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Integration of Infrastructures in Landscape – An Opportunity to Landscape Planning Improvement

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1. Introduction

This paper presents a work that was developed during three years, in a partnership between the company EDP Distribuição, SA (Grupo EDP- Energias de Portugal SA) and the Research Centre in Biodiversity and Genetic Resources of the University of Porto (CIBIO/ UP), financially supported by the PPDA - Promotion of Environmental Performance Plan - approved by the Energy Services Regulatory Authority (ERSE). The objective of this work was the production of a Manual of Good Integration Landscape Practices of the Infrastructure of the Distribution Network. This manual aims to present a set of strategies, guidelines and practices for landscaping integration, in mainland Portugal, of electrical infrastructures, namely: Substations, Lines of High, Medium and Low Voltage, Transformer Stations and Urban Cabinets.

The work had two major challenges: on the one hand, the development of technically sound solutions and proposals from the standpoint of landscape integration of these infrastructures, minimizing their impact; on the other hand, ensure ease of use and the application of this technical manual for non-specialists in the field of landscape. Thus, it was essential to know how the planning and design of these infrastructures in the company was carried out, developing a compatible methodology for landscape integration.

2. Conceptual process for the development of the manual

The principle from which the methodological and conceptual process began, developed for the construction of this Manual of Good Integration Landscape Practices of Electrical Infrastructures (figure 1) was that electrical infrastructures cause always an impact in the landscape. On the majority of cases, this impact is negative since it causes an intrusion and a change in landscape character. Therefore, it is essential to analyze and study these two variables - the landscapes and the electrical infrastructures.

Concerning landscape, it is important to understand its character that reflects the interaction of the various components of landscape, namely physical, biological, social, cultural, economic and visual. The identification of the character of the landscape allows the identification of the types of landscape with homogeneous characteristics, which requires

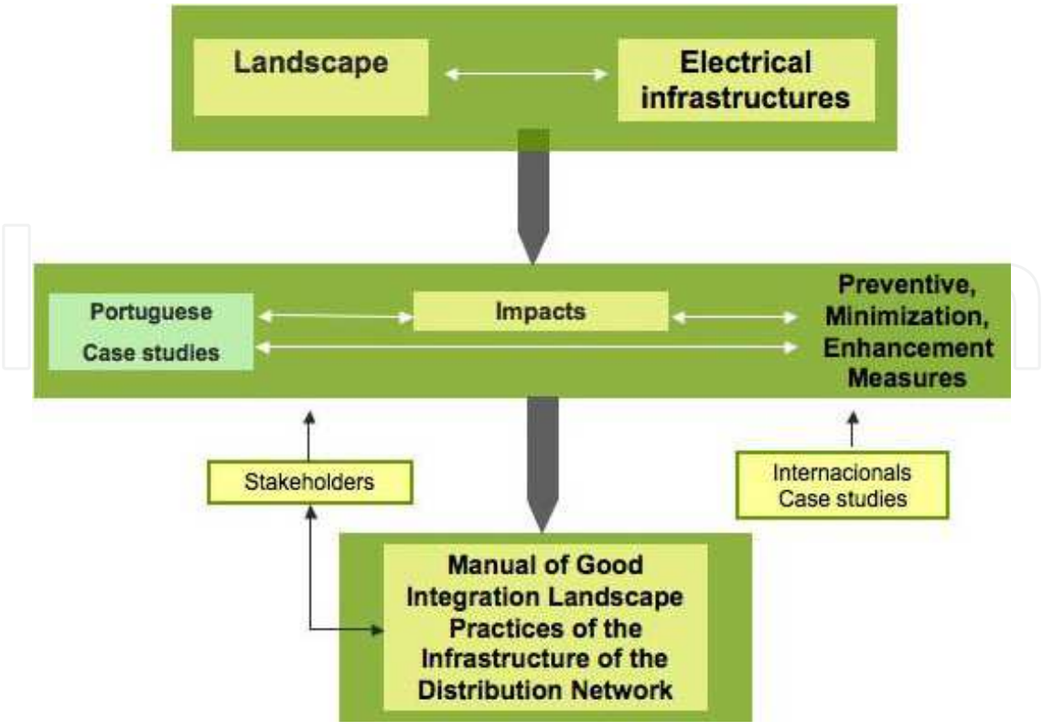


Fig. 1. Conceptual process for the development of the Manual

similar interventions, i.e., it allows the assessment of the capability of each landscape in receiving (from a spatial and visual standpoint) elements foreign to its nature, such as electrical infrastructures.

In the study of the electrical infrastructures, on the one hand, legal and technical aspects, constraints to the implementation of each infrastructure, were taken into account. On the other hand, aspects of shape and size, essential for the determination of its visual and landscape impact, were considered.

