TRANSMISSION EXPANSION PLANNING STATE OF THE ART

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Abstract.- In this paper the transmission expansion planning approaches are presented. These approaches are classified according to the structure of the power system, to the planning horizon and to the uncertainties of the power system. Transmission Expansion Planning has faced a significant change since the introduction of the deregulation; consequently it has become to be more complicated. The algorithms that have been developed to solve the problem of the planning in regulated and deregulated power systems are presented. Finally, it is presented the evolution and the planning schemes in several countries of Latin America.

I. INTRODUCTION

During the past ten years, there has been an increasing interest in the area of transmission planning. This interest is mostly due to the worldwide restructuring of the electric industry. As the new regulatory frameworks were established, the necessity of reviewing the transmission planning function has become notorious. This review must include both, models and algorithms.
Restructuring and deregulation have increased uncertainties in power systems and have unbundled the roles of network stakeholders. In regulated environment, the planners have full access to specific information, such as generation cost function, for transmission planning. On the contrary in deregulated market, transmission network owners or investors have only general information, such as load demand. Apart from that, stakeholders have different desires and expectations from performance and expansion of the system. Participants make their decision independently and strategically to maximize their own profit. Consumers, who are sensitive to electricity price, adjust their electricity usages according to the change in price. Therefore, new incentives and disincentives have emerged regarding transmission expansion decisions. Moreover unbundling the roles within stakeholders have increased the uncertainties and hence the transmission investors have to face great risk in deregulated environments. Because of these new objectives and uncertainties, new solution methods are required for transmission expansion planning in deregulated power systems.
Due to the deregulation process and to the heterogeneous characteri stics of energy markets from each country, the planning function has been adapted in diverse ways and several schemes have been proposed. In several countries the planning schemes were obtained by taking as starting point the experiences of others.

This paper begins in the Section II with the review of the uncertainties of the power system. Section III presents the transmission expansion planning approaches in the regulated and deregulated power systems and their solution methods. Section IV reviews planning schemes in some countries of Latin America. Finally the Section V presents the conclusions.

II. UNCERTAINTIES IN POWER SYSTEMS

Uncertainties are the reasons why planning is difficult and why plans are not optimal (Dowlatabadi and Toman, 1990). Uncertainty is a generic term used to describe something that is not known either because it occurs in the future or because has an impact that is unknown. The term "uncertainty" has been used to mean an "unknown" that cannot be solved deterministically or an "unknown" that can only be resolved through time.
Uncertainty arises because of incomplete information such as disagreement between information sources, li nguistic imprecision, ambiguity, impreciseness, or simply missing information. Uncertainty sometimes refers to randomness in nature or variability in data [1].
It is distinguished between "types" and "sources" of uncertainty. Sources of uncertainty refer to the areas or variables which are unknown or uncertain, while types of uncertainty refer to the nature, characteristic, or extent of uncertainty itself. Therefore: Types of uncertainty give insight to the modeling treatment, i.e. "how to model", while areas of uncertainty give insight to the variables that must be included, i.e. "what to model" [1].
In the literature some authors define several types of uncertainties. This wa y, for example, Hirst and Schweitzer (1990) describe internal uncertainties and external uncertainties, Boyd and Thompson (1980) distinguish "short term" and "long term" uncertainties. The International Energy Agency IEA (1987) classifies uncertainty into the quantifiable and the non-quantifiable. Barbier and Pearce (1990) discuss three types of uncertainties surrounding the Greenhouse Effect: the scientific uncertainties, forecasting and time-lag uncertainties. IEA (1987) suggests two types of uncertainty that surround the value of a variable, whether it is due to stoc hastic (random) variability or lack of knowledge or both [1]. Besides of the random variables, exist the non-random ones. The result is that cannot be certain of its value.
Acute areas of uncertainty in the power system are:

- Plant economics: capital, running costs
- Fuel: price, supply, availability
- Demand: shape, growth
- Technology

- Financing requirements: financing mechanisms, interest rates, revenues requirements
- market: volatility of the pool, competition
- Political/Regulatory: changing legislation, approval and licensing, timing and impact of new policy instruments
- Environmental
- Public opinion.

It is common in the transmission expansion planning to handle the uncertainties suggested by the IEA, that is to say: random uncertainties, non-random and lack of knowledge (fuzziness).

