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ANGELHY

Innovative solutions for design and strengthening of telecommunications and transmission lattice towers using large angles from high strength steel and hybrid techniques of angles with FRP strips

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Report on market needs for transmission towers

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1 Current situation of the power industry in Europe

The power industry in Europe is opposed to significant changes. Political decisions like Kyoto 1997, EU 2020 or the national efforts to push the nuclear phaseout and to increase the parts of renewable energy strongly influence the architecture of the European transmission lines.
The existing transmission lines in Europe however have insufficient capacities to carry the additional loads from renewable energy sources (e.g. wind turbines, solar panels…). In consequence, the extension and upgrading of existing lines are indispensable to reach the European climate goals and to ensure the service reliability.

Different solutions to increase the line capacities are currently applied or investigated in Europe. They can be grouped into two categories: installation of new lines and reinforcement of existing lines:

Installation of new lines:

- Extension of existing 110-kV/220-kV lines
- Installation of new 380-kV lines
- Installation of new high-voltage direct current lines (HVDC)

Reinforcement of existing lines:

- Upgrading existing lines from 110-kV/220-kV to 380-kV
- Combining direct current lines with alternative current lines (e.g. ultranet)
- Increasing the section of the conductors
- Use of high-temperature conductors (HTLS)

In general, the so-called NOVA-principle is applied to find the optimal solution for a given line [1]. The NOVA-principle regroups the different options for action, whereas it prefers the optimization or reinforcement of the existing lines to the erection of new lines, this for cost reasons.

The solutions will have an important impact on the architecture of the transmission lines and hence the typologies of the towers. The market needs for transmission towers are therefore expected to change in the coming years.
The present report sketches the potential impact on the market of transmission line towers for each solution.

2 Erection of new transmission lines

Over the last two decades, the amount of renewable energy has been consequently increased. To ensure the transportation of the produced current from the wind and solar parks to the end users in remote rural areas or the expanding urban areas, new transmission lines are required. In the present chapter, the potential influence of the installation of new transmission lines on the market needs of transmission towers is discussed.

2.1 Extension of existing 110-kV/220-kV lines

The extension of existing 110-kV/220-kV lines will only have a negligible influence on the market needs for towers. It is expected that the same tower typologies than those applied for the existing lines will be used. The tower structures for the 100-kV and 220-kV lines are quite light (Figure 2.1) and in consequence, these lines will not offer an increased market for large angle profiles or for reinforced angles profiles in future. The extensions of the existing 110-kV/220-kV lines will however induce an increased demand of standard angle profiles (≤ L140x140) in future. In addition, the use of high strength steel (e.g. S420 and S460) can lead to lighter angle profiles for the legs of the tower.

Figure 2.1: 110 kV distribution line

2.2 Erection of new 380 kV lines

380 kV lines represent the main part of the European transmission grid. The lines ensure the transmission of energy over long distances with lower electrical losses. In future, the growing parts of renewable energy will lead to an increased demand of 380 kV. The legs and cross arms of transmission towers for a 380-kV line are generally made of big angle profiles (e.g. > L150x150). Moreover, the trend goes towards 380-kV transmission towers carrying at least 4 circuits, 2 on each side of the tower body. Therefore, the transmission towers of a 380-kV line will become higher and require larger quantities of angle profiles (Figure 2.2). The possibility of using heavy angle profiles (L250x250 and L300x300) is however expected to be limited to some special designs.

As a result, the 380-kV lines are identified as a potential market for large angles (>L150x150) and/or high strength steel.

Figure 2.2: Transmission tower of a 380-kV line

2.3 Erection of HVDC lines

Although the direct current transmission has already been known since the last decades of the 19th century, it is only during the last five years it has known an upswing due to the appearance of new methods to convert AC into DC. HVDC lines allows the transmission of energy over a wider distance (> 750 km) and with lower electrical losses than equivalent HVAC lines. Therefore, they will be mainly applied in transmission grids to transport renewable energy over large distances (e.g. in Germany from the North or the Baltic Sea to the end-users in Bavaria).
HVDC lines usually operate at high voltages (400 kV – 600 kV) with bipolar direct current, which means that each circuit consists of two conductors.
The towers of the HVDC lines (Figure 2.3) have the same typology than those for the HVAC lines but they are slenderer (only 2 conductors per circuit) and taller (higher voltage).

Figure 2.3: Transmission tower for a HVDC line

It is expected that with upcoming HVDC lines, the demand of large angle profiles (> L150x150) in high strength steel could potentially increase.

