Increase resilience through investment in transmission, replacing expansion in distribution

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SUMMARY

The present work proposes a methodology of analysis that will allow us to relate the requirements of security, quality of service and product quality of the electrical distribution network with modifications and expansions of both the transmission and distribution networks.
The main idea is to evaluate different configurations, for both the transmission and distribution networks, from a technical and economic perspective to find the most cost-effective joint solution while at the same time achieving the regulatory requirements of both security and quality of service in the distribution network.

KEYWORDS

Planning, Transmission network, Distribution networks, Quality of service.

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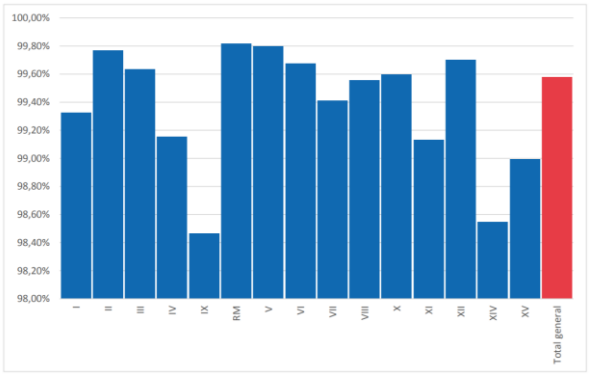
1. INTRODUCTION

The requirements and consumption needs of users of electrical systems both in Chile and in the world have changed, for example in Chile in the '80s, the national priority was increasing territorial coverage, today the focus is focused on delivering a better quality service, with high continuity and with low prices. Based on the above, various modifications have been made to the General Law of Electric Services, after this LGSE, which promote a robust, resilient and competitive electrical system with design and operation standards defined by the regulator of the electricity market, the National Energy Commission, henceforth and interchangeably CNE or Commission, seeking the economic efficiency of the system.

In Chile, the electrical systems are operated by private companies but the coordination of their operation is carried out by the Independent Coordinator of the Electric System, hereinafter Coordinator, which is an independent and technical body that watches over the economic and safe operation of the systems, guaranteeing and promoting open access to systems and monitoring the competition of the sector.

As anticipated, the concern for coverage was an early public policy in Chile, and its result is shown below with a graph with the percentages of electricity coverage in Chile, having a national electricity coverage of 99.6% and at the rural level of 96.5% (Estimated data as of January 2019, Source: Ministry of Energy, Ruta de la Luz):



Source: Energía Abierta
Chart N°1: coverage level advance

However, in terms of quality and continuity of service, SAIDI[2] levels can be observed by region for the year 2019:

[2] System Average Interruption Duration Index.

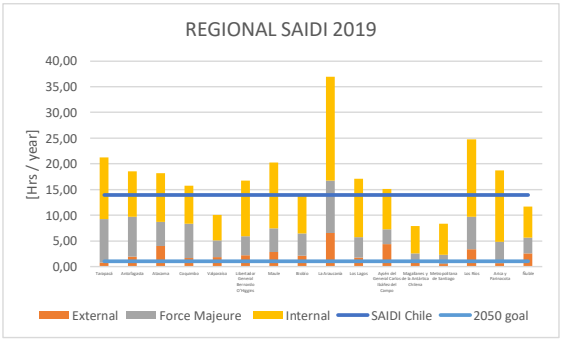


Chart N°2: Regional SAIDI 2019

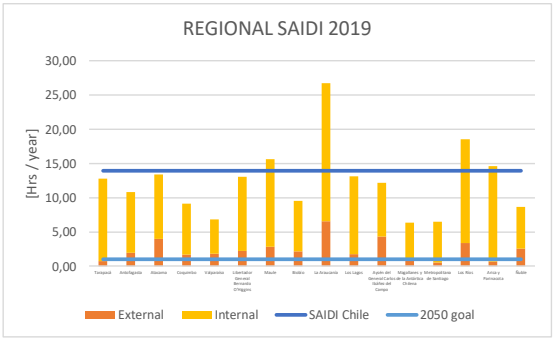


Chart N°3: Regional SAIDI 2019 without Force Majeure

From the previous graph, it is found that although interruptions caused by force majeure[3] are not considered, the sum of interruptions due to internal[4] and external[5] causes far exceeds the interruption time goal allowed proposed by 2050, goal contained in the **Energy Policy of Chile Energía 2050**, where it is stated that "*This is why, it will be sought that, by 2050, no region has more than one hour of average power supply unavailability per year, without considering force majeure*." Therefore, it is necessary to plan and evaluate the network solutions from an integral perspective, looking for the most cost-effective solutions that allow reaching the goal, situation foreseen in the LGSE, however not currently contained explicitly in the evaluation criteria used for the Preparation of the annual transmission expansion plan.

