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OPTIMIZATION OF VEGETATION MANAGEMENT WITH LIDAR INSPECTION REAL APPLICATION CASE

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SUMMARY

The authors intention with this paper is sharing the experience of ISA INTERCOLOMBIA in the implementation of high technology inspections in transmission lines to modify a vegetation management strategy from a time-based maintenance to a condition-based maintenance with cost, risk, and performance criteria. This initiative contributes to the fulfilment of the company's strategic objectives framed in the areas of sustainability, cost optimization, innovation, and digital transformation.

In the course of this document, the reader will be able to know how, based on information collected by field personnel and the use of LiDAR technology, the modification of the vegetation management strategy of the Primavera - Sogamoso 500 kV transmission line was carried out, going from an annual periodic maintenance to condition-based maintenance, obtaining an estimated saving of 24.6% in a period of 5 years. In addition, there are also benefits in terms of sustainability, reliability, and digitization of processes. With this project it was possible to reduce the environmental impact that is generated through the reduction of generous cuts of vegetation where it is not necessary and, the reduction of CO_2 emissions because there will be optimization of maintenance resources (people and vehicles) for maintenance activities. In relation to reliability and digitalization, the risk of asset failure is more controlled because with LiDAR the data is more precise and high quality and allows the creation of assets digital models. In Colombia, environmental regulations are becoming a great challenge; there are more and more restrictions to cutting vegetation under transmission lines, for example, in some cases it is possible to cut down trees and in other cases only pruning branches is allowed. That depends on the environmental license of the line and this is also another reason for looking new ways to carry out maintenance activities.

KEYWORDS

Sustainability, vegetation management, LiDAR, cost optimization, asset risk.

1. INTRODUCTION

ISA INTERCOLOMBIA oversees the operation and maintenance of around 8.200 kilometers of transmission lines in Colombia. Due to environmental conditions of the tropical zones, vegetation growth control is a periodic task with annual frequency that must be carried out in 95% of the transmission lines, representing 41% of its maintenance annual budget [1].

The vegetation control, as a strategy, has a long-term plan, where activities are scheduled with frequencies, depending on the estimated growth of vegetation in the span. This estimation was obtained from the vegetation intervention records from maintenance team, with which the risk assessment was carried out to establish the intervention frequencies.

In 2019, however, there was an unusual increase of failures associated with vegetation. After reviewing the causes in a continuous improvement process, we identified a difficulty for maintenance team to do a risk estimation of vegetation growth due to the topography in Colombia or there was overconfidence in risk management when they made an over or under estimation of clear distances between conductors and vegetation. Additionally, the actual estimation of the intervened vegetation also results in a complex process, which leads to inaccuracy in the records of the environmental impact of maintenance in view of government entities in Colombia and in the Dow Jones Sustainability Index, where ISA is present.

Faced with this situation, ISA INTERCOLOMBIA decided to undertake an improvement process to identify a cost-effective alternative to change a condition-based maintenance, with the intervention of specific sites in conjunction with an adequate management of the risk due to the reduction of clear distances caused by vegetation growth. Likewise, it was necessary for the selected alternative to improve the estimate of intervened vegetation. In this process, ISA INTERCOLOMBIA evaluated the use of LiDAR from a technical and economic point of view that allowed us to determine the selection criteria of the transmission lines in which the application of this type of technology is feasible.

As a pilot, this new methodology was applied in the Primavera - Sogamoso 500 kV transmission line, located in the eastern part of Colombia, finding that only the 36% of spans required an intensive vegetation cutting (where cut down whole trees and branches is realized in accordance with the environmental license of each transmission line). The others 64% spans required a light inspection, in order to confirm the presence of growing vegetation. This allowed us to optimize the transportation and execution time of the vegetation maintenance, as well, with a centimeter precision, know all span in risks due to growing trees. Additionally, this technology allowed us to improve the estimated volumes of intervened vegetation and to establish what trees did not require intervention, when using the maintenance records from the last three years and the LiDAR data, we defined an approximated age and size for each one, improving the carbon footprint. These changes in maintenance strategy meant an estimated costs savings of 24.6% for this transmission line between 2020 and 2025.

In 2021, the methodology was extended to eleven transmission lines located in the same geographical area, with an average expectation of savings of 18% in a period of 10 years for all of them. We found different savings for each transmission line due to its length, the weather, the geography, the access to the towers, the roads and vegetation species in the right of way.

