CROSS-BORDER TARIFICATION IN THE INTERNAL ELECTRICITY MARKET OF THE EUROPEAN UNION

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Abstract - This paper presents the regulatory principles behind the major decisions that have been already adopted or that will have to be adopted shortly at European Union level for the implementation of its Internal Electricity Market. The paper also recommends and substantiates the computational procedures that will be needed to implement these principles without unwarranted simplifications.

Keywords: transmission pricing, regional markets, cross-border tariffs, European electricity market.

1 INTRODUCTION.

Well before the deadline of February 1999 for the implementation of the European Electricity Directive 96/92/CE and until now, a global effort is taking place within the European Union (EU) and at different fronts, with the purpose of achieving a workable and efficient Internal Electricity Market (IEM).

The Florence Regulatory Forum, -which has been organized by the European Commission-, has succeeded in bringing together the different stakeholders, -Member States, regulators, system operators, consumer associations, power exchanges, brokers, etc.-, to discuss and to build some consensus on the issue that is probably most difficult to solve when trying to achieve a working regional market: regulation of access, investment and pricing of the transmission network of the concerned countries, in this case the 17 countries that participate in the IEM of the EU. As a result of the Florence process, and despite the appallingly slow rate of progress during its three years of existence, a broad preliminary consensus has been achieved on a set of fundamental issues concerning the scheme of cross-border tarification (CBT) to be adopted for the IEM.

This paper summarizes the basic principles of transmission network pricing that must underlie any sound proposal of cross-border tarification, see section 2. Then, in section 3 it presents the terms of the basic consensus that has been reached at Florence so far. Section 4 concentrates on the computation algorithms that are needed to implement the adopted cross-border tarification guidelines, in particular the methods for determining the economic compensations that must be derived from: a) utilization of external networks and b) the losses that are incurred because of cross-border transactions and loop flows.

This paper concentrates on cross-border tarification, i.e. the long-term signals that are needed to ensure network cost recovery at EU level, while maintaining economic efficiency. Short-term network signals that are derived from congestion management and losses are treated here in a more cursory way.

2 TRANSMISSION PRICING IN REGIONAL MARKETS

Transmission cost allocation criteria.

Fundamental principles of transmission pricing will be presented here schematically. Transmission pricing is the allocation of the regulated annual revenues of the transmission activity to the network users. The first attempt to design these prices should be to resort to nodal prices, since nodal prices are perfectly efficient short-term signals, i.e. geographically differentiated short-term marginal costs, see [1]. Nodal prices of energy implicitly include the effect on prices of losses & congestions in the network. They send adequate signals for decisions concerning the economic operation of generators & loads.

Strict application of nodal prices to generators and loads results in a net amount of revenues, which should be applied to partly pay for the cost of the network. Under ideal circumstances, impossible to find in practice, these revenues would suffice to pay the network total costs fully. However, these revenues are usually very insufficient to cover the total network costs (cost recovery by nodal prices typically does not exceed 20% of total transmission costs), see [2].

Thus, additional signals are needed to recover the remaining transmission network costs. These costs have to be assigned to the network users so that distortion of economic efficiency is minimized. Therefore, in the first place, these signals must be *long-term signals,* so that they will not interfere with the nodal prices. This can be achieved by designing them as annual charges (although they may be distributed monthly, for instance). Ideally these long-term signals should be consistent with the underlying cost

function of the transmission activity, so we must ask ourselves: which is the driver behind transmission investment? In the new competitive regulatory framework, investment in a new transmission line is justified whenever the present value of the aggregated benefits of all the network users (generators and consumers) is larger than the present value of the cost of the line. No existence of market power is assumed.

Then, conceptually, the solution is to charge the network cost that is not recovered through nodal prices in proportion to the benefits that the transmission network (either globally or line by line) provides to each one of its users. The resulting long-term economic signals have no purpose in the operation (i.e. short-term) timeframe; they are only meant to provide locational signals to new generators and loads -or to those considering retirement-, i.e. to inform them about the transmission network costs that are incurred because they locate or have located in one part of the network instead of in another one. We can see that in the long-term the elasticity of the potential new network users to the transmission charges (i.e., whether they will decide to install or not) depends on their expected profits, after transmission charges are duly included. This makes the allocation of transmission costs to the economic beneficiaries of the network to be based on the same underlying rationale than a Ramsey-like allocation scheme (i.e. allocate transmission costs to the network users in inverse proportion to their elasticities to the additional transmission charge).

