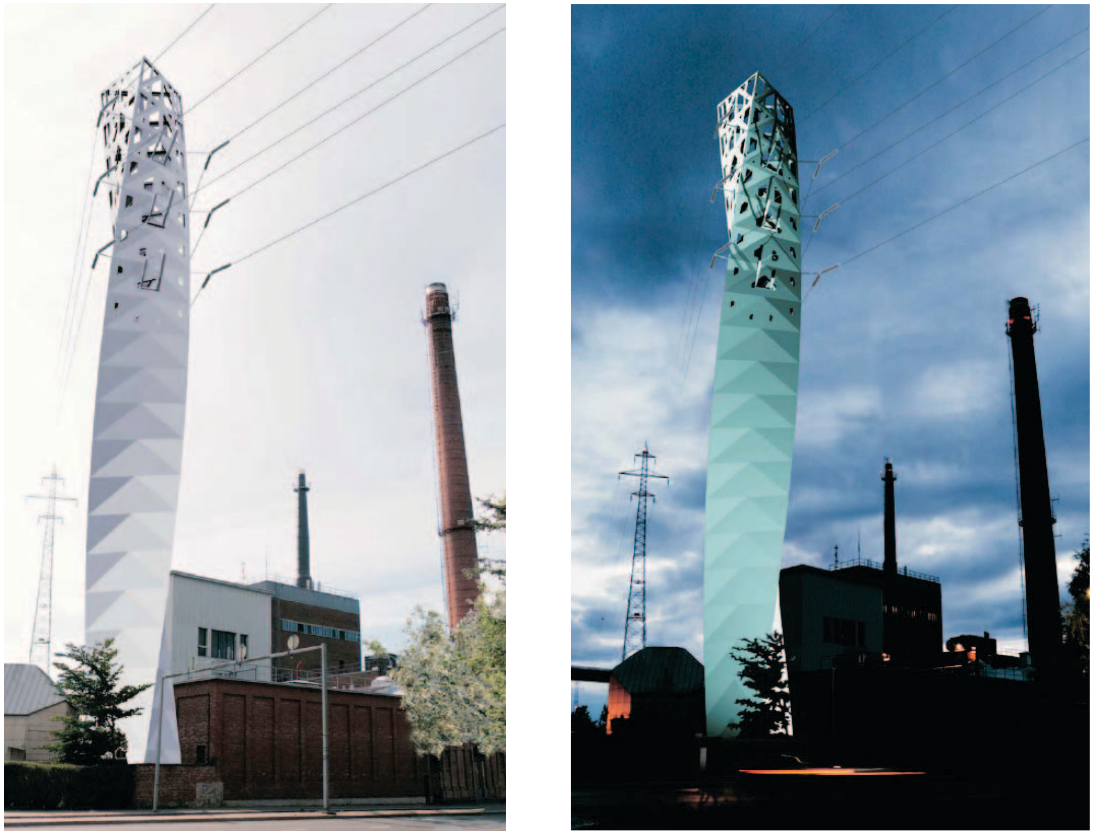


Figure 77 - Vaasa, Palosaari. Konehuone / J. Valkama

For the specific case of the so called “landscape towers”, according to the Finnish experiences, the procedure for reaching desirable environmental needs can be summarized as follows:

- A visit to the site. Special attention is paid on nearby line structures, on space limits, on the place itself and on the height of a new tower. The area is photographed from different angles.

- First drafts are made by the architect. First pencil sketches, then CAD pictures

- A design meeting is arranged with the architect, requester and design engineer. The meeting is held in a cooperative spirit.

- A collective decision for the both technically and aesthetically suitable solution for the environment is reached.

- Design meetings (4-5) are held at different stages of design.

- After dimensioning different manufacturing issues concerning the tower members had to be negotiated with the workshop. Necessary modifications to detail drawings are also made.

- Possible painting colour is defined as well as the need for illumination.

Analyzing carefully the solutions collected around the world, a curious aspect could be observed. Aiming to have public acceptance or to create a familiar atmosphere among towers and people, some solutions are designed envisaging to link them “symbolically” with “icons" of their societies like, for instance, the architecture, the history, the culture, traditional symbols, etc.
As example of such observation, it can be highlighted the aesthetic tower installed in Hameenlinna, Finland in 1999. The city of Hameenlinna, the oldest inland town in Finland, is also Professor Antti Nurmesniemi’s (Finnish design legend 1927-2003) hometown. The geometry of the tower was based

on the city's landmark, Hame Castle, which is one of Finland's medieval royal castles. It is believed to have been built at the end of the 13th century. Some similarities can be seen in the geometry of the

towers, e.g., two pitched roofs of the Hame Castle's fortress tower which are reflected on the surface of Lake Vanajavesi (Figure 78).

The upper part of the tower is painted with ultra marine blue, which links up the tower with the lake and the surroundings.

Figure 78 – Hameenlinna Landscape Tower

The tower was named "Antti's gate" after the designer A. Nurmesniemi's death, and it can be seen from the highway when arriving to the city from the South.