3 Reinforcement of existing lines

According to the NOVA-principle, the reinforcement of existing lines is preferable to the erection of new transmission lines. The erection of a new transmission line is linked to additional costs, a huge impact on the environment (e.g. deforestation) and it strongly depends on the acceptance of the inhabitants living next to the line. An economic and ecological alternative consists in the reinforcement of the existing lines. Its influence on the future market needs of transmission towers is investigated in the present chapter.

3.1 Upgrading existing lines from 110-kV/220-kV to 380-kV

The increasing amount of electric current produced by renewable energy require high-voltage transmission lines for its transport. Using existing 110-kV/220-kV grids and upgrade them to 380-kV is an attractive solution to increase the capacity of the grid.

The upgrade to 380-kV requires conductors with bigger diameters and an increased number of bundles (e.g. 1 or 2 bundles for 110-kV resp. 220-kV lines but 4 for 380-kV). In addition, the length of the insulators must be adapted to the new voltage level (e.g. 1 m or 2 m for 110-kV and 220-kV lines while 5 m for 380-kV). Furthermore, the size of the protection strip for 380-kV becomes bigger and the tower height must be increased accordingly. This is in general realized by adding segments to the existing tower body (Figure 3.1). All these reinforcement measures are directly linked to higher static loads and the tower structure must be adapted. This can be done by locally reinforcing the leg profiles of the tower (e.g. carbon strips or built-up profiles) or using heavy angle profiles for the additional segments. The diagonals can be replaced by larger angles profiles (>L150x150) in the lower segments of the tower.

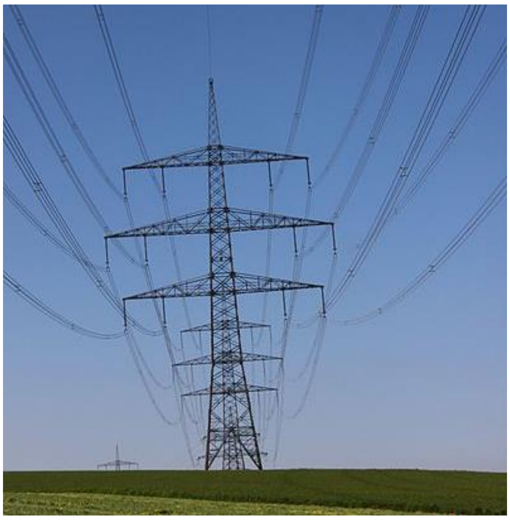

Figure 3.1: Upgrade of a 220-kV line to a 380-kV line

As a result, the upgrades of existing lines from 110-kV/220-kV to 380-kV are identified as a promising market for local reinforcement measures like the use of built-up angles and carbon strips or the use of larger angle profiles.

3.2 Ultranet

Ultranet describes the combination of high-voltage direct current lines with high-voltage alternative current lines. The concept is currently not state of the art and is tested in some pilot projects among

Europe. This concept could avoid the erection of new transmission lines and reduce the efforts and expenses for the enhancement of the line capacity.
So called hybrid-towers are used for the ultranet. A hybrid-tower is a structure which carries a HVDC and a HVAC line at the same time (Figure 3.2).

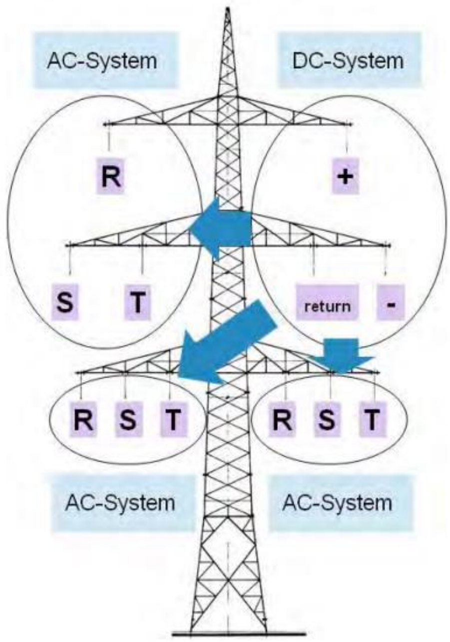

Figure 3.2: Hybrid tower typology [2]

Existing towers, originally carrying HVAC lines only, are modified in order to add a HVDC line. The modification might consist in a global reinforcement of the tower structure by using built-up angles for the leg profiles or by replacing some diagonals with larger angle profiles.
Currently it is impossible to say which is the best reinforcement measure for this kind of towers since the concept is very new and not well investigated yet. However, it might be a potential application field of large angle profiles (> L150x150) and high strength steels in future.