In parallel, it was carried out a study of practical cases - international case studies already implemented and cases presented by EDP Distribution for which landscape integration proposals were developed. The process carried out in these studies and the results obtained in terms of proposals, contributed to the definition of measures that constitute the core of this Manual. For the compiling of these measures, in addition to the bibliography research, the practical application in specific cases of new or conversion layouts of infrastructures was essential. It was a joint work of the University of Porto and the technicians of the company, which has proved to be very important for the validation of the proposed measures. On the other hand, it was also essential as a means of raising awareness and to introduce new approaches to be applied by the company technicians.

Finally the input from stakeholders heard during this project was taken into account.

3. Identification of landscape types

Landscape is something very complex and variable that, in the Portuguese context, is heavily accentuated by the geographic location, the orographic variety of the country, and

by the interaction of various ecological factors leading to a really rich and diverse landscape. This makes it advisable to attempt to identify homogeneous areas from the point of view of their character which is reflected in different types of landscape. The method developed for the identification of the types of landscapes, within this Manual, refers to a process of sequential selection of the main variables of the landscape, which ought to be considered as more relevant to landscape integration of electrical infrastructures: degree of urbanization, orography, and vegetation cover (figure 2).

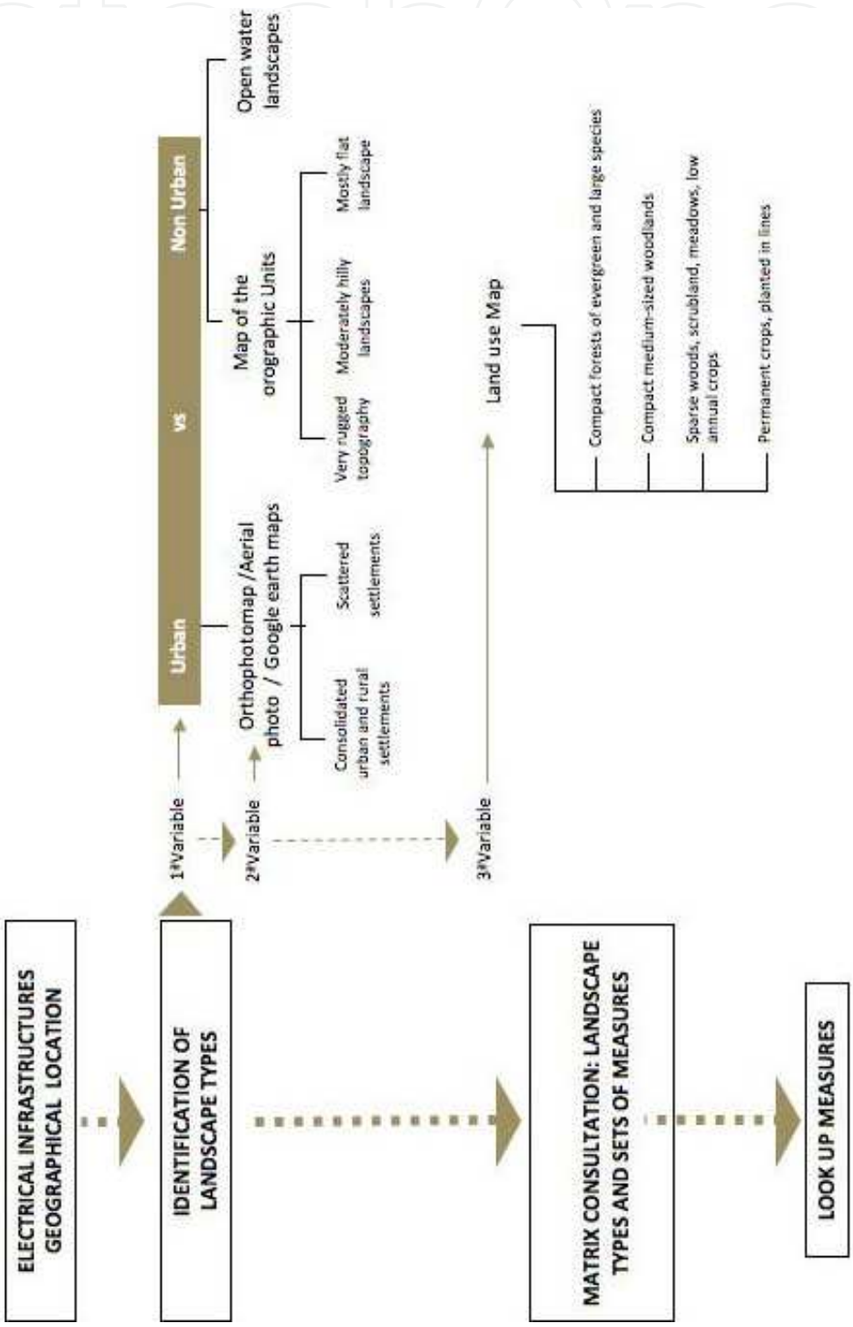


Fig. 2. Conceptual Framework for the consultation of the Manual

At first, two situations were distinguished which, by their nature, bring very different conditions: 'urban areas' and 'non-urban areas', i.e. landscapes dominated or not dominated, respectively, by the territory construction and infrastructure. Indeed, the urbanization of the territory and the consequent infrastructures introduce a significant artificiality that results in landscapes with a distinct character that encompass a very specific approach. 'Urban areas' are also landscapes where people stay longer, which means that social issues about the quality of the places where they live, work and enjoy themselves, must be taken into account.