2. THE PROBLEM

The Chilean electricity market is composed of three main segments, generation, transmission and distribution, each of which has a specific regulation under a general principle of economic efficiency, which operate interrelated with each other, both physically and economically. Through the inputs and services provided by private actors participating in these sectors, the electricity supply is guaranteed to final, free and regulated customers, who must pay, in the proportion that corresponds, such benefits.

A particular case of the regulation that was established in the LGSE for the transmission segment was the existence of two methodologies of valorisation and planning of the networks that depended on the use that each one of them was given.

Through the modifications introduced to the LGSE by Law No. 20,936 of 2016, the planning and valorisation processes of the transmission segment networks are unified, starting a participatory exercise of centralised planning of the zonal transmission segment, whose definition is the following: "constituted by power lines and substations disposed specifically for the current or future supply of regulated, territorially identifiable customers, without prejudice to the use by free customers or generation means directly connected through transmission systems granted to said transmission systems[6]"

[3] Force Majeure: Supply interruptions due to failures attributable to Force Majeure, which consider events that are irresistible and unpredictable, such as an earthquake.
[4] Internal: Supply interruptions due to failures in facilities of the electricity distribution segment companies.
[5] Externa: Supply interruptions due to failures in business facilities of the segment of electricity generation and transportation.
[6] Article 77 Definition of Zonal Transmission System, LGSE.

This planning process must cover "*the necessary expansion works of the national transmission system, of development, zonal and dedicated poles used by public service concessionaires for the supply of users sometimes to price regulation, or necessary to deliver said supply, as appropriate*[7]."

Adding that the planning "could consider the expansion of facilities belonging to the dedicated transmission segment for the connection of the expansion works" and that in this case, these works will change their qualification by passing to a member of the same segment of the work that intervened (National, Zonal or development pole). It also establishes the considerations and objectives that must be protected by the process, such as the consideration of long-term energy planning carried out by the Ministry of Energy, economic efficiency, competition, safety and diversification established by the law for the electrical system.

Considering that the zonal transmission segment is where the distribution systems are connected to the electrical system, naturally, the requirements of the distribution segment in the planning of the zonal transmission should be systematically analysed, looking for a way to quantify the technical efficiencies and improvements in quality and continuity of service that would deliver a more robust network upstream, however, the methodologies employed by both the Commission, the entity in charge of setting the plan annually and as the Coordinator who delivers his vision through a proposal, preparing it based on an analysis of economic efficiency that focuses mainly on sufficiency of the transmission system without restricting the normative requirements required of the distribution network or evaluating whether a solution in zonal transmission is more cost-effective than one in distribution. The above is increased by having in view that the regulation of both segments is different and therefore, their remuneration and planning differ looked at from the end customer's contribution.

The distribution and transmission segments have natural monopoly characteristics, and therefore there is a need for prices to be set at average cost and that a right way to determine these average costs is through a tariff concept called the *Model firm.* This scheme seeks to reflect the necessary average costs that a new company would incur (starting from scratch) in executing and installing the infrastructure necessary to provide the service in a given area, as well as the costs of administration, maintenance and operation thereof.

The model described above is applied almost 100% in the distribution segment, however, in the transmission segment it has nuances that make, without prejudice that both seek to determine the total costs of providing the service, valued at new replacement value, differ in recognition of investments, thus in transmission 100% of the physical and technical characteristics of affected networks are recognised and in distribution, an optimal network is modelled to meet demand efficiently, said modelled network must comply with current regulations without obligation to recognise the characteristics of the real network, this means a challenge about correctly carrying out the analyses of how the different projects, located in transmission or distribution, increase the resilience of the systems, improve safety, quality of service and product quality, to carry out a comparison that allows determining which are the most cost-effective projects that allow fulfilling the predetermined objectives. It is comparing should not be based on the tariff scheme that finances various solutions but rather on the technical report and the eventual reduction of long-term costs that various solutions can provide, the above in the sense that the tariff scheme must be neutral with respect to the previous evaluations.