Unfortunately, it happens that allocation of transmission costs to the economic beneficiaries is plagued with difficulties in practice. Most of the problems arise from the lack of adequate information about the generators in a competitive setting and the need to estimate the future behavior of the system. But also because it is difficult to evaluate the economic impact on the market agents of each individual line in a well developed network with some level of reliability-driven redundancy. This is why some measure of electrical use has been frequently adopted as a reasonable approximation to benefits (and it is also much easier to compute), see [3, 4]. This is the prevalent line of thought in the Florence Forum and it has been also adopted in this paper.

Since nodal prices can generally only recover a small fraction of the total transmission costs, the problem of determination of transmission tariffs that pay for transmission costs will be considered from now on in this paper to be tantamount to the problem of determination of the long-term signals, regardless whether nodal pricing is applied in a system or not (although it is recommended in general).

Non transaction-based transmission charges. An important practical conclusion that is derived from the criteria of allocation of the long-term signals is that transmission tariffs should not be transaction-based. Indeed, the adopted criterion of allocation has nothing to do with the commercial transactions that the agents are engaged in at a given moment in time, under the assumption of a working market that is competitive and with perfect information. Transmission tariffs may depend on the connection point to the network, on the nature of the agent –producer or consumer-, on the amount of power injected to or retrieved from the network and on the time of injection or withdrawal, even on the economic benefits that ideally a market agent could obtain because of the development of the network, but not on whether the agent, in a particular moment in time, is buying from or selling to a power exchange or via a bilateral contract, may it be with a local or with a foreign agent.

Avoid tariff pancaking. In the context of a regional market it is very important to recognize that what intuitively seem to be fair transmission pricing rules may lead to completely wrong results. This is the case of the still prevalent rule world-wide of charging to an international power transaction that "crosses" N countries the corresponding charge of each country "as if it were a national transaction". This seems a fair treatment from each individual country's viewpoint, but it results in a tarification system that depends more on the shape of political borders than on the physical reality of networks and flows. This pricing rule has two major defects: a) it is transaction dependent; b) the transmission tariff that is applied to the transaction is the accumulation of the tariffs of all the countries that have been "crossed", therefore resulting in the so-called "pancaking" effect, instead of some kind of average regional tariff which would have been applied in a truly open regional market without political borders. The correct approach to an efficient system of regional transmission pricing is *"the single system paradigm",* i.e. a pricing scheme that tries to get as close as it is practically possible to the transmission tariffs that would be applied if the entire region could be considered as a single country. After more than three years of efforts, the Florence Forum reached a historical agreement on its 8th meeting of February 2002 and pancaking was finally replaced by a temporary system of inter-TSO payments (see below) still quite imperfect, while working on a consensus for a longer-term mechanism that fully incorporates the principles that are stated here.

Application of the general principles. From the general principles the following basic criteria for implementation can be derived:

- If the transmission network is well meshed and there are no clear locational signals to be sent because generation and load are more or less evenly distributed and no systematic congestions are likely to occur, then the beneficiaries (or major users) of the network cannot be clearly identified on the basis of their location. According to economic theory, in the absence of a clear indication from the underlying transmission cost function, it makes sense to recur to the inverse price elasticity rule (i.e. the concept behind Ramsey pricing) in order to minimize the loss of efficiency. This rule must provide an indication on how to split the global charge between generators and consumers and then also on how to charge to individual consumers on one side and generators on the other side. Assuming there is strong competition on the generation side, the rule advises to charge transmission costs mostly to

consumers, since generation in a competitive environment is very elastic to prices and in the long-run the large elasticity of generators will result in a complete transfer of the charges to the consumers. Note that this not a trivial or universal rule, as it is sometimes heard: "consumers always pay all network charges in the end". For instance, a new generator with a very cheap energy source (e.g. hydro or natural gas), in a remote location and with no competitors, may be charged a large fraction of the transmission line that will connect it to the major load centers without turning unprofitable the project; this network charge will not be transferred in the end to the consumers. Regarding allocation to the individual consumers, the inverse elasticity rule would advise to charge more to the least elastic consumers. Note, however, this may be considered to be an unacceptable discrimination.

