Transmission Allocation Cost Methodologies: Experiences in Latin America Electricity Markets

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***Abstract*—The transmission costs assignment has been the most widely analyzed and studied problem from those related with the general problem of the distribution of costs and economic benefits shared by the participant agents in an electric power market. The economic evaluation of wheeling transactions implies a diversity of mechanism. As a common rule, this evaluation must include three main factors: a) the system security; b) the impact over generation costs, and c) the use-of-network transmission costs. Several methodologies have been proposed in the open literature, many of them are not merely directed to allocate costs efficiently but also to send economic signals to the electricity market for transmission expansion. In this paper a survey of transmission allocation costs methodologies reported in the literature is presented. Special emphasis has been put to those methodologies implemented in Latin America markets.**

***Index Terms*—Use-of-network costs.**

I. INTRODUCTION

SINCE the beginning of 1990s decade the electric energy industry in Latin America has been under a restructuring process. Today's', this process is still underway. In order to promote competition and efficiency in supply and demand, the state-owned vertically-integrated monopolies are now being separated into a number of smaller companies participating either in generation, transmission, distribution or commercialization activities. At present time, it is well known that most of the competition is circumscribed to generation activity. The transmission and distribution networks are still remaining as regional or geographical monopolies. Hence, in order to guarantee that the objective of promoting competitiveness in the other activities can be achieved, it is necessary to create a regulatory framework.

Transmission regulation rules have been developed and implemented in the Latin American countries in a wide variety of ways. During the development of the required policies, several key aspects have been put forward such as transmission system's security, and the size and the type of the electricity market to be designed [1].

In practice, due to specific characteristics of their bulk systems, the transmission cost allocation rules have been independently instrumented in each country. Chile was the first country restructuring its electricity sector whereas in some other countries this process is not yet fully build it up such as in México and Honduras. Nevertheless, in both previous cases, the participation of private companies in the generation activity has been strongly supported. This special condition has forced the development and implementation of a particular regulatory framework to assists with the transmission system services.

In the case of Mexico, a regulatory framework has been created to consent to independent power producers, IPPs, the utilization of the national grid under the self-supply scheme. Apart from this special condition, there has not been any additional major reform in the Mexican electricity sector. Since 1992 to date, a virtual market has been implemented by Comisión Federal de Electricidad, CFE, a state-owned company. This virtual mixed electricity market seeks to emulate a competitive open market. In essence, in the current Mexican regulation, an electricity transaction represents a bilateral contract within the same company. This market inconsistency has press on the development of a wheeling methodology [2].

In Latin America, the diversity electric power systems is ample. For instance, Brazil has an installed capacity around 60,000 MW [1], Panama has about 1,000 MW, whereas El Salvador and Honduras each one has no more than 600 MW [3]. This situation makes the respective market regulatory frameworks shows some discrepancies among them.

It is worth to mention that previous to the restructuring process, transmission expansion programs were executed base on security criteria, which brought many transmission networks to be oversized, resulting in extremely expensive transmission cost services. After deep analysis of high transmission services academics fingered to a new definition named economically adapted transmission network. A transmission system is labeled as economically adapted if the demand and the supply are balanced, while, at the same time, a least transmission costs condition is present without degrading the quality of the service [4]. The adaptability level of a given transmission power system can be ranked based on its performance indexes. In Bolivia, an excellent cited example, the following criteria were considered [4]:

1. The transmission system operating under steady state conditions cannot have a single element overloaded. Such condition implies that transmission limits should considered thermal limit but also the operational and security limits.
2. None nodal voltage magnitude must exceed some specified limits.

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3. The transmission system must withstand the n-1 security criteria.

Supplementary considerations can imply an exhaustive analysis on peak demand scenario. Usually, off-peak demand scenarios can handle the n-1 criteria by means of generation re-dispatching [5].

Latin-American electricity markets still face some difficulties needed to be to tackle in the short-term. For instance, the integration of regional markets a complex task to complete, mainly because the regulatory frameworks diversity and different transmission services operating in each country. A representative of previous scenario is the integration of the Centro American sectors. Similar difficulties can arise if well established markets are needed to perform regional transactions with some incipient markets. Such is the case in South American countries [1].

In the pursue of restructuring the electricity sector world-wide, a large number of methodologies for allocating transmission costs have been developed and applied to real electricity markets. These methodologies include from the simplest postage stamp up to the complex hybrid methodologies which combine embedded costs with nodal marginal prices.