Finally, through this practical exercise, the authors wish to convey to readers the importance of planning projects with a life cycle vision and strategic alignment with business objectives and the sustainable development goals (SDGs), supported by decision tools.

2. ALIGNMENT WITH OUR STRATEGY

This work was framed by the following objectives:

- To innovate in maintenance model (Time Based to Condition Based Maintenance). Related with objective 9 of SDGs.
- To optimize the vegetation maintenance cost.
- To improve the risk management due to the reduction of clear distances between conductors and vegetation.
- Contribute to the ISA sustainability index (Dow Jones) through the optimization of vegetation interventions in the right of way. Related with objective 15 of SDGs.

3. OPTIMIZATION OF VEGETATION MANAGEMENT WITH LIDAR INSPECTION ¿HOW WE IMPLEMENTED IT?

In the following paragraphs we detail the carried steps for implementation of high technology inspections with LiDAR in ISA INTERCOLOMBIA's transmission lines.

Is important to mention that, other technologies, like satellite inspections, 3D models with orthophotos was evaluated but, after a technical and economic analysis, ISA INTERCOLOMBIA found that LiDAR inspections were more accuracy and cheaper. Also, ISA INTERCOLOMBIA evaluated to using agronomical data to have a probabilistic vegetations growth functions, but, due to the different types of vegetations grown up in an only span, the accuracy is very low and request a field validation than increase the maintenance cost. For now, this is a part or a future innovation of the model, were ISA INTERCOLOMBIA are expecting to have a vegetation cartographic cross with historical maintenance records of vegetation species and LiDAR information.

3.1 CHARACTERIZATION OF TRANSMISSION LINES BY VEGETATION TYPE

The characterization of transmissions lines starts with meetings between the maintenance team and environmental engineers. The idea is to obtain specific details of the vegetation types present in the spans, the weather influence in vegetation growth, resources required to do the vegetation cutting and travels time to reach each tower. All these variables influence directly the maintenance costs.

To do this, you can use the reports of vegetation intervened in the last 3 years, span by span, for each transmission line, to identify were an intensively vegetation cutting is required or not (differentiating between cut down whole trees and branches). The result of this activity is the time it took to intervene the vegetation each span, and estimated vegetation growth rate to stablish a cut frequency and critical spans where special activities are required to avoid risks due to reduction of clear distances.

Most of our transmission lines has an annual cutting frequency, where a condition-based maintenance is not implemented span by span. Instead, the same resources are used to cutting vegetation each span of each transmission line, so, and improvement is possible to be implemented reducing outages risk and maintenance cost.

Appling this exercise, in the case of the Primavera - Sogamoso 500 kV line, it was found that vegetation cutting is carried out intensively in 36% of the spans and an optimization in the remaining 64% can be done.

3.2 SELECTION CRITERIA TO APPLY HIGH-TECHNOLOGY INSPECTIONS WITH LIDAR

The following criteria for the selection of candidate transmission lines to carry out the inspection with LiDAR technology are:

- Lines with vegetation intervention costs per kilometer above the company average or above average values from benchmarking.
- Spans with low percentages of vegetation cutting.
- Lines with man and transport hours used above the average of the company or above the average values from benchmarking.

For this study case, the Primavera - Sogamoso 500 kV line has a length of 136 kilometers with 302 spans. It is in the Magdalena Medio region, in Colombia, an area of high vegetation growth, with an annual vegetation cutting frequency in the 70% of the transmission line spans and 8 months for the remaining 30%. The same number of resources are use span by span regardless they must cut vegetation or not.

This line has a right of way of 60 meters and a 330 USD/km average cost of vegetation maintenance per year. In its maintenance, 1.860 man hours and 3.968 hours of transportation per year are used, which according to the average of ISA INTERCOLOMBIA (280 USD/km), are susceptible to improve.

3.3 MODIFICATION OF THE VEGETATION MAINTENANCE MODEL AND QUANTIFICATION OF ECONOMIC BENEFITS

To determine in which transmission lines, it is possible to apply high-tech inspections with LiDAR, a comparation between time-based maintenance to a condition-based maintenance must be done. A financial model is necessary to do so. Be careful including the economical benefices obtained with LiDAR inspection, avoiding overestimations.