[7] Article 87 ° Transmission Planning, LGSE.

3. NEW STANDARDS OF QUALITY AND CONTINUITY OF SERVICE IN THE DISTRIBUTION SEGMENT. FOCUS ON THE CLIENT.

In December 2017, the Technical Standard for Service Quality for Distribution Systems was issued, hereafter NTDx, which establishes new requirements that would allow delivery of a better quality electricity distribution service, mainly focused on customers and users. The requirements of the NTDx can be classified into the following categories: Supply Quality, Commercial Quality, Product Quality and Measurement and Monitoring Systems.

Regarding the Quality of Supply, this refers to the establishment of limits regarding the duration and frequency of interruptions that affect customers and users of distribution networks. However, the limits established in the NTDx modify the approach sustained until its publication, which mediates the time and frequency of interruptions depending on the interrupted kVAs, placing the emphasis now on the end customer individually; therefore, a Client with Higher connected power is equal in terms of measuring the indexes to one with lower connected power. This paradigm shift necessarily implies more robust and resilient networks that allow compliance with the defined standards. However, technically or cost-effectively, the solution does not always involve modifying or investing in distribution solutions, but in zonal or mixed transmission solutions.

On the other hand, the current regulatory requirements regarding the continuity of service of the transmission systems differ both in the objective and in the limits established for the final customer.

Finally, it should be taken into consideration that public policy goals are focused on the client; therefore, it is indifferent, viewed from the client where the cause of the interruption is.

4. Modifications introduced by Law N° 20,936: Focus on the planning criteria

Law No. 20,936 modified the criteria with which the expansion of the transmission must made including the concepts of slack and redundancy, and incorporated in this planning all the facilities of the transmission system classified as public service, indicating that "it will cover the works of necessary expansion of the national transmission system, development´s poles, zonal and dedicated systems used by concessionaires of public distribution service for the supply of users subject to price regulation, or necessary to deliver said supply, as appropriate ".

The objectives of the planning process established in the Law should seek economic efficiency, competence, security and diversification of the electrical system by evaluating it over 20 years.
To comply with these objectives, the Law establishes that transmission going to planning considered several aspects like a next:

a) The minimisation of risks in the supply, considering eventualities, such as increased costs or unavailability of fuels, delay or unavailability of energy infrastructure, natural disasters or extreme hydrological conditions;
b) The creation of conditions that promote supply and facilitate competition, tending to the electricity community market for supplying demand at minimum cost with the ultimate goal of supplying supplies at a minimum price;

c) Facilities that are economically efficient and necessary for the development of the electrical system, in the different energy scenarios defined by the Ministry by the provisions of Article 86, and
d) The possible modification of existing transmission facilities that allow for the necessary expansion of the system in an efficient manner.

For its part, the electric system is the "set of facilities for generating power plants, transport lines, electrical substations and distribution lines, interconnected with each other, which allow generating, transporting and distributing electrical energy."

From above writing inferred that transmission planning must ensure the efficiency of the electrical system in general and, therefore, analyse all works that are economically efficient for the supply of free and regulated supplies at a minimum cost.
The legal discussion focused on protecting the generation competition, the most relevant component of the prices of the different clients, however, the principle of economic efficiency is a transversal principle that the law imposes on planning and pricing of all segments that implicate a searching for an adequate transfer of costs to end customers.
Based on the above and taking into account the new regulatory requirements of distribution systems, it is necessary to develop a methodology that, as established by the Law, analyses the alternatives for the supply of final supplies both from the sufficiency as from the security and quality of service but seeking according to the principle of economic efficiency the most cost-effective solution.
However, as proposed in the Transmission Planning Regulation, soon to begin its process of reasoning in the Office of the Comptroller General of the Republic, the methodological provisions are established with which the planning process of the transmission, defining each stage of the process and the considerations to keep in mind in each one of them.

