A Proposal for Compensation between TSOs for Cross Border Trades

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Abstract

The increasing amount of power exchanges in the European networks makes necessary to design a method for the allocation of the grid costs incurred by these exchanges. This paper presents a method that complies with the conditions required by the regulatory authorities and is technically sound. It calculates the compensation due to a grid using a differential method, while the contributions of the grid users are calculated by the Simplified Average Participation approach.

Keywords: Cross Border Transit, Transmission grid cost allocation.

1 Introduction

In the ongoing process of deregulation of electricity markets, the power exchanges between different countries are a tool for increasing the competence. This is specially relevant in the European Internal Electricity Market where many countries, with very different degrees of liberalization, exchange big amounts of energy. These exchanges have to contribute to the cost of the grid that they use, especially if the transactions involve the facilities of a third country. Therefore, a cost allocation procedure has to be agreed in order to share them fairly among all its users in a multinational environment.

A suitable cost allocation method in multinational systems should comply with several conditions - to be non-discriminatory, to use actual grids and real power flows, to determine both the contributions to be made by each country and the compensations due to each country, to limit the technical decisions, and to be robust, i.e., small variations in the input should not lead to great variation in the output. The method used in 2006 in ETSO[1] [1] does not comply with these rules- it does not use the real flows in the actual grid, nor does it use real grid models for the evaluation of the amount of compensation to be paid to the countries whose grid is used in the exchanges. Compensations and contributions are calculated in a completely different way. For this reason, new proposals have been issued by European regulatory authorities [2] in order to be discussed. In this document, and according to the UE directives, both compensation and contributions are made between the System Operators (TSO) of the countries involved. All the exchanges between countries are named *Cross Border Trades*(CBT) according to [4]. The methods proposed in [2] and [3] may be classified as *With and Without Cross Border Flows* (WWC) methods, and *Average Participation* (AP) methods. WWC methods calculate the flows and losses in a system with and without foreign

[1] European Transmission System Operators.

transactions, allocating the difference to these last ones. The main drawback of these methods is that they base their results on fictitious and rather arbitrary situations (*without* case). Besides, they do not provide the contribution of each participating country. AP methods are based on the *Proportional Sharing Principle* [7]. They must be applied to the whole European grid, do not take into account the borders and responsibilities of national grids. In this they comply with the regulator wishes. Their main disadvantage is, however, that they do not take into account the Voltage Kirchhoff Law, and this may lead to some conclusions difficult to accept. Another family of methods are the differential methods, like the one proposed in [1]. These methods are well known and accepted, and they follow the circuit laws. However, differential methods are disregarded in [9], on the base that they are slack-dependent, or that its application involves to consider relations among very distant nodes. Both drawbacks can be avoided with an adequate formulation, as explained in this paper.

The purpose of this paper is the presentation of a method for calculating charges and contributions. It will be called DSIDC-SAP method, because a Differential Slack Invariant method using the DC load flow equations are used to evaluate the charges, and the Simplified Average Participation method is used for calculating the contributions. This method complies with the required conditions mentioned above. As stated in [4], compensations should be made among TSOs of the involved countries. Throughout the paper, the terms *country* and *TSO* will be used as synonymous.

2 Outline of the proposed method.

An adequate allocation method in multiarea system must calculate both the contributions of each country for the exchanges that it produces, and the compensations due to each country, or TSO, for the use of grid made by foreign transactions. In the proposed method, these amounts are calculated separately. The method is applied ex-post for a whole year, from solved representative load flows for each country. These solved load flows are used as the initial points for the compensation determination in each period. To find the contributions, it is necessary to know the exchanges between countries throughout a year. Although it would be advisable to have synchronized data for the whole European grid, this is not feasible by the moment.

The compensations are found analyzing each country separately, and calculating the amount of the horizontal network used by transits. This allocation is based on the sensitivities of each line flow to an increment of one transit, using the DC load flow equations. As a result of this allocation mechanism, the cost per transited MW is found, and this will be used in the contribution calculation method. Contributions are calculated using the Simplified Average Method using the cost per MW transited in each country.

