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Planning of transmission systems in Chile after the regulatory changes introduced in 2016

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SUMMARY

In Chile, until 2016 the National Energy Commission carried out a centralized planning of the trunk transmission system, which consisted of transmission assets with a voltage level of at least 220 kV, which were economically efficient and necessary to enable the supply of the totality of the demand of the electrical system, among other characteristics.

In order to carry out the planning process of the trunk transmission system, the expansion needs of these networks were projected using different inputs such as demand forecast and fuel prices evolution, among others. From these studies it was projected the economic dispatch in a multi-nodal and multi-reservoir software, and on the other hand, the behaviour of the electrical variables was analysed in accordance with the provisions of current technical regulations. Once the expansion needs were detected, which could be classified as new projects or enhancement projects, these were tendered and awarded to private companies to acquire the right to build and operate the new transmission assets.

Subsequently, with the reforms introduced during 2016 to the General Law of Electric Services, which implied important modifications in the regulatory framework of the Chilean system, the segments of the transmission system (Trunk, Subtransmission and Additional) were modified, giving rise to new segments, which in some cases presented a strong correlation with respect to the previous segments (National, Zonal and Dedicated), while in other cases they were new conceptions and paradigms that could occur in the Chilean electricity system (Development Poles).

With the modifications, an annual centralized planning of all the public service segments (National, Zonal and the Development Poles) is made, which means a planning process that goes from 500 kilovolts transmission systems down to primary distribution substations. This implies a significant increase in the number of variables, plus the creation of new methodologies, in the sense of transmission expansion criteria.

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KEYWORDS
Reforms, transmission planning, transmission segments, expansion needs, centralized planning.

I. AMENDMENTS INTRODUCED IN LAW 20.936

During 2016, Law No. 20,936 of 2016 was published [1], which introduced changes to the General Law of Electric Services (LGSE) of Chile, in particular to the transmission segment of the Chilean electricity system, consisting on: (i) new segmentation of transmission systems, (ii) transmission planning, (iii) open access regime, (iv) remuneration and transmission payment, among others. Regarding the new segmentation in the transmission system, the new law makes a National Transmission System (former Trunk), Zonal Transmission Systems (former Subtransmission), Dedicated Transmission Systems (former Additional), and also a Transmission System for Development Poles (new segment) and an International Interconnection System (new segment).

Regarding transmission planning, prior to the change of law, there was a centralized annual planning process that was done in the National Energy Commission (the regulator of Chile) only for the National Transmission segment, whose objective was to recommend specific projects that allow in supply of the demand, criteria of quality and security, according to the criteria that were established to belong to the National Transmission segment, such as: (i) variability in magnitude and direction of the power flows, (ii) nominal voltage equal or greater than 220 kV, (iii) magnitude of the flows was not determined by a small number of consumers, (iv) that the flows in the lines was not attributed exclusively to a customer or the production of a generating plant, among others. In this planning process it was possible recommend two kind of transmission types: new projects and enhancement projects. As for the former, construction operation and exploitation rights are awarded through an international public bidding process carried out by the economical dispatch center (now the National Electric Coordinator, or CEN). As for the enhancement projects, which implied modifications to the existing transmission assets, it was the responsibility of the owner of asset the tender, award and commission the projects that were set in the annual expansion plans.

As regards the remuneration system for transmission assets, it consisted of two remuneration modalities. Regarding the new projects that are fixed through the annual expansion plans, they are remunerated during 5 tariff periods (20 years) according to the value awarded in the public bidding process, whose value consists of an Investment Value Annuity (AVI) plus an Operation, Maintenance and Administration Cost (COMA). In the case of the exists assets and enhancement projects that were set in the annual expansion plans, they were remunerated according to a four-year period tariff analysis, denominated Trunk Transmission Study (ETT), which determined the AVI and COMA of transmission assets. That study, in addition to determining the payment of the transmission assets, calculated the set of transmission assets of the system, which met the criteria to be qualified in the trunk transmission segment. In addition, in the same ETT the necessary expansion needs for the Trunk Transmission System for the next four years were analyzed, considering for such effects a planning horizon of at least 10 years, developed by a Consultant and revised annually by the regulator. Finally, with respect to the payment regime, the trunk transmission assets were paid by the generators and final consumers, through allocation mechanisms based on expected use.