The next sections describe the forenamed methodologies and classify them according to the fundamental rules applied to them. In addition, practical applications in Latin American electricity markets are pointed out. The next sections are organized as follows. Section II describes the fundamentals rules of transmission service. In section III, methodologies for assigning embedded costs are fully described. Moreover, in section IV, a literature survey, focused on load flow decompositions methodologies for allocating charges on element-by-element basis, is presented. The concluding remarks and future work are detailed in section V.

II. USE-OF-NETWORK ALLOCATION COSTS FRAMEWORK

In word of the Electric Power Research Institute, EPRI, the main objective, when establishing a use-of-network allocation costs framework, is focused to define all procedures necessary to facilitate the control, the pricing, and the distribution of transmission costs. Fig. 1 shows a representation of these steps [6].

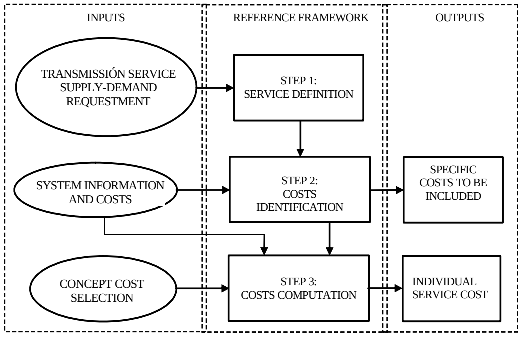

Fig. 1. Transmission service framework

As it can be seen from Fig. 1, the transmission service costs allocation relies on individual basis, where each participant has to do a contract, apart from the others participants, in order to have right of entry to the transmission network. The service costs include the service definition (i.e. firm or not), the identification, and computation costs.

Depending on the selected framework for costs identification, a given methodology can be developed and make operative when considering some details about the calculation of transmission service cost. The cost calculation can be performed previously or after the service has been completed. The costs definition is implemented for sort of different time horizons, ranging from one year to as late as a full transmission planning period (several years). The allocation cost should consider a predefined period of time, taking into consideration the peak, the off-peak, and the seasonal scenarios. An hour-to-hour time horizon is also included. Fig. 2 summarizes the relationship between these aspects [6].

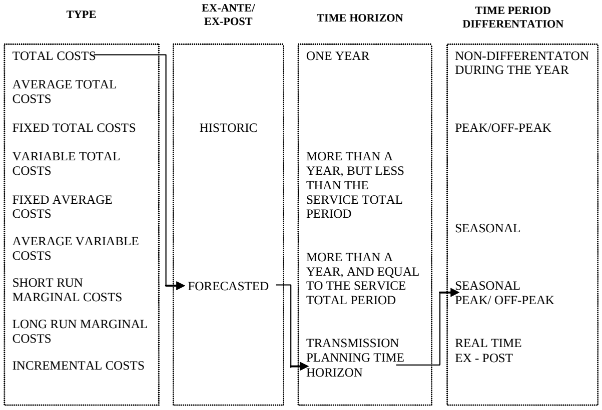

Fig. 2. Defining the economic cost concept

Regardless to the framework implemented, the economic evaluation of using the transmission network always implies a variety of components. In general, this evaluation must include items like the system security, the impact over generation costs, and the financial charges for the use-of-network transmission or allocation of network access.

For transmission systems, the structural electricity sector transformation is based on open access schemes, which considers a multilateral use of the transmission system [1]. An open access scheme is reached out when electric energy transport concessionaries allow open and non-discriminatory use of their transmission systems rights, in order to accomplish with the following general objectives [5]:

1. To promote economic efficiency.
2. To compensate concessionaries with the right price for providing transmission services.
3. To allocate well-balanced transmission costs among all transmission users.
4. To maintain the transmission network reliability.

Regarding to objective 1, the economic efficiency has been difficult to be promoted mainly because the economics of scale is presented in the transmission service, and also because this service is a natural monopoly sharing the electricity market with the competitive generation segment. This monopoly should be regulated, as has been long proposed, through applying two main concepts: a) by recovering an amount of money (the total cost of transmission service) or b) by the perfect price-cap regulation [6]. In the Latin American electricity markets, the concept b) has been not put yet on practice.