Random uncertainties: It's the deviation of those parameters which are repeatable and have a known probability distribution. Hence, their statistics can be derived from the past observations. Uncertainty in load is in this category [6].
Non-random uncertainties: It's the evolution of parameters which are not repeatable and hence their statistics cannot be derived from the past observations. Uncertainty in generation expansion is in this category [6].
Vague data (fuzziness): These are the data which can not be clearly expressed; it is concerned with ambiguity resulting from lack of knowledge [6].

Since methods of modeling random uncertainties, nonrandom uncertainties, and vagueness are different, power system uncertainties and vagueness must be identified and classified clearly before the planning process.
Sources of random uncertainties in deregulated power systems:

- Load
- Generation costs and consequently bid of generators,
- Power and bid of independent power producers (IPPs),
- Wheeling transactions, and
- Availability of generators, lines and other system facilities.

Sources of non-random uncertainties:

- Generation expansion/closures,
- Load expansion/closures,
- Installation/closure of other transmission facilities,
- Replacement of transmission facilities,
- Transmission expansion costs, and
- Market rules.

There is fuzziness in the following data:

- Degrees of importance of stakeholders in decision making,
- Degrees of importance of planning desires from the viewpoint of different stakeholders, and
- Degrees of importance of possible future scenarios.

Probabilistic methods, scenario techniques, and fuzzy decision making are used to take into account random uncertainties, non-random uncertainties, and vagueness respectively. Hence, a combination of above methods must be used for transmission expansion planning in deregulated environments [6].

III. TRANSMISSION EXPANSION PLANNING TEP APPROACHES

In general, on base of the power system structure, the approaches for the TEP can be: TEP approaches for regulated power systems and TEP approaches for deregulated power systems. Within of the regulated power system the approaches used for the planning based on the planning horizon, are: static planning approach and dynamic planning approach. Based on the power system uncertainty, both deterministic and non-deterministic approaches have been used for the planning in regulated and deregulated power systems [2] - [4].

III.I TRANSMISSION EXPANSION PLANNING TEP IN REGULATED POWER SYSTEM.

In regulated environment TEP has been traditionally centralized based on the forecasted load demand and coordinated with the generation expansion planning. The objective of TEP is to serve the forecasted load demand as economically as possible, while reliability constraints are being satisfied. Therefore TEP is formulated as an optimization problem with cost minimization as its objective function, subject to a set of economic, technical and reliability constraints [2].

A. Static Transmission Expansion Planning STEP

The planning is static if the planner seeks the optimal circuit additional set for a single year on the planning horizon, that is, the planner is not interested in determining when the circuits should be installed but in finding the final optimal network state for a future single definite situation [3]. Therefore STEP determines *where, how much* and *what* types of new facilities should be installed at the minimum cost for a given generation and load profile in a particular planning period [2].

A.1. Solution Methods in the STEP

So far, based in the optimization techniques, many algorithms have been proposed for solving the STEP problems in regulated environment. They can be generally classified into three types:
According to the procedure that was followed to obtain the expansion plan, the solution methods can be classified into three types [3]:
A.1.1 Mathematical Optimization Methods
A.1.2 Heuristic Methods
A.1.3 Meta-heuristic Methods

A.1.1 Mathematical Optimization Methods

The mathematical optimization methods find an optimum expansion plan by using a calculation procedure that solves a mathematical formulation of the problem. In the formulation, the transmission planning is posed like an optimization problem with an objective function, subject to a set of constraints. These constraints try to model great part of the technical, economic, and reliability criteria imposed to the power system expansion [3]. Due to the impossibility of considering all aspects of the transmission planning problem, the plan obtained is the optimum only under large simplifications and should be technically, financially, and environmentally verified, among other examinations, before the planner makes a decision [3].

Several TEP problems have been solved by some classical optimization techniques, such as linear programming, nonlinear programming and mixed integer programming. Additionally optimization techniques like Benders and hierarchical decomposition, interior point method (IPM), and "branch and bound" algorithm have also been used to solve TEP problem [2], [3].

Unfortunately, big practical obstacles appear to obtain the "optimal" solution when mathematical optimization techniques are used for solving the transmission planning problem. The obtained solution is usually a local optimum due to the intrinsic limitation of the optimization process, for example, convergence problems when dc load flow network model or a more detailed model is used. Apart from that, mathematical optimization methods face computational speed problem, when discrete variables are used for modeling the investments, when stochastic modeling is used for planning under uncertainty and when large scale problems are being solving [2], [3].