Other good examples of innovative tower solutions linked with "symbols" of the populations or integrated with the surroundings, are the "Mouse Head Towers" constructed in the city of Orlando (Figure 79) and those herein called "The McDonald's towers" (Figure 80) ,both in USA.

Figure 79 – The Mouse Head Tower

Figure 80 - The McDonald's towers

As already shown in chapter 7, another excellent experience focusing on the same objective is the "Haute Couture Pour Pylônes de Haute Tension" proposed by E. Paroucheva for the artistic decoration of the 225 kV OHL crossing the city of Amnéville les Thermes in France. The towers were modeled with illuminated dressing like "top models" for a fashion exhibition (Figure 81). "Towers and art" sharing the same space (Figures 82 and 83)

Figure 81 – "Haute Couture pour Pylônes de Haute Tension"

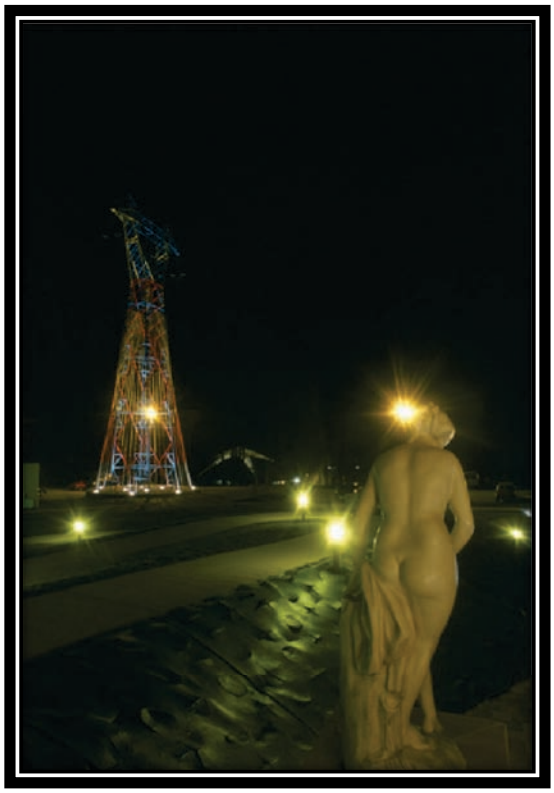


Figure 82 – "Towers and Arts"

Figure 83 – "Source Eau" – Pylône nº 11

In line with these perceptions, in Japan, “Pagoda tower” [11] and [12], has been designed, while in Mexico, “Big Hat Towers” are common solutions (Figures 84, 85)