Objective 2 is related with the distribution of transmission costs among all parties. The various methodologies proposed for this objective, and applied with adaptations in each electricity market, are classified as follows [6][7]:

(a) Methodologies based on the total amount of power negotiated encircled into the primary energy market.
(b) Methodologies based on the duration load curve for each participant.
(c) Path contracts.
(d) Methodologies based on load flows.
(e) Methodologies based on nodal marginal prices.
(f) Methodologies based on nodal incremental prices.
(g) Hybrid methodologies.

Some other aspects are taken into consideration for these methodologies, such as the following: (a) single or multiple scenarios, (b) surrogate net present value, (c) incremental transmission cost, (d) economically adapted transmission networks,, and (e) application of some decomposition load flow methods.

Each methodology is briefly described in the next section. Special emphasis is made in those methodologies based on load flows and decomposition methods.

III. ALLOCATING TRANSMISSION COSTS

The various allocating transmission cost methodologies include the simple postage stamp method [8], the trajectory path contract [9], the family of load-flow methodologies (based on the MW-Mile method), and the sophisticated formulations based on the marginal cost theory [10]. In any methodology the main objective is the allocation of the use-of-network embedded charges, for each wheeling transaction, in such a way that a real benefit is comprised for both the wheeling agents and the owner network [11].

The postage stamp method, as is well known, does not reflect the real use of the network [8]. To solve this weak point, the trajectory path contract method was developed. The method is based only in monetary aspects, while the real power flows caused by the wheeling transaction are not taked into consideration. The MW-Mile Method and all its modified approaches [8], also solves this drawback. If the operating point problem appers, this problem can solved using the dominant flow method (DFM) because, by involving the transmission capacity of each element into its formulation, the operating point is implicitly included. The DFM also helps to solve the problem of considering the counterflows in such a way that the benefit of introducing transactions that increase the transmission network capacity, resulting in a methodology economically stable. However, this methodology presents an inconsistency because it does not calculate the associated costs for counter-flows in an adequate manner when the net flow approximates to zero [8].

Different tasks need to be executed before deregulation takes place in a traditional vertical integrated industry. These tasks will determine the economic adaptability of the system for the new market atmosphere. Some of these tasks are performed to:

a) Establish clearly the costs for the different transmission elements based on characteristics and capacity.
b) Collect the technical information regarding each transmission element.
c) Analyze the technical analysis from different perspectives: economy, quality, reliability, etc.
d) Define the existent inadaptability margin due to excess/deficit.

In general terms, a methodology needs to identify those elements that do not have a definitive function under economical and reliability criteria. Simultaneously, it must identify those weak areas in which new investments need to be done.

IV. COSTS METHODOLOGIES: A REVIEW

The application of a methodology for costing the use of network involves three main stages: (a) determination of network costs, (b) determination of percentage of used network, and (c) application of a methodology relating the network costs with the percentages assigned to each user. Step (b) is the last one in methodologies not involving each transmission element. When the transmission elements are considered one by one, step (b) is related with load flow decomposition, which can be performed by several methods, including superposition with C.A. load flows, participation factor decomposition with C.D. load flows, and tracing. The methods applied in step (c) are described next.

A. Postage Stamp

The transmission cost allocation using the postage stamp is simply a rate between the amount of power transacted and the peak demand.

$$R(u) = TC\frac{P(u)}{P_{peak}} \tag{1}$$

where $R(u)$ is the transmission cost for transaction u, TC are the total transmission costs, $P(u)$ is the amount of power transacted, and P_{peak} is the system peak demand.

The methodology strives for easy calculation, an easy understandable and stable procedure. Nevertheless, this method does not reflect the neither the costs variation over long distances nor assess the congestion fees.

B. Contract path

In the contract path method a virtual path is defined between seller and buyer, which is not related with the real power flows. Thus, it is consider as an economical agreement, but this characteristic has been strongly criticized.

C. MW-Mile

This method is based on load flows throughout each transmission element. The cost assigned to each participant *u*, *R*(*u*), is calculated considering three criteria as follows.