This method intends to be a compromise between ERGEG recommendation and data availability, computation time and transparency requirements. Its implementation is easy, and may be understood and applied without major difficulties.

3 Compensations. The method DSIDC

The method DSIDC is a differential method for the allocation of grid costs to the users. This method allocates grid costs to transactions, defined as power exchanges between a generation and a load nodes. The allocation is made according to the sensitivities of branch power flows to these transactions. Therefore, for this allocations, the following problems must be addressed:

- How to define this transactions. In this method, the costs are allocated to transits, as defined below.
- How to allocate power flows to transactions. In the method, the flows are allocated using the mentioned, and later described, differential method that uses DC load flow equations.
- How to allocate costs, from the flow allocation. The proposal is to do it according to the absolute value of the flow allocation.

These choices are explained and developed in the following sections.

3.1 Allocation of grid costs to transits.

Transits are power exchanges that crosses the country, and are defined as:

$$T'_{k,ij} = \frac{P_{k\,sal,i} P_{k\,ent,j}}{R'_k} \tag{1}$$

where $T'_{k,ij}$ is the power exchange (*transit*) between the exporter node i and the importer node j and R'_k is given by

$$R'_k = \max\left(\sum_i^{N_i} P_{k\,sal,i}, \sum_j^{N_j} P_{k\,ent,j} \right) \tag{2}$$

where $P_{k\,sal,i}$ is the power export of country k through tie line i, while $P_{k\,ent,i}$ is the power import of country k through tie line j. N_i is the number of tie lines with power flow leaving the country, and N_j is the number of tie lines with power flow getting into the country.

The power flow in branch r F_{rt} allocated to a transaction t between nodes i and j, $T'_{k,ij}$, is defined as:

$$F_{rt} = \frac{dF_r}{dT'_{k,ij}} = \frac{dF_r}{dP_{k\,ent,j}} - \frac{dF_r}{dP_{k\,sal,i}} \tag{3}$$

where F_r is the power flow through branch r, $P_{k\,ent,j}$ is the power coming in country k from the outer node j, and $P_{k\,sal,i}$ is the power leaving country k to the outer node i.

As these sensitivities are calculated using the DC load flow equations, they are independent of the slack node chosen.

3.2 Cost allocation

Cost allocation to transits is made using the following equation:

$$U_{rt} = C_r \frac{|F_{rt}|}{\sum_{t=1}^{N_t} |F_{rt}|} \cdot K_r \tag{4}$$

where U_{rt} is the cost of branch r allocated to transit, C_r is the cost of the branch r, F_{rt} is given by equation (3), and N_t is the number of transits. Coefficient K_r is defined as:

$$K_r = \frac{\left|\sum_{t=1}^{N_t} F_{rt}\right|}{\left|\sum_{t=1}^{N_t} F_{rt}\right| + \left|F_r - \sum_{t=1}^{N_t} F_{rt}\right|} \quad (5)$$

This coefficient weights the branch cost allocated to transits, according to the importance of transits in the flow of branch *r*. The use of absolute values avoids undesirable effects and give more reasonable results. This is justified in [10].

From (4), the cost allocated to transit *t* can be found as

$$U_t = \sum_{r=1}^{N_r} U_{rt} \quad (6)$$

and the compensations due to country *k* can be found as

$$C_k = \sum_{t=1}^{N_t} U_t \quad (7)$$

while the cost per MW of the transits in country, π_k, can be found as

$$\pi_k = \frac{C_k}{T'_k} \quad (8)$$

where T'_k are the transits crossing country *k*.

4 Contributions. SAP method.

Contributions are found using the *Simplified Average Participation* method (SAP) [9], [8] that is based on the *Proportional Sharing Principle* (PSP) [7]. This principle, applied to countries, states that the outgoing power flows from country *k* are proportional to the incoming power flows to this country *k*. Therefore, for the application of this principle, each country is considered as a node with the whole national generation and demand connected to it, linked to each country by one branch that represents the net power exchange between both countries. Losses are not considered.