In relation to the Zonal Transmission System, its expansion was planned and built by the companies that own the transmission assets. Previously, the regulator assigned, from the total transmission system, to the zonal transmission assets according to the criteria established in the law, through a four-year process, and not in conjunction with the assignation at Trunk Transmission System assets. The latter generated regulatory problems, which could result in some transmission assets without a segment and hence, without regulated remuneration. The pricing of these networks was determined

from a model company, for which, a four-year tariff study was realized, which presents a horizon of 10 years, for which theoretical exercises were performed of: (i) dispense with assets, (ii) optimization of existing assets, and (iii) expansion of zonal transmission networks. Regarding the first, a theoretical exercise is carried out to determine which installation was not useful for the system, for which it is carried out among other analyzes based on simulations of expected use of the networks in which it was quantified whether to dispense with a particular installation implied, with respect to a base case: (a) Energy Not Provided (ENS), (b) decrease in security, and / or (c) breach of current technical regulations. On the other hand, once defined what assets would be dispensed with, a second exercise was carried out, in which these assets were not considered, to determine which system networks presented slack capacities, in the evaluation horizon, between their expected use and their technical capacity, in order to carry out a theoretical exercise on which the payment of a network optimally adjusted to its expected use would be considered for tariff purposes, eliminating inefficient gaps. Finally, the indicative expansions on the zonal transmission networks were carried out, in order to recognize the investments that the owner of the networks would have to make to comply with to supply of demand and the technical regulations in force during the analysis period (10 years).

In relation to the last transmission segment, that is to say the additional one, its rating was fixed in residual form to the regulated processes of the qualification of assets, that is, the assets that were not categorized as part of the Trunk Transmission System nor as part of Zonal Transmission Systems. In accordance with the characteristics of the assets and the specific criteria by the Law, it was mainly identified for the injection of the generating plants or for the withdrawal of the clients with not a price regulation.

After almost a decade of implementation of the regulatory model of transmission, a series of problems were observed that do not meet the new requirements of electrical systems such as: (i) it did not allow the normal development of competition in the generation segment, (ii) it did not having long-term planning; (iii) remuneration of transmission assets did not generate an incentive for the development of the generation; resulting in an uncompetitive market system with a little robustness transmission system with few slack capacities, (iv) Uncertainty in the payment that generators by the use of public service transmission assets (National and Zonal Transmission) what which resulted in the said risks being transferred in the supply contracts for end customers, (v) entry barriers by the owners of transmission assets for the connection of generation projects (unregulated open access), (vi) inefficiency in the planning of the centralized transmission carried out by the regulator with the planning carried out by the companies that own zonal transmission assets, among others [2].

Based on the above, with the new transmission law, important centralized planning tools were incorporated by the state, and specifically, the regulator should consider all transmission segments: National, Zonal, Dedicated, Development Poles and International Interconnections. In the first place, the new regulation contemplates a long-term energy planning in the electrical system that must be carried out every five years, considering different generation and consumption scenarios for these purposes, and having at least thirty years as a horizon. In addition, this planning should identify the areas where there could be power generation development poles, which are geographical areas where there are resources for the production of renewable energy, and whose use was of public interest. For its part, the transmission planning will require the aforementioned energy planning and will consider for the analysis of the system, at least twenty years. This will be carried out annually by the regulator and should promote the objectives established by the law itself, such as economic efficiency, competition, security and diversification, in turn to give signs of location for the efficient development of the generation and give greater robustness to the system. These changes are a novelty with respect to the previous electrical regulations, mainly with respect to the zonal system due the growth of the transmission assets had been realized by the private initiative. This has resulted in relevant interests have been undervalued, such as regional and local development; citizen