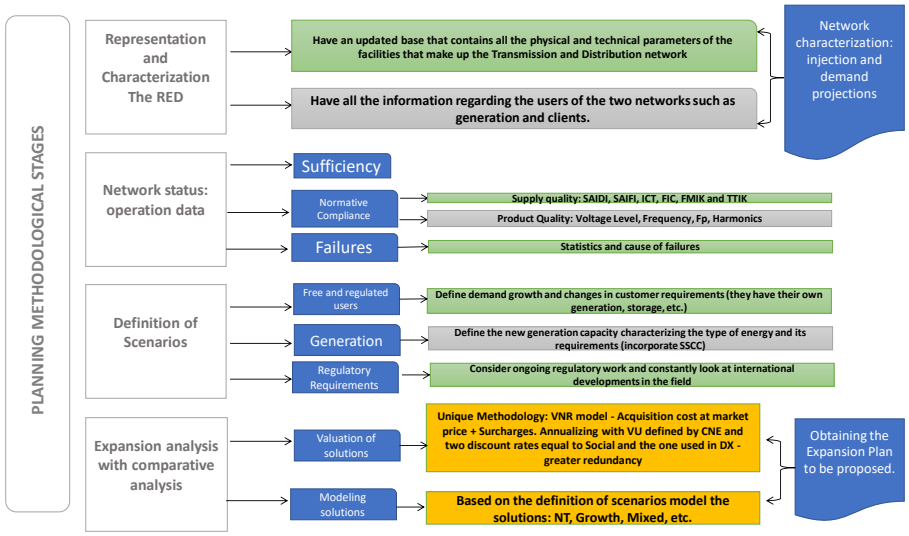
The successive stages proposed in the regulation are:
a) Preliminary analysis.
b) Analysis of Sufficiency and Operational Efficiency.
c) Analysis of Security and Quality of Service.
d) Technical Feasibility Analysis of Expansion Projects.
e) Economic Analysis of Expansion Projects.
f) Resilience Analysis.
g) Analysis of the Common Electricity Market.
h) Formation of the Expansion Plan.

In particular, at the stage called "Analysis of Operational Efficiency and Efficiency," a particular consideration is incorporated for the evaluation of the expansion works of the zonal transmission systems, allowing the Commission to consider, among other variables, the particular characteristics of the distribution systems to which they directly supply the zonal transmission facilities. Evaluating, among other things, "the incorporation of new primary distribution substations, as well as the expansion of existing ones, considering for that purpose the maximum projected demands of the area, new growths, projections of generation in distribution, load transfers in the system of distribution or representative indicators of said system, such as MVA / km, MVA / km2, rural or urban area, among others. "
For its part, the planning of the distribution networks is in the hands of the public distribution service dealers, who must at all times supply the users connected to said network, under the standards of quality and continuity of service defined by the authority. Since urban growth is not necessarily planned, and taking into account that there are urban limitations and points of income to the distribution network, primary substations that do not depend on the concessionary companies of public distribution service, the need arises that the planning of the transmission,

within its considerations, analyse the demand location requirements and regulations with which the supply must be provided to the end customers connected to said network to preserve the efficiency criteria of the electrical system, at the same time the service is provided at minimum cost and with the established standards.

5. Search for a plan that analyses all the requirements

The transmission network planning must analyse not only the adequacy requirements of the system but also its contribution to the quality and continuity of the service of both its facilities and the system in general; it is therefore proposed that for planning purposes they are carried out at minus the following stages:



As indicated in the planning process diagram, to adequately meet the regulatory requirements established for both segments is that an appropriate representation of existing networks must be available and, based on the performance of each, look for investment solutions that improve overall quality of service, focusing this analysis on the continuity of supply indexes for being the requirement with more information in both segments and where the authority has placed emphasis may be beyond what is embodied in the technical regulations. Moreover, as long as there are no registration systems or "smart meters", you can only have product quality indicators globally, that is, in substations and / or feeder headers.