For the economic valuation of the benefits that the implementation of high-tech inspections that LiDAR entails, a comparison was made with the current strategy (Described in numerals 3.1 and 3.2), where maintenance team do an annual vegetation cutting frequency in the 70% of the transmission line spans and 8 months for the remaining 30%. Important to note in this strategy that maintenance team makes an estimation of vegetation outage risk in some trees where, with a visual inspection, they consider that could be non-compliance of the clear distances. This is the mainly difference with LiDAR inspection, because with LiDAR is possible to knew all the non-compliance points with a high precision.

The proposed modification to the cutting frequency model is:

1) Year 0, LiDAR inspection with intervention of high-risk vegetation points (distance from phase to top of the tree between 0 to 7 m for 500 kV). Light inspection (A quickly inspection for intervene sprouts) is included.
2) Year 1, intervention of high slope and medium risk vegetation points (distance from phase to top of the tree between 7 to 9 m for 500 kV). Light inspection is included.
3) Year 2, intervention of medium slope and low risk vegetation (distance from phase to top of the tree between 9 to 12 m for 500 kV). Light inspection is included.
4) Year 3, intervention of low and medium slope risk vegetation. Light inspection is included.
5) Year 4, low risk vegetation intervention. Light inspection is included.
6) It starts again at point 1.

In Figure 1 we shown a graphical example of how the new model works.

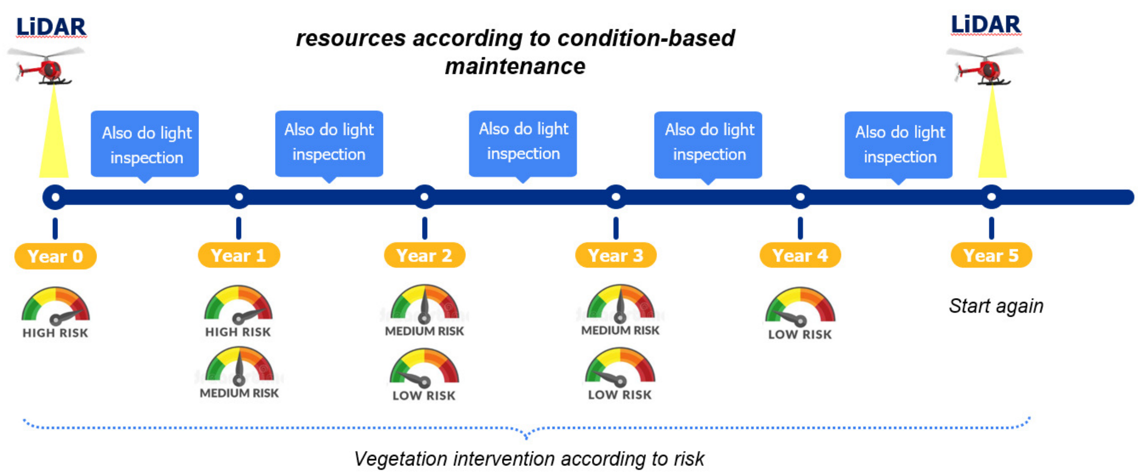

Figure 1 New vegetation maintenance model applyng LiDAR inspections

As a strategy, light inspection maintenance includes the identification from the ground of anomalies in other components of the transmission line, such as conductors, ground wires, insulators, terrain and concrete/metallic structures. The average cost of vegetation maintenance per kilometer, the labour man and transportation hours per year must be taking from your Asset Performance Management (APM). This information, and the risk estimation cost of imprecisions in your measurement or information quality must be in accordance with your organization policies.

Once the above information is available, a financial model must be applied to determine if the implementation of the inspection with LiDAR has benefits over the company's current model. Here is it determined if LiDAR inspection can be implemented or not. For example, in our context, we find that this technology is too expensive for transmission lines with lengths under 10 kilometers, because the maintenance cost is two (2) times lower than LiDAR inspection cots, so the economic analysis doesn't fit.