A.1.2 Heuristic Methods

The heuristic methods are the current alternative to the mathematical optimization methods [3]. These are inventive techniques based on engineer experience. The heuristic method, instead of using a classical optimization approach, goes step-by-step generating, evaluating, and selecting expansion options, with or without the user's help. To do this, the heuristic method performs local searches by means logical or empirical rules and/or sensitivities (heuristic rules). The heuristic process is carried out until the algorithm is not able to find anymore a better plan considering the assessment criteria that were settled down [2], [3].

One of the first heuristic methods was proposed by Garver [5]. Garver proposed fictitious "overload paths" to form "overload network". The network combines with the use of "guide numbers" to penalize those without initial transmission lines. The algorithm makes use of heuristic rule to solve TEP problem.

The use of heuristic algorithms is very attractive because good feasible solutions can be found, that is, very competitive economically, with a small computational effort. The problem of heuristic methods is that they cannot guarantee mathematical speaking the optimal solution, as the local search procedures usually terminate at local optimum results, in addition the solutions can be poor for large networks [2], [3].

A.1.3 Meta-heuristic Methods

Meta-heuristic have characteristics of both types, heuristic and mathematical optimization. These methods usually yield high quality solutions for large transmission networks with short computational time. In recent years, non-convex optimization methods, such as genetic algorithms GAs, simulated annealing SA and tabu search TS, are widely used to solve TEP problems. Other meta-heuristic approaches, such as expert systems, fuzzy set theory, greedy randomized adaptive search procedure, object-oriented models and game theory have also been proposed to perform TEP. With the advancement of artificial intelligence (AI) and hybridization techniques, new AI-based and hybridization approaches have been recently adopted in TEP [2], [3].

B. Dynamic Transmission Expansion Planning DTEP

On the other hand, if multiple years are considered and an optimal expansion strategy is outlined along the whole planning period, the planning is dynamic [3]. In addition to the determined by the STEP, the DTEP determines *when* the new facilities should be installed within the planning horizon. The objective of DTEP is minimizing the present value of all investments carried out throughout the years according to the planning periods, then, the mathematical model has time restrictions to consider the coupling among the years [2]. The dynamic planning problem is very complex and very large because it must take into accounts not only sizing and placement, but also timing considerations. This results in a large number of variables and restrictions to consider, and requires a huge computational effort especially in real power systems [3]. Therefore, often is simplified into a series of static sub problems (pseudo dynamic procedures) for achieving reasonable computational times. DTEP has frequently been neglected because the considerations of dynamic planning are complex and acceptably negligible in the long term, especially in the regulated environment [2].

B.1. Solution Methods in the DTEP
In the same way than the STEP, the mathematical methods used to solve the DTEP problem are:

B.1.1 Mathematical Optimization Methods
B.1.2 Meta-Heuristic Methods

B.1.1 Mathematical Optimization Methods
Traditional optimization methods, such as Linear Programming, Non Linear Programming, quadratic programming and dynamic programming, have been proposed to deal with DTEP problem. But the huge computational effort due to the use of mathematical optimization methods limits their applicability to DTEP problems [2].

B.1.2 Meta-heuristic Methods
Meta-heuristic methods, such as GAs, have been applied to solve DTEP problems because they have the ability to find high quality solutions in large scale complex systems. Apart from GAs, Fonseka and Miranda proposed an integrated approach of GAs, TS and SA to solve DTEP problem [2].

C. TEP DETERMINISTIC APPROACH
As in the regulated power systems as well as deregulated power systems, the deterministic approach considers only the worst cases of the system without considering the probability of occurrence or degree of importance of these cases [5].

D. TEP NON-DETERMINISTIC APPROACH
Non-deterministic methods consider many cases with assigning a probability of occurrence or a degree of importance to each of them and hence are able to model the past experience, future expectations and uncertainties [5]. The main non-deterministic approaches which have been used for TEP are:

A. Probabilistic load flow (PLF)
B. Probabilistic reliability criteria (PRC)
C. Scenario techniques
D. Decision analysis
E. Fuzzy decision making

Approaches A and B are able to take into account random uncertainties, C and D non-random uncertainties, and E imprecision and vague data (fuzziness).