- If the transmission network is such that long-term locational signals are needed and they can be more clearly identified, -because of systematic structural limitations of the network-, then the allocation of transmission costs should pay attention to location. Note that these long-term signals are no longer useful for existing generators and loads (except for those considering retirement because of economic reasons); they are meant to promote adequate siting of the new facilities and to fully recover network costs[1]. However, for the sake of simplicity and avoidance of any appearance of discrimination, most regulators choose that both the existing and the new network users must be subject to the same charges. Note that it is not very important how much of these charges is recovered through generators and how much through consumers (in most cases, as indicated before, if there is strong competition in generation the consumers will end up paying the entire bill anyway). What matter are the differences in charges among generators when they are placed in different locations, so that they have the right incentive to locate in the network and, similarly, the differences in charges among consumers.

Both situations may take place at the individual system or national level. In those countries where it is deemed that there is little need for long-term locational signals in transmission, transmission costs may be allocated to generators and consumers without any geographical differentiation. This seems to be the case in most IEM countries, see [5]. On the other hand, in those countries where long-term location signals appear to be necessary (e.g. England & Wales, Norway or Sweden), transmission charges could have geographical differentiation.

These criteria are equally valid in a regional or multinational context. If geographical differentiation of the long-term signals is not a major concern, then uniform regional transmission charges for generators and consumers could be applied in strict application of the single system paradigm. However this would require a very high level of regulatory integration and a pragmatic alternative could be to let each country charge its national tariffs to its network users, who in this way would automatically gain access to the entire IEM network.

However, the opposite situation may also be possible. At the regional level, one may also want to send long-term signals in order to indicate the most appropriate and inappropriate zones to locate new generation and load. If the locational problem is a serious one, -i.e. the economic utilization of generation resources at regional level to meet the regional load causes much stress in the existing transmission network-, then the long-term locational signals are needed. A rigorous approach would consist of assigning the cost of each one of the lines in the region to those agents that use it (or benefit from it) while ignoring any political borders. However, this regional tarification scheme may be only possible in markets with a very high level of integration. Less radical alternatives are possible, such as replacing the nodal allocation of transmission costs at regional level by compensation mechanisms among countries, which would be based on how much each country uses (or benefits from) the networks of other countries, as it will be shown below.

3 SOME RESULTS FROM THE FLORENCE FORUM

Significant advances have been made at the Florence Forum, most of them in agreement with sound transmission pricing principles[2]:

A. Separation of the treatment of short-term and long-term transmission related economic signals:

Short-term signals (operation level). It is recognized that a system of EU-wide nodal prices would be the ideal approach to send short-term efficient network signals to all the market agents. However, it is also acknowledged that in the short and mid-term this is not a politically acceptable scheme. This is why it has been agreed to make use of ad hoc mechanisms to send these short-term network signals throughout the IEM as three separate pieces: a) the price of energy in the several markets and some mechanisms that reflect the impact of b) losses and c) network constraints at IEM level. Consistency between the separate implementations of these three components of the short-term signals is needed to avoid efficiency distortions, see [5].

Long-term signals (recovery of network costs). Network cost recovery at national level will be basically achieved by the application of national tariffs to the domestic network

[1] Remember that signals that are derived from losses and congestions are short-term ones; they cannot generate the complete revenues for the required investment since: a) in general they will be too weak for that, due to the typical over-investment in transmission; b) these signals will typically be much reduced, -even almost disappear-, once the reinforcement is built.

[2] This formulation reflects the personal interpretation of the author, who has been deeply involved in the Florence process, and it may not fully coincide with the official statements that have been issued after each one of the sessions of the Forum.

users. Transmission costs may be partly recovered by the application of nodal pricing, zonal pricing or congestion management mechanisms at national or regional level. In addition, economic compensation mechanisms between countries –because of the costs that are incurred by cross-border transactions and loop flows- will increase or reduce the total network costs to be recovered at national level.

B. Economic compensations[3] among countries because of the costs incurred by cross-border transactions and loop flows.

A mechanism will be established to compensate those countries that incur into extra costs because of cross-border trade, while at the same time the mechanism charges those countries that are responsible for these costs. Therefore, there will be no cross-border tariffs, but a compensatory scheme at country level[4]. The local, -at TSO or country level-, transmission tariffs for generators (G) or loads (L) will basically provide access to the entire IEM transmission network. The net outcome of the compensatory mechanism will result in some changes to the local transmission tariffs in the different countries.

The compensations are required because of two reasons: a) losses that take place in a country because of the existence of cross-border transactions and loop flows; b) utilization of the networks of other systems because of cross-border transactions and loop flows. The compensatory mechanism consists of three basic steps: i) determination of the *compensation* that is due to each country because of the costs that are incurred by cross-border transactions and loop flows; b) determination of the *charges* that each country has to pay in order to compensate others; c) application of the *net balance* of compensation and charges of each country to its network users as a modification of their corresponding network tariff: G for generators and L for consumer loads.