Consequently, for what was named 'urban areas' two types of landscape were identified - (1) *consolidated urban and rural settlements* and (2) *scattered settlements*. This classification was defined taking into account the degree of urban consolidation, which is reflected into a higher or lower unity/density/continuity of built space. The first case presents a significant degree of consolidation while in the second case the level is low.

Since one of the aims of this process is to ensure ease of use and the application of this technical manual for non-specialists in the field of landscape, 'identification guides' were developed, using either illustrative processes or descriptive processes, to facilitate the procedures of identifying the type of landscape where an infrastructure will be placed.

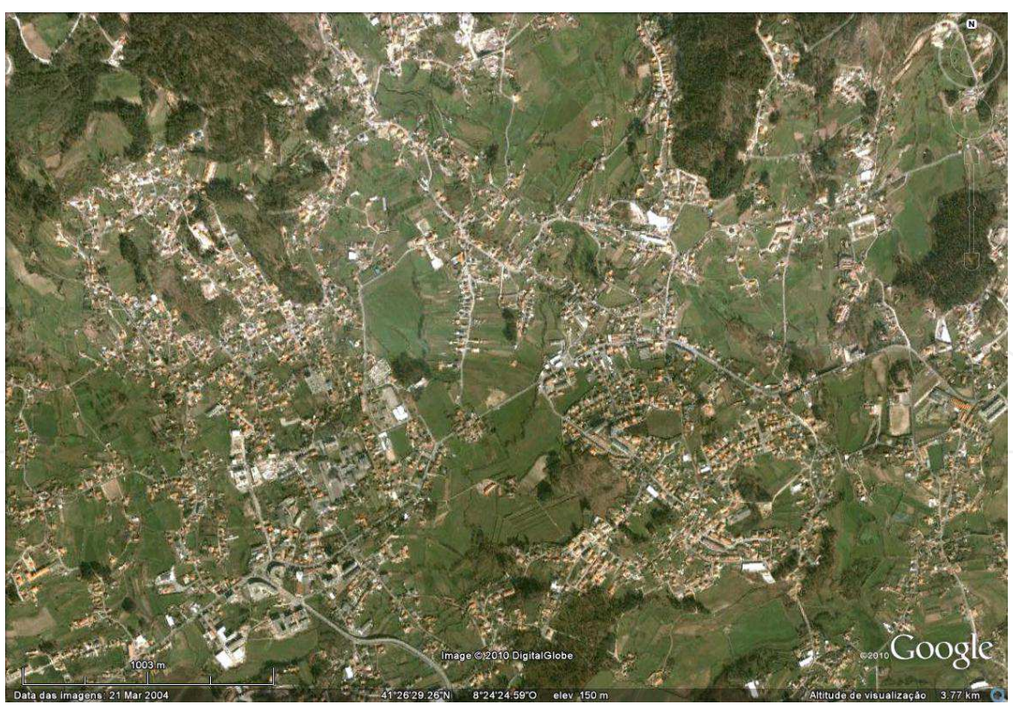
In the 'identification guide for urban areas', *Google earth* was used as an universal tool of easy and simple use in order to find examples of *consolidated urban and rural settlements* (high/medium or medium/small density of building fabric inserted in the rural landscape) - figures 3 and 4 – as well as examples of scattered settlements (dispersed/diffused building fabric contiguous and directly related to consolidated urban settlements and dispersed/diffused building fabric not contiguous to consolidated settlements) - figures 4 and 5.

Source: Google Earth

Fig. 3. Example of a consolidated urban settlement: Bragança.

Source: Google Earth

Fig. 4. Example of a consolidated rural settlement: São Marcos de Ataboeira.



Source: Google Earth

Fig. 5. Example of a scattered settlement (dispersed/diffused building fabric) contiguous and directly related to consolidated urban settlements: Joane – Guimarães

Source: Google Earth

Fig. 6. Example of a scattered settlement (dispersed/diffused building fabric) not contiguous to consolidated settlements: Avintes.