III.II TRANSMISSION EXPANSION PLANNING TEP IN DEREGULATED POWER SYSTEMS
The objective of TEP under deregulated environment is different from that in the traditional power industry [2]. Transmission network owners or stakeholders decide independently and change their strategies to maximizing their own profit than social welfare [5]. This difference brings new challenges to the transmission planning problem [2]. The main objective of transmission planning in deregulated power systems is to provide a non-discriminatory competitive environment for all stakeholders, while maintaining power system reliability. Specifically, the objective is providing the desires of stakeholders [6]. The desires of stakeholders in transmission expansion are**:**

- Encouraging and facilitating competition among electric market participants,
- Providing non-discriminatory access to cheap generation for all consumers,
- Alleviating transmission congestion,
- Minimizing the risk of investments,
- Minimizing the costs of operation and maintenance,
- Increasing the reliability of network,
- Increasing the flexibility of system operation,
- Reducing network charges, and
- Minimizing the environmental impacts.

The above objectives have different degrees of importance for different stakeholders. On the other hand, stakeholders have different weights of importance in transmission expansion decisions. This must be considered by transmission planners [6].

A. Transmission Expansion Planning Solution Methods
In deregulated market, market based approach is a widely used method. Market based planning concept is the integration of financial and engineering analysis that considers the economics as well as the physical laws of generation, load and transmission [2].
Apart from market based approaches, meta-heuristic optimization approaches, such as GA, chance constrained programming (CCP), expert system (ES), fuzzy-set theory; Pareto-based solution technique and SA have been proposed to solve TEP problems [2].
Game theory has also been applied to solve TEP planning in a deregulated environment.
Mathematical optimization approaches, such as Benders decomposition and “branch and bound” algorithm, are continuously used for TEP in deregulated environment [2].

IV. TRANSMISSION EXPANSION PLANNING SCHEMES
The planning process of the electric system expansion developed by a unique company (integrated vertically), it corresponds to the optimization of the investment and operation costs.
The problem solution of optimization looks for the minimum operation and investments cost to supply to the society of electric power with a certain level

of security valorized economically at the cost of the not-supplied energy. When not existing competition in the supply of the demand, the plan of works to carry out in generation and transmission was a variable controlled by the planner, it decreased strongly the risk associated to this process. It is so the evaluation among alternative was not made among specific projects but among plans of works. However the final solution was only good to determine the first works, due to the scarce execution of the used scenarios and the delays in setting the works [16].

A problem that state companies should face was the budgetary restrictions settled down by the central government, which affected the process of decision-make, overalls for the projects of great magnitude that produced a delay of years in the incorporation of the works [16].

The incorporation of the competition to the generation sector, changes the concept of the planning, because now each agent makes her own decisions, based on her own opinions with the purpose of getting the maximum benefit.

Before in the centralized planning, the state company was the one that defined the group of works that should be continued, assisting to technical, economic, political approaches and of geographical covering to satisfy the demand.

At the moment in the deregulated markets the regulator can have different roles according to the regulation of each country. The planning has interrelation with the agents of the market, with the concessionaires of the system, with the same regulator entity, according to the regulations of each country [16].

This way in the current scenario (deregulated environment), are distinguished three ways of carrying out the planning: one developed completely by the regulator, another developed by a group of agents and approved by the entity regulator, and the third carried out by each existent agent or future following an indicative plan carried out by the regulator. Both first they fit with a centralized planning, while the last one is decentralized [16].

In the South American countries the expansions are proposed by the interested ones, users or transmission companies and approved by some organism regulator. However in the last years Chile like consequence of the disinvestment in transmission, by means of their short law changed their transmission expansion model, passing totally from a model subject to the forces of the market without intervention from the regulator to one of controlled centralized planning and approved by the regulator without any participation of the interested ones [16].

Next, the transmission expansion planning schemes used by several countries of Latin America are presented.

A. Brazil

Brazilian electric system stands out for the interconnection of a great number of generating machines and electric power consumers, distributed in an area of continental dimensions, where about 96,5% of the capacity of generation of energy of the country is inserted in the National Interconnected System (SIN). These characteristics allow considering it only, in the world. Besides Brazil presents peculiar characteristics, which demand that, the electric generation expansion planning and the transmission system expansion planning being appropriated [11], [17]:

- Complex institutional organization, in function of your dimensions, of the regional differences and of the need of the different public and private agents' participation.
- System predominantly hydroelectric, with great reservoirs of multiannual regularization.
- Transmission systems with great distances from the power station to the principal consumption centers.
- Possibilities of inter-regional connections with use of the hydrological diversity among basins.
- Great potential of development of thermal generation stations.