The SAP method provides the value T_{kj}, which is the power crossing country *k* coming from country *j*[2]. Now, the compensation C_{kj} that a country *k* must receive from country *j*, is

$$C_{kj} = \pi_k \, T_{kj} \quad (9)$$

The contribution that the country *j* must do to country *k* because of transits is D_{jk}, where it holds that,

$$D_{jk} = C_{kj} \quad (10)$$

The compensations received by a country *k*, C_k, would be,

$$C_k = \sum_j C_{kj} = \sum_j D_{jk} \quad (11)$$

and the contributions that a country *k* must do, D_k, would be:

$$D_k = \sum_j D_{kj} = \sum_j C_{jk} \quad (12)$$

Finally, the net payment due by a country *k* , N_k, (positive or negative) would be

$$N_k = D_k - C_k \quad (13)$$

[2] It must be remarked that countries *j* and *k* may have no common border.

5 Application examples.

The method DSIDC-SAP has been applied to the European grid, for the year 2004. However, for confidentiality reasons, the results of this method applied to the European network cannot be given here. In order to show some conclusions, the method DSIDC is applied here to the test system IEEE-RTS [11] and the method SAP is applied to an exchange situation in the European network.

5.1 Compensation in IEEE-RTS system. Application of method DSIDC

The system considered is the complete (3 areas) IEEE-RTS96 system. In this example the three systems are almost equal, and they are all balanced in generation and load. Only exchange loop flows take place between them. These exchanges (active power in p.u.) may be seen in Figure 1. Load flows have been run using PSS/E. The cost of lines is assumed proportional to its length, and lines of 230 kV have a cost 3 times greater than 138 kV lines. Cost of the transformers are also estimated from average European costs. The exchanges between the areas are also shown in Figure 1, where the powers between the area nodes and the outer nodes (both represented by numbers) are given in MW.

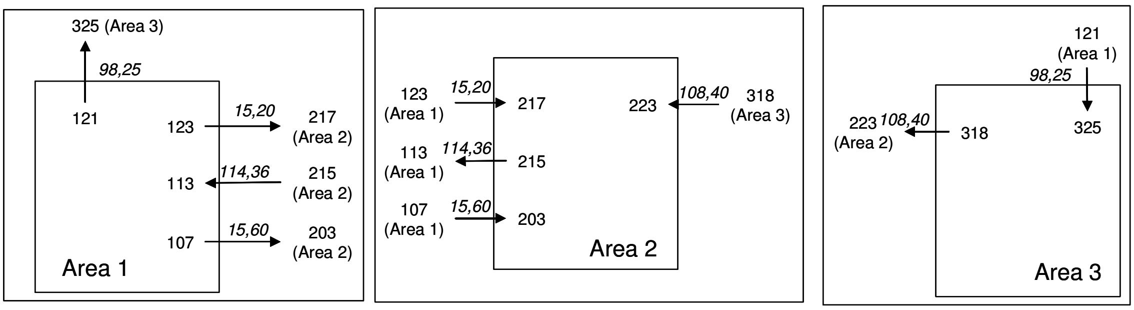

Figure 1. Power exchanges in the IEEE-RTS system. Powers are in MW.

The compensations due to each system by the others, together with the unitary cost of transits are given in Table 1. In it, the percentage of the transit with respect to the total load, as well as the Ratio between the cost allocated to transits and the system overall costs ay be seen. It can be seen that these values are very similar. This rule is also followed in most practical cases, which is a useful conclusion, allowing simplifying procedures if necessary. The unitary cost allocated to transits is also given in Table 1.

Table 1. Results for the case shown in Figure 1.

System	Transits/load (%)	Ratio (%)	π_k (€/MW)
1	3,88	3,33	6436,2
2	3,90	2,87	5575,9
3	3,32	3,94	8596,6

5.2 Contributions in the European grid. Application of the SAP method.

IEEE_RTS system only has three areas, and hence the application of the SAP method is straightforward, and uninteresting. This is why this method is applied to the European interconnected grid, in a fictitious, but realistic situation shown in Figure 2. Each country is represented by each national code. The costs of transits in each country are set at π_k = 1 €/MW for all countries (then, payments and MW are the same number).

Results of the method are given in Figure 3, where it may be observed that those countries with higher transits are the most compensated. Figure 4 shows also the results, but in this case, compared with the imports and exports of each country. In the figure, it can be observed that the exporters and importers pay also more, as they make more use of other countries' grids.