3.3 Increasing the sections of the conductors

A simple method to increase the transmission capacity is to use conductors with larger sections.
For instance, a standard conductor type 4 * 264-AL1/34-ST1A offers a maximum capacity of 1780 MVA, while a high-power conductor type 4 * 564-AL1/72-ST1A has a maximum capacity of 3000 MVA [2].
As already described in section 3.1, larger conductors increase the loads (e.g. self-weight) acting on the tower structure and reinforcement measures might be necessary. The measures may consist in using larger angle profiles for the diagonals or adding angle profiles to the leg profiles (e.g. built-up).
It is expected that the presented solution will be widely used for existing power grids throughout Europe and it might be an important market for reinforcement measures for lattice steel towers.

3.4 Use of high-temperature conductors (HTLS)

The capacity of a transmission line can be increased by replacing conventional aluminium-steel conductors with high-temperature conductors. Different types of high-temperature conductors exist [3]:

- ACSS
  A composite concentric-lay stranded conductor with one or more layers of hard drawn and annealed 1350-0 aluminium wires on a central core of steel.

- ZTACIR
  The core of the conductor is made of INVAR and covered by a thin layer of aluminium extruded on it. INVAR is an alloy composed of steel and 36-38 % nickel and has a linear expansion coefficient quasi invariable with heat.

- GTACSR
  The configuration is identical to conventional ACSR conductors. The main difference consists in the trapezoidal cross section of the aluminium wires in the internal layer closest to the core and the grease-filled gap between the steel core and the aluminium layers to resist high temperatures.

Although well known in America and Japan, the method is quite new in Europe (first test in UK in 2000).
According to the project COALPRET [3] and the different projects in America and Japan, the exchange of the conductors can be made without no further reinforcements to the support towers. As a result, the replacement of conventional conductors with high-temperature conductors is not supposed to increase the market of large angle profiles or high strength steel.

4 Latest trends in the market

Overhead transmission lines have a deep visual impact on the landscape and the environment (e.g. forest aisle). The growing parts of renewable energy however require the installation of new grids which is currently leading to conflicts with the inhabitants of the affected regions. Citizens' initiatives are formed and override the construction of new transmission towers. Therefore, several alternatives to the conventional steel lattice tower have been developed during the last years. This chapter gives a short overview on the latest trend in the market of transmission lines.

4.1 Underground cables

Compared to overhead lines, underground cables have the advantage that they are not visible in the landscape (Figure 4.1).

Figure 4.1: Laying of underground cables

Many citizens' initiatives demand underground cables instead of overhead lines for the new transmission lines and the political pressure on decisions maker is increased to switch to underground cables.
In Denmark the project "Cable Action Plan" has been initiated and foresees to exclusively use buried cables for the new 400-kV lines and for the existing 132-kV and 150-kV lines [4]. In addition, the European network operators agreed on the possibility to replace overhead lines by underground lines. However, underground cables are currently related to major drawbacks. For AC the investment costs are higher about a factor of 3 to 13 than for overhead lines and for DC about a factor of 2 to 15. Moreover, the reparations of defect cables take much longer than the reparation of overhead conductors and the underground cable present much higher electrical losses.

Finally, the environment impact of underground cable is comparable to overhead lines: the soil has to be completely substituted and the cable route must not be cultivated anymore (Figure 4.2).

Figure 4.2: Environmental impact of underground cable route

Currently, the cabling degree in the European Union is very small, in Germany underground cables for instance only present 0,3 % of the whole 220-kV and 380-kV grid [2]. However, it is expected that the cabling degree will increase and the coming years and that underground cable could potentially challenge the position of angle profiles in the market of transmission lines.

4.2 Compact towers

During the last decade, research has been carried in the field of compact transmission towers (Figure 4.3). The idea consists in developing a tower with reduced visual impact on the landscape and with potential higher acceptance by the inhabitants.
The results are slender monopole transmission towers made of steel tubes. For small towers, the tube is transported in one single piece to the construction site and erected with the help of a crane. For taller towers, the tube is segmented (as for tubular wind turbine towers) and mounted on the construction site by means of cranes.