In what concerns 'identification guide for non-urban areas', the first variable taking into account was orography - on a national scale, the main distinguishing factor to consider is the terrain. Four macro units were identified:

Unit 1 - Prevalence of landscapes with very rugged topography, i.e. valleys and hills with slopes and significant variation in height
Unit 2 - Prevalence of moderately hilly landscapes, i.e. valleys and hills with moderate slopes and variation in height
Unit 3 - Prevalence of mostly flat landscape
Unit 4 - Landscape with very diverse orography, being present moderately rough and flat reliefs, with a strong component of urbanization and infrastructure.

The objective of mapping these units (figure 7) is to provide guidance for the identification of each of these types of orography, identifying the prevalence of each one of them in the different regions of the country. It should be mentioned that the Portuguese landscape is very diverse, with large variations in orography within a short geographical area - therefore it was decided to choose to identify large patches where such a geographical predominance is found.

The second variable taking into account to 'identification guide for non-urban areas' is vegetation, considering its higher or lower capacity of visual absorption. In this case a land use map should be employed and the following types are considered:

1. Compact forests of evergreen and large species (e.g. maritime pine and eucalyptus).
2. Compact medium-sized woodlands (evergreen and/or deciduous, ex. native woods of oak, umbrella pine…).

3. Sparse woods, scrubland, meadows, low annual crops (e.g. cork oak and holm oak open woodland (*montado*), arable crops).
4. Permanent crops, planted in line (e.g., vineyard, orchards).
5. Open water landscapes (e.g., lagoons, estuaries, reservoirs and large rivers)

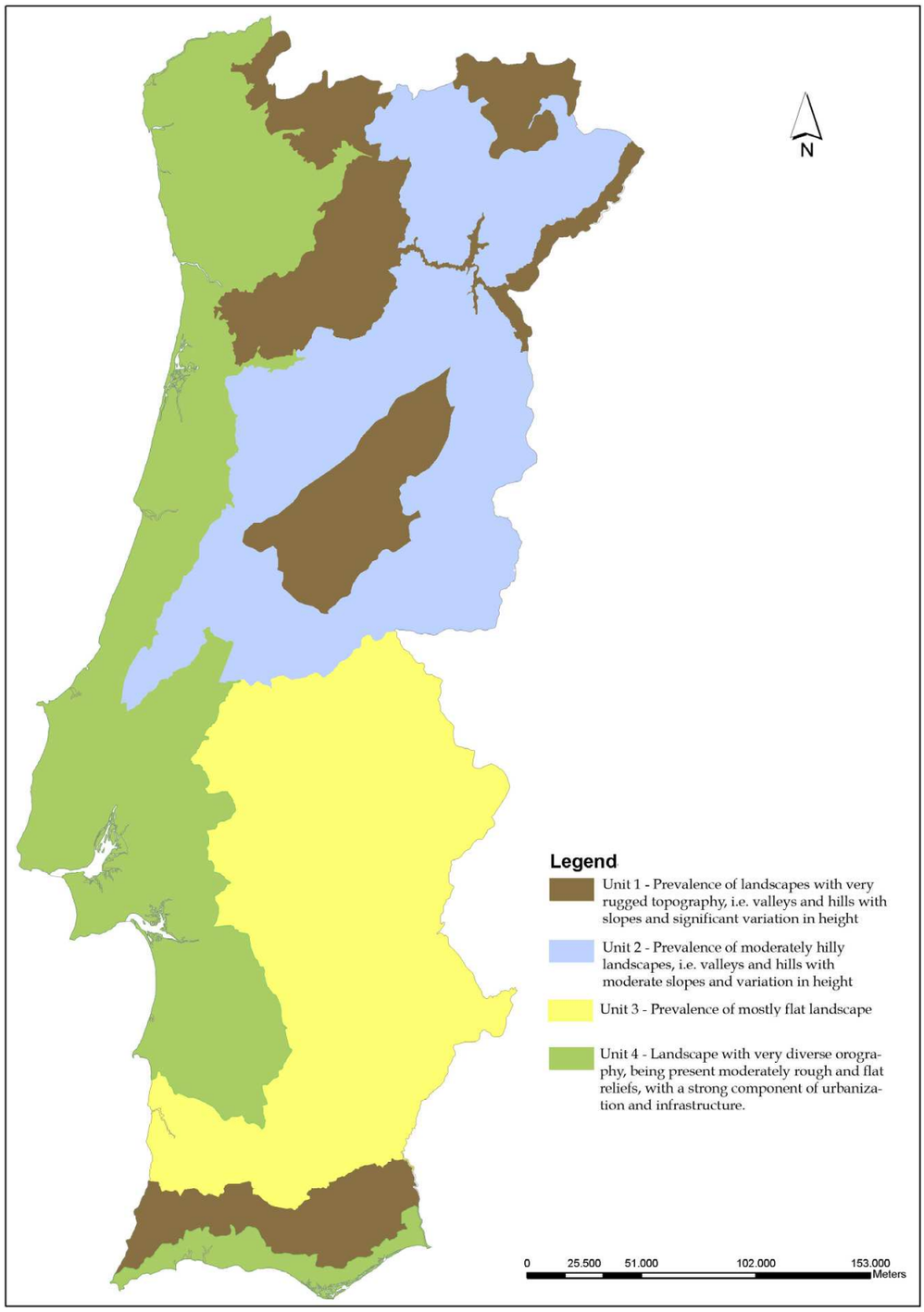


Fig. 7. Map of the orographic units for landscape integration of electrical infrastructures