C. Treatment of existing and future lines.

A method that treats existing and future transmission facilities in the same way is simpler to understand and to apply and, in principle, should be preferred. It is obvious that the "future lines" of today will become "existing lines" some years from now. If the procedures to deal with both categories of lines are different, it will be necessary to keep track of which group each line pertains to, in all future calculations. This is messy, although it can certainly be done. However, most regulators in the Florence Forum have supported the viewpoint that the existing network and the future reinforcements should be treated differently. Why? The existing lines were built under a different regulatory context, with the purpose of serving mostly national or local interests and they are presently being paid for the most part by the local users. On the contrary, future reinforcements that may be partly or totally needed for cross-border trade will be built under the rules of the IEM and the close supervision of regulators and all interested parties, with (hopefully) clear criteria to decide who benefits from the use of these reinforcements and therefore who must pay for their use. Besides, a strong level of interconnection, -and transits also, in general-, should bring also benefits to a country, such as an increased level of security or access to a broader and more competitive wholesale market. If cross-border related costs are going to be compensated, why not also the benefits.

This is clearly an open issue that requires a regulatory input. However, any sound decision should be based on the knowledge of the magnitude of the compensations and charges that would result from a scheme that is based on some measure of network utilization and losses, such as the one that is proposed in this paper. Maybe compensations could be restricted to those countries where a certain threshold in the ratio of the net value of compensations minus charges to total network costs exceeds a certain magnitude.

D. Standardized costs.

Another regulatory problem that must be faced is to go from the network utilization factors that are provided by the allocation algorithm to the economic compensations and charges that are required by the inter-TSO payment scheme. The point here is that it is not acceptable that the costs to be compensated in the different countries respond to widely different regulatory practices that result in totally disparate unitary costs of otherwise similar facilities.

The inter-TSO payments scheme, because of its very own nature, demands that the costs of the networks of different countries be shared by other countries. But one can understand the reluctance of a country M to pay a fraction of the cost of the network of another country N, where such a cost has been determined following regulatory practices that are not acceptable to country M. And the reluctance increases if it happens that the regulated per unit cost of a facility in country N (e.g. the cost of 1 km of single circuit line of 400 kV) is much higher than the per unit cost of the same item in country M. Unfortunately, these important differences in regulatory practices and per unit costs within the IEM countries are not only hypotheses but actual facts, as it has been shown in a recent study on benchmarking of transmission tariffs in the IEM countries, see [5].

Therefore, it seems that the only acceptable way to share costs of other existing networks is to establish a common standard of costs for each transmission component (e.g. 1 km of double circuit line of 220 kV or 1 kVA of a 400 kV/132 kV transformer). These standards should be based on the actual values that are currently accepted by the regulators of the IEM countries, so that it is avoided a theoretical discussion on the costs that are more adequate for this purpose, e.g. replacement versus historical costs.

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[3] In the context of the Florence Forum these compensations have been named "inter-TSO payments", since the basic entities that will be receiving and paying for these compensations are the Transmission System Operators (TSOs), which will have to reflect the net balance of compensations and payments as a credit or debit in their corresponding regulated transmission costs.

[4] Most IEM countries have a single TSO, but some have several and these rules must be applied at TSO level. In this paper country and TSO will be used without any distinction.

The determination of the costs to be shared of future "cross-border-lines" is easier. One possibility, in case the construction of the lines is assigned by a competitive bidding process, is to accept the cost of the winning bid, since it is the result of an open and competitive procedure. Another possibility is to establish a set of common standards of cost for each type of facility. In this case the cost should be the present replacement cost of the facility, and it could be determined from information requested from firms that construct, operate and maintain transmission facilities.

E. Limitations of the compensatory mechanism as a pan-European transmission tarification scheme.

The mechanism of inter-TSO payments as agreed in Florence, -since it aggregates charges and compensations at TSO level-, has very little relevance as provider of locational economic signals. Its main purpose is to compensate economically those countries whose networks are being significantly utilized by other countries and that do not use much other countries' networks (otherwise compensations and charges would be netted out with a negligible total impact). The opposite situation, -i.e. countries that use much other countries' networks whereas their networks are barely used-, is also of interest.