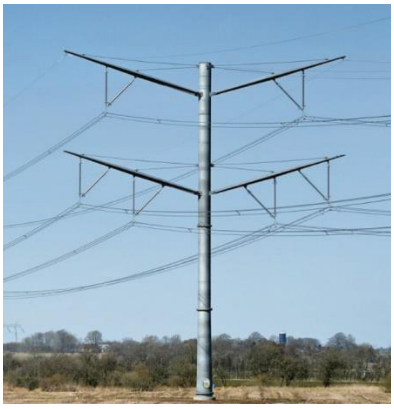

Figure 4.3: Compact tower

Their advantages in comparison to lattice towers are a reduced soil sealing due to smaller foundation areas and a well-accepted visual appearance. Their drawbacks are the high costs, the complex mounting, the corrosion, maintenance, dismantling, the flexibility of use and the disposal.
Nevertheless, it is expected, that compact towers will become a potential alternative to lattice transmission towers in the upcoming years.

4.3 The "VITRUVIO" tower

The "VITRUVIO" tower is a new generation of a "tubular-like" tower (Figure 4.4). It has been developed by the Italian steel constructor COLOMBO S.p.A. together with the Italian network operator TERNA.

Figure 4.4: The "VITRUVIO" tower

The octagonal section of the tower is composed by two interconnected structures having a square section placed at 45° (Figure 4.5). The diameter of the section is equivalent to the one of the compact monopole towers.

Figure 4.5. Octagonal cross section of the tower

A significant reduction of the weight and production costs was achieved by the use of hot rolled angles profiles made of high-strength steels S420 or S460 for the main members.

Figure 4.6: Main members of the "VITRUVIO" tower

All the connections are bolted type and allow an easy assembling of the structure. The erection of the tower can be realized with traditional methods: preassembling by section on the ground and later assembling of the tower by crane or helicopter.
The "VITRUVIO" tower can be enveloped in an external steel cover made of hot-dip galvanized steel panels. The foundation of the tower are single blocks, like for monopole towers, using stubs for connections.
The "VITRUVIO" tower can be enveloped in an external steel cover made of hot-dip galvanized steel panels. The special connection system of the panels is without bolts (Figure 4.7).

Figure 4.7: Covered tower

The tower combines the advantages of compact towers like a better visual acceptance and a reduced protection strips with a lower environmental impact with the assets of steel lattice tower as to know the easy and cheap erection with a high modular structure. In addition, the feasibility of a such tower has been demonstrated during the project.
Therefore, it can be expected that this new generation of tower will also be used for future projects and will thus lead to increase the market shares of angel profiles.

5 Conclusions

The market of transmission tower is currently undergoing major changes. In the next years, an increasing amount of renewable energy must be transmitted from the location of production to the end-users (e.g. industries and households). Therefore, different solutions have been proposed (see chapter 1).

In the present report, the potential impact of each solution on the market of angles profiles and high-strength steel is discussed. It is expected that among the solutions concerning the installation of new transmission lines, the erection of new lattice towers for 380-kV lines will potentially have the most significant influence on the needs of large angles profiles in high strength steel.

The reinforcement measures for existing transmission lines offer all, except the use of high-temperature conductors, good opportunities for the market of large angle profiles (>L150x150). The local reinforcement of existing towers can be easily managed by replacing smaller angle profiles by larger ones (e.g. for the diagonals) or by adding an additional profile to an existing one (e.g. built-up member for the legs).

Finally, the latest trend in the field of lattice towers are presented. The “VITRUVIO” tower, steel lattice tower of the next generation is a very promising solution for tall support structures of high-voltage overhead lines. It offers the advantages of both, compact towers and steel lattice tower and uses large angle profiles in high-strength steel in an optimal combination. As a result, the tower is expected to be used in future projects and to increase the demand of large angle profiles.

In conclusion, the current and future developments of the transmission lines offer good conditions to increase the market shares of angle profiles, high strength steel and local reinforcement measures of angles profiles in the field of transmission towers.

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References

[1] Netzentwicklungsplan 2016 für das Übertragungsnetz der Austrian Power Grid AG, Wien, August 2016.

[2] E. Bruns, S. Koch, J. Bauer, L. Hofmann,D. Kraetzschmer, J.-C. Sicard, F. Igel : Auswirkungen zukünftiger Netzinfrastrukturen und Energiespeicher in Deutschland und Europa. Übertragungs- und Ertüchtigungstechnologien – Einsatzbereiche, Flexibilitäten, und Wirkfaktoren. Bundesamt für Naturschutz. Teilbericht (TB) 2, Bonn, 30 April 2015.

[3] I. Zamora, A.J. Mazón, R. Criado, C. Alonso, J.R. Saenz: Uprating using high-temperature electrical conductors. University of the Basque Country and IBERDROLA S.A. Year unknown.

[4] Energinet DK: Cable action plan – 132-150 kV grids. March 2019. www.energinet.dk.

[5] Entsoe/Eurocable (2011)