participation and environmental concern; the protection of sustainability; efficiency in the planning and the use of existing transmission assets, among others. In this context, the new law takes care of these concerns and explicitly the authority when deciding the expansions of transmission assets should evaluate such objectives. To consider a centralized planning of the zonal transmission not only solves the issue of efficiencies in the development of national and zonal transmission planning, but also allows the definition of distribution substations that are required by distribution owners, considering for this the location of new substations in strategic areas according to the urban and rural growth of the population, incorporating the synergies associated with the expansions in the distribution networks made by the distribution owners themselves, among others, considering the planning of said segment (zonal transmission) starts above the voltage level of 23 kV.

On the other hand, regarding the payment and remuneration of the transmission assets, the law made a profound change to the previous model, transferring it to the final customers (both regulated and no regulated) the payment of the costs of the National Transmission Systems, Zonal and Dedicated used by regulated costumers. For this, a mechanism of single access charges was established by the use of the transmission system, called "stamping". Having said the above, in terms of planning, the new regulations allow changing the paradigm of how they should be addressed and the objectives that must be met in the planning of the electrical system, having as clear objectives how to achieve transmission, favoring the development of a generation market. That allows to reduce the prices of energy to the final clients and to incorporate in the planning a long term perspective that allows to consider aspects like the interests of the society, the care of the environment, the use of the territory and the strategic vision of the state.

As for the criteria and methodologies that have been implemented, almost four years after the publication of the new law, the regulator has had an information analysis and processing process, which generates a long-term expansion plan, ensuring objectives not only of a technical and economic nature, also of the social, environmental and security type in the supply of customers. However, considering a large number of variables in the process generates a multi-objective decision problem, including the high uncertainty that some of them have in the long term, such as demand growth, insertion of renewable energy, fuel prices, environmental requirements, public policies, among others.

The development of the current planning methodology was previously having a review of the main countries of the world that make a transmission planning, such as: Australia [3], Canada [4], Colombia [5], Great Britain [6], New Zealand [7] and the United States [8,9,10,11], among others. Likewise, some specific planning methodologies have been considered according to documents ENTSO-E [12], CIGRÉ [13] and EISPC [14]. A large part of these countries face the same paradigm, that is, to solve a problem of multiple variables, with main objective, to determine the needs of the system to guarantee the supply and reliability of electricity consumption, in addition to other objectives such as favoring the change of the energy matrix towards renewable energies, reduce prices, among others. Although they also differ in other aspects such as the periodicity of the expansion review, the horizon of analysis (medium or long term), the strategic objectives of each country. At the end, all processes end with a decision-making that requires technical criteria, economic, social or political in some cases, which will ultimately determine the transmission expansion projects that will require incorporate to the system.

II. PLANNING PROCEDURE ESTABLISHED BY LAW 20.936

Regarding the stages, procedures and deadlines involved in the annual expansion process, these are defined in Article 92 of the Law. Indeed, the process starts with the reception of a proposal for the expansion of transmission assets developed by the CEN during the first fortnight of the year, which

must be published within five business days by the regulator and making a call for the presentation of proposals by project promoters, to be submitted within 60 business days.

In order to the regulations issued for the purposes of the matter, the regulator is going to publish a Preliminary Technical Report (PTR), accepting or rejecting each of the proposals, both from the CEN and from the project promoters. In addition, it may include projects that, according to its analyses, contribute to fulfill the objectives of the transmission planning. Within 10 business days, interested participants, users and institutions, who have registered in the registry drawn up for the purpose, can submit observations to be resolved by the Commission within the next 30 business days, through the preparation of a Final Technical Report (FTR). Interested participants may go to the Panel of Experts, if they persevere in their observations or if the Commission has carried out modifications in the report and they consider that those changes must be reversed, by presenting a discrepancy to the matter. This instance includes the development of a public hearing, and within the next 50 business days, the Panel of Experts will establish a resolution, responding to the discrepancies presented. Finally, a Definitive Technical Report (DTR) is developed, including the resolutions of the Panel of Experts.

