Invested Related Pricing for Transmission Use: Drawbacks and Improvements in Brazil

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***Abstract*— The deregulation of electrical power sector aimed to introduce market mechanisms and divided the sector in four segments: generation, transmission, distribution and commercialization. Transmission has characteristics of natural monopoly and needs to have economic regulation. The transmission tariffs must collect the transmission allowed revenue (TAR), but the problem is to allocate it among the network users. Brazil adopted the Investment Cost Related Price (ICRP) method to design these tariffs. This method which is applied at Great Britain is based on a proxy of the long-run incremental cost and depends on where the agent is located. It suits well when there is just one big load center, but in the case of Brazil with its continental dimensions and a sparse load center the method has shown some drawbacks. It has been observed that the Brazilian transmission tariff is not producing the desired economic signals for the users of the transmission facilities. This paper shows the main shortcomings of the current method and proposes improvements to adapt to the characteristics of the Brazilian network. The paper also shows the main results with the actual Brazilian system.**

***Index Terms*— Transmission Wheeling Charge, Investment Cost Related Price**

I. Introduction

THE electrical power restructuring process aimed to introduce market mechanisms divided the sector in four segments: generation, transmission, distribution and commercialization. Due to the natural monopoly characteristic of transmission and distribution the market structure is usually applied only to the generation and commercialization. Therefore, transmission and distribution need to have an economic regulation and the way how the rules and the tariffs are set is very important to the development of the sector.

One of the big challenges of this new configuration is the transmission and distribution open access [1]. This open access is the key issue to incorporate competition on the other segments. It involves the transmission network capacity use, because sitting future generation and demand depends on the wheeling transaction cost.

The first step to determine the transmission wheeling charge is to obtain the necessary revenue to recover the expenses with operation, maintenance and investments of the entire transmission network. This revenue, which represents the tariff level, is collected by the transmission charges. The problem is to define how to do this cost allocation among network users, that is, the tariff structure.

The cost allocation methods can be classified in two paradigms: embedded cost or incremental cost. In the embedded methods the cost is allocated among the system users proportionally to their "extent use" of the transmission assets. They provide adequate remuneration and are easy to implement, but they are criticized due to their economic grounds [2].

The incremental methods involve the short-run incremental cost or marginal cost and long-run incremental cost. Both of them are associated only with the incremental operational cost, but the second includes also the incremental network cost. These ones are economically efficient because they can provide economic signals for operation and dimension, but they don't recover all the transmission cost.

Brazil adopted the Investment Cost Related Price (ICRP) used in England to determine the transmission tariffs [3]. The ICRP model [4-5] is used for providing appropriate locacional signals for generation and demand connected to the transmission system. This methodology mixes the marginal cost method with the postage stamp which is used to assure the Revenue Reconciliation. This approach must be judicious because it can distort the economical signal of the marginal method.

This method suits well when there is just one big load center which is not the case of Brazil that is a continental country and where at least four high demand load centers exist. One question that arises is if the method works for countries like Brazil, that is, if it emits the correct sign for new investments. In the particular case of Brazil, it has been observed that the transmission tariffs are not reproducing the real use of the transmission network.

The Brazilian electrical power system is divided in four sub-markets set by the network constraints and by the main geographic regions. But the transmission tariff is determined in one aggregated form for the entire country. This paper proposes a new structure for the Brazilian power transmission wheeling charges. The tariff will continue to follow the ICRP model but with some adjustments. Instead of using the aggregated form, the tariff will be computed for each submarket. This drastically reduces the cross-subsidies between submarkets that are currently polluted with the postage stamp component.

This paper first describes the current transmission tariff methodology in Brazil and the problems detected. Then the paper proposes some improvements on the ICRP method and presents the results obtained for the Brazilian transmission system.