The Creation of GCPS

In 1982 was created the "Grupo Coordenador do Planejamento dos Sistemas Elétricos" GCPS to formulate and coordinate the Brazilian electric section planning. This group elaborated the plans and programs of electric system expansion. GCPS was integrated by all the concessionary companies. Under the coordination of ELETROBRAS - Electric Central Brazilian S.A., GCPS promoted the studies of long, medium and short term, of the Brazilian electric system expansion. In studies of medium term with 15 year-old horizon, they settled down the transmission generation reference programs and were considered the needs of financial resources for investments and the demand of construction of power stations, transmission lines and substations. The relative decisions to the transmission and generation expansion, defining the projects and your temporary allocation, they were submitted in the Decennial Plan of Electric Section Expansion [17].

The Creation of CCPE

With the deregulation of the section, in 1997, was established the competition in the generation segment, giving preference to the commitment of power stations more attractive economically [18]. Simultaneously, the existence of a competition model was incompatible with the predominance of state companies in front of the planning. Therefore in May of 1999 was created the "Coordinating

Committee of the Electric Systems Expansion Planning" - CCPE to coordinate the expansion planning of the Brazilian electric systems, extinguished GCPS. Such measure tried to give the necessary exemption to the strategic and tactical planning of the electric sector, since until then the company of the largest generation volume in the country, ELETROBRÁS, coordinated that whole work [17].

The plan proposed by the CCPE was called "Determinative Program of the Transmission Expansion". It was mandatory with regard to the facilities considered essential to assure a good energy market. This plan was approved by the Mine and Energy Ministry and later it was sent to the "Electrical Energy National Agency" - ANEEL. ANEEL determined, by public bidding, which investor would build-operate-maintain the new transmission facilities [17].

The state segment still prevailed in this structure, assuming in general the coordination of the technical committees of the CCPE, what was not desirable, considering that managerial interests continued influencing excessively in the government decisions [17].

The Creation of EPE

The CCPE limited the studies to the expansion of the electric system, not embracing the other energy segments (petroleum, gas, coal, biomass, nuclear, etc.). It was necessary of a systemic and global vision, absolutely indispensable in the evaluation of the use of the energetic potential, inside of a perspective of long term. Of this form was created the Company of Energetic Research - EPE on March 15, 2004. EPE are a government agent. Your principal activities are concentrated in the elaboration of the essential studies for the Integrated Energetic Planning, such as; the National Energetic Balance (BEN) and the National Energetic Matrix, the Energy National Plan (PNE), the Decennial Plan of Electric System Expansion (PDEE), the Determinative Plan of the Transmission Expansion (PET), the Integrated Environmental Evaluation (AAI) of hydrographical basins, etc [17].

Transmission Expansion Plan - PET

PDEE has as objective identifies in the ten year-old horizon, the generation and transmission projects needed for the appropriate performance of the SIN. Thus, in this phase goes matching each individual utility expansion plans, i.e. place or regional reinforcements in order to meet the predicted load growth and the generation expansion plan. The outcome of this phase is the Indicative Transmission Expansion Plan (PET).

Planning with Uncertainties

The analyses of transmission planning in function of the new model of the sector, became more careful, including and strategic, face not only to the inherent uncertainties to the in the long term planning, such as the variations not foreseen in the evolution of the load, but also, to the uncertainties with relationship to the results of the energy laws. This way with the propose of minimize losses and to maximize earnings in the choice of the best expansion alternative, EPE foresees the need to adopt special techniques of decision-make, with specific tools of support for analysis in uncertainty environments, in development for CEPEL [19].

The principal challenge that is shimmered in the elaboration of the studies which compose the Decennial Plan of Transmission Expansion is the inclusion of analyses as: the generation/transmission integrated planning, the planning with uncertainties and the incorporation of the socio-environmental evaluation, among others. Now, starting from the creation of EPE the studies will develop in way integrated with the disciplines that interfere in the process of the transmission expansion as a completely. The revision of the set of criteria and procedures now existing, seeking to incorporate the most modern practices of planning in conformity with the new legislation of the electric sector is one of the most important challenges that EPE will be confronted in the beginning of your implantation [19].