It is proposed to analyse the requirements by a quality that are considered:

a) The FMIK and TTIK indices in the Control Points of the transmission system, emphasising the origin of the failure (segment), the duration of the failure, the number of affected customers (taking into account that the distribution no longer determines the indices depending on the load dropped) and the frequency of occurrence of failures at that point.
b) Once the Control Points that are very out of range have been determined, understanding that there is no specific rule today, but a suggestion by the Coordinator, analyse the necessary investments so that, at least the previous indices, are within the proposed range by the Coordinator.
c) Analyse how these improvements positively affect the customer, regardless of the source of the failure, decreasing their outage hours as well as their frequency.
d) Los índices de SAIFI, SAIDI, TIC y FIC, dando énfasis a la causa de la falla, la duración de la misma y el número de clientes afectados.

e) Based on the above indices, determine which ones are outside the permitted limits, and analyse whether the indices with higher investment or maintenance and operation in the distribution segment can be improved, and then compare whether an investment in transmission is more cost-effective not only in economic terms but additionally has greater customer coverage.
f) With all the indexes and causes thereof, generate a data that identifies the physical characteristics of the elements that are most prone to failure, whatever their type.

6. Valuation of solutions.

A fundamental stage of defining the economic convenience of an expansion plan is to analyse how cost-effective it is for the system and this, it is necessary, apart from evaluating the technical suitability of the same, to value them to determine the suitability for the system and, for so much for its users.

According to the provisions of the LGSE regarding how the facilities or the provision of a service in the pricing processes of the same are valued in the respective segments, is that it is proposed to use as a valorisation mechanism the New Replacement Value or VNR, this is because beyond that in distribution and transmission the transport or distribution service is valued differently, one through price signals and the other through the valuation of the different assets, in both it is used to define the value of the facilities the concept of VNR.

Beyond that, when analysing the bases of the last process of valorisation of the transmission and the modifications for the determination of the VAD, it can be observed that the equations are defined, concerning the determination of the valorisation of the networks, they are very similar.

7. The case analysed and conclusions.

The evaluating options for new feeding points to a distribution system made through the implementation of new substations in the zonal transmission system and their respective transmission lines.

For each of the alternatives evaluated, the new associated topology in the distribution system appears, which in this case involved changing the injection points and opening some lines in two feeders, this resulted in two topologies of the distribution network, called base cases and projects respectively.

The following table shows the percentage of variation in the expected value for both the number of customers with failure and the power with failure.

Table 1: Improve in quality of service (@ base case)

Feeder	The decrease in the number of customer interruptions [%]	The decrease in interrupted power [%]
1	-46%	-53%
2	-30%	-26%

Is clear that there is a considerable improvement in both indices concerning the base case.

On the other hand, about the quality of products, the percentage of variation is measured both in the average voltage drop and in the voltage imbalance, shown in the following table.

Table 2: Improve in quality of the product (@ base case)

Feeder	The decrease in average voltage drop [%]	The decrease in average voltage unbalance [%]
1	-67%	-73%
2	-56%	-60%0

As in the previous case, the improvement is remarkable in indices related to product quality improve considerably.

The benefits from both points of view, the continuity of service and the product quality, of the incorporation of the evaluated projects to the network are evident.
The question to answer is: How should these projects be evaluated?
If using the classic method used in the system adequacy evaluations, the economic evaluation delivers predictable results, that is, the non-recommendation of the works because it is not efficient for the system to carry out the investments from a purely economic point of view.

Another question to answer is the following: Is the baseline scenario against which the transmission solutions evaluated feasible?
Without a doubt, if it considers that there should not be a discriminatory cake among the users of the network concerning the continuity of service and quality of the network, any base scenarios used to comparate the projects must be considered or adequately complemented to be a line base comparable.
For example, consider that the improvement of continuity of service for each client benefited with the products evaluated, in the base case an alternative cost should increase for each client, such as, for example, the permanent operation of own generation to fill the system's deficiencies the alternative cost would be oversized from a systemic point of view but not from the individual point of view of the customers supplied from a system that does not meet the requirements of continuity and quality of service, the above should not be confused with the evaluation of the not supplied energy, ENS ("Energía no Suministrada"), since this last one obviates the need to have permanently the investment in the place where the clients of the capacity of autogeneration connect.

In this sense, what corresponds in the next stage would be to evaluate the best way to make the comparison.

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