3.4 RECOMMENDATIONS FOR TECHNICAL SPECIFICATION OF A LiDAR SERVICE

Below are some aspects considered and shared by ISA INTERCOLOMBIA to bear in mind when we constructed the technical specifications for contracting the LiDAR service [2]:

a) Pre-defined non-compliance classes for the analysis. In our case, the following were included: Vegetation and terrain approaches to conductors, lines crossings and constructions inside in the right-of-way.
b) Non-compliance attributes for classes, where resolution of photographs is indicated (high resolution with a Ground Sample Distance (GSD) equal to or less than 10 cm and percentages of cloudiness less than 3%), risk evaluation criteria, precision (centimeter), point density (15 points / m2), among others.
c) Definition of the study area. A 100 meter buffer with axis in the tower center is recommended. This information is mandatory for flights permissions.
d) For calibration and truthing of LiDAR generated model it was necessary to design and install some ground control points located at frequent intervals around the area.
e) Evaluate the best time of the year to get LiDAR point cloud in field because it is not recommended to execute that with rain or fog.
f) Flight plan with geodetic moorings for future analysis.
g) Information processing to classify it according to the classes defined in points a and b.
h) Records with information related to non-compliance [3], risk level, measured distance and georeferenced location of the problem.
i) Generation of vegetation cartography or forest map below the transmission line. This information is relevant to review the maintenance frequencies.
j) Two condition for precision in X, Y, Z: relative and absolute precision must be 12.5 cm or better.

Is important to consider the time to get the LiDAR results from contractor. It depends on the length of transmission line, the aircraft type or software used for analysis. Also, keep digital information safety is mandatory, to do so, is important to specify in the agreements how is it's the owner and how can be used by both parts. We recommend signing confidentiality agreements between the parties for this action.

4. RESULTS

Starting in 2020, the implementation of the new maintenance plan for the Primavera - Sogamoso 500 kV transmission line began, based on the information obtained with LiDAR technology, the characterization of the vegetation (with species classification) and the clear distance between their top to conductors.

In 2020 an optimization of 42% in the vegetation maintenance costs was achieved, making and adjustment from the cutting frequency of 8 months to 12 months of the 30% of the transmission line spans, including intervention of critical points of vegetation. In the 70% of the transmission line spans was implemented a light inspection were sprouts were cut. Figure 2 shows the savings projection in percentage between 2020 and 2029 based on the new vegetation maintenance frequency.

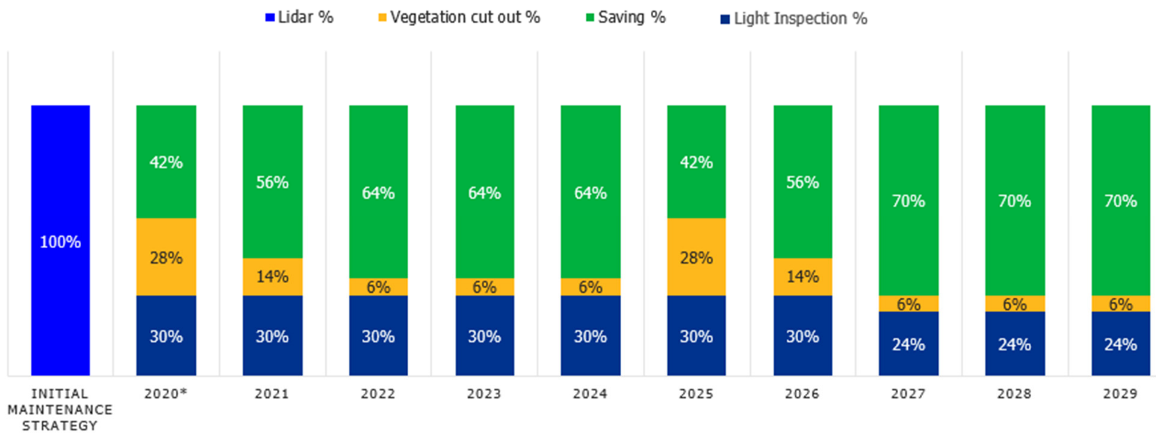

Figure 2 Savings projection (percentage) in vegetation management with LiDar inspections for Primavera - Sogamoso 500 kV transmission line

An additional result was a decrease of 324 operational hours of personnel and 296 hours of transportation to perform vegetation management.

Finally, with the information collected in LiDAR inspection, it was performed a detailed vegetation risk assessment existing in this transmission line. Each risk point identified correspond to a point in which the distance between the top of the tree and the conductor is in any of the risk category defined for us.

It is important to add that 3D model was not adjusted in terms of actual loading in time of trimming because it was considered three risk level (high, medium and low) to classify data in order to be conservatives about that.