II. ICRP METHOD IN BRAZIL

The ICRP method used in Brazil is based on a proxy of the long-run marginal cost. It derives from how an increment of 1MW at each study node affects the power flows in the circuits and then, using the unitary cost of the circuit, the marginal cost is obtained. Equation (1) shows the tariff π for the node j:

$$\pi_j^{'} = \sum_{l=1}^{N_l} \frac{C_l}{\bar{f}_l} (\beta_{lj} - \beta_{lr}) fp_l \tag{1}$$

where:

N_l total number of circuits;

C_l cost of circuit l;

$\bar{f}$ capacity of circuit l;

β_{lj} power flow variation on l for the increment of 1 pu in the node j;

β_{lr} power flow variation on l for the increment of 1 pu in the node r (reference node);

fp_l weight factor of circuit l.

The weight factor is an exogenous factor of the original method. It was incorporated in the Brazilian tariff to attenuate the locacional signal and it is calculated using equations (2) and (3):

$$fp_j = \begin{cases} 0; & r_j < r^{\min} \\ \dfrac{r_j - r^{\min}}{r^{\max} - r^{\min}}; & r^{\min} \le r_j \le r^{\max} \\ 1; & r_j > r^{\max} \end{cases} \tag{2}$$

$$r_j = \frac{|f_j|}{\bar{f}_j} \tag{3}$$

where:

f_j power flow on circuit j;

r_j loading factor of circuit j;

$r^{\min}$ lower limit for loading factor;

$r^{\max}$ upper limit for loading factor.

The current lower limit $r^{\min}$ for loading factor is 0 and the upper limit $r^{\max}$ 1 pu [6].

The costs of the circuits are standardized costs. The capacity depends on the minimum value of the three parameters: thermal limit, stability limit or voltage limit.

The power flow on the circuit is obtained using a dispatch policy defined by the regulatory agency, named here as regulated dispatch. In each geographic region, the generators are dispatched proportionally to their maximum capacities until all the sub-market corresponding demand is supplied. If there isn't sufficient generation, the generators of the neighboring region supply the deficit.

Since $\pi_j^{'}$ doesn't assure the Revenue Reconciliation, it is necessary to add another portion as it is shown in equation (4). The adjusted tariff assumes that the total revenue will be collected.

$$\pi_j = \pi_j^{'} + \frac{TAR^G - \sum_{i=1}^{NB} \pi_i^{'} P_i}{\sum_{i=1}^{NB} P_i} \tag{4}$$

Where:

π_j adjusted tariff of bus j;

TAR^G transmission allowed revenue for generators;

NB total number of buses;

P_i generation capacity on bus i.

Another characteristic of the Brazilian tariff is the different payment for generation and load. It was established that 50% of the total revenue would be paid by the generators and the other 50% by the consumers. So TAR^G is 50% of TAR. Equation (3) is related to generation tariff. To determine the load tariff it is necessary to consider in equation (4) TAR^C instead of TAR^G and D_i instead of P_i, where D_i is the demand on bus i.

The numerator of the second term represents the revenue that wasn't collected by $\pi_j^{'}$. Rearranging equation (4) gives equation (5):

$$\pi_j = \frac{TAR^G}{\sum_{i=1}^{NB} P_i} + \frac{\sum_{i=1}^{NB} (\pi_j^{'} - \pi_i^{'}) P_i}{\sum_{i=1}^{NB} P_i} \tag{5}$$

The first term represents the Postage Stamp method [7]. This method doesn't consider the site of the agent so it can distort the economic signal for new investments. The difference between the tariff of other nodes and of the current node j in the second term is obtained using equation (1) as shown in equation (6):

$$\pi_j^{'} - \pi_i^{'} = \sum_{l=1}^{N_l} \frac{C_l}{\bar{f}_l} (\beta_{lj} - \beta_{li}) fp_l \tag{6}$$

According to the second term of equation (5), the differences between the current node's tariff and the other nodes' tariffs are weighted by its generation capacity, so it can be treated as a weighted average. A virtual node appears and represents the system geometric center depicted in Figure 1. The further a study node is from the virtual node, the higher will be its tariff. One can imagine the virtual node as the point where all the buying and selling transactions are performed.