Criterion A. It considers load flows in both directions over the transmission element:

$$R(u) \;=\; \sum_{l=1}^{n_l} C_l \, \frac{f_l(u)}{\sum_{s=1}^{P} f_l(s)} \tag{2}$$

Criterion B. It considers only the magnitude of load flows regardless their directions:

$$R(u) \;=\; \sum_{l=1}^{n_l} C_l \, \frac{\left| f_l(u) \right|}{\sum_{s=1}^{P} \left| f_l(s) \right|} \tag{3}$$

Criterion C. Negative load flows (counterflows) does not cause any charge:

$$R(u) \;=\; \sum_{l=1}^{n_l} C_l \, \frac{Max\{0,\ f_l(u)\}}{\sum_{s=1}^{P} Max\{0,\ f_l(s)\}} \tag{4}$$

Where $f_l(u)$ and $f_l(s)$ are the load flow caused by participant *u* through the element *l*, and *P* is the set of participants causing the net load flow through that element.

D. Dominant Flow Method

This method is a modification from MW-Mile and has as goal to allocate fairly the cost associated with the counterflow. For this reason, the fix cost is separated in two components $R_1(u)$ and $R_2(u)$.

$R_1(u)$ has relation whit the capacity of each element which is used, called base capacity. This part of the capacity corresponds at the net flow and the cost is the sum of those transactions that contributes with positive flow, it means, that has the same direction of the net flow f_l. The criterion to evaluate this part of the cost is:

$$R_1(u) = \sum_{l=1}^{nl} C_{Bl} \, \frac{\left| f_l(u) \right|}{\sum_{s=1}^{P'} \left| f_l(s) \right|} \tag{5}$$

where P' is the subset of utilities that cause a positive flow through the element *l*, while C_{Bl} is the capacity base cost, which is:

$$C_{Bl} = CT_l \, \frac{\left| f_l \right|}{f_{nom_l}} \tag{6}$$

where f_{nom_l} is the nominal capacity from the circuit *l*.

$R_2(u)$ has relation with the difference $f_{nom_l} - \left| f_l \right|$, called additional capacity, which correspond at the circuit reserve, and as all utilities results with benefits in the reliability and security system. This part corresponding at the total cost for the circuit use is considering all the utilities, so that:

$$R_2(u) = \sum_{l=1}^{nl} C_{Al} \, \frac{\left| f_l(u) \right|}{\sum_{s=1}^{P} \left| f_l(s) \right|} \tag{7}$$

where C_{Al} is the additional capacity cost, which is evaluated by the next equation:

$$C_{Al} = CT_l \, \frac{f_{nom_l} - \left| f_l \right|}{f_{nom_l}} \tag{8}$$

Finally, the total cost for the use network, corresponding at the transaction from the utility *u* will be equal to equation

$$R(u) = R_1(u) + R_2(u) \tag{9}$$

In the case of the counterflow does not cause net flow changes of direction, then $R_1(u)$ will be equal to zero.

E. Locational Marginal Price

In the Locational Marginal Price (LMP) approach is base on the so called nodal prices. Nodal prices reflect the temporal and local variations of the energy price relating to the energy demand and power system operational characteristics [5]. The nodal price difference gives the marginal revenue as shown

$$R(u) = \left[\sum_{i \in r} \lambda_{p_i} - \sum_{m \in e} \lambda_{p_m} \right] wR(u) \tag{10}$$

F. Tracing

Tracing methods are based on the directed graph defined by power flows from individual generators to individual loads. This can be done under the consideration that flows entering any node are distributed proportionally between the outflows. The directed graph is decomposed into a set of directed sub-graphs, each one taking as its root node one of the generation nodes. For each directed sub-graph, called dominion of the generator, there are two kind of relations: (a) nodal balance in each node, in terms of active power flows incident to that node, which are function of the generators defining the graph, and (b) the net active power flow in any element is decomposed into the flows corresponding to each directed sub-graph including that element [12][13][14][15].

$$P_{im} = \sum\nolimits_k P_{Dk} \frac{P_{im}}{\sum\nolimits_j P_{Dj}} + P_{Gi} \frac{P_{im}}{\sum\nolimits_j P_{Dj} + P_{Gi}} \tag{11}$$

$$P_{Li}^{Dk} = P_{Dk} \frac{P_{Li}}{\sum\nolimits_j P_{Dj} + P_{Gi}}$$

(12)

where P_{im} is the active power flow from node *i* to node *m*, is P_{Dk} is the active power inflow to the node *i* defined for the dominion *k*, P_{Gi} is the active power generation on node *i*, P_{Li} is the active power load in node *i*, and P_{Li}^{Dk} is the part of the active power load at node *i* defined by the dominion *k*.