This philosophy is consistent with the fact that the differences in transmission tariffs among the IEM countries are presently large enough to overcome the estimated impact that the inter-TSO payments could have on the G and L tariffs. The benchmarking study on transmission tariffs [5] indicates that, for a typical large consumer (demand of 15 MW from 8 am to 24 pm on week-days), transmission tariffs in IEM countries could range between 3.5 and 14 €/MWh. It should be noted that the average integral tariff for these consumers in the IEM is in the vicinity of 45 €/MWh. Preliminary values for compensations (before netting them out with charges) that were proposed by the European Association of System Operators (ETSO) would result in an average value for all countries in the IEM in the range of 0.2 €/MWh, with a couple of countries with values as high as 0.5 €/MWh and 1.8 €/MWh. Therefore, one may conclude that harmonization of the current national transmission tariffs must be given priority over trying to use the inter-TSO payment scheme for sending EU-wide transmission-related locational signals.

F. Non-transaction based charges.

Any charges that may be derived from the inter-TSO payments scheme, because of their intrinsic nature of long-term economic signals, must not depend on the specific commercial transactions among the market agents. Therefore they must be only related to the point of connection, the nature of the agent and the time profile of the input or output of power.

G. Harmonization.

The responsibility for setting local tariffs corresponds to the national regulatory authorities, but some level of harmonization will be required regarding:

a) The split of total network costs between G and L charges. The considerations that were presented above concerning relative levels of price elasticity suggest that consumers should bear most of the costs. A maximum of 25% for generators has been recommended by the Council of European Energy Regulators (CEER). ETSO proposes to adopt a uniform pan-European G tariff (before any inter-TSO payments related adjustments).
b) The split of each tariff into an energy and a capacity component. The energy component should be eliminated for those agents (generators in particular) that are exposed to hourly energy prices, because of the effect of distortion that this additional signal might have on the short-term marginal prices.
c) The application of the net result of the compensation and charges for each country to its network users. Based on fundamental transmission pricing principles, see Annex I, CEER has proposed that net payments should be debited to all L's in importing countries and to all G's in exporting countries, while net revenues should credited to all L's in exporting countries and to all G's in importing countries.

4 PROPOSAL FOR IMPLEMENTATION

Many approaches and algorithms for transmission pricing have been proposed in the technical literature and many have been implemented in the regulatory practice, see [7] for instance. However, no transmission pricing method has been considered yet to be entirely satisfactory, even at the single country level. The major virtue of the methods to be adopted for the determination of inter-TSO payments in the IEM must be the basic soundness to withstand the criticisms of those countries that may feel to be negatively affected, so that a broad consensus may be reached or at least the methods do not find too harsh a resistance to be applied.

4.1. The network cost allocation algorithm.

The ultimate goal of a cost allocation algorithm for use in the inter-TSO payments scheme is to allocate the cost of the transmission network of a country among all countries, obviously including itself. As it was discussed before, here it will accepted that the "utilization" of a network by some agents is an acceptable proxy to the "benefits" provided by the network to these agents, and therefore a suitable criterion for cost allocation. Note that even a precise definition of use does not seem to be possible, since electricity flows cannot be tracked down as a fluid in a pipe. The best that one can do is to devise algorithms that provide an answer that is simple to understand and intuitive, that appears to be reasonable and that is able to pass the difficult test of providing reasonable results under all circumstances. Note that the inter-TSO payment mechanism is not meant to move very large amounts of money and accuracy is not a major issue. But, on the other hand, it is not desired an algorithm that presents obvious flaws and that therefore can be easily contested.

Assume a sound algorithm for allocation of use of networks, -"the network allocation algorithm"-, exists and

has been adopted. Two possible methods are "average participations" and "marginal participations", see [3, 4] for instance, as well as variations on them. In particular, the companion paper [4] compares these two methods and shows their computational intricacies and their strong and weak points. These algorithms are very simple to understand and to use, they generally provide sensible results, they take as input data the actual load flows that happen in the complete IEM system and there is some experience in their application.

Now, equipped with the "network allocation algorithm" and the results of an actual power flow for the IEM network, one can assign the utilization of every transmission line in each one of the 17 countries of the IEM to the users located in a certain number of nodes, which typically will not be too far away from the considered facility, although this obviously depends on the prevalent flow patterns. The exercise has to be repeated for a set of power flows that can be considered to reasonably represent the IEM network utilization during the considered time period (typically one year).