B. Venezuela

The Ministry of Energy and Mines, with the support of the Electric Energy National Commission and of the National Center of Administration of the Electric System formulates the Plan of Development of the National Electric Service, which have indicative character. It also determines the Plan’s duration and their period of revision, makes your pursuit and taking the measures within their reach to assure the normal execution of the same one [14].

Usually, the generation and transmission system planning was carried out in a separate way. In addition, each Electricity Utility used to make theft own expansion planning. Therefore, the results were individual plans, oriented to attend their own service areas, which later on were evaluated by Operation Office of Interconnected Systems OPSIS, which looked for theft integration in order to guarantee the best solution for the Venezuelan Electrical System [10].

During the period 2004-2005, Ministry of Energy and Petroleum MENPET together with the electrical Utilities conceived an Electricity Development Plan called National Electrical Service Development Plan (NESDP) for the term 2005-2023, where the mean premises were: considering the Government Energetic Policy and the Development of the Nation for the medium and

long term, and to find an optimal integrated generation-transmission expansion Plan that guarantees a minimal expansion cost [10].
The State challengers made to develop a methodology that allows obtaining a generation-transmission integrated Plan that preserves the technical criteria and also goes towards the optimal economic solution, using the tools for analysis available at the Venezuelan Electrical Utilities (EDELCA, CADAFE, ENELVEN y EDC) [10].

C. Argentina

The achievement of the transmission expansion plan in Argentina is one of the functions that the Government retains for itself, but making decisions only with respect to strategic aspects, e.g., revising the regulatory framework to assure appropriate market conditions. This indicative plan, called "Prospective", has a time horizon of 10 years and the "Department of Energy" of the "Ministry of Economic", updates it annually. The "Prospective" is not strictly an expansion plan, it is a study that illustrates the demand scenarios and the possible generation offers. As for the real transmission expansion development, there is a special scheme to determine what projects must be installed. Usually, the expansion is proposed by the interested party, discussed in a public inquiry, and approved by the "Ente Nacional Regulador de la Electricidad" – ENRE [11].

D. Chile

The Chilean 1982 regulation defined a user based tariff scheme with a non regulated market approach to expansion [13]. Then, the investment decisions in Chile were made in a decentralized way, there was full freedom for investment in the electrical sector, the basic objective had been to minimize barriers of entry to new investors. The transmission expansion planning was carried out by the market agents considering the economic signals that the transmission pricing scheme provides. The Chilean regulatory framework delegated the responsibility to watch over the development of the power system to the "Comisión Nacional de Energía" – CNE. In order to fulfill this function with regard to the generation and transmission, the CNE proposed periodically an indicative expansion plan that led the way toward the "economic adaptation" [11].
The criterion used in the indicative planning consists of determining those options and project sequences, proposed by private investors or defined by the regulator, which minimized the costs of investment, operation and non-served energy over a time horizon. The solutions obtained around the optimum were then analyzed with minimizing risk criteria, considering future demand growth and evolution of fuel prices [13]. It is important to point out that there was not obligation for anybody to accomplish the indicative expansion plan since it was only a suggestion about how the systems would be expanded. The authorization of the CNE was not required to undertake a new project nor the existence of that project in the indicative plan. There was a complete freedom to invest in the power sector.
Up to the mid eighties, the indicative plan was important as a good source of information for the companies' investments, while at the same time, a good support for raising funds from financing third parties. Nevertheless, differences often arose between the perception that had the authority and the private investors of the expansion of the system. Such differences were conditioned, among other reasons, by the capital costs, the demand forecast, the evolution of fuel prices and the discount rate.
From a private point of view, the investment decision will be to develop those projects that, with the tariffs and costs perceived by the private investors, produce desired return rates and/or respond to their strategic interests. In terms of the authority, the indicative plans are defined based on a social appraisal of fuel costs, investments and return rates dictated by the National Planning Ministry. The objective is to supply demand by minimizing the cost to society [13].
Time horizon of 10 years was considered to the indicative expansion plan [11]. The optimum expansion of the electrical system determined by CNE directly impacts the regulated tariff levels determined by the authority. The law indicates that every six months, the CNE must determine "nodal prices" for energy and capacity. The nodal prices represent the generation–transmission component of the final price to consumers smaller than 2 MW [13]. Therefore, the main purpose of the expansion plan was to determine the regulated generation–transmission prices that the regulated users (Demand ≤ 200 kW) must pay. These prices constituted the final economic incentives that motivated the expansion on the part of private investors [11].
As competition increased in the Chilean power sector and the introduction of natural gas combined plants reduced energy prices, a growing divergence arose between the CNE indicative plan and the investments in fact accomplished by the private sector. Differences arose in the incorporation dates of new plants and/or in generation technologies used for the expansion. The differences were so large in the CNE plans for a series of new combined cycle plants that nobody had planned to build, in an environment where investment had considerably slowed down [13].
A bad situation has developed in relation to transmission expansion. The weakness of the tariff system in financing existing installations and the expansion was exposed. The main transmission