4. Measures of landscape integration of electrical infrastructures

Having identified the type of landscape, it is possible to identify, through a guideline, the landscaping integration measures to consider in every situation. These measures are organized taking into account technical reasons, but also the process of planning and design of the company. Consequently, groups of Preventive Measures, Minimization Measures and Enhancement Measures were organized (figure 8).

Landscape types			SET OF MEASURES																	
			Preventive															Minimization		Enhan.
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Urban Areas	Consolidated urban and rural settlement		X	X	X									X	X	X	X	X	X	X
	Scattered settlements		X	X		X								X	X	X	X	X	X	X
Non Urban Areas	Prevalence of landscape with very rugged topography	Compact forests of evergreen and large species (e.g. maritime pine and eucalyptus)	X	X			X	X		X	X			X		X		X	X	X
		Compact medium-sized woodlands (evergreen and/or deciduous, ex. native woods of oak, umbrella pineÉ).	X	X			X	X		X		X		X		X		X	X	X
		Sparse woods, thickets, meadows, low annual crops	X	X			X	X						X		X		X	X	X
		Permanent crops, planted in line (e.g., vineyard, orchards)	X	X			X	X					X	X		X		X	X	X
	Prevalence of moderate hilly landscapes	Compact forests of evergreen and large species (e.g. maritime pine and eucalyptus)	X	X				X		X	X			X		X		X	X	X
		Compact medium-sized woodlands (evergreen and/or deciduous, ex. native woods of oak, umbrella pineÉ).	X	X				X		X		X		X		X		X	X	X
		Sparse woods, thickets, meadows, low annual crops	X	X				X						X		X		X	X	X
		Permanent crops, planted in line (e.g., vineyard, orchards)	X	X				X					X	X		X		X	X	X
	Prevalence of mostly fla landscape	Compact forests of evergreen and large species (e.g. maritime pine and eucalyptus)	X	X				X	X	X	X			X		X		X	X	X
		Compact medium-sized woodlands (evergreen and/or deciduous, ex. native woods of oak, umbrella pineÉ).	X	X				X	X	X		X		X		X		X	X	X
		Sparse woods, thickets, meadows, low annual crops	X	X				X	X					X		X		X	X	X
		Permanent crops, planted in line (e.g., vineyard, orchards)	X	X				X	X				X	X		X		X	X	X
	Open water landscapes (e.g., lagoons, estuaries, reservoirs and large river		X	X				X	X					X		X		X	X	X

Fig. 8. Matrix for identification of landscape integration measures in relation to landscape

Preventive Measures are used primarily to support the development of new projects, namely the layout of transmission and distribution overhead lines and the siting and implementation of substations, transformer stations and distribution cabinets. These strategic measures focus on large scale questions with a wider but integrated eye on the landscape. They are based on a macro view of the landscape, focusing on its organization and its biophysical components.

Minimization Measures apply both in existing situations and in new situations, after the consideration of the preventive measures. They aim to mitigate the impacts that infrastructures can cause, nevertheless, on the landscape. They are based on a micro view of the landscape and they focus on the physical and cultural components of the landscape. They aim the very specific integration on the ground and, as such, actions can impact both in terms of infrastructures and in terms of landscape through earth modelling, planting schemes, physical treatment of infrastructures, among others.

Enhancement Measures reflect the added value that the implementation of an infrastructure can bring, in terms of landscape. In other words, the infrastructure should be regarded as something useful or interesting to users of that landscape, through the inclusion of the social, environmental and visual purposes.

4.1 Preventive measures: Planning and design of the layout of infrastructures

Fifteen sets of Preventive Measures were considered, which are shortly described as follows:

- Set 1 - General measures for all infrastructures: they refer to issues related to preliminary studies of landscape, namely the analysis of the planning instruments of the territory, the detailed survey of the intervention area (terrain, type of land use, land cover, natural and cultural values, roads, existing overhead lines and other infrastructures), the production of studies on view-sheds and 3D simulation projects, among others (fig.9).