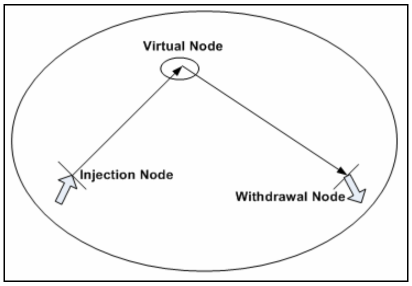

Figure 1 – Virtual node representation

III. Problems of the ICRP method in Brazil

Based on the last Brazilian transmission tariff cycle that begun on July 1st of 2006 and will end on June 30th of 2007, Figure 2 shows the weighted average bus tariffs of generators and consumers for the four sub-markets. Table 1 shows the power demand on each submarket for this tariff cycle.

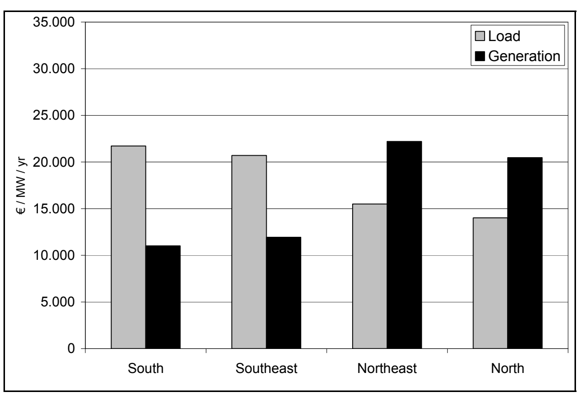

Figure 2 - Mean Tariff estimated by the aggregated form

Table 1
Generation and load for each region

	Generation [MW]	Load [MW]
South	12907,13	12196,65
Southeast	40669,36	38078,40
Northeast	7699,66	9385,92
North	5937,00	3632,08

Northeast system doesn't have sufficient power generation to supply its own load and it imports energy from other submarkets. Figure 2 shows that the generation tariffs at Northeast submarket are greater than load tariffs, which means that the signal is to add new loads and not invest in new generation. But this is not correct in terms of economic signal. On the other hand, for the South and Southeast where the total generation exceeds the load, there is a big difference between generator and consumers tariffs and the method gives an incentive to invest in generation which is also not correct.

These problems are related to the high percentage of the postage stamp component in the tariff intensified by the weight factor. Besides, the dispatch policy doesn't reproduce the numbers on Table 1.

The Brazilian system has its virtual node in the Southeast because of the concentration of generation and load. The agents located far from this center have high wheeling charges. This can explain why the nodes at Northeast region have high tariffs. Even if the injection node is close to the withdrawal node, there is a path to the virtual node as it is represented in Figure 3.

Figure 3 – Virtual node for Brazilian system

The next section proposes some improvements trying to increase the locacional sign and to develop a new concept for the ICRP method in countries with continental dimensions.

IV. Proposed improvements on the ICRP method

After the diagnosis presented in section II and comparing with experiences of other countries, this work proposes a new structure for the Brazilian power transmission wheeling charges. The tariff will continue to follow the ICRP model but with some adjustments.

The first suggestion is related to the dispatch policy. It doesn't correspond to the real generation traded at the energy auctions and bilateral contracts. It makes a balance between generation and demand for all the sub-markets and this drastically reduces the power flow on the interconnection lines (IL). Figure 4 shows a comparison of the net on the IL using the regulated dispatch and using the real dispatch of the power generators.