company TRANSELEC complained on the tariff scheme and minimized its new investments, unless payments are clearly identified [13]. A change of law was going through congress aiming at solving the problem. Consequently in March 2004 a change of law was introduced in Chile that modified previous market based transmission expansion to a regulated centralized process, directed by a multiagent committee. Under the new regulations, every four years, a consultant will asses the transmission costs and formulates expansion [12].
The process in its first stage has to determinate the value of present transmission assets, to be used for wheeling payments by generators and consumers for the following four years. Second, a transmission expansion plan will be developed, and alternative investments defined under different scenarios. Proposals will then be evaluated by the system operator and final investments decided.

E. Colombia:
In 1991, a new Political Constitution was introduced. It assigns to the State the responsibility to achieve efficiency in the provision of public services. It establishes the competition mechanism, accepts the private agent participation and strengthens the role of the State as regulator. It assigns to central, departmental and municipal governments the responsibility to ensure the public service provision and to preserve a healthy environment by their own or through third party [20].
In July of 1994, the Colombian Congress passed the Public Service Law (Law 142 of 1994) and the Electricity Law (Law 143 of 1994). Electricity Law detailed and regulated the following five areas of business of electricity industry: Generation, Interconnection, Transmission, Distribution and Trading. In practice, Interconnection is considered a part of Transmission activity.
On July the 20th of 1995 new rules, where competition is the key issue for gaining efficiency, changed the operation and the way of doing business in the Colombian power sector.
In Colombia there is also a competitive transmission environment. There is a centralized governmental office that establishes an indicative expansion plan considering information from market agents and its own predictions. This planning authority, the “Unidad de Planeación Minero/Energética” – UPME, is attached to the “Ministerio de Minas y Energía” – MME. The UPME is in charge to determine what projects are required, when they must be installed and also determines, by public bidding, which investor will build–operate–maintain the new transmission facilities [11].
For the elaboration of the Reference Expansion Plan (a long term plan, 10 years), the generating companies, the transmission service providers, the distribution service providers, and the power marketers should submit the information required for planning and the projects they wish for analysis by the UPME. Additionally, the transmission service providers are responsible for carrying out an annual study to illustrate the opportunities to use the transmission system by both existing market participants and potential new investors (new generation and load) and they must submit this studies to the UPME. The basic form of these documents, which are called “Connection Opportunities”, is defined by the Colombian Regulator (the “Comisión de Regulación de Energía y Gas” – CREG) [11].
The UPME elaborates first a Preliminary Transmission Expansion Plan, discloses it, and submits it to consideration of the “Comité Asesor de Planeamiento de la Transmisión” – CAPT1. Next, the UPME establishes the Reference Transmission Expansion Plan for the STN. The UPME determines, by public bidding, which investor will build–operate–maintain the new transmission facilities [11].

F. Uruguay
The activity of electric transport is governed by "Ley de marco Regulatorio" 16832, of the year 1997 and for the "Reglamento de Transmisión de Energía Eléctrica" RT approved by the Executive Power in June of the 2002. The transmission network is of property of the state company UTE, integrated vertically, with the exception of the lines and stations of 500 kV that interconnect the central bi-national "Salto Grande" to the transmission systems of Uruguay and Argentina and to both countries to each other.
The law framework foresees the realization of a transmission planning of the in charge of UTE and of other transmission companies that receive concessions in the future, subject to approval of the Regulator. As a result of that plan the amplifications of General Benefit are determined, the same that are included in the plan. They are denominated of General Benefit because the benefits for the group of the system overcome their investment and O&M costs. For these expansions, it is obligatory that UTE contributes the investment funds, operate and maintain the facilities. The Plan of Transmission then should indicate the new works required in the system and its sequence in the time. The global cost of each alternative is evaluated and that of less cost is selected to integrate the proposal of the Transmission Plan. After having elaborated the plan of works with their chronogram and the budget, and approved by the Directory of the Company, they are remitted to the Regulator for their final approval [21].