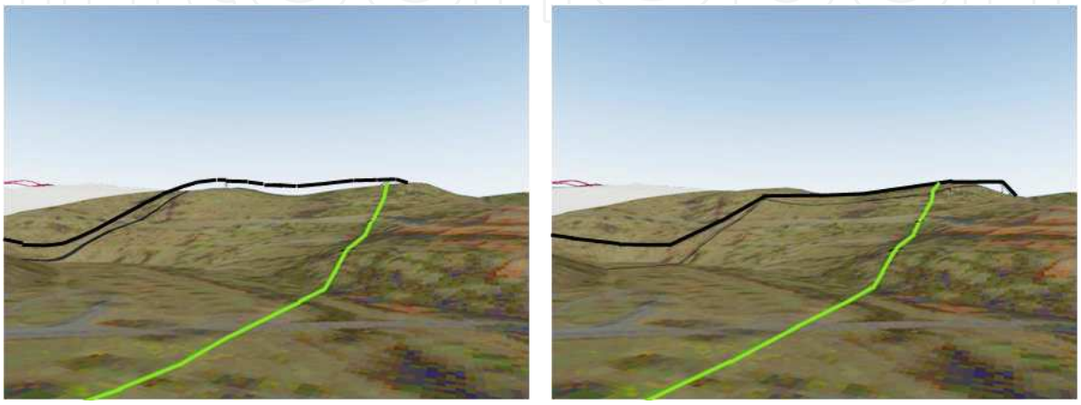


Fig. 9. 3D simulations for different line designs

- Set 2 - General Measures for transmission and distribution lines: it includes examination and evaluation of the best solutions, based on studies of visibility from the main access points since landscapes with greater capacity for visual absorption should be considered as preferential for the implementation of lines. At the same time, landscapes with high scenic and natural/cultural values, namely those with a high degree of integrity and conservation, should be kept free of overhead lines.
  It is also considered using the same pole as support for multiple distribution lines or for various infrastructures, namely telecommunications.
- Set 3 - Transmission and distribution lines in urban centers and rural consolidated settlements: consider placing the line underground as a priority solution, particularly in heritage areas. When this is not possible, consider to associate the layout of the line with other linear infrastructures and preserve, free from infrastructures, the zone of visual influence of natural and cultural heritage elements.
- Set 4 - Transmission and distribution lines in scattered urban zones and peripheries of the consolidated urban areas: select the most infrastructure areas (predominance of roads, industrial areas...) for the layout of the line.
- Set 5 - Transmission and distribution lines in hilly areas: focus on the possible deployment in less illuminated slopes, avoiding the ridge lines.
- Set 6 - Transmission and distribution lines in valley areas: prioritize the layout in areas where the valley is more engaged, in other words at points of lower visibility, following the natural depressions so that they are concealed.
- Set 7 - Transmission and distribution lines in flat zones: take in account land use - if the line finds a forest patch, focus the layout on the inside of the patch; if the line finds a

permanent crop area in line focus on the straight layout, following the linear array of the landscape; in the water landscapes, consider placing the line underground or using existing infrastructures over the water plan, e.g. bridges.

- Set 8 - Transmission and distribution lines in forest patches: focus on the crossing by stands of lower landscape quality, in particular, eucalyptus and acacia tree species, at the expense of forest patches of higher landscape value (visually and ecologically).
- Set 9 - Transmission and distribution lines in compact forests of evergreen and large species: the layout of the lines should follow existing forest roads or forest clearings; and also consider the use of off line easement areas; in the slopes steeper than 1:3, not considering paths perpendicular to the line of greatest slope (fig.10).

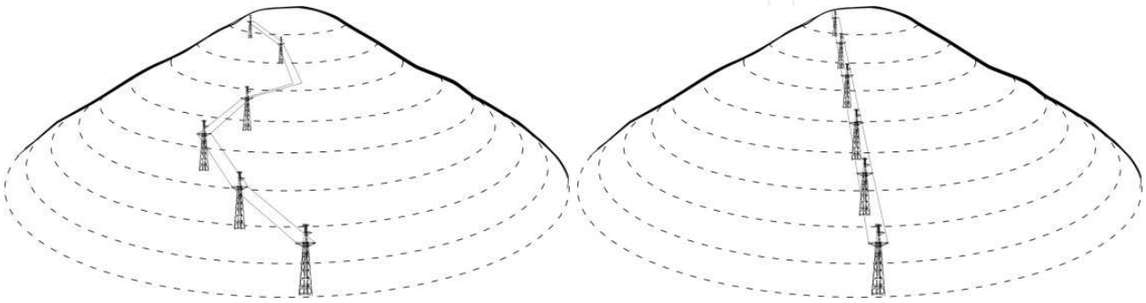


Fig. 10. Scheme explaining the preferable layout (left) of a distribution line in hilly landscapes – avoid perpendicular lines to the steepest gradient.