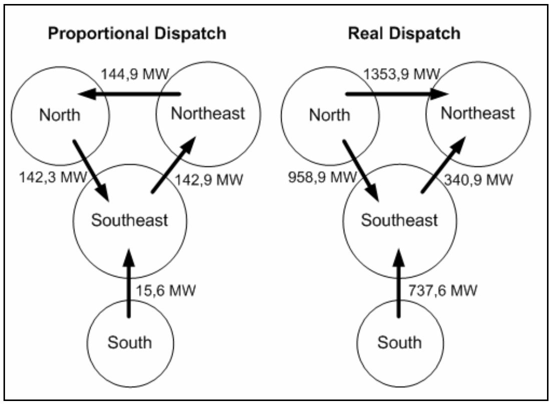

Figure 4 – Comparison of power flow on IL

It can be observed that using the regulated dispatch it is hard to identify if the sub-market imports or exports energy. The real dispatch is the average of the actual dispatches observed at the operation.

Other important suggestion concerns the weight factor. If the intention is to enhance the spatial signal it is possible to withdraw this factor from equation (1). Then maximum locacional signal will be obtained either on the circuits with low loading factor or with high loading factor.

Besides the two suggestions presented before, that is, replacing the regulated dispatch with the real dispatch and setting all the weighted factors to one, it is proposed a new structure to allocate the TAR among the agents. Instead of using the aggregated form method described in section II, the tariff can be computed for each submarket. This drastically reduces the cross-subsidies between submarkets that are currently polluted with the postage stamp component.

In this new structure each submarket pays only for its transmission assets. The costs of IL between sub-markets may be shared by the neighboring sub-markets or may be treated as a transmission capacity right [8] where the agents can bid. This paper considers the first alternative. A shared scheme is drawn in Figure 5.

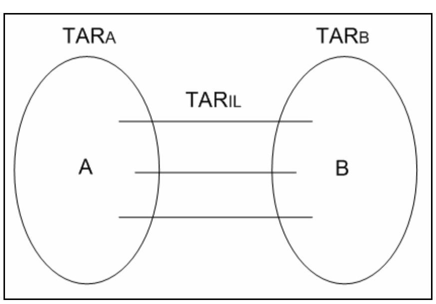

Figure 5 - Example of a system with two submarkets

Equations (7) to (10) represent the TAR segregation:

$$TAR = TAR_A + TAR_B + TAR_{IL} \tag{7}$$

$$TAR''_A = \sum_{l \in \Omega_A} C_l \tag{8}$$

$$TAR'_A = TAR \frac{TAR''_A}{TAR''_A + TAR''_B + TAR''_{IL}} \tag{9}$$

$$TAR_A = TAR'_A + TAR'_{IL} \frac{TAR'_A}{TAR'_A + TAR'_B} \tag{10}$$

where:

TAR_A transmission allowed revenue for sub-market A;
TAR_B transmission allowed revenue for sub-market B;
TAR_{IL} transmission allowed revenue for the IL;
Ω_A transmission assets pertaining to submarket A.

After this segregation of TAR, it is possible to calculate the locacional component for the example at Figure 6. Sub-market A has three generators of 100 MW and two loads of 100 MW and sub-market B has two generators of 100 MW and three loads of 100 MW. So sub-market A can export 100 MW for sub-market B to attend part of the load of B.

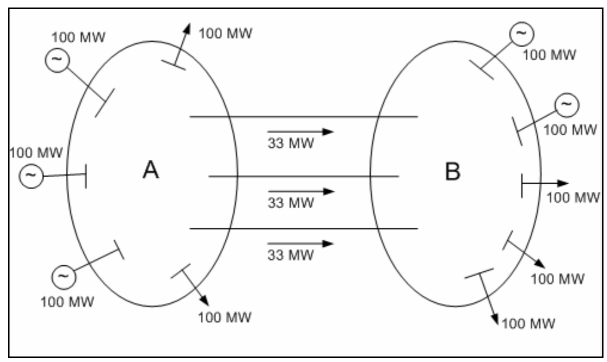

Figure 6 – Power flow on the IL

To calculate the tariffs of sub-market A the costs of B and of IL are set as null. The IL works as generation or load buses if the power flow is entering or leaving the sub-market, respectively, as it is shown in Figure 7.