G. Generation Shift Factors

This method is based on a linear model of the load flow formulation, whose coefficient matrix is a Y-nodal admittance matrix considering only the inductive series of transmission lines, which is denoted as *B*. The inverse of this matrix is *F*, whose elements are used in the next equation [9]:

$$a_{l\,j} = a_{im,\,j} = -\frac{1}{x_{im}}\left(F_{ij} - F_{mj}\right) \tag{13}$$

where *i* and *m* are the nodes associated with the transmission element l, and also indicate rows in matrix F, j indicates the power injection in node j, which can be related with the power is being selling or buying at this node by some participant.

The calculation of generation shift factors requires the selection a reference node, so that matrix *B* is nonsingular. In this node normally a generator is connected. Therefore all the participation factors for this node will be zero, and so will be the charges associated to this generator. In order to avoid this inconvenient, two approaches has been proposed: (a) nodal voltage angle permutation, and (b) calculation of generalized participation factors.

The nodal voltage angle permutation consists in select one node where there is no load or generation injection, so it does not contribute to the load flows in the transmission network. This permutation consist in subtracting the angle value obtained in the base case load flow to all the nodal voltage angles, in such a way the original load flows remain constant. After this operation, the participation factors can be calculated.

The generalized participation factors method was proposed by [16], which is described as follows. A factor $D_{i-m,j}$ relates a power injection in node *j*, with the load flow through the element connecting nodes *i* and *m*:

$$f_{i-m,\,j} = \sum_{j=1}^{n} D_{i-m,\,j}\, P_j \tag{14}$$

where *n* is the number of nodes in the power system. Factors *D* are not incremental, due they relate total load flows and total power injections. These load flows depends on the operation condition. Then, a load flow base case and participation factors, $a_{i-m,\,j}$, are needed:

$$D_{i-m,\,j} = a_{i-m,\,j} + D_{i-m,R} \tag{15}$$

where:

$$D_{i-m,R} = \frac{f_{i-m} - \sum\limits_{\substack{p=1 \\ p\neq R}}^{n_g} a_{i-m,\,p}\, P_{Gp}}{\sum\limits_{g=1}^{n_g} P_{Gg}} \tag{14}$$

For load injection changes:

$$f_{i-m} = \sum_{j=1}^{n} C_{i-m,\,j}\, P_{D\,j} \tag{15}$$

A load change in node *t*, ΔP_{Dt}, compensated by a corresponding change in some node *R*, gives place to a new load flow:

$$f_{i-m}^{nuevo} = \sum_{j=1}^{n} C_{i-m,\,j}\, P_{D\,j} + C_{i-m,t}\,\Delta P_{Dt} - C_{i-m,R}\,\Delta P_{Dt} \tag{16}$$

which can be rewritten as:

$$f_{i-m}^{nuevo} = f_{i-m} + \left(C_{i-m,t} - C_{i-m,R}\right)\Delta P_{Dt} \tag{17}$$

Assuming that the load change at node t corresponds to a negative change in power injection, it results as:

$$f_{i-m}^{nuevo} - f_{i-m} = \Delta\, f_{i-m} = -\,a_{i-m,t}\,\Delta P_{Dt} \tag{18}$$

therefore:

$$C_{i-m,t} = C_{i-m,R} - a_{i-m,t} \tag{19}$$

If all the charges are transferred to node R, and applying superposition we obtain:

$$f_{i-m}^{nuevo} - f_{i-m} = \Delta\, f_{i-m} = \sum_{\substack{j=1\\ j\neq R}}^{n} \left(-\, a_{i-m,j}\right)\left(-\Delta P_{D\,j}\right) \tag{20}$$

Also,

$$f_{i-m}^{nuevo} = -\, C_{i-m,R}\, P_{D\,R}^{'} \tag{21}$$

where

$$P_{DR}^{'} = \sum_{j=1}^{n} P_{D\,j} \tag{22}$$

Substituting these relationships, we obtain:

$$C_{i-m,R} = \frac{f_{i-m} + \sum\limits_{\substack{j=1\\ j\neq R}}^{n} a_{i-m,j} P_{D\,j}}{\sum\limits_{j=1}^{n} P_{D\,j}} \tag{23}$$