We found 59 points with high risk (distance from phase to top of the tree between 0 to 7 m), 159 points with medium risk (distance from phase to top of the tree between 7 to 9 m) and 348 low risk points (distance from phase to top of the tree between 9 to 12 m). An example of one of this high-risk point is shown in Figure 3. [4]

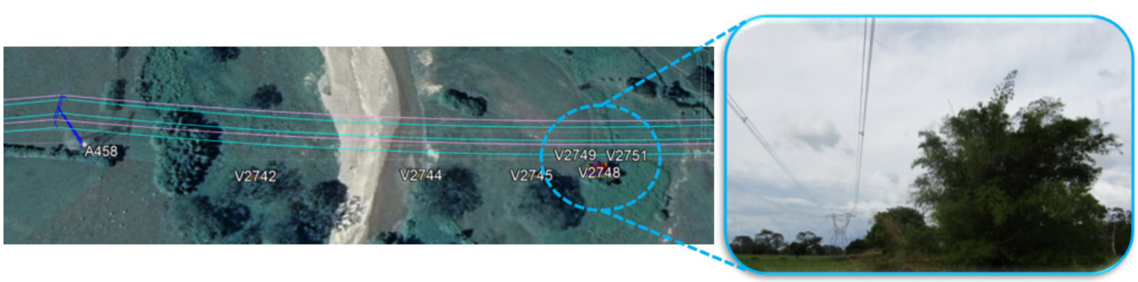

Figure 3 Example of a high-risk vegetation point identified

These points were intervened according to their level of risk, as shown in Figure 4.

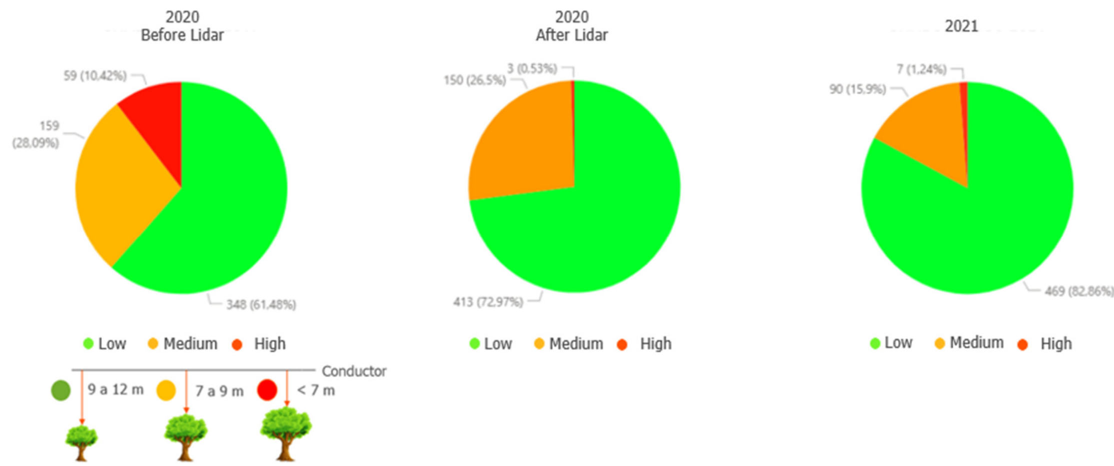

Figure 4 Risk analysis for Primavera - Sogamoso 500 kV transmission line due to vegetation approach to conductors

Note that in Figure 4, 3 points with risk persist after the intervention in 2020. These points correspond to access problems that are currently under monitoring. The rest of the line presents medium and low risks, which will be addressed accordingly in order from highest to lowest risk in 2021 and 2022.

Figure 5 shows how personal on field identify and intervened vegetation cutting down whole trees and pruning. Personal mobile and a geographical app is used to locate vegetations classify as non-compliance class (risk) in LiDAR inspection.

Figure 5 Process to identify and intervened vegetation classify with risk in LiDAR inspection

In conclusion, the maintenance activities carried out in field after the LiDAR inspection on the transmission line Primavera - Sogamoso 500 kV were useful to confirm that the incorporation of high technology inspections had a positive benefit for the risk management and the reduction of the maintenance costs.

It is important to note that, by performing selective maintenance, the amount of intervened vegetation is reduced, which translates into a benefit for the environment, a situation that is reported in the Dow Jones indicator in terms of sustainability. A summary of this information for Primavera - Sogamoso 500 kV transmission line is shown in Figure 6.