G. Perú

The transmission planning is indicative. The institution in charge for the elaboration of the Referencial Plan that contains the future investments in generation and transmission is the "Oficina Técnica del Ministerio de Energía y Minas". The "Dirección General de Electricidad" approves the Expansion Plan of the National Transmission Electric System [15].

The Electricity Referential Plan PRE is formulated by the Ministry of Energy and Mines like document promoter to giving prospective information that serves the agents of the electricity sub sector or to new agents that have the intention of participating in the taking of investment decisions, it is also directed to the entities or people with interest in the knowledge of the electric development of the country. In this document a vision of development of the electricity sub sector is presented for a ten year-old period and for the long term, considering a prospective period of up to 20 years. This expansion plan is compatible with the requirements of demand of power and energy according to the approaches of economy, security and reliability.

In consequence, the results of the PRE should be considered alone as indicative signs of technical and economic character for the generation and transmission expansion of the Interconnected Electric System, since the real execution will depend on the result of the competition of the different agents of the sector inside the existent law framework [15].

H. Panamá

The Transmission Company ETESA prepares the Expansion Plan in according with the approaches and politicians settled down by Energetic Politic Commission COPE and in agreement with the plans of development of the energetic sector adopted by the State. ETESA consults the opinion of the distribution and generation companies on the expansion plan. ETESA makes the necessary adjustments to the Plan and subjects it to the approval of the Entity Regulator of Public Services ERSP. The plan is elaborated for a 10 year-old minimum term. The Company of Transmission has the obligation of building the new expansions and reinforcements of the transmission system, and it is also taken charge of the operation and maintenance of the interconnected system. As for the generation, the expansion is subject to a competitive market, that is to say it is carried out by different investors [16].

Regarding the expansion study in if same, is not applied a complete methodology and chord to the problem to solve, because the methodology that is applied is very guided to a integrated vertically market and not to a deregulated market with different investors in generation. In this sense, although is tried to evaluate the expansion plan from the private overview, it is makes in global form as if it was an only enterprise; is very important in this sense to verify each investor's profitability. The used methodology allows that the current development of the Transmission Main System is characterized to be robust, when in a market with competition in generation the flexibility should be preferred [16].

Ecuador

The "Ley de Régimen del Sector Eléctrico" LRSE believes the wholesaler electric market, where is possible the competition in generation. According to this law the free access is allowed to the transmission and distribution systems. The transmission activity is developed under a regimen of monopoly at national level in charge of the only transmission company TRANSELECTRIC. The transmission system expansion is planned obligatorily by TRANSELECTRIC and approved by the CONELEC. Once the expansion plan is approved and published by the CONELEC, this should be executed obligatorily by TRANSELECTRIC.

The expansion plan is indicative and it has a 10 year-old horizon, but with revisions and annual brings up to date in charge of the transmitter but subject to approval of the regulator organism [15].

V. CONCLUSION

Transmission Expansion Planning approaches in both regulated and deregulated power systems have been presented and discussed. The characteristics of the deregulated power systems are different of the regulated ones. Traditionally, transmission expansion planning TEP algorithm is a least cost planning. Most research works have been done to reduce the computation time or increase the convergence towards the true optimal solutions. Deregulation has increased the uncertainties drastically and therefore transmission planner has encountered a great risk. Besides, deregulation has changed the objectives of the transmission expansion planning. Providing a non-discriminatory environment for competing stack holders is the main objective of the TEP in the deregulated power systems. To achieve the new objectives, market based criteria should be defined for TEP. TEP algorithm has to be changed so as to hand the increased uncertainties as well as minimizing total cost and maximizing profit.

With regard to the expansion variants or to the way in that is carried out the expansion, it differs in the degree of intervention of the regulator in the decisions of the agents. In countries like Peru, Ecuador, Colombia, Uruguay, Brazil, Venezuela and Panama the transmission company generally proposes the expansion, often intervening the regulator in its approval. That is to say it is carried out a centralized planning.

On the other hand, among the countries with a minor participation of the regulator and a bigger influence of economic type signs, Argentina stands out, that is to say it is carried out a decentralized planning.

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