The manner in which the charges are distributed by the use of these generalized factors is as follows:

$$FP_{i-m,j} = \frac{D_{i-m,j}^{'}\; P_{G\,j}}{\sum\limits_{k=1}^{n_g} D_{i-m,k}^{'}\; P_{G\,k}} \tag{24}$$

where:

$$D_{i-m,j}^{'} = \begin{cases} D_{i-m,j} & \text{If the factor has the same load flow sign} \\ 0 & \text{If the factor has an oposite sign} \end{cases}$$

$$FP_{i-m,j} = \frac{C_{i-m,j}^{'}\; P_{D\,j}}{\sum\limits_{k=1}^{n} C_{i-m,k}^{'}\; P_{D\,k}} \tag{25}$$

where:

$$C_{i-m,j}^{'} = \begin{cases} C_{i-m,j} & \text{If the factor has the same load flow sign} \\ 0 & \text{If the factor has an oposite sign} \end{cases}$$

V. EXPERIENCES IN LATIN AMERICAN COUNTRIES

Following some experiences around the world, the Latin American Countries have got involved in the electricity industry deregulation. This section pointed out the key factors of the most representative restructured electrical sectors in Central and South America [1][17].

A. Argentina

- A reform was introduced in 1992.
- Transmission is privately owned by three companies.
- Transmission charges are paid by generators.
- Transmission charges include replacement value, and sunk values for existing installations at privatization.
- The network to be paid is determined by the regulator.
- Methodology is based on bids and nodal pricing.
- Expansion network facilities is motivated by users, following three schemes: (a) public invitation, (b) contract between parties, and (c) exclusive transmission facilities

B. Bolivia

- Reform was promulgated in 1994.
- Transmission is owned by a private company.
- Transmission charges are paid by generators and consumers.
- Transmission charges account for value replacement, and O&M.
- The network to be paid is economically adapted and determined by the regulator.
- Methodology is based on costs and nodal pricing.
- Expansion network should be carried out by users.

C. Chile

- Reform began in 1982.
- The transmission company is state owned.
- Transmission charges are paid by generators.
- Transmission charges include the replacement value and O&M.
- The total network costs are negotiated by parties.
- Methodology is based on costs and nodal pricing.
- Transmission expansion is carried out by negotiation between parties.

D. Colombia

- Reform was introduced since 1997.
- There are several private owned transmission companies.
- Transmission charges are paid by generators (50%) and consumers (50%).
- Transmission charges include the replacement value.
- The total network cost involves an economic minimum system determined by the regulator.
- Methodology is based on bids and single bus market price.
- Transmission expansion is carried out by negotiation between parties.
- Expansion transmission is motivated and negotiated by the parties, and it is based on economic signals.

E. El Salvador

- The reform was declared in 1996.
- In 1999 the transmission company (ETESAL) was created with public and privete capital.
- Transmission charges: O&M costs, and a declared ex-ante power for charging use-of-transmisión costs over annual basis (CUST).
- Transmission charges are payed by generators.
- Methodology used: postage stamp.
- ETESAL profits are based on charges derived from power output excess over the power they declared.
- Since 2003 investment costs are considered into the charges scheme.
- Transmission expansions are in charge of ETESAL. Also, the producers can construct exclusive transmission facilities.

F. Guatemala

- Reform was promulgated in 1996.
- There are two transmission companies (ETCEE and TRELEC) with private capital.
- Transmission costs include annual investment costs, O&M, considering an economically adapted network.
- Transmission network is divided into two electrical systems named principal and secondary in order to calculate transmission tariffs.
- Transmission charges are calculated applying the postage stamp method based on the firm power associated with eache generator.
- Transmission expansions are realized under two schemes: negotiation by some of the parties and by consulting and inviting a tender for. Under the latter scheme the project has to be approved by the 70% or more of the generators.

G. Honduras

- Reestructuration of the Principal Law of the Electrical Sub-sector in 1994.
- The transmission is in charge of the Electric Energy National Company (ENEE).
- Transmission costs include investment and O&M reflected in annual present value (costos de reposicion)
- Transmission charges are based on the dominant flow method.
- The evaluation is made by considering multi scenarios.
- The transmission expansion is carried out by the ENEE, but generation companies can construct transmission facilities for particular purposes.