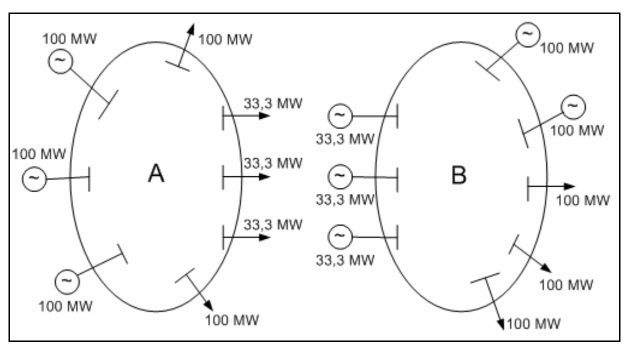

Figure 7 – IL represented as generation and load buses

The locacional tariff is computed using equation (1). Then replacing TAR^G on equation (3) with $TAR^G{}_A$ it is possible to obtain π_j for sub-market A. However given that the generators of A export energy for B, they also need to pay for the use of the network of B. So another portion corresponding to charges of the fictitious buses is added to generator at A proportionally to their maximum capacity. The same process is followed for sub-market B, considering that the load of B needs to pay for the network use of A because they import energy from this sub-market.

In the regional ICRP each sub-market has its own virtual center as depicted in Figure 8. The wheeling transaction represented has a shorter path to the virtual node of the Northeast than the original path in Figure 3.

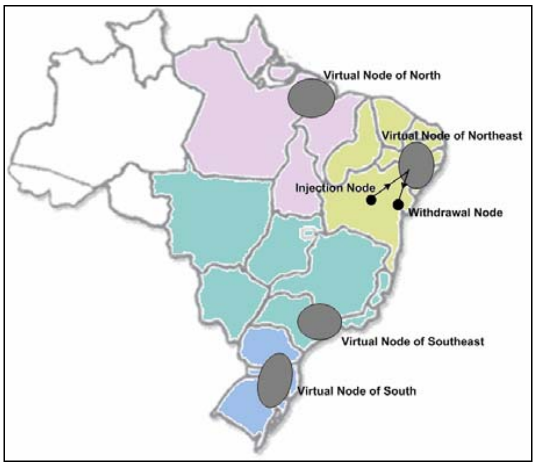

Figure 8 – Virtual Node for each sub-market

V. RESULTS

This section shows the results and influences of the cost allocation alternatives including the dispatch policy, the weight factor and the new proposed structure for the transmission wheeling charges.

Figure 9 shows the mean weighted tariff for generation and load for each submarket when the regulated dispatch is replaced with the real dispatch.

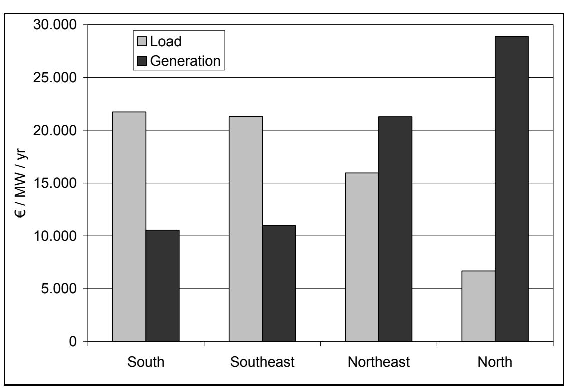

Figure 9 - Mean tariff estimated with the real dispatch

Comparing with Figure 2, the sub-market North is the most affected where there is an increase in the generation tariffs and a great decrease in the load tariff. The other sub-markets don't present considerable changes.

Figure 10 considers the regulated dispatch and withdraws the weight factor from equation (1).