Considering that through the new Law, an intermediate stage was introduced between the issue of the preliminary report and the elaboration of the definitive report (that includes the resolutions of the Panel of Experts), the risks associated to delays in the processes were reduced, since the detected inconsistencies could be amended without going to the Panel of Experts. The foregoing becomes especially relevant in attention to the greater amount of transmission assets resulting from the planning of more transmission segments. Thus, although the new Law involved the development of a new intermediate stage – the FTR - (with the associated times to its development), it allowed a reduction of the uncertainties and delays of the process itself.

Later, the Definitive Technical Report is stated in two Expansion Decrees (one for the enhancement of existing assets and another for the development of new assets), with the list of assets to be tendered for construction. In the particular case of the new assets, the associated decree additionally identifies, which assets must enter, before getting tendered, to a procedure to determine preliminary land strips, in order to identify, in advance, the potential risks associated with the concretion of new assets and to propose land strips for the tentative location of the new assets. This procedure would be carried out through the public instrument named "Strips study", to be developed by the Ministry of Energy.

Finally, it must be indicated the inclusion of a mechanism for the express development of transmission assets that, given the whole process execution times, would not be materialized in time if entering through the regular expansion way, above explained. This mechanism is contained in the article 102 of the Law, which establishes the applicable conditions for the interconnection of transmission assets, without these being part of the regular transmission expansion process. In such cases, the regulator may approve those assets, after a well-founded report justifying the urgency and need of the facility, as well as its exclusion of the regular transmission planning process, with the prior revision of CEN.

III. DEFINITION OF TRANSMISSION SEGMENTS IN THE REFORM OF THE LAW

The reform of the Law, in its articles 74° to 78°, establishes the formal definitions of the new transmission segments that replace the old denominations.

The National Transmission System is defined in article 74 as the one that allows the conformation of a common electricity market, interconnecting the other transmission segments, and is composed by

the power lines and substations that allow the development of that common market, and that make possible the supply of all the electrical system demand against different scenarios of generation, contingency and failure, and in consideration of the service quality and security requirements of the assets. In this new definition, the main differences come by: i) the incorporation of the concept of "common electricity market" into the definition of the previous homologous segment ("Trunk transmission system"), ii) the displacement of the indication of economically efficient assets, which was part of the definitions previous to the reforms, iii) the articles referred to the planning process of the transmission (discussed in the previous chapter) and iv) the flexibilization of the necessary conditions to consider a facility in the national segment (they are not directly stipulated by Law).

The new article 76 of the reform, defines the dedicated transmission segment as the one composed by the radial power lines and substations, which are interconnected to the electrical system and are essentially disposed for the supply of unregulated customers or for the injection of power plants. In addition, they are considered dedicated assets, those meshed assets that, being disposed with the previous objective, also verify that their operation does not produce significant impacts in the operation of the rest of the system. It is necessary to indicate that the main modification introduced by the reform of the Law, in relation to the old additional assets, is indicated in article 87, which allows the intervention of the dedicated assets in order to the elaboration of the annual transmission expansion plan. Thereby, with the reform, the central planning of the transmission network acquires tools to better fulfill, and in a quicker way, its objectives, by reusing existing infrastructure, and taking care at the same time, of the performance of those intervened assets. When occurring these interventions, the intervened assets will become part of one of the other transmission segments, changing the way they will be remunerated.

The law reform defines the zonal transmission systems in the Article 77. These systems are composed by power lines and substations arranged essentially for the current or future supply of regulated, and territorially identifiable customers, notwithstanding the use that unregulated customers or generation means can make, directly or through dedicated transmission systems connected to them. In this segment, there are the greatest differences in contrast to the previous regulation. In particular, zonal assets are included now with a binding nature in the annual transmission planning process; also, in the law there were specified some aspects related to the target customers to be supplied by these assets, and there were removed some provisions related to the operational characteristics required to categorize a facility as subtransmission.

Transmission systems for development poles and International Interconnection systems are not relevant for this paper purpose.