The procedure above, if applied to the entire network of the 17 IEM countries ignoring political borders and, if the cost of each line could be somehow given, would provide individual transmission tariffs for the users in every node of this network. That would be an IEM global transmission tarification mechanism, and one which provides complete locational signals, but this is not what we are looking for now, since this is not what has been agreed at Florence. As it was described above, the agreement is that "there will not be cross-border tariffs, but inter-TSO payments, whose net result for each country will be used to modify its local G and L charges".

How can we use the results of the algorithm in the context of the inter-TSO payment mechanism, as described above? It is very simple. Assume that a country M has 600 lines, that 80% of the use of line 1 has been allocated by the algorithm to nodes within country M, 15% to nodes in country N and 5% to nodes in country P. Same thing with line 2, with different percentages, and then with line 3, line 4 and so on. It is then immediate to compute the fraction of the entire network of country M that is used by its local users and how much is used by users in country N, country P and so on[5]. If we attach costs to the individual lines then we automatically obtain the total economic compensation that is owed to country M and also how much of it must be paid by country N, country P and so on.

Note that the transfer of money among countries is the same with the inter-TSO mechanism that has been just described as with a fully detailed global IEM tarification system at nodal level. The only difference is that in the later procedure the compensations that must be paid by external users are directly charged to individual network users, while in the former procedure the charges that correspond to the users of a country (or TSO) are passed to the country as a whole, to be later allocated internally in some fashion. Is this simplification acceptable? Certainly, since most countries use uniform tariffs (postage stamp rates) and therefore it makes no sense to use locational differentiation with the external compensations only; in other cases they use their particular form of locational differentiation, not compatible with individualized nodal charges resulting from an IEM network.

The basic type of algorithm that has just been recommended for the determination of the fraction of a network that needs to be compensated by external users, automatically also computes the percentages of each compensation that must be attributed to every external country. This has been shown above to be a part of the general procedure. This method correctly and implicitly takes into consideration the import and export flows, as well as any geographical consideration. Therefore there is no need to design a new allocation algorithm for this purpose.

The proposed type of allocation scheme also has other interesting properties:

- Once the method has been applied and the numerical results have been obtained, it is the time to adopt any rules concerning whether compensations will be applied to all countries or just to those who exceed a prescribed threshold of any given measure of external utilization. In this way a general rule would be applied in principle to all countries but, if so desired, the outcome would be executed only for the countries where it has a significant impact.
- The procedure can help in the definition of what has been called the "horizontal network". This is the network whose lines could be affected by cross-border flows or, in other words, the network formed by the lines whose utilization might correspond, up to a significant degree, to external users. The "network allocation algorithm" could help in finding out whether a particular line, group of lines or voltage level qualifies for belonging to the horizontal network.
- The method can be equally applied to existing or future lines. Therefore, the criterion to ascertain whether the cost of a future line should be shared or not by several countries will simply consist of examining the result of application of the proposed procedure: if a significant fraction of the responsibility in the utilization of the line (e.g. more than 10%) falls in network users that are external to the country, then the line should be considered a "cross-border line" (even if it physically lies entirely within a single country) and its cost must be shared according to the percentages that are provided by the adopted "network allocation algorithm".

We do not ignore or try to minimize in this paper the technical difficulties that will certainly arise when trying to implement a specific "network allocation algorithm". They have been discussed at length in [4]. Since the purpose of the algorithm is to quantify the extent of network utilization of each market agent, the results of the algorithm will in general be very sensitive to the choice (either explicit or

[5] It would not be correct to give the same weight to all lines, regardless of their voltage and length. The best weighting factor for tarification purposes is the individual cost of each line.

implicit in the particular method) of the "slack node", that is, the node or combination of nodes that respond to any total or marginal injection or withdrawal of power in the particular node whose level of network utilization is being studied.

4.2. Allocation of losses.

The proposed method is based on the concept of EU-wide nodal pricing but the specific procedure to be used, at least in a first phase of implementation, does not require the application of nodal prices –neither at national nor EU-wide level–. It does not require the existence of an EU compensation fund, either. The presentation of the proposed methodology is done in two steps. First, a conceptual reference situation with full regional nodal pricing will be described, so that the fundamentals of the method are understood. Second, a valid approximation of the reference case to the present conditions of the EU Internal Electricity Market is proposed as the recommended procedure. These ideas were first presented in [8].