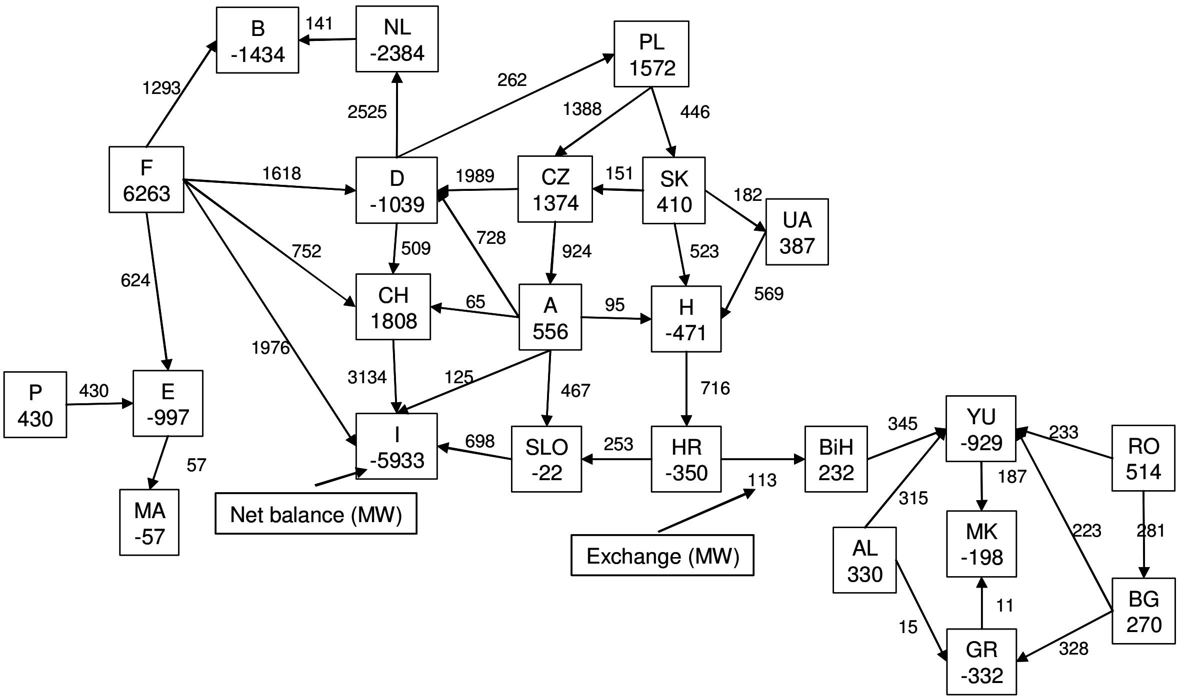

Figure 2. Power exchanges between European countries. All numbers in MW.