IV. DESCRIPTION OF THE CHILEAN ELECTRICAL SYSTEM

The list of transmission system assets used to carry out the transmission planning process for year 2017 is presented in Table 1.

Table 1: Characterization of sections of the National Electric System

Item type	Number of sections	Topology section		Topology section [%]	
		Radial	Meshed	Radial	Meshed
Lines	1039	672	367	64,7%	35,3%
Transformers HV/HV	148	83	65	56,1%	43,9%
Transformers HV/MV(*)	292	290	2	99,3%	0,7%
Transformers MV/MV	4	4	0	100,0%	0,0%

(*) MV corresponds to the voltage level of the primary distribution substations, which are up to 23 kV.

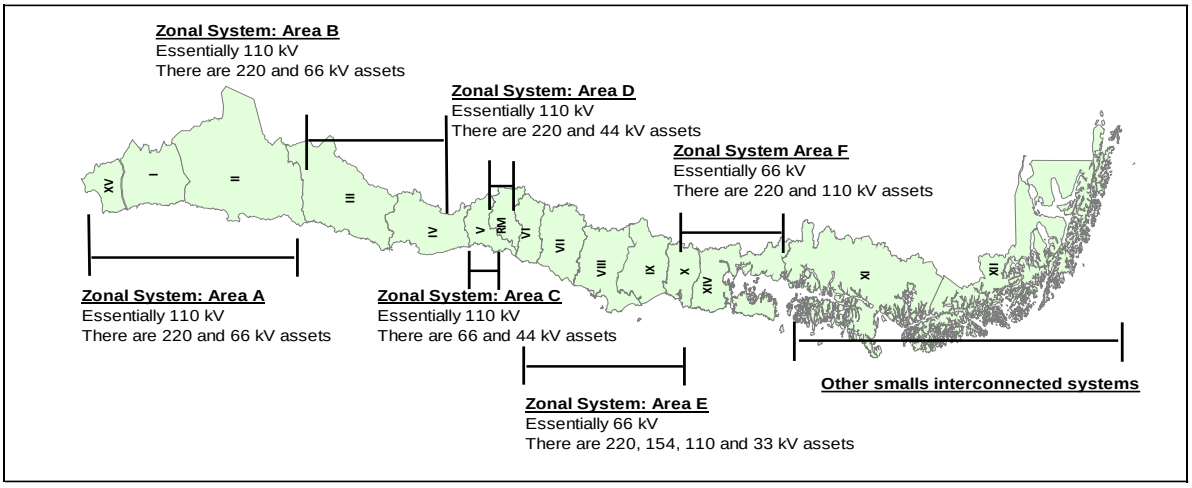
A detail of lines and their voltage level are presented on Table 2:

Table 2: Transmission Lines and their voltage level

Voltage [kV]	33	44	66	110	154	220	345	500
Number of radial lines	7	26	261	228	25	123	1	0
Number of mesh lines	0	0	52	103	29	171	0	12

In Figure 1 it is presented the geographically layout of the national electrical system is shown, in which the composition of the zonal transmission systems is highlighted.

Figure 1: geographical layout of zonal transmission system of Chile



V. METHODOLOGICAL DEVELOPMENT

The method with which the procedure to plan the transmission was constructed was developed through the following stages: (i) internal discussion in the National Energy Commission (the regulator), (ii) acquisition of studies, (iii) development of seminars with national exhibitors and international exhibitors, (iv) discussion between the regulator and a small group of specialists through working groups, (v) reception of methodological proposals by stakeholders.