H. Mexico

- Electrical Sector Reform introduced in 1992 and the Transmission Regulation Law is operating since 1994.
- The transmission is in charge of two state-owned companies (CFE and LyFC).
- Costs consider the concept of long run incremental transmission costs for a ten years time horizon.
- The methodology is a mix of the MW-mile and postage stamp methods and it involves four load flow scenarios, two of them are considering each wheeling transaction separately and chronologically ordered.
- The methodology involves also zonal energy prices for accounting for transmission losses.
- Transmission expansion is in charge of CFE and LFyC but the construction can be developed by private companies under specific contracts.

I. Nicaragua

- The reform was introduced since 2000.
- There is a national state-owned transmission company (ENTRESA).
- Costs are based on a recognized annual investment cost, which is updated each year, and also O&M costs.
- Producers and import agents pay the transmission charges.
- The charges are on monthly basis including conecction, maximum requirement of transmission capacity, and use of capacity.
- Methodology based on the postage stamp method.
- Expansion network is in charge of ENTRESA.

J. Panama

- The reform was created in 1997.
- Transmission is under a state owned company (ETESA)
- Transmission charges consider the use-of-network, conecction and integrated operating services.
- An economically adapted network is defined.
- Producers and costumers pay transmission charges over the basis of installed capacity and annual non coincident peak demand, respectively.
- Methodology is based on economical signals and load flows (marginal nodal prices and MW-mile using participation factors).
- Multi-scenarios are considered.
- Network expansion is carried out by ETESA, but transmission facilities can be constructed by other parties for their own purposes.

K. Peru

- The reform on the electric industry was published in 1992.
- The transmission network is owned by two state companies (ETECEN and ETESUR).
- Transmission charges are paid by generators, transferred in tariff to consumers.
- Transmission charges include replacement value and O&M.

- The total network cost involves an economic minimum system determined by the regulator.
- Methodology is based on costs and nodal pricing.
- Transmission expansion is carried out by negotiation between parties.
- Expansion transmission is motivated and negotiated by the parties, and it is based on economic signals.

VI. DEVELOPMENT OF REGIONAL MARKETS

The international electricity market integration has been occasionally proposed. As an example, in the last 10 years, it has been developed a great effort to create an international electricity market in Central America countries. The main problem that it has been found was the way in which the regulators and transmission companies of each country conceives the problem to assign use-of-network costs in order to permit international transactions among the Central American countries. Throughout the SIEPAC project it has been constructed a 230 kV transmission network to carry out the international electricity transactions, which nowadays have a technical limit of 300 MW. The connection of the transmission systems can be seen as shown schematically in Fig. 3, where the SIEPAC line permits the international connection. This market model has been referred as the Central American Regional Market [3]

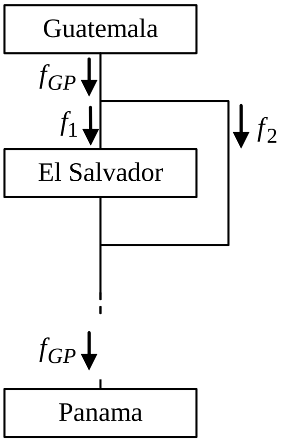

Fig. 3 Simplified scheme of the Central American Regional Market.

From this figure, it can be pointed out the following:

1. A percentage of the transaction from Guatemala to Panama (f_{PG}), which is represented by f_1, passes through all the other country networks, causing additional load flows and losses, and it will modify nodal prices in each one the national markets. Also, depending on the operating conditions it can cause congestion problems.
2. All these impacts should be evaluated in order to determine the economic impact of the transaction. To accomplish with this objective, it should be considered that there are six regulation frameworks coexisting with the one related with the regional market.
3. In the particular case of Honduras and El Salvador, the evaluation of use of transmission network is the dominant flow and the postage stamp methods, respectively. Thus, it is necessary to coordinate these two methodologies with the one made for the regional market. In order to accomplish with this objective, it has been discussed that, for the evaluation of use of network, one approach is the separation of load flows through the national networks and the SIEPAC line caused by each international transaction, as shown in Fig.3, where the impact of f_1 would be used to evaluate the use of network with the correspondent methodology of each country (in this case El Salvador), while f_2 would be used to evaluate the use of network with the SIEPAC regulation. Clearly, the design of a unique methodology would be the best choice, but this is much more difficult to achieve in the reality.