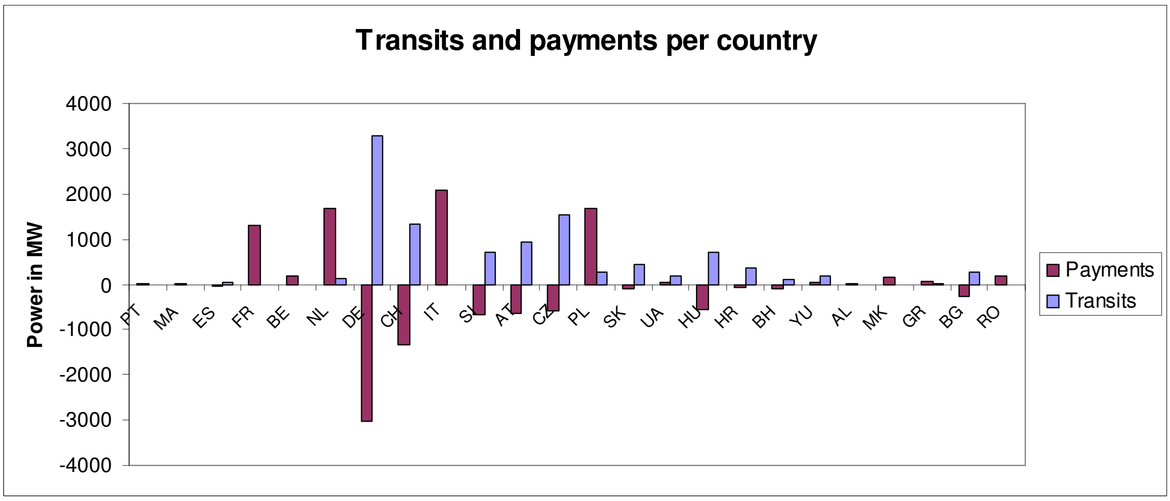

Figure 3. Results of the application of the SAP method to system in Figure 2. Comparison with transits

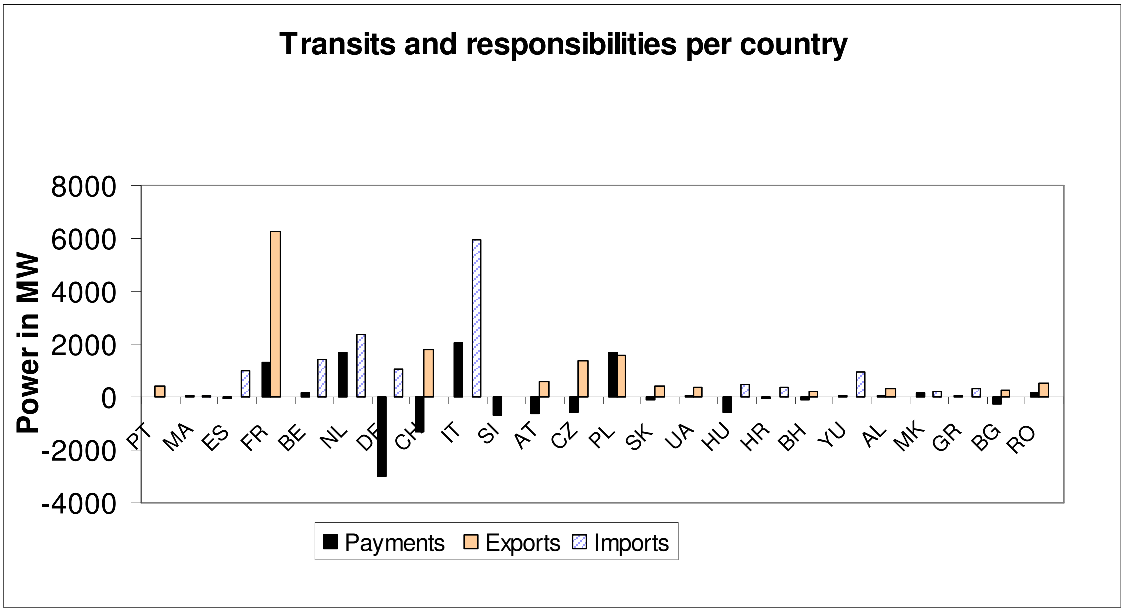

Figure 4. Results of the application of the SAP method to system in Figure 2. Comparison with exports and imports.

6 Conclusions

In this paper a method for the calculation of compensations between TSOs for Cross Border Trades has been presented called DSIDC-SAP. Its main features are:

- The compensations are found by means of a differential method using the DC load flow equations (DSIDC method), using the actual power flows through countries.
- Compensations are calculated separately for each country and the costs are allocated to transits, or power flows that cross the country. The unitary cost of transits is also calculated for each country.
- Contributions to be made by each country are calculated using the Proportional Sharing Principle applied to the power exchanges between all the countries (SAP method).
- This method complies with most the requirements of the regulatory authorities, and it is the lack of data what makes impossible to fulfil all of them.
- The method is relatively simple, easy to understand and implement, and has not heavy computation requirements.

The results have the following properties:

- The ratio between the compensations due to each country and the cost of the country grid are closely related to the ratio between transits and total load.
- The joint DSIDC-SAP method allocate most of the cost to the importing and exporting countries, while those countries more transited are more compensated.

The features and the properties of the method make it a reasonable proposal to be applied in the Internal Electricity Market of the European Union.

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