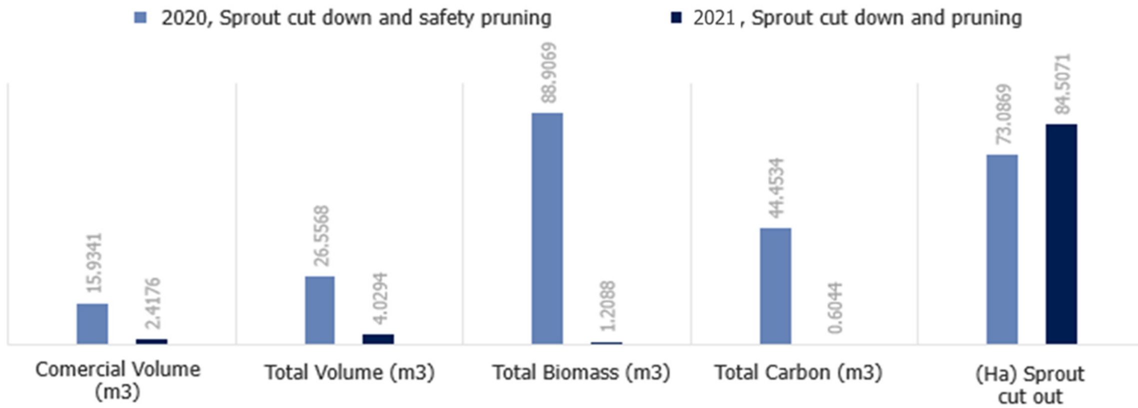

Figure 6 Environmental benefices obtained with the LiDAR inspection in Primavera - Sogamoso 500 kV transmission line

In Figure 6 is important to highlight that the increase showed in the number of hectares, is because we made more activities like pruning and sprout cut down vegetation, instead of felling trees. This type of changes is necessary because we try to avoid the trees increase their size and high because if it becomes an adult tree it would be more difficult to manage the risk due to environmental permissions we need.

In ISA INTERCOLOMBIA experience the mainly problem in this process was to define the classes for the risk points due to different types of vegetation growing in the spans. To do this, an interdisciplinary group is necessary to cover risks related with types and techniques to intervene vegetations, clear distances and possible problems with owners in the right of way that doesn´t allowed to do the maintenance. It was grateful for us find different suppliers in Colombia to do LiDAR inspections according with our specification, were the aircraft wasn´t a limitation (Each service provider could offer wherever them want to adapt the LiDAR and do the fly). Nowadays, suppliers offer ISA INTERCOLOMBIA more competitive LiDAR costs due to this experience.

5. CONCLUSIONS AND RECOMMENDATIONS

- The innovation process carried out in this case based on a service already available in the market for a specific need of the organization was satisfactory and was aligned with ISA's strategic vision.

- The capitalization of the knowledge of the field personnel in criteria for evaluating the condition of the assets is essential for the search for optimizations in the processes.

  The implementation of high-tech inspections with LiDAR in others transmission lines of ISA INTERCOLOMBIA will be carried out progressively, due to the initial investment costs. We estimate to have an annual number of 1500 to 1800 kilometers of transmission line LiDAR inspections.
  Our projections are to have full coverage by the year 2026 in transmission lines were the methodology applies.

- Currently, we are including in the business case the detection of constructions in the right of way of the transmission lines, a phenomenon that has considerably increased in the last 10 years. We foresee this type of technology as a strategic solution to manage this risk.

BIBLIOGRAPHY

[1] Gómez, D., Hernández, A., Suarez, M., Quintero, C., Hincapié, L., Guarín, S., Arango, J. C., Parra, E., & Garcés, J. C. (2016). Estrategias_de_Activos_Líneas-Transmisión.

[2] Suarez, M., Carmona, S., López, A., Gómez, D. (2019). ETN_Aquisición_Información_Gestion_Franja_Servidumbre_Líneas_Transmisión

[3] RETIE. (2013). RETIE resolución 9 0708 de agosto 30 de 2013 con sus ajustes. Resolucion 90708, 127.

[4] ITCO. (2019). Contrato de prestación de Servicio de Captura de Datos mediante Técnicas de Barrido Laser. 1400002211.