The challenges presented by Law 20.936 for the development of transmission, where the process was transformed, from a reactive to a proactive planning with respect to generation, based on a centralized process that no longer only plans transmission assets national (system with voltage installations greater than or equal to 220 kV), but also zonal systems (systems with voltage installations less than or equal to 220 kV), as well as the change in the payment scheme of transmission assets, they opened multiple questions about the criteria to be adopted in the process to face the challenges established in the Law, among which are: the minimization of the risk of supply of energy demand, the creation of conditions that promote supply and facilitate competition, as well as efficient project development. In this sense, the following methodology aspects was discussed and incorporated into the:

Definition of generation scenarios: due to the link established by the Law between Long-Term Energy Planning (PELP) and Transmission Planning (PET), it was decided to use the PELP generation scenarios adapted to the demand of planning process. In addition, the supply was segregated into geographically, because the model of PET has a greater number of nodes than the used in the PELP. The number of scenarios will always be less than those of the PELP, only if one scenario may be contained under the characteristics of others.

Projects inclusion criteria: a debate was developed between the regulator and the industry on the main lines that define the admission of the expansion project, among which are the security criteria that the system must have (N, N-1, N-2, among others), the economic criteria, the type of economic evaluation that will be used (cost-benefit, multiple criteria). Also, to estimate the operational efficiency provided by the expansion projects, the maximum use of the assets to cause an expansion (80%, 85% or 90% of uses), maximum uses differentiated by type of installation.

Methodological link between the new process and the method before regulatory changes: the link is established through the transmission system with a voltage greater than or equal to 220 kV, previously called the trunk transmission system and currently known as the national transmission system, because both have multiple technical and economic similarities in the development of the electricity market. Consequently, it is decided that the criteria for the security analysis of this system will be based on the regulatory compliance of the N-1 criterion based on the contingencies that define the technical regulations and, the sufficiency of supply and demand will be developed searching for economy efficiency in at least 50% of the generation-demand scenarios established for the planning process.

Balance between the efficiency and security of the zonal system: in view of the regulatory change established by the payment methodology of the assets and the development of the planning of this systems, the Law establishes the obligation to supply the demand, but does not indicate degree security or maximum disconnection hours that customers can receive over a period of time. Therefore, for this systems, security does not follow a strict criterion, such as national transmission (criterion N-1), but will be developed based on the economic benefits provided by the expansion projects in the system, regardless of the voltage level of the installation. It was explored to advance the expansions required by sufficiency, taking into account the benefits it provides for security.

Zonal systems and the coexistence with the distribution systems (voltage systems up to 23 kV): although the regulation establishes as a fundamental criterion the economic efficiency of the solutions, the impossibility of planning the distribution systems avoids the imposition of obligations or synergies between the distribution systems and zonal projects, so it is decided to establish methodologies that prevent the deterioration of the security conditions in the zonal system.

The size of the problem and the technological tools: the tools had to be modernized to allow the analysis of national and zonal transmission assets, in times reasonable, and to be able to model the technical characteristics that are necessary to elaborate the different studies of the expansion plan.

Variable Renewable Energies (ERV): the great penetration of intermittent generation sources (solar and wind) forced the regulator to hire studies that allow us to know the "good practices" with which international markets face the problem of the times of development of the generation assets compared to the development times of the transmission assets, as well as the needs that the system developed due to the ERV installation, with the purpose of determining the criteria for the planning of the transmission systems and the methodology to develop the simulation of the systems.

Consult the industry about the problems detected in its assets and the consequences transferred to its customers: problems were detected essentially in the zonal systems, which are mainly associated with: (i) security and quality of supply, (ii) speed of development of renewable energy variables and (iii) system congestion. With respect to the consequences transferred to the client, these consist of the loss of supply in case of accidental occurrence or events of third parties and the transfer of cost overruns due to the lack of synergy between the development of the zonal and distribution system.

Use of a public information system: It will be established as the main source of information regarding the technical characteristics of the transmission and generation assets, as well as the network topology, the public information system developed by the National Electrical Coordinator, it is based on the information that the National Electrical Coordinator requests from the owners of the assets. This is relevant with the purpose of modeling all installations according to their technical characteristics such as: (i) resistance, (ii) inductance, (iii) current-capacity curve, (iv) voltage levels, (v) features generators, among others.