- Set 10 - Transmission and distribution lines in compact medium-sized woodlands: safeguard the permanence of the existing vegetation in the 'right-of-way' areas so that the height of the pole should be as small as possible so that, together with the line, they have reduced visibility above the trees canopy.
- Set 11 – Transmission and distribution lines in agricultural areas of permanent crops: give preference to placement of poles along the lines of culture and paths since line design should follow the geometry of the fields.
- Set 12 - General measures for substations: prioritize areas with land use with less visual and ecological value and in accordance with the topography of the place to minimize the areas of excavation and landfill; develop appropriate slopes to allow their landscaping with the use of vegetation; consider, in the purchase of land to implement a substation, a marginal area to develop a landscape project aiming its integration (fig.11).
- Set 13 - Substations in urban areas: consider the integration of substations in buildings and the construction of compact substations or underground substations; consider the possibility of creating a rooftop as an opportunity for providing space of interest for public use.
- Set 14 - General measures for transformer stations: consider the integration of transformer stations in existing built structures or attached to them, the incorporation in slopes or the combination with other elements of terrain modeling; consider the transformer stations as equipment subject to architectural design (fig.12).
- Set 15 - General measures for distribution cabinets: consider the establishment of cabinets on the walls of urban properties or on other structures, to avoid cluttering the sidewalks; consider the distribution cabinets as equipment subject to architectural design.

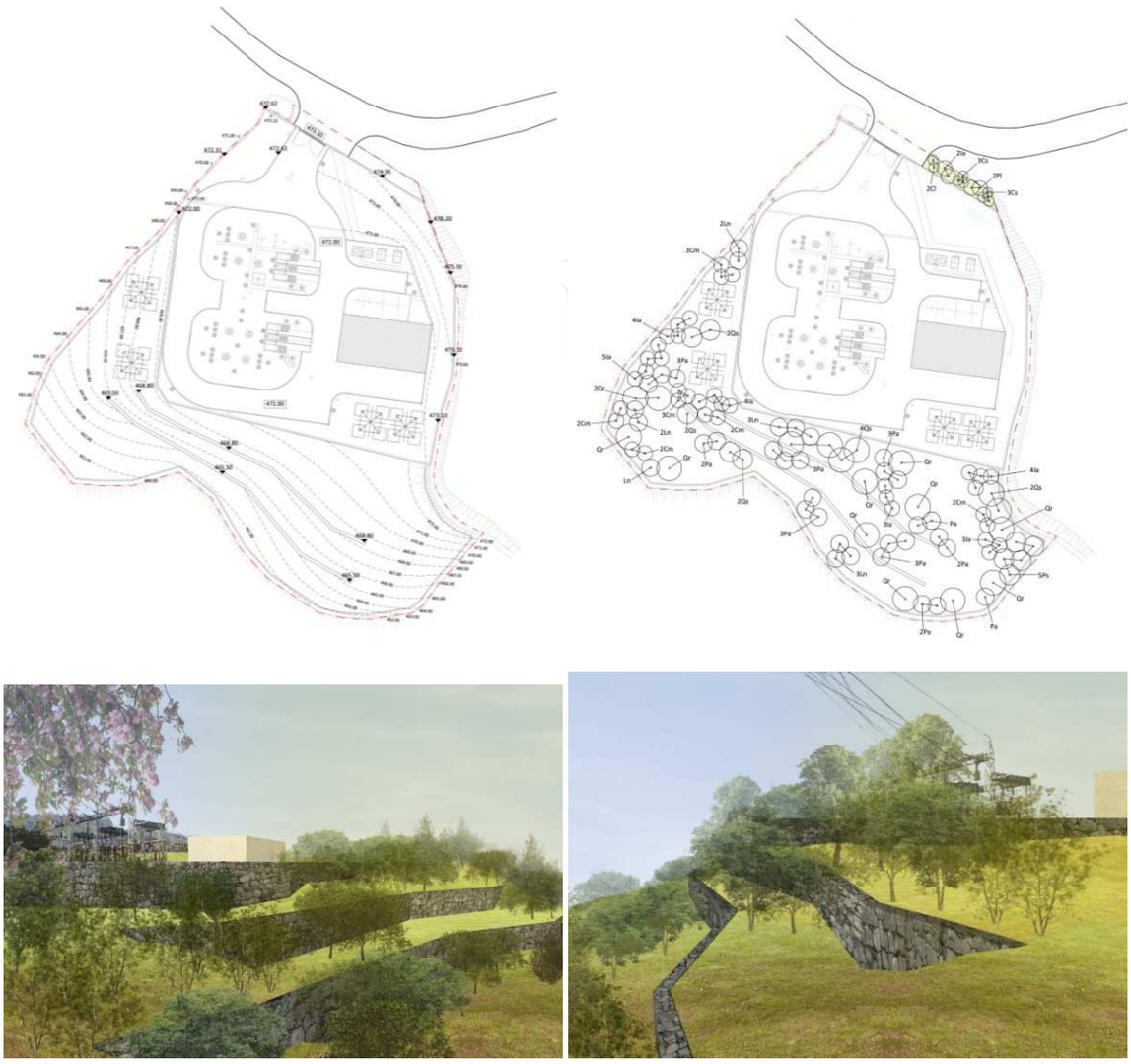
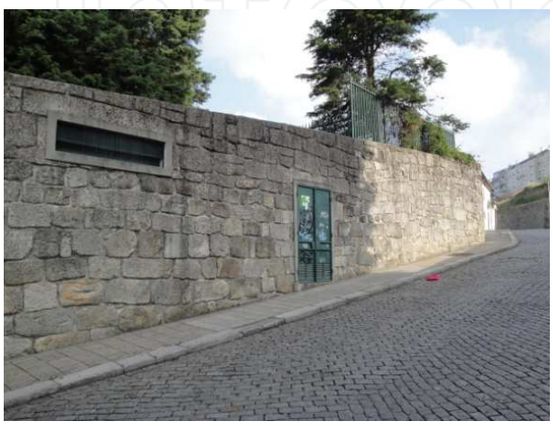