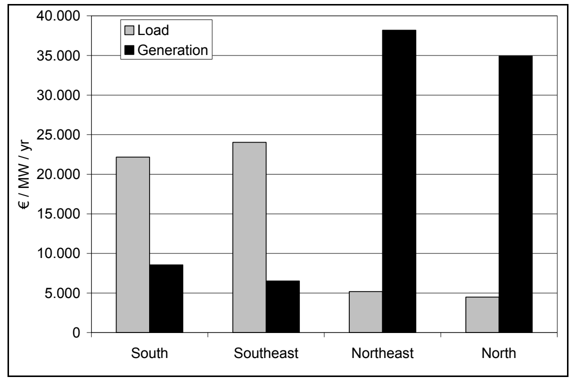

Figure 10 - Mean tariff estimated by removing weight factor

Comparing with Figure 2, it can be observed that for Southeast and South the generation tariffs decreased and the load tariffs increased. At Northeast and North the generation tariffs are very high compared to the load ones. This result increases the notion that the regulated dispatch doesn't reflect the real system operation.

Figure 11 shows the mean tariff for the adjustments together, i.e., the real dispatch and weight factors all equal to one.

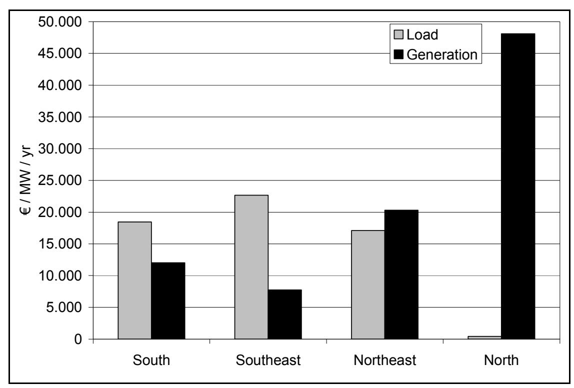

Figure 11 - Mean tariff estimated by removing weighted factor and considering the real dispatch

In this case, the new generation investments at the North region aren't viable. Comparing with Figure 2, there is an increase in the load tariff for Southeast and Northeast and a decrease in South. Concerning the generation tariffs, they decrease in Southeast and Northeast and there is a slight increase in the South. These signals are more consistent but they are still polluted with the postage stamp method.

Figure 12 shows the improvement in terms of economic signal for the generation and load at the Northeastern region when it is applied the regional ICRP provided by Equations (7) to (10). It can be observed that the economic signal seems to be more reasonable compared with the ones shown in Figure 2.

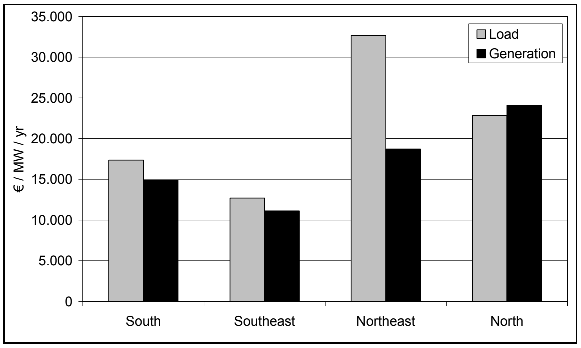

Figure 12 - Mean tariff estimated by the separated form

In the Northeast there is a high increase in the load tariffs followed by a slight decrease in the generation tariffs. In the North, both generation and load tariffs present an elevation. In the Southeast and South there is a decrease in the load tariffs but they are still greater than the generation ones. The Northeast is the only region with a big difference between the tariffs.

VI. Conclusions

This paper focused on the transmission wheeling charges based on the ICRP model. It showed that this method needs some improvements when applied to continental countries like Brazil. The suggested structure was tested on the actual Brazilian transmission system.

The dispatch policy has a great impact on the wheeling charges and should be set according to the actual operation of the system. The adjustment made by the Brazilian Regulatory Agency creating the weight factors has decreased the spatial signal. Given that the Brazilian revenue reinforcement is high, the tariff regionalization is important to minimize the cross subsidies.

The regional ICRP method produces better results in terms of sending the economic signals to the transmission users. Moreover, it detaches the interconnection lines that can be treated as Transmission Rights initializing the introduction of market structures.

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