Transmission capacity: with the intention of not planning a system with oversized or subdivided transport capacity, the following criteria are chosen: (i) Power Transformers: its maximum transfer capacity includes the stages of forced cooling enabled for the equipment, (ii) Transmission lines: The capacity of each circuit was defined taking into account the average monthly maximum temperatures that the geographical area of the country has had.

Consumption: forecast of this variable considered in the planning process comes from a study developed by the regulator, which is based on the background provided by the concession companies of the public distribution service and the National Electricity Coordinator. The report indicated above is complemented by the information contained in PELP.

VI. IMPLEMENTATION OF THE METHODOLOGY

According to the studies, debates and criteria adopted in the previous section, a methodology for the development of transmission system planning is implemented, it was analyzed for all possible scenarios, based on the following stages:

System diagnostics: This stage seeks to determine areas that during the analysis period, need expansion works to maintain or increase the sufficiency or security of the system.

The diagnosis of the transmission system is carried out for a 20-year horizon by means of an optimal system operation study, for which a hydro-thermal coordination software is used that allows multimodal and multi-reservoir modeling. To complement the results obtained from the operation study, electrical studies are carried out in the system. The preliminary analysis of the results is performed using the following criteria:

- Considering the topological characteristics, 90% of the maximum capacity of the facilities in the task of supplying the demand must not be exceeded.
- The assets must satisfy the current technical regulations (for example, voltage drop).
- The expansion needs must be met taking into account the estimated deadlines that will take the different stages of the planning process and the development times of the different types of projects (laying of new transmission lines, replacement of transmission conductors, installation of new or replacement of transformation units or construction of new substations).

Faced with deficiencies developed in the system, in the estimated time window for the development of a project, must be chosen faster processes of evaluation and execution of projects as established by the Law, these processes are outside the annual transmission planning. This other process is relevant, because centralized planning implies slower development processes than the immediate construction of a project, as indicated in section II. Therefore, for example, in case a zonal transformer is required, voltage 66/13.2 kV, to supply demand immediately, due to abrupt consumption development, then this project, considering the planning criteria, it is incorporated through the alternative indicated route.

Analysis of operational efficiency and sufficiency: This stage consists of identifying the transmission works that allow the incorporation of the supply that improves the operating costs and the failure of the National Electric System and / or that allows to satisfy the demand, in front of the different scenarios of supply and demand.
The system is divided into the areas that normally operate mesh type and radial, having as operational condition of the system the reported by the National Electric Coordinator for the year of start of the simulations, below are the information and studies on which this methodology is based:

1) Mesh type assets: Economic dispatch simulations are carried observing the projections of flows, the energy not supplied in the area, the costs of operation and system failure. To solve the problem, projects submitted by interested users or institutions are evaluated, in case there are not projects or if this is inefficient, the regulator proposes works to solve the deficit detected.
2) Radial installations: power flow simulations (AC) are carried out through all the radial installations of the system, observing which ones show a loss of sufficiency during the study period or a decrease in their tension properties that infringe the current technical norm. This kind of assets corresponds to zonal systems, on the centralized planning sense, and are analyzed using the same methodology independent of the voltage level. In both cases, the analysis is developed out based on the most demanding projected global demand for the system, always respecting the particular progression of each node.

Security analysis: The objective of this section is to determine the works that allow the national and zonal transmission system to be redundant based on the needs discovered in the "System Diagnosis" stage. The security analysis of the transmission system is divided, as a result of the minimum technical characteristics (technical standard) that each installation must have:

1) National transmission system: current technical standard for Chile establishes that the installations belonging to this segment must meet the N-1 criteria.
This stage is developed out using studies of the operation of the system, to narrow the area of interest and then, through electrical studies, the effectiveness of the work is analyzed.
2) Zonal transmission system: a cost-benefit evaluation is carried out between incorporating a new project to contribute to the security of the System, regarding the situation without project and the eventual contingency of one of the existing facilities, for which output rate probabilities are used, and the energy not supplied is valued at a short-term failure cost.