VII. CONCLUDING REMARKS

The methodologies concerning with the use of network charges in electricity markets has been briefly described. A review of those methodologies applied in almost Latin American countries has been detailed. The concluding remarks are the following:

There is a variety of methodologies to assign charges for use of transmission facilities, which have been designed considering the proper needs from each electricity market. With the electricity market evolution, regulatory framework should be changed.

In a global world like the actual, there are chances to generate electricity in such a way that the primary energy resources are utilized more efficiently. One of these chances is the creation of regional electricity markets, as the one that it has been operating in the European Community or in Central America. In the latter there have been some troubles to take these advantages completely, because of the variety of regulation frameworks. There are only two ways to solve this problem: (a) development of a regulation framework to be capable of coexist with the existing ones, and (b) to develop a completely new and unique regulation framework for all the parties involved.

REFERENCES

[1] Rudnick, H., Soto, M., Palma, R. "Use of system approaches for transmission open access pricing", *International Journal of Electrical Power and Energy Systems*, Vol. 21, No. 2, pp. 125-135. 1999.

[2] “Ley del Servicio Público de Energía Eléctrica” of Mexico. Available on http://www.cre.gob.mx

[3] Consejo de Electrificacion de America Central, “Curso de Especialización: Diseño de Mercados Eléctricos (in Spanish)”, Notes of the course Panama, Panama, Junio de 2003.

[4] Ley de Electricidad de Bolivia. Available on http://www.bolpress.com

[5] Thilo Krause, "Evaluation of Transmission Pricing Methods for Liberalized Markets: A Literature Survey," Internal Report, Swiss Federal Institute of Technology Zurich.

[6] EPRI, “Application of EPRI’s Transmission Services Costing Framework to the Development of Open Access Transmission Tariffs,” Report TR-105971, January 1996.

[7] Vojdani, C.F. Imparato, N.K. Saini, B.F. Wollenberg, H.H. Happ, "Transmission Access Issues," *IEEE/PES Winter Meeting*, New York, NY, January 1995.

[8] Marangon Lima, M.V.F. Pereira, J.L.R. Pereira, "An Integrated Framework for Cost Allocation in a Multi-owned Transmission System," *IEEE/PES Summer Meeting*, San Francisco, CA, July 1994.

[9] Richard D. Christie, Bruce F. Wollenberg, and Ivar Wangensteen, "Transmission Management in the Deregulated Environment," *Proc. of the IEEE*, Vol. 88, No. 2, pp. 170 – 195. Feb. 2000.

[10] Kovacs, A.L. Leverett, "A Load Flow Based Method for Calculating Embedded, Incremental, and Marginal Cost of Transmission Capacity," *IEEE Trans. Power Systems*, Vol. 9, No. 1. pp. 272-278. Feb. 1994.

[11] Marangon Lima, "Allocation of Transmission Fixed Charges: An Overview, " *IEEE/PES Summer Meeting*, Portland OR, July 1995.

[12] Janusz Bialek, "Allocation of Transmission Supplementary Charge to Real and Reactive Loads," IEEE/PES Summer Meeting, July 1997

[13] Janusz Bialek, "Topological and Load Distribution Factors for Supplement Charge Allocation in Transmission Open Access," *IEEE Trans. Power Systems*, vol. 12, No. 3, pp. 1185-1193. Aug. 1997.

[14] G. Strbac, D. Kirschen and S. Ahmed, "Allocating Transmission System Usage on the Basis of Traceable Contributions of Generators and Loads to Flows," *IEEE Trans. on Power Systems*, Vol. 13, No. 2, pp. 527-534. May 1998.

[15] D. Kirschen, R. Allan, G. Strbac, "Contributions of Individual Generators to Loads and Flows," *IEEE Trans. Power Systems*, Vol. 12, No. 1, pp. 52-60. Feb. 1997.

[16] Hugh Rudnick, Rodrigo Palma, Jose E. Hernandez, "Marginal Pricing and Supplement Cost Allocation in Transmission Open Access," *IEEE Trans. Power Systems*, Vol. 10, No. 2, pp. 1125-1142. May 1995.

[17] Hugh Rudnick, Juan Zolezzi, "Planificación y expansión de la transmisión en mercados eléctricos competitivos", VII Symposium of Specialists in Electric Operational and Expansion Planning, VII SEPOPE - May 23-28, 2000, Curitiba, Brasil.

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