Fig. 11. Proposed integration of a substation in northern Portugal through terracing and planting schemes according to the character of the prevailing landscape



(a)

(b)

(c) (d)

Fig. 12. Landscape integration of transformer stations in relation to structures (a) transformer station built-in a wall; (b) transformer station attached to an existing construction; (c) and (d) transformer station built by extending an existing building.

4.2 Minimization measures: Integration project and landscape treatment

Two types were considered: measures applicable to infrastructures and measures applicable to landscapes:

- Set 16 - At the infrastructure level, minimization measures include actions such as the physical treatment of the infrastructure – poles and towers, substations, transformer stations, distribution cabinets – as far as form, scale, colour, texture, and pattern are concerned, taking into account the formal features of the landscape in which they are placed.
- Set 17 – At the landscape level, minimization measures include landscape restoration treatment that mitigate the physical impact of the infrastructures in the landscape and actions that reduce the visual impact of the infrastructures themselves, namely: consolidation and planting of slopes, platforms and edges of new road access created by the installation of infrastructures; planting clumps along the 'right-of-way' areas to minimize its linear and disruptive effect; planting in the vicinity of the infrastructure in order to visually absorb it, on a scale of proximity, or next to the main points of visibility in order to frame the views to the infrastructure.

4.3 Enhancement measures: Intervention strategies for the benefit of the landscape and people, offered by the installation of infrastructures

- Set 18 - Consider the improvement of areas surrounding infrastructures or 'right-of-way' areas for social and recreational uses or to nature enhancement (green corridors, urban agriculture, bike paths, habitat restoration programs, water retention basins, among others); consider poles with particular shapes, involving in its design artistic considerations – infrasculpture or camouflaged poles; consider distribution cabinets and transformer stations as urban equipment, namely through its conversion (camouflage, coverage…) into elements of great visual interest (fig.13).

Fig. 13. Enhancement of a landscape, affected by the placement of electrical infrastructures, aiming to accommodate social and recreational functions - case study in Lisbon region.

5. Conclusion

As conclusion, it may be stated that this process - the design and development of the Manual and the interaction between landscape specialists and company technicians - was the beginning of a journey where issues concerning the value of the landscape played a major role, independently of the scale of intervention. Actually, this was the chief focus of this work – to convey the idea that landscape is a major asset that has to be respected and protected according to its quality, sensibility and character. As specialists in landscape, the authors consider that it is important not only to develop worthy landscape integration projects, but also to share the perception on landscape issues and principles with non-experts who also act in the landscape. This view implied the formulation of guidelines that could be well understood and applied to the formulation of proposals by non-specialists. Some joint projects carried out, under this work, between the authors and technicians of the Electricity Company has evidenced that the proposed guidelines can not only help to design better layouts, as far as landscape is concerned, but also to provide comprehensive guidance, i.e., serve as a framework for well-balanced designs, in general terms and after

taking into account the necessary technical issues. The Manual was only published last December and the authors expect to get more reactions from technicians and then assess the results of its implementation in practice. This monitoring and evaluation will allow future revisions and the refinement of the Manual.

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Landscape architecture is the design of outdoor and public spaces to achieve environmental, socio-behavioral, and/or aesthetic outcomes. It involves the systematic investigation of existing social, ecological, and geological conditions and processes in the landscape, and the design of interventions that will produce the desired outcome. The scope of the profession includes: urban design; site planning; town or urban planning; environmental restoration; parks and recreation planning; visual resource management; green infrastructure planning and provision; and private estate and residence landscape master planning and design - all at varying scales of design, planning and management. This book contains chapters on recent developments in studies of landscape architecture. For this reason I believe the book would be useful to the relevant professional disciplines.

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