The reference case is characterized by: a) a well-defined regional transmission network, RTN; b) a centralized algorithm that computes nodal prices just for all the nodes of the RTN; c) regulatory diversity: while some countries use nodal pricing internally, other countries do not. Under these conditions, the following procedure correctly computes the allocation of losses among the different countries:

i) Apply nodal prices at the nodes of the RTN (generators are paid and consumers pay nodal prices). This results in complete application of short-term economic signals to all users of the RTN (both to users directly connected to the RTN and, if the countries pass the signals internally, to all users). A net revenue NNR (nodal net revenue) is obtained, which should be used to reduce total charges of the RTN to its users. The problem now, in a regional context, is how to allocate these revenues to each country. Note that, if we ignore congestions, NNR only consists of charges related to losses. Any "compensations" between countries because of losses must be implicit in NNR.

ii) Consider now the existing political borders. Now, in each country A apply nodal prices both at the internal nodes of the RTN and also at the new nodes that have been created at the borders between country A and the neighboring countries. The result is a nodal net revenue NNR_A for country A.

iii) It is obvious to check that the sum of the NNR_A for all countries A in the region is the total NNR calculated before. The amount of the total revenues NNR of the RTN that corresponds to country A is precisely NNR_A.

iv) Some entity collects NNR by applying nodal prices to all physical flows entering or exiting the RTN. This amount is distributed as NNR_A to every country.

The problem is that it cannot be assumed that every country will apply nodal prices internally. As we are only interested in the allocation of losses, we shall proceed to split the nodal prices into two components: a production component (common for all prices) and a loss factor, which is different at each node (network constraints are ignored here)[6]. For each country the production component, when applied to each internal node and the flows at the borders, results in an economic deficit that is equal to the value of its internal losses when valued at the production component. On the other hand, the application of the loss factors for each country, -both at the internal nodes and the borders-, results in revenues for the country approximately equal to double of the economic value of losses. Therefore, there is a net surplus -after recovering the cost of losses- approximately equal to the economic value of losses, which can be used to pay for a part of the network costs. More specifically, the revenues R_A of system A because of losses are

$$R_A = \sum_k PN_{INTk}(D_{INTk} - G_{INTk}) + \sum_k PN_{BORk}(EXP_{BORk} - IMP_{BORk}) \quad (1)$$

where PN_{INTk} is the nodal price at any internal node k of system A, PN_{BORk} is the nodal price at any node k where the regional transmission network crosses any border of system A, D_{INTk} and G_{INTk} are the withdrawals or injections of power at the internal nodes of system A, and EXP_{BORk} and IMP_{BORk} are the export and import physical flows measured at the borders of system A.

If the nodal prices are decomposed into a single market price and node-specific loss factors LF, then the system experiences a net economic deficit equal to the total volume of transmission losses in the system times the market price. On the other hand, application of the loss factors results in a net revenue:

which is approximately equal to twice the total volume of transmission losses in the system times the market price. The

$$\sum_k LF_{INTk}(D_{INTk} - G_{INTk}) + \sum_k LF_{BORk}(EXP_{BORk} - IMP_{BORk}) \quad (2)$$

second term in the expression above is the inter-TSO loss compensation we were looking for. In effect, it accounts for all the contribution from neighboring countries to the losses in system A and it can be easily expressed in terms of bilateral transactions with the neighboring systems to system A. As with the network cost allocation algorithm, the computation of credible inter-TSO compensations and charges requires to apply the same algorithm repeatedly for a representative number of system conditions for the time period for which the cross-border tarification analysis is intended.

The selection of the slack node is also a problem here, since loss factors (which inevitably depend on the choice of slack, see[6] and [8]) are used instead of the complete nodal prices, and the final results happen to depend significantly from the chosen slack. This is still an open issue, but in principle it can be recommended to be consistent with the final choice that, explicitly or implicitly, is adopted in the mechanism for allocation of network utilization in section

[6] The split cannot be defined in a unique way. It depends on the choice of the "slack node" that is necessary to make when computing the loss factors, see [6].

4.1, as it is discussed in [4]. One interesting property of expression (2) is that the net revenue happens to be totally independent of the choice of the slack node whenever the aggregated import flows equal the aggregated export flows, i.e., when the country has no net import or export flow; in other words, when it is only "transited" or when the procedure is applied only to the "transit" component (in any way that it is decided to define it) of the import and export flows.

5 CONCLUSIONS

Despite the inevitable political interference in a process of market design involving 17 countries and numerous affected companies and institutions, the Florence Forum has succeeded in providing an ensemble of implementation guidelines for the IEM that are basically in accordance with sound regulatory principles of transmission pricing.