Figure 84 – The “Pagoda” Tower

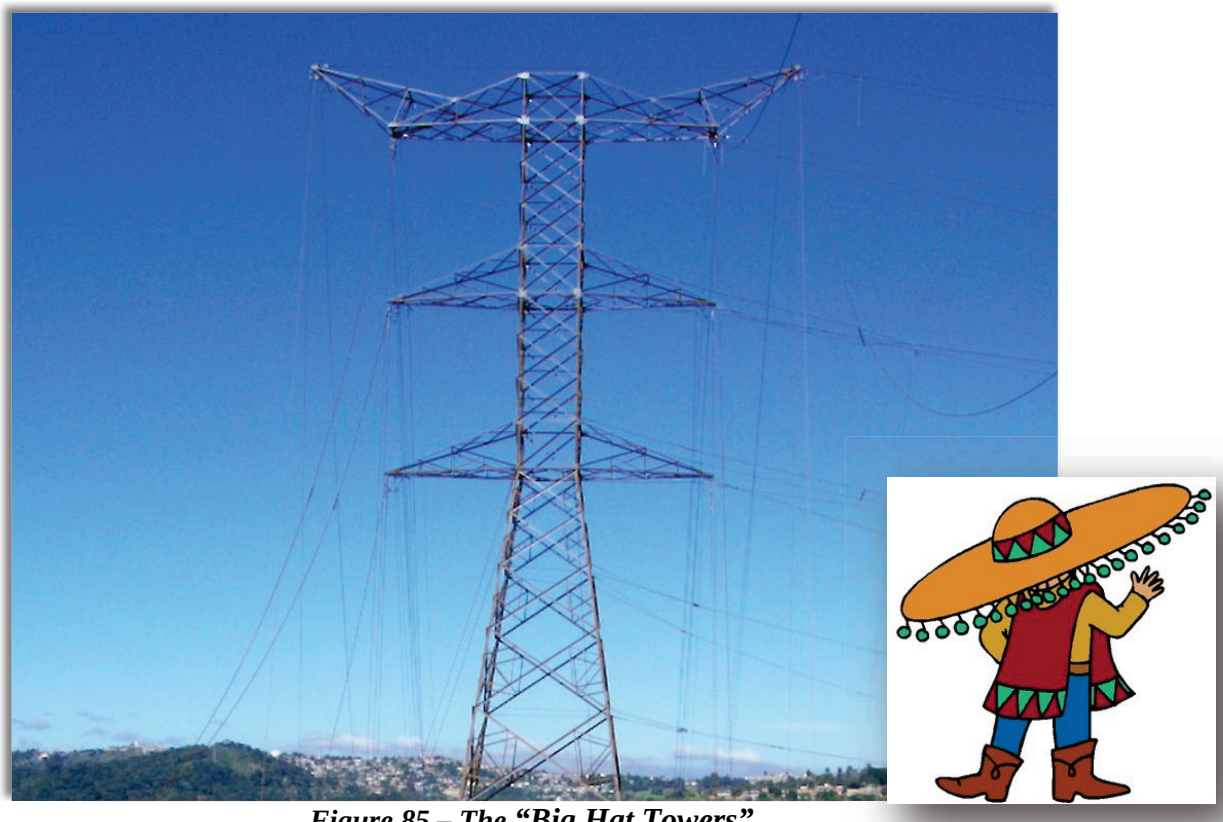


Figure 85 – The “Big Hat Towers”

There is no doubt, that people, conscious or unconsciously appreciate those solutions that lovely remind them images on the landscape.

8. CONCLUSIONS

Demand for electricity has grown dramatically over the last three decades, and the need for electricity will continue to grow. As a consequence, different regions of the world will face different challenges concerning the environmental impacts to supply more power. As far as transmission lines are concerned, some Utilities will have to construct long (up to 2500 kms) UHV overhead lines in the near future. For such lines, as reported in item 3, the so called "aesthetic solutions" will still be designed based on simplicity, invisibility, slenderness, compaction, all together driven by costs. On the other hand, in other regions of the world, the construction of new lines arouses more environmental and aesthetic concerns. With the growing demand, there will be more requests for alternative design solutions i.e. for visually attractive landscape towers. In the majority of the cases, the desirable solution is to hide the structures, putting them invisible or camouflaged. When, for any reason, this is not feasible, for sure it is always possible to make them more aesthetic, more beautiful!

9. ACKNOWLEDGEMENTS

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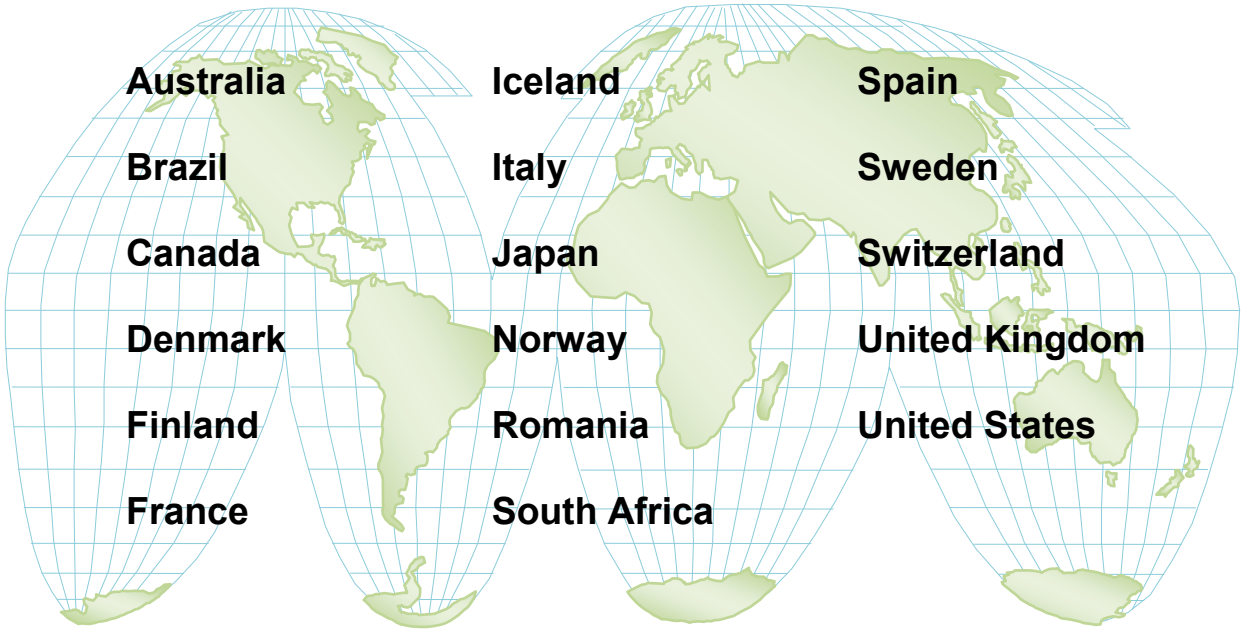
ANNEX A:

WORLDWIDE OHL AESTHETIC SOLUTIONS



Note: The names of the authors of the projects are indicated when informed. Complementary information such as, names, localization of the project, voltage of the lines, quantity of structures installed, costs, etc., can eventually be obtained through the contributors which names can be found on page 59.