Resilience Analysis: At this stage of the analysis, the national and zonal transmission expansions that allow the National Electric System to respond to extreme situations or disturbances will be determined, allowing the supply of demand without degrading the normal technical and economic operating conditions of the electrical system. According to the above, an analysis is made given the nature of the System, regarding how it would behave in the face of disturbances such as tidal waves, extreme hydrological events and fuel price shock.

Common electricity market analysis: This stage determines the expansion needs that promote the conditions of supply and facilitate competition, to supply the demand at the minimum cost and the supply at the minimum price, as established by the Law, analyzing the contribution of the expansion works resulting from the stages previous and/or proposing new. Continuing with the above, the expected difference in marginal injection costs and equivalent withdrawals from the System is compared and multiplied by the expected energy withdrawals. The above is done to compare how the System behaves once the necessary projects in the System have been determined with respect to the case without any expansion.

Other comments on the methodology: The methodological implementation of the stages described above may not necessarily follow the sequence specified after the "security analysis", since, in order to limit the works with which the systemic analyzes of resilience and common electricity market are developed, it is necessary to delimit the number of projects based on the efficiency that each of them brings to the system. In order to achieve the purpose described above, a sequential analysis scheme is developed, starting with the evaluation of a model formed by the national system and relevant areas of the zonal and additional system. This reduction is done through a hydro-thermal coordination software, and aims to implement the diagnostic stage, sufficiency analysis and security analysis to the whole national transmission system. It is important to highlight that the zone and dedicated facilities do not have transmission restrictions, with the purpose of developing a national system that supplies the consumption, or that allows injection from generators of zonal or dedicated transmission systems, according to the criteria established in the regulations.

As above, the modeling of the zonal transmission system takes as a basis the resolved works of the national transmission system, in order to avoid hiding problems of the zonal transmission system due to lack of national transmission. It is worth mentioning that some areas of the national transmission system, which sometimes do not show problems, are strongly affected by the inclusion of the entire zonal transmission system, so these areas are evaluated again in this phase. If under the new conditions, there are works of national transmission that manage to comply with the characteristics, to be included as part of the expansion plan, this is done. In another order of ideas, if it is observed that some zonal work significantly affects an area of the national transmission system, that area is reassessed but now the zonal transmission works incorporated in the region of interest are considered. Finally, it is concluded that this phase should be iterative, in order to build synergies between national and zonal transmission expansions, as well as being necessary to better represent the benefits that each project brings to the system, in order to comply with the efficiency mandate established in the Law.

VII. RESULTS

On Table N°3, are presented the results of different planning process, such as, the indicative investment values, number and type of projects.

Table N°3: Investment value and number of projects for different planning process.

Process year	Transmission segment	Type of project	Investment Value [MMUSD]	Number of projects
2015-2016	Trunk	Enhancement	222	31
		New	181	3
2016-2017	Trunk	Enhancement	141	14
		New	261	3
2016 (*)	Zonal	Enhancement	197,1	67
		New	564.2	31
2017	National	Enhancement	19	4
		New	657	7
	Zonal	Enhancement	101	38
		New	75	9
2018	National	Enhancement	76	10
		New	1.188	3
	Zonal	Enhancement	110	46
		New	82	8

(*) Transition process between private planning regime and centralized planning of zonal transmission systems.

One of the projects that have been detected necessary, based on the planning processes of Law 20.936, is an HVDC link [15], with an estimated length of 1500 km and transport capacity of at least

2000 MW, which will allow the extraction of resources from the north of the country, to take it to the consumption centers.

VIII. CONCLUSIONS

The methodology elaborated in this paper allows, through the different layers of analysis, to verify compliance with the criteria established in Article 87 of the Chilean Electricity Law.

The iterative process allows identifying and selecting, in successive stages, the candidate projects for expansion of the necessary and efficient transmission for the electrical system.

The methodology allows the atomized development of ERV in zonal systems, depending on the idle capacity of the transmission, allowing compliance with the law's efficiency mandate.

The described methodology allows developing synergy in the works of expansion between the national and zonal systems but presents difficulties in establishing correlations between the zonal and distribution systems.

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