This paper has shown that this accord does exist, but also that the present lack of harmonization in national transmission tariffs makes it meaningless today to attempt to produce useful locational signals at European level via the inter-TSO payment scheme. Inter-TSO payments for the time being are limited to provide economic compensations at TSO level for the costs that are incurred because of cross-border transactions and loop flows. Despite of this, the algorithms for the computation of the inter-TSO payments, -the algorithm of network cost allocation and the algorithm of loss allocation-, must meet some exacting requirements so that they can be the basis for a broad consensus on the implementation procedures of the IEM.

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ANNEX I. JUSTIFICATION OF THE ALLOCATION RULE OF THE NET BALANCE OF COMPENSATION AND PAYMENTS OF A TSO (OR COUNTRY) TO ITS INTERNAL NETWORK USERS.

According to the adopted inter-TSO payment scheme, the computation of compensations and charges to the different TSOs is based on two mechanisms: a) bilateral compensations and charges between neighboring TSOs because of losses; b) utilization of the network of a TSO by cross-border transactions and loop flows from other TSOs.

It has been already shown that these compensations and charges must result in transaction-independent modifications of the G and L tariffs of any given country. Next, it will be shown that, regardless of the reason behind the net payment (or credit) for a country, it is reasonable that the charge (credit) should be applied to *all* generators of the country whenever the country is exporting and to *all* consumer entities whenever the country is importing[7]. The two basic cases where payments among countries may take place will be examined separately.

Compensation of losses.

The economic signals derived from the application at TSO level of the resulting net allowances, -compensations minus charges of the loss compensation mechanism, should reflect

[7] This refers to how the charge or credit should be computed, for instance based on last year's historical flows. The allocation rule has to be individually considered for each one of the considered scenarios. The charges must be separately aggregated for the G and L categories. The resulting modification to the G and L tariffs must be applied as an annual charge.

the effect that loss factors that would be derived from nodal prices would have on the network users at TSO level.

What effects would losses have on the network users? Start with a reference situation with multiple interconnected TSOs where, for simplicity, it will be assumed that each one has a single market price (instead of multiple nodal prices). In the absence of congestions and network losses, and with fully developed international trading mechanisms, the market prices for all TSOs should be the same. With congestions and no losses, there would be several subsets of TSOs separated from one another by congestions and where the prices of the TSOs in any subset would also be the same.

The effect of adding losses to this reference model would roughly be to lower the market price in the exporting TSOs and to increase the price in the importing TSOs. Then, in order to represent approximately the same effect with the modifications to G & L because of inter-TSO payments, one should apply the following rules:

- If the net balance is negative for the country (i.e. compensation < charge), then the TSO has to pay more than to receive. In exporting TSOs charge the net balance to generators (increase G). In importing TSOs charge the net balance to consumers (increase L).
- If the net balance is positive for the country (i.e. compensation > charge), then the TSO has to receive more than it has to pay. In exporting TSOs credit the net balance to consumers (reduce L). In importing TSOs credit the net balance to generators (reduce G).

B. Compensation of some infrastructure costs.

In this case the rule must be a consequence of the procedure that is adopted to allocate the utilization of a the network of a TSO to the different network users, aggregated at TSO level. The allocation mechanism that has been proposed in section 4.1 makes use of actual physical flows in the real IEM transmission network to assign the responsibilities for the utilization of each line. What matters in this kind of allocation methods is the power that is injected or withdrawn at each node and not the commercial transaction associated to that power flow. This is in agreement with long-term nature of the charges that are derived from the procedure, as it has been indicated repeatedly.

Since inter-TSO payments are computed at the aggregated TSO level, the procedure for the internal allocation of the net balance of the resulting compensations and charges should be based on some measure of the global importing and exporting activity of each TSO. The importing (or exporting) activity of a TSO at any given moment in time is given by the net balance of the metered import minus export flows. Therefore, it is clear that, when the TSO is a net exporter, it is the generators within the TSO the ones to be charged, and equivalently for the loads when the TSO is importing. And the charge must be applied to *all* generators or to *all* loads, since network charges must be independent on commercial transactions. All generators within the TSO are equally responsible for the existence of a net export flow when the network is contemplated from a EU-wide perspective.

In conclusion, in exporting (importing) countries a positive net inter-TSO payment should result in an increment in the G tariff of all generators (in the L tariff of all consumers). Similarly, in exporting (importing) countries a positive net inter-TSO revenue should be credited as a reduction in the L tariff of all consumers (in the G tariff of all generators).